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EPBC REFERRAL PRELIMINARY DOCUMENTATION PACKAGE

KIWEF AREA 2 CLOSURE WORKS

FINAL

EPBC REFERRAL PRELIMINARY DOCUMENTATION PACKAGE
KIWEF AREA 2 CLOSURE WORKS

Revision	**V2**
Date	**16/07/2018**
Made by	**B Sinclair**
Checked by	**S Taylor**
Approved by	**F Robinson**
Description	**Ramboll Australia Pty Ltd has been engaged by Hunter Development Corporation to prepare this Preliminary Documentation Package to support an application for a Controlled Action Approval and in response to the DoEE request for information and request for further information dated 6 January 2017 and 1 February 2018 respectively**

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GLOSSARY

Term	Definition
Area 2 Rationalisation Investigation	KIWEF Area 2 (Phase 5) Closure Works – Briefing Paper (SMEC 2018)
Optimum chytrid protection range	Between 1,650 µS/cm and 2,900 µS/cm
Low Area	Cells 4, 6 and 8
Port of Newcastle Lessor	KIWEF land owner and entity proposing to undertake the action. NSW State Government entity charged with land owner administration for all land administered under the long-term lease of the Port of Newcastle
T4 Project	Port Waratah Coal Service Terminal 4 Project.
The Closure Strategy	Revised Final Landform and Capping Strategy (GHD 2009)
The Controlled Action	EPBC Ref: 2016/7670
The Project	Kooragang Island Waste Emplacement Facility Rationalised Area 2 Closure Works
The Surrender Notice	Notice to Surrender EPL 6437

ACRONYMS

Acronym	Definition
AHD	Australian Height Datum
BOS	Basic Oxygen Slag
DoEE	Department of Environment and Energy
EPA	Environment Protection Authority
EPBC Act	Environment Protection and Biodiversity Conservation Act 1999
EPL	Environment Protection Licence
GGBF	Green and Golden Bell Frog (Litoria aurea)
HDC	Hunter Development Corporation
HEW Ramsar Wetlands	Hunter Estuarine Wetland Ramsar Site
KIWEF	Kooragang Island Waste Emplacement Facility
NCIG	Newcastle Coal Infrastructure Group
OEH	Office of Environment and Heritage
PAH	Polycyclic Aromatic Hydrocarbons
PDP	Preliminary Documentation Package
PoN	Port of Newcastle
PWCS	Port Waratah Coal Service
Ramboll	Ramboll Australia Pty Ltd
TPH	Total Petroleum Hydrocarbons
UoN	University of Newcastle

EXECUTIVE SUMMARY

This PDP has been prepared to support an application for a Controlled Action Approval and in response to the request for further information from the Commonwealth Department of Environment and Energy (DoEE) for the Kooragang Island Waste Emplacement Facility (KIWEF) Rationalised Area 2 Closure Works (the Project).

The purpose of the Project is the closure of Area 2 at the KIWEF which would require capping and rehabilitation of approximately 36 hectares of historical landfill. The Project includes the installation of drainage and sediment controls, capping and re-contouring of waste emplacement areas and rehabilitation to a stable and self-sustaining final landform.

The Project is an environmental improvement project with the key objective of mitigating the future migration of site contaminants associated with the former use of the landfill to the broader environment. Inherent to the Project design are five key environmental and socio-economic features, being:

1. Containment of contaminants within a capped area to mitigate future migration to the surrounding natural environment
2. Minimisation of direct impact to existing GGBF Habitat
3. Minimisation of indirect impacts to existing GGBF Habitat
4. Sympathetic to other approved projects in Area 2
5. Creation of movement corridors for the GGBF across Area 2

Since the Referral was submitted to DoEE, HDC has undertaken a detailed review of the Project to rationalise the impacts to matters of national environmental significance to the extent practical. As a result, the following changes have been incorporated into the Project:

- Opportunities to capitalise on existing *in-situ* capping across Area 2
- Implementation of a Modified cap within the area identified as the Low Area
- Capitalise on existing capping materials across Kooragang Island, including:
  - source capping or fill material from the Peninsula Borrow Pit
  - source capping or fill material from the K7 Pre-load Area
  - source capping or fill material from the HRRP Borrow Pit
- Gain access to the Peninsula Borrow Pit via an upgraded existing haul road and other additional access tracks

The key challenges of the Project, as identified by the delegate of the Minister for the Environment and Energy the Minister (issued 2 December 2016), is management of the potential for significant impacts to MNES including:

- Green and Golden Bell Frog *(Litoria aurea)* (vulnerable) – significant impact on the GGBF is likely due to the removal of foraging habitat, potential mortality of GGBF individuals, likely changes in the salinity of pond water which is likely to favour the growth of chytrid fungus, and potential introduction of *Gambusia* to the breeding ponds.
- Hunter Estuary Wetland (HEW) Ramsar site - the GGBF is identified as a "critical ecosystem component" of the HEW Ramsar site and the proposed action is likely to impact on the habitat and lifecycle of the Kooragang Island GGBF population.

A significant amount of work has been undertaken by HDC in consultation with UoN and various technical consultants to both understand the significance of potential impacts of the Project and develop effective mitigation measures for the identified risks. The potential impacts and proposed management measures, which are the outcomes of these studies, are summarised in **Table 4-1**.

Table A-1-1: Summary of Identified Potential Impacts and Proposed Measures to Address Risk

Potential Impact	Proposed Measure
Removal of foraging habitat	Any loss of GGBF foraging habitat within Area 2 required to facilitate the Closure Works as required by the Closure Strategy, would be temporary. The Closure Works are intended to be undertaken in a manner that has been specifically designed to exclude individual GGBF from areas of disturbance, minimise the duration of disturbance and provide improved movement corridors following completion of the Closure Works, consistent with the GGBF Management Plan.
Mortality of GGBF individuals	To minimise the potential for the Project to result in mortality of GGBF individuals, it is proposed to install frog fencing prior to commencement of earthworks to exclude GGBF from Area 2. Following installation of the fences, frog surveys would be undertaken by experienced ecologists to inspect for any remaining frogs within the Works areas. Periodic inspection of fence integrity and the absence of frogs would be required throughout the Works period. The GGBF Management Plan details the required actions to be undertaken if a frog is discovered within the Works area, and all site workers would be inducted into the process.
Changes in the salinity of Pond water which is likely to favour the growth of chytrid fungus	Modelling has demonstrated that changes in hydro-salinity associated with the capping of Area 2 would be confined to Deep Pond. Deep Pond's existing salinity levels are outside the optimum chytrid protection levels 57.8% of the time. However, surveys undertaken by UoN identify Deep Pond as being utilised by the GGBF, including for breeding. Despite the existing salinity levels in Deep Pond being outside the optimum chytrid protection levels, substantive work was undertaken to minimises changes in salinity within the KIWEF drainage network and specifically Deep Pond through implementation of an alternative capping solution for Area 2. The environmental effects associated with the Project are expected to represent a small change (9.9% increase in time spent outside the optimum chytrid protection range) to the existing conditions, and are characterised as being slightly wetter and fresher.
Introduction of *Gambusia* to the breeding ponds	The Project would not increase the likelihood of *Gambusia* being transferred throughout the existing network of ponds. The Area 2 capping works are occurring on lands elevated and hydraulically isolated from the existing GGBF breeding habitat. Further, the movement corridors within Area 2 Capping Works would not provide a migratory pathway which would facilitate the distribution of Gambusia. Area 2 works will not alter the hydraulic connectivity between the surrounding ponds that would introduce the Gambusia into surrounding Gambusia free ponds. Further the Area 2 design directs water flows into Deep Pond which remains Gambusia infested through all years surveyed by UoN.

Potential Impact	Proposed Measure
Significant impacts to the HEW Ramsar site	As noted by DoEE, the GGBF is identified as a critical ecosystem component of the HEW Ramsar Site. Critical components and processes for the HEW Ramsar Site includes the GGBF and hydrology (tidal regime and freshwater inflows) which is a major influence on the distribution and extent of saltmarsh and mangroves (Brereton, R. and Taylor-Wood, E. 2010). As the capping of Area 2 would have limited influence on the hydrology of the HEW Ramsar Site (due to proximity and the significant other influencing water sources), any significant impacts to the HEW Ramsar Site from the Project would be primarily associated with the habitat and lifecycle of the Kooragang Island GGBF population. The results of the UoN GGBF monitoring indicate that the previously remediated Area 1 and Area 3 have successfully been inhabited by GGBF including observed breeding. UoN has also stated that there has been no observed negative effect to the GGBF population resulting from the capping of Area 1 and Area 3. The impacts associated with construction of the Area 2 works are temporary and the site will be shaped and revegetated to facilitate movement corridors consistent with the GGBF Management Plan and as such no long-term detrimental impacts to the GGBF population is anticipated. Further, the Project will contain contaminants that were historically deposited, minimising the potential for transportation into the HEW Ramsar Site. Overall the Project would avoid significant impact to the HEW Ramsar Site and likely provides benefits.

The work completed to predict and minimise impacts to the Kooragang Island GGBF population and the HEW Ramsar Site has demonstrated that the Project is unlikely to have a significant impact to these matters of national environmental significance, and may benefit the Kooragang Island GGBF population through the provision of movement corridors which would provide suitable habitat to encourage the movement of frogs across Area 2 to the surrounding pond networks.

Through incorporation of five key environmental and socio-economic features (described above) into the Project design and management commitments, potential impacts to the Kooragang Island GGBF population would be appropriately mitigated. Through detailed investigation and planning of capping design, the impacts to the Kooragang Island GGBF population and consequently the HEW Ramsar Site, have been minimised whilst still achieving the objectives of the Closure Strategy and mitigating the potential migration of contaminants from Area 2.

CONTENTS

LIST OF FIGURES

LIST OF TABLES

APPENDICES

Appendix 1
Referral of Proposed Action – KIWEF – Area 2 Closure Works

Appendix 2
Response to request for information

Appendix 3
DoEE Additional information Requirements

Appendix 4
DoEE further additional information Requirements

Appendix 5
SMEC Hydrological Investigation and Modelling

Appendix 6
Summary of the Impact and benefit to the Green and Golden Bell Frog (Litoria aurea) and its Habitat – University of Newcastle

Appendix 7
KIWEF Area 2 Stakeholder Consultation Register

Appendix 8
Environmental Management Plan Sub Plans(Revegetation and Water Quality)

1. INTRODUCTION

Ramboll Australia Pty Ltd (Ramboll) has been engaged by the Hunter Development Corporation (HDC) on behalf of the State of NSW (the State), for the preparation of a Preliminary Documentation Package (PDP). This PDP has been prepared to support an application for a Controlled Action Approval and in response to the request for further information from the Commonwealth Department of Environment and Energy (DoEE) for the Kooragang Island Waste Emplacement Facility (KIWEF) Rationalised Area 2 Closure Works (the Project). The regional location is identified in **Figure 1-1**.

1.1 Project Background

The KIWEF is located on the western portion of Kooragang Island. The KIWEF is bordered by the South Arm of the Hunter River to the south, the Newcastle Coal Infrastructure Group (NCIG) and Port Waratah Coal Service (PWCS) coal loading facilities to the east and PWCS rail infrastructure and Ash Island to the north and west (see **Figure 1-2**).

The KIWEF was operated as a solid waste landfill by BHP during operation of the Steelworks. It operated under Environment Protection Authority (EPA) Environment Protection Licence (EPL) 6437, however ceased operating as a landfill in 1999 following closure of the Steelworks. An agreement is in place with the EPA to close the KIWEF subject to the conditions of the Notice to Surrender the EPL (the Surrender Notice).

Previous Concept Structure Plans and Capping Strategies were prepared for the KIWEF by Robert Carr and Associates in 2004 and 2007. The capping strategy was subsequently revised by GHD (2009) in the *Revised Final Landform and Capping Strategy* (the Closure Strategy) to reflect the various developments occurring on the KIWEF being undertaken by various parties. This included a section of KIWEF known as Area 2 (see **Figure 1-2**).

At the time that a Variation of the Conditions of Surrender was granted, Area 2 included a section proposed for the PWCS Terminal 4 (T4) Project that would form part of the area's capping. The T4 Project area is shown in **Figure 1-2**. The T4 Project received bilateral approval in December 2015. While the T4 Project gained approval, there is uncertainty as to its construction. Due to these delays capping of Area 2 is required to proceed separately to the T4 Project. The Area 2 Closure Works have therefore been designed to be sympathetic to the proposed T4 Project, which was achieved through the design of temporary features that would be removed by the T4 Project if it commences.

KIWEF is one of the more significant remaining habitats of the Green and Golden Bell Frog (GGBF) (*Litoria aurea*), which is listed as a threatened species under both NSW and Federal legislation. It inhabits the fresh and brackish water wetlands within the landfill as well as other similar habitat within the industrial area of Kooragang Island. KIWEF is also situated in the lower reaches of the Hunter River Estuary, much of which is a declared Ramsar site, also protected by Federal Government *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). The Ramsar site is located approximately 300 m north of Area 2 and is demonstrated in **Figure 1-2**.

This PDP has been prepared for submission to the DoEE to support an application for a Controlled Action Approval and in response to the DoEE request for information and request for further information dated 6 January 2017 and 1 February 2018 respectively.

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FIGURE 1-1 Regional Location

EPBC Referral Preliminary Documentation Package

KIWEF Area 2 Closure Works

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FIGURE 1-2 Project Locality

EPBC Referral Preliminary Documentation Package
KIWEF Area 2 Closure Works
Hunter Development Corporation

2. THE PROJECT

The purpose of the Project is the closure of Area 2 at the KIWEF which would require capping and rehabilitation of approximately 36 hectares as shown in **Figure 2-1**. The Project includes the installation of drainage and sediment controls, capping and re-contouring of waste emplacement areas and rehabilitation to a stable and self-sustaining final landform.

In recognition of the potential impacts of the Project on the federally listed GGBF and Hunter Estuarine Wetland (HEW) Ramsar Site, a Referral (ERM 2015) was submitted to DoEE for the Project in March 2016. The Referral has been included in **Appendix 1**. Further information was provided to DoEE in September 2016 in response to request for additional information dated 2 May 2016. The *Response to Request for Information* (ERM 2016) is included in **Appendix 2**. In December 2016 DoEE determined the Project to be a Controlled Action (EPBC Ref: 2016/7670). the State received a letter regarding the Controlled Action on 6 January 2017 requesting additional information to facilitate adequate assessment of the Project (**Appendix 3**).

Since the Referral was submitted to DoEE, the State has undertaken a detailed review of the Project to rationalise the impacts to matters of national environmental significance to the extent practical. The outcomes of this investigation are described in **Section 2.3**.

A meeting was held between DoEE and the State on 29 November 2017 to discuss the developments in the Project scope following the DoEE determination of the Controlled Action and it was agreed that a variation to the Project encompassing the rationalised Project components proposed by the State was required in accordance with section 156A of the EPBC Act. In a letter dated 1 February 2018, the DoEE requested further additional information be provided to facilitate adequate assessment of the additional Project components (**Appendix 4**).

As requested by DoEE in the letter of 6 January 2017, **Section 2.1** provides an updated version of the detailed Project Description and **Section 2.3** specifically highlights the additional Project components which have been identified to better facilitate the Project. The Project components are identified in **Figure 2-2**.

2.1 The Project

Condition 4a of the Surrender Notice (as varied in May 2013 and April 2014) issued by the EPA requires that the Project be undertaken in accordance with the following documents:

- The Closure Strategy (GHD 2009)
- *Green and Golden Bell Frog Management Plan – Kooragang Island Waste Emplacement Facility Closure Works* (Golder Associates 2011)
- *Materials Management Plan - Kooragang Island Waste Emplacement Facility* (RCA Australia 2012)

The capping methodology is dictated by Condition 4h of the Surrender Notice, which requires validation that closure has been implemented in accordance with Chapter 7 of the Closure Strategy and other relevant conditions of the Surrender Notice. In doing so the Surrender Notice specifies that the mitigation measures within the documentation and management reports listed above form an inherent part of the Project.

Chapter 7 of the Closure Strategy requires that the construction of the capping would involve the following tasks:

- Establishment of erosion and sedimentation controls and construction of sedimentation basins as required.
- Remove any vegetation and strip the top 100 mm of soil. Stockpile for re-use if deemed suitable.
- Construct trunk drainage where required.

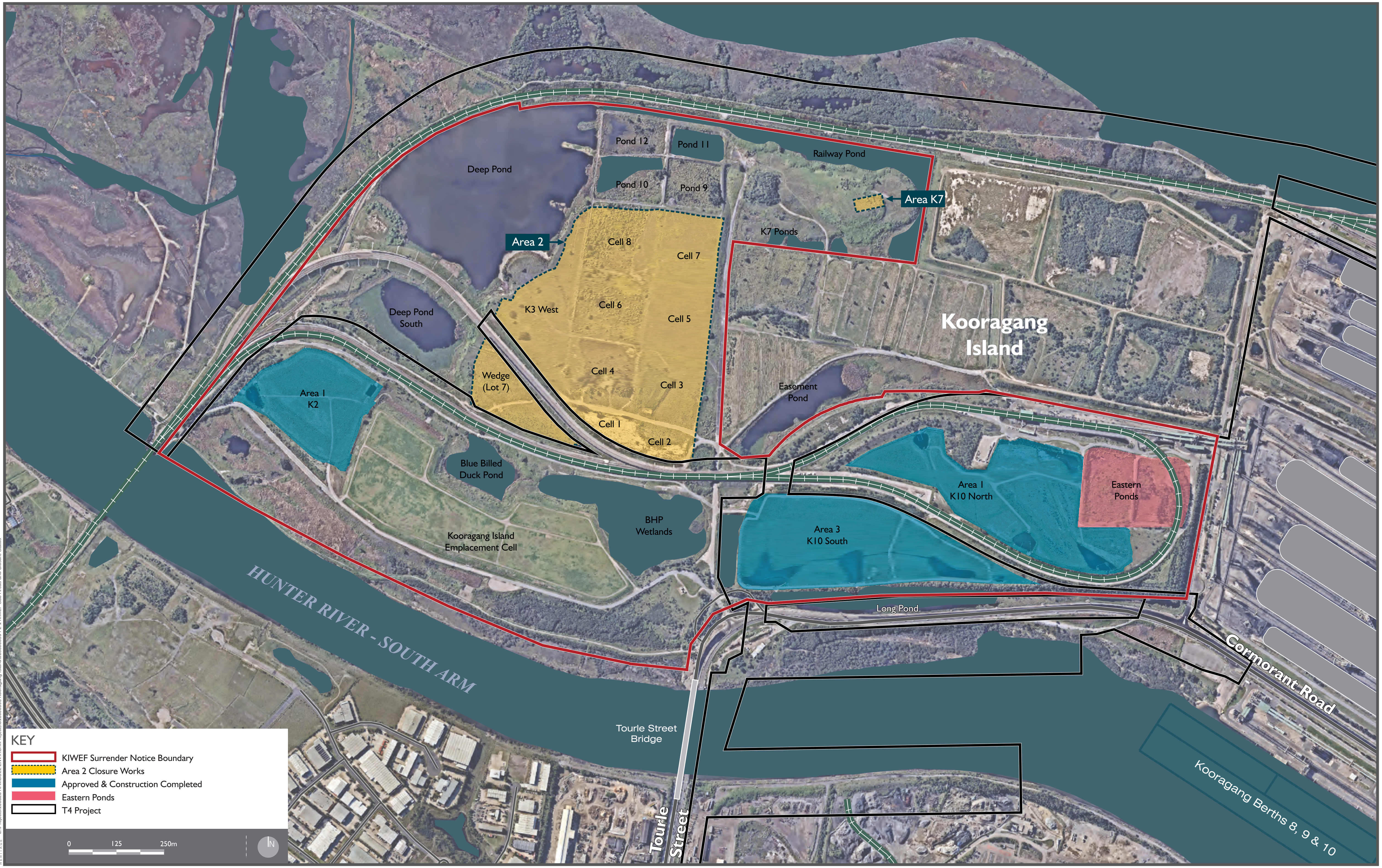

FIGURE 2-1 KIWEF Surrender Notice Closure Status

EPBC Referral Preliminary Documentation Package
KIWEF Area 2 Closure Works
Hunter Development Corporation

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FIGURE 2-2 Project Components

EPBC Referral Preliminary Documentation Package
KIWEF Area 2 Closure Works
Hunter Development Corporation

- General earthworks (cut/fill) activities to establish the regraded surface with a final minimum 1% grade. If the stripped 100mm of soil is suitable for re-use, stockpile for use in revegetation, or screen and incorporate as fill for grading. Cut from within this area, if deemed suitable, may be used as fill and capped. Additional fill shall be sourced from an approved offsite source. Earthworks shall be compacted in accordance with the Technical Specification which would be developed by the design team. Topsoil and revegetate the disturbed area if no further capping material is required.
- Place 0.5m capping material over the regraded surface at a final minimum 1% grade. Compact the capping material to achieve a maximum permeability of 1x10-7m/s. Construction of the capping layer "*should ensure that the final surface provides a barrier to the migration of water into the waste (or fill), controls emissions to water and atmosphere, promotes sound land management and conservation, and prevents hazards and protects amenity*" (EPA, 1998).
- Topsoil 100mm thick using stockpiled surface soils or imported topsoil and revegetate the disturbed area.
- Any cut material which is considered geotechnically unsuitable to use as fill shall be relocated to the proposed unsuitable material containment area.
- Any cut material which is significantly contaminated (as defined by the Materials Management Plan (RCA Australia 2012)) shall be either disposed of offsite or relocated to a nominated containment cell area as directed by the principal (the State).

Proposed departures from the above standard approach to capping as described by the Closure Strategy are presented in **Table 2-1**.

Table 2-1: Departures from Standard Capping Approach

Area	Recommended Strategy
K3	In areas identified as suitable GGBF habitat, including the area bordering the freshwater wetlands, capping would be undertaken up to within 30m of the identified habitat area, with the exception of the area located near K3/1W (which would be capped) and then revegetated. No regrading, capping or other disturbance would be undertaken within other GGBF habitat areas.
K5 (excluding Cell 5)	To reduce the risk of migration of hydrocarbons around Cell 5, the permeability is to be reduced to 1x10-8 m/s for a zone (nominally 10- 20m) adjoining the Cell 5 area.
Cell 5	Minor re-contouring of the area would be undertaken by placing compacted coal washery reject to a minimum grade of 1% to shed surface water away from the north, west and southern boundaries of the Geosynthetic Clay Liner and tie into proposed surface levels of the adjoining capped areas.
K7	Placement of Virgin Excavated Natural Material or other material as approved in the EPL in the area where only 1.6m of fill has been placed, to provide at least 3m cover over asbestos disposal areas.

2.2 Temporary Basin Design

As discussed in **Section 1.1**, the Project is located within the approved footprint of the T4 Project and as such the design must remain sympathetic to the future approved development of Area 2. However, SMEC and researchers at the University of Newcastle (UoN) have collaborated to enable the design of the movement corridors in Area 2 to incorporate features which are conducive to GGBF foraging and breeding. Key elements identified as being desirable were:

- A mosaic of ponds providing connectivity across the site
- Provision of at least one basin capable of providing a constant water source year round
- Established vegetation surrounding the basin with a preference for species diversity
- Terrestrial vegetation providing cover between ponds

- Non-symmetrical basin design

The design of the Area 2 Closure Strategy has incorporated to the extent possible these key elements to maximise the probability that the GGBF population would access Area 2. Key design features related to GGBF to be considered in the detailed design include the following:

- Basins constructed with variation in the banks to provide a variety of habitat features. **Figure 2-3** provides a conceptual example of bank variations and general basin design principles to be considered.
- Revegetation of aquatic species would be targeted at the preferred vegetation structure of the GGBF, likely to include species such as *Juncus* sp., *Typha* sp., *Bolboschoenus* sp., *Phragmites* sp. and *Shoenoplectus* sp. which all occur across the KIWEF currently. Further discussion of both aquatic and terrestrial vegetation is provided in **Section 7.4**.

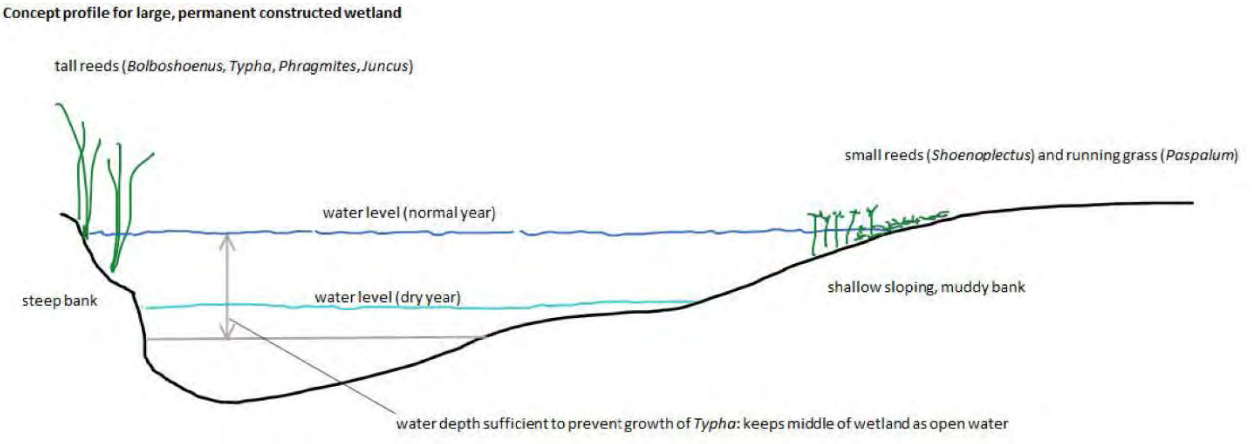

Figure 2-3: Conceptual Basin Design Principles

2.3 Proposed Project Changes

Following extensive investigations to rationalise the Project and minimise the potential impacts to the GGBF and HEW Ramsar Site, the State identified Project changes which result in either cost and time efficiencies, improved environmental outcomes, or both. HDC advised Ramboll that consultation with the EPA confirmed:

- The general support of the EPA for the proposed changes to the Project; and
- That the Project is not materially different to the approved Closure Strategy and therefore does not require a modification to the Surrender Notice.

As noted above, it was agreed with DoEE that a request to vary the Project in accordance with Section 156A of the EPBC Act should be submitted with this PDP. The letter accompanying this PDP highlights the legislative framework surrounding the variation. The following Project changes are discussed in greater detail throughout the subsequent sections and are identified on **Figure 2-4**:

- Opportunities to capitalise on existing *in-situ* capping across Area 2
- Implementation of a Modified cap within the area identified as the Low Area
- Capitalise on existing capping materials across Kooragang Island, including:
  - source capping or fill material from the Peninsula Borrow Pit
  - source capping or fill material from the K7 Pre-load Area
  - source capping or fill material from the HRRP Borrow Pit
- Gain access to the Wedge (Lot 7) and the Peninsula Borrow Pit via an upgraded existing haul road and other additional access tracks

Further detail on the management of GGBF individuals and habitat directly associated with these changes is provided in **Section 11.1**.

Project 318000395
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Version H

FIGURE 2-4 Variation Components

EPBC Referral Preliminary Documentation Package
KIWEF Area 2 Closure Works
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2.3.1 *In-situ* Capping

the State identified areas of the KIWEF where *in-situ* materials may already form an effective cap, which if avoided, would minimise the ground disturbance requirements potentially protecting areas of GGBF foraging habitat as well as providing time and cost savings. SMEC, on behalf of the State, undertook an investigation to determine whether the existing *in-situ* materials satisfied the objectives of the Closure Strategy (the Area 2 Rationalisation Investigation).

The Area 2 Rationalisation Investigation identified that the *in-situ* capping material (see **Figure 2-4**) which forms the southern section of Area 2 would meet the requirements of the Closure Strategy with minor modifications such as drainage improvements, and placement of a revegetation layer using material won from the KIWEF. As such, the reduced disturbance of this area and reduced material transfer requirement has been included in the assessment of impacts included throughout **Section 6** to **Section 11**.

2.3.2 Modified cap within the Low Area

During the hydro-salinity modelling of the Area 2 Capping Works it was identified that construction of the standard capping design as presented in the Closure Strategy and described in **Section 2.1** would result in an increase in stormwater runoff into Deep Pond (see **Figure 2-1**). Modelling indicated that the increase in stormwater runoff would result in changes to the hydrological regime within Deep Pond, specifically regarding water depth and salinity levels.

As such, the capping design was reconsidered to minimise hydrological changes and it was determined that the Low Area (see **Figure 2-2**) could be designed to retain a significant portion of the stormwater runoff within a deep soil layer overlaid by an evapotranspiration layer referred to as a Modified Cap. The Modified cap provides the opportunity to decrease the amount of stormwater run-off through greater retention and increased transpiration. The benefits of the proposed Modified cap are further discussed in **Section 6.1** and presented in full in the *KIWEF Area 2 Closure Works Area 2 Hydro Salinity Model* (SMEC 2018) included in **Appendix 5**.

The remainder of Area 2 would be capped using the standard capping design as presented in the Closure Strategy and described in **Section 2.1** with the exception of the areas specified for *in-situ* capping in **Section 2.3.1**.

2.3.3 Peninsula Borrow Pit

The Peninsula Borrow Pit provides suitable material to be utilised for capping or fill during the Project. The exclusive use of this material in the Wedge West area (see **Figure 2-4**) provides the opportunity to minimise additional disturbance resulting from required haul road improvements. This is further discussed in **Section 2.3.6**.

The removal of material from this area for fill or capping purposes may be undertaken as part of the Project. As such, the disturbance of this area has been included in the assessment of impacts included throughout **Section 6** to **Section 11**.

The methodology for extraction of this material would include:

- Completion of an ecological survey prior to and during the establishment of frog fencing around the perimeter of the works area
- Establishment of erosion and sedimentation controls
- Ecological survey of the fenced site to confirm all GGBF’s (and other fauna) captured inside the frog fencing are removed prior to commencement of ground disturbance activities
- Strip topsoil and excavate capping/fill materials
- Reshaping and stabilisation of Peninsula Borrow Pit footprint

2.3.4 K7 Preload Stockpile

The K7 Preload Stockpile provides suitable material to be utilised for capping or fill material during the Project. The removal of material from this area for fill or capping purposes may be undertaken as part of the Project. As such, the disturbance of this area has been included in the assessment of impacts included throughout **Section 6** to **Section 11**. The methodology for extraction of this material would include:

- Completion of an ecological survey prior to and during the establishment of frog fencing around the perimeter of the works area
- Establishment of erosion and sedimentation controls
- Ecological survey of the fenced site to confirm all GGBF (and other fauna) captured inside the frog fencing are removed prior to commencement of ground disturbance activities
- Vegetation removal, strip topsoil and stockpile
- Due to proximity to GGBF habitat (that is the Ponds surrounding Area K7) excavation of the approximately 33,000 m^3 of capping/fill materials would be conducted from the top down and the centre out, to minimise erosion and sediment control concerns
- Reshaping and stabilisation of K7 Preload Stockpile footprint

2.3.5 Source capping or fill material from the HRRP Borrow Pit

the State identified a potential additional source of material which may be suitable for use in capping or fill material which is known as the HRRP Borrow Pit and is identified on **Figure 2-4**. The take of material from this area for fill or capping purposes would be undertaken as part of the Project. As such, the disturbance of this area has been included in the assessment of impacts included throughout **Section 6** to **Section 11**. The methodology for extraction of this material would include:

- Completion of an ecological survey prior to and during the establishment of frog fencing around the perimeter of the works area
- Establishment of erosion and sedimentation controls
- Ecological survey of the fenced site to confirm all GGBF's (and other fauna) captured inside the frog fencing are removed prior to commencement of ground disturbance activities
- Strip topsoil, excavation of identified available volume of capping/fill materials
- Backfilling of HRRP Borrow Pit with geotechnically and environmentally suitable materials to existing ground level

2.3.6 Wedge (Lot 7) and Peninsula Borrow Pit haul road and other access tracks upgrade

To access the Wedge (Lot 7) and Peninsula Borrow Pit areas, the State would need to upgrade existing access tracks. Access roads follow the alignment shown on **Figure 2-2.** Detailed design for the access track upgrades would be undertaken as part of a design and construct component of the construction contractor package and would be required to meet the ARTC rail exclusion zone requirements.

The expected upgrades to the access track include the installation of a pipeline and culvert across an existing drainage swale and some minor recontouring works. These works are necessary to enable heavy and long vehicles movements along the existing access track that would otherwise be unsafe. The pipeline and culvert would avoid changes to the overland flows and of water under the haul road and the recontouring will enable long vehicles suitable gradient and clearances to traverse an elevated portion of the existing track. The proposed location of the upgrade works is shown of **Figure 2-4**. The extent of the works would involve the following tasks at a minimum:

- Completion of an ecological survey prior to and during the establishment of frog fencing between the active works area and identified GGBF habitat (noting the proximity of the works area to an active rail corridor).
- Establishment of erosion and sedimentation controls
- Ecological survey of the fenced site to confirm all GGBF's (and other fauna) captured inside the frog fencing are removed prior to commencement of ground disturbance activities

- Placement and compaction of additional material to flatten the access haul road and enable long vehicles (for example machinery floats) to safely traverse the access track
- Placement of a pipeline and culvert across drainage swale
- Backfilling around pipeline
- Installation of rail safety infrastructure to illustrate rail exclusion zones and limit proximity to rail line of large vehicles travelling along the access route

3. PROJECT FEATURES

The Project is an environmental improvement project with the key objective of mitigating the future migration of site contaminants associated with the former use of the landfill to the broader environment.

Inherent to the Project design are five key environmental and socio-economic features, being:

1. Containment of contaminants within a capped area to mitigate future migration to the surrounding natural environment, in accordance with the Surrender Notice
2. Minimisation of direct impact to existing GGBF Habitat
3. Minimisation of indirect impacts to existing GGBF Habitat
4. Sympathetic to other approved projects in Area 2
5. Creation of movement corridors across Area 2 designed to satisfy the provisions of the Surrender Notice and section 5.3 of the GGBF Management Plan

As noted previously the KIWEF ceased operating as a landfill in 1999 following closure of the Steelworks and an agreement is now in place with the EPA to close the landfill and relinquish EPL 6437, subject to the conditions of the Notice to Surrender the Licence described within the:

- *Approval of the Surrender of a Licence* (1111840) (DECCW 2010)
- *Variation to Surrender Notice* (1510956) (EPA 2013)
- *Variation to Surrender Notice* (1510063) (EPA 2014)

The following sections provide justification for the above Project features.

3.1 Containment of contaminants

The Closure Strategy identified a range of contaminants that could be present at the KIWEF, including:

- Ammonia
- Total Petroleum Hydrocarbons (TPH)
- Phenols
- Cyanide
- Heavy metals
- Polycyclic Aromatic Hydrocarbons (PAH)
- Asbestos
- Acids and bases

These contaminants are associated with fill materials placed across the KIWEF. While contamination across the KIWEF has generally been identified as being a low to moderate risk to human health or environment, specific areas were identified as containing significantly contaminated material that may pose a higher level of risk to human health or the environment and warrant more stringent management. Locations of significantly contaminated material (presented in **Figure 3-1**), relevant to Area 2 include:

- The former hydrocarbon disposal cell, Cell 5 (also referred to as Pond 5)
- Identified impacts in surrounding monitoring wells (BHe53, BHe50 and K3/1W)
- Asbestos burial trenches located within K7
- Basic Oxygen Slag (BOS) areas within K3 and K10

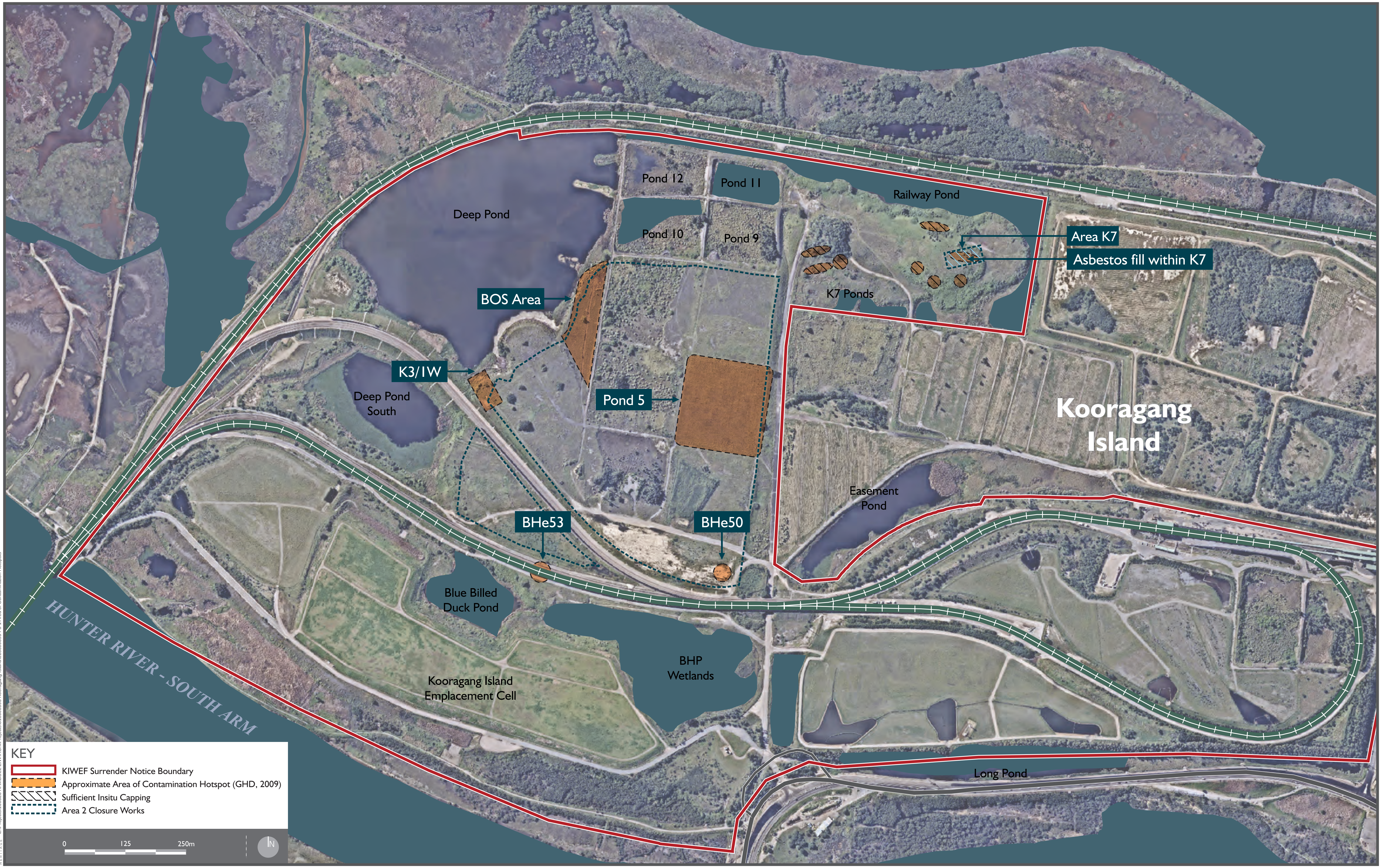

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FIGURE 3-1 Areas of Contamination Hotspots - Area 2

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KIWEF Area 2 Closure Works
Hunter Development Corporation

As such, the State considers the Project to be essential in protecting the surrounding aquatic environments, including the HEW Ramsar Site, from impacts associated with the historic contaminants that have been deposited at the KIWEF as well as meeting the regulatory requirements of the Surrender Notice.

The function of the capping is to create a low permeability layer across Area 2 that would significantly reduce infiltration and recharge to groundwater within the Area 2 Fill aquifer, resulting in a reduction in the flow velocity of groundwater which has been exposed to the contaminants identified previously in this section. The capping would also reduce the opportunity for infiltrating surface waters to interact with contaminants that are present within Area 2, limiting the volume of impacted water from reaching the groundwater system which in this location flows in the direction of the HEW Ramsar Site (refer **Section 6.1.1.2** for further discussion).

Overall, the Project is considered an environmental improvement by limiting the potential for contaminants that currently exist within the groundwater beneath Area 2 from migrating towards the surrounding GGBF habitat ponds (for example Deep Pond or HEW Ramsar Site); and reducing the quantity of clean surface waters that encounter existing contaminants that may be present beneath the site from reaching the groundwater.

3.2 Minimisation of direct impact to existing GGBF Habitat

The annual report on the *2013/2014 Field Season for Green and Golden Bell Frog on Kooragang Island* (NCIG 2015) which was used to inform the Referral for the Project, identified an area where GGBF were detected calling in the central eastern margins of Deep Pond, indicating that breeding habitat may be present. The identified potential breeding habitat is located on the western boundary of Area 2 and is identified in **Figure 3-2**. Due to the identification of this area of potential breeding habitat proximate to Area 2, a 30m buffer has been established along the western edge of Area 2, except for two areas with identified contamination issues (monitoring well K3/1W and BOS Area, refer to **Figure 3-1**) that require capping. No regrading, capping or other disturbance would be undertaken within the 30m buffer zone or other identified known or potential GGBF breeding habitat areas.

Any loss of potential GGBF foraging habitat within Area 2 required to facilitate the Closure Works as required by the Closure Strategy, would be temporary. The Closure Works are intended to be undertaken in a manner that has been specifically designed to exclude individual GGBF from areas of disturbance, minimise the duration of disturbance and provide an improved habitat outcome through the creation of movement corridors following completion of the Closure Works.

Further, in a study undertaken by UoN (2018) of other areas of the KIWEF that have previously been closed in accordance with the Closure Strategy (known as Area 1 and Area 3 (see **Figure 2-1**) and referred to as Phase 1 closure works) (see **Appendix 6**), UoN state that "*there is no evidence of negative impacts upon the Kooragang Island Litoria aurea population as a result of the Phase 1 closure works*" and suggest that the "*long-term research data indicates that the HDC Phase 1 closure works have improved potential population persistence for L. aurea.*" Therefore, while Area 2 would be temporarily disturbed, there is evidence to suggest that following the implementation of the Closure Strategy the habitat would be utilised by GGBF.

Through detailed investigation and planning of capping design, the maximum avoidance of potential GGBF habitat has been attained whilst still achieving the objectives of the Closure Strategy and mitigating the potential migration of contaminants from Area 2.

3.3 Minimisation of indirect impacts to existing GGBF Habitat

As noted in **Section 3.2** there is an area of potential GGBF breeding habitat along the central eastern margins of Deep Pond, adjacent to Area 2. DoEE also raised concern regarding the hydrological changes to Deep Pond and the corresponding impact to the Kooragang Island GGBF population. As such, a substantial amount of work has been undertaken by SMEC with regard to capping design to minimise potential water quality impacts to Deep Pond associated with the Project. This work has resulted in the design of a stable final landform which minimises direct rainfall runoff into Deep Pond, with the primary goal of mitigating a reduction in the salinity concentrations of Deep Pond.

SMEC (2018) completed a detailed discussion outlining the quantitative assessment of the changes to the hydrology and water quality of Area 2. The SMEC investigation primarily focussed on Deep Pond as the major receiving water body from the Area 2 works, however also considered the potential effects on the surrounding ponds. This report is provided in **Appendix 5** and is summarised in **Section 6.1**.

3.4 Sympathetic Design to other Approved Projects

A key objective of the Closure Strategy (GHD 2009) for the KIWEF was to "*revise the existing capping strategy on both eastern and western sections of the site, taking into consideration known proposed developments and review of new information in relation to geotechnical and environmental constraints*."

The Controlled Action is for the closure of a historical waste emplacement facility within a port side industrial area. The Controlled Action would not preclude Area 2 from being subject of future development, being either the approved PWCS T4 development or other potential future land use (which would be subject to appropriate State and Commonwealth approvals). In contrast, the Closure Work would facilitate reuse of Area 2 for economic purposes due to the installation of a hydraulic barrier between the emplaced materials and potential future occupants of the site. It would do this while minimising the effects on the existing GGBF habitat within the KIWEF and the adjoining HEW Ramsar Site, and providing movement corridors for GGBF populations. This is achieved through the considered and purposeful capping design described in **Section 2**.

The economic and social matters are discussed further in **Section 8**.

3.5 Provision of temporary potential habitat for the KIWEF GGBF population

As noted in **Section 3.4**, the Project must not preclude any approved future development within Area 2 and therefore permanent basins are not provided. The Project does however aim to provide a network of movement corridors within the capping of Area 2 which would be designed to act as suitable temporary GGBF habitat, until approved future site developments were commenced.

Studies undertaken by UoN in other areas of the KIWEF that have previously been closed in accordance with the Closure Strategy (known as Area 1 and Area 3) indicate that constructed movement corridors in these areas are being utilised by the GGBF population consistent with the measures documented under the GGBF Management Plan (see **Appendix 6**).

UoN also provides advice on improvements which could be made to the design and construction of the drainage lines and movement corridors. Key habitat improvements include the provision of:

- Aquatic and terrestrial vegetation
- Deep, permanent, open wetlands

This advice has been incorporated to the extent possible within the design of the Project including development of a Revegetation Management Plan, discussed further in **Section 7.4**.

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Project	318000395
Drawn	TO
Approved	BS
Date	20/07/2018
Version	F

FIGURE 3-2 Previously Identified Known and Potential GGBF Habitat (ERM, 2015)

EPBC Referral Preliminary Documentation Package
KIWEF Area 2 Closure Works
Hunter Development Corporation

4. DOEE REQUESTS FOR INFORMATION

The key challenges of the Project, as identified by the delegate of the Minister for the Environment and Energy (issued 2 December 2016), is management of the potential for significant impacts to MNES including:

- Green and Golden Bell Frog *(Litoria aurea)* (vulnerable) – significant impact on the GGBF is likely due to the removal of foraging habitat, potential mortality of GGBF individuals, likely changes in the salinity of pond water which is likely to favour the growth of chytrid fungus, and potential introduction of *Gambusia* to the breeding ponds.
- Hunter Estuary Wetland (HEW) Ramsar site - the GGBF is identified as a "critical ecosystem component" of the HEW Ramsar site and the proposed action is likely to impact on the habitat and lifecycle of the Kooragang Island GGBF population.

A significant amount of work has been undertaken by the State in consultation with UoN and various technical consultants to both understand the significance of potential impacts of the Project and develop effective mitigation measures for the identified risks. The potential impacts and proposed management measures, which are the outcomes of these studies, are summarised in **Table 4-1** and inform the detailed discussion presented in **Section 6** to **Section 11**.

Table 4-1: Summary of Identified Potential Impacts and Proposed Measures to Address Risk

Potential Impact	Proposed Measure
Removal of foraging habitat	Any loss of GGBF foraging habitat within Area 2 required to facilitate the Closure Works as required by the Closure Strategy, would be temporary. The Closure Works are intended to be undertaken in a manner that has been specifically designed to exclude individual GGBF from areas of disturbance, minimise the duration of disturbance and provide improved movement corridors following completion of the Closure Works, consistent with the GGBF Management Plan.
Mortality of GGBF individuals	To minimise the potential for the Project to result in mortality of GGBF individuals, it is proposed to install frog fencing prior to the commencement of earthworks to exclude GGBF from Area 2. Following installation of the fences, frog surveys would be undertaken by experienced ecologists to inspect for any remaining frogs within the Works areas. Once the fencing is installed and the construction area surveys have been undertaken to the satisfaction of the experienced ecologists, the Works can proceed without seasonal restrictions. Periodic inspection of fence integrity and the absence of frogs would be required throughout the Works period. The GGBF Management Plan details the required actions to be undertaken if a frog is discovered within the Works area, and all site workers would be inducted into the process.
Changes in the salinity of Pond water which is likely to favour the growth of chytrid fungus	Modelling has demonstrated that changes in hydro-salinity associated with the capping of Area 2 would be confined to Deep Pond. Deep Pond's existing salinity levels are outside the optimum chytrid protection levels 57.8% of the time. However, surveys undertaken by UoN identify Deep Pond as being utilised by the GGBF, including for breeding. Despite the existing salinity levels in Deep Pond not being ideal, substantive work was undertaken to inform the hydro-salinity model which has resulted in a recommended capping solution for Area 2 which minimises changes in salinity within the KIWEF drainage network and specifically Deep Pond. The environmental effects associated with the Project are expected to represent a small change (9.9% increase in time spent outside the optimum chytrid protection range) to the existing conditions, and are characterised as being slightly wetter and fresher.

Potential Impact	Proposed Measure
Introduction of *Gambusia* to the breeding ponds	The Project would not increase the likelihood of *Gambusia* being transferred throughout the existing network of ponds. The Area 2 capping works are occurring on lands elevated and hydraulically isolated from the existing GGBF breeding habitat. Further, the movement corridors within Area 2 Capping Works would not provide a migratory pathway which would facilitate the distribution of Gambusia. Area 2 works will not alter the hydraulic connectivity between the surrounding ponds that would introduce the Gambusia into surrounding Gambusia free ponds. Further the Area 2 design directs water flows into Deep Pond which remains Gambusia infested through all years surveyed by UoN.
Significant impacts to the HEW Ramsar site	As noted by DoEE, the GGBF is identified as a critical ecosystem component of the HEW Ramsar Site. Critical components and processes for the HEW Ramsar Site includes the GGBF and hydrology (tidal regime and freshwater inflows) which is a major influence on the distribution and extent of saltmarsh and mangroves (Brereton, R. and Taylor-Wood, E. 2010). As the capping of Area 2 would have limited influence on the hydrology of the HEW Ramsar Site (due to proximity and the significant other influencing water sources), any significant impacts to the HEW Ramsar Site from the Project would be primarily associated with the habitat and lifecycle of the Kooragang Island GGBF population. The results of the UoN GGBF monitoring indicate that the previously remediated Area 1 and Area 3 have successfully been inhabited by GGBF including observed breeding. UoN has also stated that there has been no observed negative effect to the GGBF population resulting from the capping of Area 1 and Area 3. The impacts associated with construction of the Area 2 works are temporary and the site will be shaped and revegetated to facilitate movement corridors consistent with the GGBF Management Plan and as such no long-term detrimental impacts to the GGBF population is anticipated. Further, the Project will contain contaminants that were historically deposited, minimising the potential for transportation into the HEW Ramsar Site. Overall the Project would avoid significant impact to the HEW Ramsar Site and likely provides benefits.

Table 4-2 and **Table 4-3** detail the DoEE requests for information and reference where each has been addressed within this PDP.

Table 4-2: DoEE Information Requirements

Requirement	Where Addressed
A. RELEVANT IMPACTS	
Hydrology and Water Quality	
1. Provide a quantitative assessment of the changes to the hydrology and water quality of Area 2, and adjacent GGBF habitat and breeding ponds potentially affected by the proposed action. The assessment must include	
a. A detailed description of the pre-capping hydrological environment, including:	
i. A site water balance quantifying surface water and groundwater contribution and inundation regimes in GGBF habitat and breeding ponds, under a range of rainfall conditions.	**Section 6.1.1**
ii. Diagrams showing pre-capping surface water and groundwater flow paths across Area 2, including K7 and adjacent ponds, under low, median and high rainfall conditions. Diagrams should show any culverts or overflow locations that may hydraulically connect cells or ponds.	**Section 6.1.1**
iii. Water quality of GGBF habitat and breeding ponds, partitioned by seasonal variation, including the percentage of time that pond water quality is within the optimal range for protection of GGBF from chytrid fungus.	**Section 6.1.1**
b. Post-capping drainage design, including the location and capacity of drainage channels, culverts, bunds and discharge points.	**Section 6.1.2**
c. An assessment of the proposed action’s impacts on hydrology and water quality, which:	
i. Describes and quantifies the proposed actions impact on hydrology, flow and inundation regimes, and water quality identified in steps 1(a)(i-iii) above.	**Section 6.1.3.1**
ii. Assesses the cumulative impacts of the proposed action and Area 1 and 3 remedial works on the hydrology and water quality of GGBF habitat and breeding ponds.	**Section 6.1.3.2**
Any assumptions or uncertainties in quantifying the pre-capping and/or post-capping hydrological or water quality environment, and their implications for the study must be clearly documented.	
2. Section 5 of the Additional Information (ERM, 2016) (provided at the project referral stage), presents research results which indicate that saline ponds (between 1,650 µs/cm - 2,900 µs/cm (tadpoles) or 4,100 µs/cm (adult GGBFs)) provide protection for amphibians against infection by chytrid fungus. However, maintenance of pre-capping salinity levels within identified GGBF habitat and breeding ponds is not proposed as a mitigation measure for the proposed action, unless a decline in the broader population is observed and the capping of Area 2 is determined to be the cause. The Department considers	

Requirement	Where Addressed
monitoring and maintenance of salinity concentrations at the optimal chytrid protection threshold range is important for the maintenance of these GGBF populations.	
a. Please provide the rationale for your proposed approach to monitor population decline rather than the protective precursor salinity levels of the relevant habitat. Please assess the relative risk that population monitoring, versus salinity monitoring, presents to the viability of the Kooragang Island GGBF population.	**Section 6.2.1**
b. Taking into account the results of the investigations from Steps 1 and 2(a), please identify any additional design, mitigation or management measures needed to minimise impacts on the Kooragang Island GGBF population due to altered hydrology and/or water quality, including whether salinity concentration and water temperature monitoring should be considered as a trigger for mitigation action, prior to any GGBF decline.	**Section 6.2.2**
Timing of the Construction Works	
3. Please provide details of the timing of construction works in relation to the key lifecycle stages of the GGBF.	**Section 6.3**
Impacts on the Kooragang Island GGBF Population	
4. Taking into account the results of investigations provided by Steps 1-3 above, please assess the proposed action's impacts to the Kooragang Island GGBF population. Please note that, following application of avoidance and mitigation measures, if the residual impacts to the Kooragang Island GGBF population are significant, an appropriate offset package will be required in accordance with the EPBC Act Environmental Offsets Policy 2012 available at: www.environment.gov.au/epbc/publications/epbc-act-environmental-offsets-policy. Please contact the Department for further advice on offsets if you consider they may be required.	**Section 6.4**
Hunter Estuary Wetland Ramsar Site	
5. Please assess the impacts of the proposed action as well as the cumulative impact of the capping works for Areas 1 & 3 and Area 2, on the HEW Ramsar site, with particular reference to the GGBF as a critical ecosystem component of the Ramsar site. Please also assess any other relevant aspects of the HEW's ecological character which are likely to be significantly impacted by the proposed action.	**Section 6.5**
B. PROPOSED AVOIDANCE, MITIGATION AND MANAGEMENT MEASURES	
6. Please provide a detailed water quality monitoring plan for the proposed action (consolidated into one chapter/section), which includes monitoring in the ponds that provide habitat for the GGBF. The plan should include details of the methods, locations, frequency, and duration of the monitoring program, investigation triggers, contingency measures and corrective actions	**Section 7.1**

Requirement	Where Addressed
7. Please provide the aspects of the Newcastle Coal Infrastructure Group (NCIG) GGBF monitoring program that will be adopted for the proposed action, including the locations, methods, frequency and duration of monitoring. Please describe the method and criteria that will be used to determine whether the proposed action has contributed to a recorded decline in the GGBF population.	**Section 7.2**
8. To prevent the spread and establishment of Gambusia, the GGBF Management Plan (Golder Associates, 2011) states that standing water should not be transferred between waterbodies. However, it is stated on page 15 of the Additional Information, Item 4, that measures that may be implemented to mitigate the impact of hydro-salinity changes include: a. release of standing surface water of suitable quality from sedimentation basins into the affected pond(s) b. provision of water into affected ponds from clean site aquifers to adjust the pond's water quality and water level c. re-direction of surface runoff from the capped site by using temporary berms and diversion channels into or away from affected ponds d. re-direction of standing surface waters from other suitable ponds into the affected pond(s). Please provide the Department with an assessment of the likelihood and significance of introducing Gambusia to the breeding ponds if these mitigation measures are employed. If the proposed action is likely to increase the risk of introducing Gambusia, please provide mitigation measures to minimise/avoid the risk to the GGBF.	**Section 7.3**
9. Please provide a monitoring and management plan for the revegetation area, which includes performance criteria, investigation triggers and contingency measures.	**Section 7.4**
C. ECONOMIC AND SOCIAL MATTERS	
10. The PDP must provide information on the relevant economic and social impacts of the action. Consideration of economic and social matters should include a discussion of the action's impacts in the local, regional and national context.	**Section 8**
D. ENVIRONMENTAL RECORD OF PERSON(S) PROPOSING TO TAKE THE ACTION	
11. The information provided must include details of any proceedings under a Commonwealth, State or Territory law for the protection of the environment or the conservation and sustainable use of natural resources against: a. The person proposing to take the action; b. For an action for which a person has applied for a permit, the person making the application. If the person proposing to take the action is a corporation, details of the corporations environmental policy and planning framework must also be included.	**Section 9**

Requirement	Where Addressed
E. OUTCOMES-BASED CONDITIONS	
12. Outcomes-based conditions may apply to your project in accordance with the Department's Outcomes-based Conditions Policy 2016 and Outcomes-based Condition Guidance 2016. Outcomes need to be specific, measurable and achievable, and should be based on robust baseline data. a. Please provide specific environmental outcomes to be achieved, and reasoning for these with reference to relevant Recovery Plans, Conservation Advices, Threat Abatement Plans, and the HEW's Ramsar ecological character statement. b. For each proposed outcome provide: i. the risks associated with achieving the outcomes ii. the measurability of the outcome, including suitable performance measures iii. appropriate baseline data upon which the outcome has been defined and justified iv. the likely impacts that the proposed outcome will address v. demonstrated willingness and capability of achieving the outcome vi. the level of knowledge about the protected matter or its surrogate, upon which outcomes were based vii. commitments to independent and periodic audits of performance towards achieving outcomes viii. discussion of the likely level of control that the proponent will have over achieving the outcome ix. discussion of the appropriateness of any surrogates for protected matter outcomes x. details of proposed management to achieve the outcome, including, but not limited to performance indicators, periodic milestones, proposed monitoring and adaptive management, and record keeping, publication and reporting processes.	**Section 10**

Table 4-3: DoEE Further Information Requirements

Requirement	Where Addressed
Assessment of any likely significant impacts on Green and Golden Bell Frog (GGBF) and Hunter Estuary Wetland (HEW) Ramsar Site from removal of stockpile and borrow pit material including the proposed haulage routes.	**Section 11.1**
Discussion and analyses of the need for capping cell 5 – Will this prevent/ slow impacts of hydrocarbon contamination on GGBF and HEW Ramsar Site.	**Section 3.1** and **11.2**
Inclusion of hydro-salinity modelled data	**Appendix 5** and summarised in **Section 6.1** and **Section 11.3**
Assessment of salinity and contamination of hydrocarbon to the GGBF and HEW Ramsar Site by Hunter Development Corporation, which includes: 1. measures to avoid or reduce impact 2. mitigation and management measures 3. likelihood of impacts.	**Section 11.4**
Discussion of how capping works and any mitigation measures are sympathetic to other EPBC conditions for proposals on the site, e.g. the T4 approval (EPBC 2011/6029).	**Section 3.4** and **11.5**
Inclusion of relevant results from the University of Newcastle on GGBF population monitoring and behavioural research.	**Section 11.6** and **Appendix 6**
Discussion of establishment of new GGBF breeding habitat (occurrences of successful breeding including driest breeding season).	**Section 11.7** and **Appendix 6**

5. CONSULTATION REGISTER

A detailed stakeholder consultation register is provided in **Appendix 7**. This details consultation undertaken to date regarding the Project. Key stakeholders which have been consulted with to date include:

- The Port of Newcastle Lessor (Port Lessor)
- Hunter Development Corporation (HDC)
- Port of Newcastle (PoN)
- Newcastle Coal Infrastructure Group (NCIG)
- Port Waratah Coal Service (PWCS)
- Environmental Protection Authority (EPA)
- Department of Environment and Energy (DoEE)
- University of Newcastle (UoN)
- Office of Environment and Heritage (OEH)

6. RELEVENT IMPACTS

This section provides a summary of the key information requirements requested by DoEE and includes a response to each including appropriate reference to sources and attachments as required in the DoEE letter issued 6 January 2017.

6.1 Hydrology and Water Quality

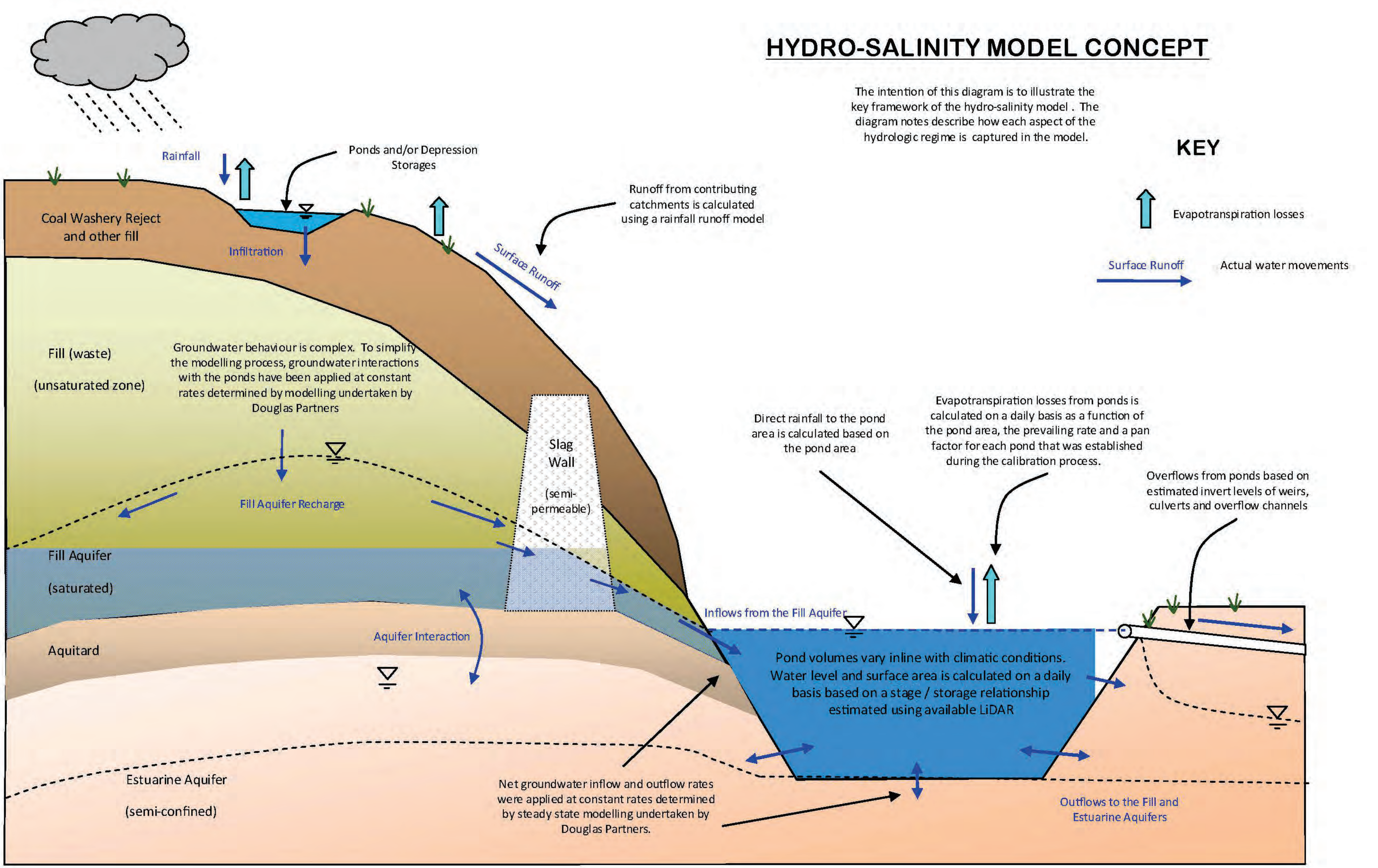
1. *Please provide a quantitative assessment of the changes to the hydrology and water quality of Area 2, and adjacent GGBF habitat and breeding ponds potentially affected by the proposed action. The assessment must include:*
   a) *A detailed description of the pre-capping hydrological environment, including:*
      i. *A site water balance quantifying surface water and groundwater contribution and inundation regimes in GGBF habitat and breeding ponds, under a range of rainfall conditions.*
      ii. *Diagram/s showing pre-capping surface water and groundwater flow paths across Area 2, including K7 and adjacent ponds, under low, median and high rainfall conditions. Diagrams should show any culverts or overflow locations that may hydraulically connect cells or ponds.*
      iii. *Water quality in GGBF habitat and breeding ponds, partitioned by seasonal variation, including the percentage of time that pond water quality is within the optimal range for protection of GGBFs from chytrid fungus.*
   b) *Post-capping drainage design, including the location and capacity of drainage channels, culverts, bunds, and discharge points.*
   c) *An assessment of the proposed action's impacts on hydrology and water quality, which:*
      i. *Describes and quantifies the proposed action's impacts on hydrology, flow and inundation regimes, and water quality identified in steps 1 (a)(i-iii) above.*
      ii. *Assesses the cumulative impacts of the proposed action and Area 1 and 3 remedial works on the hydrology and water quality of GGBF habitat and breeding ponds. Any assumptions or uncertainties in quantifying the pre-capping and/or postcapping hydrological or water quality environment, and their implications for the study, must be clearly documented.*

A quantitative *Area 2 Hydro-Salinity Model* was undertaken by SMEC (2018) to quantify the existing or 'pre-capping' hydrological and hydrogeological environment, the post capping drainage design and the potential impacts to the hydrology and water quality (hereafter referred to salinity, as intended by 1.a)iii.) resulting from the Project.

The hydro-salinity model seeks to replicate the hydro-salinity regime of each pond by modelling the following processes:

- Surface water runoff from contributing catchment areas
- Groundwater inflows into each pond
- Groundwater outflows from each pond
- Surface water flows between ponds and from some ponds to receiving waters
- Evapotranspiration losses from each pond

The Hydro-Salinity Conceptual Site Model is represented in **Figure 6-1** and is described in detail in **Appendix 5**.



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Project	318000395
Drawn	TO
Approved	BS
Date	31/05/2018
Version	A

FIGURE 6-1 Hydro-Salinity Conceptual Site Model

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KIWEF Area 2 Closure Works
Hunter Development Corporation

The model was used to determine whether capping works would affect the following key environmental conditions that are considered important to GGBF populations:

- Pond water level: The inundation regime of a pond is affected if water levels are higher or lower for a period longer than under existing conditions. When considering the effects of the change, modelling adopted the 20th percentile and 80th percentile water level values, referred to as the "trigger values".
- Salinity: When salinity exceeds 2900 µS/cm (1.8 parts per thousand (ppt)) GGBF tadpoles may have difficulty surviving. Salinity levels lower than 1650 µS/cm (1 ppt) provides no protection from the chytrid fungus. When considering the effects of the change, these values (lower bound of 1650 µS/cm and upper bound of 2900 µS/cm) are referred to as the optimum chytrid protection "threshold levels" (SMEC 2018).

The assessment undertaken by SMEC is presented in full in **Appendix 5**. The following sections provide a summary of this assessment.

6.1.1 Pre-capping hydrological environment

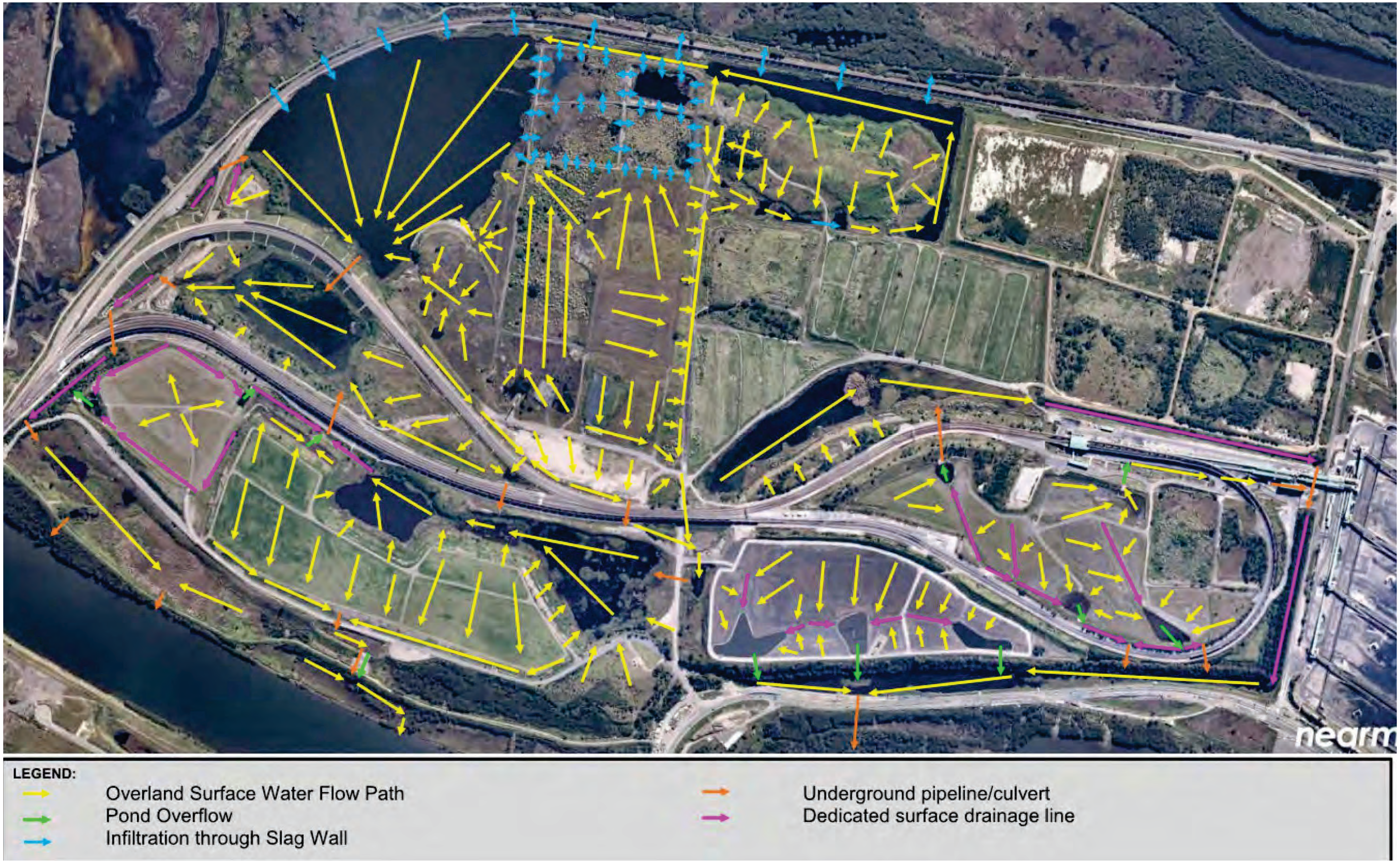
6.1.1.1 Surface Water

The primary water bodies that currently receive surface runoff from Area 2 are Deep Pond and Deep Pond (South) (collectively referred to as Deep Pond). Runoff from minor parts of Area 2 discharge via culverts beneath the NCIG rail line into Blue Billed Duck Pond and BHP Wetlands; while the runoff from Area K7 discharges into Railway Pond. All these ponds ultimately discharge into Deep Pond, as such the surface water assessment is primarily focused on the effects observed to Deep Pond although consideration was also given to the potential effects in the other surrounding ponds. The surface water flow paths across the entire KIWEF are illustrated in **Figure 6-2** and the detailed Area 2 flow paths including hydraulic connections to surrounding catchments are shown in **Figure 6-3**.

In general, the direction of flow across Area 2 is the same under most rainfall conditions, with surface water runoff, flow rates and pond water levels responding to rainfall conditions. Key existing surface water characteristics include the following:

- In very low rainfall events, runoff may not occur
- In high rainfall events, some alternative surface water flow paths from Area 2 may become active. Refer to **Figure 6-3**. The flow directions, however, would generally remain as shown on **Figure 6-2**. This would not provide a migratory pathway for *Gambusia* due to the area being elevated and hydraulically isolated from existing *Gambusia* impacted waters (further discussed in **Section 7.3**).
- **Figure 6-3** indicates that it is possible that runoff, in larger events, may flow into the following (see **Figure 2-1** for pond identification)
  - The southern end of Easement Pond
  - Pond 9

  These represent only occasional flow paths under extreme weather conditions
- A key feature of Area 2 is described as the 'Low Area' (cells 4, 6 and 8) (see **Figure 2-2**). The Low Area is characterised by:
  - Thicker vegetation resulting in increased evapotranspiration
  - Typically contains around 200 mm of weathered 'topsoil' material over a fine coal washery reject material (a sandy SILT) around 1 m thick or greater
  - Rainfall soaks into the weathered upper layer, then migrates laterally until it encounters the porous sub-surface slag walls where it can more readily connect to the groundwater table
  - No obvious surface water outlet under normal rainfall conditions
- Under most rainfall conditions, large sections of Area 2 would continue to drain into the Low Area, where water soaks away. The Low Area, with a surface elevation of around 5m AHD, remains above the water levels in the surrounding ponds, which are typically around 1m AHD

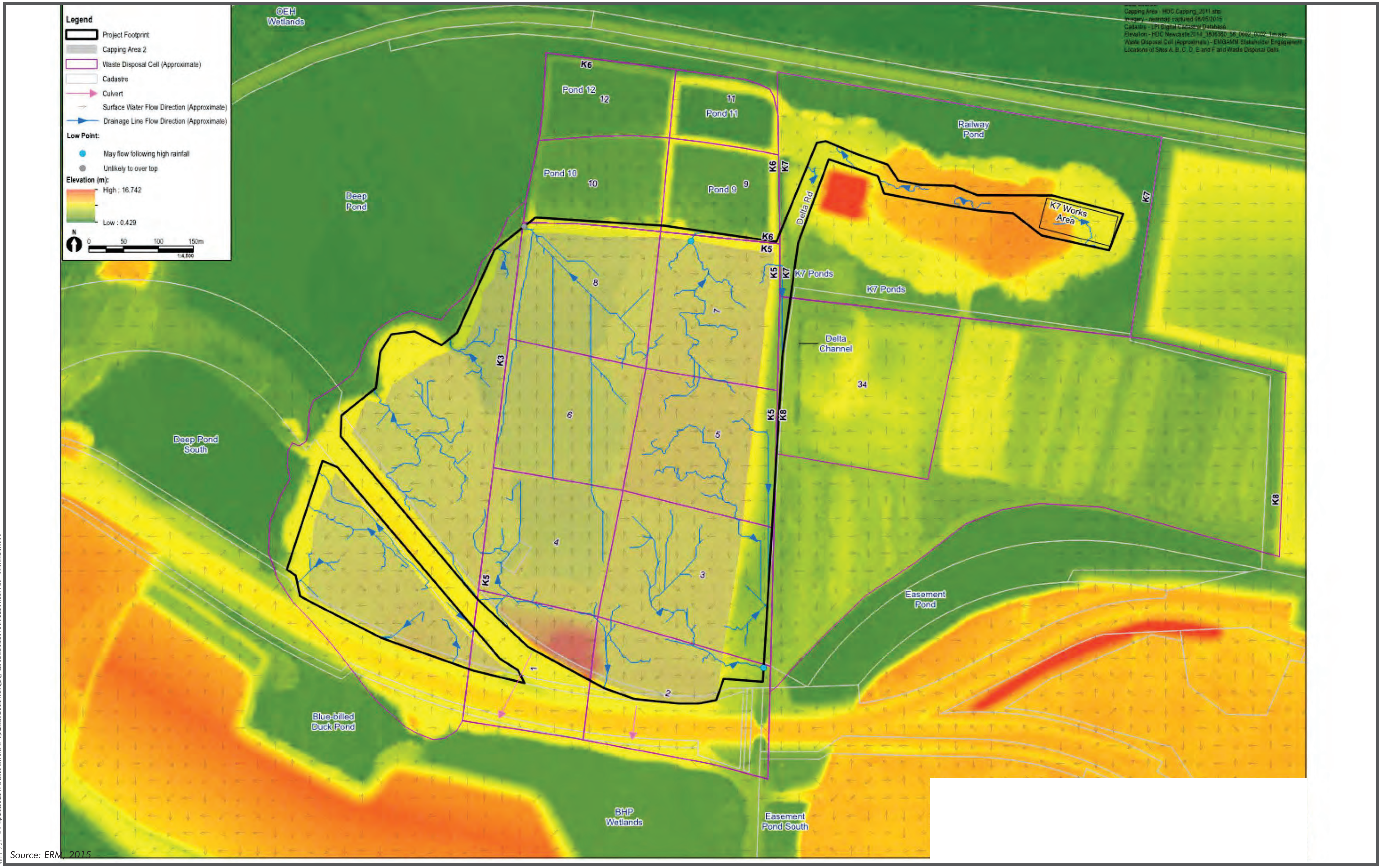


Source: SMEC, 2018

Project	318000395
Drawn	TO
Approved	BS
Date	31/05/2018
Version	A

FIGURE 6-2 Surface Water Flow Paths Across the KIWEF

EPBC Referral Preliminary Documentation Package
KIWEF Area 2 Closure Works
Hunter Development Corporation



Source: ERM, 2015

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Project 318000395
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Date 12/06/2018
Version B

FIGURE 6-3 Surface Water Flow Paths Across Area 2

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KIWEF Area 2 Closure Works
Hunter Development Corporation

6.1.1.2 Groundwater

Previous groundwater assessments undertaken across the KIWEF include:

- Appendix E - Groundwater Assessment for the Environmental Assessment for the Terminal 4 Project (EMGA Mitchell McLennan 2012)
- Response to the Department of Sustainability, Environment, Water, Population and Communities for the closure works for Area 1 and 3 (SMEC 2013)

A conceptual groundwater model is described in the T4 EA (Appendix E Groundwater Assessment). Key elements are outlined below:

- Groundwater beneath the site is present in two principal aquifers: an upper unconfined aquifer within the fill strata (the Fill Aquifer), and a deeper confined aquifer within the estuarine sediments (the Estuarine Aquifer).
- Between the two aquifers there is a layer of soft natural clays, typically between 1m and 15m thick, forming a 'leaky' aquitard that separate the two aquifers, however in some locations the aquitard may be absent.

The previous predicted groundwater contours for the fill aquifer and the estuarine aquifer are presented in **Figure 6-4** and **Figure 6-5** respectively.

Fill Aquifer

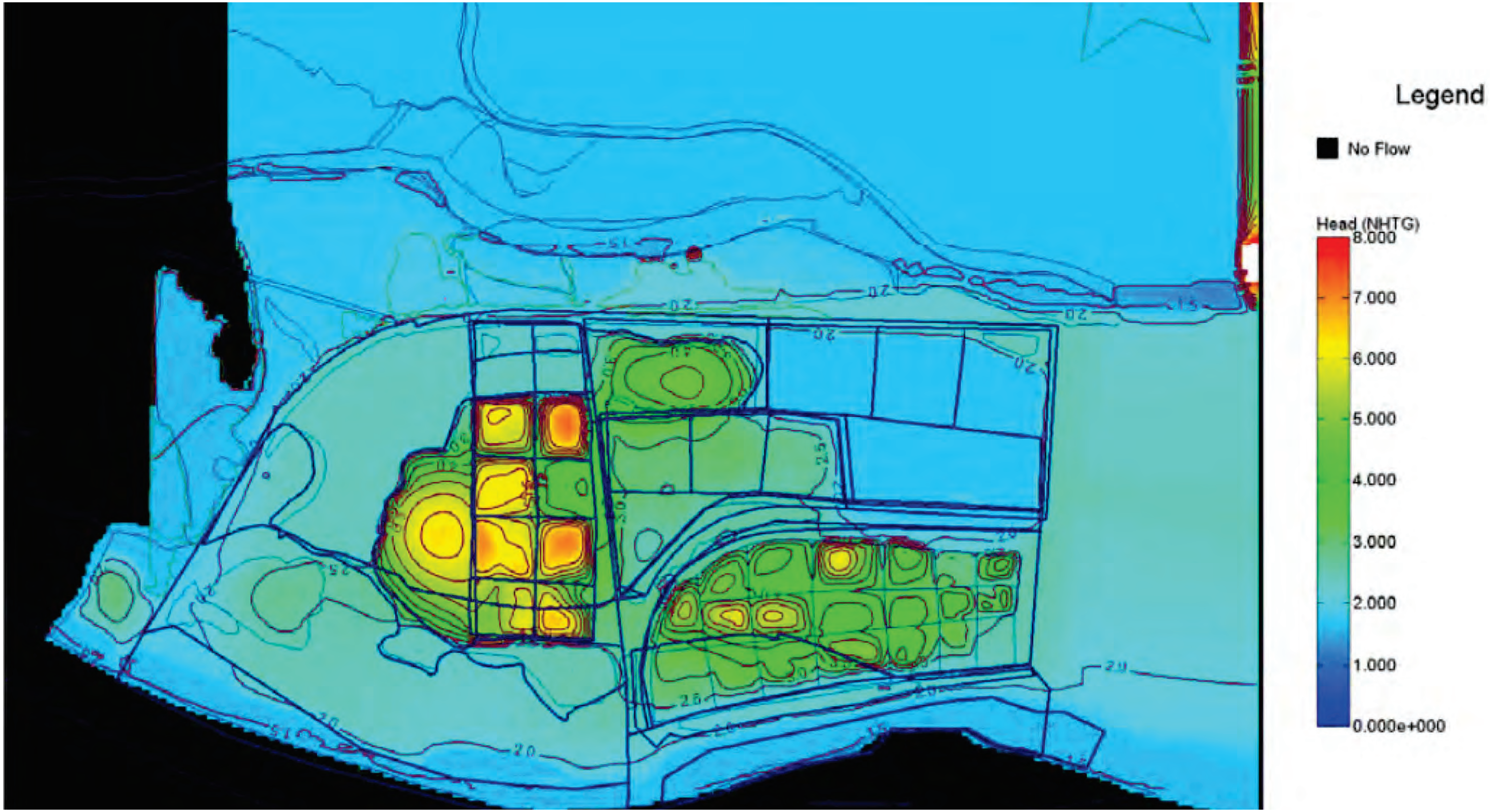
Key characteristics of the Fill Aquifer include the following:

- The fill aquifer is unconfined and the water table fluctuates with the thickness of the aquifer. Groundwater is free to drain to the surface where the water table intersects the surface, such as in drains, ponds or wetlands
- Typically, the waste in the fill aquifer was placed within slag walls, which have moderate to high permeability. The bunds are likely to be more permeable than the waste (fill)
- The Fill Aquifer is recharged by rainfall
- Groundwater in the Fill Aquifer is primarily sub-horizontal, generally flowing towards the closest surface drain features, however some vertical leakage occurs through the underlying clay aquitard
- The surrounding surface water bodies and drains form the boundary of the Fill Aquifer, and the groundwater is generally present as a 'mound' within the Area 2 fill

Estuarine Aquifer

Key characteristics of the Estuarine Aquifer include the following:

- The Estuarine Aquifer is generally confined, which means there is no free water table. The phreatic surface (the height at which water would rise to in a bore connected only to the estuarine aquifer) is above the base of the overlying clay aquitard
- The Estuarine aquifer contains sand of moderate to high permeability
- Groundwater in the estuarine aquifer flows away from a north-south, and east-west ridgeline within the KIWEF. Generally, within Area 2, groundwater flows north, west and south into the Hunter River, and the surrounding tidal wetlands



Source: Douglas Partners, 2013

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Project	318000395
Drawn	TO
Approved	BS
Date	12/06/2018
Version	B

FIGURE 6-4 Previous Predicted Groundwater Contours - Fill Aquifer

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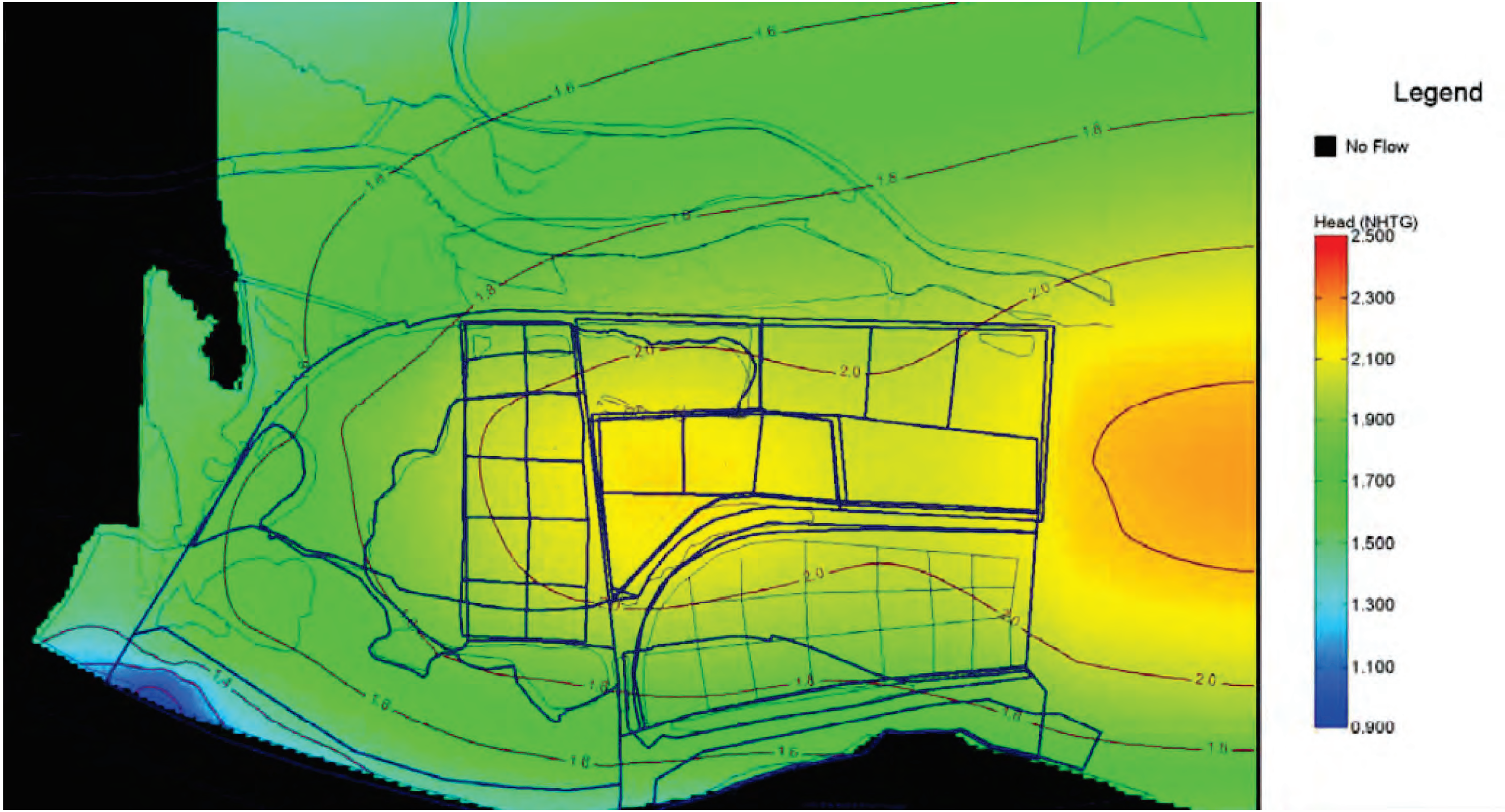
KIWEF Area 2 Closure Works
Hunter Development Corporation



Source: Douglas Partners, 2013

E:\Projects\120323 RAMBOLL ENVIRON\Projects\318000395 Kooragang Island\318000395 F6-5 Existing (Predicted) Groundwater Contours - Estuarine Aquifer

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Project	318000395
Drawn	TO
Approved	BS
Date	12/06/2018
Version	B

FIGURE 6-5 Previous Predicted Groundwater Contours - Estuarine Aquifer

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KIWEF Area 2 Closure Works
Hunter Development Corporation

6.1.1.3 Existing Conditions Summary

SMEC (2018) identified that the KIWEF ponds are not considered to have a seasonal partition, as they may be connected during larger rainfall events (or prolonged periods of rainfall), but remain separated during drying periods. Observations typically indicated that water levels decline faster over summer due to higher evaporation.

Modelling of the existing conditions has indicated that Deep Pond is within the optimum water level range (values as defined by SMEC 2018, section 3.4) 60% of the time. For the remaining 40% of the time:

- 20% of the time, Existing Conditions are below Lower Bound Water Level Value
- 20% of the time, Existing Conditions are above the Upper Bound Water Level Value

Modelling of the existing conditions has indicated that Deep Pond is within the optimum salinity range (threshold levels) only 42.2% of the time. For the remaining 57.8%:

- Existing Conditions are below the optimum chytrid protection threshold level (1,650 µS/cm) 49.3% of the time
- Existing Conditions are above the optimum chytrid protection threshold level (2,900 µS/cm) 8.5 % of the time

Conditions in other ponds are detailed in **Appendix 5**.

6.1.2 Post Capping Drainage Design

The primary aim of the Area 2 Capping Works is to meet the requirements of the EPA approved Closure Strategy. This includes development of a design consistent with the Project objectives and requirements outlined in **Section 2.1**. Further, as a result of: ongoing consultation with DoEE; input from researchers at UoN; and continual refinement of the hydro-salinity model, the design of the Area 2 capping has incorporated additional design features which minimise changes to the hydro-salinity regime of Area 2 and specifically its effect on Deep Pond.

Discussion on the design of the Area 2 capping including: bunds; culverts; and drains, is provided in section 4.2 of **Appendix 5** and will typically be the same as that constructed for Areas 1 and 3. **Figure 6-6** presents the proposed post-capping surface water flow directions. It is important to note that the Area 2 Closure Works will not alter the hydraulic connectivity between the surrounding ponds that could result in the introduction of Gambusia into surrounding ponds that are Gambusia free. Further the Area 2 design directs most water flows into Deep Pond which has been confirmed to be Gambusia infested in all surveys completed by UoN.

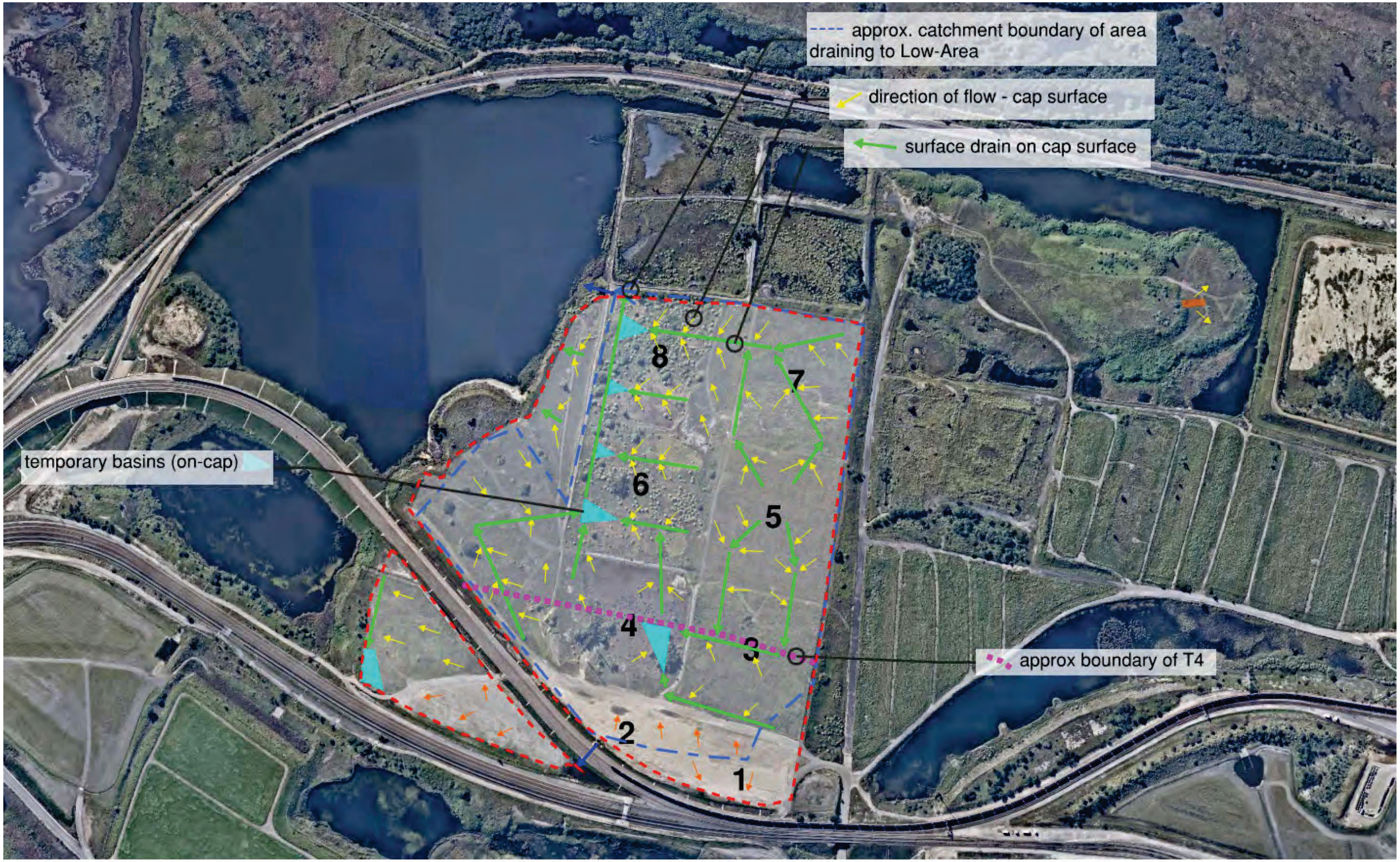
The key feature incorporated into the Area 2 capping design is the 'Modified Cap' proposed to be constructed within the Low Area. The purpose of the Modified Cap is to reduce potential hydro-salinity effects on surrounding ponds through:

- Provision of storage within the cap: via a 500 mm top layer, sourced from the existing low-permeability coal washery reject in this area. The material would not be densely compacted, so would offer deep storage of moisture
- Use of an evapotranspiration layer (in excess of the Closure Strategy requirements) within the Low Area to maximise evapotranspiration losses
- Use of a low permeability layer underneath the coal washery reject and vegetative layer to prevent deeper seepage losses into the fill aquifer
- Provision of a drainage layer, where possible, above the low permeability layer to release water that infiltrates through the top layer into surface drains or receiving water bodies

6.1.3 Predicted Impacts on Hydrology and Salinity

6.1.3.1 Area 2 Impacts

The results of the modelling demonstrate that the implementation of the proposed Area 2 Closure Works (under the Modified Cap design) result in water levels increasing slightly within the receiving water body (Deep Pond), described as slightly 'wetter' than the existing conditions.



Source: SMEC, 2018

RAMBOLL

Hunter Development Corporation

Project	318000395
Drawn	TO
Approved	BS
Date	12/06/2018
Version	B

FIGURE 6-6 Closure Site Drainage Design

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KIWEF Area 2 Closure Works

Hunter Development Corporation

After the capping of Area 2, including the proposed Modified Cap, predicted changes to water quality would result in:

- 32.3% of the time the Predicted Conditions are within the Optimum Water Quality range for chytrid protection, 1,650 µS/cm to 2,900 µS/cm (a -9.9% shift from existing)
- 94.8% of the time, Predicted Conditions are within the optimum conditions for GGBF breeding (<2,900 µS/cm, Tadpole Health Threshold) (a +3.3% shift from existing)

Based on the results of the hydro-salinity modelling, the use of a Modified Cap in the Low Area is the recommended capping solution for Area 2. The environmental effects associated with the Modified Cap are expected to represent a minor change to the existing conditions, and are characterised as being slightly wetter and fresher.

Due to the hydraulic isolation of Area 2 from other ponds across the KIWEF described in **Section 6.1.1.1**, negligible impacts are predicted for other ponds within the KIWEF. Detailed results are presented in **Appendix 5**.

6.1.3.2 Cumulative Impacts

Modelling of the KIWEF indicates no overlapping effects between the previous works (Areas 1 and 3) and the Project. The effects of the Area 2 Closure Works are independent of the previous modelled outcomes and would not exacerbate any of the conclusions of the previous investigation. The previous stages of construction were found to have effects on Easement Pond, Windmill Road Open Channel and Long Pond; while predicted effects associated with the Area 2 works were constrained within Deep Pond.

6.2 Monitoring and Maintenance of Salinity Concentrations

2. *Section 5 of the Additional Information (ERM, 2016) (provided at the project referral stage), presents research results which indicate that saline ponds (between 1,650 µS/cm - 2,900 µS/cm (tadpoles) or 4,100 µS/cm (adult GGBFs)) provide protection for amphibians against infection by chytrid fungus. However, maintenance of pre-capping salinity levels within identified GGBF habitat and breeding ponds is not proposed as a mitigation measure for the proposed action, unless a decline in the broader population is observed and the capping of Area 2 is determined to be the cause. The Department considers monitoring and maintenance of salinity concentrations at the optimal chytrid protection threshold range is important for the maintenance of these GGBF populations.*
   a) *Please provide the rationale for your proposed approach to monitor population decline rather than the protective precursor salinity levels of the relevant habitat. Please assess the relative risk that population monitoring, versus salinity monitoring, presents to the viability of the Kooragang Island GGBF population.*
   b) *Taking into account the results of the investigations from Steps 1 and 2(a), please identify any additional design, mitigation or management measures needed to minimise impacts on the Kooragang Island GGBF population due to altered hydrology and/or water quality, including whether salinity concentration and water temperature monitoring should be considered as a trigger for mitigation action, prior to any GGBF decline.*

Section 5 (Salinity Monitoring and Management) of the *Response to Request for Information* (ERM 2016) provided an outline of the hydro-salinity monitoring program currently undertaken at the KIWEF. Ongoing monitoring of salinity levels has also been incorporated into the *Kooragang Island Waste Emplacement Facility Area 2 Closure Environmental Management Plan* (EMP). The relevant sections of the EMP is provided in **Appendix 8** and is further discussed in **Section 7**. The EMP includes consideration of salinity trends against the population trends identified by UoN.

Should a pattern be identified and validated, an appropriate management trigger and response would be developed.

As noted by DoEE, it has been identified that there is a specific salinity range (between 1,650 and 2,900 µS/cm (tadpoles) or 4,100 µS/cm (adults)) within which the GGBF is afforded a level of protection against the chytrid fungus, which is identified as a key threatening process to the GGBF (DEC 2005). Investigations by UoN indicate that a network of both fresh and brackish (semi-saline) ponds is desirable to support the lifecycle of the GGBF (**Appendix 6**).

6.2.1 Rationale for your proposed approach to monitor population decline

Based on population monitoring across the KIWEF it is considered that salinity is only one GGBF habitat parameter required for the ongoing survival of the population. The following factors also have a significant influence on GGBF populations: the availability of permanent, semi-permanent and ephemeral water bodies; isolation opportunities from *Gambusia*; access to aquatic and terrestrial vegetation; and movement corridors.

Historical salinity monitoring records show that there is significant variation in salinity across the spatial network of ponds within the KIWEF, and in individual ponds. Historical monitoring within Deep Pond identifies that salinity levels in Deep Pond are outside the optimum water quality range for chytrid protection 57.8% of the time. However, GGBF surveys that were undertaken by UoN (and presented in **Appendix 6**) identify Deep Pond as being utilised by the GGBF, including for breeding despite the salinity levels not being ideal for much of the time.

Analysis has been undertaken to interrogate the relationship between salinity levels and utilisation of a pond by the GGBF at the KIWEF. Pond 11 was chosen for the interrogation due to its proximity to the Area 2 Works (located approx. 140m north of Area 2) and the large GGBF population historically observed within Pond 11. The chytrid protection thresholds values were applied to the Pond 11 salinity data for the respective UoN GGBF survey periods. The percentage of time that salinity levels in Pond 11 were recorded within the chytrid protection threshold for the UoN survey periods is presented in **Table 6-1**. Frog occupancy for the corresponding survey periods is presented in **Figure 6-7**.

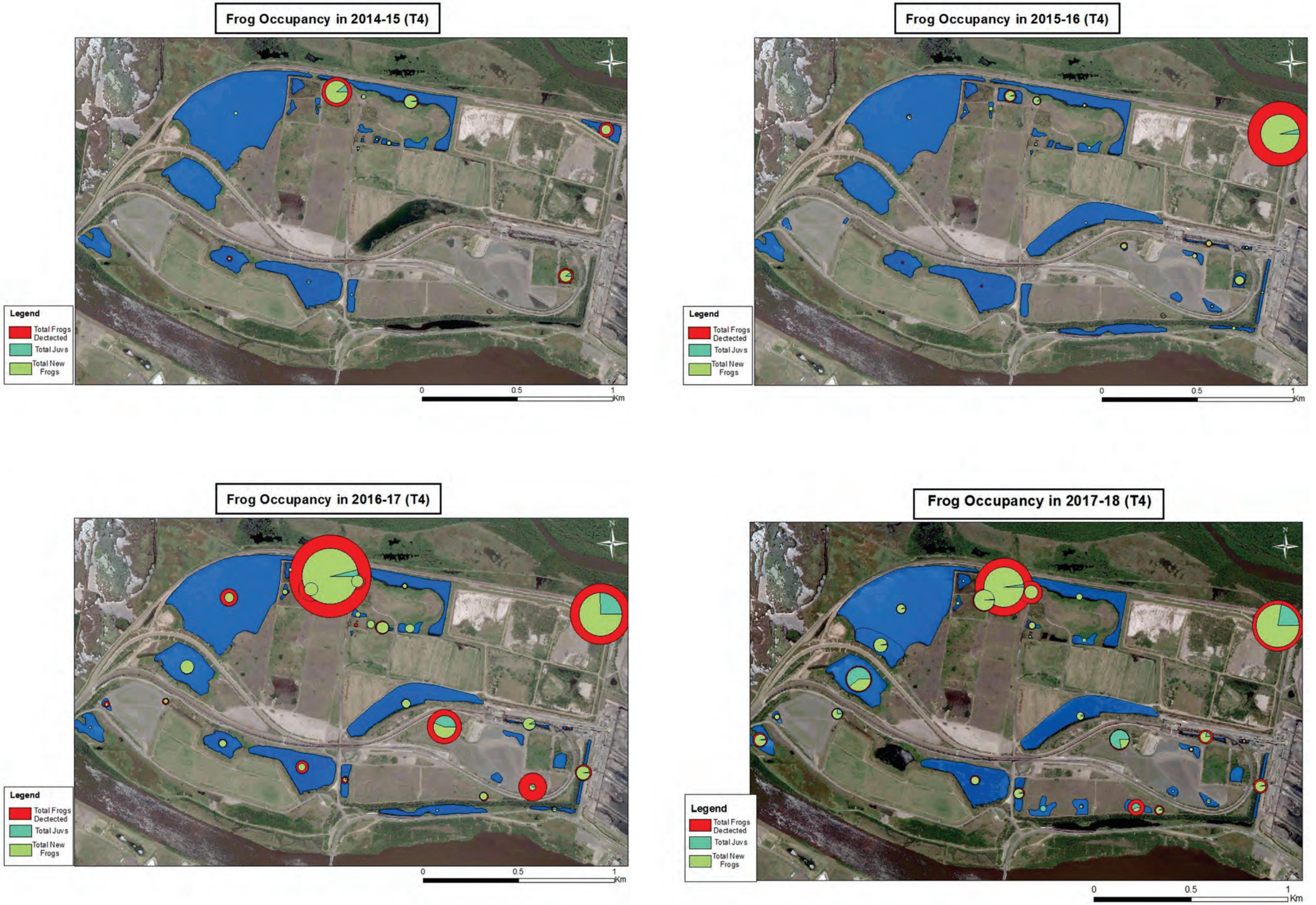
Table 6-1: Pond 11 Optimum Salinity Protection Threshold Data

Period	Below optimum salinity protection threshold	Within optimum salinity protection threshold	Above optimum salinity protection threshold
1/07/17 to 15/11/17	100%	0%	0%
1/07/16 to 30/06/17	85.3%	14.5%	0.1%
3/12/15 to 30/6/16	100%	0%	0%

The data demonstrate that although salinity levels are consistently outside the optimum protection range most of the time, Pond 11 supports both occupancy and breeding. Therefore, implementing a trigger response to a particularly low or particularly high salinity level was considered pre-emptive and potentially unnecessary. **Figure 6-7** also shows a small GGBF population observed in Deep Pond in recent years despite the high percentage of time spent below the chytrid protection threshold (49.3% of the time). The presence of GGBF populations in ponds that maintain salinity levels below the chytrid protection threshold for high percentages of time, appear to confirm that while salinity is an important factor to GGBF population health, it is not a single defining factor that should trigger an action. Rather the approach adopted for the Project aims to consider salinity in conjunction with other factors, as described above.

Further the existing salinity levels presented in Table C8 of **Appendix 5** demonstrate that only two of the presented eight ponds are within the optimum protection range more than 50% of the time. As such, the relative risk of adopting population monitoring, as opposed to salinity monitoring, presents to the viability of the Kooragang Island GGBF population is considered to be low.

However, the State will compare the salinity trends identified by the continuous data loggers (described in **Section 7.1.2**) to the GGBF population trends. Should a pattern be identified and a direct correlation be validated by a qualified ecologist, an appropriate management trigger and response would be developed.



Source: UoN, 2018

FIGURE 6-7 Green and Golden Bell Frog Occupancy

EPBC Referral Preliminary Documentation Package
KIWEF Area 2 Closure Works
Hunter Development Corporation

Project	318000395
Drawn	TO
Approved	BS
Date	26/06/2018
Version	B

6.2.2 Additional Design, Mitigation or Management Measures

Section 6.1.2 provides a discussion of the specific design features incorporated into the Project to minimise both the potential hydrological and the salinity changes within the receiving environment resulting from the Project. It has been determined that there would be a less than a 10% reduction in the percentage of time that the Deep Pond is within the optimum salinity chytrid protection threshold levels, of which only a 3.3% improvement is experienced in the upper threshold level (which would affect tadpoles).

Where possible the State has identified and incorporated additional design features within the Project to minimise impacts on the Kooragang Island GGBF population, as opposed to within post approval commitments. This has been done through the substantial iterative investigative design work completed to date.

Additional mitigation and management measures beyond those relevant to the design are discussed throughout this PDP and are summarised within **Section 7**.

6.3 Timing of the Construction Works

3. *Please provide details of the timing of construction works in relation to the key lifecycle stages of the GGBF.*

GGBF breeding generally takes place from late winter to early autumn, with a peak from January to February after heavy rainfall. The more northern and lower altitude populations (such as at the KIWEF) appear to have a longer breeding season than the more southern and higher altitude populations (DEC 2005). The current timeline for commencement of the Project has minor works (site preparation works such as temporary amenities setup) commencing between November 2018 and February 2019, and major works (ground disturbance works) approximately two months following minor works. It is anticipated that the Works would take approximately 12 months to complete.

The following methodology for management, consistent with the previous construction phases which proved successful (that is, no identified GGBF within the construction footprint after implementation of these measures), of GGBF individuals through seasonal variations and project stages has received the endorsement of the UoN frog specialists.

Installation of frog fencing is proposed prior to commencement of earthworks to exclude GGBF from direct impacts associated with the Works. Following installation of the fences, frog surveys would be undertaken by experienced ecologists to inspect for any remaining frogs within the Works areas. The completion of the clearance surveys during the Spring/Summer period would enable easier identification of GGBF within the exclusion zone, as opposed to undertaking surveys during the Winter period while the GGBF are in torpor. The optimal placement and extent of frog fencing would be discussed and agreed with experienced ecologists following completion of detailed design and construction staging methodology. Full enclosure of the Works area would provide the greatest confidence in frog exclusion.

Once the fencing is installed and the construction area surveys have been undertaken to the satisfaction of the experienced ecologists, the Works can proceed without seasonal restrictions. However, periodic inspection of fence integrity and the absence of frogs would be required throughout the Works period. The GGBF Management Plan details the required actions to be undertaken if a frog is discovered within the Works area, and all site workers would be inducted into the process.

Whilst exclusion of the GGBF from Area 2 would create a temporary barrier against GGBF travel across Area 2, the fencing would naturally guide the frogs towards other existing foraging and breeding areas. The installation of fencing would not result in the exclusion of frogs from any area of known or potential foraging and breeding areas, with the exception of the areas adjacent to Deep Pond within the Works footprint.

6.4 Impacts on the Kooragang Island GGBF Population

4. *Taking into account the results of investigations provided by Steps 1-3 above, please assess the proposed action's impacts to the Kooragang Island GGBF population.*
Please note that, following application of avoidance and mitigation measures, if the residual impacts to the Kooragang Island GGBF population are significant, an appropriate offset package will be required in accordance with the EPBC Act Environmental Offsets Policy 2012 available at:
www.environment.gov.au/epbc/publications/epbc-act-environmental-offsets-policy.
Please contact the Department for further advice on offsets if you consider they may be required.

As discussed throughout this PDP, a substantial amount of research has been undertaken to inform the final landform design, including the provision of temporary movement corridors and development of a Revegetation Management Plan (discussed further in **Section 7.4**). The proposed final landform has been designed to: achieve containment of the site contaminants; provide continuity with the previously rehabilitated Area 1 and Area 3; provide a stable landform; and provide suitable GGBF habitat within the transport routes consistent with the GGBF Management Plan.

The final landform has been specifically designed to provide temporary basins with the necessary separation from those waterways harbouring the *Gambusia* whose predation of the GGBF eggs is identified as a Key Threatening Process (DEC 2005).

Further, surveys undertaken by UoN within the Area 1 and Area 3 Closure Works areas indicate that the Closure Works has improved potential population persistence for the GGBF by providing suitable habitat, variation in inundation regimes, waterbody connectivity and *Gambusia* free basins (see **Appendix 6**). UoN also stated that there is "*no evidence of negative impacts upon the Kooragang Island Litoria aurea population as a result of the [Area 1 and Area 3] Closure Works*".

However, UoN did identify a number of GGBF habitat elements which remain missing from Area 1 and Area 3 relating to provision of deep, permanent open wetlands and aquatic and terrestrial vegetation. This advice has been incorporated to the extent possible within the detailed design of the Project. Further, a Revegetation Management Plan has been developed to maximise the establishment of appropriate vegetation species.

Due to the substantial consideration that has been given to the Kooragang Island GGBF population in the final design parameters and the commitments to relevant and outcome based mitigation and management measures, it is considered that the Project would not result in significant impacts to the GGBF Kooragang Island population and offsets are therefore not considered necessary. This is a conclusion that is supported by the UoN frog specialists.

6.5 Hunter Estuary Wetland Ramsar Site

5. *Please assess the impacts of the proposed action as well as the cumulative impact of the capping works for Areas 1 & 3 and Area 2, on the HEW Ramsar site, with particular reference to the GGBF as a critical ecosystem component of the Ramsar site. Please also assess any other relevant aspects of the HEW's ecological character which are likely to be significantly impacted by the proposed action.*

The Project, by design, would: limit the potential for contaminants within the groundwater beneath Area 2 from migrating towards the surrounding GGBF habitat including Deep Pond and the HEW Ramsar Site; and reduce the quantity of clean surface waters encountering contaminants present within fill materials from reaching the groundwater, thereby minimising the potential for both ecological and human health impacts associated with contamination.

As noted by DoEE, the GGBF is identified as a critical ecosystem component of the HEW Ramsar site. Critical components and processes for the HEW Ramsar Site includes the GGBF and hydrology (tidal regime and freshwater inflows) which is a major influence on the distribution and extent of saltmarsh and mangroves (Brereton, R. and Taylor-Wood, E. 2010). As the capping of Area 2 would have limited influence on the hydrology of the HEW Ramsar Site (due to proximity and the significant other influencing water sources), any significant impacts to the HEW Ramsar Site from the Project would be primarily associated with the habitat and lifecycle of the Kooragang Island GGBF population.

The results of the UoN GGBF monitoring presented in **Appendix 6** indicate that the movement corridors created within the previously closed Area 1 and Area 3 have been successfully utilised by GGBF. As such it is considered likely that the Project will result in further provision of appropriate corridors creating a cumulative benefit with these previously capped areas.

The impacts associated with construction of the Area 2 works are temporary and the site will be shaped and revegetated to facilitate movement corridors consistent with the GGBF Management Plan and as such no long-term detrimental impacts to the GGBF population is anticipated.

Further, the Project will contain contaminants that were historically deposited, minimising the potential for transportation into the HEW Ramsar Site. Overall the Project would avoid significant impact to the HEW Ramsar Site and likely provides benefits.

Throughout this PDP it has been demonstrated that significant work has been undertaken to minimise both direct and indirect impact (though modification to hydrology) to the GGBF population. As noted in **Section 6.4**, it is considered that the Project would not result in significant impacts to the GGBF Kooragang Island population.

7. PROPOSED AVOIDANCE, MITIGATION AND MANAGEMENT MEASURES

These sections provide a summary of the key information requirements related to avoidance, mitigation and management requested by DoEE and includes a response to each including appropriate reference to sources and attachments as required in the DoEE letter issued 6 January 2017.

7.1 Water Quality Monitoring Plan

6. *Please provide a detailed water quality monitoring plan for the proposed action (consolidated into one chapter/section), which includes monitoring in the ponds that provide habitat for the GGBF. The plan should include details of the methods, locations, frequency, and duration of the monitoring program, investigation triggers, contingency measures and corrective actions.*

7.1.1 Annual Surrender Notice Monitoring

A detailed water quality monitoring plan is detailed within the relevant EMP Sub Plan (**Appendix 8**). This section provides a summary of the key methods, locations, frequency, and duration of the monitoring program, investigation triggers, contingency measures and corrective actions.

Water monitoring at the KIWEF is undertaken consistently with the requirements of the Surrender Notice which will be undertaken annually until the Surrender Notice is relinquished or as directed by the EPA. There are 50 monitoring wells and five surface water monitoring locations listed under the Surrender Notice. **Table 7-1** and **Figure 7-1** identify the water monitoring locations.

Table 7-1: Water Quality Monitoring Locations

Aquifer	Monitoring Well ID	Frequency	Method
Fill	336A, 344A, E61S, GHD01N, K10/2, K10/2N, K5/4, K5/5N, K5/6N, K7/1, K7/4N, K8/5E.	Annually	Low flow*
Shallow Estuarine	336B, 344B, BH21S (replacement well for K3/1W), BHe29S, E61D, GHD01S, K10/2NN, K11/1, K11/2E, K11/3E, K12/10E, K12/1W, K12/6, K12/7, K12/9, K5/6NN, K7/2S, K7/4S, K8/5W, K9/2W, K9/3S, K9/4E, NCIG1 (replacement well for K12/3W).	Annually	Low flow*
Deep Estuarine	K11/1S, K11/2W, K11/3W, K12/10, K12/1E, K12/4N, K12/7E, K12/9E, K5/5S, K5/6S, K7/2N, K9/2E, K9/3N, K9/4W, NCIG2 (replacement well for K12/3N).	Annually	Low flow*
Surface Water	KS1/3, KS10/1, KS12/6, KS2/1, KS7/1	Annually	Grab sample

*Monitoring wells should be purged prior to sampling by pumping water from the wells using low flow groundwater methods, where possible. The groundwater should be purged until the physico-chemical parameters, including pH, temperature, EC, redox and dissolved oxygen stabilise to within 10% of three consecutive readings ensuring the drawdown is kept to within 10cm.

RAMBOLL

Project	318000395
Drawn	TO
Approved	BS
Date	20/06/2018
Version	D

FIGURE 7-1 KIWEF Annual Water Quality Monitoring Locations

EPBC Referral Preliminary Documentation Package
KIWEF Area 2 Closure Works
Hunter Development Corporation

The general analytical suite for all monitoring locations under the KWIEF Annual Monitoring Program is to test for the following analytes/parameters:

- Field Parameters - depth to water/product, total depth, pH, electrical conductivity, redox potential, dissolved oxygen and temperature
- Ammonia
- Phenols
- Cyanide - total, weak acid dissociable and free
- Hexavalent chromium
- Molybdenum (dissolved)
- Lead (dissolved)
- Total PAHs

However, there are some exceptions to the analytical suite, and the following analytes are not required at the listed monitoring wells:

- Phenols analysis not required for the following wells:
  - Fill: K10/2, K10/2N, K5/4, K5/5N, K7/4N, K8/5E
  - Shallow Estuarine: K10/2NN, K7/4S, K9/2W, K9/4E
  - Deep Estuarine: K5/5S, K9/2E, K9/4W
- Cyanide (total) analysis is not required for the following wells:
  - Fill: K10/2, K10/2N, K5/5N
- Molybdenum (dissolved) analysis is not required for the following wells:
  - Fill: K5/4, K5/5N, K5/6N
  - Shallow Estuarine: K5/6NN, K7/2S, K9/4E
  - Deep Estuarine: K5/5S, K5/6S, K7/2N, K9/4W
- Lead (dissolved) analysis is not required for the following wells:
  - Fill: K5/4, K5/5N, K5/6N, K7/4N
  - Shallow Estuarine: K5/6NN, K7/2S, K9/4E; K7/2S, K9/2W
  - Deep Estuarine: K5/5S, K5/6S, K7/2N, K9/2E, K9/4W

7.1.2 Continuous data logging of KIWEF Ponds

As described in the Referral for Area 1 and Area 3 Closure Works, continuous data logging is undertaken at potentially affected ponds. Thirteen monitoring points (**Figure 7-2**) have been established in ponds across KIWEF to collect data for:

- Salinity (electrical conductivity)
- Water level
- Temperature

The loggers were installed in December 2015 to record the water parameters in 20 minute increments, and are typically downloaded every 6 months (nominally in November and May of each year).

the State proposes to continue this for an additional two years following completion of the Area 2 Closure Works. This data would be considered against the water quality threshold values (for chytrid protection) and the results of the GGBF population monitoring described in **Section 7.2**.

Project 318000395
Drawn TO
Approved BS
Date 20/06/2018
Version B

FIGURE 7-2 KIWEF Continuous Data Loggers

EPBC Referral Preliminary Documentation Package
KIWEF Area 2 Closure Works
Hunter Development Corporation

7.2 Newcastle Coal Infrastructure Group GGBF monitoring program

7. *Please provide the aspects of the Newcastle Coal Infrastructure Group (NCIG) GGBF monitoring program that will be adopted for the proposed action, including the locations, methods, frequency and duration of monitoring. Please describe the method and criteria that will be used to determine whether the proposed action has contributed to a recorded decline in the GGBF population.*

It is proposed to continue the current GGBF monitoring program following the completion of the Project, to collect information on the dynamics of the GGBF population supported within known and potential habitat areas within the KIWEF and identify any effects of the Project on the GGBF population. The GGBF monitoring program will be limited to surveys within the KIWEF footprint (refer to **Figure 2-1**), including temporary basins constructed during the Project.

Monitoring parameters include:

- GGBF presence/absence, distribution, habitat utilisation, behaviour and abnormalities
- Observations of other frog species distribution, relative abundance and abnormalities
- Presence of gambusia within ponds.
- Survey Details – including the date, time, rainfall (mm), site location, number of observers and sampling effort.
- Climatic Variables – Multiple recording throughout the survey period of temperature, dew point, wet bulb temperature, barometric pressure, average wind speed, maximum wind speed and relative humidity.
- Survey method utilised (a variety of methods are used during the program, including Visual Encounter Survey, Capture-Mark-Recapture, and recording of frog observations ie calling, tadpoles and metamorphs)
- Habitats surveyed and habitat condition
- Photographs taken

The GGBF monitoring program currently adopted by NCIG extends beyond the footprint of the KIWEF, however it is proposed to continue the GGBF monitoring associated with the Project for 2 years post-completion within the KIWEF complex (that is, the Surrender Notice boundary), and 3 yearly thereafter until 2030 (to coincide with the NCIG GGBF monitoring rounds).

Analysis would be completed following each round of monitoring to identify any changes to the GGBF population. Consideration would be given to the influences of the monitoring parameters on the observed population for any given survey. Should a reduction in population be observed which is not consistent with other influencing factors (such as a season of low rainfall), further investigations would be undertaken by experts to assess the possible cause(s) and provide recommendations.

Should a decline in population be attributed to the Project, response measures will be developed and implemented in accordance with the GGBF Management Plan.

Further, as outlined in **Section 6.2.1**, salinity trends will be compared to the GGBF population trends. Should a pattern be identified and a direct correlation be validated by an appropriately qualified ecologist, an appropriate management trigger and response would be developed.

7.3 Water Management and *Gambusia*

8. *To prevent the spread and establishment of Gambusia, the GGBF Management Plan (Golder Associates, 2011) states that standing water should not be transferred between waterbodies. However, it is stated on page 15 of the Additional Information, Item 4, that measures that may be implemented to mitigate the impact of hydro-salinity changes include:*
(a) release of standing surface water of suitable quality from sedimentation basins into the affected pond(s)

(b) provision of water into affected ponds from clean site aquifers to adjust the pond's water quality and water level

(c) re-direction of surface runoff from the capped site by using temporary berms and diversion channels into or away from affected ponds

(d) re-direction of standing surface waters from other suitable ponds into the affected pond(s).

Please provide the Department with an assessment of the likelihood and significance of introducing Gambusia to the breeding ponds if these mitigation measures are employed. If the proposed action is likely to increase the risk of introducing Gambusia, please provide mitigation measures to minimise/avoid the risk to the GGBF.

Appendix E of the UoN *Summary of Impact and Benefit to the Green and Golden Bell Frog (Litoria aurea) and its Habitat* report (**Appendix 6**) identifies waterbodies that were identified to harbour *Gambusia* from 2015 to 2018. These figures demonstrate *Gambusia* presence has varied throughout this period. Localised flooding of the Hunter River in 2015 and 2016 facilitated the dispersal of fish across most wetlands on Kooragang Island. Importantly, during this period the wetlands located within Pond 10 and Pond 12 to the north of the Low Area remained free of *Gambusia*, indicating that overland flow from Deep Pond to these locations during high rainfall events is unlikely to occur.

Low rainfall in the summer of 2016-2017 led to several semi-permanent wetlands drying completely and the subsequent elimination of *Gambusia* in these wetlands. This highlights the importance of having a network of ponds with varying inundation regimes.

UoN identify that the ponds provided within Area 1 and Area 3 remain free of *Gambusia* through elevation and hydrology alteration. As such, these elements have been incorporated into the design of the Project.

A consideration of the mitigation measures described in the previous Referral as applied to the current Area 2 Cap Design, is provided in **Table 7-2**.

Table 7-2: Previously Identified Mitigation Measures as Relevant to the Project

Mitigation Measure	Current Assessment	Likelihood
(a) release of standing surface water of suitable quality from sedimentation basins into the affected pond(s)	Water will only be released from basins on the Area 2 cap that are gambusia free due to elevation and hydraulic barriers.	Very Low
(b) provision of water into affected ponds from clean site aquifers to adjust the pond's water quality and water level	This project does not intend to extract water from the aquifer to address salinity issues.	Nil
(c) re-direction of surface runoff from the capped site by using temporary berms and diversion channels into or away from affected ponds	As noted above there is no gambusia present on the capped surface. Redirection of runoff from the capped surface will therefore not increase likelihood of gambusia transfer	Nil
(d) re-direction of standing surface waters from other suitable ponds into the affected pond(s).	Following the modelling and design process, the current cap design no longer anticipates the need to actively manage salinity levels; and there is no longer an intent to transfer the water between existing ponds.	Nil

Whilst the potential impact of introduction of *Gambusia* to these ponds would be significant if it occurred, there is a Very Low likelihood that the *Gambusia* would be introduced to these waterbodies when using the proposed capping design and managed water transfer program.

7.4 Revegetation Management Plan

9. *Please provide a monitoring and management plan for the revegetation area, which includes performance criteria, investigation triggers and contingency measures.*

A detailed Revegetation and Restoration Management Plan would be developed by the Contractor undertaking the Works all will address the measures outlined with the EMP Revegetation Sub Plan (**Appendix 8**), which includes the recommendations provided by UoN. This section provides a summary of the key performance criteria, investigation triggers and contingency measures.

Appropriate terrestrial and aquatic vegetation is essential to the long-term survival of the GGBF population at the KIWEF. Both aquatic and terrestrial vegetation provides protection from predation and desiccation. The UoN in **Appendix 6** identified vegetation as a key habitat element which remains missing from Area 1 and Area 3.

UoN has identified establishment of low and shallow rooted vegetation around the basins and in the terrestrial corridors is critical in providing safe passage between sheltering and breeding wetlands. UoN states that "Dispersal [of GGBF] is at least partly dependent on connectivity of suitable habitat, and without it migration and population spread is likely to be limited"

The key attributes identified in consultation with UoN to be incorporated into the Revegetation Management Plan, include:

- Aquatic vegetation:
  - Reeds that provide good habitat cover such as *Typha*, *Bolboshoenus*, *Phragmites*, and *Juncus*
  - A mixed community is preferable to single species stands

- GGBF prefer wetlands with sections of open water. Water depth should be deep enough to prevent *Typha* spreading across the entire pond area; the reeds should be mainly at the edge of ponds
- Substrate at edges should be suitable for reed growth (i.e. not too many pebbles, sandbags, etc.)
- Areas of low blanketing vegetation are also desirable for GGBF breeding, for example, *Paspalum* grass and *Shoenoplectus rush*
- Establishing aquatic plants with planting after Closure Works: will maximise structural suitability of wetland to immigrating GGBF as soon as construction is completed

- Terrestrial vegetation:
  - Stabilise new works with sterile millet (or other suitable cover crop)
  - Retain seed bank in fill taken from site (to be reused).
  - Avoid large tree species (as roots may potentially compromise the cap)
  - Allow terrestrial species to re-colonise

Both aquatic and terrestrial vegetation establishment will be visually monitored monthly during the construction maintenance period (indicatively three months post construction post completion) to identify any areas where vegetation is failing to establish. Should vegetation not establish within the construction maintenance period then targeted seeding and/or planting would be undertaken. Biannual cap inspections will be undertaken post-construction completion in accordance with the Surrender Notice (or as directed by the EPA), to ensure the cap surface remains stable and that vegetation roots do not have the opportunity to compromise the cap integrity (that is the removal of any deep rooted plants from capped area).

8. ECONOMIC AND SOCIAL MATTERS

This section provides a summary of the key information requirements regarding social and economic matters requested by DoEE and includes a response to each including appropriate reference to sources and attachments as required in the DoEE letter issued 6 January 2017.

10. *The PDP must provide information on the relevant economic and social impacts of the action. Consideration of economic and social matters should include a discussion of the action's impacts in the local, regional and national context.*

The Controlled Action is for the closure of a historical waste emplacement facility within a port side industrial area. The Controlled Action must not preclude Area 2 from future approved developments. In contrast, the Closure Work would facilitate reuse of Area 2 for economic purposes due to the installation of a hydraulic barrier between the emplaced materials and potential future occupants of the site. It would do this while protecting the existing and proposed GGBF habitat within the KIWEF and the adjoining HEW Ramsar Site.

Whilst the undertaking of the Controlled Action would not contribute significantly to the local or regional economy, the Project would facilitate the availability of Area 2 for employment generating activities, thereby providing benefits to the local and regional economy. The completion of the Closure Work would also enable the KIWEF to be transferred to the Port of Newcastle (as per the requirements of the Port of Newcastle Long-Term Lease). The transfer would enable the Port of Newcastle to pursue future developments at the site, that would currently be obstructed by the incomplete Closure Work.

The Controlled Action is not located within an area of public space, nor is it located in close proximity to residential areas. As such the Controlled Action would not result in the loss of amenity to the community. The further isolation of contaminants deposited within Area 2 would help to protect the adjacent HEW Ramsar Site and the Hunter River, protecting the social and economic benefits these provide.

To date, no public concern has been raised regarding the closure of Area 2.

9. ENVIRONMENTAL RECORD OF PERSON(S) PROPOSING TO TAKE THE ACTION

This section provides a summary of the key information requirements regarding the environmental record of the person proposing to take the action requested by DoEE in the letter issued 6 January 2017.

11. The information provided must include details of any proceedings under a Commonwealth, State or Territory law for the protection of the environment or the conservation and sustainable use of natural resources against:
(a) the person proposing to take the action
(b) for an action for which a person has applied for a permit, the person making the application.
If the person proposing to take the action is a corporation, details of the corporation's environmental policy and planning framework must also be included.

The Port Lessor (an entity of the State) has not been part of any proceeding under Commonwealth or State law for events relating to the protection of the environment; or conservation/sustainability of a natural resource.

10. OUTCOMES BASED-CONDITIONS

This section provides a summary of the key information requirements requested by DoEE and includes a response to each including appropriate reference to sources and attachments as required in the DoEE letter issued 6 January 2017.

12. *Outcomes-based conditions may apply to your project in accordance with the Department's Outcomes-based Conditions Policy 2016 and Outcomes-based Condition Guidance 2016. Outcomes need to be specific, measurable and achievable, and should be based on robust baseline data.*
    a) *Please provide specific environmental outcomes to be achieved, and reasoning for these with reference to relevant Recovery Plans, Conservation Advices, Threat Abatement Plans, and the HEW's Ramsar ecological character statement.*
    b) *For each proposed outcome provide:*
        I. *the risks associated with achieving the outcomes*
        II. *the measurability of the outcome, including suitable performance measures*
        III. *appropriate baseline data upon which the outcome has been defined and justified*
        IV. *the likely impacts that the proposed outcome will address*
        V. *demonstrated willingness and capability of achieving the outcome*
        VI. *the level of knowledge about the protected matter or its surrogate, upon which outcomes were based*
        VII. *commitments to independent and periodic audits of performance towards achieving outcomes*
        VIII. *discussion of the likely level of control that the proponent will have over achieving the outcome*
        IX. *discussion of the appropriateness of any surrogates for protected matter outcomes*
        X. *details of proposed management to achieve the outcome, including, but not limited to performance indicators, periodic milestones, proposed monitoring and adaptive management, and record keeping, publication and reporting processes.*

The Draft Recovery Plan for Green Golden Bell Frog (DEC 2005) identifies two overall objectives. The first objective framed to operate within the first five years of the Draft Recovery Plan is to manage threats impacting on currently known populations of the GGBF, so as to stabilise and prevent further decline of the species. The longer-term objective likely to operate in a time frame of 10-20 years, but critically dependent on the success of the initial 5-year objective, is returning the GGBF to its former distribution, abundance and role in the ecosystem, wherever possible.

A specific objective is to ensure extant GGBF populations are managed to eliminate or attenuate the operation of factors that are known or discovered to be detrimentally affecting the species. Three key threatening processes identified in the Draft Recovery Plan are: habitat loss, habitat modification and disturbance; predation by the *Gambusia* fish on the eggs and tadpoles; and the pathogenic chytrid fungal disease.

The Project is committed to providing a network of temporary basins within the capping of Area 2 which would reduce freshwater runoff to Deep Pond thus minimising changes to salinity which provides protection from the chytrid fungus, while also providing suitable *Gambusia* free ponds and movement corridors for the GGBF across Area 2.

The proposed outcome based condition is:

Two years following completion of the Area 2 Capping Works, relative to the baseline data, there must be:

1. No increased distribution of the *Gambusia* as a direct result of the Project
2. No net loss to GGBF foraging or breeding habitat as a direct result of the Project
3. Provision of a temporary GGBF movement corridor

Requirement	**Comment**
The risks associated with achieving the outcomes	1. There is a very low risk of the Project resulting in an increased distribution of Gambusia. The Project would not result in any change to the connectivity of Gambusia-inhabited watercourses with Gambusia-free ponds, while the basins to be constructed as part of the Project would also be Gambusia-free 2. The existing Area 2 footprint does not include any identified GGBF breeding habitat, but may provide foraging habitat. The Project includes the construction of movement corridors across the cap and the revegetation that aims to provide GGBF foraging habitat. 3. The basins would be located so as to facilitate a GGBF movement corridor. They would remain until such time that they need to be removed for the approved T4 development
The measurability of the outcome, including suitable performance measures	1. The Gambusia monitoring described in **Section 7.3** would continue as part of the GGBF monitoring program. 2. The area of existing GGBF foraging or breeding habitat, compared to that following the Project, is measurable 3. The provision of suitably designed basins and drainage lines would be the measure for the provision of a temporary GGBF movement corridor
Appropriate baseline data upon which the outcome has been defined and justified	1. UoN has been monitoring Gambusia in KIWEF watercourses since 2015. As such there is a good understanding of the Gambusia distribution within KIWEF 2. The area of existing GGBF foraging or breeding habitat has been mapped (see **Figure 3-2** and **Figure 6-7**) 3. Monitoring of the ponds in the Area 1 and Area 3 Closure Area, as described in **Section 6.4**, supports the outcome.
The likely impacts that the proposed outcome will address	1. Predation by Gambusia is a Key Threatening Process to the GGBF 2. Loss of habitat is a key potential impact. No net loss of foraging or breeding habitat would address this potential impact. 3. The temporary corridor would allow northern GGBF populations to migrate to the proposed PWCS T4 southern corridor.
Demonstrated willingness and capability of achieving the outcome	Since 2015 the State has been implementing the requirements of the NSW EPA Surrender Notice (to cap and contain soil and groundwater contamination) using methods that not only protect the GGBF population, but have supported its continued growth. The State maintains its commitment to comply with the Surrender Notice while also achieving the listed outcomes, so as to continue to protect and promote the GGBF population.
The level of knowledge about the protected matter or its surrogate, upon which outcomes were based	The State has worked with the UoN since 2015 to further develop the understanding of the GGBF, and in particular the GGBF KIWEF population. Monitoring of the GGBF population, as well as the factors (surrogates) that could impact on the population, has been undertaken since 2015.

	As such the State has developed the outcomes with a team with specialist knowledge of the GGBF, based on long term data.
Commitments to independent and periodic audits of performance towards achieving outcomes	1. The State would continue to undertake monitoring and observations for gambusia in ponds surrounding the KIWEF site as described in **Section 7.2**. The surveys are proposed to be undertaken by independent researchers from the UoN. 2. The State would continue to undertake monitoring of habitat conditions of the KIWEF habitat as described in **Section 7.2**. The surveys are proposed to be undertaken by independent researchers from the UoN. 3. The State would continue to undertake monitoring of habitat conditions of the KIWEF habitat as described in **Section 7.2**. The surveys are proposed to be undertaken by independent researchers from the UoN.
Discussion of the likely level of control that the proponent will have over achieving the outcome	1. Following completion of the Project, the majority of capping identified within the KIWEF would be completed. The water management system that has been developed as part of the capping would not facilitate the movement of Gambusia into existing Gambusia-free areas. Any remaining capping, along with the PWCS T4 development, would need to maintain such Gambusia movement restrictions. However the State would not have control over any future project that may be proposed by another proponent that could impact on achieving the outcome. Any future proponent would need to consider potential impacts on the GGBF population. 2. The State would control the amount of GGBF foraging or breeding habitat to be disturbed for the Project 3. The State would be responsible for construction of the temporary basins and drainage lines that would be the key component of the temporary GGBF movement corridors. Vegetation establishment in the movement corridors will also be monitored in accordance with the EMP requirements and maintained as necessary. The T4 development would need to be undertaken in accordance with the T4 GGBF Relocation Plan, and be responsible for confirming that the movement corridor has facilitated movement of the northern GGBF population into the southern corridor.
Discussion of the appropriateness of any surrogates for protected matter outcomes	1. Gambusia is a Key Threatening Process to the GGBF due to its predation of GGBF tadpoles. As such it is an integral surrogate. 2. Maintaining the area of GGBF foraging or breeding habitat would play an important role in the protection of the GGBF population. 3. Provision of an appropriate temporary GGBF movement corridor would facilitate the dispersion of GGBF individuals and connectivity of GGBF populations between the network of ponds located across the KIWEF.
Details of proposed management to achieve the outcome, including, but not limited to performance indicators, periodic milestones, proposed monitoring and adaptive management, and record keeping, publication and reporting processes.	This PDP describes numerous methods and management measures that would be implemented to achieve the outcomes: • **Section 2** describes how the Project would be undertaken • **Section 3.2** describes how direct impact to GGBF habitat would be minimised, so as to result in no net loss of GGBF foraging or breeding habitat • **Section 6.1** discusses the proposed hydrology and water management

	• **Section 6.3** describes how construction would be timed and managed to minimise direct impact on GGBF • **Section 7** describes the proposed avoidance, mitigation and management measures, including: Gambusia monitoring • The GGBF Management Plan and the relevant EMP Sub Plans (**Appendix 8**) describes a number of measures that would help achieve the outcomes.

11. FURTHER INFORMATION REQUIREMENTS

11.1 Impacts on Green and Golden Bell Frog and Hunter Estuary Wetland Ramsar Site from additional surface disturbance

Assessment of any likely significant impacts on Green and Golden Bell Frog (GGBF) and Hunter Estuary Wetland (HEW) Ramsar Site from removal of stockpile and borrow pit material including the proposed haulage routes.

The Works would involve surface disturbance in the following areas:

- The Peninsula Borrow Pit and the HRRP Borrow Pit. These areas are not located in close proximity to ponds identified by UoN (2018) as utilised by the GGBF.
- The K7 Preload Stockpile. This area is located in proximity to ponds identified by UoN (2018) to be utilised by the GGBF, specifically for breeding.

Controls to be implemented to protect the GGBF and the HEW Ramsar Site are:

- Excavation of material would only be undertaken following the installation of appropriate soil and water management controls, such as sediment fencing. This would minimise potential water quality impacts within the KIWEF and the HEW Ramsar Site.
  These controls would be inspected and maintained as required throughout the Works to ensure that they continue to protect water quality.
- The program for installation and management of frog fencing described in **Section 6.3** would be implemented in any areas adjacent to potential or known GGBF habitat.
- Implementation of the ecological survey program and vegetation removal (where applicable) process described in **Section 2.3.3** (for the Peninsula Borrow Pit), **Section 2.3.4** (for the K7 Preload Stockpile), **Section 2.3.5** (for the HRRP Borrow Pit) and **Section 2.3.6** (the Peninsula Borrow Pit haul road and other access tracks upgrades).

It is considered that with the implementation of the above described mitigation and management measures which are outlined in the GGBF Management Plan and the EMP, impacts to the Kooragang Island GGBF population and subsequently the HEW Ramsar Site would be minimal and temporary.

11.2 Capping of Cell 5

Discussion and analyses of the need for capping cell 5 - will this prevent/slow impacts of hydrocarbon contamination on GGBF and HEW Ramsar Site?

As described in **Section 3.1**, during the Area 2 Rationalisation Investigation, new site conditions surrounding Cell 5 were observed that may impact the potential migration of existing contaminants within the landfill. As such, the State considers the Project to be essential in protecting the surrounding aquatic environments, including the HEW Ramsar Site, from impacts associated with the historic contaminants that have been deposited at the KIWEF.

The function of the capping is to create an impervious layer across Area 2 that would significantly reduce infiltration and recharge to groundwater within the Area 2 Fill aquifer, resulting in a reduction in the flow velocity of groundwater which has been exposed to the contaminants, as identified previously in this section. The capping would also reduce the opportunity for infiltrating surface waters to interact with contaminants that are present within Area 2, limiting the volume of impacted water from reaching the groundwater system which in this location flows in the direction of the HEW Ramsar Site (refer **Section 6.1.1.2** for further discussion).

Overall, the Project is considered an environmental improvement by limiting the potential for contaminants that currently exist within the groundwater beneath Area 2 from migrating towards the surrounding GGBF habitat ponds (for example, Deep Pond and HEW Ramsar Site); and reducing the quantity of clean surface waters that encounter contaminants present beneath the site from reaching the groundwater.

11.3 Hydro salinity modelled data

Inclusion of hydro-salinity modelled data.

Section 6.1 describes the findings of the hydro-salinity model. Further detailed information is provided in Appendix B of **Appendix 5**.

As discussed in **Section 6.1.3.1**, the modelling results demonstrate that the implementation of the proposed Area 2 Closure Works would result in:

- Predicted Conditions are within the Optimum Water Quality (Salinity) range for chytrid protection (1,650 µS/cm to 2,900 µS/cm) for 32.3% of the time, which represents a -9.9% shift from existing
- Predicted Conditions are within the optimum conditions for GGBF breeding (<2,900 µS/cm, Tadpole Health Threshold) for 94.8% of the time, which represents a +3.3% shift from existing

Modelling also indicates that there would be no overlapping effects between the previous works (Areas 1 and 3) and the Area 2 Closure Works. The effects of the Area 2 Closure Works would be independent of the previous modelled outcomes and would not exacerbate any of the conclusions of the previous investigation.

11.4 Salinity and contamination impacts to the GGBF and the HEW Ramsar site

Assessment of salinity and contamination of hydrocarbon to the GGBF and HEW Ramsar Site by Hunter Development Corporation, which includes:

1. *measures to avoid or reduce impact*
2. *mitigation and management measures*
3. *likelihood of impacts.*

As discussed in **Section 3.1** one of the primary objectives of the Project is to limit the ability for contaminated groundwater to impact on the surrounding aquatic environments.

11.4.1 Contamination

While contamination across the KIWEF has generally been identified as being a low to moderate risk to human health or environment, specific areas were identified as containing significantly contaminated material that may pose a higher level of risk to human health or the environment and warrant more stringent management. **Section 3.1** identifies these areas and summarises the findings of contamination investigations.

As such the capping is the measure to limit the potential impacts of hydrocarbons on water quality within the surrounding aquatic environments. The likelihood of impacts associated with the completion of the capping is reduced compared to the potential impacts if no capping works were undertaken and contaminants could continue to migrate toward receiving pond environments.

11.4.2 Hydro-Salinity

As discussed in **Section 2.3.1**, the State identified areas of the KIWEF where *in-situ* materials may already form an effective cap, which if avoided, would minimises the ground disturbance requirements potentially protecting areas of GGBF foraging habitat. SMEC, on behalf of the State, undertook an investigation to determine whether the existing *in-situ* materials satisfied the objectives of the Closure Strategy (the Area 2 Rationalisation Investigation).

The Area 2 Rationalisation Investigation identified that the *in-situ* capping material which forms the southern section of Area 2 would meet the requirements of the Closure Strategy with minor modifications such as drainage improvements, and placement of an evapotranspiration layer using material won from the KIWEF. As such, this reduced the required disturbance of Area 2, including potential GGBF habitat.

As noted by DoEE, it has been identified that there is a specific salinity range (between 1,650 and 2,900 µS/cm (tadpoles) or 4,100 µS/cm (adults)) within which the GGBF is afforded a level of protection against the chytrid fungus, which is identified as a Key Threatening Process to the GGBF (DEC 2005). **Section 6.1.3** summarises the findings of the hydrology and salinity modelling, while **Section 6.2** describes the inherent project elements and other measures that would be implemented to manage salinity.

The hydro-salinity modelling described in **Section 6.1** and presented Appendix B of **Appendix 5** allowed consideration of the hydro-salinity resulting from a Standard Cap over all of Area 2 (which would create increased runoff to Deep Pond). Based on these results a review of the cap design was undertaken which allowed development of a Modified Cap for part of Area 2 that improved hydro-salinity levels without compromising the capping requirements.

11.5 Sympathetic design

Discussion of how capping works and any mitigation measures are sympathetic to other EPBC conditions for proposals on the site, e.g. the T4 approval (EPBC 2011/6029).

As discussed in **Section 3.4**, the Controlled Action is for the closure of a historical waste emplacement facility within a port side industrial area. The Controlled Action would not preclude Area 2 from being subject of future development for the approved PWCS T4 development. It would not impede on the ability of the PWCS T4 development from being constructed or operated as approved, or from complying with its state and federal approvals. The elements constructed as part of the Project would be removed or superseded by the T4 development at the discretion of PWCS.

The Closure Work would facilitate reuse of Area 2 for economic purposes due to the installation of a hydraulic barrier between the emplaced materials and potential future occupants of the site. It would do this while minimising impact to the existing, and promoting the proposed, GGBF habitat within the KIWEF and the adjoining HEW Ramsar Site through the considered and purposeful capping design described in **Section 2**.

The economic and social matters are discussed further in **Section 8**.

The GGBF strategy for the T4 development is to relocate the GGBF population within the T4 development footprint to a proposed southern corridor, as shown in **Figure 11-1**. The Closure Work undertaken for Area 1 and Area 3 has already provided a substantial part of the relocation corridor included in the T4 GGBF relocation strategy.

The Area 2 Closure Work would provide further connectivity between the northern GGBF populations and the proposed southern GGBF southern corridor. This corridor is also consistent with the T4 GGBF relocation strategy.

11.6 University of Newcastle population monitoring results

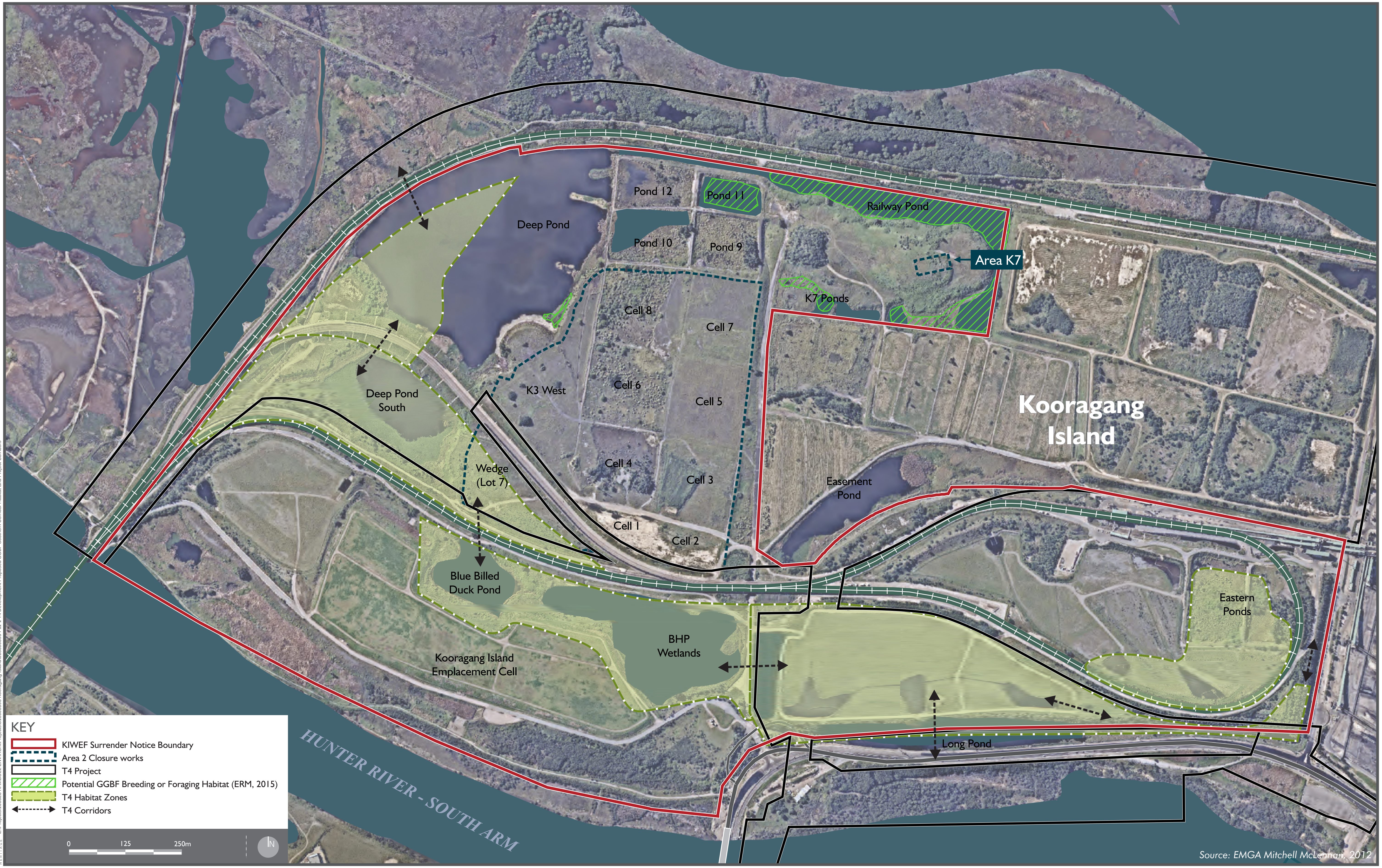
Inclusion of relevant results from the University of Newcastle on GGBF population monitoring and behavioural research.

The University of Newcastle (UoN) prepared the *Area 1 and Area 3 Closure Works for Remediation of the former BHP Kooragang Island Waste Emplacement Facility: Summary of the Impact and Benefit to the Green and Golden Bell Frog (Litoria aurea) and its Habitat* (2018). The report is presented in **Appendix 6**.

The UoN investigated the presence, breeding and persistence of the GGBF within basins constructed within Area 1 and Area 3. These basins are ephemeral, disconnected from the groundwater and are filled only by surface runoff from rainfall events. GGBF has been observed in these sediment basins during annual monitoring of the distribution, density and demography of the local population across Kooragang Island.

The UoN concluded that the presence and persistence of GGBF within Area 1 and Area 3 since completion of closure works may be attributed to a number of landform features that have created suitable movement corridors for the species. This includes: a mosaic of waterbodies with varying hydroperiods to provide opportunities for breeding and over-wintering; good connectivity between waterbodies to allow movement; isolation from groundwater to manage potential contamination; and elevation from existing overland surface water flows which could result in invasion of waterbodies by Gambusia.

The basins have been rapidly occupied by GGBF, and breeding has been recorded at all nine basins. In all cases, occupancy and breeding occurred within two years of construction and many of the basins were occupied in their first year. The UoN concluded that the observations of GGBF occupying and breeding within these basins demonstrate that provision of adequate breeding, foraging and sheltering habitat, together with adequate connectivity and the absence of Gambusia, has been successful. The UoN also concluded that such observations are evidence that the Closure Works (including the basins) for Area 1 and Area 3 provide a good model for artificial GGBF habitat creation in this area of Kooragang Island.



RAMBOLL

NSW GOVERNMENT | Hunter Development Corporation

Project	318000395
Drawn	TO
Approved	BS
Date	25/06/2018
Version	E

FIGURE 11-1 T4 Development Proposed GGBF Southern Corridor Habitat

EPBC Referral Preliminary Documentation Package
KIWEF Area 2 Closure Works
Hunter Development Corporation

11.7 Establishment of GGBF breeding habitat

Discussion of establishment of new GGBF breeding habitat (occurrences of successful breeding including driest breeding season).

As discussed in **Section 6.4** and **Section 11.6**, GGBF surveys undertaken by UoN within the Area 1 and Area 3 Closure Works areas indicate that the Closure Work has improved potential population persistence for the GGBF by providing suitable movement corridors, variation in inundation regimes, waterbody connectivity and *Gambusia*-free basins (see **Appendix 6**).

UoN (2018) states *"Of the nine constructed wetlands, six were occupied by L. aurea within a year of construction and the other three were occupied by their second year. Individuals have persisted in all of these wetlands following initial occupation whenever water is present."*

Further, UoN surveys recorded breeding in all basins created as part of the Area 1 and Area 3 Closure Works. UoN also stated that there is "*no evidence of negative impacts upon the Kooragang Island Litoria aurea population as a result of the* [Area 1 and Area 3] *Closure Works*".

Section 5.1 of **Appendix 6** discusses the demonstrated benefits of the works undertaken in Area 1 and Area 3.

12. SUMMARY OF PDP MONITORING AND MANAGEMENT COMMITMENTS

Table 12-1 provides a summary of the various monitoring and management commitments included throughout this PDP in regards to the Construction and Post-Construction Phases of the project.

Table 12-1: Summary of PDP Monitoring and Management Commitments

Aspect	Phase	Description of Requirements	Detailed Information	Duration
GGBF Population	Construction	Annual GGBF monitoring program	**Section 7.2**	Until Construction Completion
		Implementation of GGBF management measures during the Construction works, including (but not limited to): - installation of GGBF fencing and signage for exclusion zones; - GGBF clearance surveys, by experienced ecologists prior to clearing; - GGBF hygiene stations at all site entry points for personnel and vehicles (daily pre-start checks of hygiene stations); - Regular GGBF fencing maintenance inspections (minimum weekly)	EMP Annex A GGBF Management Plan	Until Construction Completion
		Assessment of imported fill from outside the KIWEF, must be sourced from an area that is assessed to have a low risk of containing Chytrid Fungus.	EMP Annex A	Until Construction Completion
		Assessment of compliance with Outcomes Based Conditions, including: 1. No increased distribution of the Gambusia as a direct result of the Project 2. No net loss to GGBF foraging or breeding habitat as a direct result of the Project 3. Provision of a temporary GGBF movement corridor	**Section 10**	Until Construction Completion
	Post-Construction	Annual GGBF monitoring program	**Section 7.2**	2 years Post Construction Completion and 3 yearly thereafter to coincide with NCIG monitoring events
		Assessment of compliance with Outcomes Based Conditions, including: 1. No increased distribution of the Gambusia as a direct result of the Project 2. No net loss to GGBF foraging or breeding habitat as a direct result of the Project 3. Provision of a temporary GGBF movement corridor	**Section 10**	2 years Post Construction Completion

Aspect	Phase	Description of Requirements	Detailed Information	Duration
Water Quality	Construction	Annual Surrender Notice Water Monitoring (groundwater and surface water)	**Section 7.1.1**	Until Construction Completion
		Continuous data logging of KIWEF pond water quality parameters, including: - Salinity (electrical conductivity) - Water Level - Temperature	**Section 7.1.2**	Until Construction Completion
		Implementation of Water Quality management measures during the Construction works, including (but not limited to): - Post rainfall checks of: sediment basin water level and water quality and erosion and sediment control functioning - Regular Inspections of: sediment basin water levels and water quality, erosion and sediment control structures, frog fences, fuel and chemical storage, stockpile bunding and covers - Sediment basin discharge or dewatering water quality sampling and analysis suitable to demonstrate pollution of water has/will not occur - if contaminated materials are encountered, they are to be managed in accordance with Materials Management Plan, and as a minimum isolated and covered to avoid runoff. - Provision of shaker grids or rumble strip at site egress points	EMP Annex B	Until Construction Completion
	Post-Construction	Annual Surrender Notice Water Monitoring (groundwater and surface water)	**Section 7.1.1**	Until Surrender Notice relinquished (or as directed by EPA).
		Continuous data logging of KIWEF pond water quality parameters, including: - Salinity (electrical conductivity) - Water Level - Temperature	**Section 7.1.2**	2 years Post Construction Completion
		Annual assessment comparing salinity trends and GGBF population trends, to determine whether management trigger and response measures are required.	**Section 7.2**	2 years Post Construction Completion
Vegetation	Construction	Disturbed areas to be revegetated within 1 month of final landforming	EMP Annex B	Until Construction Completion
		Following seeding of the construction area, monthly visual inspections of the cap to confirm vegetation establishment; arrangement of reseeding if necessary.	**Section 7.4**	Until Construction Completion
	Post-Construction	Biannual Cap Inspections to ensure vegetation does not compromise cap integrity and identify general maintenance issues as required.	**Section 7.4**	Until Surrender Notice relinquished (or as directed by EPA).

13. CONCLUSION

An agreement is in place with the EPA to close the KIWEF, subject to the conditions of the Notice to Surrender the Licence. The Project is an environmental improvement project with the key objective of mitigating the future migration of site contaminants associated with the former use of the landfill to the broader environment.

A significant amount of work has been undertaken by the State in consultation with UoN and various technical consultants to both understand the significance of potential impacts of the Project and develop effective mitigation measures for the identified risks. These mitigation measures are inherent to the Project design. The five key environmental and socio-economic considerations inherent to the Project design are:

1. Containment of contaminants within a capped area to mitigate future migration to the surrounding natural environment
2. Minimisation of direct impact to existing GGBF Habitat
3. Minimisation of indirect impacts to existing GGBF Habitat
4. Sympathetic to other approved projects in Area 2
5. Creation of movement corridors across Area 2 designed to satisfy the provisions of the Surrender Notice and section 5.3 of the GGBF Management Plan

Through incorporation of these considerations into the Project design and management commitments, potential impacts to the Kooragang Island GGBF population would be appropriately mitigated. Through detailed investigation and planning of capping design, the impacts to the Kooragang Island GGBF population and consequently the HEW Ramsar Site, have been minimised whilst still achieving the objectives of the Closure Strategy and mitigating the potential migration of contaminants from Area 2.

14. REFERENCES

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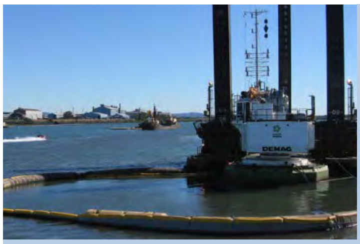
APPENDIX 1
REFERRAL OF PROPOSED ACTION – KIWEF – AREA 2 CLOSURE WORKS
















Kooragang Island Waste Emplacement Facility Area 2 Closure Works

Hunter Development Corporation

ERM Ref: 0320327 Final

December 2015

The world's leading sustainability consultancy

ERM

Referral of proposed action

Project title:	Kooragang Island Waste Emplacement Facility – Area 2 Closure Works.

1 Summary of proposed action

1.1 Short description

The proposed action is to undertake the closure and rehabilitation of Area 2 of the Kooragang Island Waste Emplacement Facility (KIWEF), near Newcastle NSW, including the installation of drainage and sediment controls, capping and re-contouring of waste emplacement areas and rehabilitation using existing surface materials.

The site is a former landfill which operated under Environmental Protection Licence (EPL) number 6437 and continues to be regulated under the NSW Protection of the Environment Operations Act 1997. Closure obligations are regulated through the NSW Environmental Protection Authority (EPA) issued conditional Surrender Notice 1111840 for EPL 6437 and subsequent variation notices being issued on 2 May 2013 (notice number 1510956) and 17 April 2014 (notice number 1520063) collectively referred to as the Surrender Notice for the remainder of this report.

The application to surrender the licence was supported by the Revised Final Landform and Capping Strategy (GHD 2009) (the Capping Strategy) developed in consultation with the EPA. The Capping Strategy was supported by a Flora and Fauna Assessment (GHD, 2010) with the aim of best managing the threat of significant environmental harm from the contaminants within the KIWEF whilst minimising risk to threatened fauna habitat. The EPA has provided an endorsement for the Revised Final Landform and Capping Strategy (GHD, 2009) as the best balance to achieve positive environmental outcomes for the site. As such the approach to closure is to as far as possible implement minimal change in all site processes namely hydrology, vegetation and surface soils while further isolating potential contaminants through a reduction of permeability through the installation of capping leading to reduced infiltration and a reduced risk of contaminant migration collectively referred to as the Closure Works for the remainder of this report.

The potential impacts to MNES have been identified as follows:

- Short term construction impacts related to clearing of existing vegetation dominated by weeds and non-native species with impacts to pond fringing habitat avoided;
- Short term construction impacts associated with sedimentation able to be managed through the implementation of erosion and sediment control controls; and
- General improvements in water quality in receiving waterbodies with slightly wetter and fresher conditions expected.

The proposed action is to implement the requirements of the Surrender Notice through implementation of the Capping Strategy for Area 2. The proposed action does not include the development and use of the site for any purpose including waste disposal. As such the Referral addresses the temporary construction impacts and ongoing potential changes to hydrology associated with the construction of a low permeability capping layer above contaminated areas, with no ongoing loss of habitat considered likely.

1.2 Latitude and longitude

Latitude and longitude details are used to accurately map the boundary of the proposed action. If these coordinates are inaccurate or insufficient it may delay the processing of your referral.

	Latitude			Longitude		
location point	degrees	minutes	seconds	degrees	minutes	seconds
Southern Section						
1	32°	52'	8.652"	151°	43'	40.070"
2	32°	52'	17.641"	151°	43'	48.904"
3	32°	52'	18.159"	151°	43'	49.870"
4	32°	52'	18.780"	151°	43'	50.233"
5	32°	52'	18.169"	151°	43'	47.408"
6	32°	52'	16.608"	151°	43'	42.389"
7	32°	52'	14.924"	151°	43'	38.574"
8	32°	52'	14.616"	151°	43'	37.929"
9	32°	52'	13.648"	151°	43'	37.701"
10	32°	52'	13.371"	151°	43'	37.213"
11	32°	52'	8.341"	151°	43'	39.253"
Northern Section						
12	32°	52'	6.252"	151°	43'	40.326"
13	32°	52'	4.982"	151°	43'	42.253"
14	32°	52'	3.322"	151°	43'	42.502"
15	32°	52'	2.513"	151°	43'	43.129"
16	32°	52'	2.389"	151°	43'	44.414"
17	32°	52'	3.038"	151°	43'	45.878"
18	32°	52'	2.476"	151°	43'	46.752"
19	32°	51'	58.658"	151°	43'	48.839"
20	32°	51'	57.158"	151°	43'	51.133"
21	32°	51'	57.614"	151°	43'	58.236"
22	32°	51'	58.416"	151°	44'	4.384"
23	32°	51'	53.843"	151°	44'	6.681"
24	32°	51'	53.765"	151°	44'	7.187"
25	32°	51'	54.368"	151°	44'	8.816"
26	32°	51'	54.893"	151°	44'	10.574"
27	32°	51'	55.635"	151°	44'	11.136"
28	32°	51'	55.855"	151°	44'	12.340"
29	32°	51'	55.921"	151°	44'	14.195"
30	32°	51'	56.365"	151°	44'	15.490"
31	32°	51'	56.419"	151°	44'	19.614"
32	32°	51'	57.312"	151°	44'	23.509"
33	32°	51'	59.000"	151°	44'	22.711"
34	32°	51'	58.266"	151°	44'	19.001"
35	32°	51'	57.229"	151°	44'	17.444"
36	32°	51'	57.069"	151°	44'	15.498"
37	32°	51'	56.598"	151°	44'	12.467"
38	32°	51'	56.244"	151°	44'	10.356"
39	32°	51'	55.423"	151°	44'	10.016"
40	32°	51'	54.609"	151°	44'	7.325"
41	32°	51'	58.482"	151°	44'	5.586"
42	32°	52'	3.697"	151°	44'	4.655"
43	32°	52'	18.851"	151°	44'	3.346"
44	32°	52'	18.694"	151°	44'	1.192"
45	32°	52'	19.674"	151°	44'	0.777"
46	32°	52'	19.821"	151°	43'	59.776"
47	32°	52'	19.812"	151°	43'	58.750"
48	32°	52'	19.570"	151°	43'	56.244"
49	32°	52'	19.048"	151°	43'	54.605"
50	32°	52'	17.096"	151°	43'	50.439"
51	32°	52'	14.813"	151°	43'	47.653"
52	32°	52'	7.213"	151°	43'	40.271"

1.3	**Locality and property description** The site is located off Cormorant Road, Kooragang Island, Newcastle, NSW. The site is bounded by Newcastle Coal Infrastructure Group rail infrastructure to the south, the Port Waratah Coal Services - Kooragang Coal Terminal railway line to the west and north and adjacent industrial land consisting of third party waste facilities to the east. Access to the site is via Cormorant Road. The site is comprised of completed and incomplete cells associated with the waste disposal facility and therefore has many levels. The landfill has been used for the disposal of by-products from the steelmaking industry primarily slag, coal washery rejects and plant refuse but also asbestos, leaded dusts, acid and lime sludge, tars and oils. To aid description, KIWEF and neighbouring third party facilities are described in relation to nominal areas labelled K1 to K13 with this referral addressing Closure Works in K3, K5 and a small section of K7 (refer to *Annex A, Figure 2*). Waste disposal was conducted in most of these areas either by application to open ground or in numbered 'disposal ponds' which constructed bund walls comprised of slag materials. While the Capping Strategy describes these as ponds, for ease of description the Referral describes them as cells on the basis that incomplete or unfilled cells also contain ponds as illustrated in Figure 1 of Annex A.		
1.4	**Size of the development footprint or work area (hectares)**	Area 2 closure works will involve the capping, contouring and rehabilitation of approximately 36 hectares of the former KIWEF.	
1.5	**Street address of the site**	Cormorant Road, Kooragang Island, NSW.	
1.6	**Lot description** Part Lots 3, 4, 5 and 7 DP1207051 and Lot 8 DP1119752.		
1.7	**Local Government Area and Council contact (if known)** The site is located within the Newcastle City Council Local Government Area (LGA) but is not subject to Local Planning controls.		
1.8	**Time frame** Closure works are estimated to commence in quarter 2 of 2016 for practical completion in June 2017.		

1.9	**Alternatives to proposed action** Were any feasible alternatives to taking the proposed action (including not taking the action) considered but are not proposed?	Yes	refer to section 2.2
1.10	**Alternative time frames etc** Does the proposed action include alternative time frames, locations or activities?	No	Preparatory works including final detailed design, securing all applicable licenses, permits and approvals and tendering for contractors is expected to take up to 9 months with works required to be completed by June 2017 in accordance with the timing agreed under the Surrender Notice. As such the timing of works is not flexible. Due to the nature of the proposed works no alternative location is possible. Refer to Section 2.2 for alternative activities considered.
1.11	**State assessment** Is the action subject to a state or territory environmental impact assessment?	Yes	Refer to Section 2.5.
1.12	**Component of larger action** Is the proposed action a component of a larger action?	No	

1.13	**Related actions/proposals** Is the proposed action related to other actions or proposals in the region (if known)?	Yes	HDC lodged a referral (Referral number 2011/5920) to DoE in mid-2011 for the full scope of the Revised Final Landform and Capping Strategy works. DoE decided that the full scope of works constituted a controlled action based on assessment of preliminary information but identified that HDC was not the appropriate applicant, given that HDC does not control the site and have no long-term interests in the land, and no benefit from the proposed action. This referral was subsequently withdrawn and HDC engaged with Newcastle Ports Corporation (the land owner at the time) to seek its support to act as the appropriate project applicant. NPC subsequently referred Area 1 and Area 3 (Referral number 2012/6464) to DoE as discussed below. It is noted that at the time of referral of Area 1 and Area 3 under referral number 2012/6464 that Area 2 was proposed to be excised from the State's Surrender Notice scope of work, and the equivalent capping and associated remediation works to appropriately manage the contamination risks to be undertaken as part of the PWCS T4 development. Construction of the PWCS T4 development has been delayed and Area 2 is now being referred in order to allow the completion of closure activities in accordance with the timings agreed under the Surrender Notice. Area 2 is not considered part of a larger activity of the full closure of all areas of KIWEF, on the following basis: • The activity assessed under referral 2012/6464 in Area K10 North and K2 are now complete with Area K10 South scheduled for completion prior to commencement of Area 2 closure; • Significant impacts have not eventuated from referral 2012/6464 and no cumulative impacts are expected to result that would render the compilation of all outstanding closure activities more significant than undertaking and assessing them individually; • The completion of each stage of closure can and has successfully been undertaken independently of each other and no stage relies on the completion of another; • The nature of the impact mechanisms being short term direct impacts associated with clearing, renders the staged completion of closure activities less impacting than the completion of clearing of all sites at one time; • Indirect impacts to Green and Golden Bell Frog population of changed pond hydro-salinity, while cumulatively impacting some ponds, do so by providing generally wetter and fresher conditions, while still retaining the variability between ponds considered critical to their survival on the site as discussed further in Section 3; and • The wetter, fresher and generally improved quality of surface water is a positive impact on other MNES and the environment in general and as such cumulative impacts are also positive. In addition to the referral 2012/6464 identified above the current referral is related (in location only) to the following referrals: • Australian Rail Track Corporation Kooragang Coal Terminal Arrival Roads (2014/7229); • Port Waratah Services Terminal 4 (T4) referral (2011/6029); and • Newcastle Coal Infrastructure Group Coal Export Terminal (2006/2987). The referral is located on land forming part of the ongoing assessment of the Port Waratah Services Terminal 4 (T4) referral (2011/6029). The proposed activity is related to T4 in location and is not part of the larger activity on the basis that: • The closure works and T4 proponents are different and operate independently of each other; • The closure works have the purpose of environmental improvement of a former landfill, while the T4 project is for the purpose of a coal export facility; • The proposed closure works are required regardless of whether the T4 development proceeds; and

			• T4 could proceed in the absence of the closure works and regardless of the closure works would require site remediation using different remediation strategies and approaches to the management of contaminants. The referral area is bisected by the NCIG Newcastle Coal Infrastructure Group (NCIG) rail fly-over assessed and decided not to be a controlled activity if undertaken in a particular manner under referral number 2006/2987. The NCIG development has implemented landfill closure obligations on parts of KIWEF in the process of completing the development but the proposed closure works are not part of the larger action of a coal export terminal for the reasons provide above in relation to T4. The Australian Rail Track Corporation Kooragang Coal Terminal Arrival Roads referral (2014/7229) relates to the rail corridor north and west of the referral area. This referral was determined not to be a controlled action.
1.14	**Australian Government funding** Has the person proposing to take the action received any Australian Government grant funding to undertake this project?	No	
1.15	**Great Barrier Reef Marine Park** Is the proposed action inside the Great Barrier Reef Marine Park?	No	

2 Detailed description of proposed action

2.1 Description of proposed action

The proposed action is to undertake the closure of Area 2 (K3 and K5) of KIWEF (refer to *Annex A, Figure 1 and 2*) in accordance with the Surrender Notice and Capping Strategy (GHD, 2009) and the placement of Virgin Excavated Natural Material or Excavated Natural Material over a small area containing asbestos within K7. The closure works are a part of the State Government's Closure Works required under approval of surrender of licence number 6437 (notice number 1111840). The remaining parts (Area 1 and Area 3) have previously been referred under referral reference number 2012/6464 with referral decision of "not a controlled action if undertaken in a particular manner" being issued on 8 October 2013.

KIWEF ceased operation in 1999 and until this time was used by BHP as a landfill for disposal of waste from the Mayfield steelworks and associated operations. KIWEF was subject to Environmental Protection License (EPL) 6437 for the scheduled action of "Waste disposal by application to land" first issued in 1999 and subsequently transferred to Regional Land Management Corporation Pty Ltd in May 2003 and then the Hunter Development Corporation (HDC) in January 2008.

HDC surrendered EPL 6437 on 8 December 2010 and the EPA issued conditional Surrender Notice 1111840 and subsequent variation notices being issued on 2 May 2013 (notice number 1510956) and 17 April 2014 (notice number 1520063) collectively referred to as the Surrender Notice for the remainder of this report. Surrender conditions relate primarily to the closure process, and describe the capping that is required across much of the area through reference to the GHD (2009) Revised Final Landform and Capping Strategy (the Capping Strategy).

The KIWEF Capping Strategy (GHD 2009) identified and described the proposed stages of capping works to be progressively completed. Due to the development of portions of the KIWEF footprint by external stakeholders, the stages of capping works were revised within a Variation of the Conditions of Surrender (Notice 1510956, issued on 2 May 2013). The current Stages of works and their status are:

- Area 1 – K2 and K10 North closure works addressed by referral 2012/6464 and completed in 2015;
- Area 2 – North of Rail Line (K3 and K5) Closure Works the subject of this referral with works to be completed by 30 June 2017; and
- Area 3 – K10 South closure works addressed by referral 2012/6464 and to be completed by 30 June 2017.

Condition 4a of the surrender notice requires that the closure works be undertaken in accordance

- 'Hunter Development Corporation - Report on KIWEF - Revised Final Landform and Capping Strategy - August 2009 - Revision 2', prepared by GHD (the Capping Strategy);
- 'Green and Golden Bell Frog Management Plan – Kooragang Island Waste Emplacement Facility Closure Works' dated 19 April 2011 and prepared by Golder Associates;
- 'K26/32 and K24/31 Ponds Action Plan– Kooragang Island Waste Emplacement Facility' dated 31 May 2011 and prepared by Golder Associates; and
- 'Materials Management Plan - Kooragang Island Waste Emplacement Facility' dated November 2012 prepared by RCA Australia.

The capping methodology is dictated by Condition 4h which requires validation that closure has been implemented in accordance with Chapter 7 of the GHD (2009) Revised Final Landform and Capping strategy and other relevant conditions of the Surrender Notice and in doing so specifies the mitigation measures within the documentation and management reports listed above.

Chapter 7 of GHD requires that the construction of the capping strategy will involve the following tasks:

- Establishment of erosion and sedimentation controls and construction of sedimentation basins as required;
- Remove any vegetation and strip the top 100 mm of soil. Stockpile for re-use if deemed suitable;
- Construct trunk drainage where required;
- General earthworks (cut/fill) activities to establish the regraded surface with a final minimum 1% grade. If the stripped 100mm of soil is suitable for re-use, stockpile for use in revegetation, or screen and incorporate as fill for grading. Cut from within this area, if deemed suitable, may be used as fill and capped. Additional fill shall be sourced from an approved offsite source. Earthworks shall be compacted in accordance with the Technical Specification. Topsoil and re-vegetate the disturbed area if no further capping material is required. Any unsuitable cut material shall be stockpiled in Stage 7 area and later capped;
- Place 0.5m capping material over the regraded surface at a final minimum 1% grade. Compact the capping material to achieve a maximum permeability of $1x10^{-7}$m/s. Construction of the capping layer "should ensure that the final surface provides a barrier to the migration of water into the waste (or fill), controls emissions to water and atmosphere, promotes sound land management and conservation, and prevents hazards and protects amenity" (EPA, 1998);
- Topsoil 100mm thick using stockpiled surface soils or imported topsoil and revegetate the disturbed area;
- Any cut material which is considered geotechnically unsuitable to use as fill shall be relocated to the proposed unsuitable material containment area; and
- Any cut material which is significantly contaminated (as defined by the materials management plan) shall be either disposed of off-site or relocated to a nominated containment cell area as directed by the principal.

Departures from the above standard approach to capping are described by the Capping Strategy in *Table 1* below.

Table 1 – Capping Strategy (2010).

Area	Recommended Strategy
K3	In areas identified as suitable GGBF habitat, including the area bordering the freshwater wetlands, capping will be undertaken up to within 30m of the identified habitat area, with the exception of the area located near K3/1W (which will be capped) and then revegetated. No regrading, capping or other disturbance will be undertaken within other Green and Golden Bell Frog habitat areas.
K5 (excluding Cell 5)	To reduce the risk of migration of impacts around Cell 5, the permeability is to be reduced to $1x10^{-8}$ m/s for a zone (nominally 10- 20m) adjoining the Cell 5 area.
Cell 5	Minor re-contouring of the area by placing compacted CWR is recommended to a minimum grade of 1% to shed surface water away from the north, west and southern boundaries of the GCL liner and tie into proposed surface levels of the adjoining capped areas.
K7	Placement of VENM or other material as approved in the EPL in the area where only 1.6m of fill has been placed, to provide at least 3m cover over asbestos disposal areas.

Further noted departures that may be required to fully implement the Capping Strategy in Area 2 include:

- No access to previously identified source of Coal Washery Reject for capping;
- Limited availability of "topsoil" requiring importation of alternative "revegetation medium" with low nutrient and low chytrid fungus risk; and
- No access to the previously identified geotechnically unsuitable material storage area (stage 7) requiring alternative disposal solutions.
- The Post HDC Remediation Runoff Flow Paths predicted by the GHD Capping Plan may also be altered to address changes in ground surfaces caused by neighbouring site developments (including the NCIG rail flyover) and the existing site topography.

Alternative Capping Source

Where possible, CWR will be won for re-use in capping where it meets geotechnical and material properties of the materials management plan. It is considered likely that there will be a deficit of appropriate capping material available within Area 2. At this stage it is unclear the source of the capping material but potential sources include:

- Surplus CWR from K10 South;
- VENM/ENM from local area construction sites; or
- Commercial sources/ quarries or other appropriately licensed sources of suitable capping and/or other fill material.

In accordance with referral number 2012/6464 in a particular manner decision, any capping materials that are imported from outside the closure works site will be sourced from an area that is demonstrated to be low in nutrients and free of chytrid fungus (to the extent possible).

Alternative revegetation medium

The existing surface soils in Area 2 is highly variable and ranges from an absence of any growth medium to fine or course coal washery reject supporting extensive non-native regrowth. It is necessary to limit stripping of "topsoil" to 100mm while ensuring a final revegetation medium of 100mm is provided in order to address the requirements of the Surrender Notice. This will require importation of a growth medium to address the deficiency in "topsoil" expected to eventuate based on requirement to exclude unsuitable materials and the complete lack of material in some areas. Subject to approval under State approval requirements, the proposed action will therefore include the importation of a regrowth material to be sourced from an area that is demonstrated to be low in nutrients and free of chytrid fungus (to the extent possible). Suitable material is expected to include crusher dust sourced from dry stockpiles at local hard rock quarries. The crusher dust has been demonstrated to support vegetation on other sites in Newcastle, is of low nutrient value and is not sourced from areas where amphibians are prevalent. Given the dry nature of the material and the absence of amphibians, the material is unlikely to contain Chytrid fungus spores or frogs infected with Chytrid fungus. The crusher dust is therefore considered to be an appropriate alternative revegetation medium for the closure works.

Geotechnically unsuitable material management

Experience in closure of other portions of KIWEF indicate high potential to encounter geotechnically unsuitable material that cannot be re-used in capping and that may be unsuitable as fill material. As the designated area for relocation envisaged in the Capping Strategy has been used by unrelated activities an alternative emplacement area will be identified during development of final detailed design. The area will be located to minimise risks to MNES through placement away from their preferred habitat and to avoid the requirement to disturb otherwise non-impacted areas of KIWEF.

Alternative post remediation runoff flow paths
The flow paths from the final design will be developed to reflect the natural flow paths created by the current site topography. The initial GHD capping plan identified several runoff flow paths that appear incongruent with the current landform. Additionally, adjacent developments have been constructed across the closure works area that will also greatly alter the proposed post remediation flow paths. Based on this assumption, it is proposed that the final design will be developed to direct surface water flows generally in the same direction as the existing water flow paths. Suitable surface water management controls will also be utilised to minimise impacts within sensitive environments such as erosion controls and sedimentation ponds.

2.2 Alternatives to taking the proposed action
Alternative approaches to closure are described in the Closure Strategy and include:
- Do nothing option; or
- Alternative capping design and methodology; or
- Alternative contamination management approach.

The Do-Nothing option
The "do-nothing" approach was considered for the site and in the absence of evidence of offsite contamination mobilisation likely to threaten harm to humans and the environment the do nothing option could be considered appropriate given the absence of intended post landfill land-use and high ecological constraints on the site. The Closure Strategy has applied a "do-nothing" approach where this has been adequately demonstrated. However, in order to satisfy Surrender Notice requirements and minimise risk of future migration of contamination the do-nothing option has been discounted in areas where the ecological impacts are able to be avoided or otherwise mitigated to an acceptable level. The proposed Capping Strategy has been endorsed as the best method of balancing contamination risks with risk of impact to ecological values of the site.

Alternative Capping Design and methodology
Alternative bulk earthworks and capping options are limited within the KIWEF due to the significant constraints of the existing NCIG rail loop, BHP emplacement cell, future use intentions of the landowner and ecological habitat. For Area 2 the alternatives are limited to alternative designs for final landform that achieve the Surrender Notice requirements while maintaining ecosystem functioning as close to its current form as possible. The final design is to consider the availability of on-site materials for use as capping, fill and revegetation medium, while the Closure Strategy was developed considering the availability of off-site disposal options and alternative remediation technologies.

Alternative Approach to Management of Contaminants
The objective of limiting potential migration of the contaminants within the landfill could otherwise be met through excavation of contamination for off-site disposal or possibly through the use of alternative remediation technologies. Off-site disposal is discounted due to the unavailability of appropriate disposal sites and that this would involve greater disturbance of the ecological values of the site. It is noted that the T4 project has developed a draft Remediation Action Plan aimed at making the site suitable for the intended use of a coal export terminal and to manage the additional risks of contaminant migration presented by additional site loading. This Remediation Action Plan is not considered a viable option for the proposed action as it increases habitat impact, is unnecessary for the protection of human and environmental health in the 'no intended post landfill land-use scenario' and is otherwise cost prohibitive in the absence of a post landfill use. The use of other remedial technologies further considered unviable due to the largely undocumented nature of the disposal practices meaning targeting specific contaminants in specific areas with appropriate remedial technologies is not possible.

2.3 Alternative locations, time frames or activities that form part of the referred action
No proposed alternatives are provided.

2.4 Context, planning framework and state/local government requirements
The principal legislation governing waste management and landfill disposal of waste in NSW is the Protection of the Environment Operations Act 1997 (POEO Act). All landfills must meet the requirements of the POEO Act and the Regulations made under that Act. The landfill occupier must not pollute waters in breach of section 120, cause air pollution in breach of sections 124, 125 or 126, or emit offensive odour in breach of section 129 of the Act. The POEO Act provides for an integrated system of licensing whereby a single schedule of activities requiring an Environmental Protection Licence (EPL) regulates all forms of pollution.

The site previously held EPL 6437 as a waste disposal facility under the POEO Act, which has since been surrendered. An Approval of the Surrender of a Licence (1111840) has been issued to HDC under Section 80(1) of the POEO Act which states a number of site specific conditions and mitigation measures that must be implemented prior to the release of the land from the Surrender Notice requirements. Measures identified within the surrender notice include capping specifications, monitoring requirements, environmental mitigation measures, the preparation and implementation of various reports and management plans. The Proposed action is intended to meet HDC's obligations under this surrender notice in Areas 2 (K3 and K5) and provide adequate cover to an identified trench containing asbestos (K7).

The site is within the Land Application Area of State Environmental Planning Policy (Three Ports) 2014 (Three Ports SEPP) and specifically is within the Three Ports Lease Area. The Three Ports SEPP is an environmental planning instrument created pursuant to the Environmental Planning and Assessment Act 1979 (EP&A Act) and has superseded the State Significant Site listing in the Major Project State Environmental Planning Policy under which previous KIWEF closure stages were assessed. As the applicable environmental planning instrument the Three Ports SEPP establishes the approval pathway under NSW planning context for the KIWEF site closure works.

Under the Three Ports SEPP development may be carried out for the purpose of Environmental Protection Works without development consent by or on behalf of a public authority on land within the Lease Area and as such be subject to assessment under Part 5 of the EP&A Act.

Environmental Protection Works are not defined in the Three Ports SEPP which notes that Words and expressions used in this Policy have the same meaning as they have in the standard instrument set out at the end of the Standard Instrument (Local Environmental Plans) Order 2006, unless otherwise defined in this Policy. Under the Local Environment Plan Standard Instrument environmental protection works means:

> *"works associated with the rehabilitation of land towards its natural state or any work to protect land from environmental degradation, and includes bush regeneration works, wetland protection works, erosion protection works, dune restoration works and the like, but does not include coastal protection works".*

ERM understands HDC has obtained legal advice to the effect that the capping works should meet this definition (or did so in relation to Area 1 and Area 3 under similar provisions of State Environmental Planning Policy (Major Development 2005).

The Three Ports SEPP does define Environmental Management Works which means:

> *"(a) works for the purpose of avoiding, reducing, minimising or managing the environmental effects of development (including effects on water, soil, air, biodiversity, traffic or amenity); and*
>
> *(b) environmental protection works".*

The works to close the landfill by installation of a capping system are best defined as environmental management works in that they are exclusively aimed at minimising and managing the contamination related environmental effects of the landfill development and as such are also considered environmental protection works. Further the proposed activity will also be designed to include the revegetation of the capped area with a natural vegetative seed mix conducive to GGBF foraging habitat and the addition of erosion and sediment controls (including drainage lines and sediment basins). The regrading of the capping layer to a minimum 1% will also encourage clean runoff, rehabilitate the land towards its natural state and protect neighbouring land from degradation by the migration of chemicals.

The proposed capping works may meet the definition of remediation under State Environmental Planning Policy 55 – Remediation of Land, where remediation means:

> *"(a) removing, dispersing, destroying, reducing, mitigating or containing the contamination of any land, or*
>
> *(b) eliminating or reducing any hazard arising from the contamination of any land (including by preventing the entry of persons or animals on the land)".*

However, it is considered more appropriate that the proposed works be considered 'environmental management works' since they include capping a formerly licensed landfill regulated under the Protection of Environment Operations Act, 1997 (POEO Act) to minimise potential future impacts of an existing development rather than actively remediating contaminated land under the Contaminated Land Management Act 1997 (CLM Act) for an intended future use. On this basis, the intent of the environmental management works provision seems more closely aligned with what is proposed than contaminated site remediation.

Remediation of land is permitted within the land use zone and SEPP 55 is not relied on to make it permissible. If SEPP 55 is considered then the same "remediation works" being the mitigation and reduction of a contamination hazard through capping are permissible without consent as "environmental management works" under the Three Ports SEPP. SEPP 55 asserts that it will prevail over inconsistent provisions of SEPP's that prohibit remediation works, but not over provisions that require consent or say that no consent is required. This means that although the Closure Works would likely meet the definition of Category 1 remediation works due to the classification of Kooragang Island as a coastal zone (which would require consent), the Three Ports SEPP would prevail and as such the closure works would not require development consent under the EP&A Act as they would be considered Category 2 remediation works.

Where a proposal does not require development consent its environmental impacts must be addressed as an "activity" under Part 5 of the EP&A Act. The proposed development is considered permissible without consent under State Environmental Planning Policy (Three Ports) 2014 and, as such, the provisions of Part 5 of the EP&A Act apply.

2.5 Environmental impact assessments under Commonwealth, state or territory legislation
The Closure Works are being assessed under the EP&A Act through the preparation of a Review of Environmental Factors under Part 5 of the EP&A Act.

Under Part 5 of the EP&A Act and for the purpose of attaining the objects of the EP&A Act relating to the protection and enhancement of the environment, a determining authority in its consideration of an activity is required to examine and take into account to the fullest extent possible all matters affecting or likely to affect the environment by reason of that activity. This includes consider the effect of an activity on:

- Any conservation agreement entered into under the National Parks and Wildlife Act 1974 and applying to the whole or part of the land to which the activity relates (not applicable);
- Any plan of management adopted under that Act for the conservation area to which the agreement relates (not applicable);
- Any joint management agreement entered into under the Threatened Species Conservation Act 1995 (not applicable),
- Any biobanking agreement entered into under Part 7A of the Threatened Species Conservation Act 1995 that applies to the whole or part of the land to which the activity relates (not applicable);
- Any wilderness area (within the meaning of the Wilderness Act 1987) in the locality in which the activity is intended to be carried on (not applicable);
- Critical habitat (consideration given to GGBF);
- In the case of threatened species, populations and ecological communities, and their habitats, whether there is likely to be a significant effect on those species, populations or ecological communities, or those habitats (relevant); and
- Any other protected fauna or protected native plants within the meaning of the National Parks and Wildlife Act 1974 (relevant).

The above consideration is undertaken in the form of the preparation and consideration of a Review of Environmental Factors by the determining authority, the public authority on whose behalf the activity is undertaken, required to form an opinion as to whether or not any significant impact is likely. Should a significant impact be likely an Environmental Impact Statement is required to be prepared for determination by the Minister of the Department of Planning and Environment. A Review of Environmental Factors is currently being progressed.

It is noted that assessment under Part 5 of the EP&A Act is an accredited assessment process under this bilateral agreement made under section 45 of the EPBC Act between the Commonwealth and NSW.

2.6 Public consultation (including with Indigenous stakeholders)
There are no formal requirements for public consultation under Part 5 of the EP&A Act. Nevertheless, consultation has been undertaken on an ongoing basis with the Landowner (Port of Newcastle Lessor Pty Ltd – a NSW State Government Entity), Port of Newcastle Lessee Pty Ltd (Holder of the land title under long term lease from the NSW Government for use and management of the land), NSW Roads and Maritime Services in relation to traffic and access and the NSW EPA in relation to completion of Surrender Notice requirements. No public consultation has been undertaken on the basis that there are no neighbours in close proximity to the site.

Because of the site's previous land use and highly modified nature, it is considered that there is no potential for impacts on items of Indigenous heritage, and the values of indigenous stakeholders. As such, no public consultation with Indigenous stakeholders has been undertaken.

The water bodies at KIWEF have become habitat for many local and migratory species. Consultation was undertaken with the Kooragang Bird Observers Group, the Society of Frogs and Reptiles, and the Shortland Wetlands Centre in relation to the development of the Capping Strategy.

2.7 A staged development or component of a larger project
Not Applicable

3 Description of environment & likely impacts

3.1 Matters of national environmental significance

3.1 (a) World Heritage Properties

Description

There are no World Heritage Properties within the Site or in the vicinity of the site.

Nature and extent of likely impact

The proposal will not have any impact on any World Heritage Properties.

3.1 (b) National Heritage Places

Description

There are no National Heritage Places within the Site or in the vicinity of the site.

Nature and extent of likely impact

The proposal will not have any impact on any National Heritage Places

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3.1 (c) Wetlands of International Importance (declared Ramsar wetlands)

Description

One Ramsar Wetland, Hunter Estuary Wetlands (ID No 24) occurs within close proximity of the Site (refer to Annex A, Figure 1). At is closest point the Hunter Estuary Wetland (Kooragang Component) occur approximately 260 meters to the north of the northern Site boundary.

The Hunter Estuary Wetlands Ramsar site is comprised of two components, Kooragang and Hunter Wetlands Centre Australia. The Kooragang component of the Hunter Estuary Wetlands Ramsar site (most relevant to this site) is located in the estuary of the Hunter River, approximately 7 km north of Newcastle on the coast of New South Wales. The Kooragang component includes Kooragang Island and Fullerton Cove, two areas that lie in the estuarine section of the Hunter River. Kooragang Island originally consisted of seven islands that were mostly separated by narrow mangrove lined channels. In the 1950s these islands were reclaimed and became "Kooragang Island". Habitat types within the Reserve include mangrove forests dominated by Grey Mangrove (*Avicennia marina*), Samphire (*Sarcocornia* sp.) saltmarsh, Paperbark (*Melaleuca sp.*) and Swamp she-oak swamp (*Casuarina glauca*) forests, brackish swamps, mudflats, and sandy beaches.

Hunter Wetlands Centre Australia is a small but unique complex of wetland types surrounded by urban development along three boundaries and is located approximately 2.5 km west of the proposed action. Previously degraded, this urban wetland has been restored. Habitat types at the Hunter Wetlands Centre Australia include restored semi-permanent/seasonal freshwater ponds and marshes, natural semi-permanent/seasonal brackish ponds and marshes, freshwater swamp forests and a coastal estuarine creek.

The Hunter Estuary Wetlands Ramsar site is important as both a feeding and roosting site for a large seasonal population of shorebirds and as a waylay site for transient migrants. Over 250 species of birds have been recorded within the Ramsar site, including 45 species listed under international migratory conservation agreements. In addition, the Ramsar site provides habitat for the nationally threatened Green and Golden Bell Frog, Red Goshawk and Australasian Bittern.

The Ramsar site was traditionally used by the Worimi, Awabakal and Pambalong peoples. There are numerous middens and campsites scattered throughout the lower Hunter River, particularly within the dunes along Stockton Bight. The Hunter Wetlands Centre Australia also contains an archaeological site that is believed to have been an area for the production of stone tools.

Currently, the Kooragang component is used for recreational and nature-based activities. The Hunter Wetlands Centre Australia actively promotes wetland conservation and wise use through communication and education, passive recreation and community involvement.

Justification of the listing criteria:

The Hunter Estuary Wetlands Ramsar site meets three of the nine criteria:

Criterion 2: The Hunter Estuary Wetlands Ramsar site supports 3 species that are nationally and internationally listed. The estuary stingray (*Dasyatis fluviorum*) listed as vulnerable on the IUCN Red List) and the green and golden bell frog (*Litoria aurea*) listed as vulnerable under the Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act) have been found within the Kooragang component of the Ramsar site. The Australasian bittern (*Botaurus poiciloptilus*) listed as endangered on both the EPBC Act and the IUCN Red List (Version 2009.1) has been found at both components of the Ramsar site.

Criterion 4: The Hunter Estuary Wetland Ramsar site supports 112 species of waterbirds and 45 species of migratory birds listed under international agreements, including the great egret (*Ardea alba*), cattle egret (*Ardea ibis*), terns (*Sterna* spp.), glossy ibis (*Plegadis falcinellus*) and white-breasted sea-eagle (*Haliaeetus leucogaster*).

The Hunter Estuary wetlands also provide refuge for waterbirds such as ducks and herons during periods of inland drought.

Criterion 6: The Hunter Estuary Wetland Ramsar site regularly supports 1% of the population of the eastern curlew (*Numenius madagascariensis*) and the red-necked avocet (*Recurvirostra novaehollandiae*).

Nature and extent of likely impact

The construction phase of the capping works will include some noise, light and vibration disturbance from machinery which may affect some species such as birds, within immediate proximity of the capping works. Given that the Ramsar site is at least 260 m from any construction disturbance, it is considered that that the effect of the proposal would be negligible because it would be of low magnitude and limited to a small extent of the Ramsar site. This rationale is based on the local analogue of Stockton Sandspit which provides a resting and feeding place for large aggregations of migratory wading birds, despite being within 100 m off Stockton Bridge/B63 Road, which has heavy vehicle traffic especially during peak hour periods.

Once the capping works are completed, it will result in less infiltration of rainwater into the landfill. This will intern result in slightly higher runoff, which will drain into the surrounding small ponds. Runoff or overtopping of ponds would then drain in to the much larger Deep Pond, ultimately entering the Hunter River South Arm, which is not part of the Ramsar site. Water entering the ponds via overland flow is likely to be less saline and have fewer contaminants than water which has percolated through the landfill areas.

While potential groundwater connections between the Ramsar site and wetland areas adjacent to the Ramsar site may exist, the proposal is highly unlikely to cause any significant changes to the water quality of the Ramsar site. Modelling of contaminant migration associated with the T4 project indicates an increased timeframe before existing contaminants within KIWEF could potentially reach the Ramsar site under a post capping scenario. The proposed action does not include any additional waste emplacement and is designed to reduce the mobilisation of contaminants within the landfill and as such impacts to the Ramsar Wetlands are likely to be beneficial thorough improved water quality.

Given the temporary and negligible effects of the construction activities and the negligible ongoing negative impacts associated with completion of the capping activities, there will be no significant impact on the ecological character of the Ramsar wetland, nor the species it contains, refer to Annex C for the Assessment of Significance.

3.1 (d) Listed threatened species and ecological communities

Description

The protected matters search tool (PMST) identified that three listed Threatened Ecological Communities (TECs), 63 listed threatened species and 73 listed migratory species have the potential to occur within 10 km of the Ecology Study Area (refer to *Annex B*). EPBC Act-listed species identified through other means, such as searches of the Atlas of NSW Wildlife (Bionet) were also considered in this assessment.

The Site has been assessed previously by GHD (2010) and a larger area, encompassing the site of the closure works, has also been assessed for T4 by Umwelt (2012). The results from these previous investigations have been reviewed and included within this assessment, in order to produce a consolidated and up to date ecological assessment and consideration of MNES.

Summary of Field Survey techniques and Effort.

ERM 2015

ERM conducted a one day site survey on 10 November 2015, in order to ground truth the other surveys and vegetation mapping conducted by GHD and Umwelt. This allowed any regeneration of the vegetation subsequent to those studies to be verified and any changes to fauna habitats to be documented. During the survey any incidental fauna species were recorded.

GHD 2010

GHD conducted field surveys between 25th February and 26th March 2009. The field surveys were undertaken by eight ecologists over two nights on three separate occasions. Refer to *Table 2* below for weather records and the specific dates of the GHD surveys. The survey techniques and duration of each investigation method is summarised in *Table 3*.

Table 2 - GHD Field Survey Dates (2010).

Date	Min Temp (˚C)	Max Temp (˚C)	Rainfall (mm)
25/02/2009	21.7	25.9	0.0
26/02/2009	21.0	23.8	0.0
11/03/2009	21.1	23.0	0.2
12/03/2009	19.0	24.6	7.6
25/03/2009	19.1	26.9	0.0
26/03/2009	17.8	26.2	0.0

Table 3 - GHD Survey Techniques and Survey Effort.

Method	Effort
Green and Golden Bell Frog	
Habitat Assessment including transects to assess vegetation type and condition. Habitats defined as known or potential habitat.	3 days/evenings over a 2 week period.
Tadpole surveys using standardised dip-net surveys in all waterbodies observed within the site. Included searches for basking metamorphs.	5 repeats of 5 sweeps.
Auditory survey followed by call playback	3 evenings spread over a 2 week period.
Tadpole/Fish Traps using net traps and bait. Checked periodically.	
Spotlighting Surveys, including counts of GGBF and capture-release to swab for chytrid and measure and measurements of snout – urostyle length. Photographs were also taken to allow potential recaptures to be identified.	6-7 hrs after sunset, 3 evenings spread over a 2 week period.
Water Quality	
Water quality parameters were collected in each pond, including: Temperature (°C), pH, Redox, Conductivity (uS), and Dissolved Oxygen (DO).	
Vegetation Mapping	
Vegetation Mapping (LHCCREMS, 2003) was reviewed and ground verified during the field surveys using quadrats and transects. Focused on EECs and TECs. Dominant species recorded with random meanders also used to pick up additional species. Vegetation map was prepared to show results.	
Bats	
Anabats were used to record bat calls at several locations in the Site, with the calls subsequently identified.	11 hours on 25th and 4 hours on 26th March 2009.
Opportunistic Observations	
Incidental records of all vertebrate species were collected throughout the survey period.	Six days/evenings.

Table 3 is compiled from data sourced from GHD 2010.

Umwelt 2012

Umwelt conducted surveys across the T4 site over four seasons in order to account for seasonal variation and to increase detectability of different species. The surveys were conducted in a large area beyond just the KIWEF Closure Works Site, however many of the targeted surveys for key species such as the GGBF (*Litoria aurea*) and Australasian Bittern (*Botaurus poiciloptilus*) were conducted in the Closure Works Site or adjacent to it. In total, 103 person-days or nights (of 8-12 hours each) were used to comprehensively sample the fauna assemblages of the T4 project area and surrounds. Opportunistic fauna recording was also completed during other surveys completed within the T4 project area. *Table 4* details the survey effort and timing of the Umwelt investigation.

Table 4– Terrestrial Fauna Survey Timing for T4 Project Area and Surrounds

Survey Area	**Season**	**Year**	**Period**	**Length**
		T4 project area		
T4 Stockyard Site	Spring	2010	11, 12, 17, 22, 25, 29 & 30 November	14 person days/nights
	Summer	2010/2011	8 & 10 February	4 person days/nights
Proposed rail and utility corridor	Summer	2011	14, 15, 16, 17, 21 & 22 February	12 person days/nights
	Autumn	2011	7 & 10 March	4 person days/nights
	Summer	2012	31 January	2 person days/nights
Targeted On-site Threatened Fauna Surveys	Autumn	2010	9, 10, 15 &16 March	8 person days/nights
	Winter	2010	6, 7 & 8 July, 18, 19 & 20 August	12 person days/nights
	Spring	2010	10, 11, 12 & 17 November	8 person days/nights
	Summer	2010/2011	8, 13, 14, 15 & 20 December, 19, 20, 24 & 27 January	18 person days/nights
Micro-bat habitat survey in mangroves	Summer	2011	15 February	2 person days/nights
	Autumn	2011	7 &10 March	4 person days/nights
		Off-site		
Off-site green and golden bell frog surveys	Summer	2011	1, 2, 3, 16 &21 February	10 person days
	Autumn	2011	24 March	2 person days/nights
	Summer	2012	18, 19 January	3 person days/nights

Table 5 further details the Umwelt survey methods and the compares the identified State Government survey requirements against the actual surveys completed.

Table 5 – Terrestrial Fauna Survey Timing for T4 Project Area and Surrounds

Survey Target	**Survey Method**	**Survey Requirement (DEC 2004)**	**Survey Effort Employed for EA**	**Habitat Stratification Units Surveyed (number of sites)**
Amphibians (including Green and Golden Bell Frog)	Nocturnal Call playback	At least one playback on each of two separate nights	20 sessions of call playback were undertaken across 7 fauna survey sites over two seasons. In addition to this, at least two sessions were undertaken at the 24 targeted green and golden bell frog sites, over at least two seasons.	Freshwater Wetland (26) Saltmarsh (1) Mangrove Forest (2) Disturbed Land (2)
	Night watercourse search	Two hours per 200 metres of water's edge	Two nocturnal watercourse surveys, each of one person-hour on two separate nights, were undertaken at the 7 fauna survey sites over two seasons. Between two and five nocturnal watercourse surveys were undertaken at the 24 targeted green and golden bell frog sites, over three seasons.	Freshwater Wetland (31)

Survey Target	Survey Method	Survey Requirement (DEC 2004)	Survey Effort Employed for EA	Habitat Stratification Units Surveyed (number of sites)
	Diurnal herpetological searches	One hour per stratification unit	Two diurnal herpetological surveys, each of one person-hour on two separate days, were undertaken at the 7 fauna survey sites, over two seasons.	Freshwater Wetland (1) Mangrove Forest (2) Saltmarsh (1) Planting (1) Disturbed Land (2)
	Opportunistic observations	-	Opportunistic observations were made throughout all surveys.	All
Reptiles	Diurnal herpetological searches	30 minute search on two separate days targeting specific habitat	Two diurnal herpetological habitat searches, each of one person-hour on two separate days, were undertaken at the 7 fauna survey sites, over two seasons.	Freshwater Wetland (1) Mangrove Forest (2) Saltmarsh (1) Planting (1) Disturbed Land (2)
	Spotlighting surveys	30 minute search on two separate nights targeting specific habitat	Two nocturnal spotlighting surveys, each of one person-hour on two separate nights, were undertaken at the 7 fauna survey sites, over two seasons.	Freshwater Wetland (1) Mangrove Forest (2) Saltmarsh (1) Planting (1) Disturbed Land (2)
	Opportunistic observations	-	Opportunistic observations were made throughout all surveys.	All
Diurnal Birds (including threatened raptors, migratory shorebirds, threatened wetland-dependent birds and threatened woodland birds)	Area search	Per stratification unit	Two diurnal bird surveys, each of one person-hour, were undertaken at the 7 fauna survey sites, over two seasons. In addition to this, bird surveys were undertaken at two sites areas considered to be 'important bird habitat' by Lindsey (2008) and Herbert (2007). Two survey periods, each comprising one person-hour, were sampled at the two locations over one season. An additional site was surveyed in the proposed rail and utility corridor on one occasion.	Freshwater Wetland (3) Mangrove Forest (2) Saltmarsh (3) Planting (1) Disturbed Land (2) Open Water (Deep Pond) (1)
	Opportunistic observations	-	Opportunistic observations were made throughout all surveys.	All

Survey Target	**Survey Method**	**Survey Requirement (DEC 2004)**	**Survey Effort Employed for EA**	**Habitat Stratification Units Surveyed (number of sites)**
Nocturnal Birds (including threatened owls, bitterns and bush-stone curlew (*Burhinus grallarius*))	Call playback surveys	Sites should be separated by 800 metres – 1km, and each site must have the playback session repeated as follows: - at least 5 visits per site, on different nights are required for the Powerful Owl, Barking Owl and the Grass Owl; - at least 6 visits per site for the Sooty Owl, and 8 visits per site for the Masked Owl are required. Sites for Bush Stone-curlew surveys should be 2-4 km apart and conducted during the breeding season.	20 sessions of call playback were undertaken across 7 fauna survey sites over two seasons. Two sessions of call playback were undertaken at the 6 targeted eastern grass owl sites, over three seasons. Two sessions of call playback were undertaken at the 13 targeted Australasian bittern sites, over four seasons.	Freshwater Wetland (14) Mangrove Forest (2) Saltmarsh (1) Planting (1) Disturbed Land (6)
Nocturnal Birds (including threatened owls, bitterns and bush-stone curlew)	Spotlighting surveys	Spotlighting for plains wanderer and bush stone-curlew by foot or from a vehicle driven in first gear.	Two nocturnal spotlighting surveys, each of one person-hour on two separate nights, were undertaken at the 7 fauna survey sites, over two seasons. Spotlighting was undertaken in conjunction with call playback surveys at the 6 targeted eastern grass owl sites and 13 targeted Australasian bittern sites, over three and four seasons, respectively.	Freshwater Wetland (14) Mangrove Forest (2) Saltmarsh (1) Planting (1) Disturbed Land(6)
	Day habitat searches	Search habitat for pellets, and likely hollows. Flushing of bush stone-curlews by walking through potential habitat.	Two diurnal flushing surveys were undertaken at 3 targeted eastern grass owl sites in preferred habitat within the T4 project area, over two seasons. Two diurnal flushing surveys of potential diurnal roost habitat, such as tall emergent aquatic vegetation, was undertaken across the 13 targeted Australasian bittern sites within the T4 project area, over four seasons. One flushing survey was undertaken on one occasion within the proposed rail and utility corridor.	Freshwater Wetland (14) Disturbed Land (3)

Survey Target	Survey Method	Survey Requirement (DEC 2004)	Survey Effort Employed for EA	Habitat Stratification Units Surveyed (number of sites)
	Opportunistic observations	-	Opportunistic observations were made throughout all surveys.	All
Mammals (excluding bats)	Hair tubes	10 large and 10 small tubes in pairs for at least 4 days and 4 nights.	Hair funnel transects were placed along a 200 metre transect at the 7 fauna survey sites. Each transect comprised 20 terrestrial hair funnels. Hair funnels remained on-site for 14 days thereby resulting in 280 trap nights per fauna site.	Freshwater Wetland (1) Mangrove Forest (2) Saltmarsh (1) Planting (1) Disturbed Land (2)
	Spotlighting surveys	2 x one hour and 1km up to 200 hectares of stratification unit, walking at approximately 1km per hour on 2 separate nights.	Two nocturnal spotlighting surveys, each of one person-hour on two separate nights, were undertaken at the 7 fauna survey sites, over two seasons.	Freshwater Wetland (1) Mangrove Forest (2) Saltmarsh (1) Planting (1) Disturbed Land (2)
	Search for scats and signs	30 minutes searching each relevant habitat, including trees for scratch marks	Two general habitat searches, each of one person-hour on two separate days, were undertaken at the 7 fauna survey sites, over two seasons.	Freshwater Wetland (1) Mangrove Forest (2) Saltmarsh (1) Planting (1) Disturbed Land (2)
	Opportunistic observations	-	Opportunistic observations were made throughout all surveys.	All
Bats (including threatened micro-bats and the grey-headed flying- fox (*Pteropus poliocephalus*))	Ultrasonic call recording (Anabat)	Two sound activated recording devices utilised for the entire night (a minimum of four hours), starting at dusk for two nights.	Anabat surveys, on two separate nights, were undertaken at the 7 fauna survey sites, over two seasons. In addition to this, Anabat surveys were conducted over two nights at nine targeted micro-bat habitat survey sites over three seasons. A targeted area search was also undertaken in mangrove habitat at two sites using a hand-held Anabat on one occasion.	Freshwater Wetland (5) Mangrove Forest (4) Saltmarsh (2) Planting (1) Disturbed Land (5) Open Water (Deep Pond) (1)
	Spotlighting surveys	2 x one hour spotlighting on two separate nights	Two nocturnal spotlighting surveys, each of one person-hour on two separate nights, were undertaken at the 7 fauna survey sites, over two seasons.	Freshwater Wetland (1) Mangrove Forest (2) Saltmarsh (1) Planting (1) Disturbed Land (2)

Survey Target	Survey Method	Survey Requirement (DEC 2004)	Survey Effort Employed for EA	Habitat Stratification Units Surveyed (number of sites)
	Stag watching	Observing potential roost hollows for 30 minutes prior to sunset and 60 minutes following sunset (recommended for gliders and possums)	Two stag watching surveys, each of one person-hour on one occasion, was undertaken at two potential mangrove micro-bat roost sites.	Mangrove Forest (2)
Bats (including threatened micro-bats and the grey-headed flying- fox)	Day habitat searches	Searches for bat excreta at or near potential habitats.	One habitat assessment was undertaken on one occasion at four potential mangrove roost sites. Dominant species cover, ground cover, presence and quantity of perch sites, litter presence, number of stags, stumps and logs were recorded.	Mangrove Forest (4)
	Opportunistic observations	-	Opportunistic observations were made throughout all surveys.	All

This table has been extracted from Umwelt 2014 and adapted for the purposes of this referral.

Likelihood of Occurrence Methodology and Impact Assessment
The list of subject species was collated from a combination of the PMST, Atlas Records and Field Surveys. Any entirely marine species (such as Cetaceans, Marine Fish and Pelagic Seabirds) were excluded from the Subject Species list given a lack of marine habitat within the Closure Works area. Species which may occasionally occur within the Closure Works area or may flyover the site (such as shorebirds) were included.

Based on the field surveys and desktop research, the likelihood of each listed threatened species and TEC listed under the EPBC Act, was assessed using the following definitions:

- Known:
  - The threatened matter has been recorded in the Ecology Study Area during recent field surveys; or
  - Database records demonstrate that the threatened matter has been known to occur in the Ecology Study Area within the last 10 year period.
- Potential:
  - The threatened matter's known distribution includes the Ecology Study Area, and suitable habitat is present within the Ecology Study Area; or
  - Database records demonstrate that the threatened matter has been known to occur in the Ecology Study Area, however has not been recorded within the last 10 years; or
  - The threatened matter is a wide ranging volant species which may 'fly-over' the Ecology Study Area, regardless of the habitat types present and has been recorded within 10 km of the Ecology Study Area.
- Unlikely:
  - The threatened matter has not been recorded within 10 km of the Ecology Study Area and suitable habitat does not occur within the Ecology Study Area; or
  - The Ecology Study Area is not within the threatened matter's known distribution; or
  - Sufficient field surveys have been conducted within the Study Area to conclude that the species is likely to be absent.

Qualitative risk matrix

The assessment of significance of impacts assigns a rating for the 'sensitivity' of the matter or habitat and a 'consequence' is applied as defined in *Table 6*. The product of the sensitivity and the consequence is the 'impact significance rating'. That is, Sensitivity x Consequence = Impact Significance Rating. This risk matrix is applied if a threatened matter has the potential to occur or is known to occur. If the risk to the matter is considered **low** then further assessment is **not** considered necessary. If the matter has a **medium, high** or **very high risk** then further assessment is required, including an assessment of significance.

Table 6 - Impact Significance Ratings for Threatened Matters.

		Consequence			
		Negligible[1]	Minor[2]	Moderate[3]	Major[4]
Sensitivity	Ecological value not listed as threatened	Low	Low	Medium	High
	Ecological value listed as Vulnerable or Migratory	Low	Medium	Medium	High
	Ecological value listed as Endangered	Medium	High	High	Very High
	Ecological value listed as Critically Endangered	Medium	High	Very High	Very High

Consequence Definitions

[1]Negligible: No impacts to an ecological community. Effect on species is within the likely normal range of variation. No removal of specific breeding habitat features.

[2]Minor: Indirect impacts to listed ecological community (eg changes to water quality, introduction of pathogens, introduction of invasive flora) which may affect a small proportion of the ecological community. Effects a small proportion of a population and Project-related mortality of a small number of individuals may occur, but does not substantially affect other species dependent on it, or the populations of the species itself. No removal of specific breeding habitat features.

[3]Moderate: Direct removal of a portion of a listed ecological community. Effects a sufficient proportion of a species population that may bring about a substantial change in abundance and/or reduction in distribution over one or more generations, but does not threaten the long term viability of that population or any population dependent on it.

[4]Major: Direct removal of a listed ecological community. Effects an entire population or species at sufficient scale to cause a substantial decline in abundance and/or change in distribution beyond which natural recruitment (reproduction, immigration from unaffected areas) may not return that population or species, or any population or species dependent upon it, to its former level within several generations, or when there is no possibility of recovery.

Species sensitivity definitions

Species sensitivities refer to the listing under either the EPBC Act or TSC Act. Where the species listings differ, the higher sensitivity is used.

Table 7 details the risk assessment process for each of the individual species identified through the PMST, Atlas Records and Field Surveys.

Table 7 - Likelihood of Occurrence Table and Risk Assessment for Threatened Entities Listed Under the EPBC Act

Species Name	Species Sensitivity		Habitat Requirements	Likelihood of Occurrence	Description of Potential Impact	Consequence of impact on species	Risk Level
	TSC Act Status	EPBC Act Status					
Amphibians							
Litoria aurea Green and Golden Bell Frog	E	V	Inhabits marshes, dams and stream-sides, particularly those containing bullrushes (*Typha* spp.) or spikerushes (*Eleocharis* spp.). Optimum habitat includes water-bodies that are unshaded, free of predatory fish such as Plague Minnow (*Gambusia holbrooki*), have a grassy area nearby and diurnal sheltering sites available. Some sites occur in highly disturbed areas (OEH 2015).	**Known.** This species has been recorded within and adjacent to the Closure Works area, including areas of known breeding habitat. A large number of field studies have been conducted in this area, including GHD 2010 and Unwelt 2012.	The Closure Works area contains potential terrestrial foraging habitat for this species which will be cleared, capped, and sequentially revegetated. Breeding areas (wetlands habitats) will not be directly impacted, however changes to hydrology may cause indirect impacts.	**Minor.**	**Moderate.**
Litoria littlejohni Littlejohns treefrog	V	V	Occurs along permanent rocky streams with thick fringing vegetation associated with eucalypt woodlands and heaths among sandstone outcrops.	**Unlikely.** There are no records of this species within the locality, and the species has not been detected during field surveys.	NA	NA	NA
Reptiles							
Hoplocephalus bungaroides Broad-headed Snake	E	V	Largely confined to Triassic and Permian sandstones, including the Hawkesbury, Narrabeen and Shoalhaven groups, within the coast and ranges in an area within approximately 250 km of Sydney. Shelters in rock crevices and under flat sandstone rocks on exposed cliff edges during autumn, winter and spring (OEH, 2015)	**Unlikely.** Suitable habitat does not exist within the Closure Works area, and there are no records within the locality.	NA	NA	NA
Birds							
Anthochaera phrygia Regent Honeyeater	CE	CE	In NSW the distribution is very patchy and mainly confined to the two main breeding areas (Capertee Valley and Bundarra-Barraba regions) and surrounding fragmented woodlands. Every few years non-breeding flocks are seen foraging in flowering coastal Swamp Mahogany and Spotted Gum forests on the upper north coast.	**Unlikely.** There are records within the locality, however suitable habitat for the species, does not occur within the Closure Works area.	NA	NA	NA

Species Name	Species Sensitivity		Habitat Requirements	Likelihood of Occurrence	Description of Potential Impact	Consequence of impact on species	Risk Level
	TSC Act Status	EPBC Act Status					
Botaurus poiciloptilus Australasian Bittern	E	E	Inhabits terrestrial and estuarine wetlands. Prefers dense vegetation including sedges, rushes and reeds.	**Known.** There several records directly adjacent to the Closure Works area recorded by Umwelt (2012).	The proposal will not remove habitat for this species as wetlands will not be cleared or modified. There is the potential for indirect affects including changes to water quality. Construction disturbance may cause the species to vacate habitats adjacent to the direct impact area.	**Minor.**	**High.**
Calidris ferruginea Curlew Sandpiper	E	CE, Mi	Generally occupies littoral and estuarine habitats, and in New South Wales is mainly found in intertidal mudflats of sheltered coasts. Also occurs in non-tidal swamps, lakes and lagoons on the coast and sometimes inland (OEH 2015).	**Known.** This species has been recorded on the mud flats surrounding Deep Pond by Umwelt. Deep pond is directly adjacent to the Closure Works area.	The proposal will not remove habitat for this species as wetlands will not be cleared or modified. There is the potential for indirect affects including changes to water quality. Construction disturbance may cause the species to vacate habitats adjacent to the direct impact area.	**Minor.**	**High.**
Grantiella picta Painted Honeyeater	V	V	Inhabits Boree, Brigalow and Box-Gum Woodlands and Box-Ironbark Forests. A specialist feeder on the fruits of mistletoes growing on woodland eucalypts and acacias. Prefers mistletoes of the genus Amyema. Insects and nectar from mistletoe or eucalypts are occasionally eaten. Nest from spring to autumn in a small, delicate nest hanging within the outer canopy of drooping eucalypts, she-oak, paperbark or mistletoe branches (OEH 2015).	**Unlikely.** Suitable habitat for this species does not occur within the site. The species has been recorded in close proximity to the Site.	NA	NA	NA
Lathamus discolor Swift Parrot	E	E	This species occurs in areas where eucalypts are flowering profusely or where there are abundant lerp (from sap-sucking bugs) infestations. Favoured feed trees include winter flowering species such as Swamp Mahogany (*Eucalyptus robusta*) and Spotted Gum (*Corymbia maculata).*	**Unlikely.** The species has not been recorded within the immediate vicinity of the Closure Works and suitable habitat does not exist within the site.	NA	NA	NA

Species Name	Species Sensitivity		Habitat Requirements	Likelihood of Occurrence	Description of Potential Impact	Consequence of impact on species	Risk Level
	TSC Act Status	**EPBC Act Status**					
Numenius madagascariensis Eastern Curlew		C E, Mi	This species preferred foraging and roosting habitat are intertidal mudflats, particularly where mangroves are present, and saltmarsh. They occur in intertidal coastal mudflats, coastal lagoons, sandy spits (Pizzey and Knight 2003). The species does not breed in Australia.	**Known.** this species has been recorded several times within the Site, especially in the Deep Pond area, which is likely to provide (sub-optimal) foraging habitat for the species. The species is associated with the periphery of wetland areas, and is unlikely to utilise other area of the closure works.	The proposal will not remove habitat for this species as wetlands will not be cleared or modified. There is the potential for indirect affects including changes to water quality. Construction disturbance may cause the species to vacate habitats adjacent to the direct impact area.	**Minor.**	**High.**
Rostratula australis Australian Painted Snipe	E	E, M	Prefers fringes of swamps, dams and nearby marshy areas where there is a cover of grasses, lignum, low scrub or open timber. Forages nocturnally on mud-flats and in shallow water. Feeds on worms, molluscs, insects and some plant-matter. Nests on the ground amongst tall vegetation, such as grasses, tussocks or reeds (OEH, 2015).	**Potential.** The species has been recorded within 1 km of the Site, during 2012 (Bionet). Field surveys have failed to detect the species however, owing to suitable habitat existing within the Closure Works area the species is considered to have the potential to occur, perhaps intermittently.	The proposed work will temporarily remove potential sub-optimal foraging and nesting habitat in the terrestrial areas. The construction activities may also disturb the species in adjacent wetland areas, causing it to temporarily vacate foraging habitat.	**Minor.**	**High.**
Mammals							
Chalinolobus dwyeri Large-eared Pied Bat	V	V	This species is found in well-timbered areas containing gullies and generally rare with a very patchy distribution in NSW. There are scattered records from the New England Tablelands and North West Slopes. It roosts in caves (near their entrances), crevices in cliffs, old mine workings and in the disused, bottle-shaped mud nests of the Fairy Martin (*Petrochelidon ariel*).	**Unlikely.** This species has been recorded in the locality at Ash Island, however there is an absence of well-timbered habitat within the Closure Works area and therefore the species is not anticipated to occur.	NA	NA	NA
Dasyurus maculatus Spotted-tailed Quoll	V	E	Recorded across a range of habitat types, including rainforest, open forest, woodland, coastal heath and inland riparian forest, from the sub-alpine zone to the coastline. Mostly nocturnal, although will hunt during the day; spends most of the time on the ground, although also an excellent climber and may raid possum and glider dens and prey on roosting birds.	**Unlikely.** This species has been recorded within the locality, however suitable habitat for this species does not exist within the Closure Works area .	NA	NA	NA

Species Name	Species Sensitivity		Habitat Requirements	Likelihood of Occurrence	Description of Potential Impact	Consequence of impact on species	Risk Level
	TSC Act Status	EPBC Act Status					
Brush-tailed Rock-wallaby Petrogale penicillata	E	V	This species often occupies rocky escarpments, outcrops and cliffs with a preference for complex structures with fissures, caves and ledges facing north. Their distribution generally follows the line of the Great Dividing Range, however this has become increasingly more fragmented.	**Unlikely.** There are no records of this species within the locality (Bionet 2015) and the habitat within the Closure Works area is unsuitable for the species	NA	NA	
Phascolarctos cinereus Koala	V	V	Feed on the foliage of more than 70 eucalypt species and 30 non-eucalypt species, but in any one area will select preferred browse species. The Area 13 Koala Plan of Management (KPOM) identifies four feed trees within the region: Forest Red Gum (*E. tereticornus*), Tallowwood (*E. microcorys*), Swamp Mahogany (*E. robusta*), and Grey Gum (*E. propinqua*) (Biolink 2008).	**Unlikely.** There are records within the locality, however suitable habitat for the species does not exist within the Closure Works area . Furthermore there is no connectivity between the Study Area and areas where the species has been recorded.	NA	NA	NA
Potorous tridactylus tridactylus Long-nosed Potoroo (SE mainland)	V	V	Inhabits coastal heaths and dry and wet sclerophyll forests. Dense understorey with occasional open areas is an essential part of habitat, and may consist of grass-trees, sedges, ferns or heath, or of low shrubs of tea-trees or melaleucas. A sandy loam soil is also a common feature. The fruit-bodies of hypogeous (underground-fruiting) fungi are a large component of the diet of the Long-nosed Potoroo. They also eat roots, tubers, insects and their larvae and other soft-bodied animals in the soil. (OEH 2015).	**Unlikely.** There are records of this species within the locality (Bionet 2014), however suitable habitat does not exist within he Closure Works area.	NA	NA	NA
Pseudomys novaehollandiae New Holland Mouse	-	V	In NSW, the New Holland Mouse is known from Royal National Park, Kangaroo Valley and from Port Stephens to Evans Head (OEH SPRAT). This species is known to inhabit open heathland, open woodland with a heathland understorey and vegetated sand dunes. Soil type may also be an important indicator of suitability of habitat, with deeper top soils and softer substrates being preferred for digging burrows.	**Unlikely.** There are records of this species within the locality (Bionet 2014), however the Closure Works area does not constitute preferred habitat, due to the lack of suitable vegetation and preferred habitat features.	NA	NA	NA

Species Name	Species Sensitivity		Habitat Requirements	Likelihood of Occurrence	Description of Potential Impact	Consequence of impact on species	Risk Level
	TSC Act Status	EPBC Act Status					
Pteropus poliocephalus Grey-headed Flying-fox	V	V	Occur in subtropical and temperate rainforests, tall sclerophyll forests and woodlands, heaths and swamps as well as urban gardens and cultivated fruit crops. Roosting camps are generally located within 20km of a regular food source and are commonly found in gullies, close to water, in vegetation with a dense canopy. Individual camps may have tens of thousands of animals and are used for mating, and for giving birth and rearing young. Site fidelity to camps is high; some camps have been used for over a century. Can travel up to 50km from the camp to forage; commuting distances are more often <20km. Feed on the nectar and pollen of native trees, in particular *Eucalyptus, Melaleuca* and *Banksia*, and fruits of rainforest trees and vines. Also forage in cultivated gardens and fruit crops (OEH 2015).	**Known.** There are numerous records of this species within the locality, including records of the species flying over the subject site (GHD 2010). Despite the presence of the species, the Closure Works area does not include any habitat likely to be utilised by the species, with no foraging or roosting resources present.	The capping works will not impact the species as the species is only anticipates to fly over the Closure Works area and no habitat for the species exists, within the Closure Works area.	**Negligible.**	**Low.**
Flora							
Allocasuarina defungens Dwarf Heath Casuarina	E	E	Dwarf Heath Casuarina grows mainly in tall heath on sand, but can also occur on clay soils and sandstone. The species also extends onto exposed nearby-coastal hills or headlands adjacent to sandplains (OEH 2015).	**Unlikely.** Records do not occur within the locality (Bionet 2015). No suitable habitat within the Closure Works area.	NA	NA	NA
Angophora inopina Charmhaven Apple	V	V	Occurs most frequently in four main vegetation communities: (i) *Eucalyptus haemastoma–Corymbia gummifera–Angophora inopina* woodland/forest; (ii) *Hakea teretifolia–Banksia oblongifolia* wet heath; (iii) *Eucalyptus resinifera–Melaleuca sieberi–Angophora inopina* sedge woodland; (iv) *Eucalyptus capitellata–Corymbia gummifera–Angophora inopina* woodland/forest	**Unlikely.** Recorded within the locality, however suitable habitat and associated vegetation types do not occur within the Closure Works area. It has not been recorded during previous field surveys.	NA	NA	NA
Commersonia prostrata Dwarf Kerrawang	E	E	Occurs on sandy, sometimes peaty soils in a wide variety of habitats.	**Unlikely.** Recorded within the locality, however suitable habitat and associated vegetation types do not occur within the Closure Works area. It has not been recorded during previous field surveys.	NA	NA	NA

Species Name	Species Sensitivity		Habitat Requirements	Likelihood of Occurrence	Description of Potential Impact	Consequence of impact on species	Risk Level
	TSC Act Status	EPBC Act Status					
Cynanchum Elegans White-flowered Wax Plant	E	E	This species usually occurs on the edge of dry rainforest vegetation. In the Hunter Valley it is known to occur at Singleton Military Area and Kooragang Island.	**Unlikely.** Suitable habitat and associated vegetation types do not occur within the Closure Works area. It has not been recorded during previous field surveys. The species has been recorded close to the Study Area on Ash Island within forested areas.	NA	NA	NA
Cryptostylis hunteriana Leafless Tongue-orchid	V	V	Does not appear to have well defined habitat preferences and is known from a range of communities, including swamp-heath and woodland. The larger populations typically occur in woodland dominated by Scribbly Gum (*Eucalyptus sclerophylla*), Silvertop Ash (*E. sieberi*), Red Bloodwood (*Corymbia gummifera*) and Black Sheoak (*Allocasuarina littoralis*); appears to prefer open areas in the understorey of this community and is often found in association with the Large Tongue Orchid (*C. subulata*) and the Tartan Tongue Orchid (*C. erecta*) (OEH 2015).	**Unlikely.** There are no records within the Locality (Bionet 2015). Not recorded within the Closure Works area and suitable woodland communities types which support this species were not recorded within the impact area.	NA	NA	NA
Diuris praecox Rough Doubletail	V	V	Grows on hills and slopes of near-coastal districts in open forests which have a grassy to fairly dense understorey. Occurs in the coastal region between Ourimbah and Nelson Bay.	**Unlikely.** Recorded within the locality, however suitable habitat and associated vegetation types do not occur within the Closure Works area. It has not been recorded during previous field surveys.	NA	NA	NA
Eucalyptus camfieldii Camfield's Stringybark	V	V	Occurs in poor coastal country in shallow sandy soils overlying Hawkesbury sandstone and coastal heath mostly on exposed sandy ridges. Usually in small scattered stands near the boundary of tall coastal heaths and low open woodland of the slightly more fertile inland areas. Associated species frequently include stunted species of narrow-leaved stringybark (E. oblonga), brown stringybark (*E. capitellata*) and scribbly gum (*E. haemastoma*).	**Unlikely.** Recorded within the locality, however suitable habitat and associated vegetation types do not occur within the Closure Works area. It has not been recorded during previous field surveys.	NA	NA	NA

Species Name	Species Sensitivity		Habitat Requirements	Likelihood of Occurrence	Description of Potential Impact	Consequence of impact on species	Risk Level
	TSC Act Status	EPBC Act Status					
Eucalyptus parramattensis subsp. Decadens Earp's Gum	V	V	The Tomago Sandbeds population is bounded by Salt Ash and Tanilba Bay in the north and Williamtown and Tomago in the south. It generally occupies deep, low- nutrient sands, often those subject to periodic inundation or where water tables are relatively high. It occurs in dry sclerophyll woodland with dry heath understorey. It also occurs as an emergent in dry or wet heathland. Often where this species occurs, it is a community dominant. Flowering occurs from November to January (OEH 2015)	**Unlikely.** Recorded within the locality, however suitable habitat and associated vegetation types do not occur within the Closure Works area. It has not been recorded during previous field surveys.	NA	NA	NA
Euphrasia arguta	CE	CE	Grows in grassy areas near rivers. Preliminary determination as CE following rediscovery of four populations in the Nundle area in 2008. Distribution highly restricted to rediscovered records.	**Unlikely.** There are no records within the Locality (Bionet 2015). Not recorded within the Closure Works area, and neither suitable nor potential habitat exists.	NA	NA	NA
Grevillea parviflora subsp. parviflora Small-flower Grevillea	V	V	Grows in sandy or light clay soils usually over thin shales. Occurs in a range of vegetation types from heath and shrubby woodland to open forest and a range of altitudes from flat, low lying areas to upper slopes and ridge crests. Often occurs in open, slightly disturbed sites such as along tracks.	**Unlikely.** Recorded within the locality, however suitable soil types and associated vegetation do not occur within the Closure Works area. It has not been recorded during previous field surveys.	NA	NA	NA
Grevillea shiressii	V	V	Known from two populations within the Gosford Local Government Area. There is also a naturalised population at Newcastle. Grows along creek banks in wet sclerophyll forest with a moist understorey in alluvial sandy or loamy soils	**Unlikely.** Recorded within the locality, however habitat does not occur within the Closure Works area. It has not been recorded during previous field surveys.	NA	NA	NA
Melaleuca biconvexa Biconvex Paperbark	V	V	Biconvex Paperbark generally grows in damp places, often near streams or low-lying areas on alluvial soils of low slopes or sheltered aspects. Flowering occurs over just 3-4 weeks in September and October. Resprouts following fire (OEH 2014).	**Unlikely.** Recorded within the locality, however suitable habitat does not occur within the Closure Works area. It has not been recorded during previous field surveys.	NA	NA	NA

Species Name	Species Sensitivity		Habitat Requirements	Likelihood of Occurrence	Description of Potential Impact	Consequence of impact on species	Risk Level
	TSC Act Status	EPBC Act Status					
Persicaria elatior Tall Knotweed	V	V	This species normally grows in damp locations, especially beside lakes and streams. It has occasionally been known to occur in swamp forest as well as in association with disturbance. This species is known to occur in two disjunct areas; in south-eastern NSW and northern NSW (OEH, 2015).	**Unlikely.** Recorded within the locality, however not within close proximity to the Closure Works area. Despite some suitable habitat existing, the species has not been detected during multiple field surveys.	NA	NA	NA
Phaius australis Lesser Swamp-orchid	E	E	Swampy grassland or swampy forest including rainforest, eucalypt or paperbark forest, mostly in coastal areas.	**Unlikely.** Not recorded within the locality and suitable habitat does not occur within the Closure Works area. It has not been recorded during previous field surveys.	NA	NA	NA
Rutidosis heterogama Heath Wrinklewort	V	V	Grows in heath on sandy soils and moist areas in open forest, and has been recorded along disturbed roadsides.	**Unlikely.** Recorded within the locality, however suitable habitat does not occur within the Closure Works area. It has not been recorded during previous field surveys.	NA	NA	NA
Streblus pendulinus Siah's Backbone		E	On the Australian mainland, Siah's Backbone is found in warmer rainforests, chiefly along watercourses. The altitudinal range is from near sea level to 800 m above sea level. The species grows in well-developed rainforest, gallery forest and drier, more seasonal rainforest (ATRP 2010 as cited in DSEWPaC 2013).	**Unlikely.** Recorded within the locality, however suitable habitat does not occur within the Closure Works area. It has not been recorded during previous field surveys.	NA	NA	NA
Syzygium paniculatum Magenta Lilly Pilly	E	V	The Magenta Lilly Pilly is found only in NSW, in a narrow, linear coastal strip from Upper Lansdowne to Conjola State Forest. Occurs on gravels, sands, silts and clays in riverside gallery rainforests and remnant littoral rainforest communities.	**Unlikely.** Recorded within the locality, however suitable habitat does not occur within the Closure Works area. It has not been recorded during previous field surveys.	NA	NA	NA

Species Name	Species Sensitivity		Habitat Requirements	Likelihood of Occurrence	Description of Potential Impact	Consequence of impact on species	Risk Level
	TSC Act Status	EPBC Act Status					
Tetratheca juncea *Black-eyed Susan*	V	V	This species is confined to the northern portion of the Sydney Basin bioregion and the southern portion of the North Coast bioregion. It is usually found in low open forest/woodland with a mixed shrub understorey and grassy groundcover.	**Unlikely.** Recorded within the locality, however suitable habitat does not occur within the Closure Works area. It has not been recorded during previous field surveys.	NA	NA	NA
Threatened Ecological Communities (TECs)							
Central Hunter Valley eucalypt forest and woodland		CE	An open forest or woodland, typically dominated by eucalypt species; it has an open to sparse mid-layer of shrubs and a ground layer of grasses, forbs and small shrubs. The canopy of the ecological community is dominated by one or more of the following four eucalypt species: Narrow-leaved Ironbark (*Eucalyptus crebra*), Spotted Gum (*Corymbia maculata*), Slaty Gum (*E. dawsonii*) and Grey Box (*E. moluccana*).	**Unlikely.** The community was not recorded within the Closure Works area as the site does not offer potential given its history of modification and the landscape position which (unmodified) would provide more meisic conditions.	NA	NA	NA
Lowland Rainforest of Subtropical Australia	E*	CE	Generally a moderately tall (≥20 m) to tall (≥30 m) closed forest (canopy cover ≥70%). Tree species with compound leaves are common and leaves are relatively large (notophyll to mesophyll). Typically there is a relatively low abundance of species from the genera *Eucalyptus*, *Melaleuca* and *Casuarina*. Buttresses are common as is an abundance and diversity of vines. The canopy comprises a range of tree species but in some areas a particular species may dominate e.g. palm forest, usually dominated by *Archontophoenix cunninghamiana* (Bangalow Palm) or *Livistona australis* (Cabbage Palm); and riparian areas dominated by *Syzygium floribundum* (syn. *Waterhousea floribunda*) (Weeping Satinash/Weeping Lilly Pilly).	**Unlikely.** Not recorded within the Closure Works area, and neither suitable nor potential habitat exists, given that the site has been cleared and extensively modified from its original condition.	NA	NA	NA

Species Name	Species Sensitivity		Habitat Requirements	Likelihood of Occurrence	Description of Potential Impact	Consequence of impact on species	Risk Level
	TSC Act Status	EPBC Act Status					
Subtropical and Temperate Coastal Saltmarsh	E#	V	The ecological community consists of dense to patchy areas of mainly salt-tolerant vegetation (halophytes) including: grasses, herbs, sedges and shrubs that may also include bare sediment as part of the mosaic). Characteristic plant species include *Gahnia filum, G. trifida, Juncus kraussii, Samolus repens, Sarcocornia quinqueflora, Sporobolus virginicus, Suaeda australis, Tecticornia pergranulata, T. arbuscula, Triglochin striata, Wilsonia backousei and W. rotundifolia.* There are a number of key diagnostic characteristics for describing the *Coastal Saltmarsh* ecological community but principally this EEC occurs on the coastal margin, along estuaries and coastal embayments and on low wave energy coasts (TSSC 2013).	An area of habitat exist within the Wetland of K6 Cell 10, which has floral assemblages similar to that of Coastal Saltmarsh. However the community within the Site is permanently disconnected from the intertidal influence and therefore is not considered part of the listed community, despite having species attributes similar to the listed community.	NA	NA	NA

Species Sensitivity Status: V – Vulnerable; E – Endangered; CE – Critically Endangered.
Mi – Migratory (under the EPBC act only)
+ Listed under the TSC Act as *Littoral Rainforest in the South East Corner, Sydney Basin and NSW North Coast Bioregions* (E,TSC Act)
* Listed under the TSC Act as *Lowland Rainforest in the NSW North Coast and Sydney Basin Bioregions,* and *Lowland Rainforest on floodplain in the NSW North Coast Bioregion* (E,TSC Act)
# Listed under the TSC Act as *Coastal Saltmarsh in the NSW North Coast, Sydney Basin and South East Corner Bioregions* (E,TSC Act)

The Likelihood of Occurrence Table and Risk Assessment considered 38 entities (*Table 6*), including Three (3) TECs, 18 Plants, seven (7) mammals, seven (7) birds, one (1) snake and two (2) frog species. Threatened species records with relation to the Closure Works site are provided in *Annex A*, *Figure 3*. Of the species considered, one (1) TEC, four (4) birds and one (1) frog species are considered to warrant further assessment, these are;

- Eastern Curlew (*Numenius madagascariensis*);
- Australian Painted Snipe *(Rostratula australis*);
- Australasian Bittern (*Botaurus poiciloptilus*);
- Curlew Sandpiper (*Calidris ferruginea*), and
- Green and Golden Bell Frog.

Nature and extent of likely impact

The key direct impact of the project is the clearance of exotic grassland and exotic shrubby grassland. This will not directly impact any of threatened shorebirds or wetland birds, which do not typically utilise these terrestrial habitats. The clearance will remove some terrestrial habitat which has the potential to provide foraging habitat for the Green and Golden Bell Frog which is discussed in detail below.

The hydrological changes resulting from the capping works is discussed in Section 3.3(b). In summary greater surface run-off will occur due to the reduced permeability of the capping layer. This will result in greater runoff into Deep Pond. As the run-off will travel through a series of sediment controls, it is anticipated that this water will have a low sediment load, especially once revegetation is complete. The corresponding reduction in ground water flowing through the landfill will reduce the amount of contaminants reaching wetlands and Deep Pond. These impacts are considered of net benefit to the Wetlands and threatened species, however given the large dilution factors and other complicating external factors such as precipitation and evaporation, the effects are likely to be undetectable. There is anticipated to be no significant impact to any of the threatened species below caused by the indirect impact of changes to water quality.

The construction works will involve heavy machinery and increased human activity within the capping area. This will temporarily increase the amount of noise and visual disturbance in an area close to Wetlands. This may disrupt shorebirds and wetland birds utilising wetland habitat adjacent to the works. This impact is temporary and it is not considered significant as there are large areas of alternative habitat within the vicinity. It is also anticipated that the birds will become habituated to the disturbance and continue foraging in the area, as demonstrated at the local analogue site of Stockton Sandspit. Additional lighting during construction works will be minimal and there is no requirement for artificial lighting during the night.

The following threatened species are threatened under the EPBC Act and are considered as having the potential to be impacted by the proposed works. They are discussed below and are also considered in the Assessments of Significance (*Annex C*)

Eastern Curlew (*Numenius madagascariensis*) – Endangered and Migratory, EPBC Act

This species typically forages where intertidal mudflats are present and has occasionally been recorded in Deep Pond (refer to *Annex A, Figure 3*). It is unlikely that the habitat within the Closure Works site is important for the species given that it is not intertidal and that few records are present. Any impacts are therefore likely to affect a very low number of individuals. The proposal will not remove habitat for this species as wetlands will not be cleared or modified. The main potential impact to this species is due to construction disturbance related to the capping works. This is a temporary impact and considered negligible given that only a very small number of individuals will be affected. The species may also become habituated to the construction disturbance and therefore still able to utilise the sub-optimal foraging habitat present in Deep Pond. The Assessment of Significance (provided in *Annex C*) undertaken concluded that the impact to this species would be **not significant**.

Australasian Bittern (*Botaurus poiciloptilus*) –Endangered, EPBC Act and TSC Act

This species inhabits terrestrial and estuarine wetlands, preferring dense vegetation including sedges, rushes and reeds. It is a cryptic species, occurring at low densities within the Hunter Estuary. Habitat within and adjacent to the Closure Works site is limited to dense areas of wetland vegetation with Common Reed and Typha. The species has been recorded on four occasions during 2010 by Umwelt (2012). Locations where Bitterns were recorded include Easement Pond, Railway Pond and K6 Cell 11. Two individuals were recorded within the later location, which may indicate a single breeding pair occurring, adjacent to the site. Breeding pairs are territorial and occupy large area, therefore it is unlikely that more than one pair occurs within close proximity to the site. The proposal will not remove habitat for this species as wetlands will not be cleared or modified. The main potential impact to this species is due to construction disturbance related to the capping works. In the worst case scenario the proposed works may cause the species to avoid areas of potential foraging or breeding habitat, immediately adjacent to the proposed capping area. The wetlands adjacent to the works area are small in size and are likely to represent a small proportion of the territory required for individual birds, therefore it is anticipated that any temporary displacement that occurs will not significantly affect the species. The species will be able to forage or breed in alternative habitat within the locality. The species may also become habituated to the construction disturbance and persist in wetland habitats close to the construction works. The Assessment of Significance (provided in *Annex C*) undertaken concluded that the impact to this species would be **not significant**.

Curlew Sandpiper (*Calidris ferruginea*) Endangered and Migratory, EPBC Act; Critically Endangered, TSC Act;

Generally occupies littoral and estuarine habitats, and in New South Wales is mainly found in intertidal mudflats of sheltered coasts. This species has been recorded foraging in large numbers at Deep Pond (up to 450) in 2003 and in small numbers between 2005 and 2007 (Lindsey 2008) and more recently by Umwelt (2012). It is likely that Deep Pond provides an intermittent foraging resource for the species and may be preferred during lower water levels due to more shallow foraging habitat becoming accessible. The proposal will not remove habitat for this species as wetlands will not be cleared or modified. The construction works will involve heavy machinery and increased numbers of people within the capping area. This may disrupt the Curlew Sandpipers foraging within the eastern areas of Deep Pond. This impact is temporary and it is **not significant** as there are large areas of alternative habitat within the vicinity. It is also anticipated that the birds will become habituated to the disturbance and may continue foraging in the area.

Green and Golden Bell Frog (*Litoria aurea*) Vulnerable, EPBC Act; Endangered, TSC Act

The Green and Golden Bell Frog, has been recorded both historically and recently within the Site. Collaborative targeted surveys by GHD and RPS HSO recorded the species on multiple occasions including both adults and tadpoles. All of these records were outside of the proposed capping area, however several records were found in close proximity to the capping area. The highest density of records was from K6 Cell 11 (*refer to Annex A, Figure 4 and 5*) with breeding also recorded in this area. Other areas in which the species was recorded includes K6 Cell 10 and 12, Easement Pond, Cell 34 and the South western Corner of K7 (often referred to as K7 Ponds or North Pond 3).

Further surveys were also completed by Umwelt within the Site and the surrounding area, between 2010 and 2011. The field surveys supported GHD's findings with a similar concentration of records as described with highest recorded concentrations of Green and Golden Bell Frog within K6 Cell 11.

The annual report on the 2013/2014 Field Season for Green and Golden Bell Frog on Kooragang Island (NCIG, 2015) provided information on the distribution of the species between September 2011 and March 2014. These surveys again supported the distribution of the species described above, however there were notably more records in Deep Pond especially where emergent vegetation was present. The species was also detected calling in the central eastern margins of Deep Pond, indicating that potential breeding habitat is present.

Annex A Figure 4 shows the records of Green and Golden Bell Frog within the site and the surrounding area. It should be noted that several of the records are spatially suspect and include a high density of individuals within wholly terrestrial areas of the site, or within open water habitat in Deep Pond. It is likely that these results are a central point survey point, reflecting effort over a much large area, with individual records lumped together to form a single point. These records could not be interrogated further as they did not have detailed attribute data. Notwithstanding these spatially suspect records, the majority of the records are accurate and show clear habitat preferences for certain wetland habitats and ponds. Umwelt has also completed habitat mapping to identify Green and Golden Bell Frog Habitat, which has been replicated within *Annex A Figure 5*.

The Table 8, below, provides an overview of the known habitat usage of site and the surrounding wetlands by the Green and Golden Bell frog, the locations of the Green and Golden Bell Frog habitat can be seen on *Annex A Figure 5*.

Table 8 – Green and Golden Bell Frog Habitat Values and Impacts

Location	**Habitat Utilisation**	**Impacts as a result of the Proposed Works**
Deep Pond	The margins of the ponds provide foraging habitat for the species and a likely refuge during dry periods of weather. There is potential for breeding to occur with calling adults recorded, however no tadpoles or metamorphs have been detected to date. Tadpole may be compromised owing to the presence of high numbers of predatory fish including native eels and exotic Eastern Gambusia, which are known to predate on their tadpoles. A number of wetland birds are also likely to prey on the species.	No direct impacts as outside of the capping area. Negligible hydrological changes.
K6 Cell 11 Railway Pond and; Other Ponds within K7	Pond areas provide important breeding habitat for GGBF, with a high density of adults, metamorphs and tadpoles recorded. Ponds are optimal habitat with no Eastern Gambusia recorded, emergent vegetation, areas of open water and unshaded areas for basking. Surrounding wetland and terrestrial habitat provide foraging resources for the species with dense native and exotic vegetation present.	No direct impacts as outside of the capping area. Negligible hydrological changes.

Location	Habitat Utilisation	Impacts as a result of the Proposed Works
K6, Cells 9,10 & 12	Mosaic of wetland and terrestrial habitats which are likely to provide drought/dry weather refuge and optimal foraging resources for the species and are within close proximity to wetland habitat and breeding habitats. There are a number of records within these areas.	No direct impacts as outside of the capping area. Negligible hydrological changes.
K5, Cells 6 & 8	These areas are highly vegetated and are likely to provide some foraging habitat for adult GGBF. They are a considerable distance from the breeding ponds and unlikely to provide habitat for metamorphs. There are a small number of records in this area. Areas of similar habitat also occur within the wider K7 area (outside of the capping area) and this habitat is not considered unique. It is not anticipated that high proportions of the population would be recorded within these areas at any given time.	Temporary clearance of all vegetation and levelling earthworks.
K3 K5: Cells 1,2,3,4,5,7	These areas are dominated by exotic grassland, without large tussock forming species or other habitat complexity which is likely to provide shelter for the species. These habitats are considered largely unsuitable for the species however individuals may occasional traverse these areas.	Temporary clearance of all vegetation and levelling earthworks.

The clearance of vegetation within K5 and K3, associated with the capping works, may cause some direct impacts to the Green and Golden Bell Frog. K5 Cell 6 and 8 in particular offer potential foraging habitat for the adult Green and Golden Bell Frog, occupying an area of approximately 5.2 ha. Dense vegetation is present including large tussocks of Pampas Grass in which the species may shelter. These areas are not directly adjacent to wetland habitat and it is considered unlikely that significant numbers of the local population are located within this area at any given time. Given the dense vegetation within the site there will be a limit to the effectiveness of preclearance surveys, designed to capture and relocate individuals outside of the impact area. Attendance of clearance work by ecologists and clearing at a measured rate is likely to be the most effective method of reducing clearance related mortality. Any frogs and other native fauna disturbed by the clearance can then be captured and relocated. These mitigation measures are further described in *Section 5*. Despite the preclearance and mitigation measures there is a residual risk of mortality to Green and Golden Bell Frogs as a result of the clearance works. The impact is not anticipated to be significant however, due to a small percentage of the population likely to occur within the area at any given time.

The capping works will also remove 5.2 ha of foraging habitat for the Green and Golden Bell Frog. This area is a small area of the total potential foraging habitat available to the population with optimal foraging habitat surrounding the wetland areas, including the K6 and K7 areas, which will not be impacted by the capping works.

The potential for indirect impacts to the Green and Golden Bell Frog are largely limited to the potential changes to the hydrology of the area, due to the capping works and in particular the potential effects on breeding habitat. It is considered that any of these impacts will be negligible resulting in no perceptible changes in the Green and Golden Bell Frog breeding habitats. Changes to hydrology of the site are discussed in *Section 3.3b*, while the hydrological implications related to the Green and Golden Bell Frog are discussed below.

GHD (2009) modelled the effects of significant rainfall events on pond water levels indicating changes up to 500mm in some ponds as a result of capping. These findings are no longer supported on the basis that maximum water levels are dictated by pond outlets based on the invert levels of weirs, culverts and overflow channels and that any short term increased water levels would dissipate rapidly. No modification is being made to physical nature of the ponds, so the maximum water levels and volumetric capacity of the ponds would not change from existing conditions. Furthermore, no significant change in minimum pond levels would occur in most of the ponds, as a result of altered future hydrology on the basis that there will be no significant change to the overall water balance for the site.

Salinity levels within waterbodies have previously been identified as of importance to the protection of Green and Golden Bell Frogs from Chytrid Fungus. Previous modelling work associated with referral number 2012/6464 for the southern portion of KIWEF closure identified that pond conditions of proximate ponds would be generally wetter and fresher.

The relationship between water quality (with a focus on salinity) and GGBF habitat can be summarised in the following ways:

- The capping works are designed to reduce contaminant loads leaving the landfill and affecting receiving waters by limiting surface water penetration into the fill aquifers. This includes mobilisation and leaching of salt content in the fill;
- The capping will increase volumes of less saline surface water runoff from capped areas, and reduce higher saline groundwater inflows into the ponds;
- Research indicates that chytrid fungal control is linked to salinity and water temperature (Stockwell, et al, 2012) with saline water acting to limit infection below the threshold that may result in mortality;

- Further research is needed to confirm if certain heavy metals (Cu and Zn) provide chytrid fungal control (Threlfall et al, 2008);
- Water temperature on standing water in ponds is related to rates of solar irradiance on pond surfaces and, as such, proposed capping works would not have a significant effect on water temperature;
- The current range of salinity within and between ponds varies significantly;
- Elevated salinity in the ponds are generally attributed to concentrating effects of evaporation during dry periods;
- Saline baseflow from the fill aquifer may also influences salinity in surrounding water bodies, but to a lesser degree than the evaporation effects; and
- Peak salinity values in low elevation ponds are recorded as high as 20 000 to 35 000 µS/cm, indicating intrusion of waters from the estuarine aquifer.

Salinity level changes have the potential to impact GGBF in two main ways. These are:

- An increase in salinity in ponds above "thresholds" that would prevent GGBF tadpole and/or adult survival or habitation; and
- Reductions in salinity below a "threshold" that may provide protection against Chytrid fungus infection or development.

SMEC (2013) reported that the independent GGBF expert, Dr Arthur White, provided guidance on these thresholds based on current GGBF research (reproduced in the *Table 9* below) and using Electrical Conductivity (EC) as a measure of salinity. It should be noted that these thresholds are indicators of the suitability of ponds as different GGBF habitat and do not constitute project triggers. They have been used in the assessment process to identify the potential for significant impacts on GGBF to occur.

Table 9 Suggested Salinity Comparison Values for KIWEF Surface Water Bodies

No Chytrid Protection	**Chytrid protection threshold[1]**	**GGBF tadpole health threshold[2] (µS/cm)**	**GGBF Adult health threshold[3] (µS/cm)**
0 – 1,650 µS/cm	1,650 µS/cm	2,900 µS/cm	4,100 µS/cm

1. EC below threshold presents increased risk of mortality resulting from Chytrid Fungus.
2. EC above threshold indicates unsuitability for GGBF tadpole survival.
3. EC above threshold indicates unsuitability as GGBF adult habitat.

These levels are interpreted as follows in assessing impacts of closure works:

- Salinity levels below 1,650 (µS/cm) (Chytrid risk bracket) were identified as sub-optimal GGBF condition with individual animals likely not afforded salinity-related protection from chytrid fungus. Chronic or long term low salinity levels below this threshold are considered to increase the risks to GGBF although it would not put individuals at immediate risk of harm in the absence of Chytrid fungus (Stockwell, 2012).
- Salinity levels between 1,650 and 2,900 (µS/cm) are considered "optimal GGBF habitat" as this range provides Chytrid protection while also providing for tadpole survival and habitation and adult breeding.
- Salinity levels between 2,900 and 4,100 (µS/cm) are considered to be suitable for adult GGBF occupation, but would not be satisfactory for tadpole survival.
- Salinity above 4,100 (µS/cm) is not considered to be suitable habitat for GGBF adults over extended periods. It is likely that adult GGBF would move away from ponds with salinity levels above 4,100 µS/cm rendering them unlikely to be used for breeding (and therefore egg laying, hatching and tadpole habitation).

Observed EC ranges within ponds potentially affected by changed hydrology post capping are presented in *Table 10* below, the locations of the ponds are illustrated on Figures within *Annex A*.

Table 10 KIWEF pond salinity ranges

Surface Water Body	**Historic Indicative Conductivity Range**
Deep Pond	1,650 – 5,250 (prior 10 years only)
Blue Billed Duck Pond	802 – 1,822
BHP Wetlands	723 – 1,424
Railway Pond	1,850 - 3,400
Easement Pond	2,100 – 3,882
Easement Pond South	450 – 1,000
K2 Basin	950 – 3,940
Windmill Road Open Channel	3,600 - 16,500
Long Pond	2,845 – 10,565
Delta Channel	No Data
K7 Ponds	No Data
Cells 9,10,11 and 12	No Data

From the above it can be seen there is considerable variability within and between ponds. Additionally some ponds are currently fluctuating between salinity levels providing no chytrid protection to levels where Green and Golden Bell Frog and tadpole survival is unlikely.

Modelling of hydro-salinity changes likely to result from the capping of Area 2 has not been undertaken and is not proposed on the basis that the level of accuracy likely to be achievable is unlikely to provide confidence beyond the observation of conditions being generally wetter and fresher. Overall it is ERM's opinion that the apparent series of divergent salinity conditions between the ponds is likely to be important through variable inter-annual wetting-drying cycles, thereby providing available aquatic habitat of suitable salinity at any time. It is likely that the maintenance of the series of ponds with variable salinity (and other water quality parameters) supports ecosystem resilience and helps sustain frog populations in relation to the set of salinity thresholds derived for Green and Golden Bell Frog ecology. The proposed activity will not reduce the variability of water quality within and between ponds despite the predicted minor move towards generally fresher conditions.

In summary, the capping works will temporarily remove an area of potential foraging habitat (5.2 ha) for adult Green and Golden Bell Frog, which may also result in some direct mortality to a small number of individuals during clearance works. The area impacted represents a small proportion of the total potential foraging habitat available to the species and due to the proposed revegetation after the works, it is considered a temporary impact. Furthermore only a small proportion of the population are likely to occur in the closure works area at any given time. Larger and more optimal foraging habitat surrounding the key wetland areas, including the K6 and K7 areas, will be retained and not impacted significantly by the action. Breeding habitat will remain unaffected by this proposal and large areas of foraging habitat will be retained. It is anticipated that the proposal will not affect the recovery of the species and the carrying capacity of the habitat within the area will remain largely unchanged. Appropriate mitigation measures and hygiene controls will prevent other factors such as Chytrid fungus and *Gambusia* becoming any more prevalent and risking impacting the species. The Assessment of Significance (provided in *Annex C*) undertaken concluded that the impact to this species would be **not significant**.

3.1 (e) Listed migratory species
Description

The PMST identified 73 migratory species listed under the EPBC Act that may occur within the locality. The Site does not include marine habitat for pelagic species, therefore entirely marine species were excluded from further individual assessment. This includes cetaceans, sharks, turtles and pelagic seabirds (such as Albatross and Petrel sp.).

Thirty seven species were considered with a likelihood of occurrence table using the criteria defined in *Section 3.1(d)*, and information from field surveys undertaken to date. Sixteen migratory species have been recorded within the Closure Works site or utilising the wetland habitat immediately adjacent to the Closure Works site. A further 10 species were considered as having the potential to occur within the site and eleven (11) species were considered unlikely to occur. These species are described in more detail in *Table 11*. The risk level within *Table 11*follows the same qualitative risk assessment tool described in *Table 6*. .

Table 11 - Likelihood of Occurrence Table and Risk Assessment for Migratory Species Listed Under the EPBC Act

Species Name	TSC Act Status	EPBC Act Status	Habitat Requirements	Likelihood of Occurrence	Description of Potential Impact	Consequence of impact on species	Risk Level
Actitis hypoleucos Common Sandpiper			The species utilises a wide range of coastal wetlands and some inland wetlands. The species has been recorded in estuaries and deltas of streams, as well as on banks further upstream; around lakes, pools, billabongs, reservoirs, dams and claypans, and occasionally piers and jetties. Generally the species forages in shallow water and on bare soft mud at the edges of wetlands. Birds sometimes venture into grassy areas adjoining wetlands. Roost sites are typically on rocks or in roots or branches of vegetation, especially mangroves (DoE 2015).	**Potential.** The species may fly over the site and has the potential to occasionally forage around the margins of the wetland habitats. The species is regularly recorded in the Estuarine locality. This species has not been detected during field surveys.	The species is not likely to occur in large numbers within the site, nor is the site likely to contain important foraging or roosting habitat.	**Negligible**.	**Low**
Apus pacificus Fork-tailed Swift			The species is of Asian origin and is primarily aerial during its migratory stay in Australia. They mostly occur over dry or open habitats, including riparian woodland and tea-tree swamps, low scrub, heathland or saltmarsh. They are also found at treeless grassland and sandplains covered with spinifex, open farmland and inland and coastal sand-dunes. (DoE 2015).	**Potential.** It has been recorded within the locality and is wide ranging. May fly over the site or forage over the site intermittently for short periods.	The Site does not contain unique or important habitat for the species, impact is limited to temporary loss of a small area of potential foraging habitat.	**Negligible**.	**Low**
Ardea alba Great Egret			The Great Egret has been reported in a wide range of wetland habitats, including swamps and marshes; margins of rivers and lakes; damp or flooded grasslands, pastures or agricultural lands; reservoirs; sewage treatment ponds; drainage channels; salt pans and salt lakes; salt marshes; estuarine mudflats, tidal streams; mangrove swamps; coastal lagoons; and offshore reefs (DoE 2014a).	**Known.** Recorded frequently within the Site with foraging habitat existing within the shallow wetland areas.	The species is likely to utilise habitat adjacent to the proposed works area for foraging. The construction works may cause the species to avoid the foraging habitat due to the temporary disturbance. This will not significantly affect the species given the large amount of similar and more optimal habitat within the hunter estuary.	**Negligible.**	**Low**

Species Name	TSC Act Status	EPBC Act Status	Habitat Requirements	Likelihood of Occurrence	Description of Potential Impact	Consequence of impact on species	Risk Level
Ardea ibis Cattle Egret			The Cattle Egret occurs in tropical and temperate grasslands, wooded lands and terrestrial wetlands. High numbers have been observed in moist, low-lying poorly drained pastures with an abundance of high grass; it avoids low grass pastures. It is commonly associated with the habitats of farm animals, particularly cattle, but also pigs, sheep, horses and deer (DoE 2014a).	**Known.** This species has been recorded within the Site and is likely to utilise the wetland margins for foraging. The species has not been recorded in large numbers.	The Site contains suitable foraging habitat, however large areas of similar and more optimal foraging habitat occur within the locality.	**Negligible.**	**Low**
Arenaria interpresa Ruddy Turnstone			In Australasia, the Ruddy Turnstone is mainly found on coastal regions with exposed rock coast lines or coral reefs. It also lives near platforms and shelves, often with shallow tidal pools and rocky, shingle or gravel beaches.	**Unlikely.** Suitable foraging habitat does not exist within the Closure Works site. The species may occasionally fly over the site as it occurs in the Hunter Estuary and surrounding coastline	NA	NA	NA
Calidris acuminata Sharp-tailed Sandpiper			In Australasia, the Sharp-tailed Sandpiper prefers muddy edges of shallow fresh or brackish wetlands, with inundated or emergent sedges, grass, saltmarsh or other low vegetation. This includes lagoons, swamps, lakes and pools near the coast, and dams, waterholes, soaks, bore drains and bore swamps, saltpans and hypersaline saltlakes inland. They also occur in saltworks and sewage farms. They use flooded paddocks, sedgelands and other ephemeral wetlands, but leave when they dry (DoE 2014a).	**Known.** The species has been recorded in high numbers within deep pond and railway pond, adjacent to the proposed works.	The species are likely to intermittently utilise habitat adjacent to the proposed works for foraging. The construction works may cause the species to avoid the foraging habitat due to the temporary disturbance. This will not significantly affect the species given the large amount of more optimal habitat within the hunter estuary.	**Negligible.**	**Low**
Calidris canutus Red Knot			In Australasia the Red Knot mainly inhabit intertidal mudflats, sandflats and sandy beaches of sheltered coasts, in estuaries, bays, inlets, lagoons and harbours; sometimes on sandy ocean beaches or shallow pools on exposed wave-cut rock platforms or coral reefs. They are occasionally seen on terrestrial saline wetlands near the coast, such as lakes, lagoons, pools and pans, and recorded on sewage ponds and saltworks, but rarely use freshwater swamps. They rarely use inland lakes or swamps	**Known.** The species has been recorded in within the deep pond area and railway pond, adjacent to the proposed works. It is frequently observed at Stockton Sandspit.	The species are likely to intermittently utilise habitat adjacent to the proposed works for foraging. The construction works may cause the species to avoid the foraging habitat due to the temporary disturbance. This will not significantly affect the species given the large amount of more optimal habitat within the hunter estuary.	**Negligible.**	**Low**

Species Name	TSC Act Status	EPBC Act Status	Habitat Requirements	Likelihood of Occurrence	Description of Potential Impact	Consequence of impact on species	Risk Level
Calidris ferruginea Curlew Sandpiper	E	CE	Generally occupies littoral and estuarine habitats, and in New South Wales is mainly found in intertidal mudflats of sheltered coasts. Also occurs in non-tidal swamps, lakes and lagoons on the coast and sometimes inland (OEH 2015).	**Known.** This species has been recorded on the mud flats surrounding Deep Pond by Umwelt. Deep pond is directly adjacent to the Site.	The proposal will not remove habitat for this species as wetlands will not be cleared or modified. Construction disturbance may cause the species to vacate habitats adjacent to the direct impact area.	**Negligible**.	**Low***
Calidris melanotos Pectoral Sandpiper			In Australasia, the Pectoral Sandpiper prefers shallow fresh to saline wetlands. The species is found at coastal lagoons, estuaries, bays, swamps, lakes, inundated grasslands, saltmarshes, river pools, creeks, floodplains and artificial wetlands. The species is usually found in coastal or near coastal habitat but occasionally found further inland. The species breeds in northern Russia and North America (DoE 2014a).	**Known.** This species has previously been recorded on one occasion in Deep Pond (Lindsey, 2007). It is rarely found in the Hunter Estuary and is likely to occasionally occurring within the site.	The proposal will not remove habitat for this species as wetlands will not be cleared or modified. Construction disturbance may cause the species to vacate habitats adjacent to the direct impact area.	**Negligible.**	**Low**
Calidris ruficollis Red-necked Stint			In Australasia, the Red-necked Stint is mostly found in coastal areas, including in sheltered inlets, bays, lagoons and estuaries with intertidal mudflats, often near spits, islets and banks and, sometimes, on protected sandy or coralline shores. They also occur in saltworks and sewage farms; saltmarsh; ephemeral or permanent shallow wetlands near the coast or inland, including lagoons, lakes, swamps, riverbanks, waterholes, bore drains, dams, soaks and pools in saltflats. They sometimes use flooded paddocks or damp grasslands.	**Known.** This species has previously been recorded in large number in Deep Pond (Lindsey, 2007). It is rarely found in the Hunter Estuary and is likely to occasionally occur within the site. This species is also more regularly recorded at Stockton Sandspit and Ash Island.	The proposal will not remove habitat for this species as wetlands will not be cleared or modified. Construction disturbance may cause the species to vacate habitats adjacent to the direct impact area.	**Negligible**.	**Low**
Calidris tenuirostris Great Knot	V		In NSW, the species has been recorded at scattered sites along the coast, typically occurring within sheltered, coastal habitats containing large, intertidal mudflats or sandflats, including inlets, bays, harbours, estuaries and lagoons. They are also often recorded on sandy beaches with mudflats nearby, sandy spits and islets and sometimes on exposed reefs or rock platforms. They migrate to Australia from late August to early September.	**Potential.** This species has been recorded, approximately 250 m from the site. The habitat within the Site is considered sub-optimal for the species given the lack of large mudflats. The wetland areas of the site may provide some foraging habitat, especially when water levels are low, exposing area of potential foraging habitat. The species may fly over the site.	The proposal will not remove habitat for this species as wetlands will not be cleared or modified. The wetland habitat is considered to be sub-optimal for this species and therefore any impacts are likely to be negligible and affecting a small number of individuals.	**Negligible**.	**Low**

Species Name	TSC Act Status	EPBC Act Status	Habitat Requirements	Likelihood of Occurrence	Description of Potential Impact	Consequence of impact on species	Risk Level
Charadrius bicinctus Double-banded Plover	V		In NSW, the species has been recorded between the northern rivers and the Illawarra, with most records coming from the Clarence and Richmond estuaries. They occur mainly on sheltered sandy, shelly or muddy beaches or estuaries with large intertidal mudflats or sandbanks. They roost during high tide on sandy beaches and rocky shores and begin foraging activity on wet ground at low tide. Their diet includes insects, crustaceans, polychaete worms and molluscs (OEH, 2015).	**Known.** The species has been recorded twice in Deep pond in 2004 and 2007. Only two individuals were recorded. The wetlands margins are likely to provide sub-optimal foraging habitat for the species**.**	The proposal will not remove habitat for this species as wetlands will not be cleared or modified. The wetland habitat is considered to be sub-optimal for this species and therefore any impacts are likely to be negligible and affecting a small number of individuals.	**Negligible**.	**Low**
Charadrius leschenaultia Greater Sand Plover			Almost entirely restricted to coastal areas in NSW, occurring mainly on sheltered sandy, shelly or muddy beaches or estuaries with large intertidal mudflats or sandbanks. Infrequently recorded in southern NSW, more frequently form northern NSW, northwards (GHD 2010)	**Unlikely**. The species has been recorded within the hunter estuary, but not within the site. Habitat is not considered suitable given the lack of expansive sand or mud flats.	NA	NA	NA
Charadrius mongolus Lesser Sand Plover			Almost entirely restricted to coastal areas in NSW, occurring mainly on sheltered sandy, shelly or muddy beaches or estuaries with large intertidal mudflats or sandbanks. Infrequently recorded in southern NSW, more frequently form northern NSW, northwards (GHD 2010).	**Unlikely**. The species has not been recorded recently within the locality, and there is a lack of large intertidal flats.	NA	NA	NA
Gallinago hardwickii Latham's Snipe			In Australia, Latham's Snipe occurs in permanent and ephemeral wetlands up to 2000 m above sea-level. They usually inhabit open, freshwater wetlands with low, dense vegetation (e.g. swamps, flooded grasslands or heathlands, around bogs and other water bodies) (DoE 2014a).	**Known.** A single individual was recorded at Deep Pond during 2006 (Lindsey, 2006). The wetland margins provide foraging habitat for this species.	The proposal will not remove habitat for this species as the wetland areas will not be cleared or modified. Construction disturbance may cause the species to vacate habitats adjacent to the direct impact area.	**Negligible.**	**Low**
Gallinago megala Swinhoe's Snipe			Occurs in a wide range of habitats including woodlands, grassland and wetland areas.	**Unlikely.** This species is not known to occur in NSW.	NA	NA	NA

Species Name	TSC Act Status	EPBC Act Status	Habitat Requirements	Likelihood of Occurrence	Description of Potential Impact	Consequence of impact on species	Risk Level
Gallinago stenura Pin-tailed Snipe			Occur on the edges of shallow freshwater swamps, ponds and lakes with emergent, sparse to dense cover of grass/sedge or other vegetation. The species is also found in drier, more open wetlands such as claypans in more arid parts of species' range. It is also commonly seen at sewage ponds; not normally in saline or inter-tidal wetlands	**Unlikely.** This species is not known to occur in NSW.	NA	NA	NA
Heteroscelus brevipes Grey-tailed Tattler			Sheltered coasts with reefs and rock platforms or with intertidal mudflats, as well as shorelines with rocks, shingle, gravel or shells, often roosting in mangroves (Birdlife).	**Potential.** The species has not been recorded within the Site however has been recorded frequently within the Lower Hunter Estuary and Kooragang wetlands. Foraging habitat within the Closure Works area is limited to the wetland margins and is considered sub-optimal.	No direct loss of foraging habitat. Construction disturbance may cause the species to vacate habitats adjacent to the direct impact area, however larger areas of more optimal habitat exist within close proximity of the site.	**Negligible.**	**Low**
Hirundapus caudacutus White-throated Needletail			In Australia, the White-throated Needletail is almost exclusively aerial, most often above wooded areas. When flying above farmland, they are more often recorded above partly cleared pasture, plantations or remnant vegetation at the edge of paddocks (DoE 2014a).	**Potential.** This species has been recorded around Ash Island and Hexham Swamp. Foraging habitat within the Site is sub-optimal but the species has the potential to fly over the site.	No impact is anticipated given that the species will still be able to fly over the site and the proposal will not affect any habitat important to this species.	**Negligible.**	**Low**
Limicola falcinellus Broad-billed Sandpiper	V		This species breeds in northern Siberia before migrating southwards in winter to Australia. In NSW, the main site for the species is the Hunter River estuary, with birds occasionally reaching the Shoalhaven estuary. They favour sheltered parts of the coast such as estuarine sandflats and mudflats, harbours, embayments, lagoons, saltmarshes and reefs as feeding and roosting habitat (OEH, 2015).	**Potential.** This species has not been recorded within the site but it has been recorded on Ash island and other parts of the Hunter Estuary. The foraging habitat and roosting habitat within the Site is sub-optimal, although the species has the potential to fly over.	The species is anticipated to occasionally fly over the Site or occasionally settle on the edge of wetland areas. Impacts are restricted to indirect impacts such as the noise associated with construction.	**Negligible.**	**Low**
Limosa lapponica Bar-tailed Godwit			The bar-tailed godwit is usually identified in coastal areas such as estuaries and tidal mudflats, although it is sometimes found inland when migrating in shallow river margins, airfields, brackish/saline inland lakes, flooded pastures, sewage ponds and shallow river margins.	**Known.** Approximately 15 individuals have been recorded within Deep Pond (Umwelt). The species is regularly recorded at Stockton Sandspit and Kooragang Dykes.	No direct loss of foraging habitat. Construction disturbance may cause the species to vacate habitats adjacent to the direct impact area, however larger areas of more optimal habitat exist within close proximity of the site.	**Negligible.**	**Low**

Species Name	TSC Act Status	EPBC Act Status	Habitat Requirements	Likelihood of Occurrence	Description of Potential Impact	Consequence of impact on species	Risk Level
Limosa limosa Black-tailed Godwit	V		This species is a migratory wading bird that breeds in Mongolia and Eastern Siberia and flies to Australia for the southern summer. In NSW, it is most frequently recorded at Kooragang Island. They are usually found in sheltered bays, estuaries and lagoons with large intertidal mudflats and/or sandflats. Further inland, it can also be found on mudflats and in water less than 10 cm deep, around muddy lakes and swamps. They forage for insects, crustaceans, molluscs, worms, larvae, spiders, fish eggs, frog eggs and tadpoles in soft mud or shallow water. They roost on low banks of mud, sand and shell bars (OEH 2015).	**Known.** This species has been observed in Deep Pond, during recent field surveys. The species is likely to occasional forage within wetland areas of the site.	No direct loss of foraging habitat. Construction disturbance may cause the species to vacate habitats adjacent to capping works, however larger areas of more optimal habitat exist within close proximity of the site.	**Negligible.**	**Low***
Merops ornatus Rainbow Bee-eater			The Rainbow Bee-eater occurs mainly in open forests and woodlands, shrublands, and in various cleared or semi-cleared habitats, including farmland and areas of human habitation (DoE 2014a).	**Unlikely.** Few records within the locality and no suitable habitat for the species exists within the site.	NA	NA	NA
Monarcha melanopsis Black-faced Monarch			The Black-faced Monarch mainly occurs in rainforest ecosystems, including semi-deciduous vine-thickets, complex notophyll vine-forest, tropical (mesophyll) rainforest, subtropical (notophyll) rainforest, mesophyll (broadleaf) thicket/shrubland, warm temperate rainforest, dry (monsoon) rainforest and (occasionally) cool temperate rainforest (DoE 2014a).	**Unlikely.** No suitable habitat exists within the Site and species has not been recorded within the Site.	NA	NA	NA
Monarcha trivirgatus Spectacled Monarch			The Spectacled Monarch prefers thick understorey in rainforests, wet gullies and waterside vegetation, as well as mangroves. The site is at the southern limit of the species range.	**Unlikely.** No suitable habitat exists within the Site and species has not been recorded within the Site.	NA	NA	NA
Myiagra cyanoleuca Satin Flycatcher			Satin Flycatchers inhabit heavily vegetated gullies in eucalypt-dominated forests and taller woodlands, and on migration, occur in coastal forests, woodlands, mangroves and drier woodlands and open forests (DoE 2014a).	**Unlikely.** No suitable habitat exists within the Site and species has not been recorded within the Site.	NA	NA	NA

Species Name	TSC Act Status	EPBC Act Status	Habitat Requirements	Likelihood of Occurrence	Description of Potential Impact	Consequence of impact on species	Risk Level
Numenius madagascariensis Eastern Curlew		C E	This species preferred foraging and roosting habitat are intertidal mudflats, particularly where mangroves are present, and saltmarsh. They occur in intertidal coastal mudflats, coastal lagoons, sandy spits (Pizzey and Knight 2003). The species does not breed in Australia.	**Known.** This species has been recorded several times within the Site, especially in the Deep Pond area, which is likely to provide (sub-optimal) foraging habitat for the species. The species is associated with the periphery of wetland areas, and is unlikely to utilise other area of the site.	The proposal will not remove habitat for this species as wetlands will not be cleared or modified. Construction disturbance may cause the species to vacate habitats adjacent to the direct impact area.	**Negligible.**	**Low***
Numenius minutus Little Curlew			The Little Curlew is most often found feeding in short, dry grassland and sedgeland, including dry floodplains and blacksoil plains, which have scattered, shallow freshwater pools or areas seasonally inundated.	**Unlikely.** The species has not been recorded in the site and the habitats present are considered sub-optimal. The species is occasionally recorded within the Hunter Estuary.	NA	NA	NA
Numenius phaeopus Whimbrel			The species inhabits a wide range of coastal habitats including: bare grasslands, coral cays, estuaries, exposed reefs, flooded paddocks, lawns, mangroves, sewage ponds, sports grounds and tidal flats.	**Known.** The species has been recorded in Deep Pond and is frequently recorded in the Hunter Estuary. Foraging habitat for the species exists adjacent within the Site around the wetland margins.	No direct loss of foraging. Construction disturbance may cause the species to vacate habitats adjacent to the direct impact area, however larger areas of more optimal habitat exist within close proximity of the site.	**Negligible.**	**Low**
Pandion haliaetus Osprey	V		Favour coastal areas, especially the mouths of large rivers, lagoons and lakes. Feed on fish over clear, open water. Breed from July to September in NSW. Nests are made high up in dead trees or in dead crowns of live trees, usually within one kilometre of the sea (OEH 2015).	**Known.** This species has been recorded flying over the site. Foraging habitat within the site is considered sub-optimal. The species is not likely to breed in the Site.	Impact to the species is likely to be negligible as the species is likely to fly over the site and will not rely on the area for significant foraging resources.	**Negligible.**	**Low**
Philomachus pugnax Ruff			Typically found on brackish, fresh or saline wetland with a preference for wetlands with exposed mudflats at the edges. It forages on exposed mudflats in shallow water and occasionally on dry mud. A rare but regular visitor to Australia.	**Potential.** This species is occasionally recorded on Kooragang Island but has not been recorded within the Site. Potential foraging habitat is present, surrounding the wetland areas.	No direct loss of foraging habitat. Construction disturbance may cause the species to vacate habitats adjacent to the direct impact area, however larger areas of more optimal habitat exist within close proximity of the site.	**Negligible.**	**Low**

Species Name	TSC Act Status	EPBC Act Status	Habitat Requirements	Likelihood of Occurrence	Description of Potential Impact	Consequence of impact on species	Risk Level
Pluvialis fulva Pacific Golden Plover			This species is typically identified in a wide range of coastal habitats in sheltered areas. It is infrequently recorded in terrestrial habitats and usually feeds on sandy or muddy shores in proximity to its roosting sites.	**Known.** Previously recorded at Deep Pond, Fine Disposal Facility Pond. Most frequently recorded in the North Arm of the Hunter River and Ash Island. The project area provides some suitable habitat for this species especially around the wetland margins.	No direct loss of foraging habitat. Construction disturbance may cause the species to vacate habitats adjacent to the direct impact area, however larger areas of more optimal habitat exist within close proximity of the site.	**Negligible.**	**Low**
Pluvialis squatarola Grey Plover			This species occurs in coastal areas, where it usually inhabits sheltered embayments, estuaries and lagoons with mudflats and sandflats, and occasionally on rocky coasts with or reef-flats. It also occurs around terrestrial wetlands such as near-coastal lakes and swamps, or salt-lakes.	**Potential.** This species is occasionally recorded on Kooragang Island but has not been recorded within the Site. Potential foraging habitat is present on the wetland margins	No direct loss of foraging habitat. Construction disturbance may cause the species to vacate habitats adjacent to the direct impact area, however larger areas of more optimal habitat exist within close proximity of the site.	**Negligible.**	**Low**
Rhipidura rufifrons Rufous Fantail			In east and south-east Australia, the Rufous Fantail mainly inhabits wet sclerophyll forests, often in gullies dominated by eucalypts usually with a dense shrubby understorey often including ferns (DoE 2014a). When on passage, they are sometimes recorded in drier sclerophyll forests and woodlands, often with a shrubby or heath understorey.	**Unlikely.** No suitable habitat exists within the Site and species has not been recorded within the Site.	NA	NA	NA
Sterna albifrons Little Tern	E		Almost exclusively coastal, preferring sheltered environments; however may occur several kilometres from the sea in harbours, inlets and rivers (with occasional offshore islands or coral cay records) Nests in small, scattered colonies in low dunes or on sandy beaches just above high tide mark near estuary mouths or adjacent to coastal lakes and islands. (OEH 2015).	**Likely.** This species has been recorded adjacent to the Site in 2007 and the species is frequently recorded in the lower Hunter Estuary. The species is likely to fly intermittently fly over the Site and may occasionally forage within the Site, although the habitat is considered sub-optimal.	Construction activities may disturb this species, however the effects are likely to be negligible given that the species is likely to occasionally fly over the site and is does not provide important habitat for the species.	**Negligible.**	**Low***
Tringa stagnatilis Marsh Sandpiper			The Marsh Sandpiper lives in permanent or ephemeral wetlands of varying salinity, including swamps, lagoons, billabongs, saltpans, saltmarshes, estuaries, pools on inundated floodplains, and intertidal mudflats and also regularly at sewage farms and saltworks.	**Known.** This species has been recorded foraging and roosting at Deep Pond. High densities of the species are found within Fullerton Cove, Ash island and the Kooragang Dykes.	No direct loss of foraging habitat. Construction disturbance may cause the species to vacate habitats adjacent to the direct impact area, however larger areas of more optimal habitat exist within close proximity of the site.	**Negligible.**	**Low**

Species Name	TSC Act Status	EPBC Act Status	Habitat Requirements	Likelihood of Occurrence	Description of Potential Impact	Consequence of impact on species	Risk Level
Xenus cinereus Terek Sandpiper	V		In Australia, has been recorded on coastal mudflats, lagoons, creeks and estuaries. Favours mudbanks and sandbanks located near mangroves, but may also be observed on rocky pools and reefs, and occasionally up to 10 km inland around brackish pools. Generally roosts communally amongst mangroves or dead trees, often with related wader species (OEH 2015).	**Potential.** There are historical records of this species within the Site (1988, Bionet) and more recent records in the vicinity of the Site. The species may occasionally fly over the site, although foraging habitat is considered suboptimal.	The proposal will not remove habitat for this species as wetlands will not be cleared or modified. Construction disturbance may cause the species to vacate habitats adjacent to the direct impact area. The impact on the species is considered negligible considering the occasional use of the habitats present within the site.	**Negligible.**	**Low**
Species Sensitivity Status: V – Vulnerable; E – Endangered; CE – Critically Endangered. Note all species are also listed migratory under the EPBC Act							

Nature and extent of likely impact

Of the Migratory species considered in *Table 7*, Eleven (11) were considered unlikely to occur and therefore require no further impact assessment. A combined total of 26 species were considered to require further assessment as they have the potential to occur or have been recorded within the Site. Assessment of significance was undertaken by ERM, in accordance with the (DoE, 2015) Significant Impact Guidelines 1.1. Species were grouped according to their habitat and foraging requirements. The assessments can be found in *Annex C* and are also summarised below.

Migratory Waders and Shorebirds

The following migratory birds were grouped together as they have the potential to utilise the wetland areas adjacent to the site. Depending on the species this may include foraging within shallow water or on the shoreline around the margins of Deep Pond.

Common Sandpiper (*Actitis hypoleucos*)
Great Egret (*Ardea alba*)
Cattle Egret (*Ardea ibis*)
Sharp-tailed Sandpiper (*Calidris acuminata*)
Red Knot (*Calidris canutus*)
Curlew Sandpiper (*Calidris ferruginea*)
Pectoral Sandpiper (*Calidris melanotos*)
Red-necked Stint (*Calidris ruficollis*)
Great Knot (*Calidris tenuirostris*)
Double-banded Plover (*Charadrius bicinctus*)
Latham's Snipe (*Gallinago hardwickii*)
Grey-tailed Tattler (*Heteroscelus brevipes*)
Broad-billed Sandpiper (*Limicola falcinellus*)
Bar-tailed Godwit (*Limosa lapponica*)
Black-tailed Godwit (*Limosa limosa*)
Eastern Curlew (*Numenius madagascariensis*)
Whimbrel (*Numenius phaeopus*)
Ruff (*Philomachus pugnax*)
Pacific Golden Plover (*Pluvialis fulva*)
Grey Plover (*Pluvialis squatarola*)
Marsh Sandpiper (*Tringa stagnatilis*)

The species listed above have either been recorded, or are considered to have the potential to occur, within or adjacent to the Closure Works site. These species are typically associated with the wetland areas, including the margins and transitional habitats. They are not anticipated to occur in the landfill areas associated with the capping works, which are elevated above the wetlands. For this reason there will be no direct loss of habitat for these migratory species and impacts will be restricted to indirect and temporary impacts.

Once the capping works are completed, it will result in less infiltration of rainwater into the landfill stockpiles. Review of previous hydrological studies has revealed that the water entering the ponds via overland flow is likely to be slightly less saline and have fewer contaminants than water which has percolated through the landfill areas (refer to *Section 3.3b*). Surface water will pass through a number of sediment controls, incorporated within the capping area to reduce sediment load. These changes to the water quality as a result of the proposal are considered positive in the long term with less contaminant reaching the wetlands area. The effects on salinity are likely to be negligible due to the large dilution factors involved.

The construction phase of the capping works will include noise, light and vibration disturbance from machinery. These impacts are likely to be most acute for Deep Pond whilst heavy machinery is operated in the K3 area and within K5 Cell 8 (refer to *Annex A, Figure 2*). The noise impacts of the construction works have the potential to disturb migratory birds to the extent that some areas of foraging habitat are avoided. This impact is most likely to affect species foraging or roosting on the shoreline in the shallow sediments or those species which utilise the areas of emergent vegetation on the eastern edge of Deep Pond. The construction activities will be temporary occurring over a period of approximately six to eight months, and during this period there will be occasions when disturbance is minimal and does not occur adjacent to the wetland areas. Construction work will be undertaken during the daytime within standard construction hours, therefore will not affect roosting birds significantly. It is difficult to predict the degree of habitat avoidance by migratory birds however it is anticipated that it will mainly affect habitat along the eastern edges of Deep Pond. It is possible that species may become accustomed to the disturbance and return to the foraging site, whilst construction is continuing. For example, Stockton Sandspit within the Hunter Estuary provides a resting roosting and foraging resource for large aggregations of migratory wading birds, despite being within 100 m of Stockton Bridge/B63 Road, which has heavy vehicle traffic especially during peak hour periods.

The proposal will not significantly affect wetland and shorebird migratory species, given that the wetland habitats and margins will not be removed or modified. Impacts will be limited to the temporary disturbance caused by construction activities which may cause some species to avoid wetland habitat adjacent to the construction.

Migratory Species with Generalist Habitat Requirements.

Fork-tailed Swift (*Apus pacificus*)
White-throated Needletail (*Hirundapus caudacutus*)

The White-throated Needletail and Fork-tailed Swift have generalist habitat requirements, occurring in a range of landscapes including disturbed areas. Both are aerial species, foraging for insects on the wing and rarely alighting whilst in Australia. The entire site has the potential to provide foraging resources given that it supports flying insects, however neither species has been recorded. As the species have generalist habitat requirements and a very wide range, habitat within the Site is not of critical importance to the species and it is unlikely to contain high proportions of the species at any time. Impacts to these species are likely to be negligible.

Migratory Species which Forage Over Open Water.

Osprey (*Pandion haliaetus*)
Little Tern (*Sterna albifrons*)

Both of these species are likely to fly over the Site and on occasion may forage over deep pond. The Site does not contain important habitat for these species or likely to contain a high proportion of a population. There are no known nest sites for Osprey in or adjacent to the site. There are no known roosting sites for Little Tern in or adjacent to the Site. There will be no direct impacts to these species. Any indirect impacts to the species would be limited to construction disturbance associated with the terrestrial capping, and would be temporary and negligible.

3.1 (f) Commonwealth marine area

(If the action is in the Commonwealth marine area, complete 3.2(c) instead. This section is for actions taken outside the Commonwealth marine area that may have impacts on that area.)

Description

There are no Commonwealth marine areas within the Site or within close proximity to the Site.

Nature and extent of likely impact

The Proposal will not have any impact on any Commonwealth marine areas.

3.1 (g) Commonwealth land

(If the action is on Commonwealth land, complete 3.2(d) instead. This section is for actions taken outside Commonwealth land that may have impacts on that land.)

Description

No Commonwealth land is located within the Site.

Nature and extent of likely impact

No impact to Commonwealth land is expected as a result of the Proposal.

3.1 (h) The Great Barrier Reef Marine Park

Description

The Site is not within the vicinity of the Great Barrier Reef.

Nature and extent of likely impact

The Proposal will not have any impact on the Great Barrier Reef.

3.1 (i) A water resource, in relation to coal seam gas development and large coal mining development

Description

N/A

Nature and extent of likely impact

N/A

3.2 Nuclear actions, actions taken by the Commonwealth (or Commonwealth agency), actions taken in a Commonwealth marine area, actions taken on Commonwealth land, or actions taken in the Great Barrier Reef Marine Park

3.2 (a)	**Is the proposed action a nuclear action?**	X	No
			Yes (provide details below)
	If yes, nature & extent of likely impact on the whole environment		
3.2 (b)	**Is the proposed action to be taken by the Commonwealth or a Commonwealth agency?**	X	No
			Yes (provide details below)

	If yes, nature & extent of likely impact on the whole environment		

3.2 (c)	**Is the proposed action to be taken in a Commonwealth marine area?**	X	No
			Yes (provide details below)
	If yes, nature & extent of likely impact on the whole environment (in addition to 3.1(f))		

3.2 (d)	**Is the proposed action to be taken on Commonwealth land?**	X	No
			Yes (provide details below)
	If yes, nature & extent of likely impact on the whole environment (in addition to 3.1(g))		

3.2 (e)	**Is the proposed action to be taken in the Great Barrier Reef Marine Park?**	X	No
			Yes (provide details below)
	If yes, nature & extent of likely impact on the whole environment (in addition to 3.1(h))		

3.3 Other important features of the environment

3.3 (a) Flora and fauna

Information from a combination of the PMST, Atlas Records and Field Surveys were used to produce a list of subject species listed under both the EPBC act and the NSW *Threatened Species Conservation Act 1995* (TSC Act). Species listed under the EPBC act have been discussed in detail in *Section 3.1* and therefore are not considered further. A total of 69 subject species were considered, including 3 amphibians, 1 reptile, 47 birds and 18 mammals. Of these subject species 18 have been recorded within the Site (refer to *Table 12*).

Table 12– Threatened Species Listed under the TSC Act, recorded within and Directly Adjacent to the Site.

Species Name	**TSC Act Status**	**EPBC Status**
Flora		
Zannichellia palustris Horned Pondweed	E	
Amphibians		
Litoria aurea Green and Golden Bell Frog	E	V
Botaurus poiciloptilus Australasian Bittern	E	E
Calidris ferruginea Curlew Sandpiper	E	CE, Mi
Circus assimilis Spotted Harrier	V	
Ephippiorhynchus asiaticus Black-necked Stork	E	
Epthianura albifrons White-fronted Chat	V	
Limosa limosa Black-tailed Godwit	V	Mi
Numenius madagascariensis Eastern Curlew		C E, Mi
Oxyura australis Blue-billed Duck	V	
Pandion cristatus Eastern Osprey	V	Mi
Stictonetta naevosa Freckled Duck	V	
Bats		
Falsistrellus tasmaniensis Eastern False Pipistrelle	V	
Miniopterus australis Little Bentwing-bat	V	

Species Name	TSC Act Status	EPBC Status
Miniopterus schreibersii oceanensis Eastern Bentwing-bat	V	
Mormopterus norfolkensis Eastern Freetail-bat	V	
Myotis macropus Southern Myotis	V	
Pteropus poliocephalus Grey-headed Flying-fox	V	V
Saccolaimus flaviventris Yellow-bellied Sheathtail-bat	V	

Flora
One threatened flora species, Horned Pondweed (*Zannichellia palustris*) was recorded within Deep Pond which is listed Vulnerable under the TSC Act. The aquatic plant species behaves as an annual and dies back in the summer. At the time of the latest field survey (November, 2015), the plant was observed as small floating pieces which, appeared to be degenerating. Owing to the species dispersal abilities, it should be considered cosmopolitan throughout Deep Pond and may colonise other areas of Wetland during flood events.

Considerable survey effort has been employed on the Site (GHD, Umwelt and ERM) with Horned Pondweed the only species recorded. Furthermore, Umwelt surveyed the larger T4 area with no additional threatened species recorded. Given the amount of field effort employed, desktop searches and consideration of habitats present it is considered unlikely that any additional flora species are likely to occur.

Horned Pondweed will not be significantly impacted by the proposal given that the wetland areas will not be modified or cleared.

Fauna
The majority of the fauna species recorded from the site are associated with the Wetland areas which will not be impacted directly by the closure works. A number of bats are listed under the TSC Act however the habitat within the Study Area is considered to be unimportant for the species with large areas of more optimal habitat existing within the vicinity of the site.

Endangered Ecological Communities (EEC)
One EEC is considered present within the site, *Freshwater Wetlands on Coastal Floodplains of The New South Wales North Coast, Sydney Basin and South East Corner Bioregions*. This community is associated with coastal areas subject to periodic flooding and in which, standing fresh water persists for at least part of the year in most years. Wetlands which meet the EEC description exist to the north and east of the proposed capping area. There are not anticipated impacts given that there will be no clearance or modification of the Wetland areas.

3.3 (b) Hydrology, including water flows
KIWEF is located within the Lower Hunter Estuary of the Hunter River catchment. The Hunter River is classed as a waterway affected by urban development. The proposed action area is located on Kooragang Island which divides the Hunter River into the Hunter River North Arm and Hunter River South Arm. The proposed activity is located over 500 metres from the South Arm and over 1400 metres from the North Arm. The Hunter River National Park and Hunter Wetlands Ramsar site are located between the proposed activity and the Hunter River North Arm but no surface water pathway exists whereby any impact to these areas associated with the proposed activity would be likely. The potential for groundwater impacts are raised in the assessment of the T4 Project with the likely result of the capping works identified as a reduction of the potential for impact associated with the contaminants within the existing landfill.

Surface drainage within and surrounding the proposed action location is characterised by a highly modified landform formed by landfilling over wetland, mangrove and island complexes. The topography of the proposed activity area is generally flat with a series of benches formed by different filling practices. Highpoints have been created on the Site by the installation of the constructed waste disposal cells (slag walls) which in places rise 9 metres above the remainder of the land. The topography has also been altered by the NCIG rail spur line, fly-over and rail loop (referral 2006/2987).

The southern section of the referral area (between the NCIG rail spur and rail flyover) slopes gently towards Deep Pond in a westerly direction with raised rail embankments surrounding the capping area to the north, east and south.

The topography and current surface water flow of the northern section of the referral area (areas north of the NCIG rail flyover) is best described in relation to key features as follows:

- Raised NCIG rail flyover forms the southern boundary of the referral area's northern section, with drainage directed to the east and west and then via culverts to the BHP Wetlands;

- An access road (referred to as Delta Road) running in a north-south direction forming the eastern boundary of the referral area;

- A steep vegetated slag embankment rising from the western side of Delta Road to a plateau formed by the completed disposal cells 1, 3, 5 and 7;

- Flat lightly vegetated areas of cells 1, 3, 5 and 7 with less than 1% gradient and minimal off site surface water flows. The likely surface water flows in high rainfall events would be directed as illustrated in *Figure 6* of *Annex A*;

- Lower but generally flat areas formed by incomplete filling in cells 2, 4, 6 and 8 bounded by protruding tops of slag cell walls with no surface water flows out of these cells considered possible;

- Slag cell walls slightly protruding to the north of completed Cell 7 and incomplete Cell 8 forming the northern boundary of the referral area and falling away to the largely unfilled cells 9 and 10 with some surface water flows possible in high rainfall events from Cell 7 into Cell 9;

- Area K3 generally draining towards the central drainage line flowing in a north westerly direction to Deep Pond; and

- A steep embankment from the western edge of K3 to deep pond.

Currently most rainfall is expected to infiltrate into the Cells, with drainage from within the referral area directed mainly to deep pond with minimal drainage directed to the east and south and north.

Drainage across the wider KIWEF area (surrounding the referral area) is complex and consists of a network of culverts, open drains, levees and constructed ponds that fill with surface runoff and ultimately drain to the Hunter River South Arm. The area surrounding the referral area includes a number of freshwater and brackish ponds (identified in *Annex A*) with typical flow paths identified as follows:

- Deep Pond which has recently been divided by the NCIG Rail Flyover but remains connected by culverts. Deep Pond is located immediately west of the referral area and collects most runoff from both the northern and southern portions of the referral area. The maximum water levels of Deep Pond are established by culverts and drainage channels that direct surface water south along the rail line via K2 Basin and to the Hunter River South Arm;

- Blue Billed Duck Pond and BHPB wetlands are separated from the referral area by the NCIG Rail Spur. These ponds receive runoff from the referral area via existing culverts beneath the NCIG Rail Spur and ultimately discharge into the southern portion of Deep Pond;

- Easement Pond currently receives minimal runoff from the outer slag wall of Area K5 via Delta Road and discharges in an easterly direction via Windmill Road Open Channel and Long Pond to the Hunter River South Arm;

- K7 Ponds receive minimal surface water flows from the referral area with maximum water level established by an access road separating North Pond 3 from Railway Pond;

- Railway Pond located in the North East corner of KIWEF and surrounding Area K7, receives water from the neighbouring PWCS fines disposal facility, runoff from K7 and the PWCS operated rail line which forms its northern bank. Railway Pond discharges in a westerly direction into Deep Pond; and

- Ponds 9, 10, 11 and 12 are formed by unfilled slag walled cells. These ponds are currently not receiving surface water flows from the referral area, with no change proposed. Ponds 9 and 11 have no direct linkages to other ponds while Pond 10 and 12 maximum water levels are established by low slag walls dividing them from Deep Pond.

Currently, surface water ponds on KIWEF are provided partly by surface water runoff from rainfall and partly by discharge from horizontal flows from the aquifer within the fill layer and the estuarine aquifer below. The water quality within surface waters is therefore influenced by the contaminants within runoff and within the fill aquifer and may also be influenced by saline conditions within the estuarine aquifer.

Surface water quality sampling has been undertaken over an extended period by a number of consultants and as a result, long term monitoring data is available for all major surface water bodies within KIWEF. Mean long term analytical results prepared by SMEC (2012) show the following areas exceeding ANZECC 2000 (95% Marine and Fresh) for a number of constituents:

- Deep Pond - mean concentrations of aluminium, cadmium, copper, chromium, manganese, mercury, zinc and cyanide are above ANZECC marine criteria;

- Hunter River - mean concentrations of cadmium, chromium, copper, mercury and zinc exceed ANZECC marine criteria. Other sources may also contribute to the water quality in Hunter River;

- Blue Billed Duck Pond – mean concentrations of aluminium, cadmium, chromium, copper, mercury, nickel and zinc exceed ANZECC freshwater criteria; and

- Easement Pond - mean concentrations of aluminium, cadmium, chromium, copper, lead, mercury, nickel and zinc exceed ANZECC freshwater criteria.

Trend analysis is not available for surface water quality data, however inspection of the dataset does not indicate any clear increasing or decreasing change in water quality. On this basis, it appears that dilution and attenuation processes are currently providing enough mitigation to result in a stable situation with respect to surface water contamination.

Pond hydrology may be altered as a result of the Proposed Activity when compared to the existing conditions, as a result of a general increase in surface water discharge from capped areas; and reduced groundwater flows due to decreased infiltration through the capped area. The changes to hydrology as a result of the proposed activity are expected to be negligible in comparison to the continuing effects of direct rainfall, evaporation and unchanged interaction with aquifers. The changes to pond hydrology at the KIWEF are expected to be limited to:

- Slightly altered wetting and drying regimes in ponds that will likely to be generally wetter due to an increase of surface water in-flows from the closure area via lined sediment basins; and

- Water quality changes in the ponds are expected to be slightly fresher with improved general water quality, due to the reduction of leached contaminants, as a result of increased surface water in-flows and reduced infiltration via the fill aquifer to surface water bodies.

Consideration of changes to the hydrology on the Green and Golden Bell Frog are considered in Section 3.1d.

3.3 (c) Soil and Vegetation characteristics
The upper profile of the soils of the referral area reflect the waste disposal operations and include areas of fine and coarse coal washery reject, granulated slag and consolidated slag cell walls with no natural soils present.

The NCIG Environmental Assessment (Resource Strategies and NCIG 2006) describes the natural soil profile (below fill materials) generally as an upper clay layer (soft silty sandy clay), a sandy layer (loose to dense sand), a lower clay layer (stiff to very stiff sandy silty clay), soft rock layers (siltstone and mudstone) and hard rock layers (sandstone). Due to the presence of the various fill materials and the historical flow paths of the Hunter River and its tributaries, the depth of each of the soil layers varies significantly.

Department of Land and Water Conservation's Newcastle 1:100 000 Soil Landscapes Map (Matthei 1995) confirm that:

- The area is described as highly disturbed due to filling and at the surface and is primarily consisted of exposed soil or Coal Washery Reject (CWR) largely covered in grasses.

- The site is underlain by Quaternary sand, silt, and clay overlying the sandstones, siltstones, claystones, coal and tuff of the Permian Tomago Coal Measures.

Vegetation

Three different vegetation communities are considered to occur within or adjacent to the Closure Work site (refer to *Annex A, Figure 5*);

- Exotic Grassland
- Exotic Shrubby Grassland, and
- Wetlands

Exotic Grassland

The majority of the Site contains exotic grassland which has colonised the capped areas of landfill. The dominant species include Red Natal Grass (*Melinis repens*), and the exotic forbs Fennel (*Foeniculum vulgare*), Purpletop (*Verbena bonariensis*) and Narrow-leaved Cottonbush (*Gomphocarpus fruticosus*). Very few native flora species are present and no threatened flora species are anticipated to occur or have been recorded by previous studies. The native Swamp Oak (*Casuarina glauca*) exists as isolated trees or small monospecific stands.

Exotic Shrubby Grassland

Exotic Shrubby Grassland areas are likely to reflect a succession of the Exotic Grassland community described above, with very similar ground cover composition. The ground cover in the Exotic Shrubby Grassland also has patches of Blady Grass (*Imperata cylindrica*), which is a native coloniser of disturbed areas. Pampas Grass (*Cortaderia selloana*) is abundant and listed as a class 3 Noxious Weed. Large shrubs and small trees are frequent, with the dominant species the naturalised Golden Wreath Wattle (*Acacia saligna*) and African Olive (*Olea europaea subsp. cuspidata*). The native Swamp Oak (*Casuarina glauca*) also exists as isolated trees or small monospecific stands. Other exotic trees and shrubs include Camphor Laurel (*Cinnamomum camphora*), Caster Oil Plant (*Ricinus communis*) and Lantana (*Lantana camera*). The native species Sydney Golden Wattle (*Acacia longifolia*) and Sweet Pittosporum (*Pittosporum undulatum*) occur in low abundances and these species are both colonisers of disturbed areas, as well as a component of more established native communities. This community occurs within the majority of Cells 6 and 8 and also extends outside of the proposed capping area into cells 9 and 10, intergrading with wetland areas.

Wetlands

Areas of freshwater wetland exist within the KIWEF Site, but are outside of the proposed capping area. The wetland communities have been described as there is a potential for indirect impacts to occur as a result of the proposed capping works. Deep Pond occurs along the western edges of the proposed capping area, it is somewhat of a misnomer, with areas of shallow water extending considerable distances from the banks, especially in the north and south of the pond. A considerable portion of the ponds margins has emergent vegetation including Common Reed (*Phragmites australis*), Broadleaf Cumbungi (*Typha orientalis*), *Bolboschoenus caldwellii*, and the exotic Sharp Rush (*Juncus acutus*). One threatened species, Horned Pondweed (*Zannichellia palustris*), listed as Vulnerable under the TSC Act, was recorded along the eastern margins of Deep Pond. Owing to the steep banks of Deep Pond the emergent wetland species flora rapidly transition to the Exotic Grassland and Exotic Grassy Shrubland communities. Wetland areas also exist within K6, cells 9-12. These include a series of semi-permeant to permeant ponds with large areas of marginal wetland vegetation and species composition similar to Deep Pond. A small area of Samphire (*Sarcocornia quinqueflora*) exists within the wetland which is growing in an area of coal washery reject.

3.3 (d) Outstanding natural features

The Site is heavily disturbed and entirely modified due to its previous use as a landfill. The wetland area complex, outside of the capping works is the most important feature within the immediate proximity as it provides habitat for a number of migratory and threatened bird species and the threated green and golden bell frog. These wetlands are not natural and are due to extensive earthworks and historic reclamation within the Lower Hunter Estuary.

3.3 (e) Remnant native vegetation

No remnant vegetation is present on site, due to the entire site being previously cleared for landfill.

3.3 (f) Gradient (or depth range if action is to be taken in a marine area)

The topography of the proposed activity area is generally flat with a series of benches formed by different filling practices. Highpoints have been created on the Site by the installation of the constructed waste disposal cells (slag walls) which in places rise 9 metres above the remainder of the land. The topography has also been altered by the NCIG rail spur line, fly-over and rail loop.

3.3 (g) Current state of the environment

The Site is highly disturbed given its former use as a landfill. The landfill has previously been capped which has become vegetated by colonising species, the majority of which are exotic weeds, including four noxious weeds. The ground cover is almost entirely exotic throughout terrestrial areas of the site. Mammalian fauna (excluding bats) is largely exotic including the Black Rat (*Rattus rattus*), European Rabbit (*Oryctolagus cuniculus*), Red Fox (*Vulpes vulpes*) and European Hare (*Lepus capensis*). The Eastern Gambusia (*Gambusia holbrookii*) was recorded in high numbers within Deep Pond.

3.3 (h) Commonwealth Heritage Places or other places recognised as having heritage values

A database search of the EPBC Act using the Protected Maters Search Tool was undertaken on the

15 September 2015 (Annex B). No Commonwealth Heritage Places were identified within the Referral Area. The search identified two Commonwealth Heritage Places within 10 km of the to the Proposed Action, being Fort Wallace at Stockton (north of the Hunter River) and Nobbys Headland at Newcastle (south of the Hunter River), both located over 5 km from the referral area and not impacted upon by the proposed activity.

3.3 (i) Commonwealth Indigenous heritage values

Due to the highly disturbed nature of the Closure Works area and its former use as a landfill, it is considered unlikely that the Proposed Action will impact on any items of Indigenous Heritage significance. An Indigenous heritage site investigation has not been undertaken for the Proposed Action.

3.3 (j) Other important or unique values of the environment

The Hunter Wetlands National Park and Ramsar wetlands exist outside of the Site. The Ramsar Site - Hunter Estuary Wetlands (ID No 24) is considered in Section 3.1(c) and an Assessment of Significance has been compiled for this MNES in Annex C.

3.3 (k) Tenure of the action area (eg freehold, leasehold)

Port of Newcastle Lessor Pty Ltd, a NSW Government Owned entity, is the owner of the referral area freehold land. Port of Newcastle Lessor Pty Ltd is the proponent of the proposed activity based on previous advice that any ongoing management obligations are most appropriately assigned to the land-owner. The land is operated and managed by Port of Newcastle Pty Ltd under a long term lease agreement. The land is also subject to an agreement for lease with Port Waratah Coal Services to facilitate the potential future use of the site as a Coal Export Terminal.

3.3 (l) Existing land/marine uses of area

The site is not currently used for any purpose beyond that of a former landfill.

3.3 (m) Any proposed land/marine uses of area

The site has been assessed and approved at a State Level for the future potential use as a Coal Export Terminal. A decision on approval under the EPBC Act is due 24 December 2015. The proposed Closure Works are associated with the Coal Export Terminal through location only.

4 Environmental outcomes

The basic principles of the closure works are to reduce surface water infiltration into the groundwater by the following means:

- Regrading of the site to minimum 1% grade to prevent ponding of surface waters;
- Drainage improvements;
- Provision of a 0.5m thick, low permeability cap; and
- Rehabilitation using existing topsoil and alternative low nutrient and chytrid free imported growth medium.

As such the intended outcome of the proposed activity is a site supporting similar levels of vegetation (whilst reducing the prevalence of noxious weeds) and providing similar surface water flows to surrounding ponds and habitat areas with a reduced contaminant load migrating from the fill material to the surrounding environment.

No ongoing loss of foraging/sheltering habitat for MNES Species, particularly GGBF will eventuate on the basis that following construction, the site will be allowed to rehabilitate and no permanent loss of habitat of any type will result.

No direct impacts to GGBF breeding habitat is proposed as clearing will be restricted to 30 metres from the mapped habitat; or in the case of the area where capping is required in closer proximity to deep pond, a steep embankment is present and works will be limited to the top of this embankment with no pond fringing vegetation to be impacted.

The potential for indirect impacts to wetlands through sedimentation will be managed through the implementation of erosion and sediment control measures appropriate for sensitive environments.

Changes in hydro-salinity are predicted to result in marginally wetter and fresher conditions based on:

- An increase in fresher surface water runoff;
- Decrease in infiltration; and
- Decrease in mobilisation of water within the more saline fill aquifer.

The installation of hydro-salinity monitoring devises has been undertaken and will be monitored throughout the duration of capping with any identified significant changes in pond hydro-salinity attributable to the proposed activity to be investigated and mitigation measures explored. It is anticipated that any changes will be extremely negligible and will not be detected due to the high dilution factors involved with Deep Pond.

5 Measures to avoid or reduce impacts

Various measures to avoid or reduce impacts are currently enforced through the Surrender Notice and associated requirements to implement various plans and strategies. Of relevance to the Referral Area are:

- Hunter Development Corporation - Report on KIWEF - Revised Final Landform and Capping Strategy - August 2009 - Revision 2, prepared by GHD (the Capping Strategy);
- 'Green and Golden Bell Frog Management Plan – Kooragang Island Waste Emplacement Facility Closure Works' dated 19 April 2011 and prepared by Golder Associates; and
- 'Materials Management Plan - Kooragang Island Waste Emplacement Facility' dated November 2012 prepared by RCA Australia.

The surrender notice also requires that the implementation of these plans and strategies to be validated through a report provided to the NSW EPA to allow the lifting of the Surrender Notice obligations. Measures of relevance to MNES protection are summarised in the Table 13 that follows:

Table 13 – MNES Mitigation Measures

Environmental Aspect	**Specific Mitigation Measures**
Handling and reuse of site material in accordance with the Materials Management Plan (MMP).	Condition 4a) of the Surrender Notice requires that by 30 June 2017, the licensee shall complete implementation of the final landform and capping strategy as detailed in the documents titled: • 'Materials Management Plan – KIWEF', dated November 2012 prepared by RCA Australia. The preferred proposed landform design philosophy is for minimal engagement with the ground, balancing earthworks within each cell where possible, cover over known contamination hotspots (described as "Level 3 materials" within the Materials Management Plan), and to keep existing materials within each cell. The priority for landfill closure is to entirely cap the site with an inert low-permeability barrier, provide drainage upgrades to prevent infiltration and to consequently reduce the risk to the environment associated with the emplaced waste. All contaminated material encountered during the landfill closure works will be assessed and categorised. This can be achieved by imposing the common distinguishing visual and olfactory characteristics, analysis of PAH concentrations and use of instrumentation (PID) to determine the default category, as set out under Table 3 (Section 5.3 of RCA MMP).
Construction soil and water management	Condition 4d) of the Surrender Notice requires that the licensee shall implement, maintain and operate erosion and sedimentation controls during the final capping process to ensure that there is no sedimentation of waterways. Section 5.1 of GGBF Management Plan (Golder Associates, 2011) requires that appropriate erosion and sediment control structures will be installed at least 30 metres upslope of known and potential GGBF habitat. These erosion and sediment control structures will be regularly inspected and maintained, particularly after significant rainfall events. Chapter 7 of the Final Landform and Capping Strategy (GHD, 2009) requires the establishment of erosion and sedimentation controls and construction of sedimentation basins as required. Section 7.4, Flora and Fauna Impact Assessment included as Appendix A, of the Revised Final Landform and Capping Strategy (GHD, 2009) requires that: • Adequate run-off, erosion and sedimentation controls should be in place during construction, particularly in areas where run-off has the potential to impact on nearby waterways, surrounding native vegetation, EEC regrowth, and existing drainage line and dam areas; and • Development of an Erosion and Sedimentation Control Plan covering the works associated with the Proposal. Erosion and sediment controls are to be installed prior to construction, and maintained throughout construction, to minimise sediment entering the adjacent waterbodies, EECs and SEPP 14 wetland areas.

Environmental Aspect	Specific Mitigation Measures
Measures to prevent GGBF mortality and significant impacts to other threatened fauna and their habitat.	Condition 4a) of the Surrender Notice requires that by 30 June 2017, the licensee shall complete implementation of the final landform and capping strategy as detailed in the documents titled: • HDC – Report on KIWEF – 'Revised Final Landform and Capping strategy' – August 2009 - Revision 2, prepared by GHD ("the Landfill and Capping Strategy"); • 'Green and Golden Bell Frog Management Plan – KIWEF Closure Works', dated 19 April 2011 and prepared by Golder Associates; Section 5.1 of the GGBF Management Plan (Golder Associates, 2011) requires: • The boundaries of known and potential Green and Golden Bell Frog habitat will be clearly identified on the ground and communicated to personnel undertaking site works as part of the site induction; • Appropriate erosion and sediment control structures will be installed at least 30 metres upslope of known and potential GGBF habitat. These erosion and sediment control structures will be regularly inspected and maintained, particularly after significant rainfall events; • All plant entering and leaving the KIWEF site will be disinfected via a wash bay. The location and procedures involved at this wash bay will form part of the site induction and training. Records will be kept; • The Principal and all contractors involved in activities in areas of known (mapped) habitat for the Green and Golden Bell Frog (and other amphibian species) will be trained in site hygiene management in accordance with the hygiene protocol. This will be part of the environmental induction and training. Records will be kept; • PPE in contact with soil, particularly boots, entering and leaving the site will be disinfected as a matter of routine, following the methods outlined in the Hygiene Protocol; • All disinfection processes will be monitored and controlled at the KIWEF site's entry and exit point. The location of these disinfection bays, and the obligations of disinfection, will be communicated during the site induction and training; • Any water required for dust suppression will be drawn from ponds established for the purpose. No water for dust suppression will be drawn from mapped GGBF ponds on the site. The establishment of dedicated dust suppression ponds will be undertaken to prevent the potential spread of Plague Minnow into ponds currently free of this species. The location and procedure for those dedicated dust suppression ponds will be communicated during the site induction and training; • If practicable, the capping and grading activities will be scheduled to occur outside of the core Green and Golden Bell Frog breeding period (that is, September to March), especially in areas adjacent to known and potential breeding habitat; • One week prior to works commencing in the disturbance area, a pre-works survey will be conducted by a qualified ecologist; and • In the event that any Green and Golden Bell Frogs are identified in the area (during pre-clearance surveys or following commencement of construction), they will be relocated (using appropriate amphibian hygiene protocols) to known and suitable Green and Golden Bell Frog habitat areas immediately adjacent to the disturbance footprint. Section 7.4 of the Final Landform and Capping Strategy (GHD, 2009) calls up the mitigation measures within the GHD Flora and Fauna Impact Assessment, which requires: • Proposed hours of construction are maintained to restrict noise and light impacts on nocturnal fauna; • Utilise an onsite ecologist during construction to re-locate any native fauna which may be displaced; • Avoid rubbish and other waste build up to deter feral animals; • Habitat features such as woody debris that may be utilised by fauna within the construction area would be retained and set-aside during the construction period for reinstatement at completion of works; • The site wide joint monitoring of the Green and Golden Bell Frog population should be continued seasonally, where feasible, from the next breeding season (spring 2009) to help best manage the population and determine if any adverse impacts have resulted from any works/modifications to Green and Golden Bell Frog habitat across Kooragang Island, before and after the emplacement capping works;

Environmental Aspect	Specific Mitigation Measures
	• Adequate run-off, erosion and sedimentation controls should be in place during construction, particularly in areas where run-off has the potential to impact on nearby waterways, surrounding native vegetation, EEC regrowth, and existing drainage line and dam areas; • Care should be taken that any noxious weeds occurring on the site are not further dispersed as a result of the Proposal. A follow up Weed Control Program may be necessary to control the encroachment of these species into surrounding areas. The landowner has a legal responsibility to control and suppress these species on their property under the Noxious Weeds Act 1995; • Stockpiling of soil that may contain seed of exotic species away from adjacent vegetation or drainage lines where they could be spread during rainfall events; • Placement of soil stockpiles away from vegetated areas; • Utilising existing disturbed corridors such as cleared areas, roads, tracks and existing easements, where possible for set up of equipment, stockpile areas and site facilities; • Development of an Erosion and Sedimentation Control Plan covering the works associated with the Proposal. Erosion and sediment controls are to be installed prior to construction, and maintained throughout construction, to minimise sediment entering the adjacent waterbodies, EECs and SEPP 14 wetland areas;and • Bitou Bush, Prickly Pear, Crofton Weed and Pampas Grass would be managed by following the Local Noxious Weed Control Plans (NCC 2006). It is recommended that the plants be removed by physical removal, as herbicides may impact Green and Golden Bell Frogs and their habitat.
Revegetation	Condition 4a) of the Surrender Notice requires that by 30 June 2017, the licensee shall complete implementation of the final landform and capping strategy as detailed in the documents titled: • HDC – Report on KIWEF – 'Revised Final Landform and Capping strategy' – August 2009 - Revision 2, prepared by GHD ("the Landfill and Capping Strategy"); Chapter 7 of Revised Final Landform and Capping Strategy (GHD, 2009) indicates that 100mm thick layer of topsoil will be utilised across the site and will be sourced using stockpiled surface soils or imported topsoil to revegetate the disturbed area. Section 7.4 of Flora and Fauna Impact Assessment (GHD, Appendix A, 2009) requires that: • Provenance native plant stock would be used for rehabilitation of the disturbed areas to maintain the genetic integrity of the vegetation communities present on site; • Revegetation of the Proposal capped areas following soil/capping material placement should be in accordance with a Revegetation and Restoration Plan; and • Restore and rehabilitate wetland communities disturbed by the Proposal in accordance with a Revegetation and Restoration Plan. Section 5.3 of the GGBF Management Plan (Golder Associates, 2011) requires that: • As part of the rehabilitation and revegetation plan for the KIWEF site, open stormwater infrastructure across the KIWEF site may be planted with species known to be favoured by Green and Golden Bell Frogs. This revegetation and rehabilitation strategy will include a 2 metre wide buffer on either side of the stormwater drains. The intention of these areas is to provide movement corridors for Green and Golden Bell Frogs across the site; • The capped areas will ideally be designed to shed water to table drains, which, in a similar manner to other stormwater infrastructure, will be vegetated with species known to be favourable to Green and Golden Bell Frogs; and • Drainage culverts will, where practicable, be vegetated and lined with rocks and objects that may provide temporary frog refuge, in the event that a frog seeks to traverse the future capped area of KIWEF.

These requirements generally reflect the "Particular Manner" requirements issued for Referral 2012/6464 which are also proposed to be incorporated into management of construction impacts associated with the proposed activity. The capping of Area 1 under Referral 2012/6464 was completed in May 2015, generally utilising the mitigation measures as described within Table 13. While the long-term effects of the Area 1 capping are difficult to determine after such a relatively short timeframe since completion, the mitigation measures implemented during the construction works were considered to be appropriate and effective in controlling the potential construction impacts to the surrounding Green and Golden Bell Frog habitats. HDC and the EPA have discussed the completion of the Area 1 capping works and the EPA has indicated that the works were conducted in accordance with the relevant management plans and the requirements of the KIWEF Surrender License. The EPA are expected to release formal advice before the end of the year to this confirm this statement.

Slight changes to the previous "Particular Manner" requirements are required to address the identified topsoil deficiency and make them applicable to the referral area should a "in a Particular Manner" decision be formed. Based on assessments and experience to date the following mitigations measures are proposed to prevent significant impacts to MNES:

1. Works described within the Referral associated with the closure of the Kooragang Island Waste Emplacement Facility must only occur within the Referral Area as illustrated on *Annex A, Figure 2*; and must be restricted to the extent required to satisfy the Surrender Notice requirements.

2. The NSW Threatened Species Management Information Circular No.6 – Service Hygiene Protocol for the Control of Disease in Frogs (April (2008) or most recent revision of that document, must be implemented on the Closure Works site during all works and any other activities undertaken as part of the action.

3. Prior to the commencement of works, Green and Golden Bell Frog (*Litoria aurea*) breeding habitat, as identified within the referral must be:

- Clearly defined on construction site plans as habitat for authorised access only; and
- Protected from unauthorised access from the closure works site by sign-posting and temporary construction fencing installed outside of *Litoria aurea* breeding habitat.

4. Temporary frog exclusion fencing must be installed to prevent movement of GGBF into the works area from likely GGBF habitat and be located to avoid additional impacts on GGBF breeding habitat.

5. Pre-clearance surveys for *Litoria aurea* must be undertaken by a qualified ecologist in all works areas or their parts prior to commencement of physical disturbance of the site. Early works associated with the establishment of site facilities, fencing and signage should be undertaken in the presence of an Ecologist. The design of the pre-clearance survey must include active surveys aimed at maximising the capture and relocation of GGBF individuals prior to physical disturbance. Any GGBF encountered during pre-clearance surveys or during works are to be captured and relocated in accordance with the GGBF Management Plan (Golder, 2011).

6. Any capping materials that are imported from outside the KIWEF facility must be sourced from an area that is demonstrated to be low in nutrients and assessed as having a low risk of containing chytrid fungus.

7. Topsoil to be used for surface layers must be sourced from within KIWEF to the extent possible and will otherwise be demonstrated to be low in nutrients and assessed as having a low risk of containing chytrid fungus.

8. Design of erosion and sediment controls must be in accordance with environmental protection standards for sensitive environments, such as (but not limited to) 'Managing Urban Stormwater – Soils and Construction' (Landcom, 2004).

9. Upon completion of works, the works area must be rehabilitated with local native vegetation species.

6 Conclusion on the likelihood of significant impacts

6.1 Do you THINK your proposed action is a controlled action?

No	No, complete section 6.2
	Yes, complete section 6.3

6.2 Proposed action IS NOT a controlled action.

The potential impacts to MNES have been identified as follows:

- Short term construction impacts related to clearing of existing vegetation dominated by weeds and non-native species with impacts to pond fringing habitat avoided;
- Short term construction impacts associated with sedimentation able to be managed through the implementation of erosion and sediment controls;
- Potential short term indirect impacts to foraging wetland birds, due to construction disturbance in the adjacent capping area; and
- General improvements in water quality in receiving waterbodies with slightly wetter and fresher conditions expected.

There is no proposed ongoing loss of habitat for any MNES species and short term impacts associated with site disturbance during construction are able to be managed using methods previously implemented on KIWEF and demonstrated to be successful in avoiding significant impacts to MNES. None of the impacts are considered to significantly affect any MNES. Adequate regulation of the proposed activity and KIWEF in general is provided through the requirements of the Surrender Notice under the Protection of the Environment Operations Act and are able to be enforced under State Legislation. Should a reduction of salinity levels beyond that expected eventuate and be attributable to the proposed activity, the discharge levels of permanent basins can be raised to reduce surface water in-flows to the affected ponds effectively returning the hydrology of the site to the pre-activity conditions.

6.3 Proposed action IS a controlled action

	Matters likely to be impacted
	World Heritage values (sections 12 and 15A)
	National Heritage places (sections 15B and 15C)
	Wetlands of international importance (sections 16 and 17B)
	Listed threatened species and communities (sections 18 and 18A)
	Listed migratory species (sections 20 and 20A)
	Protection of the environment from nuclear actions (sections 21 and 22A)
	Commonwealth marine environment (sections 23 and 24A)
	Great Barrier Reef Marine Park (sections 24B and 24C)
	A water resource, in relation to coal seam gas development and large coal mining development (sections 24D and 24E)
	Protection of the environment from actions involving Commonwealth land (sections 26 and 27A)
	Protection of the environment from Commonwealth actions (section 28)
	Commonwealth Heritage places overseas (sections 27B and 27C)

7 Environmental record of the responsible party

		Yes	No
7.1	**Does the party taking the action have a satisfactory record of responsible environmental management?** **Provide details** The Port of Newcastle Lessor Pty Ltd (PoN Lessor) is a NSW Government (State) owned entity that owns the Kooragang Island Waste Landfill Facility (KIWEF) land, which is currently leased by the State to Port of Newcastle Investments (Property) Pty Ltd under a 98 year lease that began in May 2014. The State has also entered into a Binding Terms of Agreement (BTA) with the Hunter Development Corporation (HDC) for HDC to arrange the completion of the KIWEF Closure Works as specified under the Surrender License (issued by the NSW EPA) on behalf of the land owner. HDC will oversee the implementation of the Closure Works to ensure compliance with any environmental management controls that are stipulated throughout the construction phase of the remediation works. After completion of the remediation works (including signoff by the NSW EPA), HDC will hand over control and any ongoing obligations attached to the site, to the PoN Lessor. The Hunter Development Corporation (HDC) has previously arranged similar remediation works on behalf of the State (capping of Area 1 under Referral 2012/6464, completed in May 2015). The completion of the capping of Area 1 was also undertaken in close proximity to Green and Golden Bell Frog habitats. The mitigation measures implemented for the Area 1 closure works were similar to the proposed mitigation measures for the Area 2 closure works. The mitigation measures implemented during the construction works of the Area 1 closure works were considered to be appropriate and effective in controlling the potential construction impacts to the surrounding Green and Golden Bell Frog habitats. HDC and the EPA have discussed the completion of the Area 1 capping works and the EPA has indicated that the works were conducted in accordance with the relevant management plans and the requirements of the KIWEF Surrender License. The EPA are expected to release formal advice before the end of the year to this confirm this statement.	✓	
7.2	**Has either (a) the party proposing to take the action, or (b) if a permit has been applied for in relation to the action, the person making the application - ever been subject to any proceedings under a Commonwealth, State or Territory law for the protection of the environment or the conservation and sustainable use of natural resources?** **If yes, provide details** Neither the PoN Lessor, nor the HDC have been subject to any proceedings under a Commonwealth, State or Territory law for the protection of the environment or the conservation and sustainable use of a natural resource.		✓
7.3	**If the party taking the action is a corporation, will the action be taken in accordance with the corporation's environmental policy and planning framework?** **If yes, provide details of environmental policy and planning framework** The PoN Lessor is a NSW State Government owned entity that is governed by a Board of Directors comprised of senior members from two NSW State Government owned entities being, NSW Treasury and Government Property NSW. The PoN Lessor report directly to the NSW Treasurer. HDC is a NSW State Government organisation that is governed by a Board of Directors who report to the NSW Minister for Planning. The Board sets and oversees the direction of HDC by actively participating in strategic planning and providing guidance and overseeing the performance of the Corporations policies, management and operation.	✓	
7.4	**Has the party taking the action previously referred an action under the EPBC Act, or been responsible for undertaking an action referred under the EPBC Act?** **Provide name of proposal and EPBC reference number (if known)** PoN Lessor has not submitted a previous Referral. However HDC have previously arranged the submission of the following referrals on behalf of the former KIWEF landowner Newcastle Ports Corporation another NSW State Government owned entity. The previous Referrals include: - Report for KIWEF Capping Strategy (March 2011) [Referral Withdrawn, no number provided] - Kooragang Island Waste Emplacement Facility, Capping Strategy (July 2012) [2012/6464]	✓	

8 Information sources and attachments

(For the information provided above)

8.1 References

- GHD (2009) Hunter Development Corporation - Report on KIWEF - Revised Final Landform and Capping Strategy - August 2009 - Revision 2.
- GHD (2010) Hunter Development Corporation – Revised Capping Strategy KIWEF Flora and Fauna Impact Assessment January 2010 Revision 3.
- Golder Associates (2011) 'Green and Golden Bell Frog Management Plan – Kooragang Island Waste Emplacement Facility Closure Works' dated 19 April 2011.
- Herbert, C. (2007) Distribution, Abundance and Status of Birds in the Hunter Estuary, Hunter Bird Observers Club, Special Report No.4, prepared for Newcastle City Council, September 2007.
- Lindsey, A. (2008) The birds of Deep Pond – Kooragang Island 1993 - 2007. The Whistler 2: 1-12.
- RCA (2012) 'Materials Management Plan - Kooragang Island Waste Emplacement Facility' dated November 2012.
- EMGA Mitchel McLennan (2012) T4 Project Environmental Assessment prepared for Port Waratah Coal Services Limited (Publically Available http://majorprojects.planning.nsw.gov.au/page/development-categories/transport--communications--energy---water/port---wharf-facilities/?action=view_job&job_id=4399).
- NCIG (2014) Annual Environmental Management Report, ENVIRON Australia.
- SMEC (2012) Terminal 4 Project Surface Water Assessment (Publically Available http://majorprojects.planning.nsw.gov.au/page/development-categories/transport--communications--energy---water/port---wharf-facilities/?action=view_job&job_id=4399)
- SMEC (2013) Detailed Response to SEWPaC Comments, Kooragang Island Waste Emplacement Facility – Final Report.
- Umwelt (2012) Ecological Assessment for Port Waratah Coal Services (PWCS) Proposed Terminal 4 Project, Port of Newcastle NSW.

8.2 Reliability and date of information

ERM has undertaken an extensive review of available information for the site and the documents used in preparing the referral are listed in Section 8.1. The reliability of data provided in the referral has been tested through review of multiple sources of information addressing each topic.

In relation to ecology, ERM has reviewed the listed reports and subsequently has undertaken a site inspection to ground truth the vegetation descriptions provided by both Umwelt and GHD. The ecological assessment is therefore fully reliable as it is based on extensive survey effort undertaken, assessed and ultimately approved under State Legislation for the T4 project and ground truthed to make it current.

Similarly, the understanding of water quality characteristics has been assembled based on extensive sampling effort by a number of technical specialists both on behalf of Hunter Development Corporation and in association with the T4 project and NCIG project. While sampling results reflect a single time in any given year they are considered generally indicative of the variability within and between ponds and suitable for the purposes of the assessment. Hydro-salinity loggers are also being established to monitor ongoing conditions in the waterbodies surrounding the referral area.

The hydrology and landform of the site has been interpreted based on the available survey data provided in association with the T4 project, NCIG project and in development of the Closure Strategy. The landform characteristics are described based on recent site observations and through review of available information contained within the PWCS T4 Environmental Assessment and the Final Landform and Capping Strategy. Completion of detailed design will further refine the current and proposed site landform and hydrology, but the available information is deemed adequate for the assessment of likely impacts on the basis that the detailed design will be completed with the objectives of achieving the outcomes described within the referral information.

8.3 Attachments

		Attached	Title of attachment(s)
You must attach	figures, maps or aerial photographs showing the project locality (section 1)	✓	Annex A Figures 1-6: • Figure 1 - Project Locality, with Commonwealth Heritage Places and Ramsar Wetlands • Figure 2 - Project Area, Including Referral Area and Capping Area • Figure 3 - EPBC Listed Threatened Species Recorded within the Study Area • Figure 4 - Green and Golden Bell Frog Recorded within and Adjacent to the Site • Figure 5 - Vegetation Communities and Green and Golden Bell Frog Breeding Habitat • Figure 6 - Site topography and indicative surface water flow paths
	GIS file delineating the boundary of the referral area (section 1)	✓	
	figures, maps or aerial photographs showing the location of the project in respect to any matters of national environmental significance or important features of the environments (section 3)	✓	As above
If relevant, attach	copies of any state or local government approvals and consent conditions (section 2.5)		Surrender Notice (as amended) supplied separately and publically available.
	copies of any completed assessments to meet state or local government approvals and outcomes of public consultations, if available (section 2.6)		NA
	copies of any flora and fauna investigations and surveys (section 3)		Publically Available or previously supplied
	technical reports relevant to the assessment of impacts on protected matters that support the arguments and conclusions in the referral (section 3 and 4)	✓	Annex C
	report(s) on any public consultations undertaken, including with Indigenous stakeholders (section 3)		NA

9 Contacts, signatures and declarations

Project title:

9.1 Person proposing to take action

1. Name and Title:	Sarah Strang, Company Secretary
2. Organisation	Port of Newcastle Lessor Pty Ltd
3. EPBC Referral Number	Not Known
4: ACN / ABN	ACN 165 332 981
5. Postal address	Port of Newcastle Lessor Pty Ltd; c/- Government Property NSW, Level 9, Bligh House, 4-6 Bligh Street, SYDNEY, NSW, 2000
6. Telephone:	(02) 9273 3845
7. Email:	sarah.strang@property.nsw.gov.au
8. Name of designated proponent (if not the same person at item 1 above):	Not Applicable
9. ACN/ABN of designated proponent (if not the same person named at item 1 above):	Not Applicable
I qualify for exemption from fees under section 520(4C)(e)(v) of the EPBC Act because I am:	☐ an individual; OR ☐ a small business entity (within the meaning given by section 328-110 (other than subsection 328-119(4)) of the *Income Tax Assessment Act 1997*); OR ☑ not applicable.
If you are small business entity you must provide the Date/Income Year that you became a small business entity:	Not Applicable
I would like to apply for a waiver of full or partial fees under Schedule 1, 5.21A of the EPBC Regulations. Under sub regulation 5.21A(5), you must include information about the applicant (if not you) the grounds on which the waiver is sought and the reasons why it should be made:	☑ not applicable.
Declaration	I declare that to the best of my knowledge the information I have given on, or attached to this form is complete, current and correct. I understand that giving false or misleading information is a serious offence. I agree to be the proponent for this action. I declare that I am not taking the action on behalf of or for the benefit of any other person or entity.

Signature [signature] Date 9/3/16

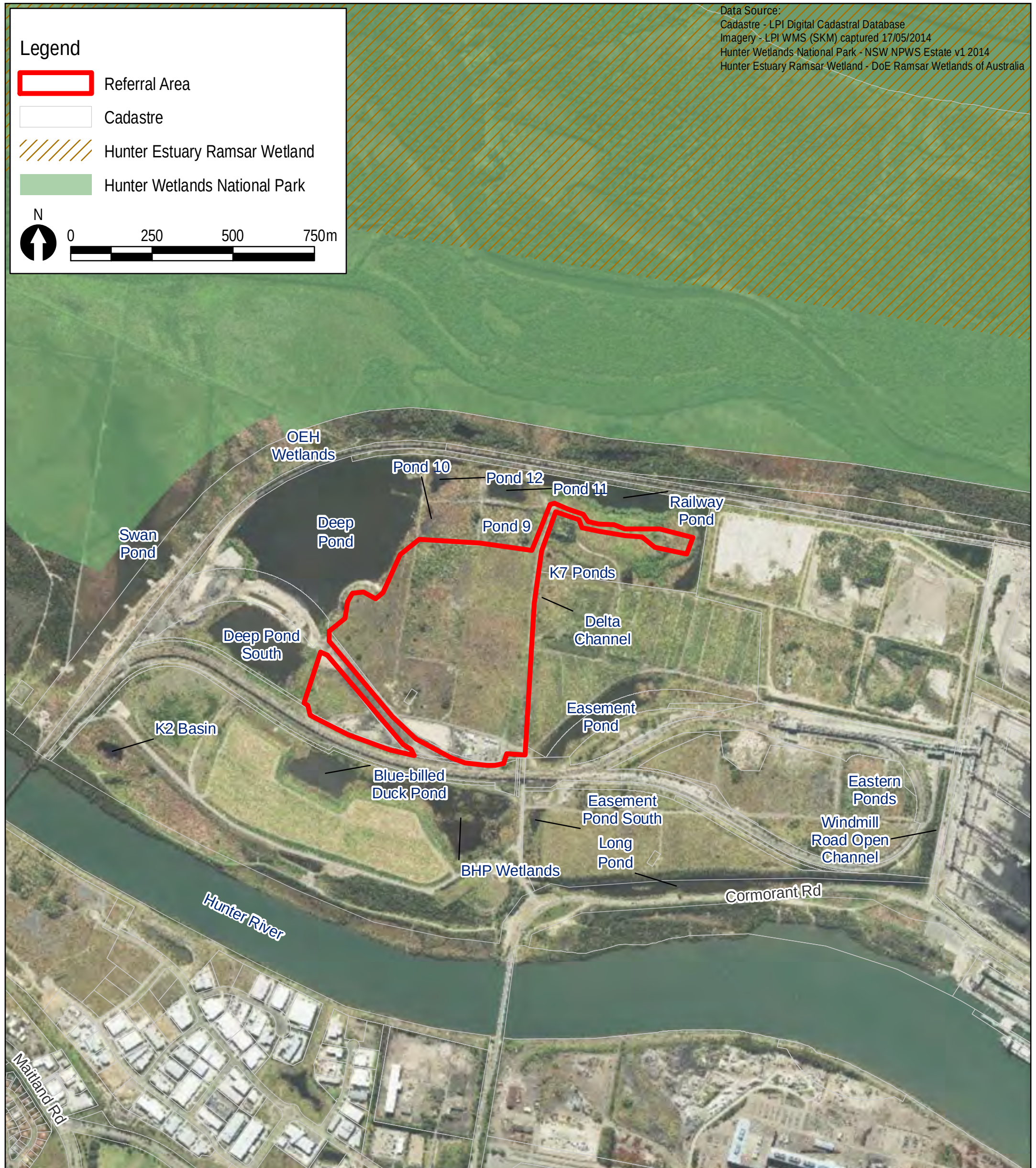
9.2 Person preparing the referral information

Name	Thomas Muddle
Title	Environmental Planner
Organisation	Environmental Resources Management Australia Pty Ltd
ACN / ABN (if applicable)	12 002 773 248
Postal address	PO Box 803, Newcastle, NSW, 2300
Telephone	+61249035500
Email	thomas.muddle@erm.com
Declaration	I declare that to the best of my knowledge the information I have given on, or attached to this form is complete, current and correct. I understand that giving false or misleading information is a serious offence.

Signature  Date 18 December 2015

Annex A

Figures



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Date:	04/12/2015	Drawing Size: A4	
Drawn By:	TC	Reviewed By: TM	

This figure may be based on third party data or data which has not been verified by ERM and it may not be to scale. Unless expressly agreed otherwise, this figure is intended as a guide only and ERM does not warrant its accuracy.

Figure 1 - Project Locality, with Commonweath Heritage Places and Ramsar Wetlands

Former Kooragang Island Waste Emplacement Facility
EPBC Act Referral

Environmental Resources Management ANZ

Auckland, Brisbane, Canberra, Christchurch, Melbourne, Newcastle, Perth, Port Macquarie, Sydney

ERM

Client:	Hunter Development Corporation	
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Date:	04/12/2015	Drawing Size: A4
Drawn By:	TC	Reviewed By: ED

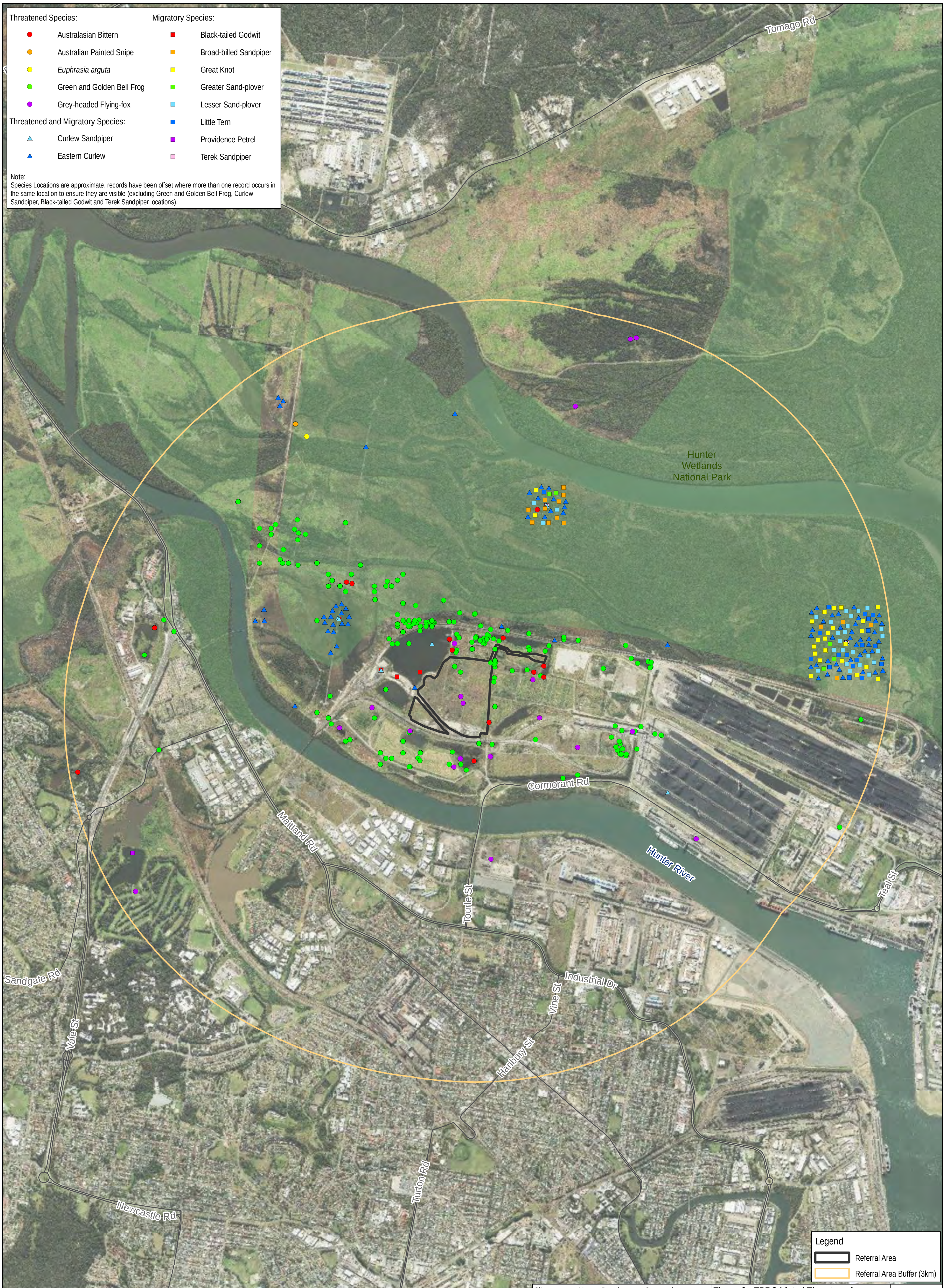
This figure may be based on third party data or data which has not been verified by ERM and it may not be to scale. Unless expressly agreed otherwise, this figure is intended as a guide only and ERM does not warrant its accuracy.

Figure 2 - Project Area, Including Referal Area and Capping Area

Former Kooragang Island Waste Emplacement Facility
EPBC Act Referral

Environmental Resources Management ANZ

Auckland, Brisbane, Canberra, Christchurch, Melbourne, Newcastle, Perth, Port Macquarie, Sydney



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Date:	23/11/2015	Drawing Size:	A3
Drawn By:	TC	Reviewed By:	ED

This figure may be based on third party data or data which has not been verified by ERM and it may not be to scale. Unless expressly agreed otherwise, this figure is intended as a guide only and ERM does not warrant its accuracy.

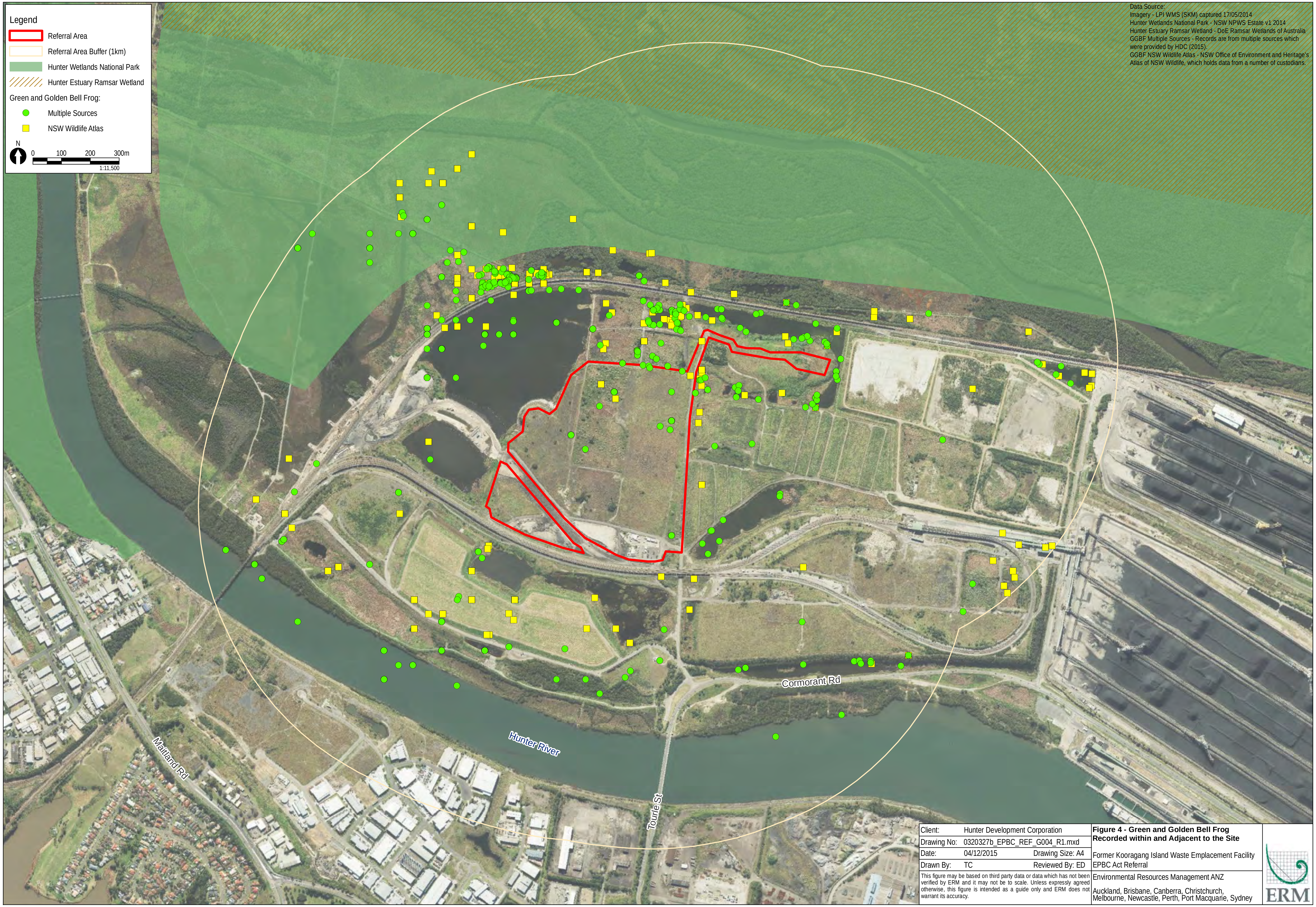
Figure 3 - EPBC Listed Threatened Species Recorded within the Study Area

Former Kooragang Island Waste Emplacement Facility
EPBC Act Referral

Environmental Resources Management ANZ

Auckland, Brisbane, Canberra, Christchurch, Melbourne, Newcastle, Perth, Port Macquarie, Sydney

ERM



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Drawn By:	TC	Reviewed By: ED	

This figure may be based on third party data or data which has not been verified by ERM and it may not be to scale. Unless expressly agreed otherwise, this figure is intended as a guide only and ERM does not warrant its accuracy.

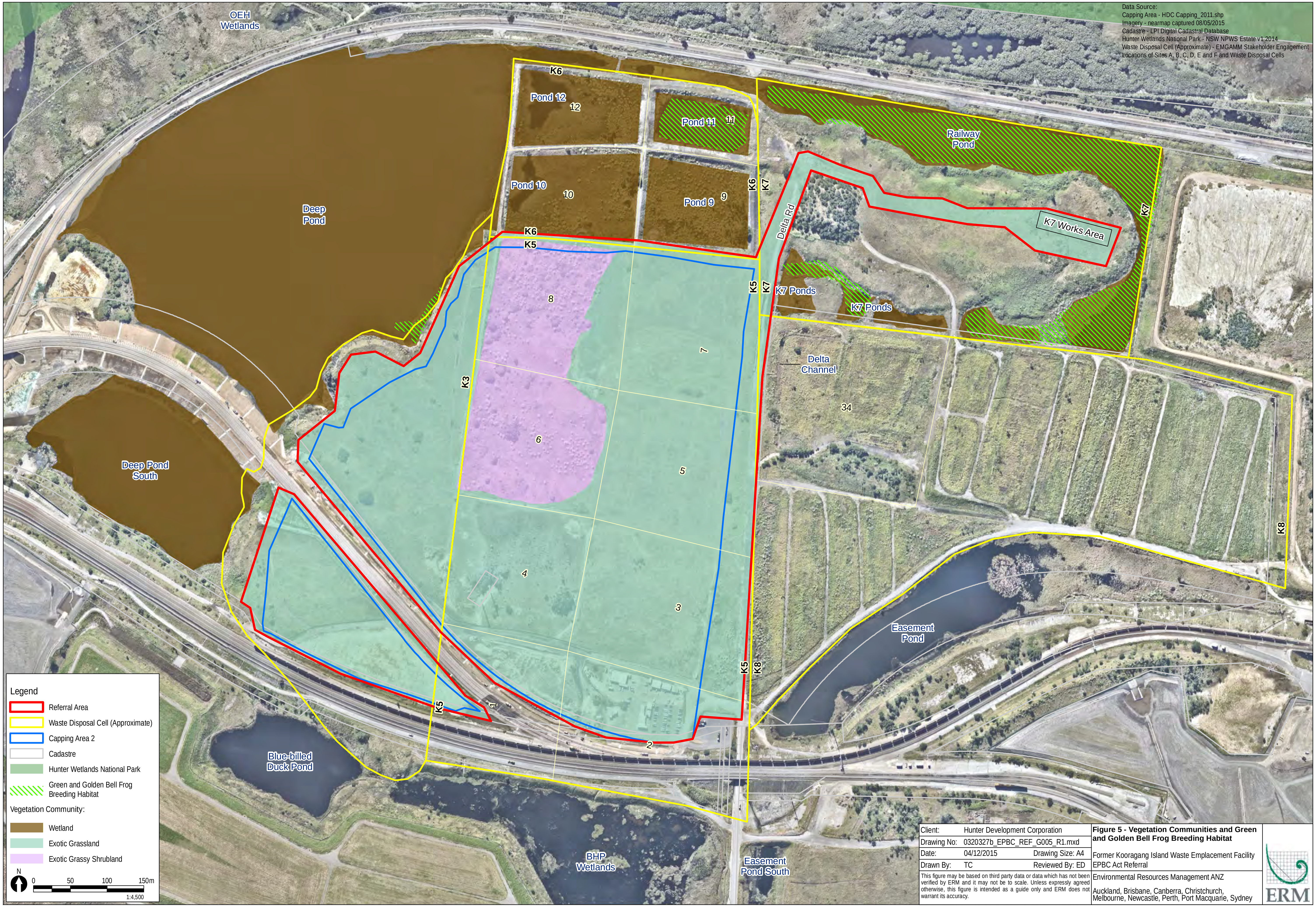
Figure 4 - Green and Golden Bell Frog Recorded within and Adjacent to the Site

Former Kooragang Island Waste Emplacement Facility
EPBC Act Referral

Environmental Resources Management ANZ

Auckland, Brisbane, Canberra, Christchurch, Melbourne, Newcastle, Perth, Port Macquarie, Sydney

ERM



Client:	Hunter Development Corporation		
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Drawn By:	TC	Reviewed By: ED	

This figure may be based on third party data or data which has not been verified by ERM and it may not be to scale. Unless expressly agreed otherwise, this figure is intended as a guide only and ERM does not warrant its accuracy.

Figure 5 - Vegetation Communities and Green and Golden Bell Frog Breeding Habitat

Former Kooragang Island Waste Emplacement Facility
EPBC Act Referral

Environmental Resources Management ANZ

Auckland, Brisbane, Canberra, Christchurch, Melbourne, Newcastle, Perth, Port Macquarie, Sydney

ERM

Client:	Hunter Development Corporation		
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Date:	08/12/2015	Drawing Size: A4	
Drawn By:	TC	Reviewed By: TM	

This figure may be based on third party data or data which has not been verified by ERM and it may not be to scale. Unless expressly agreed otherwise, this figure is intended as a guide only and ERM does not warrant its accuracy.

Figure 6 - Site Topography and Indicative Surface Water Flow Paths

Former Kooragang Island Waste Emplacement Facility
EPBC Act Referral

Environmental Resources Management ANZ

Auckland, Brisbane, Canberra, Christchurch, Melbourne, Newcastle, Perth, Port Macquarie, Sydney

ERM

Annex B

EPBC PMST

Australian Government
Department of the Environment

EPBC Act Protected Matters Report

This report provides general guidance on matters of national environmental significance and other matters protected by the EPBC Act in the area you have selected.

Information on the coverage of this report and qualifications on data supporting this report are contained in the caveat at the end of the report.

Information is available about Environment Assessments and the EPBC Act including significance guidelines, forms and application process details.

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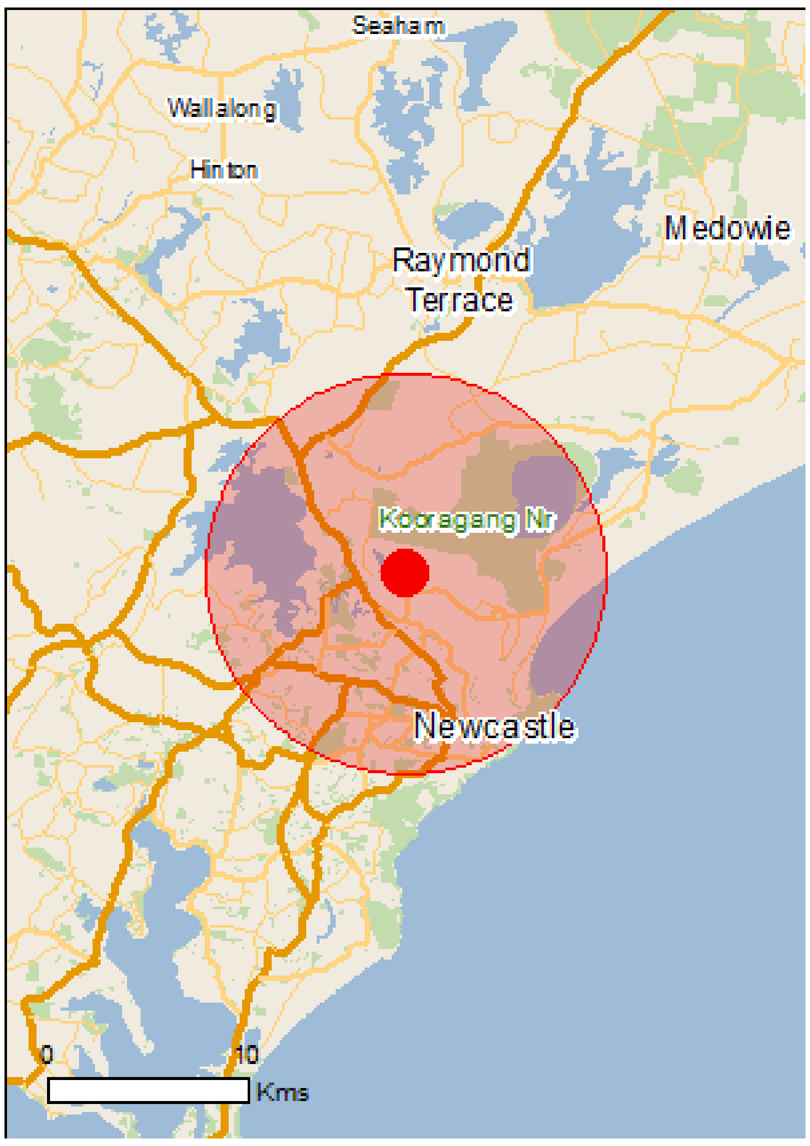

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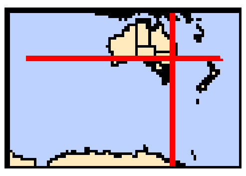

Summary

Matters of National Environmental Significance

This part of the report summarises the matters of national environmental significance that may occur in, or may relate to, the area you nominated. Further information is available in the detail part of the report, which can be accessed by scrolling or following the links below. If you are proposing to undertake an activity that may have a significant impact on one or more matters of national environmental significance then you should consider the Administrative Guidelines on Significance.

World Heritage Properties:	None
National Heritage Places:	None
Wetlands of International Importance:	1
Great Barrier Reef Marine Park:	None
Commonwealth Marine Area:	None
Listed Threatened Ecological Communities:	3
Listed Threatened Species:	63
Listed Migratory Species:	73

Other Matters Protected by the EPBC Act

This part of the report summarises other matters protected under the Act that may relate to the area you nominated. Approval may be required for a proposed activity that significantly affects the environment on Commonwealth land, when the action is outside the Commonwealth land, or the environment anywhere when the action is taken on Commonwealth land. Approval may also be required for the Commonwealth or Commonwealth agencies proposing to take an action that is likely to have a significant impact on the environment anywhere.

The EPBC Act protects the environment on Commonwealth land, the environment from the actions taken on Commonwealth land, and the environment from actions taken by Commonwealth agencies. As heritage values of a place are part of the 'environment', these aspects of the EPBC Act protect the Commonwealth Heritage values of a Commonwealth Heritage place. Information on the new heritage laws can be found at http://www.environment.gov.au/heritage

A permit may be required for activities in or on a Commonwealth area that may affect a member of a listed threatened species or ecological community, a member of a listed migratory species, whales and other cetaceans, or a member of a listed marine species.

Commonwealth Land:	16
Commonwealth Heritage Places:	2
Listed Marine Species:	94
Whales and Other Cetaceans:	14
Critical Habitats:	None
Commonwealth Reserves Terrestrial:	None
Commonwealth Reserves Marine:	None

Extra Information

This part of the report provides information that may also be relevant to the area you have nominated.

State and Territory Reserves:	6
Regional Forest Agreements:	1
Invasive Species:	47
Nationally Important Wetlands:	3
Key Ecological Features (Marine)	None

Details

Matters of National Environmental Significance

Wetlands of International Importance (Ramsar) [Resource Information]

Name	Proximity
Hunter estuary wetlands	Within Ramsar site

Listed Threatened Ecological Communities [Resource Information]

For threatened ecological communities where the distribution is well known, maps are derived from recovery plans, State vegetation maps, remote sensing imagery and other sources. Where threatened ecological community distributions are less well known, existing vegetation maps and point location data are used to produce indicative distribution maps.

Name	Status	Type of Presence
Central Hunter Valley eucalypt forest and woodland	Critically Endangered	Community may occur within area
Lowland Rainforest of Subtropical Australia	Critically Endangered	Community may occur within area
Subtropical and Temperate Coastal Saltmarsh	Vulnerable	Community likely to occur within area

Listed Threatened Species [Resource Information]

Name	Status	Type of Presence
Birds		
Anthochaera phrygia Regent Honeyeater [82338]	Critically Endangered	Foraging, feeding or related behaviour likely to occur within area
Botaurus poiciloptilus Australasian Bittern [1001]	Endangered	Species or species habitat known to occur within area
Calidris ferruginea Curlew Sandpiper [856]	Critically Endangered	Roosting known to occur within area
Dasyornis brachypterus Eastern Bristlebird [533]	Endangered	Species or species habitat likely to occur within area
Diomedea epomophora epomophora Southern Royal Albatross [25996]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Diomedea epomophora sanfordi Northern Royal Albatross [82331]	Endangered	Foraging, feeding or related behaviour likely to occur within area
Diomedea exulans antipodensis Antipodean Albatross [82269]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Diomedea exulans exulans Tristan Albatross [82337]	Endangered	Species or species habitat may occur within area
Diomedea exulans gibsoni Gibson's Albatross [82271]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area

Name	Status	Type of Presence
Diomedea exulans (sensu lato) Wandering Albatross [1073]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Fregetta grallaria grallaria White-bellied Storm-Petrel (Tasman Sea), White-bellied Storm-Petrel (Australasian) [64438]	Vulnerable	Species or species habitat likely to occur within area
Grantiella picta Painted Honeyeater [470]	Vulnerable	Species or species habitat may occur within area
Lathamus discolor Swift Parrot [744]	Endangered	Species or species habitat likely to occur within area
Macronectes giganteus Southern Giant Petrel [1060]	Endangered	Species or species habitat may occur within area
Macronectes halli Northern Giant Petrel [1061]	Vulnerable	Species or species habitat may occur within area
Numenius madagascariensis Eastern Curlew [847]	Critically Endangered	Roosting known to occur within area
Pachyptila turtur subantarctica Fairy Prion (southern) [64445]	Vulnerable	Species or species habitat known to occur within area
Phoebetria fusca Sooty Albatross [1075]	Vulnerable	Species or species habitat may occur within area
Pterodroma leucoptera leucoptera Gould's Petrel [26033]	Endangered	Species or species habitat may occur within area
Pterodroma neglecta neglecta Kermadec Petrel (western) [64450]	Vulnerable	Foraging, feeding or related behaviour may occur within area
Rostratula australis Australian Painted Snipe [77037]	Endangered	Species or species habitat likely to occur within area
Thalassarche bulleri Buller's Albatross, Pacific Albatross [64460]	Vulnerable	Species or species habitat may occur within area
Thalassarche cauta cauta Shy Albatross, Tasmanian Shy Albatross [82345]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Thalassarche cauta salvini Salvin's Albatross [82343]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Thalassarche cauta steadi White-capped Albatross [82344]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Thalassarche eremita Chatham Albatross [64457]	Endangered	Foraging, feeding or related behaviour likely to occur within area
Thalassarche melanophris Black-browed Albatross [66472]	Vulnerable	Species or species habitat may occur within area
Thalassarche melanophris impavida Campbell Albatross [82449]	Vulnerable	Species or species

Name	Status	Type of Presence
		habitat may occur within area
Fish		
Epinephelus daemelii		
Black Rockcod, Black Cod, Saddled Rockcod [68449]	Vulnerable	Species or species habitat likely to occur within area
Frogs		
Litoria aurea		
Green and Golden Bell Frog [1870]	Vulnerable	Species or species habitat likely to occur within area
Litoria littlejohni		
Littlejohn's Tree Frog, Heath Frog [64733]	Vulnerable	Species or species habitat may occur within area
Mammals		
Balaenoptera musculus		
Blue Whale [36]	Endangered	Species or species habitat may occur within area
Chalinolobus dwyeri		
Large-eared Pied Bat, Large Pied Bat [183]	Vulnerable	Species or species habitat likely to occur within area
Dasyurus maculatus maculatus (SE mainland population)		
Spot-tailed Quoll, Spotted-tail Quoll, Tiger Quoll (southeastern mainland population) [75184]	Endangered	Species or species habitat likely to occur within area
Eubalaena australis		
Southern Right Whale [40]	Endangered	Species or species habitat likely to occur within area
Megaptera novaeangliae		
Humpback Whale [38]	Vulnerable	Species or species habitat known to occur within area
Petrogale penicillata		
Brush-tailed Rock-wallaby [225]	Vulnerable	Species or species habitat may occur within area
Phascolarctos cinereus (combined populations of Qld, NSW and the ACT)		
Koala (combined populations of Queensland, New South Wales and the Australian Capital Territory) [85104]	Vulnerable	Species or species habitat known to occur within area
Potorous tridactylus tridactylus		
Long-nosed Potoroo (SE mainland) [66645]	Vulnerable	Species or species habitat likely to occur within area
Pseudomys novaehollandiae		
New Holland Mouse, Pookila [96]	Vulnerable	Species or species habitat known to occur within area
Pteropus poliocephalus		
Grey-headed Flying-fox [186]	Vulnerable	Roosting known to occur within area
Plants		
Commersonia prostrata		
Dwarf Kerrawang [87152]	Endangered	Species or species habitat likely to occur within area
Cryptostylis hunteriana		
Leafless Tongue-orchid [19533]	Vulnerable	Species or species habitat likely to occur within area
Diuris praecox		
Newcastle Doubletail [55086]	Vulnerable	Species or species habitat likely to occur within area
Eucalyptus camfieldii		
Camfield's Stringybark [15460]	Vulnerable	Species or species habitat likely to occur within area

Name	Status	Type of Presence
Eucalyptus parramattensis subsp. decadens Earp's Gum, Earp's Dirty Gum [56148]	Vulnerable	Species or species habitat known to occur within area
Grevillea parviflora subsp. parviflora Small-flower Grevillea [64910]	Vulnerable	Species or species habitat known to occur within area
Melaleuca biconvexa Biconvex Paperbark [5583]	Vulnerable	Species or species habitat known to occur within area
Persicaria elatior Knotweed [5831]	Vulnerable	Species or species habitat likely to occur within area
Phaius australis Lesser Swamp-orchid [5872]	Endangered	Species or species habitat may occur within area
Pterostylis gibbosa Illawarra Greenhood, Rufa Greenhood, Pouched Greenhood [4562]	Endangered	Species or species habitat may occur within area
Rutidosis heterogama Heath Wrinklewort [13132]	Vulnerable	Species or species habitat may occur within area
Syzygium paniculatum Magenta Lilly Pilly, Magenta Cherry, Pocket-less Brush Cherry, Scrub Cherry, Creek Lilly Pilly, Brush Cherry [20307]	Vulnerable	Species or species habitat likely to occur within area
Tetratheca juncea Black-eyed Susan [21407]	Vulnerable	Species or species habitat known to occur within area
Reptiles		
Caretta caretta Loggerhead Turtle [1763]	Endangered	Species or species habitat known to occur within area
Chelonia mydas Green Turtle [1765]	Vulnerable	Foraging, feeding or related behaviour known to occur within area
Dermochelys coriacea Leatherback Turtle, Leathery Turtle, Luth [1768]	Endangered	Species or species habitat known to occur within area
Eretmochelys imbricata Hawksbill Turtle [1766]	Vulnerable	Foraging, feeding or related behaviour known to occur within area
Hoplocephalus bungaroides Broad-headed Snake [1182]	Vulnerable	Species or species habitat likely to occur within area
Natator depressus Flatback Turtle [59257]	Vulnerable	Foraging, feeding or related behaviour known to occur within area
Sharks		
Carcharias taurus (east coast population) Grey Nurse Shark (east coast population) [68751]	Critically Endangered	Species or species habitat likely to occur within area
Carcharodon carcharias Great White Shark [64470]	Vulnerable	Species or species habitat known to occur within area
Rhincodon typus Whale Shark [66680]	Vulnerable	Species or species habitat may occur within

Name	Status	Type of Presence
		area

Listed Migratory Species [Resource Information]

* Species is listed under a different scientific name on the EPBC Act - Threatened Species list.

Name	Threatened	Type of Presence
Migratory Marine Birds		
Apus pacificus Fork-tailed Swift [678]		Species or species habitat likely to occur within area
Calonectris leucomelas Streaked Shearwater [1077]		Species or species habitat may occur within area
Diomedea antipodensis Antipodean Albatross [64458]	Vulnerable*	Foraging, feeding or related behaviour likely to occur within area
Diomedea dabbenena Tristan Albatross [66471]	Endangered*	Species or species habitat may occur within area
Diomedea epomophora (sensu stricto) Southern Royal Albatross [1072]	Vulnerable*	Foraging, feeding or related behaviour likely to occur within area
Diomedea exulans (sensu lato) Wandering Albatross [1073]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Diomedea gibsoni Gibson's Albatross [64466]	Vulnerable*	Foraging, feeding or related behaviour likely to occur within area
Diomedea sanfordi Northern Royal Albatross [64456]	Endangered*	Foraging, feeding or related behaviour likely to occur within area
Macronectes giganteus Southern Giant Petrel [1060]	Endangered	Species or species habitat may occur within area
Macronectes halli Northern Giant Petrel [1061]	Vulnerable	Species or species habitat may occur within area
Phoebetria fusca Sooty Albatross [1075]	Vulnerable	Species or species habitat may occur within area
Puffinus carneipes Flesh-footed Shearwater, Fleshy-footed Shearwater [1043]		Foraging, feeding or related behaviour likely to occur within area
Sterna albifrons Little Tern [813]		Breeding may occur within area
Thalassarche bulleri Buller's Albatross, Pacific Albatross [64460]	Vulnerable	Species or species habitat may occur within area
Thalassarche cauta (sensu stricto) Shy Albatross, Tasmanian Shy Albatross [64697]	Vulnerable*	Foraging, feeding or related behaviour likely to occur within area
Thalassarche eremita Chatham Albatross [64457]	Endangered	Foraging, feeding or related behaviour likely to occur within area
Thalassarche impavida Campbell Albatross [64459]	Vulnerable*	Species or species habitat may occur within area

Name	Threatened	Type of Presence
Thalassarche melanophris Black-browed Albatross [66472]	Vulnerable	Species or species habitat may occur within area
Thalassarche salvini Salvin's Albatross [64463]	Vulnerable*	Foraging, feeding or related behaviour likely to occur within area
Thalassarche steadi White-capped Albatross [64462]	Vulnerable*	Foraging, feeding or related behaviour likely to occur within area
Migratory Marine Species		
Balaenoptera edeni Bryde's Whale [35]		Species or species habitat may occur within area
Balaenoptera musculus Blue Whale [36]	Endangered	Species or species habitat may occur within area
Caperea marginata Pygmy Right Whale [39]		Species or species habitat may occur within area
Carcharodon carcharias Great White Shark [64470]	Vulnerable	Species or species habitat known to occur within area
Caretta caretta Loggerhead Turtle [1763]	Endangered	Species or species habitat known to occur within area
Chelonia mydas Green Turtle [1765]	Vulnerable	Foraging, feeding or related behaviour known to occur within area
Dermochelys coriacea Leatherback Turtle, Leathery Turtle, Luth [1768]	Endangered	Species or species habitat known to occur within area
Dugong dugon Dugong [28]		Species or species habitat may occur within area
Eretmochelys imbricata Hawksbill Turtle [1766]	Vulnerable	Foraging, feeding or related behaviour known to occur within area
Eubalaena australis Southern Right Whale [40]	Endangered	Species or species habitat likely to occur within area
Lagenorhynchus obscurus Dusky Dolphin [43]		Species or species habitat may occur within area
Lamna nasus Porbeagle, Mackerel Shark [83288]		Species or species habitat may occur within area
Manta birostris Giant Manta Ray, Chevron Manta Ray, Pacific Manta Ray, Pelagic Manta Ray, Oceanic Manta Ray [84995]		Species or species habitat may occur within area
Megaptera novaeangliae Humpback Whale [38]	Vulnerable	Species or species habitat known to occur within area
Natator depressus Flatback Turtle [59257]	Vulnerable	Foraging, feeding or related behaviour known to occur within area

Name	Threatened	Type of Presence
Orcinus orca Killer Whale, Orca [46]		Species or species habitat may occur within area
Rhincodon typus Whale Shark [66680]	Vulnerable	Species or species habitat may occur within area
Sousa chinensis Indo-Pacific Humpback Dolphin [50]		Species or species habitat likely to occur within area
Migratory Terrestrial Species		
Hirundapus caudacutus White-throated Needletail [682]		Species or species habitat known to occur within area
Merops ornatus Rainbow Bee-eater [670]		Species or species habitat may occur within area
Monarcha melanopsis Black-faced Monarch [609]		Species or species habitat known to occur within area
Monarcha trivirgatus Spectacled Monarch [610]		Species or species habitat likely to occur within area
Myiagra cyanoleuca Satin Flycatcher [612]		Species or species habitat known to occur within area
Rhipidura rufifrons Rufous Fantail [592]		Species or species habitat known to occur within area
Migratory Wetlands Species		
Actitis hypoleucos Common Sandpiper [59309]		Roosting known to occur within area
Ardea alba Great Egret, White Egret [59541]		Breeding known to occur within area
Ardea ibis Cattle Egret [59542]		Breeding likely to occur within area
Arenaria interpres Ruddy Turnstone [872]		Roosting known to occur within area
Calidris acuminata Sharp-tailed Sandpiper [874]		Roosting known to occur within area
Calidris canutus Red Knot, Knot [855]		Roosting known to occur within area
Calidris ferruginea Curlew Sandpiper [856]	Critically Endangered	Roosting known to occur within area
Calidris melanotos Pectoral Sandpiper [858]		Roosting known to occur within area
Calidris ruficollis Red-necked Stint [860]		Roosting known to occur within area
Calidris tenuirostris Great Knot [862]		Roosting known to occur within area
Charadrius bicinctus Double-banded Plover [895]		Roosting known to occur within area

Name	Threatened	Type of Presence
Charadrius leschenaultii Greater Sand Plover, Large Sand Plover [877]		Roosting known to occur within area
Charadrius mongolus Lesser Sand Plover, Mongolian Plover [879]		Roosting known to occur within area
Gallinago hardwickii Latham's Snipe, Japanese Snipe [863]		Roosting known to occur within area
Gallinago megala Swinhoe's Snipe [864]		Roosting likely to occur within area
Gallinago stenura Pin-tailed Snipe [841]		Roosting likely to occur within area
Heteroscelus brevipes Grey-tailed Tattler [59311]		Roosting known to occur within area
Limicola falcinellus Broad-billed Sandpiper [842]		Roosting known to occur within area
Limosa lapponica Bar-tailed Godwit [844]		Species or species habitat known to occur within area
Limosa limosa Black-tailed Godwit [845]		Roosting known to occur within area
Numenius madagascariensis Eastern Curlew [847]	Critically Endangered	Roosting known to occur within area
Numenius minutus Little Curlew, Little Whimbrel [848]		Roosting likely to occur within area
Numenius phaeopus Whimbrel [849]		Roosting known to occur within area
Pandion haliaetus Osprey [952]		Species or species habitat known to occur within area
Philomachus pugnax Ruff (Reeve) [850]		Roosting known to occur within area
Pluvialis fulva Pacific Golden Plover [25545]		Roosting known to occur within area
Pluvialis squatarola Grey Plover [865]		Roosting known to occur within area
Tringa stagnatilis Marsh Sandpiper, Little Greenshank [833]		Roosting known to occur within area
Xenus cinereus Terek Sandpiper [59300]		Roosting known to occur within area

Other Matters Protected by the EPBC Act

Commonwealth Land [Resource Information]

The Commonwealth area listed below may indicate the presence of Commonwealth land in this vicinity. Due to the unreliability of the data source, all proposals should be checked as to whether it impacts on a Commonwealth area, before making a definitive decision. Contact the State or Territory government land department for further information.

Name
Commonwealth Land -
Commonwealth Land - Australian & Overseas Telecommunications Corporation
Commonwealth Land - Australian Broadcasting Corporation
Commonwealth Land - Australian Postal Commission
Commonwealth Land - Australian Postal Corporation
Commonwealth Land - Australian Telecommunications Commission
Commonwealth Land - Commonwealth Bank of Australia
Commonwealth Land - Commonwealth Trading Bank of Australia
Commonwealth Land - Defence Housing Authority
Commonwealth Land - Defence Service Homes Corporation
Commonwealth Land - Director of War Service Homes
Commonwealth Land - Telstra Corporation Limited
Defence - ADF CAREERS REFERENCE CENTRE
Defence - OFFICES
Defence - STOCKTON RIFLE RANGE
Defence - TS TOBRUK

Commonwealth Heritage Places [Resource Information]

Name	State	Status
Historic		
Fort Wallace	NSW	Listed place
Nobbys Lighthouse	NSW	Listed place

Listed Marine Species [Resource Information]

* Species is listed under a different scientific name on the EPBC Act - Threatened Species list.

Name	Threatened	Type of Presence
Birds		
Actitis hypoleucos		
Common Sandpiper [59309]		Roosting known to occur within area
Apus pacificus		
Fork-tailed Swift [678]		Species or species habitat likely to occur within area
Ardea alba		
Great Egret, White Egret [59541]		Breeding known to occur within area
Ardea ibis		
Cattle Egret [59542]		Breeding likely to occur within area
Arenaria interpres		
Ruddy Turnstone [872]		Roosting known to occur within area
Calidris acuminata		
Sharp-tailed Sandpiper [874]		Roosting known to occur within area
Calidris canutus		
Red Knot, Knot [855]		Roosting known to occur within area
Calidris ferruginea		
Curlew Sandpiper [856]	Critically Endangered	Roosting known to occur within area
Calidris melanotos		
Pectoral Sandpiper [858]		Roosting known to occur within area
Calidris ruficollis		
Red-necked Stint [860]		Roosting known to occur within area
Calidris tenuirostris		
Great Knot [862]		Roosting known to occur within area

Name	Threatened	Type of Presence
Calonectris leucomelas Streaked Shearwater [1077]		Species or species habitat may occur within area
Catharacta skua Great Skua [59472]		Species or species habitat may occur within area
Charadrius bicinctus Double-banded Plover [895]		Roosting known to occur within area
Charadrius leschenaultii Greater Sand Plover, Large Sand Plover [877]		Roosting known to occur within area
Charadrius mongolus Lesser Sand Plover, Mongolian Plover [879]		Roosting known to occur within area
Charadrius ruficapillus Red-capped Plover [881]		Roosting known to occur within area
Diomedea antipodensis Antipodean Albatross [64458]	Vulnerable*	Foraging, feeding or related behaviour likely to occur within area
Diomedea dabbenena Tristan Albatross [66471]	Endangered*	Species or species habitat may occur within area
Diomedea epomophora (sensu stricto) Southern Royal Albatross [1072]	Vulnerable*	Foraging, feeding or related behaviour likely to occur within area
Diomedea exulans (sensu lato) Wandering Albatross [1073]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Diomedea gibsoni Gibson's Albatross [64466]	Vulnerable*	Foraging, feeding or related behaviour likely to occur within area
Diomedea sanfordi Northern Royal Albatross [64456]	Endangered*	Foraging, feeding or related behaviour likely to occur within area
Gallinago hardwickii Latham's Snipe, Japanese Snipe [863]		Roosting known to occur within area
Gallinago megala Swinhoe's Snipe [864]		Roosting likely to occur within area
Gallinago stenura Pin-tailed Snipe [841]		Roosting likely to occur within area
Haliaeetus leucogaster White-bellied Sea-Eagle [943]		Species or species habitat known to occur within area
Heteroscelus brevipes Grey-tailed Tattler [59311]		Roosting known to occur within area
Himantopus himantopus Black-winged Stilt [870]		Roosting known to occur within area
Hirundapus caudacutus White-throated Needletail [682]		Species or species habitat known to occur within area
Lathamus discolor Swift Parrot [744]	Endangered	Species or species habitat likely to occur within area

Name	Threatened	Type of Presence
Limicola falcinellus Broad-billed Sandpiper [842]		Roosting known to occur within area
Limosa lapponica Bar-tailed Godwit [844]		Species or species habitat known to occur within area
Limosa limosa Black-tailed Godwit [845]		Roosting known to occur within area
Macronectes giganteus Southern Giant Petrel [1060]	Endangered	Species or species habitat may occur within area
Macronectes halli Northern Giant Petrel [1061]	Vulnerable	Species or species habitat may occur within area
Merops ornatus Rainbow Bee-eater [670]		Species or species habitat may occur within area
Monarcha melanopsis Black-faced Monarch [609]		Species or species habitat known to occur within area
Monarcha trivirgatus Spectacled Monarch [610]		Species or species habitat likely to occur within area
Myiagra cyanoleuca Satin Flycatcher [612]		Species or species habitat known to occur within area
Numenius madagascariensis Eastern Curlew [847]	Critically Endangered	Roosting known to occur within area
Numenius minutus Little Curlew, Little Whimbrel [848]		Roosting likely to occur within area
Numenius phaeopus Whimbrel [849]		Roosting known to occur within area
Pandion haliaetus Osprey [952]		Species or species habitat known to occur within area
Philomachus pugnax Ruff (Reeve) [850]		Roosting known to occur within area
Phoebetria fusca Sooty Albatross [1075]	Vulnerable	Species or species habitat may occur within area
Pluvialis fulva Pacific Golden Plover [25545]		Roosting known to occur within area
Pluvialis squatarola Grey Plover [865]		Roosting known to occur within area
Puffinus carneipes Flesh-footed Shearwater, Fleshy-footed Shearwater [1043]		Foraging, feeding or related behaviour likely to occur within area
Recurvirostra novaehollandiae Red-necked Avocet [871]		Roosting known to occur within area
Rhipidura rufifrons Rufous Fantail [592]		Species or species habitat known to occur within area

Name	Threatened	Type of Presence
Rostratula benghalensis (sensu lato) Painted Snipe [889]	Endangered*	Species or species habitat likely to occur within area
Sterna albifrons Little Tern [813]		Breeding may occur within area
Thalassarche bulleri Buller's Albatross, Pacific Albatross [64460]	Vulnerable	Species or species habitat may occur within area
Thalassarche cauta (sensu stricto) Shy Albatross, Tasmanian Shy Albatross [64697]	Vulnerable*	Foraging, feeding or related behaviour likely to occur within area
Thalassarche eremita Chatham Albatross [64457]	Endangered	Foraging, feeding or related behaviour likely to occur within area
Thalassarche impavida Campbell Albatross [64459]	Vulnerable*	Species or species habitat may occur within area
Thalassarche melanophris Black-browed Albatross [66472]	Vulnerable	Species or species habitat may occur within area
Thalassarche salvini Salvin's Albatross [64463]	Vulnerable*	Foraging, feeding or related behaviour likely to occur within area
Thalassarche steadi White-capped Albatross [64462]	Vulnerable*	Foraging, feeding or related behaviour likely to occur within area
Tringa stagnatilis Marsh Sandpiper, Little Greenshank [833]		Roosting known to occur within area
Xenus cinereus Terek Sandpiper [59300]		Roosting known to occur within area
Fish		
Acentronura tentaculata Shortpouch Pygmy Pipehorse [66187]		Species or species habitat may occur within area
Festucalex cinctus Girdled Pipefish [66214]		Species or species habitat may occur within area
Filicampus tigris Tiger Pipefish [66217]		Species or species habitat may occur within area
Heraldia nocturna Upside-down Pipefish, Eastern Upside-down Pipefish, Eastern Upside-down Pipefish [66227]		Species or species habitat may occur within area
Hippichthys penicillus Beady Pipefish, Steep-nosed Pipefish [66231]		Species or species habitat may occur within area
Hippocampus abdominalis Big-belly Seahorse, Eastern Potbelly Seahorse, New Zealand Potbelly Seahorse [66233]		Species or species habitat may occur within area
Hippocampus whitei White's Seahorse, Crowned Seahorse, Sydney Seahorse [66240]		Species or species habitat may occur within area
Histiogamphelus briggsii Crested Pipefish, Briggs' Crested Pipefish, Briggs' Pipefish [66242]		Species or species habitat may occur within

Name	Threatened	Type of Presence
		area
Lissocampus runa Javelin Pipefish [66251]		Species or species habitat may occur within area
Maroubra perserrata Sawtooth Pipefish [66252]		Species or species habitat may occur within area
Notiocampus ruber Red Pipefish [66265]		Species or species habitat may occur within area
Phyllopteryx taeniolatus Common Seadragon, Weedy Seadragon [66268]		Species or species habitat may occur within area
Solegnathus spinosissimus Spiny Pipehorse, Australian Spiny Pipehorse [66275]		Species or species habitat may occur within area
Solenostomus cyanopterus Robust Ghostpipefish, Blue-finned Ghost Pipefish, [66183]		Species or species habitat may occur within area
Solenostomus paegnius Rough-snout Ghost Pipefish [68425]		Species or species habitat may occur within area
Solenostomus paradoxus Ornate Ghostpipefish, Harlequin Ghost Pipefish, Ornate Ghost Pipefish [66184]		Species or species habitat may occur within area
Stigmatopora argus Spotted Pipefish, Gulf Pipefish [66276]		Species or species habitat may occur within area
Stigmatopora nigra Widebody Pipefish, Wide-bodied Pipefish, Black Pipefish [66277]		Species or species habitat may occur within area
Stigmatopora olivacea a pipefish [74966]		Species or species habitat may occur within area
Syngnathoides biaculeatus Double-end Pipehorse, Double-ended Pipehorse, Alligator Pipefish [66279]		Species or species habitat may occur within area
Trachyrhamphus bicoarctatus Bentstick Pipefish, Bend Stick Pipefish, Short-tailed Pipefish [66280]		Species or species habitat may occur within area
Urocampus carinirostris Hairy Pipefish [66282]		Species or species habitat may occur within area
Vanacampus margaritifer Mother-of-pearl Pipefish [66283]		Species or species habitat may occur within area
Mammals		
Arctocephalus forsteri Long-nosed Fur-seal, New Zealand Fur-seal [20]		Species or species habitat may occur within area
Arctocephalus pusillus Australian Fur-seal, Australo-African Fur-seal [21]		Species or species habitat may occur within area
Dugong dugon Dugong [28]		Species or species habitat may occur within

Name	Threatened	Type of Presence
		area
Reptiles		
Caretta caretta		
Loggerhead Turtle [1763]	Endangered	Species or species habitat known to occur within area
Chelonia mydas		
Green Turtle [1765]	Vulnerable	Foraging, feeding or related behaviour known to occur within area
Dermochelys coriacea		
Leatherback Turtle, Leathery Turtle, Luth [1768]	Endangered	Species or species habitat known to occur within area
Eretmochelys imbricata		
Hawksbill Turtle [1766]	Vulnerable	Foraging, feeding or related behaviour known to occur within area
Natator depressus		
Flatback Turtle [59257]	Vulnerable	Foraging, feeding or related behaviour known to occur within area
Pelamis platurus		
Yellow-bellied Seasnake [1091]		Species or species habitat may occur within area

Whales and other Cetaceans [Resource Information]

Name	Status	Type of Presence
Mammals		
Balaenoptera acutorostrata		
Minke Whale [33]		Species or species habitat may occur within area
Balaenoptera edeni		
Bryde's Whale [35]		Species or species habitat may occur within area
Balaenoptera musculus		
Blue Whale [36]	Endangered	Species or species habitat may occur within area
Caperea marginata		
Pygmy Right Whale [39]		Species or species habitat may occur within area
Delphinus delphis		
Common Dophin, Short-beaked Common Dolphin [60]		Species or species habitat may occur within area
Eubalaena australis		
Southern Right Whale [40]	Endangered	Species or species habitat likely to occur within area
Grampus griseus		
Risso's Dolphin, Grampus [64]		Species or species habitat may occur within area
Lagenorhynchus obscurus		
Dusky Dolphin [43]		Species or species habitat may occur within area
Megaptera novaeangliae		
Humpback Whale [38]	Vulnerable	Species or species habitat known to occur within area
Orcinus orca		
Killer Whale, Orca [46]		Species or species habitat may occur within area
Sousa chinensis		
Indo-Pacific Humpback Dolphin [50]		Species or species habitat likely to occur

Name	Status	Type of Presence
		within area
Stenella attenuata Spotted Dolphin, Pantropical Spotted Dolphin [51]		Species or species habitat may occur within area
Tursiops aduncus Indian Ocean Bottlenose Dolphin, Spotted Bottlenose Dolphin [68418]		Species or species habitat likely to occur within area
Tursiops truncatus s. str. Bottlenose Dolphin [68417]		Species or species habitat may occur within area

Extra Information

State and Territory Reserves [Resource Information]

Name	State
Glenrock	NSW
Hexham Swamp	NSW
Hunter Wetlands	NSW
Tilligerry	NSW
Worimi	NSW
Worimi	NSW

Regional Forest Agreements [Resource Information]

Note that all areas with completed RFAs have been included.

Name	State
North East NSW RFA	New South Wales

Invasive Species [Resource Information]

Weeds reported here are the 20 species of national significance (WoNS), along with other introduced plants that are considered by the States and Territories to pose a particularly significant threat to biodiversity. The following feral animals are reported: Goat, Red Fox, Cat, Rabbit, Pig, Water Buffalo and Cane Toad. Maps from Landscape Health Project, National Land and Water Resouces Audit, 2001.

Name	Status	Type of Presence
Birds		
Acridotheres tristis Common Myna, Indian Myna [387]		Species or species habitat likely to occur within area
Alauda arvensis Skylark [656]		Species or species habitat likely to occur within area
Anas platyrhynchos Mallard [974]		Species or species habitat likely to occur within area
Carduelis carduelis European Goldfinch [403]		Species or species habitat likely to occur within area
Columba livia Rock Pigeon, Rock Dove, Domestic Pigeon [803]		Species or species habitat likely to occur within area
Lonchura punctulata Nutmeg Mannikin [399]		Species or species habitat likely to occur within area
Passer domesticus House Sparrow [405]		Species or species

Name	Status	Type of Presence
		habitat likely to occur within area
Passer montanus Eurasian Tree Sparrow [406]		Species or species habitat likely to occur within area
Pycnonotus jocosus Red-whiskered Bulbul [631]		Species or species habitat likely to occur within area
Streptopelia chinensis Spotted Turtle-Dove [780]		Species or species habitat likely to occur within area
Sturnus vulgaris Common Starling [389]		Species or species habitat likely to occur within area
Turdus merula Common Blackbird, Eurasian Blackbird [596]		Species or species habitat likely to occur within area
Frogs		
Rhinella marina Cane Toad [83218]		Species or species habitat likely to occur within area
Mammals		
Bos taurus Domestic Cattle [16]		Species or species habitat likely to occur within area
Canis lupus familiaris Domestic Dog [82654]		Species or species habitat likely to occur within area
Felis catus Cat, House Cat, Domestic Cat [19]		Species or species habitat likely to occur within area
Feral deer Feral deer species in Australia [85733]		Species or species habitat likely to occur within area
Lepus capensis Brown Hare [127]		Species or species habitat likely to occur within area
Mus musculus House Mouse [120]		Species or species habitat likely to occur within area
Oryctolagus cuniculus Rabbit, European Rabbit [128]		Species or species habitat likely to occur within area
Rattus norvegicus Brown Rat, Norway Rat [83]		Species or species habitat likely to occur within area
Rattus rattus Black Rat, Ship Rat [84]		Species or species habitat likely to occur within area
Vulpes vulpes Red Fox, Fox [18]		Species or species habitat likely to occur within area
Plants		
Alternanthera philoxeroides Alligator Weed [11620]		Species or species habitat likely to occur within area

Name	Status	Type of Presence
Anredera cordifolia Madeira Vine, Jalap, Lamb's-tail, Mignonette Vine, Anredera, Gulf Madeiravine, Heartleaf Madeiravine, Potato Vine [2643]		Species or species habitat likely to occur within area
Asparagus aethiopicus Asparagus Fern, Ground Asparagus, Basket Fern, Sprengi's Fern, Bushy Asparagus, Emerald Asparagus [62425]		Species or species habitat likely to occur within area
Asparagus asparagoides Bridal Creeper, Bridal Veil Creeper, Smilax, Florist's Smilax, Smilax Asparagus [22473]		Species or species habitat likely to occur within area
Asparagus plumosus Climbing Asparagus-fern [48993]		Species or species habitat likely to occur within area
Cabomba caroliniana Cabomba, Fanwort, Carolina Watershield, Fish Grass, Washington Grass, Watershield, Carolina Fanwort, Common Cabomba [5171]		Species or species habitat likely to occur within area
Chrysanthemoides monilifera Bitou Bush, Boneseed [18983]		Species or species habitat may occur within area
Chrysanthemoides monilifera subsp. rotundata Bitou Bush [16332]		Species or species habitat likely to occur within area
Cytisus scoparius Broom, English Broom, Scotch Broom, Common Broom, Scottish Broom, Spanish Broom [5934]		Species or species habitat likely to occur within area
Dolichandra unguis-cati Cat's Claw Vine, Yellow Trumpet Vine, Cat's Claw Creeper, Funnel Creeper [85119]		Species or species habitat likely to occur within area
Eichhornia crassipes Water Hyacinth, Water Orchid, Nile Lily [13466]		Species or species habitat likely to occur within area
Genista monspessulana Montpellier Broom, Cape Broom, Canary Broom, Common Broom, French Broom, Soft Broom [20126]		Species or species habitat likely to occur within area
Genista sp. X Genista monspessulana Broom [67538]		Species or species habitat may occur within area
Lantana camara Lantana, Common Lantana, Kamara Lantana, Large-leaf Lantana, Pink Flowered Lantana, Red Flowered Lantana, Red-Flowered Sage, White Sage, Wild Sage [10892]		Species or species habitat likely to occur within area
Opuntia spp. Prickly Pears [82753]		Species or species habitat likely to occur within area
Pinus radiata Radiata Pine Monterey Pine, Insignis Pine, Wilding Pine [20780]		Species or species habitat may occur within area
Protasparagus densiflorus Asparagus Fern, Plume Asparagus [5015]		Species or species habitat likely to occur within area
Protasparagus plumosus Climbing Asparagus-fern, Ferny Asparagus [11747]		Species or species habitat likely to occur within area
Rubus fruticosus aggregate Blackberry, European Blackberry [68406]		Species or species habitat likely to occur within area

Name	Status	Type of Presence
Sagittaria platyphylla Delta Arrowhead, Arrowhead, Slender Arrowhead [68483]		Species or species habitat likely to occur within area
Salix spp. except S.babylonica, S.x calodendron & S.x reichardtii Willows except Weeping Willow, Pussy Willow and Sterile Pussy Willow [68497]		Species or species habitat likely to occur within area
Salvinia molesta Salvinia, Giant Salvinia, Aquarium Watermoss, Kariba Weed [13665]		Species or species habitat likely to occur within area
Senecio madagascariensis Fireweed, Madagascar Ragwort, Madagascar Groundsel [2624]		Species or species habitat likely to occur within area
Solanum elaeagnifolium Silver Nightshade, Silver-leaved Nightshade, White Horse Nettle, Silver-leaf Nightshade, Tomato Weed, White Nightshade, Bull-nettle, Prairie-berry, Satansbos, Silver-leaf Bitter-apple, Silverleaf-nettle, Trompillo [12323]		Species or species habitat likely to occur within area

Nationally Important Wetlands [Resource Information]

Name	State
Hexham Swamp	NSW
Kooragang Nature Reserve	NSW
Shortland Wetlands Centre	NSW

Caveat

The information presented in this report has been provided by a range of data sources as acknowledged at the end of the report.

This report is designed to assist in identifying the locations of places which may be relevant in determining obligations under the Environment Protection and Biodiversity Conservation Act 1999. It holds mapped locations of World and National Heritage properties, Wetlands of International and National Importance, Commonwealth and State/Territory reserves, listed threatened, migratory and marine species and listed threatened ecological communities. Mapping of Commonwealth land is not complete at this stage. Maps have been collated from a range of sources at various resolutions.

Not all species listed under the EPBC Act have been mapped (see below) and therefore a report is a general guide only. Where available data supports mapping, the type of presence that can be determined from the data is indicated in general terms. People using this information in making a referral may need to consider the qualifications below and may need to seek and consider other information sources.

For threatened ecological communities where the distribution is well known, maps are derived from recovery plans, State vegetation maps, remote sensing imagery and other sources. Where threatened ecological community distributions are less well known, existing vegetation maps and point location data are used to produce indicative distribution maps.

For species where the distributions are well known, maps are digitised from sources such as recovery plans and detailed habitat studies. Where appropriate, core breeding, foraging and roosting areas are indicated under 'type of presence'. For species whose distributions are less well known, point locations are collated from government wildlife authorities, museums, and non-government organisations; bioclimatic distribution models are generated and these validated by experts. In some cases, the distribution maps are based solely on expert knowledge.

Only selected species covered by the following provisions of the EPBC Act have been mapped:

- migratory and
- marine

The following species and ecological communities have not been mapped and do not appear in reports produced from this database:

- threatened species listed as extinct or considered as vagrants
- some species and ecological communities that have only recently been listed
- some terrestrial species that overfly the Commonwealth marine area
- migratory species that are very widespread, vagrant, or only occur in small numbers

The following groups have been mapped, but may not cover the complete distribution of the species:

- non-threatened seabirds which have only been mapped for recorded breeding sites
- seals which have only been mapped for breeding sites near the Australian continent

Such breeding sites may be important for the protection of the Commonwealth Marine environment.

Coordinates

-32.86886 151.73206

Acknowledgements

This database has been compiled from a range of data sources. The department acknowledges the following custodians who have contributed valuable data and advice:

-Office of Environment and Heritage, New South Wales
-Department of Environment and Primary Industries, Victoria
-Department of Primary Industries, Parks, Water and Environment, Tasmania
-Department of Environment, Water and Natural Resources, South Australia
-Parks and Wildlife Commission NT, Northern Territory Government
-Department of Environmental and Heritage Protection, Queensland
-Department of Parks and Wildlife, Western Australia
-Environment and Planning Directorate, ACT
-Birdlife Australia
-Australian Bird and Bat Banding Scheme
-Australian National Wildlife Collection
-Natural history museums of Australia
-Museum Victoria
-Australian Museum
-South Australian Museum
-Queensland Museum
-Online Zoological Collections of Australian Museums
-Queensland Herbarium
-National Herbarium of NSW
-Royal Botanic Gardens and National Herbarium of Victoria
-Tasmanian Herbarium
-State Herbarium of South Australia
-Northern Territory Herbarium
-Western Australian Herbarium
-Australian National Herbarium, Atherton and Canberra
-University of New England
-Ocean Biogeographic Information System
-Australian Government, Department of Defence
Forestry Corporation, NSW
-Geoscience Australia
-CSIRO
-Other groups and individuals

The Department is extremely grateful to the many organisations and individuals who provided expert advice and information on numerous draft distributions.

Please feel free to provide feedback via the Contact Us page.

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Annex C

MNES Assessments Of Significance

C.1 *ANNEX C MNES SIGNIFICANT IMPACT ASSESSMENT*

This Annex presents the assessments of significance undertaken in accordance with the Significant Impact Guidelines 1.1 (DoE, 2015) for threatened species and ecological communities and migratory species that are known, or have potential to occur, within the Closure Works Area.

C.1.1 Ramsar Wetland

Hunter Estuary Wetland – ID No 245

One Ramsar Wetland, Hunter Estuary Wetlands (ID No 24) occurs within close proximity of the Site. At is closest point the Hunter Estuary Wetland (Kooragang Component) occurs approximately 260 meters to the north of the northern Site boundary. The Hunter Estuary Wetlands Ramsar site is comprised of two components, Kooragang and Hunter Wetlands Centre Australia. The Kooragang component of the Hunter Estuary Wetlands Ramsar site (most relevant to this site) is located in the estuary of the Hunter River, approximately 7 km north of Newcastle on the coast of New South Wales. The Kooragang component includes Kooragang Island and Fullerton Cove, two areas that lie in the estuarine section of the Hunter River. Kooragang Island originally consisted of seven islands that were mostly separated by narrow mangrove lined channels. In the 1950s these islands were reclaimed and became "Kooragang Island". Habitat types within the Reserve include mangrove forests dominated by Grey Mangrove, Samphire saltmarsh, Paperbark and Swamp she-oak swamp forests, brackish swamps, mudflats, and sandy beaches.

The Hunter Estuary Wetlands Ramsar site is important as both a feeding and roosting site for a large seasonal population of shorebirds and as a waylay site for transient migrants. Over 250 species of birds have been recorded within the Ramsar site, including 45 species listed under international migratory conservation agreements. In addition, the Ramsar site provides habitat for the nationally threatened Green and Golden Bell Frog, Red Goshawk and Australasian Bittern.

An action is likely to have a significant impact on the ecological character of a declared Ramsar wetland if there is a real chance or possibility that it will result in:

areas of the wetland being destroyed or substantially modified

The proposed capping works are limited to a discrete area, which does not include the Ramsar Site. Therefore no areas of the Ramsar Wetland will be destroyed or substantially modified by the proposal.

substantial and measurable change in the hydrological regime of the wetland, for example, a substantial change to the volume, timing, duration and frequency of ground and surface water flows to and within the wetland

Drainage across the wider KIWEF area surrounding the referral area is complex and consists of a network of culverts, open drains, levees and constructed ponds which fill with surface runoff and generally ultimately drain to the Hunter River South Arm. Most rainfall is expected to infiltrate, with drainage from within the referral area directed mainly to Deep Pond with minimal drainage directed to the east and south and north, in the direction of the Ramsar Wetland. Once the capping works are completed, it will result in less infiltration of rainwater into the former landfilled areas. This will intern result in slightly higher runoff, which will drain into the surrounding small ponds and Deep Pond. The water entering the ponds via overland flow is likely to be less saline and have fewer contaminants than water which has percolated through the landfill areas. There is likely to be groundwater connection between the wetland areas adjacent to the site and the Ramsar site. However the proposal is unlikely to cause any significant changes to the water quality of the Ramsar site due to the large dilution factors and distances involved. If there are any changes the water quality is likely to be improved with less contamination due to less percolation through the landfill area. In conclusion, any changes are not likely to be measurable and extremely negligible.

the habitat or lifecycle of native species, including invertebrate fauna and fish species, dependent upon the wetland being seriously affected

The construction phase of the capping works will include some noise, light and vibration disturbance from machinery which may affect some species such as birds, within immediate proximity of the capping works. Given that the Ramsar site is at least 260 m from any construction disturbance, it is considered that that the effect of the proposal will be negligible and would impact a very small portion of the Ramsar site, if at all. For example, Stockton Sandspit provides a resting and feeding place for large aggregations of migratory wading birds, despite being within 100 m of Stockton Bridge/B63 Road, which has heavy vehicle traffic especially during peak hour periods.

a substantial and measurable change in the water quality of the wetland – for example, a substantial change in the level of salinity, pollutants, or nutrients in the wetland, or water temperature which may adversely impact on biodiversity, ecological integrity, social amenity or human health, or

The capping works would reduce the amount of rainfall infiltration within the landfill area. Consequently this will increase the amount of surface flow which would not come into contact with, and be potentially impacted by the contaminants present within the mixed use landfill. This may result in a positive effect on water quality in the Wetlands adjacent to the capping works. It is anticipated that this will not have detectable effect on the Ramsar wetland owing to the distances involved and the large dilution factors, nevertheless any affects are likely to be positive in terms of water quality.

an invasive species that is harmful to the ecological character of the wetland being established (or an existing invasive species being spread) in the wetland.

The proposed capping works are limited to a discreet area, which does not include the Ramsar Site, thus limiting the direct spread of any invasive species.

The Site and the surrounding areas are dominated by weedy species including four weeds listed as noxious in the Newcastle local control area. One species, Pampas Grass is listed as Class 3 with the remaining four species; Bitou Bush, Crofton Weed and Prickly Pear listed as Class 4. Specific controls exist for Pampas Grass and Crofton Weed and they must be prevented from growing within 10 metres and 5 metres, respectively, of watercourses and property boundaries.

Chytrid fungus (*Batrachochytrium dendrobatidis*) has been recorded within the Kooragang Island Area and is considered widespread within the area. It has the potential to impact the threatened Green and Golden Bell Frog and is considered one of the factors contributing to the species decline.

Control measures will be implemented to reduce the spread of pathogens and weed material offsite, which will include hygiene procedures for personnel, machinery and equipment. Given that the invasive weeds and pathogens (Chytrid fungus) are already present within the wider Kooragang area it is unlikely that the proposed works will have any significant impact on the Ramsar Wetlands ecological character. In addition the mitigation measures will further minimise the potential for impacts to the Ramsar site.

Conclusion

The proposed action is restricted to a discreet area and there will be no direct impacts on the Ramsar site. Any indirect impacts are not likely to be measurable and are considered negligible.

C.1.1 Endangered Species

Eastern Curlew (*Numenius madagascariensis*) – Endangered and Migratory, EPBC Act

This species typically forages where intertidal mudflats are present and has occasionally been recorded in Deep Pond. It is unlikely that the habitat within the Closure Works Area is important for the species given that it is not intertidal and that few records are present. Any impacts are therefore likely to affect a very low number of individuals. The proposal will not remove habitat for this species as wetlands will not be cleared or modified. The main potential impact to this species is due to construction disturbance related to the capping works. This is a temporary impact and considered negligible given that only a very small number of individuals will be affected. The species may also become habituated to the construction disturbance and therefore still able to utilise the sub-optimal foraging habitat present in Deep Pond.

An action is likely to have a significant impact on a critically endangered or endangered species if there is a real chance or possibility that it will:

lead to a long-term decrease in the size of a population,

It is unlikely that the habitat within the Closure Works Area is important for the species given that it is not intertidal and that the species is only occasionally recorded. Any impacts are therefore likely to affect a very low number of individuals and will not have any affect at a population level.

reduce the area of occupancy of the species,

This species is migratory, occupying a very large range and breeding in the northern hemisphere. Temporary construction disturbance may cause the species to avoid small areas of sub-optimal foraging habitat, however there is other, much larger and more optimal areas of foraging habitat present within the vicinity. The area of occupancy for this species will not be significantly altered.

fragment an existing population into two or more populations,

This species is highly mobile migrating over considerable distance. The proposal will have no fragmentation effects for this species.

adversely affect habitat critical to the survival of a species,

The habitat within Deep Pond provides suboptimal foraging resources, given that it is not intertidal and few individuals have been observed occasionally utilising the habitat. The habitat within and directly adjacent to the Site, including Deep Pond, is not considered critical habitat.

disrupt the breeding cycle of a population,

The population of this species breeds in the northern hemisphere and therefore will not be affected by the proposal.

modify, destroy, remove, isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline,

The Wetland Areas will not be cleared or directly modified as a result of the capping works. Indirect hydrological changes are likely to negligible to the species and possibly positive due to the reduction of contaminated groundwater flowing into the wetland areas.

result in invasive species that are harmful to a critically endangered or endangered species becoming established in the endangered or critically endangered species' habitat,

Weed and pest management measures will be undertaken to avoid the introduction of invasive species. In consideration of the implementation of these measures, it is unlikely that the Project would result in the establishment of invasive species in potential habitat for the Eastern Curlew.

	introduce disease that may cause the species to decline, or
	The Project is not expected to introduce any diseases that may cause the species to decline. All Vehicles will be required to be clean on arrival and pass through a wheel wash on entry and exiting the site and this will limit the potential spread of disease.
	interfere with the recovery of the species.
	The main potential impact to this species is due to construction disturbance related to the capping works. This is a temporary impact and considered negligible given that only a very small number of individuals will be affected. The species recovery is not likely to be significantly affected by the proposal.
	Conclusion
	There will be no significant impact to this species, given that the habitat for this species will not be cleared or modified. Any indirect impacts as a result of the proposal are expected to be negligible.

Australasian Bittern (*Botaurus poiciloptilus*) Endangered, EPBC Act and TSC Act)	
This species inhabits terrestrial and estuarine wetlands, preferring dense vegetation including sedges, rushes and reeds. It is a cryptic species, occurring at low densities within the Hunter Estuary. Habitat within and adjacent to the Closure Works Site is limited to dense areas of wetland vegetation with Common Reed and Cumbungi. The species has been recorded on four occasions during 2010 by Umwelt. Locations where Bitterns were recorded include Easement Pond, Railway Pond and K6 Cell 11.	
An action is likely to have a significant impact on a critically endangered or endangered species if there is a real chance or possibility that it will:	
	lead to a long-term decrease in the size of a population,
	The proposal is not likely to cause any mortality of the species and given the temporary nature of the construction works and their associated disturbance, no long term impacts are anticipated for the population.
	reduce the area of occupancy of the species,
	This proposal will not remove habitat for this species as wetlands will not be cleared or modified. The main potential impact to this species is due to visual and noise disturbance related to the capping works. The wetlands adjacent to the works area are small in size and are likely to represent a small proportion of the territory required for individual birds, therefore it is anticipated that any temporary displacement that occurs will not significantly affect the species. The species will be able to forage or breed in alternative habitat within the locality. The species may also become habituated to the construction disturbance and persist in wetland habitats close to the construction works.
	fragment an existing population into two or more populations,
	The proposal will not remove any habitat suitable for this species and there will be no changes to the connectivity of existing habitats for the species.
	adversely affect habitat critical to the survival of a species,
	The Wetland Areas will not be cleared or directly modified as a result of the capping works. Indirect hydrological changes are likely to be negligible to the species and possibly positive due to the reduction of contaminated groundwater flowing into the wetland areas.
	disrupt the breeding cycle of a population,
	K6 Cell 11. Two individuals were recorded within K6 Cell, which may indicate a single breeding pair occurring, adjacent to the site. Breeding pairs are territorial and occupy a large area, therefore it is unlikely that more than one pair occurs within close proximity

to the site. In the worst case scenario the proposed works may cause the pair to avoid areas of potential foraging or breeding habitat, immediately adjacent to the proposed capping area. The wetlands adjacent to the works area are small in size and are likely to represent a small proportion of the territory required for individual birds, therefore it is anticipated that any temporary displacement that occurs will not significantly affect breeding. The species will be able to forage or breed in alternative habitat within the locality. The species may also become habituated to the construction disturbance and persist in wetland habitats close to the construction works.

modify, destroy, remove, isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline,

The Wetland Areas will not be cleared or directly modified as a result of the capping works. Indirect hydrological changes are likely to be negligible to the species and possibly positive due to the reduction of contaminated groundwater flowing into the wetland areas. It is not anticipated that the proposal will cause any decline for the species given that no mortality is anticipated and that habitat important for the species will be retained in its entirety.

result in invasive species that are harmful to a critically endangered or endangered species becoming established in the endangered or critically endangered species' habitat,

Weed and pest management measures will be undertaken to avoid the introduction of invasive species. In consideration of the implementation of these measures, it is unlikely that the Project would result in the establishment of invasive species in potential habitat for the Australasian Bittern.

introduce disease that may cause the species to decline, or

The Project is not expected to introduce any diseases that may cause the species to decline. All Vehicles will be required to be clean on arrival and pass through a wheel wash on entry and exiting the site and this will limit the potential spread of disease.

interfere with the recovery of the species.

The main potential impact to this species is due to construction disturbance related to the capping works. This is a temporary impact and considered negligible given that only a very small number of individuals will be affected and may become habituated The species recovery is not likely to be significantly affected by the proposal.

Conclusion

There will be no significant impact to this species, given that the habitat for this species will not be cleared or modified. Any indirect impacts as a result of the proposal are likely to be negligible.

Curlew Sandpiper (*Calidris ferruginea*) Endangered and Migratory, EPBC Act; Critically Endangered, TSC Act.

This species typically forages where intertidal mudflats are present and has occasionally been recorded in Deep Pond. It is unlikely that the habitat within the Closure Works Area is important for the species given that it is not intertidal and that few records are present. Any impacts are therefore likely to affect a very low number of individuals. The proposal will not remove habitat for this species, as wetlands will not be cleared or modified as part of the proposed activity. The main potential impact to this species is due to construction disturbance related to the capping works. This is a temporary impact and considered negligible given that only a very small number of individuals will be affected. The species may also become habituated to the construction disturbance and therefore still able to utilise the sub-optimal foraging habitat present in Deep Pond.

An action is likely to have a significant impact on a critically endangered or endangered species if there is a real chance or possibility that it will:

	lead to a long-term decrease in the size of a population,
	The construction works will involve heavy machinery and increased numbers of people within the capping area. This will temporarily increase the amount of noise and visual disturbance in area to the east of Deep Pond. As this disturbance is temporary, no long term impacts are anticipated for the population. There are also large areas of alternative habitat within the vicinity.
	reduce the area of occupancy of the species,
	This species is migratory, occupying a very large range and breeding in the northern hemisphere. Temporary construction disturbance may cause the species to avoid areas of foraging habitat, however there are other and much larger areas of intertidal foraging habitat present within the vicinity. The area of occupancy for this species will not be significantly altered.
	fragment an existing population into two or more populations,
	This species is highly mobile migrating over considerable distance. The proposal will have no fragmentation effects for this species.
	adversely affect habitat critical to the survival of a species,
	The habitat within Deep Pond provides foraging resources for the species however it is not considered critical to the survival of the species given it is used on an intermittent basis and that large areas of more optimal intertidal foraging habitat are present within the Lower Hunter Estuary.
	disrupt the breeding cycle of a population,
	The population of this species breeds in the northern hemisphere and therefore will not be affected by the proposal.
	modify, destroy, remove, isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline,
	The Wetland Areas will not be cleared or directly modified as a result of the capping works. Indirect hydrological changes are likely to negligible to the species and possibly positive due to the reduction of contaminated ground water flowing into the wetland areas.
	result in invasive species that are harmful to a critically endangered or endangered species becoming established in the endangered or critically endangered species' habitat,
	Weed and pest management measures will be undertaken to avoid the introduction of invasive species. In consideration of the implementation of these measures, it is unlikely that the Project would result in the establishment of invasive species in potential wetland habitat.
	introduce disease that may cause the species to decline, or
	The Project is not expected to introduce any diseases that may cause the species to decline. All Vehicles will be required to be clean on arrival and pass through a wheel wash on entry and exiting the site and this will limit the potential spread of disease.
	interfere with the recovery of the species.
	The main potential impact to this species is due to construction disturbance related to the capping works. This is a temporary impact and considered negligible given that large areas of more optimal foraging habitat are present within the vicinity. The species recovery is not likely to be significantly affected by the proposal.
	Conclusion
	There will be no significant impact to this species, given that the habitat for this species will not be cleared or modified. Any indirect impacts as a result of the proposal are likely to be negligible.

C.1.3 Vulnerable Species

Green and Golden Bell Frog (*Litoria aurea*) Vulnerable, EPBC Act; Endangered, TSC Act

The Green and Golden Bell Frog, has been recorded both historically and recently within the Site with breeding recorded in several ponds within the locality. Collaborative targeted surveys by GHD and RPS HSO recorded the species on multiple occasions including both adults and tadpoles. All of these records were outside of the proposed capping area, however several records were found in close proximity to the capping area. The highest density of records was from K6 Cell 11 with breeding also recorded in this area. Other areas in which the species was recorded includes K6 Cell 10 and 12, Deep Pond, Easement Pond, Cell 34 (Delta Channel) and K7 Ponds as shown in *Annex A, Figure 4*. Ongoing surveys by the University of Newcastle has confirmed the importance of these areas to GGBF and also recorded adults and juveniles and calling along the southern and eastern shoreline of Deep Pond. Based on these results *Annex A, Figure 5* identifies areas considered likely to accommodate breeding (or attempted breeding) events.

An action is likely to have a significant impact on a vulnerable species if there is a real chance or possibility that it will:

lead to a long-term decrease in the size of an important population of the species,

The Green and Golden Bell Frog Population within Kooragang Island can be considered an important population and part of the Key Population in the Lower Hunter, for which there is a draft Management Plan (OEH, 2007). The proposal may directly impact a small number of individuals during clearance of terrestrial habitats, however this is not considered sufficient to cause a long term decrease in the population. After capping works are completed the area will be revegetated and therefore there will be no permanent loss of foraging habitat. Breeding habitats will remain largely unaffected by the proposal with impacts limited to negligible and imperceptible indirect impacts to hydrology.

reduce the area of occupancy of an important population,

The capping works will temporarily remove an area of foraging habitat (5.2 ha) for adult Green and Golden Bell Frog. After capping works are completed the area will be revegetated, therefore the loss of habitat is considered a temporary impact. The area impacted represents a small proportion of the total potential foraging habitat available to the population, with optimal foraging habitat surrounding the wetland areas, including the K6 and K7 areas, which will not be impacted by the location of the proposed capping works (refer to *Annex A, Figure 5*). It is not anticipated that the temporary clearance of foraging habitat will significantly reduce the occupancy area for the species.

fragment an existing important population into two or more populations,

This capping area does not provide an important linkage to other areas of habitat for the species. The majority of the capping area is open exotic grassland with a paucity of shelter which would leave individuals open to predation and desiccation. Railway lines, associated embankments and roads to the south of the Site currently limit dispersal options within the area. Wetland areas and associated marginal vegetation to the east, north and east of the proposed capping works will not be affected and provide movement corridors for the species. No fragmentation of population is anticipated.

adversely affect habitat critical to the survival of a species,

The habitat within the capping works area is not considered critical habitat for the species. The majority of the area is exotic grassland, which is considered low value, however 5.2 ha of exotic shrubby grassland may provide foraging habitat for adult frogs. This represents a small proportion of the total potential foraging habitat available to the species and therefore is not considered to represent critical habitat. Optimal foraging habitat exists surrounding the wetland areas, including the K6 and K7 areas, which will not be impacted by the capping works. Breeding habitat within the vicinity of the proposed works may be considered critical habitat, however this will not be impacted by the proposal.

disrupt the breeding cycle of an important population,

The key breeding resources for the local population are a series of ponds providing habitat for spawning and tadpole development. The pond margins and associated wetland habitat are likely to provide key habitat for the development of metamorphs. These key areas of habitat will not be impacted by the proposed works as they are outside of the development footprint. Hydrological impacts will also be negligible considering that the capping area drains away from the known breeding areas into areas of lower habitat value such as Deep Pond. It is anticipated that there will be no significant changes to the breeding habitat as a result of this proposal; and the breeding cycle of this species will not be disrupted.

modify, destroy, remove, isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline,

The capping works will temporarily remove an area of potential foraging habitat (5.2 ha) for adult Green and Golden Bell Frog. After capping works are completed the area will be revegetated, therefore the loss of habitat is considered a temporary impact. This area impacted represents a small proportion of the total potential foraging habitat available to the species. Larger more optimal foraging habitat surrounding the wetland areas, including the K6 and K7 areas, will be retained. It is likely that the temporary loss of a small proportion of foraging habitat will not cause any decline for the species and frogs will be able to utilise other areas.

result in invasive species that are harmful to a vulnerable species becoming established in the vulnerable species' habitat,

Weeds are prevalent with the wetlands margins and dominant within areas of terrestrial habitat, including four species of noxious weed. The works provide an opportunity to reduce the prevalence of noxious weeds within the capping area, upon revegetation. Appropriate controls will be implemented to vehicles and equipment to avoid the introduction of any other invasive species to the site. The wetland areas should be considered restricted areas for personnel and no material should be exchanged between wetland areas, especially Deep Pond which has very high numbers of Eastern Gambusia, an invasive species which predates tadpoles.

introduce disease that may cause the species to decline, or

The Project is not expected to introduce any diseases that may cause the species to decline. Chytrid fungus has been linked to declines in the Green and Golden Bell Frog, however the pathogen is considered widespread on Kooragang island (DECC 2007) and therefore it is unlikely that the proposed works will cause any further spread. Nevertheless hygiene procedures will be implemented for personnel and equipment in order to prevent any spread of the disease. There is evidence to suggest that some salinity within Green and Golden Bell Frog habitat and breeding areas may help to prevent the prevalence of the disease. The proposed works are considered unlikely to change the hydrological conditions and water quality parameters to a level that would constitute an impact on the Green and Golden Bell Frog through reduced Chytrid fungus protection.

interfere substantially with the recovery of the species.

The decline of this species can be attributed to a number of likely factors including Chytrid fungus, predation of tadpoles by the Eastern Gambusia and habitat loss. The latter is likely to be the most significant driver in the species decline, especially the loss of breeding habitat. Breeding habitat will remain unaffected by this proposal and large areas of foraging habitat will be retained. It is anticipated that the proposal will not affect the recovery of the species and the carrying capacity of the habitat within the area will remain largely unchanged. Appropriate mitigation measures and hygiene controls will prevent other factors such as Chytrid fungus and Gambusia becoming any more prevalent and risking impacting the species recovery.

Conclusion
The capping works have avoided cells in which wetlands are present. This will minimise impacts to the species by retaining important habitat. Key impacts are limited to possible mortality of a small number of individuals during clearance of weedy terrestrial area. There are likely to be no significant impacts to this species or the population of this species.

C.1.4 Migratory Species

WETLAND BIRDS/SHOREBIRDS	
Common Sandpiper (*Actitis hypoleucos*)	Grey-tailed Tattler (*Heteroscelus brevipes*)
Great Egret (*Ardea alba*)	Broad-billed Sandpiper (*Limicola falcinellus*)
Cattle Egret (*Ardea ibis*)	Bar-tailed Godwit (*Limosa lapponica*)
Sharp-tailed Sandpiper (*Calidris acuminata*)	Black-tailed Godwit (*Limosa limosa*)
Red Knot (*Calidris canutus*)	Eastern Curlew (*Numenius madagascariensis*)
Curlew Sandpiper (*Calidris ferruginea*)	Whimbrel (*Numenius phaeopus*)
Pectoral Sandpiper (*Calidris melanotos*)	Ruff (*Philomachus pugnax*)
Red-necked Stint (*Calidris ruficollis*)	Pacific Golden Plover (*Pluvialis fulva*)
Great Knot (*Calidris tenuirostris*)	Grey Plover (*Pluvialis squatarola*)
Double-banded Plover (*Charadrius bicinctus*)	Marsh Sandpiper (*Tringa stagnatilis*)
Latham's Snipe (*Gallinago hardwickii*)	

The species listed above have either been recorded, or are considered to have the potential to occur, within or adjacent to the site. These species are typically associated with the wetland areas, including the margins and transitional habitats. They are not anticipated to occur in the landfill areas associated with the capping works, which are significantly elevated above the wetlands. For this reason there will be no direct loss of habitat for these migratory species and impacts will be restricted to indirect and temporary impacts.

Indirect impacts associated with the capping works include potential sediment runoff due to the earthworks. This will be reduced to negligible levels through sediment controls including settlement basins.

The construction phase of the capping works will include noise, light and vibration disturbance from machinery. These impacts are likely to be most acute for Deep Pond whilst heavy machinery is operated in the K3 area and within K5 Cell 8. The noise impacts of construction works have the potential to disturb migratory birds sufficiently so that some areas of foraging habitat are avoided. This impact is most likely to affect species foraging or roosting on the shoreline in the shallow sediments or those species which utilise the areas of emergent vegetation on the eastern edge of Deep Pond. The construction activities will be temporary occurring over a period of six to eight months, and during this period there will occasions when disturbance is minimal and does not occur adjacent to the wetland areas. Works will occur during daylight hours and therefore will not affect roosting birds significantly. It is difficult to predict the degree of habitat avoidance by migratory birds however it is anticipated that it will mainly affect habitat along the eastern edges of deep pond. It is possible that species may become accustomed to the disturbance and return to the foraging site, whilst construction is continuing. For example, Stockton Sandspit within the Hunter Estuary provides a resting roosting and foraging resource for large aggregations of migratory wading birds, despite being within 100 m of Stockton Bridge/B63 Road, which has heavy vehicle traffic especially during peak hour periods.

Once the capping works are completed, it will result in less infiltration of rainwater into the landfilled area. Previous studies have shown that the water entering the ponds via overland flow is likely to be slightly less saline and have fewer contaminants than water which has percolated through the landfill areas. These changes to the water quality as a result of the proposal are considered positive in the long term with less contaminant reaching the wetlands area. The effects on salinity are likely to be negligible due to the large dilution factors involved.

An action is likely to have a significant impact on a migratory species if there is a real chance or possibility that it will:

substantially modify (including by fragmenting, altering fire regimes, altering nutrient cycles or altering hydrological cycles), destroy or isolate an area of important habitat for a migratory species

Deep Pond, to the west of the proposed work area, is considered to contain important habitat for several migratory species as, on occasion, the habitat includes greater than 0.1% of the global population, including; Sharp-tailed Sandpiper (*Calidris acuminata*), Curlew Sandpiper (*Calidris ferruginea*); and Marsh Sandpiper (*Tringa stagnatilis*) (Herbert 2007).

Important habitat will not be substantially modified due to the project. Any effects to the hydrology of wetlands will be negligible and potentially improved, due to reduced leaching of contaminants from the landfill areas.

result in an invasive species that is harmful to the migratory species becoming established in an area of important habitat for the migratory species, or

The proposed works are unlikely to increase the prevalence or introduce any invasive species to the habitats on which the migratory species relies. All Vehicles will be required to be clean on arrival and pass through a wheel bath on entry and exiting the site and this will limit the potential spread of weeds or pathogens. The terrestrial areas of the site are dominated by exotic weeds, however the proposed works are unlikely to increase the spread into wetland areas.

seriously disrupt the lifecycle (breeding, feeding, migration or resting behaviour) of an ecologically significant proportion of the population of a migratory species.

The only migratory species recorded in high number are the Sharp-tailed Sandpiper (*Calidris acuminata*), Curlew Sandpiper (*Calidris ferruginea*); and Marsh Sandpiper (*Tringa stagnatilis*). These species may utilise the Deep Pond shoreline to rest, forage and roost within the site. Construction impact may cause the migratory species to avoid areas of Deep Pond primarily due to the effect of noise disturbance. This is not likely to significantly disrupt the lifecycle of any of the migratory shorebirds. Deep Pond is only likely to provide habitat for large numbers of the migratory birds on an intermittent basis. During periods of high water levels the amount of exposed mud flats are minimal and increased water depth limits the area is which wading species can feed. Migratory birds are likely to be most abundant, within Deep Pond, when water levels are low which would increase the availability of shallow water for wading species and also increase the amount of exposed margins and mud flats. As the habitat is only likely to be periodically available to large numbers of migratory species, it is unlikely that it is relied upon, as it represents an unreliable foraging resource. The mudflat and shorelines of the Hunter Estuary are a much larger and more important foraging resource, with tidal movements exposing foraging habitat on a regular basis.

Conclusion

The proposal will not significantly affect wetland and shorebird migratory species, given that the wetland habitats and margins will not be removed or modified. Impacts will be limited to the temporary disturbance caused by construction activities which may cause some species to avoid wetland habitat adjacent to the construction.

SPECIES LIKELY TO FLY OVER AND FORAGE WITHIN THE SITE

Fork-tailed Swift (*Apus pacificus*) and White-throated Needletail (*Hirundapus caudacutus*)

The Significant Impact Guidelines 1.1 (DoE 2015) requires assessment of impacts to migratory species in terms of important habitat. The Significant Impact Guidelines 1.1 defines important habitat for a migratory species as:

a. habitat utilised by a migratory species occasionally or periodically within a region that supports an ecologically significant proportion of the population of the species, and/or

b. habitat that is of critical importance to the species at particular life-cycle stages, and/or

c. habitat utilised by a migratory species which is at the limit of the species range, and/or

d. habitat within an area where the species is declining.

The White-throated Needletail and Fork-tailed Swift have generalist habitat requirements, occurring in a range of landscapes including disturbed areas. Both are aerial species, foraging for insects on the wing and rarely alighting whilst in Australia. The entire site has the potential to provide foraging resources given that it supports flying insects, however neither species has been recorded. As the species have generalist habitat requirements and a very wide range, habitat within the Site is not of critical importance to the species and it is never likely to contain high proportions of the species at any time.

The Ecology Study Area is not at the edge of the range of these species, and there is no evidence to suggest these species are declining in this region.

An action is likely to have a significant impact on a migratory species if there is a real chance or possibility that it will:

substantially modify (including by fragmenting, altering fire regimes, altering nutrient cycles or altering hydrological cycles), destroy or isolate an area of important habitat for a migratory species

The Site does not contain important habitat for these species. Impacts to the terrestrial habitat will be temporary as it will be revegetated after capping works are completed.

result in an invasive species that is harmful to the migratory species becoming established in an area of important habitat for the migratory species, or

The habitat is not considered important for the species. The terrestrial habitat is currently highly disturbed with exotic weeds dominating the vegetation. The proposed works are not likely to increase the prevalence of these weeds and all Vehicles will be required to be clean on arrival and pass through a wheel bath on entry and exiting the site and this will limit the potential spread of weeds..

seriously disrupt the lifecycle (breeding, feeding, migration or resting behaviour) of an ecologically significant proportion of the population of a migratory species.

Ecologically significant proportions of either species are not likely to occur within the site, given that they are typically dispersed over very large areas of mainland Australia.

Conclusion

These species are wide-ranging and have generalist habitat requirements. The Site is not considered to provide important habitat for these species or contain a significant proportion of the population of the species. Any impact to the species are considered temporary and negligible.

SPECIES LIKELY TO FLY OVER AND FORAGE WITHIN THE SITE

The Eastern Osprey (*Pandion cristatus*)

The Little Tern (*Sterna albifrons*)

The Significant Impact Guidelines 1.1 (DoE 2015) requires assessment of impacts to migratory species in terms of important habitat. The Significant Impact Guidelines 1.1 defines important habitat for a migratory species as:

a. *habitat utilised by a migratory species occasionally or periodically within a region that supports an ecologically significant proportion of the population of the species, and/or*

b. habitat that is of critical importance to the species at particular life-cycle stages, and/or

c. habitat utilised by a migratory species which is at the limit of the species range, and/or *d. habitat within an area where the species is declining.*

The Eastern Osprey (*Pandion haliaetus*) favours coastal areas, especially the mouths of large rivers, lagoons and lakes. The species feeds on fish over clear open water. The habitat surrounding the Site offers large areas of foraging habitat for the species and the species has been recorded flying over the site. There is potential that Deep Pond offers some potential foraging habitat for the species, however off-site wetlands and estuarine habitats in the Lower Hunter and coastal areas are considered more optimal and are of a much large area than Deep Pond. There is an absence of tall structures within the Site which would provide potential nesting resources for the species and therefore breeding is unlikely to occur on site. The habitat within the Site is not considered important for the species; and the species have not been observed foraging within the Site. Given that only one bird has been observed flying over the site despite extensive fieldwork it is not considered that a high percentage of the population will occur within the site. The species is not at the limit of its range and can be considered cosmopolitan across the east coast.

The Little Tern has been recorded adjacent to the Site in 2007, and the species is frequently recorded in the lower Hunter Estuary. The species has the potential to intermittently fly over the Site and may occasionally forage within the Site, although the habitat is considered sub-optimal. The species has not been recorded, or is expected to occur in large number within the site. The species prefers to roost on sand dunes and the sandy beaches and are therefore unlikely to roost on the Site. The habitat within the Site is not considered important habitat for the Little Tern.

An action is likely to have a significant impact on a migratory species if there is a real chance or possibility that it will:
substantially modify (including by fragmenting, altering fire regimes, altering nutrient cycles or altering hydrological cycles), destroy or isolate an area of important habitat for a migratory species
The Site does not contain important habitat for these species. There will be no direct impacts, including modification or loss of the potential foraging habitat within the Site. Any impacts to the species are likely to be limited to construction disturbance associated with the terrestrial capping works.
result in an invasive species that is harmful to the migratory species becoming established in an area of important habitat for the migratory species, or
The habitat is not considered important to either species, with Deep Pond, consisting of sub-optimal foraging habitat. The proposal is not anticipated to introduce or increase the prevalence of invasive species.
seriously disrupt the lifecycle (breeding, feeding, migration or resting behaviour) of an ecologically significant proportion of the population of a migratory species.
Ecologically significant proportions of either species are not likely to occur within the site, given that only few individuals have been recorded despite significant survey effort in and around the Site.
Conclusion
Any impact to these species is considered temporary and negligible. Impacts are limited to construction disturbance in areas adjacent to areas of potential foraging habitat. A significant proportion of a local population will not be affected by the proposal.

APPENDIX 2
RESPONSE TO REQUEST FOR INFORMATION

Response to Request for Information

Kooragang Island Waste Emplacement Facility Area 2 Closure Works

Hunter Development Corporation

ERM Ref: 0320327 Final

September 2016

The business of sustainability

ERM

Document Control: 0320327– Response to Request for Information					
				ERM Approval to Issue	
Version	Revision	Author	Reviewed by	Name	Date
Final	F01	Matthew Flower	David Dique	David Dique	21 September 2016

Kooragang Island Waste Emplacement Facility

Area 2 Closure Works

Response to Request for Information

Hunter Development Corporation

September 2016

0320327 F01 Final

www.erm.com

Prepared by:	*Claire Burnes*
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Signed:	
Date:	21 September 2016
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Position:	*Partner*
Signed:	
Date:	21 September 2016

CONTENTS

CONTENTS

ANNEXES

LIST OF FIGURES

LIST OF TABLES

1 *INTRODUCTION*

Environmental Resources Management Australia Pty Ltd (ERM) has been engaged to prepare a response to the Department of Environment's *Request for Additional Information* (DoE RFI) – *Kooragang Island Waste Emplacement Facility – Area 2 Closure Works (2016/7670)*.

This proposed action relates to part of the NSW State Government's Closure Works required under approval of surrender of licence number 6437 (notice number 1111840; referred to as the 'surrender notice') on the former Kooragang Island Waste Emplacement Facility (KIWEF) by the Hunter Development Corporation (HDC).

The KIWEF site closure is to be actioned, following its 30 year lifespan as an operational waste facility servicing the BHP's Mayfield Steelworks. The Closure Works are to be based on an Environmental Protection Agency endorsed Revised Final Landform and Capping Strategy (GHD 2009). The spatial extent of the referral area is known as Area 2 comprising K3, K5 and K7 (refer Figure 1).

1.1 *BACKGROUND*

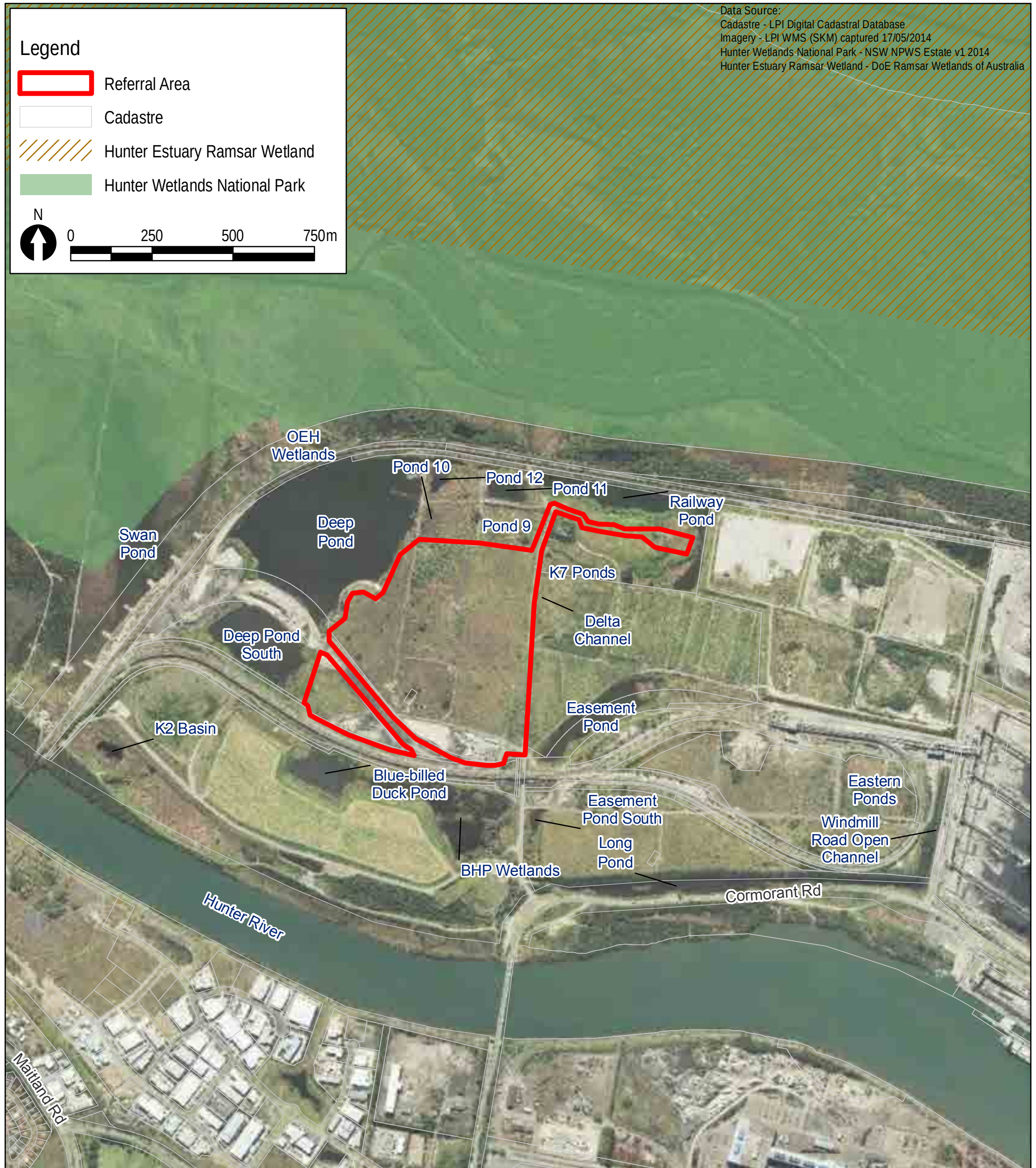
The closure works area is owned by the Port of Newcastle Lessor (PoN Lessor, a NSW Government entity) who has contracted HDC as an agent of the State, to complete the KIWEF remedial works in accordance with the Binding Terms of Agreement. The closure is regulated by the NSW EPA under the *Protection of the Environment Operations Act* through the Surrender Notice.

The site is subject to a number of potentially significant environmental constraints. In particular, the Green and Golden Bell Frog (GGBF), protected under both State and Federal legislation, is known to occur within the broader KIWEF site, including the proposed Area 2 Closure Works area.

Port of Newcastle Lessor Pty Ltd submitted a referral (Referral number 2016/7670) to the Department of Environment (DoE) on 9 March 2016. DoE subsequently issued a Request for additional information on 2 May 2016 (referred to as the 'RFI' throughought). Specific to the request, HDC engaged Douglas Partners to provide additional supporting information. The 2016 Douglas Partners report has been referenced throughout this response and is attached as *Annex A*.

1.2 *MATTERS OF THE DOE RFI AND KEY FINDINGS*

Table 1 shows the information requested by DoE. It provides a summary of PoN Lessor's responses, and identifies where in this report they are located.



Client: Hunter Development Corporation	**Figure 1 - Project Locality, with Commonweath Heritage Places and Ramsar Wetlands**	ERM
Drawing No: 0320327b_EPBC_REF_G001_R1.mxd		
Date: 04/12/2015 Drawing Size: A4	Former Kooragang Island Waste Emplacement Facility EPBC Act Referral	
Drawn By: TC Reviewed By: TM		
This figure may be based on third party data or data which has not been verified by ERM and it may not be to scale. Unless expressly agreed otherwise, this figure is intended as a guide only and ERM does not warrant its accuracy.	Environmental Resources Management ANZ Auckland, Brisbane, Canberra, Christchurch, Melbourne, Newcastle, Perth, Port Macquarie, Sydney	

Table 1 RFI Summary

Item Number	Information Request	Where Addressed	Summary of Response
Hydrology and water quality			
1	On page 12 of the referral, under Section 3. 1 (c) Wetlands of International Importance (declared Ramsar wetlands), it is mentioned that "Modelling of contaminant migration associated with the T4 project indicates an increased timeframe before existing contaminants within KIWEF could potentially reach the Ramsar site under a post capping scenario". To enable us to complete our assessment of potential impacts upon this wetland, please provide the relevant modelling documents referenced.	Section 2	Additional information has been provided and links to relevant documents included.
2	Past and current water quality characteristics (including, but not limited to, pH, salinity, turbidity, contaminant levels) of ponds and other receiving waters that would receive run-off water from areas affected by the proposed works.	Section 3, Annex A, Annex B and Annex C	Data is provided in attached documents.
3	Detailed analysis (including predictive modelling, where available) of likely changes to water quality in ponds and other receiving waters (including, but not limited to, pH, salinity, turbidity, contaminant levels) as a result of run-off from areas affected by the proposed works, particularly in relation to re-establishing and maintaining suitability of the habitat for the green and golden bell frogs (GGBF) (e.g. salinity levels may be preventing the infection of frogs by amphibian chytrid fungus), and any other potential effects of any changes on GGBFs and other EPBC Act listed species. Historic indicative conductivity ranges for KIWEF ponds (measured as salinity, IJS/cm) are presented in Table 10 (page 34 of the referral). However, the Department notes that no salinity data is provided for delta channel, K7 ponds and Cells 9, 10, 11 and 12 which are nearest to the proposed works and are a refuge for GGBF.	Section 4 and Annex A and Annex A of Annex G	A qualitative assessment focussing on the potential impacts to the ponds as a result of the Area 2 closure works has been undertaken and is provided.
4	Please provide further details on how salinity levels will be monitored to ensure they remain within suitable limits for GGBF health in response to altered site hydrology and the process, responsiveness and effectiveness of how adjustments to the salinity levels will be undertaken to ensure GGBF health (including chytrid control). Please provide details/data collected by the hydro-salinity loggers (Section 8.2).	Section 5, Annex A, Annex B and Annex C	Hydro-salinity monitoring has commenced with monitoring devices installed, which will be used for the duration of capping. Results will be considered for comparison against the three key salinity values relevant to the GGBF life cycle and chytrid protection levels. Adaptive management measures will be implemented following investigation of the change in salinity.

Item Number	Information Request	Where Addressed	Summary of Response
Green and Golden Bell Frog Management			
5	It is mentioned on page 3 under Section 1.8 that the proposed action is estimated to commence in quarter 2 of 2016 for practical completion in June 2017. Since the proposed action is going to take place on the terrestrial environment and GGBF use this area for foraging and are sensitive to disturbance during autumn and winter months (April-August), please provide details of the timing of works in relation to: key life-cycle stages of the GGBF including breeding periods; impacts upon the Australasian Bittern; and use of the site by migratory wading birds.	Section *6* and Annex D	The proposed works were scheduled to commence in quarter 3 of 2016 for completion by June 2017, however due to delays it is expected that construction will now not commence until quarter 1 of 2017. A number of controls are planned to minimise the impact to these species during breeding periods.
6	Section 5 of the referral makes reference to a Green and Golden Bell Frog Management Plan (Golder Associates, 2011). Please provide this document including details of the adequacy and capacity of the adjacent habitat to accept and maintain translocated frogs and details of the proposed temporary frog exclusion fencing preventing re-colonisation of the disturbed capping area.	Section *7* and Annex D	The management plan is attached. There is considered to be sufficient suitable habitat surrounding the proposed works area to relocate any GGBFs identified during construction. Indicative frog exclusion fencing details are also provided in this section.
7	Section 5 of the referral makes reference to the NSW Environment Protection Authority releasing formal advice confirming the completion of Area 1 capping works (EPBC 2012/6464). Please provide this formal advice and indicate the timing and outcomes of revegetation and rehabilitation of the capped areas that provide GGBF foraging habitat, and the re-colonisation of this area by GGBF.	Section *8*, Annex E and Annex F	Area 1 capping works were completed in March 2015. GGBF monitoring surveys were undertaken over summer 2015-2016 across the whole of the island, including the recently capped Area 1. GGBF were detected in three of the newly constructed ponds within Area 1, post construction activities.
8	Please provide the documentation supporting the statement in Section 6.2 of the referral that "the short term impacts associated with site disturbance during construction are able to be managed using methods previously implemented on KIWEF and demonstrated to be successful in avoiding significant impacts to MNES".	Section *9* and Annex F	Successful recolonisation following the Area 1 works supports the statement made.

2 ITEM 1 - MODELLING OF CONTAMINANT MIGRATION AND RAMSAR SITE

This Chapter responds to Item 1 requesting the documents used to make the assertion that:

> "Modelling of contaminant migration associated with the T4 project indicates an increased timeframe before existing contaminants within KIWEF could potentially reach the Ramsar site under a post capping scenario"

This quote from the referral is made based on this data source:

Douglas Partners Pty Ltd., 2012, Report on Groundwater Assessment, Proposed Terminal 4 Project, Kooragang Island, Prepared for Port Waratah Coal Services Limited. Volume 3 Appendix E of T4 Project – Environmental Assessment.

Detailed numerical modelling undertaken by Douglas Partners for the Terminal 4 Project (and documented in the above report) indicated that capping of the site would lead to a reduced flux of contaminants towards the north of the site where the RAMSAR wetlands are located. Section 11.3.4 of the report notes:

"*[Capping of the T4 site] is expected to lead to average water levels in both aquifers and therefore the flow rates and associated flux of contamination to be overall lower than pre development. Post development this trend would continue with capping associated with the development expected to lead to a net decrease in flows and water levels and therefore a net reduction in the flux of existing contamination from the T4 Project area*."

Douglas Partners (2016) reports that the reduced flux of contaminants was predicted to occur because the reduced infiltration as a result of capping would lead to reduced groundwater heads in the Fill and Estuarine Aquifers, less leaching of contaminants and reduced flow rates and subsequently an increase in groundwater and contaminant travel times.

As a follow up to the 2012 report, Douglas Partners undertook further assessment (Douglas Partners 2013) to consider four potential contaminant mitigation measures with the T4 Development, which included a specific assessment of groundwater flow times in the Estuarine Aquifer under the HDC capping scenario. The report indicated travel times will increase from about 60 to 90 years (for pre-capping conditions) to 90 to 120 years (following HDC capping).

The three relevant Douglas Partners reports are provided as below (*Table 2*).

Table 2 Relevant Water Modelling Documents

Report title	Location
Report on Groundwater Assessment, Proposed Terminal 4 Project, Douglas Partners Pty Ltd., 2012. Environmental Assessment Vol.3 App. E	http://majorprojects.planning.nsw.gov.au/index.pl?action=view_job&job_id=4399
Assessment of Mitigation Measures for Groundwater Contamination, Proposed Terminal 4 Project, Kooragang Island, Douglas Partners Pty Ltd., 2013. Response to Submissions and Preferred Project Report Vol. 2 App E	http://majorprojects.planning.nsw.gov.au/index.pl?action=view_job&job_id=4399
Report on Qualitative Assessment of Surface Water Impacts, KIWEF Area 2 Closure Works Kooragang Island, Douglas Partners Pty Ltd., 2016	Attached as Annex A

3 ITEM 2 - PAST AND CURRENT WATER QUALITY CHARACTERISTICS

This Chapter responds to Item 2 regarding provision of:

Past and current water quality characteristics (including, but not limited to, pH, salinity, turbidity, contaminant levels) of ponds and other receiving waters that would receive run-off water from areas affected by the proposed works.

Past and current water quality characteristics have been summarised in Section 4.2.3 and 5.2 of the Douglas Partners (2016) report in *Annex A*. The report identifies that testing of groundwater indicates both surface water and Fill Aquifer groundwater commonly exceed the ANZECC (2000) Trigger Values for Slightly to Moderately Disturbed Ecosystems. Analytes that typically exceed the adopted trigger values include metals, nitrogen, phosphate, cyanide and pH. Their review of the contamination data further indicated that the characteristics of surface water and groundwater are similar, with the exception of ammonia where there is a high proportion of exceedances in groundwater but a low proportion in surface water (Douglas Partners 2016).

Douglas Partners (2016) has consolidated numerous previous studies that collected historical groundwater and surface water quality parameters and contaminant analytical data for the KIWEF. The Douglas Partners (2016) report provides plotted water quality results over time between Jan 1999 and May 2016. Results are shown for five surface water sampling locations and ten groundwater sampling locations for pH, electrical conductivity, total cyanide, free cyanide, weak acid dissociable cyanide, molybdenum, chromium, phenols, iron, lead, manganese, mercury, zinc, ammonia, naphthalene, phenanthrene, anthracene, fluoranthene, benzo(a)pyrene. Further, the water level, electrical conductivity, temperature and rainfall recorded by by continuous surface water dataloggers has been plotted and presented in Appendix C of the Douglas Partners (2016) report. The location of data sampling (loggers and samples) is shown in maps provided in Appendix D of the Douglas Partners (2016) report.

4 ITEM 3 - PREDICTIVE MODELLING

This Chapter responds to Item 3 regarding the provision of:

Detailed analysis (including predictive modelling, where available) of likely changes to water quality in ponds and other receiving waters (including, but not limited to, pH, salinity, turbidity, contaminant levels) as a result of run-off from areas affected by the proposed works, particularly in relation to re-establishing and maintaining suitability of the habitat for the green and golden bell frogs (GGBF) (e.g. salinity levels may be preventing the infection of frogs by amphibian chytrid fungus), and any other potential effects of any changes on GGBFs and other EPBC Act listed species. Historic indicative conductivity ranges for KIWEF ponds (measured as salinity, µS/cm) are presented in Table 10 (page 34 of the referral). However, the Department notes that no salinity data is provided for delta channel, K7 ponds and Cells 9, 10, 11 and 12 which are nearest to the proposed works and are a refuge for GGBF.

4.1 WATER QUALITY ALTERATIONS PREDICTIVE MODELLING

4.1.1 Salinity

Douglas Partners have undertaken a qualitative assessment of the changes to surface water in relation to the proposed Area 2 capping works. The assessment looked at data points available within the wider Kooragang Island and Ash Island complex, while focussing on the potential impacts to surface water bodies within and adjacent to Area 2 throughout and following the capping works. The assessment considered potential salinity changes that were due to:

- water level fluctuations (from rainfall, run-off, infiltration);
- evaporation;
- groundwater interaction;
- tidal influences;
- contaminant concentrations; and
- temperature.

The assessment was based on review of numerous previous studies, including:

- investigations undertaken specifically for the proposed capping work;
- ongoing monitoring related to the KIWEF Environmental Protection Licence (and now the Surrender Notice); and
- other adjacent proposed developments (such as the T4 Project).

The assessment included review of water level and salinity data from automatic loggers; soil contamination data from previous investigations; surface and groundwater contamination monitoring results (from previous investigations and routine monitoring); and the results of modelling for Areas 1 and 3 capping (provided in Annex A of *Annex G*).

The Douglas Partners (2016) assessment is provided in *Annex A* and a summary of the outcomes of their investigation is provided in *Section 4.2*.

4.1.2 Other Chemicals

Douglas Partners (2016) provided a summary of predicted changes in other water quality parameters including:

- pH – pH is generally slightly alkaline in the ponds whereas rain pH can be expected to be slightly acidic. The typical range of the groundwater is in the range of 8 to 10 and likely to contribute to the alkalinity of the pond water. Reduced groundwater flows into the ponds has potential to lower pH toward neutral however this parameter may be controlled (and subsequently any impact buffered) by microorganisms and vegetation. The pH may be controlled by processes in the pond including with atmospheric carbon dioxide (CO^2) and consumption of dissolved CO^2 by vegetation or algae in the ponds.

- Turbidity – may occur from erosion or surface soils within the catchments, or flow from upstream ponds that are turbid. Rainfall and groundwater inflow will not contribute to turbidity. Turbidity generally subsides over time leading to sediment accumulating on the base of the pond. While the construction of the Area 2 cap may increase the potential for turbidity to occur during construction, best practice environmental controls will be implemented throughout the works to limit the potential for any significant impact. The site will be revegetated at the completion of the cap construction, further reducing the potential for increased turbidity. It is therefore expected that any observed increase in turbidity will be temporary in nature or can be managed..

- Contamination – The fill materials on the site are known to contain a range of contaminants, and testing of groundwater has indicated that both surface water and Fill Aquifer groundwater commonly exceed the ANZECC (2000) Trigger Values for Slightly to Moderately Disturbed Ecosystems. Analytes that typically exceed the adopted Trigger Values included heavy metals, nitrogen, phosphate, cyanide and pH. A review of the contamination data further indicated that the characteristics of the surface water and groundwater are similar (with the exception of ammonia). Groundwater flows from the Fill Aquifer into the ponds presents a similar transport pathway as for salinity, however, many contaminants, in particular organic contaminants, are reactive and have limited mobility. Inorganic contaminants (such as metals) are the most likely contaminants to be transported to the ponds from the fill.

Construction of the Area 2 cap will reduce the amount of rainwater that can infiltrate and recharge the groundwater table, thereby reducing the flow of groundwater from areas of known contamination (underneath the Area 2 cap) into the surrounding environment.

As reported in the referral submission (ERM 2015), the capping is designed to reduce the mobilisation of contaminants within the landfill and as such, impacts to the surrounding environment (including the Ramsar wetland) are likely to be beneficial through improved water quality.

As described in the referral submission (and Condition of the surrender notice), the closure will be undertaken in accordance with the Materials Management Plan (MMP) whereby any cut material which is significantly contaminated shall be disposed of off-site or relocated appropriately. Contaminated material uncovered during the construction works will be managed in accordance with a Materials Management Plan (MMP) that has widely been adopted on similar remediation projects. The MMP includes a decision matrix to categorise materials and requires experienced persons to undertake a preliminary inspection and segregation of the material based on visual and olfactory conditions. Once categorised, options for material management are determined. The Materials Management Plan has been approved by the NSW EPA and is documented within the KIWEF Surrender Notice.

4.2 *PREDICTED ALTERATIONS TO SALINITY*

As part of the Douglas Partners (2016) qualitative assessment (*Annex A*) GGBF related thresholds (as described within Table 9 of the KIWEF Area 2 Closure Works EPBC Referral (ERM 2015) were considered for comparison. In general the potential environmental change to site ponds from the proposed Area 2 capping is considered to be minimal or negligible for most ponds (Douglas Partners 2016). Similarly, this level of change is unlikely to effect the other EPBC listed bird species. A summary of the potential impacts identified by Douglas Partners from the Area 2 capping works on the surrounding ponds is provided in *Table 3*.

Table 3 Summary of Qualitative Assessment Findings

Pond	Potential Change to Environment after Area 2 Capping
Deep Pond	**Deep Pond A (northern portion of Deep Pond) – Possible reduction in salinity from reduced groundwater flows and increased runoff making it more suited to chytrid**
Blue Billed Duck Pond	Negligible change – separate to Area 2 catchment
BHP Wetlands	Minimal change
Railway Pond	Negligible change – generally separate from Area 2 catchment
Easement Pond	**Possible reduction in salinity making it more suited to chytrid, however insignificant compared to Area 1 capping**
Easement Pond South	Reduction of already low salinity, hence-minimal change
K2 Basin	Negligible change
Windmill Road Open Channel	Negligible change due to distance from Area 2
Long Pond	Minimal change due to distance from Area 2

Pond	Potential Change to Environment after Area 2 Capping
K7 Ponds	Negligible change – generally separate from Area 2 catchment and minor groundwater inflows
Cells 9, 10, 11 and 12	Pond and Pond 12 – Possible reduction of already low salinity, hence minimal change
Note: full results (including assessment of other ponds) shown in Douglas Partners 2016 in Annex A.	

The Qualitative Assessment (Douglas Partners 2016) identified that the potential for environmental change to site ponds from the proposed Area 2 capping is generally considered to be minimal or negligible for most ponds.

The report notes that while potential decreases in salinity could be expected from increased runoff and slightly decreased groundwater inflows for Easement Pond, the magnitude of impacts is expected to be lesser than those predicted by quantitative modelling conducted by SMEC for the Area 1 capping. The SMEC qualitative assessment (refer Annex A of *Annex G*) found that "*the expected effects of changes in salinity in the ponds as a result of the [Area 1 and 3] capping work is not expected to be significant*", however, "*A small increased risk of Chytrid effect has been identified in Easement Pond*". The results of monitoring, during and post Area 1 capping, have indicated no discernible changes to Easement Pond's water levels or salinity post Area 1 capping.

Recent GGBF surveys undertaken by the University of Newcastle on the KIWEF (Refer *Annex F*) located a large number GGBF tadpoles within ponds with low salinity levels (ie below the chytrid protection level) suggesting that reproduction can occur under these conditions.

Similarly for Deep Pond, there is a potential for a minor reduction of salinity levels as a result of increased runoff and decreases in groundwater flows (Douglas Partners 2016). However the salinity levels recorded within Deep Pond have historically fluctuated above and below the chytrid protection threshold prior to any capping of the KIWEF.

While there may be a minor reduction in the salinity levels of Easement Pond and Deep Pond, potentially reducing the level of chytrid protection available for adult GGBFs, the Area 2 closure works will not have any impact upon a number of surrounding ponds (eg Railway Pond and the K7 Ponds) that have higher concentrations of salinity and are known habitats for GGBF. The adult GGBF is a highly mobile species that can traverse between various ponds with differing salinity concentrations, enabling the adult GGBF to maintain its chytrid fungus protection (University of Newcastle 2016, *Annex F*).

4.3 HISTORIC INDICATIVE CONDUCTIVITY RANGES

The historic indicative conductivity ranges within Table 10 of the KIWEF Area 2 Closure Works EPBC Referral (ERM2015), did not provide salinity data for a number of ponds. The additional historical pond salinity ranges requested by DoE have been described in *Table 4*, where available.

Table 4 KIWEF Pond Salinity Ranges

Surface Water Body	Historic Indicative Conductivity Ranges
Delta Channel	This is an ephemeral channel and as a result salinity levels have not been recorded at this location.
K7 Ponds	Salinity levels for two locations within the K7 ponds are presented in Douglas Partners 2016, refer to Figures C16 and C17. Recorded salinity levels have ranged from 832 to 4,636µS/cm.
Cells 9, 10 and 12	These ponds are ephemeral and only contain water after periods of high rainfall; as a result salinity levels have not been recorded in these Cells.
Cell 11	Salinity levels are presented in Douglas Partners 2016, refer to Figure C10B. Recorded salinity levels have ranged from 433 to 1,074µS/cm.

5 *ITEM 4 – SALINITY MONITORING AND MANAGEMENT*

This Chapter responds to Item 4, which requested further details on:

> How salinity levels will be monitored to ensure they remain within suitable limits for GGBF health in response to altered site hydrology and the process, responsiveness and effectiveness of how adjustments to the salinity levels will be undertaken to ensure GGBF health (including chytrid control). Please provide details/data collected by the hydro-salinity loggers

The GGBF is highly susceptible to the amphibian Chytrid fungus that causes the disease chytridiomycosis. The University of NSW (*Annex F*) reports a link between the GGBF persistence in coastal environments and sensitivities of the causal agent Chytrid to salt. The addition of salt to water bodies in captivity and in experimental environments increases survival rates of the frogs in the presence of Chytrid (University of NSW 2016).

For this Project, as it relates to the GGBF, salinity monitoring will not be considered in isolation and results will be considered in conjunction with the GGBF Frog Monitoring Programme that monitors populations on the KIWEF site (Golder 2011).

5.1 *SALINITY MONITORING PROGRAM*

The installation of hydro-salinity monitoring devices has been undertaken and will be monitored throughout the duration of capping with any identified significant changes in pond and hydro-salinity attributable to the proposed activity to be investigated and mitigation measures explored. *Section 5.2* provides details of the monitoring locations and references the relevant reports containing the monitoring data.

5.1.1 *Salinity Trigger Limits for GGBF Health*

As has been reported in SMEC (2013) and Douglas Partners (2016) salinity comparison values must consider the life stages of the GGBF and the vulnerability to the chytrid fungus. Expert advice provided as part of the SMEC (2013) report led to adoption of three key salinity (EC) values for comparison. The values for comparison are shown in *Table 5*.

Table 5 Suggested Salinity Comparison Values for KIWEF Surface Water Bodies

No Chytrid Protection	Chytrid protection threshold[1]	GGBF tadpole health threshold[2] (µS/cm)	GGBF Adult health threshold [3] (µS/cm)
0 – 1,650 µS/cm	1,650 µS/cm	2,900 µS/cm	4,100 µS/cm

1. EC below threshold presents increased risk of mortality resulting from Chytrid Fungus.
2. EC above threshold indicates unsuitability for GGBF tadpole survival.
3. EC above threshold indicates unsuitability as GGBF adult habitat.

These levels are interpreted as follows in assessing impacts of closure works:

- Salinity levels below 1,650 (µS/cm) (Chytrid risk bracket) were identified as sub-optimal GGBF condition with individual animals likely not afforded salinity-related protection from chytrid fungus. Chronic or long term low salinity levels below this threshold are considered to increase the risks to GGBF although it would not put individuals at immediate risk of harm in the absence of Chytrid fungus (Stockwell, 2012).

- Salinity levels between 1,650 and 2,900 (µS/cm) are considered "optimal GGBF habitat" as this range provides Chytrid protection while also providing for tadpole survival and habitation and adult breeding.

- Salinity levels between 2,900 and 4,100 (µS/cm) are considered to be suitable for adult GGBF occupation, but would not be satisfactory for tadpole survival.

- Salinity above 4,100 (µS/cm) is not considered to be suitable habitat for GGBF adults over extended periods. It is likely that adult GGBF would move away from ponds with salinity levels above 4,100 µS/cm rendering them unlikely to be used for breeding (and therefore egg laying, hatching and tadpole habitation).

5.1.2 Salinity Adjustments Triggered by Monitoring

An adaptive response approach will be undertaken for GGBF habitat should salinity measure outside the range of comparison limits.

Primarily, when an impact to the population is observed a further detailed investigation will be undertaken aimed to fully understand reasons for change. This may include review of other parameters known to contribute to GGBF habitat condition (e.g. water level and water quality) and consultation with experts such that the drivers of the impact can be identified. Following these investigations, if impacts are found to be attributed to the Area 2 closure works, appropriate mitigation measures can be assigned.

Mitigations measures that may be utilised to aid in recovery in hydro-salinity would include:

- Release of standing surface water of suitable quality from sedimentation basins into the affected pond(s)

- Provision of water into affected ponds from clean site aquifers to adjust the pond's water quality and water level

- Re-direction of surface runoff from the capped site by using temporary berms and diversions into channels draining into/away from affected ponds

- Re-direction of standing surface waters from other suitable ponds into the affected pond(s)

These measures are likely to be applicable during periods of seasonal or annual effects (short term) such as natural drying cycles. For longer-term changes other mitigation measures may include:

- Diversion of catchment drainage from capped areas into affected ponds;

- Restoration of existing hydrogeological processes by permitting groundwater percolation from the base of selected sedimentation basins.

Expert input would be required for the selection of short term or longer term mitigation approaches.

5.2 HYDRO-SALINITY LOGGER LOCATIONS AND DATA

Robert Carr and Associates (RCA) undertook the monitoring and maintenance of the hydro-salinity data logger network located across the KIWEF site. RCA (December 2015) prepared the Surface Water Data Loggers – KIWEF report (refer *Annex B*). The location of each of the data loggers within the KWIEF site is presented in Attachment A of *Annex B*. The RCA data logger data is provided in *Annex C*.

Douglas Partners have compiled all available Datalogger data (including additional results recorded since December 2015 and data recorded as part of the PWCS T4 investigation) into figures that are provided in Appendix C of *Annex A*. The Douglas Partners report has also compared the recorded data against the chytrid protection thresholds (described in *Table 5*).

6 ITEM 5 - TIMING

This Chapter responds to Item 5 regarding:

> The proposed action is estimated to commence in quarter 2 of 2016 for practical completion in June 2017. Since the proposed action is going to take place on the terrestrial environment and GGBF use this area for foraging and are sensitive to disturbance during autumn and winter months (April-August), please provide details of the timing of works in relation to: key life-cycle stages of the GGBF including breeding periods; impacts upon the Australasian Bittern; and use of the site by migratory wading birds.

6.1 PREAMBLE

The proposed action was scheduled to commence in quarter 3, 2016 (ie July) and not extend longer than a 12 month period, with completion due in June 2017; however due to delays it is now likely that construction will not commence prior to quarter 1 of 2017. Construction hours are to be confined to the standard operating hours contained in the Interim Construction Noise Guidelines (ICNG) (DECC, 2009) of Monday to Friday 7 am to 6 pm, Saturday 8 am to 1 pm with no work on Sundays or public holidays. No night works are proposed.

The following points demonstrate measures to manage the risk of potential impact on GGBF, Australasian Bittern and migratory wading birds:

- no freshwater/brackish wetland habitat or significant terrestrial habitat would be cleared as part of the project;
- no activity is proposed in the mapped ponds or wetlands;
- large areas of foraging and breeding habitat are adjacent to the capping works;
- best practice construction controls (including noise, light and erosion and sediment) would be implemented in order to minimise risks on habitat that are adjacent to the proposed capping areas;
- a staged approach to the works will be used to enable the site to stabilise as the works sequentially progress; and
- capping works are located across the elevated sections of the landfill, typically between RL 9 - 10 m AHD.

6.2 *GGBF OVERWINTERING HABITATS RELEVANT TO THE PROPOSED ACTION*

Chytrid fungus significantly affects frogs during overwintering with mortality rates for infected individuals being significantly higher than the mortality for uninfected individuals (McHenry and Mahony 2016: p4). This was evidenced in the chytrid fungus being implicated in the overwinter extinction of a reintroduced GGBF population (Stockwell *et al.*, 2008 *in* McHenry and Mahony 2016: p4).

McHenry and Mahony (2016: p4) postulate that overwintering ponds within the KWIEF include K29 [HDC nomenclature, Cell 11] and K108 [referred to as the Eastern Ponds] located in the NCIG rail loop immediately east of the K10 North (Area 1) capping works. Regarding the use of the overwintering locations by GGBF, McHenry and Mahony 2016 (p15) state:

"Nevertheless, some of our results are consistent with the idea that GGBF spend the winter in deep sheltered ponds, but move out to surrounding ephemeral ponds following summer rain."

Relevant to the proposed action is the potential overwintering pond identified as K29 [Cell 11], which is approximately 70 m north west of the proposed action. The evidence supporting the potential use of Cell 11 for overwintering is that,

"K29 [Cell 11] had lower numbers of frogs than have been found in previous years. Our first survey was in mid-January, after the large rainfall event. We found very low numbers in mid-Jan, but higher numbers during the second survey in mid-February. During that second survey most of the frogs were found on the bank surrounding the pond. We suspect that these [GGBF] were returning to the pond from surrounding ephemeral wetlands (e.g. K106A [Cell 12], K106B [Cell 10], K106C [Cell 9], K103 [Railway Pond])."

McHenry and Mahony (2016) do not discuss the areas within the footprint of the Area 2 closure works as being important overwintering habitats for the GGBF. In fact the investigation states that the closure works presents opportunities to enhance the Kooragang Island GGBF habitat (p27), by creating connectivity between habitat and alternative ephemeral ponds for GGBF occupation. Further the distance between the proposed Area 2 footprint and Cell 11 would limit the potential for any significant impacts to the important overwintering habitat. The construction mitigation measures (discussed further in *Section 7*) will also limit the potential for interactions between the GGBF and the construction works.

6.3 *GGBF LIFECYCLE AND KEY MANAGEMENT ACTIONS*

The breeding period for the GGBF is between October and March, with a peak around January-February typically after heavy rain events (Pyke & White 2001; DEC 2005). Reproductive events are influenced by the weather conditions from season to season and breeding can also take place outside of these periods. Hatching takes place two to five days after ovipositing with tadpole development generally completed within 6 to 12 weeks, although in some instances they over-winter if their development is not completed before water temperatures fall (Pyke and White 2001).

No construction works or activities are proposed within potential GGBF breeding habitat. Therefore, there is no need to limit or restrict works within the GGBF core breeding period.

The species is capable of making quite large movements in a single day, up to 1.5 km, and some tagged individuals are recorded to have moved up to 3 km (Pyke and White 2001) so it is important to maintain site connectivity and movement corridors through the land adjoining the capping areas. Adult frogs do not necessarily stay near to available breeding areas and adults have been found several kilometres from the nearest breeding habitat (Pyke and White 2001).

GGBF enter a period of torpor over the winter months, sheltering in the bases of dense vegetation tussocks, beneath both natural and artificial debris including beneath the ground surface (Pyke and White 2001). Therefore, in order to retain landscape function (by presenting shelter sites), it is important not to unnecessarily disturb vegetation outside of the capping areas.

In order to avoid foraging adult GGBF and overwintering frogs in torpor on the capping areas, pre-clearance surveys for GGBF (and relocation) will be conducted immediately prior to entry of construction equipment and the areas enclosed by frog-proof fencing. Prior to the capping works commencing, areas of GGBF habitat will also be clearly delineated on the ground by frog-proof fencing with appropriate signage, as well as on the site plan. A suitably qualified ecologist will be available on-call to visit the site should GGBF be encountered during clearing and capping works. This person will also be responsible for relocating any GGBFs that may be found in the works area.

6.3.1 *Noise aspects*

The noise environment is currently characterised by continuous traffic flows along Cormorant Road, train movements along nearby rail and activities associated with coal loaders. Noise generated by the capping works will typically be continuous relating to shallow earthworks and with no activities such as rock breaking or piling with significant impact energy resulting in noise or vibration.

Noise emissions would be limited to day time standard construction hours. There will be no ongoing operational noise during the post-construction phase once capping is complete. Construction noise effects would be limited to short term disturbance of roosting and foraging animal behaviours resulting in a reduction of the occupancy rates of adjacent suitable habitat. These potential effects are limited in extent and timeframe to potential short term displacement, if at all. Other similar habitat is known to be available through the series of habitat ponds and disturbed grassland adjacent to the site.

6.3.2 Lighting aspect

No night works are proposed and, as such, no lighting impacts from glow and spill would occur. Lighting of site compounds, if required, will prioritise the need to avoid light spill out side of construction works footprint and will be undertaken in accordance with *Australian Standard 4282 – 1997 Control of the obtrusive effects of outdoor lighting*.

6.3.3 Movement

Potential movement effects include:

- interactions of vehicles and plant with the listed fauna species during clearing and earthworks; and
- the creation of barriers that limit the movement of fauna species.

The movement of machinery and vehicles during the closure works may pose a risk to GGBF during ground clearing and earthworks. Mitigations measures to reduce the potential risk include:

- the completion of pre-clearance surveys and relocation of any GGBFs located within the construction footprint;
- construction of frog exclusion fencing around the perimeter of the closure works to prevent entry / re-entry of GGBFs onto the work site; and
- locating the frog exclusion fencing such that they will not constrain inter-connective pathways and potential movement corridors for the GGBF individuals along drainage lines or lands outside of the proposed closure works site.

Such actions and measures are discussed further in the Green and Golden Bell Frog Management Plan (Golder Associates 2011) provided in Annex D. Barriers to frog and other potential fauna ground movements (such as the frog exclusion fencing) would be removed on completion of capping works.

6.4 *AUSTRALASIAN BITTERN*

The Australasian Bittern lives alone or in loose groups and favours permanent fresh-waters dominated by sedges, rushes, reeds or cutting grasses. The breeding season for this species is from October to January, and is sometimes loosely colonial but in other cases pairs have been observed to maintain territories when several are present in a reedbed (HSO 2008). The Australasian Bittern has been recorded in the Easement Pond, Railway Pond and Cell 11 south east, north east and north of the proposed action. However, as the vegetation on the Area 2 closure works site is not of sufficient density or extent to represent potential breeding habitat, the timing of the works would not affect any of the Australasian Bitterns key life cycle stages.

None of the emergent vegetation within the surrounding ponds of the Area 2 closure works will be disturbed by any construction activities and therefore no impact to potential habitat is anticipated.

6.5 *MIGRATORY WADING BIRDS*

No migratory birds listed under the EPBC Act were recorded during the field surveys undertaken by GHD in their Flora and Fauna Assessment (GHD January 2010). Several records exist within the area especially at Deep Pond (Umwelt 2012). Open water and areas of emergent vegetation are likely to be the preferred habitat for migratory species and this habitat would remain unaltered by the proposed capping works. The works are not likely to disrupt the lifecycle of migratory species (GHD January 2010) especially with the noise, light and movement mitigation measure described above. Therefore, the timing of the works is not critical in order to avoid the risk of significant impacts. Assessments of Significance under the EPBC Act also confirmed that the proposal is unlikely to have a significant impact on listed migratory wading species.

7 ITEM 6 – GGBF MANAGEMENT AND MITIGATION MEASURES

This Chapter responds to Item 6 regarding the GGBF Management Plan:

The referral makes reference to a Green and Golden Bell Frog Management Plan (Golder Associates, 2011). Please provide this document including details of the adequacy and capacity of the adjacent habitat to accept and maintain translocated frogs and details of the proposed temporary frog exclusion fencing preventing re-colonisation of the disturbed capping area.

7.1 GGBF MANAGEMENT PLAN

The *GGBF Management Plan – KIWEF Closure Works* (Golder Associates, 2011; refer *Annex D*) has been endorsed by the NSW EPA in Surrender notice #1111840 as varied (2 May 2013). These plans set out the GGBF management and mitigation measures that will be applied in undertaking the proposed action. Measures specific to the DoE RFI include:

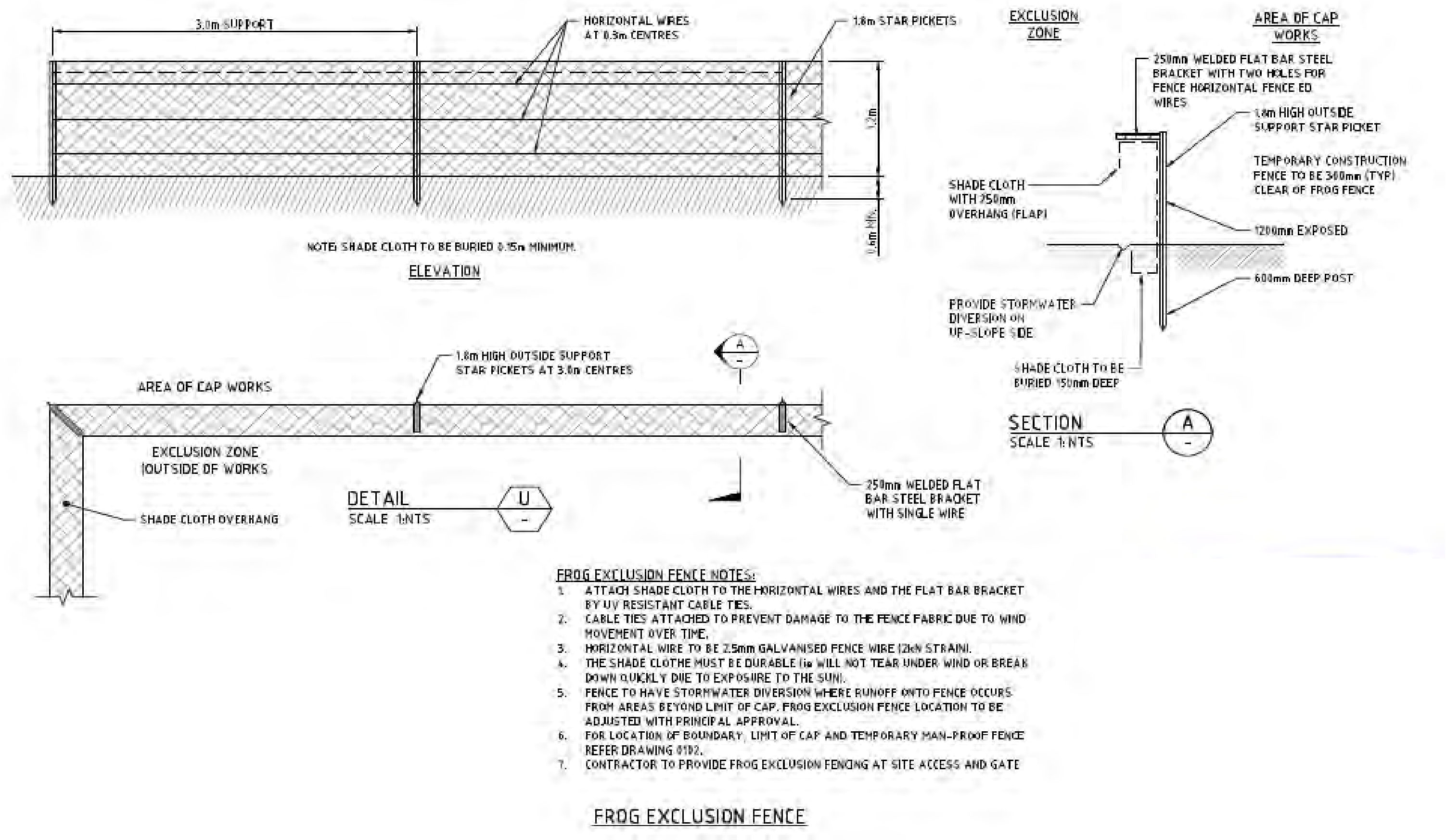
- installation of frog exclusion fencing;
- pre-clearance of the area within the frog exclusion fencing; and
- details of the release site for captured GGBF .

7.2 FROG EXCLUSION FENCING

As part of the technical specification and detailed design drawings for the proposed works, the requirement for frog exclusion fences around all earthworks has been specified, in order to discourage frog movement into the area of construction. This was successfully undertaken for the BHPB / Thiess Hunter River Remediation Project and a similar type of fence is proposed. The frog fencing will be provided in combination with a silt-sediment fence, which would be placed on the construction side of the frog fence. This will prevent sediment compromising the frog fence and also prevent fauna outside of the construction area being trapped between the two different types of fences. The option exists to either fence each area in its entirety for the duration of works or fence in a staged approach as capping works progress and will be determined when detailed works scheduling is agreed with the construction contractor.

An indicative frog exclusion fence design is shown in Figure 2. The proposed frog exclusion fencing is considered to be appropriate to prevent re-colonisation of the disturbed capping area throughout construction. The fencing will remain around the perimeter of the works until the construction activities are completed.

Figure 2 Indicative Frog Exclusion Fence Design



7.3 *"PRE-CLEARANCE" GGBF SURVEY*

Preclearance surveys will be undertaken prior to the commencement of any construction activities and after fence installation in order to reduce any physical damage being caused to adult or juvenile frogs occurring within the impact area, as outlined in the *GGBF Management Plan* (Golder Associates, 2011). Preclearance works surveys will be undertaken within proposed disturbance areas by a suitably qualified and licensed ecologist and all activities will be conducted in accordance with the relevant measures outlined in a frog hygiene protocol. The results of the pre-works surveys will be recorded and reported in the Annual Environmental Management Report (AEMR).

Diurnal visual searches as part of the pre-clearance survey would be undertaken for GGBF in areas of suitable habitat including vegetated area, especially those with tussock forming grasses, areas of rocks, timber and artificial debris located within the proposed closure works areas. Following the diurnal habitat searches, a nocturnal habitat search may be conducted to assess nocturnal usage (breeding/calling) in the habitat adjacent to the ponds proximal to capping works, for example Deep Pond, Railway Pond and K7 Ponds. Nocturnal survey techniques may include visual searching of habitat features, spotlighting, aural surveys and call play-back.

The preclearance works should be undertaken immediately after the completion of fencing. This ensures that frogs and other fauna are not contained for long periods within the construction footprint and that they are "cleared" from the area immediately prior to works commencing.

7.4 *RELEASE SITE CRITERIA AND MAPPING*

The *GGBF Management Plan* (Golder & Associates 2011) outlines that in the event that any GGBFs are observed during the diurnal or nocturnal searches within the pre-clearance survey, the relocation procedures will be initiated prior to the commencement of site disturbance works. That report outlines that the relocation procedure follows the proposed NCIG (2007) procedure, which has been accepted by the NSW Office of Environment and Heritage (OEH).

In the event that any GGBF is identified within the disturbance areas during pre-works surveys, the ecologist undertaking the pre-clearance survey will capture the frog. If the frog appears to be healthy it will be released in the immediate vicinity of the disturbance area, yet outside of potential areas of disturbance. If this is not practical due to high levels of disturbance within the surrounding area, the frog will be released into a suitable relocation area. Any frog to be relocated will be held in a cool, dark, moist place until nightfall. Where practicable, relocation will be timed to coincide with periods of recent rainfall to optimise survival. Relocation of GGBFs outside preclearance works surveys will be conducted in accordance with the relevant measures outlined in the hygiene protocol. Details of GGBFs that are relocated during pre-work surveys will be recorded and reported in the AEMR, and will include lifecycle stage, sex of individual, location where found and location of release.

It is recommended that the release site selected should be in similar habitat to that which the frog was found. For example if a GGBF was found sheltering under debris, a site should be selected with similar cover. Adult frogs found away from pond habitats do not require to be placed within a pond, although vegetated areas adjacent to a pond may be most suitable. Areas recommended for suitable release sites, based on recent density of records include the K7 Ponds and Railway Pond.

If the frog appears to be sick or dead then diagnostic behaviour tests will be conducted (Golder Associates 2011). If the frog is unlikely to survive transportation, it will be euthanased and preserved for pathological analysis. Those individuals which are expected to survive transport should be processed as detailed in the *Hygiene Protocol for the Control of Disease in Frogs* (DECC 2008).

A relocation procedure also exists for GGBF found outside of preclearance-works which is similar to that listed above, further details can be found in the *GGBF Management Plan* (Golder Associates 2011) provided as *Annex D*.

It is considered that the pond habitats within the broader KIWEF site will provide appropriate habitat, with sufficient capacity to accept any GGBFs that are relocated from within the KIWEF Area 2 construction footprint.

8 ITEM 7 - AREA 1 CAPPING WORKS RESULTS

This Chapter responds to Item 7 regarding the completion and results of the Area 1 capping works:

> The referral makes reference to the NSW Environment Protection Authority releasing formal advice confirming the completion of Area 1 capping works (EPBC 2012/6464). Please provide this formal advice and indicate the timing and outcomes of revegetation and rehabilitation of the capped areas that provide GGBF foraging habitat, and the re-colonisation of this area by GGBF.

8.1 AREA 1 COMPLETION LETTER

On 16 Feb 2016 the NSW EPA sent a letter of correspondence to HDC confirming that the Area 1 works were in accordance with the surrender notice (refer *Annex E*). The EPA letter refers to the Area 1 works being K2 and K10 North ('K10N') for which capping was completed in March 2015. Validation report and cap inspection statements were submitted to the NSW EPA on 29 September 2015.

The key milestone dates for the Area 1 capping works (Areas K2 and K10 North) are summarised in *Table 6*. Prior to the Construction Completion dates, the contractor was required to seed the vegetation layer above the capping layer. The contractor was then required to maintain possession of the site for a further 3 months to ensure that the caps integrity was maintained and the surrounding environment protected. The maintenance period also required the contractor to reseed areas of the cap with sparse vegetation coverage. At the completion of the maintenance period, it was determined that the vegetation coverage was comparable to the pre-capped state.

Table 6 Area 1 Closure Works, Key Milestone Dates

Site	Construction Completion	Maintenance Completion
K2	8 May 2015	7 August 2015
K10 North	19 May 2015	18 August 2015

8.2 GGBF RECOLONISATION

Monitoring surveys were undertaken over summer 2015-2016 across the whole of Kooragang and Ash Islands including the recently capped Area 1 (K2, K10N) (McHenry and Mahony 2016). The monitoring of Area 1 included surveys of the six artificial ponds constructed as part of the Area 1 works which measured recolonisation of those areas:

"Artificial ponds work well… The HDC ponds are larger, but given that they were only installed in 2015 it is impressive that they were used by GGBF during the 2015-2016 summer season. Adults were detected at three of the six new ponds, and large numbers of tadpoles were seen at one. These ponds are Gambusia free and within a short distance of the resident population in the rail loop pond (K108 [Eastern Ponds])".

Table 7 contains the results of the monitoring. Note that HDC's nomenclature refers to broad areas that contain multiple elements (ponds) named individually by McHenry and Mahony (2016), hence the nomenclatural equivalents provided.

The Draft Kooragang Island Green and Golden Bell Frog Survey 2015-2016 conducted by the Amphibian Research Group of the University of Newcastle is provided in *Annex F*.

Table 7 ***Area 1 GGBF Monitoring Results (McHenry and Mahony 2016)***

HDC Area Nomenclature	McHenry and Mahony (2016) Pond Nomenclature	GGBF Detected?	Relevant Comments
K2	K117	-	Gambusia not detected
K2	K118	-	Gambusia not detected
K10N	K111	Yes	Gambusia not detected
K10N	K112	-	Gambusia not detected
K10N	K113	Yes	Gambusia not detected; GGBF tadpoles observed
K10N	K114	Yes	Gambusia not detected

Based on the results of the GGBF monitoring conducted in 2015-2016 (described in *Table 7*) it appears that sediment ponds created during the KIWEF Area 1 closure works have provided suitable GGBF breeding habitat when located in close proximity to an existing GGBF population. The 2015-2016 GGBF survey identified adult GGBF's within the three ponds closest to the Eastern Ponds GGBF community, which included one pond that was found to have a large number of tadpoles. These findings indicate that the GGBF were recolonising the capped areas post completion of construction in areas adjacent to existing GGBF populations.

9 ITEM 8 - CONCLUSION SUPPORTING INFORMATION

This Chapter responds to Item 8 which requested:

The documentation supporting the statement [within] the referral that "the short term impacts associated with site disturbance during construction are able to be managed using methods previously implemented on KIWEF and demonstrated to be successful in avoiding significant impacts to MNES".

Chapter 8 details the results of the Area 1 capping works and contains links to relevant documents including the confirmation from the EPA that the cap over Area 1 had been completed. Following the completion of Area 1 capping, the GGBF survey identified the recolonisation of the Area 1 capping works (as discussed within Section 8.2). The McHenry and Mahony 2016 also postulated that:

> *"HDC is scheduled to cap the large area [Area 2] between K105A [Deep Pond], K106B [Cell 10], K29 [Cell 11], and K36 [Easement Pond South]. Incorporation of constructed wetlands, similar to those constructed [by HDC as part of the Area 1 KIWEF Capping Works] within the NCIG rail loop in 2015, are likely to provide important habitat for GGBF".*

The detection of GGBF using the artificial ponds created by Area 1 capping works (including detection of successful breeding in one artificial pond) provides evidence that the short term impacts from construction, when employing the management and mitigation measures specified, are surmountable by the GGBF which has successfully recolonised the area following the construction disturbance.

The proposed mitigation and management approach for the Area 2 closure works will adopt the same principles and learnings that were developed during the Area 1 closure works

The use of the successful mitigation measures adopted during the Area 1 capping activities are evidence that any significant impacts to MNES including the GGBF were successfully managed.

10 REFERENCES

DECC, 2008 *Hygiene Protocol for the Control of Disease in Frogs*

DECC (2009). *Interim Construction Noise Guideline*. NSW Department of Environment and Climate Change (DECC). http://www.epa.nsw.gov.au/resources/noise/09265cng.pdf

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Douglas Partners (2012) Reporting on Groundwater Assessment, Proposed Terminal 4 Project, Kooragang Island, Prepared for Port Waratah Coal Services Limited. Volume 3 Appendix F of T4 Project – Environmental Assessment.

Douglas Partners (2013) Assessment of Mitigation Measures for Groundwater Contamination, Proposed Terminal 4 Project, Kooragang Island,. Volume 2 Appendix E of T4 Project – Response to Submissions and Preferred Project Report.

Douglas Partners (2016) Report on Qualitative Assessment of Surface Water Impacts, KIWEF Area 2 Closure Works Kooragang Island.

GHD (2009) Hunter Development Corporation – Report on KIWEF – Revised Final Landform and Capping Strategy – August 2009 – Revision 2.

Golder Associates (2011). *Green and Golden Bell Frog Management Plan – Kooragang Island Waste Emplacement Facility Closure Works*. Report prepared by Golder Associates for Hunter Development Corporation; Dated 19 April 2011.

McHenry and Mahony (2016). *Kooragang Island Green and Gold Bell Frog Survey: 2015-2016*. Report prepared by Amphibian Research Group, University of Newcastle for Port Waratah Coal Services, Newcastle Coal Infrastructure Group and Hunter Development Corporation.

Robert Carr & Associates (2015). Surface Water Data Loggers Kooragang Island Waste Emplacement Facility (KIWEF) – 11 December 2015.

SMEC (2013) Detailed Response to SEWPaC Comments, Kooragang Island Waste Emplacement Facility – Final Report.

Annex A

Report On Qualitative Assessment of Surface Water Impacts (Douglas Partners, 2016)

Douglas Partners
Geotechnics | Environment | Groundwater

Integrated Practical Solutions

Report on
Qualitative Assessment of Surface Water Impacts

KIWEF Area 2 Closure Works
Kooragang Island

Prepared for
Hunter Development Corporation

Project 81209.02
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Document History

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Revision 0	1	1	Mr Grant Moylan, Hunter Development Corporation

The undersigned, on behalf of Douglas Partners Pty Ltd, confirm that this document and all attached drawings, logs and test results have been checked and reviewed for errors, omissions and inaccuracies.

	Signature	Date
Author		9 August 2016
Reviewer		9 August 2016

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Executive Summary

A qualitative assessment of surface water impacts has been undertaken in relation to proposed 'Area 2' capping works at the former Kooragang Island Waste Emplacement Facility (KIWEF). The assessment was based on a compilation and review of numerous previous studies carried out either specifically for proposed KIWEF capping works, monitoring related to EPLs or other proposed developments (such as the T4 Project). The review considered water level and salinity data from monitoring of automatic loggers, soil contamination from previous investigations, surface and groundwater contamination from both routine monitoring and previous investigations and the results of modelling undertaken for Areas 1 and 3 capping.

The assessment focussed on surface water bodies within and adjacent to the KIWEF 'Area 2' site, considering salinity changes due to a number of factors, including water level (from rainfall, run-off, infiltration), evaporation, groundwater interaction, tidal influence, contaminant concentrations and temperature.

Testing of groundwater has indicated that both surface water and Fill Aquifer groundwater commonly exceed the ANZECC (2000) Trigger Values for Slightly to Moderately Disturbed Ecosystems. Analytes that typically exceed the adopted Trigger Values included metals (As, Cd, Co, Cr, Cu, Ni, Pb and Zn), nitrogen, phosphate, cyanide and pH. A review of the contamination data further indicated that the characteristics of surface water and groundwater are similar, with the exception of ammonia which has a high proportion of exceedances in groundwater but a low proportion in surface water.

The salinity concentrations impact on the growth of the chytrid fungus and in turn on the viability of the Green and Golden Bell Frog (GGBF). While research suggests that salinity appears to be the key driver of chytrid fungus control, water body temperature is also considered to be a factor, however, research is notably limited. The monitoring results were compared to optimal conditions for GGBF habitats in relation to salinity and temperature.

Based on hydro-salinity modelling undertaken for the capping of Areas 1 and 3 it is anticipated that capping of Area 2 will reduce infiltration (leaching) and increase runoff into the ponds that are situated within and adjacent to the treated area. This is likely to result in a general lowering of salinity. Where salinity is already typically low this will not significantly change the existing conditions related to GGBF viability. However, where salinity is moderate to high the reduction in salinity, combined with favourable water temperatures, may bring it into the range where the chytrid fungus could develop.

While potential decreases in salinity could be expected from increased runoff and slightly decreased groundwater inflows for Easement Pond, the magnitude if impacts is expected to be lesser than those predicted by quantitative modelling conducted by SMEC for Area 1 capping. This similarly applies for Deep Pond which would be subject to increased runoff and decreases in groundwater flows subject to the cumulative effects of capping for Areas 1, 2 and 3.

The potential for environmental change to site ponds from the proposed Area 2 capping was generally assessed to be minimal or negligible for most ponds, with perhaps some impact on Deep Pond (North) and Easement Pond. .

Table of Contents

Report on Qualitative Assessment of Surface Water Impacts
KIWEF Area 2 Closure Works
Kooragang Island

1. Introduction

This report presents the results of a qualitative assessment of surface water impacts undertaken for proposed capping associated with the former Kooragang Island Waste Emplacement Facility (KIWEF) Area 2 closure works at Kooragang Island, New South Wales (NSW). The assessment was commissioned in an email dated 14 June 2016 from Mr Grant Moylan of Hunter Development Corporation (HDC) and was undertaken in accordance with Douglas Partners Pty Ltd (DP) proposal NCL160390.P.001.Rev0 dated 6 June 2016.

It is understood that HDC propose to construct a low permeability cap over Area 2 as part of the closure works for the KIWEF site. Area 1 has already been capped and commencement of capping for Area 3 is scheduled for August 2016. The potential impact of the Area 1 and 3 capping on water and salinity levels of ponds which provide Green and Golden Bell Frog (GGBF) habitat was previously assessed by SMEC Australia Pty Ltd (SMEC) and Environmental Resource Management Australia Pty Ltd (ERM) with groundwater inputs from DP.

Due to the proximity of the Area 2 capping works to the habitat of the GGBF, a referral was submitted under the Environmental Protection and Biodiversity Conservation Act (EPBC). Subsequently a request for information (RFI) was received from the federal Department of Environment (DoE). In summary the RFI requested information including the following:

1. Relevant details and summary of modelling outcomes from the Port Waratah Coal Services Limited (PWCS) proposed Terminal 4 Project (T4) modelling undertaken by DP which indicated reduced impacts on Ramsar wetlands to the north of the site. The T4 development site comprises a wider area of KIWEF, including Areas 1 to 3 of KIWEF;
2. Characterisation of past and current water quality characteristics of ponds and other waters that would receive runoff from affected areas;
3. Detailed analysis (including predictive modelling where available) of likely changes to water quality in ponds and other receiving waters including pH, salinity, turbidity and contaminant levels.

Currently available predictive numerical modelling comprises the previous SMEC assessment undertaken specifically for the assessment of capping of the adjacent Areas 1 and 3 (Ref 17), as well as groundwater/surface water modelling undertaken by DP for the proposed T4 development (Ref 3). The T4 development is proposed to encompass Areas 1 to 3 of KIWEF and extending to the north, east and west and involve a more extensive capping area. However, it is not known if or when the T4 development will proceed.

This report presents a summary of relevant water level and quality monitoring, an assessment of the data and previous results of numerical modelling to provide an updated and site specific conceptual hydro-salinity model for the Area 2 KIWEF site in response to the above DoE RFI. The conceptual model has been used to provide a qualitative assessment of likely impacts of the proposed Area 2 capping on water and salinity levels of ponds which it is understood acts as GGBF habitat.

2. Scope of Work

The scope of work for DP for the assessment comprised the following:

- Desktop review, compilation and integration of data:
  - Review of the documents supplied by HDC, including previous reports by others, water quality laboratory and field testing and automated datalogger records;
  - Review of information held by DP relevant to the site, including results of water quality monitoring and groundwater modelling undertaken for the broader KIWEF site.
  - Integration of DP and HDC data to provide a series of time plots for various parameters including water levels, salinity, and other relevant key chemical parameters;
  - Combine and tabulate relevant chemical testing data and compare with environmental assessment criteria.
- Review and assessment of conceptual site model including:
  - Assessment of water level and water quality trends, qualitatively linking observed behaviour to processes expected to occur on the site;
  - Review previous conceptual model by SMEC (Ref 17);
  - Addition of qualitative detail on transient processes to the conceptual model, based on observed site processes and understanding gained from previous groundwater modelling of the site;
  - Consideration of the potential impact of diffusion of salinity upwards from the Estuarine Aquifer.
- Review of proposed capping:
  - Determination of relevant aspects of proposed capping including areas of capping, grades, drainage directions, pond areas and overflow levels/interactions;
  - Comparison of proposed capping with existing conditions;
  - Comparison of proposed capping with capping in Areas 1 and 3.
- Qualitative assessment of potential impacts, specifically:
  - Consideration of previously modelled impacts for Areas 1 and 3 and consideration of the proposed Area 2 capping works;
  - Consideration of any impacts observed from the limited monitoring undertaken since capping, with consideration of previously modelled impacts from proposed capping associated with the groundwater modelling undertaken for T4;
- Consideration of the need for additional more detailed modelling to satisfy DoE RFI.

3. Site Description

KIWEF is located on the central western part of Kooragang Island, to the west of Kooragang Coal Terminal and to the east of Ash Island. Kooragang Island is located on the lower reaches of the Hunter River and comprises an island about 10 km long by 3 km wide. The island was formed by the reclamation of a number of former islands, channels and mudflats using dredged sandy materials from the river. KIWEF has a total area of approximately 197 ha and comprises several allotments.

KIWEF was formerly a licenced waste disposal site, until surrender of the Environmental Protection Licence (EPL) 6437 on 8 December 2010.

The KIWEF site is predominately reclaimed land which has previously been used for disposal of industrial waste. It is a largely modified landscape dominated by bare ground, disturbed grassland and artificially constructed drainage depressions and ponds, which now support wetland communities.

The approximate KIWEF boundary (yellow) and sub-areas are shown in Figure 1.

Figure 1: Location of KIWEF (Source SIX Maps)

The geology at the KIWEF site is shown on the 1:100,000 scale regional geology map for Newcastle (Newcastle Coalfield Regional Geology, Sheet 9321, NSW Department of Mineral Resources). The map indicates that the natural soil underlying the waste fill materials comprises Quaternary alluvium underlain by Permian aged Tomago Coal Measures.

The Quaternary alluvium consists of fine to medium grained estuarine sediments with some gravel zones, overlain by fluvial sands with further fine grained estuarine deposits at the top of the natural profile. The Tomago Coal Measures form the bedrock beneath the soil profile and comprise shale, siltstone, sandstone, conglomerate and coal.

The hydrogeology is characterised by two aquifers: an upper unconfined aquifer within the fill strata ("Upper" or "Fill" Aquifer), and a lower semi-confined aquifer in the natural sands ("Lower" or "Estuarine" Aquifer). These two aquifers are separated by an aquitard generally comprising soft to firm natural silty clay.

The KIWEF site and surrounding area comprise a number of key water key water bodies as shown in Figure 2.

Figure 2: Summary of Key Water Bodies and Monitoring Locations

Site water bodies have been subject to various environmental and hydrogeological monitoring assessments including water level and quality monitoring. Data from these assessments, where available, has been used in this qualitative assessment.

4. Background

4.1 Green and Golden Bell Frog (GGBF) Studies

The Green and Golden Bell Frog (GGBF) is a protected species under State and Federal legislation and have been identified at the KIWEF site from numerous environmental studies. The studies have indicated the broader KIWEF site "has areas mapped to be significant habitat for the [GGBF] species" (Ref 13). The habitat generally comprises existing surface water ponds and the wetland areas north, east and west of the KIWEF site separated by the northern boundary railway line.

GGBF are known to be vulnerable to the chytrid fungus and research suggests that certain salinity levels are beneficial in retarding the effect of the fungus and GGBF mortality rates. Preferable salinity levels are also reported to vary depending on the life stages of the GGBF (i.e. tadpoles, adult frogs).

This assessment has comprised a review of existing salinity concentrations in ponds and groundwater at the KIWEF site. The data has comprised field screening results, laboratory testing and the results of automated salinity loggers (Electrical Conductivity, EC) installed at selected locations within the site.

Salinity comparison values adopted by SMEC (Ref 17) for the previous assessment have been utilised for this qualitative assessment and are summarised in Table 1. As discussed in Section 5.2.1, salinity is typically estimated in the field by measuring EC.

Table 1: Summary of Suggested Salinity (Electrical Conductivity) Comparison Values for KIWEF Surface Water Bodies (SMEC, 2013, Ref 17)

Adopted Lower Bound EC Comparison Value1 (µS/cm)	Adopted Middle Range EC Comparison Value 2 (µS/cm)	Adopted Upper Bound EC Comparison Value 3 (µS/cm)
1,650 *'Chytrid Protection Range'*	2,900 *'Tadpole Health Range'*	4,100 *'Adult Health Range'*

Notes:

1. Based on potential effect of chytrid fungal infection in GGBF
2. Based on potential effect of higher saline conditions of GGBF tadpoles
3. Based on potential effect of higher saline conditions in GGBF adults

EC – Electrical Conductivity

Based on the above, salinity levels expressed as EC in the range 1,650 to 2,900 µS/cm are considered "optimal GGBF habitat" (ERM 2015, Ref 14).

SMEC (Ref 17) also indicated that while research suggests that salinity appears to be the key driver of chytrid fungus control, water body temperature and heavy metals (copper and zinc) may also be factors. Information by Piotrowski et al (2004, Ref 16) and Australian Wildlife Health Network (2014, Ref 2) provided by HDC for the purposes of this assessment indicates that water body temperature can inhibit growth. If growth is inhibited, infection to GGBF may not be fatal. The effects of temperature ranges from References 2 and 16, based on prolonged exposure are summarised in Table 2. It is noted, however that temperature ranges are approximations only and have been used as indicative values for the purposes of this assessment. Research regarding the effect of EC, heavy metals and temperature are understood to be limited.

Table 2: Summary of Suggested Temperature Effects on Chytrid Growth

Temperature 1 (°C)	Effect on Chytrid Growth	Effect of Chytrid Infection
<10°C	Growth inhibited	Infection non-fatal
10-17°C	Slow chytrid growth	Infection may be fatal
17-25°C	Chytrid growth optimal	Infection may be fatal
25-28°C	Slow chytrid growth	Infection may be fatal
>28°C	Growth inhibited	Infection non-fatal

Notes to Table 2:
1 – Temperature ranges based on prolonged exposure

The suggested EC and temperature comparison criteria in Table 1 and Table 2 are shown against plots of temperature level, EC, temperature and rainfall in Appendix C and discussed further in Section 5.2.

4.2 Assessment for PWCS Terminal 4 Project

4.2.1 Overview

Numerous reports were prepared by DP for the proposed PWCS Terminal 4 (T4) project. The T4 site included most of KIWEF (excluding the NCIG rail loop) and hence a large proportion of the work is relevant to KIWEF. The most relevant of these reports are listed below:

- 49533.02-05 Groundwater Assessment, Proposed Terminal 4 Project, Feb 2012 (Ref 3);
- 49533.02-02 Contamination Assessment, Proposed Terminal 4 Project, Feb 2012 (Ref 4);
- 49533.02-06 Assessment of Remediation Options, Proposed Terminal 4 Project, Feb 2012 (Ref 5);
- 49533.08 Baseline Groundwater and Surface Water Monitoring, Proposed Terminal 4 Project, April 2012 (Ref 6);
- 49533.09 Landfill Closure Plan, Proposed Terminal 4 Project, May 2013 (Ref 7);
- 49533.11 Baseline Groundwater Monitoring, Rounds 1 to 4, Proposed Terminal 4 Project, July 2013 (Ref 10);
- 49533.12 Remediation Action Plan (Pre-Detailed Design), Proposed Terminal 4 Project, May 2013 (Ref 8);
- 49533.14 Assessment of Mitigation Measures for Groundwater Contamination, Proposed Terminal 4 Project, May 2013 (Ref 9);
- 49533.18 Background Water Monitoring, Six Month Event (July 2014), Proposed Terminal 4 Project, September 2014 (Ref 11).

Relevant information from the above has been used in this qualitative assessment, as presented in the following sections.

4.2.2 Soil Contamination

The fill profile of KIWEF Area 2 sub-areas K3, K5 and K7 contains predominantly coarse coal washery reject and slag, which are associated with an alkaline pH and elevated concentrations of metals (most notably manganese, copper and zinc). KIWEF also contains a number of soil contamination 'hot spots' due to localised and sporadic dumping of general wastes. Contaminants include PAH, TRH and metals.

The most significant contamination within KIWEF 'Area 2' is the Pond 5, in sub area K5, which contains hydrocarbons in the form of tar sludge and tarry oils. The T4 investigations found that the disposal of tar waste extended north of Pond 5, well into Pond 7.

The asbestos burial pits in sub-area K7 are known to contain lead dust, co-disposed with the asbestos in polypropylene bags. Area K7 capping is proposed to comprise a least three metres of general fill which is not required to be low permeability.

4.2.3 Groundwater and Surface Water Quality

4.2.3.1 Fill Aquifer

In the Fill Aquifer groundwater contaminant concentrations exceeding the ANZECC criteria (trigger values) for Slightly to Moderately Disturbed Ecosystems were recorded at several locations for parameters including PAHs, ammonia, cyanide and metals (As, Co, Cr, Cu, Mn, Ni, Pb, Zn, and Se). At one location benzene and toluene also exceeded adopted trigger values.

4.2.3.2 Estuarine Aquifer

In the Estuarine Aquifer groundwater contaminant concentrations exceeding the ANZECC criteria (trigger values) for Slightly to Moderately Disturbed Ecosystems were recorded at several locations for parameters including PAHs, ammonia, cyanide and metals (As, Co, Cr, Cu, Mn, Ni, Pb, Zn, and Se).

4.2.3.3 Surface Water

Surface water samples were collected from several water bodies in and around the T4 Project area at various times by different organisations. Laboratory analysis indicated some exceedances of the ANZECC (2000) Trigger Values for Slightly to Moderately Disturbed Ecosystems. Analytes with concentrations exceeding the adopted Trigger Values included metals (As, Cd, Co, Cr, Cu, Ni, Pb and Zn), nitrogen, phosphate, cyanide and pH. Contaminants with concentrations exceeding 10 times Trigger Values included metals (Cu, Pb and Zn) and nitrogen (8 surface water sampling locations).

4.3 SMEC/ERM Assessments for Stages 1 and 3

A numerical hydro-salinity model was developed by SMEC in 2013 (Ref 17) for the proposed capping and closure works at KIWEF. A daily time step model was developed, based on a conceptual hydro-salinity model also presented in the report (further presented in Section 6.1 of this report). The model used background data to establish initial conditions and then simulated conditions using a 100 year rainfall record and monthly average pan evaporation. Groundwater inputs were provided by DP in the form of steady state mass balances for groundwater flows for each pond, based on a modification of the groundwater model developed for the T4 assessment (Ref 12). Salinity levels in the ponds were tracked on a daily time strep as inflow/outflow to either surface or groundwater and also through concentration due to evapotranspiration from the ponds.

Ponds in the immediate vicinity of the capping were assessed and comprised BHP Wetlands, Blue Billed Duck Pond, Deep Pond, Easement Pond, Easement Pond South, K2 Pond, Long Pond and Windmill Road Open Channel. These ponds are shown on Figure 1 in Appendix D as provided by HDC.

The modelling provided extensive details on changes in periods for which the ponds stay dryer or wetter than for pre-capping. The results indicated that *"only measurable impacts in pond hydrology are expected in Long Pond and Windmill Road Open Channel, with negligible impacts (less than 10%) in the other ponds. For these two ponds the model results indicate that the ponds will generally become wetter, with a lower frequency of drying out and greater frequency of being full"* (Ref 17).

In terms of salinity impacts, SMEC indicated*: "For BHP Wetlands, Blue Billed Duck Pond, Deep Pond and Easement Pond South and K2 Pond, there are not expected to be any significant changes to salinity levels." "The results for Easement Pond and Long Pond, however indicate that the proposed capping works could have lower salinity values during wet conditions (as surface runoff does not have the saline leachate component that groundwater has)….." and "Under wet conditions (i.e. typically when the ponds are full after a rainfall event), Windmill Road Open Channel exhibits higher saline conditions … In addition, there will be a slight reduction (i.e. improvement) in the salinity levels…"* (Ref 17).

A summary of the SMEC report and key results was prepared by ERM in 2013 (Ref 13) in response to the Department of Sustainability, Environment, Water, Population and Communities (SEWPaC) RFI for the proposed Areas 1 and 3 KIWEF closure works. Table 3 below, extracted from the ERM report, provides a summary of the relative periods of low and high pond water levels in the context of potential impacts on the GGBF.

Table 3: Summary of Modelled Upper and Lower Water Levels for KIWEF Ponds[1] (Excerpt from ERM, Ref 13)

Pond	Percentage of Time Ponds Predicted to be Below Existing 20th%ile Standing Water Level [2]	Percentage of Time Ponds Predicted to be Below Existing 80th%ile Standing Water Level [3]
BHP Wetlands	21%	82%
Blue Billed Duck Pond	22%	84%
Deep Pond	19%	80%
Easement Pond	21%	73%
Easement Pond South	21%	83%
K2 Basin	22%	81%
Long Pond	4%	65%
Windmill Road Open Channel	1%	72%

1: From SMEC (2013)
2: % of post construction time when water would be shallower than the existing 20th%ile level
3: % of post construction time when water would be shallower than the existing 80th%ile level

Table 4 and Figure 3, extracted from the ERM (Ref 13) report provides an overall assessment of the risk of potential impact to GGBF due to the predicted changes to pond hydrology and salinity for the proposed capping of Areas 1 and 3 .

Table 4: Summary of Pond Hydrology Changes and Risk of Potential Impact (Excerpt from ERM, 2013, Ref 13)

Pond	Comments based on Tables 2.3 and 2.4	Potentially Significant Change in Wetting and Drying Regimes Against Thresholds for GGBF Habitat?
BHP Wetlands	Low water level events predicted to occur at a greater frequency every 1.3 years in comparison to existing every 1.5 years. Duration of dry events predicted to decrease by 5 days to an average of 97 days	No
Blue Billed Duck Pond	No change is predicted to the frequency of low water level events with duration predicted to increase by 6 days to an average of 134 days	No
Deep Pond	A small decrease to once in 2.2 years is predicted to the frequency of low water level events with duration predicted to decrease by 7 days to an average of 138 days.	No
Easement Pond	Above the high water level an additional 7% of the time. Low water level events are predicted to occur at a reduced frequency of every 1.7 years (compared to existing 1.6 years) although the frequency of wet events would change from 1.7 to 1.3 years ARI. The duration of low water events is not predicted to change, although high water events would slightly extend by 12 days.	No
Easement Pond South	Above the high water level would be reduced by 3%. No change is predicted to the frequency of low water events with duration of these events predicted to increase by 6 days to an average of 98 days.	No
K2 Basin	Low water level events are predicted to occur at a greater frequency every 1.2 years in comparison to existing every 1.5 years with low water duration predicted to decrease by 10 days to an average of 92 days. No change for high water conditions.	No
Long Pond	Significantly wetter. Low water events predicted to occur at a reduced frequency to every 5.2 years from existing 1.3 years ARI and the frequency of wet periods increase to once every 1 year from the current 1.5 years with duration of wet events extending by 10 days.	No
Windmill Road Open Channel	Significantly wetter with time below the identified low water level reduced by 19% with low water events no longer predicted to occur. No increase in frequency of wet periods with average duration increased by 9 days to 58.	No

Notes:

Shading indicates ponds expected to have measureable salinity reductions as inferred by SMEC (Ref 17) / ERM (Ref 13)

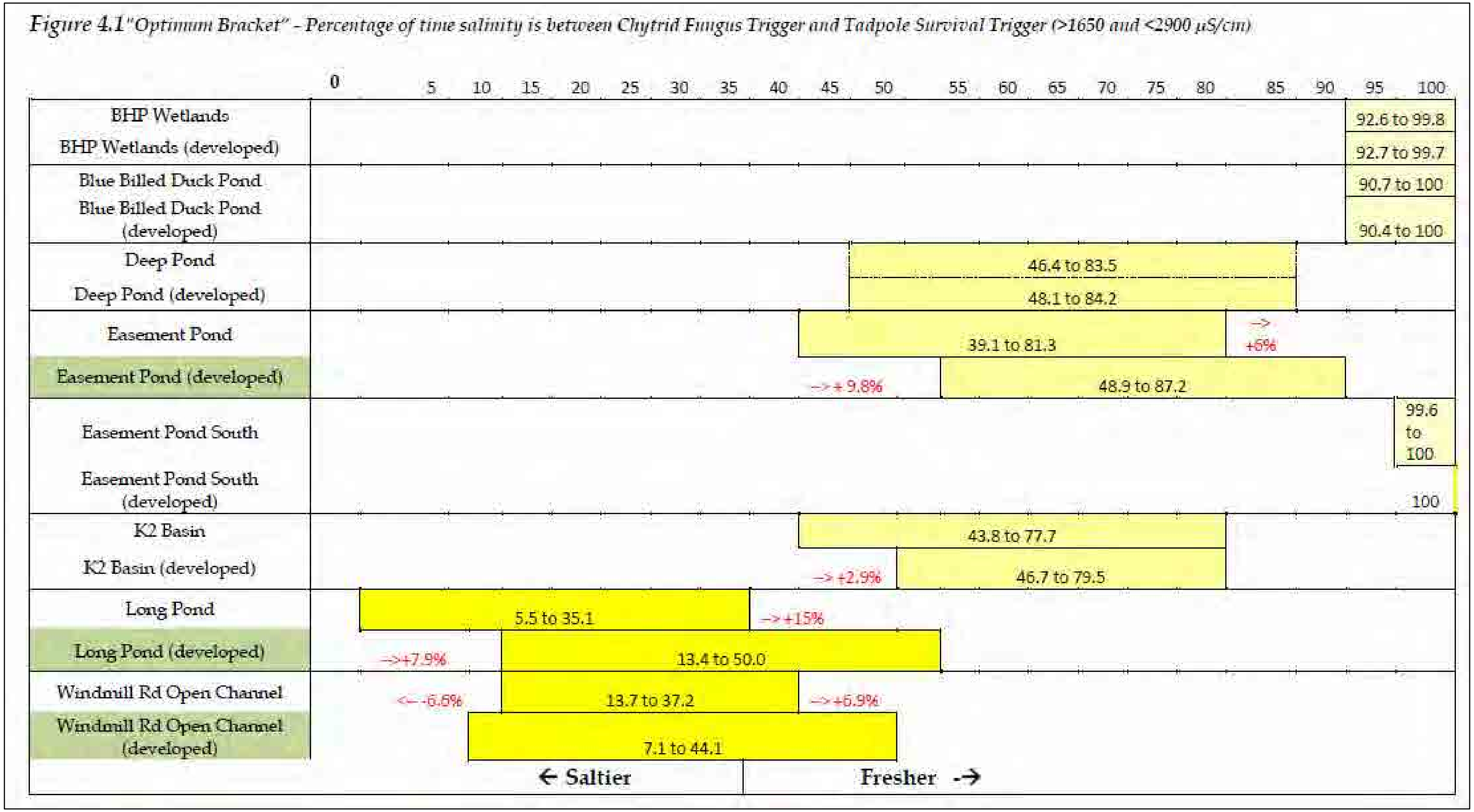


Figure 3: Percentage of Time Salinity is Optimum for GGBF and Predicted Changes (Excerpt from ERM, 2013, Ref 13)

With respect to salinity ERM (Ref 13) indicated the following:

"The SMEC (2013) hydro-salinity modelling results generally indicate changes in salinity that are expected to be minor when compared to the range of salinity conditions currently observed. The magnitude of the predicted changes in salinity regimes would be much less than 1-2% for important time categories in the majority of adjacent habitat ponds (refer Table 4.2, BHP wetland; Blue Billed Duck Pond; Deep Pond; K2 Basin; Easement Pond South).

Measurable salinity reductions are only expected in Easement Pond, Long Pond and Windmill Road Open Channel. A small increased risk of Chytrid effect has been identified in Easement Pond. The modelling identifies that the expected effects of changes in salinity in the ponds as a result of the capping work is not expected to be significant.

Based on model outputs, the capping design is confirmed as appropriate and beneficial in:

- *Separating water flow pathways (surface and groundwater) to optimise pond clean water sources;*
- *Enabling the collection and drainage of treated waters with relatively low salinity;*
- *Delivering freshwater into ponds (Long; Windmill Road Open Channel) that because of their recorded past salinities, do not appear to currently present valuable GGBF habitat;*
- *Having no discernible effect on the majority of adjacent ponds; and*
- *Promoting an integrated post-construction sustaining water cycle."*

5. Monitoring Data

5.1 Data Sources

The following data has been utilised for this assessment:

- **Water Level Data**
  - o Water level (depth), temperature and EC logger data collected by HDC for selected surface water ponds, including the depth of logger installation. The monitoring has been undertaken from May 2013 to May 2016, however, has not been continuous over this period.
  - o Groundwater and surface water level monitoring data undertaken for the proposed T4 development from November 2010 to April 2013 (Ref 3). The monitoring included automated water level and temperature monitoring in selected groundwater monitoring wells and key surface water ponds. Automated EC logging was also undertaken for seven water bodies in conjunction with level monitoring;
  - o Tide data for the Hunter River at Stockton Bridge for the full water level monitoring period November 2010 to May 2016 as provided NSW Government Public Works' Manly Hydraulic Laboratory;

- **Water Quality Data**
  - o KIWEF historical groundwater and surface water quality monitoring data which has been undertaken from 1999 to May 2016;
  - o Groundwater and surface water quality monitoring data undertaken for the proposed T4 development from November 2010 to April 2013;
- **Meteorological Data**
  - o Daily rainfall from at the PWCS' Kooragang Coal Terminal for the period November 2010 to May 2016, as provided by PWCS for the purposes of this assessment.
  - o Annual pan and mean annual rainfall data for the Bureau of Meteorology Williamtown station during the previous T4 groundwater assessment (Ref 3);

The monitoring locations are shown on Drawing 1 in Appendix D. The key water bodies and site features are shown in Figure 2, above.

5.2 Results of Monitoring

5.2.1 Automated Water Level and EC Monitoring

Water level monitoring has been undertaken by DP and HDC at the site for both the proposed T4 development (undertaken for PWCS) and the proposed KIWEF capping and closure works. Monitoring for the T4 development included both surface water and groundwater monitoring in the Upper Fill and Lower Estuarine Aquifers for the assessment of baseline conditions and trends in hydrogeology. The monitoring has been undertaken using automated pressure transducers (loggers) to record daily water level and temperature locations, typically half-hourly intervals.

Monitoring of EC was also undertaken for the T4 project from April 2012 to May 2013 using automated level, EC and temperature loggers. This monitoring was also undertaken for HDC by others from March 2013 to May 2016, however, this was limited to surface water bodies.

The summarised periods of automated water level, temperature and EC logging utilised in this assessment are summarised in Table 5.

Table 5: Summary of Datalogger Monitoring Locations in Surface Water Ponds and Groundwater (November 2011 to May 2016)

Site Feature / ID	Alternative ID	Nov 2010	Feb 2011	May 2011	Aug 2011	Nov 2011	Feb 2012	May 2012	Aug 2012	Nov 2012	Feb 2013	May 2013	Aug 2013	Nov 2013	Feb 2014	May 2014	Aug 2014	Nov 2014	Feb 2015	May 2015	Aug 2015	Nov 2015	Feb 2016	May 2016
Groundwater Wells																								
Well A04-U	-																							
Well A05-U	-																							
Well C05-U	-																							
Well A04-L	-																							
Well A05-L	-																							
Well C05-L	-																							
Surface Water																								
Easement Pond	SWDP4																							
FDF Pond	SWDP1																							
Deep Pond / Deep Pond A	SWDP2																							
Deep Pond / Deep Pond North	SWDP101																							
Rail Road Pond	SWDP7A																							
OEH Wetland 1	SWDP8																							
OEH Wetland 2	SWDP7																							
OEH Wetland 3	SWDP6																							
Swan Pond	SWDP5																							
Mosquito Creek	SWDP102																							
BHPB Wetland	SWDP103																							
Pond 11	SW Pond 11 / SWDP3																							
Windmill Road Open Channel	B02L																							
GH001S	-																							
Easement Pond South	-																							
K2 Pond	SWSMEC-K2																							
Long Pond	-																							
Deep Pond B	-																							
Pond K7	SWK7																							
Pond K7B	SWK7B																							
Railway Pond																								

Level & Temperature (DP T4 Project)
Level, Temperature & Electrical Conductivity (DP T4 Project)
Level & Temperature (HDC Assessment)
Level, Temperature & Electrical Conductivity (HDC Assessment)
Commencement of Area 1 K2 and K10 North Capping Construction Period (Oct 2014)
Completion of Area 1 K2 Capping (April 2015)
Completion of Area 1 K10 North Capping (May 2015)

Plots of water level (AHD), depth (m), EC, temperature and rainfall are included in Appendix C.

It is noted that information collected by DP for the T4 project is presented as reduced water levels to Australian Height Datum (AHD). HDC water level information is presented as both the estimated pond depth in metres and AHD. For this reason, the plots are separated for each data source. Furthermore, the data collection periods were generally undertaken at separate times.

It is noted that survey levels for B02L and Deep Pond B were not provided to DP.

The plots are presented on time scales that allow visual review of the trends for the plotted parameters. The information in Appendix C is summarised in Table 6.

Table 6: Summary of Water Parameter Plots Presented in Appendix C

Item	Data Locations	Period	Data Source	Appendix Figure No.
Groundwater Levels in Fill and Estuarine Aquifer versus Daily Rainfall	A04-U/L, A05-U/L, C05-U/L	Nov 2010 to June 2013	T4 (Ref 3)	C1
Surface Water Level versus Daily Rainfall	Generally all main KIWEF ponds and ponds north and west of the railway line	Nov 2010 to July 2013	T4 (Ref 3)	C2
Electrical Conductivity, Water Level/Depth, Temperature and Rainfall	SWDP2 Deep Pond / SWDP101 Deep Pond North	Nov 2010 to July 2012	T4 (Ref 3)	C3
	Deep Pond A / Deep Pond B	Dec 2015 to May 2016	HDC	C4
	SWDP4 Easement Pond	Nov 2010 to July 2013	T4 (Ref 3)	C5A
		Nov 2014 to Oct 2015	HDC	C5B
		Dec 2016 to May 2016	HDC	C5C
	Easement Pond South	Nov 2014 to Oct 2015	HDC	C6
	SWDP7A Railroad Pond	Nov 2010 to June 2013	T4 (Ref 3)	C7
	SWDP8 OEH Wetland 1	Feb 2011 to July 2013	T4 (Ref 3)	C8
	SWDP6 OEH Wetland 3	Feb 2011 to Dec 2011	T4 (Ref 3)	C9
	SWDP3 Pond 11	Nov 2010 to June 2013	T4 (Ref 3)	C10A
		Dec 2015 to May 2016	HDC	C10B
	Railway Pond	Dec 2015 to May 2016	HDC	C11
	Windmill Road Open Channel (B02L)	Dec 2015 to May 2016	HDC	C12A
		Mar 2013 to Mar 2014	HDC	C12B
		Nov 2014 to Mar 2015	HDC	C12C
	Eastern Ponds (GH001S)	Mar 2013 to Mar 2014	HDC	C13A
		Oct 2014 to May 2015	HDC	C13B
		Dec 2015 to May 2016	HDC	C13C
	SWDP103 BHP Wetland	July 2012 to July 2013	T4 (Ref 3)	C14A
		Oct 2014 to Nov 2015	HDC	C14B
	SMEC K2 Pond	May 2013 to May 2016	HDC	C15
	K7	Dec 2015 to May 2016	HDC	C16
	K7B	Dec 2015 to May 2016	HDC	C17
	Long Pond	Dec 2015 to May 2016	HDC	C18
Daily Rainfall Data	Port Waratah Coal Services' Kooragang Coal Terminal Weather Gauge	Nov 2010 to June 2016	T4 (Ref 3) [1]	C19

Notes:
(1) Daily rainfall data for July 2013 to June 2016 provided by PWCS for the purposes of this assessment

In general, the water level or depth data has been subject to correction for barometric effects, with the exception of Windmill Road Open Channel (B02L) and Eastern Ponds (GH001S) which have not been corrected. As discussed in Section 5.3.2, the automated EC loggers have not been compensated for temperature effects.

In general, water levels in ponds responded for rainfall events, particularly for large rainfall events, and those of consecutive days. Reponses to rainfall are discussed further in Section 5.4.5.1.

The observations of EC trends from the automated loggers are summarised in Table 7. The data has been compared against the EC and temperature assessment criteria outlined in Section 4.1.

Table 7: Summary of Results of Automated Logger Data

Surface Water Pond	Alternative ID	EC Measured by Logger (µS/cm)			Temp. Measured by Logger[1] (°C)				General Trends
		Minimum1	Maximum	Typical Range	Minimum	Maximum	Typical Range	Trends	
Deep Pond A / Deep Pond North	SWDP2 / SWDP101	1,500	5,500	1,000-4000 (Varies)	10	35	15-25	varies daily & seasonally	EC varies over a wide range. Logger becomes dry during monitoring period. EC typically decreases with rainfall.
Deep Pond B	-	500	3,100	1,000-2,000, (varies)	12	35	17-25	varies daily & seasonally	Decrease in EC particularly for large rainfall events. EC appears to vary daily with daily temperatures fluctuations.
Easement Pond	SWDP4	1500	7,500	1,700-4,000	9	35	10-25	varies daily & seasonally	Apparent increase in EC with rainfall for rainfall events greater than about 25 mm and may be due to installation of logger below sediment in a sump.
Easement Pond South	-	500	2,000	500-1,000	9	27	15-25	Varies daily & seasonally	Water level responses to rainfall apparent, however, EC range is fairly consistent over monitoring period remaining <1000µS/cm.
Pond 11	SWDP3	500	1,100	500-1,000	9	30	Highly variable	Varies daily & seasonally	Decrease in EC with large rainfall events. EC levels relatively constant at <1000 µS/cm
Railway Pond	-	1,500	3,500	1,800-2,800	14	33	18-28	Varies daily & seasonally	Decrease in EC with large rainfall events. EC varies with daily temperature effects, suggesting overestimate of EC variability. In general, EC is relatively constant at between 2,000-3,000 µS/cm. Slight increases in EC with decreasing water level depth
Windmill Road Open Channel	B02L	1,500	5,000	1,600-4,000 (varies)	10	29	15-23 18-20	For Nov 2014-Mar 2015, varies daily & seasonally For Mar 2013-Mar 2014no daily/seasonal variations	EC varies over a wide range. Varied response – generally decreases with rainfall, except for unusual response Jan 2016.
Eastern Ponds	GH001S	1,500	3,000	1,600-2,300	19	22	20-22	Temp. constant at 20-22 Mar 2013-Mar 2014 (logger possibly at greater depth over this period)	EC minimally responsive to large rainfall events (i.e. remains relatively constant). Increases in EC often coincide with temperature increases, however, temperature can lead to variations in the measured EC that is not representative of actual changes to salinity.
BHP Wetland	SWDP103	600	2,100	600-900	9	35	15-20	Varies daily & seasonally	Decrease in EC with large rainfall events. EC levels relatively constant at <1,500 µS/cm. Highest EC levels apparent at the lowest water levels.
K2 Pond	SWSMEC K2 Pond	400	7,500	1,000-5,000 (varies)	8	35	15-28	Varies daily & seasonally	EC variable over the monitoring period, and is higher for periods of higher water level. Decrease in EC with rainfall.
K7	-	1,000	2,500	1,000-1,500, varies	12	24	17-24	Varies daily & seasonally	Increase in EC with large rainfall events, decrease in EC with water depth decrease. EC appears to reach a maximum at about 2,300 µS/cm
K7B	-	1,500	4,500	(varies)	14	27	17-25	Varies daily & seasonally	Decrease in EC with large rainfall events, increase in EC with water depth recedes. EC higher than Pond K7
Long Pond	-	1,600	3,500	2,000-3,000	14	25	17-25	Varies daily & seasonally	Decrease in EC with rainfall. EC levels relatively constant at 2000-3000 µS/cm

Key	EC Range - Refer assessment range in Table 1, Section 4.1		Temperature Range – Refer assessment range in Table 2, Section 4.1		
<1,650 µS/cm			Temp.	Effect on Chytrid Growth	Effect of Chytrid Infection
	Adopted Lower Bound EC Comparison Value	*'Chytrid Protection Range'*	<10°C	Growth inhibited	Infection non-fatal (i.e. optimum)
1,650-2900 µS/cm			10-17°C	Slow chytrid growth	Infection may be fatal
	Adopted Middle Range EC Comparison Value	*'Tadpole Health Range'*	17-25°C	Chytrid growth optimal	Infection may be fatal
2900-4,100 µS/cm			25-28°C	Slow chytrid growth	Infection may be fatal
	Adopted Upper Bound EC Comparison Value	*'Adult Health Range'*	>28°C	Growth inhibited	Infection non-fatal (i.e. optimum)
>4,100 µS/cm					

Notes:

(1) – considers periods where EC has reduced due to pond drying out (i.e. likely inaccuracies in logger measurement)

As discussed, in Section 5.4.4, ponds north of the railway line including Swan Pond, OEH Wetlands 1 to 3 and Rail Road Pond are essentially hydraulically isolated from the ponds within the rail loop (as shown by T4 modelling (Ref 3)). These ponds have not been considered in any detail in this assessment as the salinity is not expected to be influenced by capping within the main KIWEF site.

5.2.2 Typical Ranges of Field Parameters

The results of field testing undertaken by DP for the T4 assessment (Ref 3) are presented in Table 8.

Table 8: Surface Water Body Field Parameters (DP, 2012, Ref 3)

Surface Water Body	8/11/2010		3/2/2011		28/2/2011		12/5/2011		1/11/2011	
	pH	EC (µS/cm)	pH	EC (µS/cm)	pH	EC (µS/cm)	pH	EC (µS/cm)	pH	EC (µS/cm)
Swan Pond (SWDP5)	7.6-8.4	22,900-43,700	7.9-8.1	67,900-76,200	8.0-8.7	68,400-73,400	8.4	56,000	8.1	25,500
Deep Pond (SWDP2)	7.8	1,020	-	-	8.6	9,300	8.1	5,500	8.3	2,100
BHP Wetland (SWDP103)	7.8	1,010	-	-	-	-	-	-	-	-
Pond 10	-	-	-	-	-	-	8.2	-	-	-
Pond 11 (SWDP3)	8.5	1,720	-	-	9.2	3,800	8.6	1,900	8.8	800
Pond 12	-	-	-	-	-	-	8.3	11,000	-	-
K7 Ponds	8.4-9.7	500-1,360	-	-	-	-	-	-	-	-
Easement Pond	7.6-8.4	950-1,890	-	-	8.9	3,800	8.8	2,200	7.5	1,500
FDF Pond (SWDP1)	7.9	4,900	-	-	-	-	7.9	10,000	-	-
Railway Pond	10.1	2,180	-	-	-	-	8.8	3,300	-	-
Rail Road Pond (SWDP7A)	-	-	8.6	14,200	-	-	-	-	8.0	2,500
OEH Wetland 1 (SWDP8)	8.4	11,000	7.4	48,000	7.8	15,600	8.7	5,500	7.5	1,500
OEH Wetland 2 (SWDP7)	7.3-8.0	1,870-4,860	7.4-8.3	34,000-48,000	8.1	49,200	8.3	30,000	-	-
OEH Wetland 3 (SWDP6)	7.7-7.9	1,760-8,540	7.4-8.1	29,800-43,600	8.4	34,700	7.6	17,000	7.6	5,050
Hunter River, South Arm (upstream)	-	-	7.6	57,000	8.1	56,200	-	-	-	-
Hunter River, South Arm (downstream)	9.0	50,800	-	-	-	-	-	-	-	-
Mosquito Creek (Moscheto Channel)	7.8	10,600	7.5-7.6	42.0-44.5	-	-	-	-	-	-
Ponds in Between Railway and OEH Wetlands	7.6-8.0	1.83	7.8-7.9	6.44-47.7	8.8	6.4	-	-	-	-

Notes to Table 8:

EC – Electrical Conductivity (µS/cm)

Where ranges are presented these are for measurements taken at different locations around the perimeter of the water bodies.

- Not Tested

Table 8 indicates the following with regard to relative salinity levels in various ponds:

- For the ponds to the north and west of the site the salinity levels are relatively high, at times approaching that of the Hunter River;
- The salinity in Deep Pond has been observed to fluctuate over a large range;
- Pond 11 seems to have a salinity consistently lower than most of the surrounding ponds including the adjacent Deep Pond;
- Railway Pond and Easement Pond has an intermediate salinity ranging from about 1,000 to 3,300 µS/cm;
- Some ponds indicated obvious variable salinity, increasing with depth, including Easement Pond.

Key water quality parameters and laboratory testing data for KIWEF ponds is shown in Table 9, as presented by ERM (Ref 13).

Table 9: Summary of Key Water Quality Parameters for KIWEF Ponds – 2006 to 2013 (Adapted from ERM, 2013, Ref 13)

Surface Water Body		Monitoring Period	pH	DO (% DO at 25°C)	EC (µS/cm) – Full Monitoring Period	EC (µS/cm) – More Recent Data*	Turbidity (NTU)	Total Suspended Solids (mg/L)	Total Nitrogen (mg/L)	Total Phosphorous (mg/L)	Total Copper (mg/L)	Total Zinc (mg/L)
ANZECC Guideline Value			7.0 to 8.5		NC	NC	50	NC	0.3	0.03	0.0013	0.016
BHP Wetland	10%ile	6/09/2006 – 25/10/2012	7.3		723	-	1	5	0.3	0.02	0.0010	0.003
	90%ile		9.2		1,424	-	45	54	2.7	0.17	0.0033	0.015
	Avg		6.0	117%	1,116	-	21	38	1.4	0.13	0.00175	0.006
Blue Billed Duck Pond	10%ile	29/11/2002 – 14/12/2012	8.2		845	-	3	7	0.8	0.04	0.0010	0.005
	90%ile		9.5		1,380	-	35	64	2.3	0.7	0.0060	0.055
	Avg		8.8		1,166	-	14	23	1.4	0.3	0.0036	0.041
Deep Pond	10%ile	17/11/1981 – 14/12/2012 (13/08/1997 – 14/12/2012)	7.8		1,900	1,752	2	4	0.8	0.03	0.0010	0.006
	90%ile		8.5		27,930	6,252	42	47	4.2	0.96	0.0300	0.151
	Avg		8.7		10,524	3,659	15	26	2.4	0.32	0.0125	0.064
Easement Pond	10%ile	20/06/1996 – 25/05/2007 (22/03/2006 – 14/12/2012)	7.5		2,038	2,010	1	5	0.6	0.02	0.0010	0.005
	90%ile		9.0		4,544	3,900	13	19.2	1.8	0.12	0.0200	0.044
	Avg		8.3		3,978	2,910	6	10	1.1	0.06	0.0191	0.021
Easement Pond South	10%ile	8/03/2012 – 14/12/2012	7.9		481	-	5	7	0.8	0.02	0.0010	0.005
	90%ile		8.3		881	-	79	62	1.5	0.22	0.0034	0.023
	Avg		8.1	75%	700	-	34	37	1.1	0.11	0.0018	0.011
Eastern Pond	10%ile	27/02/2012 – 11/01/2013	-	-	2,710	-	5	-	0.9	0.052	0.005	0.007
	90%ile		-	-	6,790	-	24	-	2.5	0.068	0.005	0.044
	Avg		-	-	4,750	-	15	-	1.8	0.06	0.005	0.024
K2 Pond	10%ile	13/08/1997 – 15/04/2012	7.5		1,554	-	-	15	-	0.32	0.004	0.053
	90%ile		8.8		5,928	-	-	648	-	1.08	0.630	0.099
	Avg		8.1	112%	3,431	-	-	240	-	0.67	0.0273	0.055
Long Pond	10%ile	4/05/1990 – 14/12/2012 (15/03/1999 – 14/12/2012)	7.8		2,945	2,945	3	2	0.4	0.05	0.0010	0.005
	90%ile		9.3		29,900	10,565	239	270	7.6	0.87	0.0240	0.193
	Avg		8.5	110%	11,166	6,332	71	48	3.2	0.35	0.0085	0.082
Windmill Road Open Channel	10%ile	13/08/1997 – 25/10/2012	7.4		3,600	-	16	13.1	0.9	0.08	0.0029	0.005
	90%ile		9.4		16,500	-	16	29.9	0.9	0.08	0.0181	0.325
	Avg		8.5	115%	3,047	-	16	21.5	0.9	0.08	0.0105	0.137

Notes to Table 9:

DO – Dissolved Oxygen

EC – Electrical Conductivity

NTU – Nephelometric Turbidity Unit

5.2.3 Green and Golden Bell Frog (GGBF) Key Habitat

GGBFs and their habitats have been identified within the KIWEF site and the surrounding wetland areas in both recent investigations and historically. For the KIWEF site the mapped habitat areas comprise man made ponds that have formed from the historical filling at the site. The combined records of recorded GGBFs and mapped habitat areas for KIWEF and the broader site are shown in Figure 4 and Figure 5 with reference to the proposed capping areas as presented by ERM (2015, Ref 14).

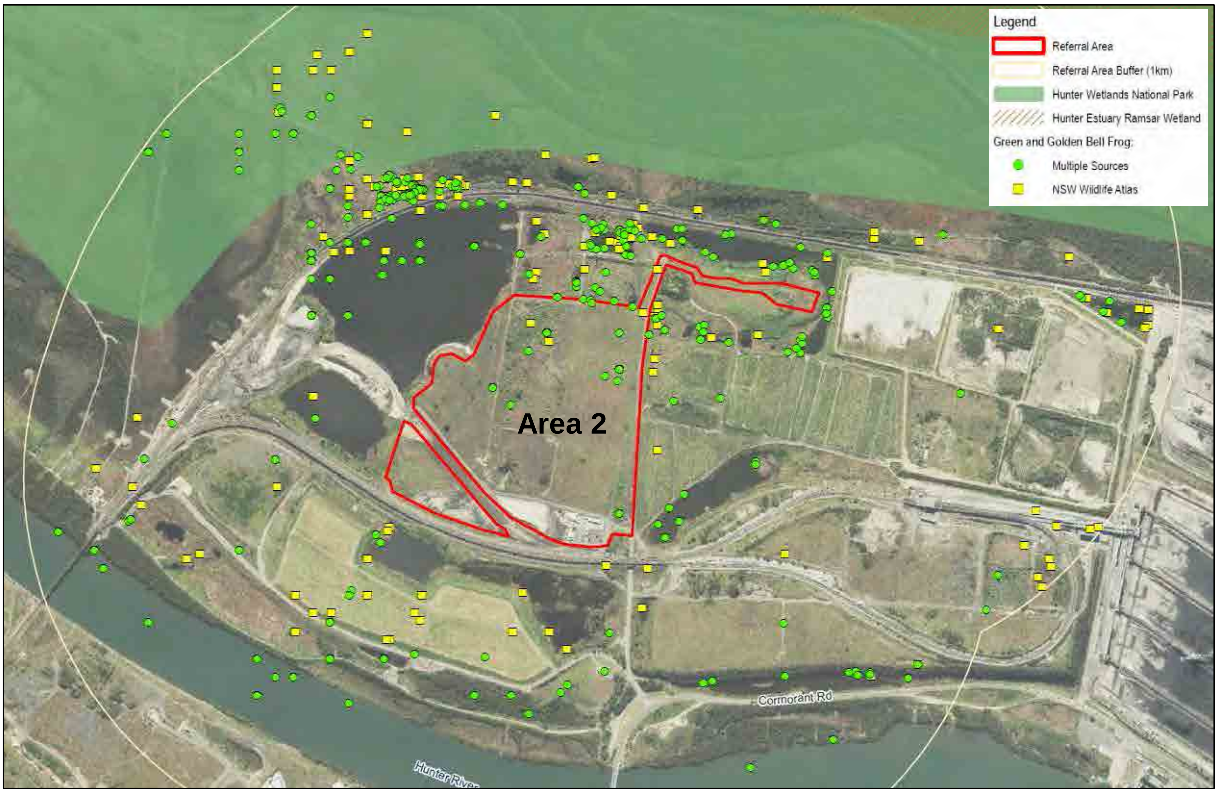


Figure 4: GGBF Occurrences (Adapted from ERM 2015, Ref 14)

Figure 5: GGBF Breeding Habitat Areas (Adapted from ERM 2015, Ref 14)

From Figure 4 and Figure 5 , the primary locations of the GGBF habitats and sightings is for ponds north-west to north-east of the proposed Area 2 capping works.

It is understood that capping will not be undertaken over the existing ponds and will be subject to environmental buffers, typically at 30 m setback distances from ponds. The proposed zones are shown in Figure 6.

Figure 6: Environmental Buffers from Mapped GGBF habitat (Image provided by HDC, 2016)

5.2.4 Water Chemistry

The results of historical water quality testing at a variety of sampling locations across the site, from surface water and groundwater in the Fill and Estuarine Aquifers have been plotted on a piper diagram as shown in Figure 7. For the Estuarine Aquifer the results have been split into wells screen in the upper and lower sections of the Aquifer. For the surface water the results have been split into those from the internal ponds and those from the tidal zone, mostly along the Hunter River. The Piper diagram provides a graphical representation of the distribution of the major cations (Calcium, Magnesium, Sodium and Potassium) and anions (Sulphate, Chloride and Bicarbonate) in each of the samples. The distribution can be used to infer source and relationship between water types.

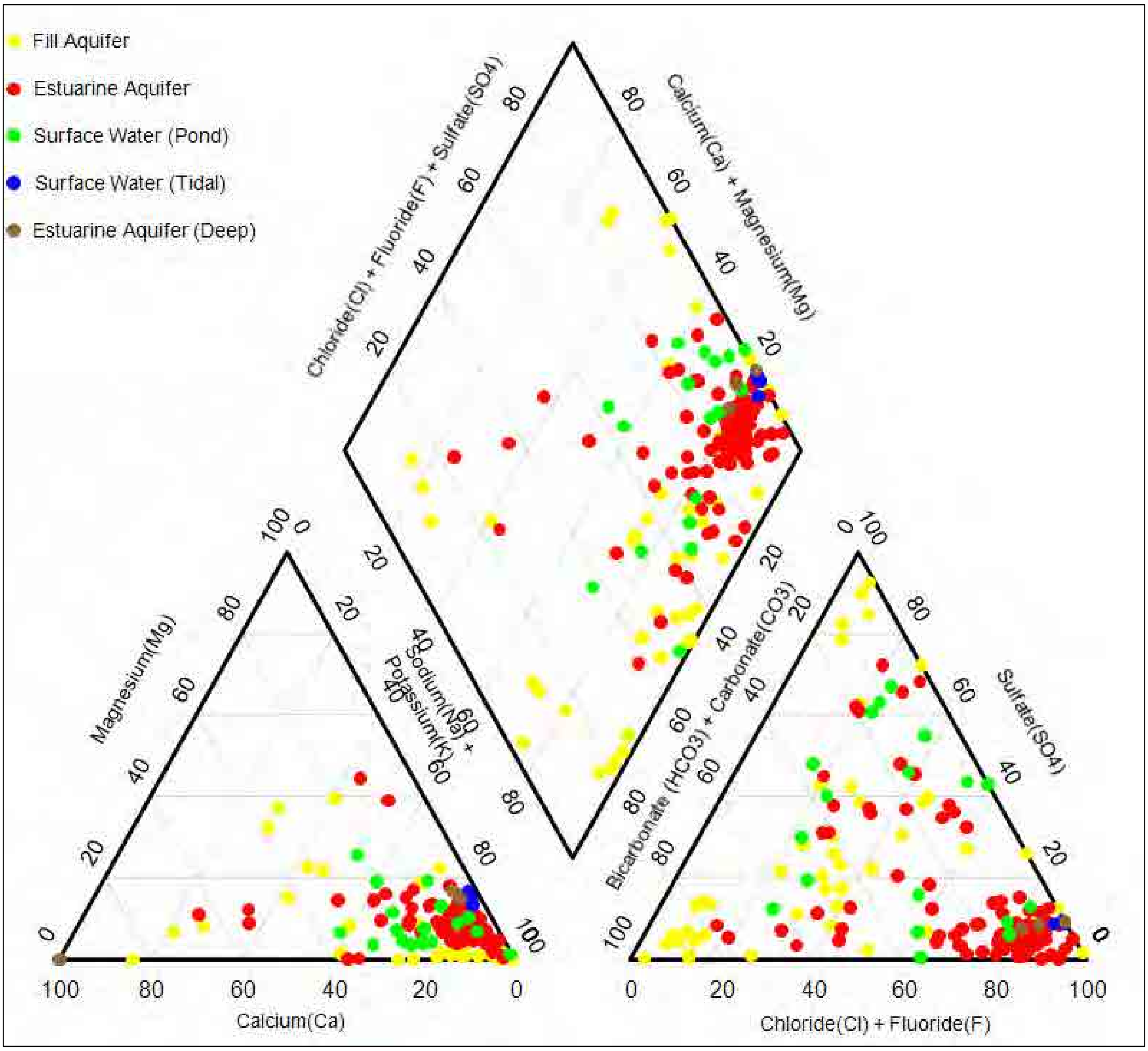


Figure 7: Piper Diagram (Tri-Linear) of Cations and Anions

The pertinent results shown in Figure 7 are as follows:

- The surface water from the tidal zone indicated a tight cluster with a strong bias towards sodium and chloride (Na-Cl), however, also with some calcium and sulphate;
- The Estuarine Aquifer is generally strongly sodium and chloride (Na-Cl) driven. The results from the deeper parts of the aquifer indicated a cluster which plots close to the surface tidal waters, consistent with the Estuarine origins of the formation. There are selected results that fall outside the Na-Cl cluster with a wider ionic distribution and these are from the upper parts of the aquifer and are likely to have been influenced by the leakage of the Fill Aquifer and surface waters from overlying aquifers;
- The Fill Aquifer water show the greatest scatter of ionic distribution. The cations are generally higher in sodium with a general scatter of the anions. The scatter of results is not surprising given the variability in fill materials placed on the site;

- The distribution of the surface water is similar to the Fill Aquifer but with much less scatter and more strongly favoured towards sodium. The results suggest a reasonably strong association with the Fill Aquifer and probably some influence from the former estuarine environment in the base of many of the ponds.

It is noted that while a significant amount of water quality information has been collected at KIWEF and surrounding sites, only limited data was available for ionic composition. The monitoring locations utilised for Figure 6 are shown on Drawing 1 in Appendix D.

5.2.5 Summary of Contamination and Comparison with ANZECC Marine

The monitoring data provided by HDC for surface and groundwater (Fill Aquifer) has been graphed and analysed for key parameters. The data covers the period 1999 to 2016, although for some parameters there are data gaps. The graphs are presented in Appendix B and include the adopted ANZECC 2000 trigger values (where available) for reference. The locations of monitoring wells are shown on Drawing 1 in Appendix D.

The adopted trigger values adopted are based on ANZECC (2000), 'Australian and New Zealand Guidelines for Fresh and Marine Water Quality' (Ref 1). Given the proximity of the site to the Hunter River and the identified ecological receptors, the trigger values are based on ANZECC 2000 guidelines for marine waters for slightly to moderately disturbed systems. These guidelines typically providing a general protection level of protection of 95% of species. In some cases where high reliability values are not available, low reliability values reported in ANZECC 2000 were adopted.

Table 10 presents an assessment of the number of exceedances of the adopted trigger values, expressed as a percentage of total samples tested, for the parameters that have ANZECC 2000 criteria. They are also separated into surface water and groundwater (Fill Aquifer) categories.

Table 10: Exceedances of Adopted ANZECC (2000) Trigger Values

Parameter	Adopted Trigger Value (mg/L)	Surface Water		Groundwater (Fill Aquifer)	
		Number of Results	% Results that Exceed Trigger Value	Number of Results	% Results that Exceed Trigger Value
pH	8.0 - 8.4	100	78.0	148	89.2
Cyanide (total)	0.004	98	37.8	145	86.9
Cyanide (free)	0.004	41	2.4	73	54.8
Cyanide (WAD)	0.004	18	50.0	35	68.6
Molybdenum	0.023	99	65.7	136	36.0
Chromium	0.0044	97	49.5	141	73.8
Lead	0.0044	98	24.5	133	30.1
Manganese	0.08	82	61.0	116	31.0
Mercury	0.0001	82	2.4	119	4.2
Zinc	0.015	82	58.5	117	34.2
Ammonia	0.91	100	5.0	150	70.0
Phenols	0.4	100	0.0	128	0.0
Naphthalene	0.05	100	0.0	150	3.3
Phenanthrene	0.0002	100	17.0	150	56.0
Anthracene	0.00004	100	97.0*	150	100.0*
Fluoranthene	0.001	100	0.0	150	8.0
Benzo(a)pyrene	0.0002	100	14.0	150	19.3

Notes to Table 10:
* ANZECC criterion below laboratory detection levels resulting in apparent exceedance of Trigger Value

It can be seen that exceedances of ANZECC trigger values in both surface waters and groundwater are common at KIWEF for most parameters, notably pH, cyanide, molybdenum, chromium, manganese and zinc. For some parameters the high proportion of exceedances is a reflection of very low ANZECC trigger values.

Additional surface water monitoring data reported by SMEC (Ref 17) included copper and nickel (raw data not provided to DP, hence not included in the foregoing assessment) which indicates that these two metals also commonly exceed the adopted ANZECC trigger values.

Reference to the graphs further indicates that the characteristics of surface water and groundwater are similar, with the exception of ammonia which has a high proportion of exceedances in groundwater but a low proportion in surface water. Exceedances of PAH compounds (naphthalene, phenanthrene, anthracene, fluoranthene and benzo(a)pyrene) also appear to be more common in groundwater compared to surface water but the differences are less pronounced.

5.3 Interpretation of Monitoring Results

5.3.1 Thermal and Salinity Processes

Surface water can be subject to various physical processes which lead to variations in both temperature and salinity with depth. One key process is stratification.

Essentially, the shallow water can be heated by sunlight making it less dense than the water below and allowing it to float, discouraging mixing with the underlying water leading to thermal stratification of the water column. The upper layer is often called the Epilimnion and can be subject to mixing as well as daily fluctuations in temperature due to the day/night cycle. It would be expected that BBGF would generally inhabit the Epilimnion. The lower layer is called the Hypolimnion which is at a lower and more constant temperature and may not fully develop in shallow ponds. There is also a transition zone between the two layers. The concepts are shown in Figure 8.

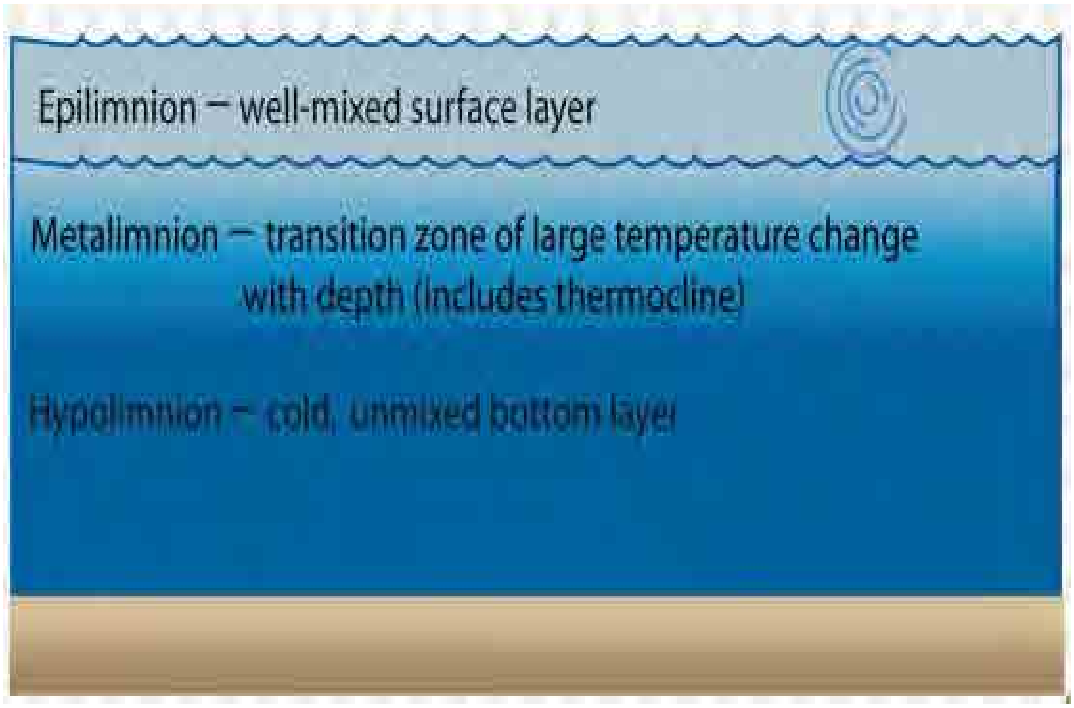
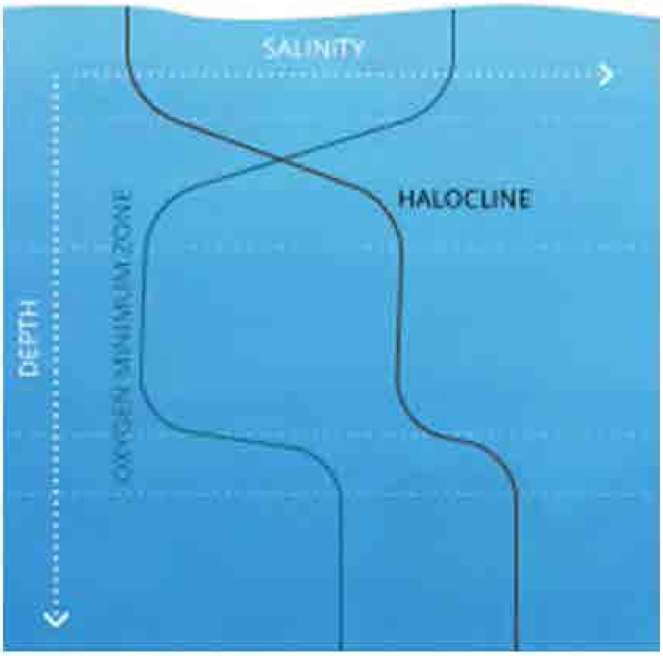


Figure 8: Thermal Stratification (Queensland Government, 2016, Ref 18)

Stratification can easily be disrupted by various processes including wind and water inflows, especially in shallow ponds. Thermal stratification can also be seasonal with clearer delineation between layers in the summer and potential "turnover" in spring / autumn leading to mixing of the water column.

Following a similar principal, stratification can also occur with salinity. Stratification can occur when water of different salinity enters a pond, such as can occur from fresher runoff entering the surface or more saline groundwater inflow occurring at depth. The Halocline is the transition zone between the less saline shallower water and the deeper more saline water as shown in Figure 9 and Figure 10. The salinity and temperature stratification often coincide.



Vertical stratification due to salinity. Deeper water has a greater density and higher salinity than the surface water.

Figure 9: Vertical Stratification (Fundamentals of Environmental Measurements, 2016, Ref 15)

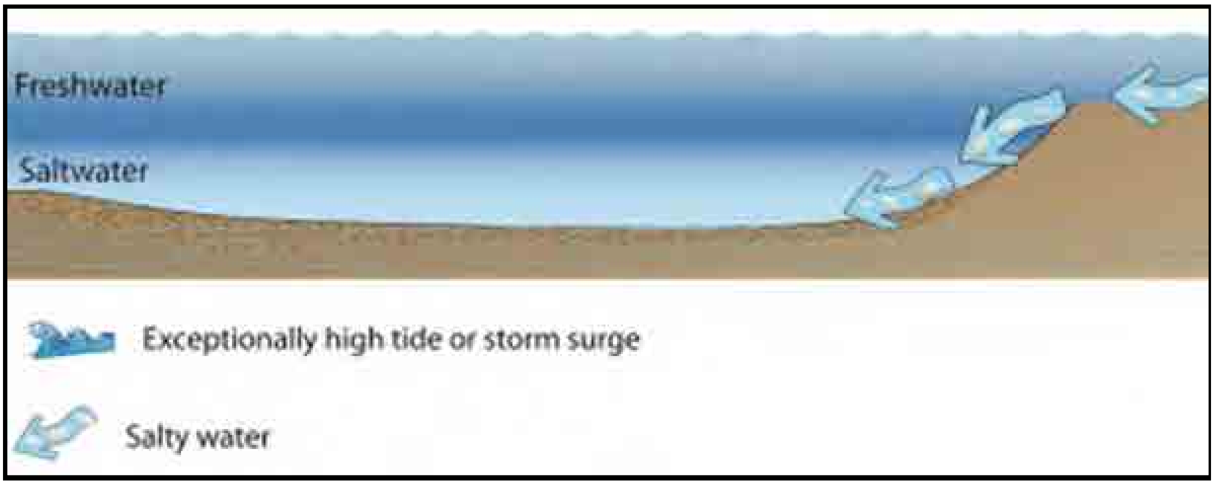


Figure 10: Vertical Salinity Stratification (Queensland Government, 2016, Ref 18)

Therefore when low salinity rainfall or surface runoff enters a pond it will typically have a diluting effect, reducing the salinity, however, depending on the presence of stratification the effects may be limited to the near surface water. Lowered water levels due to evaporative losses will typically lead to an increase in the salinity, with the effect initially being more prominent in the shallower water. However as the depth of water decreases, the stratification will no longer be maintained resulting in a relatively uniform salinity with depth. If the pond dries out the salinity will increase to the point that the salt precipitates on a dry surface.

5.3.2 Temperature Effects on Electrical Conductivity

Salinity is typically estimated in the field by measuring electrical conductivity (EC). EC can be measured using a portable meter or by installing automated loggers. The relationship between salinity (total dissolved salts) and electrical conductivity (EC) is typically about TDS (mg/L) = 0.65 EC (µS/cm), however, the correlation depends on the ionic composition and salinity of the water. The estimate is therefore approximate only.

EC varies with temperature, with changes in temperature of 1°C having up to 2% to 4% influence on EC. Most salinity loggers compensate for temperature, normalising the EC to 25^{o}C. This normalised salinity is also called specific conductance. If a correction is not made then the variations in temperature can lead to variations in the measured EC that is not representative of actual changes to salinity. This occurrence is shown in Figure 11.

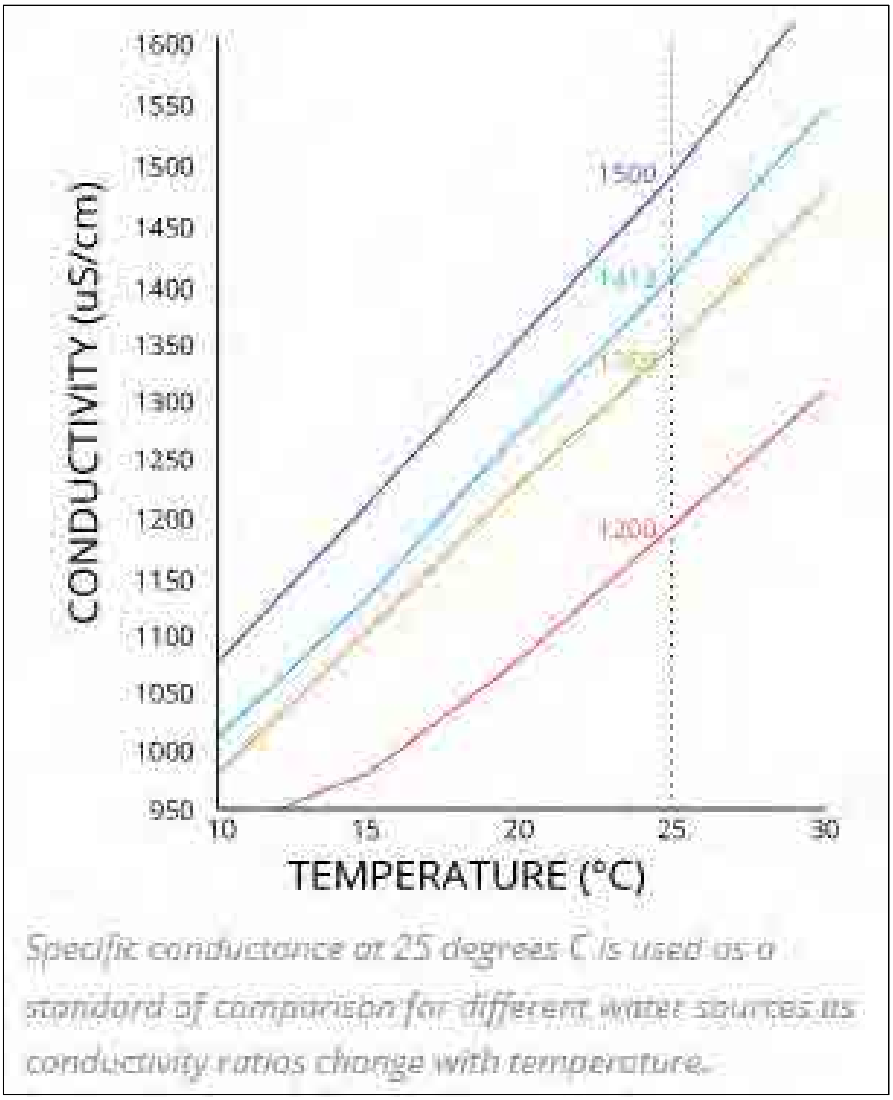


Figure 11: Relationship Between EC, Temperature and Specific Conductance (Fundamentals of Environmental Measurements, 2016, Ref 15)

5.3.3 Logger Depth

As can be inferred from the processes of thermal stratification, salinity stratification and EC variation due to temperature, the depth at which a logging instrument is installed in the water column can influence the readings. Loggers are typically installed at a fixed elevation above the base of the pond and therefore their depth within the water column will vary with the overall elevation of the water surface. A shallow logger may be measuring salinity and temperature above any thermocline/halocline with a deeper logger measuring the lower colder and more saline water below the thermocline/halocline. At times the logger may be exposed above the water line.

Variations in the water level may result in the logger transitioning across different layers of stratification and this needs to be taken into account in assessing the results. Also, it is DP's experience that the accuracy of the loggers reduces with the depth of water with artificial fluctuations in the response becoming more pronounced.

A summary of the depths of the installed HDC loggers relative to the base of the pond and the water surface is shown in Table 11.

Table 11: Depth of Installation for HDC loggers for August 2015 to May 2016

Location	Logger Install or Download	Depth of water above logger (m)	Depth of logger above sediment (m)	Approx depth of pond water - "water to sediment" (m)	Base Level of Pond (AHD)
SWSMEC K2	19/08/2015	0.3	0.2	0.5	0.56
	3/12/2015	0.21	0.07	0.37	
	17/05/2016	0.3	0.16	0.46	
SWDP103 / SW Pond 11	18/11/2014	0.5	0.18	0.68	1.10
	25/11/2015	0.7	0.17	0.87	
	3/12/2015	0.65	0.19	0.84	
	17/05/2016	0.6	0.19	0.79	
Easement Pond (SWDP4)	18/11/2014	0.64	**-0.07***	0.57	0.78
	17/10/2015	1.49	**-0.07***	1.42	
	1/12/2015	0.74	0.09	0.83	
SW K7B	3/12/2015	0.78	0.17	0.95	1.19
	17/05/2016	0.63	0.15	0.78	
SWK7	3/12/2015	0.67	0.24	0.91	1.50
	17/05/2016	0.43	0.24	0.67	
Railway Pond	3/12/2015	0.27	0.22	0.49	0.83
	17/05/2016	0.24	0.22	0.46	
Long Pond	3/12/2015	0.47	0.46	0.93	0.01
	17/05/2016	0.47	0.46	0.93	
Eastern Ponds (GH001S)	3/12/2015	0.34	**-0.12***	0.22	1.79
	17/05/2016	0.26	**-0.12***	0.14	
Easement Pond South	18/11/2014	0.47	0.17	0.64	1.33
	17/10/2015	0.66	0.17	0.83	
Deep Pond B	3/12/2015	0.35	0.07	0.42	-
	17/05/2016	0.35	0.07	0.42	
Deep Pond A	3/12/2015	0.43	0.52	0.95	0.84
	17/05/2016	0.41	0.52	0.93	
Windmill Road Open Channel (B02L)	25/11/2015	0.55	0.13	0.68	-
	3/12/2015	0.49	**-0.1**	0.39	
	17/05/2016	0.38	**-0.1**	0.28	

Notes:
***** Negative depth indicates logger installed below base of pond level

Table 11 indicates that the loggers are generally installed within about 0.3 m of the base of the ponds. Loggers in B02L, SWDP4 and GH001S seem to have been installed below the base of the ponds, presumably in a sump constructed of slotted PVC screen for some or part of the monitoring period. Loggers in Deep Pond A and Long Pond are about 0.5 m above the pond bases.

5.4 Discussion of Monitoring Results

5.4.1 Tide

Tidal data recorded by Manly Hydraulic Laboratory at Stockton Bridge for the full monitoring period of November 2010 to June 2016 is shown on Figure C19 in Appendix C. The monitoring site is located approximately 3.6 km south-east of the western boundary of KIWEF site and measures tide levels for the Hunter River (North Arm) in 15 minute intervals.

The levels measures for the period 1 November 2010 to 1 June 2016 are summarised as follows:

- Minimum tide level: -0.999 AHD;
- Maximum tide level: 1.374 AHD;
- Average tide level: 0.049 AHD.

The tide data has been plotted against selected ponds as included in Appendix C. As discussed, in Section 5.4.5.1, there was no evidence of tidal effects for ponds located within the main KIWEF site (i.e. ponds are essentially hydraulically isolated from the Hunter River).

5.4.2 Rainfall

Daily rainfall from at the PWCS' Kooragang Coal Terminal for the full monitoring period of November 2010 to June 2016 is shown on Figure C18 in Appendix C. The maximum rainfall for the period was 121.8 mm on 21 April 2015. The rainfall data has been provided by PWCS for the purposes of this assessment only.

A review of rainfall and response data for the T4 assessment indicated a better correlation for rainfall data than compared to Bureau of Meteorology weather stations at Nobbys-Newcastle (8 km, south-east) and Williamtown (13 km, north-east).

Mean annual pan evaporation and mean annual rainfall data was used by DP for the T4 assessment (Ref 3) as this was the closest available location.

5.4.3 Groundwater

5.4.3.1 Fill Aquifer Groundwater Heads

The results of groundwater level monitoring undertaken at wells A04-U, A05-U and C05-U, screened in the unconfined Fill Aquifer, from November 2010 to May 2013 are shown on Figure C1 in Appendix C. The pertinent observations are as follows:

- Groundwater levels in the Fill Aquifer respond sharply to rainfall due to infiltration of rainfall. Some locations respond more to rainfall than others, generally due to variations in the specific yield of the soil as well as the amount of infiltration, which is related to the slope of the ground and the permeability of the soil;
- The water levels generally recede quickly following rainfall and then slow, the recession becoming near linear over time;

- Groundwater levels are higher than the Estuarine Aquifer especially following rain, however following periods of prolonged dry weather the heads in some locations approach those in the underlying Estuarine Aquifer;
- The Fill Aquifer monitoring predates any surface capping.

5.4.3.2 Estuarine Aquifer Groundwater Heads

The results of groundwater level monitoring undertaken at wells A04-L, A05-L and C05-L, screened in the semi-confined Estuarine Aquifer, from November 2010 to May 2013 are shown on Figure C1 in Appendix C. The pertinent observations are as follows:

- Groundwater heads are always less than Fill Aquifer generally between about 0.8 AHD and 1.2 AHD;
- Generally less response to rainfall than for Fill Aquifer;
- Recession rate is slower than for the Fill Aquifer;
- Sub-daily fluctuations occur in response to tidal fluctuations in river. Monthly variations in groundwater levels occur in response to rolling average tidal levels;
- The increased tidal response compared to the Fill Aquifer is due to the Estuarine Aquifer being confined and having a significantly lower storage. The Estuarine Aquifer also has a more direct hydraulic connection to the river.
- Small but clear responses to even small rainfall events are evident. The results of analytical modelling undertaken for the proposed T4 project (Ref 3) indicated that this is due to the indirect effect of rainfall leading to changes in River levels which then affect the groundwater heads, in a similar manner to tidal response.
- The estuarine groundwater heads also respond over the longer term to changes in the groundwater levels in the Fill Aquifer. This is because the Estuarine Aquifer is recharged by vertical leakage down from the fill aquifer, although the low permeability of the clay aquitard subdues any short term fluctuations.
- The Estuarine Aquifer monitoring predates any surface capping.

5.4.4 Surface Water North and West of Rail Line

The ponds located to the north and west of the railway line include Swan Pond, OEH Wetlands 1 to 3 and Rail Road Pond. These ponds are essentially hydraulically isolated from the ponds within the rail loop and are subject to periodic tidal inundation. Swan Pond is subject to daily inundation from the Hunter River (South Arm). These ponds generally have higher salinity, often above 10,000 µS/cm, due to the tidal inundation. In the case of ponds such as Swan Pond and OEH Wetland 1, the salinity is exacerbated by evaporative effects and is at times greater than the salinity of the Hunter River, which is typically in the order of 57,000 µS/cm. These ponds have not been considered in any detail in this assessment as the salinity is not expected to be influenced by capping within the rail loop.

5.4.5 Surface Water South and East of Rail Line

5.4.5.1 Water Levels

Water Levels in the ponds are responsive to rainfall events, with the rise in water level typically responding within a day of the rainfall. Table 12 provides some typical responses to rainfall, which have been presented in terms of the response factor which is the ratio of the height of the increase of water levels in the ponds to the amount of rainfall at the gauging location.

There were no variations in water level observed that could be directly correlated to tidal variations or river levels. Water levels in Deep Pond A and Railway Pond which fringe the inside (to south) of the railway line were consistently observed at elevations well above the measured tide levels in the river indicating that groundwater flow occurs from the Deep Pond A and Railway pond towards the north and that flood levels in the river were not affecting the surface water levels to the south of the rail line. River levels were observed to be above the water level in Long Pond on occasions however there was no evidence of any interaction between the pond levels or river levels on the plots.

Table 12: Water Level Response to Selected Rainfall Events

Date	2010 - 2011	17 - 18 Nov 2013	26 - 28 Jan 2015	19 - 20 April 2015	3 - 7 Jan 2016	14 - 17 Jan 2016	16 - 22 March 2016
Recorded Rainfall (mm)	**Various events <100 mm**	**145**	**48.6**	**234**	**285**	**76**	**56**
Water Level Rise (m) / (Response Factor)							
Windmill Road Open Channel (B02L)	-	-	0.32 (0.7)	-	0.66 (2.3)	0.2 (3.8)	0.11(2.0)
Eastern Ponds (GH001S)	-	0.13 (0.9)	-	-	0.86 (3.0)	0.07(1.0)	0.05 (1.0)
Easement Pond (SWDP4)	(2.0)	-	-	-	-	-	-
Easement Pond North	-	-	-	0.84 (3.5)	-	-	-
Easement Pond South	-	-	-	0.7 (3.0)	-	-	-
SWSMEC-K2	-	-	-	-	0.16* (0.6)	0.06 (1.0)	0.2 (3.6)
Long Pond	(2.0)	-	-		1.0* (3.5)	0.16 (2.1)	0.1 (1.3)
Deep Pond	(1.5)	-	-	-	-	-	-
Deep Pond A North	-	-	-	-	0.67 (2.35)	0.08 (1.0)	0.06 (1.0)
Deep Pond B South	-	-	-	-	0.66 (2.35)	0.06 (0.8)	0.08 (1.4)
SW Pond 11	(1.0)	-	-	-	0.94 (3.3)	0.07 (1.0)	0.05 (1.0)
SWK7	-	-	-	-	1.03 (3.1)	0.27 (3.5)	0.24 (4.2)
SWK7B	-	-	-	-	1.3 (4.5)	0.12 (1.6)	0.04 (1.1)
Railway Pond	-	-	-	-	0.7 (2.5)	0.07 (0.9)	0.06 (1.07)

Notes:
* Plot suggests that response was affected by overspilling

For small to moderate rainfall events the magnitude of the response is typically the same as the rainfall indicating minimal surface runoff. As events get larger the response factor increases, providing an indication of the contribution of the surface water catchment / runoff to the water levels.

A number of specific observations regarding the water level traces include:

- The SWSMEC-K2 response to rainfall is markedly different to other ponds. For large events the response to rainfall is less than in other ponds suggesting that the levels are controlled by overtopping of the pond. The occurrence of temporary overflow is evident in the plots where the water levels peak and drop very quickly to a similar level before receding at typical rates. For small rainfall events the response is much more than other locations, suggesting that the pond may have a large catchment relative to its size possibly fed by channel flow from upstream. In December 2014 the logger in SWSMEC-K2 ran dry. As shown in Table 11, the logger was positioned at depths of 0.05 m to 0.2 m above the base of the pond.
- A number of other ponds have overflows which limit upper water levels at times. Information from the T4 Assessment (Ref 3) which included survey of a number of key locations indicate the following overflow levels apply:
    - Deep Pond RL 1.6 AHD;
    - Easement Pond RL 1.55 AHD (with limited flow capacity);
    - BHPB Wetland and Blue Billed Duck Pond RL 2.08 AHD – flow into Deep Pond;
    - Long Pond RL 2.6 AHD;
- Evidence of these ponds reaching their spilling levels is evident at various times for the following ponds and times:
    - Deep Pond – October 2011;
    - Easement Pond South – April 2015;
    - Long Pond – January 2016 (minor);
    - Windmill Road Open Channel B02L – January 2016;
- Water levels have been observed to follow similar trends in Pond 11 and Deep Pond suggesting a hydraulic connection via the relatively permeable slag bund walls separating the ponds;
- For GH001S (Eastern Ponds), there is a large increase in water level in February 2015 which is not observed in other loggers and does not coincide with rainfall. This is either due to artificial filling of the pond or logger malfunction.

There is no evidence of tidal effects in these locations because they are essentially hydraulically isolated from the Hunter River. Although water levels in the river become elevated during high tides and/or flood events, the measured tidal levels during the monitoring the period were not recorded higher than 1.37 AHD which is expected to be well below the water levels in the ponds at the corresponding time.

Water levels are observed to recede between rainfall events due to both evaporation and from leakage into the underlying Estuarine Aquifer. Mass balance modelling of the data from the period November 2010 to October 2011 (Ref 3) indicated that the recession rate was greater than the measured pan evaporation rate with minor component due to leakage through the base of the ponds. An exception to this was the Easement Pond where infiltration accounted for about one third of the recession and this was inferred to be due to a more permeable pond bottom that the other ponds leading to more leakage to the Estuarine Aquifer.

5.4.5.2 Temperature

A comparison of the logger temperature ranges was presented in Table 7 in Section 5.2.1 with consideration of minimum, maximum and typical ranges for the monitoring periods.

Plots of logger temperature shown in Appendix C indicate the following:

- Where loggers are shallow (typically less than about 0.5 m depth), there is a clear daily fluctuation in temperature. The fluctuation increased where loggers were installed at a shallow depth within the water body and in summer months. Temperatures typically peak in early afternoon with daily minimums overnight;
- For very shallow water, in the order of 0.1 m or less, the temperatures were observed to range from about 23°C to 35°C (SWSMEC-K2 in December 2014);
- The amplitude of the fluctuations and the overall temperature reduces with depth. Reduced temperature fluctuations were observed for loggers depths greater than about 0.5 m (e.g. Long Pong and Ponds K7 and K7B;
- The overall temperatures and amplitude also reduced in the winter months with temperatures as low as about 7°C in shallow ponds, however, more generally in the order of about 10°C.
- A number of loggers seem to be installed in sumps within the pond floor and these showed much less response to temperature fluctuations;
- There is typically a temporary drop in temperature coinciding with rainfall and increases in water levels.

The typical temperature ranges for most ponds fell within the following comparison ranges:

- 10-17°C: slow chytrid growth, infection may be fatal;
- 17-25°C chytrid growth optimal, infection may be fatal.

A number of exceptions included the following:

- Pond 11: highly variable and temperature variations appeared to be controlled by daily and seasonal effects;
- Railway Pond: temperature ranges were slightly higher, typically over the range 18-28°, additionally placing this pond in the following comparison range:
  - 25-28°C: slow chytrid growth, infection may be fatal.

As noted above, the temperature recorded by the loggers is affected by depth of the loggers within the water bodies and variable water tables. Further, the assessment criteria are approximate only and are based on prolonged exposure.

5.4.5.3 Electrical Conductivity

The range of EC in surface water bodies are shown on the plots in Appendix C with minimum, maximum and typical ranges shown in Table 7 in Section 5.2.1. The 'typical' ranges of EC values from installed loggers are summarised in Table 13.

Table 13: Summary of 'Typical' EC Range for Ponds for Monitoring Period (µS/cm)

Surface Water Pond	Typical Range EC	EC Adopted Range Comparison Values			
		Less than Lower Bound(1)	Lower to Middle Range EC	Middle to Upper Range	Above Upper Bound
		<1,650	1,650-2,900	2,900-4,100	>4,100
K7 Pond	1,000-1,500 (varies)	•			
BHP Wetland	600-900	•			
Easement Pond South	500-1,000	•			
Pond 11	500-1,000	•			
Railway Pond	1,800-2,800		•		
Long Pond	2,000-3,000		•		
Eastern Ponds	1,600-2,300		•		
Windmill Road Open Channel	1,600-4,000 (varies)		•	•	
Easement Pond	1,700-4,000		•	•	
Deep Pond B	1,000-2000 varies	•	•	•	
Deep Pond A / Deep Pond North	1,000-4,000, varies	•	•	•	•
K2 Pond	1,000-5000 (varies)	•	•	•	•
K7B Pond	Varies	•	•	•	•

Notes:
(1) – considers periods where EC has reduced due to pond drying out (i.e. likely inaccuracies in logger measurement)

The loggers indicate some complex trends with regard to electrical conductivity (EC) which can be assessed to provide a qualitative understanding of the processes occurring.

There are daily fluctuations in the EC responses which are a subdued form of the fluctuations in the temperature. It is considered this fluctuation in EC is due to the temperature dependence of EC, and there is likely no such daily fluctuation in actual salinity. Therefore an average daily EC is considered more representative. The fluctuations in EC due to temperature/depth effects can become quite severe with large fluctuations in temperature particularly when the water levels get shallow. In one instance the salinity meter dried out (SWSMEC-K2 December 2014) and this was preceded by fluctuations of up to 7000 µS/cm.

For typical rainfall events and relatively shallow loggers the salinity typically drops in response to the dilution effect of rainfall recharge and surface runoff. The EC will then typically increase during dryer periods as water levels drop in response to evaporation thereby concentrating the solution of salts in the water.

Sometimes the drop in EC following rainfall is quite temporary with the EC increasing to previous levels within a few days. This effect is evident in Long Pond, Railway Pond, Easement Pond South, SWSMEC-K2 and Deep Pond. This is probably due to temporary stratification of the water column with the fresher water initially sitting above the remnant water with the water column then remixing and reverting to a similar slightly lower EC than prior to the event. This would only be likely to occur for loggers installed below the fresher surface water lens.

In some locations and generally only for larger rainfall events, the rainfall leads to an initial drop in EC, followed by a marked increase in EC, which in some instances builds over a number of weeks and then recedes again, independent of surface water levels. This trend is particularly at the following ponds and times:

- Easement Pond (SWDP4) in April 2015 and January 2016;
- Eastern Ponds (GH001S) in April to May 2013 and January 2016 to April 2016;
- Windmill Road Open Channel (B02L) in January 2016 to February 2016;
- SW K7 in January 2016 to February 2016 and in this instance the increase is immediate with the EC staying near constant for about five weeks and then dropping suddenly.

These occurrences are shown in Figure 12 to Figure 14.

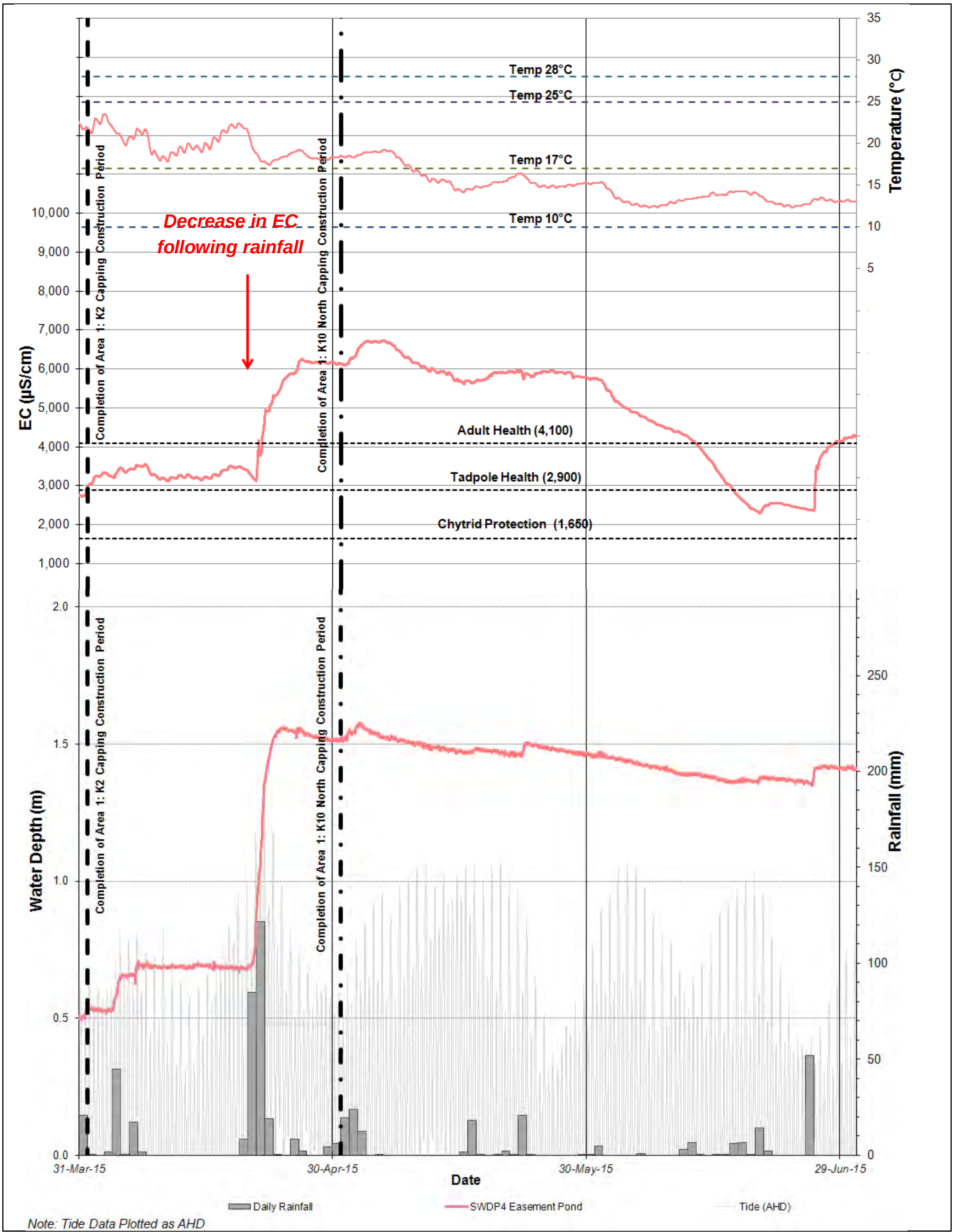


Figure 12: EC trends following rainfall for Easement Pond (SWDP4)

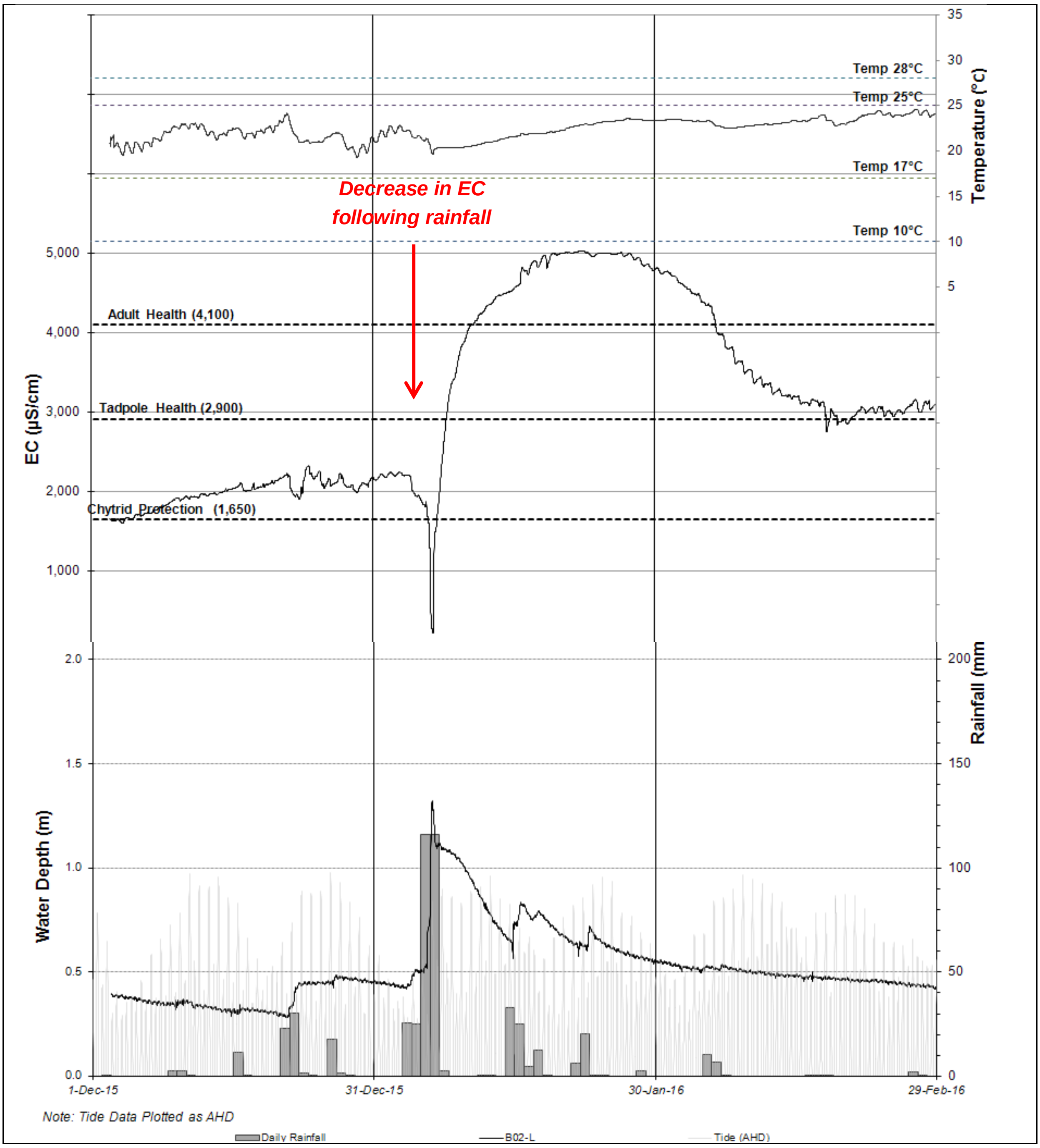


Figure 13: EC trends following rainfall for Easement Pond (B02-L)

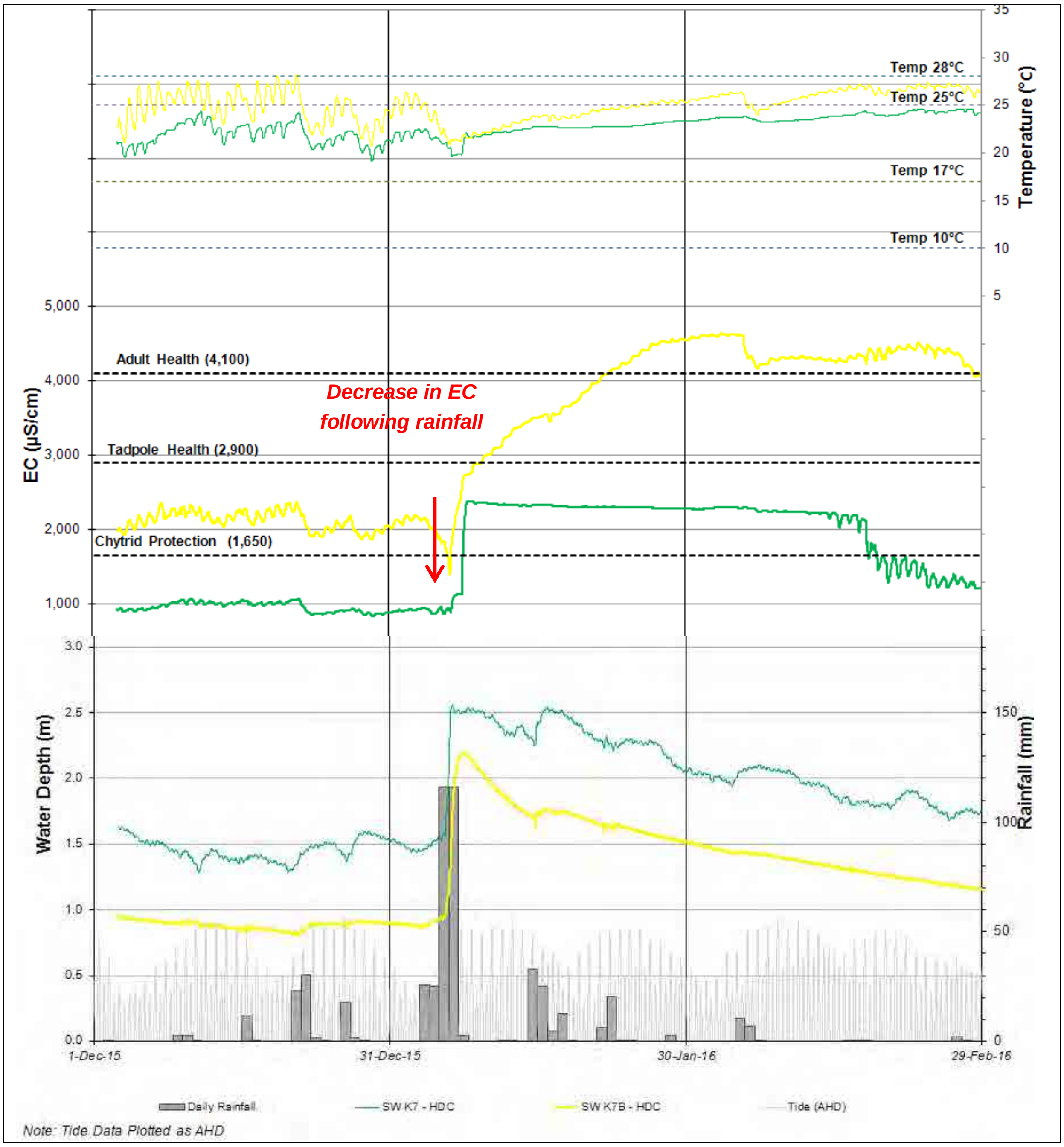


Figure 14: EC trends following rainfall for Easement Pond (K7 and K7B)

There are a number of common characteristics of the ponds showing this unusual EC response as follows:

- The ponds are relatively small or narrow;
- The ponds are generally elevated, well above potential tidal or river flooding influences;
- The loggers are generally located in sumps within the pond floor sediments. The exception to this is SWK7 which is installed 0.24 m above the pond floor, however still in the lower parts of the water column;
- The water temperatures are generally lower and fluctuate less.

A number of possible explanations for these effects have been considered as follows:

A. The rainfall events may lead to sediment entering the ponds or sediment within the ponds being disturbed leading to an increase in suspended clay particles and potentially also dissolved salts. As the sediment settles out it may initially increase EC near the base of the ponds before dropping out of suspension. It seems unlikely however that such matter would stay in suspension for weeks;

B. Large rainfall events may provide sufficient thermal change or physical disturbance to mix the whole water column, leading to saline water in the base of the ponds mixing with the shallower less saline water thereby increasing the salinity at shallower depth. The reformation of stratification could then lead to a relatively sudden drop in salinity for the shallow water and would likely be accompanied by an increase in salinity at the base of the pond. This may be a possible explanation for the behaviour at SW K7, however is unlikely to account for the behaviour at the remaining locations with loggers installed in sumps;

C. Groundwater inflows can have a large effect on increasing the salinity if the pond volume is limited. More saline groundwater would be expected to flow the base of the ponds due to its higher density. An increase in groundwater flows can be expected following significant rainfall events with the response occurring over weeks rather than months (as observed). The subsequent decrease in salinity may be due to leakage of the more saline groundwater into the floor of the ponds, or dispersion/diffusion into the water column above. This scenario seems the most plausible explanation for the behaviour at Windmill Road Open Channel (B02L), Eastern Ponds (GH001S) and Easement Pond. It is also likely that this behaviour is limited to the very base of the ponds and that the EC changes nearer the water surface are more typical of that observed in other ponds.

There is also a marked and sudden drop in EC which occur independent of water level changes. The most significant of these occurs at B-02L in January 2015 where the EC drops from about 4,000 µS/cm to less than 2,000 µS/cm and then slowly builds over a number of weeks. This phenomenon is difficult to explain with possible explanations including:

- Temporary precipitation of salt, however this seems implausible given the predominance of chloride ions, chloride being an essentially non-reactive ion;
- Possible inversion of the water column with fresh water displacing the more saline water in the base of the pond. Such an occurrence would likely only be temperature induced and there are no signs of temperature changes;
- Logger error which seems the most plausible explanation.

5.4.6 Comparison of Results Pre and Post Capping

Capping of Area 1 was completed in early to mid-2015 at the capping completion dates have been plotted on the attached results of monitoring at ponds in the proximity of the capping, including Easement Pond, Easement Pond South, B02L, GH001S, SWDP103 and SWMEC K2 Ponds. Review of plots indicated no discernible changes in the response of the parameters to climatic variations following capping and the parameters fell within the range of fluctuations per capping.

6. Conceptual Model

6.1 SMEC Hydro Salinity Model

A conceptual hydro-salinity model was developed by SMEC (Ref 17) as the basis for their numerical model as presented in Figure 15.

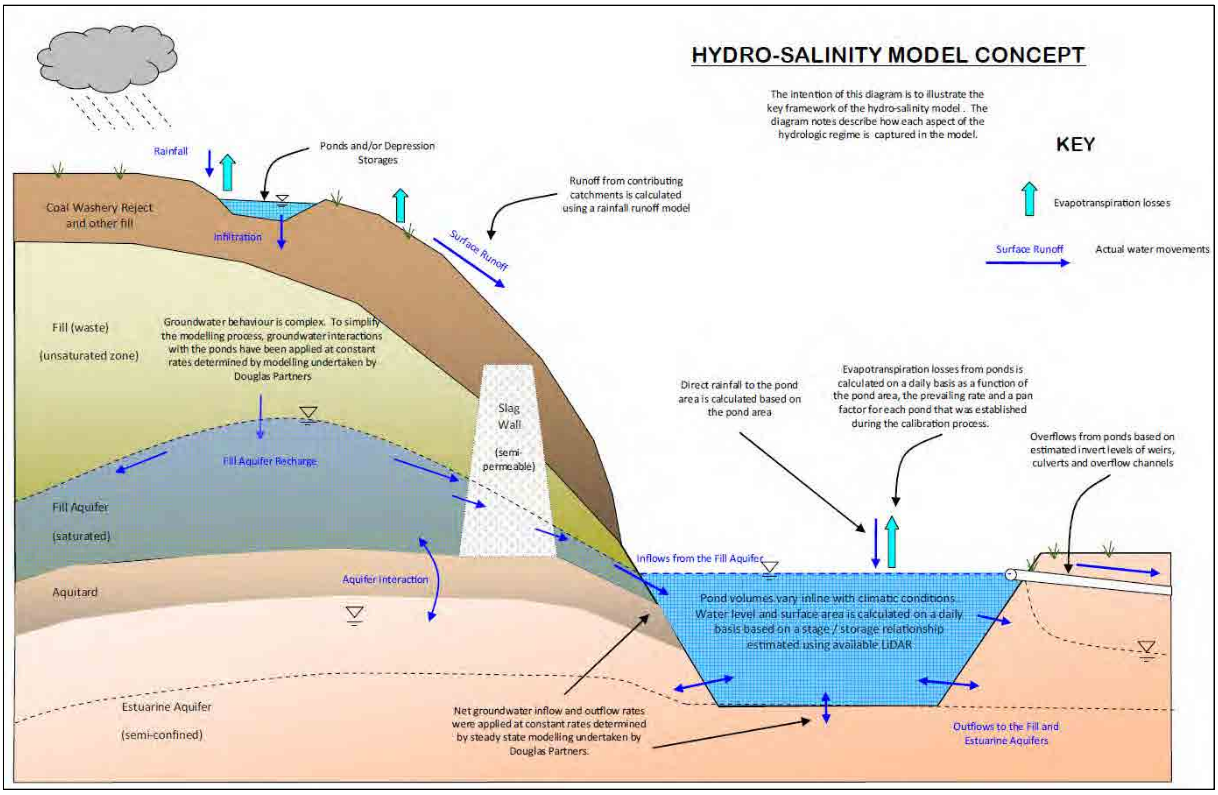


Figure 15: Hydro-Salinity Conceptual Model (SMEC Plate 16, 2013, Ref 17)

The following key processes were identified by SMEC (Ref 17) for modelling of the pre- and post-capping conditions:

- *"Surface water runoff from contributing catchment areas*
- *Groundwater inflows into each pond*
- *Groundwater outflows from each pond*
- *Surface water flows between ponds and from ponds to receiving water*
- *Evapotranspiration losses from each pond".*

6.2 Qualitative Details of Hydro-Salinity Model

DP has used the analyses of various site monitoring data and previous groundwater modelling on Kooragang Island to add additional detail and understanding to the conceptual model as follows:

Recharge

- The primary source of recharge to the ponds is from direct rainfall and surface runoff. The relative contributions vary according to the size of the surface catchment for each pond. Comparison of surface water level responses with rainfall records (Section 5.4.5.1) indicates that the proportion of runoff increases significantly for large rainfall events because of limited infiltration capacity of the soils and low land based evaporation;
- Overall groundwater recharge is a secondary source of recharge, however, it becomes an important source of recharge in times of low rainfall. In times of rainfall, direct rainfall and runoff will contribute the vast majority of recharge to the ponds. Rising ponds levels will also potentially also recharge the groundwater levels in the immediate vicinity of the ponds (losing system). In times of dry weather as pond levels drop, the groundwater inflow to the ponds will occur (gaining system);
- Only rainfall infiltrating close vicinity to the ponds is likely to enter the ponds via lateral groundwater flow, with most of the recharge to the fill aquifer continuing vertically down to the Estuarine Aquifer.

Discharge

- Mass balance modelling (Ref 3) has indicated that discharge from the ponds is primarily from evaporation;
- At times of relatively high rainfall, overspilling of the surface water may occur in some ponds including BHPB Wetlands, Blue Billed Duck Pond, Deep Pond and Long Pond. Easement Pond has a very low flow overflow. The remaining ponds are not expected to overflow;
- Leakage occurs through the base of the ponds to the underlying Estuarine Aquifer, which together with downwards flow from the Fill Aquifer are the only sources of recharge for the Estuarine Aquifer. Estuarine Clay is expected to be present in the base of the majority of the ponds with the possible exception of Eastern Ponds (GH001S). The clay is of low permeability and therefore leakage rates are generally very low compared to evaporation rates. Mass balance calculations and groundwater modelling indicates that the base of Easement Pond is relatively permeable with leakage rates of about one third that of evaporation.

Salinity

- There are likely two sources of salinity in the ponds. The first source is likely to be residual salts associated with the former estuarine mudflats, which has leached out of the clay soils in the base of most of the ponds and a Na-Cl skew is evident in the ionic composition of the water. The second source is from leaching of the fill soils, with salts entering the ponds as a dissolved phase in the groundwater inflows. This is supported by the ionic composition of the surface water being similar to that of the Fill Aquifer. The leaching from the fill aquifer is expected to be an ongoing process and could lead to increased salinity over time;
- There are very limited mechanisms for the loss of salt from the ponds. The most obvious mechanism is flushing of the ponds which can overflow. In this instance, especially in large rainfall events much of the salt load can be flushed from the system. This effect is most evident in SWSMEC-K2, however will also occur at times in Blue Billed Duck Pond, BHPB Wetland and the Deep Ponds.
- The pond waters are high in chloride which is non-reactive and therefore chemical precipitation of the salts is unlikely to occur with the exception of evaporative effects when the ponds dry out. In this case the salt is generally retained in the system and will dissolve once the water levels return;
- There may be some limited potential for losses of salinity via leakage through the pond base. The more saline water is present in the base of the ponds and the dissolved salts are likely to be mostly transported through the clay soil, possibly with some salt being sorbed to the clay;
- Upward leaching of salt from the estuarine aquifer is unlikely to occur as due to the flushing effect of the downwards leakage. Modelling has indicted that the upper levels of the Estuarine Aquifer are expected to be relatively fresh due to the flushing effect and therefore upwards diffusion is unlikely due to the absence of a significant concentration gradient. In order to assess if upwards diffusion of salt is feasible the Peclet Number relevant to the transport of sodium chloride across the clay aquitard was assessed. The results indicated for typical flow conditions the Peclet Number is great than 10 for sodium chloride, confirming that advective dispersion (downward transport of the salt with the flow of water) processes will be dominant and upwards diffusion is expected to be insignificant.
- Therefore for ponds that do not overflow, the salt load in the ponds is unlikely to reduce over time and may actually accumulate to some degree due to ongoing inflow of more saline groundwater;
- The salinity in many ponds varies both temporally and with depth. In general higher concentrations of salts can be expected during dry periods, with dilution and lower concentrations following rainfall. Salinity will also at times increase with depth. Some instances of increased salinity have occurred in the base of ponds following large rainfall events, however this is likely to be due to groundwater inflows and is generally temporary and limited to the base of the ponds.

6.3 Other Chemicals

pH

The pH of the ponds is generally slightly alkaline whereas the pH of rain can be expected to be slightly acidic. Groundwater in the fill is generally higher than the pond water, typically in the range pH 8 to 10 and this is likely contributing to the alkalinity of the pond water. The pH may well be controlled by processes in the pond including interaction with atmospheric carbon dioxide (CO_2) and consumption (respiration) of dissolved CO_2 by vegetation or algae in the ponds.

Turbidity

Turbidity may occur at times from erosion of surface soils within the pond catchments, or flow from upstream ponds which have turbid conditions. Direct rainfall and groundwater inflow will not contribute to turbidity. Turbidity generally subsides, leading to sediment forming on the pond floors.

Contamination

The fill materials on the site are known to contain a range of contaminants and testing of groundwater has indicated that both surface water and Fill Aquifer groundwater commonly exceed the ANZECC (2000) Trigger Values for Slightly to Moderately Disturbed Ecosystems. Analytes that typically exceed the adopted Trigger Values included metals (As, Cd, Co, Cr, Cu, Ni, Pb and Zn), nitrogen, phosphate, cyanide and pH. A review of the contamination data further indicated that the characteristics of surface water and groundwater are similar, with the exception of ammonia which has a high proportion of exceedances in groundwater but a low proportion in surface water.

Groundwater flow from the Fill Aquifer into the ponds presents a similar transport pathway as for salinity, however, many contaminants in particular organic contaminants are reactive and have limited mobility. Metals are the most likely contaminants to be transported to the ponds from the fill.

7. Capping

7.1 Overall Extent

The overall extend of the proposed placement of capping material for the KIWEF closure works is shown in Figure 16.

Figure 16: Proposed KIWEF Capping Area

As outlined above, Area 1 has already been capped. Commencement of capping for Area 3 is scheduled for August 2016. Both these areas have already been subject to approval.

The purpose of the capping is to reduce infiltration into and generation of potentially contaminated leachate from the former landfill cells on the site. The overall criteria for the capping include the following:

- Maximum hydraulic conductivity of $1x10^{-7}$ m/s;
- Minimum thickness of 0.5 m;
- Minimum surface grades of 1 %.

7.2 Completed Areas 1 and 3

The capping associated with Areas 1 and 3 was the subject of the previous assessment of potential salinity impacts by SMEC (Ref 17) and ERM (Ref 13). The capping associated with Area 1 K2 was commenced on October 2014 with practical completion by April 2015. The capping associated with Area 1 K10 North was commenced in October 2014 with practical completion in May 2015. Capping for Area 3, K10 South is proposed to be commence in August 2016.

The Areas 1 and 3 capping extent and concept design is shown on Figure 17 and Figure 18.

Figure 17: Capping Extent and Concept Design – Area 1 (K10 North) and Area 3 (K10 South)

Figure 18: Capping Extent and Concept Design – Area 1 (K2)

It is understood that the capping was designed with surface grading to controll runoff and follow similar surface water flow destinations to the pre-capping topography. The runoff is directed via swales into small detention basins before being directed into surface water bodies as shown in the figures above.

7.3 Proposed Area 2 Capping

The proposed extent of capping for Area 2 is shown in Figure 19 and denoted by subareas K3, K5 and K7. The detailed design of the capping has not been undertaken as yet, however, it is understood from HDC that the capping will follow similar principles to the Areas 1 and 3 capping.

Figure 19: Proposed Area 2 Capping (blue)

The proposed capping area for K3 and K5 extends over filled slag bunded cells some areas of which have already been capped with a low permeability liner (Pond 12). The capping is set back about 20 m to 100 m from the shore line of Deep Pond, about 50 m from Railway Pond and over 100 m from Easement Pond. The capping is bisected by an existing railway embankent and the southern section is separated from Blue Billed Duck Pond and BHPB Wetland by a railway embankment. Pond 11 is located to the north and is separated from the capped area by Pond 9, which is a dry bunded cell about 150 m wide.

Prior to completion of the surface capping at Area 2 K7, an additional 1.6 m of virgin soil (or similar) is prooposed for placement to achieve a 3 m cap over the former asbestos burial pits. This is not requried to be designed as a low permeability cap.

The existing surface grades and overland flow directions of the current Area 2 site are shown in Figure 20. Overland and culvert flow paths at southern extend of proposed Area 2 capping are shown in Figure 21.

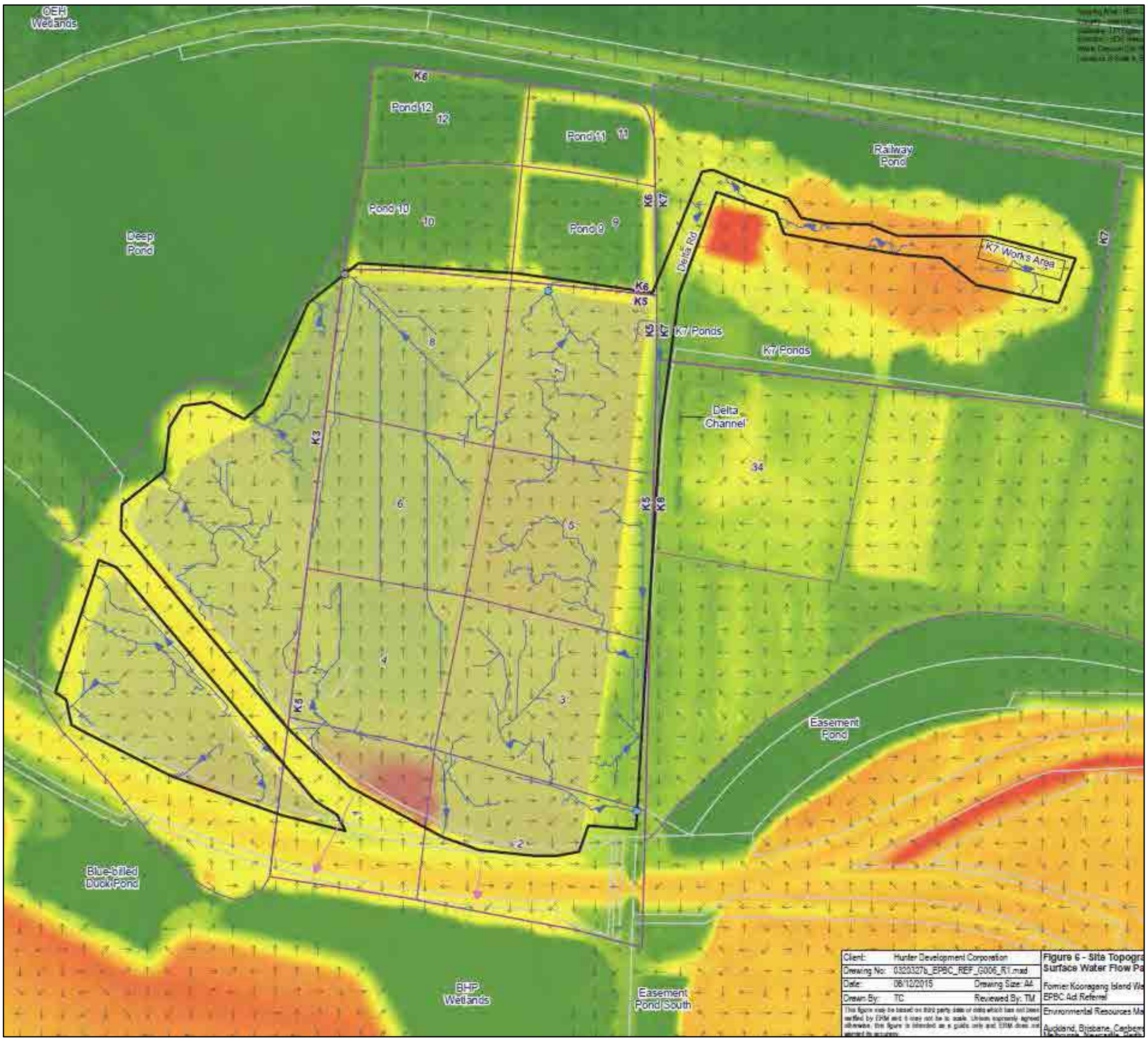


Figure 20: Area 2 Capping - Existing Surface Grades and Overland Flow Paths (ERM, 2015)

Figure 21: Overland and Culvert Flow Paths at Southern Extend of Proposed Area 2 Capping

Figure 20 indicates the following:

- Most of the western area of the capping located to the north of the rail line drains towards Deep Pond North;
- The traingular section of capping between the rail embankment to the south west seems to drain towards Deep Pond South;
- The immediate southern area of the main area of capping drains towards BHPB Wetland via culverts below the rail embankment with minor amounts discharging towards Easement Pond. This can be seen in more detail in Figure 21, below.
- The eastern parts of the capping area seem to drain towards the Delta area where it either infiltrates or overflows into Easment Pond;
- The north eastern part of the area proposed for capping drains towards the north and seems to spill into Pond 9;
- The catchments for K7 Pond, K7B Pond, Railway Pond and Easement Pond South do not overlap with the proposed capping;
- The catchment for Pond 11 is very limited and essentially confined to within the bounds of the slag bund walls. In times of low water levels there may be some run-off from the dry area within the pond and in times of higher water there would only be direct rainfall on the pond water.

8. Qualitative Assessment of Impacts

The data and conceptual understanding of surface water and groundwater processes on the site, as described in the above sections of this report has been used to provide a qualitative assessment of the likely impacts of the proposed capping with respect to key habitat of the GGBF. The assessment focuses on likely impacts with regards to pond water levels, salinity, pH, temperature, turbidity and contamination.

Placement of a low permeability cap will have the fundamental effect of reducing rainfall infiltration to groundwater as well as increasing surface run-off.

In simple terms, increased runoff and decreased groundwater flows will likely lead to faster response of pond waters following rainfall and less response from more saline groundwater. This is expected to lead to generally wetter and less saline and conditions in the ponds, consistent with the results of previous modelling by SMEC for the Areas 1 and 3 capping (Ref 17). The results of this modelling are expected to provide a good indication of the likely impacts of the Area 2 capping as the site characteristics are very similar and the capping is proposed to be designed on similar principles. Site specific nuances are discussed further below.

The lower groundwater flux into the ponds would also be expected to lead to reduced contamination levels. There is potential for increased turbidity, particularly during and following construction, which will require careful management, however, once ground cover is developed this is not expected to be an issue. In terms of pH, the reduced groundwater flows may lead to the alkaline pH dropping closer to neutral, however, the pH in the ponds may be controlled by microorganisms and vegetation, buffering any impact.

The reduced groundwater flows resulting from capping will lead in turn to reduced heads in the Estuarine Aquifer and if the effects of increased surface runoff were ignored, would also lead to a reduction in the typical pond water levels. Numerical modelling for the T4 Project (Ref 3) assessed the cumulative impacts of both the proposed Areas 1 to 3 capping as well as the subsequent more extensive capping for the surrounding KIWEF site proposed by the T4 project. The assessment assumed a capping permeability of $1x10^{-8}$ m/s, an order of magnitude less than the Areas 1 to 3 capping of criteria of $1x10^{-7}$ m/s and also assumed no additional recharge to the ponds. DP's modelling indicated that *"water levels are primarily controlled by rainfall and evaporation with groundwater flows being a relatively minor control*". Specifically the modelling indicated the following:

- Net changes to water levels in the OEH Wetlands and Rail Road Pond of less than 0.1 m;
- No impacts on the tidal flats to the north and west of the site as the conditions are controlled by tide (i.e. hydraulically separate from the main KIWEF site);
- Water levels in Blue Billed Duck Pond and BHPB Wetland could drop by up to 0.15 m (which assumes no additional recharge from runoff);
- A reduction in flow rates in the Estuarine Aquifer, in particular a reduction in flow towards the Ramsar Wetlands to the north of the site. The Estuarine Aquifer contains a variety of contaminants including heavy metals and PAHs. The results of modelling indicated that the capping would result in a significant reduction in the flux of contaminants towards the wetlands and North Arm of the Hunter River.
- A reduction in water levels in the Fill Aquifer potentially by about 2 m, would lead to reduced mobility of contamination in the filling. The lowered water levels would lead to less contamination being saturated and subject to leaching, the reduced heads would lead to less flow and flux of contaminants into the underlying Estuarine Aquifer and there would be less flow and flux of contamination towards the surface water ponds.

Given that the modelling was undertaken for a more onerous capping programme, the cumulative actual impacts of the Areas 1 to 3 capping would be subdued. Significant reductions in the migration of contamination can be expected, especially in close proximity to the capping. The impact on pond levels would be substantially less, probably less than half and this would likely be offset by increased surface runoff to the ponds, especially in wet periods. Any risk of lower pond levels due to reduced groundwater levels would probably only manifest in extended dry periods when the groundwater provides recharge to the ponds.

The expected changes in conditions are discussed on a pond by pond basis as follows.

Railway Pond

It seems that Railway Pond does not receive any run-off from the proposed Area 2 capping. Similarly groundwater recharge to the pond will come from the elevated ground within Pond K7 and not from capped areas. Therefore there will be minimal disruption to the existing local processes. The lowering of overall groundwater levels due to the cumulative effects of capping may have some influence in dry conditions, however, extrapolating from the results of modelling from T4 the change in water levels is likely to be about 0.05 m to 0.1 m or less. Any changes would be unlikely to be distinguishable from normal seasonal variations. As there is unlikely to be any disruption to surface or groundwater flows to Railway Pond, changes to the salinity regime are also not expected.

Ponds K7 and K7B

Ponds K7 and K7B are relatively small and seem to have very localised surface water catchments, which do not extend to the area of proposed capping. Assessment of the pond level responses to rainfall indicated that the catchment is no more than about three to four times the limited area of the ponds.

Groundwater recharge for Pond K7 will be from the surrounding area of K7 and possible from the Delta EMD site to the south. Similarly groundwater recharge to Pond K7 is also likely to be primarily from the surrounding K7 area. There is some possibility of limited groundwater recharge from the immediate north east corner of the capped area. The pond is separated from this area by high permeability slag bunding around Pond 7 essentially hydraulically separating the two areas.

Therefore, as with Railway Pond, there is unlikely to be any distinguishable changes to the variations in water level and salinity in Ponds K7 and K7B from the proposed capping.

Deep Pond (North)

Deep Pond North is the largest of the ponds. The pond is surrounded by relatively narrow rail embankment on all sides apart from the eastern side which represents the only significant direct land catchment for the pond. The majority this eastern catchment, apart from some fringing uncapped areas is within the north western area of proposed capping. Water level response factors for the pond range from about 1.5 for typical events, commensurate with that expected from the immediate catchment to 2.3 for larger events suggesting some contribution from overtopping of the upstream Railway Pond. As there are minimal changes expected to the hydrology of Railway Pond, little change is expected with regard to the overflows to Deep Pond. Upper water levels are also controlled by overspilling downstream and as no changes are proposed to the drainage levels, no changes to the upper water levels are expected.

In terms of groundwater inputs, Deep Pond is expected to receive inflows from the Fill Aquifer along the eastern side. Modelling of groundwater flows for the T4 development has indicated that only groundwater in reasonable proximity to the edge of ponds, say within about 50 m or so, is likely to drain to the pond, with the remainder leaking to the underlying Estuarine Aquifer. As the capping is generally set back from the edge of the ponds by about 30 m to 100 m, the impact on the groundwater catchment will be limited. Further groundwater flows are generally minor and compared to the large surface area of the Deep Pond and eastern catchment, groundwater flows are likely to be insignificant in the mass balance.

As discussed above there will be a slight lowering of the groundwater levels to the cumulative effect of the Areas 1 to 3 capping which will have a background influence on overall water levels, probably of 0.1 m or less. This is expected to be offset by increased surface runoff expected from the proposed capping and it is likely that pond levels will generally be slightly higher, however, with no change to the peak levels. Salinity levels are also expected to be generally lower.

In terms of the magnitude and duration of any changes to water levels and salinity, this is difficult to determine, however, the reason for the higher water levels is similar to that modelled in Long Pond and Windmill Road Channel (i.e. more low salinity runoff). The relative catchment area compared to the size of the ponds is significantly greater at Long Pond and Windmill Road Channel than for Deep Pond and this is consistent with higher rainfall response factors measured. While the relative impacts on water levels and salinity are likely to be less than previously predicted for Long Pond and Windmill Road Channel, the increased runoff from the capped area is generally expected to reduce salinity levels in Deep Pond (North).

Deep Pond South

Deep Pond south is downstream of Deep Pond North and hydraulically connected by culverts through the rail embankment. The characteristics of the ponds are very similar and therefore behaviours of the ponds are also expected to be very similar. Given that the proportion of the surface water catchment is probably slightly larger than in Deep Pond North there may be a very slight decrease in salinity than at Deep Pond North, but likely less than for Long Pond or Windmill Road Channel.

Ponds 11 and 12

Significant surface water is generally only observed in Ponds 11 and 12. The results of monitoring indicate that there could be some hydraulic connection with Deep Pond when water levels get above a certain point, potentially through the granular bunding along the north of the ponds. The surface water catchment for the ponds is limited to the area of the ponds, with the exception of Pond 9 which may receive some runoff from the northern area of capping.

Rainfall response factors for Pond 11 are typically 1.0 for most events however for one large event were over 3.0. This may be largely due to the geometry of the pond with part of the pond dry prior to the event, thereby increasing the surface catchment but could also be due to overspilling through the bund wall from Deep Pond. It may be possible for runoff to enter via Pond 9, however, this seems unlikely and would only occur for unusual events.

The salinity in Pond 11 generally seems to consistently less than Deep Pond, indicating that any hydraulic connection is temporary and may only occur during higher water levels where only the relatively fresh lens of water at the top of the water column is able to temporarily enter. The low salinity may also be due to the absence of any significant groundwater inflows to the pond and therefore the absence of any source of salt.

Whether or not there is a connection to Deep Pond, changes to the water level or salinity regime are unlikely. The difference in salinity indicates that any connection is only fleeting and would occur at times of high water and low salinity. Given the already typical low salinity of Pond 11, the impact would be limited and independent and natural variation in salinity would still occur due to evaporative effects in drying conditions. If there is no connection to Deep Pond then the mass balance in the Ponds 11 and 12 would not be affected by the capping apart from a possible minor decrease in overall water levels due to lowering of the Estuarine Aquifer, similar to that which could occur in Railway Pond.

Blue Billed Duck Pond and BHPB Wetland

The catchment of BHPB Wetland includes a small portion of the south eastern corner of the proposed Area 2 capping, connected via culverts under the rail embankment. This catchments is small compared to the catchment associated with capping of the Kooragang Island Emplacement Cell (KIEC), located to the west. Blue Billed Duck Pond has no catchment associated with the Area 2 capping. BHPB wetland receives overflow from Easement Pond South and Blue Billed Duck Pond receives overflow from BHPB Wetland.

The proposed capping may slightly increase the proportion of runoff from Area 2, however, the impact will be limited by the limited proportion of additional capping in the overall the catchment. Therefore there may a very minor decrease in salinity, less than would have occurred from the capping of the BHPB sediments.

Based on the modelling of T4 (Ref 3) there could also be expected to be a slight reduction in overall water levels during dry times due to the cumulative impacts of the capping, however this would be expected to be less than about 0.05 m to 0.1 m and would be further offset by the increased runoff.

Easement Pond

Easement Pond has a very limited potential proportion of its catchment in the south eastern corner of the proposed Area 2 capping. The imminent Area 1 (K10) capping is expected to lead to wetter and fresher conditions and the impact of the subsequent Area 2 is expected to be insignificant due to the very limited area contributing to runoff.

Easement Pond has a stronger connectivity to the Estuarine Aquifer than the other ponds and therefore changes in the head of the Estuarine Aquifer due to the cumulative effects of the capping will have a greater influence here. Groundwater modelling would be required to quantify the effect, however, overall it could be up to about 0.1 m. It is noted that only a proportion of this would be due to the Area 2 capping, with the Areas 1 and 3 capping also contributing. This would likely reduce the additive effects of wetting predicted by SMEC due to the Area 1 and 3 capping.

9. Conclusions

The purpose of this assessment was to provide responses to the DoE RFI as outlined in Section 1. These responses to the three key questions relating to hydrology and water quality are summarised below.

9.1 Increased Travel Times to Ramsar Wetlands

As outlined in Section 8 of this report, previous detailed numerical modelling undertaken by Douglas Partners for the Terminal 4 Project (Ref 3) indicated that capping of the site would lead to a reduced flux of contaminants towards the north of the site where the RAMSAR wetlands are located. Section 11.3.4 of Reference 3 indicated that:

"[Capping of the T4 site] is expected to lead to average water levels in both aquifers and therefore the flow rates and associated flux of contamination to be overall lower than pre development. Post development this trend would continue with capping associated with the development expected to lead to a net decrease in flows and water levels and therefore a net reduction in the flux of existing contamination from the T4 Project area."

The reduced flux of contaminants was predicted to occur because the reduced infiltration as a result of capping would lead to reduced groundwater heads in the Fill and Estuarine Aquifers, less leaching of contaminants and reduced flow rates and travel times.

A further report by DP which assessed various potential contaminant mitigation measures associated with the T4 Development (Ref 9) included a specific assessment of groundwater flow times in the Estuarine Aquifer due to the HDC capping. Table 7 of Reference 9 includes travel times from the site to the Hunter River to the north and indicated that travel times will increase from about 60 to 90 year for the pre-capping conditions to 90 to 120 years following HDC capping.

9.2 Past and Current Water Quality Characteristics

Past and current water quality characteristics have been characterised and are presented in Sections 4.2.3 and Section 5.2 of this report.

In summary testing of groundwater has indicated that both surface water and Fill Aquifer groundwater commonly exceed the ANZECC (2000) Trigger Values for Slightly to Moderately Disturbed Ecosystems. Analytes that typically exceed the adopted Trigger Values included metals (As, Cd, Co, Cr, Cu, Ni, Pb and Zn), nitrogen, phosphate, cyanide and pH. A review of the contamination data further indicated that the characteristics of surface water and groundwater are similar, with the exception of ammonia which has a high proportion of exceedances in groundwater but a low proportion in surface water.

9.3 Analyses of Likely Changes to Water Quality

A qualitative assessment of surface water impacts has been undertaken in relation to proposed 'Area 2' capping works at the former Kooragang Island Waste Emplacement Facility (KIWEF). The assessment was based on a compilation and review of numerous previous studies carried out either specifically for proposed KIWEF capping works, monitoring related to EPLs or other proposed developments (such as the T4 Project). The review considered water level and salinity data from monitoring of automatic loggers, soil contamination from previous investigations, surface and groundwater contamination from both routine monitoring and previous investigations and the results of modelling undertaken for Areas 1 and 3 capping.

The assessment focussed on surface water bodies within and adjacent to the KIWEF 'Area 2' site, considering salinity changes due to a number of factors, including water level (from rainfall, run-off, infiltration), evaporation, groundwater interaction, tidal influence, contaminant concentrations and temperature.

The salinity concentrations impact on the growth of the chytrid fungus and in turn on the viability of the Green and Golden Bell Frog (GGBF). While research suggests that salinity appears to be the key driver of chytrid fungus control, water body temperature is also considered to a factor, however, research remains notably limited. The optimal conditions for GGBF habitats are considered to be salinity in the EC range 1,650 to 2,900 µS/cm (Ref 14). Optimal temperature ranges to inhibit chytrid growth are considered to be less than 10°C and greater than 28°C, however, temperature ranges are approximations only and have been used as indicative values for the purposes of this assessment (Refs 2, 16). Electrical conductivity less than 1650 µS/cm favours chytrid fungus, as do temperatures in the range 17° to 25°C.

Based on hydro-salinity modelling undertaken for the capping of Areas 1 and 3 it is anticipated that capping of Area 2 will reduce infiltration (leaching) and increase runoff into the ponds that are situated within and adjacent to the treated area. This is likely to result in a general increase in water levels and lowering of salinity, i.e. the conditions will become wetter and fresher. Where salinity is already typically low this will not significantly change the existing conditions related to GGBF viability. However, where salinity is moderate to high the reduction in salinity, combined with favourable water temperatures, may bring it into the range where the chytrid fungus could develop (although not necessarily, as some of the existing GGBF habitats already have similar conditions for at least part of the year).

The various surface water bodies are listed in Table 14, together with the principal conclusions drawn in relation to potential changes to the environmental status quo in relation to salinity and the chytrid fungus. It should be noted that the summary is a simplification of the complex interactions at the various ponds discussed in the foregoing sections, aimed at distilling the key factors.

Table 14: Summary of Assessment Findings

Pond (refer Drawing 1, Appendix D)	Primary Mechanisms Currently Affecting Salinity	Comment	Impacts Following Area 1 Capping	Potential Change to Environment after Area 2 Capping
BHP Wetland	Runoff, temperature	Low salinity; conditions favourable for chytrid most of year	No obvious impact to water level or EC (separated from Area 1 catchment)	Minimal change
Blue Billed Duck Pond	Runoff, temperature	Low salinity; conditions favourable for chytrid most of year	No obvious impact to water level or EC (separated from Area 1 catchment)	Negligible change – separate to Area 2 catchment
Deep Pond A	Groundwater, runoff, temperature, evaporation	Moderate salinity, conditions mostly unfavourable for chytrid	No obvious impact to water level or EC (separated from Area 1 catchment)	**Possible reduction in salinity from reduced groundwater flows and increased runoff making it more suited to chytrid**
Deep Pond B	Runoff, temperature	Low salinity; conditions favourable for chytrid most of year	N/A – no data prior to commencement of capping	Reduction of already low salinity, hence-minimal change
Easement Pond	Runoff, groundwater interaction	Moderate to high salinity; conditions mostly unfavourable for chytrid	No obvious impact to water level or EC	**Possible reduction in salinity making it more suited to chytrid, however, insignificant compared to Area 1 capping**
Easement Pond South	Runoff, temperature, groundwater interaction	Low salinity; conditions favourable for chytrid most of year	N/A – no data prior to commencement of capping	Reduction of already low salinity, hence-minimal change
Eastern Ponds	Direct rainfall, evaporation	Adjacent area to be capped as part of Area 3	No obvious impact to water level or EC	Negligible change
K2 Pond	Runoff, temperature	Already capped as part of Area 1	No obvious impact to water level or EC (separated from Area 1 catchment)	Negligible change
K7 Pond	Evaporation, temperature, groundwater interaction (minor groundwater flows)	Low salinity; conditions favourable for chytrid most of year	N/A – no data prior to commencement of capping	Negligible change – generally separate from Area 2 catchment and minor groundwater inflows
K7B Pond	Evaporation, temperature, groundwater interaction (minor groundwater flows)	Variable salinity; conditions unfavourable for chytrid; conditions unfavourable for GGBF half of monitoring period	N/A – no data prior to commencement of capping	Negligible change – generally separate from Area 2 catchment and minor groundwater inflows
Long Pond	Runoff, evaporation, groundwater interaction	Moderate salinity; conditions generally unfavourable for chytrid	N/A – no data prior to commencement of capping	Minimal change due to distance from Area 2
OEH Wetland 1	Tide, Runoff, evaporation	Hydraulically separate to Area 2	No obvious impact to water level or EC (separated from Area 1)	Negligible change

Table 14: Summary of Assessment Findings (Continued)

Pond (refer Drawing 1, Appendix D)	Primary Mechanisms Currently Affecting Salinity	Comment	Impacts Following Area 1 Capping	Potential Change to Environment after Area 2 Capping
OEH Wetland 2	Tide, Runoff, evaporation	Hydraulically separate to Area 2	No obvious impact to water level or EC (hydraulically separated from Area 1)	Negligible change
OEH Wetland 3	Tide, Runoff, evaporation	Hydraulically separate to Area 2	No obvious impact to water level or EC (hydraulically separated from Area 1)	Negligible change
Ponds 11 and 12	Runoff, groundwater interaction	Low salinity; conditions favourable for chytrid most of year	No obvious impact to water level or EC (hydraulically separated from Area 1)	Possible reduction of already low salinity, hence - minimal change
Rail Road Pond	Direct rainfall, evaporation	High salinity, hydraulically separate to Area 2	No obvious impact to water level or EC (hydraulically separated from Area 1)	Negligible change
Railway Pond	Runoff, evaporation, temperature, groundwater interaction	Moderate salinity; conditions unfavourable for chytrid most of year	No obvious impact to water level or EC (separated from Area 1 catchment)	Negligible change – generally separate from Area 2 catchment
Swan Pond	Tide, runoff, evaporation	Hydraulically separate to Area 2	No obvious impact to water level or EC (hydraulically separated from Area 1)	Negligible change
Windmill Road Open Channel	Runoff, groundwater interaction, overflow from Easement Pond	Low to high salinity (variable); remote from Area 2	N/A – no data prior to commencement of capping	Negligible change due to distance from Area 2

As summarised in Table 14, the potential for environmental change to site ponds from the proposed Area 2 capping is generally considered to be minimal or negligible for most ponds.

While potential decreases in salinity could be expected from increased runoff and slightly decreased groundwater inflows for Easement Pond, the magnitude if impacts is expected to be lesser than those predicted by quantitative modelling conducted by SMEC for Area 1 capping (i.e. minimal Easement Pond catchment to be capped). With consideration of SMEC's (Ref 17) qualitative assessment *"the expected effects of changes in salinity in the ponds as a result of the [Area 1 and 3] capping work is not expected to be significant*", however, "*A small increased risk of Chytrid effect has been identified in Easement Pond*". The results of monitoring during and post Area 1 capping, have indicated no discernible changes to water levels or salinity post capping with fluctuations falling within the range of observed values prior to capping.

This similarly applies for Deep Pond which would be subject to increased runoff and decreases in groundwater flows subject to the cumulative effects of capping for Areas 1, 2 and 3.

10. References

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13. Environmental Resource Management Australia Pty Ltd (ERM, 2013), 'Kooragang Island Former Waste Emplacement Facility Landfill Closure Works: Sites K2, K10 North & K10 South', Prepared for Hunter Development Corporation, Document 0186182_Final, 3 June 2013.

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11. Limitations

Douglas Partners (DP) has prepared this report for this project at the former Kooragang Island Waste Emplacement Facility at Kooragang Island, New South Wales in accordance with DP's proposal NCL160390.P.001.Rev0 dated 6 June 2016 and acceptance received from Mr Bob Hawes dated 14 June 2016 and Hunter Development Corporation Purchase Order 45374502. The work was carried out under the Hunter Development Corporation Consultancy Agreement HDC280 dated 14 June 2016. This report is provided for the exclusive use of Hunter Development Corporation for this project only and for the purposes as described in the report. It should not be used by or relied upon for other projects or purposes on the same or other site or by a third party. Any party so relying upon this report beyond its exclusive use and purpose as stated above, and without the express written consent of DP, does so entirely at its own risk and without recourse to DP for any loss or damage. In preparing this report DP has necessarily relied upon information provided by the client and/or their agents.

The results provided in the report are indicative of the sub-surface conditions on the site only at the specific sampling and/or testing locations, and then only to the depths investigated and at the time the work was carried out. Sub-surface conditions can change abruptly due to variable geological processes and also as a result of human influences. Such changes may occur after DP's field testing has been completed.

DP's advice is based upon the conditions encountered during this investigation. The accuracy of the advice provided by DP in this report may be affected by undetected variations in ground conditions across the site between and beyond the sampling and/or testing locations. The advice may also be limited by budget constraints imposed by others or by site accessibility.

This report must be read in conjunction with all of the attached and should be kept in its entirety without separation of individual pages or sections. DP cannot be held responsible for interpretations or conclusions made by others unless they are supported by an expressed statement, interpretation, outcome or conclusion stated in this report.

This report, or sections from this report, should not be used as part of a specification for a project, without review and agreement by DP. This is because this report has been written as advice and opinion rather than instructions for construction.

The contents of this report do not constitute formal design components such as are required, by the Health and Safety Legislation and Regulations, to be included in a Safety Report specifying the hazards likely to be encountered during construction and the controls required to mitigate risk. This design process requires risk assessment to be undertaken, with such assessment being dependent upon factors relating to likelihood of occurrence and consequences of damage to property and to life. This, in turn, requires project data and analysis presently beyond the knowledge and project role respectively of DP. DP may be able, however, to assist the client in carrying out a risk assessment of potential hazards contained in the Comments section of this report, as an extension to the current scope of works, if so requested, and provided that suitable additional information is made available to DP. Any such risk assessment would, however, be necessarily restricted to the (geotechnical / environmental / groundwater) components set out in this report and to their application by the project designers to project design, construction, maintenance and demolition.

Douglas Partners Pty Ltd

Appendix A

About This Report

About this Report

Douglas Partners

Introduction

These notes have been provided to amplify DP's report in regard to classification methods, field procedures and the comments section. Not all are necessarily relevant to all reports.

DP's reports are based on information gained from limited subsurface excavations and sampling, supplemented by knowledge of local geology and experience. For this reason, they must be regarded as interpretive rather than factual documents, limited to some extent by the scope of information on which they rely.

Copyright

Borehole and Test Pit Logs

The borehole and test pit logs presented in this report are an engineering and/or geological interpretation of the subsurface conditions, and their reliability will depend to some extent on frequency of sampling and the method of drilling or excavation. Ideally, continuous undisturbed sampling or core drilling will provide the most reliable assessment, but this is not always practicable or possible to justify on economic grounds. In any case the boreholes and test pits represent only a very small sample of the total subsurface profile.

Interpretation of the information and its application to design and construction should therefore take into account the spacing of boreholes or pits, the frequency of sampling, and the possibility of other than 'straight line' variations between the test locations.

Groundwater

Where groundwater levels are measured in boreholes there are several potential problems, namely:

- In low permeability soils groundwater may enter the hole very slowly or perhaps not at all during the time the hole is left open;
- A localised, perched water table may lead to an erroneous indication of the true water table;
- Water table levels will vary from time to time with seasons or recent weather changes. They may not be the same at the time of construction as are indicated in the report; and
- The use of water or mud as a drilling fluid will mask any groundwater inflow. Water has to be blown out of the hole and drilling mud must first be washed out of the hole if water measurements are to be made.

More reliable measurements can be made by installing standpipes which are read at intervals over several days, or perhaps weeks for low permeability soils. Piezometers, sealed in a particular stratum, may be advisable in low permeability soils or where there may be interference from a perched water table.

Reports

The report has been prepared by qualified personnel, is based on the information obtained from field and laboratory testing, and has been undertaken to current engineering standards of interpretation and analysis. Where the report has been prepared for a specific design proposal, the information and interpretation may not be relevant if the design proposal is changed. If this happens, DP will be pleased to review the report and the sufficiency of the investigation work.

Every care is taken with the report as it relates to interpretation of subsurface conditions, discussion of geotechnical and environmental aspects, and recommendations or suggestions for design and construction. However, DP cannot always anticipate or assume responsibility for:

- Unexpected variations in ground conditions. The potential for this will depend partly on borehole or pit spacing and sampling frequency;
- Changes in policy or interpretations of policy by statutory authorities; or
- The actions of contractors responding to commercial pressures.

If these occur, DP will be pleased to assist with investigations or advice to resolve the matter.

Site Anomalies

In the event that conditions encountered on site during construction appear to vary from those which were expected from the information contained in the report, DP requests that it be immediately notified. Most problems are much more readily resolved when conditions are exposed rather than at some later stage, well after the event.

Information for Contractual Purposes

Where information obtained from this report is provided for tendering purposes, it is recommended that all information, including the written report and discussion, be made available. In circumstances where the discussion or comments section is not relevant to the contractual situation, it may be appropriate to prepare a specially edited document. DP would be pleased to assist in this regard and/or to make additional report copies available for contract purposes at a nominal charge.

Site Inspection

The company will always be pleased to provide engineering inspection services for geotechnical and environmental aspects of work to which this report is related. This could range from a site visit to confirm that conditions exposed are as expected, to full time engineering presence on site.

Appendix B

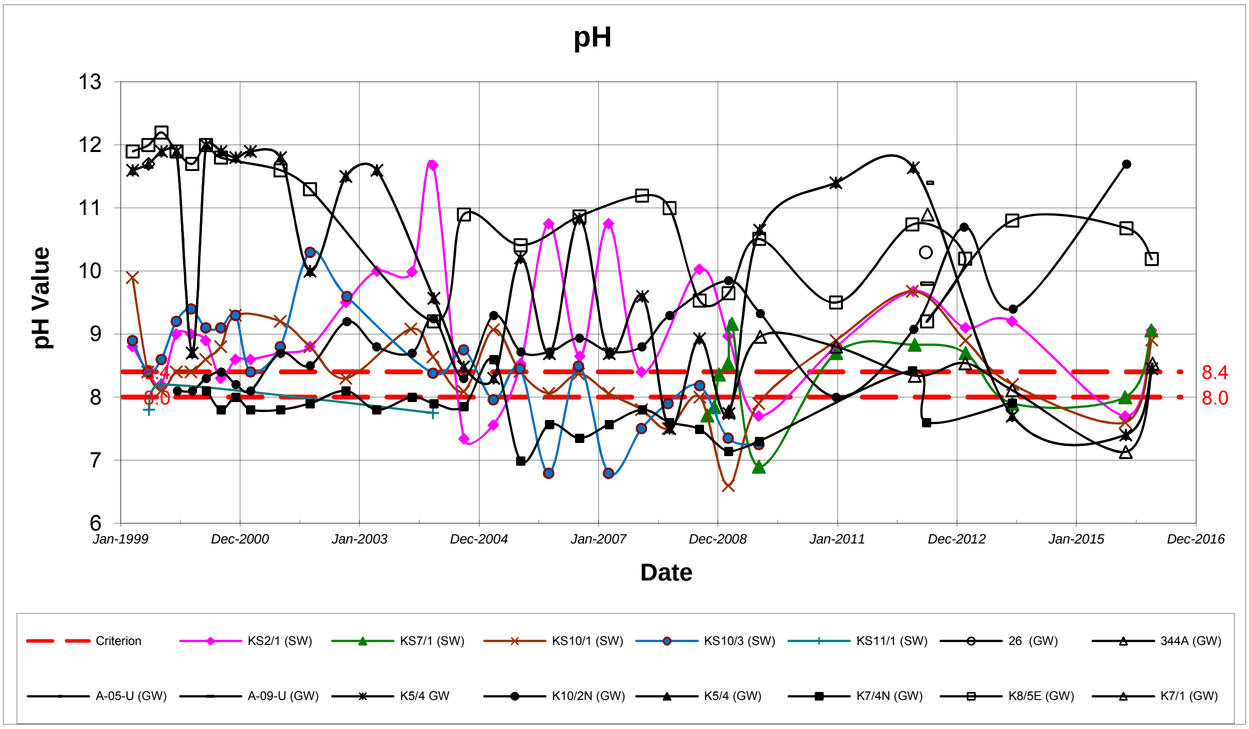
Plots of Water Quality for Key Parameters – Surface Water and Fill Aquifer

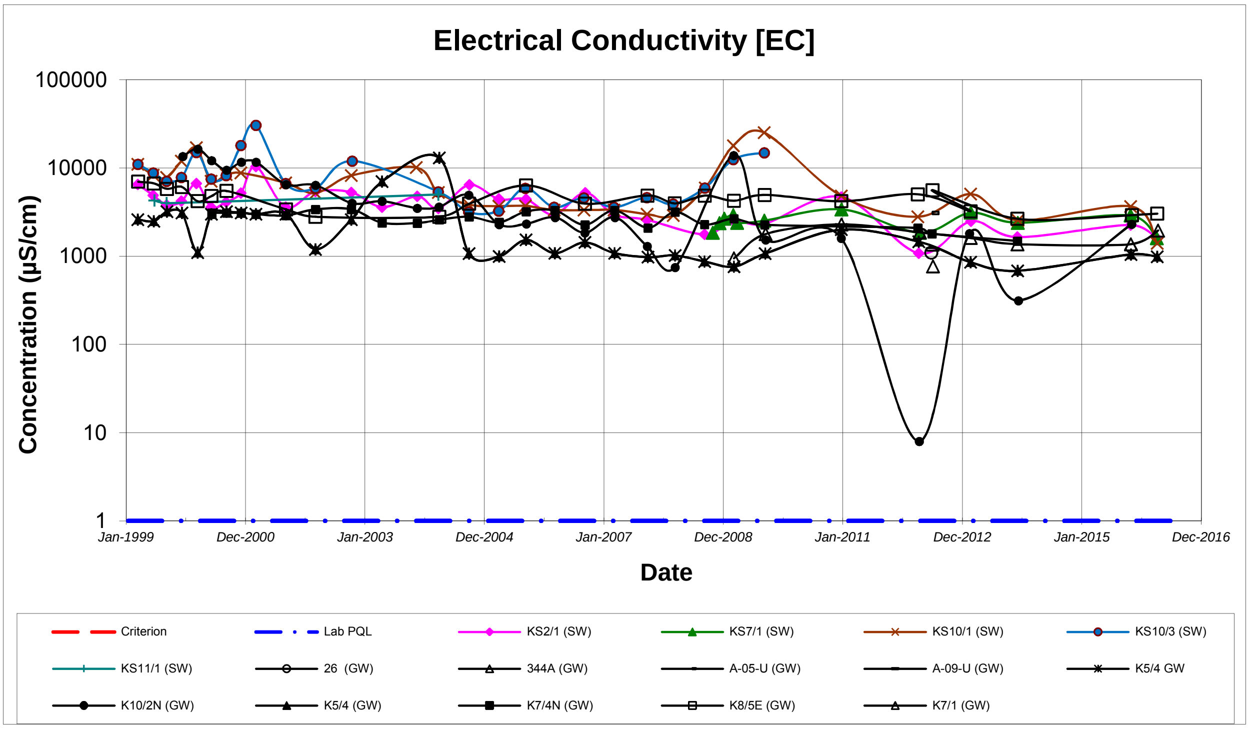
HISTORICAL WATER QUALITY MONITORING

Surface Water and Fill Aquifer

Kooragang Island Waste Emplacement Facility

Period: Jan 1999 to May 2016 **Project No:** 81209.02
Client: Hunter Development Corporation **Document No:** R.001.Rev0





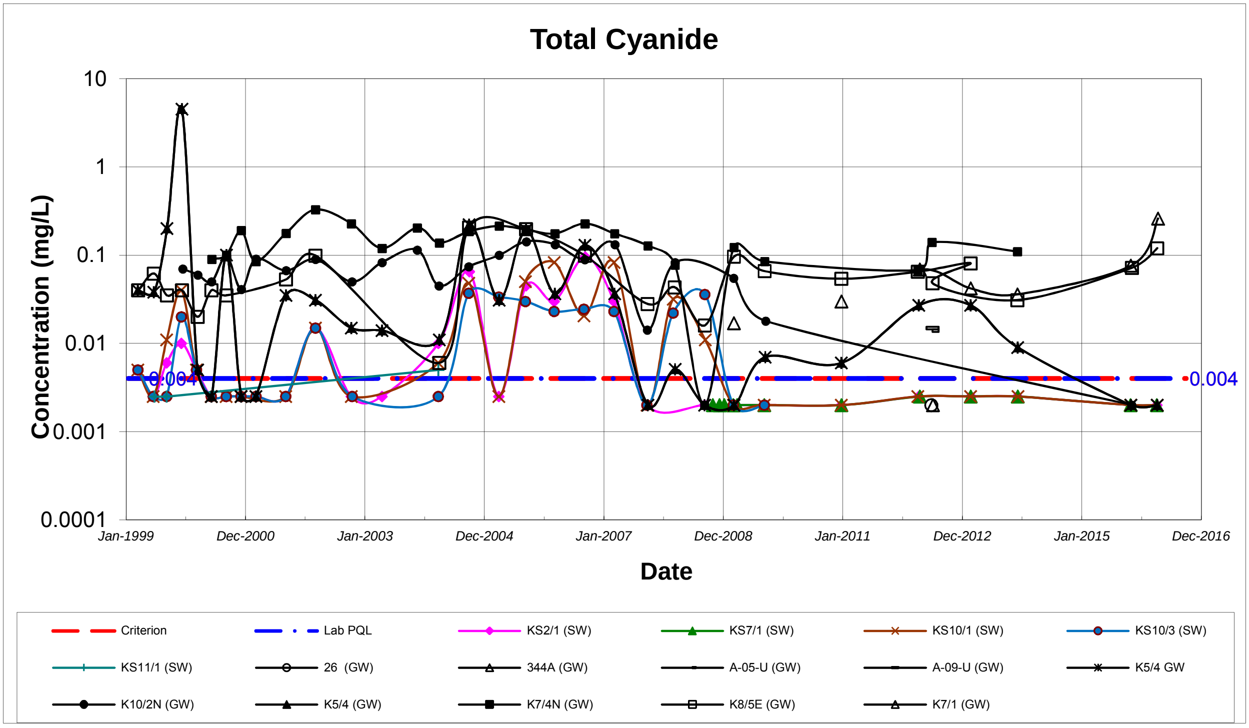
Notes:
1. Values reported below PQL are plotted as half of PQL.
2. ANZECC (2000) Fresh Criteria adopted; Marine Water criteria adopted if no Fresh value.
3. If a Criterion line is not plotted, there are No Criteria for the parameter.

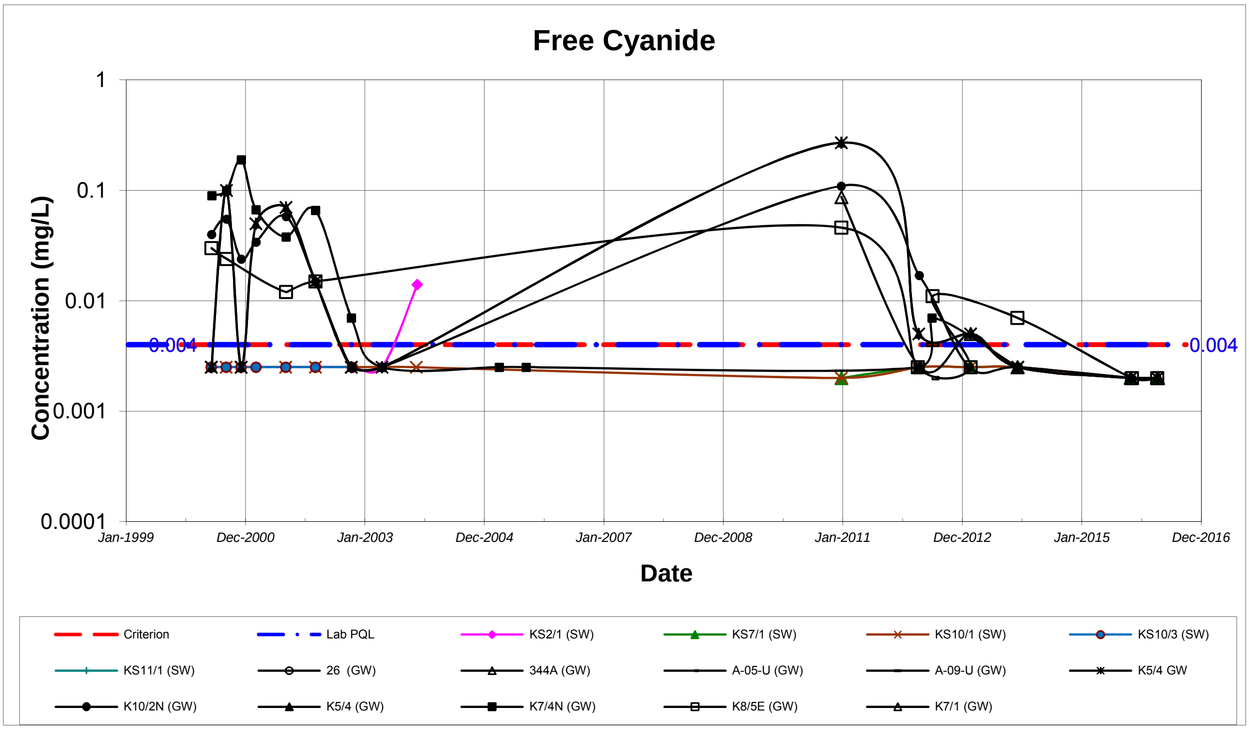
HISTORICAL WATER QUALITY MONITORING

Surface Water and Fill Aquifer

Kooragang Island Waste Emplacement Facility

Period: Jan 1999 to May 2016 **Project No:** 81209.02
Client: Hunter Development Corporation **Document No:** R.001.Rev0





Notes:
1. Values reported below PQL are plotted as half of PQL.
2. ANZECC (2000) Fresh Criteria adopted; Marine Water criteria adopted if no Fresh value.
3. If a Criterion line is not plotted, there are No Criteria for the parameter.

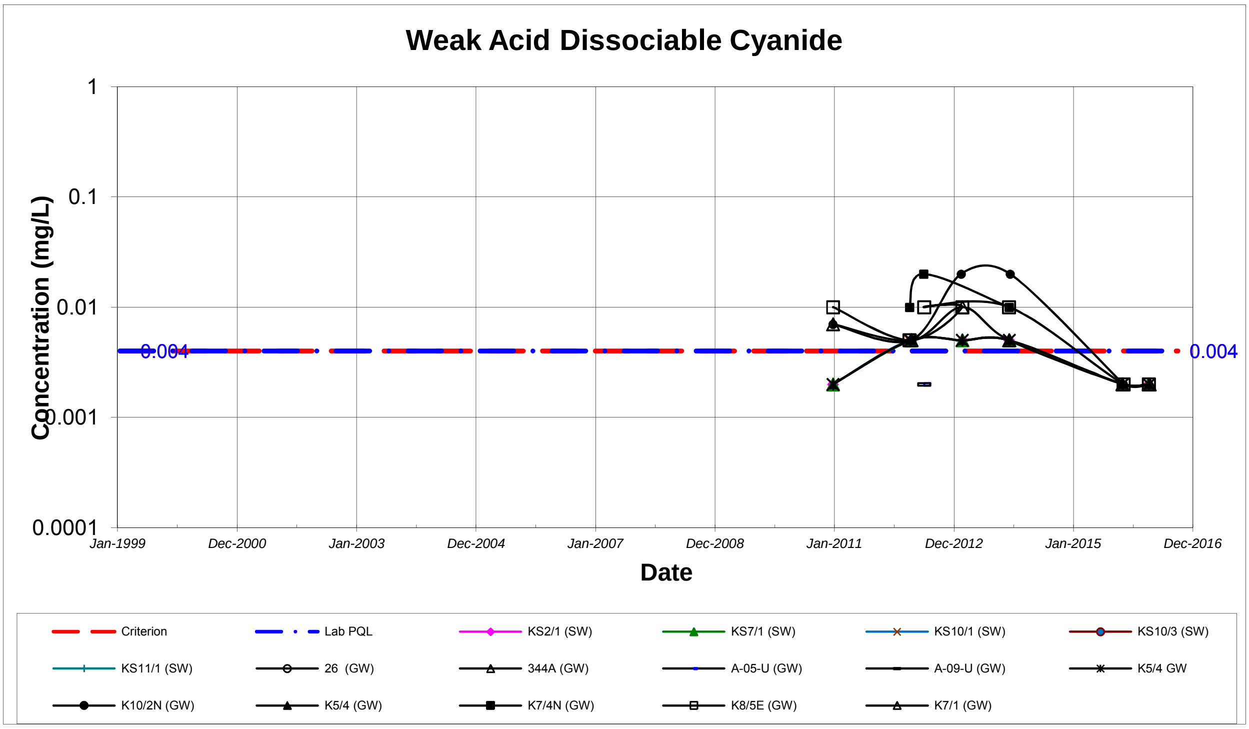
HISTORICAL WATER QUALITY MONITORING

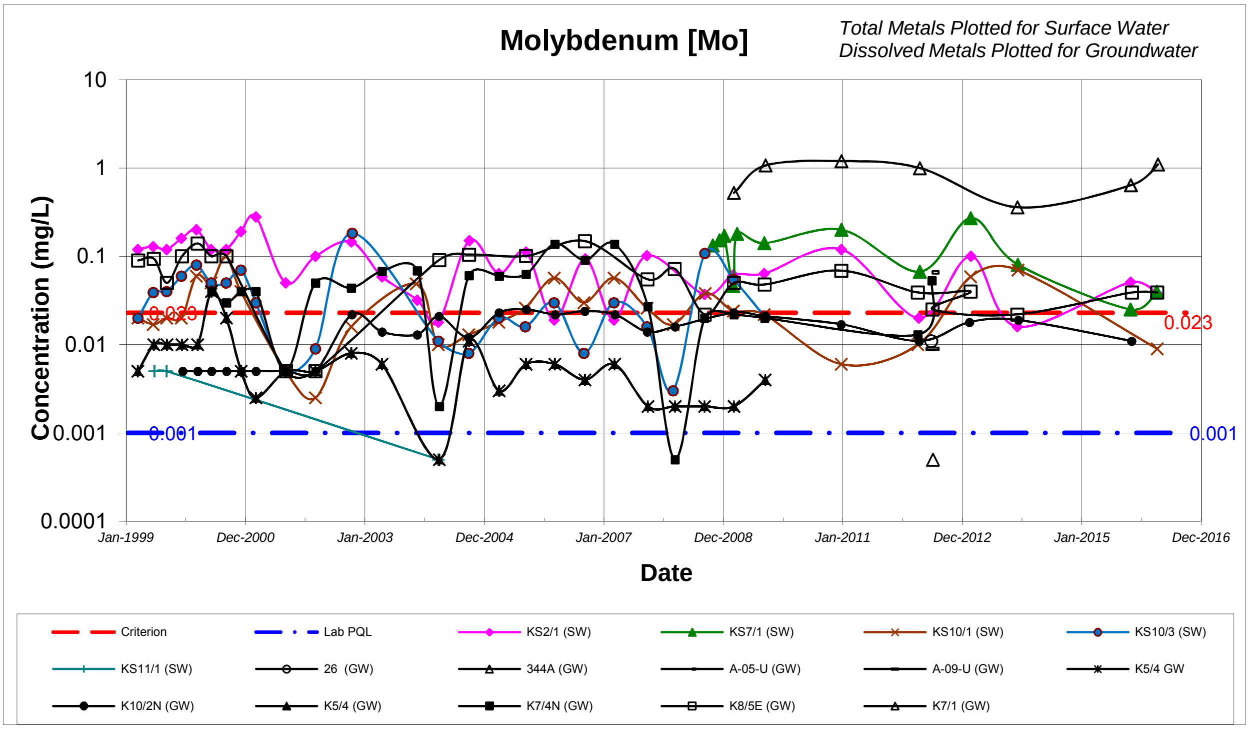
Surface Water and Fill Aquifer

Kooragang Island Waste Emplacement Facility

Period: Jan 1999 to May 2016 — **Project No:** 81209.02

Client: Hunter Development Corporation — **Document No:** R.001.Rev0





Notes:
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3. If a Criterion line is not plotted, there are No Criteria for the parameter.

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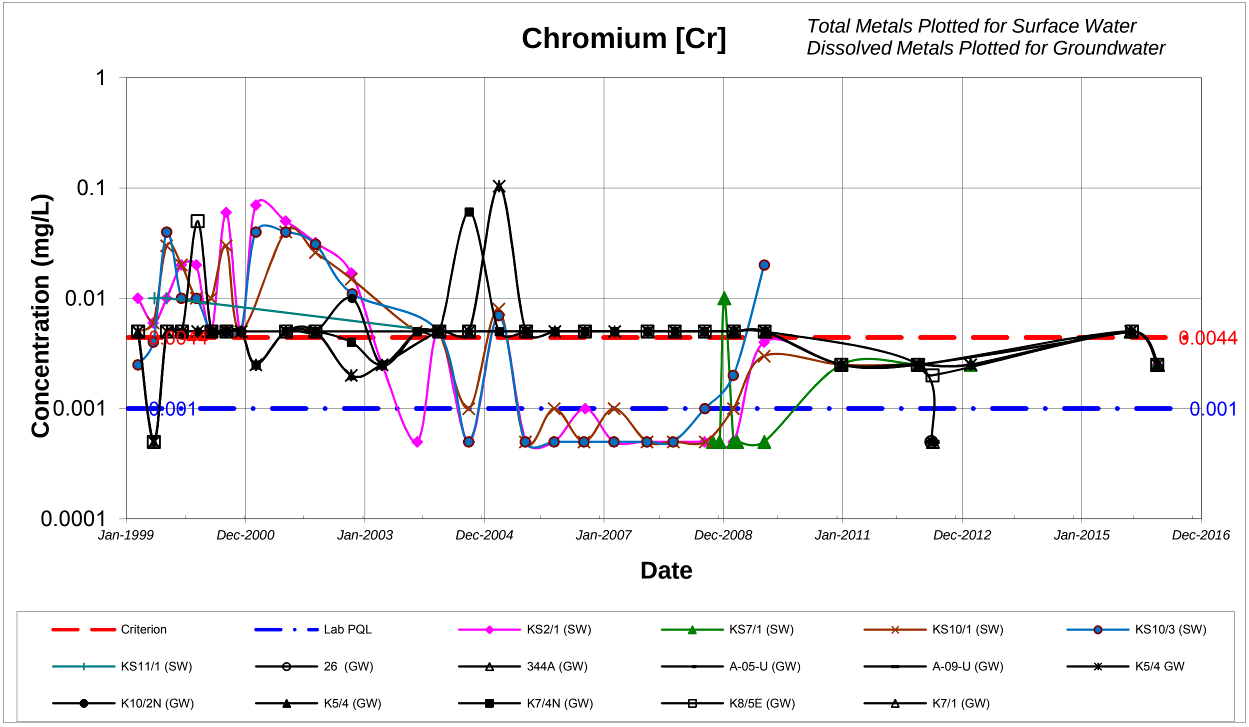
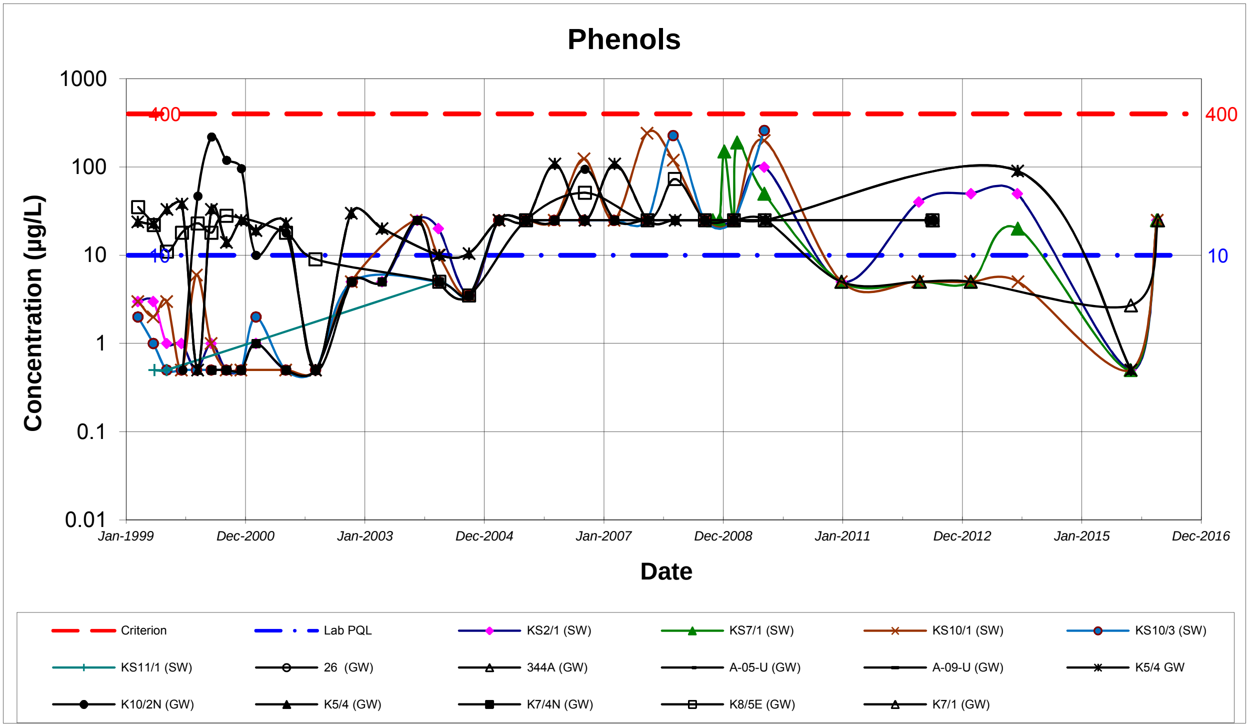
HISTORICAL WATER QUALITY MONITORING
Surface Water and Fill Aquifer
Kooragang Island Waste Emplacement Facility

Period: Jan 1999 to May 2016 **Project No:** 81209.02
Client: Hunter Development Corporation **Document No:** R.001.Rev0





Notes:
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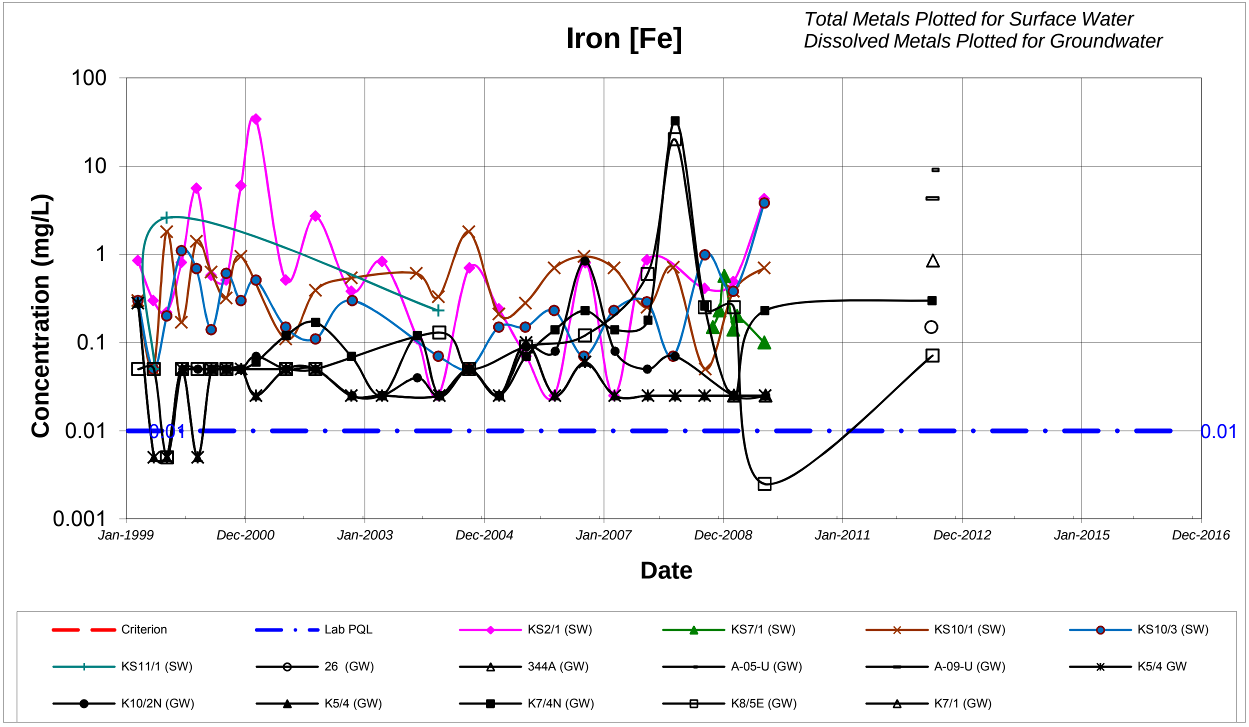
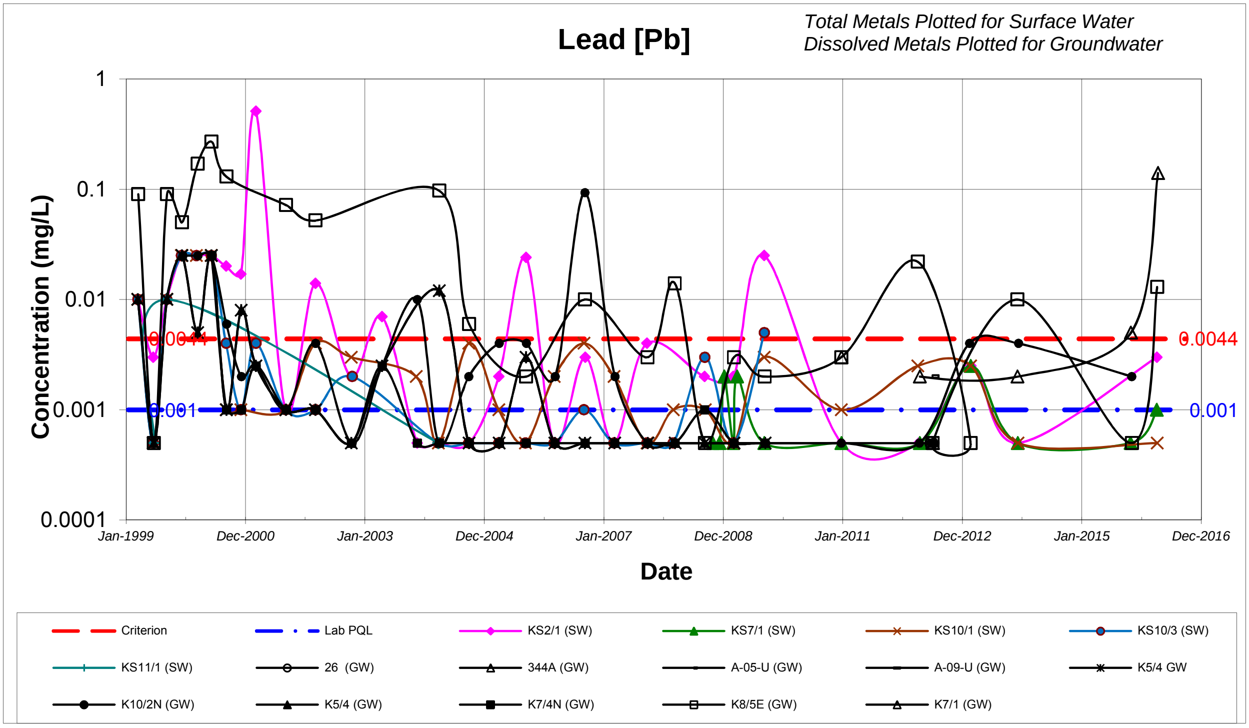
HISTORICAL WATER QUALITY MONITORING

Surface Water and Fill Aquifer

Kooragang Island Waste Emplacement Facility

Period: Jan 1999 to May 2016 **Project No:** 81209.02
Client: Hunter Development Corporation **Document No:** R.001.Rev0





Notes:
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HISTORICAL WATER QUALITY MONITORING

Surface Water and Fill Aquifer

Kooragang Island Waste Emplacement Facility

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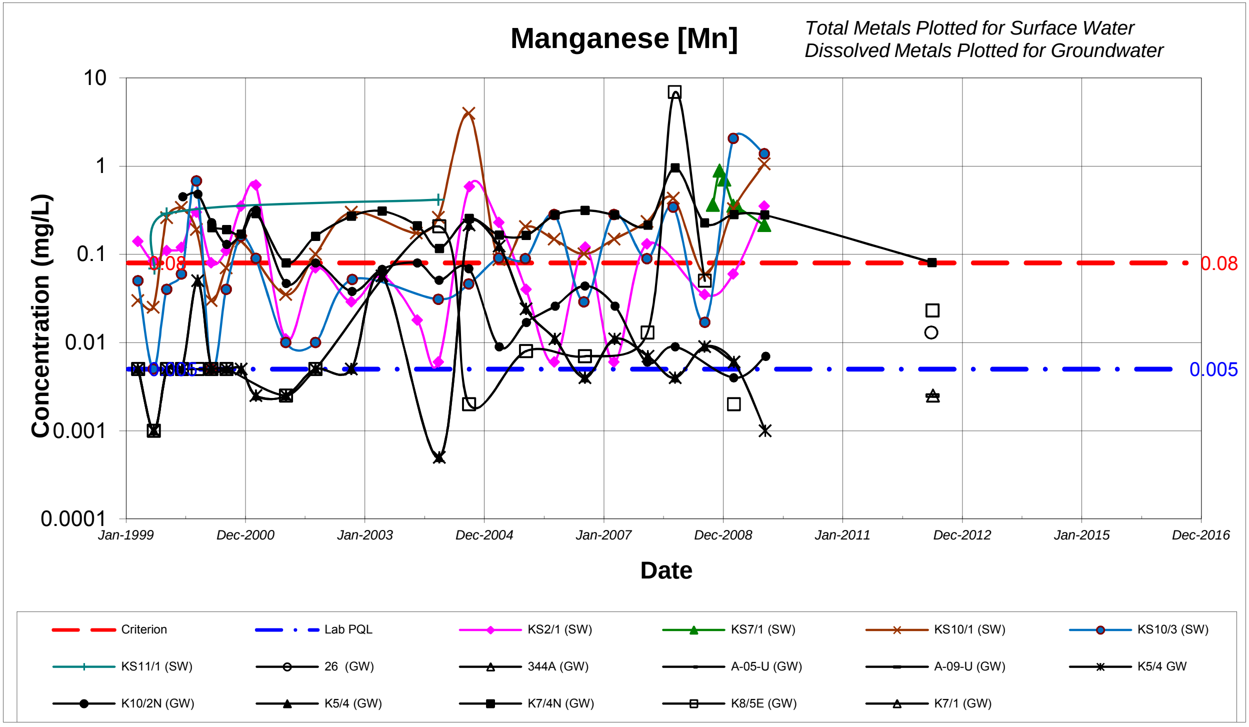

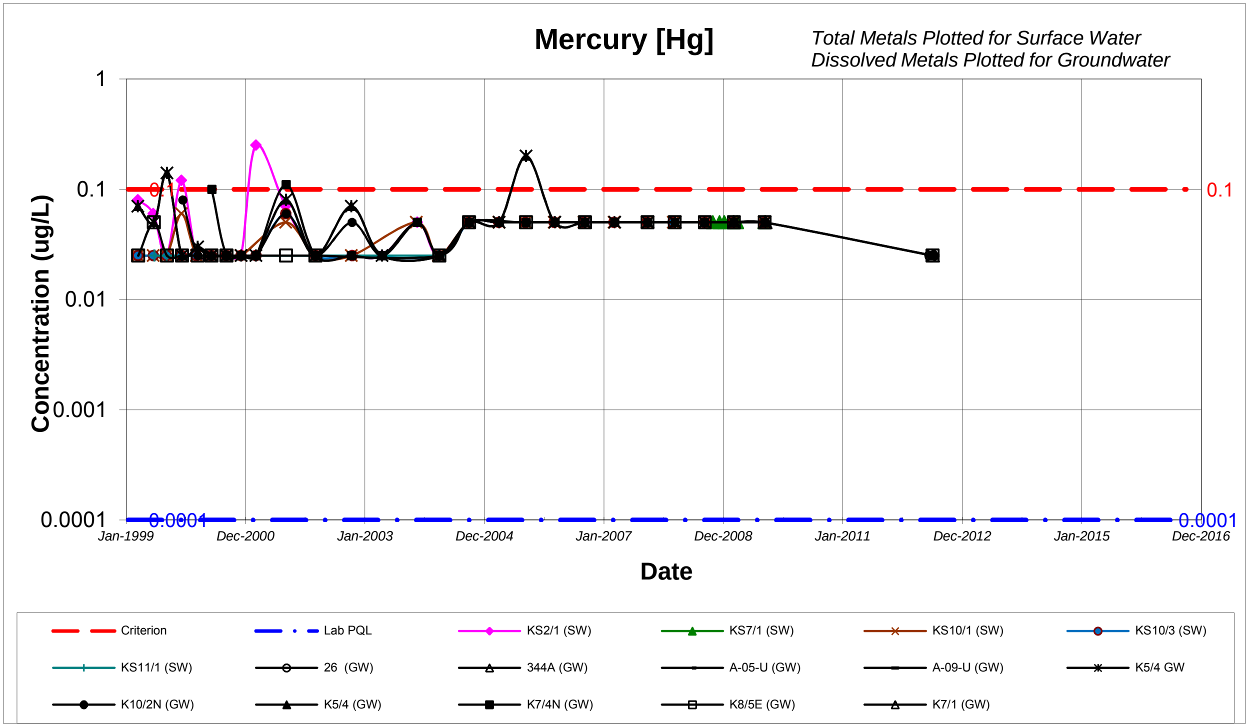

Notes:
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HISTORICAL WATER QUALITY MONITORING

Surface Water and Fill Aquifer

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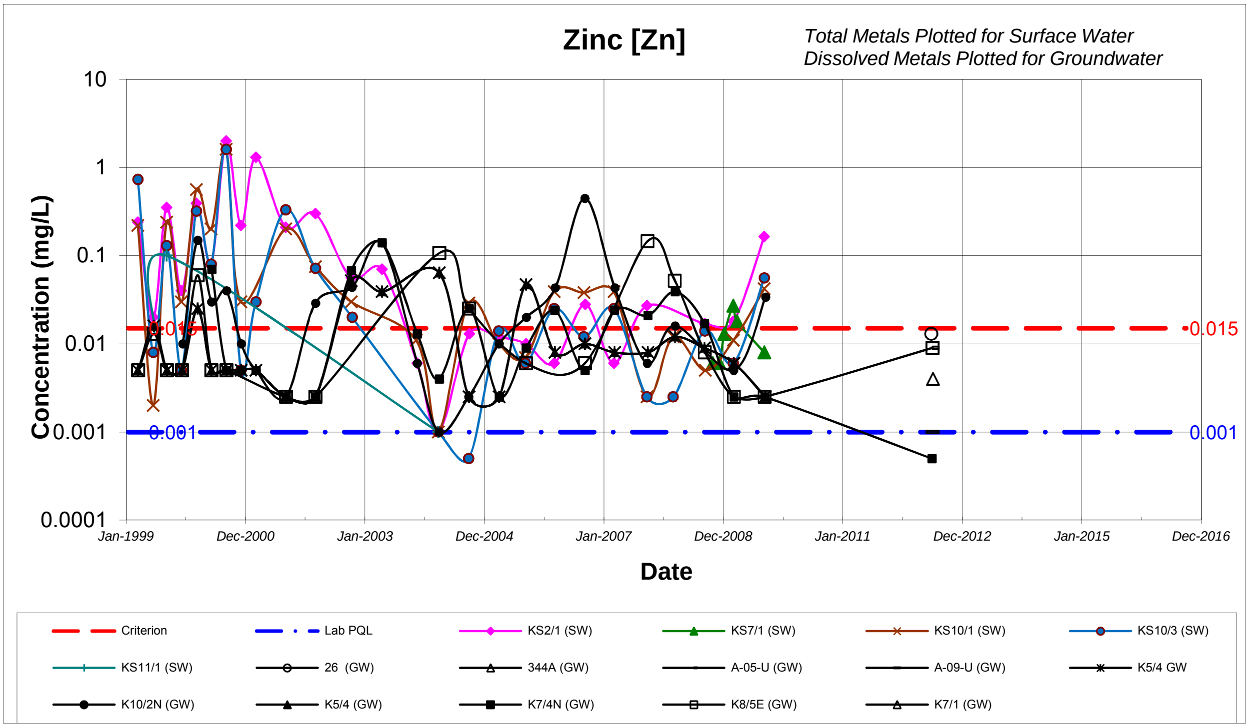

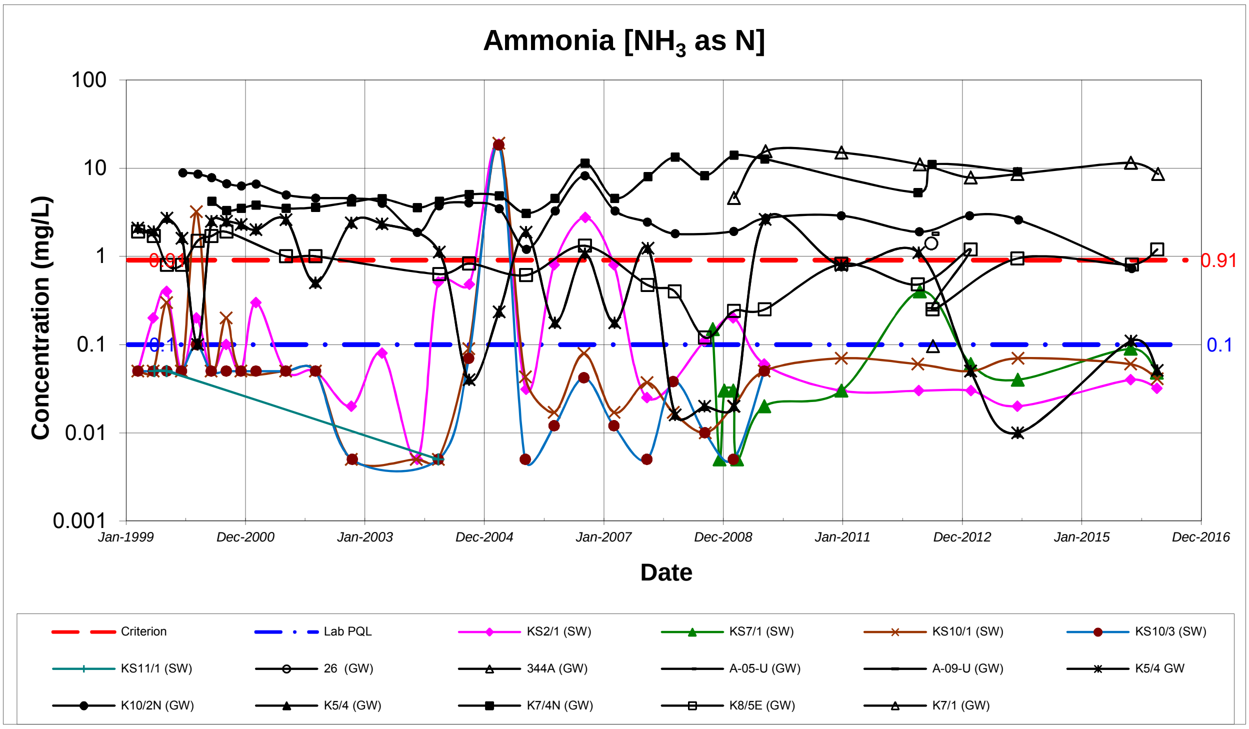

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HISTORICAL WATER QUALITY MONITORING

Surface Water and Fill Aquifer

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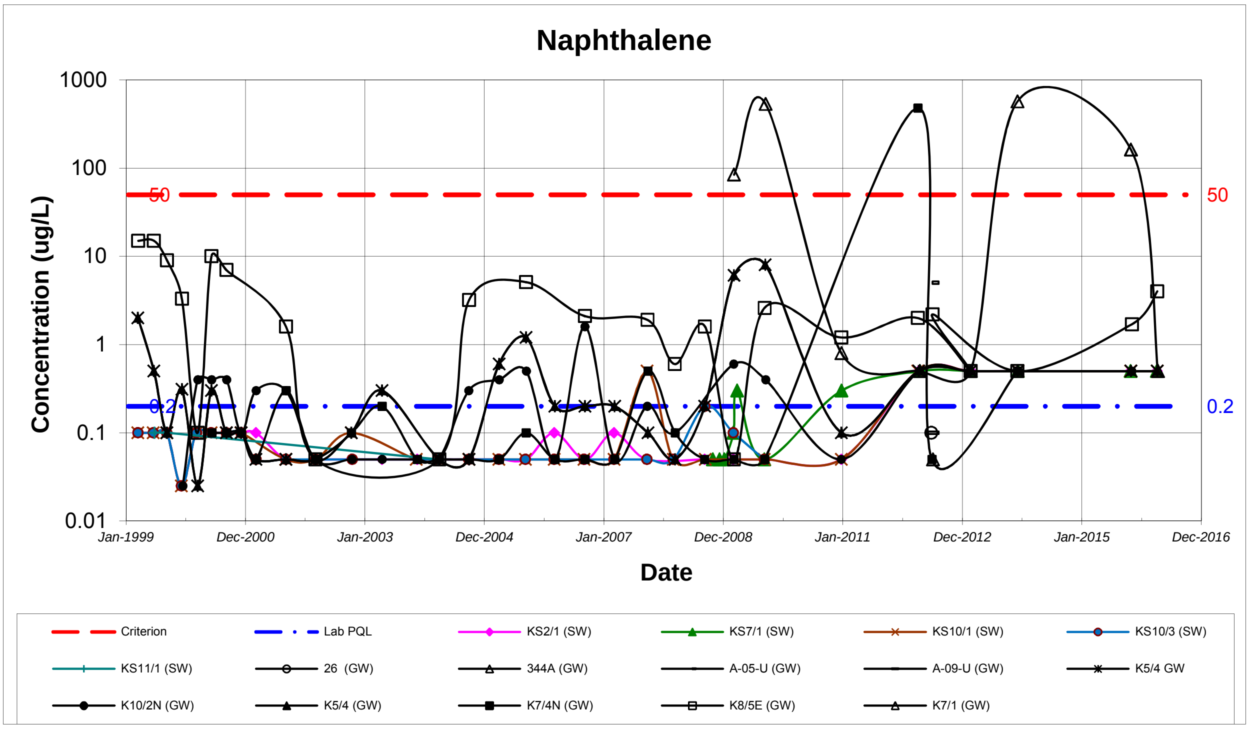

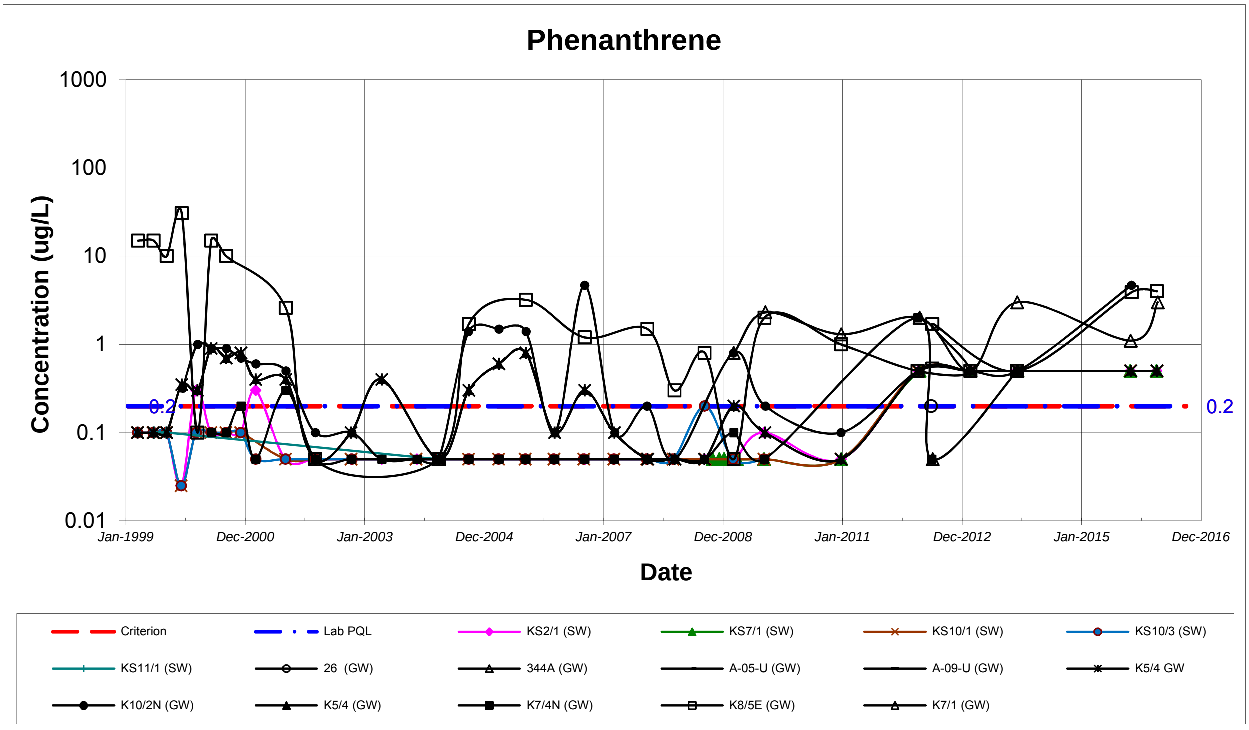

Notes:
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HISTORICAL WATER QUALITY MONITORING

Surface Water and Fill Aquifer

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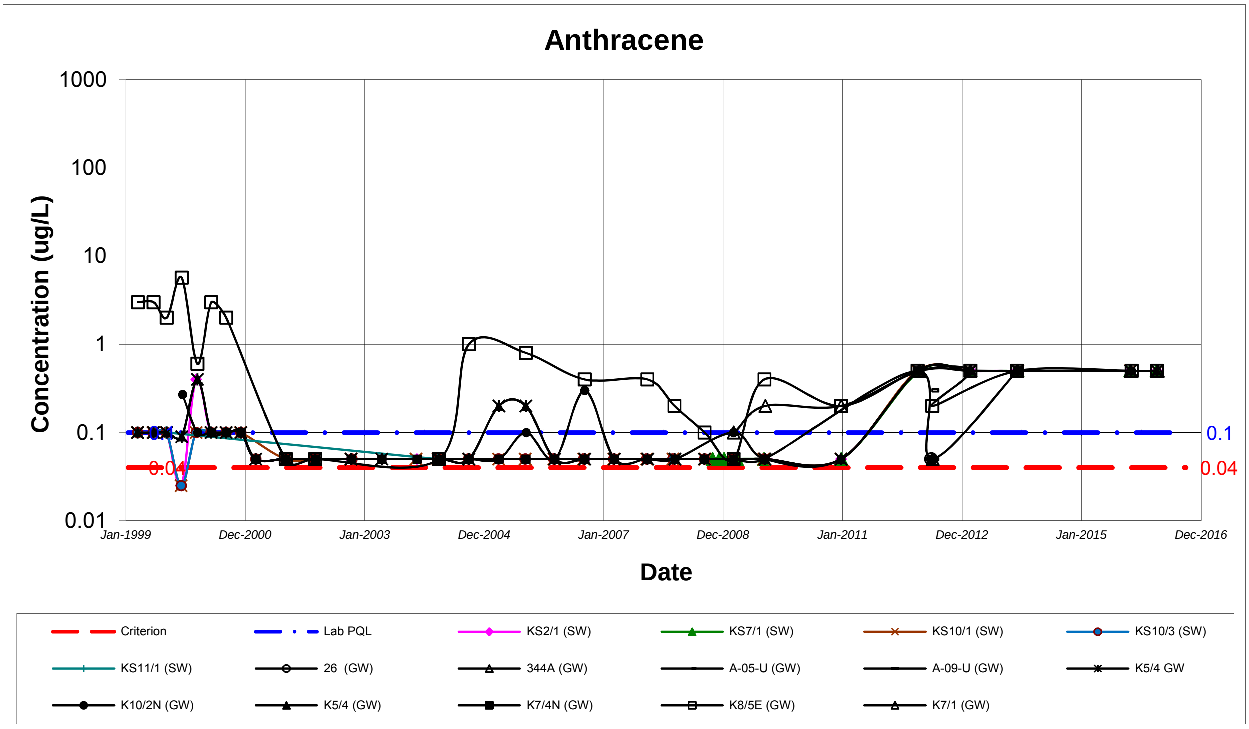

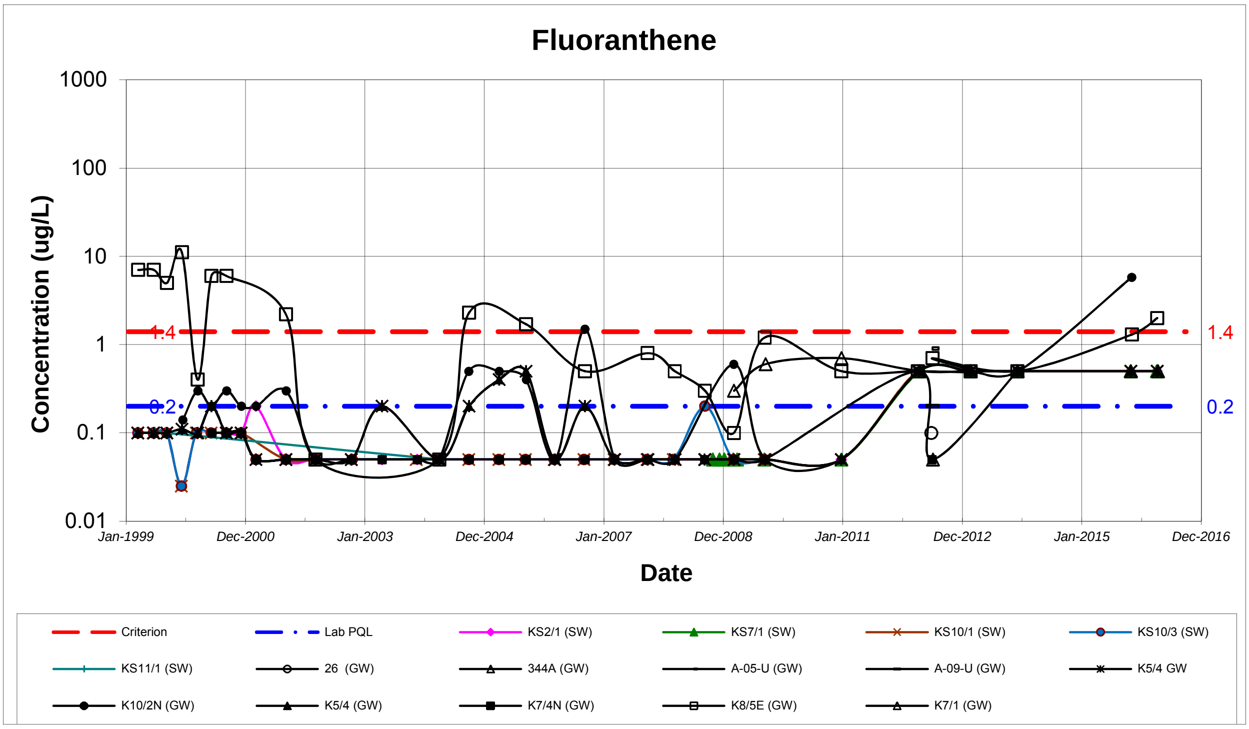

Notes:
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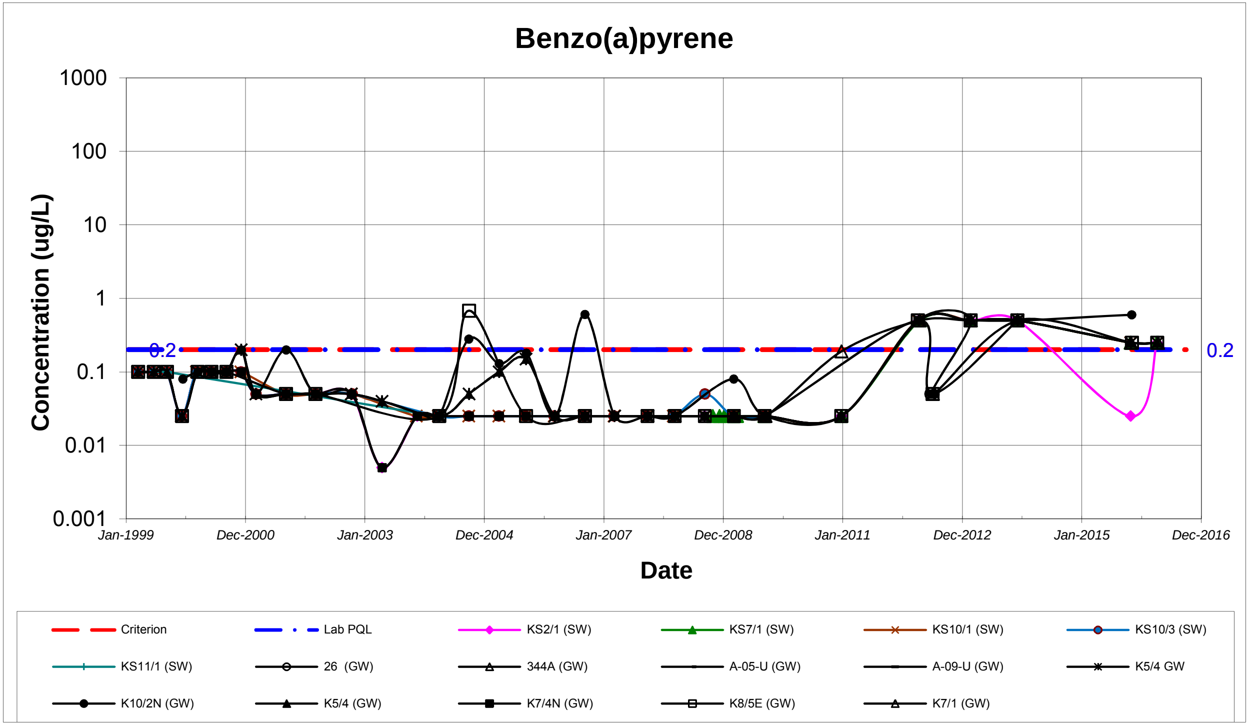
HISTORICAL WATER QUALITY MONITORING

Surface Water and Fill Aquifer

Kooragang Island Waste Emplacement Facility

Period:	**Jan 1999 to May 2016**	**Project No:**	**81209.02**
Client:	**Hunter Development Corporation**	**Document No:**	**R.001.Rev0**



Notes:

1. Values reported below PQL are plotted as half of PQL.
2. ANZECC (2000) Fresh Criteria adopted; Marine Water criteria adopted if no Fresh value.
3. If a Criterion line is not plotted, there are No Criteria for the parameter.

Appendix C

Plot of Groundwater Levels in Fill and Estuarine Aquifer versus Daily Rainfall:

- A04-U/L, A05-U/L, C05-U/L (Figure C1)

Plot of Surface Water Level versus Daily Rainfall:

- Main KIWEF Ponds and Ponds North and West of the Railway Line (Figure C2)

Plots of Electrical Conductivity, Water Level/Depth, Temperature and Rainfall

- SWDP2 Deep Pond / SWDP101 Deep Pond North (Figure C3)
- Deep Pond A / Deep Pond B (Figure C4)
- SWDP4 Easement Pond (Figures C5A, C5B, C5C)
- Easement Pond South (Figures C6)
- SWDP7A Railroad Pond (Figure C7)
- SWDP8 OEH Wetland 1 (Figure C8)
- SWDP8 OEH Wetland 3 (Figure C9)
- SWDP3 Pond 11 (Figure C10A, C10B)
- Railway Pond (Figure C11)
- B02L Windmill Road Open Channel (Figures C12A, C12B, C12C)
- GH001S Eastern Ponds (Figures C13A, C13B, C13C)
- SWDP103 BHP Wetland (Figures C14A, C14B)
- SMEC K2 Pond (Figure C15)
- K7 (Figure C16)
- K7B (Figure C17)
- Long Pond (Figure C18)

Plot of Daily Rainfall at Port Waratah Coal Services' Kooragang Coal Terminal Weather Gauge (Figure C19)

Plot of Tide Levels at Stockton Bridge versus Daily Rainfall (KCT Weather Station) (Figure C20)

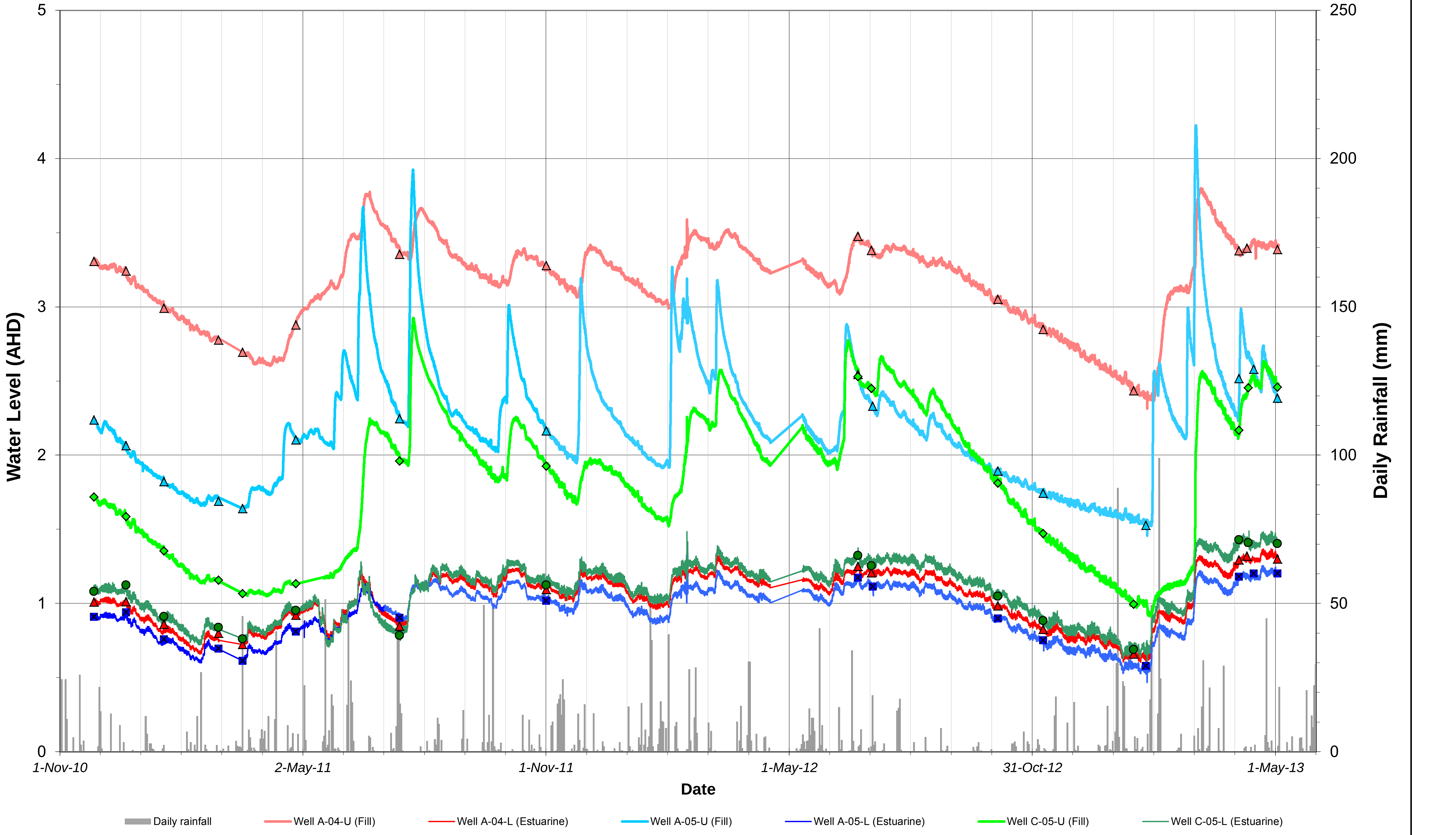


Figure C1: Groundwater Levels in Fill and Estuarine Aquifer vs Rainfall

A04-U/L, A05-U/L, C05-U/L (November 2010 to June 2013)

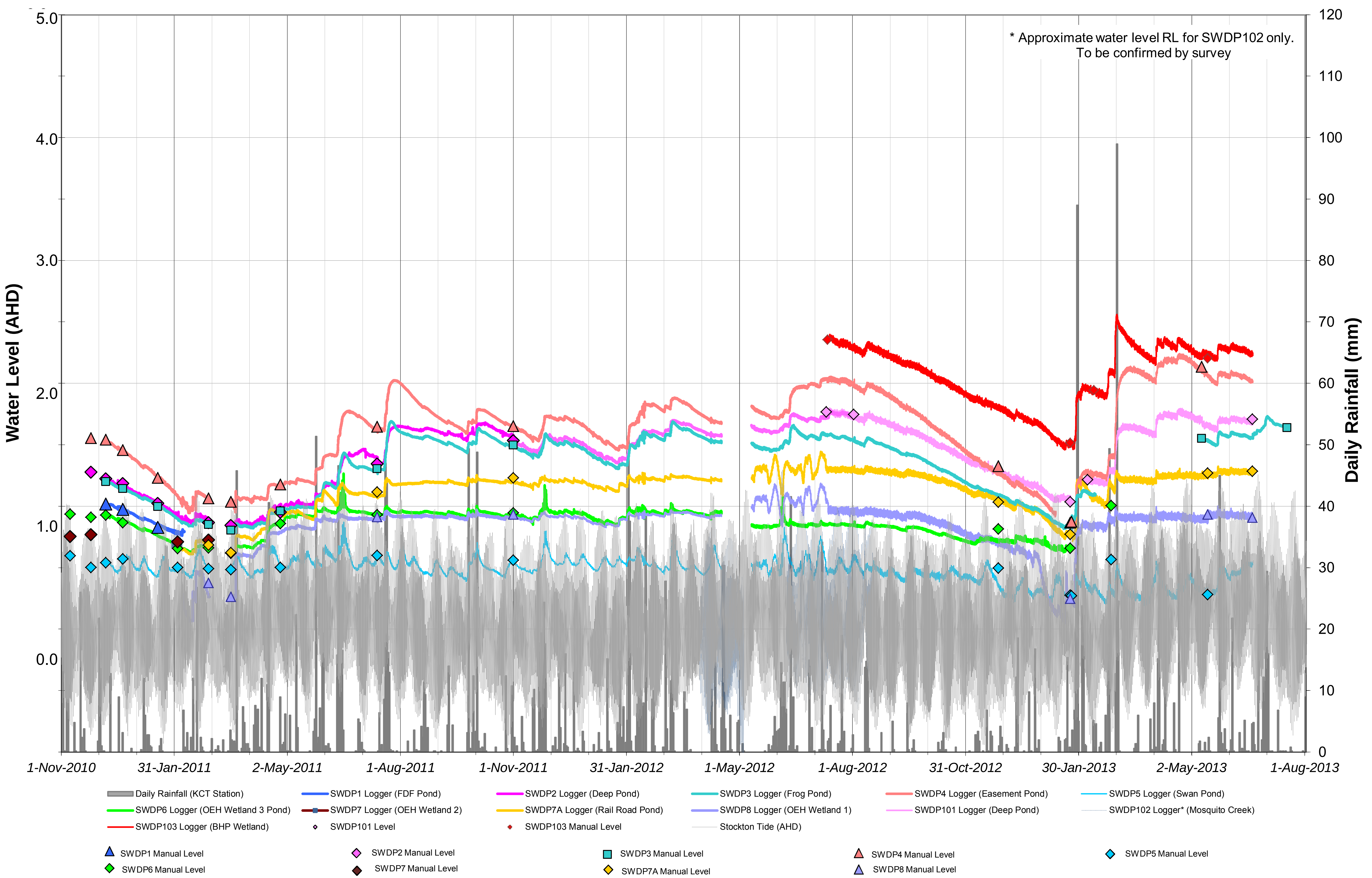
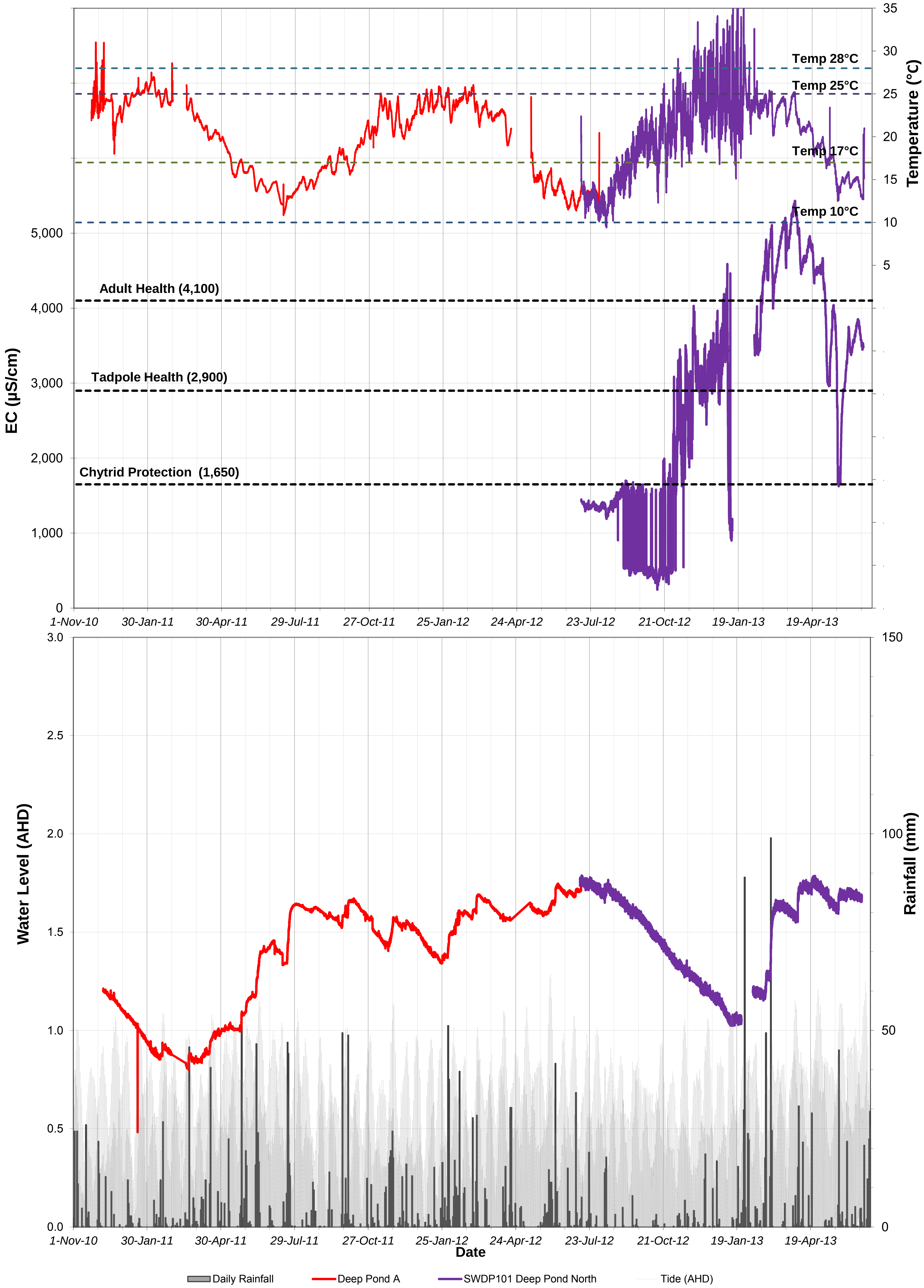
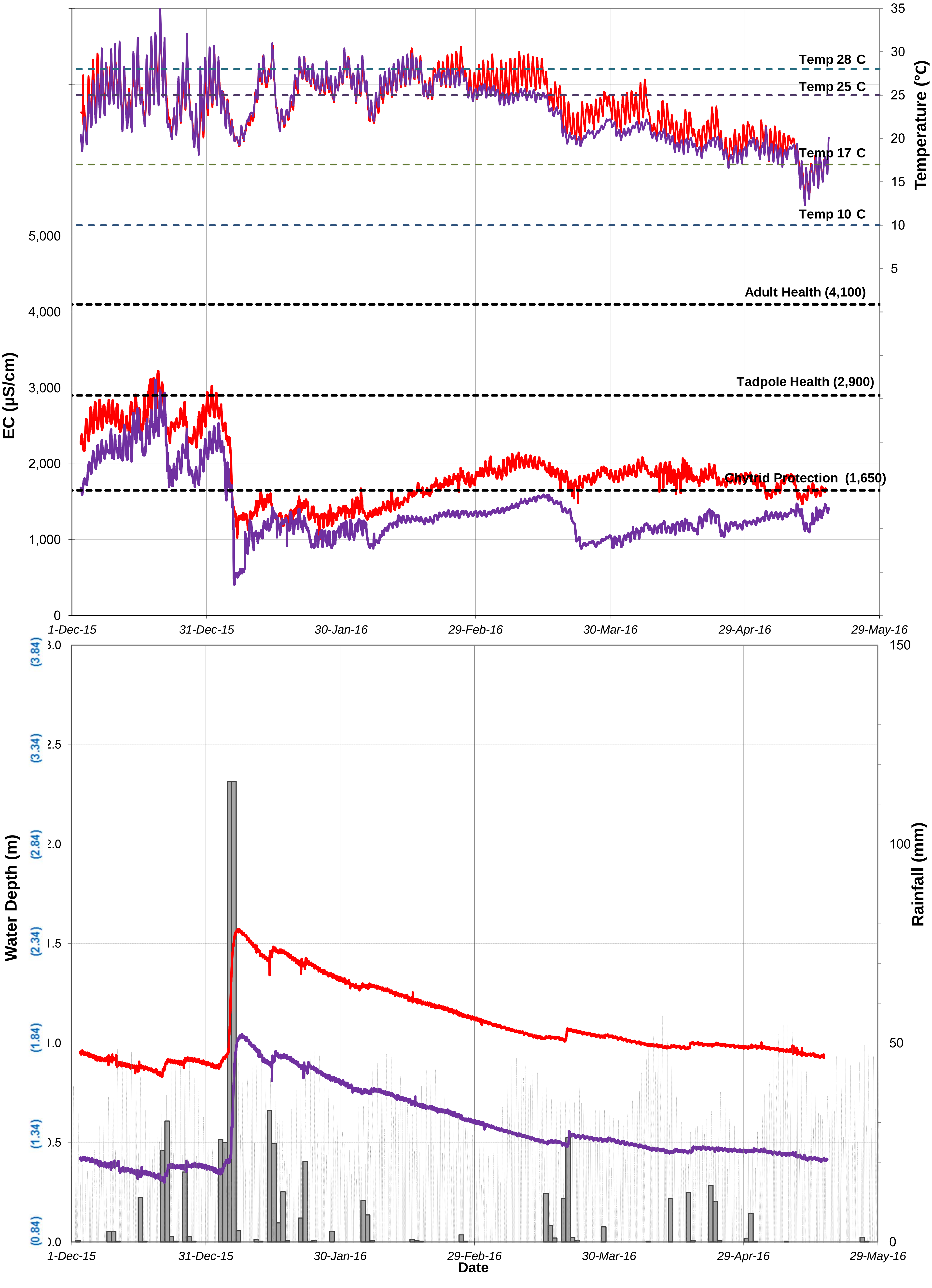


Figure C2: Surface Water Levels vs Rainfall
All Locations (November 2010 to July 2013)



Note: Tide Data Plotted as AHD

Figure C3: Electrical Conductivity, Water Level, Temperature and Rainfall - November 2010 to July 2012
SWDP2 Deep Pond A & SWDP101 Deep Pond North

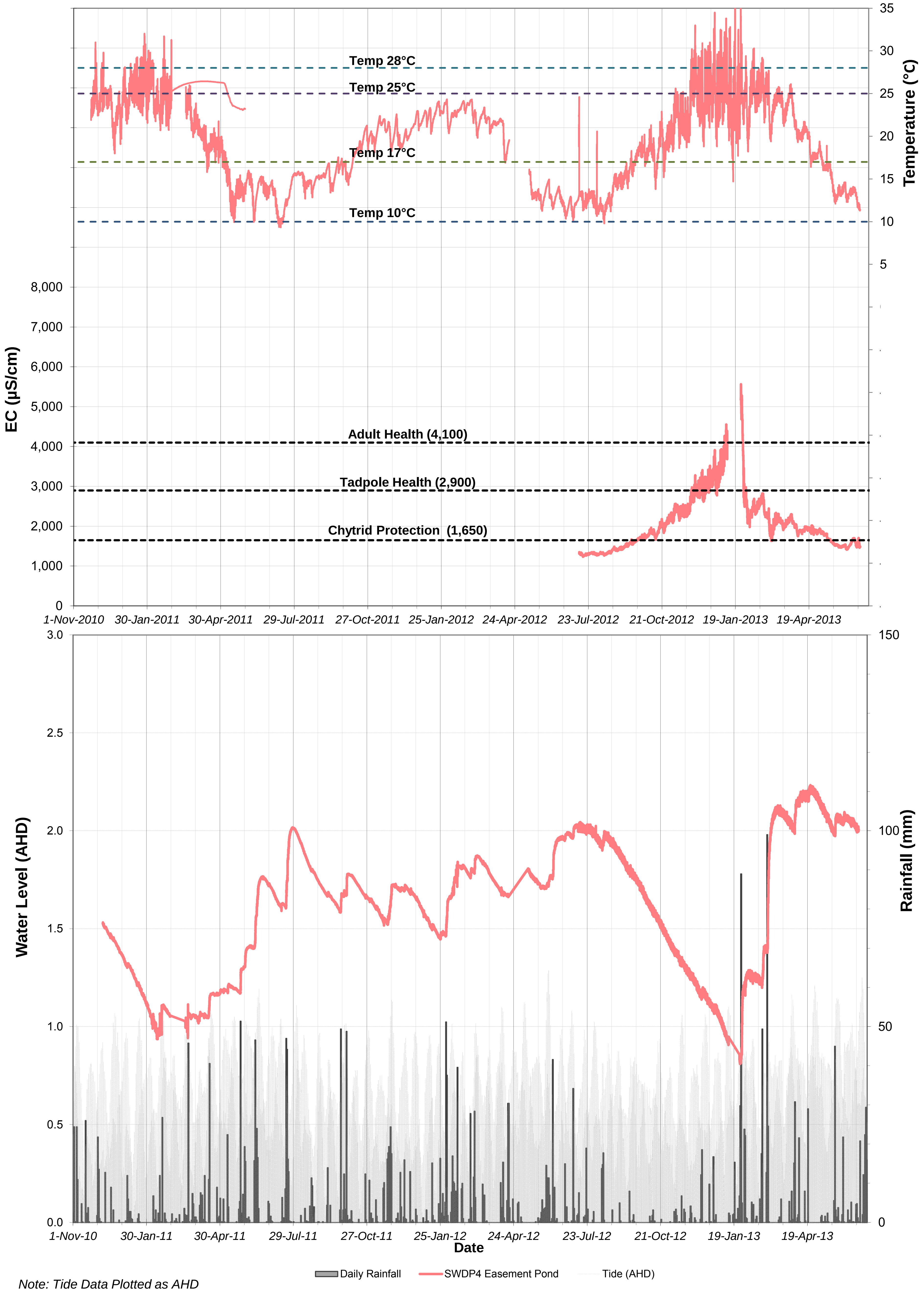


(Reduced Level in AHD) - Deep Pond A only (No survey levels for Deep Pond B)

Note: Tide Data Plotted as AHD

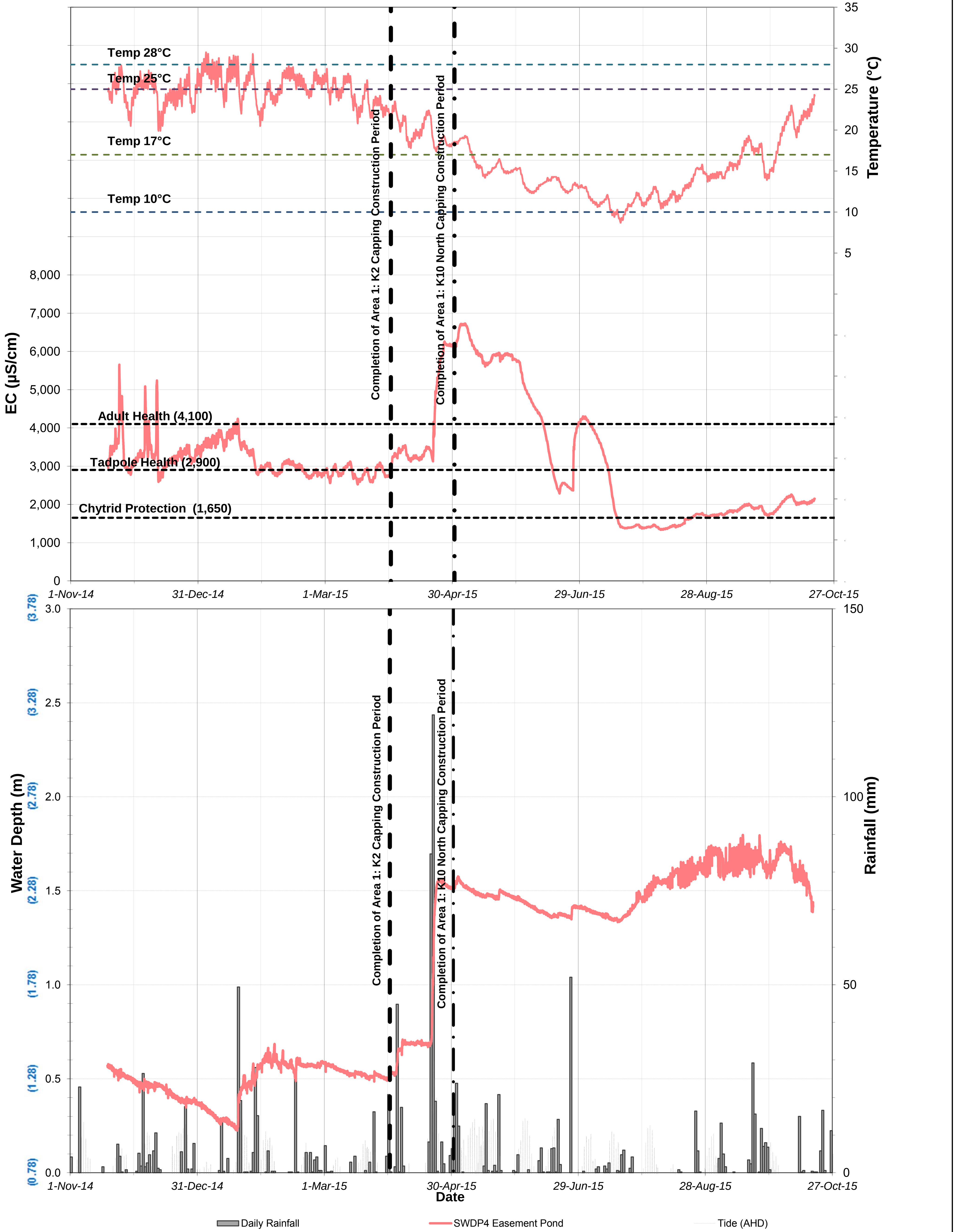
Figure C4: Electrical Conductivity, Depth, Temperature and Rainfall - December 2015 to May 2016

Deep Pond A & B



Note: Tide Data Plotted as AHD

Figure C5A: Electrical Conductivity, Water Level, Temperature and Rainfall - 1 November 2010 to July 2013
SWDP4 Easement Pond



Note: Tide Data Plotted as AHD

Figure C5B: Electrical Conductivity, Depth, Temperature and Rainfall - November 2014 to October 2015

SWDP4 Easement Pond

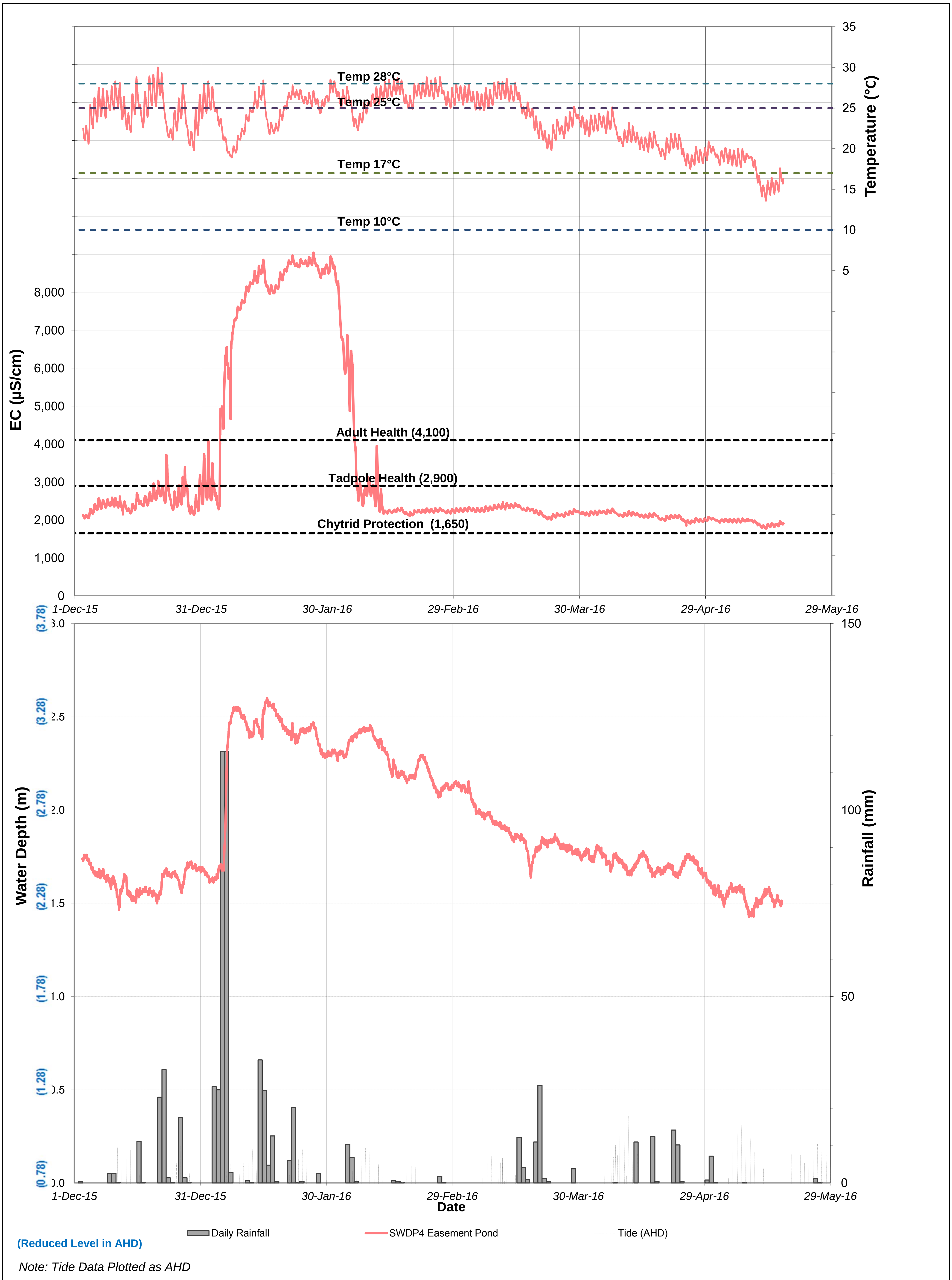
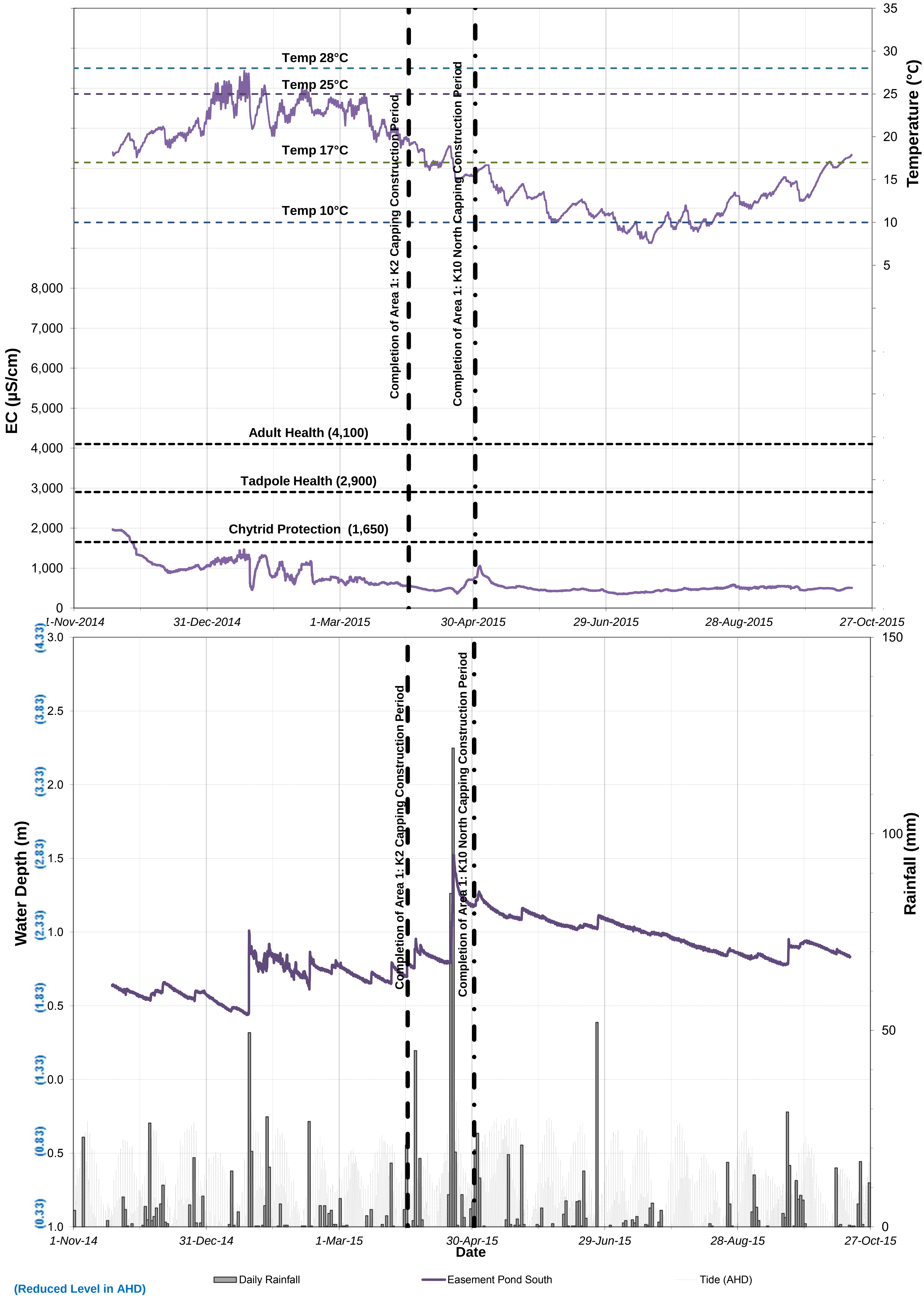
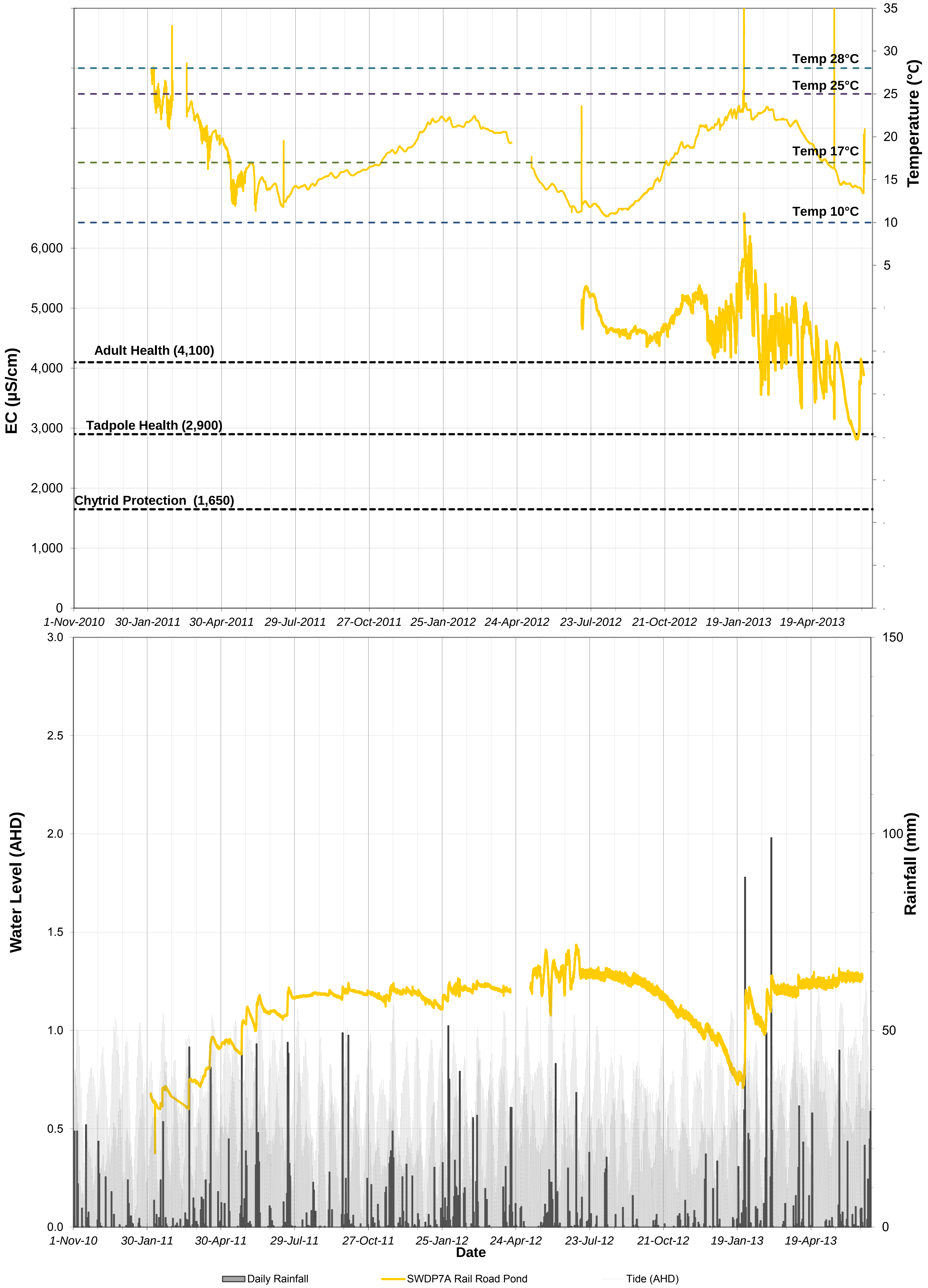


Figure C5C: Electrical Conductivity, Depth, Temperature and Rainfall - December 2015 to May 2016
SWDP4 Easement Pond



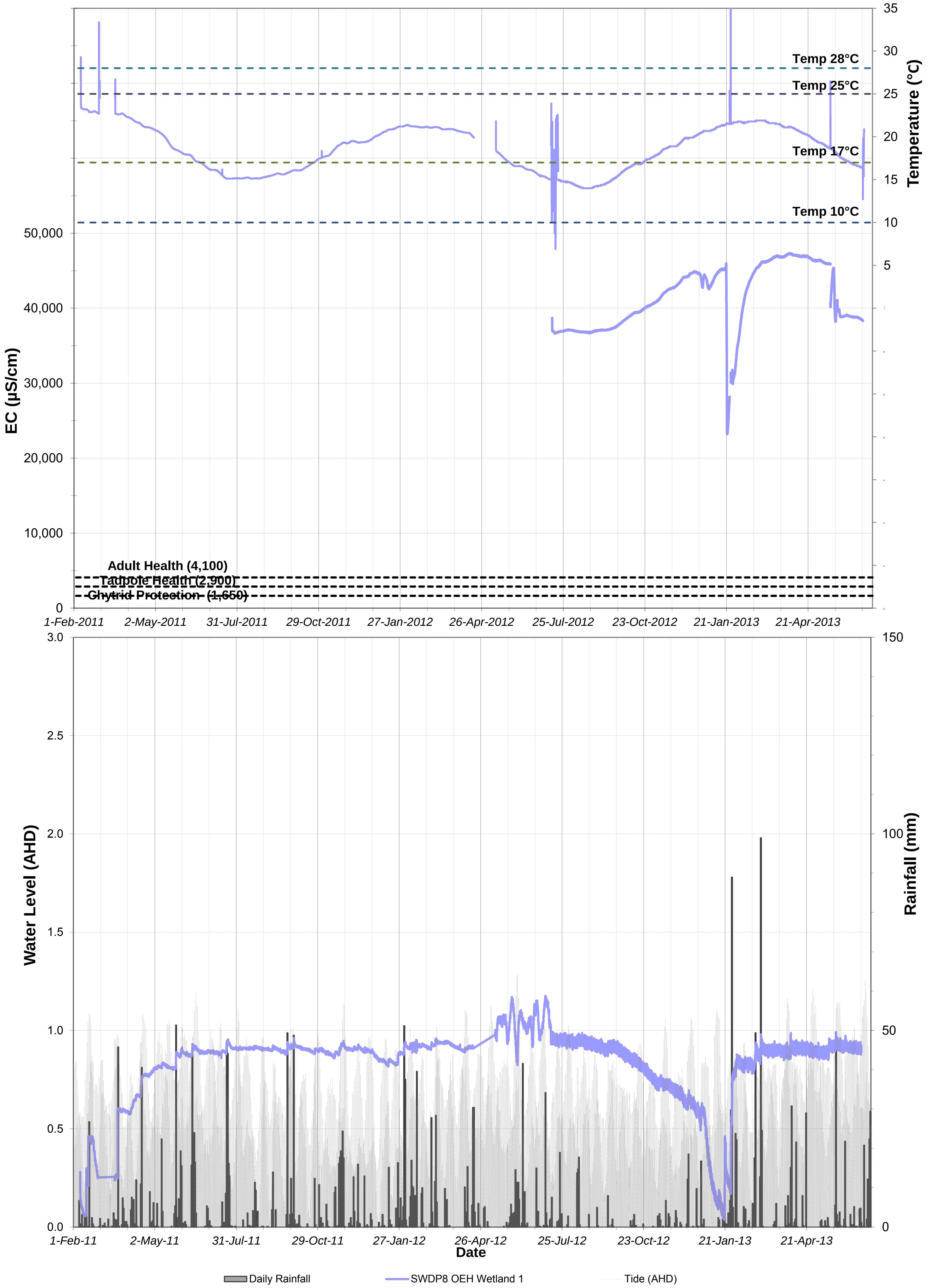
Note: Tide Data Plotted as AHD

Figure C6: Electrical Conductivity, Depth, Temperature and Rainfall - November 2014 to October 2015
Easement Pond South



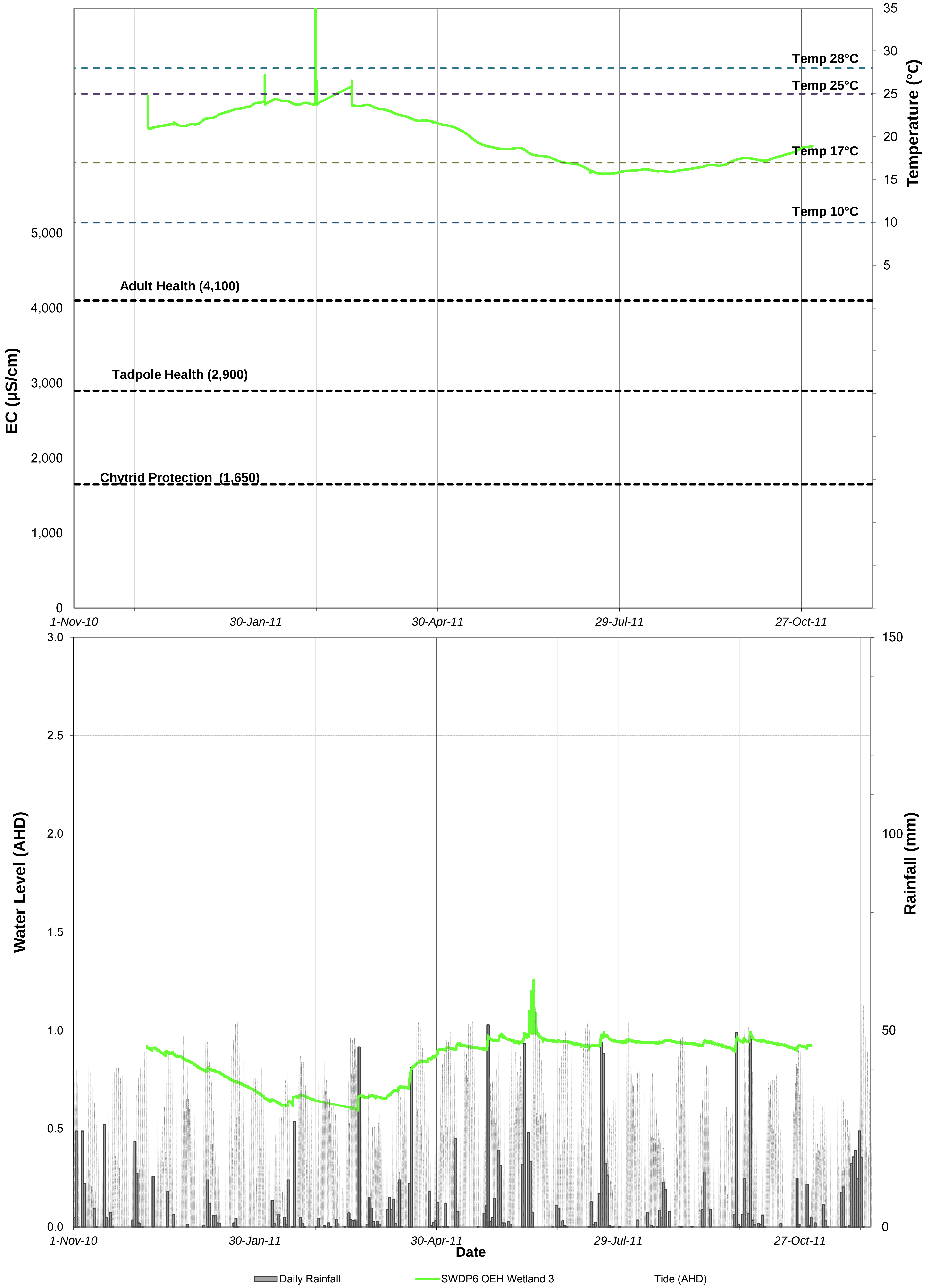
Note: Tide Data Plotted as AHD

Figure C7: Electrical Conductivity, Water Level, Temperature and Rainfall - November 2010 to June 2013
SWDP7A Rail Road Pond



Note: Tide Data Plotted as AHD

Figure C8: Electrical Conductivity, Water Level, Temperature and Rainfall - January 2011 to July 2013
SWDP8 OEH Wetland 1



Note: Tide Data Plotted as AHD

Figure C9: Electrical Conductivity, Water Level, Temperature and Rainfall - November 2010 to December 2011

SWDP6 OEH Wetland 3

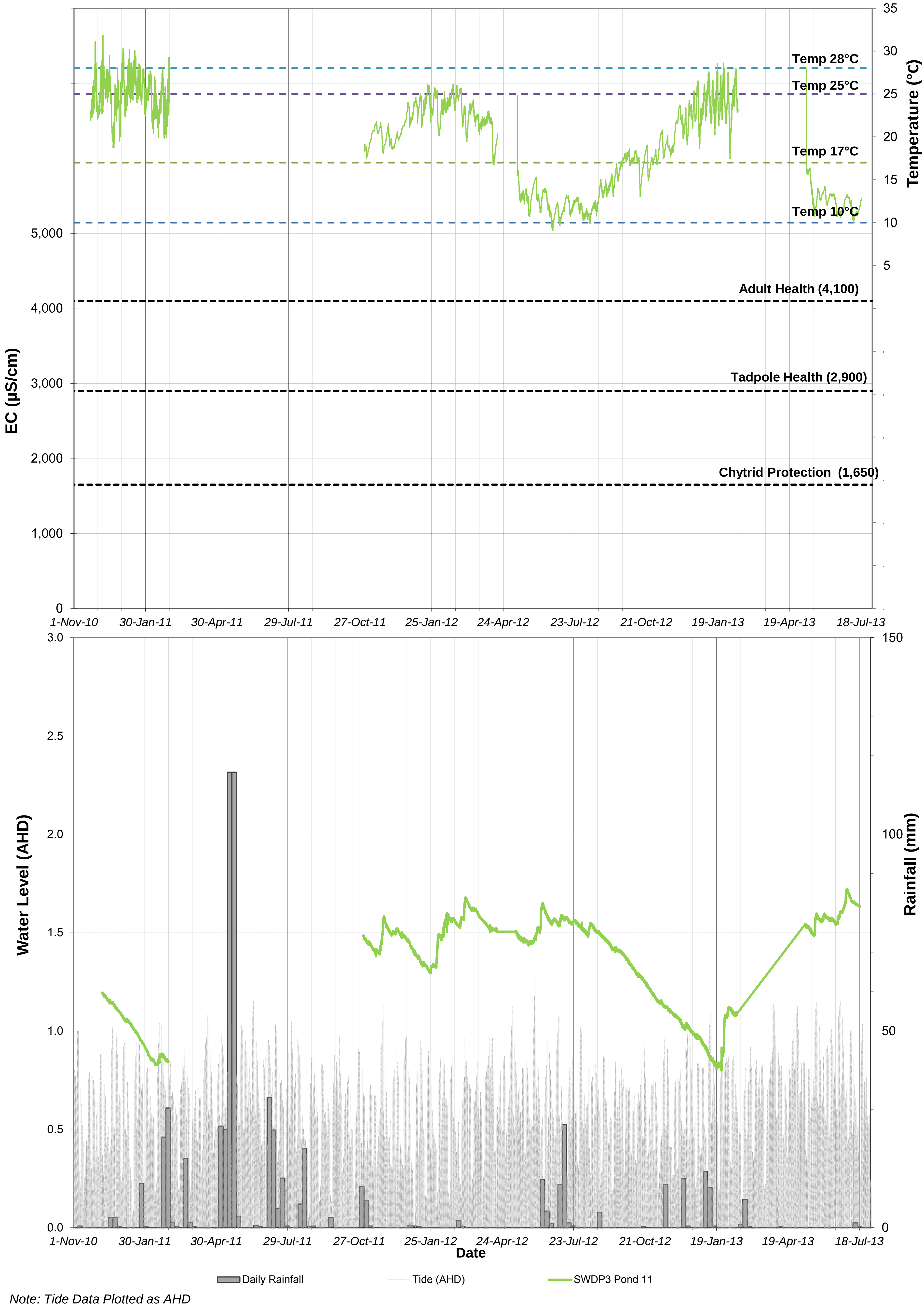
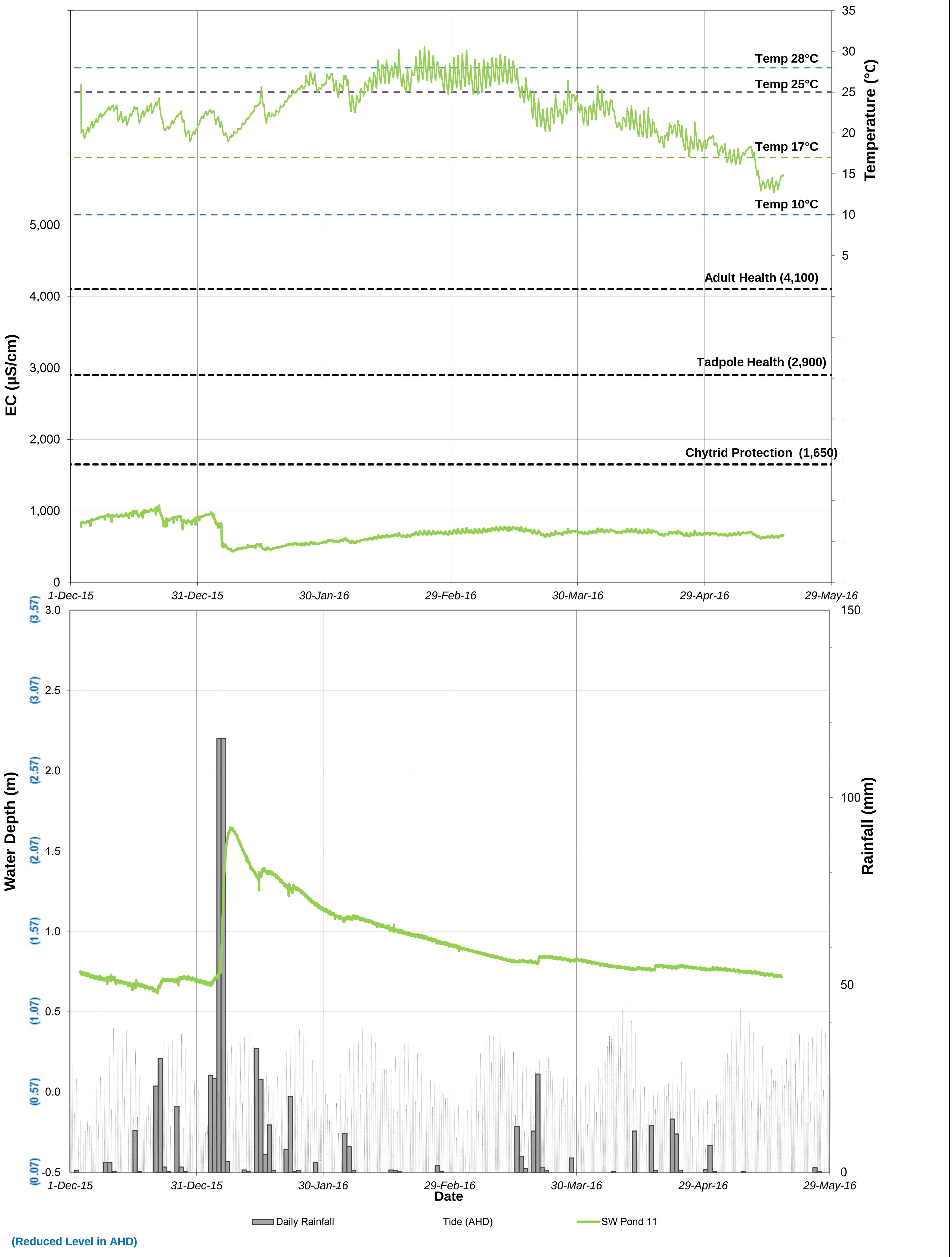


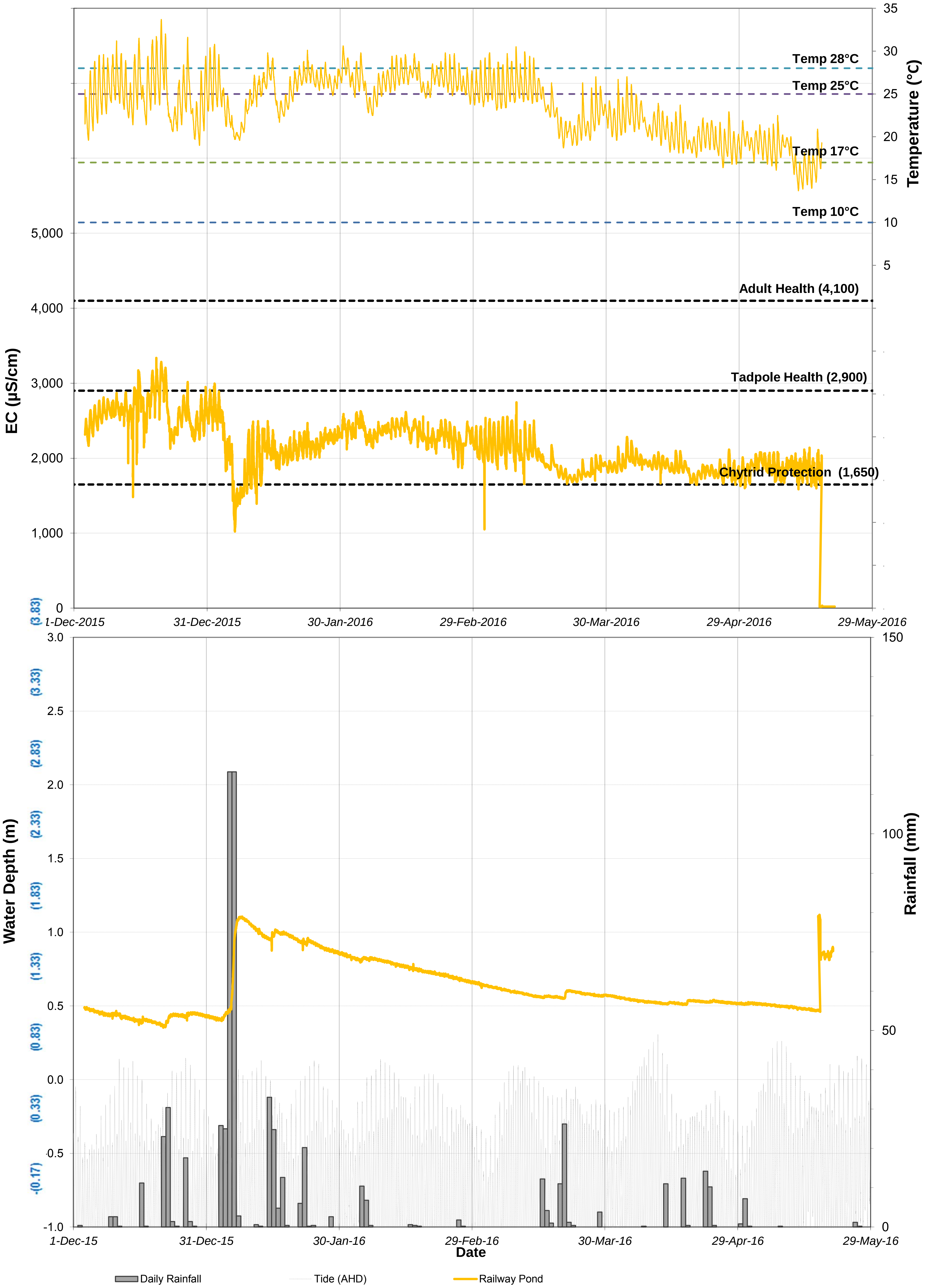
Figure C10A: Electrical Conductivity, Water Level, Temperature and Rainfall - November 2010 to June 2013
SWDP3 Pond 11



Note: Tide Data Plotted as AHD

Figure C10B: Electrical Conductivity, Depth, Temperature and Rainfall - December 2015 to May 2016

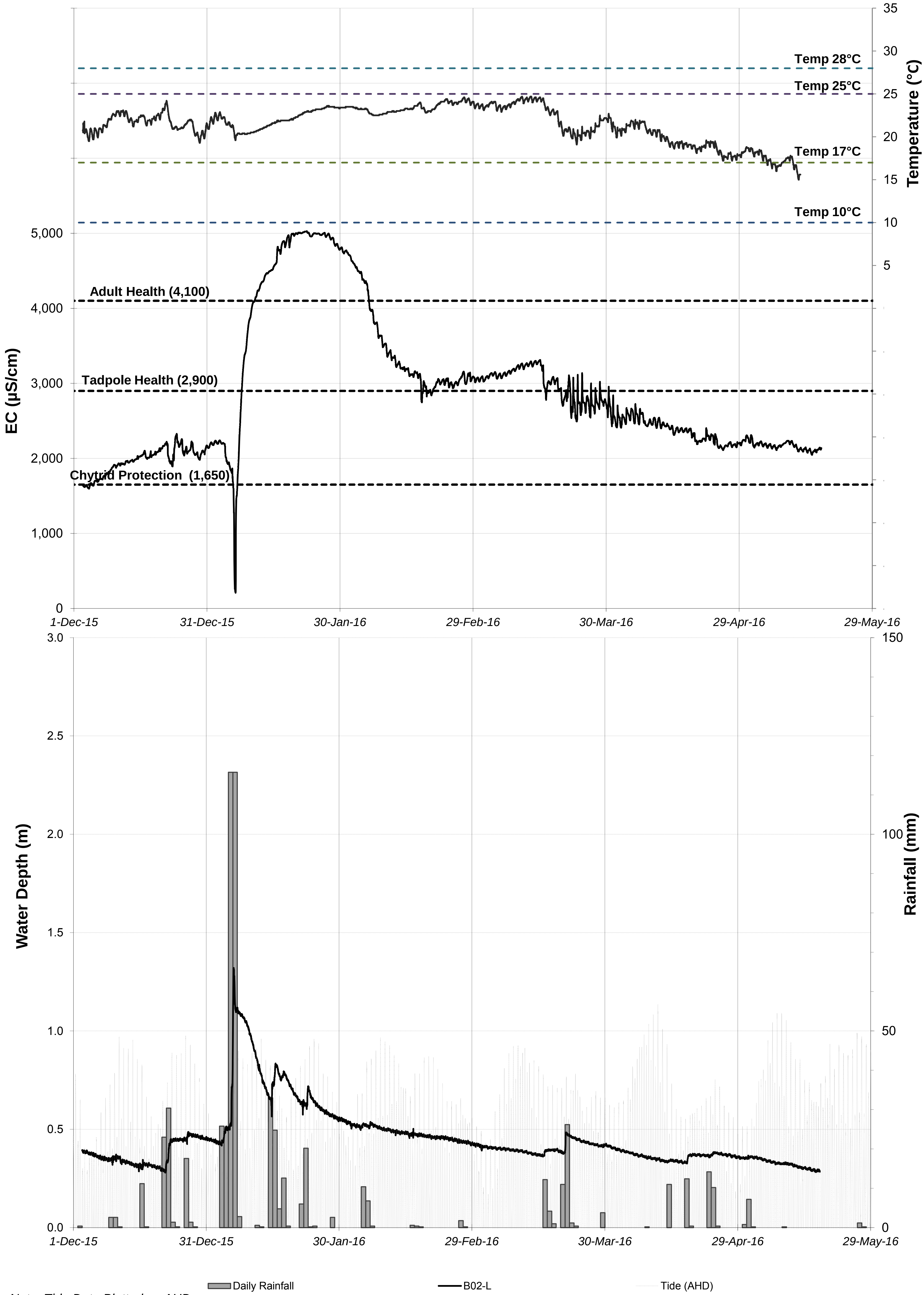
SWDP3 / Pond 11



Note: Tide Data Plotted as AHD

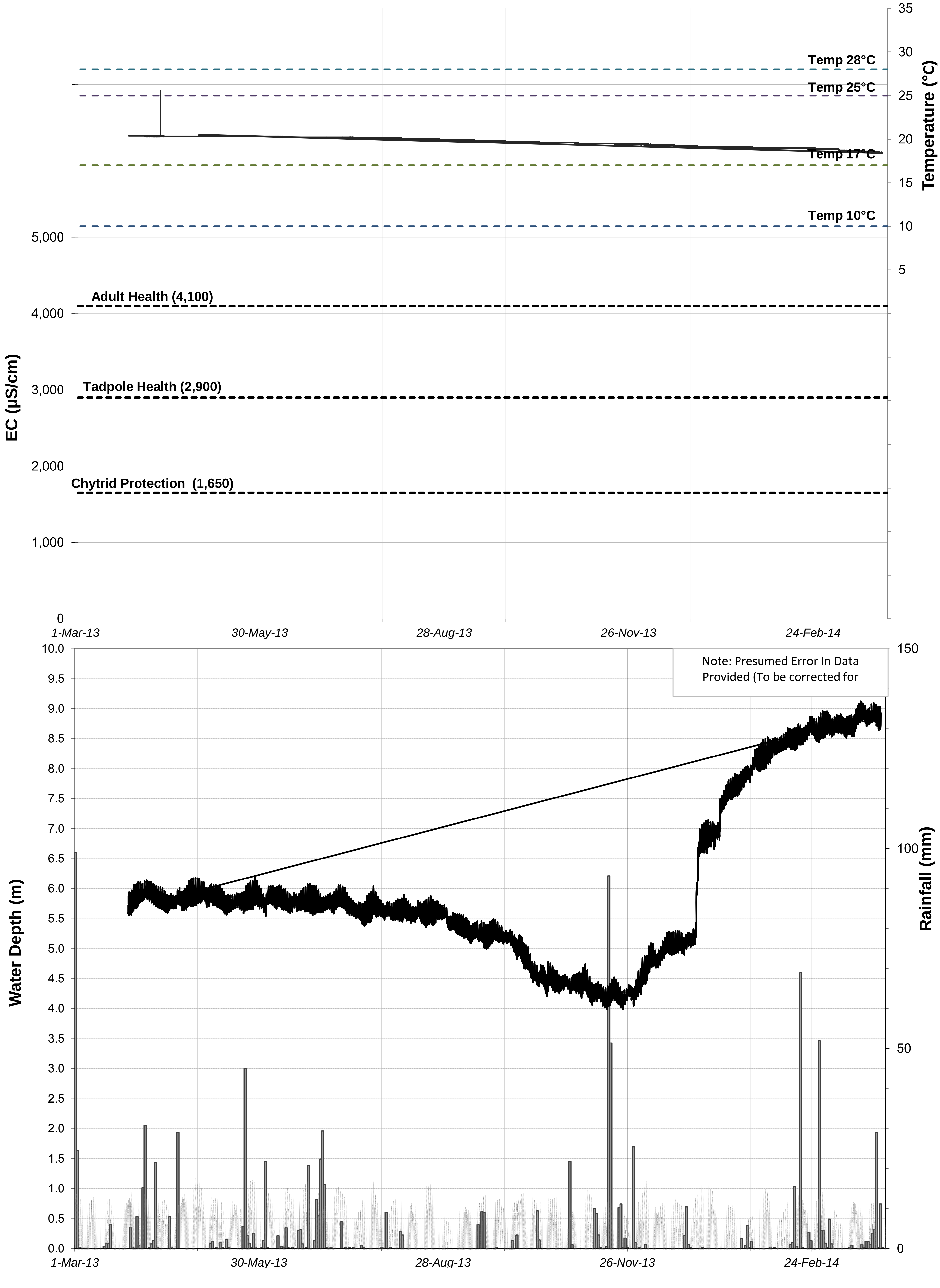
Figure C11: Electrical Conductivity, Depth, Temperature and Rainfall - December 2015 to May 2016

Railway Pond



Note: Tide Data Plotted as AHD

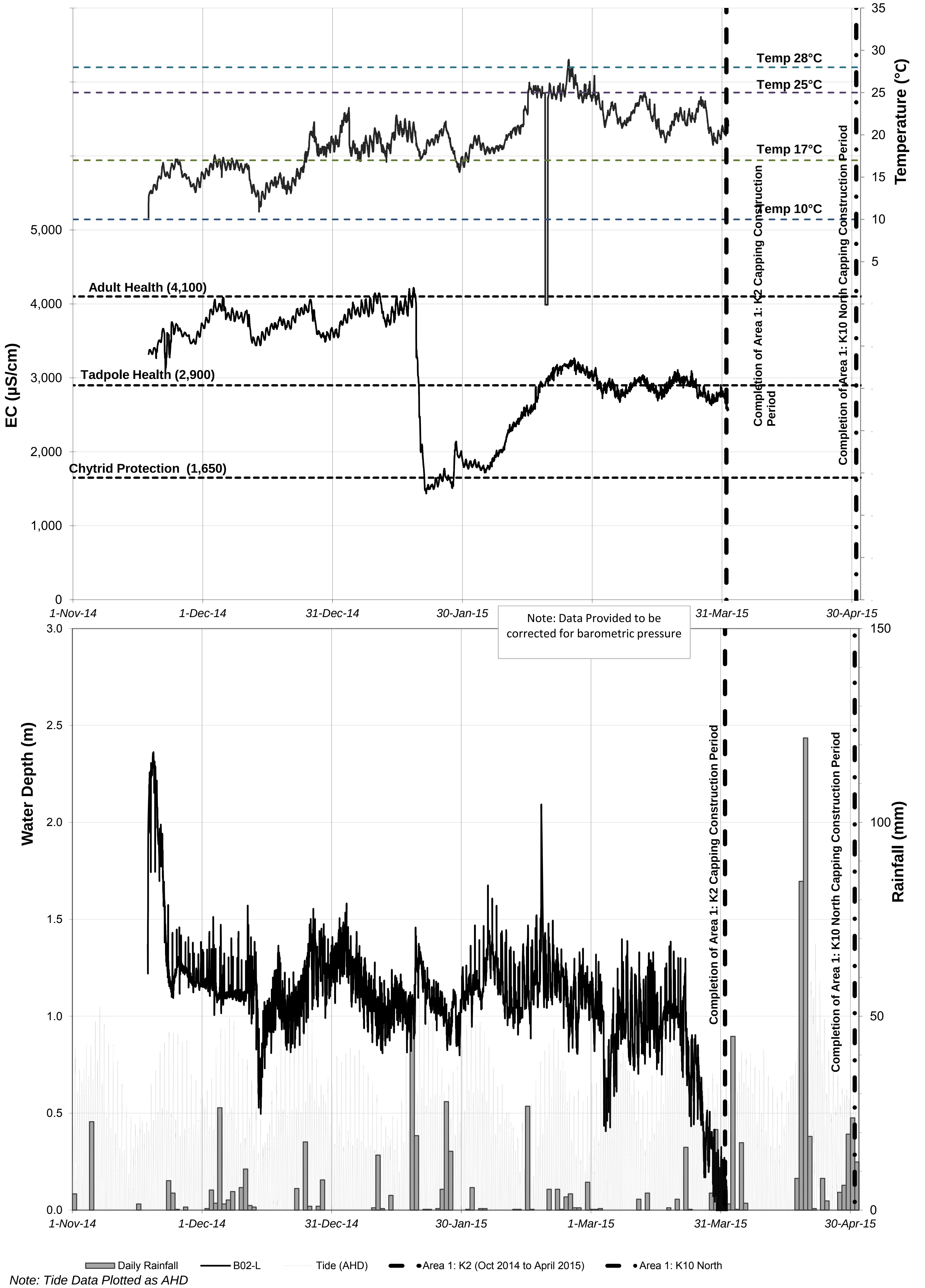
Figure C12A: Electrical Conductivity, Depth, Temperature and Rainfall - December 2015 to May 2016
B02-L Pond



Note: Tide Data Plotted as AHD

B02-L Pond

Figure C12B: Electrical Conductivity, Depth, Temperature and Rainfall - March 2013 to March 2014



Note: Tide Data Plotted as AHD

Figure 12C: Electrical Conductivity, Depth, Temperature and Rainfall - November 2014 to April 2015
B02-L Pond

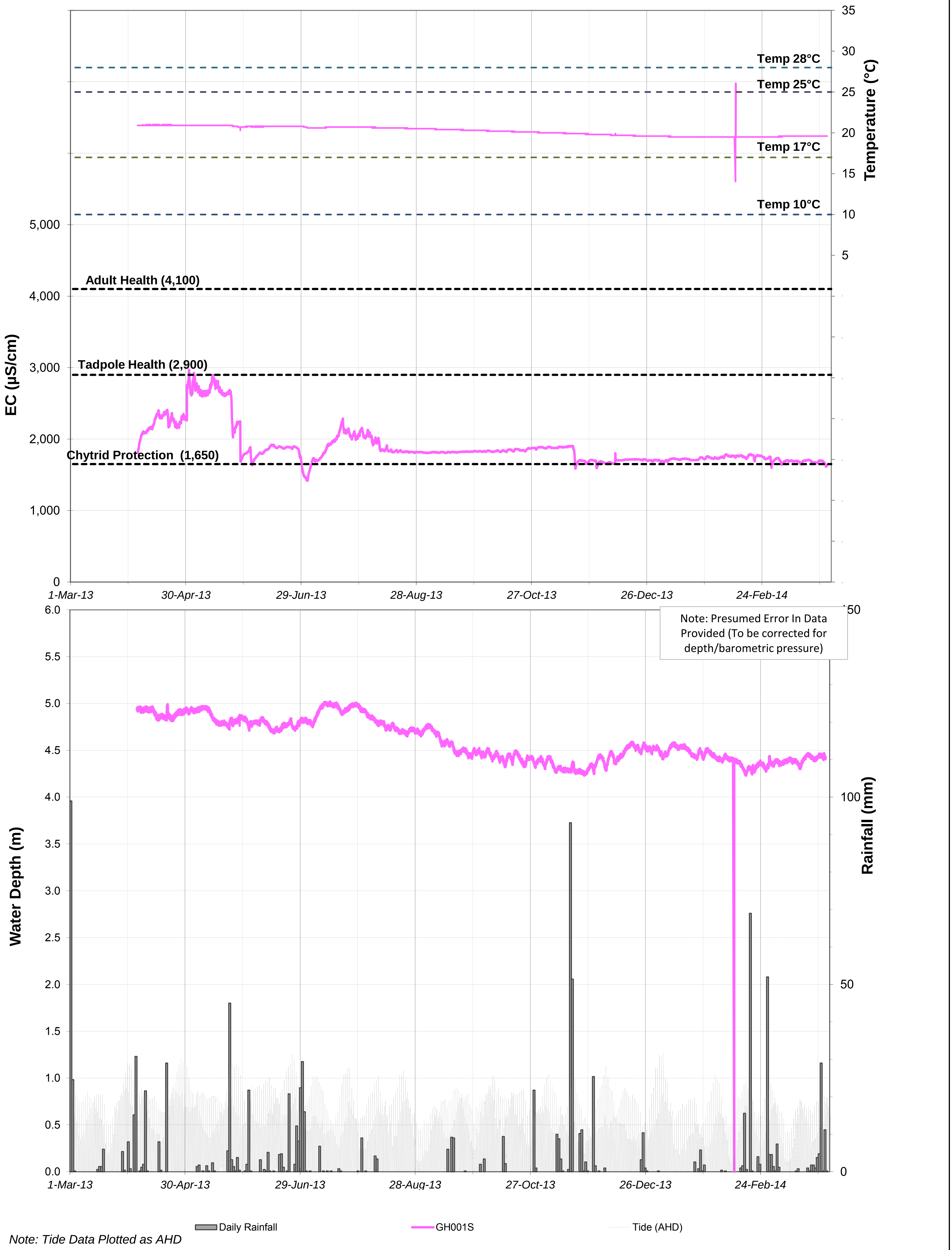
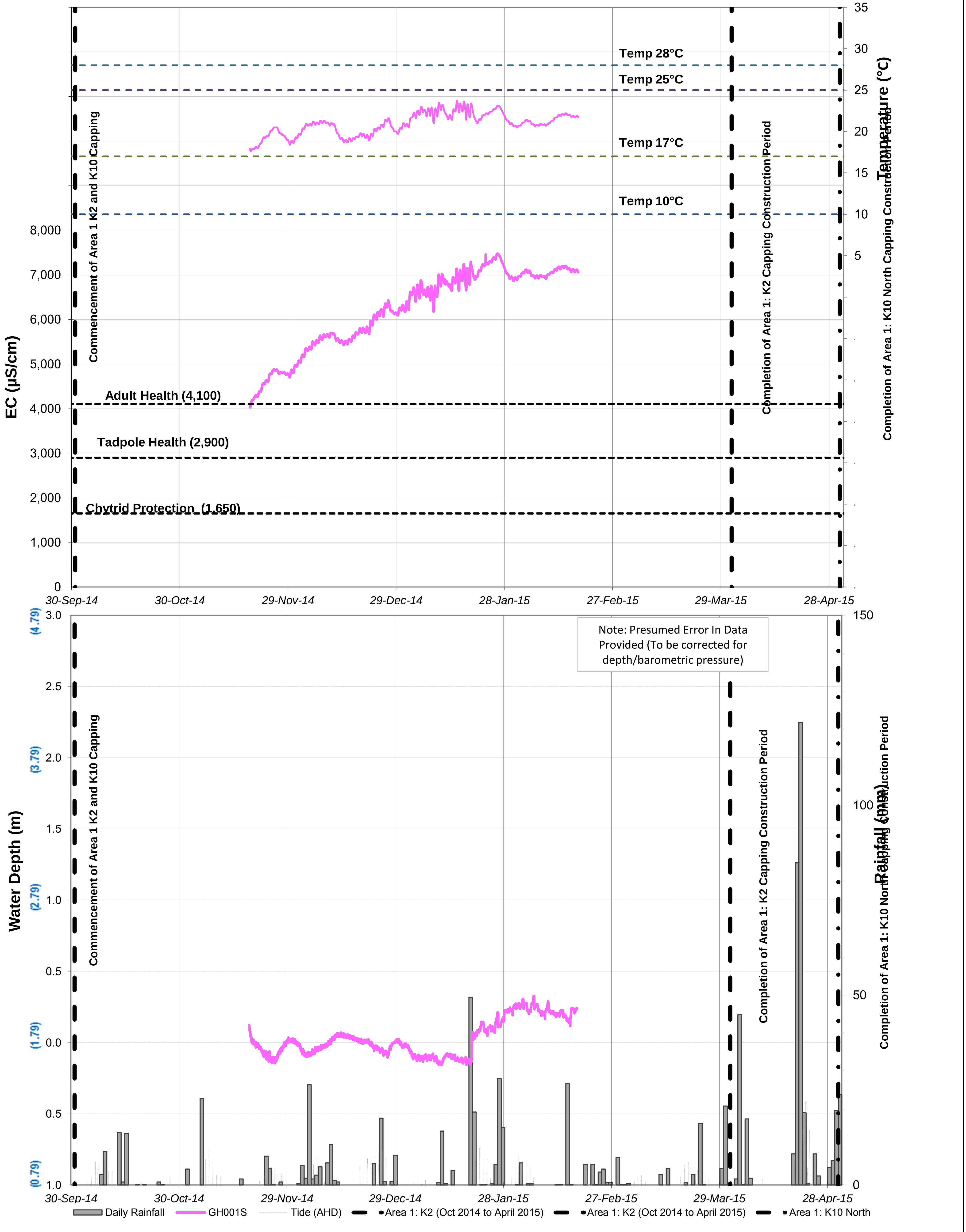


Figure C13A: Electrical Conductivity, Depth, Temperature and Rainfall - March 2013 to March 2014
GH001S Pond



(Reduced Level in AHD)

Note: Tide Data Plotted as AHD

Figure C13B: Electrical Conductivity, Depth, Temperature and Rainfall - November 2014 to March 2015

GH001S Pond

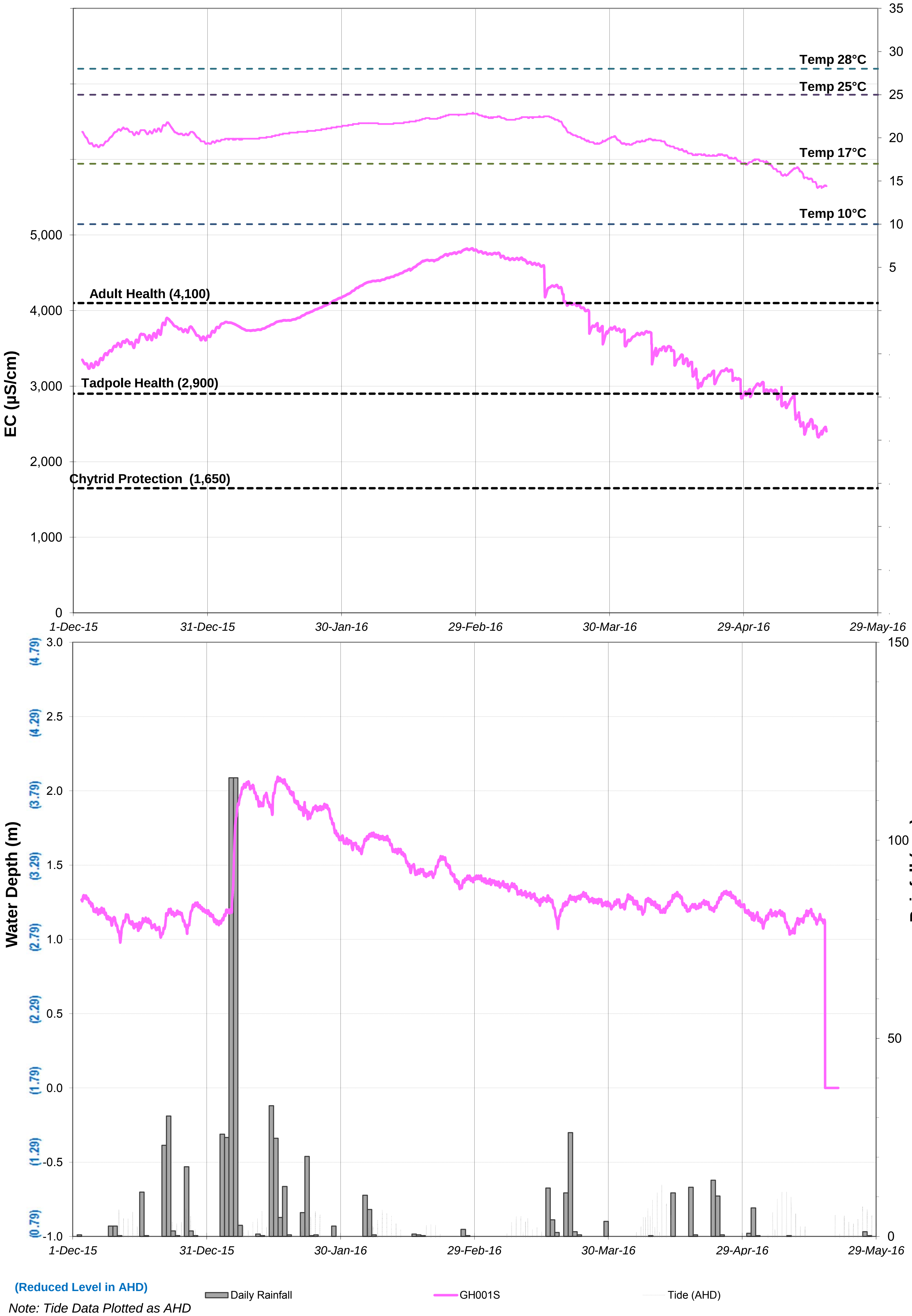
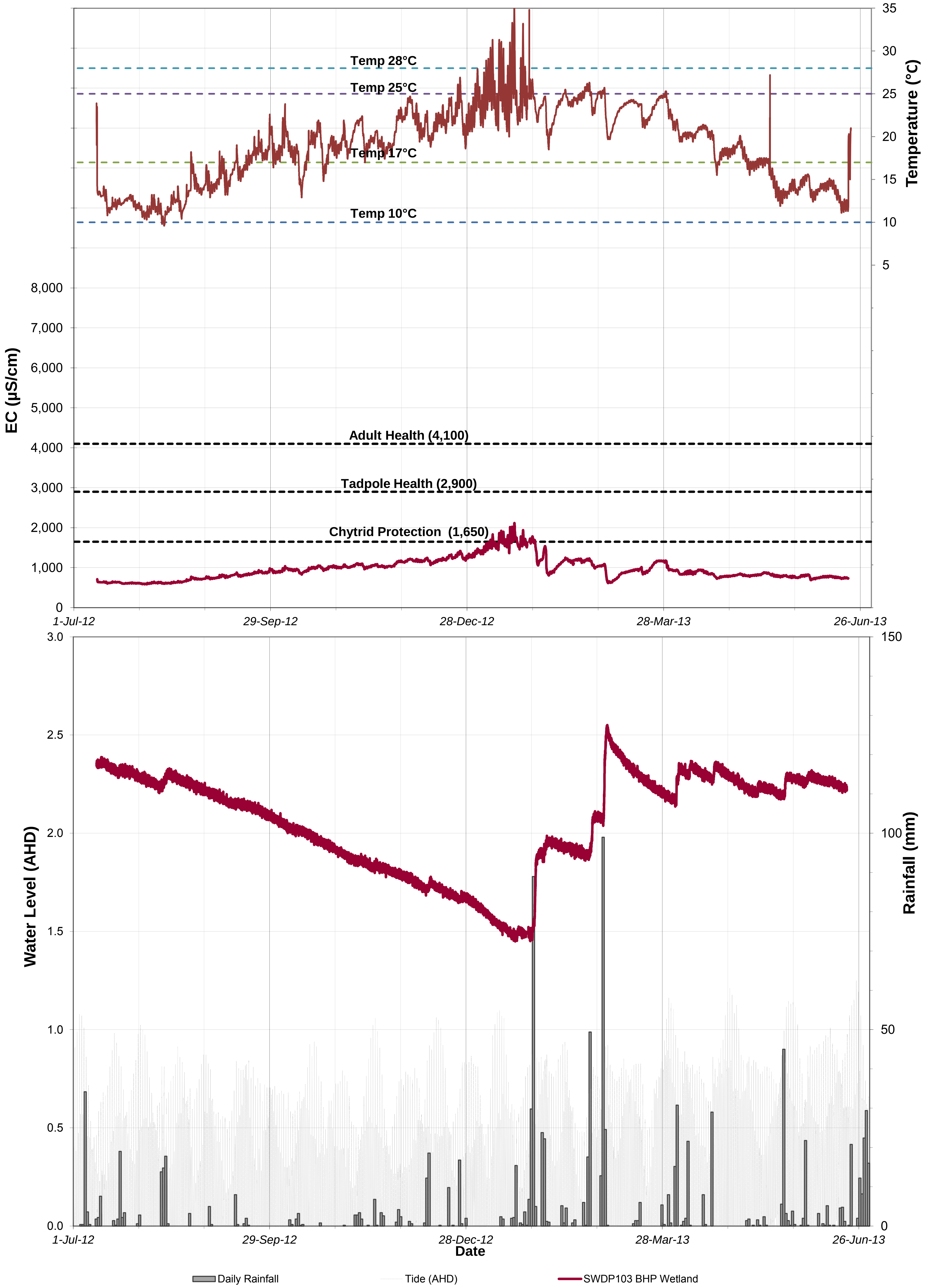
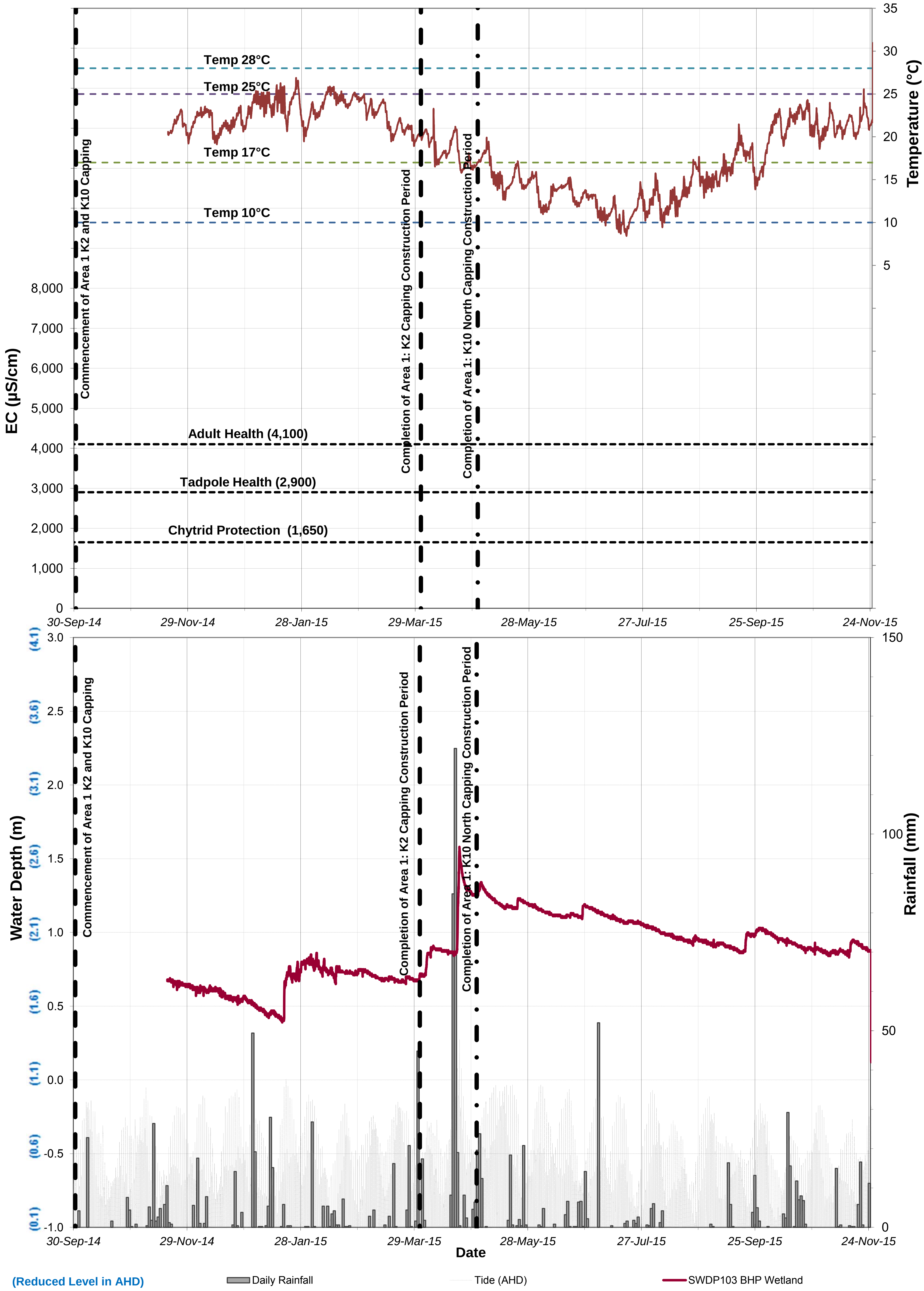


Figure C13C: Electrical Conductivity, Depth, Temperature and Rainfall - December 2015 to May 2016
GH001S Pond



Note: Tide Data Plotted as AHD

Figure C14A: Electrical Conductivity, Water Level, Temperature and Rainfall - July 2012 to July 2013
SWDP103 BHP Wetland



Note: Tide Data Plotted as AHD

Figure C14B: Electrical Conductivity, Depth, Temperature and Rainfall - October 2014 to November 2015
SWDP103 BHP Wetland

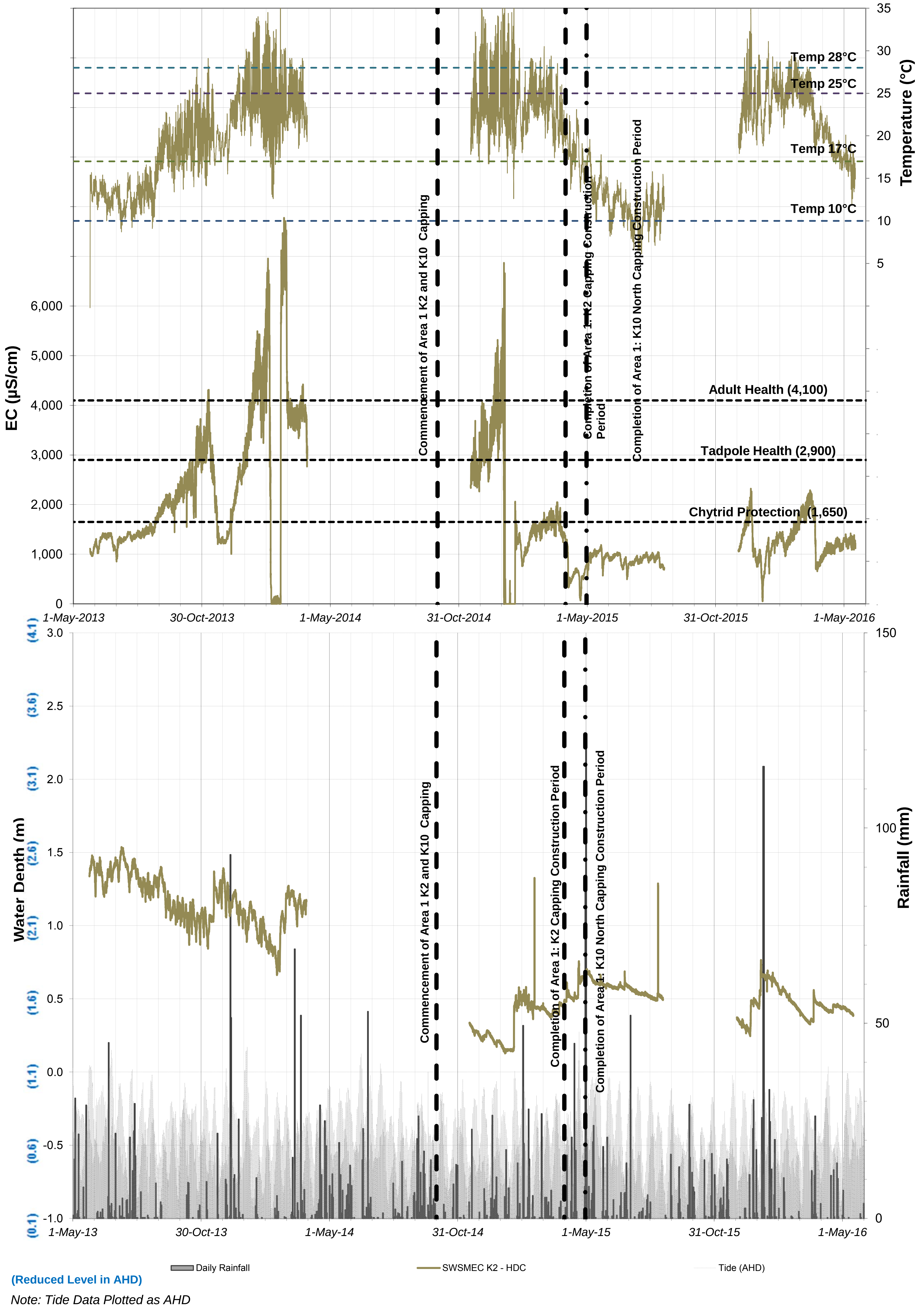
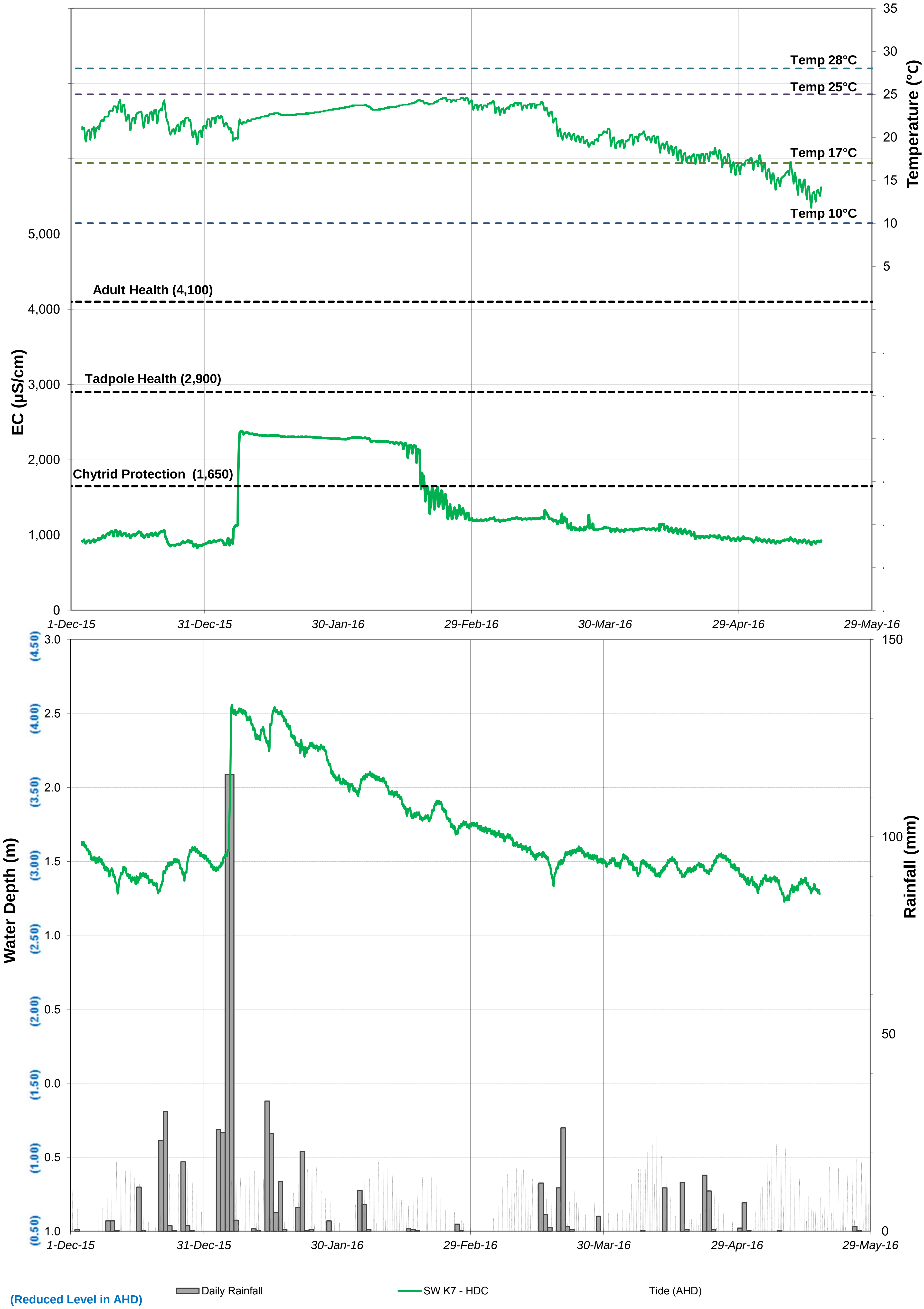


Figure C15: Electrical Conductivity, Depth, Temperature and Rainfall - May 2013 to May 2016
SWSMEC K2 Pond



Note: Tide Data Plotted as AHD

Figure C16: Electrical Conductivity, Depth, Temperature and Rainfall - December 2015 to May 2016
SWK7 Pond

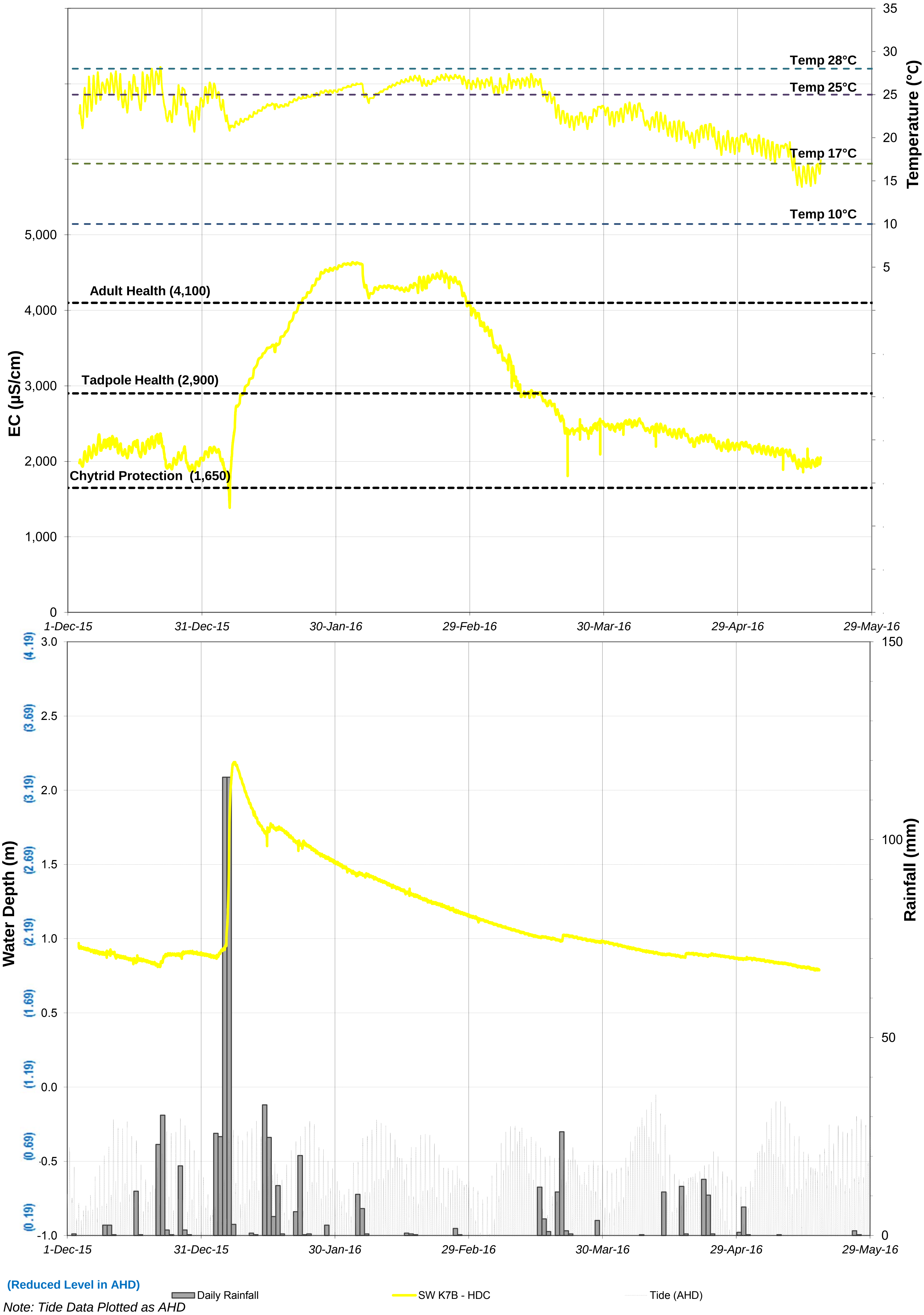


Figure C17: Electrical Conductivity, Depth, Temperature and Rainfall - December 2015 to May 2016

SWK7B Pond

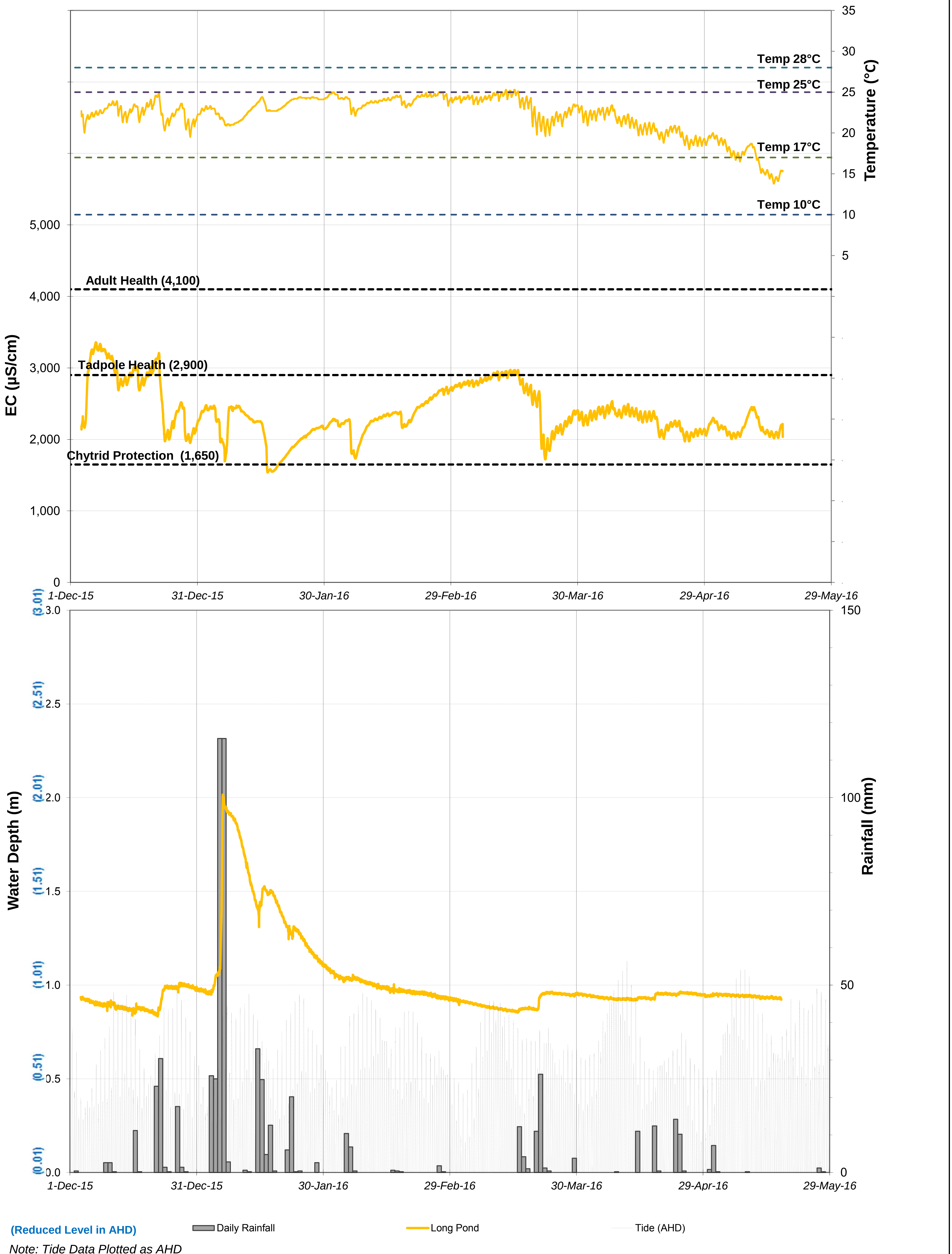


Figure C18: Electrical Conductivity, Depth, Temperature and Rainfall - December 2015 to May 2016
Long Pond

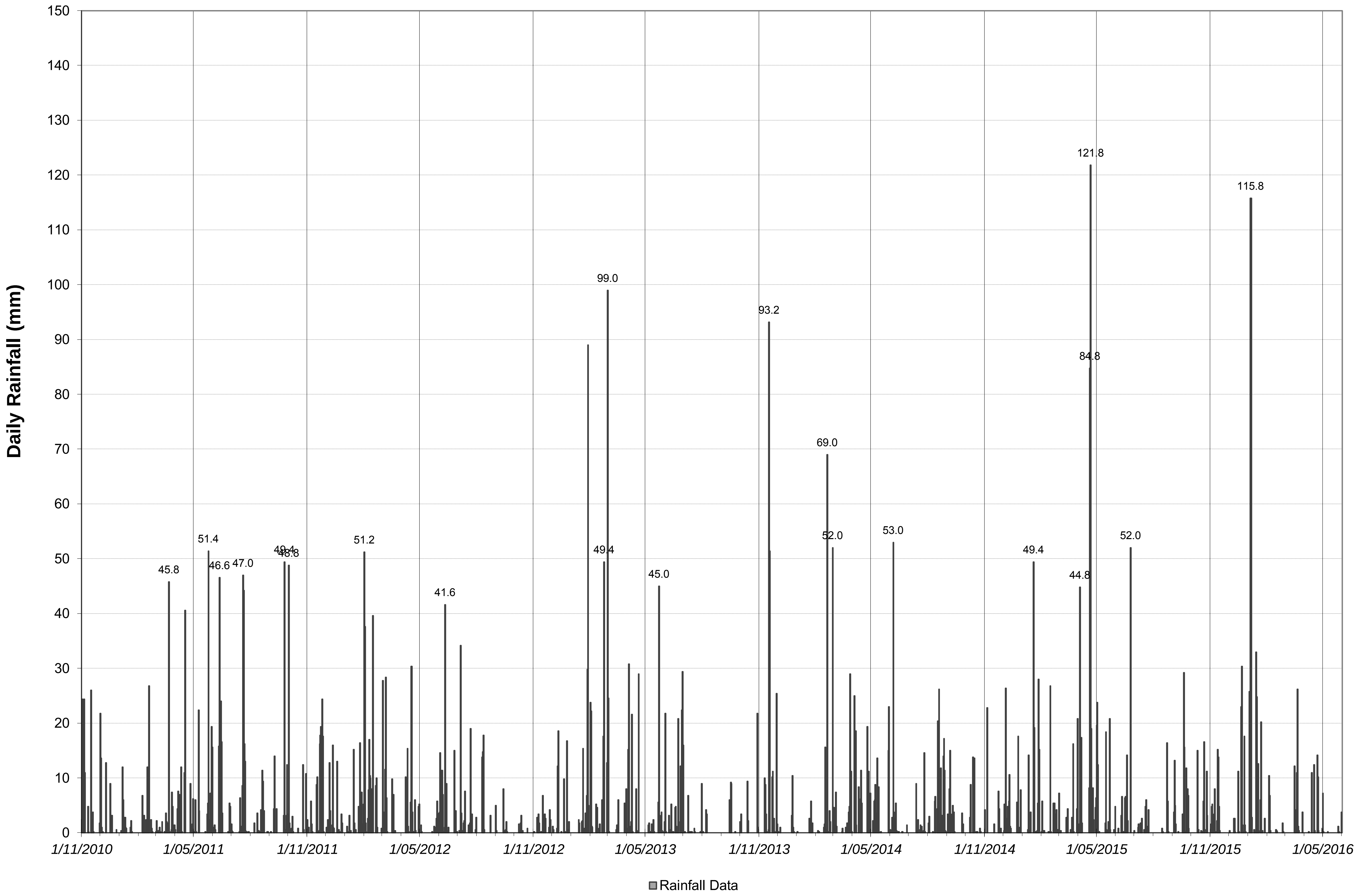


Figure C19: Daily Rainfall at PWCS' KCT Weather Station
1 November 2010 to 1 June 2016

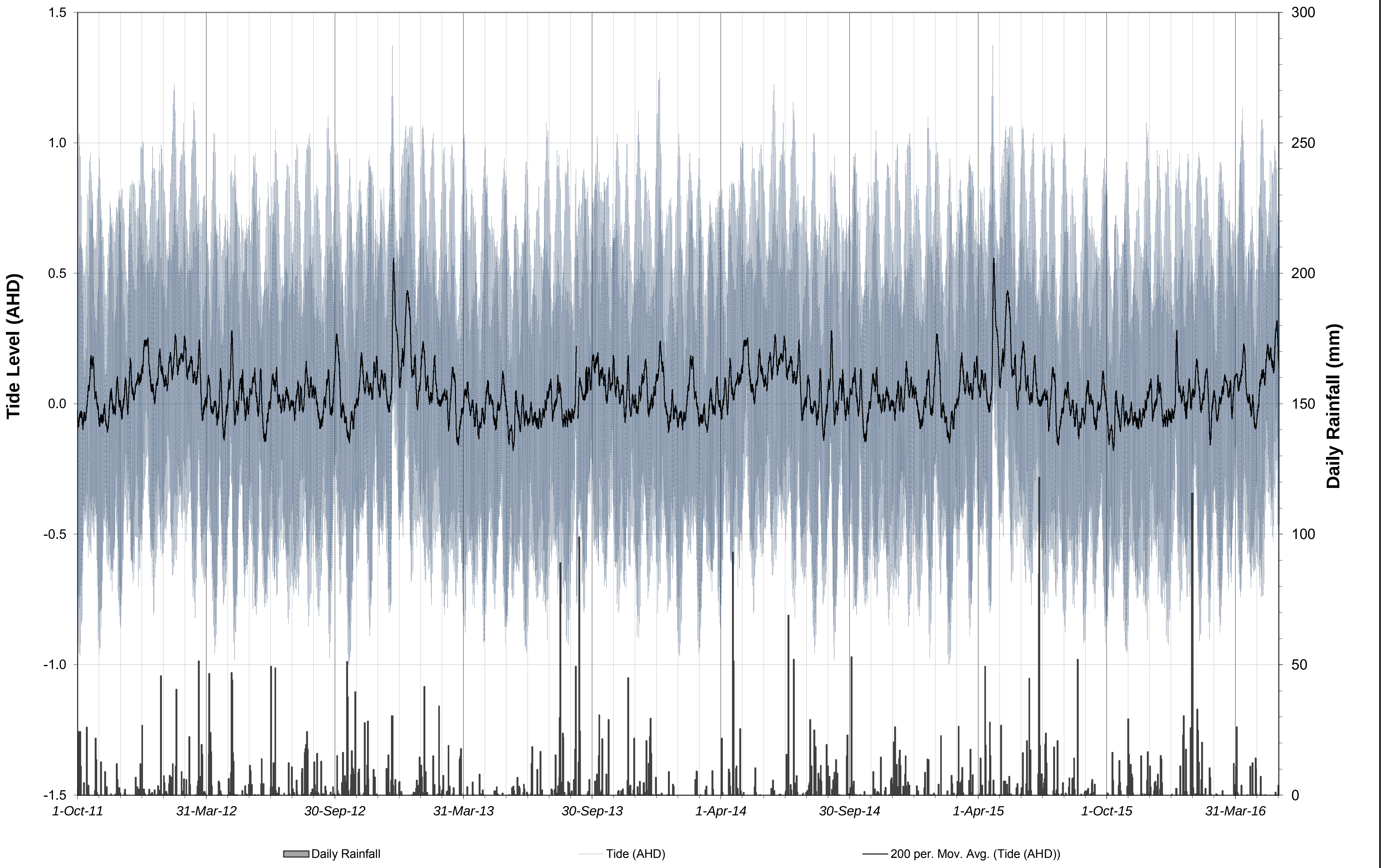
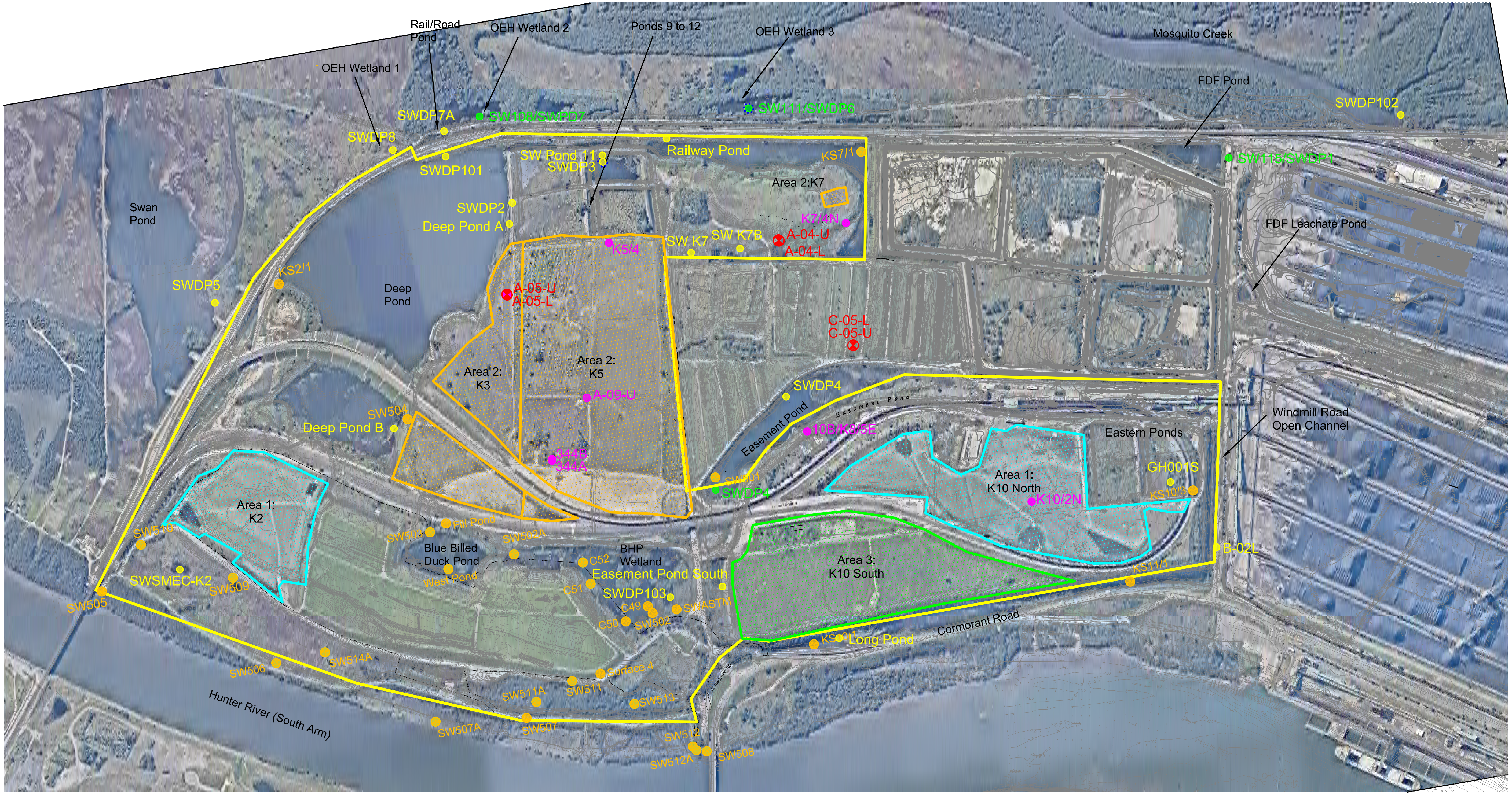


Figure C20: Tide Levels at Stockton Bridge vs Daily Rainfall (KCT Weather Station)

1 November 2010 to 1 June 2016

Appendix D

Drawing 1: Test Location Plan
Figure 1: KIWEF Data Logger Monitoring Locations
(Hunter Development Corporation)



Legend

NCIG Railway Easement	Water Level Logger Location in Groundwater Well	Approximate Surface Water Quality Location	Capping Area 1 (completed April 2015)
2009 Surface Contour (m AHD)	Approximate Location of KIWEF Boundary	Approximate Groundwater Quality Location	Proposed Capping Area 2
	Approximate Surface Water Salinity and Water Level Logger Location		Proposed Capping Area 3 (to commence August 2016)
	Approximate Surface Water Level Logger Location		

Drawing adapted from Survey Plan by Connell Hatch, Ref No HW00-00-C-61-600 dated 29.03.06, Survey from PWCS, Ref Project_AreaState-ISG_nov2011 70 Mtps.dwg, and Nearmap Image dated 4.5.16

0 100 200 300 400 500 750 1000m

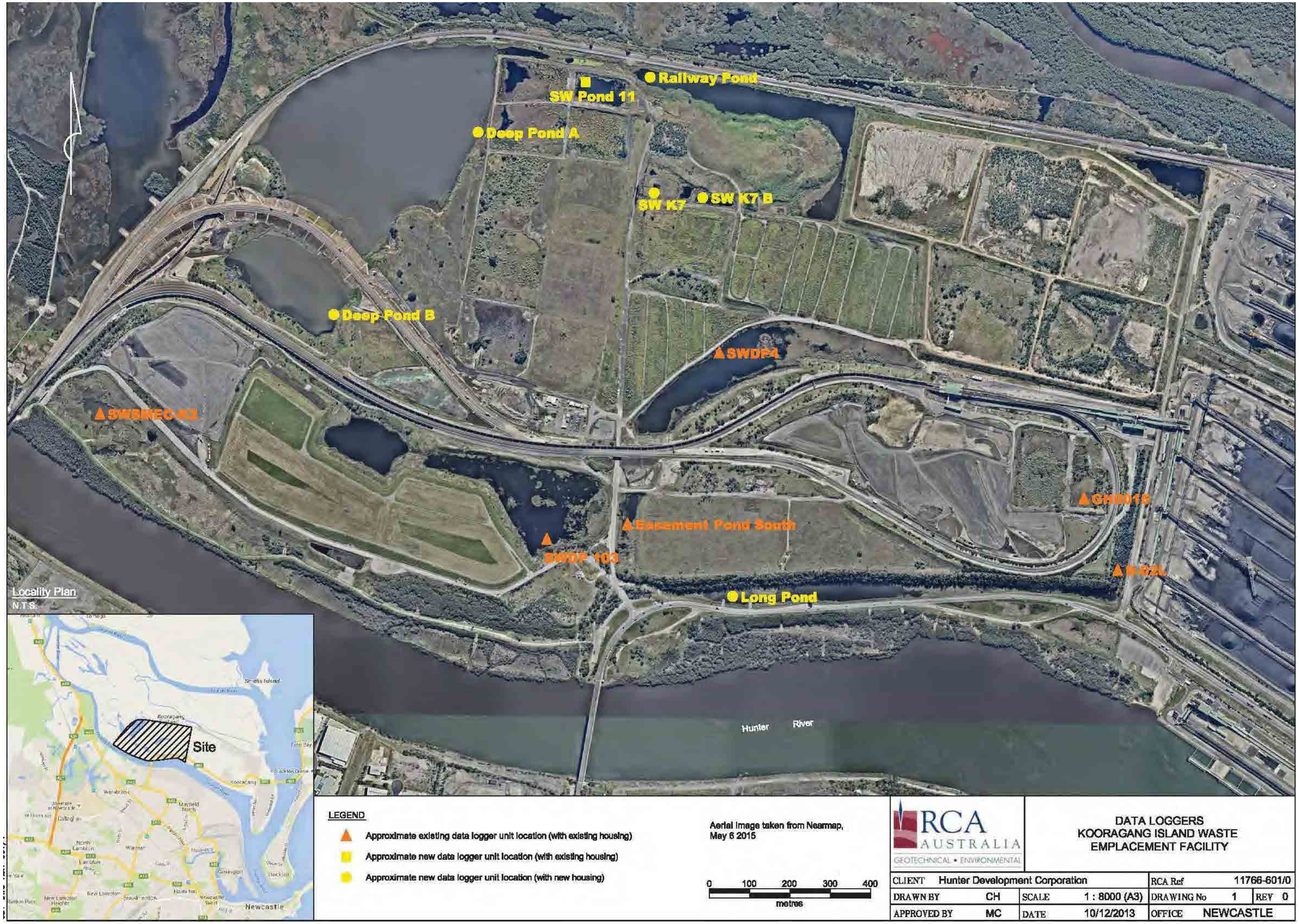
1:10,000 @ A3

Douglas Partners
Geotechnics / Environment / Groundwater

CLIENT: Hunter Development Corporation		TITLE: **Test Location Plan** **KIWEF Area 2 Closure Works** **Kooragang Island**	PROJECT No: 81209.02
OFFICE: Newcastle	DRAWN BY: PLH		DRAWING No: 1
SCALE: 1:10,000@A3	DATE: 09.08.2016		REVISION: 0

NSW GOVERNMENT | Hunter Development Corporation

Figure 1: KIWEF Data Logger Monitoring Locations



Annex B

Surface Water Data Loggers Report (RCA 2015)

RCA ref 11766-601rev0
Client ref HDC252

11 December 2015

Hunter Development Corporation
Level 5, 26 Honeysuckle Drive
NEWCASTLE NSW 2300

Attention Grant Moylan
cc Mike Bardsley

SURFACE WATER DATA LOGGERS
KOORAGANG ISLAND WASTE EMPLACEMENT FACILITY (KIWEF)

1 SITE WORKS

RCA Australia (RCA) was engaged by Hunter Development Corporation (HDC) to retrieve and download several existing data loggers and install several additional replacement/new data loggers (supplied by HDC) at various locations within the Kooragang Island Waste Emplacement Facility (KIWEF), Newcastle NSW. Locations of existing, replacement and new loggers are shown on **Drawing 1**, **Attachment A**.

RCA began works on 25 November 2015, which included:

- Five (5) existing Solinst data loggers were collected and returned to RCA for download following difficulties establishing communications with data loggers on site.
- Communications were able to be established with two (2) existing loggers (from locations SWDP-103 and Easement Pond South).
- Three (3) malfunctioning loggers (from locations SWSMEC-K2, B-02L and GH001s) were cleaned and placed on silica gel crystals within a desiccator for several days prior to further unsuccessful efforts to establish communications with loggers.
- RCA understands that the three (3) malfunctioning loggers (from locations SWSMEC-K2, B-02L and GH001s) will be returned to the distributor and/or manufacturer for attempted data recovery and repair.

- It is noted that one (1) existing logger location (345a) was unable to be located and is believed to have been lost/destroyed during RMS works adjacent to this location.

RCA returned to site on 01 December 2015, works included:

- Reinstatement of existing three (3) functioning Solinst data loggers and installation of three (3) new Solinst data loggers (supplied by HDC) to replace malfunctioning loggers.
- One (1) additional existing Solinst data logger (at location SWDP4) was also located, downloaded and re-instated.
- One (1) new Solinst data logger was installed (at location Deep Pond B), including construction of a new housing.

Site works concluded on 03 December 2015 with:

- Installation of remaining six (6) new Solinst data loggers, including construction of five (5) new housings.

A summary of data logger information is included in **Table B1**, **Attachment B**.

Photographs of logger locations and housings are shown in **Attachment C**.

2 DATA LOGGER RESULTS

Communications were able to be established with loggers from locations SWDP-103, Easement Pond South and SWDP-4.

A Solinst barologger held at the Mayfield Intermodal site approximately 3.5km away was used to correct for barometric pressure. Data was downloaded on 4 December 2015 and supplemented with historic data from the same logger held at RCA.

Gaps in historic barometric data, from 18 January 2015 to 17 February 2015, were substituted with twice daily BOM data from Williamtown, supplied by HDC.

2.1 SWDP-103

Data logger appears to be reading correctly. It is noted that the water level readings were corrected by a factor of -9.55m to account for differences in Solinst Levelogger 3001 LT F30/M10 factory settings following discussion with the manufacturer/supplier.

Data logger data and graph is presented in **Attachment D** (supplied digitally).

2.2 EASEMENT POND SOUTH

Data logger appears to be reading correctly.

Data logger data and graph is presented in **Attachment D** (supplied digitally).

2.3 SWDP-4

Data logger appears to be reading correctly.

Data logger data and graph is presented in **Attachment D** (supplied digitally).

Yours faithfully
RCA AUSTRALIA

Craig Handebo
Senior Environmental Engineer

Attachments:

Attachment A - Site drawing - Drawing 1

Attachment B - Data Logger Information Summary Table - Table B1

Attachment C - Data Logger photographs

Attachment D - Data Logger Data and Graphs - supplied digitally

Attachment A

Site Drawing

LEGEND

- ▲ Approximate existing data logger unit location (with existing housing)
- ■ Approximate new data logger unit location (with existing housing)
- ● Approximate new data logger unit location (with new housing)

Aerial image taken from Nearmap, May 6 2015

0 100 200 300 400
metres

RCA AUSTRALIA
GEOTECHNICAL • ENVIRONMENTAL

DATA LOGGERS
KOORAGANG ISLAND WASTE
EMPLACEMENT FACILITY

CLIENT	Hunter Development Corporation			RCA Ref	11766-601/0
DRAWN BY	CH	SCALE	1 : 8000 (A3)	DRAWING No	1 REV 0
APPROVED BY	MC	DATE	10/12/2013	OFFICE	NEWCASTLE

CDT-DWG-A3H-001/1

Attachment B

Data Logger Information Summary Table

Table B1: RCA summary of data logger information obtained during download of existing data loggers and installation of new/replacement loggers at KIWEF - November 2015

Logger Name/Location	Logger Serial Number	Model	GPS (UTS/UPM)	Date of Retrieval	Date of Deployment	Photo of Logger	Mount and Location	Photo of Current Mount and Location	Connect	Surveyed T.O.P (mAHD)	Measurement at date of retrieval				Measurement from data logger		Logger set to take new readings from	Logger Interval (mins)	Data Presented and Graphed	Notes
											Water to Sediment (m)	Top of Pipe to Water Level (m)	Top of Pipe to Data Logger Tip (m)	Water level above logger	* Water level above logger	Date of last reading				
SWDP-103	32014746	Solinst Levelogger 3001 LT F30/M10	0381402, 6361958	25/11/2015	1/12/2015	Yes	Existisng Good Shape	Yes	Yes	--	0.88	0.92	1.63	0.71	0.7	25/11/2015	11:40pm, 2/12/15	30	**Yes**	- Water level reading out by a factor of approximately 9.5m due to LT default factory settings. - Correction factor of -9.55m offset applied through solinst software prior to re-deployment. - Location on supplied drawing did not match logger location in pond. Drawing revised.
Easement Pond South	121068443	Solinst Levelogger 3001 LTC F30/M10	0381614, 6361855	25/11/2015	1/12/2015	Yes	Existisng Good Shape	Yes	Yes	--	0.7	0.93	1.46	0.53	0.66	17/10/2015	11:40pm, 2/12/15	20	**Yes**	--
SWDP4	121068452	Solinst Levelogger 3001 LTC F30/M10	0381778, 6362349	1/12/2015	1/12/2015	No	Existisng Good Shape	Yes	Yes	--	0.83	0.85	1.75	0.9	1.49	17/10/2015	11:40pm, 2/12/15	30	**Yes**	- Data logger believed to be sitting in sediment with slack line as data logger length set greater than housing height.
											0.83	0.85	1.59	0.74	Logging	Logging		20		- Data logger support cable shortened prior to redeployment.
SWSMEC-K2	121068442	Solinst Levelogger 3001 LTC F30/M10	0380330, 6362216	25/11/2015	Out of Service	Yes	Existisng Good Shape	Yes	No	--	0.49	0.98	1.31	0.33	--	--	--	--	No	--
	121071565	Solinst Levelogger 3001 LTC F30/M10		Replacement	1/12/2015	No			Yes						Logging	Logging	11:40pm, 2/12/15	20		--
B-02L	121068445	Solinst Levelogger 3001 LTC F30/M10	0382825, 6361855	25/11/2015	Out of Service	Yes	Existisng Good Shape	Yes	No	--	0.68	1.10	1.65	0.55	--	--	--	--	No	--
	121071610	Solinst Levelogger 3001 LTC F30/M10		Replacement	1/12/2015	No			Yes						Logging	Logging	11:40pm, 2/12/15	20		--
GH001S	131068163	Solinst Levelogger 3001 LTC F30/M10	0382738, 6362020	25/11/2015	Out of Service	Yes	Existisng Good Shape	Yes	No	--	0.26	0.89	1.28	0.39	--	--	--	--	No	- Location on supplied drawing did not match logger location in pond. Drawing revised. - Very obstructed by overgrown reeds. Difficult to find.
	121071569	Solinst Levelogger 3001 LTC F30/M10		Replacement	1/12/2015	No			Yes						Logging	Logging	11:40pm, 2/12/15	20		
354a	Missing																			- Replaced by Long Pond
Deep Pond B	121071609	Solinst Levelogger 3001 LTC F30/M10	0380871, 6362461	New	1/12/2015	No	New	Yes	Yes	--	0.4	1.02	1.38	0.36	Logging	Logging	11:40pm, 2/12/15	20	No	--
Long Pond	121071574	Solinst Levelogger 3001 LTC F30/M10	0381809, 6361791	New	3/12/2015	No	New	Yes	Yes	--	1.05	0.46	0.95	0.49	Logging	Logging	11:40pm, 2/12/15	20	No	Heavy sediment (sludge) varying in depth from 0m (on exposed slag) to 30 - 60cm
Deep Pond A	121071594	Solinst Levelogger 3001 LTC F30/M10	0381238, 6362908	New	3/12/2015	No	New	Yes	Yes	--	0.5	0.46	0.90	0.44	Logging	Logging	11:40pm, 2/12/15	20	No	Heavy sediment (sludge) varying in depth from 0m (on exposed slag) to 30 - 60cm
SW K7	121071583	Solinst Levelogger 3001 LTC F30/M10	0381670, 6362757	New	3/12/2015	No	New	Yes	Yes	--	0.8	0.60	1.30	0.7	Logging	Logging	11:40pm, 2/12/15	20	No	Heavy sediment (sludge) varying in depth from 0m (on exposed slag) to 30 - 60cm
SW Pond 11	121071579	Solinst Levelogger 3001 LTC F30/M10	0381482, 6363035	New	3/12/2015	No	Existing Required repair	Yes	Yes	--	0.77	0.77	1.30	0.53	Logging	Logging	11:40pm, 2/12/15	20	No	Heavy sediment (sludge) varying in depth from 0m (on exposed slag) to 30 - 60cm
Railway Pond	121071570	Solinst Levelogger 3001 LTC F30/M10	0381625, 6363051	New	3/12/2015	No	New	Yes	Yes	--	0.5	0.72	1.00	0.28	Logging	Logging	11:40pm, 2/12/15	20	No	Heavy sediment (sludge) varying in depth from 0m (on exposed slag) to 30 - 60cm
SW K7B	121071572	Solinst Levelogger 3001 LTC F30/M10	0381772, 6362754	New	3/12/2015	No	New	Yes	Yes	--	0.87	0.26	1.00	0.74	Logging	Logging	1:00pm, 3/12/15	20	No	Heavy sediment (sludge) varying in depth from 0m (on exposed slag) to 30 - 60cm

* Corrected for atmospheric pressure from solinst barometer data logger at Mayfield site

M14/21S	1016984	Solinst Barolgger	0383965, 6359801	4/12/2015	4/12/2015	No	No	No	Yes	--	--	--	--	--	--	--	Continued	15	--	- Data downloaded but not reset so as not to interfere with ongoing Mayfiled job (HDC222).

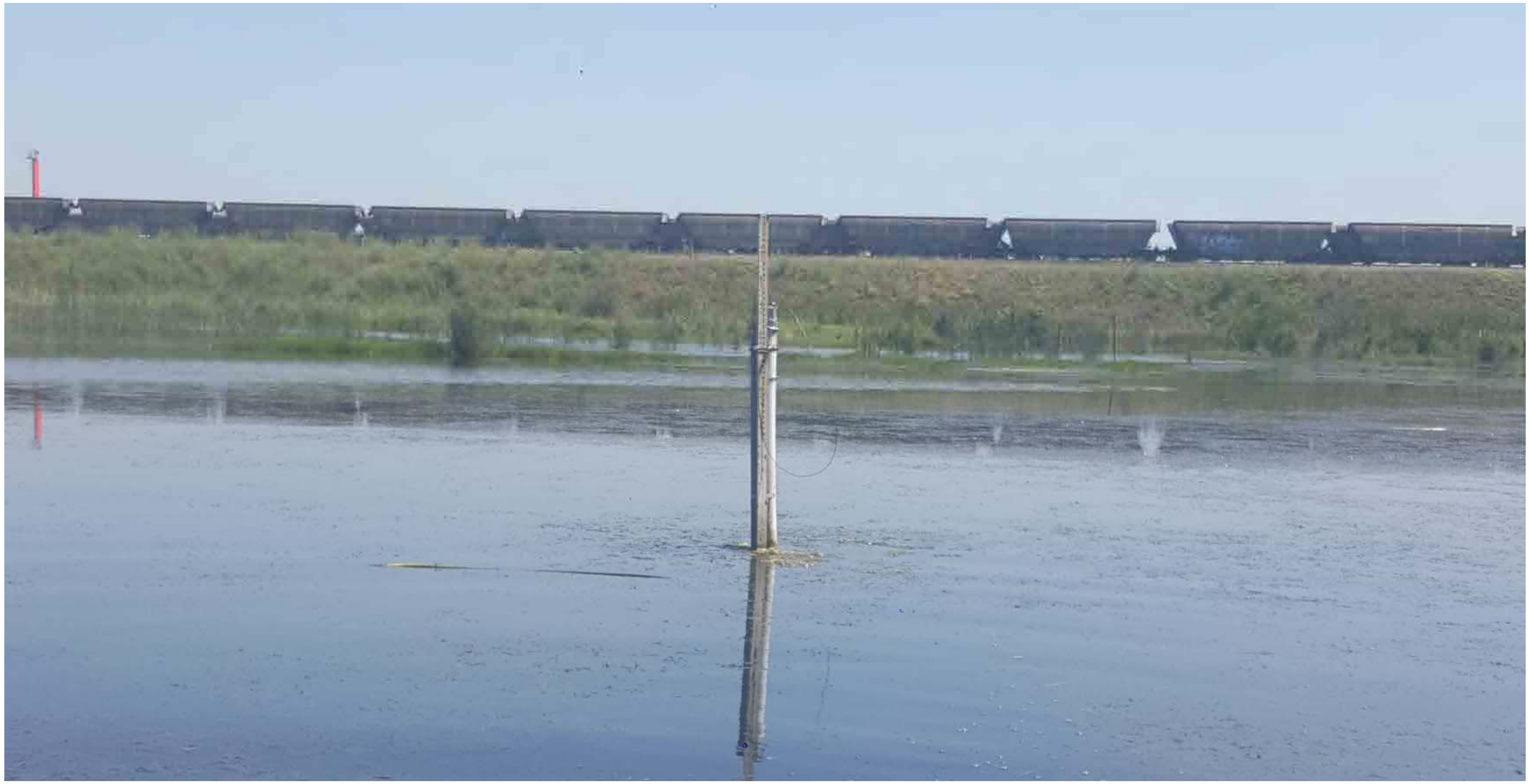
Attachment C

Data Logger Photographs

LOCATION 1 *SWDP-103*

RCA Australia

RCA ref: 11766-601/0



RCA Australia

RCA ref: 11766-601/0

LOCATION 2 *Easement Pond South*

RCA Australia

RCA ref: 11766-601/0

RCA Australia

RCA ref: 11766-601/0

LOCATION 3 *SWDP4*

RCA Australia

RCA ref: 11766-601/0

LOCATION 4 *SWSMEC-K2*

RCA Australia

RCA ref: 11766-601/0

LOCATION 5 *B-02L*

RCA Australia

RCA ref: 11766-601/0

LOCATION 6 *GH001S*

RCA Australia

RCA ref: 11766-601/0

LOCATION 7 *Deep Pond B*

LOCATION 8 *Long Pond*

LOCATION 9 *Deep Pond A*

RCA Australia

RCA ref: 11766-601/0

LOCATION 10 *SW K7*

RCA Australia

RCA ref: 11766-601/0

LOCATION 11 *SW Pond 11 (Existing housing repaired)*

RCA Australia

RCA ref: 11766-601/0

LOCATION 12 *Railway Pond (New)*

RCA Australia

RCA ref: 11766-601/0

LOCATION 13 *SW K7B*

RCA Australia

RCA ref: 11766-601/0

[KI3035C17]

ADDENDUM 1: DAMAGED DATA LOGGER REPORT for

WATER LEVEL AND ELECTRICAL CONDUCTIVITY LOGGER DATA REPORT
KOORAGNAG ISLAND WASTE EMPLACEMENT FACILITY
RCA Ref: 110077-401/0; Dated 30 June 2015.

Robert Carr and Associates (RCA) were engaged by the Hunter Development Corporation (HDC) in November 2014 to download data from 13 groundwater level loggers and 5 surface water level loggers at the Kooragang Island Waste Emplacement Facility (KIWEF). RCA found a number of the groundwater level loggers (10) and surface water level loggers (3) were defective and the data could not be downloaded. RCA removed the level loggers from the site and returned them to the supplier to be repaired and to retrieve any data stored within the logger, prior to file corruption.

On 20 July 2015, the supplier provided HDC with the retrieved packages of data from the defective loggers. The supplier indicated the damage to the loggers may have been resulted from water leakage into the units caused by either operator handling errors or temperature fluctuations. As a result of the damage, the supplier was only able to retreieve data from 6 of the returned defective level loggers. Of the 6 data packages retrieved by the supplier, 1 was from a surface water location (SWSMEC-LP, which was located within Long Pond as indicated within the RCA Report Drawing1) and the remaining 5 data packages were from groundwater locations (B355A, B355B, RCA01S, RCA01D and B101A-L,).

This report addendum reviews the data package retrieved from the surface water level logger SWSMEC-LP.

As noted within the RCA 2015 report, barometric pressure (used to compensate differences in water levels due to air pressure) was not logged at the site and, as such, an average barometric pressure was used from historical data. Based on the difference between maximum, mean and minimum barometric pressures, it is considered that there is an approximate error of ±0.2m due to compensating the data with an average barometric pressure. The surface water level loggers were also installed with nylon string which would have likely stretched under the weight of the logger over time. There may have been an increase in pressure readings due to the height of water above the water level logger increasing as the water level logger dropped inside the bore.

The comparison of the water level and electrical conductivity (EC) data retrieved from level logger SWSMEC-LP prior to the unit becoming defective are presented on Chart 1. The data is consistent with the findings of the RCA report, which identified a common trend within surface water bodies at the KIWEF, *'a decrease in EC readings are observed when water levels increase'*. There were some variations to the RCA surface water trend statement that were observed within the SWSMEC-LP data. These variations and the likely cause of the variation are described below:

- Between the 18 and 28 January 2013, the logger showed readings of little or no EC readings. The water level during the same period appears to be low in comparison to other level logger data and is likely to be representative of dry pond conditions.
- A decrease in EC readings on 3 March 2013 appears to correlate with a sharp increase in water levels at the same time, and is considered to be the result of a rainfall event.
- Sharp increases in EC readings on 28 March 2013, 28 April 2013 and 25 May 2013, correspond with Newcastle Spring Tides. Hydrosalinity modelling at Long

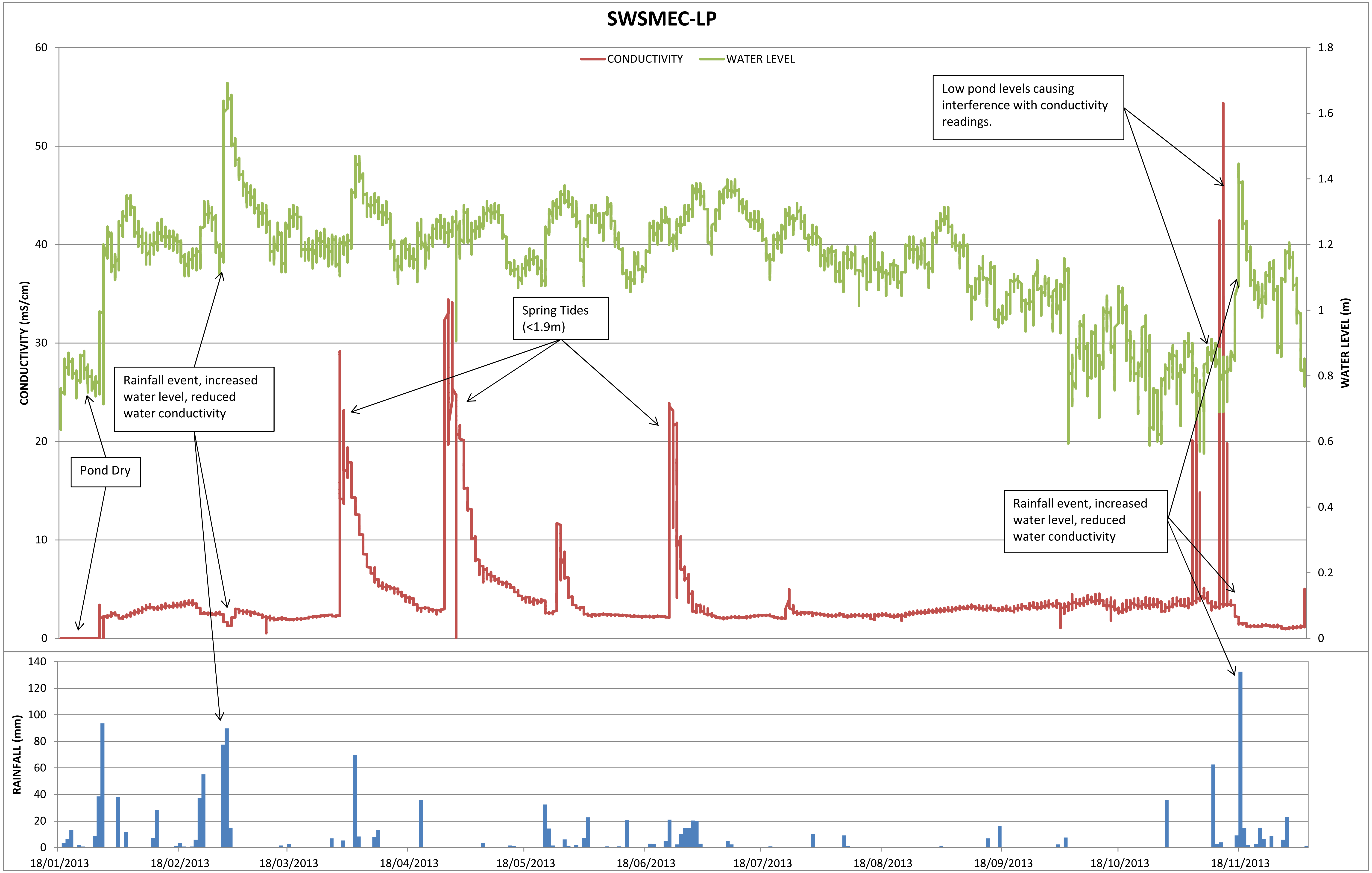
Pond identified a potential relationship between Spring Tides and the salinity levels detected within Long Pond. SMEC[1] indicated that the likely cause of the increase in salinity during Spring Tides was the interaction of estuarine waters from the Hunter River estuary with the less saline waters within Long Pond, via groundwater interaction. The mixing of the estuarine waters and those within Long Pond resulted in short sharp spikes in salinity, coinciding with the Spring Tides.

- A sharp increase in EC was recorded on 5 and 13 November 2013. The corresponding water levels during these periods were observed to be similar to the water levels recorded during January 2013, when the pond appeared to be dry. The resulting EC readings are therefore thought to be the result of instrument fouling.
- A decrease in EC readings on 18 November 2013 appears to correlate with a sharp increase in water levels and is considered to be the result of a rainfall event.

The variations described above that were observed at SWSMEC-LP during the monitoring period appear to be the result of natural variations within the Long Pond associated with the changing conditions prevalent at the time. The data retrieved from SWSMEC-LP prior to the logger becoming defective generally conforms to the KIWEF common trend within surface water bodies, where EC readings are observed to decrease as water levels increase. This trend is typical of natural surface water conditions.

[1] SMEC (May 2013), Kooragang Island Waste Emplacement Facility - Level Logger Water Level & Electrical Conductivity Data Report – May 2013.

Chart 1: Hydrograph and comparison of electrical conductivity in SWSMEC-LP (Long Pond).



Annex C

Surface Water Data (RCA 2015)

(Supplied Digitally)

Annex D

GGBF Management Plan (Golder Associates 2011)

19 April 2011

GREEN AND GOLDEN BELL FROG MANAGEMENT PLAN

Kooragang Island Waste Emplacement Facility Closure Works

Submitted to:
Hunter Development Corporation
Suite B, Level 5
PricewaterhouseCoopers Centre
26 Honeysuckle Drive
Newcastle, New South Wales 2300

REPORT

Report Number. 117623029-001-R-Rev0

Golder Associates

Executive Summary

The Kooragang Island Waste Emplacement Facility (KIWEF) is located on land owned by the New South Wales (NSW) State Property Authority, which is managed under delegated-authority by the Newcastle Port Corporation (NPC).

The KIWEF contains various wastes from the former BHP steelworks at Mayfield. Hunter Development Corporation (HDC) is in the process of closing the KIWEF via implementing certain landfill closure works, which include land-forming of waste emplacement cells and construction of a capping layer over much of the KIWEF site.

Historically, HDC was the holder of an Environment Protection Licence (EPL) over the site for the former BHP Solid Waste facility (refer to Figure 1). That EPL has now been surrendered, subject to the implementation of landfill closure works required by the NSW Office of Environment and Heritage (OEH) (formerly the NSW Department of Environment, Climate Change and Water (DECCW)). HDC, as the Agents for the Crown, are undertaking those necessary landfill closure works, on lands administered by NPC, which encompass the KIWEF (Figure 1).

The KIWEF site supports known populations and habitat of the Green and Golden Bell Frog (*Litoria aurea*). A flora and fauna impact assessment (GHD, 2010a) of the proposed landfill closure works concluded that the works are "*designed to minimise the direct and indirect impacts on biodiversity of the locality, especially in relation to the Green and Gold Bell Frog... The Proposal also addresses the risks posed from the prior disposal of BHP waste on the site*" and is unlikely to result in "*long-term decrease in the size of a population, reduce the area of occupancy of species, fragment an existing population, adversely affect habitat critical to the survival of a species, disrupt the breeding cycle of a population, modify, destroy, remove, isolate or decrease the availability or quality of habitat to the extent that a species is likely to decline, result in invasive species that are harmful to an endangered species becoming established in the endangered habitat, or interfere with the recovery of any threatened species*".

Overall, the flora and fauna impact assessment (GHD, 2010a) reported that the proposed capping strategy is unlikely to impact significantly on Green and Golden Bell Frogs, provided the works are managed through an appropriate environmental management plan.

In order to assist in minimising impacts of the landfill closure works, HDC engaged Golder Associates Pty Ltd (Golder) to develop this Green and Golden Bell Frog Management Plan (the GGBF Management Plan). HDC intend to incorporate this GGBF Management Plan into the detailed design documentation currently being developed for the landfill closure works. An Action Plan has been developed by Golder in conjunction with this GBBF Management Plan and is reported to HDC separately (Golder, 2011).

The Green and Golden Bell Frog is listed as 'endangered' under the NSW *Threatened Species Conservation Act 1995*, and 'vulnerable' under the federal *Environmental Protection and Biodiversity Conservation Act 1999*. Historically, this species was widespread across much of the Hunter Valley; however, it is now believed to be restricted to four key populations, including a large population on Kooragang Island (including the KIWEF site).

The Green and Golden Bell Frog is a relatively large species and is usually green, most often with irregular large gold spots and/or stripes. The Green and Golden Bell Frog can be regarded as somewhat of a habitat generalist, dispersing widely and maturing early. It is known to inhabit marshes, dams and stream sides and appears to prefer those water bodies where Bulrushes (*Typha* spp.) or Spikerushes (*Eleocharis* spp.) grow (NPWS, 1999). Green and Golden Bell Frogs are also known to inhabit highly disturbed sites (NPWS, 1999), such as the KIWEF site. The Green and Golden Bell Frog is known to travel significant distances across often seemingly inhospitable habitat. Distances of up to 1.5 km day/night are not unknown, particularly associated with significant rain events.

Frog Chytrid Fungus (FCF) has been identified as a key threatening process, at both the state and national level, for the Green and Golden Bell Frog (DSEWPC, 2009). FCF is widespread on Kooragang Island and Hexham Swamp, the other key Green and Golden Bell Frog population in the Newcastle area (DECC, 2007).

Section 3 of this document details the management procedures to be implemented, including identification and delineation of disturbance areas, pre-work surveys, identification of relocation areas, relocation procedures and rehabilitation of disturbed habitat, environmental induction training and site hygiene management for Chytrid fungus.

Section 4 of this document outlines the proposed monitoring programme for Green and Golden Bell Frogs at the KIWEF site. The monitoring programme includes annual review of publicly available baseline and ongoing data from other surveys including frog populations (such as that being undertaken by NCIG across the KIWEF site). An Annual Environmental Monitoring Report (AEMR) discussing the results of analysis of monitoring data will be presented to OEH.

Section 5 of this document identifies specific management and mitigation measures for disturbed areas and triggers for the development of response criteria in the unlikely event that the landfill closure works have an impact on the Green and Golden Bell Frogs. If the results of the monitoring programme indicate a decline in Green and Golden Bell Frog numbers across the site, which cannot be attributed to natural population fluctuations and variability, and is potentially a direct result of the landfill closure works, specific response criteria will be developed by HDC in consultation with the OEH.

Section 6 of this document outlines proposed review and reporting actions. HDC will report to OEH annually for 5 years following completion of the landfill closure works, unless analysis shows that Green and Golden Bell Frog populations are being impacted, then further reporting will be undertaken until a time agreed with OEH.

In accordance with the *Approval of Surrender of Licence Number 6437*, the Director-General will be notified of any incident with actual or potential significant off-site impacts on people or the biophysical environment, as soon as practicable after the occurrence of the incident. The Director-General will be provided with written details of the incident within seven days of the date on which the incident occurred.

The AEMR will be distributed to relevant government agencies and stakeholders, and copies provided to other interested parties, if requested.

In accordance with the *Approval of Surrender of Licence Number 6437*, this Management Plan will be made available on the HDC website.

Table of Contents

TABLES

FIGURES

APPENDICES

1.0 INTRODUCTION

1.1 BACKGROUND

The Kooragang Island Waste Emplacement Facility (KIWEF) is located on land owned by the New South Wales (NSW) State Property Authority, which is managed under delegated-authority by the Newcastle Port Corporation (NPC).

The KIWEF contains various wastes from the former BHP steelworks at Mayfield. Hunter Development Corporation (HDC) is in the process of closing the KIWEF via implementing certain landfill closure works, which include land-forming of waste emplacement cells and construction of a capping layer over much of the KIWEF site.

Historically, HDC was the holder of an Environment Protection Licence (EPL) over the site for the former BHP Solid Waste facility (refer to Figure 1). That EPL has now been surrendered, subject to the implementation of landfill closure works required by the NSW Office of Environment and Heritage (OEH) (formerly the NSW Department of Environment, Climate Change and Water (DECCW)). HDC, as the Agents for the Crown, are undertaking those necessary landfill closure works, on lands administered by NPC, which encompass the KIWEF (Figure 1).

The KIWEF site supports known populations and habitat of the Green and Golden Bell Frog (*Litoria aurea*). A flora and fauna impact assessment (GHD, 2010a) of the proposed landfill closure works concluded that the works are "*designed to minimise the direct and indirect impacts on biodiversity of the locality, especially in relation to the Green and Gold Bell Frog... The Proposal also addresses the risks posed from the prior disposal of BHP waste on the site*" and is unlikely to result in "*long-term decrease in the size of a population, reduce the area of occupancy of species, fragment an existing population, adversely affect habitat critical to the survival of a species, disrupt the breeding cycle of a population, modify, destroy, remove, isolate or decrease the availability or quality of habitat to the extent that a species is likely to decline, result in invasive species that are harmful to an endangered species becoming established in the endangered habitat, or interfere with the recovery of any threatened species*".

Overall, the flora and fauna impact assessment (GHD, 2010a) reported that the proposed capping strategy is unlikely to impact significantly on Green and Golden Bell Frogs, provided the works are managed through an appropriate environmental management plan.

In order to assist in minimising impacts of the landfill closure works, HDC engaged Golder Associates Pty Ltd (Golder) to develop this Green and Golden Bell Frog management plan (the GGBF Management Plan) to support the landfill closure works. HDC intend to incorporate this GGBF Management Plan into the detailed design documentation currently being developed by HDC for the landfill closure works.

This GGBF Management Plan has been prepared in accordance with HDC's Request for Tender No. 141 ("Green & Golden Bell Frog Management Plan and Action Plan for K26/32 Ponds: KIWEF"), dated February 2011, and Golder's responding proposal, dated 28 February 2011 as accepted via a letter from HDC emailed to Golder on 16 March 2011. This Management Plan has been prepared via review of documentation provided by HDC to Golder on 22 March 2011, a visual site visit by Golder personnel and written commentary from HDC.

An Action Plan for the K26/K32 Ponds has been developed by Golder in conjunction with this GBBF Management Plan and is reported to HDC in a separate document (Golder, 2011).

1.2 A SUMMARY OF WORKS COMPLETED TO DATE

A range of studies have been completed by others in relation to the Green and Golden Bell Frogs on the KIWEF site since its hand over to the Crown in 2002. The most recent relevant studies are listed in the following. It is noted that other previous studies are summarised in these works, and, therefore, are not identified here.

- Revised Capping Strategy, Flora and Fauna Impact Assessment, Rev 3 (GHD, 2010a).
- March 2011 Green and Golden Bell Frog (Litoria aurea) Survey at the Kooragang Island Waste Emplacement Facility (Umwelt, 2011).
- Revised Final Landform and Capping Strategy, Rev 4, (GHD, 2010b).

The key findings of those reports, as relevant to the ongoing management of Green and Golden Bell Frogs on the KIWEF site, are presented below.

1.2.1 Flora and Fauna Impact Assessment

The flora and fauna impact assessment of the revised capping strategy was undertaken as part of the EPL surrender, which the then DECCW required to identify any impacts resulting from the implementation of the final capping strategy on Green and Golden Bell Frogs (and other threatened species). The assessment was also required to identify associated mitigation measures for those species and their habitats.

Key Findings

The key findings of the flora and fauna impact assessment (GHD, 2010a) comprised the following:

- The assessment identified areas of known and potential Green and Golden Bell Frog Habitat (as indicated on Figure 1), and determined the presence, relative abundance and distribution of Green and Golden Bell Frogs on the KIWEF site, and the adjacent Ash Island. A summary of the locations and numbers of Green and Golden Bell Frogs recorded on the KIWEF site is presented in Figure 1. During the assessment (that is February and March 2009), 59 Green and Golden Bell Frogs were recorded from the KIWEF and surrounding area; 38 individuals were recorded on the KIWEF site.
- Two important factors to note, as identified in the report, are:
  - The Green and Golden Bell Frog's ongoing survival on Kooragang Island, and the KIWEF site, may be related to the protection that the brackish wetland habitat provides from the Chytrid fungus (Stockwell, pers. comm., in GHD, 2010a).
  - The terrestrial habitats and ephemeral water bodies supported on the KIWEF site and the larger Kooragang Island may provide important movement corridor refuges for Green and Golden Bell Frogs (Hamer *et al.*, 2008, in GHD, 2010a).
- Potential changes to water quality, especially salinity, may adversely affect the Green and Golden Bell Frogs on the KIWEF site.
- The *in situ* contaminated materials present across the KIWEF site will be addressed by the capping strategy. There is, therefore, the potential for water quality in, and adjacent to, the capped location to remain similar or improve.
- The capping strategy was designed to minimise changes to hydrology. As noted, however, the construction of the NCIG rail loop has impacted on the known Green and Golden Bell Frog habitat supported in the K26 and K32 cells, and potentially already altered the hydrology of these ponds.
- Where the proposed capping strategy would impact on streamside vegetation and banks, and, hence, potential Green and Golden Bell Frog habitat, that vegetation would be reinstated immediately following capping works to a state as close as possible to the original.
- Plague Minnow (*Gambusia holbrooki*), a known predator of Green and Golden Bell Frog tadpoles, was recorded in ponds across the KIWEF site.
- The assessment considered that the capping strategy would result in minimal fragmentation or isolation of currently interconnecting areas of Green and Golden Bell Frog habitat. The capping strategy would

leave areas of appropriate habitat in areas within the KIWEF site and the adjacent Hunter Estuary National Park.

- That vegetation that may be cleared or capped is considered unlikely to constitute key foraging habitat for Green and Golden Bell Frogs.
- The potential cumulative impacts on Green and Golden Bell frogs and their habitat across the local area from other proposals, is unknown; particularly impacts on potential movement between populations north and south. Furthermore, inference is made that competition for resources, required by the species, may have potentially increased because of the translocation of individuals into suitable areas on the KIWEF site from areas impacted by other proposals. However, the proposed "*capping strategy aims to avoid increasing these pressures while dealing with the potentially harmful pollutants on site*" and "*is unlikely to add to these previous impacts or add to cumulative adverse impacts on threatened species at the KIWEF site*".
- Overall, the assessment reports that the proposed capping strategy is unlikely to impact significantly on Green and Golden Bell Frogs, provided the works are managed through an appropriate environmental management plan. Those assessments of significance were undertaken in accordance with the Commonwealth's *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) and the NSW *Environmental Planning and Assessment Act 1979* (EPA Act).

Mitigation Measures

The following mitigation measures were recommended in the flora and fauna impact assessment:

- A 30 m buffer zone is proposed around fresh and brackish water wetlands, ponds, and identified areas of Green and Golden Bell Frog habitat.
- If it is identified that works will occur in Green and Golden Bell Frog habitat (such as the fringing habitat near Deep Pond), one week prior to those works commencing, a pre-clearance survey is required to be conducted by a qualified ecologist. In the event that any Green and Golden Bell Frogs are identified, they will be relocated (using appropriate amphibian hygiene protocols).
- Once works are complete, the restoration and rehabilitation of that habitat should be undertaken.
- Control of noxious weeds on the site should be undertaken limiting the use of herbicides, which may be detrimental to Green and Golden Bell Frogs.
- Maintenance of the current hydrological and water chemistry regimes; in particular, low levels of salinity in the brackish wetlands, which may protect amphibian species from the Chytrid fungus. The maintenance of runoff volumes into these areas may help conserve appropriate salinity levels.
- Similarly, general erosion and sediment control should be implemented to limit the transport of other contaminants across the KIWEF site.
- Capping and grading activities should be conducted outside of the Green and Golden Bell Frog's core breeding period (that is, September to March). If works need to be undertaken during this time, they should be limited to areas outside of recognised breeding habitat. For the purposes of this GGBF Management Plan, breeding habitat is defined as areas within or immediately adjacent to emergent, aquatic macrophytes.
- Standing water should not be transferred between waterbodies, to prevent the spread and establishment of the Plague Minnow.
- Suitable hygiene protocols must be developed and adhered to for all plant and personnel entering the KIWEF site to avoid the spread of Chytrid fungus.

- Compensatory habitat for the Green and Golden Bell Frog may be considered as part of the capping strategy. For example, the capping works may facilitate rehabilitation of suitable Green and Golden Bell Frog habitat. However, HDC has indicated that it is not intending to create artificial habitat, interfere with existing habitat, nor are seeking to modify frog population numbers or habitat.

- Ongoing, long-term monitoring of the Green and Golden Bell Frog population across the entire KIWEF site, and adjacent areas, such as the NCIG facility, should be undertaken seasonally. This data will help identify if any adverse impacts have affected the Green and Golden Bell Frog population and habitat across Kooragang Island.

1.2.2 March 2011 Survey

The March 2011 survey of GGBF (Umwelt, 2011) targeted the rail loop area, including K26 and K32 Ponds (as well as K24 and K31 Ponds). Overall, this survey was suitable for its purpose. However, the following comments are made in relation to the survey scope and its findings. Those comments were used to assist in the development of the Action Plan for the K26/K32 Ponds (Golder, 2011).

- No detailed surface water quality data have been collected and analysed for the standing water in the Ponds.

- It is known that some contaminants are detrimental to frog embryos and development, as well as known to lead to malformations in frogs for example, Abbasi and Soni, 1984; Anon., 1999, Arrieta *et al.*, 2004, Guillermo *et al.*, 2000; Marquis *et al.*, 2006; Rice *et al.*, 2002; Stabenau *et al.*, 2006; Wang and Jia, 2008). Some surface water chemistry data are available (see NCIG, 2008, in GHD, 2010b) that indicate values exceeding ANZECC trigger values for aquatic ecosystems; however, these are limited. In the absence of detailed water chemistry data, there is no baseline to compare for the long-term monitoring of the water quality, correlated with the frog populations. This represents a significant data gap.

- Data on the periodicity of the standing water in the cells has not been collected. Such data would assist in the understanding of the impacts of changes in local hydrology, such as may have occurred during construction of the NCIG rail loop.

- The mere presence of calling males may not be a useful indicator of successful breeding in the ponds. This, to some extent, has been alluded to in both the GHD (2010) and the Umwelt (2011) studies in that no tadpoles were recorded in the cells during either of those studies.

- The presence of juveniles may be a valid indicator of a sustainable population as this species is known to emigrate over large distances. Therefore, it would be useful to confirm that there has been effective breeding over one or more seasons, with tadpoles that survive to adulthood.

- The baseline comparison that the Umwelt (2011) report makes with the GHD (2010) results, in particular, that "There is no substantial change in the numbers recorded from 2009 to 2011." (page 8) needs to be further qualified. A stable number of frogs each year over a relatively short time frame could result from a variety of factors (such as low mortality or in-migration) and is not necessarily confirmation of sustainable breeding.

To meet HDC's requirements regarding management of contamination and frog habitat at the Ponds it is recommended that these data gaps are addressed by HDC.

1.2.3 Capping Strategy

The objectives of the capping strategy were to "*reduce risks to the environment associated with migration of contaminated groundwater and to prevent the risk of biological harm associated with contaminated soil and groundwater*" (GHD, 2010b). This objective had the associated objectives of preserving and maintaining habitat for shorebirds and other threatened species, and endangered ecological communities.

The strategy assessed the KIWEF based on sub-areas, with each sub-area assessed for the requirement for capping, and the effects that capping may have on the ecology. The locations of those sub-areas are presented on Figure 1. In terms of impacts to ecology, in particular the ecology of the Green and Golden Bell Frog, the following sub-areas were important:

- K1 – This sub-area presents a low risk to the surrounding environment from contamination. Capping of this area would have a significant impact on the ecology of the area.
- K2 – This sub-area presents a low to moderate risk to the surrounding environment from contamination. Capping of this area could impact on Green and Golden Bell Frog habitat.
- K3 – This sub-area presents a low to moderate risk to the surrounding environment from contamination. Capping of the fringing areas of this sub-area may have an impact on Green and Golden Bell Frog habitat. Therefore, capping is suggested only up to within 30 m of that habitat, with the exception of the area located near K3/1W.
- K4 (deep pond) – Contamination in this sub-area presents a low risk to the environment. However, filling and capping of this sub-area will have a significant impact on Green and Golden Bell Frog habitat, and the overall ecology of the area.
- K6 – This sub-area presents a low risk from contamination. However, capping of this sub-area will have a significant impact on the ecology of the area.
- K7 – The sub-area presents a low to moderate risk to the environment from contamination. Capping of the edges of the site will significantly impact on Green and Golden Bell Frog habitat.
- K26/K32 cells – These cells present a high risk to the environment. However, they also support Green and Golden Bell Frog habitat. Capping is not recommended, but rather a monitoring and risk assessment be completed. Details of recommended actions for the K26/K32 Ponds are presented in an Action Plan (Golder, 2011).

Based on the above assessment, a capping strategy was developed that minimised the impacts to Green and Golden Bell Frog habitat. A brief summary of the other sub-areas, suggested for capping, is provided below.

- K5 (excluding pond 5) – This sub-area presents a low to moderate risk to the environment from contamination. There is no significant Green and Golden Bell Frog habitat in this area; therefore, capping is an option.
- Pond 5 – Migration of contaminants from this sub-area may impact the estuarine aquifer. This sub-area does not support significant Green and Golden Bell Frog habitat. Therefore, capping is an option.
- K10 (excluding K26/K32) – The sub-area presents a low to moderate risk to the environment from contamination. The BOS area presents a moderate risk to the environment. Capping is suggested for this area.

1.3 Other Relevant Management Plans and Guidelines

This GGBF Management Plan should be read and in conjunction with the following management plans and guidelines, which are relevant to the Green and Golden Bell Frog population on Kooragang Island and the KIWEF:

- *Coal Export Terminal Green and Golden Bell Frog Management Plan* (Newcastle Coal Infrastructure Group (NCIG) (Document No. GGBFMP-R01-E.DOC, 2007)) (the NCIG management plan)
- *Draft Management Plan for the Green and Golden Bell Frog Key Population in the Lower Hunter* (Department of Environment and Climate Change (DECC) (NSW) 2007) (the Lower Hunter management plan)
- *Significant impact guidelines for the vulnerable Green and Golden Bell Frog (*Litoria aurea*)* (Department of Sustainability, Environment, Water, Populations and Communities (DSEWPC), Nationally threatened species and ecological communities; Background paper to the EPBC Act policy statement 3.19, 2009)
- *Best practice guidelines: Green and Golden Bell Frog habitat* (DECC, 2008)
- *Protecting and restoring Green and Golden Bell Frog habitat* (DECC, 2008)
- *Draft Recovery Plan for the Green and Golden Bell Frog (*Litoria aurea*).* (DECC, 2005)
- *Threatened Species Management Information Circular No.6, Hygiene Protocol for the Control of Disease in Frogs* (NPWS, 2001) (the hygiene protocol) (Appendix A).

1.4 Project Approval

This GGBF Management Plan has been developed in order to partly address the KIWEF site's *Approval of Surrender of Licence Number 6437*, dated 8 December 2010, Condition 5.b), which requires the following:

b) The licensee shall prepare and submit a Green and Golden Bell Frog Management Plan to the EPA for approval by 13 April 2011. The Plan shall encompass the entire premises occupied by the licensee and include, but not be limited to:

i) Management measures to be undertaken to minimise the spread of the amphibian Chytrid fungus including:

> *(i) the training of project personnel in site hygiene management; and*
>
> *(ii) site hygiene procedures for project personal, mobile plant and equipment, in accordance with the NPWS Hygiene Protocol for the Control of Disease in Frogs 2001; and*

ii) Measures to maintain, restore and enhance Green and Golden Bell Frog habitat, including movement corridors across the site.

Additionally, obligations exist under the DSEWPC's *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) as to the protection of this nationally threatened species. These obligations are detailed in the EPBC Act policy statement 3.19 (see above for reference), as well as the significant impact criteria set out in the NSW *Threatened Species Conservation Act 1995* (TSC Act).

1.5 Objectives of this Plan

In relation to Green and Golden Bell Frogs on the KIWEF site, one of the overall aims of the KIWEF landfill closure works is to manage those works in a manner that does not impact threatened species and their habitat, and to restore small areas of temporary disturbance to their original (or better) condition. To that end, the objectives of this GGBF Management Plan are:

1) To maintain the existing Green and Golden Bell Frog populations supported on the KIWEF site.

2) To reduce the spread of the amphibian Chytrid fungus (*Batrachochytrium dendrobatidis*).

3) To protect the existing Green and Golden Bell Frog habitat on the KIWEF site.

4) To increase connectivity between the existing areas of Green and Golden Bell Frog habitat on the KIWEF site.

5) To restore Green and Golden Bell Frog habitat that may be disturbed during the landfill closure works to a condition as-good or better than prior to the works.

Hence, this GGBF Management Plan aims to assist HDC in the implementation of appropriate environmental management measures during the KIWEF closure works.

1.6 Scope and Use of this Plan

The scope of this GGBF Management Plan covers that area known as the KIWEF (Figure 1), before, during and after landfill closure works.

This GGBF Management Plan has been prepared in accordance with the relevant state guidelines as identified in Section 1.3.

This GGBF Management Plan will be reviewed and updated by those responsible for undertaking the detailed design and associated documentation to ensure that it is current at the time that the landfill closure works are tendered. Once tendered, the Contractor will incorporate the revised GGBF Management Plan into their Environmental Management Plans (EMP). Where there is any conflict between the provisions of this GGBF Management Plan and Contractors' obligations under their respective contracts, including the various statutory requirements (that is, licences, permits, project approval conditions and relevant laws), the contract and statutory requirements are to take precedence. In the case of any real or perceived ambiguity between elements of this GGBF Management Plan and the above statutory requirements, the Contractor shall first gain clarification from HDC, prior to implementing that element of this GGBF Management Plan over which the ambiguity is identified.

It is intended that this GGBF Management Plan should complement those studies identified in Section 1.2. To that end, this management plan should be supplemented by publicly available monitoring results collected by others for projects on Kooragang Island. For example, it is understood that the NCIG plan requires monitoring to occur on an annual basis until 2020, as outlined in the EPBC Act Particular Matter conditions for that project. The NCIG monitoring data will be useful input into management of Green and Golden Bell Frogs on the KIWEF site.

1.7 Structure of this Plan

The structure of this GGBF Management Plan is provided below. This structure has been adopted to address the requirements as specified in the HDC brief (document number HDC141), and be in accordance with required guidelines.

- Section 2: Provides a profile of the Green and Golden Bell Frog, including its key identifying features in the field, similar species on the KIWEF site, general ecology relevant to the KIWEF site, its conservation status and distribution on the KIWEF site.

- Section 3: Details the management procedures to be implemented, including identification and delineation of disturbance areas, pre-work surveys, identification of relocation areas, relocation procedures and rehabilitation of disturbed habitat, environmental induction training and site hygiene management for Chytrid fungus.

- Section 4: Outlines the monitoring programme for the KIWEF site.

- Section 5: Response criteria and mitigation measures, including comparison with previous data collected at the site, and procedures to be followed if a decline in the Green and Golden Bell Frog population is detected.

- Section 6: Lists the reporting and review requirements of this management plan.
- Section 7: Lists references cited in this Green and Golden Bell Frog Management Plan and other supporting information.

GREEN AND GOLDEN BELL FROG MANAGEMENT PLAN

HUNTER DEVELOPMENT CORPORATION

SITE LOCATION

LEGEND

- Kooragang Island Waste Emplacement Facility License Area
- Known and Potential Habitat Areas (GHD, 2010)
- Capping Extent Landfill Closure Works
- HDC Closure Area 2010

NOTES

Imagery provided by The Hunter Development Corporation 16/03/2011
Data digitised from Land & Property Management Authority Request for Tender - RFT No. HDC141. February 2011 Appendix A - Site and Access Map

0 40 80 160 240 320 400 metres

SCALE (at A3) 1:10,000

Coordinate System: GDA 1994 MGA Zone 56

PROJECT: 117623029
DATE: 18/04/2011
DRAWN: AJW
CHECKED: TC

FIGURE 1

Golder Associates

2.0 SPECIES PROFILE – GREEN AND GOLDEN BELL FROG (*LITORIA AUREA*)

2.1 Conservation Status

2.1.1 Listing

The Green and Golden Bell Frog's conservation status is listed as follows:

- **Endangered** under the NSW *Threatened Species Conservation Act 1995*
- **Vulnerable** under the federal *Environmental Protection and Biodiversity Conservation Act 1999.*

2.1.2 Known Populations

The Green and Golden Bell Frog is estimated to have disappeared from 90% of its former range within NSW over the last 30 years (Pyke and White, 1996; DECC, 2007), although populations in Victoria are believed to be secure (Gillespie, 1996).

There are about 45 known populations of Green and Golden Bell Frog within NSW (DECC, 2007). Of these, only a few occur in conservation reserves; Kooragang Island Nature Reserve supports the closest protected population to the KIWEF site (DECC, 2007). Historically, this species was widespread across much of the Hunter Valley; however, it is now believed to be restricted to four key populations:

- a large population on Kooragang Island (including the KIWEF site)
- small, isolated populations at Sandgate on the margins of Hexham Swamp
- a meta-population in the Gillieston Heights/East Maitland, Ravensdale areas (also including Wentworth Swamp)
- a meta-population in the Ravensworth/Liddell/Bayswater area.

2.1.3 Management and Recovery Plans

To "ensure that the Lower Hunter population is successfully managed and monitored such that the species continues to persist in the Lower Hunter and that 'measures' of the two populations' viability are maintained or improved over time", the following key documents are important:

- *Draft Management Plan for the Green and Golden Bell Frog Key Population in the Lower Hunter* (Department of Environment and Climate Change (DECC) (NSW) 2007) (the Lower Hunter management plan)
- *Draft Recovery Plan for the Green and Golden Bell Frog (*Litoria aurea*)*(DECC, 2005).

2.2 Key Distinguishing Features

The following provides some key diagnostic features that are important for quick and easy field-identification of this species.

2.2.1 Adult Frogs

- Relatively large, muscular species with robust body form and smooth skin compared to other species known to inhabit the KIWEF site (Barker *et al.*, 1995).
- The background colouration is usually green, most often with irregular large spots and/or stripes of gold (Barker *et al.*, 1995), refer to Figure 2. It should be noted that adults can vary considerably in pattern; however, the background colouration will always be green.

- Males vary in size from 60 to 70 mm (snout to vent length (SVL)); females vary from 65 to 110 m SVL (Tyler and Knight, 2009). Typically, most individuals being in the range of 60 to 80 mm SVL (DEC, 2005).
- A white or cream stripe extends from above the nostril, over the eye and ear (tympanum) and continues as a fold down the side (Robinson, 1998). There is usually a darker stripe below the white stripe, and another pale stripe from below the eye, extending to the base of the forearm (Robinson, 1998).
- The groin area, and behind the thighs, is usually pale blue or bluish-green, particularly in breeding males (Tyler and Knight, 2009). Mature males may also have a yellowish darkening of the throat area (DEC, 2005).
- The tympanum is usually brown (Tyler and Knight, 2009).
- The belly is usually creamish-white (DEC, 2005); the lower sides of the body are adorned with raised glandular, creamish-coloured spots of irregular size.
- The eye has a horizontally elliptical pupil and a golden yellow iris. The toes are three-quarters to nearly fully webbed (Robinson, 1998).

Figure 2: Adult Green and Golden Bell Frog (Litoria aurea)
(Source: A. White (2007), as in the NCIG plan)

2.2.2 Tadpoles

- Relatively large, reaching 65 to 100 mm at limb bud development stage (DEC, 2005). May be confused with other large-bodied tadpoles of species in the KIWEF site; for example, Peron's Tree Frog (*Litoria peronii*).
- Deep bodied and possess long tails with a high fin that extends almost half way along the body (refer to Figure 3).
- Although not typically used in field identification given the need for a microscope, the mouthparts consist of two upper and three lower labial rows (Anstis, 2002).

Figure 3: Tadpole Green and Golden Bell Frog (Litoria aurea)
(Source: A. White (2007), as in the NCIG plan)

2.2.3 Similar Species within the KIWEF Area

The Green and Golden Bell Frog should not be confused with any other species in the KIWEF area, given its very distinctive features and large size, wart-free skin, expanded finger and toe pads, and lack of spotting or marbling on the hind side of the thigh (Robinson, 1998).

Nevertheless, to the untrained eye, metamorphosing individuals may be confused with the adults and metamorphs of the following species that are known to occur on the KIWEF site:

- Eastern Dwarf Tree Frog (*Litoria fallax*)

  This species is also green, but lacks any of the golden markings on the back and presents with a plain, single colour.

- Peron's Tree Frog (*Litoria peronii*)

  Adults have bright yellow with black mottling on armpits, groin, and backs of thighs. The back texture is rough, and often is covered with faint, emerald spots, giving its other common name, the Emerald-spotted Treefrog.

- Broad-palmed Rocket Frog (*Litoria latopalmata*)

This species ranges from light to dark brown on its back, sometimes with darker blotches. The backs of the thighs are yellow and dark brown.

- Spotted Marsh Frog (*Limnodynastes tasmaniensis*)

  Adults usually have large regularly-shaped olive green blotches on the back and sometimes have a yellow, red, or orange mid-dorsal stripe. The background colouration is not green.

2.3 Aspects of Ecology Important for Management

2.3.1 Preferred Habitat

The Green and Golden Bell Frog can be regarded as somewhat of a habitat generalist, dispersing widely and maturing early. It is known to inhabit marshes, dams and stream sides and appears to prefer those water bodies where Bulrushes (*Typha* spp.) or Spikerushes (*Eleocharis* spp.) grow (NPWS, 1999). In the Lower Hunter region, such plant species as Salt Marsh Rush (*Juncus kraussi*), Coast Club Rush (*Schoenoplectus subulatus*), and Salt Couch (*Sporobolus virginicus*) are indicators of habitat suitability for Green and Golden Bell Frogs (DECC, 2007). Such habitat is typically unshaded, free of Plague Minnow (*Gambusia holbrooki*), have a grassy area nearby and diurnal sheltering sites (NPWS, 1999).

Green and Golden Bell Frogs are also known to inhabit highly disturbed sites (NPWS, 1999), such as the KIWEF site.

Typically, Green and Golden Bell Frogs will require habitat for breeding, foraging, shelter, movement and over wintering. All such habitat types occur across the KIWEF site, and have been incorporated under the banner of known and potential Green and Golden Bell Frog habitat by GHD (2010a). These habitat areas are indicated on Figure 1.

2.3.2 Habits

The Green and Golden Bell Frog is frequently active during the day, although it is known to forage at night on insects, as well as other frogs (Cogger, 2000; Barker *et al.*, 1995; NPWS, 1999). Tadpoles are known to feed on algae and other vegetative matter (NPWS, 1999; Anstis, 2002).

The Green and Golden Bell Frog exhibits strong migration tendencies, and is known to travel significant distances across often seemingly inhospitable habitat (DECC, 2007). Distances of up to 1.5 km in a single day/night are not unknown (Wellington, 1998; Pyke and White, 2001; DECC, 2007). It should be noted that such movements most often occurred during or immediately after significant rain events.

2.3.3 Breeding

The Green and Golden Bell Frog usually breeds in summer when conditions are warm and wet, typically after rain (Cogger, 2000; Barker, *et al.*, 1995). The core breeding period for this species is generally accepted to be between September and February (DECC, 2007), provided sufficient rainfall occurs during this time.

Males call while floating in water and females produce a floating raft of eggs, which gradually settle to the bottom (NPWS, 1999).

Tadpoles take around six weeks to develop depending on environmental conditions (for example, temperature) (Pyke and White, 1996; NPWS, 1999).

Adult male Green and Golden Bell Frogs may only live for around two years in a hostile environment but, typically, life expectancy is likely to vary markedly according to the quality of the habitat (Goldingay and Newell, 2005).

2.3.4 Threats

Frog Chytrid Fungus (FCF) has been identified as a key threatening process, at both the state and national level, for the Green and Golden Bell Frog (DSEWPC, 2009). FCF is widespread on Kooragang Island and Hexham Swamp, the other key Green and Golden Bell Frog population in the Newcastle area (DECC, 2007).

Recent evidence suggests that occasional exposure to saline influences and/or certain contaminants may be attenuating the effects of the FCF (DECC, 2007). Such saline and polluted conditions occur on the KIWEF site. Hypotheses supporting this scenario are presently being tested by M. Stockwell and M. Mahoney from the University of Newcastle (NCIG, 2007).

3.0 MANAGEMENT PROCEDURES

3.1 Identification and Delineation of Disturbance Areas

Known and potential Green and Golden Bell Frog habitat is located across the KIWEF site and surrounds. GHD (2010a) identified and mapped that habitat (as identified in Figure 5.5 of their report), which is presented in Figure 1 of this GGBF Management Plan. Prior to capping works commencing, this habitat will be clearly identified on the ground (with appropriate signage), and the locations of it communicated to personnel undertaking works on the site. This communication will be undertaken as part of the site induction (refer to section 3.3), and will include obligations of personnel to maintain and protect that habitat.

Ponds P and Q (that is, cells K26 and K32) will be subject to a separate Action Plan (Golder, 2011) due to their significance as habitat and the presence of contaminated soil and groundwater.

3.2 Identification of Areas of Disturbance to Habitat

As part of the capping strategy, a small proportion of the known and potential Green and Golden Bell Frog habitat may be disturbed. This habitat area comprises the fringing habitat adjacent to Deep Pond, that is the area located near K3/1W and the BOS area (Figure 1).

The frogs will be relocated within the KIWEF during the capping works.

3.3 Environment Induction and Training

All HDC personnel, contractors and sub-contractors will undergo environmental induction and training before commencing work on-site. As it pertains to the Green and Golden Bell Frog, information addressed during this training will include (NCIG, 2007):

- Green and Golden Bell Frog profile and identification (Section 2).
- Identification of Green and Golden Bell Frog habitat areas. Project personnel will be prohibited from entering Green and Golden Bell Frog habitat areas located outside defined works areas.
- Site hygiene management in accordance with the Hygiene Protocol (Section 3.4).
- Procedures to be followed in the event Green and Golden Bell Frogs are found (Section 3.6).

3.4 Site Hygiene Management

The proposed hygiene management protocol described below largely follows that prepared by NCIG (2007), which has been accepted by OEH.

FCF (refer to section 2.3.4) has the potential to adversely affect Green and Golden Bell Frogs. It is known to occur on Kooragang Island, and potentially on the KIWEF site. Infection occurs through waterborne zoospores released from an infected amphibian in water (NPWS, 2001) and the fungus infects both frogs and tadpoles (Berger *et al.*, 1999). Therefore, the spread of FCF can occur via the movement of water around the site and/or soil attached to equipment (both plant and personal protective equipment).

Typical clinical signs of frogs infected with FCF (after Berger *et al.*, 1999) include:

- lethargy
- loss of appetite
- skin discoloration
- presence of excessive sloughed skin
- sitting unprotected during the day with hind legs held loosely to the body.

3.4.1 Hygiene Training

To reduce the likelihood of spreading FCF, all HDC employees and contractors involved in activities in areas of known habitat for the Green and Golden Bell Frog (and other amphibian species) will be trained in site hygiene management in accordance with the hygiene protocol (Appendix A). This will be part of the environmental induction and training (Section 3.3).

3.4.2 Inspection and Disinfection of Mobile Plant

Any mobile plant entering and leaving the KIWEF site during the closure and capping activities will be routinely disinfected at a designated wash bay.

Similarly, personal protective equipment (PPE) of HDC employees and contractors entering and leaving the site will be disinfected as a matter of routine, following the methods outlined in the Hygiene Protocol (Appendix A).

Inspection and disinfection of mobile plant, and affected PPE, will be undertaken at a designated, concrete-bunded disinfection area at the entrance of the KIWEF site. The location of this area, and the disinfection procedure, will be incorporated into the site induction and training programme (refer to Section 3.3).

3.5 Pre-works Surveys for Disturbance Areas

Pre-works surveys will include targeted active searches of potential Green and Golden Bell Frog habitat located within proposed disturbance areas. These surveys will be undertaken by a suitably qualified and licensed ecologist.

The pre-works surveys (and, if applicable, relocation activities) will be conducted to minimise disruption to breeding activities and the need to relocate tadpoles or metamorphs, where practicable. All these activities will be conducted in accordance with the relevant measures outlined in the hygiene protocol (Section 3.4).

Habitat resources typically associated with the lifecycle components of the Green and Golden Bell Frog (for example, ponded areas, rocks, logs, tussock forming vegetation and other cover) will be searched during a diurnal visual inspection.

Following the diurnal habitat searches, a nocturnal habitat search may be conducted to assess nocturnal usage (that is, breeding/calling) in the habitat supported in the disturbance area, if the surveys are conducted during the core breeding season. The nocturnal habitat searches may include:

- searching of habitat features, which were searched during the day
- spotlighting
- call play-back.

In the event that any Green and Golden Bell Frogs are observed during the diurnal or nocturnal searches, the relocation procedures outlined in Section 3.6 will be initiated prior to the commencement of disturbance works. In some cases a frog-proof fence may be used to protect the frogs in-situ or to exclude frogs from the surveyed area.

The results of the pre-works surveys will be recorded and reported in the Annual Environmental Management Report (AEMR) (Section 6).

3.6 Green and Golden Bell Frog Relocation Procedures

The proposed relocation procedure described below largely follows that proposed by NCIG (2007), which has been accepted by OEH.

3.6.1 Relocation Procedure during Pre-works Surveys

In the event a Green and Golden Bell Frog is identified within the disturbance areas during pre-works surveys, the following relocation procedure will be initiated:

a) The ecologist undertaking the pre-clearance survey will capture the frog.

b) If the frog appears to be healthy:

   a. A suitable release location in the immediate vicinity of the disturbance area, yet outside of potential areas of disturbance, will be identified by the ecologist.

   b. The frog will be released into the relocation area. Any frog to be relocated will be held in a cool, dark, moist place until nightfall. Where practicable, relocation will be timed to coincide with periods of recent rainfall to optimise chances of survival of the frog.

c) If the frog appears to be sick, or is dead:

   a. the procedures outlined in Section 3.6.3 will be followed.

Relocation of Green and Golden Bell Frogs during pre-works surveys will be conducted in accordance with the relevant measures outlined in the hygiene protocol (Section 3.4).

Details of Green and Golden Bell Frogs that are relocated (that is, lifecycle stage and sex of individual [if possible], location where found and location of release) conducted during pre-works surveys will be recorded and reported in the AEMR (Section 6).

3.6.2 Relocation Procedure Outside of Pre-works Surveys

In the event a frog is observed within the KIWEF site outside of the designated pre-works surveys (for example, within an area already disturbed), and is thought to be a Green and Golden Bell Frog, the following relocation procedure will be initiated if the frog is likely to be harmed by the capping works:

a) The observer will notify the HDC's Environmental Representative, or suitably-qualified ecologist, of the frog's location.

b) The Environmental Representative, or suitably-qualified ecologist, will determine whether the frog is likely to be harmed by works.

c) If the frog is likely to be harmed by works, a suitably-qualified ecologist, will capture the frog.

d) If the frog appears to be healthy:

   a. A suitable release location (that is, one of the potential relocation areas identified on Figure 1) will be identified by the ecologist.

   b. The frog will be released into the relocation area. Any frog to be relocated will be held in a cool, dark, moist place until nightfall. Where practicable, relocation will be timed to coincide with periods of recent rainfall to optimise chances of survival of the frog.

e) If the frog appears to be sick, or is dead:

   a. the procedures outlined in Section 3.6.3 will be followed.

Relocation of Green and Golden Bell Frogs outside pre-works surveys will be conducted in accordance with the relevant measures outlined in the hygiene protocol (Section 3.4).

Details of Green and Golden Bell Frogs that are relocated (that is, lifecycle stage and sex of individual [if possible], location where found and location of release) during pre-work surveys will be recorded and reported in the AEMR (Section 6).

3.6.3 Procedures for Handling Sick or Dead Green and Golden Bell Frogs

Table 1 presents the range of symptoms that may be exhibited by sick or dying frogs, while Table 2 provides diagnostic behaviour tests, which can be used to determine if a frog is sick (for example, infected with FCF) (after NCIG, 2007).

Table 1: Symptoms of sick and dying frogs

Appearance	Behaviour
■ Darker or blotchy upper (dorsal) surface ■ Swollen hind limbs ■ Very thin or emaciated ■ Reddish/pink-tinged lower (ventral) surface and/or legs and/or webbing or toes ■ Skin lesions (sores, lumps) ■ Infected eyes ■ Obvious asymmetric appearance	■ Lethargic limb movements, especially hind limbs ■ Abnormal behaviour (e.g. a nocturnal burrowing frog sitting in the open during the day and making no vigorous attempt to escape when approached) ■ Little or no movement when touched

Source: after NPWS (2001)

Table 2: Diagnostic behaviour tests – sick frogs will fail one or more of the following tests

Test	Healthy	Sick
■ Gently touch with finger	■ Frog will blink.	■ Frog will not blink.
■ Turn frog on its back	■ Frog will flip back over.	■ Frog will remain on its back.
■ Hold frog gently by its mouth	■ Frog will use its forelimbs to try to remove grip	■ No response from frog

Source: after NPWS (2001)

In the event that a Green and Golden Bell Frog appears to be sick, or is dead, the following procedures will be followed (after NPWS, 2001):

- Disposable gloves will be worn when handling all frogs, as well as sick or dead frogs.
- To prevent cross-contamination, new gloves and a clean plastic bag will be used for each frog specimen.
- Frogs exhibiting one or more of the symptoms for sick frogs listed in Table 1 or 2, and considered unlikely to survive transportation will be euthanised[1].
- Sick frogs likely to survive transportation will be placed into either a moistened cloth bag with some damp leaf litter, or into a partially-inflated, clean plastic bag with damp leaf litter. All frogs will be kept separate during transportation.
- Dead frogs will be kept cool and preserved as soon as possible. The belly of the frog will be cut open and the specimen placed in preservative (approximately 10 times the volume of the specimen). Specimens will be preserved in either 65% ethanol or 10% buffered formalin.
- The recipient of the sick or dead frog will be contacted to confirm the appropriate procedure prior to transport[2].

[1] Terminally ill frogs will be placed into a container with the bottom covered with 3% chloral hydrate (NPWS, 2001).

- Containers will be labelled with the following details: date, location and species (if known).
- Standardised collection form will be filled out and a copy sent with the specimen (in Appendix A).
- Individual containers will be used for each specimen.

Details of sick or dead Green and Golden Bell Frogs found at the KIWEF site will be recorded and reported in the AEMR (Section 6).

[2] A list of potential sick and dead frog recipients is provided in Attachment 4 (NPWS, 2001), including Associate Professor Michael Mahony of the School of Biological Sciences, University of Newcastle.

4.0 GREEN AND GOLDEN BELL FROG MONITORING PROGRAMME

Baseline monitoring of the Green and Golden Bell Frog has been undertaken by GHD (2010 and Umwelt (2011).

NCIG has also implemented a monitoring programme that collects data that includes the Green and Golden Bell Frog populations on the KIWEF site.

The NCIG monitoring will be conducted annually until 2020 and then three-yearly till 2030. On the basis that the NCIG monitoring programme continues to be implemented, HDC do not propose to undertake any further monitoring, other than that specified in the Action Plan for the K26/K32 Ponds (Golder, 2011).

HDC propose to annually review the NCIG data to ensure that it meets HDC's requirements. The overall objective of HDC's review of the Green and Golden Bell Frog monitoring programme is to monitor the dynamics of the Green and Golden Bell Frog populations supported within known and potential habitat areas within the KIWEF site. The intention of the review programme will be to ascertain if the landfill closure works have an effect on the population.

Monitoring parameters that will be used for comparison will include, yet not be limited to:

a) Green and Golden Bell Frog presence/absence, distribution, habitat utilisation, behaviour and abnormalities.

b) observations of other frog species distribution, relative abundance and abnormalities.

c) habitat condition.

d) date

e) time of day

f) rainfall (mm)

g) site location (GPS co-ordinates and map location)

h) survey method utilised

i) sampling effort

j) habitats surveyed

k) weather conditions (including temperature)

l) number of observers

m) photographs taken

HDC will report to OEH annually for 5 years following the completion of the landfill closure works, unless analysis shows that Green and Golden Bell Frog populations are being impacted, then further reporting will be undertaken until a date agreed with OEH.

Monitoring and research to understand better the extent and dynamics of Green and Golden Bell Frog populations is a proposed action of the Draft Recovery Plan (DECC, 2005). This action has been adopted as a strategy to achieve the objectives of the Lower Hunter Management Plan. The results of this monitoring programme would contribute to this action/strategy.

The results of the monitoring programme will be recorded and reported in the AEMR (Section 6).

5.0 RESPONSE CRITERIA AND SPECIFIC MITIGATION AND MANAGEMENT MEASURES

The following proposed mitigation measures have been developed based on a review of information provided by GHD (2010a) and a review of site conditions.

5.1 Management of All Disturbance Areas

The following mitigation measures will be implemented to manage areas proposed for disturbance.

- The boundaries of all Green and Golden Bell Frog habitat will be clearly identified on the ground.
- Appropriate erosion and sediment control structures will be installed at least 30 metres upslope of all such habitat areas. These erosion and sediment control structures will be regularly inspected and maintained, particularly after significant rainfall events.
- All plant entering and leaving the KIWEF site will be, as a matter of routine, disinfected via a wash bay. The location and procedures involved at this wash bay will form part of the site induction and training (see Section 3.3). Records will be kept.
- Similarly, all HDC employees and contractors involved in activities in areas of known habitat for the Green and Golden Bell Frog (and other amphibian species) will be trained in site hygiene management in accordance with the hygiene protocol (Appendix A). This will be part of the environmental induction and training (Section 3.3). Records will be kept.
- All PPE in contact with soil, particularly boots, of HDC employees and contractors entering and leaving the site will be disinfected as a matter of routine, following the methods outlined in the Hygiene Protocol (Appendix A).
- All disinfection processes will be monitored and controlled at the KIWEF site's entry and exit point. The location of these disinfection bays, and the obligations of disinfection, will be communicated during the site induction and training (Section 3.3).
- All water required for dust suppression will be drawn from ponds established for the purpose. No water for dust suppression will be drawn from current ponds on the site. The establishment of dedicated dust suppression ponds will be undertaken to prevent the potential spread of Plague Minnow into ponds currently free of this species. The location and procedure for those dedicated dust suppression ponds will be communicated during the site induction and training (Section 3.3).
- Stormwater diversion measures, if required, will be put in place to maintain the current hydrological regime for the site.
- If practicable, the capping and grading activities will be scheduled to occur outside of the core Green and Golden Bell Frog breeding period (that is, September to March), especially in areas adjacent to known and potential breeding habitat.

5.2 Specific Management Measures for Disturbed Areas

The following mitigation measures will be implemented to manage areas proposed for disturbance. It should be noted that these measures do not negate the need for the measures outlined in Section 5.1.

- The disturbance area will be clearly delineated on the site plan and on the ground. The boundaries of the area and its location will be made known to all personnel involved during the site induction (refer to Section 3.3).
- One week prior to works commencing in the disturbance area, a pre-works survey will be conducted by a qualified ecologist (refer to Section 3.5 for a suggested survey protocol).

- In the event that any Green and Golden Bell Frogs are identified in the area, they will be relocated (using appropriate amphibian hygiene protocols) to known and suitable Green and Golden Bell Frog habitat areas immediately adjacent to the disturbance footprint (refer to Section 3.6 for appropriate relocation procedures).
- The works will be scheduled to occur outside of the core breeding period for Green and Golden Bell Frogs, that is, September to March.
- An on-site, suitably-qualified ecologist will be available during all clearing and capping works undertaken in the habitat areas to be disturbed. This person will be available to relocate Green and Golden Bell Frogs that may be found in the disturbance footprint during capping activities.
- In an attempt to limit the potential for Green and Golden Bell Frogs to enter the disturbance footprint, and if practicable, a frog-proof barrier will be erected around the disturbance footprint.
- Appropriate erosion and sediment control measures will be put in place around the disturbance area, prior to any works commencing, to prevent sediment from moving into adjacent habitat.
- Once works are complete, the restoration and rehabilitation of that habitat will be undertaken in accordance with a rehabilitation and revegetation plan.

5.3 Measures to Enhance Restore and Maintain Habitat

It is noted that the proposed capping works have been designed to minimise impacts on Green and Golden Bell Frog Habitat and will impact upon only two small areas.

It is anticipated that the mitigation measures presented in Sections 5.1 and 5.2 will assist in the management of the Green and Golden Bell Frogs, and their habitat on the KIWEF site, during and immediately following the landfill closure work, and the associated activities. In addition to those, the following mitigation measures have been developed to assist, where practicable, in the enhancement, restoration and maintenance of Green and Golden Bell Frog habitat following the completion of the landfill closure works.

- The capping strategy has been designed to limit and ultimately reduce the exposure of potential Green and Golden Bell Frog habitat, and the wider ecosystems of Kooragang Island, to soil and groundwater contaminants.
- As part of the rehabilitation and revegetation plan for the KIWEF site, open stormwater infrastructure across the KIWEF site may be planted with species known to be favoured by Green and Golden Bell Frogs. This revegetation and rehabilitation strategy will include a 2 metre wide buffer on either side of the stormwater drains. The intention of these areas is to provide movement corridors for Green and Golden Bell Frogs across the site.
- The capped areas will ideally be designed to shed water to table drains, which, in a similar manner to other stormwater infrastructure, will be vegetated with species known to be favourable to Green and Golden Bell Frogs.
- Drainage culverts will, where practicable, be vegetated and lined with rocks and objects that may provide temporary frog refuge, in the event that a frog seeks to traverse the future capped area of KIWEF.
- The drainage culverts in the NCIG rail loop may provide additional areas that can be rehabilitated to facilitate the migration and dispersal of the Green and Golden Bell Frog (Connell Hatch, 2008, in GHD, 2010b).

5.4 Response Criteria

5.4.1 General Site Environmental Management

As part of the overall environmental management plan for the site, during the landfill closure works, the HDC's environmental representative will conduct weekly inspections of all the management measures identified in Sections 5.1, 5.2 and 5.3. The results of these inspections will be recorded and a summary provided in the AEMR.

Should non-conformances be identified, HDC's environmental representative will contact the Site Foreman within 24 hours and request a remediation action. The Site Foreman will have 48 hours to correct the non-conformance.

5.4.2 Population Monitoring

If the results of the monitoring programme indicate a decline in Green and Golden Bell Frog numbers across the site, which cannot be attributed to natural population fluctuations and variability, and is potentially a direct result of the landfill closure works, specific response criteria will be developed by HDC, in consultation with the OEH. The aim of these response criteria will be to determine whether declining populations (if evident from the monitoring programme [Section 4]) are directly attributable to the capping project.

6.0 REPORTING AND REVIEW

In accordance with the *Approval of Surrender of Licence Number 6437*, the Director-General will be notified of any incident with actual or potential significant off-site impacts on people or the biophysical environment, as soon as practicable after the occurrence of the incident. The Director-General will be provided with written details of the incident within seven days of the date on which the incident occurred.

HDC will prepare an Annual Environmental Management Report (AEMR) that:

a) Reviews the performance of the capping project against this management plan.

b) Provides an overview of environmental management actions and summarises monitoring results over the 12 month reporting period.

c) Continues on an annual basis for a minimum of five years following completion of the Landfill Closure Works.

d) Will be phased out on presentation of adequate information to establish that the Landfill Closure Works have had no measurable impacts to Green and Golden Bell Frog populations on the KIWEF site. In the unlikely event that changes in the Green and Golden Bell Frog population are observed, which appear to be attributable to the Landfill Closure Works, extended review will be undertaken. This may involve a more detailed monitoring and investigation programme to address the potential cause of the decline in those areas. The programme will aim to identify direct evidence indicating that the Landfill Closure Works contributed to the decline. The details of that programme will be developed through discussion with OEH.

The AEMR will be distributed to relevant government agencies and stakeholders, and copies provided to other interested parties, if requested.

In accordance with the *Approval of Surrender of Licence Number 6437*, this management plan will be made available on the HDC website.

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Report Signature Page

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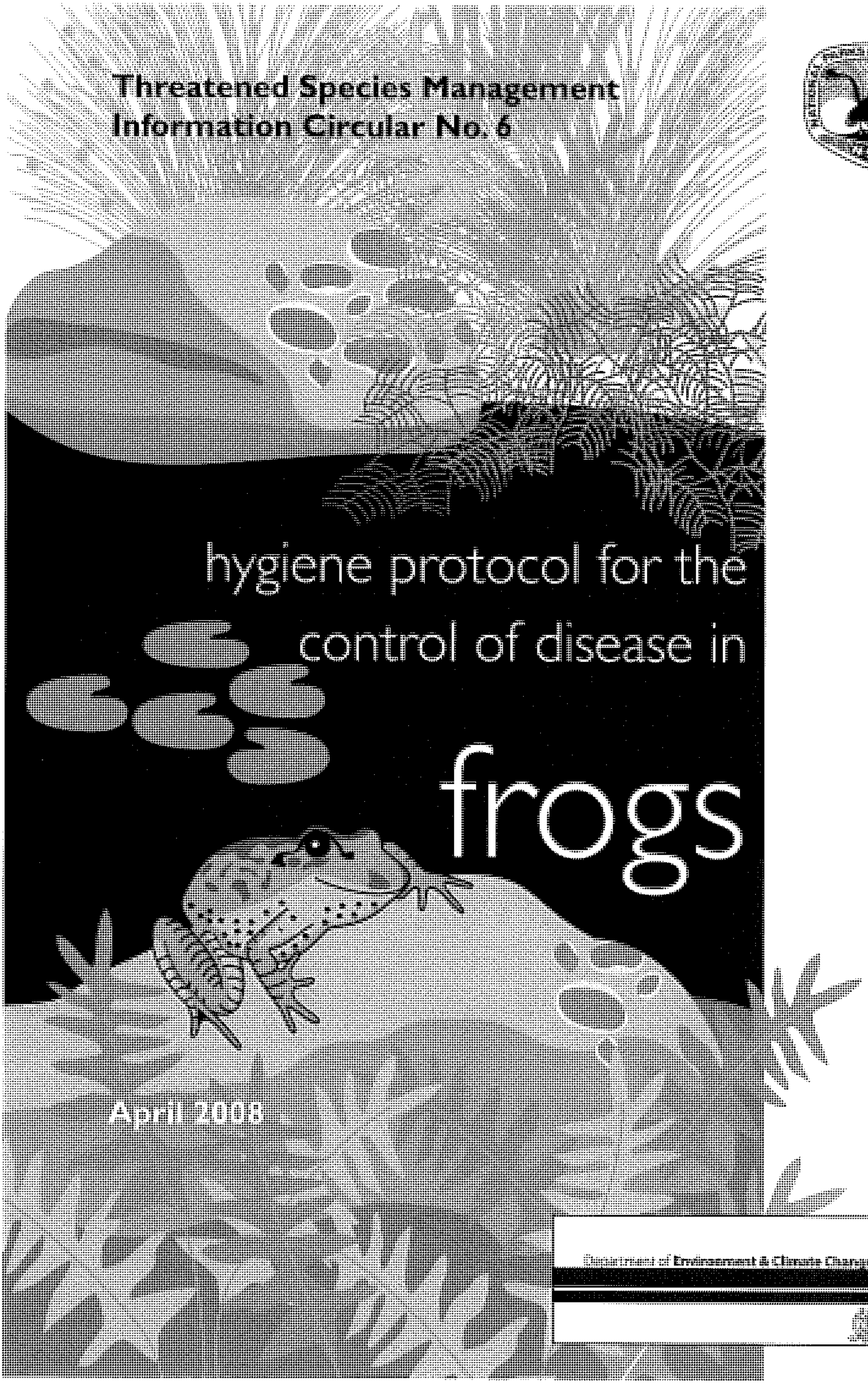
APPENDIX A

Hygiene Protocol for the Control of Disease in Frogs

Threatened Species Management
Information Circular No. 6



hygiene protocol for the control of disease in frogs

April 2008

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This hygiene protocol is an adaptation of the Declining Amphibian Population Task Force (DAPTF) Fieldwork Code of Practice and the recommendations of Speare et al. (1999) and has drawn on recommendations from earlier guidelines prepared by Environment ACT.

Foundation for National Parks and Wildlife funded the printing of this protocol.

hygiene protocol for the control of disease in frogs

1 introduction

This information circular outlines measures to:

- Prevent or reduce disease causing pathogens being transferred within and between wild populations of frogs.
- Ensure captive frogs are not infected prior to release.
- Deal safely with unintentionally transported frogs.
- Assist with the proper identification and management of sick and dead frogs in the wild.

1.1 Who should read this document?

This protocol is intended for use by all researchers, wildlife consultants, fauna surveyors and students undertaking frog field-work. In addirion, the protocol should be read by Department of Environment and Climate Change (DECC) personnel, frog keepers, wildlife rescue and carer organisations, herpetological/frog interest groups/ societies, fauna park/zoo operators/workers and other individuals who regularly deal with or are likely to encounter frogs.

This protocol outlines the expectations of the DECC regarding precautionary procedures to be employed when working with frog populations. The intention is to promote implementation of hygiene procedures by all individuals working with frogs. New licences and licence renewals will be conditional upon incorporation of the protocol. The DECC recognises that some variation from the protocol may be appropriate for particular research and frog handling activities. Such variation proposals should accompany any licence application or renewal to the DECC.

1.2 Background

1.2.1 Amphibian Chytrid Fungus

The apparent decline of frogs, including extinctions of species and local populations, has attracted increased international and national concern. Many potential causes for frog declines have been proposed (eg see Pechmann et al., 1991; Ferrero and Bergin, 1993; Pechmann and Wilbur, 1994; Pounds and Crump, 1994; Pounds et al., 1997). However, the patterns of decline at many locations suggest that epidemic disease maybe the cause (Richards et al., 1993; Laurance et al., 1996; Alford and Richards, 1997). Recent research has implicated a water-borne fungal pathogen *Batrachochytrium dendrobatidis* as the likely specific causative agent in many of these declines both in Australia and elsewhere (Berger et al., 1998; 1999). This agent is commonly known as the amphibian or frog chytrid fungus and is responsible for the disease Chytridiomycosis (Berger et al., 1999).

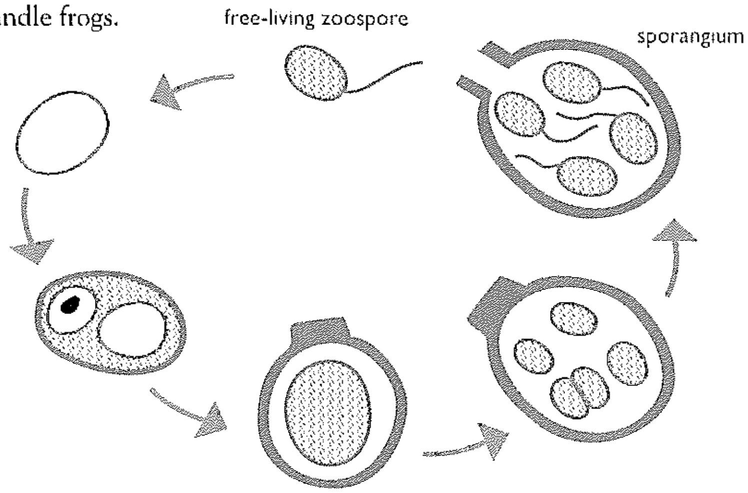
B. dendrobatidis is a form of fungus belonging to the phylum Chytridiomycota. Most species within this phylum occur as free-living saprophytic fungi in water and soil and have been found in almost every type of environment including deserts, artic tundra and rainforest and are considered important primary biodegraders (Powell 1993). *B. dendrobatidis* is a unique parasitic form of Chytridiomycete fungi, in that it invades the skin of amphibians, including tadpoles, often causing sporadic deaths with up to 100% mortality in some populations. Chytridiomycosis has been detected in over 40 species of native amphibian in Australia (Mahony and Workman 2000). However, it is not currently known whether the fungus is endemic or exotic to Australia.

The infective stage of B. *dendrobatidis* is the zoospore and transmission requires water (Berger et al.,1999). Zoospores released from an infected amphibian can potentially infect other amphibians in the same water. More research is needed on the dynamics of infection in the wild. B. *dendrobatidis* is known to be susceptible to seasonal temperature changes, dehydration, salinity, water pH, light, nutrition and dissolved oxygen (Berger et al., 1999).

1.3 Objectives

The objectives of the hygiene protocol are to:

- Recommend best-practice procedures for DECC personnel, researchers, consultants and other frog enthusiasts or individuals who handle frogs.
- Suggest workable strategies for those regularly working in the field with frogs or conducting fieldwork activities in wetlands and other aquatic environments where there is the potential for spreading pathogens such as the frog chytrid fungus.
- Provide background information and guidance to people who provide advice or supervise frog related activities.
- Provide standard licence conditions for workers engaged in frog related activities.
- Inform Animal Care and Ethics Committees (ACEC) for their consideration when granting research approvals.



Life cycle of frog chytrid fungus from infective free-living zoospore stage to sporangium (adapted from L. Berger).

2 site hygiene management

A checklist of risk management procedures and recommended standard hygiene kit is provided in Appendix 1. Please note Footnote 1 on page 4.

Individuals studying frogs often travel and collect samples of frogs from multiple sites. Some frog populations can be particularly sensitive to the introduction of infectious pathogens such as the frog chytrid fungus. Also, the arrangement of populations in the landscape may make frogs particularly vulnerable to transmission of infectious pathogens. Therefore, it is important that frog workers recognise the boundaries between sites and undertake measures which reduce the likelihood of spreading infection.

Where critically endangered species or populations of particular risk are known to occur, this protocol should be applied over very short distances ie a single site may need to be subdivided and treated as separate sites.

When planning to survey multiple sites, always start at a site where frog chytrid fungus is not known to be present before entering other infected areas.

2.1 Defining a site

Defining the boundary of a site maybe problematic. In some places, the boundary between sites will be obvious but in others, less so. Undertaking work at a number of sites or conducting routine monitoring at a series of sites within walking distance creates obvious difficulties with boundary definitions. It is likely that defining the boundary between sites will differ among localities. It may be that a natural or constructed feature forms a logical indicator of a site boundary eg a road/track, a large body of water such as a river or the sea, a marked habitat change or a catchment boundary.

As a guiding principle, each individual waterbody should be considered a separate site.

When working along a river or stream or around a wetland or a series of interconnecting ponds it is reasonable, in most instances, to treat such examples as a single site for the purposes of this protocol. Such a case would occur in areas where frogs are known to have free interchange between ponds.

Where a stream consists of a series of distinctive tributaries or sub-catchments or where there is an obvious break or division then they should be treated as separate sites, particularly if there is no known interchange of frogs between sites.

2.2 On-site hygiene

When travelling from site to site it is recommended that the following hygiene precautions be undertaken to minimise the transfer of disease from footwear, equipment and/or vehicles.

Footwear

Footwear must be thoroughly cleaned and disinfected at the commencement of fieldwork and between each sampling site.

This can be achieved by initially scraping boots clear of mud and standing the soles in a disinfecting solution. The remainder of the boot should be rinsed or sprayed with a disinfecting solution that contains *benzalkonium chloride* as the active ingredient. Disinfecting solutions should be prevented from entering any water bodies.

Rubber boots such as 'gum boots' or 'Wellingtons' are recommended because of the ease with which they can be cleaned and disinfected.

Several changes of footwear bagged between sites might be a practical alternative to cleaning.

Equipment

Equipment such as nets, balances, callipers, bags, scalpels, headlamps, torches, wetsuits and waders etc that are used at one site must be cleaned and disinfected before re-use at another site.

Disposable items should be used where possible. Non-disposable equipment should be used only once during a particular field exercise and disinfected later or disinfected at the site between uses using procedures outlined in 2.4 below.

Vehicles

Where necessary, vehicle tyres should be sprayed/flushed with a disinfecting solution in high-risk areas.

Transmission of disease from vehicles is unlikely to be a problem. However, if a vehicle is used to traverse a known frog site, which could result in mud and water being transferred to other bodies of water or frog sites, then wheels and tyres should undergo cleaning and disinfection. This should be carried out at a safe distance from water bodies, so that the disinfecting solution can infiltrate soil rather than run-off into a nearby water body.

Spraying with 'toilet duck' (active ingredient *benzalkonium chloride*) is recommended to disinfect car wheels and tyres.

Cleaning of footwear before getting back into the car will prevent the transfer of pathogens from/to vehicle floor and control pedals.

2.3 Handling of frogs in the field

The spread of pathogenic organisms, such as the frog chytrid fungus, may occur as a result of handling frogs.

Frogs should only be handled when necessary.

Where handling of frogs is necessary the risk of pathogen transfer should be minimised as follows:

- Hands should be either cleaned and disinfected between samples or a new pair of disposable gloves used for each sample[1]. This may be achieved by commencing with a work area that has a dish containing a disinfecting solution and paper towels.
- A 'one bag – one frog' approach to frog handling should be used especially where several people are working together with one person processing frogs and others doing the collecting. Bags should not be reused.
- A 'one bag – one sample' approach to tadpole sampling should be used. Bags should not be reused.

Researchers who use toe clipping or Passive Integrated Transponder (PIT) tagging are likely to increase the risk of transmitting disease between frogs due to the possibility of directly introducing pathogens into the frogs' system. This can be minimised by using:

- Disposable sterile instruments
- Instruments disinfected previously and used once
- Instruments disinfected in between each frog

Disinfecting solutions containing *benzalkonium chloride* are readily available from local supermarkets. Some brands include Toilet Duck, Sanpic, New Clenz and Pine Clean.

[1] As a principle, this protocol assumes that not all frogs in an infected pond will be contaminated by the frog chytrid fungus. The infective load of a body of water may not be high enough to cause cross contamination of individual frogs in the same pond. Therefore care should be taken to use separate gloves and bags and clean hands for each sample, to avoid transmission of high infective loads between individuals.

Open wounds from toe clipping and PIT tagging should be sealed with a cyanoacrylate compound such as *Vetbond©* to reduce the likelihood of entry of pathogens. The DECC ACEC further recommends the application of topical anaesthetic *Xylocaine©* cream and *Betadine©* disinfectant (1% solution) before and after any surgical procedure. This should then be followed by the wound sealant.

All used disinfecting solutions, gloves and other disposable items should be stored in a sharps or other waste container and disposed or sterilised appropriately at the completion of fieldwork. Disinfecting solutions must not come into contact with frogs or be permitted to contaminate any water bodies

2.4 Disinfection Methods

Disinfecting agents for hands and equipment must be effective against bacteria and both the vegetative and spore stages of fungi. The following agents are recommended:

- Chloramine and Chlorhexidine based products such as *Halamid©*, *Halasept©* or *Hexifoam©* are effective against both bacteria and fungi. These products are suitable for use on hands, footwear, instruments and other equipment. The manufacturers instructions should be followed when preparing these solutions.
- Bleach and alcohol (ethanol or methanol), diluted to appropriate concentrations can be effective against bacteria and fungi. However, these substances may be less practical because of their corrosive and hazardous nature.

  When using methanol either:

  - immerse in 70% methanol for 30 minutes or
  - dip in 100% methanol then flame for 10 seconds or boil in water for 10 minutes

Fresh bleach (5% concentration) may be also effective against other frog pathogens such as Rana Virus.

Some equipment not easily disinfected in these ways can be effectively cleaned using medical standard 70% isopropyl alcohol wipes – *Isowipes©*.

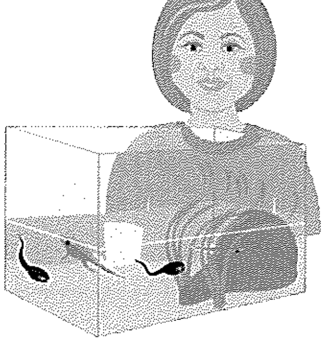
3 captive frog hygiene management

3.1 Housing frogs and tadpoles

Frogs and tadpoles should only be removed from a site when absolutely necessary.

When it is necessary for frogs or tadpoles to be collected and held for a period of time, the following measures should be undertaken:

- Animals obtained at different sites should be kept isolated from each other and from other captive animals.
- Aquaria set up to hold frogs should not share water, equipment or any filtration system. Splashes of water from adjacent enclosures or drops of water on nets may transfer pathogens between enclosures.
- Prior to housing frogs or tadpoles, ensure that tanks, aquaria and any associated equipment are disinfected.
- Tanks and equipment should be cleaned, disinfected and dried immediately after frogs/tadpoles are removed.



Careful maintenance of your enclosures will ensure a safe and hygienic environment for captive frogs and tadpoles.

When contemplating a release of captive bred tadpoles for conservation purposes a Translocation Proposal should be submitted to the DECC and pathological screening for disease should be undertaken (see also DECC Translocation Policy). Tadpoles can be tested by randomly removing 10 individuals at 6 weeks and again at 2 weeks before anticipated release. Testing could be undertaken by the pathology section at Taronga Zoo, Newcastle University, CSIRO Australian Animal Health Laboratories at Geelong and James Cook University at Townsville. Such an arrangement would need to be negotiated by contacting one of these institutions well before the anticipated release date. (see Appendix 2 for contact details)

DECC have licenced NSW Schools to allow students and/or teachers to remove tadpoles for classroom life cycle studies. They are authorised to remove individuals from only one location, each school also requires endorsement from Department of Education and Training Animal Care and Ethics Committee and comply with this protocol.

Tadpoles collected for these purposes are to be obtained from the local area of the school and are not to be obtained from DECC Reserves. As soon as tadpoles have transformed, froglets must be returned to the exact point of capture. Tadpoles from different locations are not to be mixed.

Antifungal cleansing treatments to clear tadpoles of the frog chytrid fungus are currently being trialed. In the future, such a treatment may be an added procedure required prior to froglet releases.

Detailed information on safely maintaining frogs in captivity is provided in Voigt (2001).

3.2 Tadpole treatment

In most instances:

Release to the wild of tadpoles held or bred in captivity should be avoided.

3.3 Frog treatment

The rigour with which frogs must be treated to ensure pathogens are not introduced to native populations means that any proposal for the removal of adult frogs (particularly threatened species) from wild populations should be given careful consideration.

When it is essential for frogs to be removed from the wild, the following should apply.

Individuals to be released should be quarantined for a period of 2 months and monitored for any signs of illness or disease.

Frogs must not be released if any evidence of illness or infection is detected. If illness is suspected, further advice must be sought from a designated frog recipient (Appendix 2) as soon as possible to determine the nature of the problem. Chytridiomycosis can be diagnosed in live frogs by microscopical examination of preserved toe clips or from shedding skin samples. Research is still in progress on the development of a simple technique for the detection of Chytridiomycosis and a treatment for infected frogs.

Current methods which may be used include:

- A technique for the treatment of potentially infected frogs is to place the frogs individually in a 1mg/L benzalkonium chloride solution for 1 hour on days 1, 3, 5, 9, 11 and 13 of the treatment period. Frogs are then isolated/quarantined for two months. This and other possible treatments are documented in Berger and Speare (1998)
- *Betadine©* and *Bactone©* treatments have also been used on adult frogs with some success (M. Mahony, Newcastle University pers. comm.)
- *Itraconazole©* is an expensive drug which has been used successfully (Lee Berger CSIRO Australian Animal Health Laboratory pers. comm.). Information on this method is available on the Website http://www.jcu.edu.au/school/PHTM/frogs/adms/attach6.pdf.

Frogs undergoing treatment should be housed individually and kept separate from non-infected individuals.

3.4 Displaced frogs

Displaced frogs are those native frog species and introduced Cane Toads (Bufo marinus) which have been unintenrionally transported around the country with fresh produce, transported produce and landscaping supplies. Procedures to be undertaken when encountering introduced/displaced native frog species (as well as Cane Toads) are as follows.

3.4.1 Banana box frogs

'Banana Box' frog is the term used to describe several native frog species (usually Litoria gracilenta, L. infrafrenata, L. bicolor and L. caerulea) commonly transported in fruit and vegetable shipments and landscaping supplies. In the past, well meaning individuals have attempted to return these frogs to their place of origin but this is usually impossible to do accurately. There is risk of spread of disease if these frogs are transferred from place to place.

It is strongly recommended that:

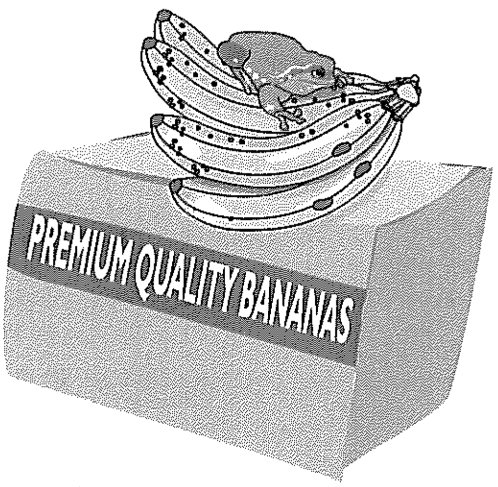
Displaced Banana Box frogs should be treated as if they are infected and should not to be freighted anywhere for release to the wild unless specifically approved by DECC.

When encountering a displaced frog:

- Contact a licensed wildlife carer organisation to collect the animal. The frog should then undergo a quarantine period of 2 months along with an approved disinfection treatment.
- Post-quarantine, the frog (if one of the species identified above) may be transferred to a licensed frog keeper. All other species require the permission from DECC Wildlife Licensing and Management Unit (WLMU) prior to transfer. Licensed carer groups are to record and receipt frogs obtained and disposed of in this way.
- Licensed Frog Keepers are to list these frogs in their annual licence returns to DECC.

Frogs held by licensed frog keepers are not to be released to the wild except with specific DECC approval.

Displaced frogs may be made available to recognised institutions for research projects, display purposes or perhaps offered to the Australian Museum as scientific specimens once approval has been provided by the DECC WLMU.



Frogs are often unintentionally transported with fresh produce and landscaping supplies. They are collectively known as 'banana box' or displaced frogs.

3.4.2 Cane toads

Cane toads are known carriers of the Frog chytrid fungus and should not be knowingly transported or released to the wild.

If a cane toad is discovered outside of its normal range, it should be humanely euthanased in accordance with the recommended NSW Animal Welfare Advisory Council procedure (see Appendix 3). Care should be taken to avoid euthanasia of native species due to mistaken identity.

3.4.3 Local frog species

Frogs encountered on roads, around dwellings and gardens or in swimming pools should not be considered as displaced frogs.

Frogs encountered in these situations should be assisted off roads, away from dwellings, or out of swimming pools preferably to the nearest area of vegetation or suitable habitat.

Incidences of frogs spawning or tadpoles appearing in swimming pools should be referred to a wildlife carer/rescue organisation for assistance (see Appendix 4).

Contact the Frogwatch Helpline if you are unsure whether a frog is a local species or displaced.

An NPWS information brochure titled 'Cane Toads in NSW' provides further information on cane toads and assistance with identification of some of the commonly misidentified native species. This information is also available on the DECC website.

4 sick or dead frogs

Unless an obvious cause of illness or death is evident (eg predation or road mortality): Sick or dead frogs encountered in the wild should be collected and disposed of in accordance with the procedures described in section 4.2 below.

4.1 Symptoms of sick and dying frogs

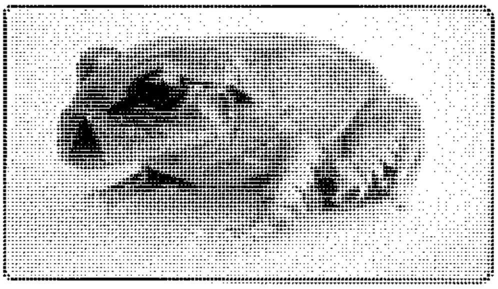
Sick and dying frogs exhibit a range of symptoms characteristic of chytrid infection. Symptoms may be expressed in the external appearance or behaviour of the animal. A summary of these symptoms are described below. More detailed information can be found in Berger et al., (1999) or at the James Cook University Amphibian Disease website at: http://www/jcu.edu.au/school/phtm/PHTM/frogs/ampdis.htm.

Appearance (one or more symptoms)

- darker or blotchy upper (dorsal) surface
- reddish/pink-tinged lower (ventral) surface and/or legs and/or webbing or toes
- swollen hind limbs
- very thin or emaciated
- skin lesions (sores, lumps)
- infected eyes
- obvious asymmetric appearance

Behaviour (one or more symptoms)

- lethargic limb movements, especially hind limbs
- abnormal behaviour (eg a nocturnal, burrowing or arboreal frog sitting in the open during the day and making no vigorous attempt to escape when approached)
- little or no movement when touched



Great barred frog (*Mixophyes fasciolatus*) with severe Chytrid infection — note lethargic attitude and sloughing skin. Photo: L. Berger

Diagnostic behaviour tests

Sick frogs will fail one or more of the following tests:

test	healthy	sick
Gently touch with finger	Frog will blink	Frog will not blink above the eye
Turn frog on its back	Frog will flip back over	Frog will remain on its back
Hold frog gently by its mouth	Frog will use its forelimbs to try to remove grip	No response from frog

4.2 What to do with sick or dead frogs

A procedure for the preparation and transport of a sick or dead frog is given below[2]. Adherence to this procedure will ensure the animal is maintained in a suitable condition for pathological examination and assist the DECC and researchers to determine the extent of the disease and the number of species affected.

- Disposable gloves should be worn when handling sick or dead frogs. Avoid handling food and touching your mouth or eyes as this could transfer pathogens and toxic skin secretions from some frog species.
- New gloves and a clean plastic bag should be used for each frog specimen to prevent cross-contamination. When gloves are unavailable, use an implement to transfer the frog to a container rather than using bare hands.
- If the frog is dead, keep the specimen cool and preserve as soon as possible (as frogs decompose quickly after death making examination difficult). Specimens can be fixed/preserved in 70% ethanol or 10% buffered formalin.

Cut open the belly and place the frog in about 10 times its own volume of preservative. Alternatively, specimens can be frozen (although this makes tissues unsuitable for some tests). If numerous frogs are collected, some should be preserved and some should be frozen. Portions of a dead frog can be sent for analysis eg a preserved foot, leg or a portion of abdominal skin.

- The container should be labelled showing at least the species, date and location. A standardised collection form is provided in Appendix 5.
- If the frog is alive but unlikely to survive transportation (death appears imminent), euthanase the frog (see Appendix 3) and place the specimen in a freezer. Once frozen, the specimen is ready for shipment to the address provided below.
- If the frog is alive and likely to survive transportation, place the frog into either a moistened cloth bag with some damp leaf litter or into a plastic bag with damp leaf litter and partially inflated before sealing. Remember to keep all frogs separated during transportation.
- Preserved samples can be sent in jars or wrapped in wet cloth, sealed in bags and placed inside a padded box.
- Send frozen samples in an esky with dry ice (available from BOC/CIG Gas outlets).
- Place live or frozen specimens into a small styrafoam esky (available from K-Mart/Big W for approximately $2.50).
- Seal esky with packaging tape and address to one of the laboratories listed in Appendix 4.
- Send the package by courier.

Further information on sick and dying frogs is available on the Amphibian Disease Home Page at http://www.jcu.edu.au/dept/PHTM/frogs/ampidis.htm — in particular refer to *'What to do with dead or ill frogs'*.

[2] The measures described below are standard procedures and may vary slightly depending on the distance and time required to reach the intended recipient. Contact the intended recipient of the sick or dead frog prior to sending to confirm the appropriate procedure.

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appendix I

hygiene protocol checklist and field kit

The following checklist and field kit are designed to assist with minimising the risk of transferring pathogens between frogs.

Have you considered the following questions before handling frogs in the field:

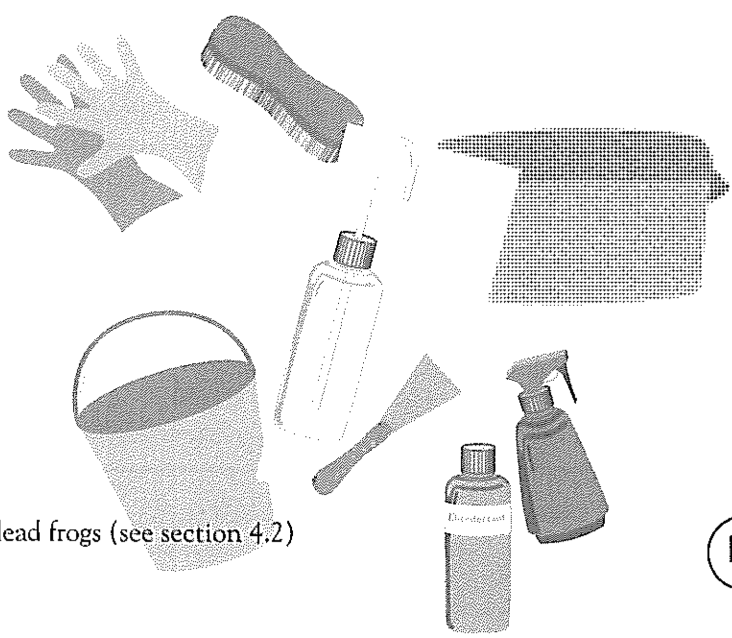
- Has your proposed field trip been sufficiently well planned to consider hygiene issues?
- Have you taken into account boundaries between sites (particularly where endangered species or populations at risk are known to occur)?
- Have footwear disinfection procedures been considered and a strategy adopted?
- Have you planned the equipment you will be using and developed a disinfection strategy?
- Are you are planning to visit sites where vehicle disinfection will be needed (consider both vehicle wheels/tyres and control pedals) and if so, do you have a plan to deal with vehicle disinfection?
- Have handling procedures been planned to minimise the risk of frog to frog pathogen transmission?
- Do you have a planned disinfection procedure to deal with equipment, apparel and direct contact with frogs?

If you answered NO to any of these questions please re-read the relevant section of the DECC Hygiene Protocol for the Control of Disease in Frogs and apply a suitable strategy.

Field hygiene kit

When planning to survey frogs in the field a portable field hygiene kit should be assembled to assist with implementing this protocol. Recommended contents of a field hygiene kit would include:

- Small styrofoam eski
- Disposable gloves
- Disinfectant spray bottle (atomiser spray) and/or wash bottle
- Disinfecting solutions
- Wash bottle
- Scraper or scrubbing brush
- Small bucket
- Plastic bags large and small
- Container for waste disposal
- Materials for dealing with sick and dead frogs (see section 4.2)



appendix 2

Always contact the relevant specialist prior to sending a sick or dead frog. In some cases, only wild frogs will be assessed for disease. Analysis may also attract a small fee per sample.

designated sick and dead frog recipients

Contact one of the following specialists to arrange receipt and analyse sick and dead frogs. Make contact prior to dispatching package:

Karrie Rose
Australian Registry if Wildlife Health
Taronga Conservation Society, Australia
PO Box 20
MOSMAN NSW 2088

Phone: 02 9978 4749
Fax: 02 9978 4516
Krose@zoo.nsw.gov.au

Diana Mendez or
Rick Speare
School of Public Health,
Tropical Medicine and
Rehabilitation Sciences
James Cook University
Douglas Campus
TOWNSVILLE QLD 4811

Phone: 07 4796 1735
Fax: 07 4796 1767
Diana.Mendez@jcu.edu.au
Richard.Speare@jcu.edu.au

Michael Mahony
School of Biological Sciences
University of Newcastle
CALLAGHAN NSW 2308

Phone: 02 4921 6014
Fax: 02 4921 6923
bimjm@cc.newcastle.edu.au

For information on frog keeping licences and approvals to move some species of displaced frog contact:

Co-ordinator, Wildlife Licensing
Wildlife Licensing and Management Unit
DECC
PO Box 1967
Hurstville NSW 1481
Ph 02 9585 6481
Fax 02 9585 6401
wildlife.licensing@environment.nsw.gov.au

For information on the possible identity of displaced frogs contact:

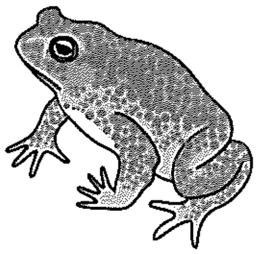
Frog and Tadpole Society (FATS)
Frogwatch Helpline

Ph: 0419 249 728

appendix 3

NSW Animal Welfare Advisory Council methodology

The NSW Animal Welfare Advisory Council procedure for humanely euthanasing cane toads or terminally ill frogs is stated as follows:



- Using gloves, or some other implement, place cane toad or terminally ill frog into a plastic bag.
- Cool in the refrigerator to 4°C.
- Crush cranium with a swift blow using a blunt instrument.

Note: Before killing any frog presumed to be a cane toad, ensure that it has been correctly identified and if outside the normal range for cane toads in NSW (north coast) that local DECC regional office is informed.

appendix 4

licensed wildlife carer and rescue organisations

Following is a list of wildlife rehabilitation groups licensed by Department of Environment and Climate Change (NSW):

Northern NSW

Australian Seabird Rescue
For Australian Wildlife Needing Aid (FAWNA)
Friends of the Koala
Friends of Waterways (Gunnedah)
Great Lakes Wildlife Rescue
Koala Preservation Society of NSW
Northern Rivers Wildlife Carers
Northern Tablelands Wildlife Carers
Tweed Valley Wildlife Carers
Seaworld Australia
WIRES branches in Northern NSW

Southern NSW

Looking After Our Kosciuszko Orphans (LAOKO)
Native Animal Network Association
Native Animal Rescue Group
Wildcare Queanbeyan
WIRES branches in Southern NSW

Sydney, Hunter and Illawarra

Hunter Koala Preservation Society
Ku-ring-gai Bat Colony Committee
Kangaroo Protection Co-operative
Native Animal Trust Fund
Organisation for the Rescue and Research of Cetaceans (ORRCA)
Sydney Metropolitan Wildlife Services
Wildlife Aid
Wildlife Animal Rescue and Care (Wildlife ARC)
Waterfall Springs Wildlife Park
Oceanworld
Wildlife Care Centre, John Moroney Correctional Centre
Koalas in Care
WIRES branches around Sydney, Hunter and Illawarra

Western NSW

Rescue and Rehabilitation of Australian Native Animals (RRANA)
RSPCA Australian Capital Territory Inc.
Wildlife Carers Network (Central West)
WIRES branches in Western NSW
Cudgegong Wildlife Carers

[4] Note: some of these organisations may not care for frogs.

appendix 5 — sick or dead frog collection form

Sender details:

name: address: postcode:

phone: (w) (h) fax: email:

Collector details: (where different to sender)

name: address: postcode:

phone: (w) (h) fax: email:

Specimen details:

record no: no. of specimens: species name: date collected: day/month/year

time collected: sex: male/female status at time of collection: healthy(H)/ sick(S)/ dead(D) date sent: day/month/year

location: map grid reference: (easting) (northing)

reason for collection:

Batch details for multiple species collection:

species	no.	locality	(AMG)	date	sex	status (H/S/D)

habitat type: eg creek, swamp, forest vegetation type: eg rainforest, sedgeland micro habitat: eg creek bank, under log, amongst emergent vegetation, on ground in the open

unusual behaviour of sick frogs: eg lethargic, convulsions, sitting in the open during the day, showing little or no movement when touched.

dead frogs appearance: eg thin, reddening of skin on belly and/or toes, red spots, sore, lumps or discolouration on skin

deformed frogs: eg limb(s) missing, abnormal shape or length dead/sick tadpoles: eg numbers/behaviour

unusual appearance of egg masses: eg grey or white eggs recent use of agricultural chemicals in area: eg pesticides, herbicides, fertilisers

other potential causes of sickness/mortality/comments/additional information:

NSW
NATIONAL
PARKS AND
WILDLIFE
SERVICE

General inquiries: PO Box A290 South Sydney 1232
Phone: 9995 5000 or 1300 361967
Fax: 02 9995 5999 **Web site:** www.environment.nsw.gov.au

Department of **Environment & Climate Change** NSW

APPENDIX B

Limitations

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Golder Associates

Annex E

NSW EPA Area 1 Works Completion Confirmation Letter

NSW EPA

Our reference: DOC15/384610-10; EF 13/5651
Contact: Rebecca Scrivener, 4908 630
Electronic correspondence to: hunter.region@epa.nsw.gov.au

HUNTER DEVELOPMENT CORPORATION
19 FEB 2016

16 FEB 2016

Mr Mike Bardsley
Environmental Manager
Hunter Development Corporation
PO Box 813
NEWCASTLE NSW 2300

Email: mike.bardsely@hdc.nsw.gov.au

Dear Mr Bardsley

KOORAGANG ISLAND WASTE EMPLACEMENT FACILITY
FINAL CAPPING AND CAP VALIDATION OF AREA 1

I refer to your letter dated 25 September 2015 providing validation and cap inspection reports for Area 1 of Kooragang Island Waste Emplacement Facility as required by Surrender Notice 111184 and subsequent variations. I note Area 1 consists of land areas referred to as 'K2', which is located on the western side of Kooragang Island, and 'K10N', which is situated within the coal rail loop operated by Newcastle Coal Infrastructure Group on Kooragang Island.

The Environment Protection Authority (EPA) acknowledges the validation reports were prepared by a suitably qualified person, being ERM Pty Ltd, and were reviewed by an EPA-accredited contaminated site auditor, Ramboll Environ Australia Pty Ltd. Ramboll Environ Australia Pty Ltd confirmed that the capped areas were capped in accordance with the capping strategy and surrender notice requirements.

The EPA accepts the validation reports which confirm that the cap performance criterion ($K=1x10^{-7}m/s$) has been achieved. The EPA notes remedial works were carried out following the first six-monthly cap inspection in August 2015 to address some erosion and scouring within drainage lines as well as reseeding areas in both K2 and K10N.

With regards to your reference to 'completion' and future cap inspections for Area 1, this letter may be used as confirmation that installation of the cap over Area 1 has been completed.

The EPA does not intend to vary Surrender Notice 111184 to remove ongoing monitoring requirements for Area 1. Rather, ongoing cap inspections of Area 1 remain the responsibility of Hunter Development Corporation (HDC) until all capping requirements of Surrender Notice 111184 have been met.

Surrender Notice 111184, and subsequent variations, required the following actions in relation to Area 1:

- Capping and closure works to be completed by 31 December 2014 (condition 4(b));
- Provision of a written validation report within three months of completion of the installation of the final cap (condition 4(h)) (ie end of March 2015); and

- Provision of a written statement of results of inspections of cap condition with the first statement due to the EPA on 30 June 2015.

The EPA notes the following:

- HDC advised of delays in capping completion dates during November/December 2014;
- Capping and closure works of Area 1 were completed at the end of March 2015;
- Validation report and cap inspection statements were submitted on 29 September 2015.

The EPA strongly encourages HDC to ensure the final cap completion date of 30 June 2017 is achieved and reporting dates, including ongoing cap inspection statements for Area 1, are met.

If you wish to discuss any of the above further, please contact Rebecca Scrivener on 4908 6830.

Yours sincerely

MITCHELL BENNETT
Head, Regional Operations Unit - Hunter
Environment Protection Authority

Annex F

Draft Kooragang Island GGBF Survey 2015-2016

DRAFT

Kooragang Island Green and Gold Bell Frog Survey

2015-2016

Conducted by the Amphibian Research Group,

University of Newcastle, on behalf of

Port Waratah Coal Services, Newcastle Coal Infrastructure Group, and Hunter Development Corporation

Report prepared by Colin McHenry and Michael Mahony

May 2016

Contents

1. Introduction

1.1 Background to the study

Annual monitoring of the Green and Golden Bell Frog (*Litoria aurea*)(GGBF) population on Kooragang and Ash Islands (KI & AI) has been undertaken for five years. This program aims to investigate three specific questions relating to GGBF population ecology on the island, including:

1. What is the estimated population size of the green and golden frog on Kooragang Island?
2. What is the demographic composition of the green and golden bell frog population on Kooragang Island?
3. How do green and golden bell frogs utilise the landscape on Kooragang Island?

Over the period of the monitoring, surveys have employed two main field techniques in a consistent manner such that a longer-term picture can be obtained of the population ecology. Capture-mark-recapture and visual encounter surveys (VES) have been employed to collect data to address these objectives (Clulow et al, 2012; Clulow et al, 2013; Clulow et al, 2014; Campbell et al, 2015). Over the period that monitoring has been undertaken the scope of the program has been expanded to address questions surrounding GGBF persistence in some habitats but not others and to inform best habitat creation practice.

1.2 Background to the problem

The green and golden bell frog decline

The green and golden bell frog was once common and widespread throughout the east coast of Australia from northern New South Wales to southern Victoria and its adjacent tablelands (Pyke and White 2001). Since the 1960s a decline was observed and the green and golden bell frog is now known to have undergone a dramatic reduction in its distribution and abundance (Mahony et al, 2013; White and Pyke 1996; Pyke and White 2001). Today, the green and golden bell frog persists in less than 10% of its historical distribution, and occupies about 40 known sites today (Mahony et al, 2013; White and Pyke 1996). Populations that were once reported on the Central Tablelands appear to be extinct, having not been observed since the early 1970s (White and Pyke 1996; White and Pyke 1999), and until a recent rediscovery of a small population in Queanbeyan (Patmore 2001; Wassens and Mullins 2001), they were believed to be extinct in the Southern Tablelands, having not been observed there since 1980 (Osborne, Littlejohn et al. 1996). In addition to those in the highlands, many populations have also been lost along the foothills and coastal plain of the Hunter, Sydney and Shoalhaven regions where they were once common (Daly 1995; White and Pyke 1996; Mahony 1999).This reduction has resulted in the species being listed as endangered in New South Wales under the *Threatened Species Conservation Act 1995* and as vulnerable nationally under the *Environment Protection and Biodiversity Conservation Act 1999.* Two key populations are named for the Lower Hunter region, one of which occupies Kooragang Island (DECC 2007, there named Kooragang/Ash Island).

Causes of the decline and disappearance of bell frog populations

There is considerable evidence that the green and golden bell frog was once common in the Hexham Swamp/Kooragang Island area of Newcastle (Hamer et al., 2004). The species apparently declined rapidly in the 1980s and by the 1990s the only confirmed breeding site south of the Hunter River was in the 2HD wetlands at Sandgate. This population disappeared some time prior to 2006, leaving only the population on Kooragang/Ash Island.

More broadly the range contraction of the threatened bell frog species occurred rapidly, suggesting a causal agent that was able to act over short time periods was involved (Hamer et al., 2009). They disappeared from nearly all inland, high altitude areas of their respective ranges (Courtice and Grigg, 1975, Hamer et al., 2009, Mahony, 1999a, White and Pyke, 2008, White and Pyke, 1996) alongside a suite of co-occurring frog species that did not appear to decline. These consistencies with the disease hypothesis suggest that chytridiomycosis may have played a role in bell frog declines and, if so, that the effects of this disease must be less severe in areas where bell frogs have persisted (Mahony et al, 2013). The NSW National Parks and Wildlife Service Draft Recovery Plans for *L. aurea* lists disease (specifically chytridiomycosis) as a threat to the persistence of these species, and several observations of infection and die-offs are referred to therein (DEC, 2005a, DEC, 2005b, NSW NPWS, 2001).

Bell frogs are highly susceptible to the amphibian Chytrid fungus that causes the disease chytridiomycosis. Experimental exposure of *L. aurea* to the Chytrid fungus results in 100% of individuals showing terminal signs of chytridiomycosis in captivity (Stockwell et al., 2010). Although the impacts of disease are expected to be more severe in captive environments, such high susceptibility in *L. aurea* hosts suggests that the Chytrid fungus has the potential to constrain population size and cause extinctions. Multistate modelling of the Kooragang Island *L. aurea* population supports this, showing significantly lower over-winter survival rates in infected individuals (0.1) than uninfected (0.56) which was predicted to cause the population to decline at twice the rate of an otherwise uninfected population (Stockwell, 2011). These studies indicate that large-scale unobserved seasonal die-offs may occur in bell frog populations during cold periods when both bell frog detectability and survey frequency are low. In addition, the chytrid fungus has been implicated as the causal agent in the overwinter extinction of a reintroduced *L. aurea* population in the Hunter Region of NSW (Stockwell et al., 2008). Such die-offs and extinctions have serious implications for the ability of remaining isolated populations to persist with infection, particularly in the presence of demographic and environmental stochasticity.

The existence of a link between the bell frog persistence in coastal environments and sensitivities of the causal agent Chytrid to salt, has been suggested several times (Berger et al., 2009, Mahony, 1999a, White, 2006) and significant negative correlations have been found in bell frog habitat between infection loads and the salinity of water bodies (Stockwell, 2011). An inhibitory effect of 3-4 ppt sodium chloride on fungal growth and infective capacity has also been confirmed experimentally (Stockwell, 2011). These results suggest that bell frogs may currently persist in areas with a saline influence as they act as environmental refuges from the effects of the Chytrid fungus. The addition of salt to water bodies, both in captivity and in an experimental reintroduction site has also been found to increase bell frog survival rates in the presence of Chytrid (Stockwell, 2011), suggesting that this may be used in management.

Apart from Chytrid, the two most commonly cited causal agents for the bell frog decline are habitat modification and predation by the introduced mosquito fish *Gambusia holbrooki*. Many historic bell frog sites have been altered, particularly through filling and drainage of wetlands and floodplains for agriculture, trampling of waterways by feral horses and pigs and urban and industrial development (Clancy 1996; Daly 1996; Van De Mortel and Goldingay 1998; Lewis and Goldingay 1999; White and Pyke 1999). Correlations between the loss of suitable habitat and bell frog population extinctions have been made and appear to be exacerbated by the loss of connectedness between habitat and the subsequent impacts of demographic and environmental stochasticity, and low levels of genetic exchange on small populations (White and Pyke 1996; Goldingay 2008; White and Pyke 2008).

The mosquito fish is known to prey upon the eggs and tadpoles of many frog species including the green and golden bell frog (Morgan and Buttemer 1996) and can significantly reduce survivorship, both in laboratory-based experiments (Morgan and Buttemer 1996; Pyke and White 2000) and in the field (White and Pyke 2008). In addition, bell frog tadpoles appear to be completely naïve to the presence of mosquito fish, showing no avoidance or refuge seeking behaviours (Hamer, Lane et al. 2002). The timing of the earliest bell frog declines coincided with the expansion of mosquito fish populations throughout NSW (White and Pyke 1996) and numerous sites where bell frogs remain are associated with an absence of the mosquito fish (White and Pyke 1996; Lewis and Goldingay 1999; Pyke, White et al. 2002).

In addition to the direct effects of predation, the presence of mosquito fish in permanent water bodies may also have resulted in a shift in the type of habitat utilised for breeding. Bell frogs appear to have bred in permanent water bodies more frequently in the past than they do now and this may be because ephemeral water bodies that dry frequently do not sustain populations of mosquito fish (Pyke and White 1996; Hamer, Lane et al. 2002; Pyke, White et al. 2002). However, breeding in ephemeral water bodies carries the risk of pond drying before tadpoles can metamorphose and unlike many other species, bell frog tadpoles do not appear to be plastic in their development rate, being unable to metamorphose more rapidly in response to declining water levels (Hamer, Lane et al. 2002).

1.3 Research objectives

Conservation efforts to mitigate the effects of habitat loss and other pressures causing GGBF decline often involve the management, restoration or creation of habitat, which depends upon a thorough understanding of habitat requirements and population demography. Research efforts have attempted to characterize particular features of habitat that bell frogs use (Pyke and White 1996; Penman 1998; Christy 2000; Hamer 2002; Pyke, White et al. 2002; Garnham 2009; Pollard 2009; Midson 2010). However, as discussed above, it may be that the habitat where bell frogs are observed are not the preferred habitat of the frog, and that the presence of an introduced predatory fish causes the frogs to select other habitats, some of which may be sub-optimal for their development. However, each habitat study found bell frogs to be associated with a different suite of variables, suggesting that it may be a generalist in its habitat requirements. The green and golden bell frog is an opportunistic colonising species with high dispersal ability and fecundity (Pyke and White 2001; Hamer, Lane et al. 2007) which also suggests that it should readily establish populations in suitable habitat. This has caused confusion as to why the species never seems to occupy all seemingly appropriate water bodies in a particular area where it is present, and why occupancy of ponds (presence/absence) can change regularly both within a season and from season to season.

Five attempts have been made to create bell frog habitat to date, using similar habitat templates (Mahony et al, 2013; Pyke and White 1996), and only one has resulted in the establishment of a breeding population (Pyke, Rowley et al. 2008; Stockwell, Clulow et al. 2008; White and Pyke 2008). Although these studies have increased our knowledge of various aspects of bell frog biology and ecology, the low rate of success in establishing populations illustrates our current lack of understanding regarding the habitat preferences and requirements of this species. Given the development pressures placed on much of the existing bell frog habitat, this urgently needs to be resolved. Despite the intensive research effort that has gone into understanding bell frog habitat requirements, very little has included a temporal (across time) component and this may prove to be vitally important in this understanding. Similarly, the unit of study focused upon in these investigations has consistently been the individual water body. However, bell frog habitat selection may be based on smaller or larger scales than this. Therefore, an understanding of how bell frogs utilize a landscape temporally and spatially is required if their distribution is to be understood and habitat effectively managed or created.

The specific objective of the Kooragang and Ash Islands green and golden bell frog population ecology research program, that this report addresses, is to build upon the ecological, population and demographic data gathered through field surveys since the 2010/2011 summer seasons by reporting on the outcome of the surveys conducted in the 2015/2016 season. This enables us to begin to build a picture of the GGBF population on KI/AI both spatially and temporally, which in turn help us to understand the dynamics that might be driving the population, and provide an aid as to how best to manage the population moving into the future, considering the need to balance future developments on KI and maintain a resilient population of GGBFs.

In particular, to make habitat creation and enhancement work effectively for the bell frog it is necessary to have a detailed understanding of the structure of the bell frog population as it currently exists on KI/AI. This required repeated surveys similar to the past years and involves a combination of capture-mark-recapture and visual encounter survey (VES) techniques. In addition to the surveys that were carried out in water bodies over the past five years, water management ponds created within the NCIG rail loop by Hunter Development Corporation (HDC) were included this year's surveys.

2. Methods

2.1 Survey techniques

There were two types of survey used:

i. **V**isual **E**ncounter **S**urvey (**VES**)

ii. **C**apture-**M**ark-**R**ecapture (**CMR**)

Both survey types involved systematic, surveying by between 2-6 people, at night surveys using >150 lumen LED head torches. Surveys started by listening for calls, and then making a call and listening for a response, prior to commencing the survey. The survey itself involves walking slowing through the pond and surrounding terrestrial habitat, paying careful attention to vegetation as GGBF tend to associate with vegetation (mainly various species of reeds). Where ponds were too deep for wading, we used a surf board, with an experienced board rider in a full-length wetsuit (previous surveys have used small canoes).

For each survey, each surveyor recorded

i. Start and end times of survey,
ii. Any frogs (GGBF or other species) heard calling
iii. Water depth (qualitative)
iv. Presence/absence of *Gambusia*
v. Other non-target species of frog seen
vi. For each GGBF encountered:
    - Time
    - Habitat structure (Tree, Reed, Grass, Rock, Ground, Aquatic)
    - Height from ground/water surface
    - Distance from water's edge (where in terrestrial habitat)
    - Size (adult/juvenile)
    - Was animal observed calling?
    - Other details

We attempted to capture all GGBF observed. This was done using a thin plastic bag (sandwich bags'), or, if the vegetation structure made using the bags too difficult, by hand. Captured frogs were labelled with a capture code, and tied in the bag with sufficient air. If the frog was touched during capture, we washed hands with disinfectant gel. The capture sight was marked with flagging tape. Capture rate was 677 of 1,283 of frogs encountered (53%)

Captured frogs were processed as follows:

i. Scanned using a Passive Induction Transponder (PIT) reader to see if the frog had been previously chipped.
ii. If the frog had a PIT tag, the number was recorded.
iii. Visual inspection of frog for injuries, recent toe clippings, nuptial pads (to identify males from females).
iv. Snout-Vent-Length was measured using callipers.
v. Body weight was measured using a 10g, 60g or 100g spring balance (Pesola). The frog was weighed in the bag, and then the bag was weighed separately.

vi. The frog was swabbed for chytrid fungus by the standard protocol used by the UoN Amphibian Research Lab (2 strokes on each side of the animal for each of: flank, inguinal region, posterior thigh, palms of hands, soles of feet).

vii. If the animal had not been previously tagged:
   - A small tissue samples (piece of webbing from a foot) was taken using a biopsy punch and stored in 70% ethanol.
   - A PIT tag was injected subcutaneously into the lower back and manipulated into the inguinal region.

Data Recording: Tissue samples and swabs were marked using the bar code from the PIT label.

Processing time: Processing took approximately 10 person minutes per frog. An example of the datasheet used to record data during processing is shown (see **Appendix**).

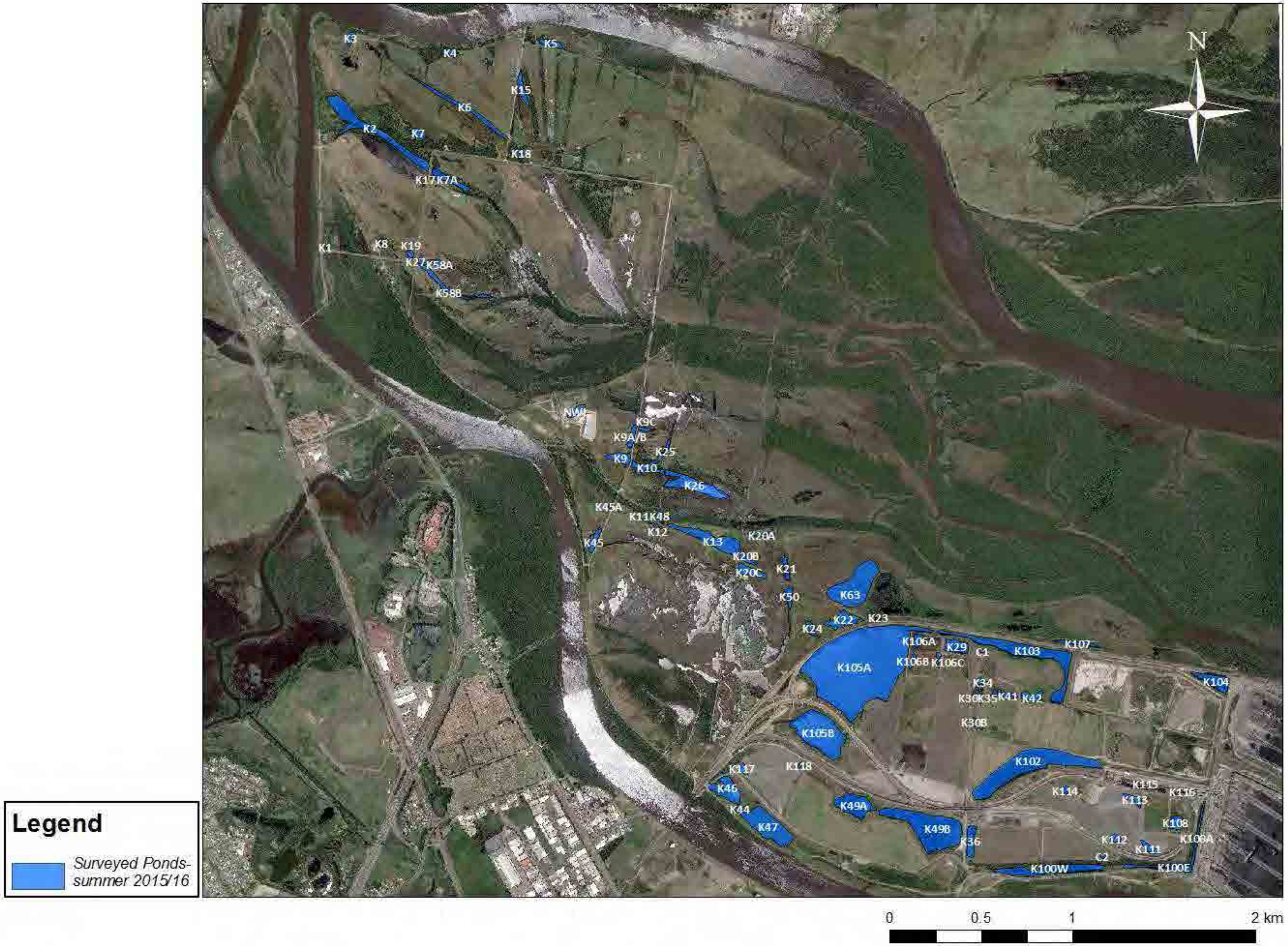
Frogs were returned to their point of capture after completion of the survey.

In **V**isual **E**ncounter **S**urveys, the entire pond was surveyed for a maximum of 30 minutes. Care was taken not to overlap surveys by each person, or to search the same area more than once. We attempted to keep a uniform survey speed at each pond, although that did vary between and within ponds depending on vegetation density. Any frogs captured were processed at the end of the survey, and frogs were then released at their point of capture.

In **C**apture-**M**ark-**R**ecapture surveys, ponds were surveyed intensively. Parts of the pond were often surveyed multiple times by the same person, and by different people. There was no maximum search time; rather, we attempted to survey the whole pond and overlapping an area was not precluded. In larger ponds (K29, K104, K108) a survey sweep might take >90 minutes. After the first sweep, captured frogs were processed and held whilst we made a second sweep of the pond. Processed frogs were released at the point of capture at end of the survey. CMR surveys typically involved 3 to 4 consecutive nights of intensive surveys; however, during the first CMR at K104 we captured so many frogs (>40 each night) that we were unable to process them all on the same night. In this case, the frogs were processed as early as possible the next day and released that evening; the next survey would then be the following evening (i.e. a 2 day gap between consecutive surveys.

Climatic conditions: Climatic variables were recorded at regular intervals during each night of surveying. We recorded: temperature, dew point, wet bulb temperature, barometric pressure, average wind speed, maximum wind speed, & relative humidity, using a multi-probe instrument (Kestrel).

Pond Overview - Kooragang Island survey area



2.2 Wetlands

The reference system for Kooragang wetlands used by the University of Newcastle was updated in April 2016; all of the data presented here reflects that numbering system.

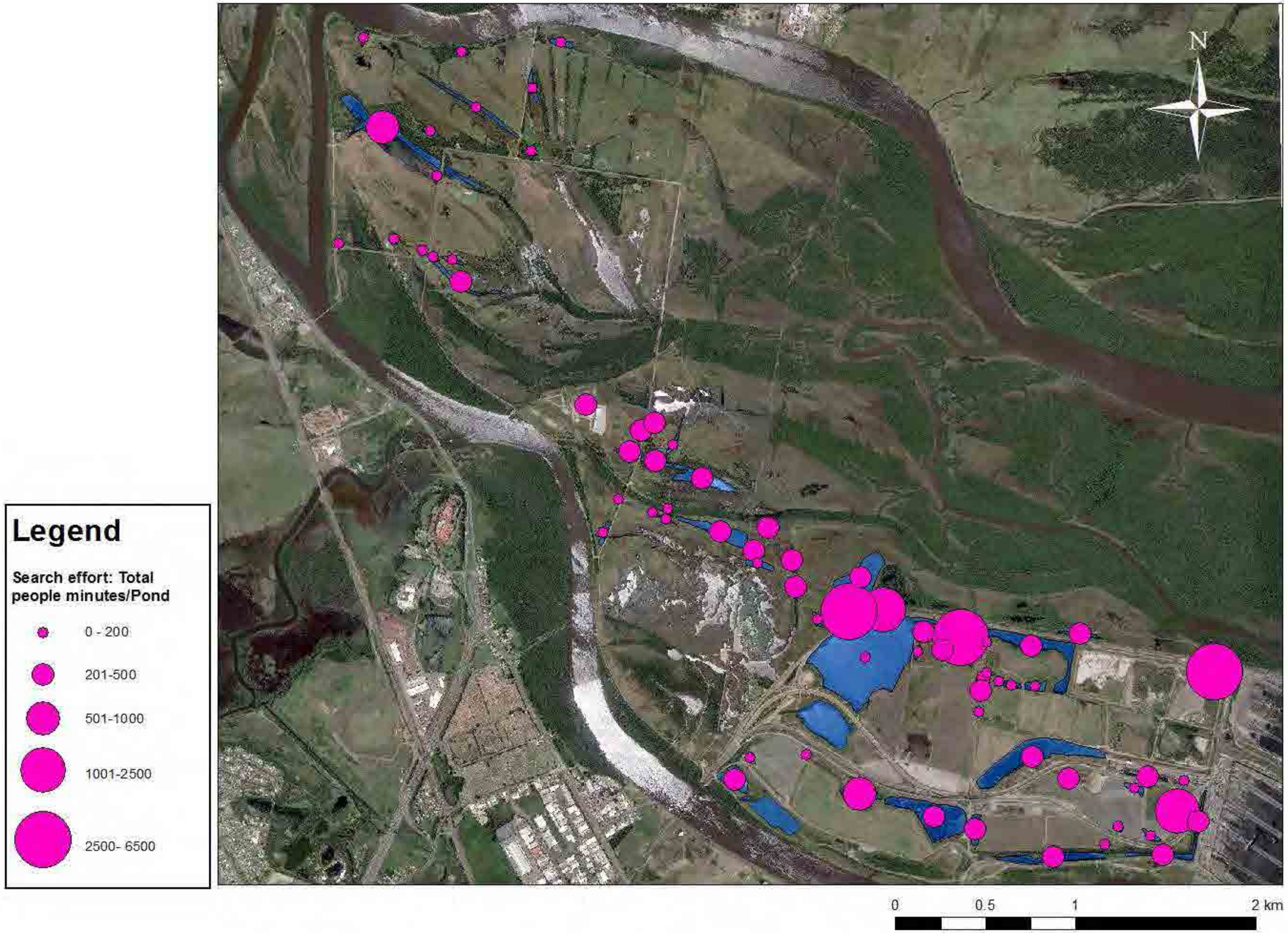
Wetlands were designated as belonging to one of 3 regions:

1. Northwestern: this is the region of the National Park close to the access bridge at Hexham, and including Scott's Point. There are 17 ponds (not including the newly constructed NCIG Compensatory Habitat Wetlands, of which there an additional 18 wetlands), most of which are small with thick reeds. The extent of open water regions is small - in most ponds, the flooded area is covered with dense *Typha* and *Phragmites*, although K2 (wet meadow) is a large pond with open water. Most ponds dry seasonally; only K4 is permanent, whilst K2, K3, and K7A are decadal wetlands.
2. Central: these are the ponds in the National Park close to Bell Frog Track. There are 23 ponds. They include several larger ponds with open water surrounded by reeds (K10, K22, K23, K25, K26, K45), some ponds that are highly ephemeral (essentially, flooded grass; K9, K9A/B, K9C, K20A, K20C, K45A, K50, K63), and several ponds that have dense reeds (K11, K12, K13, K20B, K21, K24, K48). There is a recently constructed pond (NWL – BHP-Billiton Compensatory Habitat Wetlands), and one close to mangrove (K107). Many of the ponds are seasonally ephemeral, and several (K10, K22, K25, K26) dry out at a decadal scale; only K23 and K107 are permanent.
3. Southern (Industrial Zone): these ponds are managed by organisations involved with the Industrial Zone, i.e. they do not fall under NPWS jurisdiction. There are 38 ponds, with a wide variety of sizes. Unlike the NPWS, most ponds are permanent. The Industrial Zone includes the largest (K49A, K49B, K102, K103, K105) and smallest (C1, C2, K30, K30A, K106C, K114) ponds on the island. There are several newly constructed ponds (6 ponds constructed during the 'capping by HDC during 2015: K111, K112, K113, K114, K117, K118), whose hydrology is not yet known but which will probably contain water in all El Nino years (i.e. decadal). There are 3 ponds that are adjacent to the Industrial Zone site along the roadside, which fall under the jurisdiction of the Roads and Maritime Service: K100A, K100E, and K100W - these are grouped here as part of Industrial Zone. One pond (K104) is designated as PWCS but is publically accessible.

In terms of Jurisdiction, we divided ponds into 6 categories.

- National Parks and Wildlife (NPWS): 40 ponds (North and Central regions)
- Port Waratah Coal Services (PWCS): 22 ponds (Industrial Zone)
- Newcastle Coal Infrastructure Group (NCIG): 3 ponds (Industrial Zone)
- Hunter Development Corporation (HDC): 7 ponds (Industrial Zone)
- Ponds previously managed by BHP, but which now fall under HDC induction (BHP): 3 ponds (Industrial Zone)
- Road & Maritime Service (RMS): 3 ponds (Industrial Zone).

Search effort - summer survey period 2015/16



2.3 Search effort

We surveyed 78 ponds; 17 in the North part of the Island, 23 in the Central Part, and 38 in the Southern part (Industrial Zone).

- Total search time was 5,305 minutes.
- Total search effort (people x time) was 15,060 person-minutes.

- There were 2 rounds of surveys; the first in December to mid-January, the second from late January to February. During each Round, one VES was performed at each pond, and a CMR survey was performed at K22-23, L29, and K104.

- Search effort was consistent between ponds. Search effort was not determined by pond area, as we had a maximum search time of 30 minutes at each pond (for VES). For large ponds such as K105 ('Deep pond'), we targeted areas of good potential habitat (reed patches on eastern shoreline).

- This is the first year that K104 has been included as a CMR site. In previous years, the three CMR sites have been K22-23 (these two ponds counted as one site for CMR because of their proximity to each other), K29 ('the Cell'), and K29 ('the Rail Loop'). K29 was intended as a CMR site for the 2015-206 surveys, and we commenced a CMR survey in the first round in early January, but detection rates were too low (13 frogs in 888 person-minutes of search effort) to produce a useful recapture rate (>20%) - accordingly, we used K104 as a CMR site instead.

- Delays in Industrial Zone inductions (ropes training for K29, NCIG inductions) meant that the first round was not completed until mid-Jan. As there was a large rain event in early January, that delay meant that we did not survey some ponds before frogs had dispersed from over-winter sites to ephemeral ponds. This is expected to have affected observations and occupancy in K29 and K108 in particular, which are postulaed to be over-wintering sites.

3.Results

The surveys focus on 5 major questions:

1) What is the estimated population size of the green and golden frog on Kooragang Island?
2) What is the demographic composition (size/age classes, males vs females) of the green and golden bell frog population on Kooragang Island?
    a. How much recruitment is known, and where is it occurring?
3) How do green and golden bell frogs utilise the landscape on Kooragang Island?
    a. What is the distribution of GGBF on Kooragang?
    b. What factors affect distribution, abundance, and recruitment?

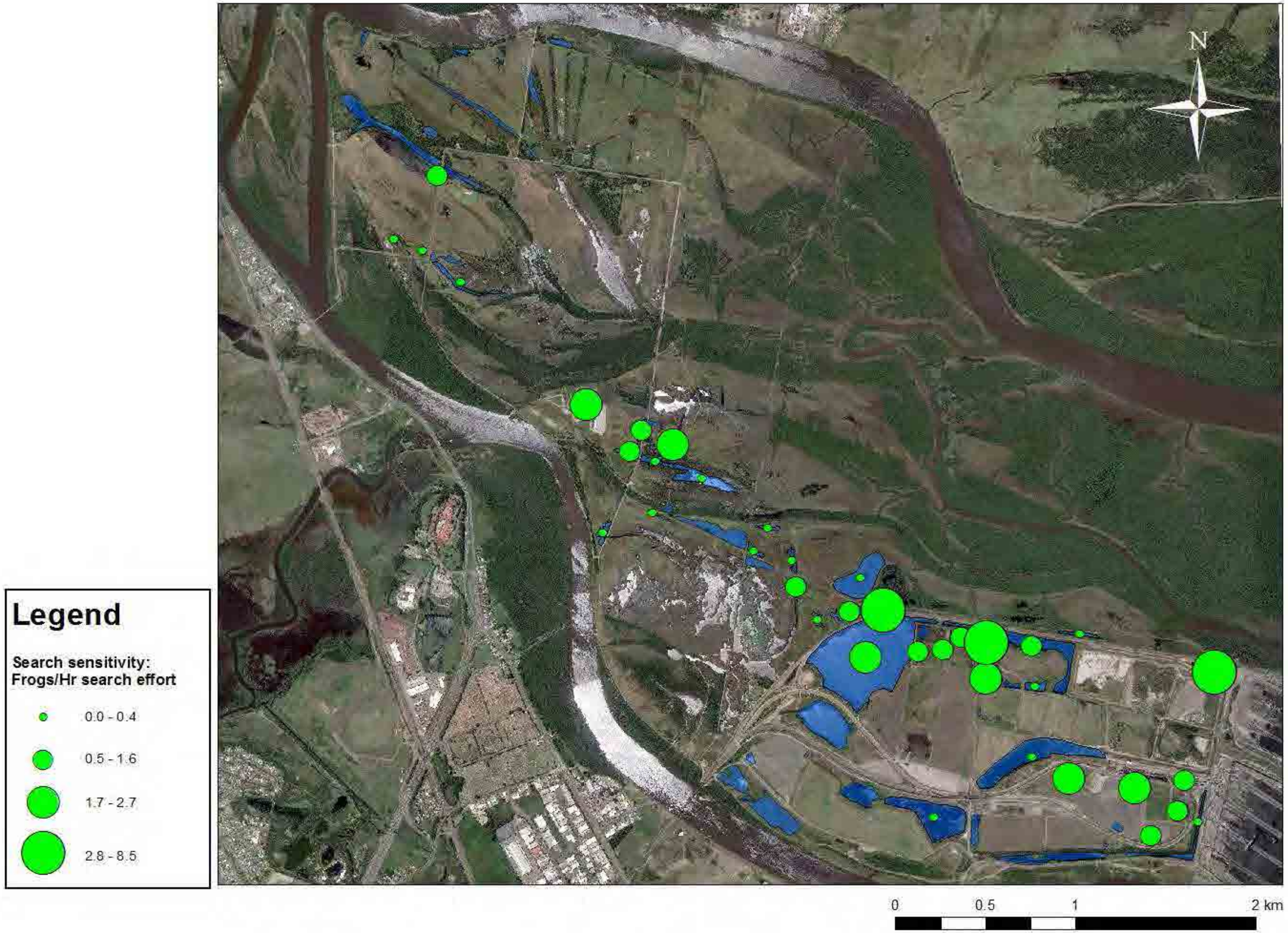
3.1 What is the estimated population size of the green and golden frog on Kooragang Island?

There are two methods of answering this question:

a. 'Raw count': an estimate based upon 'known alive'.
    - Total detections: 1,283
    - Total captures: 677
    - Number unique frogs captured (not including recaptures): 539
    - Percentage unique frogs: 539/677 = 79.6%
    - 'Naïve' estimate of frog population: 79.6% x 1,283 = 1,021 frogs

b. Population estimate based upon Capture-Mark-Recapture data: These models are being finalised. And will be included in the final report

Search sensitivity - summer survey period 2015/16



3.2 What is the demographic composition (size/age classes, males vs females) of the green and golden bell frog population on Kooragang Island?

a) How much recruitment is known, and where is it occurring?

Detection showed a bias towards males in the first round of surveys (November –December 2015), and towards females in the second round (January-February 2016).

- A high proportion of juveniles towards the end of the second round (largely due to the CMR at K22-23 in late February) possibly indicates animals that were spawned in the early part of the season, prior to the rain of late Dec - early Jan.
- The high proportion of males (74%) encountered in the round 1 CMR were mainly from K104, and were encountered shortly after the early January rain when male calling behaviour was very high.
- Mainly males were encountered at large ponds with open water; K104, K111, K113, K114, C1, K29, K105, K23, K25, and NWL.
- Female dominated ponds were those that are postulated to be 'overwintering' sites (K29, K108), or smaller ephemeral ponds (K8, K19, K17 in the North island; K9A/B, K26, K20A, K21, K50 in the Central region; K106B, in Industrial Zone). Small numbers of females were found at K102, K115, K116, K100A, and K100E.
- Juveniles dominated captures at two ponds: K22 and K9. A single juvenile was found at each of K58B and K103.
- Size classes indicate that most adult frogs are very young, i.e. between 6 and 12 months old. There is a small cohort of 1-2 year-old adults, and an even smaller cohort of >2 year-olds.

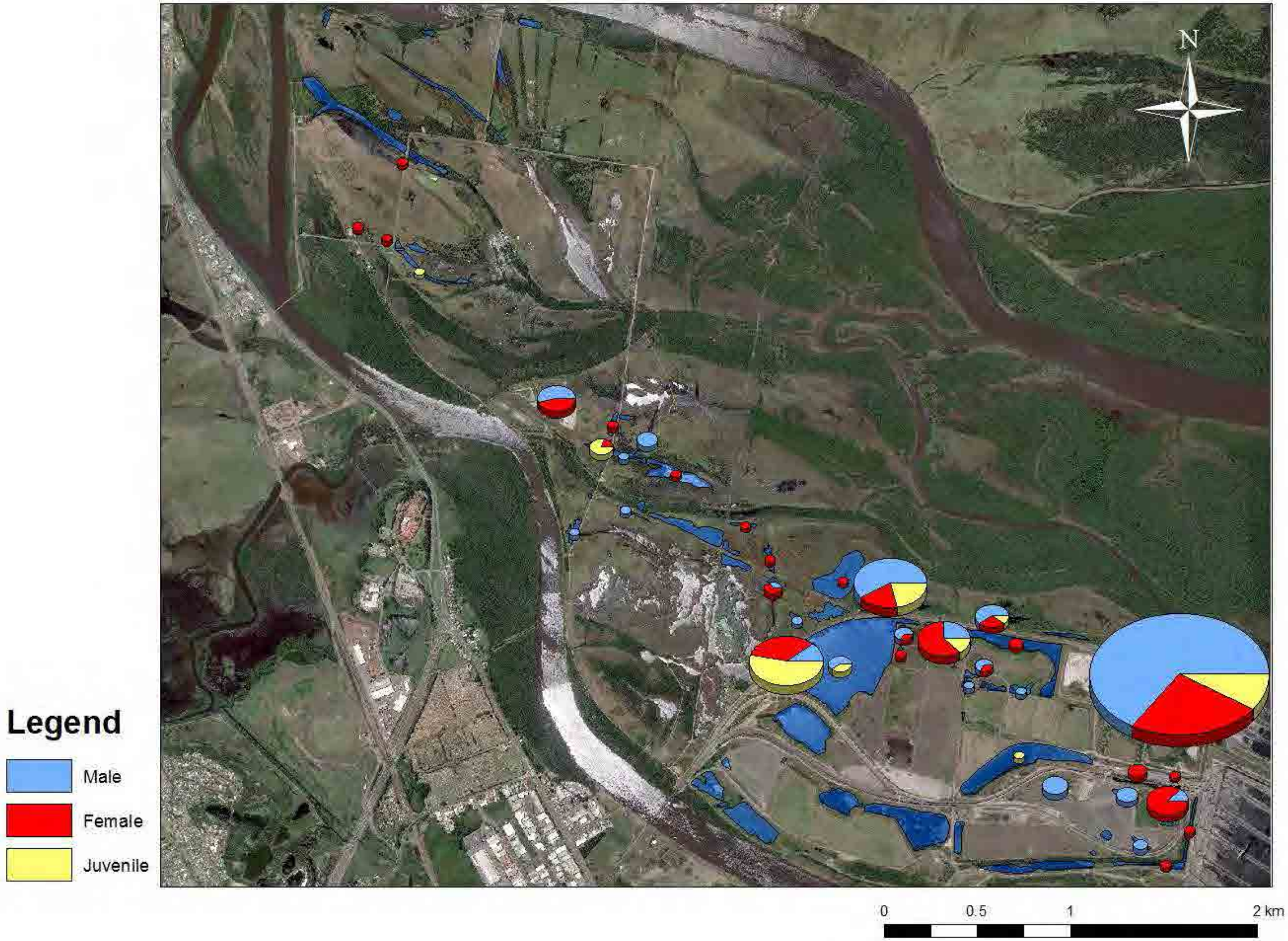
<u>Persistence and movement:</u>
Nearly all recaptured individuals were animals marked in this season, and most were from the same pond that they were caught at:

- No animals caught from previous years? (currently double checking previous years tags).
- There was no large migration – the only movement between ponds detected was between K22 and K23, which are neighbouring ponds; but numerous small migrations from permanent ponds to nearby ephemeral ponds at the time of maximum male calling.

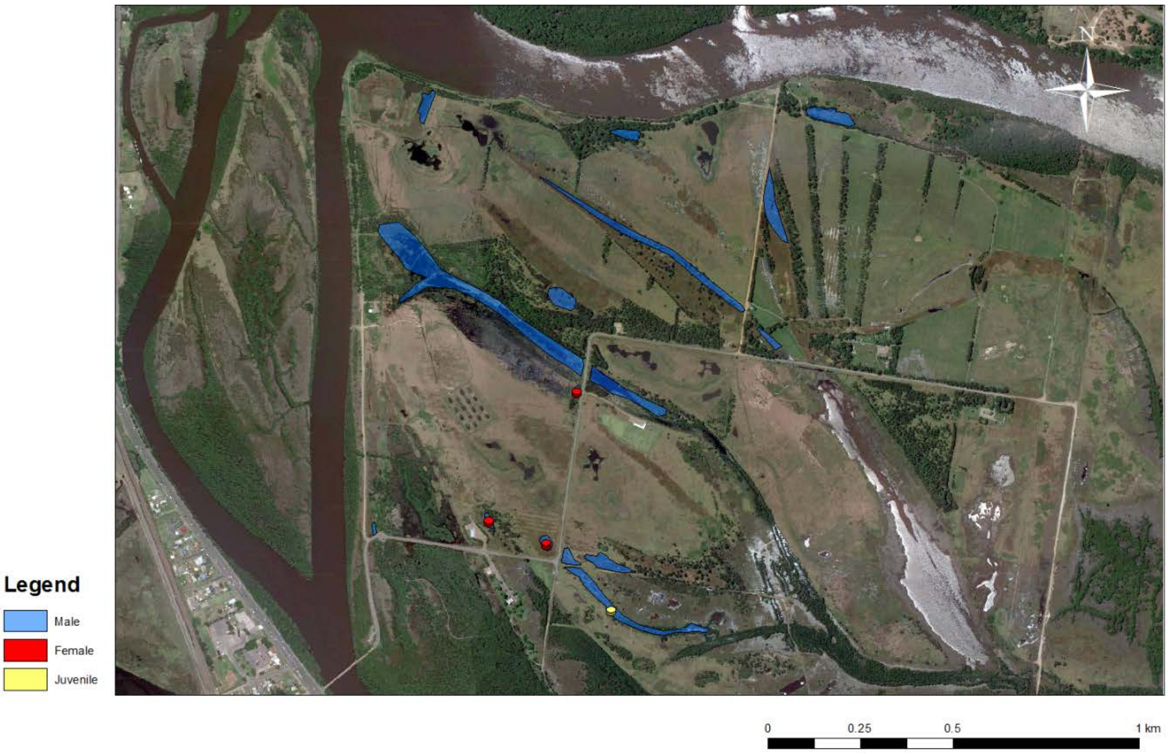
Nevertheless, some of our results are consistent with the idea that GGBF spend the winter in deep sheltered ponds, but move out to surrounding ephemeral ponds following summer rain.

- K22-23 had large numbers of frogs in early-mid December, but low numbers during VES in late Jan to early Feb. Appreciable numbers were not detected until late February. This is consistent with animals moving out to surrounding ephemeral ponds following the summer rain of late December / early January, and moving back to K22-23 with the approach of autumn. Large numbers of juveniles were detected at these ponds in late February; we think these animals were moving in from nearby ephemeral ponds where they had recently metamorphosed. We found no evidence of tadpoles or metamorphs at K22 or K23.
- K108 had very low numbers of frogs in mid-January. This was the first survey, and occurred after the early January rain event. In previous years this pond has had high numbers of GGBF, and it is possible that when we surveyed it the frogs had already dispersed to surrounding ephemeral ponds (e.g. K111, K112, K113).
- Similarly, K29 had lower numbers of frogs than have been found in previous years. Our first survey was in mid-January, after the large rainfall event. We found very low numbers in mid-Jan, but higher numbers during the second survey in mid-February. During that second survey most of the frogs were found on the bank surrounding the pond. We suspect that these were returning to the pond from surrounding ephemeral wetlands (e.g. K106A, K106B, K106C, K103).

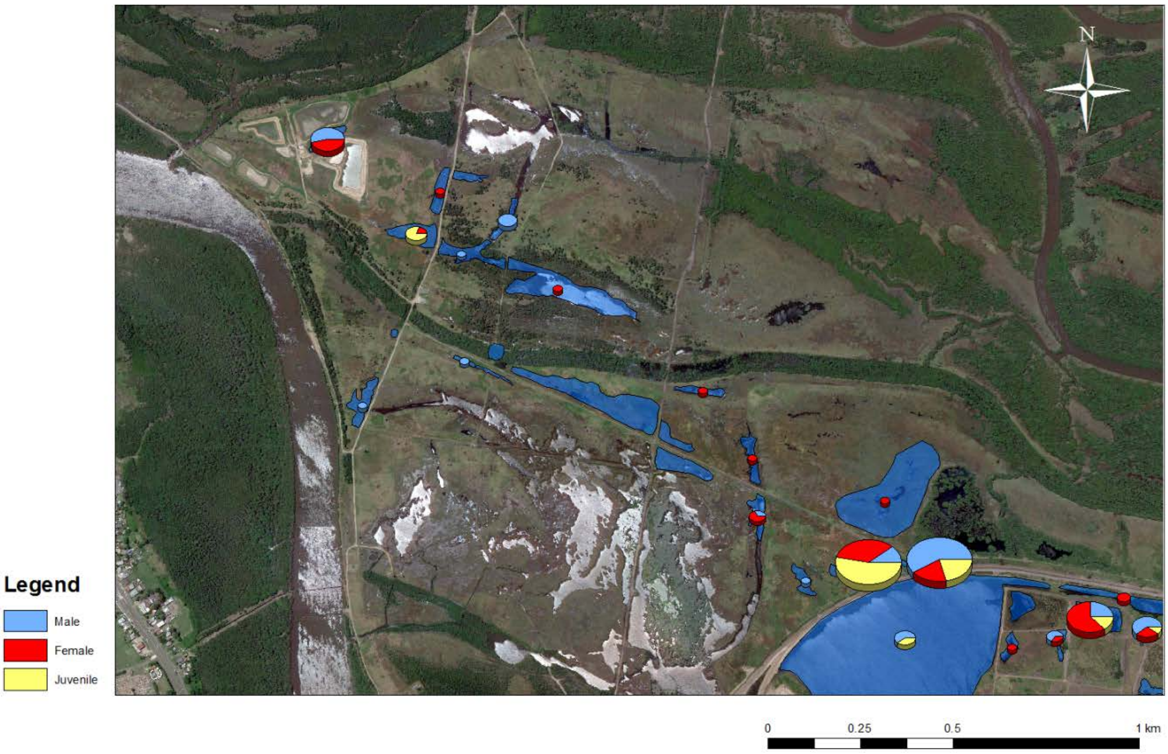
Pond Demographics- Number of animals caught by sex



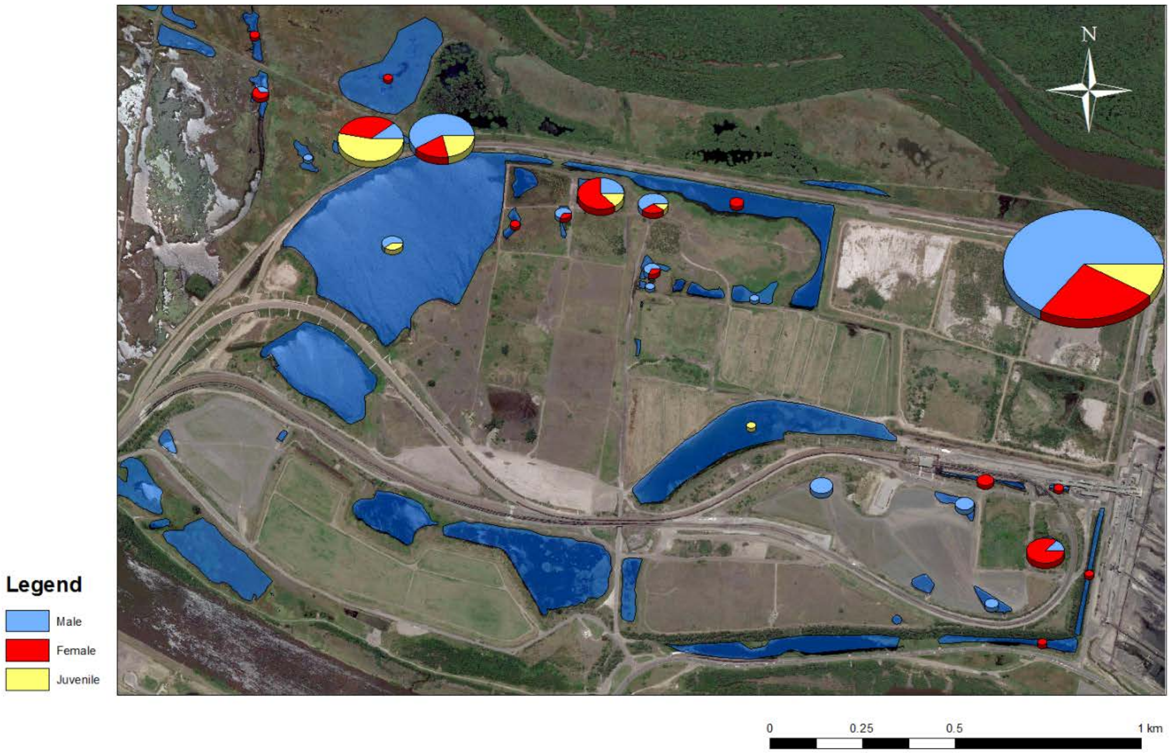
NW Kooragang - Pond Demographics: Animals caught by sex



Central Kooragang - Pond Demographics: Animals caught by sex



SE Kooragang - Pond Demographics: Animals caught by sex



In addition to visual detection, calling was heard at numerous ponds, especially in January and early February.

- Large choruses were heard at K104, C1, K103, K106C, and K105A.
- Calling was also heard along Bell Frog Track (K13/K20A, K20C), and in K25.
- And from the new HDC ponds within the rail-loop (K111, K113, and K114), and near K108.
- Calling was also heard from some ponds that were not part of the survey:
    - In small flooded waterways on either side of Pacific National Drive, between K100A and K104 (north of the NCIG gates).
    - North of the mangrove that runs immediately north of the PWCS rail, in the region of K23 to K107
    - North of K13
    - East of K26
    - West of K9A/B (from the direction of NWL, but not that far away)
    - South of K2 (in the direction of the NCIG Trial ponds).

3.3 How do green and golden bell frogs utilise the landscape on Kooragang Island?

3.3.1 What is the distribution of GGBF on Kooragang?

- GGBF were found mainly in the Industrial Zone, somewhat in the Central Kooragang region, and hardly at all in the Northwest region of the Island.

- Visual Encounter Surveys detected 4 frogs in the Northwest, 129 in the Central region, and 298 in Industrial Zone. Corresponding Search effort was 1,631 minutes, 3,403 minutes, and 5,023 minutes respectively. Net detection rates were 0.0025 frogs per person-minutes for Northwest Kooragang, 0.0379 frog/p-mins for Central Kooragang, and 0.0593 frogs/p-mins for Industrial Zone (or, 408 person minutes to find a frog in the Northwest region, 26 person-minutes in Central region, and 17 person-minutes to find a frog in the Industrial Zone).

- In the Central region, VES detected frogs mainly in three regions:
    - K22-23 (which has been a hotspot for years)
    - K9-K10-K25-K26 complex
    - NWL.

  In Visual Encounter Surveys, K22-23 had the highest numbers (32 and 53 respectively), followed by NWL (19). Taken together, the K9-K10-K25-K26 complex had 13. Search effort was 869, 279, and 808 person-minutes respectively. Numbers were low in the other ponds (mainly centred around Bell Frog Track); 13 frogs for a search effort of 1,447 person-minutes.

- In the Industrial Zone region, the highest numbers (and the stand-out pond for the island) was K104:
    - 223 frogs were detected during VES in a total of 599 person-minutes.
    - This included a single survey (110 person minutes) in the ephemerally flooded roadway area near the rail-line (K104A - treated in this analysis as part of K104) that detected 91 frogs in a 22 minute period, on the 7th January (just after the large rain event on the 5-6th Jan). There appears to have been a large breeding event in this pond in the previous year; and consistent with this, most of the animals encountered were of a size that indicates they were younger than 12 months old.

- The next best detection rate was at the C1 cluster ponds (14 adult frogs in 85 person-minutes search effort, followed by the new HDC ponds K114 (9 frogs in 117 person-minutes) and K113 (5 frogs in 70 person minutes). At K108 ('Rail Loop') we detected 13 frogs in 888 minutes. Most surveying at K29 ('the Cell') was for CMR, which detected 29 frogs in 1334 person minutes.

- In the Industrial Zone, frog distribution is highest along the 'northern' rail corridor (K105A, K106, K29, K103, C1, K104), and around K108 ('the Rail Loop') and the new HDC ponds (K11, K112, K113, and K114) within the NCIG rail loop.

- Abundance was low in the 'southern' corridor along Comorant Road (K100A, K100E, K100W, C2, K36), the old 'BHP' ponds (K49A-B), and the ponds in the SW corner (K46); total of 10 frogs detected for 1,322 person-minutes search effort. Apparently the new HDC ponds on that western side (K117, K118) have yet to be colonised by GGBF. Note that we did not survey K44, K47, or K105B.

- In the middle region (along the NCIG conveyor dump house), we detected one frog in the large 'boomerang' pond K102, but 8 frogs in the two NCIG 'conveyor 'ponds (K115 & K116). We did not test for water quality, but it is doubtful that these conveyor ponds would be considered high quality habitat - nevertheless, GGBF apparently make use of them well enough.

3.3.2 Factors that affect distribution, abundance and recruitment

Evidence of recruitment at a pond was limited to the presence of tadpoles and/or metamorphs. Eggs are difficult to detect, while calling indicates reproductive intent but not necessarily a result. Tadpoles were collected in the field and identified in the lab, using the key in Anstis (2013). Metamorphs were identified on the basis of colouration and size.

- Tadpoles were detected at K9C, C1, K106A, K106B, and K113 (the latter being one of the new HDC ponds within the NCIG rail loop)
- Metamorphs were detected at K106A, K106B, K104, C1, and K58B.

Taken together, this indicates one instance of recruitment in the North, 1 in the Central region, and 5 in the Industrial Zone.

- There was a huge recruitment event at K106A and K106B; on February 11 we detected large densities of tadpole and metamorphs in shallow flooded grass. We estimated density to be >5 per square meter, i.e. >10,000 tadpoles and metamorphs across these two ponds.

- The artificial ponds in the Industrial Zone also supported bell frog recruitment, with good numbers of tadpoles in two of the C1 ponds, and also in one of the new HDC ponds (K113).

- Note that calling and tadpoles were reported by NICG staff in a small ephemeral 'puddle' by the road near the conveyor dump station (K120). We were unable to find GGBF tadpoles at this pond but the habitat is consistent with GGBF presence, calling was heard in the area, and there are nearby ponds with confirmed frogs (K102, K115, K113, K114).

- Amplecting pairs were seen at K104A following heavy rain in early January.

With ongoing work on this species, we are starting to gain an understanding of the abiotic and biotic factors that affect GGBF distribution and abundance.

- At a landscape scale, the effect of the chytrid fungus disease has led to widespread reduction of the population in NSW, and range contraction to a small number of locations, contrasting with a previously widespread distribution across the state. Remaining population strongholds are generally coastal and many are on industrial or ex-industrial sites. The Kooragang Island population is an important one.
- Chytrid-linked mortality is highest in adults, and during winter months. Various abiotic factors may mitigate the impact of chytrid; salinity, water quality, and ambient temperatures have all been linked.
- In terms of demography, chytrid appears to increase annual mortality to the extent that very few animals survive their second winter; however, females become reproductively mature at 2 years old. In chytrid-free populations, a significant proportion of the population is between 3 and 5 years old.
- The ecological characteristics of GGBF are those of a 'weed' species; they seem to prefer disturbed habitats and are capable of prolific reproduction in suitable conditions.

The Kooragang Island population of GGBF is heavily infected with chytrid fungus (Stockwell et al. 2013, 2016). The distribution of frogs across the island is thus determined by other factors. Three potential factors are:

i. Pond hydrology,

ii. Vegetation,
iii. Presence and abundance of the plague minnow *Gambusia*.

i. Pond hydrology: This was analysed at a coarse scale. Ponds were designated as being
   - Permanent, i.e. always holding water
   - Seasonal, i.e. holding water during the summer of most years but drying out at some point in the year
   - Decadal, i.e. usually holding water year-round, but drying out in very dry years (e.g. El Nino events).

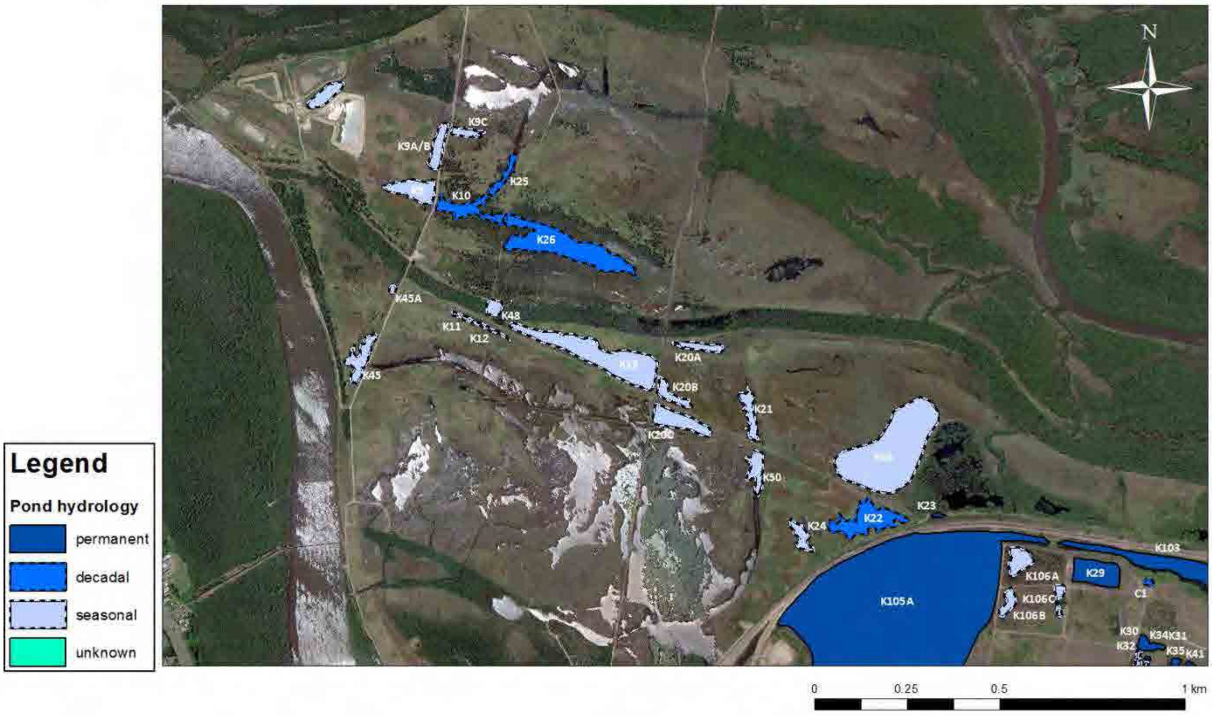
   Since all of the numbered ponds are at least seasonal wetlands, we did not include ephemeral flooded wetlands in this scheme (i.e. areas that flood for short time after particularly heavy rain). These ephemeral 'puddles' may nevertheless be important for GGBF reproductive behaviour.

   As described above, the three regions of the island differ broadly in terms of pond hydrology.
   - The Northwest part of the Island has mainly seasonal ponds, the Central has mainly decadal ponds, and the southern part (Industrial Zone) has mainly permanent ponds. We found that GGBF numbers were highest at Industrial Zone and lowest in the North region.
   - Whilst this pattern is certainly interesting, we do not fully understand the causal relationships between pond hydrology and GGBF abundance, especially since most detected evidence of breeding is in ephemeral wetlands.

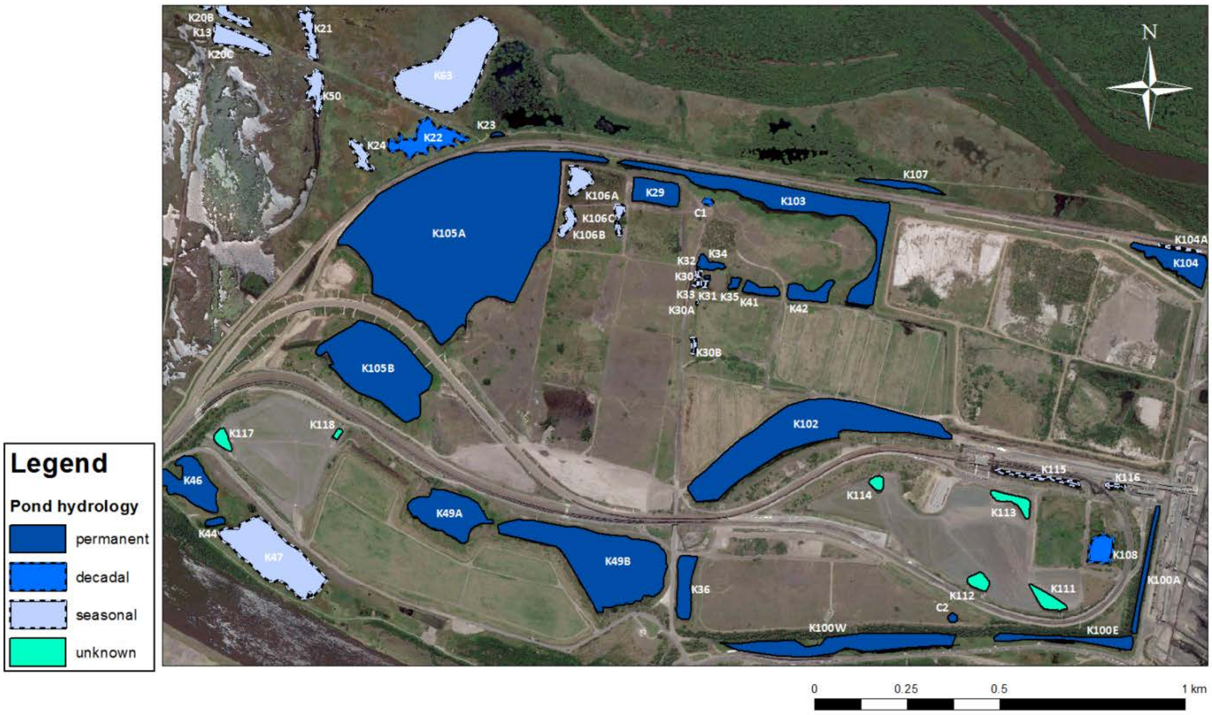
ii. Vegetation: vegetation structure is linked to hydrology, and also to disturbance. Reduction of grazing and other ecologically disruptive processes in the National Park may be promoting the development of climax vegetation structure in the Northwest and Central Part of the island, whilst land use across the Industrial Zone site may have slowed development of climax communities in the Southern region.
   - At a smaller scale, we found that adult frogs were strongly associated with *Juncus* reeds at the edge of open water. Dense single species stands of *Typha* or *Phragmites* had lower abundances of frogs, but patches where *Typha* or *Phragmites* were mixed with *Juncus* had good densities. Flooded grass with nearby stands of reeds were also spots where we detected a large number of frogs.
   - Frogs were rarely found more than 5 metres away from water, the exceptions being:
     - at K9, where they were found in dense grass that had been flattened by large animals,
     - on the road between K22 and K23, where they were found in the branches of wattle trees
     - At K29 ('the Cell'), where they were found at the top of the embankment surrounding the pond.
   - In three of the ponds (K9C, K106A, K106B) where we found tadpoles, they were in shallow flooded grass. Any nearby reeds were small or not dense. The other two ponds where tadpole were detected were the artificial ponds C1 and K113.

Pond Hydrology - NW Kooragang

Pond Hydrology - Central Kooragang



Pond Hydrology - SE Kooragang

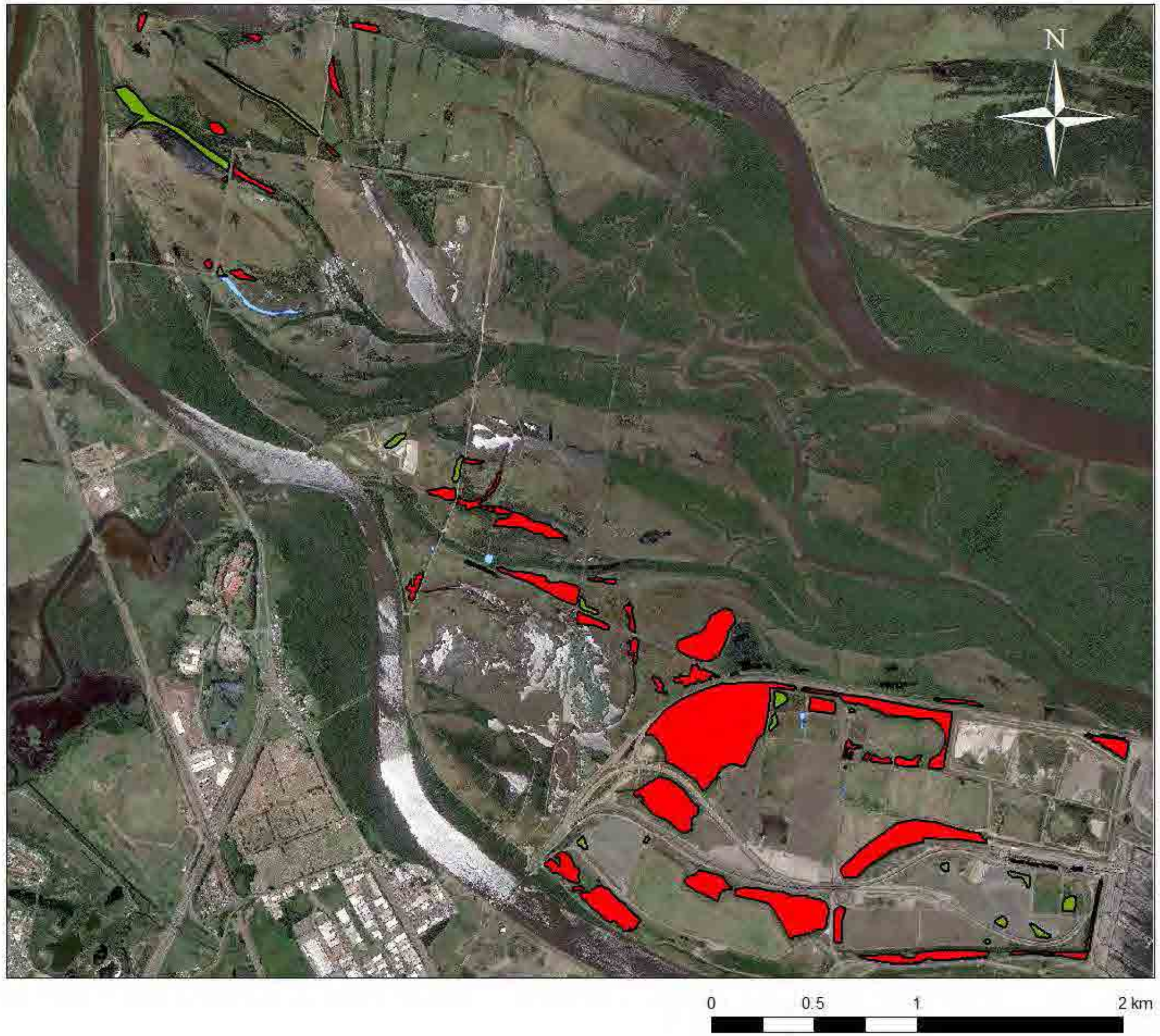


iii. *Gambusia*: Plague minnows are present across the Island; recent widespread flooding in April 2015 apparently allowed them to disperse to ponds that had previously been free of *Gambusia*. Whilst *Gambusia* are too small to predate on adult GGBF, they are capable of attacking eggs, tadpoles, and metamorphs.

- *Gambusia* were detected in 59 ponds; only 19 of the surveyed ponds are considered to be free of *Gambusia*.
- Although sample sizes are small, GGBF breeding was detected in 3 ponds that have *Gambusia* (K9C, K104, K58B). Four of the 7 ponds with GGBF breeding were *Gambusia* free (K106A, K106B, K113, C1). Given the small numbers of *Gambusia*-free ponds across the island, this suggests a link between breeding success and the absence of *Gambusia*, i.e. 31% of *Gambusia*-free ponds had breeding compared with 5% of ponds with *Gambusia* present.
- The 4 ponds with the highest number of tadpoles/metamorphs were the 4 ponds that are free of *Gambusia*. In particular, the very high numbers of tadpoles and metamorphs at K106A and K106B are noteworthy as these are large, shallow seasonal ponds with no *Gambusia* present.

The effect of other factors, such as weather, if difficult to uncouple. Night-time temperatures were consistently mild (low 20s) across the survey season, with only a small number of nights that were above 25°C or below 20°C.

Distribution of gambusia - Kooragang Island



Legend

Gambusia presence

- Unknown
- None detected
- Present

4. Key points - Discussion

4. Discussion

This section has not yet been written. Below we provide a list of major points coming from the annual survey that we will be addressing.

1. **This was a good year for Green and Gold Bell Frogs**
    - Large numbers and several instances of large recruitment
    - A result of an unusually large summer rainfall event in early January

2. **GGBF appear to do best within a habitat mosaic that includes:**
    - Sheltered permanent ponds (e.g. K22-23, K29, K108, K104). Note that, of these, only K108 is *Gambusia*-free. By sheltered here we are referring to the 'cells' in the Industrial Zone that are below the landscape surface.
    - Nearby seasonal and/or ephemeral ponds:
        - For K22-23, these may include K63, K50, K21.
        - For K29, these may include K106A, K106B, K106C.
        - For K108, these may include K111, K112, K113, K114.
        - For K104, these may include K104A, and the unnamed ephemeral ponds by the side of the road along Pacific National Drive (northern half)
    - Access to ponds that lack *Gambusia* is likely to be important for successful reproduction.
        - For frogs in the K29 region, K106A and K106B provide this.
        - For frogs in the K22-23 region, most nearby ponds have *Gambusia*. The frogs may use ephemeral flooded grassland that we did not survey. Note that K106A and K106B are close to K22-23.
        - For K104, this is probably K104A in normal years. The extreme rainfall this year resulted in the main pond at K104 rising to a height where it connected with the flooded section of access road, so *Gambusia* were able to infiltrate K104A. K104A is expected to dry out each year, and in more 'normal' years should provide *Gambusia*-free ephemeral habitat.
    - Preferred vegetation structure appears to be a mix of *Juncus* and other reeds surrounding at least some open, permanent water.

3. **The low numbers of GGBF in the northwest of the island may thus be linked to:**
    - Lack of permanent ponds (we acknowledge that should have changed with the construction of the NCIG Compensatory Habitat Wetlands, and the evidence of frogs being detection in this area of the island in 2015/2016 is a considerable change from the past when very few individuals were detected).
    - Vegetation structures which are dense stands of *Typha* and *Phragmites*, with little open water (linked to pond hydrology)
    - Lack of *Gambusia*-free ephemeral ponds.

    Conversely, the high numbers of GGBF within the Industrial Zone site are linked to:
    - The presence of sheltered permanent ponds with nearby seasonal/ephemeral wetlands
    - Access to *Gambusia*-free ponds
    - A 'disturbed' vegetation profile with large areas of open water.

4. **Timing of surveys at 'over-wintering' ponds is important:**

- We probably missed the main numbers of frogs at K108 and K29 because these were first surveyed after the summer rainfall.

5. **Artificial ponds work well….**
   - Both designs used at the Industrial Zone - the plastic tubs at the Cluster ponds, and the landscaped settlement ponds at the HDC capping – are effective for bell frogs.
   - Although small in area, the C1 cluster pond supports relatively high densities of adult frogs and 2 of the 6 tubs had tadpoles (in large numbers).
   - The HDC ponds are larger, but given that they were only installed in 2015 it is impressive that they were used by GGBF during the 2015-2016 summer season. Adults were detected at three of the six new ponds, and large numbers of tadpoles were seen at one. These ponds are *Gambusia* free and within a short distance of the resident population in the rail loop pond (K108).
   - Note that a single adult GGBF was observed at the C2 cluster in late December, but no frogs were observed there in the subsequent Visual Encounter Surveys.
   - Largest numbers of GGBF in the National Park were in K22-23. Numbers were low in mid-December, before the summer rain events, but there were large numbers of males calling in the nearby flooded grassland in mid-January.

6. **The importance of connectivity:**
   - The lack of frogs at the C2 cluster pond, and the western HDC capping ponds (K117, K118), emphasise the importance of connectivity between ponds (the mosaic habitat model, and overcoming isolation by distance).
   - C2 and K117-118 are somewhat further away from ponds that are known to support large numbers of frogs.
   - Conversely, the northern cluster ponds (C1) and the eastern HDC capping ponds (K111-114) are all close to ponds with large numbers of GGBF. In particular, they are each close to 'over-wintering' ponds: C1 to K29 ('the Cell'), and K111-114 to K108 (the 'Rail loop' pond).
   - This pattern may change in the next couple of seasons, however. Until recently, the closest ponds to C2 have been K100W and K100E; these ponds have never supported large numbers of GGBF. K108 is a long way from C2, but the new HDC capping ponds now provide suitable ponds between C2 and K108. The new pond K112 in particular is close to C2, and whilst this was the only one of the four new eastern HDC ponds that did not appear to have frogs this season, it is close to K111 (which did have GGBF) and is a similar construction. We predict that K112 will be used by GGBF next year, and that as a result C2 may become colonised by enough adults to sustain reproductive activity similar to that observed at the other cluster ponds.
   - For the new western HDC ponds (K117-118), the nearest where GGBF were detected is K49A. We did not find frogs at the pond immediately to the south (K46). Other nearby ponds (K46, K47, K105B) were not surveyed; at present, whether there are enough nearby frogs to colonised these new ponds is unknown.

7. **Most of the Kooragang GGBF are in ponds in the northern part of Industrial Zone**
   - The ponds with the highest abundance of frogs are K104, C1, K29, K22, and K23, all of which lie along the existing corridor. Additional ponds in this corridor that have GGBF are K103, K106A, K106B, K106C, and K105A. Between them, these ponds accounted for 92% of frogs detected (1183 out of 1283).

These comments relate to some specific management issues at Industrial Zone

i. **Enhancement of 'southern' corridor**

- The current low numbers of frogs along the southern edge of Industrial Zone likely results (at least in part) from low connectivity with the more densely inhabited ponds along the northern edge. Increasing numbers of frogs in this corridor will require improved connectivity, ephemeral ponds that are suitable for breeding, and sheltered 'overwintering' ponds.
- The low number of GGBF using the BHP-B wetlands (K49A and K49B) is difficult to understand, but is consistent with surveys in the past 2 years. The large size, suitable aquatic and terrestrial habitat of these wetlands would suggest they should support GGBFs. It is most likely that lack of connectivity and not habitat quality is the factor most responsible for low numbers in this habitat.

ii. **The 'northern' rail corridor**

- At present, this is the stronghold of the GGBF Kooragang population.
- Activities in this area can potentially have a large impact on the Kooragang GGBF population. Mitigation strategies should commence early to minimise any negative effects of development activities upon the population. Potentially, a network of alternative habitats, with high connectivity to the existing ponds, will promote dispersal of GGBF from the existing ponds of the northern corridor. This will require careful planning, construction of artificial habitat, and will need several seasons. Manual relocation of any remaining animals should be considered a last resort.

iii. **Capping of area to south-east of K105A**

- HDC is scheduled to cap the large area between K105A, K106B, K29, and K36. Incorporation of constructed wetlands, similar to those constructed within the NCIG rail loop in 2015, are likely to provide important habitat for GGBF.
- The proximity of this new capping to the 'northern rail corridor' and K106 (see below) may provide opportunities to enhance the GGBF population in the middle part of Industrial Zone, and minimise the impact of the proposed development along the northern corridor.

iv. **K106:**

- The observation of a large breeding event at K106A and K106B this year emphasises the importance of ponds that provide shallow, flooded grass habitat without dense reeds, and free of *Gambusia*.
- The raised walls around each of these ponds were probably what kept *Gambusia* out during the April 2015 flood, and are thus an important feature of these ponds.
- Given the large recruitment event in the 2015-16 season, we predict that the population around these ponds will be high in 2016-17; as with K104 this year (see (v) below) following a large reproductive event in 2014-15, most animals will be < 12 months old. This recruitment pulse in the middle part of the Industrial Zone site may present opportunities relating to (ii) and (iii) above.

v. **K104:**

- At present, this is the pond on Kooragang Island with the highest number of GGBF.
- Most frogs are young, following a large reproductive event last year (2014/2015).
- Minimal reproduction was observed this year.
- The larger permanent wetland falls under PWCS jurisdiction, but the ephemeral wetland that occurs on its northern boundary after heavy rainfall is within the rail corridor (under the management of the Australian Rail Track Corporation- ARTC). ARTC use the nearby car-park

and control the rail corridor. The ephemeral wetlands K104A, which may be an important breeding habitat, lies partly within the rail corridor. Given the high turnover of the GGBF population, failure of breeding again in 2016-17 may lead to a population crash at this pond; this would have serious consequences for the standing population of Kooragang Island.

- Given the importance of this pond at present, the environmental management of the pond should coordinate the different organisations using this area. At present, this does not happen - for example, several wattle trees adjacent to the rail corridor were felled in February 2016 without any consultation with PWCS.
- More than 200 frogs were PIT tagged at this pond this year; these may provide valuable data on survivorship and movement next year (see below).

Knowledge Gaps

Although understanding of GGBF biology and the Kooragang Island population has improved with the last decade of research, there remain some important questions.

1. What is the optimal habitat mosaic for GGBF? In particular, how can the North part of the island be managed for higher numbers of frogs? Will increasing the number of permanent ponds, or clearing the thicker stands of *Typha* and *Phragmites*, lead to increased numbers. Perhaps a combination of these is required, accompanied by nearby *Gambusia*-free ephemeral ponds?

2. We don't understand the pattern of chytrid infection across the island. In particular, we don't know if infection levels are uniform across the Island, with the higher GGBF numbers in the south part being enabled by some other biotic or abiotic factors; or, instead, whether chytrid levels are higher in the north part of the island, leading to reduced numbers there. We don't know if certain habitat features mitigate against chytrid (although salinity is suspected to be important). Since chytrid is an important cause of adult mortality, a better understanding of this pattern is likely to lead to better management strategies.

3. Although it seems likely from the data presented here that *Gambusia* has some effect on GGBF recruitment, this point has been controversial in the past since it is evident that this predator is not the prime cause of the widespread decline in GGBF populations. The answer to this question is of importance to the Kooragang GGBF population - since *Gambusia* can potentially be managed and eliminated from some wetlands, it is important to know if this is a worthwhile strategy and what the effect will be.

4. Meta-Population dynamics: despite considerable effort spent on PIT tagging frogs, we have very little direct information on the movement of GGBF across the Kooragang landscape. Understanding the movement of frogs between ponds, and how far they can move, is of vital importance in determining landscape connectivity, the extent of meta-population structure across the Island, and in assessing the potential impact of any development. PIT tags are appropriate technology for frogs but rely on recapturing individuals, and whilst recapture works well across a limited time of intensive sampling at a specific pond, recapture rates at larger spatial-temporal scales are very low. (That said, the large number of animals tagged at K104 this season may provide enough animals to detect survivorship and movement in the vicinity of K104 next season.) Radio tracking removes the need to regularly recapture animals, but bell frogs have been found to be sensitive to the attachment of radio transmitters. One approach that could provide the necessary information is an analysis of population genetics across the Island; this is logistically feasible with current technology.

Assumptions applied to survey effort and population modelling

***Comments*:** We assume that survey efforts were consistent across the entire monitoring season. In reality, there are several important sources of variation:

- Within individuals: survey effectiveness can vary with motivation, fatigue, urgency, and concentration. Green and Gold Bell Frogs are generally cryptic, and difficult to see in the different vegetation structures that they are sitting in. Individual surveyors may develop good search images for some types of vegetation (e.g. *Juncus* reeds), but have a poor search image for frogs in grass. One major variable is experience; a person doing frog surveys will improve their detection rate markedly with experience.
- Between individual surveyors: people differ with visual acuity, concentration, endurance, and levels of experience. Sometimes height is a factor - a frog can be seen at a low angle more easily than from a higher angle, or vice versa. Smaller people may get tired and lose concentration when bashing though thick, tall vegetation, or be less able to wade through deep water.
- Within and between sites: GGBF are cryptic and are difficult to see; moreover, they are well camouflaged in a variety of vegetation types. They are particularly difficult to spot in dense vegetation, and so ponds with dense reeds (many of the ponds on the northwest part of Kooragang, such as K1, K8, K19, K7, K18, K15, K5, K4; also K13, K20, K24, K108, K46) are expected to have low detection rates for a given abundance of frogs. The highest probability of detection seems to be in ponds that have a narrow band of *Juncus* reeds surrounding open water that is >3 metres across and >1 metre deep (e.g. K23; southern side of K104); during summer, the frogs sit on the edge of the vegetation. Parts of a pond with dense *Typha* and especially *Phragmites* may hold large numbers of GGBF, but have low detection rates. Weather conditions are also expected to influence detection probability; warmer nights with low wind speeds seem to be better for detecting GGBF. Temporal variation in frog detectability can occur across one evening (frogs seem to be more detectable past 1 hour after sunset), across consecutive nights (with weather), and across the season; the evidence is that some ponds (e.g. K23, K29, K108) are over-wintering sites, from which frogs disperse to ephemeral ponds during the mid-summer and then return to towards autumn.

Recognising these potential sources of variation is one matter; quantifying them so that they could be incorporated into models estimating abundance is another. At present, we assume the detection probability does not change for each person, is constant between people, and is similar between ponds, time of night, and date.

Acknowledgements

All field work was conducted under approval of the University Animal Care and Ethics Committee, Animal Research Authority No.A2011-164, and under the Scientific Licence of Dr Mahony (NPWS SL100190). We wish to acknowledge the logistic support of Nick Godfrey-Smith (PWCS), Phillip Reid (NCIG) and Mike Bardsley (HDC) in the conduct of this research program.

References

Appendix

Figure 1.1 Datasheets used for processing frogs

L. *aurea* Frog Data Sheet PWCS/NCIG Summer 15/16

Date: **Site location:** **Pond No's:** **Team members:**

Capture Info			Identification			Ethics*	Microhabitat			Morphology					
Pond	Time	Frog call?	Capt Code	ID (PIT tag)	Rec ap?	NAD	HT (cm)	Structure	From edge (cm)	Wgt (g)	Bag (g)	SVL (mm)	Sex (M,F,J)	Nups?	Other Observations

**Record a cross in the 'NAD' column where abnormalities are detected. Where an abnormality has been detected, use the detailed frog monitoring sheet to note details of the abnormality, subsequent monitoring, and actions.*

Kestral 1
Time: $Wind_{max}$:
RH: $Wind_{av}$:
DP: Temp:
Press: Bulb:

Kestral 2
Time: $Wind_{max}$:
RH: $Wind_{av}$:
DP: Temp:
Press: Bulb:

Kestral 3
Time: $Wind_{max}$:
RH: $Wind_{av}$:
DP: Temp:
Press: Bulb:

Notes:

Capture Info			Identification			Ethics*	Microhabitat			Morphology					
Pond	Time	Frog call?	Capt Code	ID (PIT tag)	Recap?	NAD	HT (cm)	Structure	From edge (cm)	Wgt (g)	Bag (g)	SVL (mm)	Sex (M,F,J)	Nups ?	Other Observations

Safety equipment and procedures

Relevant PPE is chest-high waders, gloves, and protection against insects by thick clothing and strong repellent. The guidelines for the Amphibian Research Lab concerning life-jackets are that they are recommended for water depths >1.5. Reflector vests are recommended. Survey groups should have a minimum of two people (preferably three). Where multiple teams are working concurrently, they should maintain contact via radio and/or mobile phone. Team members should carry spare batteries at all times, and be able to change the batteries of their head-torch in the dark. Team members should always be in eyesight and earshot of each other. In the event of flooding waders in deep water, the protocol is to release the straps and swim out of them - do not attempt to swim with full waders. First aid kits are kept in vehicles, and at least one person on each team has a current first aid certificate.

Risk assessment is performed at the start of the survey season, with a Take5 at the start of each survey night. Major risks for GGBF survey work on Kooragang Island include:

- Summer storm cells involving heavy rain and lightning. Because of the landscape, lightning is considered to be a high risk. If a lightning storm approaches, teams should seek shelter (preferably, off the Island). If caught in lightning, remain in vehicle (which provides a protective Faraday cage).
- Other people on the Island: Kooragang Island is somewhat infamous for anti-social behaviour at night time. In general, we keep away from other people after dark. Where other people are present we stay together as a group. If people approach a pond while we are surveying we may opt to turn-off head-torches whilst they are near (this circumstance is the only time where reflector vests can be a liability).
- Venomous animals: there are plenty of spiders on the island, but no aggressive or dangerous species (it is not suitable habitat for funnel-webs). There are undoubtedly plenty of snakes,

including potentially dangerous large elapids such as Eastern brown snakes and red-bellied black snakes, but we hardly ever see these at night time. We encountered only one snake in the 2015-16, a small marsh snake. With the flooding in 2015-16, however, there may be a boom in rodent populations in 2016-2017 and so the numbers of large elapids may increase.
- Climbing equipment (for K29): Many of the ponds in the Industrial Zone are old waste disposal cells, with steep sloped artificial embankments. Whilst some ponds (e.g. K103, K106C, K108) have safe entry points, K29 can only be accessed down a steep-embankment, which is approximately 5 metres high with a slope of 45%. Ropes are used to assist climbing in and out of this pond, following protocols developed by PWCS (the relevant jurisdiction).

Comments: Most safety protocols are fairly 'common sense' and we experienced no safety incidents in this season's survey. Safety protocols under the PWCS, NCIG, and HDC protocols at Industrial Zone are somewhat more stringent than those used by the University of Newcastle Amphibian Research Group; most of the additional complexity is administrative (inductions, JSAs, etc). However, there are some important points of difference:
- On Industrial Zone, lifejackets must be worn when near any water, regardless of water depth.
- On Industrial Zone, reflector vests must be worn at all times.
- The use of ropes at K29 is set up so that each person is independently in control of ascent and descent. This requires the use of complex harnesses, descenders, and ascenders. The procedure takes up a lot of time should be simplified.

Summer 2015-16 Kooragang Island survey for Green and Gold Bell Frog (GGBF) *Litoria aurea*

Colin McHenry, Bede Moses, & Michael Mahony

	Total	VES	CMR	
Total ponds surveyed	78	78	4	
Total pond surveys	223	179	44	
Nights of field work	38			
Total search time	5,305	3,300	2,005	(mins)
Total search effort	15,060	10,057	5,003	(person mins)

Ponds with GGBF detected	42
Ponds with GGBF breeding	7

Ponds with *Gambusia*	65

Frogs detected	1,283
Frogs captured	677
Unique frogs captured	539

Frogs detected in:	VES	CMR	Total
NPWS ponds	133	134	267
PWCS ponds	256	718	974
NCIG ponds	8		8
HDC ponds	29		29
BHP (HDC ema) ponds	2		2
RMS	3		3

Percentage of	between 6 and 12 months	1 - 2 years	> 2 years
Male	36.0%	13.7%	0.2%
Females	13.0%	19.6%	1.5%
Total number	**338**	**184**	**9**

Take home points:

1. This was a good year for GGBF, with large numbers detected and a large breeding event in K106 - a result of very high summer rainfall this year.
2. Constructed wetlands on T4 are performing well, with respect to frog abundance and breeding.
3. There is a link between breeding (presence of tadpoles or metamorphs) and ponds being free of *Gambusia.*
4. Size structure of the population suggests a very high turnover of individuals, with most animals encountered being less than 1 year old.
   - Mortality rates after 1 yr are high (a result of chytrid)
   - Recruitment depends on >2 yr old females, but these make up less than 2% of the population.

- The population depends upon the reproductive effort of a small number of animals that survive their 2nd winter. Very few of these survive their 3rd. Consequently, the Kooragang population may be vulnerable to a small number (i.e. 2) of consecutive 'bad' years.
- The T4 site is highly important for the Kooragang GGBF population. In particular, the 'Northern Rail Corridor' is home to most of the animals detected.

Survey Team
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Bede Moses
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Maddy Sergas
Cormac McHenry
John-Paul King
Rhys Corrigan

Pond Overview - Kooragang Island survey area

Survey Ponds on Kooragang Island

- Ponds grouped into 3 regions:
    1. NW island (NPWS)
    2. Central island (NPWS)
    3. South island (Industrial Zone)
- UoN pond reference system updated as of April 2016

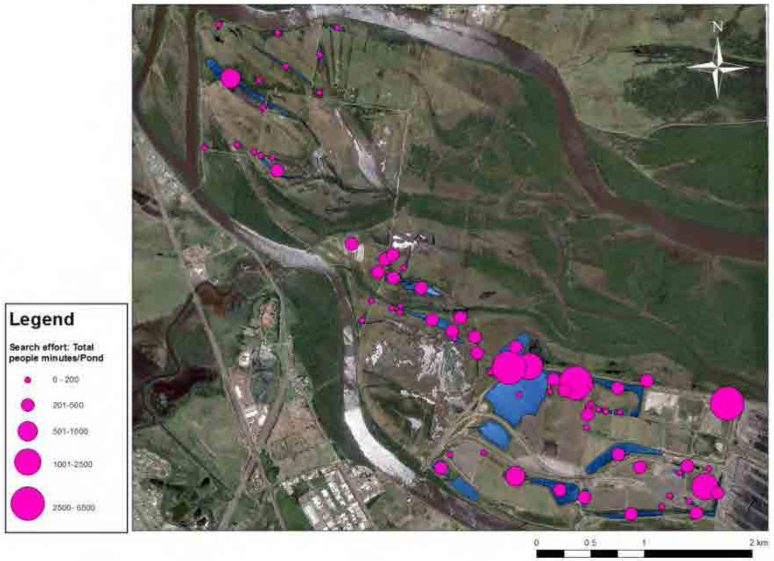
Surveys

1. Visual Encounter Surveys (**VES**)
    - between 2 and 6 people (usually 3) evenly spaced, walking at a constant pace (slow enough to have a good chance of seeing any frogs)
    - maximum 30 mins

1. Capture-Mark-Recapture (**CMR**)
    - repeated intensive surveys for 3-5 consecutive nights
    - Sites:
        1. K22-23 - Central island (NPWS)
        2. K29 ('the Cell') – Industrial Zone (PWCS, NCIG & HDC)
        3. K104 - T4 (PWCS)

Note: K108 ('the Rail Loop') has been used as a CMR site in previous years. However, our capture rate was low this year (search effort >1000 p.mins, capture rate < 1 frog per 16 minutes). We therefore used K104 as a CMR site (for the first time).

Search effort - summer survey period 2015/16



Search effort was consistent across most ponds
- Five ponds show very large search effort - the 4 CMR ponds, and K108 (aborted CMR in round 1)

Search sensitivity - summer survey period 2015/16

Search sensitivity shows the frogs encountered per person.minute of search effort , and is used here as a proxy for **GGBF adundance.**
- In addition to the 5 'CMR' sites:
    - The **new HDC** ponds within the NCIG rail loop (eastern side of T4) show good numbers of frogs, especially given that these ponds were constructed less than 1 year ago
    - The **Cluster 1** pond (near the Cell) also have good numbers
- In the Central part of the island
    - K9-K9A/B-K25 have good densities of GGBF.
        - Note that breeding was detected at K9C - see page 8
    - The constructed **NWL** pond has high densities

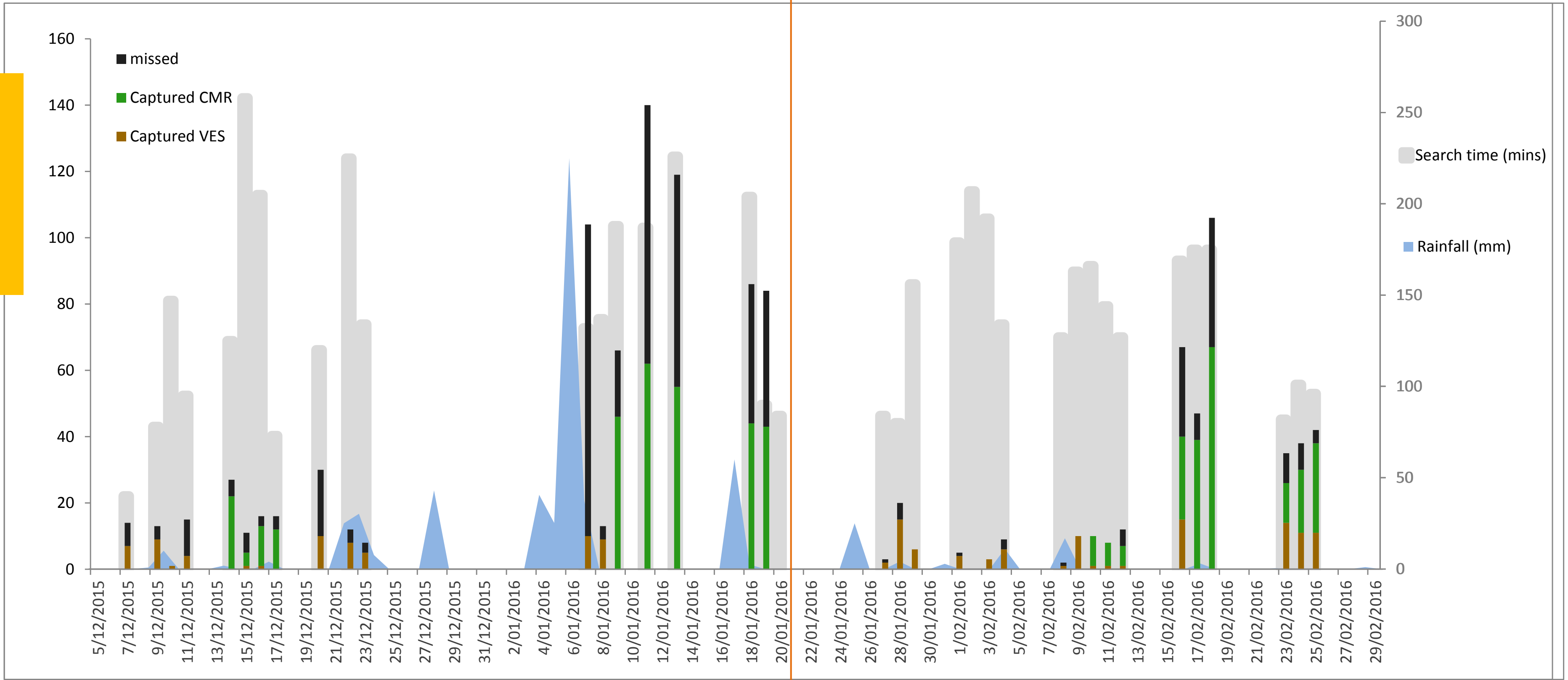
- The '**Northern Rail Corridor"** is clearly important, with high abundance of frogs The new habitats within the '**Rail Loop**' show promise. The Southern Corridor of T4 has low numbers of GGBF

Surveys were conducted between 5th Dec 2015 and 25 Feb 2016.

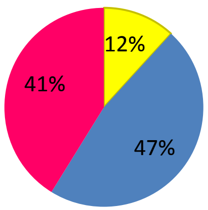
We detected a large number of Bell frogs- more than 1,200. This was likely due to:

1. An **extreme rainfall** event in early January, which stimulated breeding behaviour
2. Intensive CRM surveying at **K104**, which evidentially has high numbers of GGBF

Capture data includes recaptures (total captured + missed = total detected)

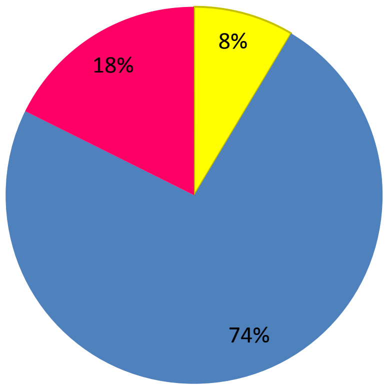


VES Round 1



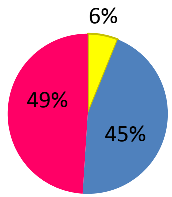
total captures: 68

total captures: 221



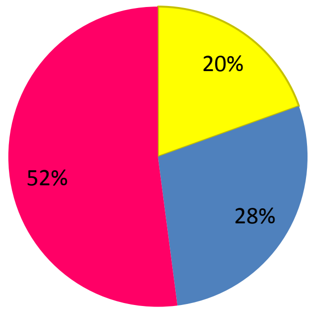
CMR Round 1

VES Round 2



total captures: 49

total captures: 169

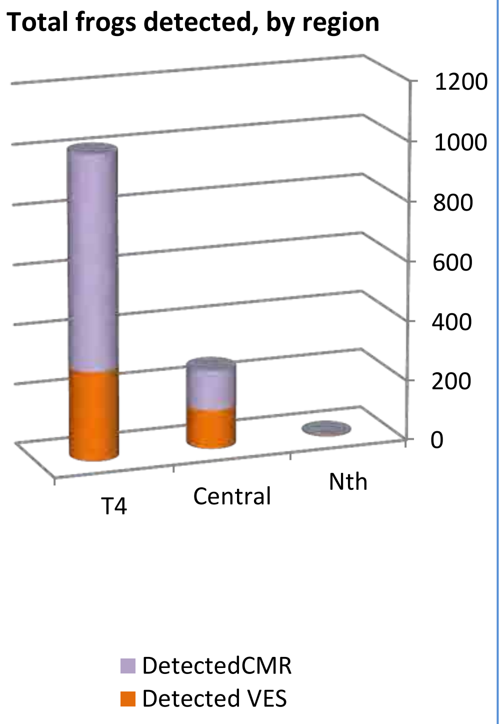


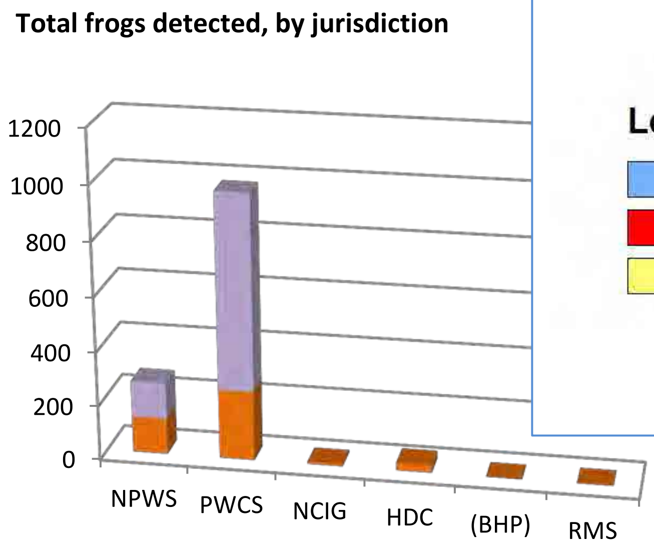
CMR Round 2

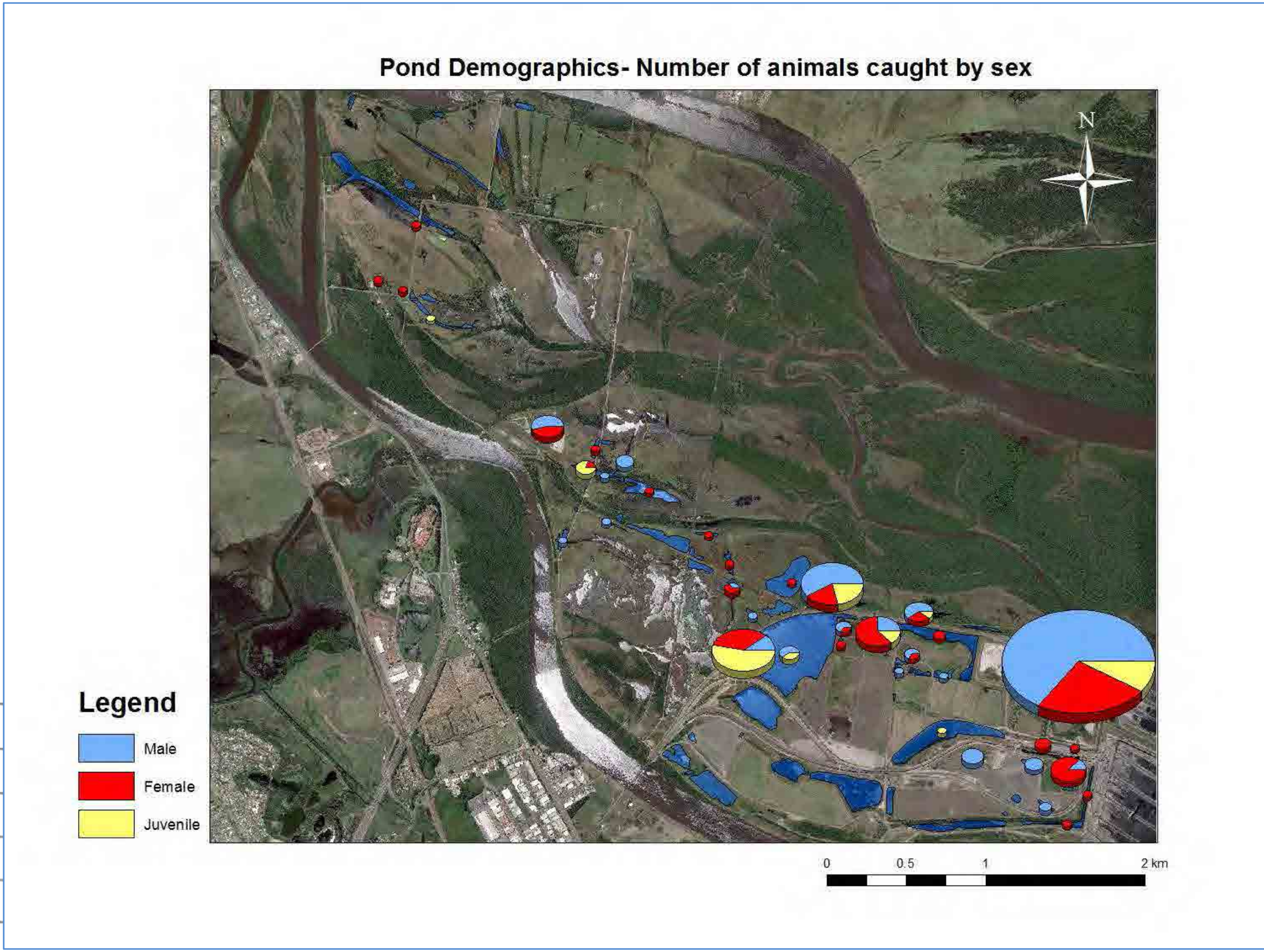
Demographic data (pie charts) do not include recaptured animals

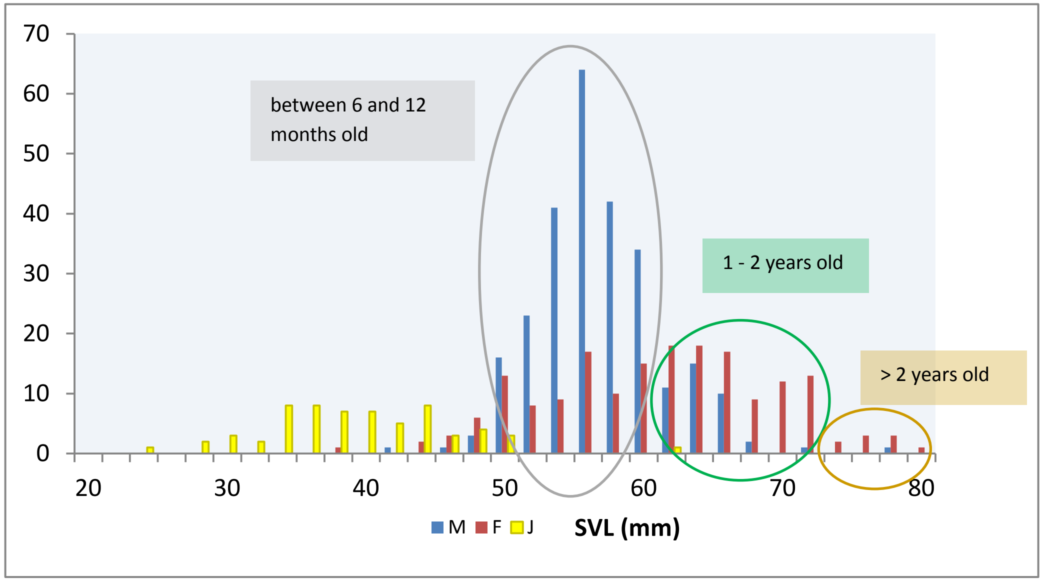
GGBF numbers in the **Northwest** part of the Island are **low**. There are better numbers in the Central (NPWS) part, but **most** animals detected were in the Industrial Zone

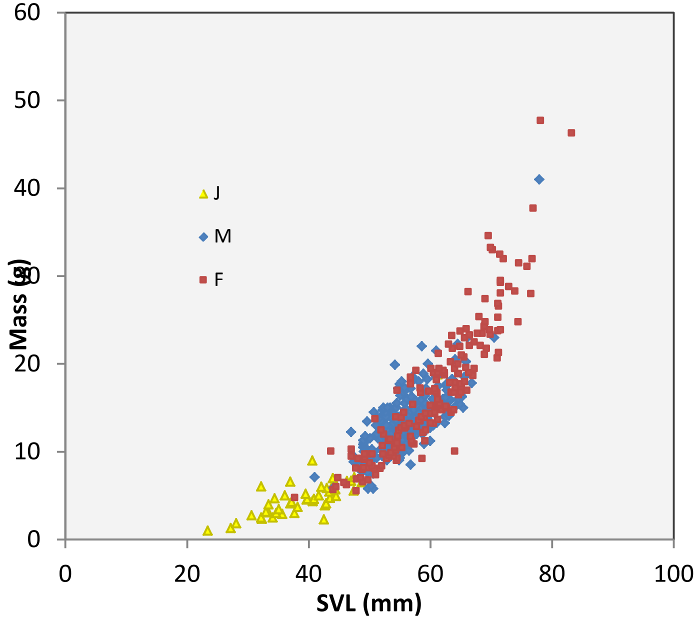
- (difference in numbers cannot be explained by Search Effort - see page 8)
- The highest number of frogs are on PWCS ponds, followed by NPWS.







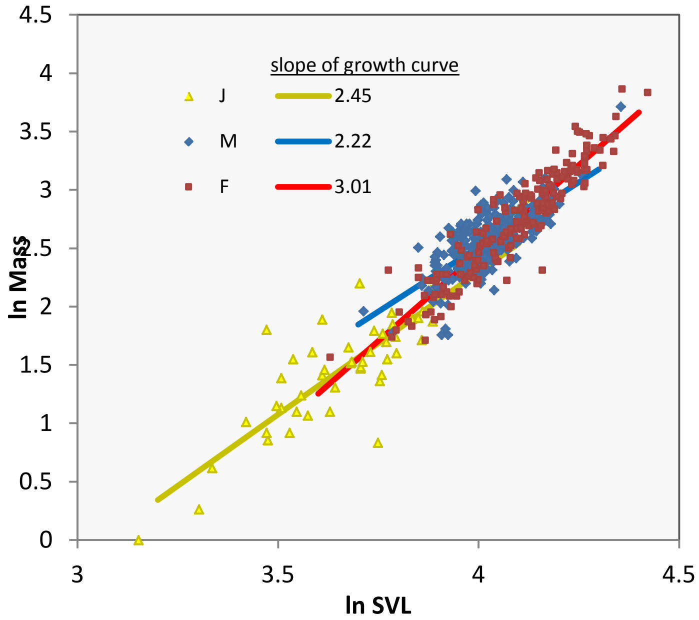


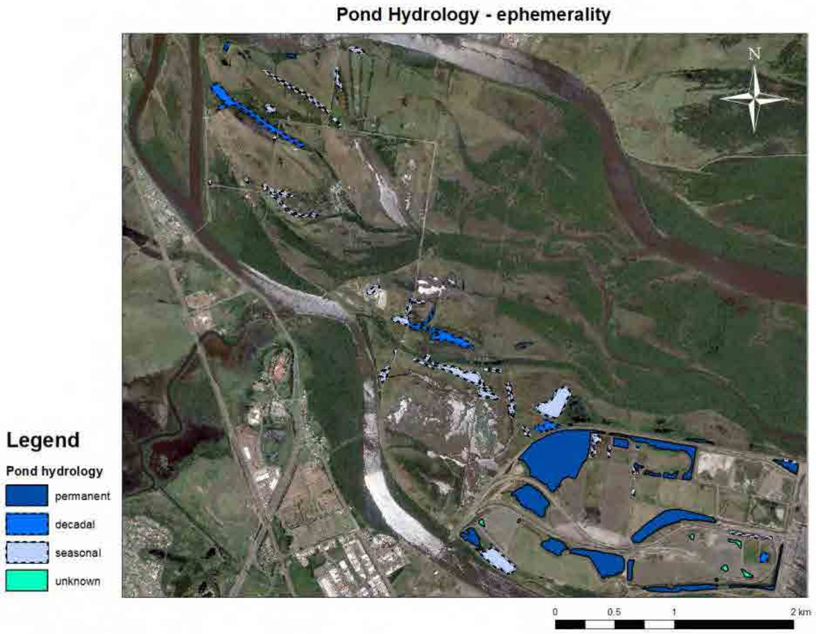


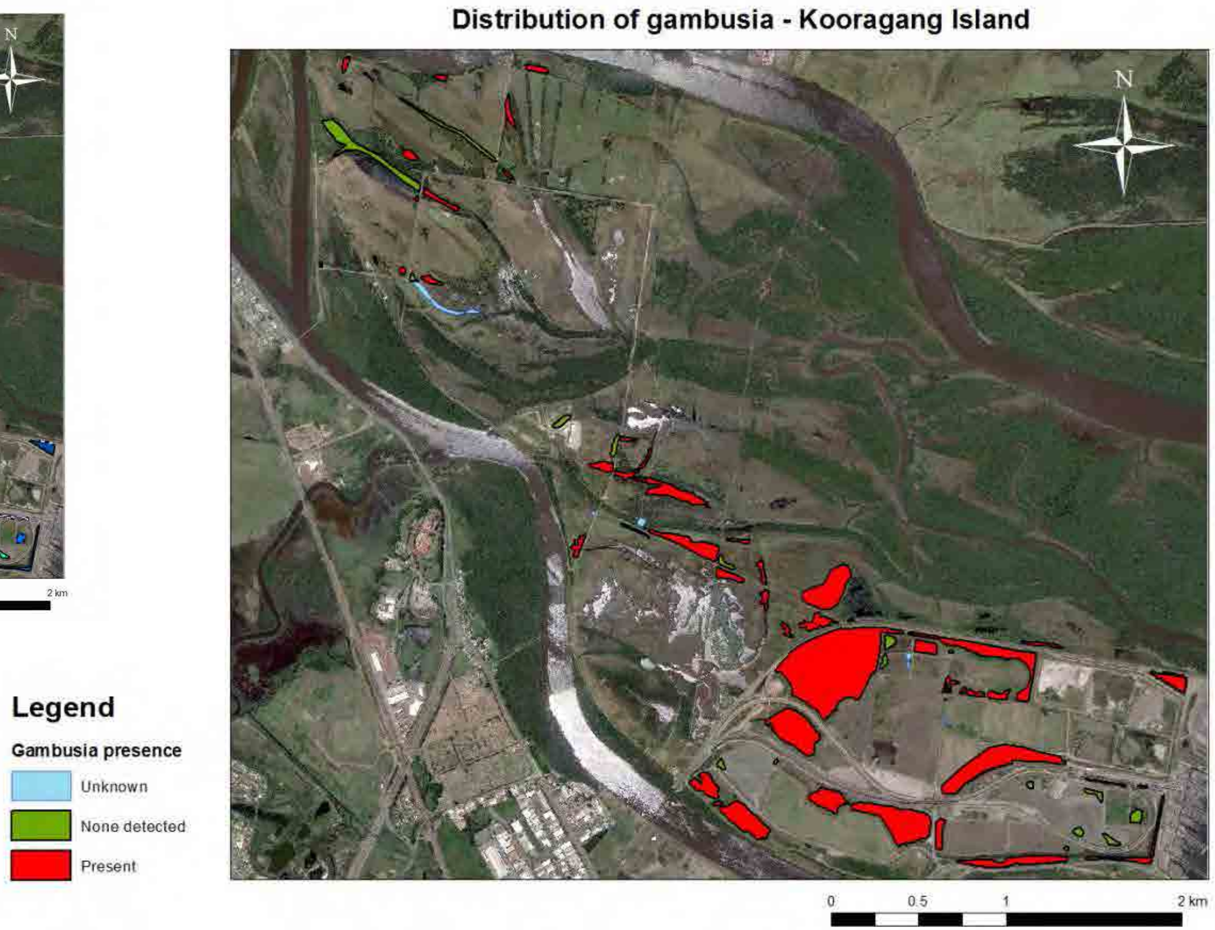
The frequency of size classes show that **most animals are young** (less than 1 yr old).

- The high number of males in this cohort may well be **reproductively active** (which is why they were so visible after the rain event)
- There are virtually **no males** older than 2 yrs
- Only **females >2 yrs** lay eggs. The number of these females is **very low** (8 out of 531 animals captured)

Size vs mass data for >500 individual frogs shows that males and females have slightly different growth curves

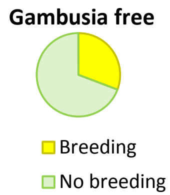






The April 2015 floods spread *Gambusia* over large parts of the island - only 19 of the surveyed ponds appear to be free of *Gambusia*

There is a clear link between the absence of *Gambusia* and evidence of reproductive success for the frogs - a much higher proportion of *Gambusia*-free ponds had tadpoles and/or metamorphs



Total ponds with

Breeding	*Gambusia*	No *Gambusia*
none	56	15
tads/mets	3	**4**
	59	19

Totals for search effort, **detection rate** (upper bars), and **pond area** (lower bars) for the 78 ponds surveyed. Ponds are grouped by **Jurisdiction** and ordered by net detection rate.

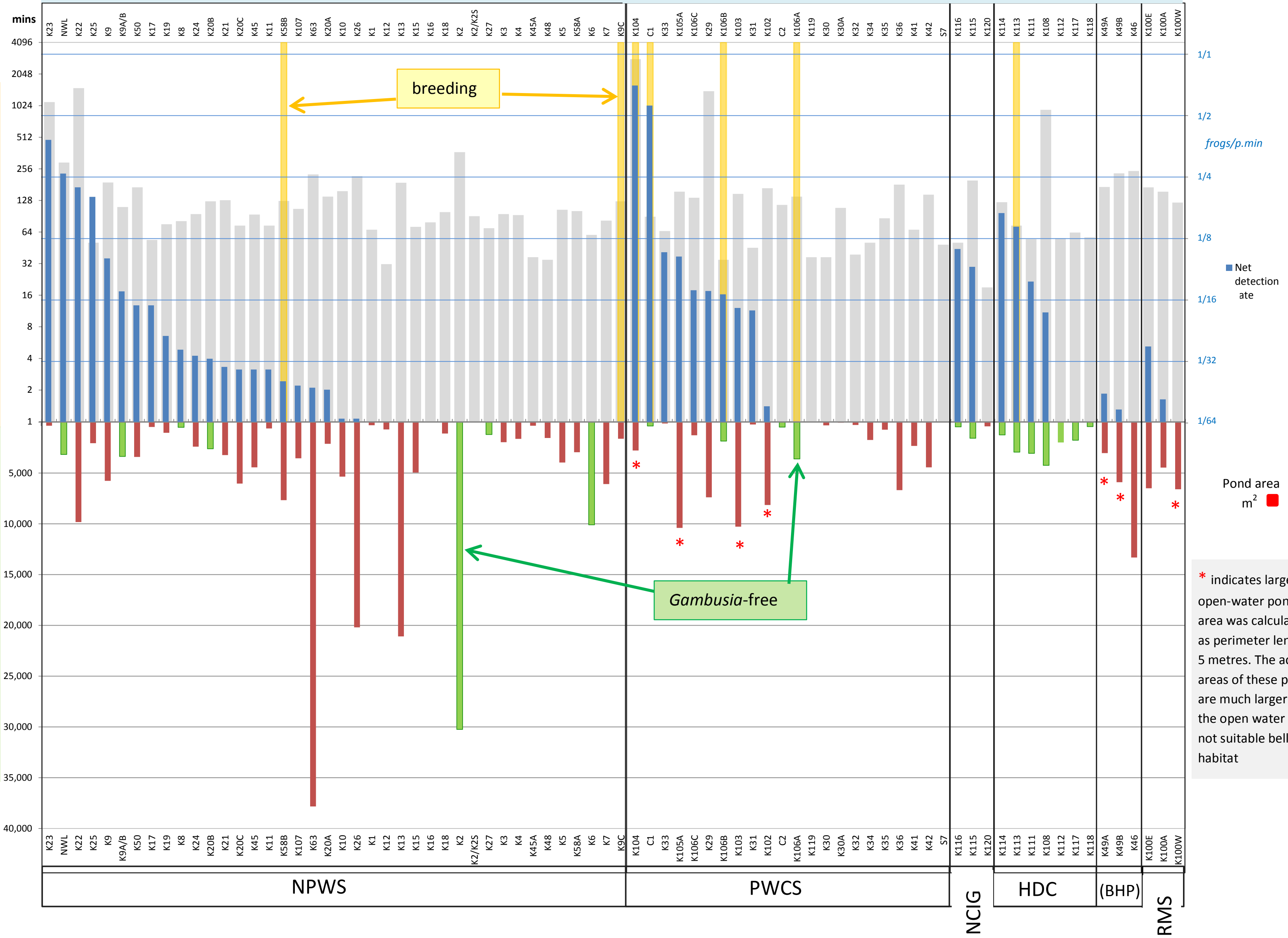
- **Search effort** is the total *person.minutes* per pond
- **Net detection rate** is the number of frogs detected per minute
- **Pond area** measured from GIS

Breeding (as evidenced by presence of tadpoles or metamorphs):

- Recorded in 7 ponds
- 4 of those ponds were free of *Gambusia*
- The other 3 were in shallow ephemeral ponds (K58A, K9C, K104A)
- There was a **large** breeding event at **K106A** and **K106B**, with thousands of tadpoles and metamorphs observed in mid-February
- With respect to **constructed ponds**, tadpoles were seen in one of the new HDC ponds (K113) and the northern cluster ponds (C1)

Gambusia are present in most ponds (59/78):

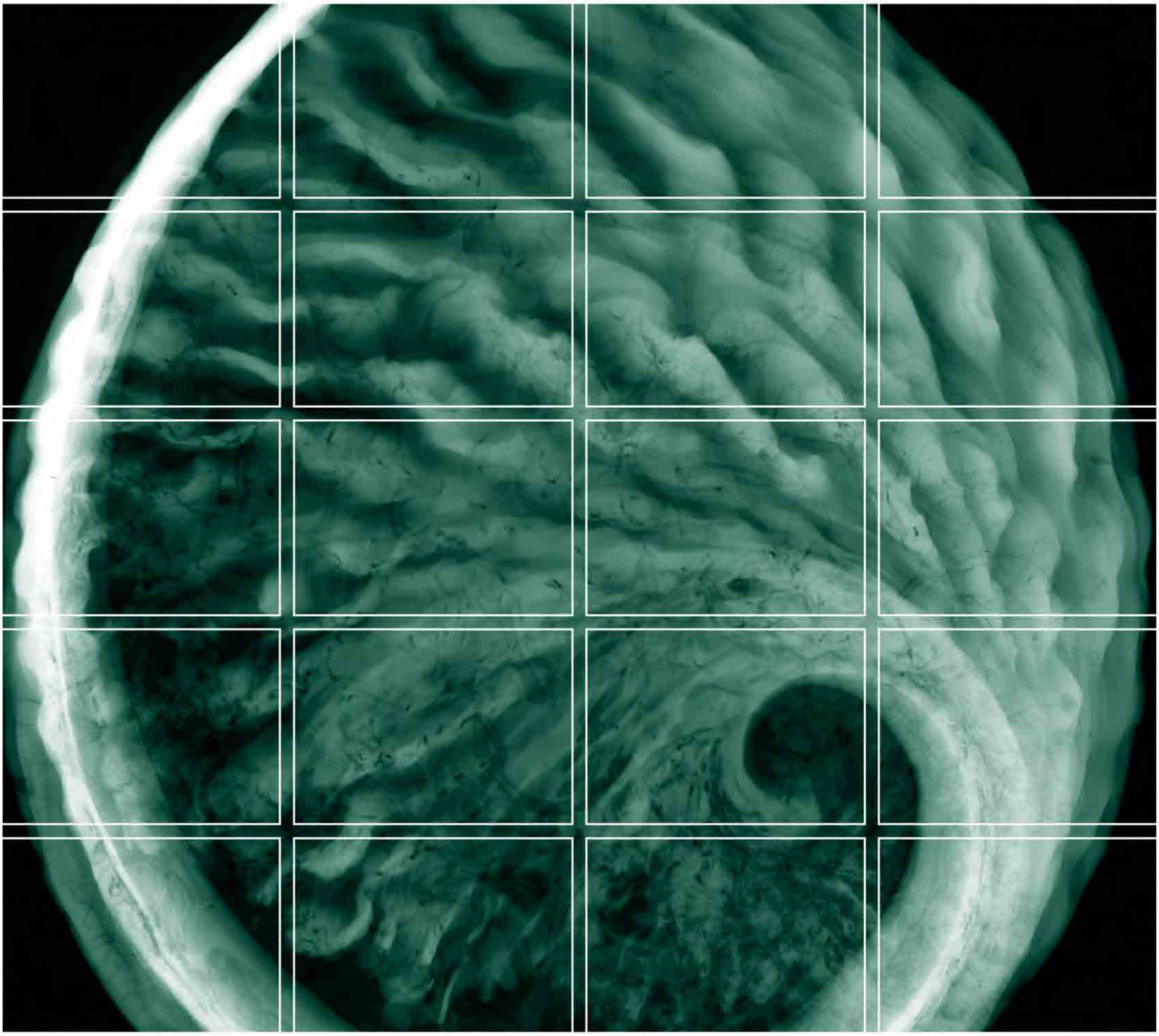
- There is a strong correlation between *Gambusia*-free ponds and **breeding**
- Although they have a small number of ponds, **NCIG** (2 out of 3) and **HDC** (7/7) are largely *Gambusia* free
- All **constructed habitats** (cluster ponds, new HDC ponds, NWL) are free of *Gambusia*
- K104A was *Gambusia*-free until the **large rainfall** on the 6th January (which connected it with K104) – in 'normal' years this would probably remain free of *Gambusia*



* indicates large open-water ponds; area was calculated as perimeter length x 5 metres. The actual areas of these ponds are much larger but the open water is not suitable bell frog habitat

Annex G

Kooragang Island Former Waste Emplacement Facility Landfill Closure Works: Sites K2, K10 North & K10 South, Response to SEWPaC Requests for Information (ERM 2013)



Kooragang Island Former Waste Emplacement Facility Landfill Closure Works:
Sites K2, K10 North & K10 South

Response to SEWPaC Requests for Information

Hunter Development Corporation

July 2013

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Kooragang Island Former Waste Emplacement Facility Landfill Closure Works:

Sites K2, K10 North & K10 South

Response to SEWPaC Requests for Information

Hunter Development Corporation

July 2013

0186182_Final_Version 2

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Prepared by:	*Thomas Muddle*
Position	*Project Manager*
Signed:	
Date:	*22 July 2013*
Approved by:	*Troy Collie*
Position:	Partner
Signed:	
Date:	*22 July 2013*

Environmental Resources Management Australia Pty Ltd Quality System

Quality ISO 9001

Quality-ISO-9001-PMS302

CONTENTS

CONTENTS

CONTENTS

LIST OF FIGURES

LIST OF TABLES

CONTENTS

EXECUTIVE SUMMARY

The Kooragang Island Waste Emplacement Facility (KIWEF) ceased operation in 1999 following a 30 year lifespan as an operational waste facility servicing BHPB's Mayfield Steelworks. In 2002, the NSW State Government gave responsibility for the KIWEF Closure Works to the Regional Land Management Council (RLMC) and, in 2008, RLMC was renamed the Hunter Development Corporation (HDC).

Newcastle Port Corporation (NPC) is the current owner of the land. HDC acts as NPC's agent in completing certain aspects of land management including the KIWEF closure works. The proposed closure works are to take place in areas known as K2, K10 South and K10 North (the Proposal). The Proposal's location and the layout of proposed capped areas, which form the basis of the referral, are provided in Figure 1.1.

The Proposal is to be completed in accordance with the requirements of the approval of surrender of licence number 6437 held by HDC (Surrender Notice number 1111840 as varied 2 May 2013 issued by the Environmental Protection Agency (EPA)). The detailed design has been based on the EPA-approved Revised Final Landform and Capping Strategy (GHD, 2009). The varied Surrender Notice 1111840 recognises that the Proposal may be undertaken synergistically with the proposed Port Waratah Coal Service Terminal 4 (T4) development, should it be approved.

NPC referred the Proposal (EPBC Referral number 2012/6464) to the Department of Sustainability, Environment, Water, Population and Communities (SEWPaC) on 12 July 2012. SEWPaC requested additional information on 3 August 2012. This document presents key elements of the detailed investigations and technical analyses undertaken by SMEC (2013) to address those SEWPaC requests.

The SMEC (2013) key findings are summarised as follows:

- *works are not proposed in known or mapped GGBF habitat areas;*
- *the proposal provides significant benefits to the environment by limiting the potential for contaminated material from emplaced fill leaching into the surrounding environment;*
- *improvements are predicted in water quality due to the capping works which would provide ecological benefits to listed protected species;*
- *potential negative effects would not be of a magnitude that would significantly impact on GGBF, Australasian Bittern or migratory bird habitat;*
- *it is highly unlikely that the proposed works would disrupt the breeding cycle of any species;*
- *areas of appropriate foraging and breeding habitat would be retained within and adjacent to the proposal site;*
- *it is not necessary to have any restrictions on the timing of works, from the perspective of seasonality and fauna ecology;*

- *the capping works will not provide additional water pathways by which Mosquito Fish (Gambusia holbrooki) could migrate;*

- *the hydro-salinity regime of ponds immediately downgradient of the works will generally become slightly wetter and less saline as a result of the capping works.*

Based on the above findings based on SMEC (2013) model outputs, the capping design is confirmed as appropriate and beneficial in:

- *separating water flow pathways (surface and ground water) to optimise clean water sources for habitat ponds;*

- *enabling the collection and drainage of treated waters with relatively low salinity;*

- *delivering freshwater into ponds (Long; Windmill Rd Open channel) that, because of their recorded past elevated salinities, would not have provided optimal GGBF habitat in the past;*

- *having no discernible effect on hydro-salinity conditions in the majority of adjacent ponds; and*

- *promoting an integrated post-construction sustaining water cycle across the managed landform.*

1 INTRODUCTION

Environmental Resources Management Australia Pty Ltd (ERM) has been engaged to prepare a response to the *SEWPaC Request for Information* (SEWPaC RFI). This proposed action relates to part of the NSW State Government's Closure Works required under approval of surrender of licence number 6437 (notice number 1111840) on the former Kooragang Island Waste Emplacement Facility (KIWEF) by the Hunter Development Corporation (HDC).

The KIWEF site closure is to be actioned, following its 30 year lifespan as an operational waste facility servicing the BHP's Mayfield Steelworks. The Closure Works are to be based on an *Environmental Protection Agency Revised Final Landform and Capping Strategy* (GHD, 2009) but are limited specifically to Areas K2, K10 South and K10 North (the Proposal). The proposal location and layout are provided in *Figure 1.1*.

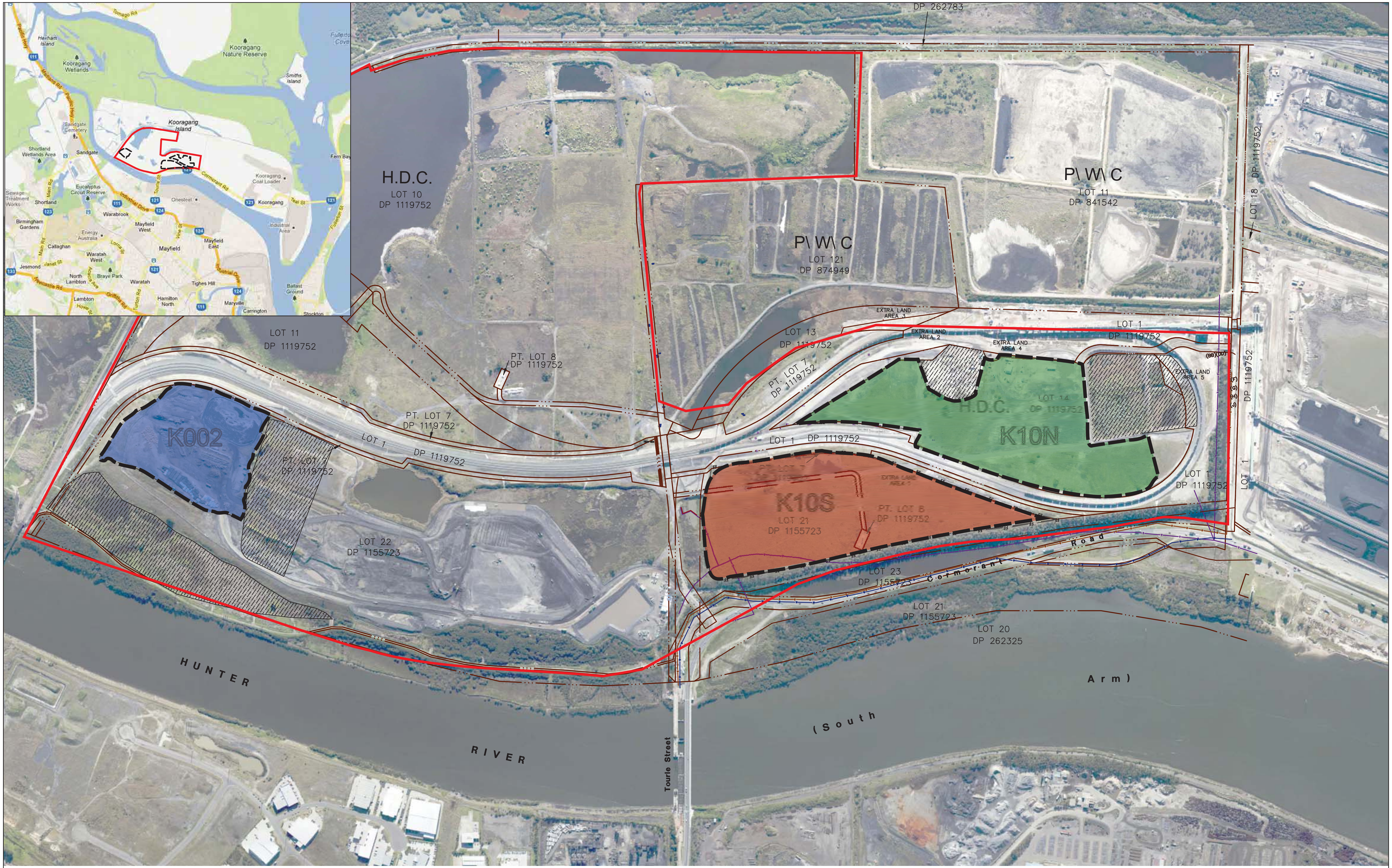
The extent of the referral area, as originally referred, matches up with that of the full Closure Works. The referral application form (GHD, 2012) includes a statement that the works are not a component of a larger action (Section 1.12) but Section 2.7 discusses potential Phase 2 of the closure works being K3, K5 and K7, should the proposed Port Waratah Coal Services T4 proposal not proceed. The referral notes the potential need for a subsequent and separate referral to be made for the K3, K5 and K7 closure areas.

However, the SMEC (2013) modelling and environmental impact assessment undertaken to date on the activities subject to this referral demonstrate that there is not potentially a significant impact in the northern portion of the Closure Works from K2, K10 South and K10 North capping.

1.1 BACKGROUND

HDC is the NSW Government entity responsible for the implementation of the closure of the former BHP Newcastle Steelworks KIWEF. The closure is regulated by the NSW EPA under the *Protection of the Environment Operations Act*. The landfill is currently owned by the NSW State Property Authority (SPA) and administered by the delegated land owner being the Newcastle Port Corporation (NPC).

The site is subject to a number of potentially significant environmental constraints. In particular, the Green and Golden Bell Frog (GGBF), protected under State and Federal legislation, occurs on the broader KIWEF closure site which has areas mapped to be significant habitat for the species. A number of environmental investigations have been undertaken to assess the Proposal and a document relationship map is presented in *Figure 1.2*.



Legend

- Overall KIWEF Closure Works Area
- Closure Works Subject of this REF
- Area K2
- Area K10 North
- Area K10 South

N

0 80 160 240m

Source:
HDC/SMEC Dwg No. 0000-0003 Rev C 15/11/2012

Client:	Hunter Development Corporation
Drawing No:	0186182h_SEWPaC_Res_C001_R0.cdr
Date:	13/05/2013 Drawing size: A3
Drawn by:	JD Reviewed by: TM

This figure may be based on third party data or data which has not been verified by ERM and it may not be to scale. Unless expressly agreed otherwise, this figure is intended as a guide only and ERM does not warrant its accuracy.

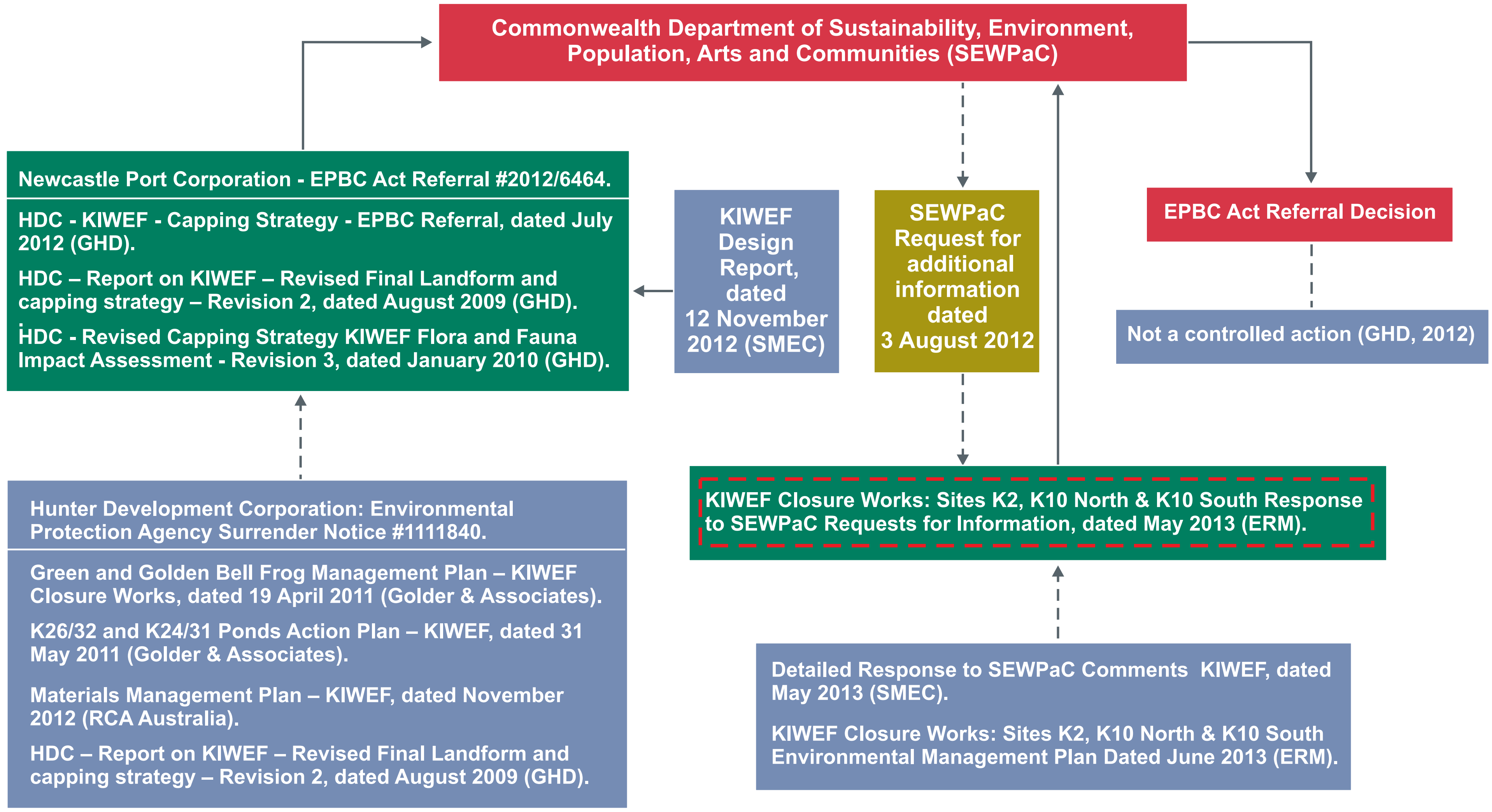
Figure 1.1 - Project Location and Layout

Former Kooragang Island Waste Emplacement Facility
Landfill Closure Works: Sites K2, K10 North & South
SEWPaC Response

Environmental Resources Management ANZ

Auckland, Brisbane, Canberra, Christchurch, Hunter Valley, Melbourne, Perth, Port Macquarie, Sydney

ERM



Legend

- Primary Information Document
- Supporting Information Document
- Referral Decision
- This Document

Client:	Hunter Development Corporation
Drawing No:	0186182h_SEWPaC_Res_C008_R0.cdr
Date: 23/05/2013	Drawing size: A4
Drawn by: JD	Reviewed by: TM

This figure may be based on third party data or data which has not been verified by ERM and it may not be to scale. Unless expressly agreed otherwise, this figure is intended as a guide only and ERM does not warrant its accuracy.

Figure 1.2 - KIWEF Document Relationship Map

Former Kooragang Island Waste Emplacement Facility Landfill Closure Works: Sites K2, K10 North & South SEWPaC Response

Environmental Resources Management ANZ

Auckland, Brisbane, Canberra, Christchurch, Hunter Valley, Melbourne, Perth, Port Macquarie, Sydney

ERM

In 2010, HDC submitted Revised Final Landform and Capping Strategy version 2 dated December 2009, supported by a *Flora and Fauna Assessment* (GHD, 2010), to the Office of Environment and Heritage (OEH). HDC gained OEH endorsement of the strategy in late 2010. OEH accepted that the project was unlikely to present a significant risk to GGBF. However, it recommended that HDC refer the project to the Commonwealth department of Sustainability, Environment, Water, Population and Communities (SEWPaC) for further determination under the *Environment Protection and Biodiversity Conservation Act* (EPBC Act). NPC subsequently referred the Proposal (Referral number 2012/6464) to the SEWPaC on 12 July 2012. SEWPaC requested additional information on 3 August 2012.

HDC engaged SMEC to prepare a detailed Design Report for the proposal. The Design Report, titled *Detailed Response to SEWPaC Comments, Kooragang Island Waste Emplacement Facility* (SMEC, 2012) provides relevant background and design information used in the preparation of the detailed design documents, the sources of information relied upon, critical assumptions made, outstanding issues, alternatives considered as well as justification for preferred solutions. SMEC were also engaged to undertake detailed investigations on site hydrology in relationship to Matters of National Environmental Significance (SMEC, 2013) to guide a response to the SEWPaC RFI, provided in *Annex A*. ERM was subsequently commissioned to provide a response to the SEWPaC RFI which is embodied in this report based on the findings of SMEC (2013).

It is noted that the project will also be assessed under Part 5 of the NSW *Environmental Planning and Assessment Act 1979* as the proposed development is permissible without consent under State Environmental Planning Policy (Major Projects) 2005. A Review of Environmental Factors (REF) is currently being prepared that assesses the environmental risks and impacts of the proposal and will incorporate any required management and mitigation measures into project planning.

1.2 MATTERS OF THE SEWPAC RFI AND KEY FINDINGS

Table 1.1 shows the information requested by SEWPaC. It provides a summary of NPC's responses, and identifies where in this report they are located.

Table 1.1 SEWPaC request and Key Findings described in this Response

Information request	Where Addressed	Summary of response
Detailed analysis of how current vs future changes to pond depths could affect pond suitability as habitat for Green and Golden Bell Frog (GGBF), listed migratory birds and the Australasian Bittern over time, in relation to: vegetation, pond morphology and volumetric capacity, longevity of water level changes etc. *Please also provide details of possible mitigation measures which could be implemented if changes are found to be having an adverse effect on any of the species or their habitat, and thresholds which could trigger these actions.*	*Chapter 2*	Additional surface flows would result from impermeable capping causing a slight increase in freshwater volumes from the areas capped. These are predicted to result in changes in water level or wetting and drying periods with reduced dry periods in Long Pond and Windmill Road Open Channel. This may constitute a beneficial outcome to key GGBF habitat. The quantum of change in hydro-salinity condition is very small in other potentially affected ponds. Ecological thresholds for GGBF health are presented (based on pond water level and pond salinity) and these are interpreted for both existing and proposed developed conditions. These thresholds show that not all ponds meet "optimum" conditions currently. Under the developed condition in the long term, increased periods of "optimum" conditions would occur, especially in Long Pond and Windmill Rd Open Channel which are currently too brackish for GGBF habitat. Detailed analysis supports the conclusion that altered hydro-salinity does not impact GGBF habitat and in the long term is likely to result in beneficial outcomes to GGBF populations on Kooragang Island.
Past (if available) and current water quality characteristics (ie pH, salinity, turbidity, contaminant levels etc) of ponds that would receive run-off from areas affected by the proposed works.	*Chapter 3*	This section identifies large variability in water quality across ponds on or near the KIWEF sites. It establishes water quality to provide a baseline for sound temporal comparisons for monitoring future effects.
Detailed analysis of likely changes to water quality in ponds (including pH, salinity, turbidity, contaminants etc) as a result of runoff from areas affected by the proposed works, particularly in relation to maintaining suitability of the habitat for the Green and Golden Bell Frog (eg salinity levels may be preventing the infection of frogs by amphibian Chytrid Fungus), and any other potential effects of any changes on	*Chapter 4*	In the context of frog biology, the Proposal has the greatest potential to impact water quality (salinity) as a result of altered site hydrology.. Other water quality parameters were assessed by SMEC (2013) in the context of high natural variability of pond waters. Surface water run-off is to be treated in appropriately sized sediment basins to reduce turbidity (and total suspended sediments) prior to discharge. Sediment basins for treatment would be installed immediately before the development of the capped areas. Construction inspection and monitoring would verify the adequacy of site management measures.

Information request	Where Addressed	Summary of response
GGBFs and other EPBC Act listed species. *Please discuss the characteristics of the capping materials (such as topsoil) and any other materials proposed to be used in relation to possible influences on water quality changes.*		The relationship between salinity, the risk of chytrid fungus and GGBF health for existing and developed conditions was analysed in detail. SMEC (2013) included judgements by Dr A White about salinity tolerances in order to derive thresholds that enable impact assessment, management and monitoring actions. Because of the potential risk of enriched dissolved nutrients in runoff and leachate, topsoil is not currently proposed to be imported. The use of imported topsoil is to be avoided where possible but, in the event of topsoil being required, it will be appropriately treated and/or sourced to minimise the risk of chytrid fungus and enriched runoff.
Details of the timing of works in relation to key life-cycle stages of the GGBF, Australasian Bittern and use of the site by migratory wading birds. *Discuss aspects that could affect these species (eg noise, lighting, movement etc) and demonstrate that the timing of works will minimise disturbance to these species, particularly during key life-cycle stages (ie breeding periods).* *It is noted that Deep Pond constitutes "important habitat" (see EPBC Act significant impact guidelines) for several species of listed migratory birds. For example, refer to the Environmental Assessment for the Port Waratah Coal Services T4 Project, which can be accessed on the NSW DP&I website.*	*Chapter 5*	During construction, ground disturbance would be limited to elevated areas which contain a cover of modified non-native grasses. No work activity or ground disturbance would occur within the adjacent to ponds or within mapped GGBF habitat. The proposal is unlikely to indirectly affect key life cycle stages of GGBF so it is not necessary to require seasonal restriction to construction work schedules because: • Work areas for capping are limited to K2, K10 North and K10 South, each over the course of 12 months or less. These areas do not contain mapped key GGBF habitat; • Site based management measures would be adopted. Measures such as daytime construction works only; use of sediment controls and frog fencing; and the early installation of stormwater basins would manage the risk of construction impacts. Furthermore, drainage and hydrological modelling shows no more than low levels of long term hydrologic modification are likely in ponds and, overall, considered beneficial to managing GGBF habitat. Important habitat at Deep Pond is not subject to significant hydrologic effects from capping works at K2 (or other areas to be capped) and the changed run-off volume would likely to be insignificant in comparison to direct surface run-off and groundwater inflow in Deep Pond's catchment.

Information request	Where Addressed	Summary of response
Details of any GGBF monitoring program (as recommended by the Flora and Fauna Assessment) to ensure impacts on GGBF are minimised. For example: *a) Methods for monitoring the presence/absence and abundance of GGBFs in suitable habitat on site, before, during and after works commence;* *b) Methods for monitoring water quality in ponds affected by the proposal;* *c) Thresholds which would indicate adverse impacts on GGBFs or their habitat; and* *d) Adaptive responses if adverse impacts on GGBFs or their habitat were identified.*	*Chapter 6*	Relevant lead and lag indicators of GGBF population and habitat health are identified and linked through the adoption of thresholds to adaptive responses. Impact prediction shows that a small specific change in hydro-salinity is likely to result from additional surface waters from rainfall-runoff (after treatment) sourced largely from K10 capping. Detailed analysis presented in *Chapter 2* soundly underpins the conclusion that there would be no significant impact on GGBF habitat quality. When compared with the nominated thresholds, the changed hydro-salinity would be beneficial in the long term for GGBF habitat. Monitoring proposed include: a) GGBF abundance and distribution monitoring within and surrounding ponds identified as potentially affected by proposed action and pre-clearance GGBF surveys of works area; frog relocation in the event that individuals are found; and on-call ecologist with frog handling capabilities to identify and relocate individuals during works; b) Continuous water level and salinity loggers in potentially affected ponds; and sediment pond water quality monitoring prior to discharge; c) salinity thresholds for GGBF Chytrid protection, tadpole health and adult health established and used to develop extended wetting or drying regime triggers for adaptive management; and d) Adaptive managagment measures established to re-direct future surface water to ponds showing 'signs of stress' using a number of temporary measures and, where mitigation fails, the potential conversion of sediment ponds to constructed wetlands or re-establishment of existing infiltration regime. Ongoing monitoring provides a precautionary measure and to validate the prediction, based on a framework and methods for monitoring to test null hypotheses supported by: • A project specific experimental design with putative impact "priority" ponds; • Key GGBF population indicators and GGBF habitat water quality parameters; • If needed, other actions and adaptive measures that may correct undue trends relative to the established thresholds.

Information request	Where Addressed	Summary of response
Provide a map which clearly shows all areas of GGBF habitat (not restricted to areas where frogs were found during 2009) in relation to the proposed 30m buffers from works, and describe how these buffers would be demarcated in the field so that they are clearly visible to workers during construction works.	*Figure 1.3* and *Chapter 7*	*Chapter 7* provides clarification on proposed 30 m buffers. In particular, the 30 m buffer to works was specifically proposed in the original capping strategy in relation to requirement for seasonal restrictions on any proposed clearing within identified GGBF habitat associated with Area K3, well distant from any works from this proposal. No works are proposed within mapped GGBF habitat. Some works are proposed with 30 m of mapped GGBF habitat, as illustrated in *Figure 1.3*, and this is consistent with the approved capping strategy. With the establishment of frog exclusion fencing and construction footprint demarcation, there is a very low likelihood of accidental encroachment to mapped GGBF habitat. A map is provided in *Figure 1.3* to illustrate the 30 m distance to mapped GGBF habitat in relation to Areas K2, K10 North and K10 South.
Details of any hygiene protocol designed to minimise the risk of introducing or spreading amphibian Chytrid Fungus to, on or from the site prior to, during and after any works associated with the project, which is consistent with the NSW National Parks and Wildlife Service Hygiene Protocol for the Control of disease in Frogs.	*Chapter 8*	Hygiene protocols would be in accordance with NSW National Parks and Wildlife Service *Hygiene Protocol for the Control of Disease in Frogs*.
Details of any mitigation measures to ensure that water would not be transferred or connected (ie during high rainfall periods) from ponds containing the fish Gambusia holbrooki to ponds which do not contain this species.	*Chapter 9*	Abstraction of water from on-site ponds for use during construction would not occur. As part of the post-construction landform design, there is no altered or additional drainage that would cause greater drainage inter-connectivity across the site for movement of exotic fish. There is no scheduled routine transfer of water between ponds in the post-construction phase.
Details of any mitigation measures to minimise impacts on GGBFs during construction works, for example by: *a) Construction and ongoing, regular maintenance of frog-proof fencing around the perimeter of works areas;* *b) "Pre-clearance" surveys for GGBFs (undertaken by a suitably qualified and experienced person) inside fenced areas*	*Chapter 10*	*GGBF Management Plan – KIWEF Closure Works* (Golder & Associates, 2011) has been endorsed by the NSW EPA in Surrender Notice #1111840 as varied 2 May 2013) and includes commitment to hygiene protocols, frog-proof fencing and pre-clearance surveys.

Information request	Where Addressed	Summary of response
within one week prior to works taking place; and *c) Developing criteria for and selecting release sites for any GGBFs captured during pre-clearance surveys, and a map showing selected release sites.*		
A description of how areas affected by the capping works would be stabilised and revegetated, including measures to mitigate effects of stormwater, sediment and erosion run-off. *Discussion as to the likely success of revegetation in the K2 area, which will not be covered with topsoil after capping. Please outline any characteristics of the revegetated areas or their ongoing management that will make them suitable as GGBF habitat in the long term.*	*Chapter 11*	The key risk avoidance measure for potentially altered surface water quality would be to maintain a 'like for like' surface, so use of imported topsoil is not proposed.

1.3 *SUMMARY OF POTENTIAL IMPACTS ON GGBF POPULATIONS AND GGBF HABITAT*

The capping design purposefully accounts for partial redirection of rainfall into runoff that increases surface flow volumes with low salinity (via sedimentation basins) to receiving waters forming GGBF habitat ponds. The intention of capping is primarily to reduce infiltration and in turn reduce leaching of higher salinity groundwater which potentially contains contaminants. The result of net increase in the surface water volumes draining along existing channels, pathways and ponds would be to provide additional relatively fresh water to GGBF habitat.

Based on SMEC (2013) hydro –salinity modelling, the hydro-salinity regimes of ponds immediately downstream of the capping works will generally have higher standing water levels after rainfall and be less saline. Hydrology modelling also showed that ponds would contain water at slightly higher levels for slightly longer periods. The greatest magnitude of change is predicted to be experienced in Long Pond and Windmill Road Open Channel and to a lesser degree K2 Basin and Easement Pond. The SMEC analysis confirms a strong correlation between salinity and water level in ponds with salinity increasing as water levels decrease due to concentrating effects of evaporation.

As noted by SEWPaC, current research has confirmed a link between salinity level and prevention of mortality in frogs from chytrid fungus (Stockwell, 2013). An independent GGBF expert also provided advice on salinity thresholds for GGBF including salinity levels providing:

- chytrid fungus protection (greater than 1650 µS/cm),
- breeding habitat (less than 2900 µS/cm); and
- adult living habitat (less than 4100 µS/cm).

The SMEC model results indicate the capping design generally results in beneficial outcomes for GGBF as the ponds would have, on average, suitable foraging and breeding habitat for more time. This would occur typically during drier periods due to ponds retaining fresher water for longer.

Specific effects were predicted for individual ponds but overall there is a resultant beneficial effect of extra fresh water in surface drainage. The series of ponds across the site with a diversity of water quality conditions may support a natural resilience to natural wetting and drying cycles. This inter-relationship would be maintained after the construction of the Proposal.

The capping strategy successfully balances the need to limit the infiltration of rainfall into fill and groundwater with utilising the surface runoff for enhanced site management outcomes.

1.4 PROPOSAL DESCRIPTION

The following Proposal description is based on the information provided in the SMEC (2012) Design Report on key development components and construction activities.

The Proposal is described in the *Kooragang Island Waste Emplacement Facility Capping Strategy EPBC Referral* (GHD, 2012) with detailed guidance contained within the SMEC (2012) draft design report with final detailed design being completed as of July 2013. The proposed construction methodology developed in the Capping Strategy generally is as follows:

- for K10 North and K10 South, surface grading levels are restricted to interface with the NCIG rail loop catch drains and culverts, forcing low points to these locations;
- implementation of hygiene protocol consistent with the NSW National Parks and Wildlife *Service Hygiene Protocol for the Control of disease in Frogs* prior to entry to site;
- pre-clearance surveys for GGBF within works area in advance of all earthworks including installation of frog proof fencing and erosion and sediment controls;
- installation of erosion and sediment controls designed to meet the highest protection standard for environmentally sensitive environments based on *Managing Urban Stormwater - Soils and Construction*, (Landcom, 2004) as well as documents from other States and Internationally (such as "International Erosion Control Association – Australasia");
- installation of zero discharge controls in K10 north prior to installation of off-site capping materials;
- removal of vegetation and strip and stockpile re-useable topsoils and capping materials;
- grade works area to minimum 1%. Cut from within this area, if deemed suitable, may be used as fill. Additional fill (if necessary) shall be sourced from an approved offsite source to achieve grades;
- construct capping layer to minimum of 0.5 m from materials available onsite or sourced from off-site sources, compacted with permeability of $1x10^{-7}$ m/s; and
- cover final surface with stockpiled surface soils and revegetate.

The KIWEF referral area, works area, proximate potentially GGBF breeding habitat, proposed GGBF abundance and distribution monitoring locations and hydro-salinity logger locations are illustrated *Figure 1.3*. .

Legend

- Works Area
- Boundary of Proposed Action Referral Area
- Proximate Potential GGBF Breeding Habitat & Proposed GGBF Abundance & Distribution Survey Areas
- Phase 2 of Closure Works Subject to Potential Future Referral
- Hydro Salinity Logger Location
- Typical Current Pond Surface Water Area
- Potential Pond Surface Water Area (Wet Conditions)
- Inferred Flowpath
- Indicative Flowpath

N

0 150m

Source:
HDC/SMEC Fig No.3 Proj No. 30012008 6/12/2012

Client:	Hunter Development Corporation	
Drawing No:	0186182h_SEWPaC_Res_C002_R2.cdr	
Date:	24/07/2013	Drawing size: A3
Drawn by:	JD	Reviewed by: TM

This figure may be based on third party data or data which has not been verified by ERM and it may not be to scale. Unless expressly agreed otherwise, this figure is intended as a guide only and ERM does not warrant its accuracy.

Figure 1.3 - KIWEF Referral Area and Key Features

Former Kooragang Island Waste Emplacement Facility
Landfill Closure Works: Sites K2, K10 North & South
SEWPaC Response

Environmental Resources Management ANZ

Auckland, Brisbane, Canberra, Christchurch, Hunter Valley, Melbourne, Perth, Port Macquarie, Sydney

ERM

1.5 POTENTIAL GGBF IMPACT PATHWAYS

The EPBC referral listed potential impacts to GGBF, listed migratory birds and the Australasian Bittern as reasons for the referral but ultimately concluded that the proposed action would not significantly impact these species. The referral documentation previously lodged relies on the following assessment reports:

- GHD (2009) *Report on KIWEF Revised Final Landform and Capping Strategy Revision 4, December 2009* (the capping strategy); and
- GHD (2010) *Revised Capping Strategy KIWEF Flora and Fauna Impact Assessment Revision 3, January 2010.*

1.5.1 *Designing for Impact Avoidance*

The assessments listed above include a threatened species habitat assessment that identifies potential impacts resulting from the implementation of the Capping Strategy for the site. The assessments identify mitigation measures for threatened species and their habitats, including the Green and Golden Bell Frog (GGBF) and migratory shore bird species (GHD 2010). Both assessments related to a works area greater than that addressed within current SEWPaC referral, but are nonetheless relevant to this document. The key changes to the current proposed action in relation to the Capping Strategy (GHD, 2009) and *Flora and Fauna Impact Assessment* (GHD, 2010) include:

- project footprint reduced from 60 hectares (Ha) to 32.7 ha;
- the areas K3, K5 & K7 as shown in the Capping Strategy are proposed to be undertaken in synergy with the Port Waratah Coal Service's (PWCS) Terminal 4 (T4) project. The State's Surrender Notice has been varied to allow this. In the event that T4 does not proceed, capping obligations in these areas will revert to HDC and additional assessment and a separate referral will be required for those areas not contained within this referral;
- as a result of the agreement with PWCS, works covered by this referral are no-longer proposed in immediate proximity to wetland fringing vegetation and previously mapped GGBF habitat;
- use of imported off-site capping material limited to capping in K10 North where insufficient on-site material is available. Run-off is to be controlled by zero discharge erosion and sediment controls during construction where necessary;
- clearing limited to existing revegetation on areas to be capped. Pre-clearance surveys for GGBF would be completed within construction works area and the works area enclosed by frog proof fencing;
- no clearing of fringing vegetation or previously mapped GGBF Habitat;

- no clearing of *Freshwater Wetlands on Coastal Floodplains in the NSW North Coast, Sydney Basin and South East Corner Bioregions* Endangered Ecological Community (EEC); and

- no clearing of *Coastal Saltmarsh in the NSW North Coast, Sydney Basin and South East Corner Bioregions* EEC.

These modifications to the proposal have eliminated direct impact of MNES species. The Proposal may indirectly impact MNES species due to short term clearing of potential foraging habitat for the Australasian Bittern and short term barriers to frog movement in the form of frog exclusion fencing across elevated sections of the KIWEF site. These potential impacts would not be significant due to:

- vegetation clearing being limited to already disturbed non-native grassland;

- disturbed grassland is considered unlikely to form the primary foraging resource for any threatened fauna species identified within the vicinity of the site. There are substantial areas of disturbed grassland identified in the local area including on Ash Island and at Hexham Swamp (Umwelt, 2012);

- disturbance would be limited to construction and revegetation stages of the proposal; and

- temporary frog exclusion fencing would be limited to the period of construction.

Notwithstanding, the sensitivity of the site in relation to GGBF and migratory species habitat means that risks of indirect effects require identification and assessment and where appropriate monitoring and mitigation is proposed.

1.5.2 *Residual impact mechanisms to GGBF*

With no direct significant impacts to GGBF habitat, the residual impacts would be limited to indirect effects on GGBF and their habitat including pond hydrology, pond water quality and water levels and modified biological interactions. Threats to GGBF are summarised by SMEC (2013) as:

- changes to pond salinity levels (EC) (refer to *Chapter 4*);

- changes to wetting and drying regimes in the habitat ponds (refer to *Chapter 2)*;

- changes in pond water chemistry, including:

    - increase to algal levels (refer to *Chapter 11*);

- changes to Dissolved Oxygen (DO) levels. DO is an indicator of eutrophication occurring in the ponds, associated with catchment runoff quality or frequency or pond water cycle (refer to *Chapter 2*);

- changes to pond water temperature (refer to *Chapter 4*); and

- changes to suspended sediments or turbidity in the ponds (refer to *Chapter 11*).

Potential effects are discussed in the following chapters to present responses to SEWPaC's request for additional information.

2 *POND HYDROLOGY*

This Chapter provides a response to the SEWPAC request for more information regarding the Proposal's potential impacts on pond suitability as GGBF habitat. It summarises the detailed analysis by SMEC (2013) of how future changes to pond depths could affect pond suitability as habitat over time, in relation to factors such as vegetation, pond morphology, volumetric capacity and longevity of water level changes.

2.1 *PREDICTED CHANGES IN POND OPERATING DEPTHS OVER TIME*

Future pond hydrology may vary when compared to existing conditions because of an increase in surface water discharge from capped areas and reduced groundwater flows due to decreased permeability. There will be no redirection of surface water drainage from one pond to another. The changes to hydrology as a result of the Proposal would include:

- slightly altered minimum pond levels;
- slightly altered wetting and drying regimes in ponds; and
- water quality changes.

The resultant changes in pond levels and wetting and drying regimes, together with implications for GGBF are summarised as follows:

> *"…the water level and wetting and drying regimes indicated by the above results show that for the majority of the ponds there are not expected to be any significant changes, ie BHP Wetlands, Blue Billed Duck Pond, Deep Pond, Easement Pond, Easement Pond South, and K2 Pond. Minor changes are expected in Long Pond and Windmill Road Open Channel, but these changes are not expected to impact on GGBF or other threatened species. There are no significant changes predicted to the Eastern Ponds as a result of the proposed capping works, as there is no change to the contributing catchment area to these ponds, and only minor changes to the groundwater regime" (SMEC 2013 pp13-14).*

Further details of how these conclusions were reached are presented below. The identified potential water quality changes and related implications for GGBF are presented in *Chapter 4.*

2.1.1 *Pond water levels and volumetric capacity*

Maximum water levels are dictated by pond outlets based on estimated invert levels of weirs, culverts and overflow channels. No modification is being made to physical nature of the ponds, so the maximum water levels and volumetric capacity of the ponds would not change from existing conditions. Furthermore, no significant change in minimum pond levels would occur in most of the ponds as a result of altered future hydrology (SMEC 2013).

Slightly higher low water levels were predicted for Long Pond and Windmill Road Open Channel. These ponds would have a deeper depth than they would have under existing conditions.

Table 2.1 identifies the existing and predicted altered minimum water levels in potentially affected ponds.

Table 2.1 Modelled Existing and Predicted Future Water Levels

	Easement Pond	**Windmill Rd Open Channel**	**Long Pond**	**Easement Pond South**	**BHP Wetlands**	**Blue Billed Duck Pond**	**Deep Pond**	**K2 Basin**
Estimated Pond Base Level [1]	0.40	0.66	0.46	1.30	0.70	0.40	0.40	0.50
1st %ile Water Level (m AHD)	0.85 **(0.83)**	1.16 **(1.38)**	0.75 **(0.95)**	1.64 **(1.63)**	0.92 **(0.92)**	0.99 **(0.98)**	0.92 **(0.94)**	0.50 **(0.50[2])**
Maximum (discharge) Water Level (m AHD)	2.60	2.46	1.86	3.00	2.00	2.50	2.00	2.00
%ile exceedance of discharge water level	1 **(1)**	1**(4)**	1**(3)**	3**(2)**	4**(3)**	7**(6)**	2**(2)**	2**(2)**

1. Inferred from 100% probability of exceedance values in SMEC (2013) model.
2. Model predicts dry conditions for 4% of the time under developed conditions as opposed to 3% under existing conditions.
3. **brackets and bold** indicates modelled level under developed scenario**.**

Table 2.1 shows that the modelled changes in pond low water levels are typically very small, between one and two centimetres. Only in Long Pond and Windmill Road Open Channel would the minimum standing water level be changed measurably. These changes would have the effect of slightly higher standing water levels at times when the water depth in those ponds is low. This effect is better described by examining wetting-drying regimes and Probability of Exceedance analysis (refer *Section 2.2*).

Changes in pond hydrology are only expected in Long Pond and Windmill Road Open Channel with these changes being associated with generally wetter conditions, although the maximum water level would remain the same (SMEC 2013).

As such, the GHD (2012) *KIWEF Capping Strategy – EPBC Referral* indicating that the vegetation communities on the periphery of the ponds that are associated with periodic inundation would simply migrate up or down gradient appears valid. Therefore, no significant change to the habitat of fauna species and ecological communities would occur.

2.2 *ALTERED WETTING AND DRYING REGIMES AND ECOLOGICAL EFFECTS*

SMEC (2013) modelled existing and proposed wetting and drying regimes for affected ponds with the changes summarised in *Table 2.2*. Notable predictions are alternately highlighted in these tables. SMEC (2013) also sought comment from GGBF expert Dr Arthur White on the water level, frequency and duration "thresholds" to identify potential impacts on GGBF associated with modelled results.

Table 2.2 Summary of Modelled Upper and Lower Water Levels for KIWEF Ponds [1]

Pond	Percentage of Time Ponds predicted to be Below existing 20th%ile Standing Water Level [2]	Percentage of Time Ponds predicted to be Below existing 80th%ile Standing Water Level [3]
BHP Wetlands	21%	82%
Blue Billed Duck Pond	22%	84%
Deep Pond	19%	80%
Easement Pond	21%	73%
Easement Pond South	21%	83%
K2 Basin	22%	81%
Long Pond	4%	65%
Windmill Rd Open Channel	1%	72%

1: from SMEC (2013)
2: % of post construction time when water would be shallower than the existing 20th%ile level
3: % of post construction time when water would be shallower than the existing 80th%ile level

The effect of slightly wetter conditions over the longer term can be seen in *Table 2.2*. The largest predicted effects would be in Long Pond, Windmill Road Open Channel and Easement Pond where typically the post construction condition would result in more time when a high water level in the pond would occur. This same effect is shown in another way in *Table 2.3* and *Table 2.4.*

Table 2.3 Existing & Predicted Drying Cycle (Low Water) for KIWEF Ponds

Pond	Low Water Level Frequency[1]		Average Duration of Low Water Level Events	
	Existing	Predicted post construction	Existing	Predicted post construction
BHP Wetlands	1 in 1.5 Years	1 in 1.3 Years	102 Days	97 Days
Blue Billed Duck Pond	1 in 1.8 Years	1 in 1.8 Years	128 Days	134 Days
Deep Pond	1 in 2.1 Years	1 in 2.2 Years	145 Days	138 Days

Pond	Low Water Level Frequency[1]		Average Duration of Low Water Level Events	
	Existing	Predicted post construction	Existing	Predicted post construction
Easement Pond	1 in 1.6 Years	1 in 1.7 Years	111 Days	111 Days
Easement Pond South	1 in 1.3 Years	1 in 1.3 Years	92 Days	98 Days
K2 Pond	1 in 1.5 Years	1 in 1.2 Years	102 Days	92 Days
Long Pond	1 in 1.3 Years	1 in 5.2 Years	94 Days	59 Days
Windmill Rd Open Channel	1 in 1.2 Years	N/A	86 Days	0

Source: From SMEC (2013)

1: a water level lower than the 20th percentile level that exceeds a 4 week period.

Table 2.4 Existing & Predicted Wetting Cycle (High Water) for KIWEF Ponds

Pond	High Water Level Frequency[1]		Average Duration of High Water Level Events	
	Existing	Predicted Developed	Existing	Predicted Developed
BHP Wetlands	1 in 1.4 Years	1 in 1.5 Years	89 Days	87 Days
Blue Billed Duck Pond	N/A	N/A	N/A	N/A
Deep Pond	1 in 1.5 Years	1 in 1.5 Years	102 Days	106 Days
Easement Pond	1 in 1.7 Years	1 in 1.3 Years	107 Days	119 Days
Easement Pond South	1 in 3.5 Years	1 in 4.7 Years	59 Days	55 Days
K2 Pond	1 in 1.8 Years	1 in 1.9 Years	110 Days	109 Days
Long Pond	1 in 1.5 Years	1 in 1 Years	100 Days	110 Days
Windmill Rd Open Channel	1 in 50 Years	1 in 50 Years	49 Days	58 Days

Source: From SMEC (2013)

1: a water level higher than the 80th percentile level that exceeds a 6 week period.

As part of the SMEC (2013) scope, Dr Arthur White indicated that impacts attributable to altered inundation hydrology would be expected to GGBF if, in post construction conditions:

- low water level durations were for a period of at least **four weeks longer** than under existing conditions; or,
- **six weeks longer** in high water level duration.

These thresholds can be interpreted in relation to modelled outputs to make predictions about potential impacts to GGBF against these stated wetting-drying thresholds (*Table 2.5*).

By way of summary, the maximum lengthening in any of the ponds in the extended duration drying and wetting was six and ten days, respectively.

Table 2.5 Summary of Pond Hydrology changes and Risk of Potential Impact

Pond	Comments based on *Tables 2.3 & 2.4*	Potentially significant change in wetting and drying regimes against thresholds for GGBF habitat?
BHP Wetlands	Low water level events predicted to occur at a greater frequency every 1.3 years in comparison to existing every 1.5 years. Duration of dry events predicted to decrease by 5 days to an average of 97 days.	No
Blue Billed Duck Pond	No change is predicted to the frequency of low water level events with duration predicted to increase by 6 days to an average of 134 days.	No
Deep Pond	A small decrease to once in 2.2 years is predicted to the frequency of low water level events with duration predicted to decrease by 7 days to an average of 138 days.	No
Easement Pond	Above the high water level an additional 7% of the time. Low water level events are predicted to occur at a reduced frequency of every 1.7 years (compared to existing 1.6 years), although the frequency of wet events would change from 1.7 to 1.3 years ARI. The duration of low water events is not predicted to change, although high water events would slightly extend by 12 days.	No
Easement Pond South	Above the high water level would be reduced by 3%. No change is predicted to the frequency of low water events with duration of these events predicted to increase by 6 days to an average of 98 days.	No
K2 Basin	Low water level events are predicted to occur at a greater frequency every 1.2 years in comparison to existing every 1.5 years, with low water duration predicted to decrease by 10 days to an average of 92 days. No change for high water conditions.	No
Long Pond	Significantly wetter. Low water events predicted to occur at a reduced frequency to every 5.2 years from existing 1.3 years ARI and the frequency of wet periods increase to once every 1year from the current 1.5 years with duration of wet events extending by 10 days.	No
Windmill Rd Open Channel	Significantly wetter with time below the identified low water level reduced by 19% with low water events no longer predicted to occur. No increase in frequency of wet periods with average duration increased by 9 days to 58.	No

Eastern Ponds

Hydro salinity modelling was not undertaken by SMEC (2013) for the Eastern Ponds. SMEC (2013) present Douglas Partners groundwater modelling results and summarise impacts to pond depth and salinity at that site as follows:

> *"The proposed capping works will have no impact on the surface water aspects of the hydro-salinity for Eastern Ponds. That is because the catchment areas and the*

pond characteristics are to remain unchanged, meaning that runoff and evapotranspiration in the ponds will be consistent with existing conditions".

and

"The total reduction in the groundwater inflows and outflows of the Eastern Ponds are 4.43 m^3 /day and 3.32 m^3 /day respectively. The contributing surface water catchment of these ponds totals approximately 5 hectares, of which the majority of catchment is pond surface area (resulting in direct rainfall to the pond, ie 100% runoff). This would yield an average pond inflow of over 100 m^3 /day. Hence the change in groundwater flows identified above would represent less than 5% of the total inflow volume from surface runoff, making the relative impacts to the hydrologic and salinity regime of the Eastern Ponds insignificant".

2.3 *SUMMARY OF POTENTIAL EFFECTS ON HYDROLOGY*

The modelling results above indicate that, with the exception of Long Pond and Windmill Road Open Channel, the predicted change in pond hydrology would not be discernible from the variability that currently exists between the ponds and within each pond in time. The model predicted very small changes in pond depth in most ponds with the only notable change being a "shift" towards generally wetter conditions in Long Pond and Windmill Road Open Channel. Dr Arthur White has indicated that reduced dry periods in these ponds would constitute a beneficial outcome to the GGBF (SMEC, 2013: p13).

The SMEC (2013) detailed analysis supports the conclusion that altered hydro-salinity does not impact GGBF habitat or habitat of listed migratory birds of the Australasian Bittern and in the long term is likely to result in beneficial outcomes to GGBF populations on Kooragang Island. As no significant hydrological impacts have been identified as a result of the Proposal, no specific hydrological mitigation measures are considered to be required. Hydro-salinity monitoring and adaptive management measures are included in SMEC (2013) and discussed further in *Chapter 6* of this document.

3 *BASELINE WATER QUALITY CHARACTERISTICS*

This Chapter addresses the SEWPAC request for information on past and existing water quality of the ponds that would receive flows from the capped areas. This Chapter summarises baseline water quality characteristics of these ponds using data sourced from a number of studies that examine water quality on Kooragang Island.

3.1 *DESCRIPTION OF AVAILABLE DATA*

Water quality monitoring data taken from across the broader KIWEF site from a number of investigations has been summarised in *Table 3.1*. Sources of data include but are not limited to:

- Newcastle Coal Infrastructure Group Rail Loop;
- Port Waratah Coal Service T4 Environmental Assessment;
- BHPB Hunter River Remediation Project;
- University of Newcastle within the Eastern Ponds for HDC – KIWEF; and
- Regional Land Management Corporation / HDC Environmental Protection Licence monitoring data (ongoing).

Table 3.1 provides a summary of key water quality parameters for potentially affected ponds. A consolidated set of tables, with calculated percentile and mean values and comparisons against relevant ANZECC Guideline values is provided in *Annex A* of SMEC (2013).

3.2 *RECENT MONITORING DATA*

SMEC (2013b) reported on actual level logger water level and electrical conductivity results for eighteen (18) level loggers of which five were installed within surface water bodies. The report effectively addressed a six month period from November 2012 to April 2013.

SMEC (2013b) reported "….that review of the water level graphs for the surface water bodies indicated that over the six month monitoring period, there were four to five recharge events. Also review of the water level/EC graphs indicated that there was a trend between water level within surface water bodies and salinity levels within the ponds. Typically, as water levels within the ponds increased, there is a corresponding reduction in salinity levels. This is due to the influx of freshwater runoff into the surface water bodies, which in turn dilutes the salinity within the surface water bodies." So it can be concluded (as it is intiuitvely) that salinity and water level are inversely correlated. Also SMEC (2013) stated that "…overall, the ponds currently exhibit a very strong correlation between pond water level and salinity, with levels currently exceeding the natural upper bound threshold values that allow for the breeding of GGBF". However, there was no information in available data sheets to show the relationship between water quality concentrations and water level. Having been established this important relationship enables use of pond water level as a practical surrogate for developing adapative management triggers for the future.

Table 3.1 Summary of Key Water Quality parameters for KIWEF Ponds (SMEC 2013)

Surface Water Body		**Monitoring Period**	**pH**	**Dissolved Oxygen (% DO at 25°C)****	**Electrical Conductivity (µS/cm) - Full Monitoring Period**	**Electrical Conductivity (µS/cm) - More Recent Data***	**Turbidity (NTU)**	**Total Suspended Solids (mg/L)**	**Total Nitrogen (mg/L)**	**Total Phosphorus (mg/L)**	**Total Copper (mg/L)**	**Total Zinc (mg/L)**
ANZECC Guideline Value			**7 to 8.5**		**NC**	**NC**	**6-50*****	**NC**	**0.3**	**0.03**	**0.0013**	**0.016**
BHP Wetlands	10%ile	6/09/2006 - 25/10/2012	7.3		723	-	1	5	0.3	0.02	0.0010	0.003
	90%ile		9.2		1424	-	48	84	2.7	0.17	0.0033	0.010
	Mean		8.0	117%	1116	-	21	38	1.4	0.13	0.00175	0.006
Blue Billed Duck Pond	10%ile	29/11/2002 - 14/12/2012	8.2		845	-	3	7	0.8	0.04	0.0010	0.005
	90%ile		9.5		1380	-	35	64	2.3	0.70	0.0050	0.055
	Mean		8.8		1166	-	14	23	1.4	0.30	0.0036	0.041
Deep Pond	10%ile	17/11/1981 - 14/12/2012 (*13/08/1997 - 14/12/2012*)*	7.8		1900	1752	2	4	0.8	0.03	0.0010	0.006
	90%ile		9.5		27930	6252	42	47	4.2	0.96	0.0300	0.151
	Mean		8.7		10524	3659	16	26	2.4	0.32	0.0125	0.084
Easement Pond	10%ile	20/08/1996 - 25/05/2007 (*22/03/2006 - 14/12/2012*)*	7.5		2038	2010	1	5	0.6	0.02	0.0010	0.005
	90%ile		9.0		4544	3950	13	19.2	1.8	0.12	0.0200	0.044
	Mean		8.3		3978	2910	6	10	1.1	0.06	0.0101	0.021
Easement Pond South	10%ile	8/03/2012 - 14/12/2012	7.9		481	-	5	7	0.6	0.02	0.0010	0.005
	90%ile		8.3		881	-	79	82	1.5	0.22	0.0034	0.023
	Mean		8.1	75%	703	-	34	37	1.1	0.11	0.0018	0.011
Eastern Ponds	10%ile	27/02/2012 – 11/01/2013	-	-	2710	-	5	-	0.9	0.052	0.005	0.007
	90%ile		-	-	6790	-	24	-	2.8	0.068	0.005	0.044
	Mean		-	-	4750	-	15	-	1.8	0.06	0.005	0.024

Surface Water Body		Monitoring Period	pH	Dissolved Oxygen (% DO at 25°C)**	Electrical Conductivity (µS/cm) - Full Monitoring Period	Electrical Conductivity (µS/cm) - More Recent Data*	Turbidity (NTU)	Total Suspended Solids (mg/L)	Total Nitrogen (mg/L)	Total Phosphorus (mg/L)	Total Copper (mg/L)	Total Zinc (mg/L)
K2 Pond	10%ile	13/08/1997 - 16/04/2012	7.5		1554	-	-	15	-	0.32	0.0043	0.013
	90%ile		8.8		5928	-	-	648	-	1.08	0.0620	0.099
	Mean		8.1	112%	3431	-	-	240	-	0.67	0.0273	0.055
Long Pond	10%ile	4/05/1990 - 14/12/2012 (*15/03/1999 - 14/12/2012*)*	7.8		2945	2845	3	2	0.6	0.05	0.0010	0.005
	90%ile		9.3		29900	10565	239	270	7.6	0.87	0.0240	0.193
	Mean		8.5	110%	11166	6332	71	70	3.2	0.35	0.0086	0.082
Windmill Rd Open Channel	10%ile	13/08/1997 - 25/10/2012	7.4		3600	-	16	13.1	0.9	0.08	0.0029	0.005
	90%ile		9.4		16500	-	16	29.9	0.9	0.08	0.0181	0.325
	Mean		8.5	115%	9547	-	16	21.5	0.9	0.08	0.0105	0.137

1. * - Historical EC Testing prior to 1997 / 1999 in these ponds was found to have salinity elevated above current levels. It is unsure if this is a real condition or possibly a monitoring error. SMEC have reported two ranges of these values given this situation - Refer to Appendix A in SMEC (2013) for full data records.
2. ** - Dissolved Oxygen derived from limited hand held meter readings only *** ANZECC (2000) Lowland rivers

4 ANALYSIS OF FUTURE WATER QUALITY

This chapter addresses SEWPAC's request for a detailed analysis of likely changes to water quality in the receiving ponds. This chapter provides detailed analysis of likely changes to water quality in ponds (including pH, salinity, turbidity, contaminants) as a result of drainage, being treated runoff, from areas affected by the proposed works. The analysis pays particular attention to maintaining suitability of the habitat for the GGBF, and other potential effects of any changes on GGBFs and other EPBC Act listed species. This chapter also discusses the characteristics of the capping materials (such as topsoil) and any other proposed materials in relation to possible influences on water quality changes.

4.1 CAPPING MATERIAL CHARACTERISTICS

In Areas K2 and K10 South, the cap will consist primarily of existing coal washery rejects (CWR) sourced from site. Additional material will be imported from off-site for capping in K10 North due to an identified deficit in onsite material in this area. CWR consists of materials such as coal fines, rock, sand and soil. The capping design and materials management plan has been approved by the NSW EPA in the Conditions of Surrender (as varied 2 May 2013).

On each area to be capped, existing topsoil shall be used as part of the protective revegetation layer. The use of in situ materials in the revegetation layer will minimise the risk of effects on water quality from allochthonous materials.

Topsoil is not proposed to be imported. However, if imported topsoil is required, it will be appropriately sourced to avoid importing chytrid to the site. Topsoil sourced from areas remote from frog habitat will be used, if required, as these areas do not host chytrid fungus. The chosen design avoids the use of imported topsoils, such as sandy loams, as these may risk introducing high nutrients and/or fungi in uncontrolled runoff.

4.2 SUMMARY OF PREDICTED CHANGES ON WATER QUALITY

As discussed in *Chapter 2*, pond hydrology is predicted to change slightly as a result of the modified runoff volumes associated with the proposed capping works. These changes are related to the predicted increase in surface water volumes from capped areas and reduced groundwater flows, as well as redirection of some surface water runoff. The pond hydrology implications of the project include water quality, and are summarised as follows:

> *"In general, improvements in water quality due to the capping works would provide ecological benefits to all species. Any negative changes would not be of a magnitude that would significantly impact on GGBF, Australasian Bittern*

or migratory bird habitat. The capping works would also provide significant benefits to the environment in general by limiting the potential for contaminated material from the fill leaching into the surrounding environment." (SMEC, 2013 p3).

The capping of the site has been designed to contain significant risk of contamination from previous industrial activities. Containment beneath capping would decrease the load of potential contaminants entering ponds, leading to an overall improvement in water quality and future ecosystem health in habitat ponds. The capping has therefore been designed to produce a significant environmental benefit not just to the site, but to the broader Hunter River estuary.

The capping however has the potential to affect specific water quality parameters linked to the survival of GGBF. Changes to salinity have the potential to impact GGBF.

4.3 PREDICTED WATER QUALITY - SALINITY

Water quality is a key factor in GGBF habitat. The capping works have the potential to change water quality at the site, particularly salinity. The relationship between salinity and GGBF habitat can be summarised in the following ways:

- the capping works are designed to reduce leachate and contaminant loads leaving the landfill and affecting receiving waters by limiting surface water penetration into the fill aquifers. This includes mobilisation and leaching of salt content in the fill;
- the capping will increase volumes of less saline surface water runoff from capped areas, and reduce higher saline groundwater inflows into the ponds;
- research indicates that chytrid fungal control is linked to salinity and water temperature (Stockwell, *et al*, 2012) with saline water acting to limit infection below the threshold that would result in mortality;
- further research is needed to confirm if certain heavy metals (Cu and Zn) provide chytrid fungal control (Threlfall *et al*, 2008);
- water temperature on standing water in ponds is related to rates of solar irradiance on pond surfaces and, as such, proposed capping works would not have a significant effect on water temperature;
- the current range of salinity in the ponds varies significantly;
- elevated salinity in the ponds are generally attributed to concentrating effects of evaporation during dry periods;

- saline leachate baseflow from the landfill cells also influences the salinity, but to a lesser degree than the evaporation effects;

- peak salinity values in low elevation ponds are recorded as high as 20 000 to 35 000 µS/cm, indicating intrusion of waters from the estuarine aquifer; and

- currently there is a very strong correlation between pond water level and salinity, with levels currently exceeding the threshold values that allow for the breeding of GGBF in some ponds.

The SMEC (2013) detailed analysis was based on salinity focussed water quality modelling as this is identified as the key potential impact mechanism on GGBF habitat.

Salinity has the potential to impact GGBF in two main ways. These are:

- an increase in salinity in ponds above "thresholds" that would prevent GGBF tadpole and/or adult survival or habitation; and,

- reductions in salinity below a "threshold" that may provide protection against Chytrid fungus infection or development.

SMEC (2013) reported that the independent GGBF expert provided guidance on these thresholds, reproduced in *Table 4.1*, based on current GGBF research. It should be noted that these thresholds are indicators of the suitability of ponds as GGBF habitat and do not constitute project triggers. They have been used in the assessment process to identify the potential for significant impacts on GGBF to occur.

Table 4.1 Suggested Salinity Comparison Values for KIWEF Surface Water Bodies

Chytrid protection threshold[1]	GGBF tadpole health threshold[2] **(µS/cm)**	**GGBF Adult health threshold [3] (µS/cm)**
1,650 µS/cm	2,900 µS/cm	4,100 µS/cm

1. EC below threshold presents increased risk of mortality resulting from Chytrid Fungus.
2. EC above threshold indicates unsuitability for GGBF tadpole survival.
3. EC above threshold indicates unsuitability as GGBF adult breeding habitat.

Salinity levels below 1650 (µS/cm) (Chytrid risk bracket) were identified as sub-optimal GGBF condition with individual animals likely not afforded salinity-related protection from chytrid fungus. Chronic or long term low salinity levels below this threshold were considered to risk impact on GGBF although it would not put individuals at immediate risk of harm in the absence of Chytrid fungus (Stockwell, 2012). It is also noted that, with the exception of Long Pond and Windmill Rd Open Channel, all ponds that were assessed have ponded water with salinity below 1650 µS/cm.

4.3.1 *Salinity and GGBF Habitat management*

Salinity levels between 1650 and 2900 (µS/cm) are considered "optimal GGBF habitat" as this range is interpreted by SMEC (2013) to provide Chytrid protection while also providing for tadpole survival and habitation and adult breeding. Salinity levels between 2900 and 4100 (µS/cm) were reported by SMEC (2013) to be suitable for adult GGBF occupation typically limited to breeding periods. Salinity above 4100 (µS/cm) was not considered by SMEC (2013) to be suitable habitat for GGBF adults over extended periods.

It is likely that adult GGBF would move away from ponds with salinity levels above 4100 µS/cm rendering them unlikely to be used for breeding (and therefore egg laying, hatching and tadpole habitation). Any change in water quality conditions to salinity ranges below this threshold would constitute a beneficial effect on GGBF habitat.

SMEC (2013) have modelled the predicted changes in pond salinity for each pond potentially affected by capping. A comparison of the percentage of time in each salinity "bracket" between existing and post capping conditions is presented in *Table 4.2*.

The diagram presented in *Figure 4.1* summarises the metrics of *Table 4.2* but notably, in addition to the predicted salinity change in priority ponds, it also shows an existing site-wide salinity effect that is potentially critical in the management of GGBF habitat. *Figure 4.1* shows that the set of ponds are grouped in three (3) salinity categories which have been typified for the existing and proposed habitat thresholds, although they could just as readily be shown for the summary statistics for salinity.

These categories group:

- freshwater ponds (BHP Wetland; BB Duck Pond; Easement Pond South);
- fresh-brackish ponds (Deep Pond; Easement Pond; K2 Basin); and
- brackish-saline ponds (Long Pond; Windmill Rd Open Channel).

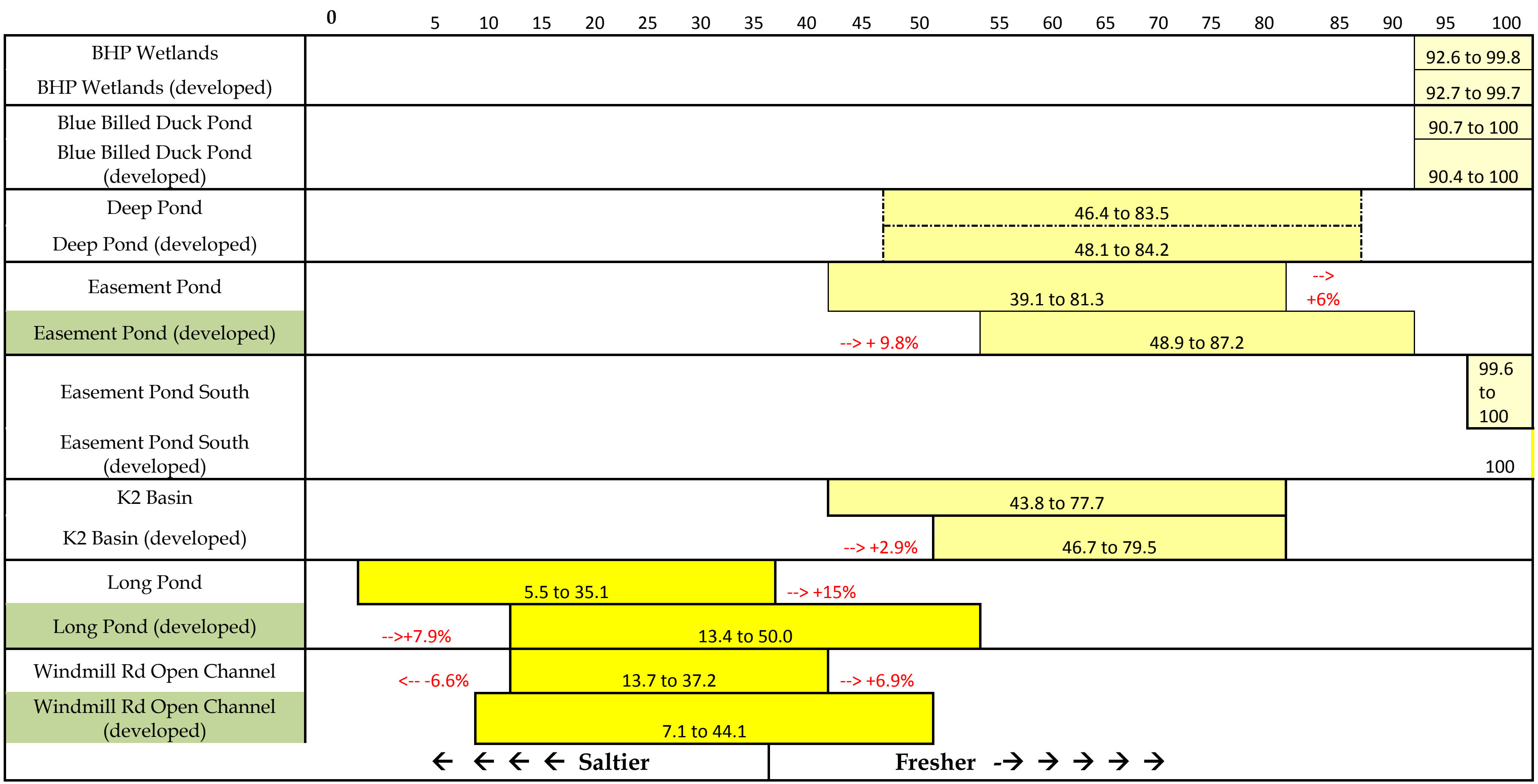
Overall, the apparent series of divergent salinity conditions between the ponds is likely to be important through variable inter-annual wetting-drying cycles, thereby providing available aquatic habitat of suitable salinity at any time. It is likely that the maintenance of the series of ponds with variable salinity (and other water quality) supports ecosystem resilience and helps sustain frog populations in relation to the set of salinity thresholds derived for GGBF ecology. The salinity range of Long Pond and Windmill Rd Open Channel is not reduced and is predicted as more brackish conditions to become generally more like Deep, Easement and K2 ponds.

Table 4.2 GGBF Habitat thresholds and Pond Salinity "Brackets"

Pond	"No Chytrid protection Bracket" Percentage of Time Salinity is below Chytrid Fungus Trigger (< 1650 µS/cm)			"Optimum Bracket" Percentage of Salinity is between Chytrid Fungus Trigger and Tadpole Trigger (>1650 and <2900 µS/cm)			"Adult GGBF Habitat Bracket" Percentage of Time Salinity is above tadpole habitat threshold and below adult habitat threshold (>2900 and <4100 µS/cm)			"Unsuitable Habitat Bracket" Percentage of Salinity is above adult habitat threshold (>4100 µS/cm)		
	Existing	**Proposed**	**Percent change**	**Existing**	**Proposed**	**Percent change**	**Existing**	**Proposed**	**Percent change**	**Existing**	**Proposed**	**Percent change**
BHP Wetlands	**92.6%**	**92.7%**	0.1%	7.2%	7.0%	-0.2%	0.2%	0.3%	0.0%	0.0%	0.0%	0.0%
Blue Billed Duck Pond	**90.7%**	**90.4%**	-0.3%	9.3%	9.6%	0.3%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Deep Pond	**46.4%**	**48.1%**	1.8%	37.1%	36.1%	-1.0%	9.4%	8.9%	-0.5%	7.1%	6.8%	-0.3%
Easement Pond	39.1%	**48.9%**	9.9%	**42.2%**	38.3%	-3.9%	11.7%	8.4%	-3.3%	7.1%	4.4%	-2.7%
Easement Pond South	**99.6%**	**100%**	0.4%	0.4%	0.0%	-0.4%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
K2 Basin	**43.8%**	**46.7%**	2.9%	33.9%	32.8%	-1.1%	18.0%	16.9%	-1.1%	4.3%	3.7%	-0.6%
Long Pond	5.5%	13.4%	7.8%	29.6%	**36.6%**	7.0%	20.3%	20.7%	0.4%	**44.5%**	29.3%	-15.2%
Windmill Rd Open Channel	13.7%	7.1%	-6.7%	23.5%	37.0%	13.5%	6.9%	6.3%	-0.6%	**55.9%**	**49.7%**	-6.3%

1. **bold** indicates the predominant salinity condition in each pond.
2. interpreted from SMEC (2013) modelling results.
3. beneficial outcomes are associated with both – and + changes depending on "bracket"

Figure 4.1"Optimum Bracket" - Percentage of time (in yellow) when salinity is between Chytrid Fungus Threshold and Tadpole Survival Threshold (>1650 and <2900 µS/cm)



4.3.2 *Salinity Effects and GGBF Habitat in Priority Ponds*

Chapter 3 showed that the largest predicted change in pond salinity would be in Long Pond; Windmill Rd Open Channel and, to a much lesser extent, Easement Pond. The analysis, summarised in *Table 4.2*, also presents that same effect but in a way that shows its relevance against salinity thresholds derived for GGBF ecology.

Note, typical salinity conditions in priority ponds are these:

- Long Pond: mean salinity = 11 200 μS/cm.
- Windmill Rd Open Channel: mean salinity = 9500 μS/cm.

These elevated existing levels indicate that neither Long Pond nor Windmill Rd Open Channel are likely to have been or currently be significant GGBF habitats as these ponds very often exceed the upper bound of preferred GGBF salinity as determined by SMEC (2013) and shown in *Table 4.1*. The modelled reduction in typical salinity conditions at these ponds is entirely beneficial to their future potential as GGBF habitat because there is greater proportion of time when salinity would be lower than 4100 μS/cm, so it would tend to become more suitable as adult breeding habitat.

The following gives further specific interpretation for priority ponds, where a change in long term salinity was modelled and may be evident in the longer term.

Long Pond

At present, Long Pond salinity is frequently naturally at a level that makes it unsuitable GGBF habitat, with 44.5% of the time above 4100 **μS/cm.** During wet periods there are currently lengthy periods of time within the Optimal bracket (29.6%) and those that suit adult GGBF habitat (20.3%).

The SMEC (2013) modelling predicts a reduction in salinity equating to an extra 15% of time in lower salinity brackets: the 'Optimum' bracket (7%) and 'No Chytrid protection' Bracket (7.8%). On balance, salinity in the pond is more often lower than the 'Unsuitable GGBF habitat' threshold, so this is identified as a beneficial impact on GGBF, as Long Pond becomes habitable more frequently (and following rain) when GGBF adults are known to breed.

Windmill Road Open Channel

At present, Windmill Rd Open Channel salinity is frequently naturally within the range making it unsuitable GGBF habitat, with 55.9% of time above 4100 **μS/cm.** During wet periods there are currently lengthy periods of time within the Optimal bracket (23.5%) and those that specifically suit adult GGBF habitat. The SMEC (2013) modelling predicts an overall reduction in average salinity and the variability of salinity shown as 6.3% less time above the 'Unsuitable GGBF habitat' threshold and 6.7% less time spent below the 'No

Chytrid Fungus protection' threshold. A corresponding increase in time in the 'Optimal' bracket was modelled (an increase of 13.5% to 37% of time). This is a beneficial impact on GGBF habitat in Windmill Rd Open Channel.

Easement Pond

Under existing conditions, Easement Pond is typically within the 'Optimum Salinity' bracket, but there are also periods (almost 40%) within the 'No Chytrid protection' bracket. Because of its typically fresh water condition and the addition of periods of fresh surface water inflows, a ten percent increase in time in the "No Chytrid protection bracket" was modelled. This would be partly offset by a three percent decrease in the "Unsuitable GGBF habitat bracket" (SMEC, 2013). This is an increased risk of Chytrid effects in this pond.

Impact Summary

The SMEC (2013) hydro-salinity modelling results generally indicate changes in salinity arising from the capping that are expected to be minor when compared to the range of salinity conditions currently observed. The magnitude of the predicted changes in salinity regimes would be much less than 1-2% for important time categories in the majority of adjacent habitat ponds (refer *Table 4.2;* BHP wetland; Blue Billed Duck Pond; Deep Pond; K2 Basin; Easement Pond south).

Measurable salinity reductions are only expected in Easement Pond, Long Pond and Windmill Rd Open Channel. A small increased risk of Chytrid effect has been identified in Easement Pond. The modelling identifies that the expected effects of changes in salinity in the ponds as a result of the capping work is not expected to be significant.

Based on model outputs, the capping design is confirmed as appropriate and beneficial in:

- separating water flow pathways (surface and ground water) to optimise pond clean water sources;
- enabling the collection and drainage of treated waters with relatively low salinity;
- delivering freshwater into ponds (Long; Windmill Rd Open channel) that, because of their recorded past salinities, do not appear to currently present valuable GGBF habitat;
- having no discernible effect on the majority of adjacent ponds; and
- promoting an integrated post-construction sustaining water cycle.

4.4 *PREDICTED WATER QUALITY – OTHER CHARACTERISTICS*

Other water quality characteristics are considered below in order to assess their applicability to ongoing monitoring and site management.

4.4.1 *pH*

Table 3.1 provides a summary of current water quality for the KIWEF ponds indicating that pH levels vary significantly between ponds. SMEC (2013) identify that slightly alkaline conditions are believed to originate from leachate generated from the landfill. As such, the most likely effect as a result of capping the site will be a slight shift to pH neutrality. This is unlikely to have a significant impact as GGBF habitat has been recorded across a broad range from acidic to alkaline conditions.

4.4.2 *Turbidity and Nutrients*

As shown in *Table 3.1,* SMEC (2013) identified that past turbidity within pond waters was variable within each pond, different between each of the ponds and, with an historical mean turbidity across all pond waters of 25 NTU, exceeded the 95% ANZECC Water Quality value for marine / estuarine water. There is potential for turbidity within the ponds to increase during and immediately post-construction as a result of erosion and sediment loading from the proposed capping works. This would stabilise as vegetation and compaction would reduce sediment load in surface runoff.

Best practice erosion and sediment controls for sensitive environments are to be installed prior to capping works commencing. Erosion and sediment control basins have been designed to capture sediment laden runoff from earthworks, and stormwater discharges will be controlled and monitored for quality. In areas where imported material is required for capping, zero discharge measures will be provided through the temporary closure of culverts.

No significant changes to suspended sediments (resulting in turbidity) within the ponds is likely post-construction because, once the site is developed and capped:

- surface layers will be stabilised;
- vegetation would re-establish; and
- sediment basins will remain in place and capture and treat stormwater runoff.

The design incorporates the use of insitu Coal Washery Reject (CWR) material to be re-worked into a low permeability cap which will not induce any long terms changes in surface water runoff. Imported capping material is required in K10 North but, once installed, this would be covered with the existing CWR as the top soil. No imported material is planned to be used for topsoils so no long term effect on nutrient condition in the ponds would result. Water quality monitoring would be undertaken for nutrients to verify ongoing conditions against the historical baseline (refer *Table 3.1*) in each priority pond during the construction phase.

4.4.3 *Contaminants*

SMEC (2013) identified that contaminants may potentially mobilise from the landfill based on past site history. Metal concentrations generally exceed those in ANZECC Guidelines at the majority of the KIWEF ponds. Because of the saline-brackish nature of priority ponds, the ANZECC guideline values for marine waters have been adopted. Where not available, the default trigger levels for freshwater have been used for comparison purposes.

The mean concentrations of the following key potential contaminants exceed the 95% ANZECC guideline values in the majority of KIWEF ponds:

- *Aluminium*: Concentrations range between 0.005 to 11.5mg/L – 95% ANZECC Guideline value for freshwater (0.055mg/L);
- *Boron*: Concentrations range between 0.14 to 2.72mg/L – 95% ANZECC Guideline value for freshwater (0.37mg/L);
- *Cobalt*: Concentrations range between 0.001 to 0.1mg/L – 95% ANZECC Guideline value for marine water (0.001mg/L);
- *Chromium:* Concentrations range between 0.001 to 0.1mg/L – 95% ANZECC Guideline value for marine water (0.0044mg/L), exceeded at five (5) of the ponds;
- *Copper*: Concentrations range between 0.001 to 0.08mg/L – 95% ANZECC Guideline value for marine water (0.0013mg/L);
- *Manganese:* Concentrations range between 0.005 to 3.95mg/L – 95% trigger value criteria (0.08mg/L);
- *Molybdenum*: Concentrations range between 0.001 to 0.405mg/L – 95% trigger value criteria (0.023mg/L), exceeded at 5 of the ponds;
- *Lead*: Concentrations range between 0.001 to 0.58mg/L – 95% ANZECC Guideline value for marine water (0.0044mg/L);
- *Zinc*: Concentrations range between 0.001 to 2mg/L with mean values exceeding the 95% ANZECC Guideline value for marine water (0.015mg/L);
- *Cadmium*: Concentrations range between 0.0001 to 0.1mg/L – 99% ANZECC Guideline value for marine water (0.0007mg/L);
- *Nickel:* Concentrations range between 0.001 to 0.245mg/L – 99% ANZECC Guideline value for marine water (0.007mg/L) exceeded at 5 of the ponds;
- *Selenium:* Concentrations range between 0.001 to 0.05mg/L – 99% ANZECC Guideline value for freshwater (0.005mg/L); and

- *Mercury*: Concentrations range between 0.00001 to 0.05mg/L – 99% ANZECC Guideline value for marine water (0.0001mg/L) exceeded at 5 of the ponds.

These metal concentrations may be due to leachate from the adjacent landfill. The proposed capping is designed to reduce the infiltration rate and the egress of contaminated groundwater from the past waste emplacement areas. A reduction in heavy metal concentrations in pond waters would provide benefits to species including GGBF, Australasian Bittern and other migratory birds.

5 *TIMING OF WORKS*

This Chapter provides a response to SEWPAC's request for more information on the Proposal's timing in relation to key life-cycle stages of the GGBF, Australasian Bittern and use of the site by migratory wading birds. This Chapter provides details of potential impacts of the timing of works in relation to key life-cycle stages of these species, and provides details on measures to minimise disturbance from the works.

5.1 *PREAMBLE*

The capping project will be staged but construction activities at any one location would not extend longer than an estimated 12 month timeframe. Construction hours are to be confined to the standard operating hours contained in the Interim Construction Noise Guidelines (ICNG) of Monday to Friday 7 am to 6 pm, Saturday 8 am to 1 pm with no work on Sundays or public holidays. No night works are proposed.

The following points demonstrate measures to manage the risk of potential impact on GGBF, Australasian Bittern and migratory wading birds:

- no freshwater/brackish wetland habitat or significant terrestrial habitat would be cleared as part of the project;
- no activity is proposed in the mapped ponds, wetlands or in recorded GGBF habitat areas;
- large areas of foraging and breeding habitat are adjacent to the capping works;
- best practice construction controls (including noise, light and erosion and sediment) would be implemented in order to minimise risks on habitat that are adjacent to the proposed capping areas;
- a staged approach to the works will be used to enable the site to stabilise as the works sequentially progress; and
- capping works are located across the elevated sections of the landfill, typically between RL 9 - 10 m AHD.

5.2 *GGBF LIFECYCLE AND KEY MANAGEMENT ACTIONS*

The breeding period for the GGBF is between October and March, with a peak around January-February typically after heavy rain events (Pyke & White, 2001; DEC 2005). Reproductive events are influenced by the weather conditions from season to season and breeding can also take place outside of these periods. Hatching takes place two to five days after ovipositing with tadpole development generally completed within six to 12 weeks, although in some instances they over-winter if their development is not completed before water temperatures fall (Pyke and White, 2001).

No construction works or activities are proposed within potential GGBF breeding habitat. Therefore, there is no need to limit or restrict works within the GGBF core breeding period.

The species is capable of making quite large movements in a single day, up to 1.5 km, and some tagged individuals are recorded to have moved up to 3 km (Pyke and White, 2001) so it is important to maintain site connectivity and movement corridors through the land adjoining the capping areas. Adult frogs do not necessarily stay near to available breeding areas and adults have been found several kilometres from the nearest breeding habitat (Pyke and White, 2001).

GGBF enter a period of torpor over the winter months, sheltering in the bases of dense vegetation tussocks, beneath both natural and artificial debris including beneath the ground surface (Pyke and White 2001). Therefore, in order to retain landscape function (by presenting shelter sites), it is important not to unnecessarily disturb vegetation outside of the capping areas.

In order to avoid foraging adult GGBF and overwintering frogs in torpor on the capping areas, pre-clearance surveys for GGBF will be conducted immediately prior to entry of construction equipment and the areas enclosed by frog-proof fencing. Prior to the capping works commencing, areas of GGBF habitat will also be clearly delineated on the ground by frog-proof fencing with appropriate signage, as well as on the site plan. A suitably qualified ecologist will be available on-call to visit the site should GGBF be encountered during clearing and capping works. This person will also be responsible for relocating any GGBFs that may be found in the works area.

5.2.1 Noise aspects

The noise environment is currently characterised by continuous traffic flows along Cormorant Road, train movements along nearby rail and activities associated with coal loaders. Noise generated by the capping works will typically be continuous relating to shallow earthworks and with no activities such as rock breaking or piling with significant impact energy resulting in noise or vibration.

Noise emissions would be limited to day time standard construction hours. There will be no ongoing operational noise during the post-construction phase once capping is complete. Construction noise effects would be limited to short term disturbance of roosting and foraging animal behaviours resulting in a reduction of the occupancy rates of adjacent suitable habitat. These potential effects are limited in extent and timeframe to potential short term displacement, if at all. Other similar habitat is known to be available through the series of habitat ponds and disturbed grassland adjacent to the site.

5.2.2 *Lighting aspect*

No night works are proposed and, as such, no lighting impacts from glow and spill would occur. Lighting of site compounds, if required, will prioritise the need to avoid light spill out side of construction works footprint and will be undertaken in accordance with *Australian Standard 4282 – 1997 Control of the obtrusive effects of outdoor lighting*.

5.2.3 *Movement*

Potential movement effects include:

- interactions of vehicles and plant with listed fauna during clearing and earthworks; and
- barriers to animal movement.

Once on the capping area, movement of machinery and vehicles is a risk posed during ground clearing and earthworks because of the potential to co-occur with GGBF individuals. Mitigations measures include:

- pre-clearance surveys and relocation;
- frog exclusion fencing to prevent entry / re-entry of GGBFs onto the work site; and
- frog exclusion fencing or barriers will not constrain inter-connective pathways and potential movement of individuals along drainage lines or lands outside of the capped areas.

Such actions and measures are discussed further in *Chapter 10*. Barriers to frog and other potential fauna ground movements would be removed on completion of capping works.

5.3 *AUSTRALASIAN BITTERN*

The Australasian Bittern lives alone or in loose groups and favours permanent fresh-waters dominated by sedges, rushes, reeds or cutting grasses. The breeding season for this species is from October to January, and is sometimes loosely colonial but in other cases pairs have been observed to maintain territories when several are present in a reedbed (HSO 2008). Records for the Australasian Bittern exist to the east and west of the site and potential foraging habitat for the Australian Bittern occurs within the site. However, as the vegetation on the site is not of sufficient density or extent to represent potential breeding habitat, the timing of the works would not affect any of the birds key life cycle stages.

None of the emergent vegetation surrounding ponds is to be disturbed by any construction activities and therefore no impact to potential habitat is anticipated.

SMEC (2013) provides additional discussion of available mitigation measures for the Australasian Bittern.

5.4 *MIGRATORY WADING BIRDS*

No migratory birds listed under the EPBC Act were recorded during the field surveys undertaken by GHD in their Flora and Fauna Assessment (GHD, January 2010). Several records exist within the area especially at Deep Pond (Umwelt, 2012). Open water and areas of emergent vegetation are likely to be the preferred habitat for migratory species and this habitat would remain unaltered by the proposed capping works. The works are not likely to disrupt the lifecycle of migratory species (GHD, January 2010) especially with the noise, light and movement mitigation measure described above. Therefore, the timing of the works is not critical in order to avoid the risk of significant impacts. Assessments of Significance under the EPBC Act also confirmed that the proposal is unlikely to have a significant impact on listed migratory wading species.

SMEC (2013) provides additional discussion of available mitigation measures for listed migratory wading birds.

6 *PROPOSED GGBF MONITORING PROGRAM*

This Chapter provides details of proposed the GGBF and habitat monitoring program which aims to detect potential impacts on GGBF, including by describing:

a) *Methods for monitoring the presence/absence and abundance of GGBFs in suitable habitat on site, before, during and after works commence; (Section 6.3)*

b) *Methods for monitoring water quality in ponds affected by the proposal; (Section 6.4)*

c) *Thresholds which would indicate adverse impacts on GGBFs or their habitat; (Section 6.5); and*

d) *Adaptive responses if adverse impacts on GGBFs or their habitat were identified (Section 6.6).*

6.1 BACKGROUND

Context to future monitoring is given below by reviewing past survey and investigation methods.

6.1.1 Flora & Fauna Assessment 2009 (GHD, 2010)

The GGBF monitoring program proposed by GHD (2010) was based on a survey program during February to March 2009. It included the following activities conducted over three surveys:

- tadpole and metamorph surveys using standardised dip-net surveys, and searches for basking metamorphosing frogs;
- tadpole / fish traps using netted fish traps and a light bait;
- call playback and auditory surveys; and
- habitat spotlight survey following the auditory surveys, examining suitable sites using a spotlight for all frog species. Photographing individual frogs, all captured individuals were photographed so that individuals may be distinguished, if required, during ensuing sampling events.

GHD recommended that a "*…site wide joint monitoring of the Green and Golden Bell Frog population should be continued seasonally, where feasible, from the next breeding season to help best manage the population and determine if any adverse impacts have resulted from any works/modifications to Green and Golden Bell Frog habitat across Kooragang Island, before and after the emplacement capping works.*"

It was also recommended by GHD that the Kooragang population be monitored long-term following the methods utilised in the current Green and Golden Bell Frog Monitoring Program in order to gauge the potential impacts of previous development on Kooragang Island. The monitoring program would consider information from recent studies of the local population including Hamer *et al* (2008).

The GHD study recommended that monitoring of the population should be undertaken by all concerned parties within the range of the population, including Kooragang Island and Ash Island. It would require an adaptive and comprehensive management plan, approved by all parties (including DECC, now OEH), which would drive rapid responses to any potentially threatening processes to encourage the local Green and Golden Bell Frog population to recover. The basis of such a combined approach to monitoring and management of the Green and Golden Bell Frog population has been undertaken by HDC and BHP Billiton for recent past surveys.

SMEC (2013) summarises current and historic GGBF monitoring including:

- RPS Harper Somers O'Sullivan in 2006, 2007 & 2008 for BHP Billiton;
- GHD (for HDC) in 2009 across the KIWEF site;
- Umwelt (for HDC) in March 2011 within K10 North;
- University of Newcastle (for HDC) within the Eastern Ponds;
- PWCS across Kooragang Island; and
- NCIG in the GGBF Environmental offset areas on Ash Island.

Other organisations may be similarly involved in this research and the production of a site-wide management plan. Furthermore, SMEC (2013) also recognise the activity of other proponents on Kooragang Island in that the current Port Waratah Coal Services (PWCS) Terminal 4 (T4) proposal commits to implementing a comprehensive monitoring program that includes data on the GGBF populations near the KIWEF site. The T4 program, and data, subject to its approval and once available, would be able reviewed to ascertain if those works and/or approved capping works have had a discernible effect on the GGBF with regard to key ecological parameters. Also SMEC (2013) refers to supporting GGBF monitoring that is specified in the Action Plan for the K26/K32 ponds (Golder & Associates, May 2011).

6.1.2 Identification of What Constitutes Suitable Habitat And Where It Is Potentially 'At Risk'?

Aquatic habitat is suitable if it continues in time with pre-existing properties of form and function including those shown in *Table 6.1* below.

The assigned potential impact ratings are described in *Chapters 2* and *4* of this document.

Table 6.1 Aquatic Habitat Characteristics

Key habitat component	Typical characteristics	Impact rating & location of "Priority" Ponds
Pond dimensions and landform integrity (direct)	Pond shape; area; bathymetry; connectivity; movement corridors	Very low to nil potential in any modelled pond.
Water sources, quality and hydrological cycle (indirect)	Rates and periodicity (water levels); surface and groundwater inflow quality; pond hydrography; salinity range and levels (plus water chemistry)	With management, low potential. Highest predicted fractional hydro-salinity modification at Priority Ponds - Long Pond and Windmill Road Open Channel. K2 Basin may potentially be effected by nearby capping.
Species interactions and ecosystem integrity (indirect)	Chytrid fungus; Gambusia; Weed and algal growth; eutrophication processes.	With management, nil to low potential in existing priority or other modelled ponds.

Note, the physical state of ponds would not be altered by proposed works - directly or indirectly - during the short period of capping on adjacent lands.

With the passage of time during the post-construction stage, habitat pond hydrology would not change significantly. There would only be a slight hydrology effect, so only water quality aspects of habitat condition are relevant for that extended post construction phase.

The largest potential effect in altered hydro-salinity, and thereby frog ecology, would occur over the longer term in:

- Long Pond;
- Windmill Road Open Channel; and to a lesser extent; and
- Easement Pond.

K2 Basin adjacent to K2 capping works may also potentially be affected directly by construction work runoff. The proposed works would only slightly, and not significantly, affect hydro-salinity conditions in the long term.

These three ponds have been termed "priority" ponds for the purposes of being the priority for focussing and structuring investment and management effort in:

- planning, construction and operational measures;
- site based management; and
- impact monitoring, testing and performance reporting.

Nevertheless, on the basis that all potentially affected ponds are noted to spend some below the Juvenile GGBF survival threshold, all water bodies proximate to the works area have been identified as potential GGBF breeding habitat as illustrated in *Figure 1.3*. Hydro-salinity monitoring and GGBF abundance and distribution monitoring is proposed in all such areas. It is expected that the predictions of the hydro-salinity model (SMEC 2013) would be verified by the monitoring results during the periods outlined in the experimental design below. It is also noted that the labelling of these ponds as potential GGBF breeding habitat is based solely on salinty and should not be interpreted as definitive GGBF habitat. GHD (2010) undertook GGBF habitat assessment and the methodology and results of this assessment are presented in *Chapter 7*.

6.2 EXPERIMENTAL DESIGN AND STATISTICAL BASIS FOR IMPACT MONITORING

This section is presented to determine a valid framework for monitoring key sites (eg "priority" ponds) through time.

6.2.1 *Statement of Impact and Working Hypotheses*

Water quality initially flowing into "priority" ponds may potentially be affected during construction, but that risk would be mitigated by adopting runoff control measures and treatments for quality aspects such as TSS/turbidity.

With the passage of time during the post-construction phase, habitat pond condition would not change significantly as there would be only be a slight hydrology (hydro-salinity) effect, as previously detailed. Only water quality aspects of pond habitat condition would be relevant for the extended post-construction phase in priority ponds even under the predicted situation of improved GGBF habitat (salinity) conditions.

Below are null hypotheses created as the basis of impact monitoring that match the prediction of no significant impact. Monitoring (and adaptive management) would primarily focus on the habitat quality and frog ecology in priority ponds during each of the construction and post construction phases. Meeting the null hypotheses established for impact monitoring would verify the environmental assessment prediction of no significant environmental impact (GHD, 2010) in relation to ponds potentially affected by capping works on K10 North, K10 South and K2).

Null impact hypotheses:

a) *For GGBF parameters:*

There will not be a detectable change in abundance in time for GGBF key ecological parameters in Kooragang Is "priority" ponds (potentially affected by capping works on K10 North, K10 South and K2).[1]

b) *For GGBF habitat indicators:*

GGBF habitat indicator threshold levels in Kooragang Is "priority" ponds will be met. However, should there be non-conformance, the null hypothesis will not be rejected unless there is a statistically significant difference in the rate of non-conformance with reference (or other unaffected) ponds (a space x time interaction).

Note the following in relation to the GGBF habitat hypothesis:

- triggers would be established for GGBF habitat lead indicators to make adaptive management to correct trends approaching the indicator threshold levels stated above;
- inter-annual wetting-drying cycle (such as El Nino events) must be taken into consideration, so the rate of occurrence of any exceedance must be factored into the determination, particularly during prolonged dry periods; and
- notwithstanding mitigations applied during the construction phase, TSS/turbidity also serve as an indicator of potential construction effects, due to runoff quality.

6.2.2 *Experimental Design for Monitoring: B-A-C-I Style*

An experimental design can be established to contrast the factors and levels stated in the hypotheses.

Table 6.2 Spatial Factors of Balanced Experimental Design

Spatial factor	Putative "Impact" (Test)	Reference (Control[1])[2]
Ponds	Long Pond	Deep Pond
	Windmill Road Open Channel	Blue Billed Duck Pond
	Easement Pond	(Other)
	---------------------------------------	--
	K2 Basin (construction)	K2 Basin (post-construction)

1. To provide statistical rigour to the design, use of 'Reference' ponds during the construction + post-construction phases
2. The experimental design must be considered in relation to other probable works by others on KI. Data from Other "Reference" ponds may be suitable.

[1] Any difference in GGBF ecology results in time in putative impact ("priority") ponds may actually be because of natural variability in pond hydrochemical baseline conditions, especially under extremes of site-wide wetting-drying cycles. KI "reference" ponds or other brackish-saline habitat ponds (eg OEH wetland 1) could be adopted to moderate such temporal changes in GGBF ecology parameters.

Table 6.3 Temporal Factors of Experimental Design

Temporal factor	Before Construction	During Construction	Post construction
Period	Up to Dec 2013	Jan 2014 –Dec 2014 [1]	Jan 2015 to Dec 2017

1- Specified timeframe for K10 North and K2

A significant effect would be detected by a temporal change, being:

Construction period (turbidity/TSS)

Putative Impact Ponds x Construction ≠ Putative Impact Ponds x Before

(Putative Impact x Post Construction)

Post construction phase (EC; water level)

Putative Impact Ponds x Post Construction ≠ Putative Impact x Before

(Putative Impact x Construction)

Note, if a more detailed two-factor monitoring design is adopted (using reference ponds that may be prone to separate potential effects by other KI developments), then space-by-time statistical interaction between levels of the two factors (Ponds x Period) would indicate a significant effect.

6.2.3 Monitoring Parameters

A set of parameters and indicators have been specified for frog habitat and ecology for the duration of the program as follows.

Key parameters of GGBF ecology include:

- specimen abundance (presence/ absence);
- population distribution and habitat utilisation; and
- animal behaviour and any recorded physiological abnormalities.

Primary GGBF habitat indicators include:

- electrical conductivity / salinity of surface waters; and
- habitat pond water level.

Supplementary aquatic habitat indicators would also include:

- physical quality condition (temperature; dissolved oxygen; pH); and

- chemical quality condition (nitrogen; phosphorus; turbidity/total suspended solids[2]).

This set of primary and supplementary habitat indicators provide a series of monitoring and assessment parameters for habitat condition through time.

SMEC (2013) reported that any comparison values for short term effects, turbidity and TSS (ie triggers and thresholds) will be set in the Construction Environmental Monitoring Plan (CEMP) to be applied to the works.

6.3 PROPOSED FUTURE MONITORING OF PONDS FOR K2, K10 NORTH & K10 SOUTH CAPPING PROPOSAL

This is in response to the inquiry relating to:

"a) Methods for monitoring the presence/absence and abundance of GGBFs in suitable habitat on site, before, during and after works commence"

The methods for monitoring on the site relate to two equally important components being:

- parameters relating to the ecology of GGBF– the receptor potentially 'at risk' (a lag indicator); and

- indicators of the habitat quality – the potential impacting mechanism (a lead indicator).

A set of target parameters relating to both frog population and animal health, and indicators of habitat condition is proposed. The methods relate to ways of providing accurate and meaningful data in relation to the stated parameters and primary indicators. The parameters and indicators are specified in *Section 6.2.3.*

Port Waratah Coal Service (PWCS) and Newcastle Coal Infrastructure Group (NCIG) have existing monitoring obligations and have made a future commitment to undertake GGBF abundance and distribution monitoring across Kooragang Island and some surrounding areas. Their proposed monitoring locations overlap the KIWEF area of this proposal and referral. To avoid duplication, NPC has established an agreement to share the monitoring data. It is likely that this agreement would see NPC contribute financially to the monitoring project and sharing access to the results.

Notwithstanding the wider monitoring program, NPC commits to GGBF abundance and distribution monitoring undertaken annually within (and surrounding) ponds identified as both "priority" and other proximate ponds.

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[2] This indicator will also be directly applied to the pre-construction and construction monitoring comparisons

The proposed monitoring areas are illustrated in *Figure 1.3*. To avoid any doubt, ponds where NPC will require abundance and distribution monitoiring are:

- Windmill Road Open Channel ('priority');
- Long Pond ('priority');
- Easement Pond ('priority');
- Easement Pond South;
- Eastern Ponds;
- K2 Basin;
- BHP Wetlands;
- Blue Billed Duck Pond; and
- southern shores of Deep Pond.

Pre-clearance surveys will also be undertaken on the proposed disturbance footprints of the capped areas and any GGBF interactions recorded will be included in GGBF monitoring results. After pre-clearance, monitoring of ponds will be undertaken on an annual basis.

The results of GGBF abundance and distribution monitoring, for which NPC has partial responsibility, will be made available on a website. Publishing of the results of the wider monitoring program are an item for discussion between NPC with other parties who have existing monitoring obligations. In the event that the full monitoring results are to be made publically available, NPC will provide a link from its website to the location at which they are available.

This GGBF abundance and distribution monitoring would verify impact predictions (ie no significant impact) and provide data on the protected species, however, these measurements are recognisable as "lag" indicators, so not well suited for corrective actions, should they be needed. As such results of GGBF abundance and distribution monitoring are not proposed as triggers for adaptive management actions. This is primarily a result of the highly mobile nature of GGBF individuals. Previous survey data for GGBF records have been illustrated in *Figure 7.1*. However, the species is capable of making quite large movements in a single day, up to 1.5 km. Dr White has previously indicated the variability of salinity levels within and between ponds was a possible reason that the GGBF was so mobile on Kooragang Island, in that they likely migrate in and out of ponds depending on salinity values. As such the absence of GGBF in a location where they have been previously recorded is not considered a reliable indicator of a negative impact associated with the project.

Therefore, monitoring for habitat quality condition by hydro-salinity logging, provides information on "lead" indicators to enable adaptive management upon meeting or exceeding established triggers and thresholds. These have been clearly developed by SMEC (2013) for known GGBF habitat ponds for KIWEF in relation to salinity/electrical conductivity and water level.

6.4 *WATER QUALITY MONITORING METHODS*

This responds to the query relating to:

b) Methods for monitoring water quality in ponds affected by the proposal

The largest potential long term effect in altered hydro-salinity is predicted by SMEC (2013) to occur in:

- Long Pond;
- Windmill Road Open Channel; and
- Easement Pond.

Primary (and supplementary aquatic habitat indicators) are listed in *Section 6.2.3.*

This set of primary and supplementary habitat indicators provide a base series of monitoring and assessment parameters for habitat condition through time. The nature of water quality effects are predicted to differ between the construction and post-construction phases, thus:

- during construction, effects would relate to a risk of sediment loads transmitted from the active work areas into down-gradient ponds (if unmitigated); and
- during post-construction phase, effects would relate to altered hydrology (largely predicted to be a small effect from surface hydrology), which has been largely mitigated by design.

6.4.1 *Temporal Staging of GGBF Habitat Monitoring*

The experimental basis for testing the working hypothesis is outlined in *Section 6.2.2*. *Table 6.4* provides further details on the staging of water quality monitoring in the Before, During (Construction) and After (Post-construction) works phases when examining frog ecology.

Table 6.4 Summary of GGBF Monitoring (derived from SMEC, 2013)

Monitoring Period	GGBF Monitoring	Water Quality Parameters (other than water EC and level)	Salinity (EC) Water Level Turbidity [a]	Internal Performance Reporting	Outcomes
Pre-Construction	Parameters stated and utilisation of existing data available water quality data listed in SMEC (2013).		Continuous, using existing level / EC loggers [a]	Annual	Establishment of comprehensive baseline water quality conditions is required to enable potential future impacts to be reliably identified.
Construction			Continuous, using existing level / EC loggers [a]	Quarterly	More-intensive monitoring during the construction period is recommended to identify any short term impacts to water quality that may occur during construction.
Post-construction 12 months immediately after construction completion			Continuous, using existing level / EC loggers.	Quarterly	More-intensive monitoring during the immediate post-construction period to identify changes to water quality as the landform stabilises post construction.
Up to 3 years post construction			Continuous, using existing level /EC loggers	Annual	Relaxation of monitoring intensity as the potential for acute changes to water quality reduces as landform stabilised.

a) Plus daily in-pond turbidity in pre-construction and construction phases only

6.4.2 *Water Quality Monitoring (Construction Phase)*

SMEC (2013) stated that the methods for monitoring water quality would include the use of multi-parameter instruments that have the capability to measure real time data in the field. Moreover, water quality sampling and analysis of a wide range of parameters also forms part of the water quality monitoring already established within ponds.

At present, water samples are also sent to NATA accredited laboratories and analysed for the suite of supplementary aquatic habitat indicators in the pre-construction phase to generate a baseline. A large range of water quality parameters are currently monitored on the site, and the key supplementary parameters outlined above. Ponds would be monitored on at least a monthly basis for total suspended sediments (turbidity) and daily in the immediate lead up to and during the capping works program. Supplementary indicators would be continued on the same monitoring frequency as in pre-construction (baseline) phase.

Salinity in monitored ponds would be measured continuously through monitoring devices (as currently installed[3]). As water quality and water level are generally related, depth sensors are used on the multi-probe packs to determine standing water depth in each of the monitored ponds.

6.4.3 *Water Quality Monitoring (Post-Construction)*

A hydro-salinity monitoring network has been commissioned and established by HDC. Ponds with hydro-salinity loggers currently installed are:

- Windmill Road Open Channel;
- Long Pond;
- Eastern Ponds;
- Easement Pond (negotiated access through PWCS);
- Easement Pond South;
- BHP Wetlands (negotiated access through PWCS);
- Deep Pond (negotiated access through PWCS); and,
- K2 Basin.

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[3] Note Easement Pond, BHP Wetlands and Deep Pond loggers were previously installed by Douglas Partners for PWCS T4 Environmental Assessment and the proponent has negotiated access to or control of data sources.

HDC also plan to install a hydro-salinity logger in Blue Billed Duck Pond by 31 July 2013. This will provide hydro-salinity monitoring coverage of all ponds with the potential for an effect from the project and reference sites (as listed in *Table 6.2*). Hydro-salinity monitoring sites are illistrated in *Figure 1.3*.

Continuous water level and salinity loggers will be maintained within all ponds for a period of up to three years after completion of the capping works, to provide a means of tracking when triggers are met, gain an understanding of possible changes in pond water levels as a result of the project and to test and confirm the working hypothesis.

6.5 THRESHOLDS AND TRIGGERS FOR LONG TERM GGBF HABITAT MANAGEMENT

This responds to the query relating to:

c) Thresholds which would indicate adverse impacts on GGBFs or their habitat

Thresholds (and triggers) have been developed for lead indicators that may show an adverse trend on GGBF habitat quality, in preference to the detection of an adverse trend or effect on the GGBF population itself during the post-construction phase. The basis of GGBF habitat management in the long term is based on the dual set of suitable ambient conditions being:

- presence of water for aquatic habitat (as predetermined by a trigger set at a lower bound level); and
- salinity condition of the standing waters.

At any point in time, these two characteristics co-exist. Only at the point where the water level trigger is not met (when water levels are actually lower than the stated lower bound), the combination of the two indicators would be jointly interpreted, noting that this is only prone to occur when prolonged regional drying across all KI ponds would occur.

This section summarises information on GGBF habitat indicators derived from SMEC (2013) on hydro-salinity processes, predicted effects and GGBF management with the derived thresholds presented in *Table 6.5* and *Table 6.6*.

Table 6.5 Suggested Salinity Thresholds for KIWEF Surface Water Bodies

Chytrid Fungus protection threshold[1] **(µS/cm)**	GGBF tadpole health threshold[2] **(µS/cm)**	**GGBF Adult health threshold [3] (µS/cm)**
1,650 µS/cm	2,900 µS/cm	4,100 µS/cm

1. EC below threshold presents increase risk of mortality resulting from Chytrid Fungus.
2. EC above threshold indicates unsuitability of water quality for GGBF tadpole survival.
3. EC above threshold indicates unsuitability of water quality as GGBF adult habitat.

Elevation, hydrology and water level is specific to each pond on KIWEF. The following water level summary statistics have been generated by SMEC (2013).

Table 6.6 Summary of Water Level Heights for KIWEF Ponds

Pond	Minimum predicted future water level [1]; Threshold (m, AHD)	"Lower bound" water level Trigger, based on 20th percentile past water level (m, AHD)	80th percentile past water level (m, AHD)[2]	Minimum Typical Operating Range (m)
BHP Wetlands	0.92	1.2	1.9	0.7
Blue Billed Duck Pond	0.98	1.6	2.5	0.9
Deep Pond	0.94	1.3	1.8	0.5
Easement Pond	0.83	1.4	2.0	0.6
Easement Pond South	1.63	2.2	2.6	0.4
K2 Pond	0.5	1.1	1.9	0.8
Long Pond	0.95	1.1	1.7	0.6
Windmill Rd Open Channel	1.38	1.4 (1.6[3])	2.4	1.0

1. *These levels are shown in *Table 1 Section 2*.
2. The 80th percentile condition is the level after which water quality becomes fresher than average meaning that EC thresholds of *Table 6.5* would typically apply. Spill from each specified pond occurs at invert RLs greater than the 80th%ile levels.
3. A level of 1.6m AHD represents the future low 20th%ile (approx) at this site.

The modelled water levels provided by SMEC (2013) can be further interpreted, as shown in *Table 2.1*, and an explanation of pond water levels in *Chapter 2*.

Note that the adoption of pond-specific water level 'triggers' would:

- provide lead time to consider, review and adopt adaptive measures as required;
- be met at least 0.3 to 0.6 m before the threshold water levels; and
- be raised to 1.6 mAHD for Windmill Rd Open Channel given the predicted elevated standing water level.

Exceeding established bounds and developing operating rules provide 'triggers' to manage GGBF habitat water level and salinity(see *Table 6.5*).

A summary of the triggers are shown in *Tables 6.7* and *6.8*.

Table 6.7 "Brackish-shallow" water pond conditions - level and duration triggers

Priority Pond	Existing	Predicted	Existing plus 4 week drying period	Low water level (m, AHD)
Easement Pond	111 Days	111 Days	139 Days	1.4
Long Pond	94 Days	59 Days	122 Days	1.1
Windmill Rd Open Channel	86 Days	0	114 Days	1.6

Table 6.8 "Fresh" water pond conditions - duration triggers

Priority Pond	Existing	Predicted	Existing plus 6 week wetting period	Water level (m, AHD)
Easement Pond	107 Days	119 Days	149 Days	Bankfull
Long Pond	100 Days	110 Days	142 Days	Bankfull
Windmill Open Channel	49 Days	58 Days	91 Days	Bankfull

*this typically gives an assigned trigger deemed to be conservative.

The derivation and specifications for the use of triggers is shown in *Section 6.5.1*

6.5.1 *Specific triggers for adaptive actions*

The largest potential long term effect on hydro-salinity is predicted by SMEC (2013) to occur in:

- Long Pond;
- Windmill Road Open Channel; and
- Easement Pond.

The risk of undue long term effects and using triggers for adaptive management measures is considered in more detail here. It is worthy of re-iteration that there is no indication from predictions that undue hydro-salinity effects will arise as:

- additional fresh rainfall-runoff will drain, after collection in sedimentation basins, into GGBF habitat ponds; and,
- currently, brackish GGBF habitat ponds (Long Pond and Windmill Rd Open Channel) will become slightly wetter and fresher as a result and a general tendency.

Therefore, these triggers have been presented as a failsafe mechansim, should the hydro-salinity of the site (and the quality in the ponds) not perform according to the hydro-salinity model in the post-construction period. Although improbable, it is not impossible that water cycle does not result in modelled trends.

Specifically, meeting or exceeding the salinity thresholds and water level triggers shown in *Tables 6.7* and *6.8* would invoke one or a number of adaptive management and corective actions on the site's water cycle management. Before considering the precedence, sequencing or timing of such adaptive actions, other factors become important to understand, including:

- planned routine monitoring at the priority (and reference) ponds which permits checking and regular assessment of key habitat characteristics (pond depth and salinity), so temporal trends would be readily apparent. That trend in pond quality and quantity would clearly indicate condition so influence the proponent's readiness and ability to apply the identified adaptive measures. Effectively, this approach makes time available to decide and act on emerging data and information;

- water cycle management for GGBF ponds adjacent the site that avoids the effect of drying ponds derived from the capped areas;

- noting that Long Pond and Windmill Road Open Channel are known to be the most brackish ponds; currently 44.5% and 55.9% of time pond salinity is greater than 4100 µS/cm, naturally higher than what has been judged as optimal GGBF adult habitat; and

- showing the combination of aquatic habitat factors of water depth and salinity results in a set of predictable conditions as shown in the following tables, based on a strong positive correlation and curvilinear relationship between pond water level and water EC as described in *Section 3.3.*

Priority Pond "Brackish" Water Conditions Trigger

This operating rule (the 'brackish/shallow trigger') sets a point at which further consideration and potential implementation of adaptive measures would be triggered, thus:

1) When:

   a) pond depth is less than the lower bound trigger levels shown in *Table 6.7* for periods of greater than four consecutive weeks longer than under existing conditions (an extended drying period[4]); or

[4] Refer *Section 2.2* for information on derivation of impact mechanisms on GGBF habitat

b) when water level is higher than the lower bound, salinity above the upper bound of the GGBF adult bracket stated in *Table 6.9* for periods of greater than four consecutive weeks longer than under existing conditions, (other than in Long Pond at times when there is evidence of direct tidal intrusion into the pond);

and,

2) After valid comparison of the temporal drying/salinizing trend and condition in the priority ponds made against that of conditions in the same ponds in the past and against the current conditions in reference ponds (also planned to be monitored and assessed contemporaneously – refer *Section 6.2*).

Table 6.9 "Brackish-shallow" water pond conditions - aquatic habitat Water Level and Salinity Thresholds for Priority Ponds

Priority Pond	**Water Level**		**Salinity[4]**	
	Minimum predicted future water level [1]; Threshold level (m, AHD)	**"Lower bound" water level Trigger, based on 20th percentile past water level (m, AHD)**	**GGBF Adult "bracket"[2] (µS/cm)**	
Easement Pond	0.83	1.4	2900	4100
Long Pond	0.95	1.1	2900	4100
Windmill Rd Open Channel	1.38	1.4 (1.6[3])	2900	4100

1. These levels are shown in *Table 1 Section 2*.
2. Under low water conditions, pond waters would only be at the saline end of the derived salinity thresholds (ie not fresh).
3. A level of 1.6 mAHD represents the future low 20th%ile (approx) at this site.
4. EC levels shown in *Table 4.2* and *Figure 4.1*

Adaptive measures will only be applied if both conditions (1) and (2) are met. Condition (2) is to 'test' if the priority pond(s) is significantly different than reference ponds, based on data analysis, tests of statistical signficance and interpretation.

Note that the SMEC (2013) hydro-salinity model predicted (as summarised in *Table 4.2* and *Figure 4.1*) that the general tendency of altered hydro-salinity is towards wetting and making 'fresher' the waters in those priority ponds which, under present conditions, are as follows:

- Long Pond: mean salinity = 11 200 µS/cm
- Windmill Rd Open Channel: mean salinity = 9500 µS/cm

It is worth noting given the frequency and occurrence of elevated salinity in these ponds that their present habitat value for tadpoles and adult GGBFs alike cannot be high, other than for short periods of time. Note condition (1) above would tend to be exceeded in the developed case, based on modelled precictions, between one-third to half of the time (refer *Table 4.2* showing 29.3% and 49.7% respectively greater than adult GGBF habitat bracket), which is less than the rate in the past. However, as the basis of that impact prediction derived from SMEC (2013), it appears unlikely that the trigger would be met after the moderating effect of BACI statistical comparison. Notwithstanding, the precedence, sequencing or timing of such adapative actions derived from a trigger are described in *Section 6.6.3.*

In this way, monitoring would need to show consistent divergence from modelled effects and exceedance of thresholds over a period of time to activate the trigger before corrective actions would be applied. The 'brackish/shallow trigger'would apply for the period of the post construction monitoring.

Priority Pond Water Condition Trigger (Other Than When Depths Are "Low" Or Quality Is "Brackish")

Under this situation, there is no preclusion to high standing water levels in ponds as that condition arises because of a high incidence and/or intensity of rainfall over the site. The result would tend to be fresh runoff waters into adjacent ponds. At such times, ponds may brim with water and overflow.

This operating rule (the 'fresh trigger') sets a point at which further consideration and potential implementation of adaptive measures would be triggered, thus:

1) Salinity below the lower bound of the GGBF "optimum" bracket stated in *Table 4.2* for periods of greater than six consecutive weeks **longer** in high water level duration (and extended wetting period[5]);

   and,

2) After valid comparison of the temporal drying/salinizing trend and condition in the priority ponds made against that of conditions in the same ponds in the past and against the current conditions in reference ponds (also planned to be monitored and assessed contemporaneously – refer *Section 6.2*).

In this way, monitoring would need to show consistent divergence from modelled effects and exceedance of thresholds over a period of time to activate the trigger before corrective actions would be applied.

Adaptive measures will only be applied if the condition in the 'test' priority pond is significantly different than reference ponds, according to condition

[5] Refer to *Section 2.2.* for information on derivation of impact mechanisms on GGBF habitat

(2). Note condition (1) above would tend to be met more often (that is below 1650 µS/cm post construction, based on modelled predictions), as follows:

- Long Pond: 5.5% (at present) to 13.4% of time (future developed);
- Windmill Rd Open Channel: 13.7% (at present) to 7.1% of time (future developed); and
- Easement Pond: 39.1% (at present) to 48.9% of time (future developed).

However, as the basis of that impact prediction derived from SMEC (2013), it appears unlikely that the trigger would be met after the moderating effect of BACI statistical comparison, particularly for Easement Pond against K2 Basin and Deep Pond (which have similar hydro-salinity regimes to it). For Long Pond and Windmill Road Open Channel, an unacceptable trend would be if waters were fresher for longer periods (that is, much less than 1650 µS/cm and/or attained that condition well prior to and for longer periods than other reference ponds such as Deep Pond and K2 Basin). Given the naturally typical brackish quality of these two ponds, this occurrence is highly unlikely.

This 'fresh trigger'would apply for the period of the post construction monitoring.

6.6 *ADAPTIVE ACTIONS RELATING TO THRESHOLDS AND TRIGGERS*

This responds to SEWPaC queries relating to:

d) *Adaptive responses if adverse impacts on GGBFs or their habitat were identified (3 August 2012)*

and further inquiry by email on 2 July 2013:

> *What would trigger adaptive management actions? (eg if hydro-salinity monitoring indicates that salinity levels are outside of suggested thresholds, would adaptive management responses be applied immediately, or would monitoring need to show consistent breaches of the thresholds over a certain period of time before corrective actions would be applied?)*

6.6.1 *Summary of adaptive management measures*

A summary of adaptive actions (responses and mitigation measures) for GGBF habitat management is provided below. The following hierarchy of actions and measures would be considered and implemented upon meeting or exceeding triggers and thresholds set for long-term GGBF habitat quality, as indicated by SMEC (2013):

a) Initially, further detailed investigation would be undertaken to determine the reasons for the detected change. This would involve detailed scrutiny of the water level and water quality monitoring results to ascertain in which parts of the site the hydrology and water quality are changing most (in relation to possible site wide drying effects). This would also enable GGBF experts to understand the ecosystem processes affecting change within the habitat and to assess these in relation to monitoring data on GGBF populations (for instance, in relation to its suitability for breeding of adults over summer or survival of tadpoles afterwards). If such investigations conclude positively (using the hypotheses), then there are a number of possible additional mitigating measures that could be instigated.

b) Possible temporary physical mitigation measures to aid recovery in hydro-salinity would include:

   (a) release of standing surface water of suitable quality from sedimentation basins into the affected pond(s);

   (b) provision of water into affected ponds from clean site aquifers to adjust the pond's water quality and water level;

   (c) re-direction of surface runoff from the capped site by using temporary berms and diversions into channels draining into / away from affected ponds; and

   (d) re-direction of standing surface waters from other suitable[6] KI ponds into the affected pond(s).

Such measures would typically be applicable in the short term at times of seasonal and annual effects, such as those related to natural drying cycles, but where the impacted ponds show an additional hydro-salinity effect.

c) Possible long term physical mitigation measures to aid recovery would include:

   (a) diversion of catchment drainage from capped areas into affected ponds; and

   (b) restoration of existing hydrogeological processes by permitting groundwater percolation from the base of selected[7] sedimentation basins.

These types of measure may be possible because of a large difference in elevation between the cap areas (RL 9 to 10 m, AHD) and the receiving water ponds (RL 1 to 3 m, AHD).

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[6] Suitability would be determined by experts based on the quality of waters and the risk of transfer of disease and predators.

[7] Such basins would generally be proximal to priority ponds such as Long Pond and Windmill Rd Open Channel

SMEC (2013) proposed a hypothetical example of this being applied – for example, if salinity within Long Pond (which is typically brackish) was to decrease beyond the EC threshold (into chytrid-suspect levels) as a result of the reduction in groundwater inflows from the adjacent capped area, and this is found to detrimentally affect the GGBF population, then there would be potential to provide lower salinity surface water towards Easement Pond South, which has a much smaller contributing catchment area, and therefore would likely have capacity to accept additional lower salinity runoff from adjoining areas that currently drain to Long Pond.

SMEC (2013) also reported another possible recovery mitigation measure being that the constructed sedimentation basins, proposed as part of the capping works as runoff control and treatment, could be re-vegetated to enhance their presence as a constructed wetland and possible additional GGBF habitat. This adaptive response is based on a potential, in the long term, for sedimentation basins as constructed wetlands to enhance connectivity, breeding/rearing habitat and refuge for GGBF across the broader KI site.

Construction management measures are detailed in *Chapter 10*.

6.6.2 Hierarchy of Adaptive and Corrective Actions

The precedence, sequencing or timing of such adaptive actions derived from a trigger are described here. Theoretically, a trigger may more likely occur due to the occurrence of elevated salinity. This is because a 'fresh trigger' almost exclusively relates to extensive rainfall across the whole site and evidence shows that ponds other than the priority ponds loose chytrid protection condition more frequently (and earlier) after rainfall events.

The adaptive management and corrective actions shown in the following sections would be implemented should the conditions for either the 'brackish' and 'fresh' triggers in priority ponds be met as described in *Secion 6.5.*

Should the 'brackish/shallow trigger' described in *Table 6.7* be exceeded, the proposed hierarchy of adaptive actions would be as shown in *Table 6.10.* Should the 'fresh trigger' described in *Table 6.8* be exceeded, the proposed hierarchy of adaptive actions would be as shown in *Table 6.11*. These are shown in each table in an hierarchical order.

Table 6.10 Derivative Actions from Activation of Brackish/ Shallow Trigger

Action Hierarchy	Time frame	Adaptive actions	Support actions
↓	Corrects potential effects in the short term If required, apply any or all of the actions within 3 months of trigger condition. Further field response monitoring to establish further listed actions as corrective actions (as below).	Where possible, release of standing surface water of suitable fresh quality (EC <<4100 μS/cm) from associated sedimentation basins into the affected priority pond(s).	• Waters would be, where possible, gravity fed or pumped; • Suitability of waters would be checked for gambusia, contaminants and chytrid; • Conduct response monitoring for further corrective actions.
↓		Where possible, provision of water into affected priority pond(s) from clean KI aquifers** to adjust the pond's water quality and level.	• Suitability of waters would be checked for EC and contaminants and known from past monitoring; • Waters would be pumped; • Conduct response monitoring for further corrective actions.
		Standing surface waters from other suitable KI ponds ** (such as Deep Pond) into the affected pond(s).	• Suitability of waters would be checked for gambusia, contaminants and chytrid; • Waters would be transferred by pumping; • Conduct response monitoring for further corrective actions.
↓	Corrects potential effects in medium-longer term; If required, apply within 12 months of trigger condition.	Re-direction of surface runoff from the capped site (by using simple berms and diversions into channels) draining into affected priority ponds.	• Inspect grade of capped areas to identify diversion requirements of Easement Pond drainage waters towards WMOC and Long Pond (or vice versa). • Install minor works to suit.

Action Hierarchy	Time frame	Adaptive actions	Support actions
↓	Corrects potential effects in the longer term; If required, apply within 3 years of trigger condition	Restoration of site's hydrogeological processes by permitting groundwater percolation from the base of selected sedimentation basins.	• Conduct hydrogeological and engineering design for suitable intervention. • Renovate existing sedimentation baisns and structures.
		Rehabiliation of sedimentation basin pond margins with native groundcover and aquatic emergents as potential aquatic habitat.	• Prepare rehabilitation and vegetation management plan in accordance with applicable guidelines including GGBF Management Plan.

** Abstraction or use of surface or groundwaters may separately require licensing in NSW; consideration should be given to the potential effect of groundwater drawdown on any groundwater dependent or other ecosystem.

Table 6.11 Derivative Actions from Activation of "Fresh" Trigger

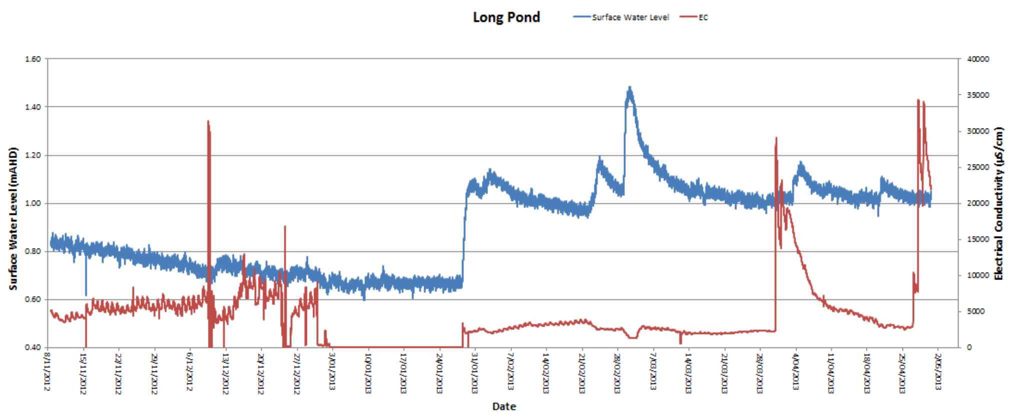
Action Hierarchy	Time frame	Adaptive actions	Support actions
↓	Corrects effects in the short term. If required, apply any or all of the actions within 3 months of trigger condition. Further field response monitoring to establish further listed actions as corrective actions (as below).	Where possible, release of standing surface water of suitable brackish quality from associated sedimentation basins into the affected priority pond(s).	• Waters would be pumped or, where possible, gravity fed; • Suitability of waters would be checked for gambusia and contaminants; • Conduct response monitoring for further corrective actions.
		Where possible, provision of water into affected priority pond(s) from clean site saline aquifers to raise the pond's EC quality.**	• Suitability of waters would be checked for EC and contaminants; • Such waters would be known from past monitoring; • Waters would be pumped. • Conduct response monitoring for further corrective actions.
		Surface waters from other suitable sources such small volumes of Hunter River tidal water into the affected pond(s).**	• Suitability of waters would be checked for water quality including contaminants; • Waters would be transferred by pumping; • Conduct response monitoring for further corrective actions.
	Medium-long term effect If required, apply within 12 months of trigger condition	Re-direction of surface runoff from the capped site (by using simple berms and diversions into channels) draining away/towards Easement Pond.	• Inspect grade of capped areas to identify diversion requirements of Easement Pond, WMOC and Long Pond drainage. • Install minor works to suit.

** Abstraction or use of surface or groundwaters may separately require licensing in NSW; consideration should be given to the potential effect of groundwater drawdown on any groundwater dependent or other ecosystem.

6.7 *VALIDATING 'TRIGGERS' AGAINST MODELLED AND MONITORED CONDITIONS*

A cross check of the proposed triggers (for ecological relevance) can be made by examining both recent and modelled hydro-salinity data for each of the priority ponds. These existing conditions typify the baseline for extended drying periods for future trigger assessments based on the relatively dry interannual conditions of 2011-2013.

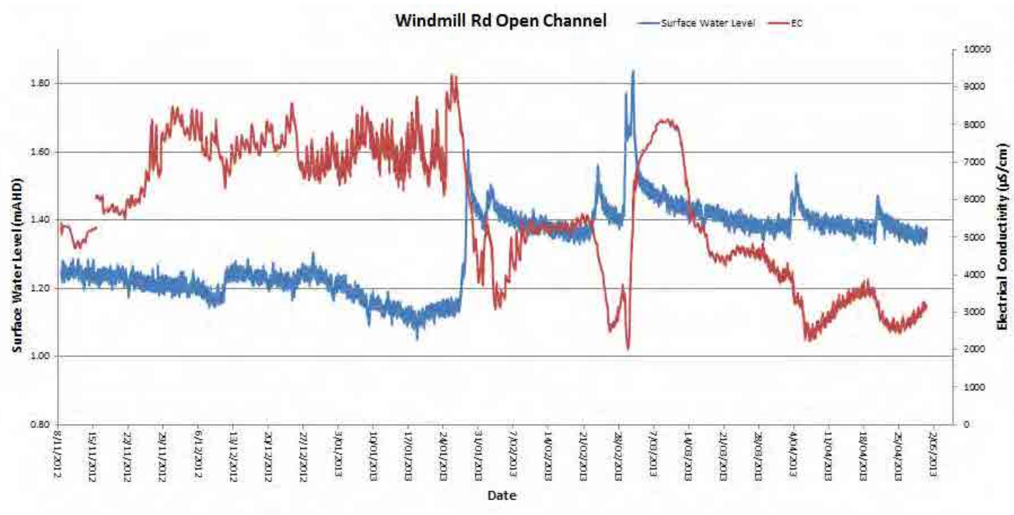
Long Pond



Data for six months from Long Pond from late 2012 to early 2013 are shown above. These data show:

- typical brackish to weakly saline conditions with four spikes in EC (>25,000 µS/cm) related to flood tide tidal intrusions;
- because of naturally preceding dry conditions, the water level declined from 0.9m at the start of the reporting period (that is, less than 1.1 mAHD 20th%ile "low" trigger) to 'near dry' for a period of approximately three months (approximately 100 days) before rainfall inflows elevated standing water to above the 'brackish/low water' trigger. Note that 122 days is set as the 'low level' duration trigger;
- at times after rainfall when water levels exceeded 1.0 mAHD (Jan-Mar 2013), EC was less than 5000 µS/cm. In the future, similar conditions may meet a pre-condition for the trigger;
- heavy rainfall in early March 2013 resulted in a pond water depth increase and a slight EC reduction;
- SMEC (2013) modelling showed that when predicted water level exceeded 1.1 mAHD EC was less than 5000 µS/cm, exceeding 4100 µS/cm for only short periods of two to four weeks; and
- rainfall and runoff was insufficient during the periods to assess the 'fresh' trigger.

Windmill Road Open Channel

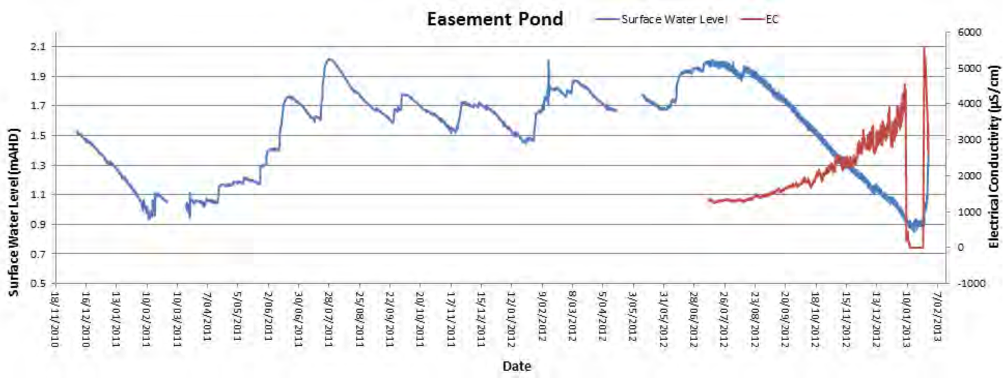


Monitoring data for the 6 months from late 2012 to early 2013 are shown above. These data show:

- typical brackish conditions (EC <10,000 µS/cm);
- because of naturally dry conditions, the water level declined from 1.2 m at the start of the reporting period (that is, less than 1.4 mAHD 20th%ile low level) to 'near dry' for a period of approximately three months (approximately 100 days) before rainfall inflows elevated standing water to above the 'brackish/low water' trigger and EC was less than 4000µS/cm. Note that 114 days is set as the 'low level' duration trigger;
- heavy rainfall in early March 2013 resulted in a pond water depth increase and slight EC reduction, but additional rainfall, while causing pond water levels to increase, were associated with an short term increase in EC;
- SMEC (2013) modelling showed that when predicted water level exceeded 1.4 mAHD, EC was generaly of the range 2000-5000 µS/cm, exceeding 4,100 µS/cm only once for a short period of two to four weeks; and
- rainfall and runoff was insufficient during the periods to assess the 'fresh' trigger.

Note, after capping works, the new 20th%ile water level is predicted to be 1.6 mAHD being wetter than under existing conditions.

Easement Pond

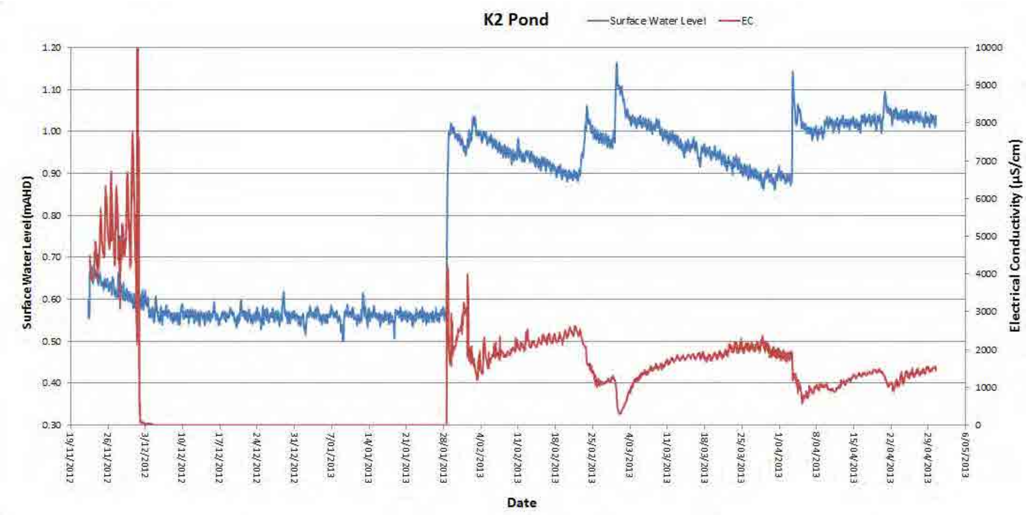


Monitoring data for over two years - late 2010 to early 2013 - are shown above. These data show:

- typical brackish conditions (EC <6,000 µS/cm);
- over the period of 2011-2012 (between June 2011 and continuing to the end of October 2012) water level was higher than the 'brackish-shallow' trigger level of 1.4 mAHD. Available data suggest that waters were often less than 2000 µS/cm;
- because of naturally dry conditions after October 2012, pond level declined by mid Jan 2013 to almost completely dry before which water quality increased its salt content to approximately 4500 µS/cm;
- note that 139 days is set as the 'low level' duration trigger. Pond level was less than 1.4m AHD between Dec 2010 and mid June 2011 over a duration of 6 months (approximately 180 days) so in excess of the trigger. Note that, against that established trigger, futher assessment would have had to be made against condition (2) '…valid comparison of the temporal drying/salinizing trend and condition in the other ponds';
- SMEC (2013) modelling for the same monitoring period showed that, outside of the dry condition elevated salinity, EC ranged between 1500 and 2500µS/cm; and
- rainfall and runoff was insufficient during the periods to assess the 'fresh' trigger.

K2 Basin

K2 Basin is shown as it is a comparison to the priority (putative impact) ponds above.



Monitoring data for the six months from late 2012 to early 2013 are shown above. These data show:

- typical fresh water conditions (EC <3,000 µS/cm) when pond water level was greater than 0.9 m AHD;

- because of naturally dry conditions, the water level declining from 0.7 m at the start of the reporting period to 'near dry' for a period of approximately two months (approximately 60 + days) before rainfall inflows elevated standing water to about 1.0mAHD and EC between 2000 and 4000µS/cm. Note that the existing 20^{th}%ile 'low' water level is 1.1 mAHD, so like the other ponds at the same time, the effect of dry weather was evident with standing water generally operating in a range of 0.9 m to 1.1 m;

- SMEC (2013) modelling showed that the level/salinity trace was similar to the other ponds and when predicted water level exceeded 1.1 mAHD (equivalent to the 'low' trigger level) the EC was generally in the range 1000 -4000 µS/cm;

- because of the fresh nature of the pond, rainfall and runoff was sufficient during the period to result in water quality of less than 1650 µS/cm occurring at times when water in the priority ponds were higher than the 'fresh' trigger.

The strong similarity of the temporal trace reflects the importance of Condition (2) in each trigger of comparing the priority (putative impact) ponds against reference ponds.

7 GGBF HABITAT BUFFER ZONES

This Chapter describes proposed provision of buffers from works areas in response to the SEWPaC request to provide a map which clearly shows GGBF habitat (not restricted to areas where frogs were found during 2009) in relation to the proposed 30 m buffers from works, and describe how buffers would be demarcated in the field so that they are clearly visible to workers during construction works.

7.1 BACKGROUND TO RESPONSE

The approved capping strategy proposed a 30 m buffer in relation to capping works in area K3 only. To quote from the original source, GHD (2009) states:

> *"To maximise habitat protection, the capping strategy has provided a 30 m ecological habitat buffer to the Deep pond, with the exception of the BOS area and near monitoring well K3/1W, which are to be capped and revegetated. As identified in the GHD Flora and Fauna Impact Assessment (2009), due to the presence of the Green and Golden Bell Frog, construction activities in this buffer should be undertaken outside the Green and Golden Bell Frog core breeding period of September to February".*

As such, the recommended buffer was not intended to exclude construction works entirely from within 30 m of GGBF habitat. Instead it was intended to restrict construction within GGBF habitat that exists within 30 m of Deep Pond to outside key breeding areas and periods. This clarification to enable the practical and effective use of 30 m buffers must be noted and this approach has been applied to further interpretations here.

The need for 30 m habitat buffers is reduced by the excision of areas K3, K5 & K7 as shown in the GHD (2009) Capping Strategy from the current scope of capping works. As a result, works covered by this EPBC referral are no longer proposed in any wetland fringing vegetation or within potential GGBF breeding habitat. The risk of unintended intrusion into GGBF habitat is also considered to now be low.

SMEC (2013) identify the following key points in relation to GGBF habitat interactions:

- the capping works will occur on elevated sections of the landfill (typically around 9 - 10 mAHD);
- no works are proposed in the ponds or in known or potential GGBF breeding habitat areas, which are typically found fringing the ponds, below 2 - 3 mAHD;
- the detailed design, matches the boundaries provided in the Approved Capping Strategy (GHD, 2009);

- frog exclusion fences will be installed prior to other capping works in order to discourage frog movement into the area of construction; and
- the frog proof fences would be marked with marker tape to make them clearly visible and be used for construction safety and to prevent any earthwork machinery or material storage entering GGBF habitat areas.

Notwithstanding the above discussion, *Figure 7.1* is reproduced from SMEC (2013) illustrates the extend of the proposed capping works, the subject of this referral, in relation to a 30 m zone to previously identified and GGBF habitat prepare based on various documentation. *Figure 7.1* illustrating areas of GGBF habitat adjacent to the proposed capping works for K2, K10 North and K10 South, together within the proposed 30m buffer from the works.

The habitat mapped is largely based on GHD (2010) who undertook a habitat assessment which included ground-truthing and validation of habitats identified during the desktop review and identification of any potential habitat for the Green and Golden Bell Frog. The assessment methodology is reported as follows:

> *"Survey transects were reportedly undertaken along all drainage lines, water bodies and potential foraging habitat. A plant species list was compiled and general species abundances determined in order to establish vegetation types, in accordance with the DECC classification system for groundwater dependant communities. These vegetation surveys enabled the assessment of biodiversity values and the quantification of the presence and abundance of potential Green and Golden Bell Frog habitat.*
>
> *Following the field investigations a scaled map of the Proposal site identifying the location of known or potential Green and Golden Bell Frog habitat was prepared and can be seen in Figure 5-5. This map also identifies areas of preferred Green and Golden Bell Frog habitat and areas considered appropriate for habitat reconstruction".*

As discussed in is *Section 5.2 and 6.1* GGBFs can be found in various habitats and are highly mobile. This is evident in the recorded sightings mapped as outside the mapped indicative existing GGBF habitat recorded by SMEC (2013). For this reason the management measures outlined in this document are aimed at ensuring the full works area is subject to pre-clearance surveys and all water proximate water bodies are monitored for altered hydro-salinity regimes.

The siting of sedimentation basins at the periphery of the capped areas and their planned use as an integral part of the design should also be noted as important in water and ultimately GGBF habitat (water quality) management.

Legend

- Proposed KIWEF Closure Site
- Indicative Existing GGBF Habitat (Golder & Associates, April 2011)
- Indicative T4 Footprint
- Approximate 30m from Boundary of Mapped GGBF Habitat
- Typical Current Pond Surface Water Area
- Potential Pond Surface Water Area (Wet Conditions)
- Known GGBF Sighting Location (UMWELT, February 2012)
- Indicative Flowpath

N

0 150m

Source:
HDC/SMEC Fig No.3 Proj No. 30012008 6/12/2012

Client:	Hunter Development Corporation	
Drawing No:	0186182h_SEWPaC_Res_C009_R0.cdr	
Date:	19/07/2013	Drawing size: A3
Drawn by:	JD	Reviewed by: TM

This figure may be based on third party data or data which has not been verified by ERM and it may not be to scale. Unless expressly agreed otherwise, this figure is intended as a guide only and ERM does not warrant its accuracy.

Figure 7.1 - Indicative GGBF Habitat and Known Sightings

Former Kooragang Island Waste Emplacement Facility
Landfill Closure Works: Sites K2, K10 North & South
SEWPaC Response

Environmental Resources Management ANZ

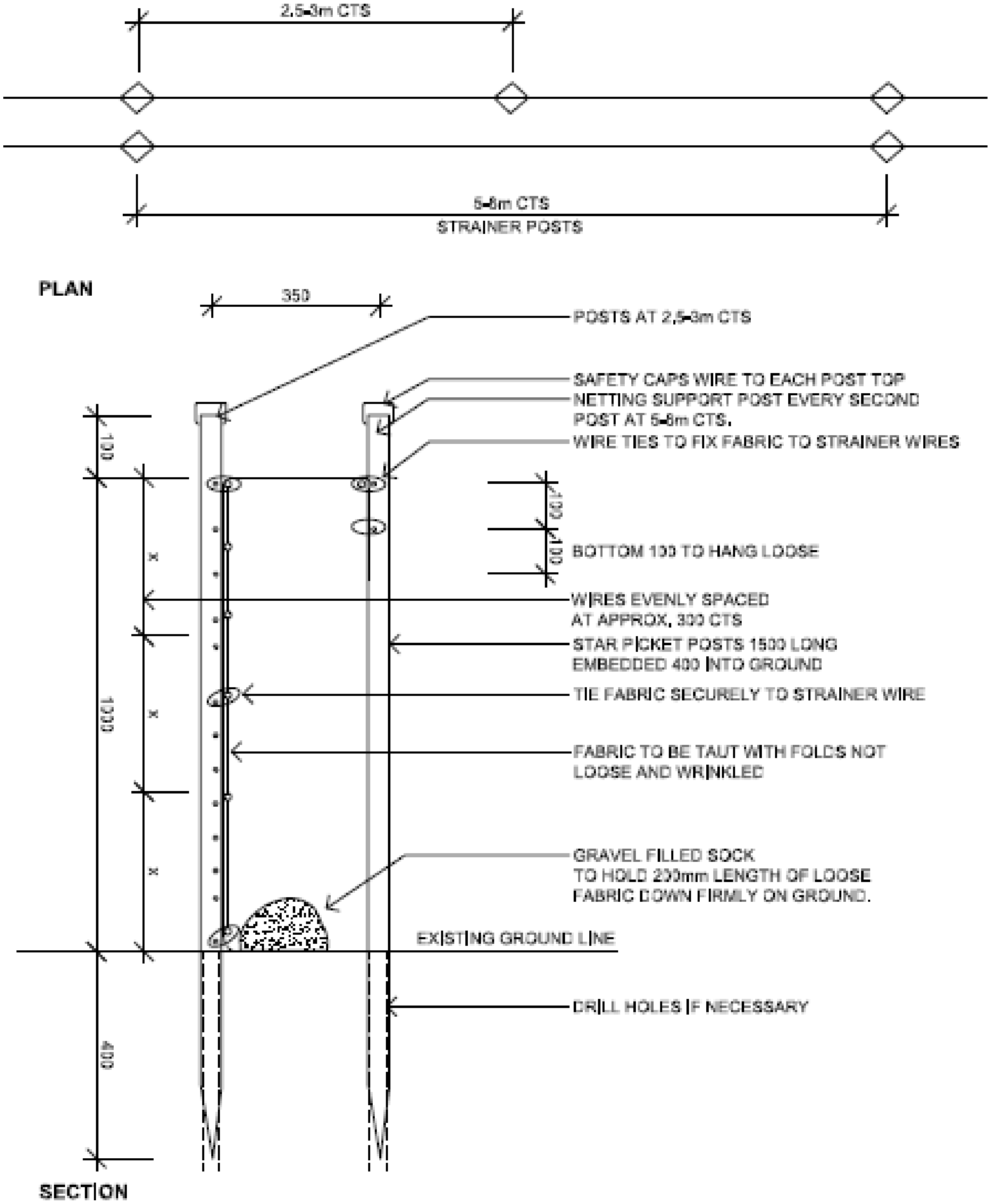
Auckland, Brisbane, Canberra, Christchurch, Hunter Valley, Melbourne, Perth, Port Macquarie, Sydney

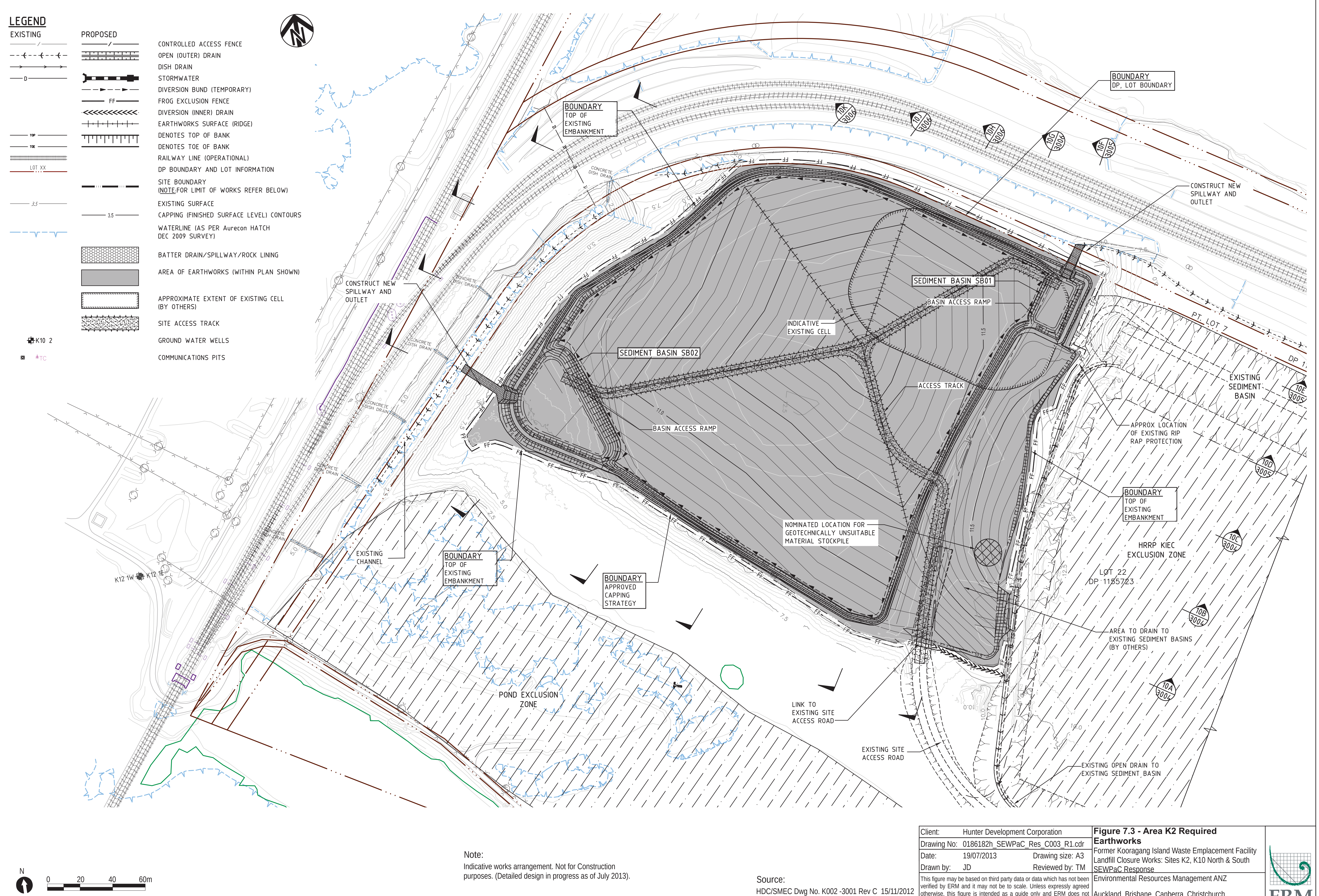
ERM

7.2 *GGBF BUFFER ZONES*

The extent of proposed works will be demarcated as a boundary in the field through the installation of frog exclusion fencing and 1.8 m high construction fences. Possible frog fence design is illustrated in *Figure 7.2* noting that alternative designs exist. Frog fence locations are illustrated in the 95% draft general arrangement plans reproduced in *Figure 7.3, Figure 7.4* and *Figure 7.5* noting that these provide a general indication of the proposed capping works and are not final design drawings for construction purposes. Final desing was currently in preporation as at July 2013 with no material changes expected. Where the distance is less than 30 m there is no evidence that land within the fence would provide useful buffer to mapped GGBF habitat.

Figure 7.2 Frog exclusion fence details





Note:

Indicative works arrangement. Not for Construction purposes. (Detailed design in progress as of July 2013).

Source:

HDC/SMEC Dwg No. K002 -3001 Rev C 15/11/2012

Client:	Hunter Development Corporation
Drawing No:	0186182h_SEWPaC_Res_C003_R1.cdr
Date:	19/07/2013 — Drawing size: A3
Drawn by:	JD — Reviewed by: TM

This figure may be based on third party data or data which has not been verified by ERM and it may not be to scale. Unless expressly agreed otherwise, this figure is intended as a guide only and ERM does not warrant its accuracy.

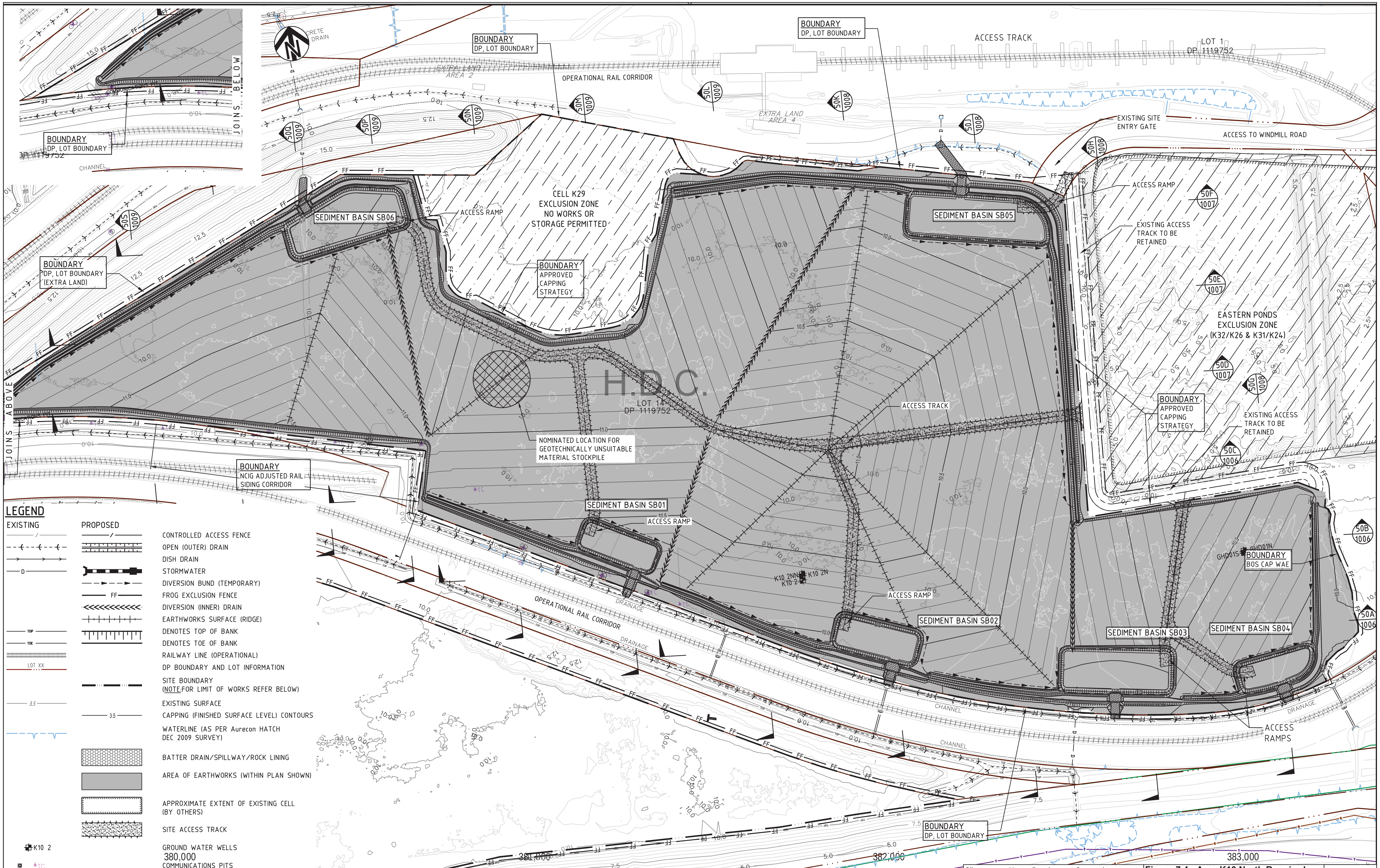
Figure 7.3 - Area K2 Required Earthworks

Former Kooragang Island Waste Emplacement Facility
Landfill Closure Works: Sites K2, K10 North & South
SEWPaC Response

Environmental Resources Management ANZ

Auckland, Brisbane, Canberra, Christchurch, Hunter Valley, Melbourne, Perth, Port Macquarie, Sydney

ERM



Note:
Indicative works arrangement. Not for Construction purposes. (Detailed design in progress as of July 2013).

Source:
HDC/SMEC Dwg No. K10N-1001 Rev C 15/11/2012

Client:	Hunter Development Corporation
Drawing No:	0186182h_SEWPaC_Res_C004_R1.cdr
Date:	19/07/2013 — Drawing size: A3
Drawn by:	JD — Reviewed by: TM

This figure may be based on third party data or data which has not been verified by ERM and it may not be to scale. Unless expressly agreed otherwise, this figure is intended as a guide only and ERM does not warrant its accuracy.

Figure 7.4 - Area K10 North Required Earthworks

Former Kooragang Island Waste Emplacement Facility
Landfill Closure Works: Sites K2, K10 North & South
SEWPaC Response

Environmental Resources Management ANZ

Auckland, Brisbane, Canberra, Christchurch,
Hunter Valley, Melbourne, Perth, Port Macquarie, Sydney

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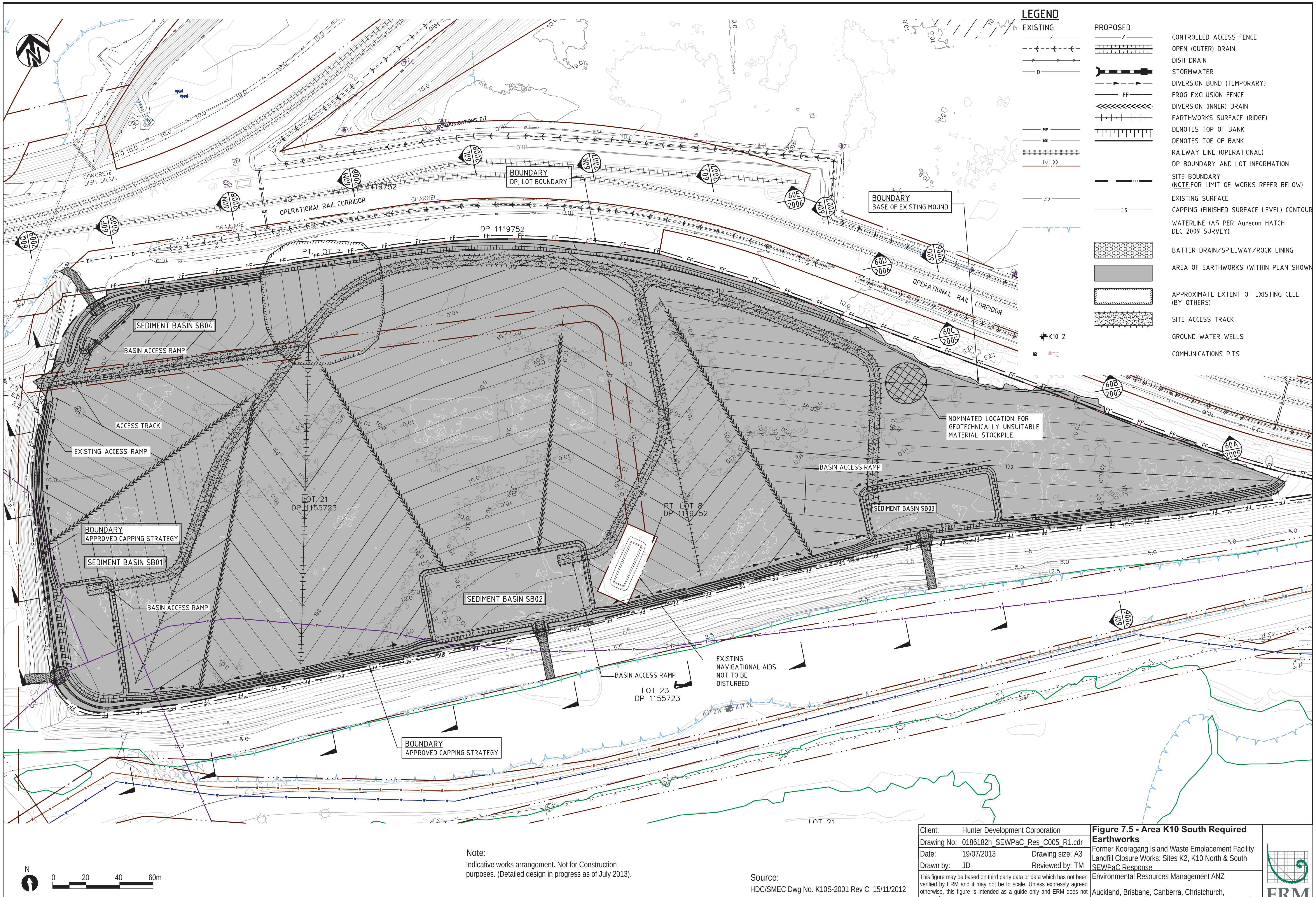

Note:

Indicative works arrangement. Not for Construction purposes. (Detailed design in progress as of July 2013).

Source:

HDC/SMEC Dwg No. K10S-2001 Rev C 15/11/2012

Client:	Hunter Development Corporation
Drawing No:	0186182h_SEWPaC_Res_C005_R1.cdr
Date:	19/07/2013 — Drawing size: A3
Drawn by:	JD — Reviewed by: TM

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Figure 7.5 - Area K10 South Required Earthworks

Former Kooragang Island Waste Emplacement Facility
Landfill Closure Works: Sites K2, K10 North & South
SEWPaC Response

Environmental Resources Management ANZ

Auckland, Brisbane, Canberra, Christchurch, Hunter Valley, Melbourne, Perth, Port Macquarie, Sydney

ERM

8 *AMPHIBIAN HYGIENE PROTOCOL*

This Chapter provides a summary of proposed hygiene protocol designed to minimise the risk of introducing or spreading amphibian Chytrid fungus to, on or from the site prior to, during and after capping works or associated activities. The reference document for these controls is the *Hygiene protocol for the control of disease in frogs* (DECC, 2008).

8.1 *HYGIENE PROTOCOL DETAILS*

Chytrid fungus infection occurs through waterborne zoospores released from an infected amphibian in water, with the fungus having the potential to infect both tadpoles and frogs. The fungus can spread through movement of water around the site.

A hygiene protocol aimed at addressing this risk are provided in the *GGBF Management Plan – KIWEF Closure Works* (Golder & Associates, 2011). This plan is endorsed by the NSW EPA in Surrender notice #1111840 as varied (2 May 2013). All proposed controls have been developed with reference to the *Hygiene protocol for the control of disease in frogs* (DECC, 2008).

Golder & Associates (2011) list the following specific measures to be applied:

- all plant entering and leaving the KIWEF site will be disinfected via a wash-bay;
- all PPE and equipment coming in contact with soil will be disinfected when entering or leaving site;
- water used for dust suppression will be sourced only from constructed sediment control dams and transfer of water between areas will be restricted; and
- disinfection procedures will follow the methods outlined in the *Hygiene protocol for the control of disease in frogs* (DECC, 2008) and be monitored and recorded.

HDC is currently preparing the detailed design and tender documentation for the landfill closure works, including the over-arching Environmental Management Plan (EMP) with guiding principles for environmental management of the site (the "KIWEF EMP"). The tender documents will require the successful contractor to prepare a Construction Environment Management Plan (CEMP) that requires adherence to the GGBF Management Plan (Golder & Associates 2011), as well as the overarching site EMP.

The *Green and Golden Bell Frog Management Plan – Kooragang Island Waste Emplacement Facility Closure Works* document prepared by Golder & Associates (April 2011) will be incorporated into the documentation for the KIWEF landfill closure. The document discusses a wide range of management procedures designed to protect GGBFs from pre-work surveys through to environmental induction training and site hygiene management for chytrid fungus. The document was prepared with reference to the GGBF Management Plan prepared by NCIG (2007).

9 *GAMBUSIA HOLBROOKI MITIGATION MEASURES*

This Chapter provides details of proposed mitigation measures to prevent increased potential for the spread of *Gambusia holbrooki,* a known predator of tadpoles. The following information is summarised from SMEC (2013).

9.1 *GAMBUSIA HOLBROOKI MANAGEMENT DETAILS*

Gambusia management details are provided in *GGBF Management Plan – KIWEF Closure Works* (Golder & Associates, 2011). This plan is endorsed by the NSW EPA in Surrender notice #1111840 as varied (2 May 2013).

The detailed design of landfill closure works, generally maintains runoff catchments to the existing conditions, within the context of the already highly modified site. The key aim and benefit of the capping works is to limit infiltration into the landfill, preferentially resulting in a greater volume of surface water available for pond inflow. This results in a slight change in surface water volumes to priority ponds and to the frequency of flow between ponds, however there will not be change to the physical connections (channels, flow paths, culverts) between the ponds by which *Gambusia* may migrate. Work proposed by others may alter flow paths and allow *Gambusia* migration between ponds affected by this proposal.

The majority of surface water bodies at KIWEF are presently connected through a series of channels, flow paths, culverts or as water moving through the aquifers. Given this, it is difficult to adopt any mitigation measures that stop the transfer of water and aquatic biota between ponds during high flows after rainfall events without significantly altering the existing regime.

Importantly, construction water would not be drawn from KI ponds nor transferred between water bodies during the construction phase. HDC have committed to not use site water from ponds for dust suppression or any other purpose during construction.

Adherence to frog hygiene protocols would manage the potential for inadvertent *Gambusia* transfer. Mitigation measures to ensure that *Gambusia* would not be transferred between ponds, include site induction training and disinfection of boots, vehicles and machinery. All surveys have been conducted in accordance with the NSW National Parks and Wildlife Service Hygiene Protocols (refer to *Section 8*).

10 CONSTRUCTION PHASE MITIGATION MEASURES

This Chapter provides details of proposed mitigation measures to minimise impacts on GGBFs during construction works.

10.1 GGBF MANAGEMENT PLAN

The *GGBF Management Plan – KIWEF Closure Works* (Golder, 2011) has been endorsed by the NSW EPA in Surrender notice #1111840 as varied (2 May 2013). These plans set out the GGBF management and mitigation measures that will be applied in undertaking the proposed action. Measures include:

- installation, inspection and maintenance of appropriate erosion and sediment control devices up gradient from GGBF habitat;
- implementation of frog hygiene protocols as proposed in Golder & Associates 2011 and summarised in Chapter *8 including frog relocation procedures*;
- delineation of disturbance areas on site plans and on the ground (refer to *Sections 7.2* and *10.2;* and
- pre-clearance surveys of GGBF habitat within disturbance footprint.

10.2 FROG-PROOF FENCING

As part of the technical specification and detailed design drawings for the proposed works, the requirement for frog exclusion fences around all earthworks has been specified, in order to discourage frog movement into the area of construction. This was successfully undertaken for the BHP / Thiess Hunter River Remediation Project (HRRP) adjacent to K2, and a similar type of fence is proposed. The frog fencing will be provided in combination with a silt-sediment fence, which would be placed on the construction side of the frog fence. This will prevent sediment compromising the frog fence and also prevent fauna outside of the construction area being trapped between the two different types of fences. The option exists to either fence each area in its entirety for the duration of works or fence in a staged approach as capping works progress and will be determined when detailed works scheduling is agreed with the construction contractor.

Frog fence details are provided in *Chapter 7.*

10.3 "PRE-CLEARANCE" GGBF SURVEY

Preclearance surveys will be undertaken prior to the commencement of any construction activities and after fence installation (per 10.1) in order to reduce any physical damage being caused to adult or juvenile frogs occurring within the impact area, as outlined in the *GGBF Management Plan* (Golder & Associates, 2011). Preclearance works surveys will be undertaken within proposed disturbance areas by a suitably qualified and licensed ecologist and all activities will be conducted in accordance with the relevant measures outlined in the hygiene protocol. The results of the pre-works surveys will be recorded and reported in the Annual Environmental Management Report.

Diurnal visual searches would be undertaken for GGBF in areas of suitable habitat including vegetated area, especially those with tussock forming grasses, areas of rocks, timber and artificial debris. Following the diurnal habitat searches, a nocturnal habitat search may be conducted to assess nocturnal usage (breeding/calling) in the habitat adjacent to the ponds proximal to capping works, for example the surrounds of Easement Pond, Easement Pond South, Windmill Road Open Channel, Long Pond, and the K2 Pond. Nocturnal survey techniques may include visually searching of habitat features, spotlighting, aural surveys and call play-back.

The preclearance works should be undertaken immediately after the completion of fencing. This ensures that frogs and other fauna are not contained for long periods within the construction footprint and that they are "cleared" from the area immediately prior to works commencing.

10.4 RELEASE SITE CRITERIA AND MAPPING

The *GGBF Management Plan* (Golder & Associates, 2011) outlines that in the event that any GGBFs are observed during the diurnal or nocturnal searches, the relocation procedures will be initiated prior to the commencement of disturbance works. That report outlines that the relocation procedure follows the proposed NCIG (2007) procedure, which has been accepted by OEH.

In the event that any GGBF is identified within the disturbance areas during pre-works surveys, the ecologist undertaking the pre-clearance survey will capture the frog. If the frog appears to be healthy it will be released in the immediate vicinity of the disturbance area, yet outside of potential areas of disturbance. If this is not practical due to high levels of disturbance within the surrounding area, the frog will be released into a suitable relocation area. Any frog to be relocated will be held in a cool, dark, moist place until nightfall. Where practicable, relocation will be timed to coincide with periods of recent rainfall to optimise survival. Relocation of GGBFs outside preclearance works surveys will be conducted in accordance with the relevant measures outlined in the hygiene protocol. Details of GGBFs that are relocated during pre-work surveys will be recorded and reported in Annual Environmental Monitoring Reports (AEMR), and will include lifecycle stage, sex of individual, location where found and location of release.

It is recommended that the release site selected should be in similar habitat to that which the frog was found. For example if a GGBF was found sheltering under debris, a site should be selected with similar cover. Adult frogs found away from pond habitats do not require to be placed within a pond, although vegetated areas adjacent to a pond may be most suitable. Areas recommended for suitable release sites, based on recent density of records include the areas surrounding Long Pond for K10 South, Eastern Ponds for K10 North and Deep Pond for K2.

If the frog appears to be sick or dead then diagnostic behaviour tests will be conducted (Golder & Associates 2011). If the frog is unlikely to survive transportation, it will be euthanized and preserved for pathological analysis. Those individuals which are expected to survive transport should be processed as detailed in the *Hygiene Protocol for the Control of Disease in Frogs* (DECC, 2008).

A relocation procedure also exists for GGBF found outside of preclearance-works which is similar to that listed above, further details can be found in the *GGBF Management Plan* (Golder & Associates, 2011).

11 SITE STABILISATION AND REVEGETATION

This Chapter describes how areas affected by the capping works would be stabilised and revegetated, including measures to mitigate effects of stormwater runoff, sediment and erosion control and the likely success of revegetation in the K2 area.

11.1 CAPPING CHARACTERISTICS

The key management measure for avoiding the risk of altered surface water quality is advised by SMEC (2013) as maintaining a 'like for like' surface. This would minimise changes in water quality to downstream receiving water quality (subject to the monitoring and assessment of preceding Chapters).

Critical consideration has also been given to either using or avoiding imported topsoil and/or inorganic fertilisers to increase revegetation potential. However, this will no longer be pursued as a viable site management method, because a concern of increased risk of water quality changes in habitat ponds.

All three developed areas (K2, K10 North and K10 South) on the site are proposed to be covered with a re-vegetation layer that sits above the proposed impermeable cap. The revegetation layer is proposed to consist of existing topsoil, which typically consists of Coal Washery Reject (CWR) material. The existing CWR material is weathered, and currently supports vegetation growth in a ground cover as illustrated in *Figure 11.1*.

SMEC (2013) identified the following key soil constraints in additional sampling:

- the soil profile over K2 is very uniform and is strongly alkaline, moderately saline and very low in Nitrogen, Phosphorus and moderately low in Potassium;

- the K10 is uniform but compared to K2 not as alkaline, not as saline, is deficient in Nitrogen, Phosphorus and to a lesser extent Potassium.

Notwithstanding these potential constraints, SMEC (2013) conclude as follows:

"the existing topsoil material to be used for the revegetation layer currently supports significant vegetation and generally is very well vegetated to the extent necessary to stabilize the soil. Given the potential implications on chytrid fungus and nutrient export risk it is preferable to not undertake significant soil amelioration and instead, appropriate species that would be compatible with the low nutrient and or sodic soils present. This will ensure that no chytrid fungus is introduced via importation of ameliorates, and that receiving waters (GGBF habitat) are not at risk of nutrient loads, algal blooms or eutrophication.

Photograph 1

Typical vegetation growth currently found within K2 (recent photograph).

Photograph 3

Typical vegetation growth currently found within K10 North (recent photograph).

Photograph 5

Typical vegetation growth currently found within K10 South (recent photograph).

Photograph 2

Typical vegetation growth currently found within K2 (recent photograph).

Photograph 4

Typical vegetation growth currently found within K10 North (recent photograph).

Photograph 6

Typical vegetation growth currently found within K10 South (recent photograph).

Client:	Hunter Development Corporation		**Figure 11.1 - Typical Vegetation Growth Found within K2, K10 North and K10 South** Former Kooragang Island Waste Emplacement Facility Landfill Closure Works: Sites K2, K10 North & South SEWPaC Response
Drawing No:	0186182h_SEWPaC_Res_C001_R0.cdr		
Date:	16/05/2013	Drawing size: A4	
Drawn by:	JD	Reviewed by: TM	
This figure may be based on third party data or data which has not been verified by ERM and it may not be to scale. Unless expressly agreed otherwise, this figure is intended as a guide only and ERM does not warrant its accuracy.			Environmental Resources Management ANZ Auckland, Brisbane, Canberra, Christchurch, Hunter Valley, Melbourne, Perth, Port Macquarie, Sydney

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One area of concern raised by SEWPaC was revegetation in K2, using existing topsoils. The K2 area was recently stripped of all vegetation for the Hunter River Remediation Project and subsequently regenerated and stabilised with no soil amelioration being necessary, using stock methods of stabilisation by common seeding methods. The successful revegetation of K2 by BHP Billiton in 2012 is a clear demonstration that this soil supports a variety of native vegetation in its current form, without amelioration. The approach employed by BHP Billiton appears to have been successful, as the vegetation has taken hold within a matter of months, without maintenance".

11.2 STORMWATER, EROSION AND SEDIMENT CONTROLS

All surface water flows from capping areas will be controlled by capture and retention in purpose built sediment basins that provide retention of design runoff events. Erosion and sediment control will be designed, installed and managed as follows:

- design of erosion and sediment controls to meet the environmental protection standards for sensitive environments based on *Managing Urban Stormwater - Soils and Construction*, (Landcom, 2004 as well as documents from other States and internationally (such as "International Erosion Control Association – Australasia"); and
- construction of sediment basins before clearing associated areas from where runoff is sourced; and
- use of lined basins to remain in place post construction for perpetual capture, retention and settling of suspended sediments in stormwater prior to release when ponds overtop.

The creation of GGBF habitat by sedimentation basins is not actively proposed. The intention of the capping works is to return the site to as close to the existing landform as possible with improved surface drainage characteristics, reduced percolation through soil profiles and groundwater infiltration rates.

The existing foraging and movement opportunities for fauna would be re-established post construction through the advent of natural processes. Sediment basins and drainage channels in place post-construction may be used opportunistically by GGBF as connective corridors, foraging habitat, breeding or rearing habitat.

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Umwelt (Australia) Pty Ltd (2012) **Ecological Assessment for Port Waratah Coal Services (PWCS) Proposed Terminal 4 (T4) Project, Port of Newcastle** Prepared on Behalf of PWCS, February 2012.

Annex A

SMEC (2013) Detailed Response to SEWPaC Comments

Detailed Response to SEWPaC Comments

Kooragang Island Waste Emplacement Facility

May 2013 Ref.30012008

AUSTRALIA | ASIA | MIDDLE EAST | AFRICA | PACIFIC

Project Name:	Kooragang Island Waste Emplacement Facility – Detailed Response to comments from the Department of Sustainability, Environment, Water, Population and Communities – Final Report
Project Number:	30012008
Report for:	Hunter Development Corporation

PREPARATION, REVIEW AND AUTHORISATION

Revision #	Date	Prepared	Reviewed	Approved for Issue
1 (Preliminary Internal Draft)	6/12/2012	H. Nelson J. Ford	H. Nelson J. Ford B. Patterson	
2 (Draft)	26/02/13	B. Patterson / A. White / H. Nelson / J. Ford / C. Schultz / T. Newsome	B Patterson	
3 (Final Draft)	22/03/13	B. Patterson / A. White / H. Nelson / J. Ford / C. Schultz / C. Kuczera / P. Carolan / T. Newsome	B Patterson	
4 (Final)	12/04/13	B. Patterson / A. White / H. Nelson / J. Ford / C. Schultz / C. Kuczera / P. Carolan / T. Newsome	C Kuczera / B Patterson	B Patterson
5 (Final Review)	17/05/13	B. Patterson / A. White / H. Nelson / J. Ford / C. Schultz / C. Kuczera / P. Carolan / T. Newsome	B Patterson	B Patterson

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TABLE OF CONTENTS

FIGURES

INTRODUCTION & SUMMARY OF KEY FINDINGS

The Applicant for the proposal for the Kooragang Island Waste Emplacement Facility (KIWEF) Closure Works is the Newcastle Port Corporation (NPC). Hunter Development Corporation (HDC) has the role of assisting NPC in the formulation of a design and any approvals necessary for the works. As such, HDC has engaged SMEC Australia Pty Ltd (SMEC) to assist in providing a response to the Department of Sustainability, Environment, Water, Population and Communities (SEWPaC) request for more information regarding the referral made to SEWPaC under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act).

This report forms the ***Stage 2 – Detailed Review of Issues Raised by SEWPaC.*** It has been prepared in response to the ten (10) requests for more information raised by SEWPaC (EPBC Ref: 2012/6464, 3 August 2012) to the KIWEF EPBC Referral (GHD, July 2012).

The Stage 2 detailed review has been prepared using the work undertaken as part of the Stage 1 study in combination with additional studies. The methodology used to prepare this Stage 2 detailed review includes:

- Review of the issues raised by SEWPaC;
- Review of relevant data available to address the issues raised;
- Preparing summaries of the data available to address SEWPaC issues;
- Identification of any knowledge/data gaps;
- Recommendations /options to address the knowledge gaps and provide a response to SEWPaC; and
- Undertaking additional studies to supplement existing information, including seeking expert opinion from hydro-geologists and ecologists.

The recommendations for a response made in the Stage 1 study form the Scope of Work for this ***Stage 2 Assessment***.

SMEC gratefully recognise the contributions of Will Wright and Stephen Jones from Douglas Partners for input into the groundwater modelling and Dr Arthur White for ecological input on the Green and Golden Bell Frog (GGBF) aspects of the study.

SMEC would also like to thank Port Waratah Coal Services for sharing data used to provide this advice.

Structure of this Report

From its initial assessment of the referral lodged by HDC (GHD, July 2012), SEPWaC raised ten issues that required further information. This report has been structured to address each of these issues on a per chapter basis. The issue raised by SEWPaC is quoted at the start of each chapter in grey.

Section 11 outlines the hydro-salinity modelling methodology and results.

Key Findings

The following is a summary of the key findings of the study:

1. No works are proposed in the ponds or in known GGBF habitat areas, which are typically found fringing the ponds. The capping works will occur on elevated sections of the landfill, typically between RL 9–10m AHD. The only works which may impact on fringing areas of the ponds will be the construction of sedimentation basin outlets, as illustrated in **Plate 1** and **Plate 2** below.

Plate 1: Figure 4a – K10 Capping Area showing GGBF Habitat Areas and Proposed Stormwater Management Controls

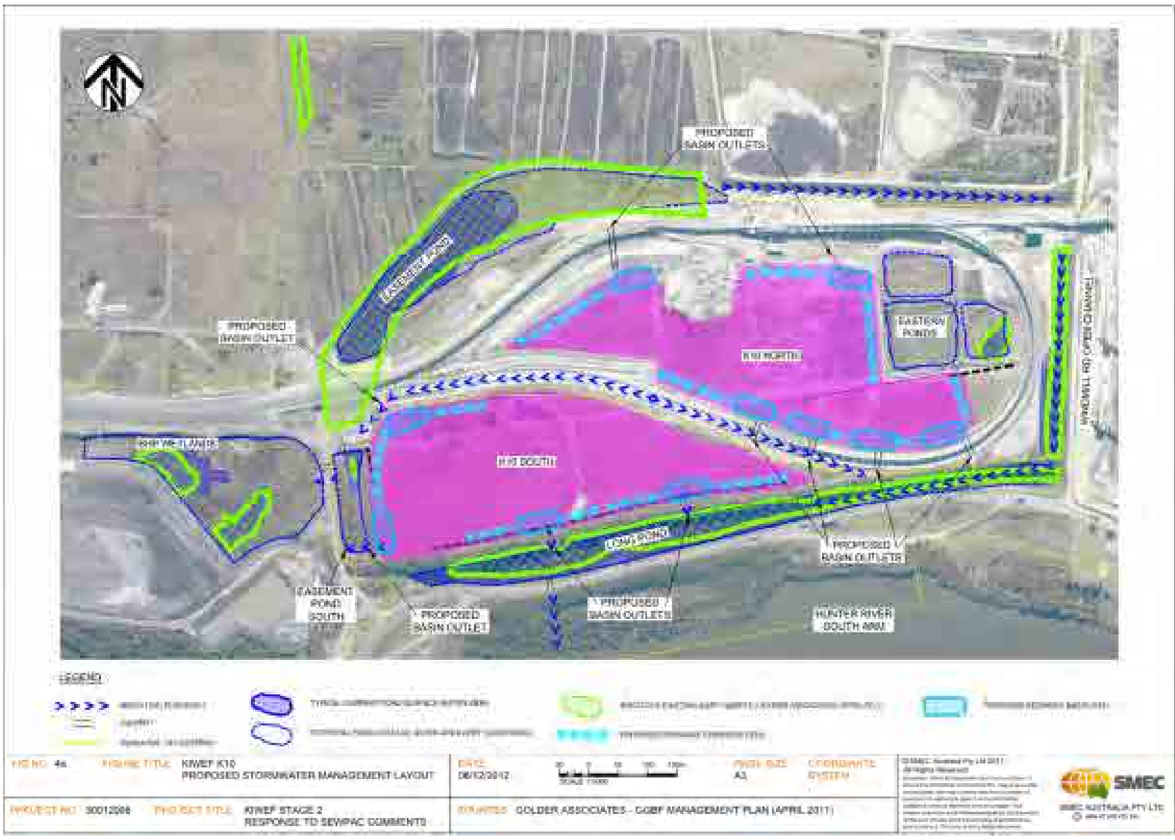


Plate 2: Figure 4B – K2 Capping Area showing GGBF Habitat Areas and Proposed Stormwater Management Controls

2. In general, improvements in water quality due to the capping works would provide ecological benefits to all species. Any negative changes would not be of a magnitude that would significantly impact on GGBF, Australasian Bittern or migratory bird habitat. The capping works would also provide significant benefits to the environment in general by limiting the potential for contaminated material from the fill leaching into the surrounding environment. The capping design has been approved by the OEH (NSW EPA) in the Conditions of Surrender.

3. Previous studies (*Revised Capping Strategy KIWEF – Flora and Fauna Impact Assessment Revision 3* (GHD, January 2010) concluded that the proposal would not significantly impact on Australasian Bittern. Assessments of Significance under the EPBC Act also confirmed that the proposal is unlikely to have a significant impact on listed migratory wading species.

   Specific monitoring of the Australasian Bittern and migratory wading species would be problematic, given their mobile nature. Therefore, vegetation habitat and water quality monitoring is proposed. Mitigation measures for these species mostly center around minimising impact on vegetation communities and pond water quality. As outlined above, generally the works are expected to improve water quality in the ponds.

4. In terms of the relative effect of the timing of the works, it is considered unlikely that the proposed disturbance would disrupt the breeding cycle of any species as no significant freshwater / brackish wetland habitat or terrestrial habitat would be cleared. Also, areas of appropriate foraging and breeding habitat would be retained within and adjacent to the proposal site. Therefore, it is not considered

to be necessary to have any restrictions on the timing of works, from a seasonal perspective. Other controls are required, such as controls on water quality and noise in order to minimise impact on habitat areas that are adjacent to the proposed works areas

5. There will be no change to the actual physical connections (channels, flow paths, culverts) between the ponds as a result of the capping works. Therefore, the capping works will not provide additional water pathways by which Mosquito Fish (*Gambusia Holbrooki)* can migrate. It is difficult to adopt any mitigation measures that stop the transfer of water between ponds during high rainfall events without significantly altering the existing hydrologic/hydraulic regime.

   Importantly, it has been recommended that water is not transferred between water bodies during the construction phase. There is potential that *Gambusia* can also be transferred between water bodies through lack of adequate frog hygiene protocols. Mitigation measures to be implemented to ensure that *Gambusia* would not be transferred between ponds include site induction training and disinfection of boots, vehicle and machinery, and the prevention of water transfer between ponds during construction.

6. The closure works are required to cap a previous industrial landfill site at Kooragang Island.

   Three separate areas (called K2, K10 North and K10 South) are to be covered with a soil cap made up of re-worked existing material, which predominantly consists of Coal Washery Reject (CWR). **Figure 4a** and **Figure 4b** show the areas of the site proposed to be capped. This existing material will be supplemented in some parts of the site with clean imported fill material to make up the required volume of capping material to satisfy requirements from the NSW Office of Environment and Heritage (OEH) as part of the landfill closure requirements.

   On top of the cap will sit a re-vegetation layer which will consist of existing 'topsoil', which typically consists of CWR material and other fill. The existing CWR material is highly weathered, and currently supports some existing vegetation growth (typically weeds).

   The existing weathered CWR topsoil material will be retained in order to prevent the introduction of any chytrid fungal spores or nutrients. It is believed that the current weathered CWR material, once re-spread will support an adequate vegetation cover to prevent erosion and sedimentation. The intention of re-using existing CWR material is to maintain a 'like for like' surface which will help minimise changes in water quality to downstream receiving waters and potential impacts on GGBF. The capping work will be staged to limit the extent of disturbance at any one time.

7. A review of previous reports and additional monitoring and modelling of the hydro-salinity regime of each waterbody was undertaken as part of this investigation. These assessments concluded that the hydro-salinity regime of ponds immediately downstream of the works will generally become wetter and less saline as a result of the capping works. These changes occur due to a predicted increase of low salinity surface runoff and a reduction in higher salinity groundwater inflow into the ponds. Modelling results indicate that the changes will not be significant. Hence, significant impacts to the GGBF and other threatened species are not expected.

Modelling also confirmed that there are no significant changes predicted to the Eastern Ponds as a result of the proposed capping works, as there is no change to the contributing catchment area to these ponds, and only minor changes to the groundwater regime.

8. Water quality may potentially degrade during the construction phase of the proposed capping works, but will stabilise over time. Pond nutrients and algal levels may rise in the period immediately after capping due to the disturbance of the topsoil layer materials. This will be mitigated by a range of measures including the careful selection of capping and reȑvegetation soil materials to ensure replacement of “like for like” soil properties and through appropriate design of erosion and sedimentation controls. Once the landform stabilises, it is likely that runoff quality will reach a new equilibrium position not substantially or significantly different to the existing conditions.

9. The Environmental Assessment for the T4 Project (EMM for Port Waratah Coal Services, February 2012) commits to a comprehensive and targeted monitoring program for GGBF and water quality across Kooragang Island. This information will be available to the Applicant.

Plate 3 below shows the extent of GGBF sightings across the Kooragang Island and Ash Island areas, while Plate 4 shows a more detailed extent of GGBF confirmed sightings around the KIWEF site areas (Umwelt, February 2012)

Plate 3: **Plan showing confirmed sightings of GGBF within Kooragang Island / Ash Island area (Umwelt, February 2012)**

Plate 4: Detail showing GGBF sightings within KIWEF part of Kooragang Island (Umwelt, February 2012)

In order to reduce the risk of data gaps between the proposed T4 monitoring program and those required to assess the specifics of the KIWEF Landfill Closure Proposal, an independent recognised GGBF expert will review the T4 data collection programs. If required, these will be supplemented with existing data.

Following the assessment of the body of information available to the Applicant for adequacy and relevance, the Applicant would provide a submission to the satisfaction of SEWPaC that defines the information to be deemed reliable. The parameters will be monitored for 3 years after construction. Data from T4 together with data from the existing onřsite water level and salinity loggers will be compiled into annual reports provided to SEWPAC.

The Annual Report to SEWPaC will include a summary of the seasonal GGBF population dynamics and water quality observations, benchmarked against the volume of baseline data that has been assembled. The Annual Report would provide a conclusion on the relative GGBF abundance and dynamics and any anomalies observed in habitat and or population. The Annual Report will be undertaken by a recognised GGBF specialist, supplemented by other relevant experts and would be undertaken for a minimum of three (3) years postř construction. Following the three year period, the need for further monitoring would be reviewed with SEWPaC.

10. Should changes become apparent in the future, then the proponent will undertake Recovery Plan mitigation measures for GGBF, including detailed scrutiny of the water level and water quality monitoring. This monitoring will be used to ascertain in which parts of the site the hydrology and water quality are

changing, and to enable GGBF experts to understand the drivers affecting the changes within the habitat areas.

If these investigations conclude that there is an identifiable impact associated with the landfill capping, then there are a number of possible mitigating measures that could be instigated to ameliorate any impacts. These include the conversion of the proposed sedimentation control ponds to constructed wetlands, to mitigate pollutant export to the ponds and to provide additional compensatory GGBF habitat.

11. The KIWEF Capping Strategy – EPBC Referral (GHD, July 2012) details a range of frog hygiene protocols that will be adopted in order to minimise the risk of introducing or spreading chytrid fungus. Measures such as disinfecting vehicle tyres, washing down vehicles before entering and leaving the site, disinfecting PPE, such as boots, waders and equipment are already being undertaken and will continue to be adhered to as part of the Proposal. The reference document for these controls is the Hygiene Protocol for the Control of Disease in Frogs (DECC, 2008).

12. The following construction phase mitigation measures are proposed to mitigate potential impacts on GGBFs during the construction works:

    - No Construction activities are proposed within GGBF habitat areas.
    - Prior to the capping works commencing, areas of known GGBF habitat will be clearly identified/delineated on the ground with appropriate signage as well as on the site plan.
    - Installation of a frog-proof barrier around the disturbance footprint. Frog proof fences would be marked with marker tape to make them clearly visible.
    - Pre-works surveys will be undertaken within the proposed disturbance areas by a suitably qualified ecologist at least one week prior to works commencing including the use of frog hygiene protocols.
    - An ecologist will be available on-call to visit the site should GGBF be encountered during clearing and capping works. This person will also be responsible for relocating any GGBFs that may be found in the works area.

13. As discussed above, a revegetation layer is proposed on top of the capping layer, which will consist of existing ‘topsoil’, which typically contains CWR material and some other fill. It is understood that CWR material may potentially inhibit the growth of water borne fungal pathogens such as *Batrachochytrium Dendrobatidis*, or frog chytrid fungus.

    Maintaining a ‘like for like’ surface will help minimise changes in water quality to downstream receiving waters and potential impacts on GGBF.

1 ITEM 1 – CURRENT VS FUTURE PONDS DEPTHS

Item 1 – Detailed analysis of how current vs future changes to pond depths could affect pond suitability as habitat for Green and Golden Bell Frog (GGBF), listed migratory birds and the Australasian Bittern over time, in relation to: vegetation, pond morphology and volumetric capacity, longevity of water level changes etc.

Please also provide details of possible mitigation measures which could be implemented if changes are found to be having an adverse effect on any of the species or their habitat, and thresholds which could trigger these actions.

1.1 Analysis of the Potential Impacts to Pond Hydrology, and Suitability of Habitat

The capping works for K2, K10 North and K10 South will occur on elevated sections of the landfill, typically between RL 9ř10m AHD. No significant works are proposed in the ponds or in known GGBF habitat areas, which are typically found fringing the ponds. The only works which may impact on fringing areas of the ponds will be the construction of sedimentation basin outlets, as illustrated in **Figure 4a** and **Figure 4b**.

Plate 5: Figure 4a – K10 Capping Area showing GGBF Habitat Areas and Proposed Stormwater Management Controls

Plate 6: Figure 4B – K2 Capping Area showing GGBF Habitat Areas and Proposed Stormwater Management Controls

The capped areas are proposed to be covered with a reřvegetation layer that sits on top of the proposed cap. The revegetation layer is proposed to consist of existing ‘topsoil’, which typically consists of CWR material and other fill. Suitable vegetation will be planted to assist in stabilising the reřvegetation layer. This vegetation and the reřvegetation layer will reduce the potential for runoff that may affect water quality and in turn habitat.

A review of previous reports and additional monitoring and modelling of the hydrologic regime of each waterbody was undertaken as part of this investigation. These assessments concluded that the hydrologic regime of ponds immediately downstream of the works will generally become wetter as a result of the capping works. These changes occur due to a predicted increase in surface runoff, offset by a reduction in groundwater inflow into the ponds. Modelling results indicate that the changes will not be significant. Hence, significant impacts to the GGBF are not expected.

Continuous monitoring of pond water levels will be undertaken to continue to establish baseline data, and to ensure impacts are not significant during and post construction of the proposed capping works.

Indicative comparison values have been derived to ensure that the monitoring is focused on the parameters that most relate to the threatened species in question. Planned construction phase mitigation measures and recovery plan mitigation measures have been identified in the event that significant impacts can be attributed to the works.

1.1.1 Review of Previous Studies

Previous studies have indicated that changes in pond water levels as a result of the capping strategy do not necessarily constitute an impact to the threatened species. For example, the *Report on KIWEF – Revised Final Landform and Capping Strategy – Rev 4* (GHD, 2009) – Section 6 concludes that it is considered unlikely for the capping strategy to result in a significant impact on the Green and Golden Bell Frog (GGBF) *Litoria aurea*, migratory birds or endangered ecological communities on the site, because:

- Limited vegetation would be removed for the proposal;
- The capping strategy has been designed to minimise any changes in hydrology and as such, changes to water levels, nutrient loadings and temperatures would be minimised;
- Capping of potentially toxic substances would improve the long‐term quality of these waters by preventing pollutants from surfacing and migrating through the food chain; and
- None of these species are likely to be breeding within the Proposed Action Works Area (i.e. on top of the landfill cells which are some 6‐8m above the habitat areas).

Furthermore, the 2012 GHD Capping Strategy (*KIWEF Capping Strategy – EPBC Referral* (GHD, July 2012)) indicated that the vegetation communities on the periphery of the ponds (*that are associated with periodic inundation*) would simply migrate up or down gradient. This would not necessarily result in any significant change to the habitat of the fauna species and ecological community in question.

In addition, the above document reiterates as follows:

> "*temporary changes in water level in some ponds are unlikely to significantly impact the ecology of these systems, as most species which form these communities are adapted to fluctuations in water availability and respond accordingly. Moreover the changes in water levels may support additional habitat for these species, in providing larger areas of fringing reedlands and wetland habitat, or greater levels of semi-permanent water which may extend breeding habitat availability while still providing the fluctuation in wetting and drying that currently occurs across the KIWEF site"*

Notwithstanding this assessment, any changes to pond hydrology do have the potential to impact on GGBF. The precautionary principle would suggest that sufficient monitoring should be implemented. Therefore HDC has developed a monitoring regime. The regime includes establishing thresholds to implement additional investigations, and if required develop a Recovery Plan that includes mitigation measures that will be implemented should impacts become apparent.

1.1.2 Installation of Additional Water Level Monitoring Devices

Following review of existing baseline data, it was concluded that there is limited data on the periodicity of the standing water levels despite water levels being recorded at discrete times previously. Subsequently, the relationship between surface water runoff and groundwater on Kooragang Island was not clear. There was also limited information on the frequency and duration of standing surface water that is suitable for the successful breeding of the GGBF.

To further understand the periodicity of standing water levels and the influence of groundwater on pond water levels, continuous water level loggers were recently installed by SMEC and Douglas Partners as part of this investigation. The loggers were installed at both surface water and groundwater locations around the KIWEF site in order to monitor water levels on a continuous basis.

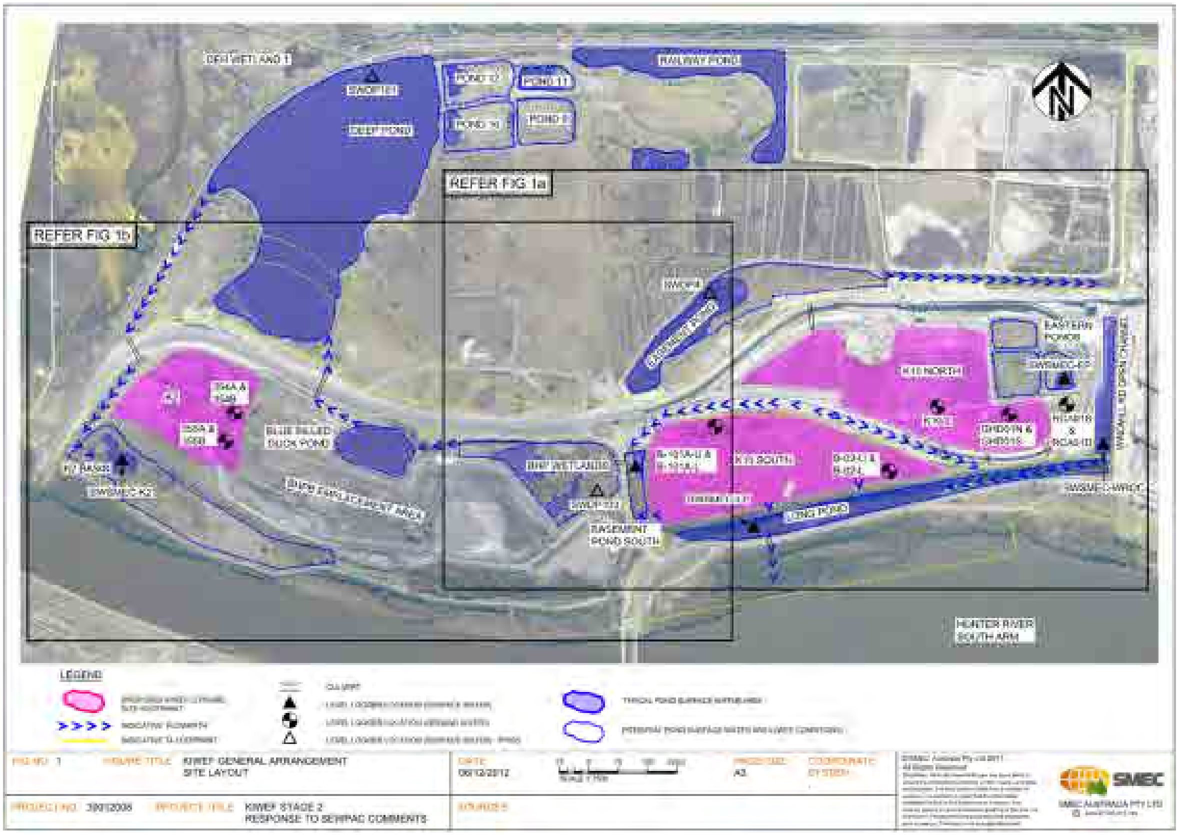
Level loggers were installed within the following ***surface water*** locations (refer **Figure 1**):

- Long Pond;
- Easement Pond South;
- ‘K2’ Basin;
- ‘Windmill Rd’ Open Channel; and
- Eastern Ponds.

Additional surface water data is available at Easement Pond, BHP Wetlands and Deep Pond from level loggers previously installed by Douglas Partners for the PWCS T4 Environmental Assessment.

Level loggers were installed for this study at thirteen (13) ***groundwater*** locations in both the fill aquifer and estuarine aquifers (refer **Figure 1** for locations).

Plate 7: **Figure 1 – KIWEF Site – Water Level Monitoring Locations**



1.1.3 Water Level Comparison Values

Discussions with GGBF expert ecologist, Dr Arthur White indicated that a means of determining the relative impact of water level variation is for the comparison of an undisturbed pond against those of the impacted ponds.

However, due to the complexity of the surface and groundwater interactions, and the large amount of variability in relative catchment area to pond ratios, and other development works proposed at the KIWEF site, it would be difficult to establish similarity comparisons between affected and unaffected ponds at KIWEF.

It is therefore suggested that the best means of establishing whether there is a change in hydrologic regime within the ponds is longer term continuous monitoring data.

From a low pond water level perspective affecting the GGBF, Dr Arthur White has indicated that impacts would be seen if the proposed case ponds have low water levels for a period of four (4) weeks or longer than under existing conditions. Similarly, for wetting regimes, Dr White has indicated that impacts would be seen post capping works if the ponds have high water levels for a period of six (6) weeks or longer than under existing conditions.

Table 1 below outlines suggested water level comparison values for the KIWEF water bodies. These have been applied to determine the frequency that water levels exceed these values to determine any potential changes to hydrological regimes.

In order to define what are "low" and "high" water level conditions in the ponds, SMEC have adopted, the 20th percentile and 80th percentile water level values derived from the existing conditions hydro-salinity modelling.

Table 1: Summary of Suggested Water Level Comparison Values for KIWEF Surface Water Bodies

Pond	Adopted lower bound water level comparison value, based on 20th percentile current water level value (m, AHD)	Adopted upper bound water level comparison value, based on 80th percentile current water level value (m, AHD)
BHP Wetlands	1.2	1.9
Blue Billed Duck Pond	1.6	2.5
Deep Pond	1.3	1.8
Easement Pond	1.4	2.0
Easement Pond South	2.2	2.6
K2 Pond	1.1	1.9
Long Pond	1.1	1.7
Windmill Rd Open Channel	1.4	2.4

Water Level Modelling Results

The results outlined in **Section 11.5** compare the potential changes in hydrological regimes to typical threshold comparison values for water level, that relate to the GGBF as outlined in **Table 1** above. Results of water level variation are also included in **Appendix F**. According to Dr Arthur White, in relation to GGBF, the amount of additional time that the ponds stay dry or wet is at least of equal importance to the frequency of dry or wet conditions.

Model results provided in **Section 11.5** indicate that only measurable impacts in pond hydrology are expected in Long Pond and Windmill Road Open Channel, with negligible impacts (i.e. less than 10%) in the other ponds. For these two ponds, the model results indicate that the ponds will generally become wetter, with a lower frequency of drying out and greater frequency of being full.

The results indicate that for the majority of ponds, there would not be any significant changes to the low water levels (i.e. pond drying regime). For Long Pond, the frequency of low water level events would change from about a 1 year frequency, to about a 5 year frequency, and that the average dry period will change from about 90+ days, to approximately 60 days. This indicates that Long Pond will generally exhibit reduced periods with very low water levels. Discussions with Dr Arthur White indicate that this is likely to be a benefit to the GGBF species.

For Windmill Road Open Channel, currently, this exhibits periods of low water level, approximately once every year. This is predicted to change such that the pond would not expect to dry out completely at all. Again, this is expected to be a benefit to the GGBF species.

The results also indicate that most of the ponds are not expected to have any significant changes in terms of the potential effects of increasing pond water levels. For Long Pond and Windmill Road Open Channel, the proposed capping works would have a slight impact on pond “wetting” regimes. However these minor changes in pond hydrology would not affect either GGBF or other threatened species. A slight benefit would accrue from an increase in the wetted perimeter of the ponds, which would be subject to periodic inundation, and hence provide additional breeding areas for the GGBF and other species.

Eastern Ponds

Groundwater Modelling of the Eastern ponds has been undertaken (Refer **Appendix D**, Douglas Partners, 2013). However, surface water hydrologic modelling of the Eastern Ponds has been omitted from this report due to the following reasons:

- The proposed capping works will have no impact on the surface water aspects of the hydrology for the Eastern Ponds. That is because the catchment areas and the pond characteristics are to remain unchanged, meaning that runoff and evapotranspiration in the ponds will be consistent with existing conditions.
- The frequency of overflows from the Eastern Ponds to other downstream ponds is expected to be low. This is due to both the high embankments around the Eastern Ponds and the relatively small size of their contributing catchment area relative to their effective storage.
- Groundwater interaction will be the only potential impact associated with proposed capping works, therefore impacts to these ponds have been assessed using the groundwater modelling results (Refer **Appendix D**, Douglas Partners, 2013).

Table 12 and **Table 13** in **Section 11.5.1** provide groundwater modelling results for the Eastern Ponds under existing and proposed capped conditions (Refer Douglas Partners report in **Appendix D**).

It is noted from these results that the total reduction in the groundwater inflows and outflows of the Eastern Ponds are 4.43 m^3/day and 3.32 m^3/day respectively. Hence the change in groundwater flows identified above would represent a relatively low percentage of the total inflow volume from surface runoff (typically approximately 100m^3/day on average – refer **Section 11.5.1**), making the relative impacts to the hydrologic and salinity regime of the Eastern Ponds insignificant.

Summary

In summary, the water level and wetting and drying regimes indicated by the above results show that for the majority of the ponds there are not expected to be any significant changes, i.e. BHP Wetlands, Blue Billed Duck Pond, Deep Pond, Easement Pond, Easement Pond South, and K2 Pond. Minor changes are expected in Long Pond and Windmill Road Open Channel, however these changes are not expected to impact on GGBF or other threatened species. There are no significant changes predicted to the Eastern Ponds as a result of the proposed capping works, as there is no change to the contributing catchment area to these ponds, and only minor changes to the groundwater regime.

With regular monitoring there will be an opportunity to consider mitigation measures such as those outlined below in **Section 1.2** .

1.2 Proposed GGBF Adaptive Response / Recovery Plan Mitigation Measures

The following adaptive response / recovery plan mitigation measures for GGBF have been identified, should impacts become apparent:

1. Should the specific thresholds be exceeded whereby a demonstrable impact of the works has been observed, then initially further detailed investigation will be undertaken to ensure that the reasons for a change are fully understood. This may involve detailed scrutiny of the water level monitoring to ascertain in which parts of the site the hydrology is changing, and to enable GGBF experts to understand the drivers affecting change within the habitat areas. If these investigations conclude that there is definitely some impact associated with the landfill capping, then there are a number of possible mitigating measures that could be instigated to ameliorate any impacts that are occurring.
2. Possible physical recovery plan mitigation measures that may be employed include the sedimentation control ponds that are proposed as part of the works could be planted out as constructed wetlands, to provide additional GGBF habitat. Discussion with GGBF experts indicates that shallow ponds of this nature would be ideal breeding habitat for the GGBF.

1.3 Determining an Impact on Australasian Bittern and Migratory Wading Species – Thresholds / Triggers and Possible Mitigation Measures

1.3.1 Background

The *Revised Capping Strategy KIWEF – Flora and Fauna Impact Assessment Revision 3* (GHD, January 2010) assesses the potential impacts to Migratory Birds, namely Australasian Bittern, and other migratory wading species. Potential foraging habitat is present for the Australasian Bittern and other wetland bird species; however vegetation within the site is not of sufficient density or extent to represent potential breeding habitat.

Note that since the revised report (GHD, January 2010) was completed, the capping design has been revised in a manner that does not require the removal of any of the existing habitat for the species. The capping has been specifically designed to conserve the pond and adjacent wetland habitats and reduce potential impacts. Moreover, other areas of potential habitat are located adjacent to the Proposal site within the Hunter Estuary National Park, which contains large areas of the vegetation communities and habitat types representative of those found at the site. Due to the fact that there is actually no significant potential habitat to be removed, it is considered unlikely that the proposal would adversely impacts these species.

As such, GHD (January, 2010) concluded that the proposal would not significantly impact the Australasian Bittern. Assessments of Significance under the EPBC Act also confirmed that the proposal is unlikely to have a significant impact on listed migratory wading species.

These conclusions were based on:

- The capping strategy has been designed to minimise any changes in hydrology.
- In the large unfilled cells adjacent to the capped areas of the site, no changes in water levels are expected.
- Temporary changes in water level in some ponds are unlikely to significantly impact the ecology of these systems, as most species which form these communities are adapted to fluctuations in water availability and respond accordingly.
- Increases in water levels may support additional habitat for these species, in providing larger areas of fringing reedlands and wetland habitat, or greater levels of semi‑permanent water which may extend breeding habitat availability while still providing the fluctuation in wetting and drying that currently occurs across the site.
- The capping of toxic substances would improve the long‑term quality of these waters.
- The capping strategy would improve the integrity of the banks surrounding the ponds, preventing pollutants from surfacing and migrating through the food chain.

Nonetheless, it is considered important to develop appropriate monitoring measures for the Australasian Bittern and other wading birds species.

The bird species of interest would only be sporadically visiting the site and it would be difficult to obtain sufficient data to statistically verify any significant impact. However, as an alternative, monitoring the changes to the ponds near to the capped areas is relatively easy. Water quality can be monitored and changes in water characteristics can be readily recorded. Similarly, water depth can be readily measured and any changes suitably noted. In addition, existing vegetation extent and composition can be tracked through time.

1.3.2 Recommended Monitoring Procedures for Australasian Bittern and Migratory Wading Species

Specific monitoring of the Australasian Bittern and migratory wading species would be problematic, given their mobile nature. Therefore, vegetation habitat and water quality monitoring is proposed. Details are outlined below.

Vegetation Monitoring

Prior to implementing the capping strategy, a vegetation monitoring program will commence. This will involve mapping the extent and distribution of existing vegetation within habitat areas suitable for the Australasian Bittern and migratory wading species in close proximity to the ponds and other areas affected by the capping strategy. The survey will also list the general composition of species present.

On an annual basis, for up to three (3) years after the capping strategy is complete, the vegetation sampling will be replicated to monitor any changes. If any of the changes are deemed to be detrimental to attracting or supporting the Australasian Bittern and migratory species, a new vegetation management plan will be developed and implemented.

Water Quality Monitoring

From a bird species perspective, the key issues for the ponds are that the existing water quality does not degrade. Critical parameters such as the nutrient and algal levels in the ponds are important to ensure that the existing ponds do not become eutrophic, affecting the use of the ponds by bird species for feeding. Also, excessive sedimentation of the ponds should be avoided so that the ponds do not become clogged with sediment. Sediment is also an efficient transporter of other contaminants. Mitigating any impacts of sedimentation is important to limiting the export of other contaminants to the ponds and downstream receiving waters. Generally the proposed works will improve water quality through the amelioration of the export of contaminants from the fill, which is the main reason for the project.

Section 5.3 outlines water quality monitoring parameters and procedures that are to be implemented for the GGBF. Given the above, these monitoring parameters and procedures are suitable for the purposes of the Australasian Bittern and other migratory wading species.

1.3.3 Triggers for Detecting Impacts to Australasian Bittern and Migratory Wading Species

The following triggers are proposed for vegetation and water quality for these species.

Vegetation Triggers

If there is a 50% decrease or increase in the extent of existing vegetation that cannot be attributed to natural circumstances or general growth patterns then a new vegetation management plan will be developed and implemented in association with regulatory authorities. In addition, during each monitoring phase the success of any re-vegetation strategies will be assessed and measures implemented if re-growth rates (i.e. successful establishment and spread) are not consistent with typical patterns.

Water Quality Monitoring

Section 5.4 outlines water quality comparison values that are to be implemented for the GGBF. These values would be suitable for the purposes of the Australasian Bittern and other migratory wading species.

1.3.4 Mitigation Measures for Australasian Bittern and Migratory Wading Species

Proposed mitigating measures that are relevant to the Australasian Bittern and migratory wading species include:

- Utilising an ecologist who is available on-call during construction to re-locate any displaced native fauna.
- Avoiding rubbish and other waste build-up to deter feral pests.
- Habitat features such as woody debris that may be utilised by fauna within the construction area would be retained and set-aside during the construction period.
- Adequate run-off, erosion and sedimentation controls would be in place during construction, particularly in areas where run-off has the potential to impact nearby waterways, surrounding native vegetation, and existing drainage line and dam areas.

- Care would be taken to ensure any noxious weeds occurring onsite are not further dispersed as a result of the proposal. A follow up weed control program would be developed if necessary.
- Soil stockpiles that may contain seed of exotic species would be located away from adjacent vegetation or drainage lines to prevent dispersal during rainfall events.
- Soil stockpiles would be located away from vegetated areas.
- Utilising disturbed corridors such as cleared areas, roads, tracks and existing easements, where possible for set up of equipment, stockpile areas and site facilities.
- Development of an Erosion and Sedimentation Control Plan covering the works associated with the Proposal. Erosion and sediment controls would be installed prior to construction, and maintained throughout construction, to minimise sediment entering the adjacent ponds and wetland areas.
- The design proposes to strip and stockpile any existing topsoil for re-use within the project. Existing topsoil will stockpiled separately and turned over to minimise the existing weed population. Re-vegetation with a combination of native local grass species combined with ameliorant species (e.g. that can fix nitrogen and that are salt and alkali tolerant) will ensure a denser vegetation cover than is currently exhibited at the site.
- Revegetation of the Proposal capped areas following soil/capping material placement would be in accordance with a Revegetation and Restoration Plan.
- Bitou Bush, Crofton Weed and Pampas Grass would be managed by following the Local Noxious Weed Control Plans (NCC, 2006) – with physical removal of plants, preferred over herbicides.
- Implement a Vegetation Monitoring Plan, as part of the Revegetation and Restoration Plan, before construction commences and for up to three (3) years after the capping strategy has been completed.

Recovery Plan Mitigation Measures, should the monitoring indicate that there are negative impacts as a result of the capping, would include:

- Developing and implementing a new Revegetation and Restoration Plan if the existing vegetation extent changes to the detriment of the Australasian Bittern and Migratory Wading Species or if the re-vegetation strategy is unsuccessful.

1.4 Key Relevant Reference Documents

- *Report on KIWEF - Revised Final Landform and Capping Strategy – Rev 4* (GHD, 2009) – **Section 6.4**.
- *Revised Capping Strategy KIWEF – Flora and Fauna Impact Assessment Revision 3* (GHD, January 2010) – **Section 6.2**, **Section 6.3**.
- *Green and Golden Bell Frog Management Plan – Kooragang Island Waste Emplacement Facility Closure Works* (Golder Associates, 19 April 2011) – **Section 1.2.1**.

- *2011/2012 ecological surveys for the Green and Golden Bell Frog (Litoria aurea) at the Kooragang Island Waste Emplacement Facility* (University of Newcastle, April 2012) – **Section 5**.
- *KIWEF Capping Strategy – EPBC Referral* (GHD, July 2012) – **Section 3.3 (b)**, **Section 4**.
- *Survey of KIWEF: December 2008 (Aurecon Hatch), December 2009 (Aurecon Hatch), June 2009 (Aurecon Hatch)* with standing water levels.
- *Australian and New Zealand guidelines for fresh and marine water quality. Volume 1, The guidelines / Australian and New Zealand Environment and Conservation Council, Agriculture and Resource Management Council of Australia and New Zealand (ANZECC, 2000).*
- *Sodium Chloride Inhibits the Growth and Infective Capacity of the Amphibian Chytrid Fungus and Increases Host Survival Rates* (Stockwell, Clulow, Mahony, 2012).
- *Groundwater Modelling – KIWEF Landfill Closure, Kooragang Island, Douglas Partners, 12 March 2013.*
- *Groundwater Modelling – Eastern Ponds – KIWEF Landfill Closure, Kooragang Island – Douglas Partners, 10 April 2013.*

2 ITEM 2 – WATER QUALITY SUMMARY

Item 2 – Past (if available) and current water quality characteristics (i.e. pH, salinity, turbidity, contaminant levels etc.) of ponds that would receive run-off from areas affected by the proposed works.

2.1 Water Quality Data Summary

The second of SEWPAC's requests for information was a request for additional water quality data. A significant amount of water quality monitoring has been undertaken across the broader KIWEF site for a number of investigations, including but not limited to:

- Newcastle Coal Infrastructure Group Rail Loop;
- Port Waratah Coal Service T4 Environmental Assessment;
- BHPB Hunter River Remediation Project; and
- Under EPL 6437 and subsequent closure notice N1111840, the State (RLMC / HDC) has undertaken both surface and groundwater monitoring at KIWEF since March 1999. This comprises the full spectrum of organic and inorganic monitoring required by the former EPL and the current surrender notice. This includes University of Newcastle within the Eastern Ponds for HDC ‐ KIWEF.

This information has been summarised into one consolidated set of tables, with calculated percentile and mean values and comparisons against relevant ANZECC Guideline values – refer **Appendix A**.

Table 2 outlines key water quality parameters for KIWEF surface water bodies that will directly/indirectly receive run‐off from the proposed capped areas. **Figure 1** shows the locations of these ponds.

Plate 8: Figure 1 – KIWEF Site – Water Level Monitoring Locations

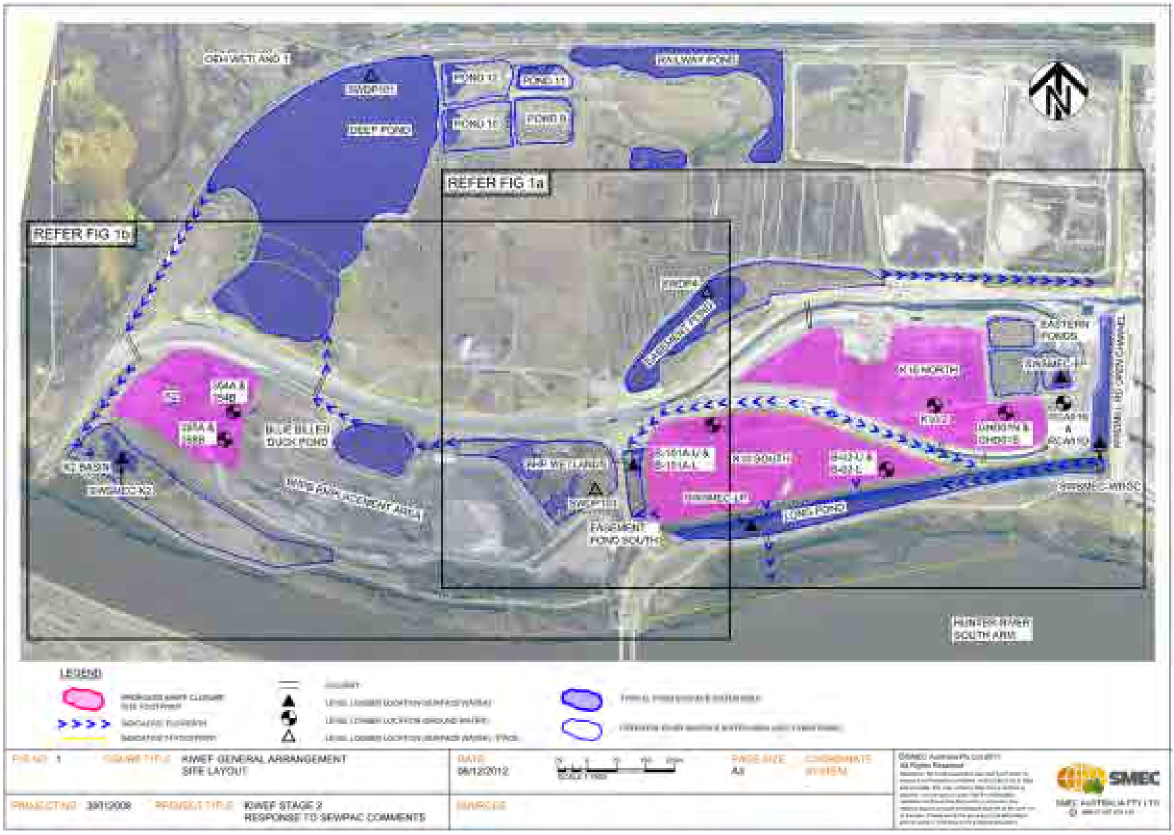


Table 2: Summary of Key Water Quality Parameters for KIWEF Ponds

Surface Water Body		Monitoring Period	pH	Dissolved Oxygen (% DO at 25 o C)**	Electrical Conductivity (µS/cm) - Full Monitoring Period	Electrical Conductivity (µS/cm) - More Recent Data*	Turbidity (NTU)	Total Suspended Solids (mg/L)	Total Nitrogen (mg/L)	Total Phosphorus (mg/L)	Total Copper (mg/L)	Total Zinc (mg/L)
ANZECC Guideline Value			7 to 8.5		NC	NC	50	NC	0.3	0.03	0.0013	0.016
BHP Wetlands	10%ile	6/09/2006 - 25/10/2012	7.3		723	-	1	5	0.3	0.02	0.0010	0.003
	90%ile		9.2		1424	-	48	84	2.7	0.17	0.0033	0.010
	avg		8.0	117%	1116	-	21	38	1.4	0.13	0.00175	0.006
Blue Billed Duck Pond	10%ile	29/11/2002 - 14/12/2012	8.2		845	-	3	7	0.8	0.04	0.0010	0.005
	90%ile		9.5		1380	-	35	64	2.3	0.70	0.0050	0.055
	avg		8.8		1166	-	14	23	1.4	0.30	0.0036	0.041
Deep Pond	10%ile	17/11/1981 - 14/12/2012 *(13/08/1997 - 14/12/2012)**	7.8		1900	1752	2	4	0.8	0.03	0.0010	0.006
	90%ile		9.5		27930	6252	42	47	4.2	0.96	0.0300	0.151
	avg		8.7		10524	3659	16	26	2.4	0.32	0.0125	0.084
Easement Pond	10%ile	20/08/1996 - 25/05/2007 *(22/03/2006 - 14/12/2012)**	7.5		2038	2010	1	5	0.6	0.02	0.0010	0.005
	90%ile		9.0		4544	3950	13	19.2	1.8	0.12	0.0200	0.044
	avg		8.3		3978	2910	6	10	1.1	0.06	0.0101	0.021
Easement Pond South	10%ile	8/03/2012 - 14/12/2012	7.9		481	-	5	7	0.6	0.02	0.0010	0.005
	90%ile		8.3		881	-	79	82	1.5	0.22	0.0034	0.023
	avg		8.1	75%	703	-	34	37	1.1	0.11	0.0018	0.011
Eastern Ponds	10%ile	27/02/2012 – 11/01/2013	-	-	2710	-	5	-	0.9	0.052	0.005	0.007
	90%ile		-	-	6790	-	24	-	2.8	0.068	0.005	0.044
	avg		-	-	4750	-	15	-	1.8	0.06	0.005	0.024
K2 Pond	10%ile	13/08/1997 - 16/04/2012	7.5		1554	-	-	15	-	0.32	0.0043	0.013
	90%ile		8.8		5928	-	-	648	-	1.08	0.0620	0.099
	avg		8.1	112%	3431	-	-	240	-	0.67	0.0273	0.055
Long Pond	10%ile	4/05/1990 - 14/12/2012 *(15/03/1999 - 14/12/2012)**	7.8		2945	2845	3	2	0.6	0.05	0.0010	0.005
	90%ile		9.3		29900	10565	239	270	7.6	0.87	0.0240	0.193
	avg		8.5	110%	11166	6332	71	70	3.2	0.35	0.0086	0.082
Windmill Rd Open Channel	10%ile	13/08/1997 - 25/10/2012	7.4		3600	-	16	13.1	0.9	0.08	0.0029	0.005
	90%ile		9.4		16500	-	16	29.9	0.9	0.08	0.0181	0.325
	avg		8.5	115%	9547	-	16	21.5	0.9	0.08	0.0105	0.137

Note: * – Historical EC Testing prior to 1997 / 1999 in some ponds was found to have levels of salinity elevated above current levels. It is unsure if this is a real change, or possibly a monitoring error. SMEC have reported two ranges of these values for clarity – Refer to **Appendix A** for full data record.
** – Dissolved Oxygen derived from limited hand held meter readings only
For summarisation of contaminant concentrations, refer to more detailed Tables in **Appendix A**

2.2 Key Reference Documents

- Under EPL 6437 and subsequent closure notice N1111840, the State (RLMC / HDC) has undertaken both surface and groundwater monitoring at KIWEF since March 1999 to present. This data was provided to SMEC in spreadsheet format.
- *Risk Assessment Kooragang Island Waste Emplacement Facility* (RCA, July 2006) – **Section 5.6.2.1** & **Appendix D**.
- *Report on KIWEF - Revised Final Landform and Capping Strategy – Rev 4* (GHD, 2009) – **Section 3.2.3**, **Section 6.2**.
- *Revised Capping Strategy KIWEF – Flora and Fauna Impact Assessment Revision 3* (GHD, January 2010) – **Appendix H**.
- *KIWEF Groundwater and Surface Water Rationalisation Report* (GHD, October 2010) –**Section 2.2** – **Figure 1** & **Figure 2**.
- *K26/K32 and K24/K31 Ponds Action Plan – Kooragang Island Waste Emplacement Facility* (Golder Associates, 31 May 2011) – **Section 2.4.4**.
- *2011/2012 ecological surveys for the Green and Golden Bell Frog (Litoria aurea) at the Kooragang Island Waste Emplacement Facility* (University of Newcastle, April 2012) – **Section 3.2**, **Section 4.1**.
- *Australian and New Zealand guidelines for fresh and marine water quality. Volume 1, The guidelines / Australian and New Zealand Environment and Conservation Council, Agriculture and Resource Management Council of Australia and New Zealand (ANZECC, 2000).*
- *GGBF Surface Water Results – Kooragang Island Waste Emplacement Facility (JN 8992), RCA Australia (December 2012).*

Note: A more comprehensive list of surface water quality data references is contained within **Appendix A**.

3 ITEM 3 – WATER QUALITY ANALYSIS OF PONDS FOR PROPOSAL

Item 3 – Detailed analysis of likely changes to water quality in ponds (including pH, salinity, turbidity, contaminants etc) as a result of runoff from areas affected by the proposed works, particularly in relation to maintaining suitability of the habitat for the Green and Golden Bell Frog (e.g. salinity levels may be preventing the infection of frogs by amphibian Chytrid Fungus), and any other potential effects of any changes on GGBFs and other EPBC Act listed species.

Please discuss the characteristics of the capping materials (such as topsoil) and any other materials proposed to be used in relation to possible influences on water quality changes.

3.1 Water Quality effects in the Ponds

It is expected that water quality parameters will potentially increase during the construction phase of the proposed capping works (*e.g. pond nutrients and algal levels may rise in the period immediately after capping due to a flux of sediment and attached nutrients*). This will be mitigated by the careful selection of capping and re‑vegetation soil materials and through appropriate design of erosion and sedimentation controls. Once the landform stabilises, it is likely that runoff quality will reach a new equilibrium position.

In general, improvements in water quality will result from the proposed capping works. The decreased level of contaminants entrained into the receiving waters as a result of the reduction in leachate from the contaminated fill will provide ecological benefits to all species. Any negative changes would not be of a magnitude that would significantly impact on GGBF, Australasian Bittern or migratory bird habitat.

The key aim and benefit of the capping works is to prevent surface water infiltration into the landfill and the subsequent generation of contaminated leachate. The capping works will result in a greater volume of surface water runoff, and reduced contaminated leachate from the fill aquifer migrating to the surface ponds. Changes as a result of the landfill cap would influence salinity, pH, heavy metals and nutrient concentrations in the ponds. Each of these effects is discussed in more detail below.

It is important to emphasise that the proposed cap will be covered with a layer of revegetation material in which natural processes such as infiltration and evapotranspiration will still occur. The moisture content will be slightly higher than it would otherwise have been without the cap as the cap will limit deep infiltration into the landfill cell, and some increases in runoff are expected to occur. However, the difference is relatively small and would not be comparable to predicted runoff from a bare impervious surface.

The Stage 1 review undertaken (SMEC, 2012) identified that there was limited information on potential changes to salinity and water levels in ponds as affected by climate variability and the proposed K2, K10 North and K10 South capping works. Therefore, continuous salinity monitoring and a hydro‑salinity model have been developed as part of this study in order to identify how changes in total KIWEF catchment characteristics might affect the pond water levels and salinity levels.

3.1.1 Metals

Concentrations of metals generally exceed the ANZECC Guideline values at the majority of the KIWEF ponds monitored. The ANZECC trigger value guidelines for marine waters have been adopted where available. Where not available, the default trigger levels for freshwater have been used for comparison purposes.

The following key metals have mean values that exceed the 95% ANZECC trigger value guidelines in the majority of KIWEF ponds:

- *Aluminium*: Concentrations range between 0.005 to 11.5mg/L – 95% ANZECC Guideline value for freshwater (0.055mg/L);
- *Boron*: Concentrations range between 0.14 to 2.72mg/L – 95% ANZECC Guideline value for freshwater (0.37mg/L);
- *Cobalt*: Concentrations range between 0.001 to 0.1mg/L – 95% ANZECC Guideline value for marine water (0.001mg/L);
- *Chromium:* Concentrations range between 0.001 to 0.1mg/L – 95% ANZECC Guideline value for marine water (0.0044mg/L), exceeded at five (5) of the ponds;
- *Copper*: Concentrations range between 0.001 to 0.08mg/L – 95% ANZECC Guideline value for marine water (0.0013mg/L);
- *Manganese:* Concentrations range between 0.005 to 3.95mg/L – 95% trigger value criteria (0.08mg/L);
- *Molybdenum*: Concentrations range between 0.001 to 0.405mg/L – 95% trigger value criteria (0.023mg/L), exceeded at 5 of the ponds;
- *Lead*: Concentrations range between 0.001 to 0.58mg/L – 95% ANZECC Guideline value for marine water (0.0044mg/L); and
- *Zinc*: Concentrations range between 0.001 to 2mg/L with mean values exceeding the 95% ANZECC Guideline value for marine water (0.015mg/L).

In addition, the following key metals have mean values that exceed the 99% ANZECC trigger value guidelines in the majority of KIWEF ponds:

- *Cadmium*: Concentrations range between 0.0001 to 0.1mg/L – 99% ANZECC Guideline value for marine water (0.0007mg/L);
- *Nickel:* Concentrations range between 0.001 to 0.245mg/L – 99% ANZECC Guideline value for marine water (0.007mg/L) exceeded at 5 of the ponds;
- *Selenium:* Concentrations range between 0.001 to 0.05mg/L – 99% ANZECC Guideline value for freshwater (0.005mg/L); and
- *Mercury*: Concentrations range between 0.00001 to 0.05mg/L – 99% ANZECC Guideline value for marine water (0.0001mg/L) exceeded at 5 of the ponds.

The above summary indicates that the ponds generally have levels of these metals that are significantly elevated above normal levels. This is likely due to significant leachate contamination from the adjacent landfill cells.

The proposed capping is intended to reduce the outflow of contaminated groundwater from the waste emplacement areas, however some metals will still be released. A reduction in heavy metal concentrations in pond waters would provide benefits to all species including GGBF, Australasian Bittern and other migratory bird species.

3.1.2 pH

Current water quality results for the KIWEF ponds indicate that pH levels range between 7.9 to 8.9 (based on 20^{th} and 80^{th} percentile average for all ponds) with an average value of 8.4. It is thought the existing alkaline conditions originate from leachate generated from the landfill cells. Threlfall *et al*, 2008 stated that the optimum range for growing *B. dendrobatidis* (Chytrid Fungus) is between pH 6 and 7.

The most likely effect as a result of capping the site will be a slight shift towards pH neutrality. This is unlikely to have a significant impact, as GGBF habitats have been found to vary from acidic to alkaline conditions.

3.1.3 Turbidity and Nutrients

Turbidity

Turbidity levels within the ponds range between 5.5 to 35 NTU (based on 20^{th} and 80^{th} percentile average for all ponds), with the mean values of approximately 25 NTU exceeding the 95% ANZECC Water Quality trigger values for marine / estuarine water, which is 10 NTU. There is potential for turbidity levels within the ponds to increase during and immediately post-construction as a result of erosion and sedimentation as a result of the proposed capping works.

To mitigate potential increase in turbidity, a number of sedimentation basins have been incorporated into the design for K2, K10 North and K10 South. The location of the proposed sedimentation basins is illustrated in **Figure 4a** and **Figure 4b**.

The basins have been designed to capture sediment laden runoff from all areas of earthworks. In addition to sedimentation basins, sediment fences will be located downstream of any stockpile areas. Once the site has been capped and vegetation has established, no significant changes to existing turbidity levels within the ponds are likely.

Nutrients

Nutrients measured as Total Phosphorous and Total Nitrogen within the ponds range between 0.09 to 0.32 mg/L (based on 20^{th} and 80^{th} percentile average for all ponds) for TP and 0.75 to 2.29 mg/L (20^{th} and 80^{th} percentile) for TN. The mean values (0.25 mg/L for TP and 1.63 mg/L for TN) are elevated above 95% ANZECC Water Quality trigger values for marine / estuarine water which are 0.03 mg/L (TP) and 0.3 mg/L (TN), respectively. The elevated levels of nutrients at eth site are likely to be caused by leachate from eth industrial landfill. Therefore the proposed capping design is expected to generally improve the nutrient levels entering eth ponds from the landfill.

The design incorporates the use of insitu CWR material. The CWR is to be re-worked into a low permeability cap with some areas importing a native soil material, which will not induce any long terms changes in surface water runoff. The intention is not to introduce significant volumes of imported material into the cap. There will not be any long terms impacts on nutrient levels in the ponds.

The design proposes to strip and stockpile any existing topsoil for re-use within the project. Re-vegetation with a combination of native local grass species combined with ameliorant species (e.g. that can fix nitrogen) will ensure a denser vegetation cover than is currently exhibited at the site.

This vegetation cover will provide two key benefits over the current sparse vegetation cover:

1. It will control the dispersion of contaminants, such as sediment and nutrients that could otherwise wash off the landfill due to erosion of the cap during rainfall events.
2. It will reduce runoff when compared to a bare cap. A reasonable topsoil cover with vegetation cover will act to trap rain falling on the cap and encourage evapoř transpiration, and hence potentially ameliorate any increased runoff potential as a result of the capping.

The design allows for ređuse of the existing topsoils, without adding significant nutrients or compost that could possibly introduce excessive nutrient runoff or chytrid fungus, while maintaining a reasonable vegetation cover. Details of the proposed topsoil and reř vegetation proposal are outlined under **Section 10.1** .

3.1.4 Salinity

The capping works are designed to reduce leachate by limiting surface water penetration into the fill aquifer. The capping will increase volumes of less saline surface water runoff from capped areas, and reduce higher saline groundwater inflows into the ponds. These changes are likely to reduce the salinity levels in the ponds though a reduced concentrating effect from evaporation (due to an increase in surface water runoff) and reduced inflows of saline leachate. However, the tradeřoff is a key environmental benefit as the capping works are designed to reduce contaminant levels leaving the landfill and affecting receiving waters (i.e. both the ponds and the Hunter River Estuary).

Batrachochytrium dendrobatidis is the chytrid fungus that infects frogs. It is understood that frogs may still be infected by the fungus, but that saline water acts to keep the level of infection, such as the number of organisms, below the threshold that would result in mortality.

Research indicates that possible key water quality drivers for chytrid fungal control could be salinity and water temperature (Stockwell, *et al*, 2012) and / or certain heavy metals (Cu and Zn) (Threlfall *et al*, 2008). The balance of research indicates that salinity is the most likely driver, however, it would be reasonable to state that further research would be needed to confirm the link between metals and chytrid fungal control.

The proposed capping works would not have any significant impact on water temperature, as an analysis of water temperature over time indicates that water temperature in the ponds is mostly driven by solar radiance on the pond surface. This is unlikely to change as a result of the proposed capping works.

Threlfall *et al*, (2008) indicated that while there was an initial reaction to metal (Cu and Zn) toxicity for chytrid fungus, this was short lived, and more conclusive experiments were required to confirm the findings. Frog Chytrid has been detected on the Kooragang Island site and salinity levels are likely limiting its impact.

The current range of salinity in the ponds (as outlined in **Table 2**, in **Section 2.1**) varies significantly. Some ponds such as BHP Wetlands, Blue Billed Duck Pond and Easement Pond South have salinity values, the 20^{th} percentile representing lower bound and 80^{th} percentile representing upper bound values, in the lower ranges between 700 to 1,400 µS/cm (0.4 ppt to 0.9 ppt). Deep Pond, Easement Pond and K2 Pond have salinity values in the mid range between 1,700 to 6,000 µS/cm (1.0 ppt to 3.6 ppt), and the remaining ponds Long Pond and Windmill Road Open Channel exhibiting higher salinity values between 3,000 to 16,000 µS/cm (1.8 ppt to 9.6 ppt).

As noted in **Appendix A**, peak salinity values can reach as high as 20,000 to 35,000 µS/cm, indicating the intrusion of estuarine waters from the estuarine aquifer. These isolated incidents were observed in Long Pond, Windmill Road Open Channel and K2 Pond during low pond water level conditions.

The water level and salinity monitoring indicates that higher salinity conditions in the ponds are generally attributed to concentrating effects of evaporation during dry periods. Saline leachate baseflow from the landfill cells also influences the salinity, but to a lesser degree than the evaporation effects.

Hydro-salinity modelling was undertaken to estimate the potential effects of the proposed landfill closure on pond salinity levels, under a range of climatic conditions. This modelling (refer **Section 11**) generally indicates that affected ponds will become marginally wetter and less saline. Model results are discussed further in **Section 11.5.3** .

Key factors will be the level of compaction of the proposed revegetation layer, and the density of vegetation above the capped area. Initially some leaching will be expected from the revegetation layer, with salts and nutrients being more mobile during the early stages after construction has been completed.

Overall, the ponds currently exhibit a very strong correlation between pond water level and salinity, with levels currently exceeding the natural upper bound threshold values that allow for the breeding of GGBF. Modelling currently predicts that the changes are expected to be very minor in terms of the range of salinity expected to be observed in the ponds. The effects of changes in salinity in the ponds as a result of the capping work is not expected to be significant.

In general, improvements in water quality would provide ecological benefits to all species. Any negative changes would not be of a magnitude that would significantly impact on GGBF, Australasian Bittern or migratory bird habitat.

3.2 Characteristics of Capping Materials

The cap will consist primarily of existing CWR sourced from site. Additional material will be imported from off-site as required. CWR is the waste product resulting from washing coal. CWR consists of materials such as coal fines, rock, sand and soil. The capping design has been approved by the NSW EPA in the Conditions of Surrender. The successful Contractor will be required to ensure that the capping material selected complies with the over-arching 'KIWEF EMP' for the site which includes best-practice stormwater controls.

In all cases, existing topsoil shall be used as part of the protective revegetation layer. The use of in situ materials in the revegetation layer will minimise changes to water quality and subsequently help to minimise any potential impacts on GGBF habitat. The design seeks to avoid, where possible, the use of fully imported topsoils such as sandy loam as these may introduce high nutrients and/or chytrid fungus, and would alter the water quality of site runoff.

The capping and re-vegetation work will be staged so as to limit the extent of disturbance at any one time.

The existing topsoil material to be used for the re-vegetation layer currently supports significant vegetation and generally is very well vegetated to the extent necessary to stabilize the soil. Given the potential implications on chytrid fungus and nutrient export risk it is preferable to not undertake significant soil amelioration and instead, appropriate species that would be compatible with the low nutrient and or sodic soils present. This will ensure that no chytrid fungus is introduced via importation of ameliorates, and that receiving waters (GGBF habitat) are not at risk of nutrient loads, algal blooms or eutrophication.

One area of concern raised by SEWPaC was re‑vegetation in K2, using existing topsoils. The K2 area was recently stripped of all vegetation for the Hunter River Remediation Project and subsequently regenerated and stabilised with no soil amelioration being necessary, using stock methods of stabilisation by common seeding methods. The successful re‑vegetation of K2 by BHP Billiton in 2012 is a clear demonstration that this soil supports a variety of native vegetation in its current form, without amelioration. The approach employed by BHP Billiton appears to have been successful, as the vegetation has taken hold within a matter of months, without maintenance (refer **Plate 7** below for recent photograph of this area of the site).

Plate 9: K2 Area – Photo Taken April 2013 showing successful native species and consistent ground cover limiting soil erosion

A native seed mix is proposed supplemented with other ameliorant species that are able to withstand the current soil type (low Nitrogen, etc). More details are provided under **Section 10.1.1** .

In terms of mitigation measures, erosion and sedimentation controls including sedimentation basins will be provided. In addition, care will be taken that any noxious weeds occurring on the site are not further dispersed as a result of the Proposal. To manage weeds, the topsoil would be stripped, stockpiled and turned over in a manner that sterilises the soil of any existing seed. The re‑vegetation would be controlled by introduction of native species that are compatible with the soil.

3.3 Key Reference Documents

- *Report on KIWEF - Revised Final Landform and Capping Strategy – Rev 4* (GHD, 2009) – **Section 7**.

- *Green and Golden Bell Frog Management Plan – Kooragang Island Waste Emplacement Facility Closure Works* (Golder Associates, 19 April 2011) – **Section 1.2.1**.
- *K26/K32 and K24/K31 Ponds Action Plan – Kooragang Island Waste Emplacement Facility* (Golder Associates, 31 May 2011) – **Section 2**, **Section 2.4.4**.
- *KIWEF Capping Strategy – EPBC Referral* (GHD, July 2012) – **Section 3.3(b)**.
- *Threlfall, C., Jolley, D. F., Evershed, N., Goldingay, R. & Buttemer, W. A. (2008). Do Green and Golden Bell Frogs Litoria aurea occupy habitats with fungicidal properties? Australian Zoologist, 34 (3), 350-360.*
- *Sodium Chloride Inhibits the Growth and Infective Capacity of the Amphibian Chytrid Fungus and Increases Host Survival Rates* (Stockwell, Clulow, Mahony, 2012).

4 ITEM 4 – TIMING OF WORKS

Item 4 – Details of the timing of works in relation to key life-cycle stages of the GGBF, Australasian Bittern and use of the site by migratory wading birds.

Discuss aspects that could affect these species (e.g. noise, lighting, movement etc.) and demonstrate that the timing of works will minimise disturbance to these species, particularly during key life-cycle stages (i.e. breeding periods).

It is noted that Deep Pond constitutes "important habitat" (see EPBC Act significant impact guidelines) for several species of listed migratory birds. For example, refer to the Environmental Assessment for the Port Waratah Coal Services T4 Project, which can be accessed on the NSW DP&I website.

4.1 Timing of Works

No significant freshwater/brackish wetland habitat or terrestrial habitat would be cleared as part of the project. In terms of the relative effect of the timing of the works, it is unlikely that the proposed works would disrupt the breeding cycle of any of the threatened species.

Areas of appropriate foraging and breeding habitat would be retained within and adjacent to the Proposal site. Therefore, it is not critical to the key life cycle stages of threatened species when the works take place from a seasonal perspective.

Other controls would be implemented, such as controls on water quality, noise and lighting in order to minimise impact on habitat areas that are adjacent to the proposed works areas. A staged approach to the works will be used to enable the site to stabilise as the works progress. This will also enable lessons learnt from earlier sections of the proposed capping works to be implemented as works progress.

The capping works for K2, K10 North and K10 South will occur on elevated sections of the landfill, typically between RL 9ř10m AHD. No significant works are proposed in the ponds or in known GGBF habitat areas, which are typically found fringing the ponds. The only works which may impact on fringing areas of the ponds will be the construction of sedimentation basin outlets, as illustrated in **Figure 4a** and **Figure 4b**.

4.1.1 Green and Golden Bell Frog

The GGBF is a spring – summer breeder. Most activity is recorded at night during warmer months when this species is observed breeding and feeding and diurnal basking behaviour has been observed in summer. During cooler months they are observed to be active, but to a far lesser degree. They can be relatively wide ranging in their movements and have been observed sheltering 300m from their breeding site (HSO, 2008).

Overall, it is considered unlikely that the proposed works would disrupt the breeding cycle as no significant freshwater/brackish wetland habitat or terrestrial habitat would be cleared. Also, areas of appropriate foraging and breeding habitat would be retained or reinstated within and adjacent to the Proposal site. Therefore, it is not critical to the key life cycle stages of threatened species when the works take place from a seasonal perspective.

4.1.2 Australasian Bittern

The breeding season of the Australasian Bittern is from October to January. Potential foraging habitat for the Australian Bittern occurs within the site. However, as the vegetation on the site is not of sufficient density and extent to represent potential breeding habitat, the timing of the works would not affect any of its key life cycle stages.

This species is believed to be sedentary in permanent habitat with possible regular short distance movements during winter and occasional irruptions associated with wet years. Records for the Australasian Bittern exist to the east and west of the site.

The Australasian Bittern lives alone or in loose groups and favours permanent freshř waters dominated by sedges, rushes, reeds or cutting grasses. Breeding is sometimes loosely colonial but in other cases pairs have been observed to maintain territories when several are present in a reedbed (HSO 2008).

4.1.3 Migratory Wading Birds

Migratory bird species that could possibly occur, based on GHD (2010) include:

- Barřtailed Godwit (*Limosa lapponica*);
- Blackřtailed Godwit (*Limosa limosa*);
- Broadřbilled Sandpiper (*Limosa lapponica*);
- Common Greenshank (*Tringa nebularia*);
- Curlew Sandpiper (*Calidris ferruginea*);
- Great Egret (*Ardea alba*);
- Latham's Snipe (*Gallinago hardwickii*);
- Lesser Sand Plover (*Charadrius mongolus*);
- Marsh Sandpiper (*Tringa stagnatilis*);
- Pacific Golden Plover (*Pluvialis fulva*);
- Pectoral Sandpiper (*Calidris melanotus*);
- Red Knot (*Calidris canutus*);
- Redřnecked Stint (*Calidris ruficollis*);
- Ruff (*Philomachus pugnax*);
- Sharpřtailed Sandpiper (*Calidris acuminate*); and
- Whiteřbellied Sea Eagle (*Haliaeetus leucogaster*).

Although there are previous records of Common Greenshank, Curlew Sandpiper, Marsh Sandpiper, Redřnecked Stint and Sharpřtailed Sandpiper in the area (Herbert 2007, HBOC 2008), no migratory birds listed under the EPBC Act were recorded during the field surveys undertaken by GHD in their Flora and Fauna Assessment (GHD, January 2010). Therefore, it is considered unlikely that the study area supports important habitat for migratory species.

The proposal is considered unlikely to modify, destroy or isolate an area of important habitat for these species as the capping strategy has been designed to minimise any changes in hydrology and prevent potentially toxic substances and pollutants from surfacing and migrating through the food chain. Additionally, as the works are unlikely to impact these threatened species, the timing of the works is not a consideration.

Open water and the majority of the reed and sedge areas that may be utilised by these species would remain unaltered. The works are therefore not likely to disrupt the lifecycle of migratory species, particularly given the majority of the reed and sedge habitat that may be utilised by these species would remain unaltered (GHD, January 2010).

4.1.4 Mitigation Measures for GGBF During Construction

Project specific construction phase mitigation measures for GGBF have been identified in **Section 9** .

4.1.5 Mitigation Measures for Australasian Bittern and Migratory Wading Birds

The following mitigation measures during construction are proposed for the above species:

- Noise and vibration would be kept to a minimum during construction. No night works are proposed, so light impacts are not considered to be an issue. Plant and equipment will be maintained in a proper and efficient manner to minimise potential for excessive noise levels.
- Utilise an ecologist who is available onřcall during construction to veřlocate any displaced native fauna.
- Avoid rubbish and other waste build up to deter feral pests.
- Habitat features such as woody debris that may be utilised by fauna within the construction area would be retained and setřaside during the construction period.
- Adequate runřoff, erosion and sedimentation controls would be in place during construction, particularly in areas where runřoff has the potential to impact on nearby waterways, surrounding native vegetation, and existing drainage line and pond areas.
- Care would be taken to ensure any noxious weeds occurring onsite are not further dispersed as a result of the proposal. A follow up weed control program will be implemented if considered necessary.
- Stockpiling of soil that may contain seed of exotic species would be away from adjacent vegetation or drainage lines where they could be spread during rainfall events.
- Placement of soil stockpiles away from vegetated areas.
- Utilising disturbed corridors such as cleared areas, roads, tracks and existing easements, where possible for set up of equipment, stockpile areas and site facilities.

- Development of an Erosion and Sedimentation Control Plan covering the works associated with the Proposal. Erosion and sedimentation controls would be installed prior to construction, and maintained throughout construction, to minimise sediment entering the adjacent ponds, and sensitive receiving waters.
- The design proposes to strip and stockpile any existing topsoil for re-use within the project. Existing topsoil will stockpiled separately and turned over to minimise the existing weed population. Re-vegetation with a combination of native local grass species combined with ameliorant species (e.g. that can fix nitrogen and that are salt and alkali tolerant) will ensure a denser vegetation cover than is currently exhibited at the site.
- Revegetation of the Proposal capped areas following soil/capping material placement would be in accordance with a Revegetation and Restoration Plan
- Implement a Vegetation Monitoring Plan, as part of the Revegetation and Restoration Plan, before and for up to three (3) years after the capping strategy has been completed.
- Suggested recovery Plan Mitigation measures include the development and implementation of a new Revegetation and Restoration Plan if the existing vegetation extent changes to the detriment of the GGBF, Australasian Bittern and Migratory Wading Species or if the re-vegetation strategy is unsuccessful.

4.2 Key Reference Documents

- *Flora & Fauna Assessment for Proposed Waste Emplacement Site – HDC Land at Kooragang Island* (HSO, December 2008) – **Section 6.1, Section 6.4.1**, **Section 8**.
- *Revised Capping Strategy KIWEF – Flora and Fauna Impact Assessment Revision 3* (GHD, January 2010) – **Section 6**, **Section 7**.
- *Green and Golden Bell Frog Management Plan – Kooragang Island Waste Emplacement Facility Closure Works* (Golder Associates, 19 April 2011) – **Section 1.2.1, Section 5.1, Section 5.2**.
- *KIWEF Capping Strategy – EPBC Referral* (GHD, July 2012) – **Section 4**.
- *T4 Project Environmental Assessment – Main Report volume 1, Chapter 10* (EMM EMGA, February 2012).

5 ITEM 5 – GGBF MONITORING PROGRAM

Item 5 – Details of any GGBF monitoring program (as recommended by the Flora and Fauna Assessment) to ensure impacts on GGBF are minimised.

For example:

a) Methods for monitoring the presence/absence and abundance of GGBFs in suitable habitat on site, before, during and after works commence;

b) Methods for monitoring water quality in ponds affected by the proposal;

c) Thresholds which would indicate adverse impacts on GGBFs or their habitat; and

d) Adaptive responses if adverse impacts on GGBFs or their habitat were identified.

5.1 Previous Monitoring Studies / Ongoing Monitoring Programs for GGBF

5.1.1 Summary

A number of previous GGBF monitoring surveys have been carried out on the site to date, including:

- RPS Harper Somers O'Sullivan in 2006, 2007 & 2008 for BHP Billiton;
- GHD (for HDC) in 2009 across the KIWEF site; and
- Umwelt in March 2011 within K10 North (for HDC).

In addition, a program of ongoing GGBF monitoring is being carried out as follows:

- University of Newcastle (for HDC) within the Eastern Ponds; and
- PWCS across Kooragang Island.

NCIG are also undertaking ongoing monitoring (annually until 2020 & then threeῐyearly until 2030). However, this is only to occur in the GGBF Environmental offset areas on Ash Island.

The current monitoring would be evaluated annually for effectiveness, and in particular understanding the potential impacts on GGBF from the capping works. Currently employed methods for monitoring the presence/absence and abundance of GGBFs include the following:

- Tadpole and Metamorph Surveys;
- Tadpole / Fish Traps;
- Call Playback and Auditory Surveys;
- Habitat Spotlight Survey;
- Photographing individual frogs; and
- Chytrid Sampling and Analysis.

5.1.2 Previous Monitoring Studies for GGBF

A summary of the previous studies is outlined below.

RPS Harper Somers O'Sullivan in 2006, 2007 & 2008 for BHP Billiton

A habitat assessment was carried out by a RPS HSO and GGBF specialist Dr Arthur White to determine the relative value of the habitat present on site for the GGBF. Habitat mapping involved aerial photograph interpretation (API) to map the community(s) extent; detailed site inspections to delineate microřhabitat types present; and mapping of delineated areas with subřmetre accurate GPS equipment.

GHD (for HDC) in 2009 across the KIWEF site

The survey program was undertaken during February to March 2009 (GHD, January 2010). It included the following activities on three survey occasions.

- Tadpole and metamorph surveys using standardised dipřnet surveys, and searches for basking metamorphosing frogs.
- Tadpole / fish traps using netted fish traps and a light bait.
- Call playback and auditory surveys.
- Habitat spotlight survey following the auditory surveys, examining suitable sites using a spotlight for all frog species. Photographing individual frogs, all captured individuals were photographed so that individuals may be distinguished during ensuing sampling events.

Umwelt (2011) for HDC

Umwelt (2011) followed the same methodology as that employed by GHD for a second round of baseline monitoring within the K10 North Area over four nights in February/ March 2011. Two types of habitat assessments were undertaken as part of the survey, these include:

i) Rapid assessment – thorough visual inspection from walking / driving over specific transects; and

ii) Habitat Assessment within the Eastern Ponds.

5.1.3 Ongoing Monitoring Programs

NCIG Monitoring (ongoing)

NCIG has implemented a monitoring program that includes data on the GGBF populations on Ash Island. This program will be conducted annually until 2020 and then threeřyearly until 2030. A number of parameters will be assessed, including presence/ absence, distribution, habitat utilisation, behaviour and abnormalities.

Eastern Pond Monitoring – 2009 and 2011 (Golder Associates for HDC)

Monitoring is as specified in the Action Plan for the K26/K32 ponds, referred to as the 'Eastern Ponds' in this document (Golder, May 2011). The work was undertaken by Golder Associates on behalf of HDC. HDC are currently reporting to OEH annually for five (5) years following completion of the landfill closure works, unless analysis shows that GGBF populations are being impacted, then further reporting will be undertaken until a date agreed with OEH (Golder, April 2011).

Monitoring in 2009 identified the presence of 11 frogs (9 heard on call playback, one observed and one captured) at the K26/K32 ponds. The monitoring in 2011 identified 10 frogs (8 captured and measured) frogs. The total numbers of individuals actually present at the Ponds may be less than that reported due to the potential for recounting of individuals, but could also be more if individuals were missed.

The K26/K32 monitoring program developed by Golder, May 2011, expanded on baseline monitoring to include collection of water quality, habitat and population data collection over at least four to five years.

Eastern Ponds Monitoring – Early and Late February 2012 (University of Newcastle for HDC)

The University of Newcastle (2012) undertook monitoring in early and late February 2012, to comply with recommendations by Golder (May 2011). The methodology is summarised below:

- Habitat condition assessment and recording by meandering surveys across the study area. The habitat assessment confirmed the extent and depth of standing water at the time of the study. A full habitat map of the site was prepared from this data.
- Standardised dip‑netting surveys (south eastern cell) were completed each day for 4 consecutive days on two separate occasions. Any fish that were captured were also identified and recorded.
- Tadpole and fish trapping (south eastern cell). Twenty five tadpole traps were set out over a four day and night period on two separate occasions. Any fish that were captured were also identified and recorded.
- Juvenile and metamorph surveys diurnal visual encounter surveys were conducted over a four day period on two separate occasions.
- Auditory surveys were conducted at each of the three water bodies each night prior to visual encounter surveys.
- Visual encounter (spotlighting) surveys and mark‑ recapture. Visual encounter surveys (VES) were conducted at all ponds immediately following auditory surveys.
- Chytrid sampling and analysis. Upon collection, each GGBF that was caught was swabbed in a standardised manner, swabs were then stored at –4 ºC until they were analysed using qPCR.

The University of Newcastle concluded that, apart from the issue of vegetation succession and diminishing stands of open water (see comment below under "Adaptive Responses"), the subject site appears to contain sufficient amounts of suitable vegetation and other refuge habitat characteristics, such as rocks and bare ground for foraging.

T4 Environmental Assessment – Umwelt (February 2012) for PWCS

Umwelt undertook a review of all available GGBF monitoring data, in particular unpublished studies undertaken by the University of Newcastle in 2011 ("*Leu, S.T. (2011) Research priorities for the green and golden bell frog (Litoria aurea) on Kooragang Island. Unpublished report, University of Newcastle*").

Plate 10 below shows the extent of GGBF sightings across the Kooragang Island and Ash Island areas, while **Plate 11** shows a more detailed extent of GGBF confirmed sightings around the KIWEF site areas (Umwelt, February 2012).

Plate 10: Plan showing confirmed sightings of GGBF within Kooragang Island / Ash Island area (Umwelt, February 2012)

Plate 11: Detail showing GGBF sightings within KIWEF part of Kooragang Island (after Umwelt, February 2012)

Umwelt also undertook a number of rounds of GGBF monitoring across the T4 site. This monitoring included areas associated with the KIWEF Landfill closure site, in particular Long Pond, which was identified in the study as a potential GGBF breeding habitat.

Umwelt's 2010ř11 GGBF Monitoring was undertaken in as outlined below:

Season	Month	Total Days	Person-hours
Autumn 2010	March	4 days/nights	16.5
Spring 2010	November	6 days/nights	22
Summer 2010-11	December	3 days/nights	18
	January	3 days/nights	6
Autumn 2011	March	4 days/nights	11
Totals		**20 days/nights**	**73.5**

GGBF were found in 21 of the 43 ponds studied across the T4 site and surrounds and sighting was confirmed in the following ponds:

i) OEH Wetland 1 (north of the T4 Project Area and well north of the KIWEF site);

ii) within the KCT Rail Loop (outside of the T4 Project area and well East of the KIWEF site)

iii) Railway Pond (northern end of T4 Project Area, away from KIWEF site)

iv) Pond 11 (northern end of T4 Project Area, away from KIWEF site); and

v) Long Pond (adjacent to KIWEF site).

Plate 12 below shows the ponds that Umwelt identified as key GGBF breeding habitat within the vicinity of the T4 project area (Umwelt, February 2012).

Plate 12: Detail showing GGBF breeding areas on Kooragang Island (after Umwelt, February 2012)

Umwelt also found that the presence of the *Gambusia holbrookii* did not influence waterbody occupancy and GGBF tadpoles were found coexisting with this species in some instances. In contrast, other studies suggest that *Gambusia* is a major threat to the GGBF and that the presence of this fish species has been demonstrated to reduce the breeding success of the GGBF.

The University of Newcastle investigations referenced by the T4 study (Umwelt, February 2012) indicate that the GGBF population is estimated to be approximately 900 individuals, spread across Kooragang Island including within the T4 project area. The investigations indicated that the GGBF is actively reproducing and dispersing across the T4 project area and also dispersing from adjacent OEH estate lands to the north of the T4 project area. The report also concludes that water quality features (i.e. salinity levels and contaminants) are likely to be key features in population persistence for the Kooragang population and changes to these are therefore likely to be a risk factor for the species' persistence. The report also mentions that wetting and drying cycles of ponds may also be important for GGBF.

5.2 Methods for Monitoring GGBFs

5.2.1 Pre-works Surveys for Disturbance Areas

Pre-works surveys will be undertaken within proposed disturbance areas by a suitably qualified and licensed ecologist at least one week prior to works commencing. The pre-works surveys will be conducted to minimise disruption to breeding activities and the need to relocate tadpoles or metamorphs, where practicable.

Habitat resources typically associated with lifecycle components of the GGBF will be searched during the day and nocturnal habitat searches carried out if it is the breeding season. This would include spotlighting and call play‐back. If relocation is necessary procedures would follow those outlined by Golder Associates (April 2011).

5.2.2 GGBF Monitoring

Construction Phase and Post Construction Monitoring

The Environmental Assessment for the T4 Project (EMM for Port Waratah Coal Services (PWCS), February 2012) commits to a comprehensive and targeted monitoring program for GGBF (and water quality) across Kooragang Island. This information will be available to the Applicant. Therefore, the Applicant proposes to utilise this program to inform both baseline and post capping development scenarios. The T4 monitoring program is proposed to include the development of detailed performance criteria and a methodology to assess population viability in consultation with relevant authorities and leading GGBF specialists. PWCS propose that a carefully considered survey approach will be required and that detailed analyses or population modelling will be used to develop an understanding of the success of management actions for the GGBF population.

In order to ensure that there are no data gaps between the proposed T4 monitoring program and those required to assess the specifics of the KIWEF Landfill Closure Proposal, the Applicant will engage the services of an independent recognised GGBF expert to comprehensively review the T4 data collection programs, which will be supplemented with existing data available to the Applicant (e.g. baseline water quality data summarised in **Section 2.1** , and shown in detail in **Appendix A**, including data currently being collected by HDC for the Eastern Ponds).

Following the assessment of the body of information available to the Applicant for adequacy and relevance, the Applicant would provide a submission to the satisfaction of SEWPaC that defines the information is deemed reliable.

The Applicant has also committed to an Annual Report to SEWPaC, which will include a summary of the seasonal GGBF population dynamics (and water quality observations), benchmarked against the volume of baseline data that has been assembled. The Annual Report would provide a conclusion on the relative GGBF abundance and dynamics and any anomalies observed in habitat and or population. The Annual Report will be prepared by a recognised GGBF specialist, supplemented by other relevant experts and would be undertaken for a minimum of three years post‐construction.

Table 3 below summarises the proposed GGBF Monitoring approach.

Table 3: Summary of GGBF Monitoring Approach

<table>
<tr><th>Monitoring Period</th><th>GGBF Monitoring</th><th>Water Quality Parameters (other than Salinity)</th><th>Salinity (EC) and Water Level</th><th>Reporting Period</th><th>Outcomes</th></tr>
<tr><td>Baseline Data - Lead up to Construction</td><td rowspan="4" colspan="2">Utilisation of existing data available to the HDC / NPC – including comprehensive water quality data listed in Section 2, monitoring in the Eastern Ponds, undertaken in accordance with notice N1111840 and added to the body of information collected and provided by PWCS as part of the T4 Project</td><td>Continuous (using existing level /EC loggers)</td><td>Annual</td><td>Establishment of comprehensive baseline water quality conditions is required to enable potential future impacts to be reliably identified.</td></tr>
<tr><td>During Construction</td><td>Continuous (using existing level /EC loggers)</td><td>Quarterly</td><td>More intensive monitoring during the construction period is recommended to identify any short term impacts to water quality that may occur during construction.</td></tr>
<tr><td>12 months immediately after construction completion</td><td>Continuous (using existing level /EC loggers)</td><td>Quarterly</td><td>More intensive monitoring during the immediate post-construction period is recommended to identify changes to water quality as the landform stabilises post construction.</td></tr>
<tr><td>Up to 3 years after construction completion</td><td>Continuous (using existing level /EC loggers)</td><td>Annual</td><td>Relaxation of monitoring intensity as the potential for acute changes to water quality is less likely once the landform is stabilised.</td></tr>
</table>

All pond areas that could be potentially impacted by the capping works would be included as frog monitoring sites, i.e. principally Easement Pond, Easement Pond South, Long Pond, Windmill Road Open Channel and the K2 Basin.

As a minimum, monitoring will record the presence /absence of GGBF at the site on the basis of male calling and ground surveys that are timed (*i.e. a record of how long surveys are carried out for. This is important in order to indicate the length of time a particular area has been surveyed for*). Calling activity will be recorded at each visit as "calling before call simulation" and "calling response after call simulation". The sites will be dip netted and all tadpoles caught will be recorded.

Additional monitoring proposed is specified in the Action Plan for the K26/K32 ponds (Golder, May 2011). HDC will report to OEH annually for 3 years following completion of the landfill closure works, unless analysis shows that GGBF populations are being impacted, then further reporting will be undertaken until a date agreed with OEH.

5.3 Methods of Monitoring Water Quality in the Ponds Affected by the Proposal

5.3.1 Available Baseline Data

There is a significant amount of baseline data relating to surface water and groundwater quality for the site. This information has been compiled and is presented in **Section 2** . Any data gaps, as they relate to the information that is important to the various protected species of concern, have been addressed by additional monitoring undertaken by the Applicant.

5.3.2 Background

Kooragang Island is populated by the GGBF which is listed as endangered under the NSW *Threatened Species Conservation Act 1995* and listed as vulnerable under the Commonwealth *Environment Protection and Conservation Act 1999*. These frogs periodically inhabit pond areas close to the proposed capped sites.

The proposed capping is a measure that will improve the containment of the wastes and reduce or prevent leakage into the surrounding environment. Capping the waste emplacement sites will result in changes to the local topography and hence potentially impact surface water run‑off regimes in these areas. It may also result in changes to the composition of the run‑off quality. These changes may affect the ponds down gradient of the capped areas and hence, may impact on the GGBF.

GGBF are highly mobile frogs that move across Kooragang Island in response to environmental conditions. At different times of the year, the frogs may be active at different sites, and in other years the frogs may utilise sites not inhabited in previous years. The mobility of the frogs, combined with the "boom or bust" nature of their populations, means that there is always uncertainty about GGBF numbers and activity at any site on the island at any given time. This variability means that ascribing a particular impact to changes in frog activity or abundance is extremely difficult to reliably achieve.

5.3.3 Key Potential Water Quality Impacts on GGBF

Key potential impacts on the GGBF and other species include:

- Significant changes to salinity levels (EC);
- Significant changes to wetting and drying regimes in the ponds;

- Increase to nutrient levels (TP, TN) due to proposed imported topsoil materials;
- Increase to algal levels;
- Significant changes to Dissolved Oxygen (DO) levels. DO is an indicator of eutrophication occurring in the ponds, due a possible change in catchment runoff quality or frequency;
- Significant changes to water temperature; and
- Significant changes to suspended sediments levels in the ponds.

The only way to definitively identify potential impacts on GGBF is to compare GGBF monitoring data for existing and proposed conditions. Due to the irregular nature of the GGBF movements, long term data sets in the order of 5 to 10 years would be required to establish reliable trends. This data does not exist for GGBF for existing conditions and would take 5 to 10 years to establish for proposed conditions.

Given these limitations, a data base of existing conditions has been established based on a review of available data and water quality, water level and GGBF monitoring that has been undertaken. Monitoring of proposed conditions is described as follows.

5.3.4 Proposed Conditions Water Quality Monitoring

Methods for monitoring water quality in ponds affected by capping works include the use of handheld multiͲparameter instruments that have the capability to measure real time data in the field and the collection of samples for laboratory analysis. While a large range of water quality parameters are currently monitored on the site, the key parameters identified for GGBF are outlined below in **Table 5**.

If not already being undertaken, these parameters would be monitored in the ponds on a regular basis up to and during the capping period (to establish a baseline of data), and then quarterly for three (3) years following completion of the capping works.

Where there is found to be a lack of sufficient data to establish suitable baseline trends for future comparison, some parameters would be monitored in the ponds on a regular basis up to and during the capping period to establish a baseline of data.

Water quality monitoring would then likely match the frequency required by the T4 Project, at least for a period of three (3) years following completion of the capping works. At the end of the three year period, the relative changes in GGBF numbers and pond water quality will be assessed, and a decision made regarding whether monitoring needs to continue.

Due to the high level of variability in the pond salinity levels as a result of changes from evaporative and freshwater runoff events, it is important that *continuous monitoring* of salinity (EC) and pond water level is continued so that any trends in the data can be observed in comparison to variability in runoff. Therefore, salinity would be measured continuously through the currently installed continuous EC monitoring devices located in each of the ponds and relevant groundwater monitoring bores.

Comparison values for detecting changes to pond water quality that potentially impact threatened species will be established through current and ongoing water quality monitoring. In the case of salinity, salinity monitoring will compare key GGBF comparison values to baseline trends.

5.4 Thresholds for Detecting Impacts on GGBF

5.4.1 GGBF Comparisons

Using the abovementioned monitoring approach, an annual review of changes in frog presence and activity as well as water quality and water level monitoring results would become the means for detecting possible adverse impacts on frogs at the test sites.

The precise details for the frog monitoring and timing of surveys would be established as soon as possible (once T4 Monitoring details are available) and surveys following the agreed guidelines commenced as soon as possible.

Details of proposed GGBF monitoring will be agreed with SEWPaC during the spring and summer periods (October to March) prior to the capping period, during the capping period and then annually during the breeding season for three (3) years after the capping works have been completed. A significant proportion of the required GGBF monitoring will be carried out for the T4 project. All wetland areas that could be potentially impacted indirectly due to water quality changes by the capping works would be included as frog monitoring sites. These areas are Easement Pond, Easement Pond South, Long Pond, Windmill Road Open Channel and the K2 Basin.

Where there is a difference between data that is to be captured for the T4 Project, and the monitoring program required and agreed with SEWPaC, additional monitoring will be commissioned by the Applicant.

5.4.2 Water Quality Monitoring

Physical Stressors - Salinity

Due to the highly variable nature of salinity values, and their dependence on antecedent climatic conditions, it is not possible to set salinity comparison values, based on historical trends, as, for example, 80th percentile type comparison values will be frequently exceeded due to natural variability in the salinity values.

Discussions were held with GGBF specialist, Dr Arthur White, and the following factors were taken into account in order to determine appropriate salinity comparison values, for GGBF:

- The current range of salinity in the ponds (as outlined in **Table 2**, in **Section 2.1**) varies significantly, with some ponds such as BHP Wetlands, Blue Billed Duck Pond and Easement Pond South having salinity values in the lower ranges between 700 to 1,400 µS/cm (0.4 ppt to 0.9 ppt), while others such as Deep Pond, Easement Pond and K2 Pond having salinity in the mid range between 1,700 to 6,000 µS/cm (1.0 ppt to 3.6 ppt), and the remaining ponds Long Pond and Windmill Road Open Channel exhibiting higher salinity values between 3,000 to 16,000 µS/cm (1.8 ppt to 9.6 ppt).
- Dr White indicated that GGBF tadpoles would have difficulty when salinity exceeds 2,900 µS/cm (1.75 ppt), and that GGBF adults would be adversely affected by salinity exceeding 4,100 µS/cm (2.5 ppt). This indicates that for some of the ponds, the majority of the time, the water quality is currently too saline to provide suitable GGBF habitat. It may be that the frogs can only use the ponds during periods of freshwater flushing, and / or prefer to breed in shallow freshwater pools outside of the main ponds. Dr White also indicated that this was possibly one of the reasons that the GGBF was so mobile on

Kooragang Island, in that they likely migrate in and out of ponds, depending on salinity values.

- Chytrid Fungus – research (Stockwell, *et al*, 2012) indicates that salinity ranging between 1650–6,600 µS/cm (1ř4 ppt) results in lower host frog infection rates. This indicates that a possible lower bound comparison level should be 1,650 µS/cm (1 ppt), as at levels below this, Chytrid Fungus could be an issue to the GGBF species.

It is therefore suggested that the best means of establishing whether there is a change in the hydrořsalinity regime within the ponds is to assess any potential change against typical comparison values that have been derived from the above effects of salinity on GGBF / Chytrid Fungus.

Therefore, in terms of establishing middle and upper bound comparison values, it was determined that the change in pond salinity should be measured against the values where tadpoles and adult frogs are affected by higher salinity levels (i.e. typically 2,900 µS/cm (1.75 ppt) for GGBF tadpoles and 4,100 µS/cm (2.5 ppt) for adult GGBF.

For a lower bound comparison value, it is suggested that this is based on the point at which Chytrid Fungal infections could affect GGBF health, i.e. = 1650 µS/cm (1.0 ppt).

Table 4 below outlines the suggested upper and lower bound salinity comparison values.

Table 4: Summary of Suggested Salinity Comparison Values for KIWEF Surface Water Bodies

Adopted lower bound salinity comparison value [1] (µS/cm)	Adopted middle range salinity comparison value [2] (µS/cm)	Adopted upper bound salinity comparison value [3] (µS/cm)
1,650 µS/cm	2,900 µS/cm	4,100 µS/cm

Notes: 1. based on potential effect of chytrid fungal infection in GGBF
2. based on potential effect of higher saline conditions of GGBF tadpoles
3. based on potential effect of higher saline conditions of GGBF adults

If impacts are found to occur then additional investigations and examination of water quality trends would take place to determine whether there is an onřgoing trend, or whether the comparison values are exceeded simply due to adverse climatic conditions. Once a trend is established, then further investigations, and possibly recovery /mitigation actions would be implemented, if required.

The above comparison values have been applied to the preliminary hydrořsalinity modelling undertaken as part of these investigations (refer **Section 11**), to provide an example of how the guideline values could be applied in the future for post construction monitoring results, as they become available.

Physical/Chemical Comparison Values (other than Salinity)

Table 5 outlines possible comparison values for water quality parameters (other than salinity), based on the 80th percentile values from the available data.

Final comparison values will be set at the Construction Environmental Monitoring Plan (CEMP) stage of the project and agreed with SEWPaC.

Table 5: Summary of Suggested Key Water Quality Comparison Values for KIWEF Surface Water Bodies

Surface Water Body		Monitoring Period	pH lower^	pH upper	EC (µS/cm) Full Monitoring Period	EC (µS/cm) More Recent Data*	Turbidity (NTU)	TSS (mg/L)	TN (mg/L)	Nitrates & Nitrites NOx (mg/L)	TP (mg/L)
ANZECC Guideline Value			**7.0**	**8.5**	**N/A**	**N/A**	**10**	**N/A**	**0.3**	**0.015**	**0.03**
BHP Wetlands	80%ile	6/09/2006 - 25/10/2012	7.5	8.8	1400	-	37	34	2.5	0.018	0.12
Blue Billed Duck Pond	80%ile	29/11/2002 - 14/12/2012	8.3	9.3	1250	-	15	37	1.8	0.036	0.20
Deep Pond	80%ile	17/11/1981 - 14/12/2012 (*13/08/1997-14/12/2012*)*	8.1	9.1	21020	4856	32	22	3.3	0.136	0.36
Easement Pond	80%ile	20/08/1996 - 25/05/2007 (*22/03/2006-14/12/2012*)*	7.8	8.8	3546	3400	11	15	1.5	0.172	0.08
Easement Pond South	80%ile	8/03/2012 - 14/12/2012	8.0	8.2	858	-	52	54	1.4	0.206	0.17
Eastern Ponds	80%ile	27/02/2012 - 11/01/2013	-	-	6280	-	22	-	2.5	0.408	0.066
K2 Pond	80%ile	13/08/1997 - 16/04/2012	7.7	8.5	3964	-	-	96	-	0.320	0.97
Long Pond	80%ile	4/05/1990 - 14/12/2012 (*15/03/1999-14/12/2012*)*	7.9	9.0	17930	8400	81	77	4.6	0.120	0.54
Windmill Rd Open Channel	80%ile	13/08/1997 - 25/10/2012	7.9	9.1	12480	-	16	27.8	0.9	0.930	0.08

Notes * Historical EC Testing prior to 1997 / 1999 in some ponds was found to have elevated levels of salinity well above current levels. It is unsure if this is a real change, or possibly a monitoring error. SMEC have reported two ranges of these values for clarity – Refer to Appendix A for full data record.

^ 20%ile values for lower bound pH

N/A Not Available in ANZECC guidelines.

Adaptive Responses / Possible Mitigation Measures for GGBF

Possible adaptive responses / mitigation measures for impacts on GGBF have been identified in **Section 1.2** . A summary is provided below. The following possible adaptive response / recovery plan mitigation measures for GGBF have been identified, should impacts become apparent:

1. Should the specific thresholds be exceeded whereby a demonstrable impact of the works has been observed, then initially further detailed investigation will be undertaken to ensure that the reasons for a change are fully understood. This may involve detailed scrutiny of the water level and water quality monitoring to ascertain in which parts of the site the hydrology and water quality are changing, and to enable GGBF experts to understand the drivers affecting change within the habitat areas. If these investigations conclude that there is definitely impacts associated with the landfill capping, then there are a number of possible mitigating measures that could be instigated to ameliorate any impacts that are occurring.
2. Possible physical recovery plan mitigation measures that may be employed include the sedimentation control ponds that are proposed as part of the works could be planted out as constructed wetlands, to mitigate nutrient export and to provide possible additional GGBF habitat. Discussion with GGBF experts indicates that shallow ponds of this nature would be ideal breeding habitat for the GGBF.

5.5 Key Reference Documents

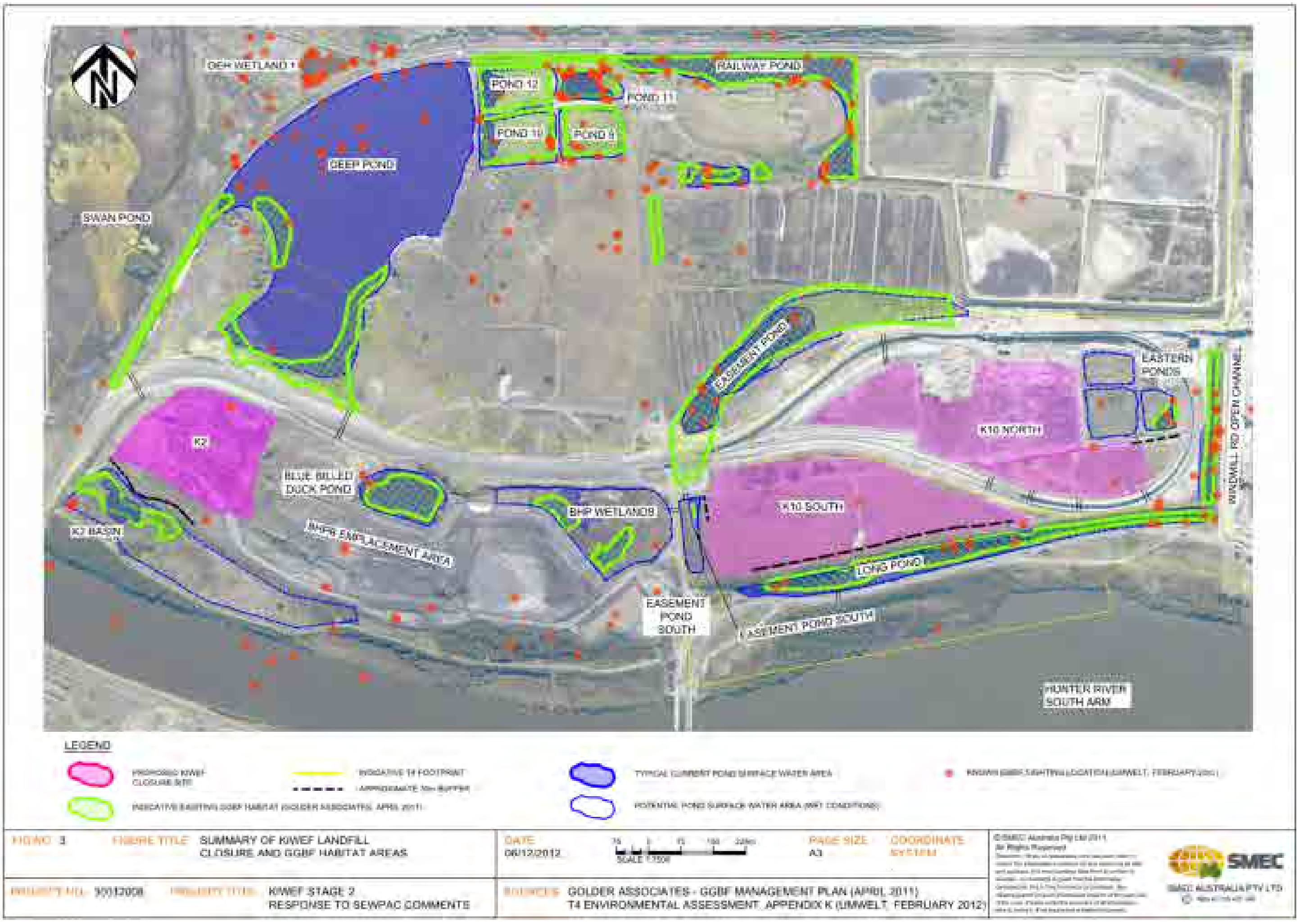
- *Flora & Fauna Assessment for Proposed Waste Emplacement Site – HDC Land at Kooragang Island* (HSO, December 2008) – **Section 2.2**.
- *Revised Capping Strategy KIWEF – Flora and Fauna Impact Assessment Revision 3* (GHD, January 2010) – **Section 4**, **Section 4.6**, **Section 4.5**, **Section 5.2**.
- *Green and Golden Bell Frog Management Plan – Kooragang Island Waste Emplacement Facility Closure Works* (Golder Associates, 19 April 2011) – **Section 4.0**, **Section 5.4.2**.
- *March 2011 Green and Golden Bell Frog (Litoria aurea) Survey at the Kooragang Island Waste Emplacement Facility* (Umwelt, April 2011) – **Section 2.2** and **Section 2.3.2**.
- *K26/K32 and K24/K31 Ponds Action Plan – Kooragang Island Waste Emplacement Facility* (Golder Associates, 31 May 2011) – **Section 4.0**, **Section 4.2**, **Section 4.4**, **Section 7.2**.
- *2011/2012 ecological surveys for the Green and Golden Bell Frog (Litoria aurea) at the Kooragang Island Waste Emplacement Facility* (University of Newcastle, April 2012) – **Section 3.3**, **Section 5** & **Section 5.1**.
- *T4 Project Environmental Assessment – Appendix K* (EMM EMGA, February 2012) – *Ecological Assessment for Port Waratah Coal Services (PWCS) – Proposed Terminal 4 (T4) Project, Port of Newcastle NSW* (Umwelt, February 2012). **Section 4.2.3.1 – Amphibians.**

6 ITEM 6 – GGBF HABITAT MAPPING

Item 6 – Provide a map which clearly shows all areas of GGBF habitat (not restricted to areas where frogs were found during 2009) in relation to the proposed 30m buffers from works, and describe how these buffers would be demarcated in the field so that they are clearly visible to workers during construction works.

The documentation outlined in **Section 6.1** was used to prepare a map illustrating areas of GGBF habitat adjacent to the proposed capping works for K2, K10 North and K10 South, together within the proposed 30m buffer from the works (refer **Figure 3**). In some locations, the nature of the terrain may limit the size of the buffer.

Figure 3 – Summary of KIWEF Landfill Closure Works, Indicative GGBF Habitat Areas and Recorded GGBF Sighting Locations



The capping works will occur on elevated sections of the landfill (typically around 9–10m AHD), with no works proposed in the ponds or in known GGBF habitat areas, which are typically found fringing the ponds, below 2 to 3m AHD. **Figure 3** illustrates the proposed limit of the capping works within K2, K10 North and K10 South.

The GHD Flora and Fauna Strategy (2009) identified a 30 metre buffer zone adjacent to areas of known GGBF habitat, where possible. The document also provided boundaries for the proposed capping works, with the distance from the earthworks boundary and the buffer varying. The detailed design, where possible, matches the boundaries provided in the Approved Capping Strategy (GHD, 2009). There will be minor works for stormwater discharge outlet structures within the buffer zone and habitat zone, which are unavoidable, but minor in nature.

The detailed design and tender documentation for the landfill closure works include technical specification and detailed design drawings for the works. These include the requirement for frog exclusion fences around all proposed areas of earthwork in order to discourage frog movement into the area of construction. Fencing will also be used for construction safety and to prevent any earthwork machinery or material storage entering GGBF habitat areas. The 30 metre buffer varies according to capping requirements and site constraints.

Prior to any construction work commencing onsite, all personnel undertaking site inductions would be made aware of the known areas of GGBF habitat. In addition, prior to the capping works commencing, areas of known GGBF habitat will be clearly identified/delineated on the ground with appropriate signage as well as on the site plan. The frog proof fences would be marked with marker tape to make them clearly visible.

Plate 13 shows a schematic of proposed capping works in relation to GGBF habitat.

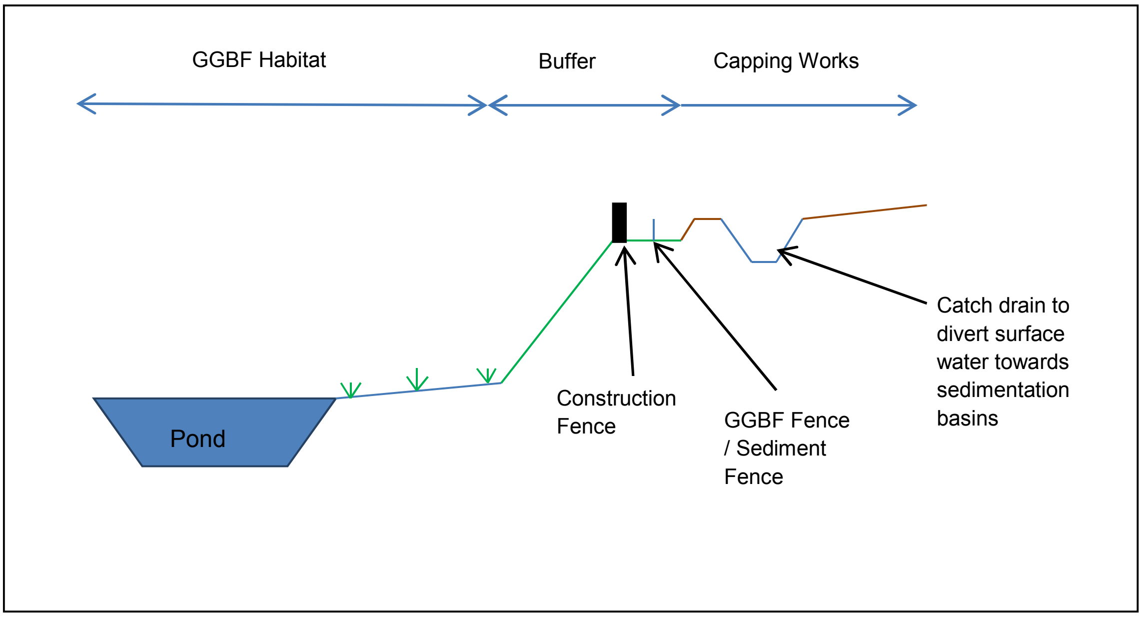


Plate 13: Schematic of proposed capping works in relation to GGBF habitat

Figures 4A and **4B** outlined in illustrate areas where the works will intrude into the 30m buffer areas.

Plate 14: Figure 4a – K10 Capping Area showing GGBF Habitat Areas and Proposed Stormwater Management Controls

Plate 15: Figure 4B – K2 Capping Area showing GGBF Habitat Areas and Proposed Stormwater Management Controls

6.1 Key Reference Documents

The following previous studies have been undertaken in relation to mapping GGBF habitat at the KIWEF site:

- *Flora & Fauna Assessment for Proposed Waste Emplacement Site – HDC Land at Kooragang Island* (HSO, December 2008) – **Figure 3.3** illustrates GGBF core habitat within a section of the KIWEF site;

- *Revised Capping Strategy KIWEF – Flora and Fauna Impact Assessment Revision 3* (GHD, January 2010) – **Figure 5.5** illustrates GGBF recorded habitat areas, as well as buffer zones;

- *Green and Golden Bell Frog Management Plan – Kooragang Island Waste Emplacement Facility Closure Works* (Golder Associates, 19 April 2011) – **Figure 1** illustrates known and potential GGBF habitat areas, **Section 5.1** and **5.2** discuss how 30m buffer zones will be marked with appropriate signage and communicated during site inductions;

- *March 2011 Green and Golden Bell Frog (Litoria aurea) Survey at the Kooragang Island Waste Emplacement Facility* (Umwelt, April 2011) – **Figure 3.1** illustrates the study area (i.e. K10N) and identifies potential area within K10N for GGBF breeding and refuge. **Figure 3.2** illustrates GGBF records within K10N;

- *2011/2012 ecological surveys for the Green and Golden Bell Frog (Litoria aurea) at the Kooragang Island Waste Emplacement Facility* (University of Newcastle, April 2012) – **Section 3.3.1** (**Figure 1** illustrates tadpole trapping locations), **Section 4.1.1.2** (**Figure 10** illustrates the distribution of GGBF either sighted or captured within the Eastern Pond, at the K10 site); and

- *KIWEF Capping Strategy – EPBC Referral* (GHD, July 2010) – Refer **Figure 2.1** for map of proposed capping strategy and GGBF habitat impact area.

In addition to the above documents that have been specifically prepared for the KIWEF, the following additional documents have been prepared for other projects on Kooragang Island. These include, but are not limited to the following:

- *NCIG Coal Export Terminal Green and Golden Bell Frog Management Plan* (NCIG, October 2007) – **Figure 2** illustrates GGBF habitat within the KIWEF site and Figure 3 illustrates records of the GGBF in the vicinity of the project; and

- *T4 Project Environmental Assessment – Main Report volume 1, Chapter 10* (EMM EMGA, February 2012) – **Figure 10.6** illustrates GGBF records within and adjacent to the KIWEF site. Also – *Appendix K – Ecological Assessment for Port Waratah Coal Services (PWCS) – Proposed Terminal 4 (T4) Project, Port of Newcastle NSW* (Umwelt, February 2012). **Section 4.2.3.1 – Amphibians.**

7 ITEM 7 – HYGIENE PROTOCOLS (FROGS)

Item 7 – Details of any hygiene protocol designed to minimise the risk of introducing or spreading amphibian Chytrid Fungus to, on or from the site prior to, during and after any works associated with the project, which is consistent with the NSW National Parks and Wildlife *Service Hygiene Protocol for the Control of disease in Frogs*.

7.1 Summary

Chytrid fungus infection occurs through waterborne zoospores released from an infected amphibian in water, with the fungus having the potential to infect both tadpoles and frogs. The fungus can therefore spread through movement of water around the site.

The *KIWEF Capping Strategy – EPBC Referral* (GHD, July 2012) details a range of frog hygiene protocols that will be adopted in order to minimise the risk of introducing or spreading chytrid fungus. Measures such as disinfecting vehicle tyres, washing down vehicles before entering and leaving the site, disinfecting PPE, such as boots, waders and equipment are already being undertaken and will continue to be adhered to as part of the Proposal. The reference document for these controls is the *Hygiene protocol for the control of disease in frogs* (DECC, 2008).

Table 6 outlines the potential impacts, the implications and how the proposed management measures/hygiene protocols will address them.

Table 6: Summary of potential impacts, implications and management measures / hygiene protocols to address the potential impacts

Potential Impacts	Implications	Proposed Frog Management Measures / Hygiene Protocols
• Spread of chytrid fungus around the site through vehicular movement; • Spread of chytrid fungus around the site through personnel working on-site (e.g. through PPE such as boots, waders & equipment); • Spread of chytrid fungus around the site through movement of water between ponds; • Potential release of infected GGBFs; • Infected GGBF's not being properly identified; • Incorrect handling/transporting of GGBFs.	• Spread of chytrid fungus through the GGBF population around the KIWEF site and possibly to neighbouring sites.	• The capping strategy for the KIWEF site has been undertaken in a way to minimise any changes to the existing hydrologic/hydraulic regime at the site, which will reduce the risk of transferring chytrid fungus between ponds around the KIWEF site. • All HDC employees & Contractors involved in activities within areas of known GGBF habitat to be trained in site hygiene management in accordance with the Protocol for the Control of Disease in Frogs (DECC, 2008); • Pre-work surveys will be undertaken by a suitably qualified and licensed ecologist; • Site hygiene management measures will be undertaken, including tyres of vehicles to be sprayed with an appropriate disinfectant solution (e.g. Halamid, Halasept & Hexifoam); • Cleaning and disinfecting equipment such as footwear, nets and waders before/after use to reduce any risk of transporting the chytrid fungus between ponds; • Further advice will be sought by a designated frog

		recipient if any GGBF is found to show signs of illness or infection; • Protocols on methods in handling and transporting frogs, such as: • using a new pair of gloves for each sample; and • Adopting a 'one bag-one frog' approach to frog handling. • Any sick or dead GGBFs encountered will be collected and disposed of in accordance with Section 4.2 of the 'Hygiene protocol for the control of disease in frogs (DECC, 2008).

7.2 Details of Hygiene Protocols

The detailed design and tender documentation for the landfill closure works, the over-arching Environmental Management Plan (EMP) with guiding principles for environmental management of the site (the "KIWEF EMP") all include management measures and hygiene protocols to be implemented during construction. The tender documents require the successful contractor to prepare a Construction Environmental Management Plan (CEMP) that requires adherence to the GGBF Management Plan, as well as the overarching site EMP, including adherence to frog hygiene protocols.

To minimise the risk of spreading chytrid fungus occurring, all contractors involved in activities within areas of known habitat for the GGBF (and other amphibian species) will be trained in site hygiene management in accordance with the *Protocol for the Control of Disease in Frogs* (DECC, 2008).

The *Green and Golden Bell Frog Management Plan – Kooragang Island Waste Emplacement Facility Closure Works* document prepared by Golder Associates (April 2011) is incorporated into the detailed design and documentation for the KIWEF landfill closure. The document discusses a wide range of management procedures designed to protect the frog, from pre-work surveys through to environmental induction training and site hygiene management for chytrid fungus. The document was prepared with reference to the GGBF Management Plan prepared by NCIG (2007) which was accepted by OEH.

In addition, the GGBF Management Plan (Golder, April 2011) states that *any mobile plant entering and leaving the KIWEF site during the closure and capping activities will be routinely disinfected at a designated wash bay. Similarly, personal protective equipment (PPE) of HDC employees and contractors entering and leaving the site will be disinfected as a matter of routine, following the methods outlined in the Hygiene Protocol .* The inspection and disinfection activities will be undertaken at a designated, concrete bunded disinfection area at the entrance to the KIWEF site. This designated area will be outlined in the site induction/training program.

The *Hygiene protocol for the control of disease in frogs* (DECC, 2008) outlines information on:

- The prevention/reduction of disease causing pathogens being transferred within and between wild population of frogs;
- Eliminating the risk of frogs being infected prior to their release;
- Protocols on methods of transporting frogs; and
- The identification and management of sick and dead frogs in the wild.

The document discusses a range of frog hygiene protocols recommended to reduce the spread of chytrid fungus. These include, but are not limited to the following:

- Cleaning and disinfecting equipment such as footwear before/after use to reduce any risk of transporting the chytrid fungus between ponds;
- Spraying/flushing vehicle tyres with a disinfectant solution in high risk areas;
- Methods of handling frogs (cleaning hands, 'one bag – one frog' policy); and
- Disinfection methods (e.g. Halamid, Halasept and Hexifoam).

The above protocols are also covered/recommended in the following documents:

- *Revised Capping Strategy KIWEF – Flora and Fauna Impact Assessment Revision 3* (GHD, January 2010);
- *Ecological Surveys for the Green and Golden Bell Frog (Litoria aurea) at the Kooragang Island Waste Emplacement Facility* (University of Newcastle, 2012); and
- Flora & Fauna Assessment for Proposed Waste Emplacement Site – HDC Land at Kooragang Island (RPS HSO, 2008).

7.3 Key Reference Documents

- *KIWEF Capping Strategy – EPBC Referral* (GHD, July 2012) – **Section 3.3 (b)**, **Section 4**.
- *Flora & Fauna Assessment for Proposed Waste Emplacement Site – HDC Land at Kooragang Island* (HSO, December 2008) – **Section 6.1.2** & **Section 8**.
- *Revised Capping Strategy KIWEF – Flora and Fauna Impact Assessment Revision 3* (GHD, January 2010) – **Section 4.2.8**.
- *March 2011 Green and Golden Bell Frog (Litoria aurea) Survey at the Kooragang Island Waste Emplacement Facility* (Umwelt, April 2011) – **Section 2.1.3**.
- *Green and Golden Bell Frog Management Plan – Kooragang Island Waste Emplacement Facility Closure Works* (Golder Associates, 19 April 2011) – **Section 3.4**.
- NSW National Parks and Wildlife Service *Hygiene protocol for the control of disease in frogs* (DECC, 2008).
- *2011/2012 ecological surveys for the Green and Golden Bell Frog (Litoria aurea) at the Kooragang Island Waste Emplacement Facility* (University of Newcastle, April 2012) – **Section 3.2**, **Section 3.3**.

8 ITEM 8 – GAMBUSIA HOLBROOKI TRANSFER

Item 8 – Details of any mitigation measures to ensure that water would not be transferred or connected (i.e. during high rainfall periods) from ponds containing the fish Gambusia holbrooki to ponds which do not contain this species.

8.1 Summary

There will be no change to the actual physical connections (channels, flow paths, culverts) between the ponds as a result of the capping works. Therefore the capping works will not provide new water pathways by which *Gambusia* can migrate. Given this, it is difficult to adopt any specific mitigation measures that stop the transfer of water between ponds during high rainfall events without significantly altering the existing hydrologic/hydraulic regime.

Importantly water will not be transferred between water bodies during the construction phase. There is potential that *Gambusia* can also be transferred between water bodies through lack of adequate frog hygiene protocols. Mitigation measures to be implemented to ensure that *Gambusia* would not be transferred between ponds include site induction training and disinfection of boots, vehicles and machinery.

8.2 Detailed Review

The majority of surface water bodies at KIWEF are presently connected through a complex series of channels, flow paths, culverts, or as water moving through the aquifers. Ponds within the KIWEF site are hydraulically connected, with these connections being somewhat unavoidable. For example, there appears to be a connection between the BHP Wetlands (*Gambusia* present) and Blue Billed Duck Pond (no *Gambusia* present), as illustrated in **Appendix B**, taken from the *Revised Capping Strategy KIWEF – Flora and Fauna Impact Assessment Revision 3* (Figure 5.5 – GHD, January 2010).

The proposed works will not involve direct work on existing connections between the KIWEF water bodies. The detailed design of landfill closure works generally maintains runoff catchments to the existing conditions, within the context of the already highly modified site.

The key aim and benefit of the capping works is to prevent infiltration into the landfill (and generation of leachate), however this may result in a greater volume of surface water runoff (as discussed in **Section 1**). Subsequently, this may result in a change to the frequency of the flows between ponds. However, there will be no change to the actual physical connections (channels, flow paths, culverts) between the ponds by which *Gambusia* may migrate.

There is potential that *Gambusia* can also be transferred between water bodies through lack of adequate frog hygiene protocols. A number of relevant documents detail mitigation measures to ensure that *Gambusia* would not be transferred between ponds, including the GGBF Management Plan (Golder, April 2011).

Section 7 outlines mitigation measures, including following the frog hygiene protocols, previously discussed in this response such as site induction training, disinfection of boots, vehicle, and machinery. No water from habitat ponds will be used for dust suppression or any other purpose during the construction phase of the project.

Students from the University of Newcastle are currently undertaking a study of the GGBF within the K10 area of KIWEF to satisfy the requirements of HDCs landfill closure requirements as well as to cover the requirements of the Surrender Notice #1111840 issued by the Office of Environment and Heritage (OEH). As part of the surveys being undertaken, strict hygiene protocols are being implemented to reduce the risk of spreading *Gambusia*. All surveys have been conducted in accordance with the NSW National Parks and Wildlife Service Hygiene Protocols. For example waders were disinfected by soaking in a bleach solution with 2% sodium hypochlorite and all equipment used was disinfected by spraying with 70% ethanol (University of Newcastle, 2012).

8.3 Key Reference Documents

- *Revised Capping Strategy KIWEF – Flora and Fauna Impact Assessment Revision 3* (GHD, January 2010). **Section 7.1** & **Figure 5.5**.
- 2011/2012 ecological surveys for the Green and Golden Bell Frog (Litoria aurea) at the Kooragang Island Waste Emplacement Facility (University of Newcastle, April 2012) – **Section 3.2**.

9 ITEM 9 – GGBF MITIGATION MEASURES DURING CONSTRUCTION

Item 9 – Details of any mitigation measures to minimise impacts on GGBFs during construction works, for example by:

a) Construction and ongoing, regular maintenance of frog-proof fencing around the perimeter of works areas;

b) "Pre-clearance" surveys for GGBFs (undertaken by a suitably qualified and experienced person) inside fenced areas within one week prior to works taking place; and

c) Developing criteria for and selecting release sites for any GGBFs captured during pre-clearance surveys, and a map showing selected release sites.

9.1 Summary of Mitigation Measures for minimising harm to GGBF during Construction

Detailed mitigation measures for the construction phase are to be prepared as part of the KIWEF Construction Environmental Management Plan. These measures would be further developed by the construction contractor in the Construction Environmental Management Plan (CEMP).

The following construction phase mitigation measures are the minimum proposed to eliminate, minimise and mitigate potential impacts on GGBFs during construction works, and will form the basis of the KIWEF Construction Environmental Management Plan:

- No Construction activities are proposed within GGBF Habitat areas, therefore there is no need to limit works to outside of the GGBF core breeding period (October–March);
- Prior to the capping works commencing, areas of known GGBF habitat will be clearly identified/delineated on the ground with appropriate signage as well as on the site plan. The frog proof fences would be marked with marker tape to make them clearly visible. Furthermore, the GGBF Management Plan requires the installation of a frog-proof barrier around the disturbance footprint;
- Pre-works surveys will be undertaken within proposed disturbance areas by a suitably qualified and licensed ecologist. Pre-works surveys will be conducted to minimise disruption to breeding activities and the need to relocate tadpoles or metamorphs, where practicable;
- The pre-works surveys will be undertaken one week prior to works commencing in the disturbed area;
- All pre-works surveys will be in accordance with relevant sections of the frog hygiene protocols;
- A suitably qualified ecologist will be available on-call to visit the site should GGBF be encountered during clearing and capping works. This person will also be responsible for relocating any GGBFs that may be found in the works area during capping activities; and
- A map illustrating the selected release sites is contained within **Appendix B** (Figure 1 – Golder, April 2011).

Section 1.2 of this report also outlines possible recovery plan mitigation measures that could be implemented to address possible future impacts on the GGBF. The important note being that recovery plan mitigation measures should ***only*** be instigated if it can be demonstrated that there is a definite impact on the GGBF numbers as a result of the proposed capping works.

GGBF are highly mobile frogs that move across Kooragang Island in response to environmental conditions. The mobility of the frogs means that there is always uncertainty about GGBF numbers and activity. This variability means that ascribing a particular impact to changes in frog activity or abundance is problematic.

Should the specific monitoring thresholds be exceeded whereby a demonstrable impact of the works has been observed, then initially further detailed investigation will be undertaken to ensure that the reasons for a change are fully understood, followed by investigation of the most effective recovery plan mitigation measures, should they be required. The recovery plan mitigation measures would be developed by expert ecologists, hydrologists and engineers working as a team to achieve the best possible outcomes. **Section 1.2** outlines some possible adaptive response / recovery plan mitigation measures that could be implemented, should the need arise including the possible conversion of the sediment basins to GGBF habitat ponds.

Similar mitigation measures to those previously outlined are discussed in Section 10.5.2 of the PWCS T4 Environmental Assessment (EMM EMGA, February 2012). These measures include avoiding key areas of GGBF habitat (this proposal does not propose any works within GGBF habitat areas), minimisation of surface water and groundwater impacts on GGBF habitat, undertaking pre-clearance surveys and following frog hygiene protocols.

9.2 Detailed Review

9.2.1 Frog Proof Fencing

As part of the technical specification and detailed design drawings for the proposed works there will be the requirement for frog exclusion fences around all earthworks to discourage frog movement into the area of construction. This was successfully undertaken for the BHP / Thiess Hunter River Remediation Project (HRRP) adjacent to K2, and a similar type of fence is proposed. The frog fencing will be provided in combination with a sediment fence.

9.2.2 Pre-Clearance Surveys

The GGBF Management Plan (Golder, April 2011) discusses a wide range of management procedures designed to protect the GGBF, from pre-work surveys through to environmental induction training and site hygiene management for chytrid fungus. Section 3.5 of the GGBF Management Plan discusses the inclusion of GGBF pre-works surveys for disturbance areas.

Pre-works surveys will be undertaken within proposed disturbance areas by a suitably qualified and licensed ecologist. All activities will be conducted in accordance with the relevant measures outlined in the hygiene protocol. The pre-works surveys will be undertaken one week prior to works commencing in the disturbed area.

The GGBF Management Plan also states that habitat resources typically associated with the lifecycle components of the GGBF (for example, ponded areas, rocks, logs, tussock forming vegetation and other cover) will be searched during a diurnal visual inspection.

Following the diurnal habitat searches, a nocturnal habitat search may be conducted to assess nocturnal usage (that is, breeding/calling) in the habitat in the area adjacent to the ponds potentially affected by the capping works ř i.e. the surrounds of Easement Pond, Easement Pond South, Windmill Road Open Channel, Long Pond, and the K2 Pond.

The nocturnal habitat searches may include:

- Searching of habitat features, which were searched during the day;
- Spotlighting; and
- Call playřback.

The results of the preřworks surveys will be recorded and reported in the Annual Environmental Management Report.

9.2.3 Criteria for Release Sites for GGBFs Captured During Surveys

The GGBF Management Plan (Golder, April 2011) Section 3.6 outlines that in the event that any GGBFs are observed during the diurnal or nocturnal searches, the relocation procedures will be initiated prior to the commencement of disturbance works. In some cases a frog proof fence may be used to protect the frogs inřsitu or to exclude frogs from the surveyed area.

The report discusses GGBF relocation procedures, including:

- Relocation procedures during preřworks surveys;
- Relocation procedures outside of preřworks surveys; and
- Procedures for handling sick or dead GGBFs.

The report outlines that the relocation procedure described largely follows the proposed NCIG (2007) procedure, which has been accepted by OEH.

In the event that any GGBF is identified within the disturbance areas during preřworks surveys, the following relocation procedure will be initiated:

a) The ecologist undertaking the preřclearance survey will capture the frog;

b) If the frog appears to be healthy:

    i) A suitable release location in the immediate vicinity of the disturbance area, yet outside of potential areas of disturbance, will be identified by the ecologist.

    ii) The frog will be released into the relocation area. Any frog to be relocated will be held in a cool, dark, moist place until nightfall. Where practicable, relocation will be timed to coincide with periods of recent rainfall to optimise chances of survival of the frog.

c) If the frog appears to be sick, or is dead, then **Section 3.6.3** (GGBF Management Plan, Golder Associates, 2011) outlines procedures for handling sick or dead GGBFs, including a range of symptoms that may be exhibited by sick or dying frogs, diagnostic tests used to determine if a frog is sick, as well as procedures to follow in the event that a GGBF appears to be sick. A brief summary (Ref: NPWS, 2001) of the required procedures for handling sick or dead frogs is outlined below:

    i) Disposable gloves when handling all frogs (including sick or dead frogs) – new gloves and clean plastic bag will be used for each frog specimen.

ii) Frogs exhibiting one or more of the symptoms of sick frogs and that are considered unlikely to survive transportation will be euthanised.

iii) Sick frogs likely to survive transportation will be placed into either a moistened cloth bag with some damp leaf litter, or into a partially-inflated, clean plastic bag with damp leaf litter. All frogs will be kept separate during transportation. Individual containers will be used for each specimen.

iv) Dead frogs will be kept cool and preserved as soon as possible. The belly of the frog will be cut open and the specimen placed in preservative (approximately 10 times the volume of the specimen). Specimens will be preserved in either 65% ethanol or a 10% buffered formalin.

v) The recipient of the sick or dead frog will be contacted to confirm the appropriate procedure prior to transport.

vi) Containers will be labeled with date, location and species.

vii) A standardised collection form will be filled out and a copy sent with the specimen.

Relocation of GGBFs outside pre-works surveys will be conducted in accordance with the relevant measures outlined in the hygiene protocol.

Details of GGBFs that are relocated (that is, lifecycle stage and sex of individual [if possible], location where found and location of release) during pre-work surveys will be recorded and reported in the Annual Environmental Management Report.

A map showing the selected GGBF release sites is contained within **Appendix B**.

9.3 Key Reference Documents

- *Flora & Fauna Assessment for Proposed BHP Waste Emplacement Site – HDC Land at Kooragang Island* (HSO, December 2008) – **Sections 6.1.2** and **6.1.3**, **Section 7**, **Section 8**.
- *Revised Capping Strategy KIWEF – Flora and Fauna Impact Assessment Revision 3* (GHD, January 2010) – **Section 7** & **Figure 5-5**.
- *Green and Golden Bell Frog Management Plan – Kooragang Island Waste Emplacement Facility Closure Works* (Golder Associates, 19 April 2011) – **Section 3.6**, **Section 5.0**, **Section 5.2**, **Figure 1**, **Section 7** & **Section 8**.
- *KIWEF Capping Strategy – EPBC Referral* (GHD, July 2012) – **Section 4**.
- *PWCS T4 Environmental Assessment (*EMM EMGA, February 2012)
- *Threatened Species Management Information Circular No. 6 – Hygiene Protocol for the Control of Disease in Frogs.* National Parks and Wildlife Service (NPWS, 2001).

10 ITEM 10 – CAPPING AND REVEGETATION

Item 10 –	**A description of how areas affected by the capping works would be stabilised and revegetated, including measures to mitigate effects of stormwater, sediment and erosion run-off.** **Discussion as to the likely success of revegetation in the K2 area, which will not be covered with topsoil after capping. Please outline any characteristics of the revegetated areas or their ongoing management that will make them suitable as GGBF habitat in the long term.**

10.1 Proposed Measures to Stabilise, Revegetate and to Mitigate the Effects of Stormwater, Sediment and Erosion Runoff

10.1.1 Proposed Revegetation Layer Treatment Areas

All three areas (K2, K10 North and K10 South) of the site are proposed to be covered with a re-vegetation layer that sits on top of the proposed cap. The revegetation layer is proposed to consist of existing 'topsoil', which typically consists of CWR material and other fill. The existing CWR material is weathered, and currently supports existing vegetation growth (typically weeds).

It is understood that CWR material may potentially inhibit the growth of water borne fungal pathogens such as *Batrachochytrium Dendrobatidis*, commonly known as amphibian or frog chytrid fungus, responsible for the disease Chytridiomycosis (Berger et al., 1999; NSW National Parks and Wildlife Service [NPWS], 2001; DECC, pers comm., 2008).

In addition, maintaining a 'like for like' surface will help minimise changes in water quality to downstream receiving waters and potential impacts on GGBF. Based on soil testing the existing soils are low in nutrients, but there is a concern that the introduction of nutrients and compost material could have detrimental impacts on the GGBF species through algal blooms due to high nutrient runoff, or through the introduction of chytrid fungus through the importation of compost material.

Existing topsoil will be stockpiled, turned over to prevent re-colonisation by existing weed species, and re-spread to form a homogeneous layer. A native seed mix will be applied, typically using a hydraulic hydro-mulching technique. The seed mix will also include ameliorants such as species that can fix their own nitrogen, to assist in plant colonisation of the re-vegetation layer.

It is thought that native species are more likely to prevail in the low nutrient soils on the site.

10.1.2 Stabilisation/Revegetation Measures

The following measures are proposed to reduce the likelihood of stormwater, sediment and erosion and nutrient runoff during the proposed work:

- Construction of sedimentation basins;
- Planting of native plant seed mix, supplemented with ameliorant species that are able to fix nitrogen in the soil;

- Regular inspection and maintenance of erosion and sedimentation control devices during construction, particularly following significant rainfall events;
- Once works are complete, the restoration and rehabilitation of any disturbed habitat will be undertaken in accordance with a rehabilitation and revegetation plan; and
- The capped areas will be designed to shed water to table drains, which, in a similar manner to other stormwater infrastructure, will be vegetated with species that will absorb nutrients.

10.1.3 Revegetation Success

Soil Testing Results

Following review of the issues raised in the *Request for additional information* from SEWPaC (EPBC Ref: 2012/6464, 3 August 2012), additional soil testing was also undertaken within the K2 and K10 South areas. Prior to this, soil testing had only been undertaken within the K10 North area.

Soil samples were sent to the Sydney Environmental Soil Laboratory Australia for analysis. Results of this soil testing and photos illustrating the current vegetation growth within K2 and K10 (including K10 North and K10 South respectively) are included in **Appendix C**.

The soil profile in K2 area is very uniform and is strongly alkaline, moderately saline and very low in Nitrogen, Phosphorus and moderately low in Potassium. The very low available Nitrogen is due to the high Carbon to Nitrogen ratio. A C/N ratio of over 20 is associated with a tendency to nitrogen depletion. The soils are characterised by coaliferous fragments. Some of the samples were wet indicating poor drainage.

The K10 area is also uniform but is not as alkaline and not saline at all. It is however just as deficient in Nitrogen, Phosphorus and to a lesser extent Potassium.

Soil Amelioration Recommendations

HDC proposes to avoid the use of fully imported topsoils such as sandy loam, as these may introduce high nutrients and/or chytrid fungus, and may result in different water quality of runoff, and subsequently have adverse impacts on the GGBF.

Due to concerns related to nutrient runoff into the ponds and the introduction of chytrid fungus, the design does not include the addition of nutrients or composting materials, other than those included in normal spray-seed hydro-mulching for a native spray seed mix.

A provenance native vegetation seed mix is proposed that will also include a number of “medics” in the seeding mix such as *Medicago polymorpha,* which is an example of an alkali tolerant legume that will fix Nitrogen and improve the Carbon/Nitrogen ratio over time. Appropriate selection of salt and alkali tolerant cover crops for the first year or two is also important, and these will be selected in the applied seed mix. Potential winter active crops would be Grain Barley and Burr medic. These winter active crops are both salt and alkali tolerant.

The Contractor will be asked to provide evidence to the Principal that all organic material that is to be added to the topsoil (e.g. spray-seed hydro-mulch) has been thermally treated and is free from animal pathogens including chytrid fungus.

Design Documentation

A technical specification which includes the re-use of existing materials where required and includes the above re-vegetation recommendations forms part of the construction contract. During construction, the Contractor will also adhere to best-practice stormwater controls. The stormwater basins have been sized in accordance with the recommendation of appropriate NSW Government guidelines (Managing Urban Stormwater – Soils and Construction [‘Blue Book”], Landcom, 2004) and include recommendations for wet basins, and the testing of water prior to discharge.

The revegetation layer will protect the cap (via armouring alone), however successful revegetation is preferred in the longer term to stabilise the site. Re-vegetation will reduce on-going maintenance, mitigate downstream sedimentation and will be beneficial to GGBF in the long-term.

Risk Assessment and Proposed Revegetation Layer

The introduction of a re-vegetation layer on top of the cap poses very minor risks for the GGBF, but importantly provides significant longer term benefits such as the improvement of the plant covering of the capped areas. This in turn reduces the chances of sediment and nutrient runoff in the longer term, as well as ameliorating any potential increase in surface water runoff as a result of the capping works. Increased runoff has the potential to impact the ponds from a hydrological and salinity perspective. However, based on recent modelling any relative impacts on water levels and salinity in the ponds is not expected to be significant for the GGBF or other threatened species (refer – **Section 11**).

Management Measures for Imported Material

Management measures to mitigate potential negative impacts from the use of imported material are:

- Any composting material imported to the site associated with applied hydro-mulches etc. would be treated to reduce the potential for chytrid fungus to be imported onto the site. All imported material will be sourced from an appropriate commercial supplier and will be prepared to Australian Standards (e.g. AS 4419(2003) – Soils for Landscaping and Garden Use and AS 4454 (2012) Composts, Soil Conditioners and Mulches. All soil blending techniques will be approved by HDC prior to use. All material used for composting shall be controlled on-site such that undesirable compounds do not leach into the ponds.

- Following the application of the revegetation layer, a program of downstream monitoring of algal level through Chlorophyll-a, Nitrogen and Phosphorus levels will be undertaken.

- The monitoring regime will ensure that should monitoring of Chlorophyll-a levels exceed existing background levels, indicating possible algal outbreaks in the ponds close to the capped areas, this would trigger a detailed analysis of the water in these ponds, particularly Nitrogen levels. Should elevated Nitrogen levels be exhibited in the runoff water, the strategy would be to investigate the contributing catchment areas to see whether there are means to reduce contributing nutrient levels, such as augmentation of the proposed sedimentation basins to form constructed wetlands, and / or manually harvest and remove surface algae as a means of reducing the Nitrogen load in the ponds.

- In addition to the above recommendations, the proposed sedimentation basins and collection drains would be planted with shallow rooting sedges and grasses that would assist in the removal of excessive plant nutrients prior to entering the ponds (effectively acting as constructed wetlands). Suitable plant species include:

- Juncus kraussi;
- Juncus ursitatus;
- Themeda australis (Kangaroo Grass);
- Danthonia sp. (Wallaby Grass);
- Cyperus difformis;
- Cyperus gracilis; and
- Cyperus laevigatus.

The additional benefit of creating constructed wetlands from the proposed sedimentation basins is that they could potentially form GGBF habitat.

10.1.4 Suitability of Capping for GGBF Habitat

The capping works will occur on elevated sections of the landfill with no works proposed in the ponds or in known GGBF habitat areas.

The design incorporates several features that could potentially provide habitat for the GGBF within the capped/re‐vegetated area, including possibly future retro‐fitting of the proposed sedimentation basins and stormwater infrastructure areas to form GGBF habitat, and the planting of the capped areas with native species (as well as non‐native nitrogen‐fixing, alkali and salt resistant plant species) to be potentially favourable to GGBFs.

10.2 Key Reference Documents

- *Report on KIWEF Revised Final Landform and Capping Strategy Revision 4* (GHD, December 2009) – **Section 7.2**, **Section 8**, **Section 9.1**, **Section 9.5, *Appendix H - Materials Management Plan***.
- *Green and Golden Bell Frog Management Plan – Kooragang Island Waste Emplacement Facility Closure Works* (Golder Associates, 19 April 2011) – **Section 5.1** and **Section 5.2, Section 5.3***.*
- *KIWEF Capping Strategy – EPBC Referral* (GHD, July 2012) – **Section 4**.
- *SESL Laboratory Test Results* (November 2012).

11 HYDROBSALINITY MODELLING

11.1 Background

A daily timeȑstep hydroȑsalinity model has been prepared by SMEC as part of this study. The model was developed in order to identify any potential impacts to KIWEF water bodies as a result of the proposed capping.

The modelling was undertaken to provide supporting information in a manner that will assist the GGBF ecologist and other decision makers to understand key hydroȑsalinity changes to the water bodies as a result of the proposed capping of fill areas. This appendix describes the modelling approach, key assumptions and results.

11.2 Model Framework

The hydroȑsalinity model seeks to replicate the key hydroȑsalinity regime of each pond by modelling the following processes for existing and proposed conditions:

- Surface water runoff from contributing catchment areas
- Groundwater inflows into each pond
- Groundwater outflows from each pond
- Surface water flows between ponds and from some ponds to receiving waters
- Evapotranspiration losses from each pond

Plate 13 below outlines the hydroȑsalinity conceptual model that was used to develop the hydroȑsalinity numerical model.

Plate 16: Hydro-salinity Conceptual Model

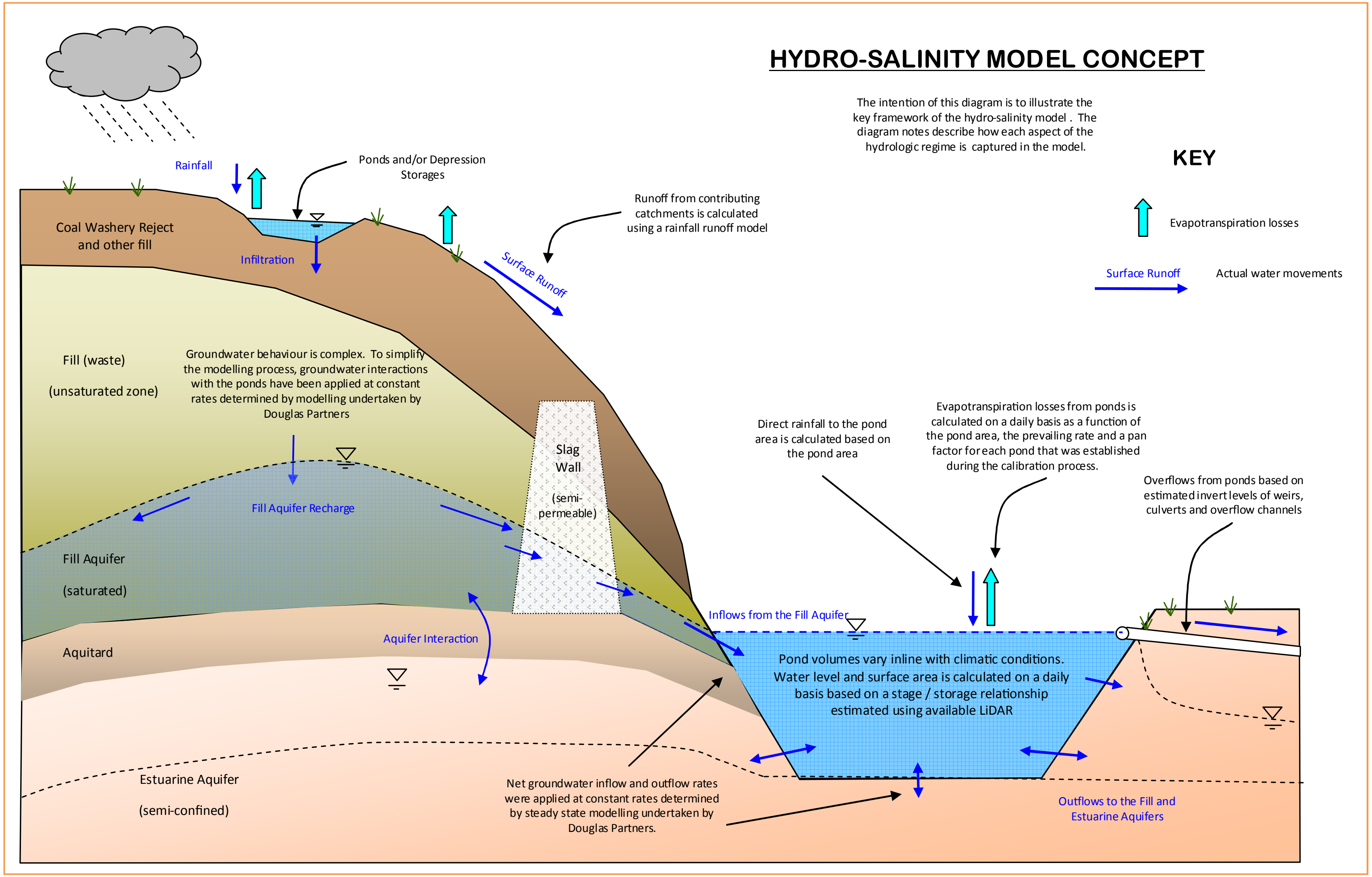


Figure 5, below outlines a model schematic that conceptually describes the key hydrologic processes modeled in each pond.

Plate 17: Figure 5 – Hydro-Salinity Model Schematic Flow Diagram

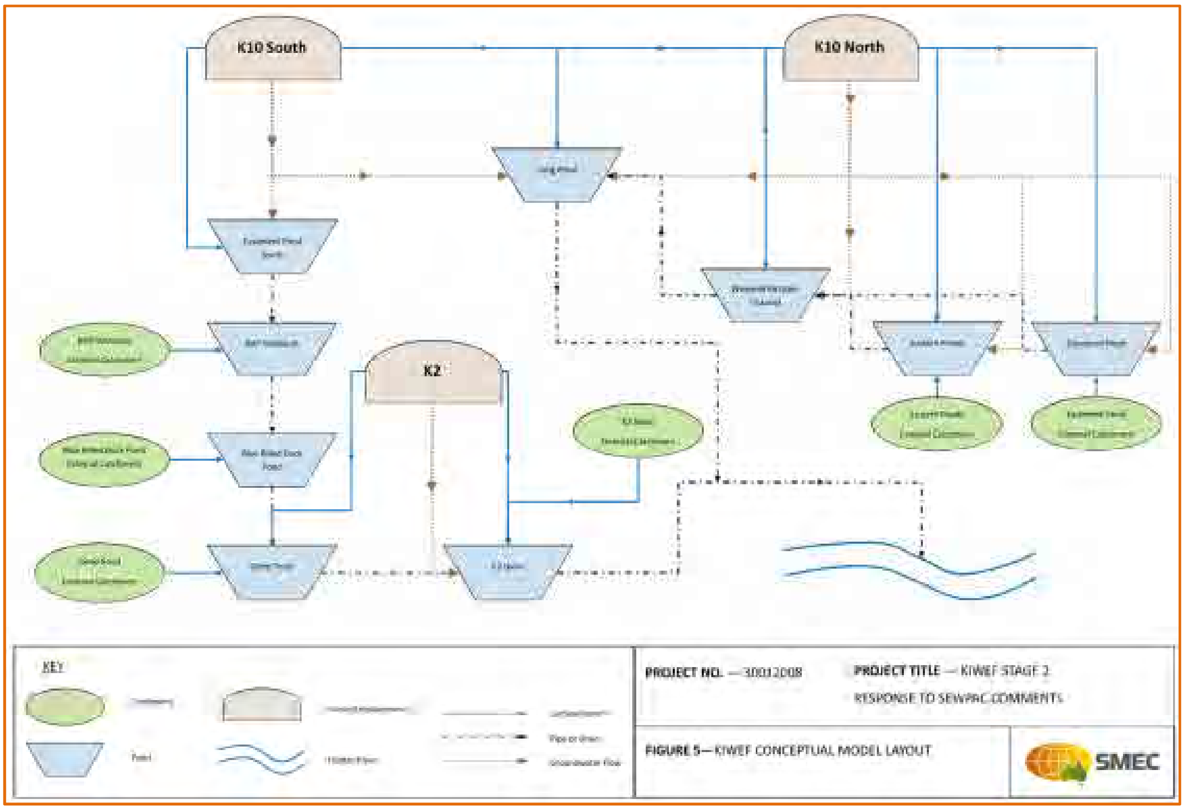


Figure1a and **Figure 1b** illustrate the pond areas and overflow paths for each of the modeled water bodies. **Figure 2a** and **Figure 2b** illustrate long sections through K10 and K2 ponds respectively, outlining the key hydrologic and water quality processes for both the existing and proposed conditions.

Plate 18: Figure 1a – Surface Water Layout at KIWEF BPond Areas and Overflow Paths

Plate 19: Figure 1b – Surface Water Layout at KIWEF BPond Areas and Overflow Paths

Plate 20: Figure 2a – Indicative Section through K10 Landfill Cell

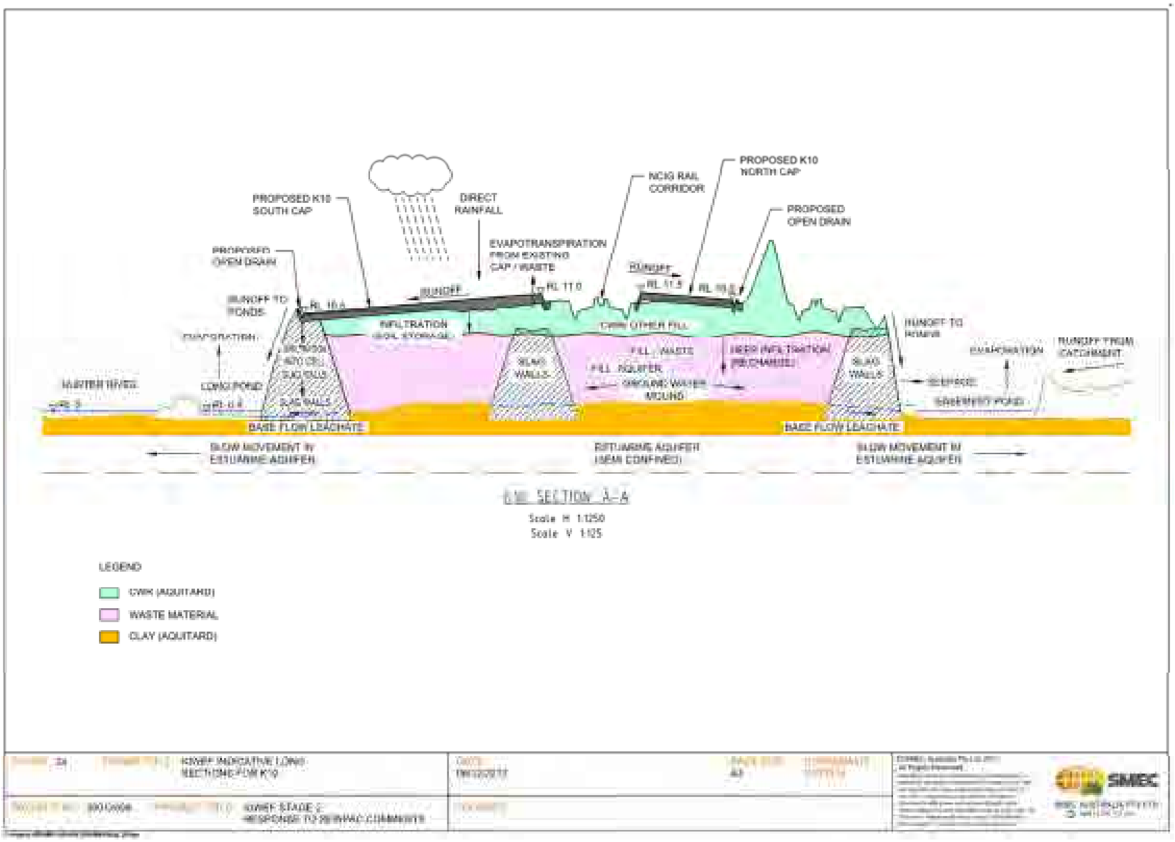
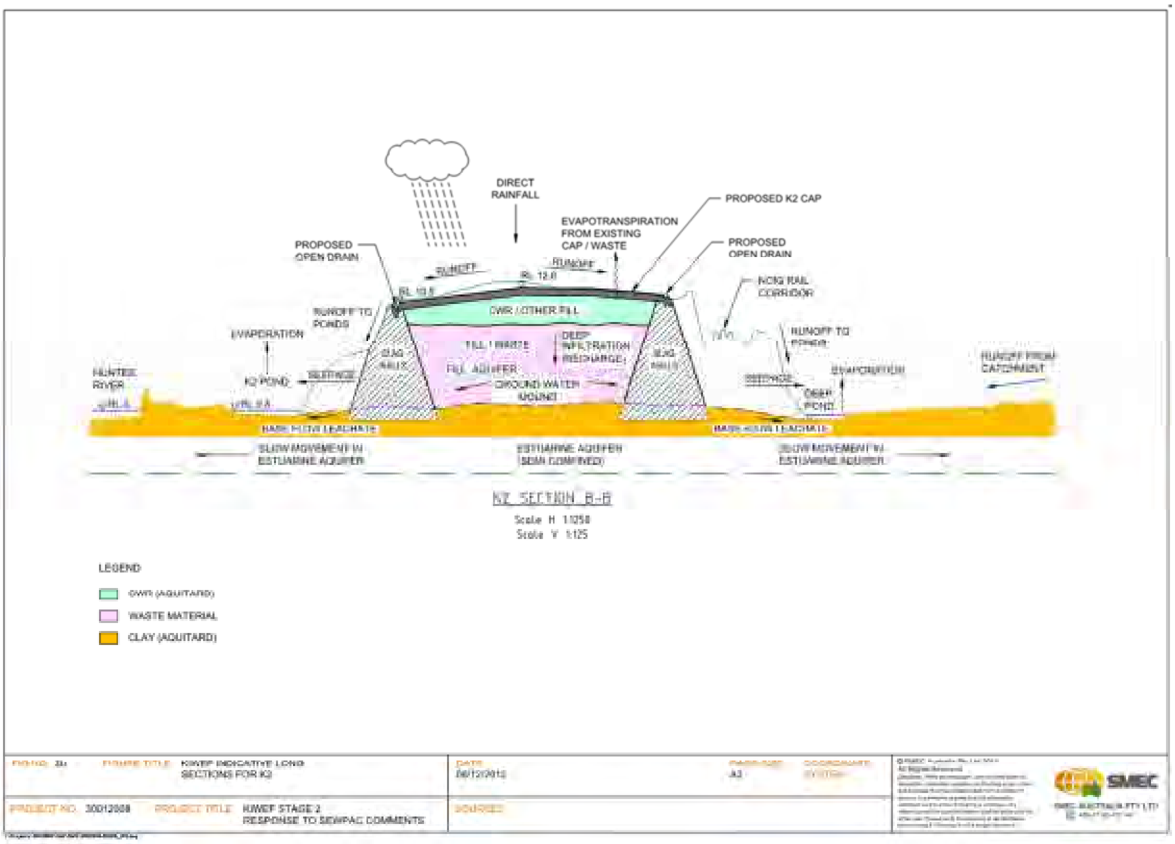


Plate 21: Figure 2b – Indicative Section through K10 Landfill Cell



The model utilises available long term water level and salinity measurements for the ponds, as well as groundwater modelling (MODFLOW Surfact) results provided by Douglas Partners.

Longer term monitoring data indicates that the higher saline conditions in the ponds occur due to evaporative effects, rather than estuarine water inflows. This is because higher saline conditions have been generally observed after extended dry periods, and not after significant wet periods, when estuarine aquifer levels are elevated, nor during periods when significant high tide levels could be influencing the pond salinity levels. There have been some observations of possible estuarine aquifer or Hunter River water intrusion into Long Pond and K2 pond, but this is infrequent.

These observations were generally confirmed through discussion with Douglas Partners (pers comm. Will Wright, Douglas Partners, January 2013) who indicated that groundwater monitoring and MODFLOW Surfact modelling undertaken for the T4 project established that the ponds are perched above the estuarine aquifer levels for the majority of the time and therefore the estuarine aquifer is unlikely to have a major influence on pond levels or water quality. Therefore, the SMEC hydro-salinity model has been constructed without any interactions with saline water in the Estuarine Aquifer or Hunter River (other than for seepage from the ponds and the underlying estuarine aquifer, which has been defined by Douglas Partners in their modelling).

The modelling has been designed based on the assumption that the key drivers for any impact from the capping of the landfill areas affecting water levels and quality in the ponds are likely to be:

i) *Capping impacts on infiltration and recharge.* Capping will reduce the amount of infiltration (recharge) entering the fill aquifer, which will cause the current groundwater levels within the fill aquifer to reach a new (lower) equilibrium position. This lowered fill aquifer groundwater level will likely result in a lower hydrostatic head driving leachate towards the ponds, which in turn leads to reduced volumes of ground water inflows in the ponds and possibly reduced salinity level in the ponds.

ii) *Capping impacts on Runoff.* The capping will improve the surface water runoff efficiency from the capped areas, resulting in more surface runoff from the capped area. This will likely result in the ponds becoming wetter and less saline.

11.2.1 Data Used for the Hydro-salinity Modelling

The model made use of relevant information extracted from previous studies, including the MODFLOW Surfact groundwater modelling by Douglas Partners for the T4 project.

The following background data was used in building and calibrating the model:

- Data from previous water related studies, including:
  - Groundwater modelling (MODFLOW modelling by Douglas Partners for the T4 Project);
  - Drainage/Capping Studies (HELP modelling by RCA); and
  - Other T3 and T4 study results (such as the baseline contamination studies by EES).
- Model output from Douglas Partners MODFLOW Surfact Model to define the groundwater flow movements into and out of ponds for both existing and post-capping scenarios – refer **Appendix D** for Douglas Partners MODFLOW output results.

- Measured salinity levels over a long time period, as outlined in **Section 2.1**
- Measured groundwater and pond water levels and salinity as measured by SMEC and Douglas Partners using continuous level loggers, as described in **Section 1.1.2**
- BoM Rainfall data from the Newcastle Nobby's Gauge (61055).
- Site specific (PWCS) evapo‐transpiration data and BoM Monthly average evaporation data.

11.3 Model Build

The hydro‐salinity model was developed using a Visual‐Basics Program that has been developed independently by SMEC. The key features of the model are described below:

- The model runs on a daily time‐step and requires daily rainfall and evaporation rates as model inputs. The model results are available on a daily time step, but can be reported as annual averages to simplify the model results.
- The model runs as a continuous simulation and applies a long term (100 year) rainfall record that includes a wide range of embedded dry and wet periods as well as major flood events. The model results are processed to provide a statistical representation of the pre and post capping conditions, under a full range of climatic conditions.
- Groundwater flows into and out of ponds have been applied at constant rates, as derived from the Douglas Partners MODFLOW Surfact modelling (refer **Appendix D**).
- Water transfers between ponds, demands and sources can be controlled using transfer rules that are based on stage / discharge relationships derived from survey of the existing pond outlet culverts and other control structures. This function allows for the spill of water between the ponds, as outlined in **Figure 4a** and **Figure 4b.**
- Salt concentrations and loads are tracked throughout the water balance model. Inflow salinity concentrations are required for surface and groundwater sources, based on historic monitoring data.
- Salinity levels in the ponds are tracked on a daily time step, as inflow / outflow to either surface and groundwater, and also through concentration due to evapotranspiration from the ponds.

11.3.1 Climatic Data

In order to facilitate a comprehensive assessment of a range of climatic conditions, a 100 year simulation period was adopted for the hydro‐salinity model. This simulation period applies the observed rainfall record from BoM Station 61055 (Newcastle Nobby's) which contains a continuous daily record from 1913 to 2012.

The average monthly potential evapotranspiration rates listed in **Table 7** were applied to the model.

Table 7: Adopted Monthly Evaporation Data

Month	Evaporation (mm/day)
January	6.8
February	5.7
March	4.8
April	4.0
May	2.3
June	2.2
July	2.2
August	3.1
September	4.0
October	4.8
November	6.0
December	6.5

Pan evaporation factors were also applied to the above evaporation data in order to achieve a reasonable calibration fit. The adopted pan evaporation parameters are provided in **Table 8**.

11.3.2 Rainfall Runoff Model

The KIWEF area incorporates approximately 180 ha of contributing catchment area to the ponds. Runoff from these catchment areas will be collected in the numerous ponds that form part of the site.

Surface water runoff characteristics are dependent on a number of factors including meteorological influences such as rainfall and evapotranspiration and environmental factors such as soil types and vegetation coverage. While factors such as rainfall can be estimated from available data records, analysis of long‑term pond water level records would be required to reliably determine runoff characteristics. As there are no long term pond water level records for the site the following modelling approach was adopted:

- A rainfall runoff model was developed for each pond sub‑catchment.
- Short term collected water level monitoring results were initially used to calibrate the model parameters (over a 2 to 3 month period of collected data between November 2012 and January 2013).
- A three year calibration period was used, which included monthly spot water level and salinity data for some ponds.

Calibration plots for existing conditions are outlined in **Appendix E**.

It should be noted that it is not possible to calibrate the model for proposed conditions, This could be carried out in future, once the proposed capping works are completed, should the need arise.

11.3.3 Model Water Sources and Sinks

Water Sources for the ponds include:

- Surface runoff from catchments within the KIWEF site.
- Groundwater seepage into the ponds (provided by Douglas Partners from their MODFLOW Surfact model – refer **Appendix D**); and
- Overflow from adjacent (upstream) ponds.

Water outflows (sinks) for each of the ponds include:

- Evapotranspiration losses based on a dynamic pond surface area calculation, which is calculated from the estimated stage / storage relationship for each pond (stage / storage relationships were estimated using LiDAR survey). Pan factors were applied individually to each pond to achieve a reasonable fit to available water level data collected during dry periods.
- Groundwater seepage out of the ponds (provided by Douglas Partners from their MODFLOW Surfact model – refer **Appendix D**).
- Overflow from each pond to adjacent downstream ponds, or discharge to the Hunter River Estuary.

Table 8 below outlines the adopted catchment areas and pond surface areas for each pond, derived from LiDAR survey data and other available information.

Table 8: Adopted Model parameters – Pond Sub-Catchment Areas, Pond Average Surface Areas and Pan Evaporation Coefficient

Pond	Catchment Area Existing Conditions (ha)	Catchment Area Proposed Conditions (ha)	Average Pond Surface Area (ha)	Pan Evaporation Coefficient Applied for Calibration Purposes
BHP Wetlands	21	21	3.95	0.9
Blue Billed Duck Pond	10	10	1.40	1.2
Deep Pond	62	63.3	18.05	0.9
Easement Pond	25	24.8	3.25	1.1
Easement Pond South	11	7.5	0.50	1.0
K2 Pond	23	20.6	3.40	1.1
Long Pond	18	26.8	2.35	1.0
Windmill Rd Open Channel	2.5	6.3	0.45	1.3
Totals	**172.5**	**180.3**	**33.35**	

Contributing catchment areas were modified for the proposed case monitoring, based on the landfill capping design (SMEC, 2012).

11.3.4 Estimated Salinity of Water Sources

Expected salinity values were estimated for the surface and groundwater sources that are incorporated into the hydro-salinity model. Where possible, salinity values were established from available surface water and ground water monitoring data. Salinity values were varied accordingly as a means of assisting with the model calibration.

11.4 Calibration of Existing Conditions Model

Calibration of the hydro‑salinity model was undertaken to determine a best fit to existing water level and salinity monitoring data.

Appendix E includes plots showing a comparison of the water level and salinity (EC) concentrations for each of the ponds modeled.

11.5 Water Level Modelling Results

The results outlined in **Table 9**, **Table 10** and **Table 11** compare the potential changes in hydrological regimes to typical threshold comparison values for water level, that relate to the GGBF as outlined in **Section 5.4** . Results of water level variation are also included in **Appendix F**. According to Dr Arthur White, in relation to GGBF, the amount of additional time that the ponds stay dry or wet is of at least equal importance to the frequency of dry or wet conditions.

Table 9 outlines the results of the hydrologic modelling of the ponds, in relation to water level variability between existing and proposed conditions. The upper and lower bound comparison values outlined in **Table 1** have been adopted to demonstrate the relative change in pond hydrology.

Table 9: Summary of Expected Changes on Upper and Lower Bound Water Level Comparison Values for KIWEF Ponds

Pond	Percentage of Time Existing Conditions are below Lower Bound Water Level Comparison Value	Percentage of Time Proposed Capped Site is predicted to be below Lower Bound Water Level Comparison Value	Relative Change in Lower Bound Comparison Value	Percentage of Time Existing Conditions are above Upper Bound Water Level Comparison Value	Percentage of Time Proposed Capped Site is predicted to be above upper Bound Water Level Comparison Value	Relative Change in Upper Bound Comparison Value
BHP Wetlands	20%	21%	1%	20%	18%	-2%
Blue Billed Duck Pond	20%	22%	2%	20%	16%	-4%
Deep Pond	20%	19%	-1%	20%	20%	0%
Easement Pond	20%	21%	1%	20%	27%	7%
Easement Pond South	20%	21%	1%	20%	17%	-3%
K2 Basin	20%	22%	2%	20%	19%	-1%
Long Pond	20%	4%	-16%	20%	35%	15%
Windmill Rd Open Channel	20%	1%	-19%	20%	28%	8%

Note – Blue Indicates no significant change, Green Indicates a Positive Change and Yellow indicates slight negative change predicted. Results are discussed below.

Model results provided in **Table 9** indicate that only measurable impacts in pond hydrology are expected in Long Pond and Windmill Road Open Channel, with negligible impacts (i.e. less than 10%) in the other ponds. For these two ponds, the model results indicate that the ponds will generally become wetter, with a lower frequency of drying out and greater frequency of being full.

Table 10 presents model results for the low water levels threshold. This is a comparison between the frequency and duration that the existing ponds have low water levels under current conditions, with the frequency that they would have low water levels under proposed conditions. A low water level event is counted as an event that has a water level lower than the 20th percentile level indicated in **Table 1**, that exceeds the 4 week period, as defined by the GGBF Specialist in **Section 5.4** .

Table 10: Summary of Expected Changes to Lower Water Level Duration for KIWEF Ponds

Pond	Existing Low Water Level Frequency	Existing Average Duration of Low Water Events	Proposed Low Water Level Frequency	Proposed Average Duration of Low Water Events
BHP Wetlands	1 in 1.5 Years	102 Days	1 in 1.3 Years	97 Days
Blue Billed Duck Pond	1 in 1.8 Years	128 Days	1 in 1.8 Years	134 Days
Deep Pond	1 in 2.1 Years	145 Days	1 in 2.2 Years	138 Days
Easement Pond	1 in 1.6 Years	111 Days	1 in 1.7 Years	111 Days
Easement Pond South	1 in 1.3 Years	92 Days	1 in 1.3 Years	98 Days
K2 Pond	1 in 1.5 Years	102 Days	1 in 1.2 Years	92 Days
Long Pond	1 in 1.3 Years	94 Days	1 in 5.2 Years	59 Days
Windmill Rd Open Channel	1 in 1.2 Years	86 Days	N/A	N/A

Note – Blue Indicates no significant change, Green Indicates a Positive Change and Yellow indicates slight negative change predicted. Results are discussed below.

– N/A denotes that windmill road open channel does not completely dry out for the 100 year modelling period.

The results in **Table 10** indicate that for the majority of ponds, there would not be any significant changes to the low water levels (i.e. pond drying regime). For Long Pond, the frequency of low water level events would change from about a 1 year frequency, to about a 5 year frequency, and that the average dry period will change from about 90+ days, to approximately 60 days. This indicates that Long Pond will generally exhibit reduced periods with very low water levels. Discussions with Dr Arthur White indicate that this is likely to be a benefit to the GGBF species.

For Windmill Road Open Channel, currently, this exhibits periods of low water level, approximately once every year. This is predicted to change such that the pond would not expect to dry out completely at all. Again, this is expected to be a benefit to the GGBF species.

Table 11 Error! Reference source not found. presents similar model results for wetting regimes, i.e. the frequency that pond water level is above the upper bound comparison value for existing and proposed conditions.

Table 11: Summary of Expected Impacts on Wetting Regimes for KIWEF Ponds

Pond	Existing Wetting Regime Frequency	Existing Average Duration of Wetting Events	Proposed Wetting Regime Frequency	Proposed Average Duration of Wetting Events
BHP Wetlands	1 in 1.4 Years	89 Days	1 in 1.5 Years	87 Days
Blue Billed Duck Pond	N/A	N/A	N/A	N/A
Deep Pond	1 in 1.5 Years	102 Days	1 in 1.5 Years	106 Days
Easement Pond	1 in 1.7 Years	107 Days	1 in 1.3 Years	119 Days
Easement Pond South	1 in 3.5 Years	59 Days	1 in 4.7 Years	55 Days
K2 Basin	1 in 1.8 Years	110 Days	1 in 1.9 Years	109 Days
Long Pond	1 in 1.5 Years	100 Days	1 in 1 Years	110 Days
Windmill Rd Open Channel	1 in 50 Years	49 Days	1 in 50 Years	58 Days

Note – Blue Indicates no significant change, Green Indicates a Positive Change and Yellow indicates slight negative change predicted. Results are discussed below.

– N/A denotes that Blue Bill Duck Pond does not completely fill up for the 100 year modelling period.

The results indicate that most of the ponds are not expected to have any significant changes in terms of the potential effects of increasing pond water levels. For Long Pond and Windmill Road Open Channel, the proposed capping works would have a slight impact on pond "wetting" regimes. However these minor changes in pond hydrology would not affect either GGBF or other threatened species. A slight benefit would accrue from an increase in the wetted perimeter of the ponds, which would be subject to periodic inundation, and hence provide additional breeding areas for the GGBF and other species.

11.5.1 Eastern Ponds

Hydro-salinity modelling of the Eastern Ponds has been omitted from this report due to the following reasons:

- The proposed capping works will have no impact on the surface water aspects of the hydro-salinity for Eastern Ponds. That is because the catchment areas and the pond characteristics are to remain unchanged, meaning that runoff and evapotranspiration in the ponds will be consistent with existing conditions.
- The frequency of overflows from the Eastern Ponds to other downstream ponds is expected to be low. This is due to both the high embankments around the Eastern Ponds and the size of their catchment relative to their effective storage.
- Groundwater interaction will be the only potential impact associated with proposed capping works, therefore impacts to these ponds have been

qualitatively assessed using the groundwater modelling results (Refer **Appendix D**, Douglas Partners, 2013).

The following **Table 12** and **Table 13** provide groundwater modelling results for the Eastern Ponds under existing and proposed capped conditions (Refer Douglas Partners report in **Appendix D**).

Table 12: Groundwater Inflow Impacts to the Eastern Ponds Due to the Proposed Capping

Pond	NW - Eastern Pond	SW - Eastern Pond	SE - Eastern Pond	NE - Eastern Pond	Total
Existing Total Inflow (m^3/day)	15.14	3.19	5.67	6.12	30.12
Proposed Total Inflow (m^3/day)	12.46	2.13	5.44	5.66	25.69
Difference (m^3/day)	-2.68	-1.06	-0.23	-0.46	-4.43
Percentage Difference	-17.7%	-33.2%	-4.1%	-7.5%	-14.7%

Note – All results from Douglas Partners, refer **Appendix D**)

Table 13: Groundwater Outflow Impacts to the Eastern Ponds Due to the Proposed Capping

Pond	NW - Eastern Pond	SW - Eastern Pond	SE - Eastern Pond	NE - Eastern Pond	Total
Existing Total Outflow (m^3/day)	42.79	31.49	28.14	18.98	121.40
Proposed Total Outflow (m^3/day)	40.48	30.92	28.04	18.64	118.08
Difference (m^3/day)	-2.31	-0.57	-0.10	-0.34	-3.32
Percentage Difference	-5.4%	-1.8%	-0.4%	-1.8%	-2.7%

Note – All results from Douglas Partners, refer **Appendix D**)

As notable in **Table 12** and **Table 13**, the total reduction in the groundwater inflows and outflows of the Eastern Ponds are 4.43 m^3/day and 3.32 m^3/day respectively. The contributing surface water catchment of these ponds totals approximately 5 hectares, of which the majority of catchment is pond surface area (resulting in direct rainfall to the pond, i.e. 100% runoff). This would yield an average pond inflow of over 100 m^3/day. Hence the change in groundwater flows identified above would represent less than 5% of the total inflow volume from surface runoff, making the relative impacts to the hydrologic and salinity regime of the Eastern Ponds insignificant.

11.5.2 Summary

In summary, the water level and wetting and drying regimes indicated by the above results show that for the majority of the ponds there are not expected to be any significant changes, i.e. BHP Wetlands, Blue Billed Duck Pond, Deep Pond, Easement Pond, Easement Pond South, and K2 Pond. Minor changes are expected in Long Pond and Windmill Road Open Channel, but these changes are not expected to impact on GGBF or other threatened species. There are no significant changes predicted to the Eastern Ponds as a result of the proposed capping works, as there is no change to the contributing catchment area to these ponds, and only minor changes to the groundwater regime.

11.5.3 Salinity Modelling Results

Model results provided in **Table 14** below summarises the results compared to typical comparison values for salinity (EC), that relate to the GGBF, derived from discussions with the GGBF Ecologist, Dr Arthur White, as outlined in **Section 5.4** . **Appendix F** also shows these results graphically. The following results are reported in this section for key KIWEF ponds:

- Expected changes on GGBF Salinity Comparison Values;
- Expected Changes on Upper and Lower Bound Water Level Comparison Values;
- Expected Changes to Lower Water Level Regimes – in terms of duration of low water levels.
- Expected Changes to Higher Water Level Regimes – in terms of duration of high water levels.

Table 14: Summary of Expected Changes on GGBF Salinity Comparison Values for KIWEF Ponds

Pond	Percentage of Time Existing Conditions Salinity is below Chytrid Fungal Comparison Value = 1650 µS/cm	Percentage of Time Proposed Conditions Salinity is below Chytrid Fungal Comparison Value = 1650 µS/cm	Relative Change in Chytrid Fungal Comparison Value	Percentage of Time Existing Conditions Salinity is below Tadpole GGBF Comparison Value = 2900 µS/cm	Percentage of Time Proposed Conditions Salinity is below Tadpole GGBF Comparison Value = 2900 µS/cm	Relative Change in Tadpole GGBF Comparison Value	Percentage of Time Existing Conditions Salinity is below Adult GGBF Comparison Value = 4100 µS/cm	Percentage of Time Proposed Conditions Salinity is below Adult GGBF Comparison Value = 4100 µS/cm	Relative Change in Adult GGBF Comparison Value
BHP Wetlands	92.6%	92.7%	0.1%	99.8%	99.7%	0.0%	100%	100%	0.0%
Blue Billed Duck Pond	90.7%	90.4%	-0.3%	100%	100%	0.0%	100%	100%	0.0%
Deep Pond	46.4%	48.1%	1.8%	83.4%	84.3%	0.8%	92.9%	93.2%	0.3%
Easement Pond	39.1%	48.9%	9.9%	81.3%	87.2%	5.9%	92.9%	95.6%	2.7%
Easement Pond South	99.6%	100%	0.4%	100%	100%	0.0%	100%	100%	0.0%
K2 Pond	43.8%	46.7%	2.9%	77.7%	79.5%	1.8%	95.7%	96.3%	0.6%
Long Pond	5.5%	13.4%	7.8%	35.2%	50.0%	14.8%	55.5%	70.7%	15.2%
Windmill Rd Open Channel	13.7%	7.1%	-6.7%	37.2%	44.1%	6.9%	44.1%	50.3%	6.3%

Note – Blue Indicates no significant change, Green Indicates a Positive Change and Yellow indicates slight negative change predicted. Results are discussed below.

Model results provided in **Table 14** compare the salinity regimes for existing and developed conditions to the salinity thresholds established in **Section 5.4** . For BHP Wetlands, Blue Billed Duck Pond, Deep Pond, Easement Pond South, and K2 Pond, there are not expected to be any significant changes to salinity levels.

The results for Easement Pond and Long Pond, however indicate that the proposed capping works could have lower salinity values during wet conditions (as surface runoff does not have the saline leachate component that groundwater has) that could potentially lead to increases in chytrid fungal levels in the host GGBF species. However, these two ponds also exhibit lower levels of salinity during dry conditions, which would be a slight benefit to the GGBF, in that there is a slight reduction in the higher salinity values that could positively affect GGBF breeding capacity, due to potential impacts on tadpoles and adult frogs using the ponds during higher saline conditions.

Under wet conditions, (i.e. typically when the ponds are full after a rainfall event), Windmill Road Open Channel exhibits higher saline conditions, which could be a driver for a slight decrease in chytrid fungal levels in the host GGBF species. In addition, there will be a slight reduction (i.e. improvement) in the salinity levels during dry conditions, where the modelling indicates a slight lowering of the salinity levels, which could positively affect GGBF breeding capacity, due to potential impacts on tadpoles and adult frogs using the ponds during higher saline conditions.

Overall, the relative changes in these ponds are considered to be relatively minor and / or a net benefit to GGBF breeding. With regular monitoring, there will be an opportunity to consider contingent mitigation measures such as the potential to reconfigure the proposed sediment basins as GGBF habitat ponds.

Summary

Overall, the above hydro-salinity changes in these ponds are considered to be relatively minor. With regular monitoring there will be an opportunity to consider mitigation measures such as those outlined in **Section1.2** .

Appendix F outlines plots showing the relative changes in pond water level and salinity in the ponds as a result of the proposed capping strategy.

APPENDIX A: WATER QUALITY SUMMARY (ITEM 2)

NOTES

- *The summary of surface water results has used information provided by others. The information has NOT been independently verified or reviewed to eliminate possible errors, and as such has been taken at face value;*
- *This water quality summary output is based on analytical lab results only;*
- *Any lab result values that were found to be less than the laboratory detection limit are expressed as the lab PQL limit for statistical analysis purposes (e.g. a lab value of <0.01mg/L is stated as 0.01mg/L in this table); and*
- *Further notes outlined within consolidated table.*

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- Coalbridge Operations Pty Ltd surface water monitoring data for Port Waratah Coal Services – Baseline Environmental Monitoring Program, Kooragang Coal Terminal (T4), July 2012 – December 2012; and
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KIWEF Surface Water Monitoring Results - BHP Wetlands

ANALYTES			Metals								
			Ba - Total	Be - Total	Bo - Total	Cd -Total	Cd - Dissolved	Co - Total	Cr - Total	Cr - Dissolved	Cu -Total
Units			mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
ANZECC CRITERIA			NC	NC	0.37	0.0007	0.0007	0.001	0.0044	0.0044	0.0013
Laboratory PQL *			0.001	0.001	0.05	0.01	0.01	0.01	0.01	0.01	0.01
		count	4	4	4	8	11	6	8	13	8
		90 %ile	0.076	0.001	0.62	0.0001	0.0002	0.001	0.001	0.004	0.003
		80 %ile	0.067	0.001	0.60	0.0001	0.0002	0.001	0.001	0.003	0.003
		average	0.059	0.001	0.41	0.0001	0.0003	0.001	0.001	0.002	0.002
		20 %ile	0.049	0.001	0.22	0.0001	0.0001	0.001	0.001	0.001	0.001
		10 %ile	0.048	0.001	0.18	0.0001	0.0001	0.001	0.001	0.001	0.001
SWC49	BHP Wetlands	6/09/2006					0.0002			0.002	
SWC50	BHP Wetlands	6/09/2006					0.0002			0.001	
SWC51	BHP Wetlands	6/09/2006					0.0002			0.002	
SWC52	BHP Wetlands	6/09/2006					0.0002			0.002	
SWASTM	BHP Wetlands	6/09/2006					0.002			0.005	
SW502	BHP Wetlands	4/12/2008					0.0001			0.001	
SW502	BHP Wetlands	24/04/2009					0.0001			0.001	
SW502	BHP Wetlands	17/08/2009					0.0001			0.001	
SW502	BHP Wetlands	17/09/2009					0.0001			0.001	
SW502	BHP Wetlands	11/11/2009				0.0001			0.001	0.004	0.001
SW502A	BHP Wetlands	17/08/2009					0.0001			0.001	
SW502A	BHP Wetlands	17/09/2009					0.0001			0.001	
SW502A	BHP Wetlands	11/11/2009				0.0001			0.001	0.004	0.004
502	BHP Wetlands	8/03/2012				0.0001		0.001	0.001		0.001
502	BHP Wetlands	26/07/2012	0.047	0.001	0.14	0.0001		0.001	0.001		0.001
502	BHP Wetlands	25/10/2012	0.086	0.001	0.27	0.0001		0.001	0.001		0.002
502A	BHP Wetlands	8/03/2012				0.0001		0.001	0.001		0.003
502A	BHP Wetlands	26/07/2012	0.05	0.001	0.63	0.0001		0.001	0.001		0.001
502A	BHP Wetlands	25/10/2012	0.054	0.001	0.58	0.0001		0.001	0.001		0.001

ANALYTES			Metals										
			Cu - Dissolved	Fe - Total	Fe - Dissolved	Hexavalent Chromium	Mn - Total	Mn - Dissolved	Mo - Total	Mo - Dissolved	Ni - Total	Ni - Dissolved	Pb - Total
Units			mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
ANZECC CRITERIA			0.0013	NC	NC	NC	0.08	0.08	0.023	0.023	0.007	0.007	0.0044
Laboratory PQL *			0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.001	0.01	0.001	0.01
		count	11	12	13	6	6	13	6	13	6	13	6
		90 %ile	0.005	0.65	0.35	0.010	0.483	1.160	0.012	0.008	0.002	0.002	0.001
		80 %ile	0.004	0.46	0.27	0.010	0.475	0.804	0.005	0.006	0.001	0.001	0.001
		average	0.003	0.30	0.16	0.008	0.283	0.478	0.005	0.005	0.001	0.002	0.001
		20 %ile	0.001	0.13	0.04	0.005	0.180	0.051	0.001	0.003	0.001	0.001	0.001
		10 %ile	0.001	0.12	0.03	0.005	0.133	0.041	0.001	0.002	0.001	0.001	0.001
SWC49	BHP Wetlands	6/09/2006	0.001		0.37			0.22		0.005		0.001	
SWC50	BHP Wetlands	6/09/2006	0.001		0.46			0.51		0.005		0.001	
SWC51	BHP Wetlands	6/09/2006	0.001		0.19			0.04		0.006		0.001	
SWC52	BHP Wetlands	6/09/2006	0.001		0.28			0.14		0.006		0.001	
SWASTM	BHP Wetlands	6/09/2006	0.01		0.01			0.29		0.005		0.009	
SW502	BHP Wetlands	4/12/2008	0.001		0.15			1.2		0.002		0.001	
SW502	BHP Wetlands	24/04/2009	0.001		0.05			0.07		0.005		0.001	
SW502	BHP Wetlands	17/08/2009	0.005	0.14	0.04			0.03		0.004		0.001	
SW502	BHP Wetlands	17/09/2009	0.002	0.25	0.1			0.06		0.003		0.002	
SW502	BHP Wetlands	11/11/2009		0.95	0.25			0.11		0.016		0.001	
SW502A	BHP Wetlands	17/08/2009	0.004	0.13	0.03			0.045		0.008		0.001	
SW502A	BHP Wetlands	17/09/2009	0.001	0.12	0.05			1		0.002		0.001	
SW502A	BHP Wetlands	11/11/2009		0.67	0.12			2.5		0.004		0.001	
502	BHP Wetlands	8/03/2012		0.13		0.005	0.49		0.001		0.001		0.001
502	BHP Wetlands	26/07/2012		0.08		0.01	0.085		0.001		0.001		0.001
502	BHP Wetlands	25/10/2012		0.36		0.01	0.280		0.001		0.001		0.001
502A	BHP Wetlands	8/03/2012		0.13		0.005	0.18		0.005		0.002		0.001
502A	BHP Wetlands	26/07/2012		0.19		0.01	0.475		0.019		0.001		0.001
502A	BHP Wetlands	25/10/2012		0.48		0.01	0.190		0.005		0.001		0.001

ANALYTES			Metals								Cyanide			Total Recoverable Hydrocarbons			
			Pb - Dissolved	Sb - Total	Se - Total	Sn - Total	Zn - Total	Zn - Dissolved	Hg - Total	Hg - Dissolved	Total Cyanide	Free Cyanide	WAD Cyanide	TRH C_6 - C_9	TRH C_{10} - C_{14}	TRH C_{15} - C_{28}	TRH C_{29} - C_{36}
Units			mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L CN	mg/L	mg/L	mg/L	mg/L	mg/L
ANZECC CRITERIA			0.0044	NC	0.005	NC	0.015	0.015	0.0001	0.0001	0.004	0.004	0.004	NC	NC	NC	NC
Laboratory PQL *			0.01	0.001	0.002	0.001	0.01	0.01	0.00005	0.0004	0.005	0.005	0.005	0.1	0.1	0.2	0.2
		count	13	4	6	4	6	13	8	11	19	6	8	16	17	17	17
		90 %ile	0.003	0.001	0.010	0.001	0.010	0.074	0.0004	0.0004	0.005	0.004	0.004	0.40	0.1	2.9	0.2
		80 %ile	0.001	0.001	0.010	0.001	0.007	0.072	0.0003	0.0004	0.005	0.004	0.004	0.40	0.1	1.0	0.2
		average	0.003	0.001	0.007	0.001	0.006	0.031	0.0002	0.0003	0.004315789	0.004	0.004	0.11	0.1	0.9	0.2
		20 %ile	0.001	0.001	0.001	0.001	0.003	0.004	0.0001	0.0001	0.004	0.004	0.004	0.01	0.1	0.1	0.1
		10 %ile	0.001	0.001	0.001	0.001	0.003	0.003	0.0001	0.0001	0.004	0.004	0.004	0.01	0.1	0.1	0.1
SWC49	BHP Wetlands	6/09/2006	0.001					0.073		0.0001	0.005			0.4	0.1	0.2	0.2
SWC50	BHP Wetlands	6/09/2006	0.001					0.01		0.0001	0.005			0.4	0.1	0.2	0.3
SWC51	BHP Wetlands	6/09/2006	0.001					0.07		0.0001	0.005			0.4	0.1	0.2	0.2
SWC52	BHP Wetlands	6/09/2006	0.001					0.006		0.0001	0.005			0.4	0.1	0.2	0.2
SWASTM	BHP Wetlands	6/09/2006	0.02					0.074		0.0005	0.005				0.1	0.2	0.2
SW502	BHP Wetlands	4/12/2008	0.001					0.1		0.0001	0.005			0.04	0.1	0.2	0.2
SW502	BHP Wetlands	24/04/2009	0.001					0.003		0.0004	0.004			0.01	0.05	0.11	0.1
SW502	BHP Wetlands	17/08/2009	0.001					0.013		0.0004	0.004			0.01	0.05	1.1	0.1
SW502	BHP Wetlands	17/09/2009	0.001					0.019		0.0004	0.004			0.01	0.05	2.5	0.1
SW502	BHP Wetlands	11/11/2009	0.003					0.002	0.0004		0.004		0.004	0.01	0.05	3.5	0.13
SW502A	BHP Wetlands	17/08/2009	0.001					0.014		0.0004	0.004			0.01	0.05	0.75	0.1
SW502A	BHP Wetlands	17/09/2009	0.001					0.003		0.0004	0.004			0.01	0.05	0.53	0.1
SW502A	BHP Wetlands	11/11/2009	0.001					0.012	0.0004		0.004		0.004	0.01	0.05	5.4	0.32
502	BHP Wetlands	8/03/2012			0.001		0.002		0.00005		0.004	0.004	0.004				
502	BHP Wetlands	26/07/2012		0.001	0.01	0.001	0.005		0.0001		0.004	0.004	0.004	0.02	0.05	0.1	0.05
502	BHP Wetlands	25/10/2012		0.001	0.01	0.001	0.013		0.0001		0.004	0.004	0.004	0.02	0.05	0.19	0.15
502A	BHP Wetlands	8/03/2012			0.001		0.003		0.00005		0.004	0.004	0.004				
502A	BHP Wetlands	26/07/2012		0.001	0.01	0.001	0.007		0.0001		0.004	0.004	0.004	0.02	0.05	0.1	0.05
502A	BHP Wetlands	25/10/2012		0.001	0.01	0.001	0.005		0.0001		0.004	0.004	0.004	0.02	0.05	0.1	0.05

KIWEF Surface Water Monitoring Results - Blue Billed Duck Pond

ANALYTES			Basic					Alkalinity				Organic Carbon		Anions												
			pH	Conductivity	Turbidity	TSS	TDS	Hydroxide OH-	Carbonate CO_3^-	Bicarbonate HCO_3^-	Hardness (as $CaCO_3$)	DOC	TOC	Chloride	Fluoride F	Ammonia	Sulphite	Sulphide	Sulphur	Sulphate SO_4	Nitrate as N	Nitrite as N	NO_x (NO_2 + NO_3)	Total Kjeldahl Nitrogen as N	Total Nitrogen as N	Reactive Phosphorus as P
Units			pH units	mS/cm	NTU	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
ANZECC CRITERIA			7 to 8.5	NC	10	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	0.91	NC	0.001	NC	NC	0.7	NC	0.015	NC	0.3	NC
Laboratory PQL *			-	1	0.1	5	5	2	2	0	1	1	1	0.1	0.05	0.1	2	0.5	0.5	0.4	0.05	0.05	0.05	0.1	0.1	0.01
		count	16.0	16	7	10	3	1	1	1	6	2	1	10	3	10	1	4	2	6	4	4	10	8	8	2
		90 %ile	9.5	1380	35	64	632	2	6.9	390	380	10.9	11	248	4.8	0.311	2	0.5	50.1	246	0.04	0.04	0.12	2.2	2.3	0.01
		80 %ile	9.3	1250	15	37	604	2	6.9	390	150	10.8	11	239	4.1	0.218	2	0.5	47.2	160	0.03	0.03	0.04	1.8	1.8	0.01
		average	8.8	1166	14	23	567	2	6.9	390	213	10.4	11	172	3.2	0.143	2	0.5	38.5	134	0.02	0.02	0.05	1.4	1.4	0.01
		20 %ile	8.3	960	3	7.8	520	2	6.9	390	120	10.0	11	118	2.0	0.038	2	0.5	29.8	63	0.01	0.01	0.01	0.8	0.8	0.01
		10 %ile	8.2	845	3	7	520	2	6.9	390	120	9.9	11	108	1.9	0.029	2	0.5	26.9	62	0.01	0.01	0.01	0.8	0.8	0.01
SW503	blue billed	4/12/2008	8.6	1000				2	6.9	390	150	11	11	90	1.9	0.04			24	63	0.05	0.05	0.1			
SW503	blue billed	24/04/2009	8.1	700							120					0.1										
SW503	blue billed	17/08/2009	9.1	870			520				120					0.1		0.5		91						
SW503	blue billed	17/09/2009	9	990		30	520				130					0.5		0.5		100						
SW503	blue billed	11/11/2009	9.3	1100		63	660				150					0.2		0.5		60						
503	blue billed	8/03/2012	9.5	960		5								120		0.062							0.005	1.6	1.6	
503	blue billed	27/06/2012	8.62	820	2.8	8								136									0.02	0.7	0.7	
503	blue billed	26/07/2012	8.2	973	3.2	8								172		0.02					0.01	0.01	0.01	0.8	0.8	0.01
503	blue billed	28/08/2012	8.2	1060	3.8	14								155									0.01	1.0	1.0	
503	blue billed	27/09/2012	8.61	1090	4.9	9								198									0.01	0.9	0.9	
503	blue billed	25/10/2012	9.5	1250	4.3	7								237		0.03					0.02	0.01	0.02	1.4	1.4	0.01
503	blue billed	27/11/2012	8.9	1320	17.8	14								252									0.01	1.9	1.9	
503	blue billed	14/12/2012	8.7	1440	60.3	71								248									0.27	2.9	3.2	
Fill Pond	blue billed	29/11/2002	8.3	2860							610				5.5	0.29				331	0.01	0.01	0.02			
West Pond	blue billed	6/09/2006	9.6	1100								9.8		110	2.1	0.09	2	0.5	53	160						
SW6	Blue billed	25/05/2007	8.96	1130																						

KIWEF Surface Water Monitoring Results - Blue Billed Duck Pond

ANALYTES													Cyanide			Total Recoverable Hydrocarbons					BTEX								
			Pb - Total	Pb - Dissolved	Sb - Total	Se - Total	Sn - Total	Zn - Total	Zn - Dissolved	Hg - Total	Hg - Dissolved	Total Cyanide	Free Cyanide	WAD Cyanide	TRH C_6 - C_9	TRH C_{10} - C_{14}	TRH C_{15} - C_{28}	TRH C_{29} - C_{36}	Total TRH C_6 - C_{36}	Benzene	Toluene	Ethyl-benzene	Total Xylenes	Total PAHs	Naphthalene	Acenaphtylene	Acenaphthene	Fluorene
Units			mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L CN	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
ANZECC CRITERIA			0.0044	0.0044	NC	0.005	NC	0.015	0.015	0.0001	0.0001	0.004	0.004	0.004	NC	NC	NC	NC	NC	0.5	0.18	0.08	0.2	NC	0.05	NC	NC	NC
Laboratory PQL *			0.01	0.01	0.001	0.002	0.001	0.01	0.01	0.00005	0.0004	0.005	0.005	0.005	0.1	0.1	0.2	0.2	0.6	0.001	0.001	0.001	0.003	0.003	0.0002	0.0002	0.0002	0.0002
		count	10	6	7	9	7	10	6	7	9	11	3	4	10	10	10	10	7	10	9	10	10	8	11	11	11	11
		90 %ile	0.012	0.002	0.001	0.010	0.001	0.055	0.029	0.0002	0.0004	0.005	0.004	0.004	0.08	0.10	0.2	0.2	0.68	0.0019	0.0036	0.0028	0.0057	0.0208	0.0010	0.0010	0.0010	0.0010
		80 %ile	0.002	0.001	0.001	0.010	0.001	0.021	0.026	0.0001	0.0004	0.005	0.004	0.004	0.03	0.06	0.2	0.2	0.53	0.0010	0.0020	0.0020	0.0030	0.0128	0.0010	0.0010	0.0010	0.0010
		average	0.008	0.001	0.001	0.009	0.001	0.041	0.014	0.0001	0.0002	0.004	0.004	0.004	0.06	0.06	0.1	0.1	0.43	0.0018	0.0023	0.0021	0.0050	0.0080	0.0006	0.0006	0.0006	0.0006
		20 %ile	0.001	0.001	0.001	0.010	0.001	0.005	0.006	0.0001	0.0001	0.004	0.004	0.004	0.01	0.05	0.1	0.1	0.26	0.0009	0.0010	0.0009	0.0019	0.0016	0.0001	0.0001	0.0001	0.0001
		10 %ile	0.001	0.001	0.001	0.008	0.001	0.005	0.004	0.0001	0.0001	0.004	0.004	0.004	0.01	0.05	0.1	0.1	0.26	0.0005	0.0009	0.0005	0.0014	0.0016	0.0001	0.0001	0.0001	0.0001
SW503	blue billed	4/12/2008		0.001					0.031		0.0001	0.005			0.04	0.1	0.2	0.2	0.54	0.0005	0.0005	0.0005	0.0015	0.0016	0.0001	0.0001	0.0001	0.0001
SW503	blue billed	24/04/2009		0.001					0.002		0.0004	0.004			0.01	0.05	0.1	0.1	0.26	0.001	0.001	0.001	0.003	0.0016	0.0001	0.0001	0.0001	0.0001
SW503	blue billed	17/08/2009		0.001					0.006		0.0004	0.004			0.01	0.05	0.1	0.1	0.26	0.001	0.001	0.001	0.003	0.0016	0.0001	0.0001	0.0001	0.0001
SW503	blue billed	17/09/2009		0.001					0.015		0.0004	0.004			0.01	0.05	0.1	0.1	0.26	0.001	0.001	0.001	0.003	0.0016	0.0001	0.0001	0.0001	0.0001
SW503	blue billed	11/11/2009		0.001					0.006	0.0004		0.004		0.004	0.01	0.05	0.1	0.1		0.001	0.001	0.001	0.003	0.0016	0.0001	0.0001	0.0001	0.0001
503	blue billed	8/03/2012	0.001			0.001		0.001			0.00005	0.004	0.004	0.004						0.000001	0..000001	0.000001	0.000003		0.0001	0.0001	0.0001	0.0001
503	blue billed	27/06/2012	0.001		0.001	0.01	0.001	0.005			0.0001																	
503	blue billed	26/07/2012	0.001		0.001	0.01	0.001	0.006			0.0001	0.004	0.004	0.004	0.02	0.05	0.1	0.05		0.001	0.002	0.002	0.002		0.001	0.001	0.001	0.001
503	blue billed	28/08/2012	0.001		0.001	0.01	0.001	0.005		0.0001																		
503	blue billed	27/09/2012	0.001		0.001	0.01	0.001	0.005		0.0001																		
503	blue billed	25/10/2012	0.001		0.001	0.01	0.001	0.020		0.0001		0.004	0.004	0.004	0.02	0.05	0.1	0.05		0.001	0.002	0.002	0.002		0.001	0.001	0.001	0.001
503	blue billed	27/11/2012	0.001		0.001	0.01	0.001	0.006		0.0001																		
503	blue billed	14/12/2012	0.006		0.001	0.01	0.001	0.024		0.0001																		
Fill Pond	blue billed	29/11/2002	0.067			0.01		0.33			0.0003	0.005			0.02	0.05	0.275	0.166	0.511	0.001	0.002	0.002	0.002	0.032	0.002	0.002	0.002	0.002
West Pond	blue billed	6/09/2006		0.002					0.026		0.0001	0.005			0.4	0.1	0.2	0.2	0.9	0.01	0.01	0.01	0.03	0.008	0.0005	0.0005	0.0005	0.0005
SW6	Blue billed	25/05/2007	0.001					0.007		0.0001		0.005			0.025	0.025	0.1	0.1	0.25					0.016	0.001	0.001	0.001	0.001

KIWEF Surface Water Monitoring Results - Deep Pond

ANALYTES			Basic					Alkalinity				Organic Carbon		Anions													Cati	
			pH	Conductivity	Turbidity	TSS	TDS	Hydroxide OH-	Carbonate CO_3^-	Bicarbonate HCO_3^-	Hardness (as $CaCO_3$)	DOC	TOC	Chloride	Fluoride F	Ammonia	Sulphide	Sulphur	Sulphate SO_4	Nitrate as N	Nitrite as N	NO_x ($NO_2 + NO_3$)	Total Kjeldahl Nitrogen as N	Total Nitrogen as N	Reactive Phosphorus as P	Total Phosphorus	Na	Mg
Units			pH units	µS/cm	NTU	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
ANZECC CRITERIA			7 to 8.5	NC	10	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	0.91	0.001	NC	NC	0.7	NC	0.015	NC	0.3	NC	0.03	NC	NC
Laboratory PQL *			-	1	0.1	5	5	2	2	0	1	1	1	0.1	0.05	0.1	0.5	0.5	0.4	0.05	0.05	0.05	0.1	0.1	0.01	0.01	0.1	0.1
count			111	112	22	73	5	1	1	1	5	1	1	74	9	88	3	1	4	52	52	72	28	28	8	28	27	30
90 %ile			9.5	27930	42	47	4500	2	9.6	350	242	12	14	11480	3.04	0.63	0.50	60	207	0.16	0.05	0.18	4.16	4.16	0.31	0.96	646	36
80 %ile			9.1	21020	32	22	4300	2	9.6	350	214	12	14	8540	2.82	0.34	0.50	60	204	0.08	0.01	0.14	3.20	3.32	0.16	0.36	584	33
average			8.7	10524	16	26	2580	2	9.6	350	198	12	14	4261	2.26	0.43	0.50	60	185	0.05	0.02	0.07	2.35	2.43	0.12	0.32	385	25
20 %ile			8.1	2548	3	5	1180	2	9.6	350	168	12	14	357	1.68	0.04	0.50	60	166	0.01	0.01	0.01	0.84	1.00	0.01	0.05	263	19
10 %ile			7.8	1900	2	4	1140	2	9.6	350	164	12	14	12	1.2	0.02	0.50	60	163	0.01	0.01	0.01	0.70	0.84	0.01	0.03	160	18
KS2/1	Deep Pond	17/11/1981	9.5	28000		8								11200		0.06				0.01	0.01	0.02						
KS2/1	Deep Pond	10/02/1982	8.3	40000		17								17700		0.16				0.01	0.01	0.02						
KS2/1	Deep Pond	11/05/1982	8.8	32000		7								14300		0.07				0.01	0.01	0.02						
KS2/1	Deep Pond	14/06/1984	9.7	17600		21								7500		0.04				0.07	0.01	0.08						
KS2/1	Deep Pond	5/12/1984	9.1	18800		9								7750		0.92				0.01	0.01	0.02						
KS2/1	Deep Pond	27/06/1985	8.8	19300		22								7500		1				0.08	0.07	0.15						
KS2/1	Deep Pond	10/04/1986	8	22200		10								9380		0.18				0.14	0.01	0.15						
KS2/1	Deep Pond	2/07/1987	8.3	28200		15								11000		0.04				0.01	0.01	0.02						
KS2/1	Deep Pond	16/08/1988	10.5	14000		6								4850		0.04				0.01	0.01	0.02						
KS2/1	Deep Pond	7/02/1989	9.2	17800		6								6850		0.17				0.03	0.01	0.04						
KS2/1	Deep Pond	7/08/1991	9.2	12200		31								4850		0.21				0.01	0.01	0.02						
KS2/1	Deep Pond	4/05/1990	9.2	8600		2								3000		0.36				0.03	0.02	0.05						
KS2/1	Deep Pond	5/12/1990	8.3	10000		20																						
KS2/1	Deep Pond	25/03/1991	8.9	23400		120								8950		0.9				0.01	0.01	0.02						
KS2/1	Deep Pond	22/08/1991	9.5	22100		2								8000		0.1				0.01	0.01	0.02						
KS2/1	Deep Pond	19/08/1992	9	24000		1								8000		0.2				0.01	0.01	0.02						
KS2/1	Deep Pond	30/11/1993	8.7	21200		15								7300		0.2				0.07	0.01	0.08						
KS2/1	Deep Pond	10/08/1994	8.9	20300		1								7300		0.01				0.02	0.01	0.03						
KS2/1	Deep Pond	10/08/1995	9.2	22600		2								8000		0.1				0.02	0.01	0.03						
KS2/1	Deep Pond	12/08/1996	9	16600		19								4200		0.1				0.01	0.01	0.02						
KS2/1	Deep Pond	9/09/1996																										
KS2/1	Deep Pond	13/08/1997	9.1	7700		33								2200		0.6				0.1	0.1	0.2						
KS2/1	Deep Pond	15/03/1999	8.8	6500												0.1												
KS2/1	Deep Pond	17/06/1999	8.4	4900												0.2												
KS2/1	Deep Pond	7/09/1999	8.2	3800												0.4												
KS2/1	Deep Pond	7/12/1999	9	4200												0.1												
KS2/1	Deep Pond	6/03/2000	9	6700												0.2												
KS2/1	Deep Pond	5/06/2000	8.9	3600												0.1												
KS2/1	Deep Pond	4/09/2000	8.3	4100												0.1												
KS2/1	Deep Pond	4/12/2000	8.6	5200												0.1												
KS2/1	Deep Pond	5/03/2001	8.6	10400												0.3												
KS2/1	Deep Pond	3/09/2001	8.7	3600												0.1												
KS2/1	Deep Pond	4/03/2002	8.8	5400												0.1												
KS2/1	Deep Pond	9/10/2002	9.5	5300												0.02												
KS2/1	Deep Pond	16/04/2003	10	3600												0.08												
KS2/1	Deep Pond	17/11/2003	9.99	4790												0.01												
KS2/1	Deep Pond	25/03/2004	11.68	3490												0.51												
KS2/1	Deep Pond	30/09/2004	7.34	6440												0.48												
KS2/1	Deep Pond	29/03/2005	7.56	4460												18.6												
KS2/1	Deep Pond	12/09/2005	8.53	4420												0.031												
KS2/1	Deep Pond	03/03/2006	10.75	2960												0.8												
KS2/1	Deep Pond	08/09/2006	8.65	5250												2.76												
KS2/1	Deep Pond	03/03/2007	10.75	2960												0.8												
KS2/1	Deep Pond	21/09/2007	8.4	2582												0.025												
KS2/1	Deep Pond	29/02/2008	No surface water																									
KS2/1	Deep Pond	08/09/2008	10.03	1765												0.11												
KS2/1	Deep Pond	03/03/2009	9.0	2540												0.2												
KS2/1	Deep Pond	07/09/2009	7.7	2319												0.06												
KS2/1	Deep Pond	23/12/2010	8.8	4700												0.03												
KS2/1	Deep Pond	10/04/2012	9.7	1080												0.03												
KS4/1	Deep Pond	12/08/1997	9	7700		32	4700							2200		0.1												
KS4/1	Deep Pond	31/08/1998		7000			4200							1900	2.1	0.1												
KS7/1	Deep Pond	17/01/1981	8.7	33000		29								13500		0.09				0.01	0.01	0.02						
KS/71	Deep Pond	10/02/1982	9.2	43000		12								19000		0.14				0.01	0.01	0.02						
KS7/1	Deep Pond	11/05/1982	9.3	35000		8								15400		0.04				0.01	0.01	0.02						
KS7/1	Deep Pond	31/08/1983																										
KS7/1	Deep Pond	16/09/1983	8.7	27300		13								12000		0.13				0.02	0.01	0.03						
KS7/1	Deep Pond	14/06/1984	9.4	19700		9								8400		0.02				0.06	0.01	0.07						
KS7/1	Deep Pond	05/12/1984	9.6	22300		47								9400		0.16				0.01	0.01	0.02						
KS7/1	Deep Pond	27/06/1985	8.8	22200		56								8750		0.09				0.02	0.01	0.03						
KS7/1	Deep Pond	10/04/1986	8.1	2600		6								11600		0.14				0.08	0.01	0.09						
KS7/1	Deep Pond	02/07/1987	8.4	32800		6								13200		0.03				0.01	0.01	0.02						
KS7/1	Deep Pond	16/08/1988	9.9	13500		4								4600		0.02				0.01	0.01	0.02						
KS7/1	Deep Pond	07/02/1989	8.6	23700		8								9100		0.05				0.02	0.01	0.03						
KS7/1	Deep Pond	07/08/1991	9.1	13800		7								5600		0.06				0.01	0.01	0.02						
KS7/1	Deep Pond	04/05/1990	9.1	11000		2								3880		0.18				0.08	0.01	0.09						
KS7/1	Deep Pond	05/12/1990	7.8	17700		10																						
KS7/1	Deep Pond	25/03/1991	9.1	36900		2								22		0.2				0.01	0.01	0.02						
KS7/1	Deep Pond	07/08/1991	9.1	13800		7								10		0.06				0.01	0.01	0.02						
KS7/1	Deep Pond	22/08/1991	8	28800		18								12		0.7				0.04	0.04	0.08						
KS7/1	Deep Pond	19/08/1992	7.8	30300		12								13	1.2	1.1				0.01	0.01	0.02						
KS7/1	Deep Pond	17/08/1993	8.7	30200		20								11	1.2	0.2				0.43	0.02	0.45						
KS7/1	Deep Pond	10/08/1994	8.7	22800		16								8	2	0.1				0.26	0.1	0.36						
KS7/1	Deep Pond	10/08/1995	8.7	13700		9.1								7.2	2.4	0.1				0.01	0.01	0.02						
KS7/1	Deep Pond	12/08/1996	8.2	11300		6.8								3.3	3.2	0.5				0.04	0.05	0.09						
KS7/1	Deep Pond	12/08/1997	8.6	7300		4.5								1.8	2.5	0.1				0.1	0.1	0.2						
KS7/1	Deep Pond	31/08/1998	8.8	5300		4.2								1	3	0.1				0.01	0.01	0.02						
SW1	Deep Pond	25/05/2007	8.82	4422																							0.1	
SW2	Deep Pond	25/05/2007	8.96	2650																								
SW3	Deep Pond	25/05/2007	8.81	4460																								
SW4	Deep Pond	25/05/2007	7.94	4260																								
SW5	Deep Pond	25/05/2007	8.55	4030																								

KIWEF Surface Water Monitoring Results - Deep Pond

ANALYTES			ons		Metals																								
			K	Ca	Al - Total	As - Total	As - Dissolved	Ba - Total	Be - Total	Bo - Total	Cd -Total	Cd - Dissolved	Co - Total	Cr - Total	Cr - Dissolved	Cr $^{6+}$- Total	Cu -Total	Cu - Dissolved	Fe - Total	Fe - Dissolved	Hexavalent Chromium	Mn - Total	Mn - Dissolved	Mo - Total	Mo - Dissolved	Ni - Total	Ni - Dissolved	Pb - Total	Pb - Dissolved
Units			mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
ANZECC CRITERIA			NC	NC	0.055	0.013	0.013	NC	NC	0.37	0.0007	0.0007	0.001	0.0044	0.0044	0.0044	0.0013	0.0013	NC	NC	NC	0.08	0.08	0.023	0.023	0.007	0.007	0.0044	0.0044
Laboratory PQL *			0.2	0.1	0.01	0.002		0.001	0.001	0.05	0.01	0.01	0.01	0.01	0.01	0.005	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.001	0.01	0.001	0.01	0.01
		count	26	30	33	52	5	22	22	22	81	51	47	103	51	5	81	51	100	50	11	103	50	71	5	52	5	107	52
		90 %ile	77	41	1.12	0.004	0.005	0.095	0.001	1.13	0.0100	0.010	0.020	0.018	0.010	0.005	0.030	0.03	2.05	0.10	0.010	0.42	0.14	0.13	0.10	0.100	0.002	0.050	0.047
		80 %ile	75	39	0.40	0.003	0.005	0.080	0.001	1.00	0.0100	0.010	0.010	0.010	0.010	0.005	0.020	0.01	0.77	0.06	0.010	0.25	0.08	0.10	0.09	0.100	0.002	0.020	0.020
		average	52	34	0.62	0.003	0.003	0.078	0.001	0.75	0.0120	0.009	0.010	0.009	0.009	0.005	0.013	0.01	1.31	0.03	0.009	0.17	0.08	0.07	0.08	0.032	0.002	0.022	0.020
		20 %ile	43	30	0.05	0.001	0.002	0.069	0.001	0.60	0.0001	0.010	0.001	0.001	0.010	0.005	0.001	0.01	0.12	0.01	0.005	0.02	0.01	0.03	0.07	0.002	0.002	0.001	0.010
		10 %ile	26	28	0.04	0.001	0.002	0.068	0.001	0.43	0.0001	0.010	0.001	0.001	0.010	0.005	0.001	0.01	0.07	0.01	0.005	0.01	0.01	0.02	0.07	0.001	0.002	0.001	0.010
KS2/1	Deep Pond	17/11/1981									0.01	0.01		0.01	0.01		0.01	0.01	0.11	0.01		0.01	0.02					0.01	0.01
KS2/1	Deep Pond	10/02/1982									0.01	0.01		0.01	0.01		0.02	0.01	0.62	0.01		0.21	0.01					0.01	0.01
KS2/1	Deep Pond	11/05/1982									0.01	0.01		0.01	0.01		0.02	0.01	0.43	0.03		0.04	0.02					0.01	0.01
KS2/1	Deep Pond	14/06/1984									0.01	0.01		0.01	0.01		0.01	0.01	0.22	0.01		0.07	0.05					0.01	0.01
KS2/1	Deep Pond	5/12/1984									0.01	0.01		0.01	0.01		0.01	0.01	0.04	0.03		0.25	0.09					0.01	0.01
KS2/1	Deep Pond	27/06/1985									0.01	0.01		0.01	0.01		0.02	0.01	0.25	0.01		0.2	0.13					0.01	0.01
KS2/1	Deep Pond	10/04/1986									0.01	0.01		0.01	0.01		0.01	0.01	0.29	0.1		0.14	0.9					0.01	0.01
KS2/1	Deep Pond	2/07/1987									0.01	0.01		0.01	0.01		0.01	0.01	0.18	0.01		0.08	0.03					0.01	0.01
KS2/1	Deep Pond	16/08/1988									0.01	0.01		0.01	0.01		0.02	0.01	0.14	0.01		0.04	0.01					0.01	0.01
KS2/1	Deep Pond	7/02/1989									0.01	0.01		0.01	0.01		0.05	0.05	0.19	0.01		0.12	0.02					0.02	0.02
KS2/1	Deep Pond	7/08/1991									0.01	0.01		0.01	0.01		0.05	0.01	0.5	0.03		0.03	0.03					0.02	0.02
KS2/1	Deep Pond	4/05/1990									0.01	0.01		0.01	0.01		0.01	0.01	0.09	0.01		0.02	0.01					0.01	0.01
KS2/1	Deep Pond	5/12/1990									0.01	0.01		0.01	0.01		0.01	0.01										0.04	0.01
KS2/1	Deep Pond	25/03/1991				0.004					0.01	0.01	0.01	0.01	0.01		0.01	0.01	3.1	0.11		0.36	0.11	0.27		0.01		0.01	0.01
KS2/1	Deep Pond	22/08/1991				0.004					0.01	0.01	0.02	0.01	0.01		0.04	0.04	0.18	0.01		0.02	0.01	0.08		0.01		0.02	0.01
KS2/1	Deep Pond	19/08/1992				0.002					0.01	0.01	0.01	0.01	0.01		0.01	0.01	1	0.01		0.16	0.01	0.01		0.1		0.26	0.13
KS2/1	Deep Pond	30/11/1993				0.002					0.01	0.01	0.02	0.01	0.01		0.02	0.01	0.43	0.01		0.24	0.08	0.05		0.1		0.1	0.1
KS2/1	Deep Pond	10/08/1994				0.002					0.01	0.01	0.01	0.01	0.01		0.01	0.01	0.35	0.04		0.01	0.01	0.02		0.1		0.01	0.01
KS2/1	Deep Pond	10/08/1995				0.002					0.01	0.01	0.01	0.02	0.02		0.01	0.01	0.11	0.03		0.01	0.01	0.02		0.1		0.05	0.05
KS2/1	Deep Pond	12/08/1996				0.002					0.01	0.01	0.01	0.01	0.01		0.03	0.01	0.45	0.1		0.03	0.01	0.07		0.1		0.05	0.01
KS2/1	Deep Pond	9/09/1996																											
KS2/1	Deep Pond	13/08/1997				0.002					0.01	0.01	0.1	0.01	0.01		0.02	0.01	0.67	0.1		0.34	0.01	0.06		0.1		0.02	0.02
KS2/1	Deep Pond	15/03/1999												0.01					0.85			0.14		0.12				0.02	
KS2/1	Deep Pond	17/06/1999												0.006					0.3			0.084		0.129				0.003	
KS2/1	Deep Pond	7/09/1999												0.01					0.22			0.11		0.12				0.02	
KS2/1	Deep Pond	7/12/1999												0.02					0.81			0.12		0.16				0.05	
KS2/1	Deep Pond	6/03/2000												0.02					5.6			0.3		0.2				0.05	
KS2/1	Deep Pond	5/06/2000												0.01					0.58			0.08		0.12				0.05	
KS2/1	Deep Pond	4/09/2000												0.06					0.51			0.11		0.12				0.02	
KS2/1	Deep Pond	4/12/2000												0.01					6			0.35		0.19				0.017	
KS2/1	Deep Pond	5/03/2001												0.07					34			0.61		0.28				0.51	
KS2/1	Deep Pond	3/09/2001												0.05					0.51			0.011		0.05				0.002	
KS2/1	Deep Pond	4/03/2002												0.032					2.7			0.07		0.1				0.014	
KS2/1	Deep Pond	9/10/2002												0.017					0.38			0.029		0.146				0.002	
KS2/1	Deep Pond	16/04/2003												0.005					0.83			0.057		0.059				0.007	
KS2/1	Deep Pond	17/11/2003												0.001					0.11			0.018		0.032				0.001	
KS2/1	Deep Pond	25/03/2004												0.01					0.05			0.006		0.018				0.001	
KS2/1	Deep Pond	30/09/2004												0.001					0.7			0.584		0.151				0.001	
KS2/1	Deep Pond	29/03/2005												0.007					0.24			0.23		0.064				0.002	
KS2/1	Deep Pond	12/09/2005												0.001					0.07			0.04		0.112				0.024	
KS2/1	Deep Pond	03/03/2006												0.001					0.05			0.006		0.019				0.001	
KS2/1	Deep Pond	08/09/2006												0.001					0.8			0.121		0.094				0.003	
KS2/1	Deep Pond	03/03/2007												0.001					0.05			0.006		0.019				0.001	
KS2/1	Deep Pond	21/09/2007												0.001					0.86			0.131		0.102				0.004	
KS2/1	Deep Pond	29/02/2008																											
KS2/1	Deep Pond	08/09/2008												0.001					0.41			0.035		0.037				0.002	
KS2/1	Deep Pond	03/03/2009												0.001					0.49			0.06		0.062				0.002	
KS2/1	Deep Pond	07/09/2009												0.004					4.24			0.352		0.064				0.025	
KS2/1	Deep Pond	23/12/2010												0.005										0.12				0.001	
KS2/1	Deep Pond	10/04/2012												0.005										0.02				0.001	
KS4/1	Deep Pond	12/08/1997				0.002					0.01	0.01	0.1	0.01			0.01	0.01	0.76	0.1		0.2	0.01	0.03		0.1		0.02	0.02
KS4/1	Deep Pond	31/08/1998				0.002					0.01	0.01	0.01	0.02	0.01		0.01	0.01	0.19	0.1		0.01	0.01	0.08		0.1		0.02	0.02
KS7/1	Deep Pond	17/01/1981									0.01	0.01		0.01	0.01		0.01	0.01	0.16	0.01		0.08	0.3					0.01	0.01
KS/71	Deep Pond	10/02/1982									0.01	0.01		0.01	0.01		0.03	0.03	0.67	0.01		0.07	0.01					0.01	0.01
KS7/1	Deep Pond	11/05/1982									0.01	0.01		0.01	0.01		0.01	0.01	0.1	0.02		0.02	0.01					0.01	0.01
KS7/1	Deep Pond	31/08/1983																											
KS7/1	Deep Pond	16/09/1983									0.01	0.01		0.01	0.01		0.01	0.01	0.04	0.02		0.14	0.04					0.01	0.01
KS7/1	Deep Pond	14/06/1984									0.01	0.01		0.01	0.01		0.01	0.01	0.09	0.02		0.02	0.03					0.01	0.01
KS7/1	Deep Pond	05/12/1984									0.01	0.01		0.01	0.01		0.01	0.01	0.07	0.04		0.31	0.03					0.01	0.01
KS7/1	Deep Pond	27/06/1985									0.01	0.01		0.01	0.01		0.02	0.01	0.12	0.01		0.24	0.3					0.01	0.01
KS7/1	Deep Pond	10/04/1986									0.01	0.01		0.01	0.01		0.01	0.01	0.38	0.08		0.12	0.14					0.01	0.01
KS7/1	Deep Pond	02/07/1987									0.01	0.01		0.01	0.01		0.01	0.01	0.02	0.01		0.04	0.01					0.01	0.01
KS7/1	Deep Pond	16/08/1988									0.01	0.01		0.01	0.01		0.01	0.01	0.02	0.01		0.02	0.01					0.01	0.01
KS7/1	Deep Pond	07/02/1989									0.01	0.01		0.01	0.01		0.05	0.05	0.72	0.01		0.1	0.02					0.02	0.02
KS7/1	Deep Pond	07/08/1991									0.01	0.01		0.01	0.01		0.05	0.01	0.12	0.02		0.01	0.01					0.02	0.02
KS7/1	Deep Pond	04/05/1990									0.01	0.01		0.01	0.01		0.01	0.03	0.01	0.03		0.02	0.01					0.01	0.01
KS7/1	Deep Pond	05/12/1990									0.01	0.01		0.01	0.01		0.01	0.01										0.01	0.01
KS7/1	Deep Pond	25/03/1991				0.002					0.01	0.01	0.02	0.01	0.01		0.01	0.01	0.18	0.04		0.01	0.01	0.08		0.01		0.02	0.01
KS7/1	Deep Pond	07/08/1991									0.01	0.01		0.01	0.01		0.05	0.01	0.12	0.02		0.01	0.01					0.02	0.02
KS7/1	Deep Pond	22/08/1991				0.004					0.01	0.01	0.02	0.01	0.01		0.04	0.04	0.48	0.01		0.1	0.01	0.07		0.02		0.03	0.01
KS7/1	Deep Pond	19/08/1992				0.002					0.01	0.01	0.01	0.01	0.01		0.02	0.02	0.63	0.05		0.37	0.03	0.04		0.1		0.09	0.09
KS7/1	Deep Pond	17/08/1993				0.002					0.01	0.01	0.03	0.01	0.01		0.03	0.02	0.15	0.01		0.08	0.01	0.06		0.1		0.1	0.1
KS7/1	Deep Pond	10/08/1994				0.002					0.01	0.01	0.01	0.01	0.01		0.01	0.01	0.21	0.01		0.11	0.08	0.05		0.1		0.01	0.02
KS7/1	Deep Pond	10/08/1995				0.002					0.01	0.01	0.02	0.01	0.01		0.02	0.01	0.22	0.04		0.11	0.05	0.06		0.1		0.05	0.05
KS7/1	Deep Pond	12/08/1996				0.002					0.01	0.01	0.01	0.01	0.01		0.03	0.01	0.35	0.1		0.1	0.01	0.08		0.1		0.03	0.01
KS7/1	Deep Pond	12/08/1997				0.003					0.01	0.01	0.01	0.02	0.01		0.02	0.01	0.23	0.1		1.7	0.91	0.07		0.1		0.02	0.02
KS7/1	Deep Pond	31/08/1998				0.002					0.01	0.01	0.01	0.02	0.01		0.01	0.01	0.16	0.1		0.2	0.18	0.09		0.1		0.02	0.02
SW1	Deep Pond	25/05/2007			0.036	0.001					0.1					0.005	0.005					0.038				0.005		0.001	
SW2	Deep Pond	25/05/2007			0.034	0.001					0.1					0.005	0.005					0.01				0.005		0.001	
SW3	Deep Pond	25/05/2007			0.053	0.0011					0.1					0.005	0.005					0.01				0.005		0.001	
SW4	Deep Pond	25/05/2007			0.042	0.001					0.1					0.005	0.005					0.028				0.005		0.001	
SW5	Deep Pond	25/05/2007			0.085	0.001					0.1					0.005	0.005					0.012				0.005		0.001	

KIWEF Surface Water Monitoring Results - Deep Pond

ANALYTES										Cyanide			Total Recoverable Hydrocarbons					BTEX									
			Sb - Total	Se - Total	Sn - Total	Zn - Total	Zn - Dissolved	Hg - Total	Hg - Dissolved	Total Cyanide	Free Cyanide	WAD Cyanide	TRH C_6 - C_9	TRH C_{10} - C_{14}	TRH C_{15} - C_{28}	TRH C_{29} - C_{36}	Total TRH C_6 - C_{36}	Benzene	Toluene	Ethyl-benzene	Total Xylenes	Total PAHs	Naphthalene	Acenaphtylene	Acenaphthene	Fluorene	Phenanthrene
Units			mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L CN	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
ANZECC CRITERIA			NC	0.005	NC	0.015	0.015	0.0001	0.0001	0.004	0.004	0.004	NC	NC	NC	NC	NC	0.5	0.18	0.08	0.2	NC	0.05	NC	NC	NC	0.0006
Laboratory PQL *			0.001	0.002	0.001	0.01	0.01	0.00005	0.0004	0.005	0.005	0.005	0.1	0.1	0.2	0.2	0.6	0.001	0.001	0.001	0.003	0.003	0.0002	0.0002	0.0002	0.0002	0.0002
		count	22	47	21	104	52	78	4	48	42	14	34	34	34	34	22	19	19	19	19	55	69	69	69	69	69
		90 %ile	0.001	0.010	0.001	0.151	0.06	0.00024	0.00040	0.030	0.014	0.004	0.20	0.20	0.60	0.60	1.60	0.001000	0.002000	0.002000	0.003000	0.0113	0.0010	0.0010	0.0010	0.0010	0.0010
		80 %ile	0.001	0.010	0.001	0.064	0.02	0.00010	0.00040	0.008	0.010	0.004	0.10	0.10	0.60	0.54	1.60	0.001000	0.002000	0.002000	0.003000	0.0030	0.0010	0.0005	0.0006	0.0005	0.0007
		average	0.001	0.006	0.001	0.084	0.02	0.00077	0.00033	0.010	0.007	0.004	0.07	0.09	0.76	0.28	0.97	0.000816	0.001237	0.001237	0.002027	0.2944	0.0003	0.0003	0.0003	0.0003	0.0003
		20 %ile	0.001	0.002	0.001	0.010	0.01	0.00005	0.00028	0.004	0.004	0.004	0.02	0.05	0.10	0.10	0.43	0.000800	0.000800	0.000800	0.001800	0.0015	0.0001	0.0001	0.0001	0.0001	0.0001
		10 %ile	0.001	0.001	0.001	0.006	0.01	0.00005	0.00019	0.004	0.004	0.004	0.01	0.05	0.10	0.05	0.26	0.000001	0.000001	0.000001	0.000003	0.0015	0.0001	0.0001	0.0001	0.0001	0.0001
KS2/1	Deep Pond	17/11/1981				0.01	0.01																				
KS2/1	Deep Pond	10/02/1982				0.01	0.01																				
KS2/1	Deep Pond	11/05/1982				0.01	0.01																				
KS2/1	Deep Pond	14/06/1984				0.01	0.05																				
KS2/1	Deep Pond	5/12/1984				0.01	0.02																				
KS2/1	Deep Pond	27/06/1985				0.04	0.01																				
KS2/1	Deep Pond	10/04/1986				0.02	0.01																				
KS2/1	Deep Pond	2/07/1987				0.04	0.01																				
KS2/1	Deep Pond	16/08/1988				0.01	0.01																				
KS2/1	Deep Pond	7/02/1989				0.05	0.01																				
KS2/1	Deep Pond	7/08/1991				0.07	0.22																				
KS2/1	Deep Pond	4/05/1990				0.01	0.01																				
KS2/1	Deep Pond	5/12/1990				0.05	0.07																				
KS2/1	Deep Pond	25/03/1991		0.002		0.1	0.01	0.00012			0.012											0.0033	0.0005	0.0002	0.0002	0.0002	0.0002
KS2/1	Deep Pond	22/08/1991		0.003		0.05	0.01	0.00015			0.01											0.003	0.0002	0.0002	0.0002	0.0002	0.0002
KS2/1	Deep Pond	19/08/1992		0.002		0.01	0.01	0.00023			0.006											0.0043	0.001	0.0002	0.0004	0.0002	0.0005
KS2/1	Deep Pond	30/11/1993		0.002		0.02	0.01	0.0011			0.005		0.1	0.1	0.3	0.3	0.8					0.003	0.0002	0.0002	0.0002	0.0002	0.0002
KS2/1	Deep Pond	10/08/1994		0.002		0.02	0.01	0.00001			0.001		0.2	0.2	0.6	0.6	1.6					0.003	0.0002	0.0002	0.0002	0.0002	0.0002
KS2/1	Deep Pond	10/08/1995		0.002		0.01	0.01	0.0004			0.002		0.2	0.2	0.6	0.6	1.6					0.003	0.0002	0.0002	0.0002	0.0002	0.0002
KS2/1	Deep Pond	12/08/1996		0.002		0.06	0.01	0.00002			0.005		0.2	0.2	0.6	0.6	1.6					0.003	0.0002	0.0002	0.0002	0.0002	0.0002
KS2/1	Deep Pond	9/09/1996																				0.003	0.0002	0.0002	0.0002	0.0002	0.0002
KS2/1	Deep Pond	13/08/1997		0.002		0.05	0.04	0.05			0.016		0.1	0.1	0.5	0.5	1.2					0.003	0.0002	0.0002	0.0002	0.0002	0.0002
KS2/1	Deep Pond	15/03/1999				0.24		0.00008		0.01												0.003	0.0002	0.0002	0.0002	0.0002	0.0002
KS2/1	Deep Pond	17/06/1999				0.02		0.00006		0.005												0.003	0.0002	0.0002	0.0002	0.0002	0.0002
KS2/1	Deep Pond	7/09/1999				0.35		0.00005		0.006												0.003	0.0002	0.0002	0.0002	0.0002	0.0002
KS2/1	Deep Pond	7/12/1999				0.04		0.00012		0.01												0.00075	0.00005	0.00005	0.00005	0.00005	0.00005
KS2/1	Deep Pond	6/03/2000				0.39		0.00005		0.01												0.0033	0.0002	0.0002	0.0002	0.0002	0.0003
KS2/1	Deep Pond	5/06/2000				0.08		0.00005		0.005	0.005											0.003	0.0002	0.0002	0.0002	0.0002	0.0002
KS2/1	Deep Pond	4/09/2000				2		0.00005		0.005	0.005											0.003	0.0002	0.0002	0.0002	0.0002	0.0002
KS2/1	Deep Pond	4/12/2000				0.22		0.00005		0.005	0.005											0.003	0.0002	0.0002	0.0002	0.0002	0.0002
KS2/1	Deep Pond	5/03/2001				1.3		0.00025		0.005	0.005											0.0019	0.0001	0.0001	0.0001	0.0001	0.0003
KS2/1	Deep Pond	3/09/2001				0.21		0.00007		0.005	0.005											0.0016	0.0001	0.0001	0.0001	0.0001	0.0001
KS2/1	Deep Pond	4/03/2002				0.3		0.00005		0.03	0.005											0.0016	0.0001	0.0001	0.0001	0.0001	0.0001
KS2/1	Deep Pond	9/10/2002				0.056		0.00005		0.005	0.005											0.0016	0.0001	0.0001	0.0001	0.0001	0.0001
KS2/1	Deep Pond	16/04/2003				0.07		0.00005		0.005	0.005											0.00142	0.0001	0.0001	0.0001	0.0001	0.0001
KS2/1	Deep Pond	17/11/2003				0.006		0.0001			0.014											0.0015	0.0001	0.0001	0.0001	0.0001	0.0001
KS2/1	Deep Pond	25/03/2004				0.002		0.00005		0.01												0.0015	0.0001	0.0001	0.0001	0.0001	0.0001
KS2/1	Deep Pond	30/09/2004				0.013		0.0001		0.065												0.0015	0.0001	0.0001	0.0001	0.0001	0.0001
KS2/1	Deep Pond	29/03/2005				0.012		0.0001		0.005												0.0015	0.0001	0.0001	0.0001	0.0001	0.0001
KS2/1	Deep Pond	12/09/2005				0.01		0.0001		0.045												0.0015	0.0001	0.0001	0.0001	0.0001	0.0001
KS2/1	Deep Pond	03/03/2006				0.006		0.0001		0.03												0.0015	0.0001	0.0001	0.0001	0.0001	0.0001
KS2/1	Deep Pond	08/09/2006				0.028		0.0001		0.0953												0.0015	0.0001	0.0001	0.0001	0.0001	0.0001
KS2/1	Deep Pond	03/03/2007				0.006		0.0001		0.03												0.0015	0.0001	0.0001	0.0001	0.0001	0.0001
KS2/1	Deep Pond	21/09/2007				0.027		0.0001		0.004												0.0014	0.0001	0.0001	0.0001	0.0001	0.0001
KS2/1	Deep Pond	29/02/2008																									
KS2/1	Deep Pond	08/09/2008				0.017		0.0001		0.004												0.0015	0.0001	0.0001	0.0001	0.0001	0.0001
KS2/1	Deep Pond	03/03/2009				0.018		0.0001		0.004													0.0001	0.0001	0.0001	0.0001	0.0001
KS2/1	Deep Pond	07/09/2009				0.164		0.0001		0.004													0.0001	0.0001	0.0001	0.0001	0.0001
KS2/1	Deep Pond	23/12/2010								0.004	0.004	0.004											0.0001	0.0001	0.0001	0.0001	0.0001
KS2/1	Deep Pond	10/04/2012								0.005	0.005	0.01										16	0.001	0.001	0.001	0.001	0.001
KS4/1	Deep Pond	12/08/1997		0.002		0.1	0.06	0.00005			0.01		0.1	0.1	0.5	0.5	1.2					0.003	0.0002	0.0002	0.0002	0.0002	0.0002
KS4/1	Deep Pond	31/08/1998		0.002		0.06	0.01	0.00005			0.02		0.1	0.1	0.5	0.5	1.2					0.003	0.0002	0.0002	0.0002	0.0002	0.0002
KS7/1	Deep Pond	17/01/1981				0.02	0.01																				
KS/71	Deep Pond	10/02/1982				0.02	0.02																				
KS7/1	Deep Pond	11/05/1982				0.1	0.02																				
KS7/1	Deep Pond	31/08/1983																									
KS7/1	Deep Pond	16/09/1983				0.01	0.02																				
KS7/1	Deep Pond	14/06/1984				0.01	0.01																				
KS7/1	Deep Pond	05/12/1984				0.01	0.05																				
KS7/1	Deep Pond	27/06/1985				0.01	0.09																				
KS7/1	Deep Pond	10/04/1986				0.01	0.01																				
KS7/1	Deep Pond	02/07/1987				0.02	0.01																				
KS7/1	Deep Pond	16/08/1988				0.01	0.01																				
KS7/1	Deep Pond	07/02/1989				0.02	0.01																				
KS7/1	Deep Pond	07/08/1991				0.01	0.01																				
KS7/1	Deep Pond	04/05/1990				0.01	0.06																				
KS7/1	Deep Pond	05/12/1990				0.01	0.01																				
KS7/1	Deep Pond	25/03/1991		0.002		0.08	0.01	0.00005			0.005																
KS7/1	Deep Pond	07/08/1991				0.01	0.01				0.00001																
KS7/1	Deep Pond	22/08/1991		0.002		0.07	0.01	0.00004			0.015																
KS7/1	Deep Pond	19/08/1992		0.002		0.01	0.01	0.00082			0.007											0.003	0.0002	0.0002	0.0002	0.0002	0.0002
KS7/1	Deep Pond	17/08/1993		0.002		0.09	0.01	0.00065			0.005		0.1	0.1	0.3	0.3	0.8					0.0032	0.0004	0.0002	0.0002	0.0002	0.0002
KS7/1	Deep Pond	10/08/1994		0.002		0.02	0.02	0.00003			0.015		0.2	0.2	0.6	0.6	1.6					0.003	0.0002	0.0002	0.0002	0.0002	0.0002
KS7/1	Deep Pond	10/08/1995		0.002		0.03	0.01	0.00029			0.01		0.2	0.2	0.6	0.6	1.6					0.003	0.0002	0.0002	0.0002	0.0002	0.0002
KS7/1	Deep Pond	12/08/1996		0.002		0.06	0.01	0.00002			0.01		0.2	0.2	0.6	0.6	1.6					0.003	0.0002	0.0002	0.0002	0.0002	0.0002
KS7/1	Deep Pond	12/08/1997		0.002		0.29	0.1	0.00005			0.01		0.1	0.1	0.5	0.5	1.2					0.003	0.0002	0.0002	0.0002	0.0002	0.0002
KS7/1	Deep Pond	31/08/1998		0.002		0.05	0.01	0.00005			0.01		0.1	0.1	0.5	0.5	1.2					0.003	0.0002	0.0002	0.0002	0.0002	0.0002
SW1	Deep Pond	25/05/2007				0.005		0.0001		0.005			0.025	0.097	0.52	0.1	0.742					0.016	0.001	0.001	0.001	0.001	0.001
SW2	Deep Pond	25/05/2007				0.005		0.0001					0.025	0.025	0.48	0.1	0.63					0.016	0.001	0.001	0.001	0.001	0.001
SW3	Deep Pond	25/05/2007				0.005		0.0001		0.005			0.025	0.083	0.45	0.1	0.658					0.016	0.001	0.001	0.001	0.001	0.001
SW4	Deep Pond	25/05/2007				0.005		0.0001					0.025	0.025	0.1	0.1	0.25					0.016	0.001	0.001	0.001	0.001	0.001
SW5	Deep Pond	25/05/2007				0.005		0.0001		0.005			0.025	0.025	0.1	0.1	0.25					0.016	0.001	0.001	0.001	0.001	0.001

KIWEF Surface Water Monitoring Results - Deep Pond

ANALYTES			Polycyclic Aromatic Hydrocarbons													Organochlorine/Organophosphate Pesticides					Total PCBs
			Anthracene	Fluoranthene	Pyrene	Benz(a)anthracene	Chrysene	Benzo(b)&(k)fluoranthene	Benzo(a)pyrene	Indeno(1.2.3-cd)pyrene	Dibenzo(ah)anthracene	Benzo(ghi)perylene	1-Methylnaphthalene	2-Methylnaphthalene	Phenols	Total OCPs	Aldrin + Dieldrin	Chlordane	DDT	Heptachlor	
Units			mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
ANZECC CRITERIA			0.00001	0.001	NC	NC	NC	NC	0.0001	NC	NC	NC	NC	NC	0.4	NC	NC	0.00003	0.000006	0.00001	NC
Laboratory PQL *			0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0001	0.0001	0.001	0.00002	0.00002	0.00001	0.00002	0.00002	0.09
		count	69	69	69	69	69	58	69	69	69	69	1	1	57	1	1	1	1	1	1
		90 %ile	0.0010	0.0010	0.0010	0.0010	0.0010	0.0007	0.0006	0.0010	0.0010	0.0010	0.0001	0.0001	0.050000	0.000380	0.000020	0.000020	0.000010	0.000020	0.000800
		80 %ile	0.0006	0.0005	0.0005	0.0005	0.0005	0.0002	0.0003	0.0005	0.0005	0.0005	0.0001	0.0001	0.050000	0.000380	0.000020	0.000020	0.000010	0.000020	0.000800
		average	0.0003	0.0003	0.0003	0.0003	0.0003	0.0004	0.0003	0.0003	0.0003	0.0003	0.0001	0.0001	0.025053	0.000380	0.000020	0.000020	0.000010	0.000020	0.000800
		20 %ile	0.0001	0.0001	0.0001	0.0001	0.0001	0.0002	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.001000	0.000380	0.000020	0.000020	0.000010	0.000020	0.000800
		10 %ile	0.0001	0.0001	0.0001	0.0001	0.0001	0.0002	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.000007	0.000380	0.000020	0.000020	0.000010	0.000020	0.000800
KS2/1	Deep Pond	17/11/1981																			
KS2/1	Deep Pond	10/02/1982																			
KS2/1	Deep Pond	11/05/1982																			
KS2/1	Deep Pond	14/06/1984																			
KS2/1	Deep Pond	5/12/1984																			
KS2/1	Deep Pond	27/06/1985																			
KS2/1	Deep Pond	10/04/1986																			
KS2/1	Deep Pond	2/07/1987																			
KS2/1	Deep Pond	16/08/1988																			
KS2/1	Deep Pond	7/02/1989																			
KS2/1	Deep Pond	7/08/1991																			
KS2/1	Deep Pond	4/05/1990																			
KS2/1	Deep Pond	5/12/1990																			
KS2/1	Deep Pond	25/03/1991	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002			0.000009						
KS2/1	Deep Pond	22/08/1991	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002			0.000004						
KS2/1	Deep Pond	19/08/1992	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002			0.000002						
KS2/1	Deep Pond	30/11/1993	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002			0.000003						
KS2/1	Deep Pond	10/08/1994	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002			0.000002						
KS2/1	Deep Pond	10/08/1995	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002			0.000001						
KS2/1	Deep Pond	12/08/1996	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002			0.000002						
KS2/1	Deep Pond	9/09/1996	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002									
KS2/1	Deep Pond	13/08/1997	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002			0.003						
KS2/1	Deep Pond	15/03/1999	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002			0.003						
KS2/1	Deep Pond	17/06/1999	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002			0.003						
KS2/1	Deep Pond	7/09/1999	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002			0.001						
KS2/1	Deep Pond	7/12/1999	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005			0.001						
KS2/1	Deep Pond	6/03/2000	0.0004	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002			0.001						
KS2/1	Deep Pond	5/06/2000	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002			0.001						
KS2/1	Deep Pond	4/09/2000	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002			0.001						
KS2/1	Deep Pond	4/12/2000	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002			0.001						
KS2/1	Deep Pond	5/03/2001	0.0001	0.0002	0.0002	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001			0.001						
KS2/1	Deep Pond	3/09/2001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0002	0.0001	0.0001	0.0001	0.0001			0.001						
KS2/1	Deep Pond	4/03/2002	0.0001	0.0001	0.0001	0.0001	0.0001	0.0002	0.0001	0.0001	0.0001	0.0001			0.001						
KS2/1	Deep Pond	9/10/2002	0.0001	0.0001	0.0001	0.0001	0.0001	0.0002	0.0001	0.0001	0.0001	0.0001			0.01						
KS2/1	Deep Pond	16/04/2003	0.0001	0.0001	0.0001	0.0001	0.0001	0.0002	0.00001	0.0001	0.0001	0.0001			0.01						
KS2/1	Deep Pond	17/11/2003	0.0001	0.0001	0.0001	0.0001	0.0001	0.0002	0.00005	0.0001	0.0001	0.0001			0.05						
KS2/1	Deep Pond	25/03/2004	0.0001	0.0001	0.0001	0.0001	0.0001	0.0002	0.00005	0.0001	0.0001	0.0001			0.02						
KS2/1	Deep Pond	30/09/2004	0.0001	0.0001	0.0001	0.0001	0.0001	0.0002	0.00005	0.0001	0.0001	0.0001			0.007						
KS2/1	Deep Pond	29/03/2005	0.0001	0.0001	0.0001	0.0001	0.0001	0.0002	0.00005	0.0001	0.0001	0.0001			0.05						
KS2/1	Deep Pond	12/09/2005	0.0001	0.0001	0.0001	0.0001	0.0001	0.0002	0.00005	0.0001	0.0001	0.0001			0.05						
KS2/1	Deep Pond	03/03/2006	0.0001	0.0001	0.0001	0.0001	0.0001	0.0002	0.00005	0.0001	0.0001	0.0001			0.05						
KS2/1	Deep Pond	08/09/2006	0.0001	0.0001	0.0001	0.0001	0.0001	0.0002	0.00005	0.0001	0.0001	0.0001			0.05						
KS2/1	Deep Pond	03/03/2007	0.0001	0.0001	0.0001	0.0001	0.0001	0.0002	0.00005	0.0001	0.0001	0.0001			0.05						
KS2/1	Deep Pond	21/09/2007	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.00005	0.0001	0.0001	0.0001			0.05						
KS2/1	Deep Pond	29/02/2008																			
KS2/1	Deep Pond	08/09/2008	0.0001	0.0001	0.0001	0.0001	0.0001	0.0002	0.00005	0.0001	0.0001	0.0001			0.05						
KS2/1	Deep Pond	03/03/2009	0.0001	0.0001	0.0001	0.0001	0.0001	0.0002	0.00005	0.0001	0.0001	0.0001			0.05						
KS2/1	Deep Pond	07/09/2009	0.0001	0.0001	0.0001	0.0001	0.0001	0.0002	0.00005	0.0001	0.0001	0.0001			0.1						
KS2/1	Deep Pond	23/12/2010	0.0001	0.0001	0.0001	0.0001	0.0001	0.0002	0.00005	0.0001	0.0001	0.0001	0.0001	0.0001	0.00001						
KS2/1	Deep Pond	10/04/2012	0.001	0.001	0.001	0.001	0.001	0.002	0.001	0.001	0.001	0.001			0.04						
KS4/1	Deep Pond	12/08/1997	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002			0.003						
KS4/1	Deep Pond	31/08/1998	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002			0.001						
KS7/1	Deep Pond	17/01/1981																			
KS/71	Deep Pond	10/02/1982																			
KS7/1	Deep Pond	11/05/1982																			
KS7/1	Deep Pond	31/08/1983																			
KS7/1	Deep Pond	16/09/1983																			
KS7/1	Deep Pond	14/06/1984																			
KS7/1	Deep Pond	05/12/1984																			
KS7/1	Deep Pond	27/06/1985																			
KS7/1	Deep Pond	10/04/1986																			
KS7/1	Deep Pond	02/07/1987																			
KS7/1	Deep Pond	16/08/1988																			
KS7/1	Deep Pond	07/02/1989																			
KS7/1	Deep Pond	07/08/1991																			
KS7/1	Deep Pond	04/05/1990																			
KS7/1	Deep Pond	05/12/1990																			
KS7/1	Deep Pond	25/03/1991													0.002						
KS7/1	Deep Pond	07/08/1991													0.002						
KS7/1	Deep Pond	22/08/1991													0.003						
KS7/1	Deep Pond	19/08/1992	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002			0.002						
KS7/1	Deep Pond	17/08/1993	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002									
KS7/1	Deep Pond	10/08/1994	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002									
KS7/1	Deep Pond	10/08/1995	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002									
KS7/1	Deep Pond	12/08/1996	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002									
KS7/1	Deep Pond	12/08/1997	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002									
KS7/1	Deep Pond	31/08/1998	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002									
SW1	Deep Pond	25/05/2007	0.001	0.001	0.001	0.001	0.001	0.002	0.001	0.001	0.001	0.001									
SW2	Deep Pond	25/05/2007	0.001	0.001	0.001	0.001	0.001	0.002	0.001	0.001	0.001	0.001									
SW3	Deep Pond	25/05/2007	0.001	0.001	0.001	0.001	0.001	0.002	0.001	0.001	0.001	0.001									
SW4	Deep Pond	25/05/2007	0.001	0.001	0.001	0.001	0.001	0.002	0.001	0.001	0.001	0.001									
SW5	Deep Pond	25/05/2007	0.001	0.001	0.001	0.001	0.001	0.002	0.001	0.001	0.001	0.001									

KIWEF Surface Water Monitoring Results - Easement Pond South

ANALYTES			Basic				Anions									Cations								
			pH	Conductivity	Turbidity	TSS	Chloride	Ammonia	Nitrate as N	Nitrite as N	NO_x (NO_2 + NO_3)	Total Kjeldahl Nitrogen as N	Total Nitrogen as N	Reactive Phosphorus as P	Total Phosphorus	Na	Mg	K	Ca	Al - Total	As - Total	Ba - Total	Be - Total	Bo - Total
Units			pH units	mS/cm	NTU	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
ANZECC CRITERIA			7 to 8.5	NC	10	NC	NC	0.91	0.7	NC	0.015	NC	0.3	NC	0.03	NC	NC	NC	NC	0.055	0.013	NC	NC	0.37
Laboratory PQL *			-	1	0.1	5	0.1	0.1	0.05	0.05	0.05	0.1	0.1	0.01	0.01	0.1	0.1	0.2	0.1	0.01	0.002	0.001	0.001	0.05
		count	5	5	4	5	5	5	4	4	5	5	5	4	5	5	5	5	5	5	5	4	4	4
		90 %ile	8.3	881	79	82	151	0.070	0.282	0.017	0.278	1.4	1.5	0.01	0.22	128	14	14	57	1.56	0.003	0.084	0.001	0.30
		80 %ile	8.2	858	52	54	132	0.070	0.234	0.014	0.206	1.3	1.4	0.01	0.17	117	13	14	54	1.11	0.002	0.079	0.001	0.29
		average	8.1	703	34	37	101	0.041	0.140	0.013	0.117	1.0	1.1	0.01	0.11	88	10	10	42	0.70	0.002	0.063	0.001	0.25
		20 %ile	8.0	612	9	9	50	0.025	0.034	0.010	0.009	0.7	0.8	0.01	0.03	55	6	6	33	0.22	0.002	0.048	0.001	0.21
		10 %ile	7.9	481	5	7	45	0.015	0.022	0.010	0.007	0.6	0.6	0.01	0.02	50	5	5	27	0.13	0.002	0.042	0.001	0.19
SW203	EasePondSouth	8/03/2012	8.4	350		10	39	0.005			0.005	0.9	0.9		0.03	45	3.6	4.7	21	0.88	0.002			
SW203	EasePondSouth	26/07/2012	7.9	738	1.2	5	122	0.03	0.05	0.01	0.05	0.4	0.4	0.01	0.01	111	6	14	41	0.04	0.002	0.036	0.001	0.31
SW203	EasePondSouth	25/10/2012	8.1	847	14.0	40	120	0.07	0.01	0.01	0.01	1.4	1.4	0.01	0.15	86	12	14	53	0.27	0.002	0.090	0.001	0.23
SW203	EasePondSouth	11/12/2012	8.2	678	106	110	53	0.07	0.33	0.02	0.35	1.3	1.6	0.01	0.27	57	15	6	60	2.02	0.002	0.071	0.001	0.17
SW203	EasePondSouth	14/12/2012	7.97	904	16.6	18	170	0.03	0.17	0.01	0.17	0.8	1	0.01	0.1	140	13	13	36	0.31	0.003	0.056	0.001	0.27

KIWEF Surface Water Monitoring Results - Easement Pond South

ANALYTES			Polycyclic Aromatic Hydrocarbons														
			Naphthalene	Acenaphtylene	Acenaphthene	Fluorene	Phenanthrene	Anthracene	Fluoranthene	Pyrene	Benz(a)anthracene	Chrysene	Benzo(a)pyrene	Indeno(1.2.3-cd)pyrene	Dibenzo(ah)anthracene	Benzo(ghi)perylene	Phenols
Units			mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
ANZECC CRITERIA			0.05	NC	NC	NC	0.0006	0.00001	0.001	NC	NC	NC	0.0001	NC	NC	NC	0.4
Laboratory PQL *			0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.001
		count	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
		90 %ile	0.0010	0.0010	0.0010	0.0010	0.0010	0.0010	0.0010	0.0010	0.0010	0.0010	0.0005	0.0010	0.0010	0.0010	0.05
		80 %ile	0.0010	0.0010	0.0010	0.0010	0.0010	0.0010	0.0010	0.0010	0.0010	0.0010	0.0005	0.0010	0.0010	0.0010	0.05
		average	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	0.0004	0.0008	0.0008	0.0008	0.05
		20 %ile	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	0.0004	0.0008	0.0008	0.0008	0.05
		10 %ile	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0003	0.0005	0.0005	0.0005	0.05
SW203	EasePondSouth	8/03/2012	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.05
SW203	EasePondSouth	26/07/2012	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.0005	0.001	0.001	0.001	0.05
SW203	EasePondSouth	25/10/2012	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.0005	0.001	0.001	0.001	0.05
SW203	EasePondSouth	11/12/2012	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.0005	0.001	0.001	0.001	0.05
SW203	EasePondSouth	14/12/2012	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.0005	0.001	0.001	0.001	0.05

KIWEF Surface Water Monitoring Results - Easement Pond

ANALYTES			pH	Conductivity	Turbidity	TSS	TDS	Hydroxide OH-	Carbonate CO_3^-	Bicarbonate HCO_3^-	Hardness (as $CaCO_3$)	DOC	TOC	Chloride	Fluoride F	Ammonia	Sulphide	Sulphur	Sulphate SO_4	Nitrate as N	Nitrite as N	NO_x (NO_2 + NO_3)	Total Kjeldahl Nitrogen as N	Total Nitrogen as N	Reactive Phosphorus as P	Total Phosphorus	Na
Units			pH units	µS/cm	NTU	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
ANZECC CRITERIA			7 to 8.5	NC	10	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	0.91	0.001	NC	NC	0.7	NC	0.015	NC	0.3	NC	0.03	NC
Laboratory PQL *			-	1	0.1	5	5	2	2	0	1	1	1	0.1	0.05	0.1	0.5	0.5	0.4	0.05	0.05	0.05	0.1	0.1	0.01	0.01	0.1
S3	easement	12/12/2008																									
S3	easement	22/01/2009																									
S3	easement	24/02/2009	8.15	3490																							653
S3	easement	19/03/2009	7.47	4260										1160					189								718
S3	easement	24/04/2009	7.7	3740																							
S3	easement	19/05/2009	7.9	3630										983					216								601
S3	easement	23/06/2009	7.66	2200																							
S3	easement	23/07/2009	8.23	3040																							
S3	easement	19/08/2009																									
SW114	easement	11/05/2011	8.8	2200										460		0.005						0.005	0.6	0.6			
SW114	easement	8/03/2012	7.8	1700		5								240		0.005						0.005	1.2	1.2		0.03	270
SW114	easement	27/06/2012	8.63	1670	1.2	6								291								0.02	0.6	0.6		0.05	290
SW114	easement	26/07/2012	8.1	1720	2.3	6								303		0.02				0.01	0.01	0.01	0.6	0.6	0.01	0.02	326
SW114	easement	28/08/2012	8.5	1850	1.2	6								289								0.02	0.5	0.5		0.02	335
SW114	easement	27/09/2012	8.95	2000	3.9	7								365								0.01	0.7	0.7		0.08	370
SW114	easement	25/10/2012	9.2	2380	4.5	5								438		0.04				0.01	0.01	0.01	0.9	0.9	0.01	0.05	431
SW114	easement	27/11/2012	8.4	2880	8.4	12								532								0.01	1.4	1.4		0.07	554
SW114	easement	11/12/2012	8.2	3000	13.8	20								505		0.03				0.2	0.01	0.2	2	2.2	0.01	0.12	522
SW114	easement	14/12/2012	8.45	3050	13.2	14								518		0.02				0.19	0.01	0.19	1.6	1.8	0.01	0.17	589
SW7	easement	25/05/2007	8.89	2237																							
SW8	easement	25/05/2007	7.8	2502																							
SW501	easement	4/12/2008	7.1	2500				2	2	110	360	9.4	10	290	2.1	0.01		240	600	0.05	0.05	0.1					370
SW501	easement	24/04/2009	8.7	2400							360					0.1											
SW501	easement	17/08/2009	8.1	2300			1600				370					0.1	0.5		330								
SW501	easement	17/09/2009	8.7	2700		5	1700				350					0.4	0.5		590							0.03	
SW501	easement	11/11/2009	8.5	3400		28	1900				420					0.1	0.5		530							0.06	

KIWEF Surface Water Monitoring Results - Easement Pond

ANALYTES			Cations			Metals																							
			Mg	K	Ca	Al - Total	As - Total	As - Dissolved	Ba - Total	Be - Total	Bo - Total	Cd -Total	Cd - Dissolved	Co - Total	Cr - Total	Cr - Dissolved	Cr $^{6+}$- Total	Cu -Total	Cu - Dissolved	Fe - Total	Fe - Dissolved	Hexavalent Chromium	Mn - Total	Mn - Dissolved	Mo - Total	Mo - Dissolved	Ni - Total	Ni - Dissolved	Pb - Total
Units			mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
ANZECC CRITERIA			NC	NC	NC	0.055	0.013	0.013	NC	NC	0.37	0.0007	0.0007	0.001	0.0044	0.0044	0.0044	0.0013	0.0013	NC	NC	NC	0.08	0.08	0.023	0.023	0.007	0.007	0.0044
Laboratory PQL *			0.1	0.2	0.1	0.01	0.002		0.001	0.001	0.05	0.01	0.01	0.01	0.01	0.01	0.005	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.001	0.01	0.001	0.01
		count	36	32	36	36	29	5	8	8	8	32	7	35	34	8	2	38	7	35	8	6	15	8	26	5	37	5	29
		90 %ile	23	71	186	0.100	0.020	0.003	0.229	0.001	1.760	0.0500	0.0100	0.050	0.100	0.010	0.005	0.020	0.020	0.216	0.100	0.055	0.217	0.549	0.100	0.048	0.020	0.003	0.100
		80 %ile	21	63	150	0.100	0.020	0.002	0.175	0.001	1.634	0.0500	0.0100	0.050	0.100	0.010	0.005	0.020	0.018	0.100	0.100	0.010	0.141	0.332	0.100	0.037	0.020	0.002	0.100
		average	16	55	124	0.081	0.011	0.002	0.100	0.001	1.359	0.0229	0.0043	0.023	0.043	0.005	0.005	0.010	0.008	0.111	0.057	0.024	0.094	0.181	0.066	0.032	0.017	0.002	0.052
		20 %ile	12	43	68	0.020	0.001	0.002	0.044	0.001	1.078	0.0001	0.0001	0.001	0.001	0.001	0.005	0.001	0.001	0.050	0.014	0.010	0.031	0.022	0.023	0.022	0.001	0.001	0.002
		10 %ile	10	38	65	0.010	0.001	0.002	0.043	0.001	1.038	0.0001	0.0001	0.001	0.001	0.001	0.005	0.001	0.001	0.050	0.010	0.008	0.022	0.017	0.019	0.020	0.001	0.001	0.001
KS8/1	easment	20/08/1996					0.002					0.01	0.01	0.01	0.01	0.01		0.03	0.02	0.28	0.1		0.06	0.01	0.04		0.1		0.02
KS8/1	easment	13/08/1997					0.002					0.01	0.01	0.02	0.01	0.01		0.02	0.02	0.1	0.1		0.06	0.03	0.03		0.1		0.02
KS8/1	easment	31/08/1998					0.002					0.01	0.01	0.01	0.02	0.01		0.01	0.01	0.24	0.1		0.09	0.06	0.04		0.1		0.02
S1	easement	22/03/2006																											
S1	easement	5/04/2006																											
S1	easement	17/05/2006																											
S1	easement	20/06/2006																											
S1	easement	19/07/2006																											
S1	easement	22/08/2006	19.21	49.5	130.7	0.1	0.02							0.05	0.1			0.02		0.1					0.11		0.02		0.1
S1	easement	27/09/2006	21.57	47.1	105.9	0.1	0.02					0.05		0.05	0.1			0.02		0.1					0.1		0.02		0.1
S1	easement	25/10/2006	15	43.1	101.8	0.1	0.02							0.05	0.1			0.02							0.1		0.02		0.1
S1	easement	15/11/2006	23.6	62.3	120.5	0.1	0.02					0.05		0.05	0.1			0.02		0.1					0.1		0.02		0.1
S1	easement	13/12/2006																											
S1	easement	10/01/2007																											
S1	easement	14/02/2007																											
S1	easement	14/03/2007																											
S1	easement	27/04/2007																											
S1	easement	22/05/2007	14	46	100	0.1	0.02					0.05		0.05	0.1			0.02		0.1					0.1		0.02		0.1
S1	easement	28/06/2007																											
S1	easement	16/09/2008																											
S1	easement	15/10/2008																											
S1	easement	18/11/2008	19	38	68	0.01						0.0001		0.001	0.001			0.001		0.05							0.001		
S1	easement	12/12/2008																											
S1	easement	22/01/2009																											
S1	easement	24/02/2009																											
S1	easement	19/03/2009																											
S1	easement	24/03/2009																											
S1	easement	19/05/2009	15	46	116	0.02						0.0001		0.001	0.001			0.002		0.05							0.002		
S1	easement	23/06/2009																											
S1	easement	23/07/2009																											
S1	easement	19/08/2009																											
S2	easement	22/03/2006																											
S2	easement	5/04/2006																											
S2	easement	17/05/2006																											
S2	easement	20/06/2006																											
S2	easement	19/07/2006																											
S2	easement	22/08/2006	17.1	84.5	440.5	0.1	0.02					0.05		0.05	0.1			0.02		0.1					0.1		0.02		0.1
S2	easement	27/09/2006	14.05	47.6	172.5	0.1	0.02					0.05		0.05	0.1			0.02		0.1					0.1		0.02		0.1
S2	easement	25/10/2006	16.7	48.2	113.8	0.1	0.02							0.09	0.1			0.02							0.1		0.02		0.1
S2	easement	15/11/2006	23	64	117.8	0.1	0.02					0.05		0.05	0.1			0.02		0.1					0.1		0.02		0.1
S2	easement	13/12/2006																											
S2	easement	10/01/2007																											
S2	easement	14/02/2007																											
S2	easement	14/03/2007																											
S2	easement	27/04/2007																											
S2	easement	22/05/2007	12	49	94	0.1	0.02					0.05		0.05	0.1			0.02		0.1					0.1		0.02		0.1
S2	easement	28/06/2007																											
S2	easement	16/09/2008																											
S2	easement	15/10/2008																											
S2	easement	18/11/2008	16	96	210	0.02						0.0001		0.001	0.001			0.001		0.05							0.001		
S2	easement	12/12/2008	23	98	252	0.07								0.001				0.003		0.05							0.001		
S2	easement	22/01/2009																											
S2	easement	24/02/2009																											
S2	easement	19/03/2009																											
S2	easement	24/04/2009																											
S2	easement	19/05/2009	13	54	123	0.01						0.0001		0.001	0.001			0.002		0.05							0.001		
S2	easement	23/06/2009																											
S2	easement	23/07/2009																											
S2	easement	19/08/2009																											
S3	easement	22/03/2006																											
S3	easement	5/04/2006																											
S3	easement	17/05/2006																											
S3	easement	20/06/2006																											
S3	easement	19/07/2006																											
S3	easement	22/08/2006	16.47	58.6	192.8	0.1	0.02					0.05		0.05	0.1			0.02		0.1					0.1		0.02		0.1
S3	easement	27/09/2006	23.66	63.5	149.6	0.1	0.02					0.05		0.05	0.1			0.02		0.1					0.1		0.02		0.1
S3	easement	25/10/2006	23.2	66.6	178.6	0.1	0.02							0.05	0.1			0.02							0.1		0.02		0.1
S3	easement	15/11/2006																											
S3	easement	13/12/2006																											
S3	easement	10/01/2007																											
S3	easement	14/02/2007																											
S3	easement	14/03/2007																											
S3	easement	27/04/2007																											
S3	easement	22/05/2007	11	47	97	0.1	0.02					0.05		0.05	0.1			0.02		0.1					0.1		0.02		0.1
S3	easement	28/06/2007																											
S3	easement	16/09/2008																											
S3	easement	15/10/2008																											
S3	easement	18/11/2008																											

KIWEF Surface Water Monitoring Results - Easement Pond

ANALYTES											Cyanide			Total Recoverable Hydrocarbons					BTEX								
			Pb - Dissolved	Sb - Total	Se - Total	Sn - Total	Zn - Total	Zn - Dissolved	Hg - Total	Hg - Dissolved	Total Cyanide	Free Cyanide	WAD Cyanide	TRH C_6 - C_9	TRH C_{10} - C_{14}	TRH C_{15} - C_{28}	TRH C_{29} - C_{36}	Total TRH C_6 - C_{36}	Benzene	Toluene	Ethyl-benzene	Total Xylenes	Total PAHs	Naphthalene	Acenaphtylene	Acenaphthene	Fluorene
Units			mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L CN	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
ANZECC CRITERIA			0.0044	NC	0.005	NC	0.015	0.015	0.0001	0.0001	0.004	0.004	0.004	NC	NC	NC	NC	NC	0.5	0.18	0.08	0.2	NC	0.05	NC	NC	NC
Laboratory PQL *			0.01	0.001	0.002	0.001	0.01	0.01	0.00005	0.0004	0.005	0.005	0.005	0.1	0.1	0.2	0.2	0.6	0.001	0.001	0.001	0.003	0.003	0.0002	0.0002	0.0002	0.0002
		count	8	8	30	8	37	8	19	10	13	8	6	15	15	15	15	9	11	11	11	11	14	19	19	19	19
		90 %ile	0.020	0.003	0.020	0.001	0.044	0.039	0.0020	0.0004	0.005	0.010	0.004	0.10	0.10	0.53	0.50	1.28	0.0010	0.0020	0.0020	0.0030	0.0155	0.0010	0.0010	0.0010	0.0010
		80 %ile	0.016	0.003	0.020	0.001	0.023	0.026	0.0003	0.0004	0.005	0.010	0.004	0.05	0.10	0.50	0.26	1.20	0.0010	0.0020	0.0020	0.0030	0.0141	0.0010	0.0010	0.0010	0.0010
		average	0.007	0.002	0.014	0.001	0.021	0.019	0.0004	0.0002	0.005	0.006	0.004	0.04	0.07	0.22	0.18	0.70	0.0009	0.0012	0.0012	0.0022	0.0067	0.0005	0.0006	0.0005	0.0005
		20 %ile	0.001	0.001	0.010	0.001	0.006	0.008	0.0001	0.0001	0.004	0.004	0.004	0.01	0.05	0.10	0.05	0.26	0.0010	0.0010	0.0010	0.0020	0.0016	0.0001	0.0001	0.0001	0.0001
		10 %ile	0.001	0.001	0.002	0.001	0.005	0.007	0.0001	0.0001	0.004	0.004	0.004	0.01	0.04	0.10	0.05	0.26	0.0005	0.0005	0.0005	0.0015	0.0016	0.0001	0.0001	0.0001	0.0001
KS8/1	easment	20/08/1996	0.01		0.002		0.09	0.06	0.00002			0.01		0.2	0.2	0.6	0.6	1.6					0.0034	0.0002	0.0002	0.0002	0.0002
KS8/1	easment	13/08/1997	0.02		0.003		0.03	0.03	0.00031			0.01		0.1	0.1	0.5	0.5	1.2					0.003	0.0002	0.0002	0.0002	0.0002
KS8/1	easment	31/08/1998	0.02		0.002		0.06	0.01	0.00005			0.01		0.1	0.1	0.5	0.5	1.2					0.003	0.0002	0.0002	0.0002	0.0002
S1	easement	22/03/2006																									
S1	easement	5/04/2006																									
S1	easement	17/05/2006																									
S1	easement	20/06/2006																									
S1	easement	19/07/2006																									
S1	easement	22/08/2006			0.05		0.02																				
S1	easement	27/09/2006			0.02		0.02																				
S1	easement	25/10/2006					0.02																				
S1	easement	15/11/2006			0.02		0.02																				
S1	easement	13/12/2006																									
S1	easement	10/01/2007																									
S1	easement	14/02/2007																									
S1	easement	14/03/2007																									
S1	easement	27/04/2007																									
S1	easement	22/05/2007			0.04		0.03		0.002																		
S1	easement	28/06/2007																									
S1	easement	16/09/2008																									
S1	easement	15/10/2008																									
S1	easement	18/11/2008			0.01		0.005		0.0001																		
S1	easement	12/12/2008																									
S1	easement	22/01/2009																									
S1	easement	24/02/2009																									
S1	easement	19/03/2009																					0.0143	0.001	0.0013	0.001	0.001
S1	easement	24/03/2009																									
S1	easement	19/05/2009			0.01		0.006		0.0001																		
S1	easement	23/06/2009																									
S1	easement	23/07/2009																									
S1	easement	19/08/2009																									
S2	easement	22/03/2006																									
S2	easement	5/04/2006																									
S2	easement	17/05/2006																									
S2	easement	20/06/2006																									
S2	easement	19/07/2006																									
S2	easement	22/08/2006			0.02		0.02																				
S2	easement	27/09/2006			0.02		0.02																				
S2	easement	25/10/2006					0.02																				
S2	easement	15/11/2006			0.02		0.02																				
S2	easement	13/12/2006																									
S2	easement	10/01/2007																									
S2	easement	14/02/2007																									
S2	easement	14/03/2007																									
S2	easement	27/04/2007																									
S2	easement	22/05/2007			0.02		0.02		0.002																		
S2	easement	28/06/2007																									
S2	easement	16/09/2008																									
S2	easement	15/10/2008																									
S2	easement	18/11/2008			0.01		0.006		0.0001																		
S2	easement	12/12/2008					0.061																				
S2	easement	22/01/2009																									
S2	easement	24/02/2009																									
S2	easement	19/03/2009																					0.014	0.001	0.001	0.001	0.001
S2	easement	24/04/2009																									
S2	easement	19/05/2009			0.01		0.013		0.0001																		
S2	easement	23/06/2009																									
S2	easement	23/07/2009																									
S2	easement	19/08/2009																									
S3	easement	22/03/2006																									
S3	easement	5/04/2006																									
S3	easement	17/05/2006																									
S3	easement	20/06/2006																									
S3	easement	19/07/2006																									
S3	easement	22/08/2006			0.02		0.02																				
S3	easement	27/09/2006			0.02		0.02																				
S3	easement	25/10/2006					0.02																				
S3	easement	15/11/2006																									
S3	easement	13/12/2006																									
S3	easement	10/01/2007																									
S3	easement	14/02/2007																									
S3	easement	14/03/2007																									
S3	easement	27/04/2007																									
S3	easement	22/05/2007			0.02		0.02		0.002																		
S3	easement	28/06/2007																									
S3	easement	16/09/2008																									
S3	easement	15/10/2008																									
S3	easement	18/11/2008																									

KIWEF Surface Water Monitoring Results - Easement Pond

ANALYTES			Pb - Dissolved	Sb - Total	Se - Total	Sn - Total	Zn - Total	Zn - Dissolved	Hg - Total	Hg - Dissolved	Total Cyanide	Free Cyanide	WAD Cyanide	TRH C_6 - C_9	TRH C_{10} - C_{14}	TRH C_{15} - C_{28}	TRH C_{29} - C_{36}	Total TRH C_6 - C_{36}	Benzene	Toluene	Ethyl-benzene	Total Xylenes	Total PAHs	Naphthalene	Acenaphtylene	Acenaphthene	Fluorene
Units			mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L CN	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
ANZECC CRITERIA			0.0044	NC	0.005	NC	0.015	0.015	0.0001	0.0001	0.004	0.004	0.004	NC	NC	NC	NC	NC	0.5	0.18	0.08	0.2	NC	0.05	NC	NC	NC
Laboratory PQL *			0.01	0.001	0.002	0.001	0.01	0.01	0.00005	0.0004	0.005	0.005	0.005	0.1	0.1	0.2	0.2	0.6	0.001	0.001	0.001	0.003	0.003	0.0002	0.0002	0.0002	0.0002
S3	easement	12/12/2008																									
S3	easement	22/01/2009																									
S3	easement	24/02/2009					0.017																				
S3	easement	19/03/2009			0.01		0.005		0.0001														0.014	0.001	0.001	0.001	0.001
S3	easement	24/04/2009																									
S3	easement	19/05/2009			0.01		0.016		0.0001																		
S3	easement	23/06/2009																									
S3	easement	23/07/2009																									
S3	easement	19/08/2009																									
SW114	easement	11/05/2011			0.001		0.011		0.0001		0.018			0.01	0.05	0.1	0.1		0.001	0.001	0.001	0.003	0.0016	0.0001	0.0001	0.0001	0.0001
SW114	easement	8/03/2012			0.001		0.001		0.00005		0.004	0.004	0.004						0.000001	0.000001	0.000001	0.000003		0.0001	0.0001	0.0001	0.0001
SW114	easement	27/06/2012		0.001	0.01	0.001	0.005		0.0001																		
SW114	easement	26/07/2012		0.001	0.01	0.001	0.008		0.0001		0.005	0.004	0.004	0.02	0.05	0.1	0.05		0.001	0.002	0.002	0.002		0.001	0.001	0.001	0.001
SW114	easement	28/08/2012		0.001	0.01	0.001	0.005			0.0001																	
SW114	easement	27/09/2012		0.001	0.01	0.001	0.008			0.0001																	
SW114	easement	25/10/2012		0.001	0.01	0.001	0.006			0.0001	0.004	0.004	0.004	0.02	0.05	0.1	0.05		0.001	0.002	0.002	0.002		0.001	0.001	0.001	0.001
SW114	easement	27/11/2012		0.003	0.01	0.001	0.034			0.0001																	
SW114	easement	11/12/2012		0.002	0.01	0.001	0.024			0.0001	0.004	0.004	0.004	0.02	0.05	0.1	0.05		0.001	0.002	0.002	0.002		0.001	0.001	0.001	0.001
SW114	easement	14/12/2012		0.004	0.01	0.001	0.06			0.0001	0.004	0.004	0.004	0.02	0.05	0.1	0.05		0.001	0.002	0.002	0.002		0.001	0.001	0.001	0.001
SW7	easement	25/05/2007					0.005		0.0001		0.005			0.025	0.025	0.1	0.1	0.25					0.016	0.001	0.001	0.001	0.001
SW8	easement	25/05/2007					0.005		0.0001		0.005			0.025	0.025	0.55	0.17	0.77					0.016	0.001	0.001	0.001	0.001
SW501	easement	4/12/2008	0.001					0.009		0.0001	0.005			0.04	0.1	0.2	0.2	0.54	0.0005	0.0005	0.0005	0.0015	0.0016	0.0001	0.0001	0.0001	0.0001
SW501	easement	24/04/2009	0.001					0.003		0.0004	0.004			0.01	0.05	0.1	0.1	0.26	0.001	0.001	0.001	0.003	0.0016	0.0001	0.0001	0.0001	0.0001
SW501	easement	17/08/2009	0.001					0.009		0.0004	0.004			0.01	0.05	0.1	0.1	0.26	0.001	0.001	0.001	0.003	0.0016	0.0001	0.0001	0.0001	0.0001
SW501	easement	17/09/2009	0.001					0.019		0.0004	0.004			0.01	0.05	0.1	0.1	0.26	0.001	0.001	0.001	0.003	0.0016	0.0001	0.0001	0.0001	0.0001
SW501	easement	11/11/2009	0.001					0.008	0.0004		0.004		0.004	0.01	0.05	0.1	0.1		0.001	0.001	0.001	0.003	0.0016	0.0001	0.0001	0.0001	0.0001

KIWEF Surface Water Monitoring Results - Easement Pond

ANALYTES			Polycyclic Aromatic Hydrocarbons												Organochlorine/Organophosphate Pesticides					Total PCBs
			Phenanthrene	Anthracene	Fluoranthene	Pyrene	Benz(a)anthracene	Chrysene	Benzo(b)&(k)fluoranthene	Benzo(a)pyrene	Indeno(1.2.3-cd)pyrene	Dibenzo(ah)anthracene	Benzo(ghi)perylene	Phenols	Total OCPs	Aldrin + Dieldrin	Chlordane	DDT	Heptachlor	
Units			mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
ANZECC CRITERIA			0.0006	0.00001	0.001	NC	NC	NC	NC	0.0001	NC	NC	NC	0.4	NC	NC	0.00003	0.000006	0.00001	NC
Laboratory PQL *			0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.001	0.00002	0.00002	0.00001	0.00002	0.00002	0.09
		count	19	19	19	19	19	19	14	19	19	19	19	14	1	1	1	1	1	1
		90 %ile	0.0010	0.0010	0.0010	0.0010	0.0010	0.0010	0.0017	0.0006	0.0010	0.0010	0.0010	0.050	0.000	0.000	0.000	0.000	0.000	0.001
		80 %ile	0.0010	0.0010	0.0010	0.0010	0.0010	0.0010	0.0010	0.0005	0.0010	0.0010	0.0010	0.050	0.000	0.000	0.000	0.000	0.000	0.001
		average	0.0006	0.0005	0.0005	0.0005	0.0005	0.0005	0.0006	0.0004	0.0005	0.0005	0.0005	0.040	0.000	0.000	0.000	0.000	0.000	0.001
		20 %ile	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0002	0.0001	0.0001	0.0001	0.0001	0.006	0.000	0.000	0.000	0.000	0.000	0.001
		10 %ile	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0002	0.0001	0.0001	0.0001	0.0001	0.001	0.000	0.000	0.000	0.000	0.000	0.001
KS8/1	easment	20/08/1996	0.0005	0.0002	0.0003	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.001						
KS8/1	easment	13/08/1997	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.001						
KS8/1	easment	31/08/1998	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.001						
S1	easement	22/03/2006																		
S1	easement	5/04/2006																		
S1	easement	17/05/2006																		
S1	easement	20/06/2006																		
S1	easement	19/07/2006																		
S1	easement	22/08/2006																		
S1	easement	27/09/2006																		
S1	easement	25/10/2006																		
S1	easement	15/11/2006																		
S1	easement	13/12/2006																		
S1	easement	10/01/2007																		
S1	easement	14/02/2007																		
S1	easement	14/03/2007																		
S1	easement	27/04/2007																		
S1	easement	22/05/2007																		
S1	easement	28/06/2007																		
S1	easement	16/09/2008																		
S1	easement	15/10/2008																		
S1	easement	18/11/2008																		
S1	easement	12/12/2008																		
S1	easement	22/01/2009																		
S1	easement	24/02/2009																		
S1	easement	19/03/2009	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.0005	0.001	0.001	0.001							
S1	easement	24/03/2009																		
S1	easement	19/05/2009																		
S1	easement	23/06/2009																		
S1	easement	23/07/2009																		
S1	easement	19/08/2009																		
S2	easement	22/03/2006																		
S2	easement	5/04/2006																		
S2	easement	17/05/2006																		
S2	easement	20/06/2006																		
S2	easement	19/07/2006																		
S2	easement	22/08/2006																		
S2	easement	27/09/2006																		
S2	easement	25/10/2006																		
S2	easement	15/11/2006																		
S2	easement	13/12/2006																		
S2	easement	10/01/2007																		
S2	easement	14/02/2007																		
S2	easement	14/03/2007																		
S2	easement	27/04/2007																		
S2	easement	22/05/2007																		
S2	easement	28/06/2007																		
S2	easement	16/09/2008																		
S2	easement	15/10/2008																		
S2	easement	18/11/2008																		
S2	easement	12/12/2008																		
S2	easement	22/01/2009																		
S2	easement	24/02/2009																		
S2	easement	19/03/2009	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.0005	0.001	0.001	0.001							
S2	easement	24/04/2009																		
S2	easement	19/05/2009																		
S2	easement	23/06/2009																		
S2	easement	23/07/2009																		
S2	easement	19/08/2009																		
S3	easement	22/03/2006																		
S3	easement	5/04/2006																		
S3	easement	17/05/2006																		
S3	easement	20/06/2006																		
S3	easement	19/07/2006																		
S3	easement	22/08/2006																		
S3	easement	27/09/2006																		
S3	easement	25/10/2006																		
S3	easement	15/11/2006																		
S3	easement	13/12/2006																		
S3	easement	10/01/2007																		
S3	easement	14/02/2007																		
S3	easement	14/03/2007																		
S3	easement	27/04/2007																		
S3	easement	22/05/2007																		
S3	easement	28/06/2007																		
S3	easement	16/09/2008																		
S3	easement	15/10/2008																		
S3	easement	18/11/2008																		

KIWEF Surface Water Monitoring Results - Easement Pond

ANALYTES			Phenanthrene	Anthracene	Fluoranthene	Pyrene	Benz(a)anthracene	Chrysene	Benzo(b)&(k)fluoranthene	Benzo(a)pyrene	Indeno(1.2.3-cd)pyrene	Dibenzo(ah)anthracene	Benzo(ghi)perylene	Phenols	Total OCPs	Aldrin + Dieldrin	Chlordane	DDT	Heptachlor	Total PCBs
Units			mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
ANZECC CRITERIA			0.0006	0.00001	0.001	NC	NC	NC	NC	0.0001	NC	NC	NC	0.4	NC	NC	0.00003	0.000006	0.00001	NC
Laboratory PQL *			0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.001	0.00002	0.00002	0.00001	0.00002	0.00002	0.09
S3	easement	12/12/2008																		
S3	easement	22/01/2009																		
S3	easement	24/02/2009																		
S3	easement	19/03/2009	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.0005	0.001	0.001	0.001							
S3	easement	24/04/2009																		
S3	easement	19/05/2009																		
S3	easement	23/06/2009																		
S3	easement	23/07/2009																		
S3	easement	19/08/2009																		
SW114	easement	11/05/2011	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0002	0.0001	0.0001	0.0001	0.0001	0.1						
SW114	easement	8/03/2012	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001		0.0001	0.0001	0.0001	0.0001	0.05						
SW114	easement	27/06/2012																		
SW114	easement	26/07/2012	0.001	0.001	0.001	0.001	0.001	0.001		0.0005	0.001	0.001	0.001	0.05						
SW114	easement	28/08/2012																		
SW114	easement	27/09/2012																		
SW114	easement	25/10/2012	0.001	0.001	0.001	0.001	0.001	0.001		0.0005	0.001	0.001	0.001	0.05						
SW114	easement	27/11/2012																		
SW114	easement	11/12/2012	0.001	0.001	0.001	0.001	0.001	0.001		0.0005	0.001	0.001	0.001	0.05						
SW114	easement	14/12/2012	0.001	0.001	0.001	0.001	0.001	0.001		0.0005	0.001	0.001	0.001	0.05						
SW7	easement	25/05/2007	0.001	0.001	0.001	0.001	0.001	0.001	0.002	0.001	0.001	0.001	0.001							
SW8	easement	25/05/2007	0.001	0.001	0.001	0.001	0.001	0.001	0.002	0.001	0.001	0.001	0.001							
SW501	easement	4/12/2008	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0002	0.0001	0.0001	0.0001	0.0001	0.01	0.00038	0.00002	0.00002	0.00001	0.00002	0.0008
SW501	easement	24/04/2009	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0002	0.0001	0.0001	0.0001	0.0001	0.05						
SW501	easement	17/08/2009	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0002	0.0001	0.0001	0.0001	0.0001	0.05						
SW501	easement	17/09/2009	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0002	0.0001	0.0001	0.0001	0.0001	0.05						
SW501	easement	11/11/2009	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0002	0.0001	0.0001	0.0001	0.0001	0.05						

KIWEF Surface Water Monitoring Results - Eastern Pond

ANALYTES			Basic			Alkalinity		Anions								Cations								
			Conductivity	Turbidity	TDS	Carbonate CO_3^-	Bicarbonate HCO_3^-	Chloride	Ammonia	Sulphate SO_4	Nitrate as N	NO_x ($NO_2 + NO_3$)	Total Kjeldahl Nitrogen as N	Total Nitrogen as N	Total Phosphorus	Na	Mg	K	Ca	As - Total	As - Dissolved	Cd -Total	Cd - Dissolved	Cr - Total
Units			mS/cm	NTU	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
ANZECC CRITERIA			NC	10	NC	NC	NC	NC	0.91	NC	0.7	0.015	NC	0.3	0.03	NC	NC	NC	NC	0.013	0.013	0.0007	0.0007	0.0044
Laboratory PQL *			1	0.1	5	5	5	0.1	0.01	0.4	0.05	0.05	0.1	0.1	0.01	0.1	0.1	0.1	0.1	0.005	0.001	0.0005	0.0001	0.005
count			2	3	1	3	3	3	3	3	3	3	3	3	2	3	3	3	3	3	3	3	3	3
90 %ile			6.79	23.8	1200	5	308	2140	0.038	108	0.53	0.534	2.6	2.8	0.068	1086	28.6	63.6	189.2	0.005	0.0038	0.0005	0.00018	0.005
80 %ile			6.28	21.6	1200	5	286	1880	0.036	87	0.40	0.408	2.2	2.5	0.066	972	25.2	60.2	158.4	0.005	0.0036	0.0005	0.00016	0.005
average			5	15	1200	5	237	1310	0.027	54	0.23	0.233	1.6	1.8	0.06	737	19	51	113	0.005	0.0027	0.0005	0.00013	0.005
20 %ile			3	8	1200	5	184	698	0.018	15	0.01	0.018	0.8	1.1	0.054	480	11.88	41.6	58.2	0.005	0.0018	0.0005	0.0001	0.005
10 %ile			3	5	1200	5	172	564	0.014	13	0.01	0.014	0.8	0.9	0.052	430	10.84	38.8	55.6	0.005	0.0014	0.0005	0.0001	0.005
	Eastern Ponds	27/02/2012	2.2	2.7	1200	5	160	430	0.01	22	0.66	0.66	0.8	1.5	0.05	380	9.8	36	53	0.005	0.003	0.0005	0.0002	0.005
	Eastern Ponds	29/11/2012		15		5	330	1100	0.03	11	0.02	0.03	0.8	0.8		630	15	50	66	0.005	0.004	0.0005	0.0001	0.005
	Eastern Ponds	11/01/2013	7.3	26		5	220	2400	0.04	130	0.01	0.01	3.1	3.1	0.07	1200	32	67	220	0.005	0.001	0.0005	0.0001	0.005

KIWEF Surface Water Monitoring Results - Eastern Pond

ANALYTES			Metals													Total Recoverable Hydrocarbons				BTEX					
			Cr - Dissolved	Cu -Total	Cu - Dissolved	Mo - Total	Mo - Dissolved	Ni - Total	Ni - Dissolved	Pb - Total	Pb - Dissolved	Zn - Total	Zn - Dissolved	Hg - Total	Hg - Dissolved	TRH C_6 - C_9	TRH C_{10} - C_{14}	TRH C_{15} - C_{28}	TRH C_{29} - C_{36}	Benzene	Toluene	Ethyl-benzene	Total Xylenes	Naphthalene	Acenaphtylene
Units			mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
ANZECC CRITERIA			0.0044	0.0013	0.0013	0.023	0.023	0.007	0.007	0.0044	0.0044	0.015	0.015	0.0001	0.0001	NC	NC	NC	NC	0.5	0.18	0.08	0.2	0.05	NC
Laboratory PQL *			0.001	0.005	0.001	0.005	0.001	0.005	0.001	0.005	0.001	0.005	0.005	0.0001	0.0001	0.02	0.05	0.1	0.1	0.001	0.001	0.001	0.003	0.001	0.001
		count	3	3	3	1	1	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
		90 %ile	0.001	0.005	0.002	0.047	0.038	0.005	0.001	0.007	0.001	0.0442	0.0386	0.00010	0.00010	0.020	0.050	0.100	0.100	0.001	0.001	0.001	0.003	0.0010	0.0010
		80 %ile	0.001	0.005	0.002	0.047	0.038	0.005	0.001	0.007	0.001	0.037	0.030	0.00010	0.00010	0.020	0.050	0.100	0.100	0.001	0.001	0.001	0.003	0.0010	0.0010
		average	0.001	0.005	0.001	0.047	0.038	0.005	0.001	0.006	0.001	0.024	0.019	0.00010	0.00010	0.020	0.050	0.100	0.100	0.001	0.001	0.001	0.003	0.0010	0.0010
		20 %ile	0.001	0.005	0.001	0.047	0.038	0.005	0.001	0.005	0.001	0.010	0.005	0.00010	0.00010	0.020	0.050	0.100	0.100	0.001	0.001	0.001	0.003	0.0010	0.0010
		10 %ile	0.001	0.005	0.001	0.047	0.038	0.005	0.001	0.005	0.001	0.007	0.005	0.00010	0.00010	0.020	0.050	0.100	0.100	0.001	0.001	0.001	0.003	0.0010	0.0010
	Eastern Ponds	27/02/2012	0.001	0.005	0.002			0.005	0.001	0.005	0.001	0.005	0.005	0.0001	0.0001	0.02	0.05	0.1	0.1	0.001	0.001	0.001	0.003	0.001	0.001
	Eastern Ponds	29/11/2012	0.001	0.005	0.001			0.005	0.001	0.005	0.001	0.017	0.005	0.0001	0.0001	0.02	0.05	0.1	0.1	0.001	0.001	0.001	0.003	0.001	0.001
	Eastern Ponds	11/01/2013	0.001	0.005	0.001	0.047	0.038	0.005	0.001	0.008	0.001	0.051	0.047	0.0001	0.0001	0.02	0.05	0.1	0.1	0.001	0.001	0.001	0.003	0.001	0.001

KIWEF Surface Water Monitoring Results - Eastern Pond

ANALYTES			Polycyclic Aromatic Hydrocarbons												
			Acenaphthene	Fluorene	Phenanthrene	Anthracene	Fluoranthene	Pyrene	Benz(a)anthracene	Chrysene	Benzo(b)&(k)fluoranthene	Benzo(a)pyrene	Indeno(1.2.3-cd)pyrene	Dibenzo(ah)anthracene	Benzo(ghi)perylene
Units			mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
ANZECC CRITERIA			NC	NC	0.0006	0.00001	0.001	NC	NC	NC	NC	0.0001	NC	NC	NC
Laboratory PQL *			0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.002	0.001	0.001	0.001	0.001
		count	3	3	3	3	3	3	3	3	3	3	3	3	3
		90 %ile	0.0010	0.0010	0.0010	0.0010	0.0010	0.0010	0.0010	0.0010	0.0020	0.0010	0.0010	0.0010	0.0010
		80 %ile	0.0010	0.0010	0.0010	0.0010	0.0010	0.0010	0.0010	0.0010	0.0020	0.0010	0.0010	0.0010	0.0010
		average	0.0010	0.0010	0.0010	0.0010	0.0010	0.0010	0.0010	0.0010	0.0020	0.0010	0.0010	0.0010	0.0010
		20 %ile	0.0010	0.0010	0.0010	0.0010	0.0010	0.0010	0.0010	0.0010	0.0020	0.0010	0.0010	0.0010	0.0010
		10 %ile	0.0010	0.0010	0.0010	0.0010	0.0010	0.0010	0.0010	0.0010	0.0020	0.0010	0.0010	0.0010	0.0010
	Eastern Ponds	27/02/2012	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.002	0.001	0.001	0.001	0.001
	Eastern Ponds	29/11/2012	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.002	0.001	0.001	0.001	0.001
	Eastern Ponds	11/01/2013	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.002	0.001	0.001	0.001	0.001

KIWEF Surface Water Monitoring Results - K2 Pond

ANALYTES			Basic				Alkalinity				Organic Carbon	
			pH	Conductivity	TSS	TDS	Hydroxide OH-	Carbonate CO_3^-	Bicarbonate HCO_3^-	Hardness (as $CaCO_3$)	DOC	TOC
Units			pH units	mS/cm	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
ANZECC CRITERIA			7 to 8.5	NC	NC	NC	NC	NC	NC	NC	NC	NC
Laboratory PQL *			-	1	5	5	2	2	0	1	1	1
		count	19	19	6	7	2	2	2	11	2	2
		90 %ile	8.8	5928	648	2220	2	2	1071	230	50.7	83.1
		80 %ile	8.5	3964	96	1760	2	2	1042	210	49.4	80.2
		average	8.1	3431	240	1500	2	2	955	246	46	72
		20 %ile	7.7	1800	23	1200	2	2	868	80	42	63
		10 %ile	7.5	1554	15	1160	2	2	839	72	40	60
KS1/3	K2 Pond/Wetland	13/08/1997	8	4800	6	2700						
KS1/3	K2 Pond/Wetland	31/08/1998	8.6	2300	1200							
KS1/3	K2 Pond/Wetland	29/10/2008	8.0	1368								
KS1/3	K2 Pond/Wetland	8/12/2008	8.4	3000								
KS1/3	K2 Pond/Wetland	9/01/2009	7.7	10440								
KS1/3	K2 Pond/Wetland	3/03/2009	7.9	3940								
KS1/3	K2 Pond/Wetland	7/09/2009	7.1	2334								
KS1/3	K2 Pond/Wetland	16/04/2012	8.8	2340								
SW509	K2 Pond/Wetland	8/12/2008	7.6	4000			2	2	810	230	39	57
SW509	K2 Pond/Wetland	24/04/2009	7.7	1800						80		
SW509	K2 Pond/Wetland	17/08/2009	7.7	1900		1200				140		
SW509	K2 Pond/Wetland	17/09/2009	7.9	2400	30	1200				150		
SW509	K2 Pond/Wetland	11/11/2009	8.5	3100	23	1900				210		
SW510	K2 Pond/Wetland	8/12/2008	7.6	13000			2	2	1100	1500	52	86
SW510	K2 Pond/Wetland	24/04/2009	9.4	1600						31		
SW510	K2 Pond/Wetland	17/08/2009	9	1800		1100				110		
SW510	K2 Pond/Wetland	17/09/2009	8.3	2000	96	1200				72		
SW510	K2 Pond/Wetland	11/11/2009	8.1	2100	82	1200				96		
SW514A	K2 Pond/Wetland	24/04/2009	6.8	960						83		

ANALYTES			Anions									
			Chloride	Fluoride F	Ammonia	Sulphide	Sulphur	Sulphate SO_4	Nitrate as N	Nitrite as N	NO_x ($NO_2 + NO_3$)	Total Phosphorus
Units			mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
ANZECC CRITERIA			NC	NC	0.91	0.001	NC	NC	0.7	NC	0.015	0.03
Laboratory PQL *			0.1	0.05	0.1	0.5	0.5	0.4	0.05	0.05	0.05	0.01
		count	4	4	19	6	2	8	4	4	4	4
		90 %ile	2980	2.25	0.600	0.5	181	229	0.205	0.205	0.410	1.083
		80 %ile	2260	2.10	0.452	0.5	162	156	0.160	0.160	0.320	0.966
		average	1573	1.78	0.499	0.5	105	126	0.093	0.093	0.185	0.673
		20 %ile	678	1.42	0.066	0.5	47	42	0.010	0.010	0.020	0.348
		10 %ile	579	1.36	0.026	0.5	28	13	0.010	0.010	0.020	0.324
KS1/3	K2 Pond/Wetland	13/08/1997	1300	1.9	0.1				0.01	0.01	0.02	
KS1/3	K2 Pond/Wetland	31/08/1998	480	1.5	0.1				0.01	0.01	0.02	
KS1/3	K2 Pond/Wetland	29/10/2008			0.42							
KS1/3	K2 Pond/Wetland	8/12/2008			0.01							
KS1/3	K2 Pond/Wetland	9/01/2009			0.09							
KS1/3	K2 Pond/Wetland	3/03/2009			0.01							
KS1/3	K2 Pond/Wetland	7/09/2009			0.6							
KS1/3	K2 Pond/Wetland	16/04/2012			0.03							
SW509	K2 Pond/Wetland	8/12/2008	810	2.4	0.03		9.1	9.9	0.1	0.1	0.2	
SW509	K2 Pond/Wetland	24/04/2009			0.1							
SW509	K2 Pond/Wetland	17/08/2009			0.1	0.5		150				
SW509	K2 Pond/Wetland	17/09/2009			0.5	0.5		97				0.81
SW509	K2 Pond/Wetland	11/11/2009			0.1	0.5		14				1.2
SW510	K2 Pond/Wetland	8/12/2008	3700	1.3	6.2		200	390	0.25	0.25	0.5	
SW510	K2 Pond/Wetland	24/04/2009			0.1							
SW510	K2 Pond/Wetland	17/08/2009			0.1	0.5		160				
SW510	K2 Pond/Wetland	17/09/2009			0.6	0.5		100				0.38
SW510	K2 Pond/Wetland	11/11/2009			0.1	0.5		85				0.3
SW514A	K2 Pond/Wetland	24/04/2009			0.2							

ANALYTES			Cations									
			Na	Mg	K	Ca	Al - Total	As - Total	As - Dissolved	Cd -Total	Cd - Dissolved	Co - Total
Units			mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
ANZECC CRITERIA			NC	NC	NC	NC	0.055	0.013	0.013	0.0007	0.0007	0.001
Laboratory PQL *			0.1	0.1	0.2	0.1	0.01	0.002		0.01	0.01	0.01
		count	2	11	2	11	6	2	11	4	11	2
		90 %ile	2149	33	109	39	1.550	0.002	0.008	0.0100	0.0100	0.0910
		80 %ile	1998	29	99	38	1.500	0.002	0.007	0.0100	0.0001	0.0820
		average	1545	33	67	45	0.655	0.002	0.005	0.0051	0.0019	0.0550
		20 %ile	1092	9	34	17	0.200	0.002	0.003	0.0001	0.0001	0.0280
		10 %ile	941	8	24	15	0.175	0.002	0.002	0.0001	0.0001	0.0190
KS1/3	K2 Pond/Wetland	13/08/1997						0.002		0.01	0.01	0.1
KS1/3	K2 Pond/Wetland	31/08/1998						0.002		0.01	0.01	0.01
KS1/3	K2 Pond/Wetland	29/10/2008										
KS1/3	K2 Pond/Wetland	8/12/2008										
KS1/3	K2 Pond/Wetland	9/01/2009										
KS1/3	K2 Pond/Wetland	3/03/2009										
KS1/3	K2 Pond/Wetland	7/09/2009										
KS1/3	K2 Pond/Wetland	16/04/2012										
SW509	K2 Pond/Wetland	8/12/2008	790	33	13	39			0.007		0.0001	
SW509	K2 Pond/Wetland	24/04/2009		8.3		18			0.004		0.0001	
SW509	K2 Pond/Wetland	17/08/2009		17		29	0.15		0.002		0.0001	
SW509	K2 Pond/Wetland	17/09/2009		19		29	0.23		0.004		0.0001	
SW509	K2 Pond/Wetland	11/11/2009		29		38	0.2		0.004	0.0001		
SW510	K2 Pond/Wetland	8/12/2008	2300	210	120	260			0.01		0.0001	
SW510	K2 Pond/Wetland	24/04/2009		2.6		8.1			0.004		0.0001	
SW510	K2 Pond/Wetland	17/08/2009		14		22	0.25		0.003		0.0001	
SW510	K2 Pond/Wetland	17/09/2009		8.5		15	1.5		0.008		0.0001	
SW510	K2 Pond/Wetland	11/11/2009		10		22	1.6		0.007	0.0001		
SW514A	K2 Pond/Wetland	24/04/2009		9.9		17			0.001		0.0001	

KIWEF Surface Water Monitoring Results - K2 Pond

ANALYTES			Metals																		
			Cr - Total	Cr - Dissolved	Cu -Total	Cu - Dissolved	Fe - Total	Fe - Dissolved	Mn - Total	Mn - Dissolved	Mo - Total	Mo - Dissolved	Ni - Total	Ni - Dissolved	Pb - Total	Pb - Dissolved	Se - Total	Zn - Total	Zn - Dissolved	Hg - Total	Hg - Dissolved
Units			mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
ANZECC CRITERIA			0.0044	0.0044	0.0013	0.0013	NC	NC	0.08	0.08	0.023	0.023	0.007	0.007	0.0044	0.0044	0.005	0.015	0.015	0.0001	0.0001
Laboratory PQL *			0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.001	0.01	0.001	0.01	0.01	0.002	0.01	0.01	0.00005	0.0004
		count	10	13	4	11	13	13	7	13	8	11	2	11	8	13	2	7	13	9	9
		90 %ile	0.020	0.009	0.062	0.010	3.892	0.656	2.094	1.060	0.023	0.040	0.100	0.003	0.021	0.016	0.002	0.099	0.038	0.00040	0.00040
		80 %ile	0.020	0.004	0.044	0.006	3.332	0.252	1.747	0.432	0.018	0.034	0.100	0.002	0.020	0.001	0.002	0.093	0.026	0.00022	0.00040
		average	0.008	0.003	0.027	0.004	2.653	0.262	0.913	0.355	0.012	0.019	0.100	0.002	0.009	0.004	0.002	0.055	0.016	0.00016	0.00033
		20 %ile	0.001	0.001	0.005	0.001	0.658	0.044	0.184	0.040	0.005	0.006	0.100	0.001	0.0014	0.001	0.002	0.016	0.003	0.00008	0.00028
		10 %ile	0.001	0.001	0.004	0.001	0.530	0.024	0.068	0.012	0.004	0.002	0.100	0.001	0.001	0.001	0.002	0.013	0.001	0.00005	0.00010
KS1/3	K2 Pond/Wetland	13/08/1997	0.02	0.01	0.02	0.01	0.53	0.11	0.08	0.07	0.03		0.1		0.02	0.02	0.002	0.06	0.04	0.00005	
KS1/3	K2 Pond/Wetland	31/08/1998	0.02	0.01	0.08	0.01	0.53	0.1	0.05	0.01	0.02		0.1		0.02	0.02	0.002	0.08	0.01	0.00005	
KS1/3	K2 Pond/Wetland	29/10/2008	0.005				13.5		1.99		0.016				0.023			0.104		**0.0001**	
KS1/3	K2 Pond/Wetland	8/12/2008	0.001				1.6		0.6		0.007				0.001			0.009		**0.0001**	
KS1/3	K2 Pond/Wetland	9/01/2009	0.02				2.78		2.25		0.012				0.003			0.022		**0.0001**	
KS1/3	K2 Pond/Wetland	3/03/2009	0.003				3.94		0.776		0.006				0.002			0.015		**0.0001**	
KS1/3	K2 Pond/Wetland	7/09/2009	0.001				1.86		0.645		0.004				0.004			0.096		**0.0001**	
KS1/3	K2 Pond/Wetland	16/04/2012	0.005								0.003				0.001						
SW509	K2 Pond/Wetland	8/12/2008		0.001		0.001		0.74		0.5		0.002		0.002		0.001			0.049		0.0001
SW509	K2 Pond/Wetland	24/04/2009		0.001		0.001		0.15		0.095		0.006		0.001		0.001			0.002		0.0004
SW509	K2 Pond/Wetland	17/08/2009		0.001		0.006	0.85	0.05		0.18		0.017		0.001		0.001			0.015		0.0004
SW509	K2 Pond/Wetland	17/09/2009		0.001		0.002	0.99	0.08		0.33		0.009		0.001		0.001			0.001		0.0004
SW509	K2 Pond/Wetland	11/11/2009	0.001	0.004	0.004		1.3	0.08		0.31		0.021		0.001		0.001			0.029	0.0004	
SW510	K2 Pond/Wetland	8/12/2008		0.003		0.001		0.32		1.6		0.012		0.002		0.001			0.014		0.0001
SW510	K2 Pond/Wetland	24/04/2009		0.001		0.001		0.02		0.01		0.022		0.001		0.001			0.001		0.0004
SW510	K2 Pond/Wetland	17/08/2009		0.001		0.003	0.41	0.01		0.02		0.049		0.002		0.001			0.005		0.0004
SW510	K2 Pond/Wetland	17/09/2009		0.001		0.002	2.5	0.04		0.11		0.034		0.004		0.001			0.021		0.0004
SW510	K2 Pond/Wetland	11/11/2009	0.001	0.004	0.005		3.7	0.1		0.18		0.04		0.003		0.001			0.007	0.0004	
SW514A	K2 Pond/Wetland	24/04/2009		0.001		0.003		1.6		1.2		0.001		0.002		0.001			0.015		0.0004

ANALYTES			Cyanide			Total Recoverable Hydrocarbons					BTEX				
			Total Cyanide	Free Cyanide	WAD Cyanide	TRH C_6 - C_9	TRH C_{10} - C_{14}	TRH C_{15} - C_{28}	TRH C_{29} - C_{36}	Total TRH C_6 - C_{36}	Benzene	Toluene	Ethyl-benzene	Total Xylenes	Total PAHs
Units			mg/L	mg/L CN	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
ANZECC CRITERIA			0.004	0.004	0.004	NC	NC	NC	NC	NC	0.5	0.18	0.08	0.2	NC
Laboratory PQL *			0.005	0.005	0.005	0.1	0.1	0.2	0.2	0.6	0.001	0.001	0.001	0.003	0.003
		count	17	3	3	13	13	13	13	11	11	11	11	11	14
		90 %ile	0.005	0.028	0.0088	0.09	0.10	0.44	0.44	1.20	0.0010	0.0010	0.0010	0.0030	0.003
		80 %ile	0.004	0.026	0.0076	0.04	0.10	0.20	0.20	0.54	0.0010	0.0010	0.0010	0.0030	0.002
		average	0.004	0.018	0.006	0.03	0.07	0.18	0.18	0.49	0.0009	0.0010	0.0009	0.0026	1.145
		20 %ile	0.004	0.011	0.004	0.01	0.05	0.10	0.10	0.26	0.0010	0.0010	0.0010	0.0030	0.002
		10 %ile	0.004	0.008	0.004	0.01	0.05	0.10	0.10	0.26	0.0005	0.0010	0.0005	0.0010	0.002
KS1/3	K2 Pond/Wetland	13/08/1997		0.03		0.1	0.1	0.5	0.5	1.2					0.003
KS1/3	K2 Pond/Wetland	31/08/1998		0.02		0.1	0.1	0.5	0.5	1.2					0.003
KS1/3	K2 Pond/Wetland	29/10/2008	0.004												
KS1/3	K2 Pond/Wetland	8/12/2008	0.004												
KS1/3	K2 Pond/Wetland	9/01/2009	0.004												
KS1/3	K2 Pond/Wetland	3/03/2009	0.004												
KS1/3	K2 Pond/Wetland	7/09/2009	0.004												
KS1/3	K2 Pond/Wetland	16/04/2012	0.005	0.005	0.01										**16**
SW509	K2 Pond/Wetland	8/12/2008	0.005			0.04	0.1	0.2	0.2	0.54	0.0005	0.002	0.0005	0.001	0.0016
SW509	K2 Pond/Wetland	24/04/2009	0.004			0.01	0.05	0.1	0.1	0.26	0.001	0.001	0.001	0.003	0.0016
SW509	K2 Pond/Wetland	17/08/2009	0.004			0.01	0.05	0.1	0.1	0.26	0.001	0.001	0.001	0.003	0.0016
SW509	K2 Pond/Wetland	17/09/2009	0.004			0.01	0.05	0.1	0.1	0.26	0.001	0.001	0.001	0.003	0.0016
SW509	K2 Pond/Wetland	11/11/2009	0.004		0.004	0.01	0.05	0.1	0.1		0.001	0.001	0.001	0.003	0.0016
SW510	K2 Pond/Wetland	8/12/2008	0.005			0.04	0.1	0.2	0.2	0.54	0.0005	0.0005	0.0005	0.001	0.0016
SW510	K2 Pond/Wetland	24/04/2009	0.004			0.01	0.05	0.13	0.1	0.29	0.001	0.001	0.001	0.003	0.0016
SW510	K2 Pond/Wetland	17/08/2009	0.004			0.01	0.05	0.1	0.1	0.26	0.001	0.001	0.001	0.003	0.0016
SW510	K2 Pond/Wetland	17/09/2009	0.004			0.01	0.05	0.1	0.1	0.26	0.001	0.001	0.001	0.003	0.0016
SW510	K2 Pond/Wetland	11/11/2009	0.004		0.004	0.01	0.05	0.1	0.1		0.001	0.001	0.001	0.003	0.0016
SW514A	K2 Pond/Wetland	24/04/2009	0.004			0.01	0.05	0.15	0.1	0.31	0.001	0.001	0.001	0.003	0.0016

KIWEF Surface Water Monitoring Results - K2 Pond

ANALYTES			Polycyclic Aromatic Hydrocarbons																Organochlorine/Organophosphate Pesticides					Total PCBs
			Naphthalene	Acenaphtylene	Acenaphthene	Fluorene	Phenanthrene	Anthracene	Fluoranthene	Pyrene	Benz(a)anthracene	Chrysene	Benzo(b)&(k)fluoranthene	Benzo(a)pyrene	Indeno(1.2.3-cd)pyrene	Dibenzo(ah)anthracene	Benzo(ghi)perylene	Phenols	Total OCPs	Aldrin + Dieldrin	Chlordane	DDT	Heptachlor	
Units			mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
ANZECC CRITERIA			0.05	NC	NC	NC	0.0006	0.00001	0.001	NC	NC	NC	NC	0.0001	NC	NC	NC	0.4	NC	NC	0.00003	0.000006	0.00001	NC
Laboratory PQL *			0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.001	0.00002	0.00002	0.00001	0.00002	0.00002	0.09
		count	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	19	2	2	2	2	2	2
		90 %ile	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.2240	0.0004	0.00002	0.00002	0.00001	0.00002	0.0008
		80 %ile	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0002	0.0001	0.0001	0.0001	0.0001	0.0880	0.0004	0.00002	0.00002	0.00001	0.00002	0.0008
		average	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0003	0.0002	0.0002	0.0002	0.0002	0.0785	0.0004	0.00002	0.00002	0.00001	0.00002	0.0008
		20 %ile	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0002	0.0001	0.0001	0.0001	0.0001	0.0100	0.0004	0.00002	0.00002	0.00001	0.00002	0.0008
		10 %ile	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0002	0.0001	0.0001	0.0001	0.0001	0.0082	0.0004	0.00002	0.00002	0.00001	0.00002	0.0008
KS1/3	K2 Pond/Wetland	13/08/1997	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.001						
KS1/3	K2 Pond/Wetland	31/08/1998	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.001						
KS1/3	K2 Pond/Wetland	29/10/2008																0.1						
KS1/3	K2 Pond/Wetland	8/12/2008																0.28						
KS1/3	K2 Pond/Wetland	9/01/2009																0.34						
KS1/3	K2 Pond/Wetland	3/03/2009																0.05						
KS1/3	K2 Pond/Wetland	7/09/2009																0.21						
KS1/3	K2 Pond/Wetland	16/04/2012	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.002	0.001	0.001	0.001	0.001	0.01						
SW509	K2 Pond/Wetland	8/12/2008	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0002	0.0001	0.0001	0.0001	0.0001	0.01	0.00035	0.00002	0.00002	0.00001	0.00002	0.0008
SW509	K2 Pond/Wetland	24/04/2009	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0002	0.0001	0.0001	0.0001	0.0001	0.05						
SW509	K2 Pond/Wetland	17/08/2009	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0002	0.0001	0.0001	0.0001	0.0001	0.05						
SW509	K2 Pond/Wetland	17/09/2009	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0002	0.0001	0.0001	0.0001	0.0001	0.05						
SW509	K2 Pond/Wetland	11/11/2009	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0002	0.0001	0.0001	0.0001	0.0001	0.08						
SW510	K2 Pond/Wetland	8/12/2008	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0002	0.0001	0.0001	0.0001	0.0001	0.01	0.00035	0.00002	0.00002	0.00001	0.00002	0.0008
SW510	K2 Pond/Wetland	24/04/2009	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0002	0.0001	0.0001	0.0001	0.0001	0.05						
SW510	K2 Pond/Wetland	17/08/2009	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0002	0.0001	0.0001	0.0001	0.0001	0.05						
SW510	K2 Pond/Wetland	17/09/2009	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0002	0.0001	0.0001	0.0001	0.0001	0.05						
SW510	K2 Pond/Wetland	11/11/2009	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0002	0.0001	0.0001	0.0001	0.0001	0.05						
SW514A	K2 Pond/Wetland	24/04/2009	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0002	0.0001	0.0001	0.0001	0.0001	0.05						

KIWEF Surface Water Monitoring Results - Long Pond

ANALYTES			Basic				Anions									Cations														
			pH	Conductivity	Turbidity	TSS	Chloride	Ammonia	Nitrate as N	Nitrite as N	NO_x ($NO_2 + NO_3$)	Total Kjeldahl Nitrogen as N	Total Nitrogen as N	Reactive Phosphorus as P	Total Phosphorus	Na	Mg	K	Ca	Al - Total	As - Total	Ba - Total	Be - Total	Bo - Total	Cd -Total	Cd - Dissolved	Co - Total	Cr - Total	Cr - Dissolved	Cu -Total
Units			pH units	µS/cm	NTU	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
ANZECC CRITERIA			7 to 8.5	NC	10	NC	NC	0.91	0.7	NC	0.015	NC	0.3	NC	0.03	NC	NC	NC	NC	0.055	0.013	NC	NC	0.37	0.0007	0.0007	0.001	0.0044	0.0044	0.0013
Laboratory PQL *			-	1	0.1	5	0.1	0.1	0.05	0.05	0.05	0.1	0.1	0.01	0.01	0.1	0.1	0.2	0.1	0.01	0.002	0.001	0.001	0.05	0.01	0.01	0.01	0.01	0.01	0.01
		count	56	56	15	27	26	37	15	15	26	17	17	6	17	17	17	17	17	17	25	15	15	15	24	13	22	55	10	27
		90 %ile	9.3	29900	239	270	14500	0.140	0.270	0.110	0.240	7.560	7.640	0.110	0.87	1444	91	85	79	5.82	0.009	0.11	0.001	2.10	0.0100	0.0100	0.019	0.014	0.010	0.024
		80 %ile	9.0	17930	81	77	11000	0.100	0.112	0.030	0.120	4.600	4.600	0.040	0.54	1226	62	58	74	1.12	0.004	0.07	0.001	2.07	0.0100	0.0100	0.010	0.010	0.010	0.010
		average	8.5	11166	71	70	5529	0.663	0.075	0.036	0.071	3.153	3.188	0.047	0.35	910	46	51	53	1.42	0.004	0.06	0.001	1.59	0.0043	0.0077	0.007	0.008	0.010	0.009
		20 %ile	7.9	3540	4	5	760	0.017	0.010	0.010	0.010	0.720	0.720	0.010	0.06	558	21	32	36	0.04	0.001	0.04	0.001	1.08	0.0001	0.0041	0.001	0.001	0.010	0.001
		10 %ile	7.8	2945	3	2	548	0.010	0.010	0.010	0.010	0.600	0.600	0.010	0.05	367	17	28	24	0.04	0.001	0.03	0.001	0.95	0.0001	0.0001	0.001	0.001	0.010	0.001
KS10/1	long pond	4/05/1990	9.6	18100		1	6880		0.01	0.01	0.02														0.01	0.01		0.01	0.01	0.01
KS10/1	long pond	5/12/1990	9	30900		39																			0.01	0.01		0.01	0.01	0.01
KS10/1	long pond	25/03/1991	7.6	54900		310	24100		0.01	0.01	0.02										0.002				0.01	0.01	0.04	0.01	0.01	0.01
KS10/1	long pond	22/08/1991	8.2	28900		22	11000		0.04	0.2	0.24										0.002				0.01	0.01	0.02	0.01	0.01	0.04
KS10/1	long pond	10/08/1992	9.4	24000		2	8100		0.01	0.01	0.02										0.002				0.01	0.01	0.01	0.01	0.01	0.01
KS10/1	long pond	30/11/1993	8.6	39100		11	14000		0.04	0.01	0.05										0.002				0.01	0.01	0.02	0.01	0.01	0.03
KS10/1	long pond	10/08/1994	9.1	33800		1	12000		0.03	0.01	0.04										0.002				0.01	0.01	0.01	0.01	0.01	0.01
KS10/1	long pond	10/08/1995	8.9	38200		2	25000		0.08	0.11	0.19										0.002				0.01	0.01	0.01	0.01	0.01	0.01
KS10/1	long pond	12/08/1996	8.9	40800		39	15000		0.3	0.11	0.41										0.002				0.01	0.01	0.01	0.01	0.01	0.03
KS10/1	long pond	12/08/1997	9	25300		2	9100		0.03	0.01	0.04										0.002				0.01	0.01	0.01	0.01	0.01	0.02
KS10/1	long pond	15/03/1999	9.9	11000				0.1																				0.01		
KS10/1	long pond	17/06/1999	8.4	8300				0.1																				0.006		
KS10/1	long pond	7/09/1999	8.1	7800				0.3																				0.03		
KS10/1	long pond	7/12/1999	8.4	12000				0.1																				0.02		
KS10/1	long pond	6/03/2000	8.4	17000				3.2																				0.01		
KS10/1	long pond	5/06/2000	8.6	7100				0.1																				0.01		
KS10/1	long pond	4/09/2000	8.8	8400				0.2																				0.03		
KS10/1	long pond	4/12/2000	9.3	8800				0.1																				0.01		
KS10/1	long pond	5/03/2001	No surface water																											
KS10/1	long pond	3/09/2001	9.2	6800				0.1																				0.04		
KS10/1	long pond	4/03/2002	8.8	5200				0.1																				0.026		
KS10/1	long pond	10/10/2002	8.3	8200				0.01																				0.015		
KS10/1	long pond	16/04/2003	No surface water																											
KS10/1	long pond	10/11/2003	9.08	10130				0.01																				0.01 (2)		
KS10/1	long pond	25/03/2004	8.64	5280				0.01																				0.01		
KS10/1	long pond	27/09/2004	8.09	3850				0.09																				0.001		
KS10/1	long pond	29/03/2005	9.07	3690				19.1																				0.008		
KS10/1	long pond	07/09/2005	8.41	3720				0.043																				0.001		
KS10/1	long pond	03/03/2006	8.06	3350				0.017																				0.001		
KS10/1	long pond	01/09/2006	8.37	3330				0.079																				0.001		
KS10/1	long pond	03/03/2007	8.06	3350				0.017																				0.001		
KS10/1	long pond	21/09/2007	7.8	3000				0.037																				0.001		
KS10/1	long pond	29/02/2008	7.5	2890				0.017																				0.001		
KS10/1	long pond	11/09/2008	8	5950				0.01																				0.001		
KS10/1	long pond	03/03/2009	6.6	17930				0.02																				0.001		
KS10/1	long pond	07/09/2009	7.9	25200				0.1																				0.003		
KS10/1	long pond	24/12/2010	8.9	4800				0.07																				0.005		
KS10/1	long pond	08/03/2012	8.3	2100		75	450	0.005			0.005	1.6	1.6		0.09	390	19	26	34	0.13	0.002					0.0001		0.001		0.001
KS10/1	long pond	03/04/2012	9.68	2800				0.06																				0.005		
KS10/1	long pond	27/06/2012	7.86	1820	4.6	8	389				0.02	0.7	0.7		0.09	333	20	22	56	0.03	0.001	0.056	0.001	0.59		0.0001		0.001		0.002
KS10/1	long pond	26/07/2012	8	2650	5.6	9	646	0.02	0.01	0.01	0.01	0.8	0.8	0.04	0.13	542	27	30	52	0.12	0.001	0.048	0.001	1.08		0.0001		0.001		0.003
KS10/1	long pond	28/08/2012	8.2	3130	5.9	23	681				0.01	1.3	1.3		0.25	622	30	34	53	0.36	0.002	0.038	0.001	1.49	0.0001		0.001	0.001		0.001
KS10/1	long pond	27/09/2012	8.17	3540	5	7	760				0.01	1.1	1.1		0.41	720	32	36	48	0.12	0.001	0.032	0.001	1.50	0.0001		0.001	0.001		0.001
KS10/1	long pond	25/10/2012	8.7	4320	50.0	77	884	0.04	0.01	0.01	0.01	4.8	4.8	0.18	0.98	874	33	45	42	0.88	0.004	0.046	0.001	1.98	0.0001		0.001	0.001		0.002
KS10/1	long pond	27/11/2012	9.0	5770	207.0	264	1170				0.02	3.8	3.8		0.55	1210	34	55	27	8.92	0.010	0.046	0.001	2.10	0.0006		0.002	0.012		0.01
KS10/1	long pond	11/12/2012	9.3	4920	260	252	939	0.04	0.29	0.01	0.29	17.7	18	0.01	1.75	1070	23	47	20	5.32	0.015	0.025	0.001	2.07	0.0002		0.002	0.005		0.008
KS10/1	long pond	14/12/2012	9.76	5280	483	380	1040	0.04	0.24	0.01	0.24	9.3	9.5	0.03	0.79	1230	14	50	14	6.57	0.021	0.037	0.001	2.72	0.0004		0.003	0.01		0.012
KS11/1	long pond	18/03/1999	No surface water																											
KS11/1	long pond	24/06/1999	7.8	4300				0.1																				0.01		
KS11/1	long pond	7/09/1999	8.2	4000				0.1																				0.01		
KS11/1	long pond	7/12/1999	No surface water																											
KS11/1	long pond	6/03/2000	No surface water																											
KS11/1	long pond	5/06/2000	Not sampled																											
KS11/1	long pond	11/12/2003	No surface water																											
KS11/1	long pond	25/03/2004	7.75	4990				0.01																				0.01		
KS11/1	long pond	07/09/2005	Not Sampled																											
KS11/1	long pond	03/03/2006	Not Sampled																											
KS11/1	long pond	1/09/2006	Not Sampled																											
KS11/1	long pond	08/03/2012	7.7	1900		280	400	0.005			0.005	6.4	6.4		0.5	320	13	32	59	0.12	0.002				0.0001		0.001	0.001		0.001
KS11/1	long pond	27/06/2012	7.89	4040	1.3	5	1040				0.02	0.3	0.3		0.01	750	42	45	80	0.02	0.001	0.055	0.001	0.87	0.0001		0.001	0.001		0.001
KS11/1	long pond	26/07/2012	7.9	4230	3.1	12	1130	0.04	0.01	0.01	0.01	0.6	0.6	0.01	0.05	844	46	48	82	0.04	0.001	0.054	0.001	1.09	0.0001		0.001	0.001		0.001
KS11/1	long pond	28/08/2012	7.8	4200	2.1	8	968				0.01	0.6	0.6		0.04	772	48	48	79	0.04	0.001	0.051	0.001	1.07	0.0001		0.001	0.001		0.001
KS11/1	long pond	27/09/2012	8.02	5320	4.3	10	1370				0.01	0.8	0.8		0.13	1050	66	59	72	0.12	0.001	0.062	0.001	1.37	0.0001		0.001	0.001		0.001
KS11/1	long pond	25/10/2012	8.3	6940	5.1	5	1800	0.04	0.01	0.01	0.01	0.9	0.9	0.01	0.06	1300	81	75	61	0.14	0.002	0.082	0.001	1.88	0.0001		0.001	0.001		0.001
KS11/1	long pond	27/11/2012	8.5	8740	23.0	37	2370				0.01	1.7	1.7		0.12	1660	106	101	56	1.18	0.007	0.123	0.001	2.09	0.0003		0.001	0.003		0.004
KS11/1	long pond	14/12/2012	8.54	9210	4.5	5	2540				0.12	1.2	1.3		0.07	1790	143	109	74	0.05	0.006	0.145	0.001	1.96	0.0001		0.001	0.001		0.001

KIWEF Surface Water Monitoring Results - Long Pond

ANALYTES			Metals																Cyanide			Total Recoverable Hydrocarbons					BTEX				
			Cu - Dissolved	Fe - Total	Fe - Dissolved	Hexavalent Chromium	Mn - Total	Mn - Dissolved	Mo - Total	Ni - Total	Pb - Total	Pb - Dissolved	Sb - Total	Se - Total	Sn - Total	Zn - Total	Zn - Dissolved	Hg - Total	Total Cyanide	Free Cyanide	WAD Cyanide	TRH C_6 - C_9	TRH C_{10} - C_{14}	TRH C_{15} - C_{28}	TRH C_{29} - C_{36}	Total TRH C_6 - C_{36}	Benzene	Toluene	Ethyl-benzene	Total Xylenes	Total PAHs
Units			mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L CN	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
ANZECC CRITERIA			0.0013	NC	NC	NC	0.08	0.08	0.023	0.007	0.0044	0.0044	NC	0.005	NC	0.015	0.015	0.0001	0.004	0.004	0.004	NC	NC	NC	NC	NC	0.5	0.18	0.08	0.2	NC
Laboratory PQL *			0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.001	0.002	0.001	0.01	0.01	0.00005	0.005	0.005	0.005	0.1	0.1	0.2	0.2	0.6	0.001	0.001	0.001	0.003	0.003
		count	10	53	9	8	52	9	54	25	56	10	15	25	15	53	10	52	35	26	10	11	11	11	11	5	8	8	8	8	31
		90 %ile	0.022	1.720	0.100	0.037	0.545	0.236	0.080	0.100	0.045	0.104	0.008	0.010	0.001	0.193	0.021	0.00010	0.045	0.016	0.005	0.20	0.20	0.60	0.60	1.60	0.001000	0.002000	0.002000	0.002000	0.0030
		80 %ile	0.020	0.946	0.088	0.010	0.401	0.020	0.057	0.020	0.020	0.060	0.003	0.010	0.001	0.073	0.012	0.00010	0.022	0.010	0.004	0.20	0.20	0.60	0.60	1.60	0.001000	0.002000	0.002000	0.002000	0.0030
		average	0.017	0.886	0.049	0.020	0.321	0.134	0.041	0.021	0.022	0.041	0.003	0.007	0.001	0.082	0.013	0.00009	0.015	0.011	0.005	0.08	0.10	0.37	0.31	1.36	0.000750	0.001500	0.001500	0.001501	0.5183
		20 %ile	0.010	0.210	0.010	0.007	0.069	0.010	0.010	0.001	0.001	0.010	0.001	0.002	0.001	0.006	0.010	0.00005	0.004	0.004	0.004	0.02	0.05	0.10	0.05	1.12	0.000401	0.000801	0.000801	0.000802	0.0015
		10 %ile	0.010	0.112	0.010	0.005	0.030	0.010	0.008	0.001	0.001	0.010	0.001	0.002	0.001	0.005	0.010	0.00005	0.004	0.004	0.004	0.02	0.05	0.10	0.05	0.96	0.000001	0.000001	0.000001	0.000003	0.0015
KS10/1	long pond	4/05/1990	0.01	0.28	0.06		0.01	0.01			0.01	0.02				0.01	0.01														
KS10/1	long pond	5/12/1990	0.01								0.01	0.14				0.01	0.01			0.022											
KS10/1	long pond	25/03/1991	0.01	0.94	0.08		1.1	1.1	0.03	0.02	0.01	0.01		0.002		0.07	0.01	0.00014		0.01											
KS10/1	long pond	22/08/1991	0.04	0.57	0.01		0.12	0.02	0.03	0.02	0.58	0.01		0.002		0.04	0.01	0.00001		0.008											
KS10/1	long pond	10/08/1992	0.02	0.17	0.01		0.03	0.01	0.01	0.1	0.04	0.04		0.002		0.01	0.01	0.00015		0.005											
KS10/1	long pond	30/11/1993	0.02	0.3	0.01		0.1	0.02	0.08	0.1	0.1	0.1		0.003		0.02	0.01	0.00028		0.005		0.1	0.1	0.3	0.3	0.8					0.0034
KS10/1	long pond	10/08/1994	0.01	0.11	0.02		0.02	0.02	0.01	0.1	0.01	0.01		0.002		0.01	0.02	0.00001		0.01		0.2	0.2	0.6	0.6	1.6					0.003
KS10/1	long pond	10/08/1995	0.01	0.21	0.05		0.02	0.01	0.01	0.1	0.05	0.05		0.002		0.02	0.01	0.00022		0.01		0.2	0.2	0.6	0.6	1.6					0.003
KS10/1	long pond	12/08/1996	0.02	0.4	0.1		0.05	0.01	0.03	0.01	0.02	0.01		0.002		0.06	0.01	0.00002		0.04		0.2	0.2	0.6	0.6	1.6					0.003
KS10/1	long pond	12/08/1997	0.02	0.12	0.1		0.01	0.01	0.02	0.01	0.02	0.02		0.002		0.03	0.03	0.00005		0.1		0.1	0.1	0.5	0.5	1.2					0.0032
KS10/1	long pond	15/03/1999		0.3			0.03		0.02		0.02					0.22		0.00005	0.01												0.003
KS10/1	long pond	17/06/1999		0.1			0.025		0.017		0.001					0.002		0.00005	0.005												0.003
KS10/1	long pond	7/09/1999		1.8			0.26		0.02		0.02					0.24		0.00005	0.011												0.003
KS10/1	long pond	7/12/1999		0.17			0.34		0.02		0.05					0.03		0.00006	0.04												0.00075
KS10/1	long pond	6/03/2000		1.4			0.19		0.06		0.05					0.56		0.00005	0.01												0.003
KS10/1	long pond	5/06/2000		0.63			0.03		0.05		0.05					0.2		0.00005	0.005	0.005											0.003
KS10/1	long pond	4/09/2000		0.32			0.07		0.1		0.002					1.6		0.00005	0.005	0.005											0.003
KS10/1	long pond	4/12/2000		0.95			0.14		0.04		0.002					0.03		0.00005	0.005	0.005											0.00282
KS10/1	long pond	5/03/2001																													
KS10/1	long pond	3/09/2001		0.11			0.035		0.01		0.002					0.2		0.00005	0.005	0.005											0.0016
KS10/1	long pond	4/03/2002		0.39			0.1		0.005		0.004					0.075		0.00005	0.03	0.005											0.0016
KS10/1	long pond	10/10/2002		0.54			0.3		0.016		0.003					0.03		0.00005	0.005	0.005											0.0016
KS10/1	long pond	16/04/2003																													
KS10/1	long pond	10/11/2003		0.61			0.174		0.049		0.002					0.011		0.0001		0.005											0.0015
KS10/1	long pond	25/03/2004		0.33			0.263		0.01		0.001					0.002		0.00005	0.006												0.0015
KS10/1	long pond	27/09/2004		1.8			3.95		0.013		0.004					0.029		0.0001	0.048												0.0015
KS10/1	long pond	29/03/2005		0.21			0.087		0.018		0.001					0.01		0.0001	0.005												0.0015
KS10/1	long pond	07/09/2005		0.28			0.205		0.026		0.001					0.007		0.0001	0.05												0.0015
KS10/1	long pond	03/03/2006		0.7			0.148		0.057		0.002					0.039		0.0001	0.083												0.0015
KS10/1	long pond	01/09/2006		0.95			0.101		0.03		0.004					0.038		0.0001	0.0205												0.0015
KS10/1	long pond	03/03/2007		0.7			0.148		0.057		0.002					0.039		0.0001	0.083												0.0015
KS10/1	long pond	21/09/2007		0.25			0.235		0.026		0.001					0.005		0.0001	0.004												0.0018
KS10/1	long pond	29/02/2008		0.71			0.433		0.017		0.001					0.012		0.0001	0.0318												0.0015
KS10/1	long pond	11/09/2008		0.1			0.06		0.038		0.002					0.005		0.0001	0.011												0.0015
KS10/1	long pond	03/03/2009		0.38			0.327		0.024		0.001					0.011		0.0001	0.004												
KS10/1	long pond	07/09/2009		0.7			1.06		0.022		0.003					0.042		0.0001	0.004												
KS10/1	long pond	24/12/2010							0.006		0.001								0.004	0.004	0.004										
KS10/1	long pond	08/03/2012		0.28		0.005	0.074		0.014	0.001	0.001			0.001		0.006		0.00005	0.004	0.004	0.004						0.000001	0.000001	0.000001	0.000003	
KS10/1	long pond	03/04/2012							0.01		0.005								0.005	0.005	0.01										16
KS10/1	long pond	27/06/2012		0.76			0.546		0.009	0.001	0.001		0.001	0.01	0.001	0.01		0.0001													
KS10/1	long pond	26/07/2012		0.6		0.01	0.273		0.024	0.002	0.001		0.001	0.01	0.001	0.008		0.0001	0.004	0.004	0.004	0.02	0.05	0.1	0.05		0.001	0.002	0.002	0.002	
KS10/1	long pond	28/08/2012		0.63			0.180		0.028	0.001	0.002		0.001	0.01	0.001	0.011		0.0001													
KS10/1	long pond	27/09/2012		0.53			0.210		0.020	0.001	0.001		0.001	0.01	0.001	0.007		0.0001													
KS10/1	long pond	25/10/2012		1.36		0.01	0.278		0.079	0.001	0.004		0.001	0.01	0.001	0.017		0.0001	0.004	0.004	0.004	0.02	0.05	0.12	0.25		0.001	0.002	0.002	0.002	
KS10/1	long pond	27/11/2012		7.5			0.295		0.227	0.012	0.023		0.006	0.01	0.001	0.123		0.0001													
KS10/1	long pond	11/12/2012		5.16		0.01	0.200		0.241	0.009	0.023		0.01	0.01	0.001	0.104		0.0001	0.004	0.004	0.004	0.02	0.05	0.58	0.2		0.001	0.002	0.002	0.002	
KS10/1	long pond	14/12/2012		6.64		0.1	0.257		0.260	0.012	0.032		0.012	0.01	0.001	0.163		0.0001	0.004	0.004	0.004	0.02	0.05	0.48	0.22		0.001	0.002	0.002	0.002	
KS11/1	long pond	18/03/1999																													
KS11/1	long pond	24/06/1999		0.1			0.069		0.005		0.001					0.015		0.00005	0.005												0.003
KS11/1	long pond	7/09/1999		2.6			0.29		0.01		0.02					0.1		0.00005	0.005												0.003
KS11/1	long pond	7/12/1999																													
KS11/1	long pond	6/03/2000																													
KS11/1	long pond	5/06/2000																													
KS11/1	long pond	11/12/2003																													
KS11/1	long pond	25/03/2004		0.23			0.416		0.001		0.001					0.002		0.00005	0.005												0.0015
KS11/1	long pond	07/09/2005																													
KS11/1	long pond	03/03/2006																													
KS11/1	long pond	1/09/2006																													
KS11/1	long pond	08/03/2012		0.66		0.005	0.15		0.005	0.001	0.001			0.001		0.006		0.00005	0.004	0.004	0.004						0.000001	0.000001	0.000001	0.000003	
KS11/1	long pond	27/06/2012		0.18			0.082		0.008	0.001	0.001		0.001	0.01	0.001	0.005		0.0001													
KS11/1	long pond	26/07/2012		0.29		0.01	0.505		0.01	0.002	0.001		0.001	0.01	0.001	0.006		0.0001	0.004	0.004	0.004	0.02	0.05	0.1	0.05		0.001	0.002	0.002	0.002	
KS11/1	long pond	28/08/2012		0.25			0.451		0.011	0.001	0.001		0.001	0.01	0.001	0.006		0.0001													
KS11/1	long pond	27/09/2012		0.36			0.534		0.03	0.001	0.001		0.001	0.01	0.001	0.005		0.0001													
KS11/1	long pond	25/10/2012		0.21		0.01	0.301		0.063	0.001	0.001		0.001	0.01	0.001	0.005		0.0001	0.004	0.004	0.004	0.02	0.05	0.1	0.05		0.001	0.002	0.002	0.002	
KS11/1	long pond	27/11/2012		0.99			0.852		0.126	0.004	0.005		0.002	0.01	0.001	0.024		0.0001													
KS11/1	long pond	14/12/2012		0.09			0.604		0.063	0.002	0.001		0.002	0.01	0.001	0.005		0.0001													

KIWEF Surface Water Monitoring Results - Long Pond

ANALYTES			Polycyclic Aromatic Hydrocarbons																	
			Naphthalene	Acenaphtylene	Acenaphthene	Fluorene	Phenanthrene	Anthracene	Fluoranthene	Pyrene	Benz(a)anthracene	Chrysene	Benzo(b)&(k)fluoranthene	Benzo(a)pyrene	Indeno(1.2.3-cd)pyrene	Dibenzo(ah)anthracene	Benzo(ghi)perylene	1-Methylnaphthalene	2-Methylnaphthalene	Phenols
Units			mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
ANZECC CRITERIA			0.05	NC	NC	NC	0.0006	0.00001	0.001	NC	NC	NC	NC	0.0001	NC	NC	NC	NC	NC	0.4
Laboratory PQL *			0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0001	0.0001	0.001
		count	42	42	42	42	42	42	42	42	42	42	34	42	42	42	42	1	1	46
		90 %ile	0.0010	0.0010	0.0010	0.0010	0.0010	0.0010	0.0010	0.0010	0.0010	0.0010	0.0002	0.0005	0.0010	0.0010	0.0010	0.0001	0.0001	0.050
		80 %ile	0.0005	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0001	0.0001	0.050
		average	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0002	0.0002	0.0003	0.0003	0.0003	0.0001	0.0001	0.033
		20 %ile	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0002	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.001
		10 %ile	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0002	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.001
KS10/1	long pond	4/05/1990																		0.011
KS10/1	long pond	5/12/1990																		
KS10/1	long pond	25/03/1991																		0.002
KS10/1	long pond	22/08/1991																		0.004
KS10/1	long pond	10/08/1992																		0.002
KS10/1	long pond	30/11/1993	0.0006	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002			0.001
KS10/1	long pond	10/08/1994	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002			0.004
KS10/1	long pond	10/08/1995	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002			0.003
KS10/1	long pond	12/08/1996	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002			0.001
KS10/1	long pond	12/08/1997	0.0004	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002			0.001
KS10/1	long pond	15/03/1999	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002			0.003
KS10/1	long pond	17/06/1999	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002			0.002
KS10/1	long pond	7/09/1999	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002			0.003
KS10/1	long pond	7/12/1999	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005			0.001
KS10/1	long pond	6/03/2000	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002			0.006
KS10/1	long pond	5/06/2000	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002			0.001
KS10/1	long pond	4/09/2000	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002			0.001
KS10/1	long pond	4/12/2000	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.00002			0.001
KS10/1	long pond	5/03/2001																		
KS10/1	long pond	3/09/2001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0002	0.0001	0.0001	0.0001	0.0001			0.001
KS10/1	long pond	4/03/2002	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0002	0.0001	0.0001	0.0001	0.0001			0.001
KS10/1	long pond	10/10/2002	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0002	0.0001	0.0001	0.0001	0.0001			0.01
KS10/1	long pond	16/04/2003																		
KS10/1	long pond	10/11/2003	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0002	0.00005	0.0001	0.0001	0.0001			0.05
KS10/1	long pond	25/03/2004	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0002	0.00005	0.0001	0.0001	0.0001			0.01
KS10/1	long pond	27/09/2004	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0002	0.00005	0.0001	0.0001	0.0001			0.007
KS10/1	long pond	29/03/2005	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0002	0.00005	0.0001	0.0001	0.0001			0.05
KS10/1	long pond	07/09/2005	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0002	0.00005	0.0001	0.0001	0.0001			0.05
KS10/1	long pond	03/03/2006	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0002	0.00005	0.0001	0.0001	0.0001			0.05
KS10/1	long pond	01/09/2006	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0002	0.00005	0.0001	0.0001	0.0001			0.124
KS10/1	long pond	03/03/2007	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0002	0.00005	0.0001	0.0001	0.0001			0.05
KS10/1	long pond	21/09/2007	0.0005	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.00005	0.0001	0.0001	0.0001			0.241
KS10/1	long pond	29/02/2008	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0002	0.00005	0.0001	0.0001	0.0001			0.12
KS10/1	long pond	11/09/2008	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0002	0.00005	0.0001	0.0001	0.0001			0.05
KS10/1	long pond	03/03/2009	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0002	0.00005	0.0001	0.0001	0.0001			0.05
KS10/1	long pond	07/09/2009	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0002	0.00005	0.0001	0.0001	0.0001			0.2
KS10/1	long pond	24/12/2010	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0002	0.00005	0.0001	0.0001	0.0001	0.0001	0.0001	0.00001
KS10/1	long pond	08/03/2012	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001		0.0001	0.0001	0.0001	0.0001			0.05
KS10/1	long pond	03/04/2012	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.002	0.001	0.001	0.001	0.001			0.01
KS10/1	long pond	27/06/2012																		
KS10/1	long pond	26/07/2012	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001		0.0005	0.001	0.001	0.001			0.05
KS10/1	long pond	28/08/2012																		
KS10/1	long pond	27/09/2012																		
KS10/1	long pond	25/10/2012	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001		0.0005	0.001	0.001	0.001			0.05
KS10/1	long pond	27/11/2012																		
KS10/1	long pond	11/12/2012	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001		0.0005	0.001	0.001	0.001			0.05
KS10/1	long pond	14/12/2012	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001		0.0005	0.001	0.001	0.001			0.05
KS11/1	long pond	18/03/1999																		
KS11/1	long pond	24/06/1999	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002			0.001
KS11/1	long pond	7/09/1999	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002			0.001
KS11/1	long pond	7/12/1999																		
KS11/1	long pond	6/03/2000																		
KS11/1	long pond	5/06/2000																		
KS11/1	long pond	11/12/2003																		
KS11/1	long pond	25/03/2004	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0002	0.00005	0.0001	0.0001	0.0001			0.01
KS11/1	long pond	07/09/2005																		
KS11/1	long pond	03/03/2006																		
KS11/1	long pond	1/09/2006																		
KS11/1	long pond	08/03/2012	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001		0.0001	0.0001	0.0001	0.0001			0.05
KS11/1	long pond	27/06/2012																		
KS11/1	long pond	26/07/2012	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001		0.0005	0.001	0.001	0.001			0.05
KS11/1	long pond	28/08/2012																		
KS11/1	long pond	27/09/2012																		
KS11/1	long pond	25/10/2012	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001		0.0005	0.001	0.001	0.001			0.05
KS11/1	long pond	27/11/2012																		
KS11/1	long pond	14/12/2012																		

KIWEF Surface Water Monitoring Results - Windmill Rd Open Channel

ANALYTES			Basic				Anions									Cations				Metals								
			pH	Conductivity	Turbidity	TSS	Chloride	Ammonia	Nitrate as N	Nitrite as N	NO_x (NO_2 + NO_3)	Total Kjeldahl Nitrogen as N	Total Nitrogen as N	Reactive Phosphorus as P	Total Phosphorus	Na	Mg	K	Ca	Al - Total	As - Total	Ba - Total	Be - Total	Bo - Total	Cd -Total	Cd - Dissolved	Co - Total	Cr - Total
Units			pH units	mS/cm	NTU	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
ANZECC CRITERIA			7 to 8.5	NC	10	NC	NC	0.91	0.7	NC	0.015	NC	0.3	NC	0.03	NC	NC	NC	NC	0.055	0.013	NC	NC	0.37	0.0007	0.0007	0.001	0.0044
Laboratory PQL *			-	1	0.1	5	0.1	0.1	0.05	0.05	0.05	0.1	0.1	0.01	0.01	0.1	0.1	0.2	0.1	0.01	0.002	0.001	0.001	0.05	0.01	0.01	0.01	0.01
		count	26	26	1	2	2	26	2	2	2	1	1	1	1	1	1	1	1	1	2	1	1	1	2	1	2	26
		90 %ile	9.4	16500	16	29.9	10966	0.100	0.856	0.190	1.045	0.9	0.9	0.01	0.08	1190	44	70	92	0.66	0.002	0.113	0.001	1.74	0.00901	0.01	0.0091	0.036
		80 %ile	9.1	12480	16	27.8	9932	0.100	0.762	0.170	0.930	0.9	0.9	0.01	0.08	1190	44	70	92	0.66	0.002	0.113	0.001	1.74	0.00802	0.01	0.0082	0.011
		average	8.5	9547	16	21.5	6830	0.769	0.480	0.110	0.585	0.9	0.9	0.01	0.08	1190	44	70	92	0.66	0.002	0.113	0.001	1.74	0.00505	0.01	0.0055	0.011
		20 %ile	7.9	4590	16	15.2	3728	0.010	0.198	0.050	0.240	0.9	0.9	0.01	0.08	1190	44	70	92	0.66	0.002	0.113	0.001	1.74	0.00208	0.01	0.0028	0.001
		10 %ile	7.4	3600	16	13.1	2694	0.010	0.104	0.030	0.125	0.9	0.9	0.01	0.08	1190	44	70	92	0.66	0.002	0.113	0.001	1.74	0.00109	0.01	0.0019	0.001
KS10/3	WindmillRd Open Channel	13/08/1997	9	32000		11	12000	0.2	0.95	0.21	1.16										0.002				0.01	0.01	0.01	0.01
KS10/3	WindmillRd Open Channel	15/03/1999	8.9	11000				0.1																				0.01
KS10/3	WindmillRd Open Channel	17/06/1999	8.4	8800				0.1																				0.004
KS10/3	WindmillRd Open Channel	7/09/1999	8.6	7100				0.1																				0.04
KS10/3	WindmillRd Open Channel	7/12/1999	9.2	7800				0.1																				0.01
KS10/3	WindmillRd Open Channel	6/03/2000	9.4	15000				0.1																				0.01
KS10/3	WindmillRd Open Channel	5/06/2000	9.1	7500				0.1																				0.01
KS10/3	WindmillRd Open Channel	4/09/2000	9.1	8200				0.1																				0.01
KS10/3	WindmillRd Open Channel	4/12/2000	9.3	18000				0.1																				0.01
KS10/3	WindmillRd Open Channel	5/03/2001	8.4	30500				0.1																				0.04
KS10/3	WindmillRd Open Channel	3/09/2001	8.8	6700				0.1																				0.04
KS10/3	WindmillRd Open Channel	4/03/2002	10.3	5900				0.1																				0.031
KS10/3	WindmillRd Open Channel	15/10/2002	9.6	12000				0.01																				0.011
KS10/3	WindmillRd Open Channel	16/04/2003	no surface water																									
KS10/3	WindmillRd Open Channel	11/11/2003	dry at time of sampling																									
KS10/3	WindmillRd Open Channel	25/03/2004	8.4	5380				0.01																				0.01
KS10/3	WindmillRd Open Channel	27/09/2004	8.8	3170				0.07																				0.001
KS10/3	WindmillRd Open Channel	29/03/2005	8.0	3260				18.3																				0.007
KS10/3	WindmillRd Open Channel	7/09/2005	8.5	5900				0.01																				0.001
KS10/3	WindmillRd Open Channel	3/03/2006	6.8	3600				0.012																				0.001
KS10/3	WindmillRd Open Channel	1/09/2006	8.5	4590				0.042																				0.001
KS10/3	WindmillRd Open Channel	3/03/2007	6.8	3600				0.012																				0.001
KS10/3	WindmillRd Open Channel	21/09/2007	7.5	4640				0.01																				0.001
KS10/3	WindmillRd Open Channel	29/02/2008	7.9	3920				0.038																				0.001
KS10/3	WindmillRd Open Channel	10/09/2008	8.2	5960				0.01																				0.001
KS10/3	WindmillRd Open Channel	3/03/2009	7.4	12480				0.01																				0.002
KS10/3	WindmillRd Open Channel	7/09/2009	7.3	14930				0.1																				0.02
KS10/3	WindmillRd Open Channel	25/10/2012	8.0	6300	16.0	32	1660	0.05	0.01	0.01	0.01	0.9	0.9	0.01	0.08	1190	44	70	92	0.66	0.002	0.113	0.001	1.74	0.0001		0.001	0.003

KIWEF Surface Water Monitoring Results - Windmill Rd Open Channel

ANALYTES																				Cyanide			Total Recoverable Hydrocarbons				BTEX				
			Cr - Dissolved	Cu -Total	Cu - Dissolved	Fe - Total	Fe - Dissolved	Hexavalent Chromium	Mn - Total	Mo - Total	Ni - Total	Pb - Total	Pb - Dissolved	Sb - Total	Se - Total	Sn - Total	Zn - Total	Zn - Dissolved	Hg - Total	Total Cyanide	Free Cyanide	WAD Cyanide	TRH C_6 - C_9	TRH C_{10} - C_{14}	TRH C_{15} - C_{28}	TRH C_{29} - C_{36}	Benzene	Toluene	Ethyl-benzene	Total Xylenes	Total PAHs
Units			mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L CN	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
ANZECC CRITERIA			0.0044	0.0013	0.0013	NC	NC	NC	0.08	0.023	0.007	0.0044	0.0044	NC	0.005	NC	0.015	0.015	0.0001	0.004	0.004	0.004	NC	NC	NC	NC	0.5	0.18	0.08	0.2	NC
Laboratory PQL *			0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.001	0.002	0.001	0.01	0.01	0.00005	0.005	0.005	0.005	0.1	0.1	0.2	0.2	0.001	0.001	0.001	0.003	0.003
		count	1	2	1	26	1	1	26	26	2	26	1	1	2	1	26	1	26	25	9	1	2	2	2	2	1	1	1	1	18
		90 %ile	0.010	0.018	0.020	0.88	0.1	0.010	0.511	0.075	0.2305	0.035	0.020	0.001	0.009	0.001	0.325	0.02	0.0001	0.032	0.006	0.004	0.092	0.095	0.460	0.455	0.001	0.002	0.002	0.002	1.5
		80 %ile	0.010	0.016	0.020	0.61	0.1	0.010	0.282	0.055	0.216	0.020	0.020	0.001	0.008	0.001	0.080	0.020	0.0001	0.026	0.005	0.004	0.084	0.090	0.420	0.410	0.001	0.002	0.002	0.002	1.5
		average	0.010	0.011	0.020	0.46	0.1	0.010	0.239	0.039	0.1725	0.009	0.020	0.001	0.006	0.001	0.137	0.020	0.0001	0.014	0.005	0.004	0.060	0.075	0.300	0.275	0.001	0.002	0.002	0.002	0.9
		20 %ile	0.010	0.005	0.020	0.11	0.1	0.010	0.029	0.011	0.129	0.001	0.020	0.001	0.004	0.001	0.006	0.020	0.0001	0.005	0.005	0.004	0.036	0.060	0.180	0.140	0.001	0.002	0.002	0.002	0.5
		10 %ile	0.010	0.003	0.020	0.09	0.1	0.010	0.019	0.009	0.1145	0.001	0.020	0.001	0.003	0.001	0.005	0.020	0.0001	0.004	0.005	0.004	0.028	0.055	0.140	0.095	0.001	0.002	0.002	0.002	0.1
KS10/3	WindmillRd Open Channel	13/08/1997	0.01	0.02	0.02	0.12	0.1		0.04	0.02	0.1	0.02	0.02		0.002		0.03	0.02	0.00005		0.01		0.1	0.1	0.5	0.5					0.003
KS10/3	WindmillRd Open Channel	15/03/1999				0.3			0.05	0.02		0.02					0.73		0.00005	0.01											1.50
KS10/3	WindmillRd Open Channel	17/06/1999				0.1			0.005	0.039		0.001					0.008		0.00005	0.005											1.50
KS10/3	WindmillRd Open Channel	7/09/1999				0.2			0.04	0.04		0.02					0.13		0.00005	0.005											1.50
KS10/3	WindmillRd Open Channel	7/12/1999				1.1			0.06	0.06		0.05					0.01		0.00005	0.02											0.38
KS10/3	WindmillRd Open Channel	6/03/2000				0.69			0.68	0.08		0.05					0.32		0.00005	0.01											1.50
KS10/3	WindmillRd Open Channel	5/06/2000				0.14			0.01	0.05		0.05					0.08		0.00005	0.005	0.005										1.50
KS10/3	WindmillRd Open Channel	4/09/2000				0.61			0.04	0.05		0.004					1.6		0.00005	0.005	0.005										1.50
KS10/3	WindmillRd Open Channel	4/12/2000				0.3			0.16	0.07		0.002					0.01		0.00005	0.005	0.005										1.50
KS10/3	WindmillRd Open Channel	5/03/2001				0.51			0.09	0.03		0.004					0.03		0.00005	0.005	0.005										0.75
KS10/3	WindmillRd Open Channel	3/09/2001				0.15			0.02	0.01		0.002					0.33		0.00006	0.005	0.005										0.80
KS10/3	WindmillRd Open Channel	4/03/2002				0.11			0.02	0.009		0.002					0.072		0.00005	0.03	0.005										0.80
KS10/3	WindmillRd Open Channel	15/10/2002				0.3			0.052	0.183		0.002					0.02		0.00005	0.005	0.005										0.80
KS10/3	WindmillRd Open Channel	16/04/2003																													
KS10/3	WindmillRd Open Channel	11/11/2003																													
KS10/3	WindmillRd Open Channel	25/03/2004				0.07			0.031	0.011		0.001					0.002		0.00005	0.005											0.78
KS10/3	WindmillRd Open Channel	27/09/2004				0.1			0.046	0.008		0.001					0.001		0.0001	0.037											0.78
KS10/3	WindmillRd Open Channel	29/03/2005				0.15			0.091	0.02		0.001					0.014		0.0001	0.0337											-
KS10/3	WindmillRd Open Channel	7/09/2005				0.15			0.089	0.016		0.001					0.006		0.0001	0.03											-
KS10/3	WindmillRd Open Channel	3/03/2006				0.23			0.282	0.03		0.001					0.025		0.0001	0.023											
KS10/3	WindmillRd Open Channel	1/09/2006				0.07			0.029	0.008		0.001					0.012		0.0001	0.0245											-
KS10/3	WindmillRd Open Channel	3/03/2007				0.23			0.282	0.03		0.001					0.025		0.0001	0.023											0.775
KS10/3	WindmillRd Open Channel	21/09/2007				0.29			0.089	0.016		0.001					0.005		0.0001	0.004											<PQL
KS10/3	WindmillRd Open Channel	29/02/2008				0.07			0.342	0.003		0.001					0.005		0.0001	0.0221											<PQL
KS10/3	WindmillRd Open Channel	10/09/2008				0.99			0.017	0.108		0.003					0.014		0.0001	0.036											0
KS10/3	WindmillRd Open Channel	3/03/2009				0.38			2.06	0.055		0.001					0.006		0.0001	0.004											0.1
KS10/3	WindmillRd Open Channel	7/09/2009				3.81			1.38	0.021		0.005					0.056		0.0001	0.004											<PQL
KS10/3	WindmillRd Open Channel	25/10/2012		0.001		0.76		0.01	0.201	0.022	0.245	0.001		0.001	0.01	0.001	0.008		0.0001	0.004	0.004	0.004	0.02	0.05	0.1	0.05	0.001	0.002	0.002	0.002	

KIWEF Surface Water Monitoring Results - Windmill Rd Open Channel

ANALYTES			Polycyclic Aromatic Hydrocarbons															
			Naphthalene	Acenaphtylene	Acenaphthene	Fluorene	Phenanthrene	Anthracene	Fluoranthene	Pyrene	Benz(a)anthracene	Chrysene	Benzo(b)&(k)fluoranthene	Benzo(a)pyrene	Indeno(1.2.3-cd)pyrene	Dibenzo(ah)anthracene	Benzo(ghi)perylene	Phenols
Units			mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
ANZECC CRITERIA			0.05	NC	NC	NC	0.0006	0.00001	0.001	NC	NC	NC	NC	0.0001	NC	NC	NC	0.4
Laboratory PQL *			0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.001
		count	26	26	26	26	26	26	26	26	26	26	25	26	26	26	26	26
		90 %ile	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.139
		80 %ile	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.050
		average	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0001	0.0002	0.0002	0.0002	11.949
		20 %ile	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0002	0.0001	0.0001	0.0001	0.0001	0.001
		10 %ile	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.001
KS10/3	WindmillRd Open Channel	13/08/1997	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002
KS10/3	WindmillRd Open Channel	15/03/1999	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.002
KS10/3	WindmillRd Open Channel	17/06/1999	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.001
KS10/3	WindmillRd Open Channel	7/09/1999	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.001
KS10/3	WindmillRd Open Channel	7/12/1999	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.001
KS10/3	WindmillRd Open Channel	6/03/2000	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.001
KS10/3	WindmillRd Open Channel	5/06/2000	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.001
KS10/3	WindmillRd Open Channel	4/09/2000	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.001
KS10/3	WindmillRd Open Channel	4/12/2000	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.001
KS10/3	WindmillRd Open Channel	5/03/2001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.002
KS10/3	WindmillRd Open Channel	3/09/2001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0002	0.0001	0.0001	0.0001	0.0001	0.001
KS10/3	WindmillRd Open Channel	4/03/2002	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0002	0.0001	0.0001	0.0001	0.0001	0.001
KS10/3	WindmillRd Open Channel	15/10/2002	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0002	0.0001	0.0001	0.0001	0.0001	0.01
KS10/3	WindmillRd Open Channel	16/04/2003																
KS10/3	WindmillRd Open Channel	11/11/2003																
KS10/3	WindmillRd Open Channel	25/03/2004	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0002	0.00005	0.0001	0.0001	0.0001	0.01
KS10/3	WindmillRd Open Channel	27/09/2004	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0002	0.00005	0.0001	0.0001	0.0001	0.007
KS10/3	WindmillRd Open Channel	29/03/2005	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0002	0.00005	0.0001	0.0001	0.0001	0.05
KS10/3	WindmillRd Open Channel	7/09/2005	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0002	0.00005	0.0001	0.0001	0.0001	0.05
KS10/3	WindmillRd Open Channel	3/03/2006	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0002	0.00005	0.0001	0.0001	0.0001	0.05
KS10/3	WindmillRd Open Channel	1/09/2006	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0002	0.00005	0.0001	0.0001	0.0001	0.05
KS10/3	WindmillRd Open Channel	3/03/2007	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0002	0.00005	0.0001	0.0001	0.0001	0.05
KS10/3	WindmillRd Open Channel	21/09/2007	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.00005	0.0001	0.0001	0.0001	0.05
KS10/3	WindmillRd Open Channel	29/02/2008	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.00005	0.0001	0.0001	0.0001	0.228
KS10/3	WindmillRd Open Channel	10/09/2008	0.0002	0.0001	0.0001	0.0001	0.0002	0.0001	0.0002	0.0002	0.0001	0.0001	0.0002	0.00005	0.0001	0.0001	0.0001	0.05
KS10/3	WindmillRd Open Channel	3/03/2009	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0002	0.00005	0.0001	0.0001	0.0001	50
KS10/3	WindmillRd Open Channel	7/09/2009	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0002	0.00005	0.0001	0.0001	0.0001	260
KS10/3	WindmillRd Open Channel	25/10/2012	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001		0.0005	0.001	0.001	0.001	0.05

NOTES

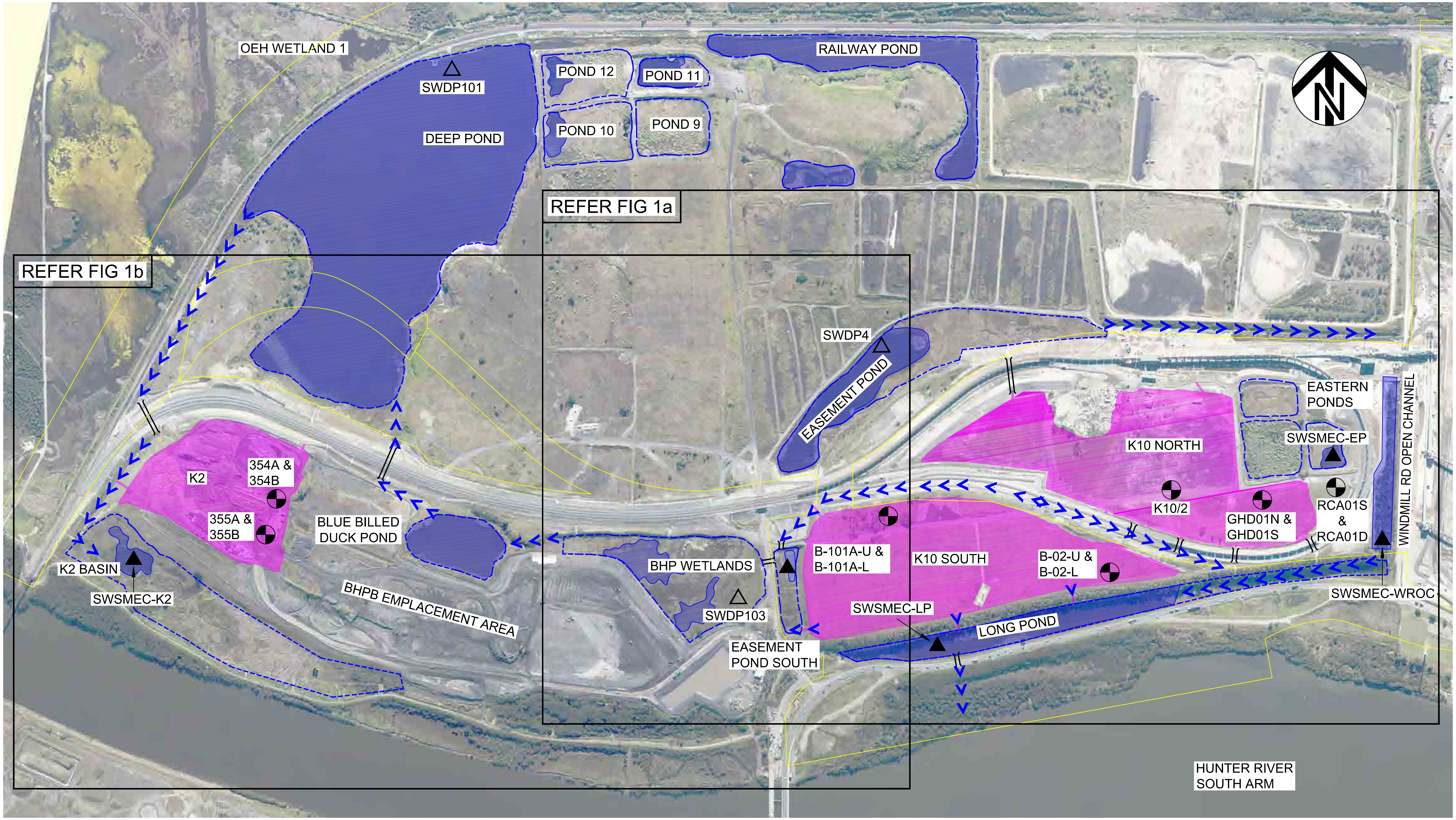
Notes for ALL tables:
Results expressed in mg/L unless otherwise stated
NC - No Criteria
Total PAH - Sum of positive PAH + PQL values
Total TRH - Sum of positive TRH values + PQL values
Total OCP - Sum of positive OCP + PQL values
* - Most common Laboratory PQL within the data set

Results exceed ANZECC 2000 Trigger Values for Slightly to Moderately Disturbed Systems (Refs 20 & 21)
The above summary table of surface water testing results has used information provided by others. The information has **NOT** been independently verified or reviewed to eliminate possible errors, and as such has been taken at face value.

0.0005 Result appears incorrect and is most likely a typo/unit conversion error

General Notes Relating to ANZECC (2000) Criteria (Ref 20):
Trigger values for toxicants for slightly to moderately disturbed systems from Table 3.4.1 of ANZECC 2000 Guidelines (Marine Water Trigger Values adopted - Fresh Water Trigger Values used where no marine water quality values are provided)
Trigger values for physical and chemical stressors for slightly disturbed ecosystems (ie pH, NOx, TP, Ammonia) from Table 3.3.2 of ANZECC 2000 Guidelines (Estuarine ecosystem type adopted)
Arsenic - Arsenic(V) trigger value adopted (conservative)
Chromium - Chromium(VI) trigger value adopted (conservative)
Mercury - Inorganic mercury trigger level
Selenium - Total Selenium trigger level
Fluoride - Long Term Trigger Values (up to 100 yrs)
Total Xylene - Sum of m&p-Xylene and o-Xylene
Phenols - Trigger Value for Phenol not Total Phenols (Conservative)
95% Low Reliability Trigger Value Criteria used (99% protection level applied where recommended) for Manganese, Molybdenum, Toluene, Ethyl Benzene, Phenanthrene, Anthracene, Fluoranthene, Benzo(a)pyrene,and Sulphide
Trigger value for turbidity taken from Table 3.3.3 of ANZECC 2000 Guidelines - slightly disturbed ecosystems in south-east Australia (Estuarine & marine)

APPENDIX B: FIGURES



LEGEND

PROPOSED KIWEF CLOSURE SITE FOOTPRINT	CULVERT	TYPICAL POND SURFACE WATER AREA	
INDICATIVE FLOWPATH	LEVEL LOGGER LOCATION (SURFACE WATER)	POTENTIAL POND SURFACE WATER AREA (WET CONDITIONS)	
INDICATIVE T4 FOOTPRINT	LEVEL LOGGER LOCATION (GROUND WATER)		
	LEVEL LOGGER LOCATION (SURFACE WATER) - PWCS		

FIG NO. 1 FIGURE TITLE KIWEF GENERAL ARRANGEMENT SITE LAYOUT

DATE 06/12/2012

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SCALE 1:7500

PAGE SIZE A3

COORDINATE SYSTEM .

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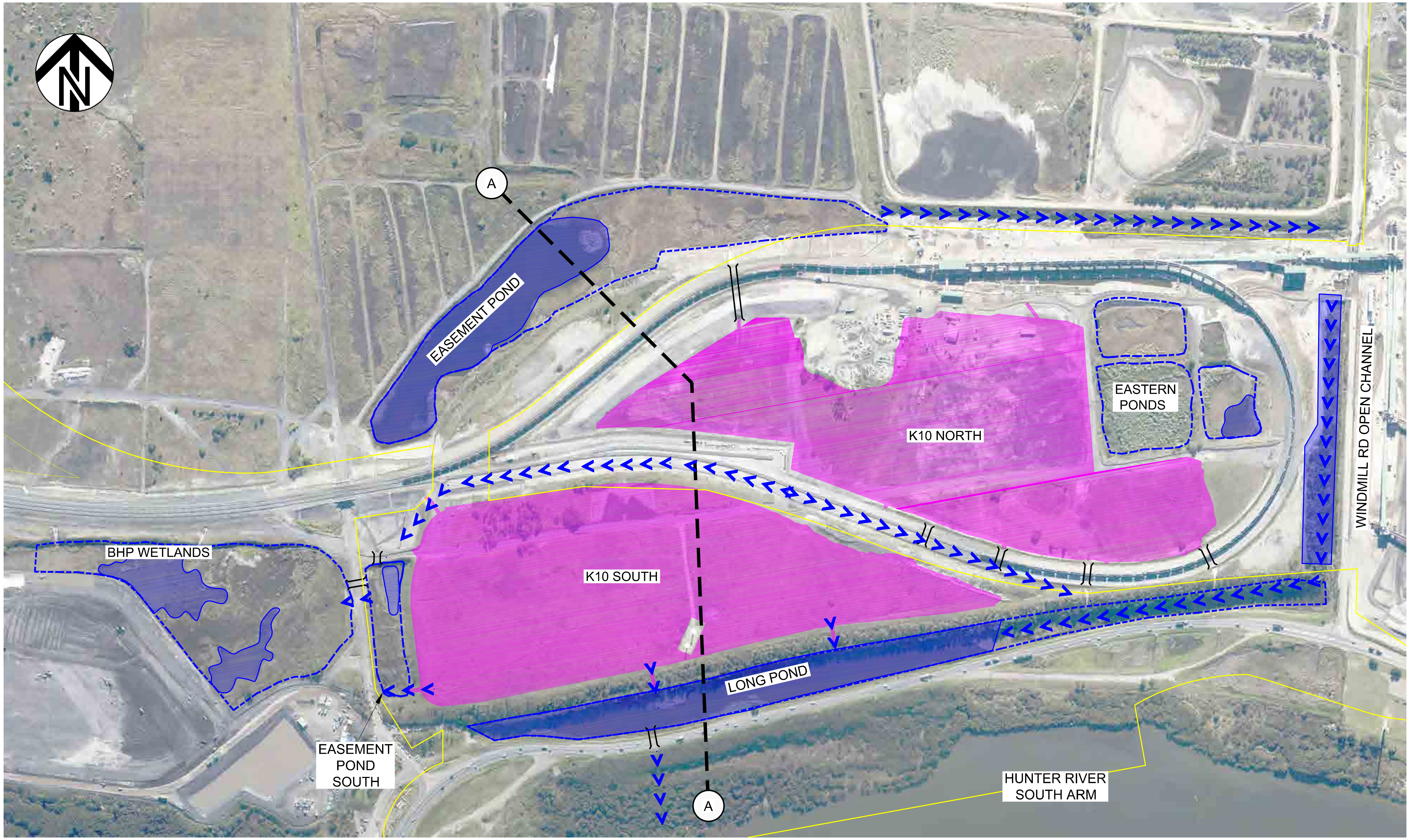
PROJECT NO. 30012008 PROJECT TITLE KIWEF STAGE 2 RESPONSE TO SEWPAC COMMENTS

SOURCES

T:\Projects\30012008\CAD\DWG\30012008-FIG01 [03].dwg



LEGEND

- INDICATIVE FLOWPATH
- CULVERT
- INDICATIVE T4 FOOTPRINT
- A — A REFER FIGURE 2 FOR LONG SECTION
- TYPICAL CURRENT POND SURFACE WATER AREA
- POTENTIAL POND SURFACE WATER AREA (WET CONDITIONS)

FIG NO. 1a	FIGURE TITLE KIWEF K10 SURFACE WATER LAYOUT	DATE 06/12/2012 SCALE 1:5000 (50 0 100 200)	PAGE SIZE A3	COORDINATE SYSTEM .
PROJECT NO. 30012008	PROJECT TITLE KIWEF STAGE 2 RESPONSE TO SEWPAC COMMENTS	SOURCES		

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LEGEND

- INDICATIVE FLOWPATH
- CULVERT
- INDICATIVE T4 FOOTPRINT
- B — B REFER FIGURE 2 FOR LONG SECTION
- TYPICAL CURRENT POND SURFACE WATER AREA
- POTENTIAL POND SURFACE WATER AREA (WET CONDITIONS)

FIG NO. 1b	FIGURE TITLE KIWEF K2 SURFACE WATER LAYOUT	DATE 06/12/2012 SCALE 1:5000 (50 0 100 200)	PAGE SIZE A3	COORDINATE SYSTEM .
PROJECT NO. 30012008	PROJECT TITLE KIWEF STAGE 2 RESPONSE TO SEWPAC COMMENTS	SOURCES		

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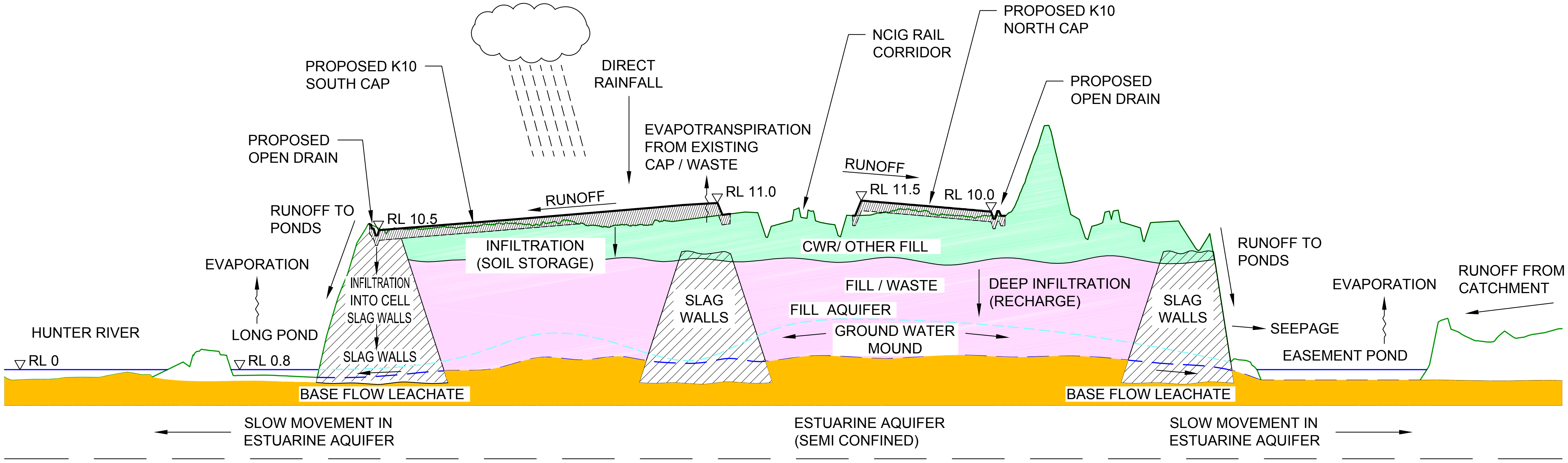

K10 SECTION A-A

Scale H 1:1250
Scale V 1:125

LEGEND

- CWR (AQUITARD)
- WASTE MATERIAL
- CLAY (AQUITARD)

FIG NO. 2a	FIGURE TITLE KIWEF INDICATIVE LONG SECTIONS FOR K10	DATE 06/12/2012	PAGE SIZE A3	COORDINATE SYSTEM .
PROJECT NO. 30012008	PROJECT TITLE KIWEF STAGE 2 RESPONSE TO SEWPAC COMMENTS	SOURCES		

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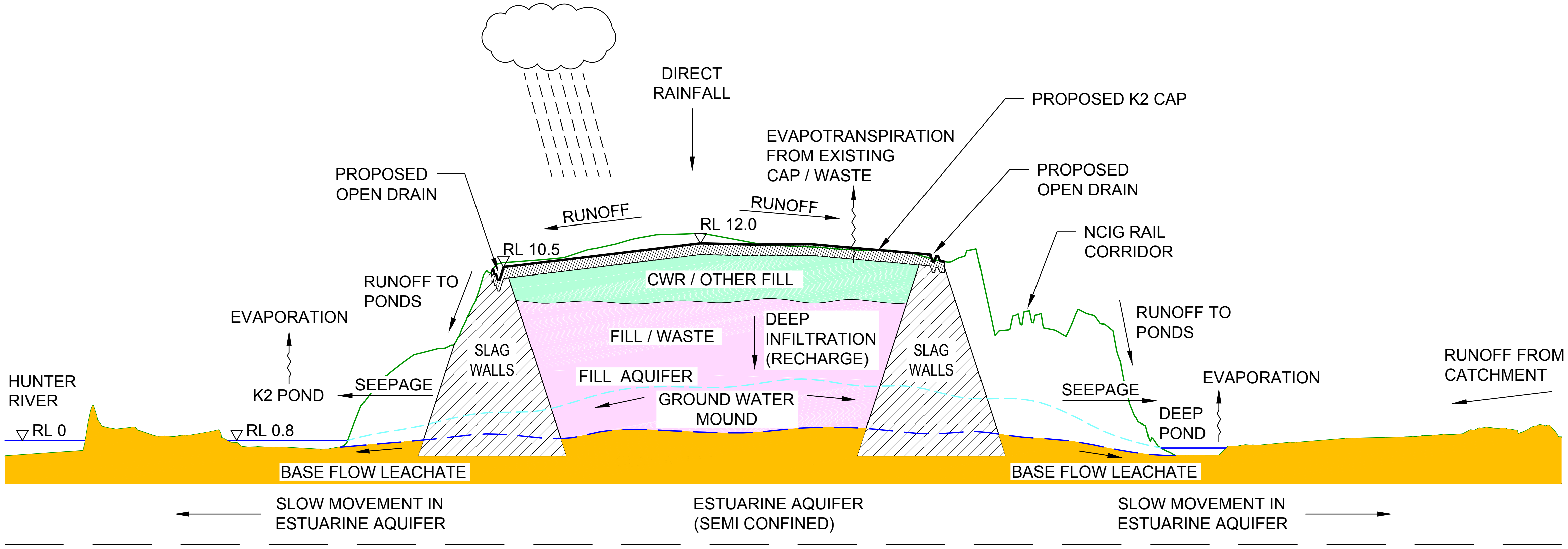

K2 SECTION B-B

Scale H 1:1250
Scale V 1:125

LEGEND

- CWR (AQUITARD)
- WASTE MATERIAL
- CLAY (AQUITARD)

FIG NO. 2b	FIGURE TITLE KIWEF INDICATIVE LONG SECTIONS FOR K2	DATE 06/12/2012	PAGE SIZE A3	COORDINATE SYSTEM .		
PROJECT NO. 30012008	PROJECT TITLE KIWEF STAGE 2 RESPONSE TO SEWPAC COMMENTS	SOURCES				

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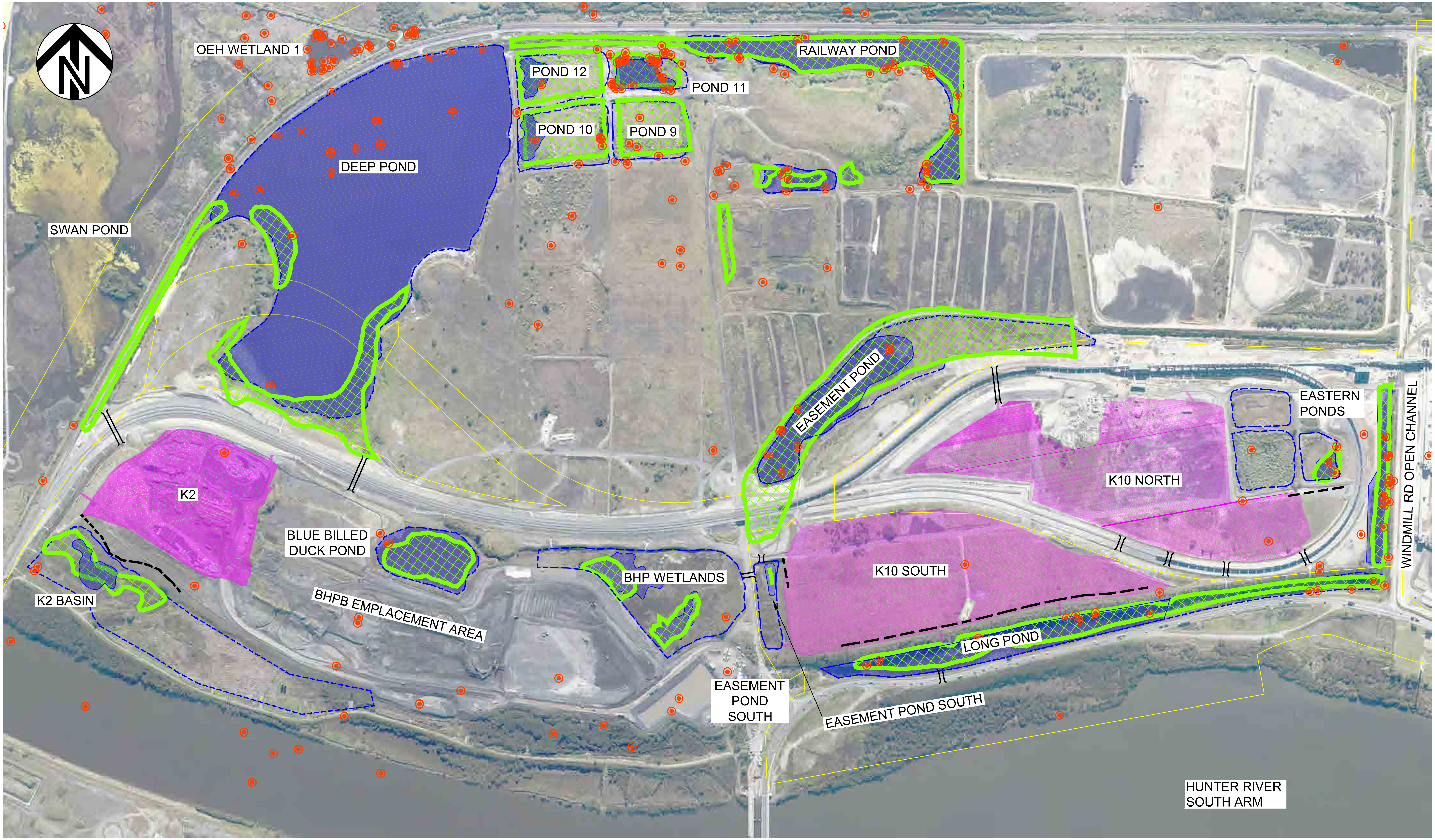

LEGEND

PROPOSED KIWEF CLOSURE SITE

INDICATIVE EXISTING GGBF HABITAT (GOLDER ASSOCIATES, APRIL 2011)

INDICATIVE T4 FOOTPRINT

APPROXIMATE 30m BUFFER

TYPICAL CURRENT POND SURFACE WATER AREA

POTENTIAL POND SURFACE WATER AREA (WET CONDITIONS)

KNOWN GGBF SIGHTING LOCATION (UMWELT, FEBRUARY 2012)

FIG NO. 3	FIGURE TITLE: SUMMARY OF KIWEF LANDFILL CLOSURE AND GGBF HABITAT AREAS	DATE 06/12/2012	75 0 75 150 225m SCALE 1:7500	PAGE SIZE A3	COORDINATE SYSTEM .
PROJECT NO. 30012008	PROJECT TITLE: KIWEF STAGE 2 RESPONSE TO SEWPAC COMMENTS	SOURCES	GOLDER ASSOCIATES - GGBF MANAGEMENT PLAN (APRIL 2011) T4 ENVIRONMENTAL ASSESSMENT, APPENDIX K (UMWELT, FEBRUARY 2012)		

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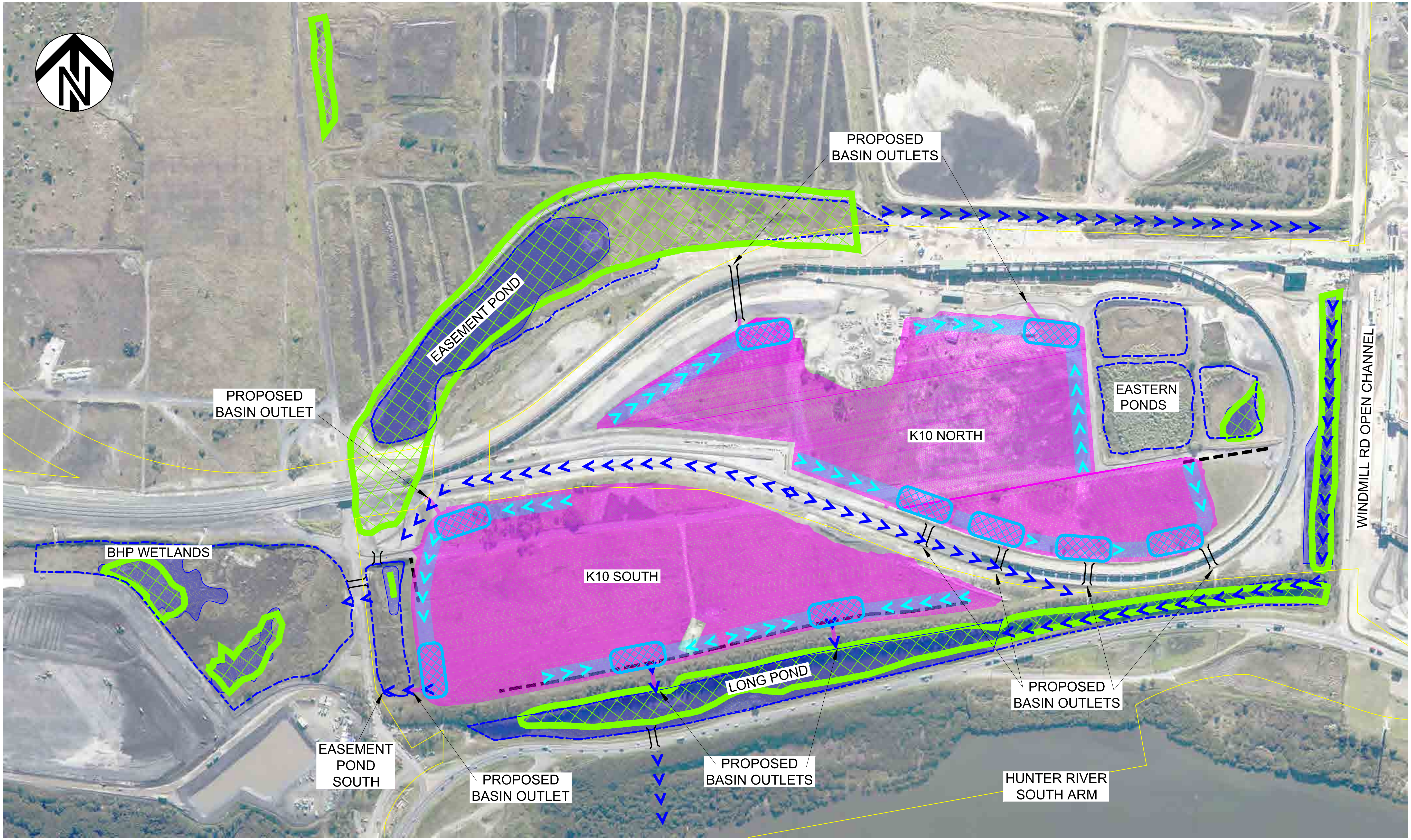

LEGEND

INDICATIVE FLOWPATH

CULVERT

INDICATIVE T4 FOOTPRINT

TYPICAL CURRENT POND SURFACE WATER AREA

POTENTIAL POND SURFACE WATER AREA (WET CONDITIONS)

INDICATIVE EXISTING GGBF HABITAT (GOLDER ASSOCIATES, APRIL 2011)

PROPOSED DRAINAGE CORRIDOR (NTS)

PROPOSED SEDIMENT BASIN (NTS)

FIG NO. 4a	FIGURE TITLE KIWEF K10 PROPOSED STORMWATER MANAGEMENT LAYOUT	DATE 06/12/2012	50 0 50 100 150m SCALE 1:5000	PAGE SIZE A3	COORDINATE SYSTEM .	
PROJECT NO. 30012008	PROJECT TITLE KIWEF STAGE 2 RESPONSE TO SEWPAC COMMENTS	SOURCES GOLDER ASSOCIATES - GGBF MANAGEMENT PLAN (APRIL 2011)				

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LEGEND

INDICATIVE FLOWPATH
CULVERT
INDICATIVE T4 FOOTPRINT
TYPICAL CURRENT POND SURFACE WATER AREA
POTENTIAL POND SURFACE WATER AREA (WET CONDITIONS)
INDICATIVE EXISTING GGBF HABITAT (GOLDER ASSOCIATES, APRIL 2011)
PROPOSED DRAINAGE CORRIDOR (NTS)
PROPOSED SEDIMENT BASIN (NTS)

FIG NO. 4b	FIGURE TITLE KIWEF K2 PROPOSED STORMWATER MANAGEMENT LAYOUT	DATE 06/12/2012	50 0 50 100 150m SCALE 1:5000	PAGE SIZE A3	COORDINATE SYSTEM .
PROJECT NO. 30012008	PROJECT TITLE KIWEF STAGE 2 RESPONSE TO SEWPAC COMMENTS	SOURCES GOLDER ASSOCIATES - GGBF MANAGEMENT PLAN (APRIL 2011)			

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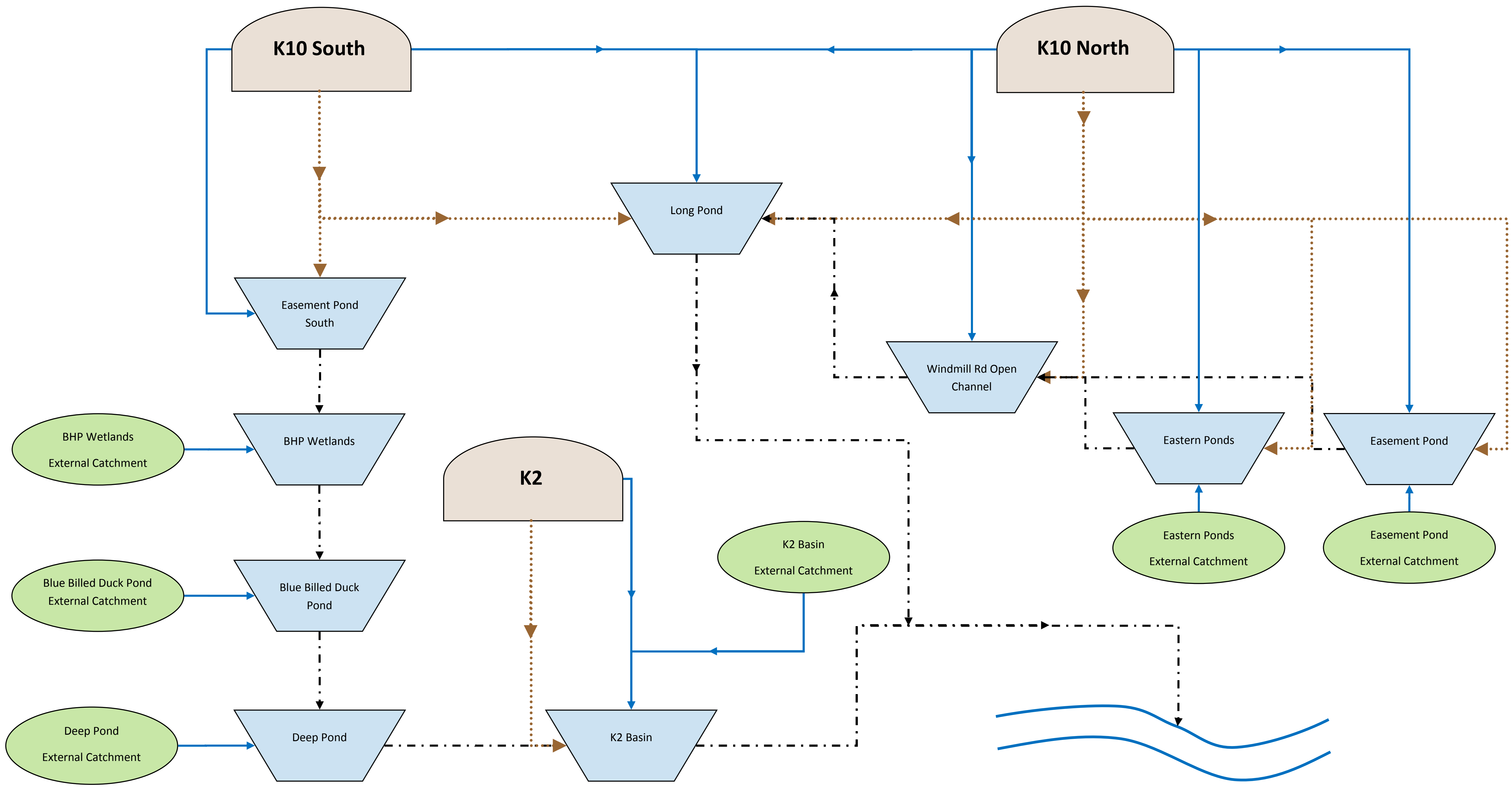


KEY

- Catchment
- Pond
- Waste Emplacement
- Hunter River
- Surface Runoff
- Pipe or Drain
- Groundwater Flow

PROJECT NO. — 30012008

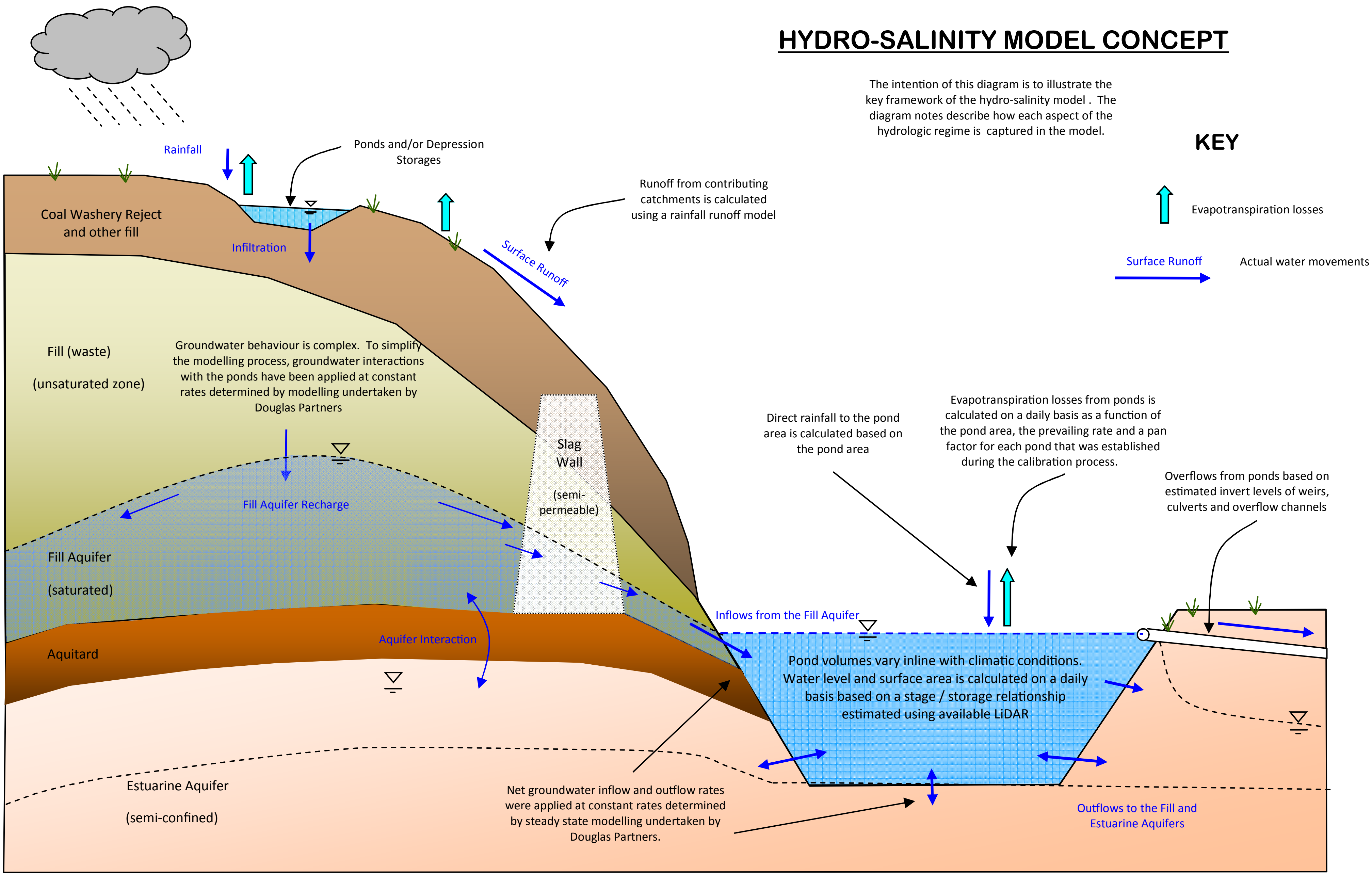
PROJECT TITLE — KIWEF STAGE 2

RESPONSE TO SEWPAC COMMENTS

FIGURE 5—KIWEF CONCEPTUAL MODEL LAYOUT

SMEC

HYDRO-SALINITY MODEL CONCEPT



APPENDIX C: PHOTOS OF EXISTING TOPSOIL AREAS AND VEGETATION COVER

Existing K2 Area

Typical vegetation grow th currently found w ithin the K2 area is show n below in **Plate C1**.

Plate C1: Typical vegetation growth currently found within K2 (photos taken 22 Nov 2012)

Existing K10 Area

Typical vegetation grow th w ithin the K10 North area is show n below in **Plate C2**.


Plate C2: Typical vegetation growth currently found within K10 North (photos taken 18 May 2012 & 17 June 2012)

Typical vegetation grow th currently found w ithin the K10 South area is show n below in **Plate C3**.


Plate C3: Typical vegetation growth currently found within K10 South (photos taken 22 November 2012)

APPENDIX D: DOUGLAS PARTNERS REPORT ON GROUNDWATER IMPACTS OF PROPOSED CAPPING WORKS

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Geotechnics / Environment / Groundwater

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Project 81209.01
12 March 2013
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SMEC Australia Pty Ltd
PO Box 1346
NEWCASTLE NSW 2300

Attention: Mr Ben Patterson

Email: ben.patterson@smec.com.au

Dear Sirs

Groundwater Modelling
KIWEF Landfill Closure
Kooragang Island

1. Introduction

This letter present selected outputs from a groundwater model developed by Douglas Partners Pty Ltd (DP) for the western parts of Kooragang Island, New South Wales. The work was carried out for SMEC Australia Pty Ltd.

DP has developed a groundwater model for the western section of Kooragang Island as part of the environmental assessment for the proposed Port Waratah Coal Services (PWCS) Terminal 4 (T4) Project. This modelling included calibration of groundwater flows according to the existing site condition. This calibrated steady state model have been adjusted to include the proposed capping of the Kooragang Island Waste Emplacement Facility (KIWEF) site.

The agreed scope of work was as follows:

- Utilise existing calibrated steady state model for T4 site and surrounds;
- Apply proposed capping using a recharge rate of 140 mm/year;
- Assess changes in groundwater flow rates between the capped areas of the site and adjacent surface water bodies;
- Provide changes in mass balance budgets for each of the adjacent water bodies.
- Provided results in a brief summary report.

For details of the development and calibration of the base model, reference should be made to Reference 1.

2. Proposed Development

It is understood that capping of the KIWEF site is proposed in locations as shown by the purple areas shown in Figure 1. Estimates of recharge following capping are understood to indicate an average yearly infiltration rate of 140 mm per year for the proposed capping strategy.

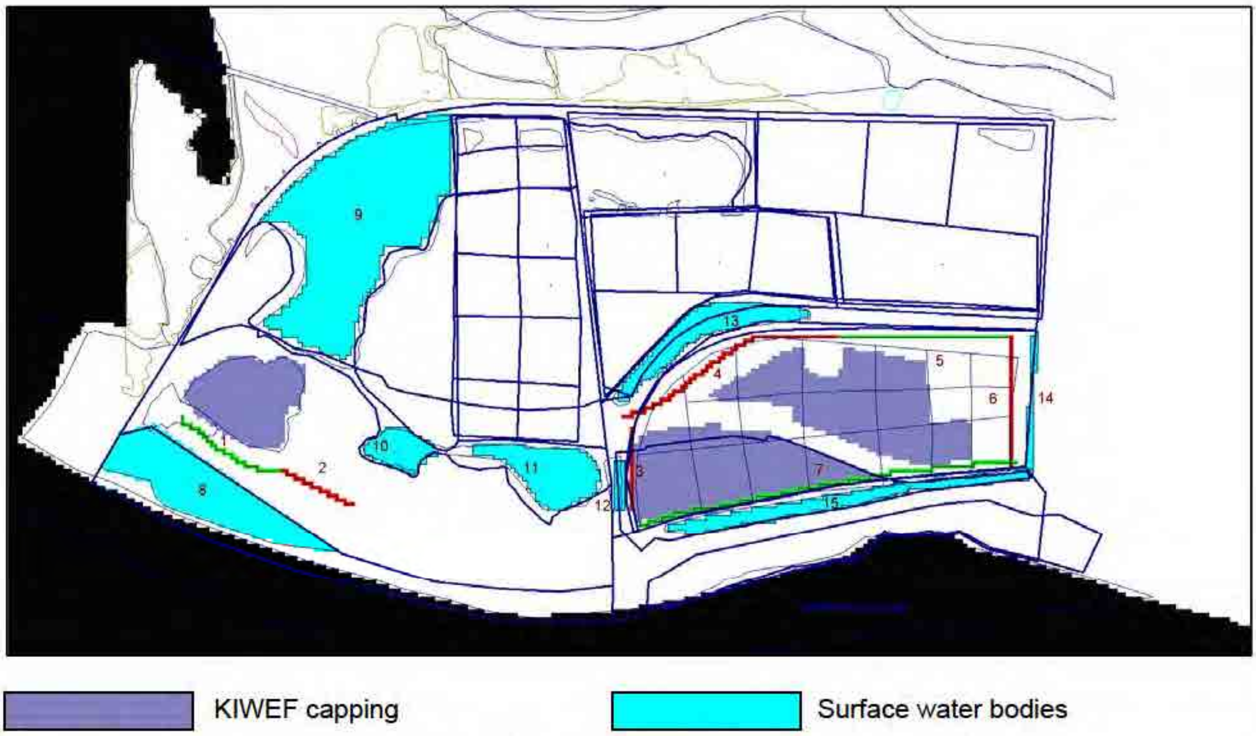

Figure 1: Extent of KIWEF Capping and Mass Balance Zones

The section lines across which changes in groundwater flow rates have been assessed are shown on Figure 1 in red and green and have been labelled 1 to 7. Figure 1 also shows the zones over which changes in mass balance have been assessed. These generally correspond with surface water bodies and are shown as blue areas and are labelled 8 to 15.

3. Base Model

The calibrated base model for the overall site was calibrated to a single point in time, that being 25 November 2010. Review of rainfall and evapotranspiration records indicated that for the month preceding November 2012, rainfall and evapotranspiration were 10% above annual average levels. Therefore for the purposes of the calibration a multiplication factor of 1.1 was applied to the annual rainfall and evaporation figures, prior to estimation of recharge multipliers.

The recharge multipliers (proportion of rainfall that occurs as recharge) adopted from the calibration are presented in Appendix B of Reference 1. For the areas proposed to be capped, the calibrated recharge multiplier was 0.23 for the main zones in Site B and 0.28 for the isolated area on the western part of the site (south of Deep Pond). This relates back to an annual average recharge of 267 mm/year and 329 mm/year. It is noted that there was limited calibration data for these parts of the site (outside T4 footprint) and therefore the calibration is considered to be less accurate than for the main T4 site.

Evaporation was taken as 100% of annual average pan evaporation for open water bodies and for land areas as 20% of annual average pan evaporation at the surface, decreasing to an extinction depth of 2 m.

Resulting calibrated heads in the Fill Aquifer and Estuarine Aquifer are presented in Figures 2 and 3, with units in Newcastle Harbour Tide Gauge (NHTG) datum.

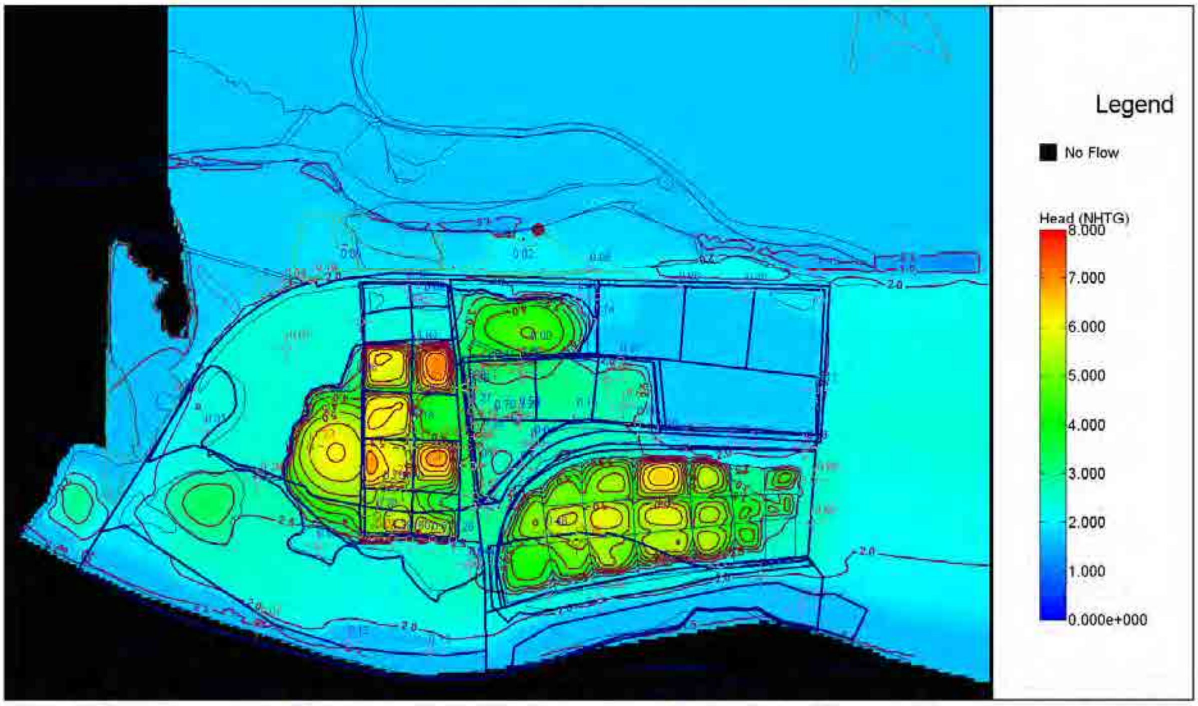

Figure 2: Computed Contours and Colour Flood of Groundwater Head in Layer 1 (Fill Aquifer), 0.5 m NHTG Contour Intervals

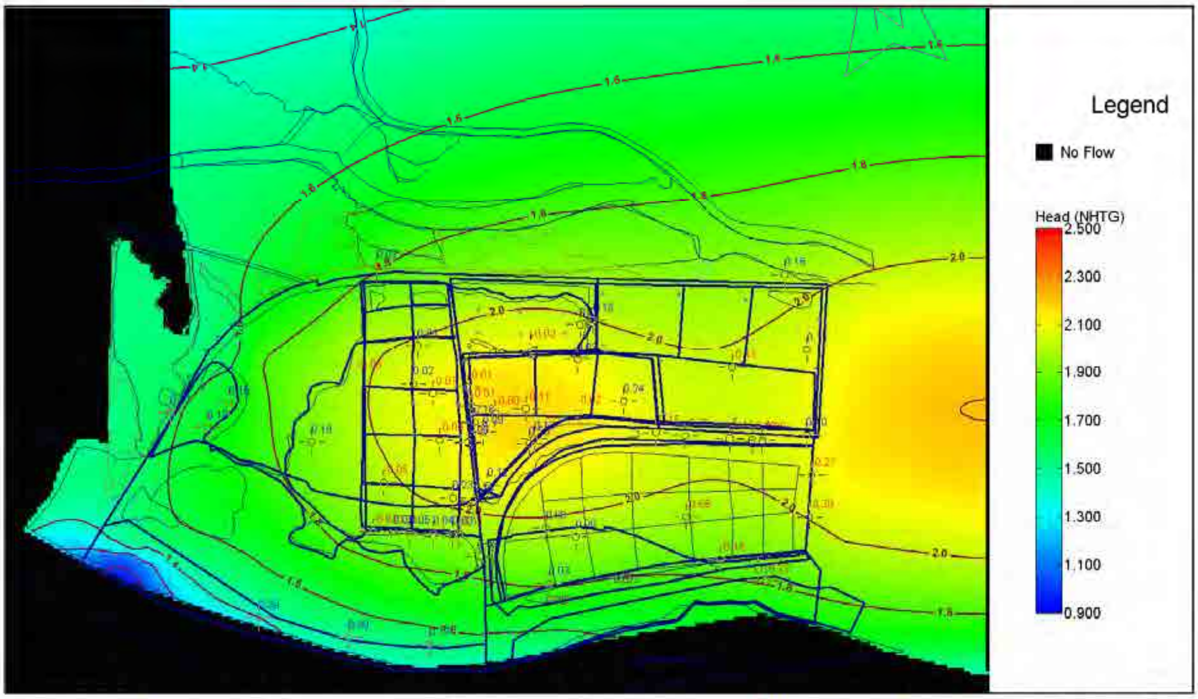

Figure 3: Computed Contours and Colour Flood of Groundwater Head in Layer 3 (Estuarine Aquifer), 0.2 m NHTG Contour Intervals

4. Modelling

Section lines were added to the existing calibrated model for each of the groundwater flow lines where groundwater flows are required. In a similar manner zones were defined for the surface water bodies where mass balance assessment was required.

The model was then run for the existing site condition case.

The model was next adjusted to include the proposed KIWEF capping at a rate of 140 mm/year factored by 1.1 to be equivalent to the calibrated steady state condition.

5. Results

The resulting head distributions for the KIWEF capped site case are presented in Figures 4 and 5.

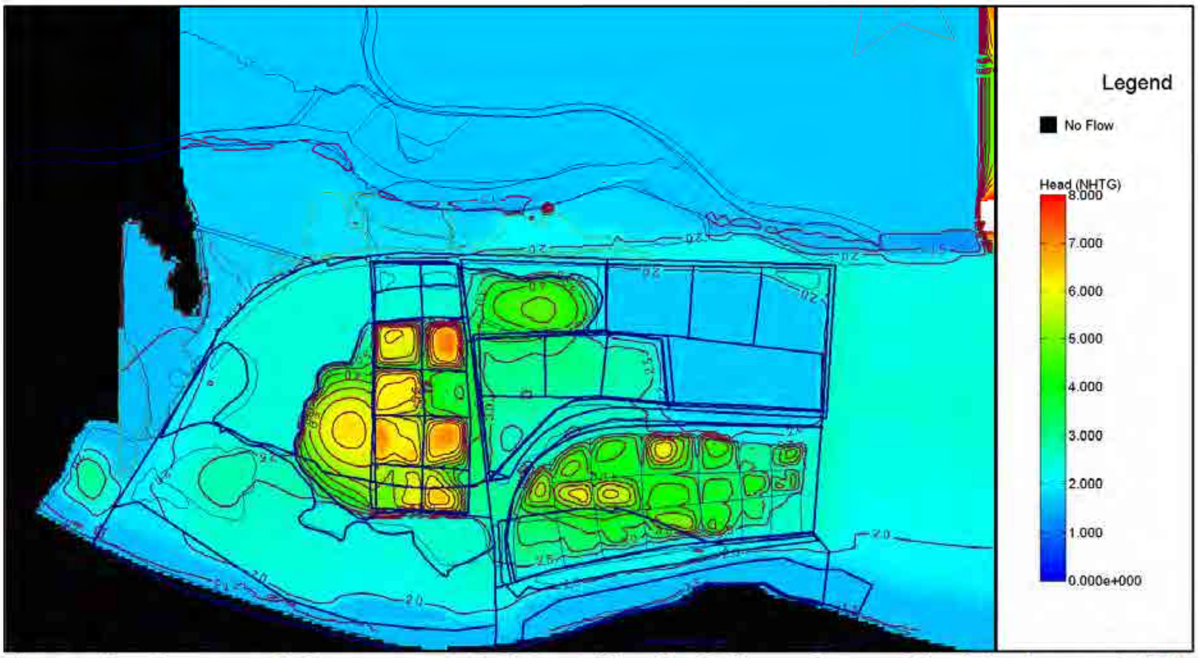

Figure 4: Computed Contours and Colour Flood of Groundwater Head in Layer 1 (Fill Aquifer), 0.5 m NHTG Contour Intervals – with KIWEF Capping

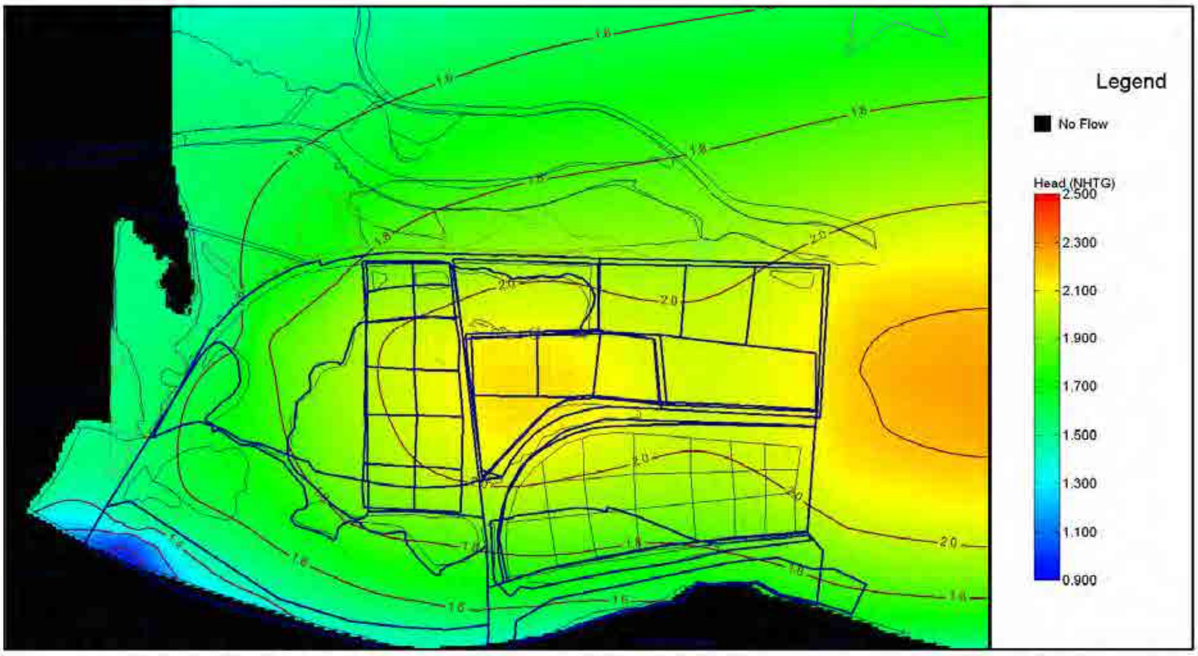

Figure 5: Computed Contours and Colour Flood of Groundwater Head in Layer 3 (Estuarine Aquifer), 0.2 m NHTG Contour Intervals – with KIWEF Capping

The changes in groundwater flows in the Fill Aquifer across Sections 1 to 15 are presented in Table 1.

Table 1: Changes in Groundwater Flow Rates Across Section Lines

Section Line No	Overall Flow Direction Across Section	Overall Flow Across Section Line Toward Pond/Drain (m^3/day)		% Change In Flow
		Existing Site	KIWEF Capped Site	
1	South west	45.4	38.3	- 15.6%
2	South	29.7	25.2	- 15.2%
3	West	6.8	3.7	- 45.7%
4	North west	32.3	26.6	- 17.4%
5	North	46.0	39.3	- 14.4%
6	East	15.9	14.9	- 6.7%
7	South	72.7	52.7	- 27.5%

The changes in mass balance for each of the surface water bodies 8 to 15 are presented in Tables 2 to 9.

The groundwater flows which form part of the mass balance are presented in terms of the following directions of flow:

- Xmin: Horizontal flow to/from westerly direction;
- Xmax: Horizontal flow to/from easterly direction;
- Ytop: Horizontal flow to/from northerly direction;
- Ybottom: Horizontal flow to/from southerly direction;
- Zbottom: Vertical flow to/from underlying aquifers.

Table 2: Mass Balance (m^3/day)for Zone 8 – Southern Wetlands

Description	Existing Site Condition		Proposed KIWEF Capping	
	Inflow	Outflow	Inflow	Outflow
Xmin	3.3	14.4	3.3	14.1
Xmax	37.6	0.0	33.5	0.0
Y top	80.3	0.0	73.0	0.0
Y bottom	0.0	137.9	0.0	135.0
Z bottom	0.0	3.0	0.0	3.0
Recharge	259.5	0.0	259.5	0.0
ET	0.0	133.7	0.0	133.6
Drain	0.0	91.7	0.0	83.5
TOTAL	380.7	380.7	369.3	369.2

Table 3: Mass Balance (m^3/day) for Zone 9 – Deep Pond

Description	Existing Site Condition		Proposed KIWEF Capping	
	Inflow	Outflow	Inflow	Outflow
Xmin	11.2	12.5	10.4	11.9
Xmax	23.4	35.7	25.8	31.4
Y top	7.7	39.3	8.2	36.5
Y bottom	37.7	9.0	33.6	8.3
Z bottom	0.0	7.8	0.0	7.4
Recharge	1129.1	0.0	1118.0	0.0
ET	0.0	1104.9	0.0	1100.7
Drain	0.0	0.0	0.0	0.0
TOTAL	1209.1	1209.1	1196.1	1196.2

Table 4: Mass Balance (m^3/day) for Zone 10 – Blue Billed Duck Pond

Description	Existing Site Condition		Proposed KIWEF Capping	
	Inflow	Outflow	Inflow	Outflow
Xmin	15.2	1.9	13.1	2.0
Xmax	9.0	8.0	10.2	7.8
Y top	21.4	0.0	22.7	0.0
Y bottom	0.7	25.4	0.4	25.8
Z bottom	0.0	18.8	0.0	18.9
Recharge	100.6	0.0	100.6	0.0
ET	0.0	92.9	0.0	92.7
Drain	0.0	0.0	0.0	0.0
TOTAL	147.0	147.0	147.1	147.1

Table 5: Mass Balance (m^3/day) for Zone 11 – BHPB Wetland

Description	Existing Site Condition		Proposed KIWEF Capping	
	Inflow	Outflow	Inflow	Outflow
Xmin	0.0	34.7	0.0	34.3
Xmax	24.6	0.2	23.4	0.2
Y top	16.2	0.3	16.4	0.2
Y bottom	2.0	31.6	1.8	31.2
Z bottom	0.0	5.9	0.0	6.0
Recharge	224.3	0.0	224.3	0.0
ET	0.0	194.5	0.0	194.0
Drain	0.0	0.0	0.0	0.0
TOTAL	267.1	267.1	265.9	265.9

Table 6: Mass Balance (m^3/day) for Zone 12 - Easement Pond South

Description	Existing Site Condition		Proposed KIWEF Capping	
	Inflow	Outflow	Inflow	Outflow
Xmin	0.0	15.9	0.0	14.0
Xmax	2.7	0.4	1.2	1.0
Y top	2.7	0.0	2.5	0.0
Y bottom	0.0	1.9	0.0	1.8
Z bottom	0.0	1.3	0.0	1.2
Recharge	18.0	0.0	18.0	0.0
ET	0.0	3.8	0.0	3.7
Drain	0.0	0.0	0.0	0.0
TOTAL	23.4	23.4	21.7	21.7

Table 7: Mass Balance (m^3/day) for Zone 13 – Easement Pond

Description	Existing Site Condition		Proposed KIWEF Capping	
	Inflow	Outflow	Inflow	Outflow
Xmin	5.0	3.5	5.2	4.2
Xmax	3.0	4.4	2.5	4.8
Y top	5.3	7.4	4.6	8.0
Y bottom	11.9	1.7	8.6	2.5
Z bottom	0.0	63.6	0.0	66.5
Recharge	267.8	0.0	267.8	0.0
ET	0.0	202.5	0.0	202.3
Drain	0.0	9.9	0.0	0.5
TOTAL	293.0	293.0	288.7	288.7

Table 8: Mass Balance (m^3/day) for Zone 14 - Long Pond East

Description	Existing Site Condition		Proposed KIWEF Capping	
	Inflow	Outflow	Inflow	Outflow
Xmin	8.8	10.8	7.7	10.8
Xmax	4.7	10.4	5.4	9.1
Y top	0.5	6.4	0.5	6.2
Y bottom	0.4	34.9	0.4	36.2
Z top	0.0	0.0	0.0	0.0
Z bottom	0.0	0.7	0.0	0.6
Recharge	51.3	0.0	51.3	0.0
ET	0.0	2.5	0.0	2.4
Drain	0.0	0.0	0.0	0.0
TOTAL	65.7	65.7	65.3	65.3

Table 9: Mass Balance (m^3/day) for Zone 15 – Long Pond South

Description	Existing Site Condition		Proposed KIWEF Capping	
	Inflow	Outflow	Inflow	Outflow
Xmin	6.4	14.5	4.7	15.5
Xmax	0.0	19.1	0.0	17.6
Y top	149.6	0.0	132.7	0.0
Y bottom	0.0	256.9	0.0	239.9
Z top	0.0	0.0	0.0	0.0
Z bottom	0.0	4.3	0.0	4.1
Recharge	269.0	0.0	269.0	0.0
ET	0.0	130.2	0.0	129.4
Drain	0.0	0.0	0.0	0.0
TOTAL	425.0	425.0	406.5	406.5

6. Reference

1. Douglas Partners (2012), "Report on Groundwater Assessment, Proposed Terminal 4 Project, Kooragang Island", Project 49533.02-05, Rev 6 (Final), February 2012.

7. Limitations

Douglas Partners (DP) has prepared this report for this project at Kooragang Island in accordance with DP's proposal dated 4 February 2013 and acceptance received from SMEC Australia Ltd, dated 7 February 2013. The work was carried out under DP's Conditions of Engagement. This report is provided for the exclusive use of SMEC Australia Ltd and Hunter Development Corporation for this project only and for the purposes as described in the report. It should not be used by or relied upon for other projects or purposes on the same or other site or by a third party. DP has necessarily relied upon information provided by the client and/or their agents.

In preparing this report, with the consent of Port Waratah Coal Services (PWCS), DP has used a groundwater model, which was originally developed for Project T4. PWCS accept no liability for the results or any implications of the results arising from using the model for this, non T4 related, assessment.

The results provided in the report are indicative of the sub-surface conditions on the site only at the specific sampling and / or testing locations, and then only to the depths investigated and at the time the work was carried out, as outlined in Reference 1. Sub-surface conditions can change abruptly due to variable geological processes and also as a result of human influences. Such changes may occur after DP's field testing has been completed.

DP's advice is based upon the conditions encountered during previous investigations presented in Reference 1. These previous investigations did not include detailed assessment of the proposed KIWEF site to be capped. Furthermore the model calibration was focused on the adjacent T4 site and not specifically the KIWEF site to be capped. The accuracy of the advice provided by DP in this report may be affected by undetected variations in ground conditions across the site between and beyond the sampling, testing and calibration locations.

This report must be read in conjunction with all of the attached and should be kept in its entirety without separation of individual pages or sections. DP cannot be held responsible for interpretations or conclusions made by others unless they are supported by an expressed statement, interpretation, outcome or conclusion stated in this report.

This report, or sections from this report, should not be used as part of a specification for a project, without review and agreement by DP. This is because this report has been written as advice and opinion rather than instructions for construction.

Please contact either of the undersigned for clarification of the above as necessary.

Yours faithfully
Douglas Partners Pty Ltd

Reviewed by

Alex Nivlet
Hydrogeologist

Principal
Will Wright

Attachments: About This Report

About this Report

Douglas Partners

Introduction

These notes have been provided to amplify DP's report in regard to classification methods, field procedures and the comments section. Not all are necessarily relevant to all reports.

DP's reports are based on information gained from limited subsurface excavations and sampling, supplemented by knowledge of local geology and experience. For this reason, they must be regarded as interpretive rather than factual documents, limited to some extent by the scope of information on which they rely.

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Borehole and Test Pit Logs

The borehole and test pit logs presented in this report are an engineering and/or geological interpretation of the subsurface conditions, and their reliability will depend to some extent on frequency of sampling and the method of drilling or excavation. Ideally, continuous undisturbed sampling or core drilling will provide the most reliable assessment, but this is not always practicable or possible to justify on economic grounds. In any case the boreholes and test pits represent only a very small sample of the total subsurface profile.

Interpretation of the information and its application to design and construction should therefore take into account the spacing of boreholes or pits, the frequency of sampling, and the possibility of other than 'straight line' variations between the test locations.

Groundwater

Where groundwater levels are measured in boreholes there are several potential problems, namely:

- In low permeability soils groundwater may enter the hole very slowly or perhaps not at all during the time the hole is left open;
- A localised, perched water table may lead to an erroneous indication of the true water table;
- Water table levels will vary from time to time with seasons or recent weather changes. They may not be the same at the time of construction as are indicated in the report; and
- The use of water or mud as a drilling fluid will mask any groundwater inflow. Water has to be blown out of the hole and drilling mud must first be washed out of the hole if water measurements are to be made.

More reliable measurements can be made by installing standpipes which are read at intervals over several days, or perhaps weeks for low permeability soils. Piezometers, sealed in a particular stratum, may be advisable in low permeability soils or where there may be interference from a perched water table.

Reports

The report has been prepared by qualified personnel, is based on the information obtained from field and laboratory testing, and has been undertaken to current engineering standards of interpretation and analysis. Where the report has been prepared for a specific design proposal, the information and interpretation may not be relevant if the design proposal is changed. If this happens, DP will be pleased to review the report and the sufficiency of the investigation work.

Every care is taken with the report as it relates to interpretation of subsurface conditions, discussion of geotechnical and environmental aspects, and recommendations or suggestions for design and construction. However, DP cannot always anticipate or assume responsibility for:

- Unexpected variations in ground conditions. The potential for this will depend partly on borehole or pit spacing and sampling frequency;
- Changes in policy or interpretations of policy by statutory authorities; or
- The actions of contractors responding to commercial pressures.

If these occur, DP will be pleased to assist with investigations or advice to resolve the matter.

About this Report

Site Anomalies

In the event that conditions encountered on site during construction appear to vary from those which were expected from the information contained in the report, DP requests that it be immediately notified. Most problems are much more readily resolved when conditions are exposed rather than at some later stage, well after the event.

Information for Contractual Purposes

Where information obtained from this report is provided for tendering purposes, it is recommended that all information, including the written report and discussion, be made available. In circumstances where the discussion or comments section is not relevant to the contractual situation, it may be appropriate to prepare a specially edited document. DP would be pleased to assist in this regard and/or to make additional report copies available for contract purposes at a nominal charge.

Site Inspection

The company will always be pleased to provide engineering inspection services for geotechnical and environmental aspects of work to which this report is related. This could range from a site visit to confirm that conditions exposed are as expected, to full time engineering presence on site.

Douglas Partners Pty Ltd
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Warabrook NSW 2304
PO Box 324
Hunter Region MC NSW 2310
Phone (02) 4960 9600
Fax (02) 4960 9601

Project 81209.01
10 April 2013
PWW:kly
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SMEC Australia Pty Ltd
PO Box 1346
NEWCASTLE NSW 2300

Attention: Mr Ben Patterson

Email: ben.patterson@smec.com.au

Dear Sirs

Groundwater Modelling – Eastern Ponds
KIWEFF Landfill Closure
Kooragang Island

1. Introduction

Further to DPs report of 19 February 2013, this addendum provides mass balances for four small ponds located in the north east corner of K10 – designated Eastern Ponds. These ponds were not specifically included in the previous model, however have been added by including recharge and evaporation functions consistent with the other surface water bodies in the model. The basis of the modelling, nomenclature an limitations from the previous report apply to this Addendum.

The results for each Pond are presented in Tables 10 to 12 below.

Table 10: Mass Balance (m^3/day)for Zone 16 – Eastern Pond - NW

	Existing Site Condition		Proposed KIWEFF Capping	
Description	**Inflow**	**Outflow**	**Inflow**	**Outflow**
Xmin	0.8	1.39	0.5	3.15
Xmax	0.84	9.8	0.86	7.43
Y top	0.0	16.8	0.0	15.6E
Y bottom	13.5	0.0	11.1	0.0
Z bottom	0.0	14.8	0.0	14.3
Recharge	100.0	0.0	100.0	0.0
ET	0.0	72.6	0.0	72.1
Drain	0.0	0.0	0.0	0.0
TOTAL	115	115	113	113

Table 11: Mass Balance (m^3/day) for Eastern Ponds – SW Pond

	Existing Site Condition		Proposed KIWEFF Capping	
Description	**Inflow**	**Outflow**	**Inflow**	**Outflow**
Xmin	1.67	2.49	0.78	2.50
Xmax	1.29	6.06	1.35	5.58
Y top	0.05	7.13	0.0	6.48
Y bottom	0.18	3.20	0.0	4.55
Z bottom	0.0	12.61	0.0	11.81
Recharge	87.38	0.0	86.32	0.0
ET	0.0	59.08	0.0	57.50
Drain	0.0	0.0	0.0	0.0
TOTAL	90.57	90.57	88.4	88.4

Table 12: Mass Balance (m^3/day) for Eastern Ponds – SE Pond

	Existing Site Condition		Proposed KIWEFF Capping	
Description	**Inflow**	**Outflow**	**Inflow**	**Outflow**
Xmin	2.45	1.29	2.28	1.35
Xmax	0.0	4.74	0.00	4.61
Y top	3.22	1.50	3.16	1.51
Y bottom	0.0	12.05	0.0	12.01
Z bottom	0.0	8.56	0.0	8.51
Recharge	64.88	0.0	64.88	0.0
ET	0.0	42.42	0.0	42.34
Drain	0.0	0.0	0.0	0.0
TOTAL	70.56	70.56	70.32	70.32

Table 13: Mass Balance (m^3/day) for Eastern Ponds – NE Pond

	Existing Site Condition		Proposed KIWEFF Capping	
Description	**Inflow**	**Outflow**	**Inflow**	**Outflow**
Xmin	3.24	0.84	2.84	0.86
Xmax	0.08	6.10	0.08	5.81
Y top	0.0	2.48	0.0	2.41
Y bottom	2.80	3.22	2.74	3.16
Z bottom	0.0	6.34	0.0	6.40
Recharge	27.28	0.0	27.28	0.0
ET	0.0	14.41	0.0	14.30
Drain	0.0	0.0	0.0	0.0
TOTAL	33.40	33.40	32.94	32.94

The minor changes to the model lead to some minor changes in the mass balance of immediate adjacent ponds, such as Long Pond, however these were less than 5%.

Please contact either of the undersigned for clarification of the above as necessary.

Yours faithfully
Douglas Partners Pty Ltd

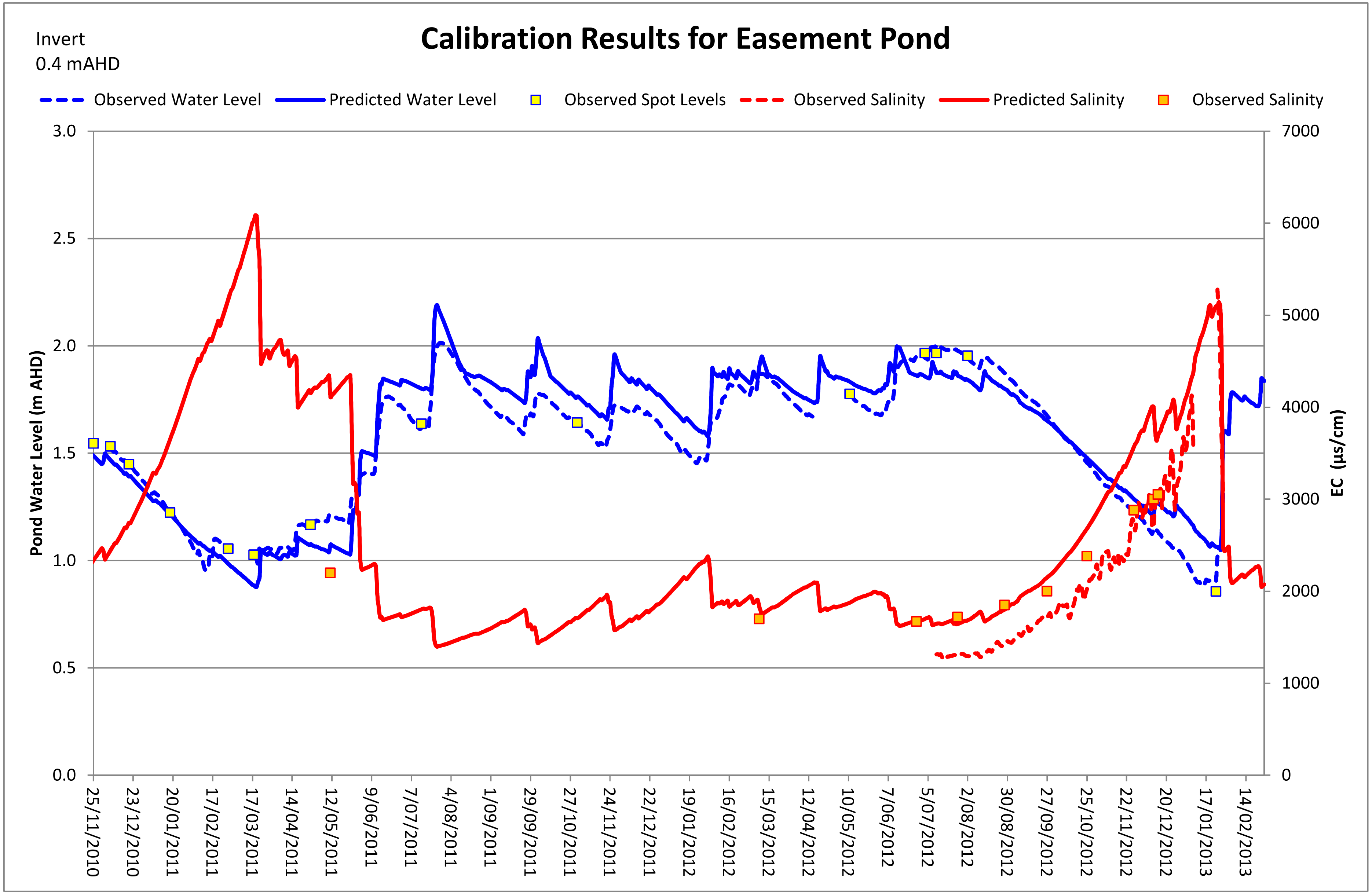
Reviewed by

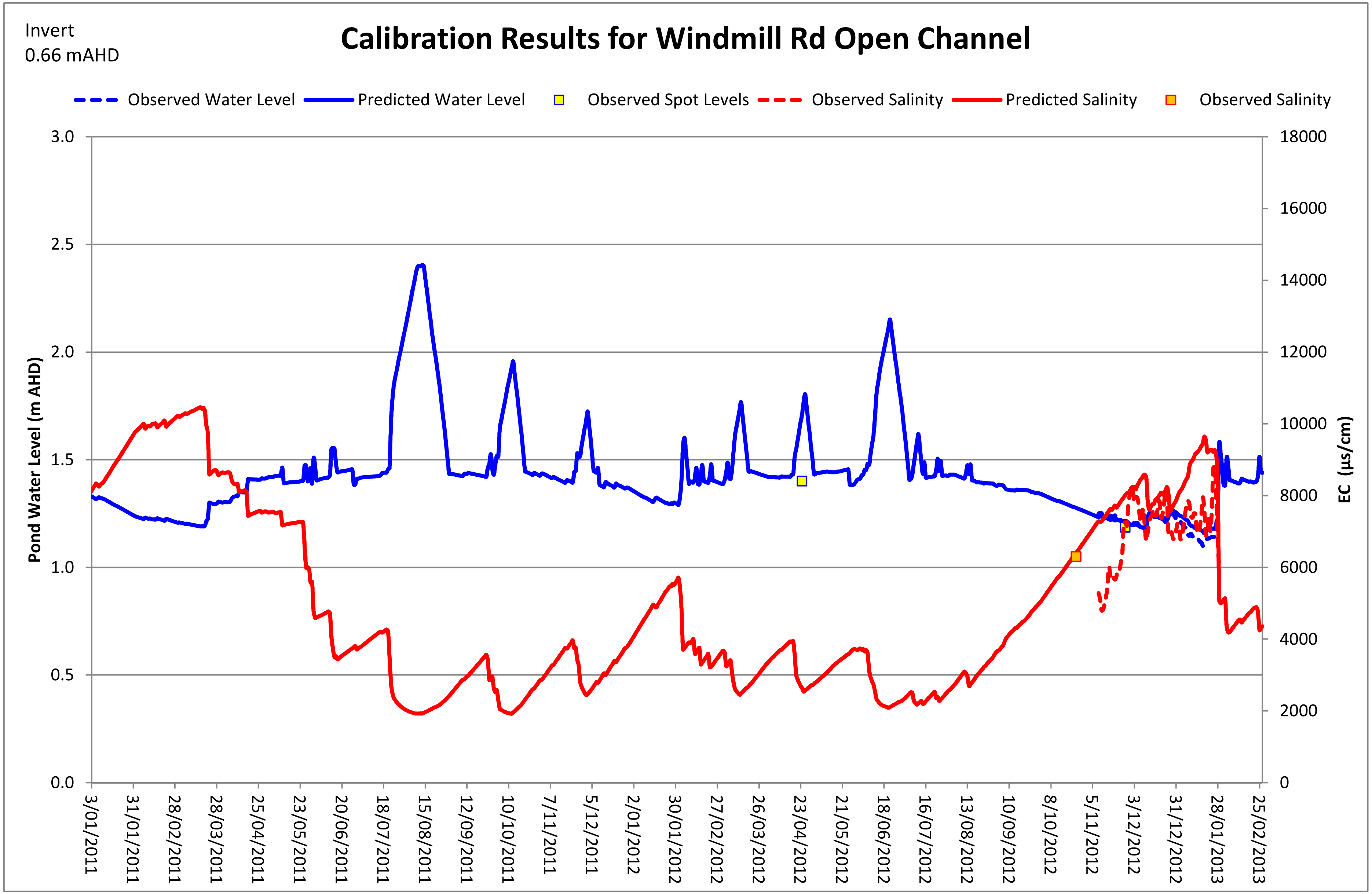
Alex Nivlet
Hydrogeologist

Principal
Will Wright

Attachments: About This Report

APPENDIX E: HYDRO-SALINITY MODEL CALIBRATION PLOTS


Invert
0.4 mAHD
Calibration Results for Easement Pond
Observed Water Level
Predicted Water Level
Observed Spot Levels
Observed Salinity
Predicted Salinity
Observed Salinity
Pond Water Level (m AHD)
EC (µs/cm)
3.0
2.5
2.0
1.5
1.0
0.5
0.0
7000
6000
5000
4000
3000
2000
1000
0
25/11/2010
23/12/2010
20/01/2011
17/02/2011
17/03/2011
14/04/2011
12/05/2011
9/06/2011
7/07/2011
4/08/2011
1/09/2011
29/09/2011
27/10/2011
24/11/2011
22/12/2011
19/01/2012
16/02/2012
15/03/2012
12/04/2012
10/05/2012
7/06/2012
5/07/2012
2/08/2012
30/08/2012
27/09/2012
25/10/2012
22/11/2012
20/12/2012
17/01/2013
14/02/2013



Invert
0.66 mAHD
Calibration Results for Windmill Rd Open Channel
Observed Water Level
Predicted Water Level
Observed Spot Levels
Observed Salinity
Predicted Salinity
Observed Salinity
Pond Water Level (m AHD)
EC (µs/cm)
3.0
2.5
2.0
1.5
1.0
0.5
0.0
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
3/01/2011
31/01/2011
28/02/2011
28/03/2011
25/04/2011
23/05/2011
20/06/2011
18/07/2011
15/08/2011
12/09/2011
10/10/2011
7/11/2011
5/12/2011
2/01/2012
30/01/2012
27/02/2012
26/03/2012
23/04/2012
21/05/2012
18/06/2012
16/07/2012
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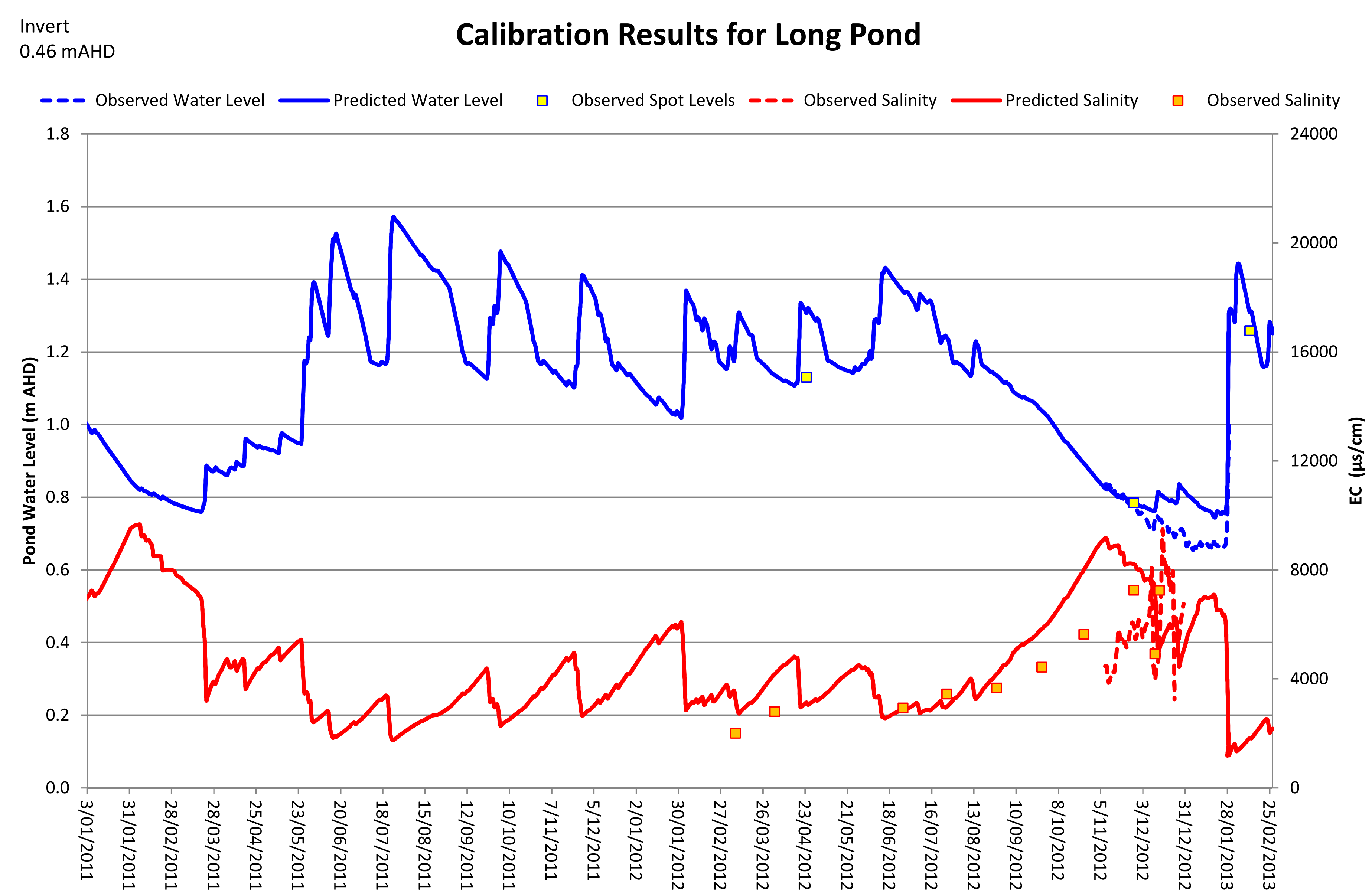
3/12/2012
31/12/2012
28/01/2013
25/02/2013



Invert
0.46 mAHD
Calibration Results for Long Pond
Observed Water Level
Predicted Water Level
Observed Spot Levels
Observed Salinity
Predicted Salinity
Observed Salinity
Pond Water Level (m AHD)
EC (µs/cm)
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
24000
20000
16000
12000
8000
4000
0
3/01/2011
31/01/2011
28/02/2011
28/03/2011
25/04/2011
23/05/2011
20/06/2011
18/07/2011
15/08/2011
12/09/2011
10/10/2011
7/11/2011
5/12/2011
2/01/2012
30/01/2012
27/02/2012
26/03/2012
23/04/2012
21/05/2012
18/06/2012
16/07/2012
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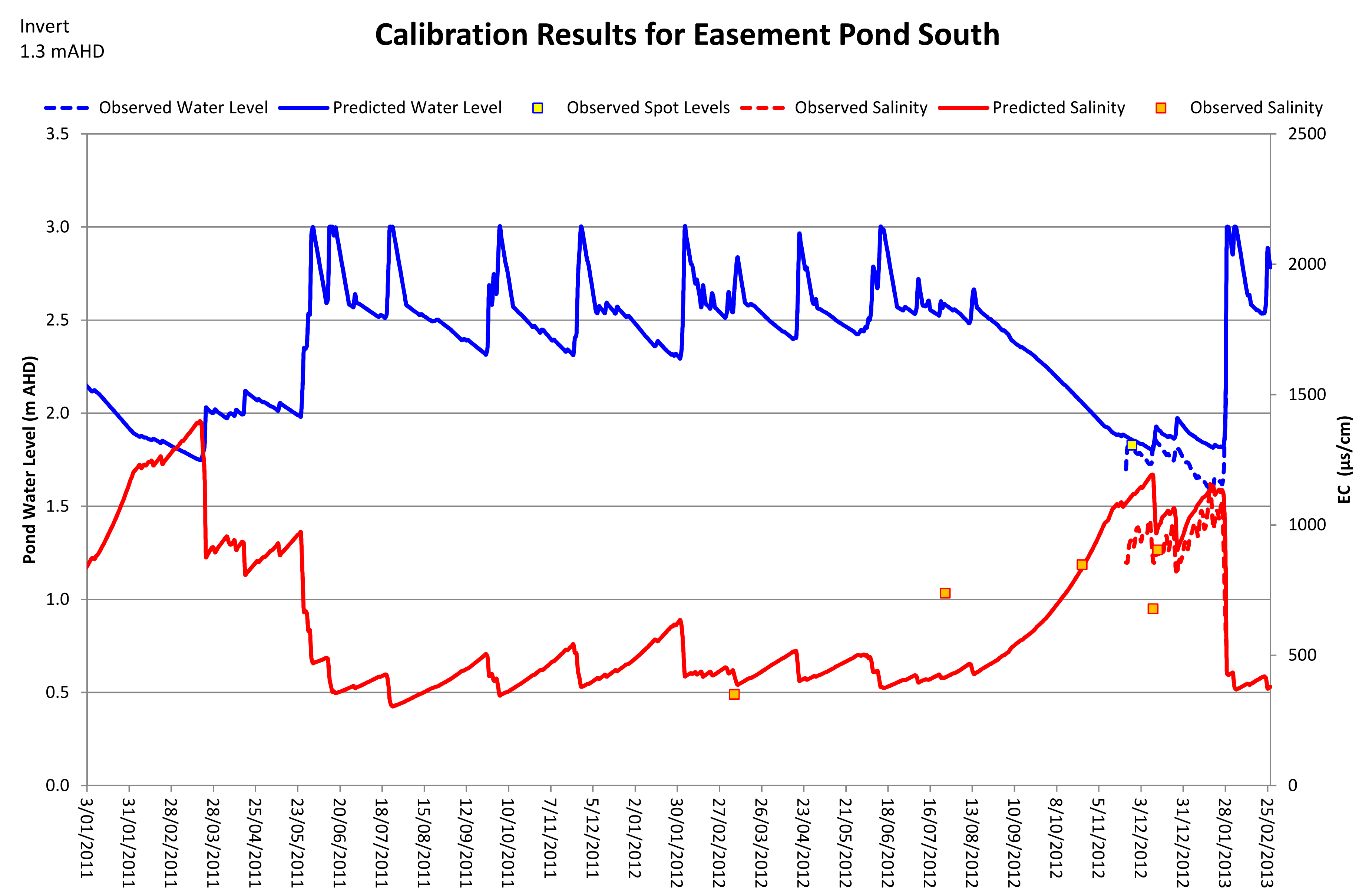
31/12/2012
28/01/2013
25/02/2013


Invert
1.3 mAHD
Calibration Results for Easement Pond South
Observed Water Level
Predicted Water Level
Observed Spot Levels
Observed Salinity
Predicted Salinity
Observed Salinity
Pond Water Level (m AHD)
EC (µs/cm)
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
2500
2000
1500
1000
500
0
3/01/2011
31/01/2011
28/02/2011
28/03/2011
25/04/2011
23/05/2011
20/06/2011
18/07/2011
15/08/2011
12/09/2011
10/10/2011
7/11/2011
5/12/2011
2/01/2012
30/01/2012
27/02/2012
26/03/2012
23/04/2012
21/05/2012
18/06/2012
16/07/2012
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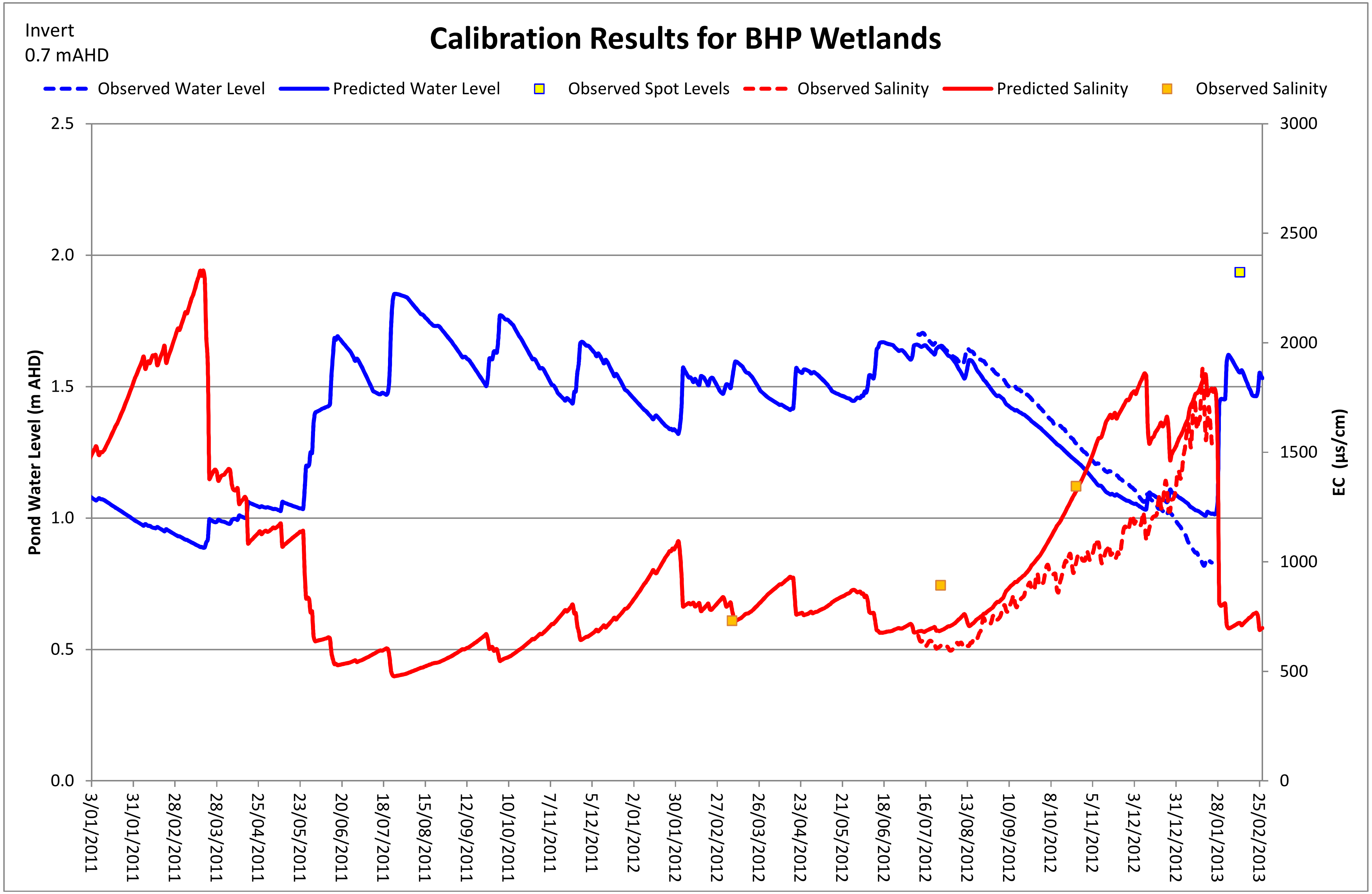
8/10/2012
5/11/2012
3/12/2012
31/12/2012
28/01/2013
25/02/2013



Invert
0.7 mAHD
Calibration Results for BHP Wetlands
Observed Water Level
Predicted Water Level
Observed Spot Levels
Observed Salinity
Predicted Salinity
Observed Salinity
Pond Water Level (m AHD)
EC (µs/cm)
2.5
2.0
1.5
1.0
0.5
0.0
3000
2500
2000
1500
1000
500
0
3/01/2011
31/01/2011
28/02/2011
28/03/2011
25/04/2011
23/05/2011
20/06/2011
18/07/2011
15/08/2011
12/09/2011
10/10/2011
7/11/2011
5/12/2011
2/01/2012
30/01/2012
27/02/2012
26/03/2012
23/04/2012
21/05/2012
18/06/2012
16/07/2012
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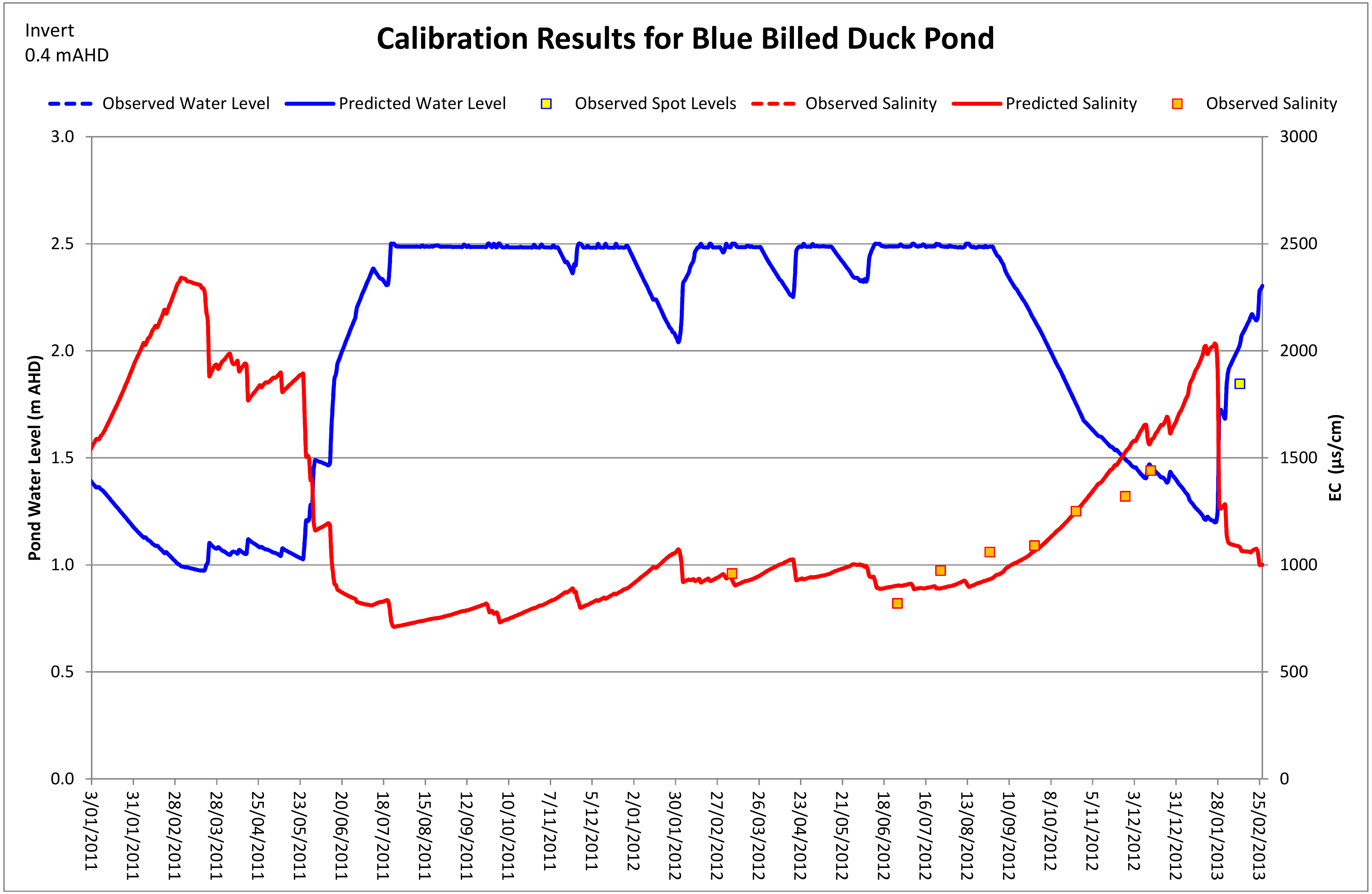
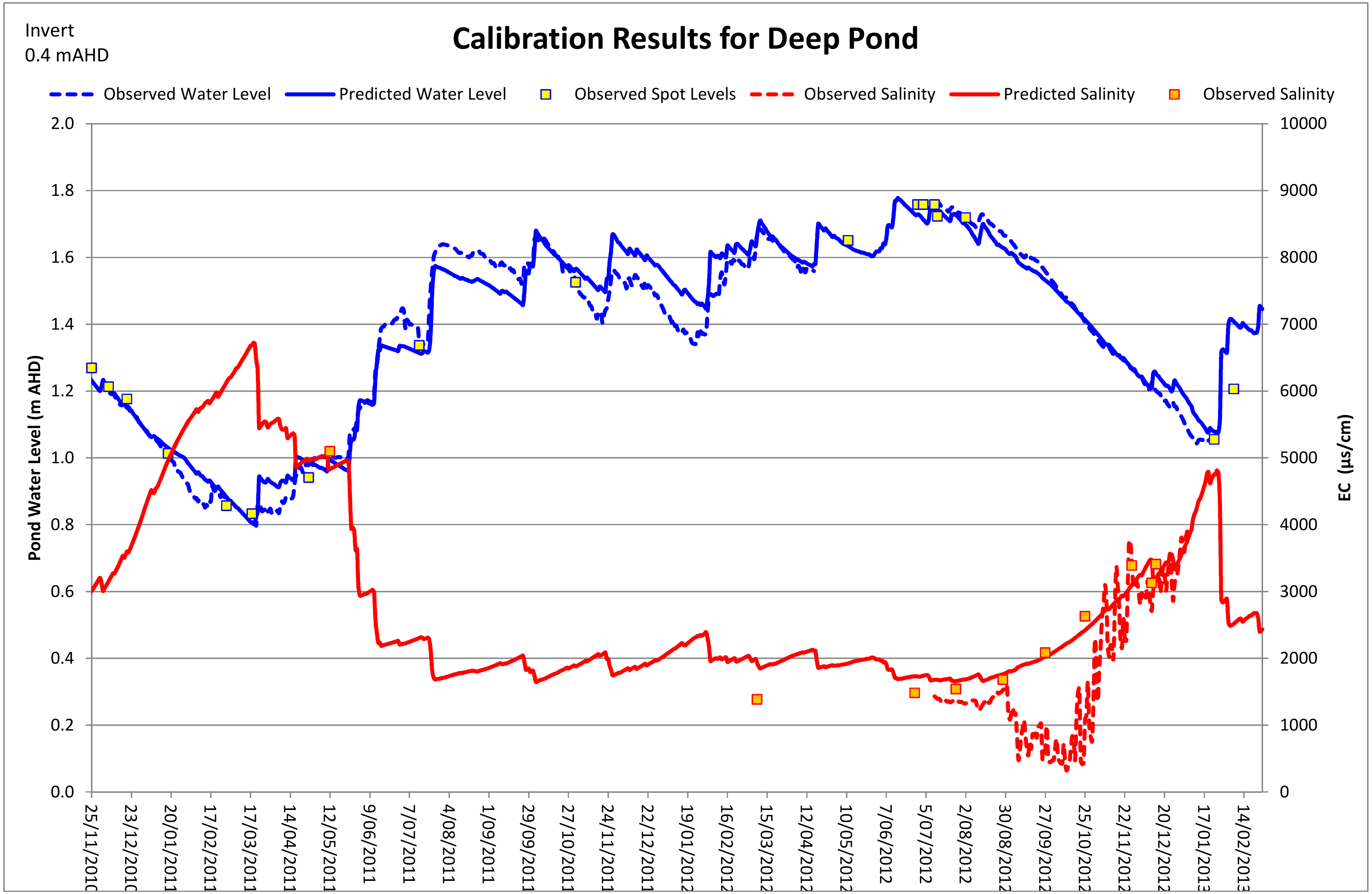
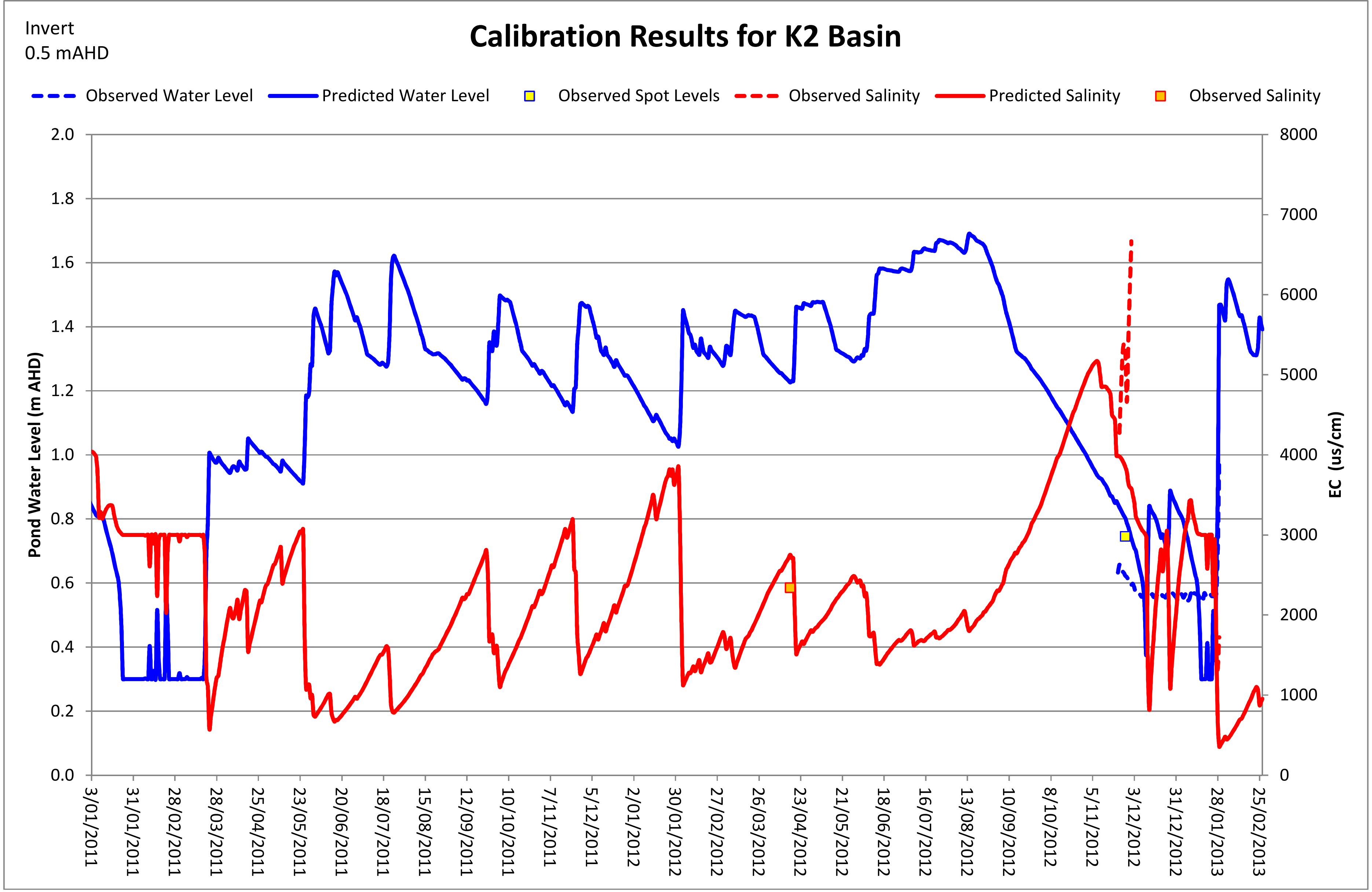
3/12/2012
31/12/2012
28/01/2013
25/02/2013



Invert
0.4 mAHD
Calibration Results for Blue Billed Duck Pond
Observed Water Level
Predicted Water Level
Observed Spot Levels
Observed Salinity
Predicted Salinity
Observed Salinity
Pond Water Level (m AHD)
EC (µs/cm)
3.0
2.5
2.0
1.5
1.0
0.5
0.0
3000
2500
2000
1500
1000
500
0
3/01/2011
31/01/2011
28/02/2011
28/03/2011
25/04/2011
23/05/2011
20/06/2011
18/07/2011
15/08/2011
12/09/2011
10/10/2011
7/11/2011
5/12/2011
2/01/2012
30/01/2012
27/02/2012
26/03/2012
23/04/2012
21/05/2012
18/06/2012
16/07/2012
13/08/2012
10/09/2012
8/10/2012
5/11/2012
3/12/2012
31/12/2012
28/01/2013
25/02/2013

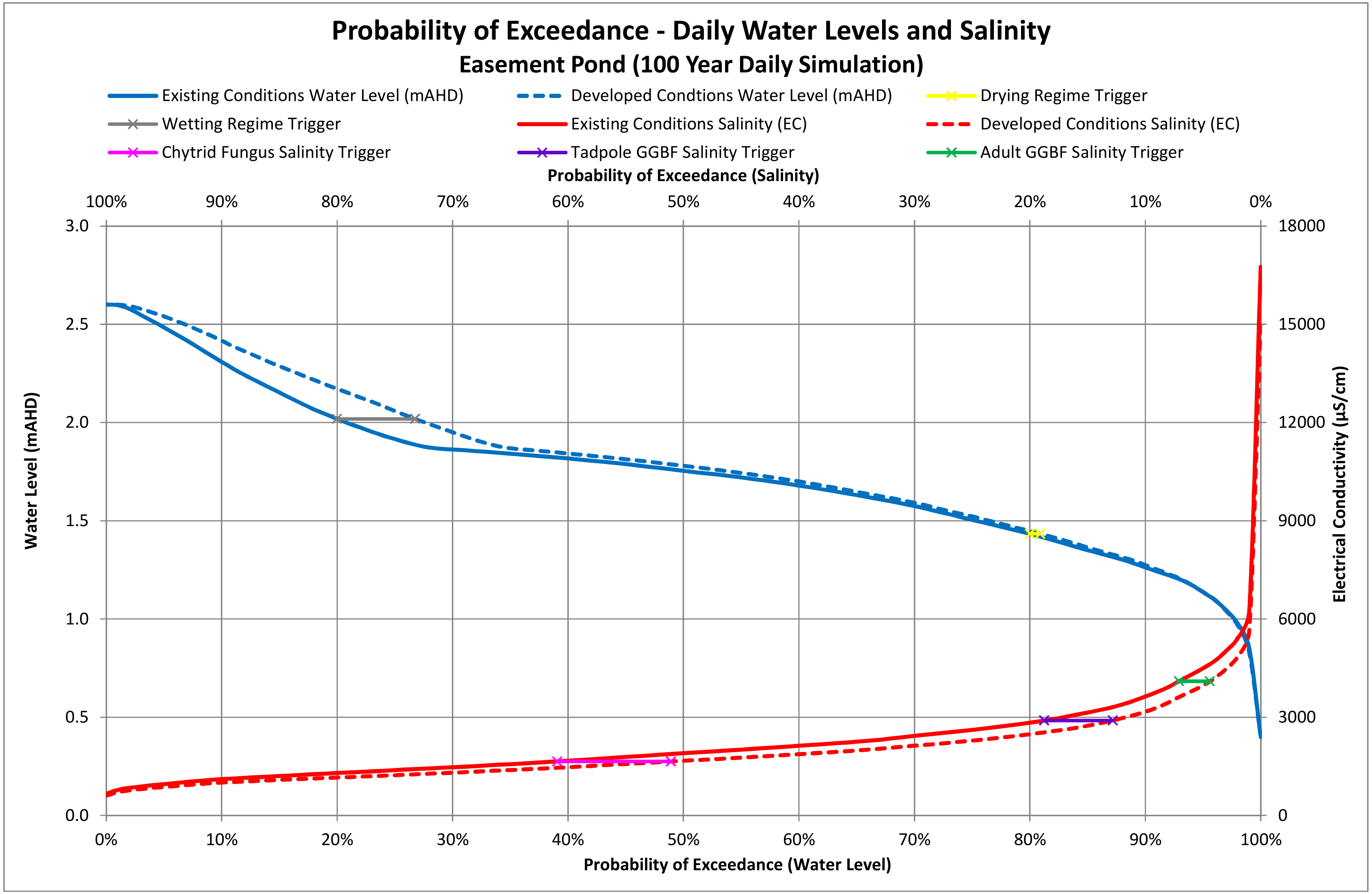


Invert
0.4 mAHD
Calibration Results for Deep Pond
Observed Water Level
Predicted Water Level
Observed Spot Levels
Observed Salinity
Predicted Salinity
Observed Salinity
Pond Water Level (m AHD)
EC (µs/cm)
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
25/11/2010
23/12/2010
20/01/2011
17/02/2011
17/03/2011
14/04/2011
12/05/2011
9/06/2011
7/07/2011
4/08/2011
1/09/2011
29/09/2011
27/10/2011
24/11/2011
22/12/2011
19/01/2012
16/02/2012
15/03/2012
12/04/2012
10/05/2012
7/06/2012
5/07/2012
2/08/2012
30/08/2012
27/09/2012
25/10/2012
22/11/2012
20/12/2012
17/01/2013
14/02/2013

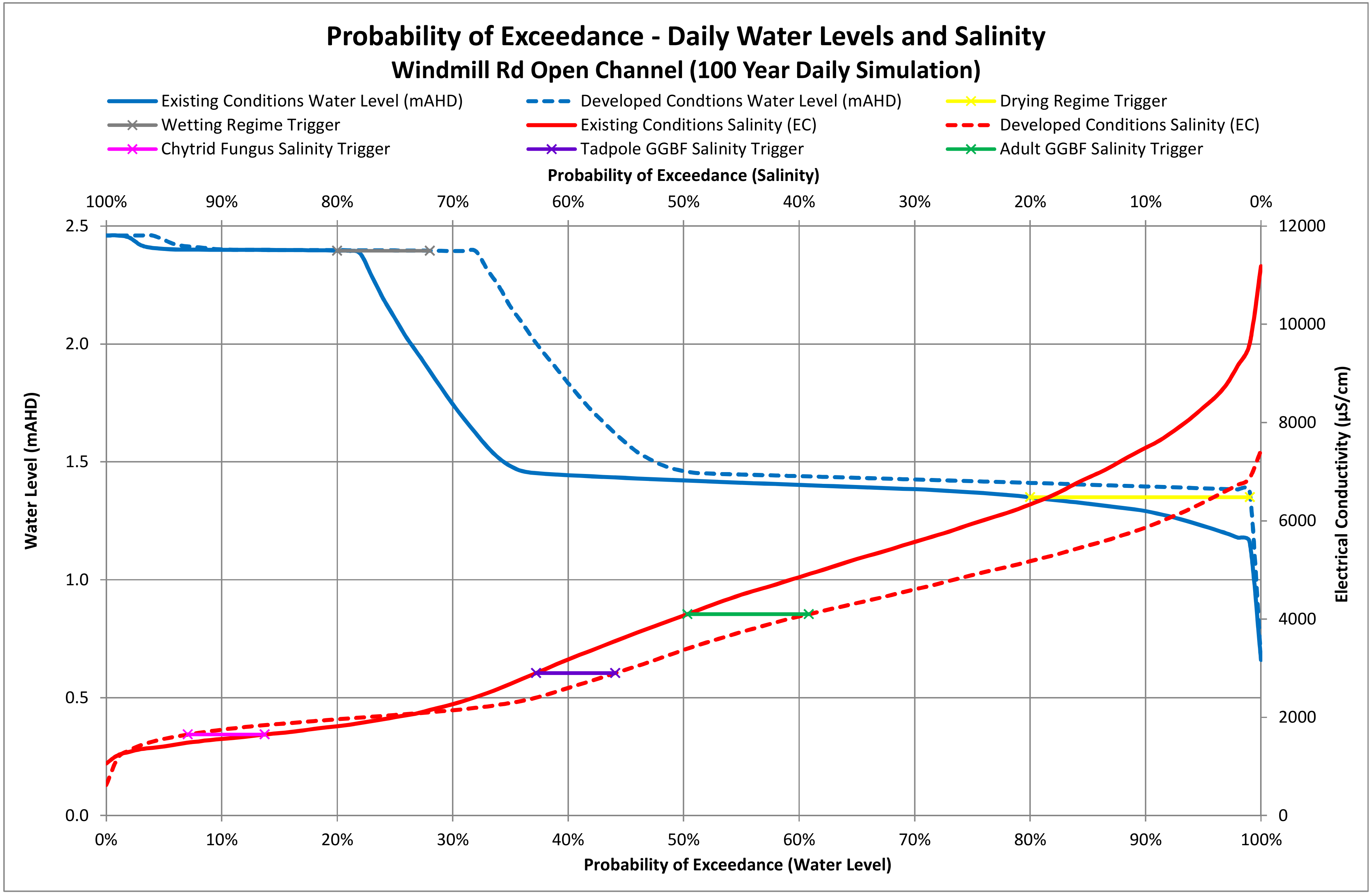


Calibration Results for K2 Basin
Invert
0.5 mAHD
Observed Water Level
Predicted Water Level
Observed Spot Levels
Observed Salinity
Predicted Salinity
Observed Salinity
Pond Water Level (m AHD)
EC (us/cm)
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
8000
7000
6000
5000
4000
3000
2000
1000
0
3/01/2011
31/01/2011
28/02/2011
28/03/2011
25/04/2011
23/05/2011
20/06/2011
18/07/2011
15/08/2011
12/09/2011
10/10/2011
7/11/2011
5/12/2011
2/01/2012
30/01/2012
27/02/2012
26/03/2012
23/04/2012
21/05/2012
18/06/2012
16/07/2012
13/08/2012
10/09/2012
8/10/2012
5/11/2012
3/12/2012
31/12/2012
28/01/2013
25/02/2013

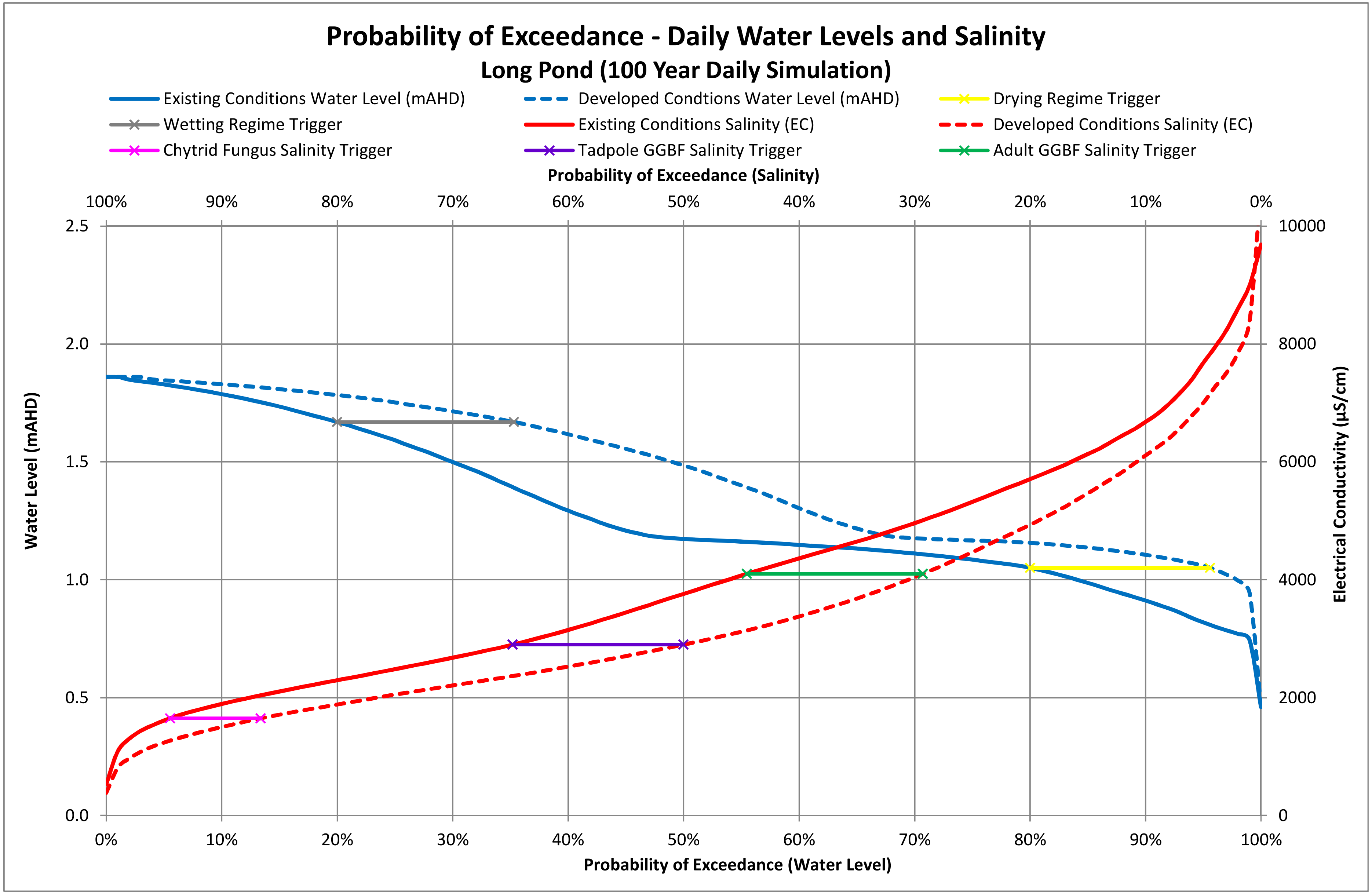
APPENDIX F: HYDRO-SALINITY MODEL RESULTS PLOTS



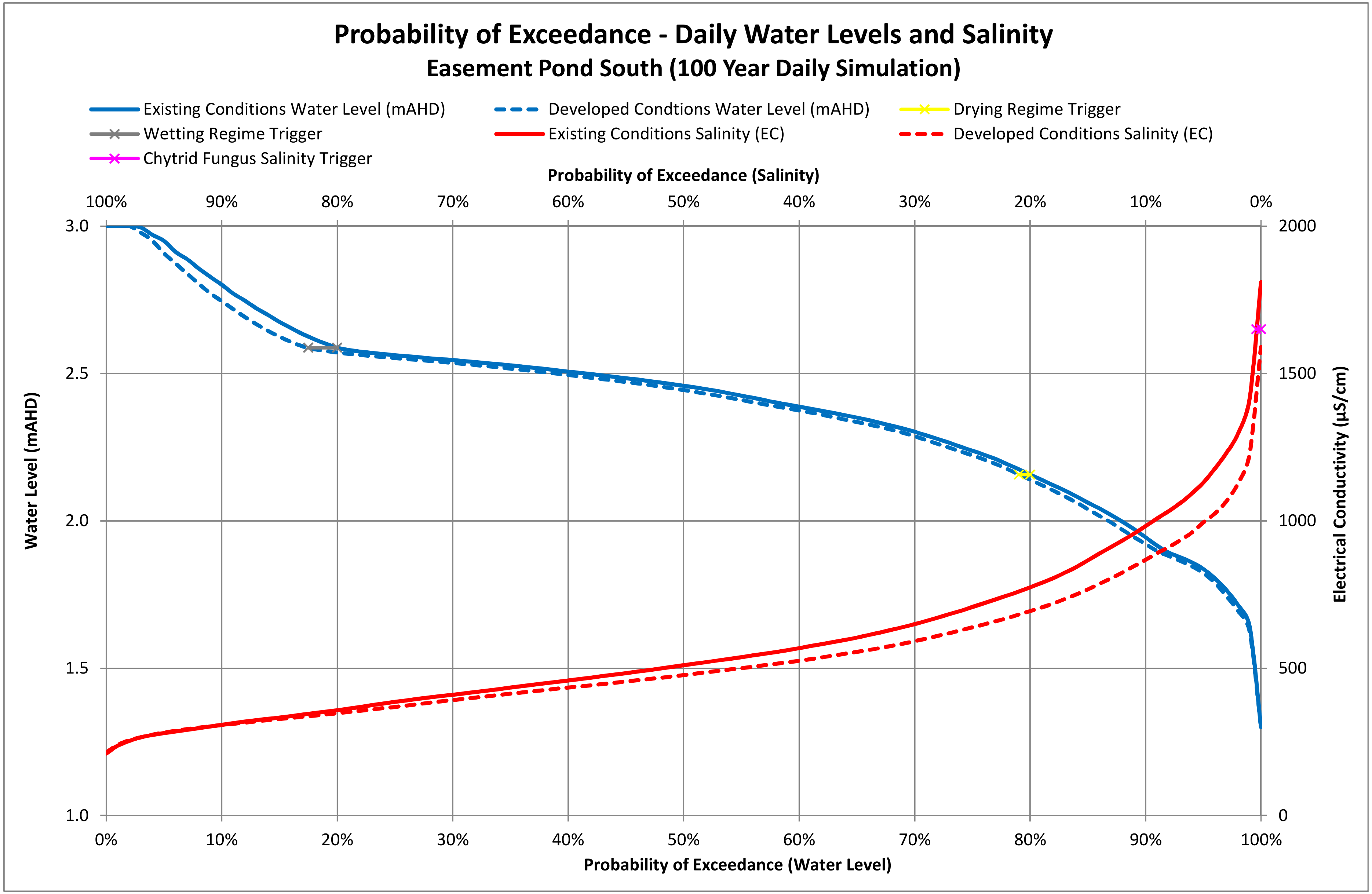
Probability of Exceedance - Daily Water Levels and Salinity
Easement Pond (100 Year Daily Simulation)
Existing Conditions Water Level (mAHD)
Developed Condtions Water Level (mAHD)
Drying Regime Trigger
Wetting Regime Trigger
Existing Conditions Salinity (EC)
Developed Conditions Salinity (EC)
Chytrid Fungus Salinity Trigger
Tadpole GGBF Salinity Trigger
Adult GGBF Salinity Trigger
Probability of Exceedance (Salinity)
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Water Level (mAHD)
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Electrical Conductivity (µS/cm)
18000
15000
12000
9000
6000
3000
0
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Probability of Exceedance (Water Level)



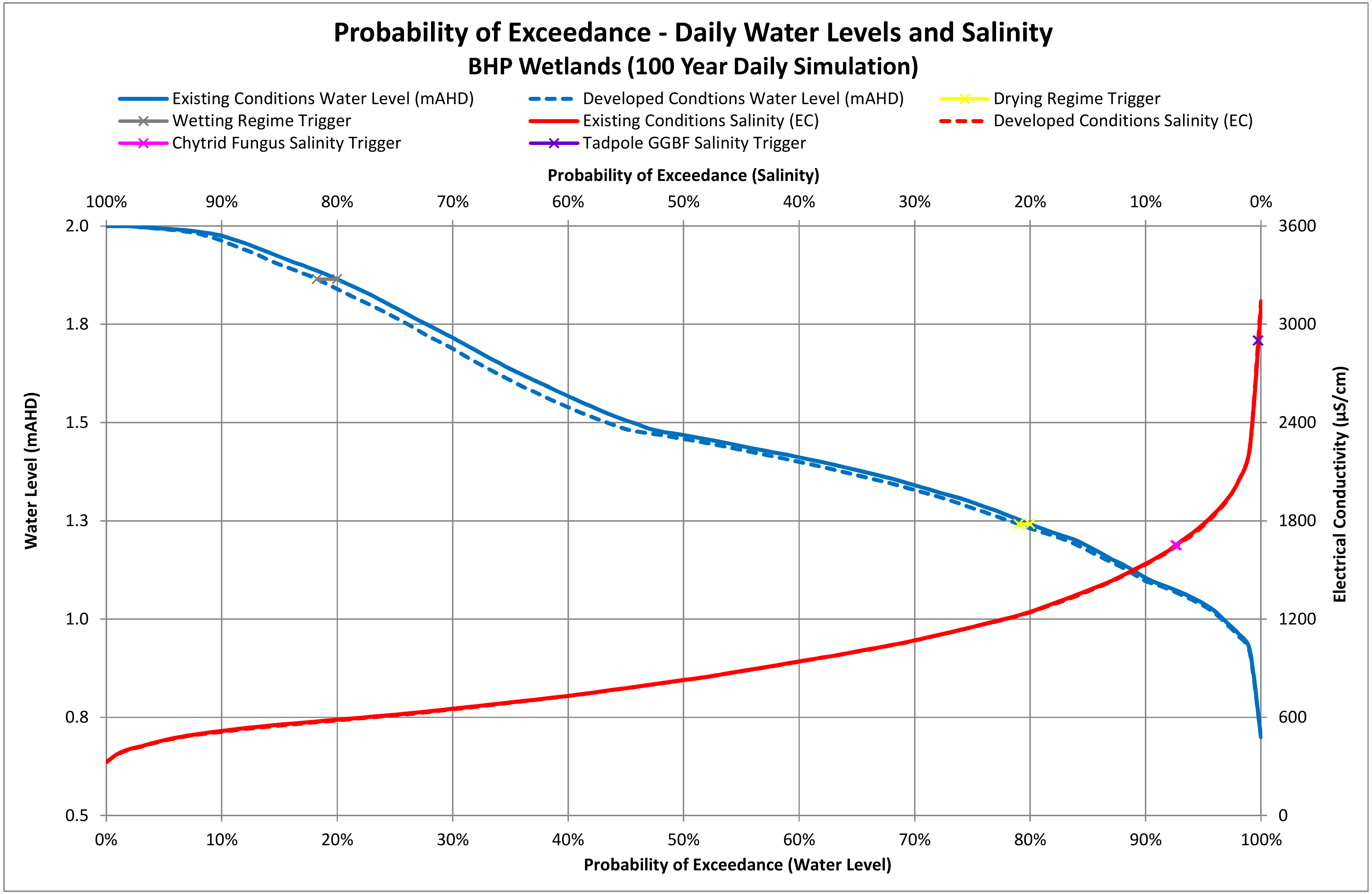
Probability of Exceedance - Daily Water Levels and Salinity
Windmill Rd Open Channel (100 Year Daily Simulation)
Existing Conditions Water Level (mAHD)
Developed Condtions Water Level (mAHD)
Drying Regime Trigger
Wetting Regime Trigger
Existing Conditions Salinity (EC)
Developed Conditions Salinity (EC)
Chytrid Fungus Salinity Trigger
Tadpole GGBF Salinity Trigger
Adult GGBF Salinity Trigger
Probability of Exceedance (Salinity)
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Water Level (mAHD)
2.5
2.0
1.5
1.0
0.5
0.0
Electrical Conductivity (µS/cm)
12000
10000
8000
6000
4000
2000
0
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Probability of Exceedance (Water Level)



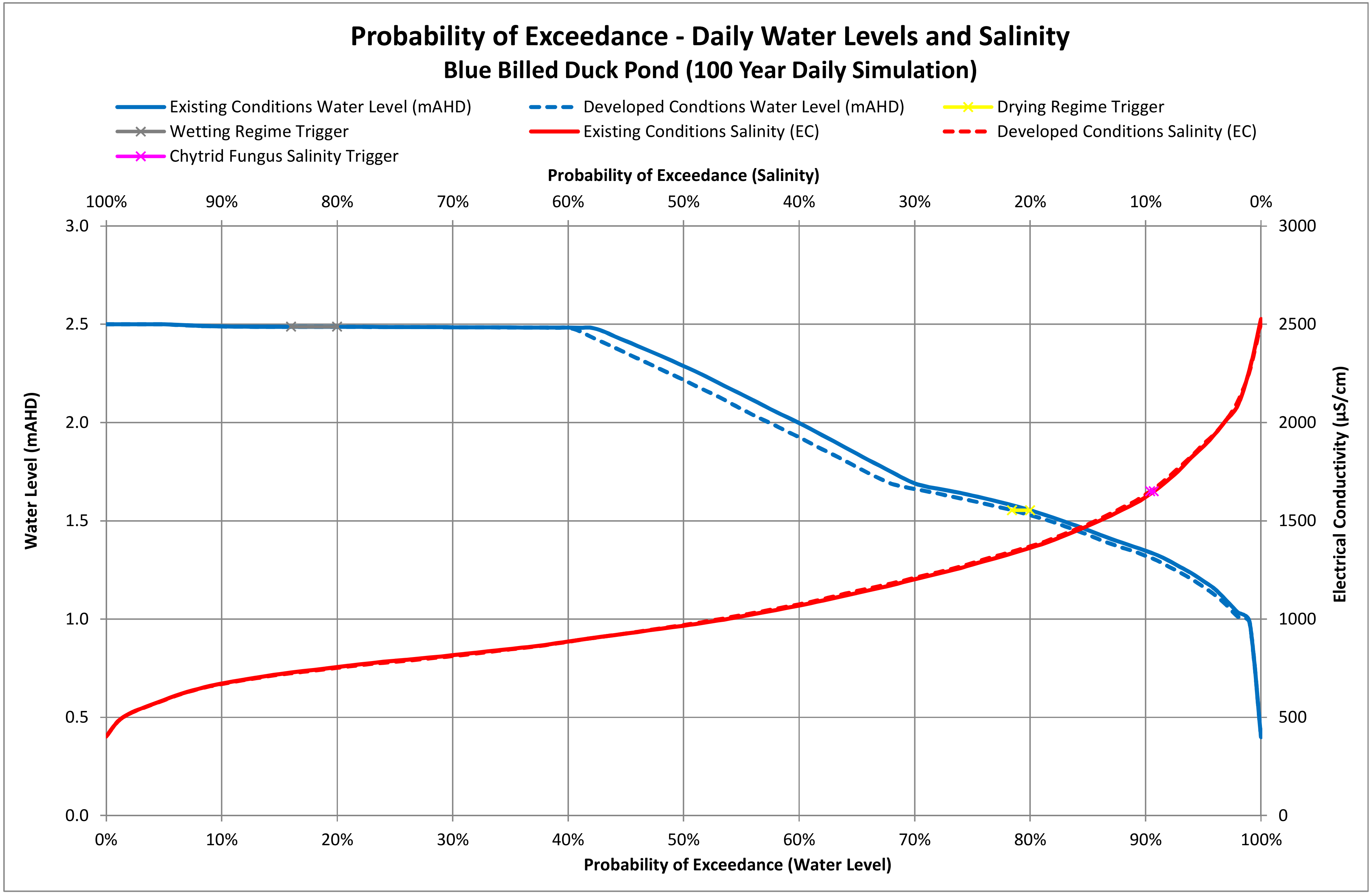
Probability of Exceedance - Daily Water Levels and Salinity
Long Pond (100 Year Daily Simulation)
Existing Conditions Water Level (mAHD)
Developed Condtions Water Level (mAHD)
Drying Regime Trigger
Wetting Regime Trigger
Existing Conditions Salinity (EC)
Developed Conditions Salinity (EC)
Chytrid Fungus Salinity Trigger
Tadpole GGBF Salinity Trigger
Adult GGBF Salinity Trigger
Probability of Exceedance (Salinity)
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Water Level (mAHD)
2.5
2.0
1.5
1.0
0.5
0.0
Electrical Conductivity (µS/cm)
10000
8000
6000
4000
2000
0
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Probability of Exceedance (Water Level)



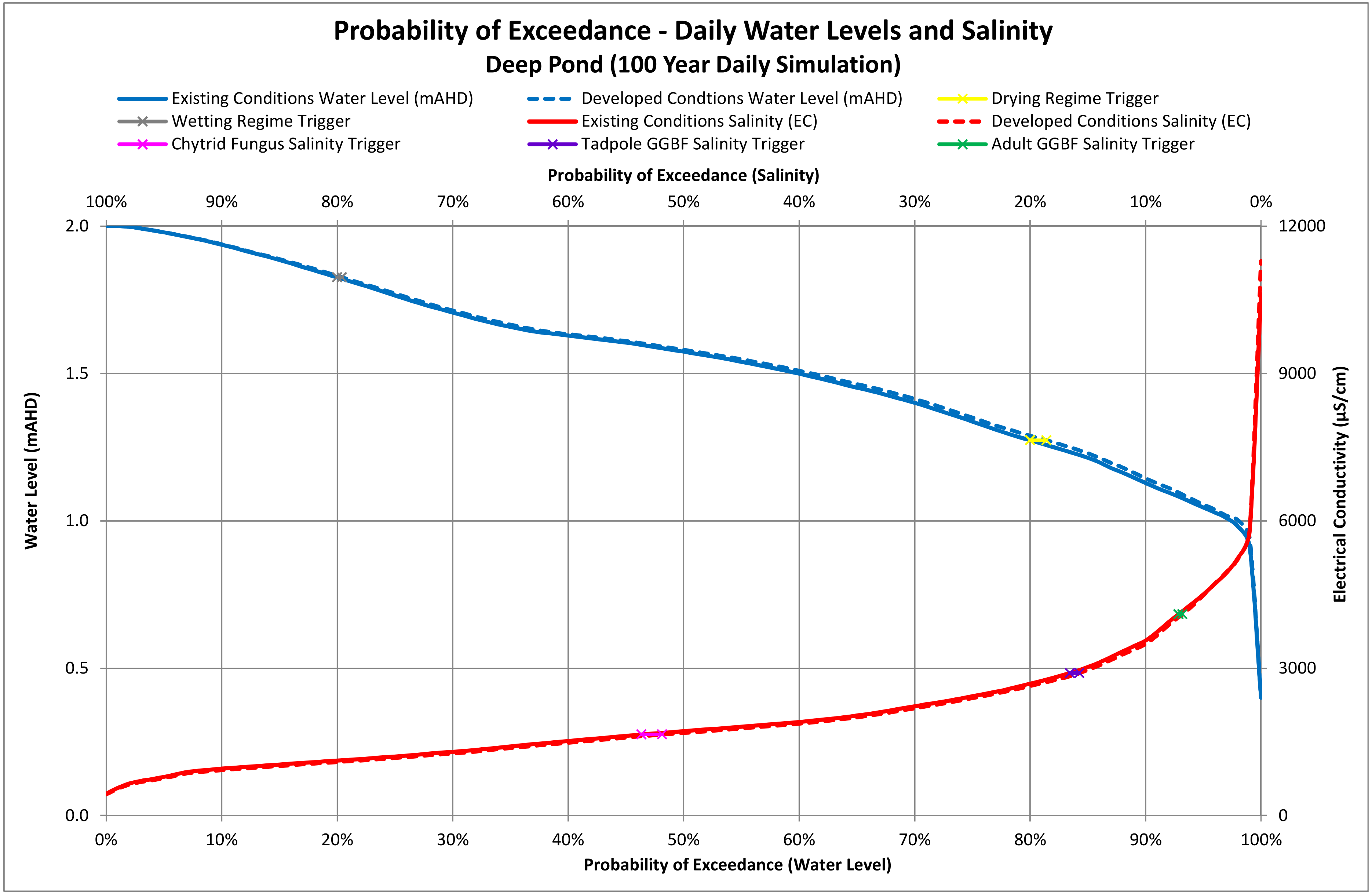
Probability of Exceedance - Daily Water Levels and Salinity
Easement Pond South (100 Year Daily Simulation)
Existing Conditions Water Level (mAHD)
Developed Condtions Water Level (mAHD)
Drying Regime Trigger
Wetting Regime Trigger
Existing Conditions Salinity (EC)
Developed Conditions Salinity (EC)
Chytrid Fungus Salinity Trigger
Probability of Exceedance (Salinity)
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Water Level (mAHD)
3.0
2.5
2.0
1.5
1.0
Electrical Conductivity (µS/cm)
2000
1500
1000
500
0
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Probability of Exceedance (Water Level)



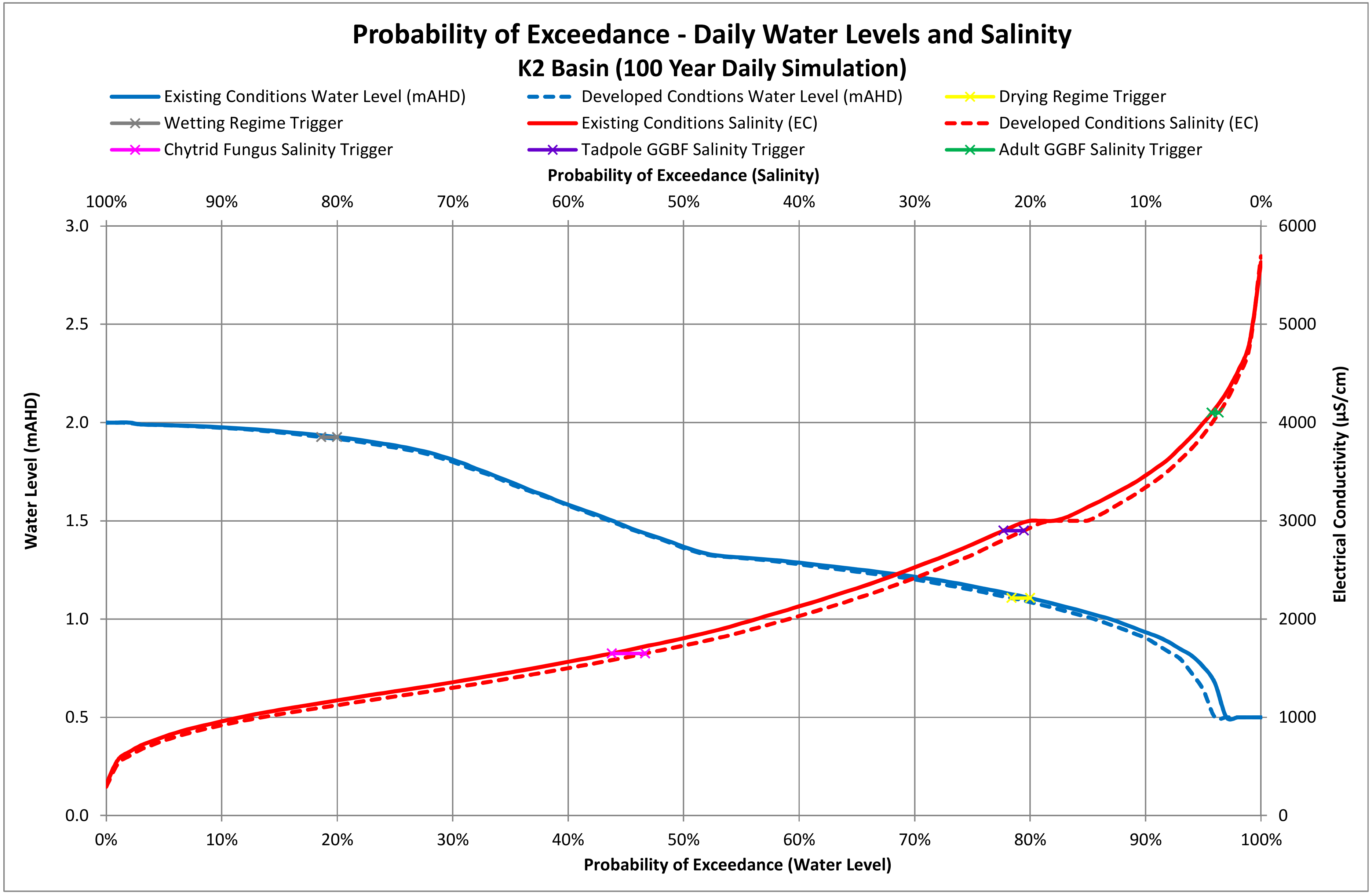
Probability of Exceedance - Daily Water Levels and Salinity
BHP Wetlands (100 Year Daily Simulation)
Existing Conditions Water Level (mAHD)
Developed Condtions Water Level (mAHD)
Drying Regime Trigger
Wetting Regime Trigger
Existing Conditions Salinity (EC)
Developed Conditions Salinity (EC)
Chytrid Fungus Salinity Trigger
Tadpole GGBF Salinity Trigger
Probability of Exceedance (Salinity)
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
2.0
1.8
1.5
1.3
1.0
0.8
0.5
3600
3000
2400
1800
1200
600
0
Water Level (mAHD)
Electrical Conductivity (µS/cm)
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Probability of Exceedance (Water Level)



Probability of Exceedance - Daily Water Levels and Salinity
Blue Billed Duck Pond (100 Year Daily Simulation)
Existing Conditions Water Level (mAHD)
Developed Condtions Water Level (mAHD)
Drying Regime Trigger
Wetting Regime Trigger
Existing Conditions Salinity (EC)
Developed Conditions Salinity (EC)
Chytrid Fungus Salinity Trigger
Probability of Exceedance (Salinity)
100% 90% 80% 70% 60% 50% 40% 30% 20% 10% 0%
Water Level (mAHD)
3.0 2.5 2.0 1.5 1.0 0.5 0.0
Electrical Conductivity (µS/cm)
3000 2500 2000 1500 1000 500 0
0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%
Probability of Exceedance (Water Level)



Probability of Exceedance - Daily Water Levels and Salinity
Deep Pond (100 Year Daily Simulation)
Existing Conditions Water Level (mAHD)
Developed Condtions Water Level (mAHD)
Drying Regime Trigger
Wetting Regime Trigger
Existing Conditions Salinity (EC)
Developed Conditions Salinity (EC)
Chytrid Fungus Salinity Trigger
Tadpole GGBF Salinity Trigger
Adult GGBF Salinity Trigger
Probability of Exceedance (Salinity)
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
2.0
1.5
1.0
0.5
0.0
Water Level (mAHD)
12000
9000
6000
3000
0
Electrical Conductivity (µS/cm)
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Probability of Exceedance (Water Level)



Probability of Exceedance - Daily Water Levels and Salinity
K2 Basin (100 Year Daily Simulation)
Existing Conditions Water Level (mAHD)
Developed Condtions Water Level (mAHD)
Drying Regime Trigger
Wetting Regime Trigger
Existing Conditions Salinity (EC)
Developed Conditions Salinity (EC)
Chytrid Fungus Salinity Trigger
Tadpole GGBF Salinity Trigger
Adult GGBF Salinity Trigger
Probability of Exceedance (Salinity)
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Water Level (mAHD)
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Electrical Conductivity (µS/cm)
6000
5000
4000
3000
2000
1000
0
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Probability of Exceedance (Water Level)

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APPENDIX 3
DOEE ADDITIONAL INFORMATION REQUIREMENTS

Australian Government
Department of the Environment and Energy

EPBC Ref: 2016/7670

Ms Sarah Strang
Port of Newcastle Lessor Pty Ltd
Level 9, Bligh House
4-6 Bligh Street
Sydney 2000

Dear Ms Strang

Additional information required for preliminary documentation.

Kooragang Island Waste Emplacement Facility – Area 2 Closure Works, off Cormorant Road, Kooragang Island, Newcastle, NSW

I am writing to you in relation to your proposal to undertake closure and rehabilitation of Area 2 (K3 and K5 and a small section of K7), which is approximately 36 hectares of the Kooragang Island Waste Emplacement Facility (KIWEF) near Newcastle, NSW.

On 2 December 2016, the Minister's delegate decided that this proposal is a controlled action and that it will be assessed by preliminary documentation. Further information will be required to be able to assess the relevant impacts of the proposed action.

Details outlining the further information required are at Attachment A.

Details on the assessment process and the responsibilities of the proponent are set out in the enclosed fact sheet. Further information is available from the Department's website at http://www.environment.gov.au/epbc.

If you have any questions about the assessment process or further information required, please contact the project officer, Yin Phyu, by email to yin.phyu@environment.gov.au, or telephone (02) 6274 1750 and quote the EPBC reference number shown at the beginning of this letter.

Yours sincerely

Dane Roberts
Acting Assistant Secretary
Assessments (NSW, ACT) and Fuel Branch
6 January 2017

Preliminary Documentation Requirements for:

Kooragang Island Waste Emplacement Facility – Area 2 Closure Works, off Cormorant Road, Kooragang Island, Newcastle, NSW (EPBC 2016/7670)

General content, format and style

The preliminary documentation package (PD) should be a stand-alone document, which includes all information provided in your initial referral (updated or corrected as necessary) as well as the additional information requested below.

The documentation should enable interested stakeholders and the Minister to understand the environmental consequences of the proposed development. The information provided should be objective, clear, succinct, and where appropriate, supported by maps, plans, diagrams or other descriptive detail.

The level of analysis and detail in the PD should reflect the level of expected impacts on the environment. Any variables or assumptions made in the assessment should be clearly stated and discussed. The extent to which limitations, if any, of available information may influence the conclusions of the environmental assessment should be discussed.

Assessment should clearly address any standards or criteria published by the Commonwealth Department of the Environment and Energy (the Department) that are relevant to matters being assessed, and appropriate reference must be made to any relevant policy documents, including how the policy requirements and objectives have been met.

The PD should be written so that any conclusions reached can be independently assessed. To this end, all sources must be appropriately referenced using the Harvard standard. The reference list should include the address of any web pages used as data sources. The PD should also include a list of persons or agencies consulted and the names of, and work done by, the persons involved in preparing the documentation.

Detailed technical information, studies or investigations supporting the text of the main document should be included as appendices, or at least directly linked to avoid readers having to search for the documents. Any such documents that are not already available to the public should be made available at appropriate locations at least during the period for public display of the PD.

If it is necessary to make use of material that is considered to be confidential in nature, the proponent should consult the Department on the preferred presentation of that material, before submitting the documents to the Department.

The PD should be produced on A4 size paper capable of being photocopied, with maps and diagrams on A4 or A3 size and in colour. The proponent should consider the format and style of the document appropriate for publication on the internet. The capacity of the website to store data and display the material may have some bearing on how the document is constructed.

The additional information must include a copy of these guidelines and a table referencing the headings and sub-headings below to indicate where the information fulfilling the guidelines is included in the PD.

Assessment Requirements

The PD should fully assess the direct and indirect impacts upon all *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) listed threatened species and ecological communities and Ramsar wetlands. Consequently, should the assessment identify impacts upon other matters to those identified herein, the Department should be contacted with a view to including these matters in the assessment.

From the information provided to date, the Department considers that the following protected matters may be significantly impacted by the proposed action:

- Green and Golden Bell Frog (GGBF) (*Litoria aurea*) – vulnerable
- Hunter Estuary Wetland (HEW) Ramsar Site

In order to adequately assess the likely scale and potential impacts of the proposed action on the matters listed above, additional information is required as follows.

A. Relevant Impacts

Hydrology and water quality

1. Please provide a quantitative assessment of the changes to the hydrology and water quality of Area 2, and adjacent GGBF habitat and breeding ponds potentially affected by the proposed action. The assessment must include:
   a) A detailed description of the pre-capping hydrological environment, including:
      i) A site water balance quantifying surface water and groundwater contribution and inundation regimes in GGBF habitat and breeding ponds, under a range of rainfall conditions.
      ii) Diagram/s showing pre-capping surface water and groundwater flow paths across Area 2, including K7 and adjacent ponds, under low, median and high rainfall conditions. Diagrams should show any culverts or overflow locations that may hydraulically connect cells or ponds.
      iii) Water quality in GGBF habitat and breeding ponds, partitioned by seasonal variation, including the percentage of time that pond water quality is within the optimal range for protection of GGBFs from chytrid fungus.
   b) Post-capping drainage design, including the location and capacity of drainage channels, culverts, bunds, and discharge points.
   c) An assessment of the proposed action's impacts on hydrology and water quality, which:
      i) Describes and quantifies the proposed action's impacts on hydrology, flow and inundation regimes, and water quality identified in steps 1(a)(i-iii) above.

ii) Assesses the cumulative impacts of the proposed action and Area 1 and 3 remedial works on the hydrology and water quality of GGBF habitat and breeding ponds.

Any assumptions or uncertainties in quantifying the pre-capping and/or post-capping hydrological or water quality environment, and their implications for the study, must be clearly documented.

2. Section 5 of the Additional Information (ERM, 2016) (provided at the project referral stage), presents research results which indicate that saline ponds (between 1,650 μs/cm – 2,900 μs/cm (tadpoles) or 4,100 μs/cm (adult GGBFs)) provide protection for amphibians against infection by chytrid fungus. However, maintenance of pre-capping salinity levels within identified GGBF habitat and breeding ponds is not proposed as a mitigation measure for the proposed action, unless a decline in the broader population is observed and the capping of Area 2 is determined to be the cause. The Department considers monitoring and maintenance of salinity concentrations at the optimal chytrid protection threshold range is important for the maintenance of these GGBF populations.

   a) Please provide the rationale for your proposed approach to monitor population decline rather than the protective precursor salinity levels of the relevant habitat. Please assess the relative risk that population monitoring, versus salinity monitoring, presents to the viability of the Kooragang Island GGBF population.

   b) Taking into account the results of the investigations from Steps 1 and 2(a), please identify any additional design, mitigation or management measures needed to minimise impacts on the Kooragang Island GGBF population due to altered hydrology and/or water quality, including whether salinity concentration and water temperature monitoring should be considered as a trigger for mitigation action, prior to any GGBF decline.

Timing of construction works

3. Please provide details of the timing of construction works in relation to the key life-cycle stages of the GGBF.

Impacts on the Kooragang Island GGBF Population

4. Taking into account the results of investigations provided by Steps 1-3 above, please assess the proposed action's impacts to the Kooragang Island GGBF population.

   Please note that, following application of avoidance and mitigation measures, if the residual impacts to the Kooragang Island GGBF population are significant, an appropriate offset package will be required in accordance with the *EPBC Act Environmental Offsets Policy 2012* available at: www.environment.gov.au/epbc/publications/epbc-act-environmental-offsets-policy.

   Please contact the Department for further advice on offsets if you consider they may be required.

Hunter Estuary Wetland Ramsar Site

5. Please assess the impacts of the proposed action as well as the cumulative impact of the capping works for Areas 1 & 3 and Area 2, on the HEW Ramsar site, with particular reference to the GGBF as a critical ecosystem component of the Ramsar site. Please also assess any other relevant aspects of the HEW's ecological character which are likely to be significantly impacted by the proposed action.

B. Proposed avoidance, mitigation and management measures

6. Please provide a detailed water quality monitoring plan for the proposed action (consolidated into one chapter/section), which includes monitoring in the ponds that provide habitat for the GGBF. The plan should include details of the methods, locations, frequency, and duration of the monitoring program, investigation triggers, contingency measures and corrective actions.

7. Please provide the aspects of the Newcastle Coal Infrastructure Group (NCIG) GGBF monitoring program that will be adopted for the proposed action, including the locations, methods, frequency and duration of monitoring. Please describe the method and criteria that will be used to determine whether the proposed action has contributed to a recorded decline in the GGBF population.

8. To prevent the spread and establishment of Gambusia, the GGBF Management Plan (Golder Associates, 2011) states that standing water should not be transferred between waterbodies. However, it is stated on page 15 of the Additional Information, Item 4, that measures that may be implemented to mitigate the impact of hydro-salinity changes include:

   (a) release of standing surface water of suitable quality from sedimentation basins into the affected pond(s)

   (b) provision of water into affected ponds from clean site aquifers to adjust the pond's water quality and water level

   (c) re-direction of surface runoff from the capped site by using temporary berms and diversion channels into or away from affected ponds

   (d) re-direction of standing surface waters from other suitable ponds into the affected pond(s).

   Please provide the Department with an assessment of the likelihood and significance of introducing Gambusia to the breeding ponds if these mitigation measures are employed. If the proposed action is likely to increase the risk of introducing Gambusia, please provide mitigation measures to minimise/avoid the risk to the GGBF.

9. Please provide a monitoring and management plan for the revegetation area, which includes performance criteria, investigation triggers and contingency measures.

C. Economic and social matters

10. The PD must provide information on the relevant economic and social impacts of the action. Consideration of economic and social matters should include a discussion of the action's impacts in the local, regional and national context.

D. Environmental record of person(s) proposing to take the action

11. The information provided must include details of any proceedings under a Commonwealth, State or Territory law for the protection of the environment or the conservation and sustainable use of natural resources against:

    (a) the person proposing to take the action

    (b) for an action for which a person has applied for a permit, the person making the application.

    If the person proposing to take the action is a corporation, details of the corporation's environmental policy and planning framework must also be included.

E. Outcomes based-conditions

12. Outcomes-based conditions may apply to your project in accordance with the Department's *Outcomes-based Conditions Policy 2016* and *Outcomes-based Condition Guidance 2016.* Outcomes need to be specific, measurable and achievable, and should be based on robust baseline data.

    (a) Please provide specific environmental outcomes to be achieved, and reasoning for these with reference to relevant Recovery Plans, Conservation Advices, Threat Abatement Plans, and the HEW's Ramsar ecological character statement.

    (b) For each proposed outcome provide:

    i. the risks associated with achieving the outcomes

    ii. the measurability of the outcome, including suitable performance measures

    iii. appropriate baseline data upon which the outcome has been defined and justified

    iv. the likely impacts that the proposed outcome will address

    v. demonstrated willingness and capability of achieving the outcome

    vi. the level of knowledge about the protected matter or its surrogate, upon which outcomes were based

    vii. commitments to independent and periodic audits of performance towards achieving outcomes

    viii. discussion of the likely level of control that the proponent will have over achieving the outcome

    ix. discussion of the appropriateness of any surrogates for protected matter outcomes

    x. details of proposed management to achieve the outcome, including, but not limited to performance indicators, periodic milestones, proposed monitoring and adaptive management, and record keeping, publication and reporting processes.

APPENDIX 4
DOEE FURTHER ADDITIONAL INFORMATION REQUIREMENTS

Further information to be included in addition to the PD requirements sent on 6 January 2017 **(<u>Attachment A</u>)**

1. Assessment of any likely significant impacts on Green and Golden Bell Frog (GGBF) and Hunter Estuary Wetland (HEW) Ramsar Site from removal of stockpile and borrow pit material including the proposed haulage routes.
2. Discussion and analyses of the need for capping cell 5 – will this prevent/slow impacts of hydrocarbon contamination on GGBF and HEW Ramsar Site?
3. Inclusion of hydro-salinity modelled data.
4. Assessment of salinity and contamination of hydrocarbon to the GGBF and HEW Ramsar Site by Hunter Development Corporation, which includes:
    1. measures to avoid or reduce impact
    2. mitigation and management measures
    3. likelihood of impacts.
5. Discussion of how capping works and any mitigation measures are sympathetic to other EPBC conditions for proposals on the site, e.g. the T4 approval (EPBC 2011/6029).
6. Inclusion of relevant results from the University of Newcastle on GGBF population monitoring and behavioural research.
7. Discussion of establishment of new GGBF breeding habitat (occurrences of successful breeding including driest breeding season).

APPENDIX 5
SMEC HYDROLOGICAL INVESTIGATION AND MODELLING

Member of the Surbana Jurong Group

KIWEF Area 2 Closure Works

Area 2 Hydro-Salinity Model

Prepared for: Hunter Development Corporation
Reference No: 30011921
23/05/2018

Document/Report Control Form

File Location Name:	30011921 – KIWEF Area 2
Project Name:	KIWEF Area 2 Closure Works
Project Number:	30011921
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The information within this document is and shall remain the property of:

Hunter Development Corporation

Table of Contents

Appendices

Glossary

Term or Abbreviation	Description
Closure Works – Areas	

Term or Abbreviation	Description
Area 2	Closure Works to be undertaken within the KIWEF and the subject of this report. Works cover areas sometimes referred to as K3, K5 and K7
Area 1	Closure works completed in 2014, for areas sometimes referred to as K10 North and K2
Area 3	Closure works completed in 2016, for an area sometimes referred to as K10 South
General Terms	
Cap	Materials compacted across the site to form a low permeability layer that meets the requirements of the "Surrender Notice".
Standard Cap	A cap as installed in Areas 1 and 3 comprising a 100mm revegetation layer over a 500mm thick layer of low-permeability compacted material
Modified Cap	A cap proposed for sections of Area 2 that comprises relatively uncompacted site-won material over a low permeability layer, which satisfies the requirements of the Surrender notice, and maximises storage and evapotranspiration opportunities from the uncompacted site-won material.
Composite Cap	A cap consisting of multiple layers of material such as geotextiles, geomembrane liners, Geosynthetic Clay Liner (GCL), geogrid, drainage, backfill and topsoil.
Closure Plan	A Closure Plan was developed and submitted to the NSW EPA - the Revised Final Landform and Capping Strategy, December 2009 (Revision 4, GHD). The Closure Plan was approved by the NSW EPA, and the KIWEF EPL6437 was surrendered pursuant to a s80 Notice of Surrender of a License under the PoEO Act (dated 8 December 2010).
CWR	Coal Washery Reject. Material present at KIWEF that is recommended in the Final Landform and Capping Strategy (the closure plan) and approved by NSW EPA for use as a final cap.
DoEE	Commonwealth Department of Environment and Energy (DoEE)
GGBF	Green and Golden Bell Frog (litoria aurea), a threatened species of frog with local, state and national significance present at KIWEF

HDC	Hunter Development Corporation. HDC is the agent of the Crown responsible for arranging the necessary closure works to meet the State's obligations on KIWEF.
k	'k' (lower case) refers to an historical label for each of the waste emplacement cells of KIWEF. Cells are typically characterised by slag walls and filled or partly filled with varying waste materials.
K	'K' (upper case) refers to large areas of the KIWEF that are to be capped as part of the closure works.
KIWEF	Kooragang Island Waste Emplacement Facility (KIWEF) refers to the former landfill area covered by EPL 6437.
KIWEF GGBF Management Plan	A stand-alone KIWEF Green and Golden Bell Frog (GGBF) Management Plan produced by the Principal as a part of meeting EPA approval (Surrender Notice) requirements
Leachate	Water within the landfill.
Low Area	An area within K5 (Area 2) that typically contains around 200 mm of weathered 'topsoil' material over a fine CWR material (sandy SILT) around 1m thick or greater.
MNES	Matters of National Environmental Significance, including the Green and Golden Bell Frog and internationally listed RAMSAR wetlands (Hunter Estuary Wetlands)
NCIG	Newcastle Coal Infrastructure Group (NCIG) who have operations adjacent to Area 2
OEH	NSW Department of Office Environment and Heritage that includes the Environmental Protection Authority (EPA) and incorporates the former DECCW. Generally, this relevant authority is now referred to as the NSW EPA.
Permeability	The rate at which water can move through the pore spaces of soil or other material.
PoN	Port of Newcastle Investments (trading as Port of Newcastle) is the current lease holder of the state-owned lands leased under a 98 year contract in 2014, including the KIWEF. PoN manages the KIWEF lands.
Revegetation layer	A topsoil layer sourced from on-site placed over the final cap, then appropriately re-vegetated and stabilised to protect the cap.
SMEC 2013	The report, *'KIWEF SEWPaC SMEC Detailed Review – Revision No. 5'* SMEC (2013). The report formed a written response to ten (10) requests for information raised by SEWPaC (EPBC Re: 2012/6464)
Surrender Notice	The Surrender Notice was issued by the NSW EPA with the "Approval of the Surrender of a Licence No. 6437" (the "Surrender Notice" and associated "Conditions of Surrender"). It refers to the NSW EPA Notice 1111840 dated 8/11/10 as amended. The Surrender Notice has also been modified with subsequent notices issued by the EPA being: • KIWEF Surrender Variation Notice Number 1510956 issued 15 May 2013. • KIWEF Surrender Variation Notice Number 1520063 issued 17 April 2014.
Temporary pond	Sediment basins, usually lined, and installed on the cap to provide water quality improvements, and design where possible in accordance with the Blue Book.
T4	The Proposed Terminal 4 Project. The proposed T4 project is anticipated to extend over much of the Area 2 Closure Works
T4 EA	The report *'T4 Project Environmental Assessment'* (EMGA Mitchell McLennan, 2012) including the technical appendices
Water quality	The key focus of this investigation in terms of water quality within the ponds refers to variations in salinity. Water quality and salinity are used interchangeably throughout this report.

Executive Summary

The Hunter Development Corporation are a NSW Government Agency tasked with arranging the closure of a former industrial landfill at Kooragang Island on behalf of the State land owner, Port Lessor Pty Ltd. SMEC were engaged by HDC to progress the design and technical inputs to the project, which requires a Commonwealth Approval under the EPBC Act (1999).

The project is necessary to meet regulatory requirements of the NSW Environmental Protection Authority and is essential to manage risks associated with contaminated soil and groundwater at the site. The project is a high priority to protect nearby sensitive receptors from contaminants within the landfill. The core objective of the project is environmental protection.

Landfill Closure involves earthworks to create free drainage and installation of a low permeability cap to minimise surface water infiltration. To date, two of three stages of Closure Works have been completed, to the satisfaction of the NSW EPA.

The project is complicated by presence of an endangered amphibian, *Litoria Aurea,* in wetlands embedded within the landfill. *Litoria Aurea* are in decline, in part due to a contagious disease known as *chytridiomycosis,* caused by an introduced fungus. *Litoria Aurea* is listed nationally as vulnerable and as endangered under NSW legislation.

SMEC have been informed by HDC, that research and monitoring (conducted by the University of Newcastle) confirms persistence of *Litoria Aurea* at KIWEF may rely (in-part) on water characteristics of the landfills wetlands, which are mildly saline. Research has demonstrated that low levels of salinity reduces the severity of *chytridiomycosis*, creating favourable conditions for *Litoria Aurea's* survival.

A key objective of the Closure Works is therefore to minimise risk of change in hydrology and water quality in habitat areas, with a focus on salinity. HDC has responded by conducting continuous long-term monitoring of groundwater and surface waters for use in the calibration of a numerical model capable of predicting effects of the works.

Modelling of prior stages (Areas 1 and 3, undertaken by SMEC in 2013) predicted minor changes in downstream wetlands, summarised as being slightly wetter (ie higher water levels) and fresher, with no significant changes that would materially affect the function of the habitat. Post-construction water quality monitoring observations following completion of the Area 1 and 3 Closure Works is not inconsistent with the model predictions; and the previous model has therefore been used as the baseline data for the modelling of the final phase (Area 2). Further, HDC has informed SMEC that monitoring conducted by University of Newcastle researchers has confirmed no apparent significant impact arising from the completion of Areas 1 and 3, further validating the results of the previous hydro-salinity modelling.

The final stage of the Closure Works (in Area 2) has been determined to be a Controlled Action, requiring Commonwealth approval with assessment to be conducted on the basis of a Preliminary Documentation Package (PDP). A requirement of the PDP ***(Item 1)*** is that additional modelling is to be conducted to quantify the effects of the final stage on ***Hydrology and Water Quality***.

This report provides a comprehensive response to Item 1***.*** It describes the expansion of the model used to predict the environmental effects of Areas 1 and 3 capping, to include catchments relevant to the Area 2, and the integration of new data for model calibration and refinement. This report details a quantitative assessment of the Area 2 project effects and has also been used to assess different capping options to minimise risk.

Key findings of the hydro-salinity modelling for this final stage is summarised as follows:

- **Cap Design - Assessment of a Standard Cap:** installation of a 500mm thick low permeability surface cap, similar to that used in prior stages (Areas 1 and 3), has been modelled to assess effects on wetland water levels and salinity. The model has identified only minor changes to Deep Pond, with negligible effects elsewhere.
- **Design Refinement- Assessment of a Modified Cap:** the model was used to assess the effects of a modified design over part of the Area 2 works. This method relies on a low permeability layer to prevent infiltration, positioned below a thick vegetation layer (ie minimum 500mm thickness) referred to as an evapotranspiration layer. It is slightly favoured over standard cap in that a greater portion of surface water is retained within the vegetation layer, reducing changes in water balances in surrounding ponds. The model confirmed slightly better outcomes in respect of hydro-salinity, compared to a standard cap.

The outcomes of a Modified Cap including evapotranspiration layer, deployed over part of Area 2 are marginally improved over a standard cap, but nevertheless of quantifiable benefit, from a hydro-salinity perspective. The Modified Cap including evapotranspiration layer will also support more substantial terrestrial vegetation than a standard cap, anticipated to be a further improvement in respect of provision of movement corridors for *Litoria Aurea*. HDC has therefore indicated it intends to invest in a modified cap over part of the site.

The model for the Area 2 Modified Cap design, predicts relatively minor hydrological and salinity changes in Deep Pond as a result of the project, which are described as providing slightly wetter and fresher conditions on completion, similar to observations of earlier stages. The modelling has concluded that Deep Pond will retain a mildly saline character that is indicated to be suitable habitat conditions for the *Litoria Aurea,* without substantial change in hydro-salinity or hydrology following the completion of the Area 2 works.

The Area 2 Closure Works are a final stage of the State's statutory requirements for the landfill closure project. Works have been conducted over several years, with robust monitoring to assess baseline conditions, modelling to predict outcomes and post construction monitoring to verify outcomes. The proposed works are consistent with the prior stages that have been completed and are expected to represent a minor disturbance to the salinity of a single pond at the KWIEF, whilst satisfying the State's obligations to close the KIWEF landfill.

1. Introduction

HDC submitted a referral to the DoEE under the EPBC Act to undertake the KIWEF Area 2 Closure Works. The DoEE determined that the works could affect the GGBF and therefore considered the Area 2 Closure Works to be a Controlled Action, requiring Commonwealth Approval.

In order for the DoEE to assess and approve the works, HDC are required to provide the DoEE with a Preliminary Documentation Package (PDP), which includes various site details. HDC has engaged SMEC to address ***Item 1 Hydrology and Water Quality*** of the PDP request, which is reproduced in **Table 1** below:

Table 1 - PDP Item 1 Hydrology and Water Quality -

PDP item	Where Item is Addressed
1. Provide a quantitative assessment of the changes to the hydrology and water quality of Area 2, and adjacent GGBF habitat and breeding ponds potentially affected by the proposed action. The assessment must include:	Throughout this report
a. A detailed description of the pre-capping hydrological environment, including:	Section 2
i. A site water balance quantifying surface water and groundwater contribution and inundation regimes in GGBF habitat and breeding ponds, under a range of rainfall conditions.	Section 2 and 3
ii. Diagrams showing pre-capping surface water and groundwater flow paths across Area 2, including K7 and adjacent ponds, under low, median and high rainfall conditions. Diagrams should show any culverts or overflow locations that may hydraulically connect cells or ponds.	Section 2.1 and 2.2
iii. Water quality of GGBF habitat and breeding ponds, partitioned by seasonal variation, including the percentage of time that pond water quality is within the optimal range for protection of GGBF's from chytrid fungus.	Section 3.4
b. Post-capping drainage design, including the location and capacity of drainage channels, culverts, bunds and discharge points.	Section 4.2
c. An assessment of the proposed action's impacts on hydrology and water quality, which:	Section 5
i. Describes and quantifies the proposed actions impact on hydrology, flow and inundation regimes, and water quality identified in steps 1(a)(i-iii) above.	Sections 5.1 and 5.2
ii. Assesses the cumulative impacts of the proposed action and Area 1 and 3 remedial works on the hydrology and water quality of GGBF habitat and breeding ponds.	Section 5.3
Any assumptions or uncertainties in quantifying the pre-capping and/or post-capping hydrological or water quality environment, and their implications for the study must be clearly documented.	Section 2 and 3

2. Existing Conditions

2.1. Surface Water Drainage

For this assessment, 'Existing Conditions' refers to the current KIWEF site, as of early 2018.

- **Figure 1** shows surface water flow paths across the entire KIWEF, under Existing Conditions;
- **Figure 2** shows surface water flow paths across Area 2; and
- **Figure 3** shows the receiving water bodies across the entire KIWEF site.

The primary water bodies that currently receive surface runoff from Area 2 is Deep Pond and Deep Pond (South). Runoff from minor parts of Area 2 discharge via culverts beneath the rail line into Blue Billed Duck Pond and BHP Wetlands. Runoff from Area K7 discharges into Railway Pond. All these ponds ultimately discharge into Deep Pond, which is the main receiving water body within the project area.

The PDP item 1(a)-(ii) requests: *Diagrams showing pre-capping surface water and groundwater flow paths across Area 2, including K7 and adjacent ponds, under low, median and high rainfall conditions. Diagrams should show any culverts or overflow locations that may hydraulically connect cells or ponds.*

In general, the direction of flow across Area 2 is the same under most rainfall conditions, with surface water runoff, flow rates and pond water levels responding to the rainfall conditions.

- In very low rainfall events, runoff may not occur;
- In high rainfall events, some alternative surface water flow paths may become active due to 'overtopping' or linking of the catchments draining to the blue lines shown on **Figure 2**. The flow directions, however, will generally remain as shown on **Figure 1**.
- **Figure 2** indicates that it is possible that runoff, in larger events, may flow into the following
  - Easement Pond South;
  - Pond 9.

  These represent only occasional flow paths under extreme weather conditions.
- A key feature of Area 2 is described as the 'low area' (cells 4, 6 and 8). This area is characterised by:
  - Thicker vegetation resulting in increased evapotranspiration;
  - Typically contains around 200 mm of weathered 'topsoil' material over a fine coal washery reject (CWR) material (a sandy SILT) around 1 m thick or greater;
  - It is thought that the rainfall soaks into the weathered upper layer, then migrates laterally until it encounters the porous sub-surface slag walls where it can more readily connect to the groundwater table;
  - Under normal rainfall conditions, has no obvious surface water outlet.
- Under most rainfall conditions, large sections of the site will continue to drain into the Low Area, where water soaks away. The low area, with a surface elevation of around 5m AHD, remains well above the water levels in the surrounding ponds, which are typically around 1m AHD.

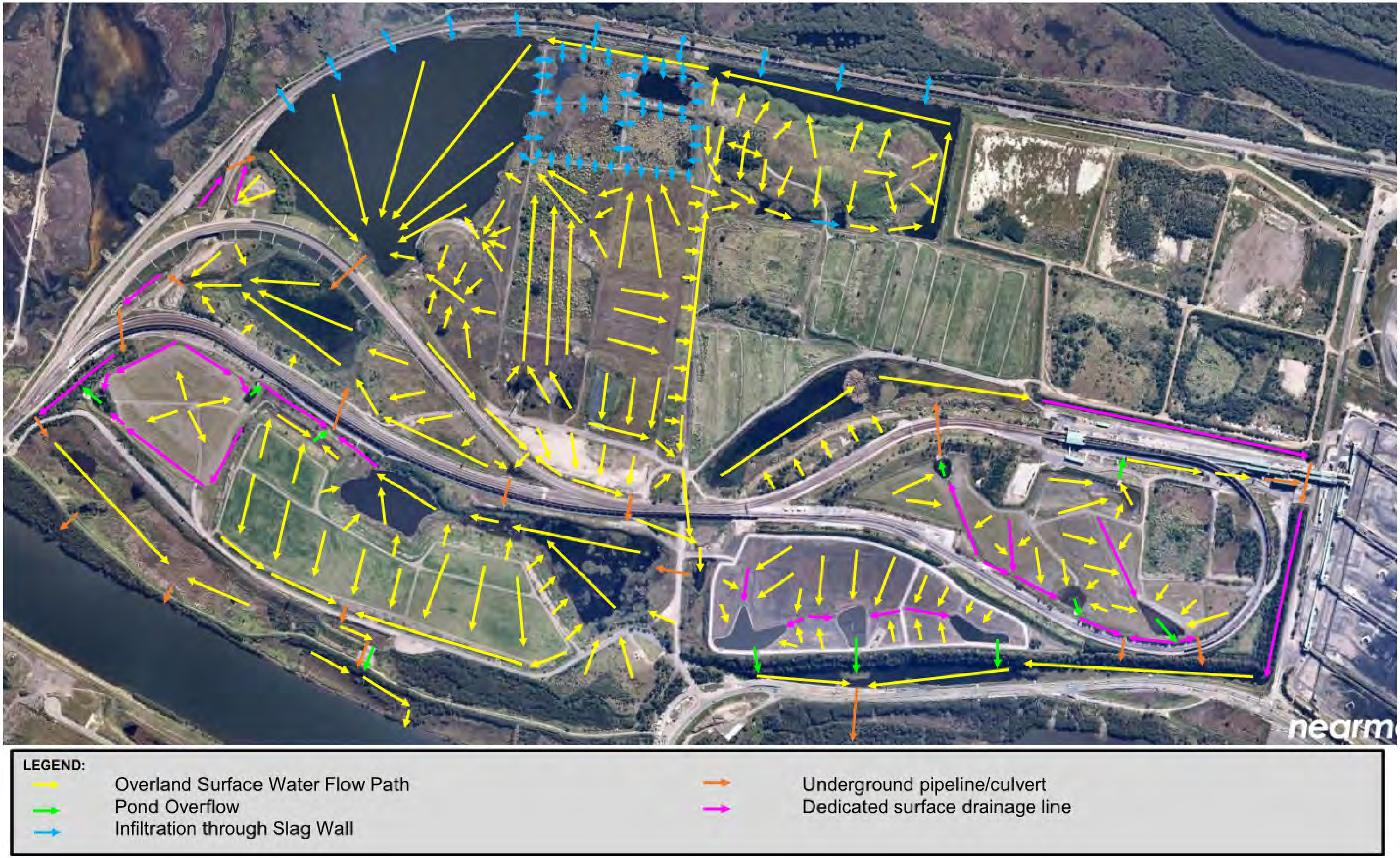


Figure 1 – Surface Water Flow Paths, KIWEF - Existing Site Conditions (Aerial image source: NEARMAP)

Figure 2 – Area 2 - Topography and Indicative Surface Water Flow Paths – Existing Conditions (source: ERM 2016)

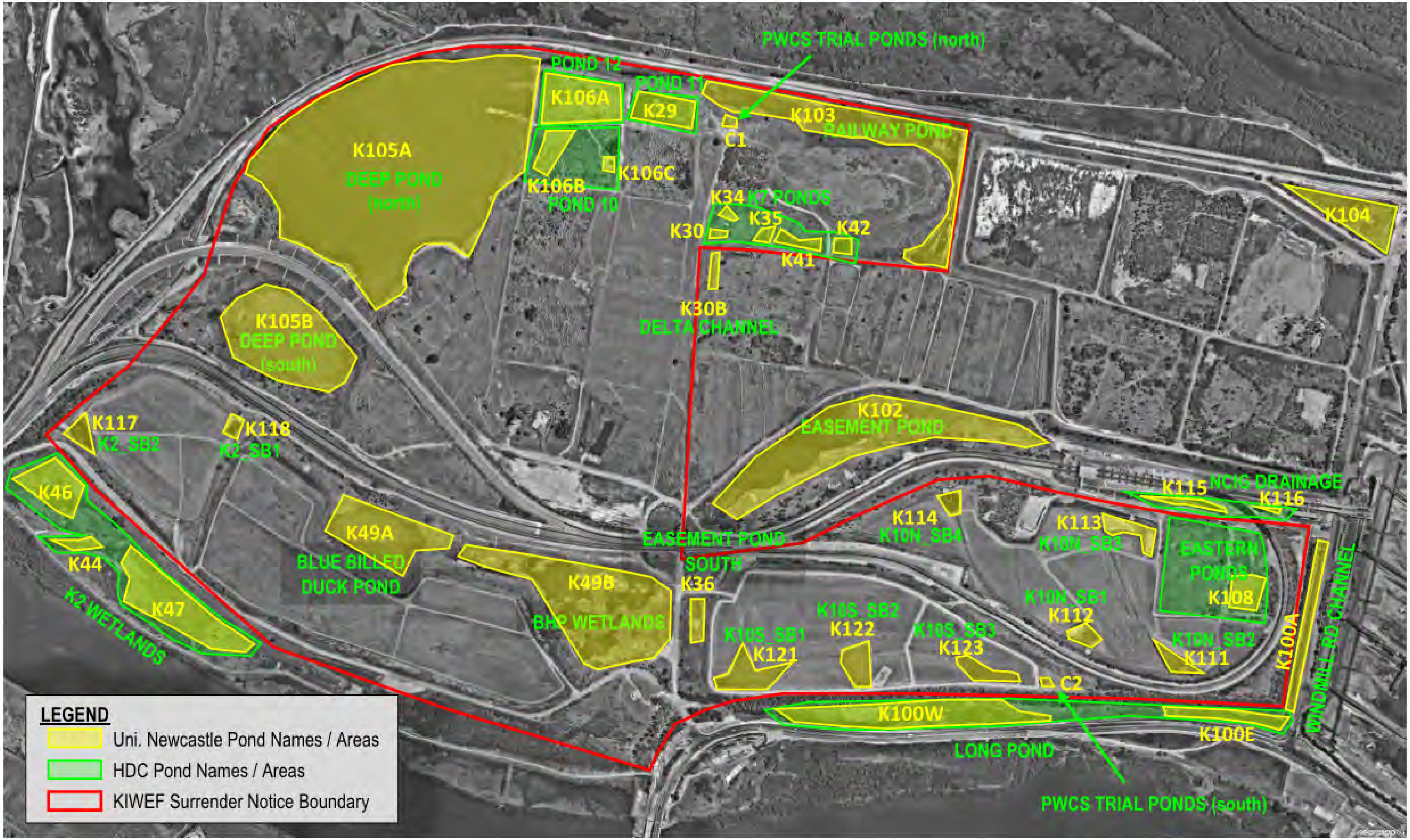


Figure 3 – Existing Receiving Water Bodies across KIWEF (Aerial image source: NEARMAP)

2.2. Groundwater

Groundwater across KIWEF has been described in detail in a range of documents including:

- Environmental Assessment for the Proposed Terminal 4 Project, Kooragang Island (T4 EA); and
- Response to the Department of Sustainability, Environment, Water, Population and Communities (SEWPaC) on the closure works for Area 1 and 3 (SMEC, 2013).

A conceptual groundwater model is described in the T4 EA (Appendix E Groundwater Assessment). Key points are outlined below:

- Groundwater beneath the site is present in two principal aquifers: an upper unconfined aquifer within the fill strata (the Fill Aquifer), and a deeper confined aquifer within the estuarine sediments (the Estuarine Aquifer); and
- Between the two aquifers there is a layer of soft natural clays, typically between 1m and 15m thick, forming a 'leaky' aquitard that separate the two aquifers, however in some locations the aquitard may be absent.

Fill Aquifer

- The fill aquifer is unconfined and the water table fluctuates with the thickness of the aquifer. Groundwater is free to drain to the surface where the water table intersects the surface, such as drains, ponds or wetlands;
- Typically, the waste in the fill aquifer was placed within slag bunds, which have moderate to high permeability. The bunds are likely to be more permeable than the waste (fill);
- The Fill Aquifer is recharged by rainfall;
- Groundwater in the Fill Aquifer is primarily sub-horizontal, generally flowing towards the closest surface drain features, however some vertical leakage occurs through the underlying clay aquitard; and
- The surrounding surface water bodies and drains form the boundary of the Fill Aquifer, and the groundwater is generally present as a 'mound' within the Area 2 fill (visible on Drawings 5.07 of Appendix E of the T4-EA, and included here as **Appendix D**).

Estuarine Aquifer

- The Estuarine Aquifer is generally confined, which means there is no free water table. The phreatic surface (the height at which water would rise to in a bore connected only to the estuarine aquifer) is above the base of the overlying clay aquitard;
- The Estuarine aquifer contains sand of moderate to high permeability; and
- Groundwater in the estuarine aquifer flows away from a north-south, and east-west ridge-line within the KIWEF (visible on Drawings 5.08 of Appendix E of the T4-EA, and included here as **Appendix D**). Generally, within Area 2, groundwater flows north, west and south into the Hunter River, and the surrounding tidal wetlands.

Groundwater levels pre-capping of Area 1 and 3 are reported in the T4 EA (Appendix E Groundwater Assessment). Since that time, capping of Area 1 and 3 has occurred, which is expected to have altered groundwater levels. In the SMEC 2013 report, predicted groundwater contours were provided for the KIWEF site following completion of the Area 1 and 3 capping works. Schematics of the groundwater levels in the fill aquifer and estuarine aquifer are provided in **Figure 4** and **Figure 5** below. These figures show elevated groundwater levels within the estuarine and fill aquifers near the centre of Area 2. Flow paths are perpendicular to the groundwater contours.

The direction of groundwater flow is expected to be generally similar under most rainfall conditions. In the Fill Aquifer, groundwater levels fluctuate in response to rainfall, re-charge of the aquifer, and leakage to the Estuarine Aquifer.

A summary of recent groundwater monitoring between 2013 and 2017 is provided below for wells at, or near, Area 2 (wells K5/4, K5/5N and K5/6N).

- Within the Fill Aquifer, groundwater levels vary by around 1 m between a dry period and wet period; and
- Within the Estuarine Aquifer, groundwater levels vary by around 0.2 m between a dry period and wet period.

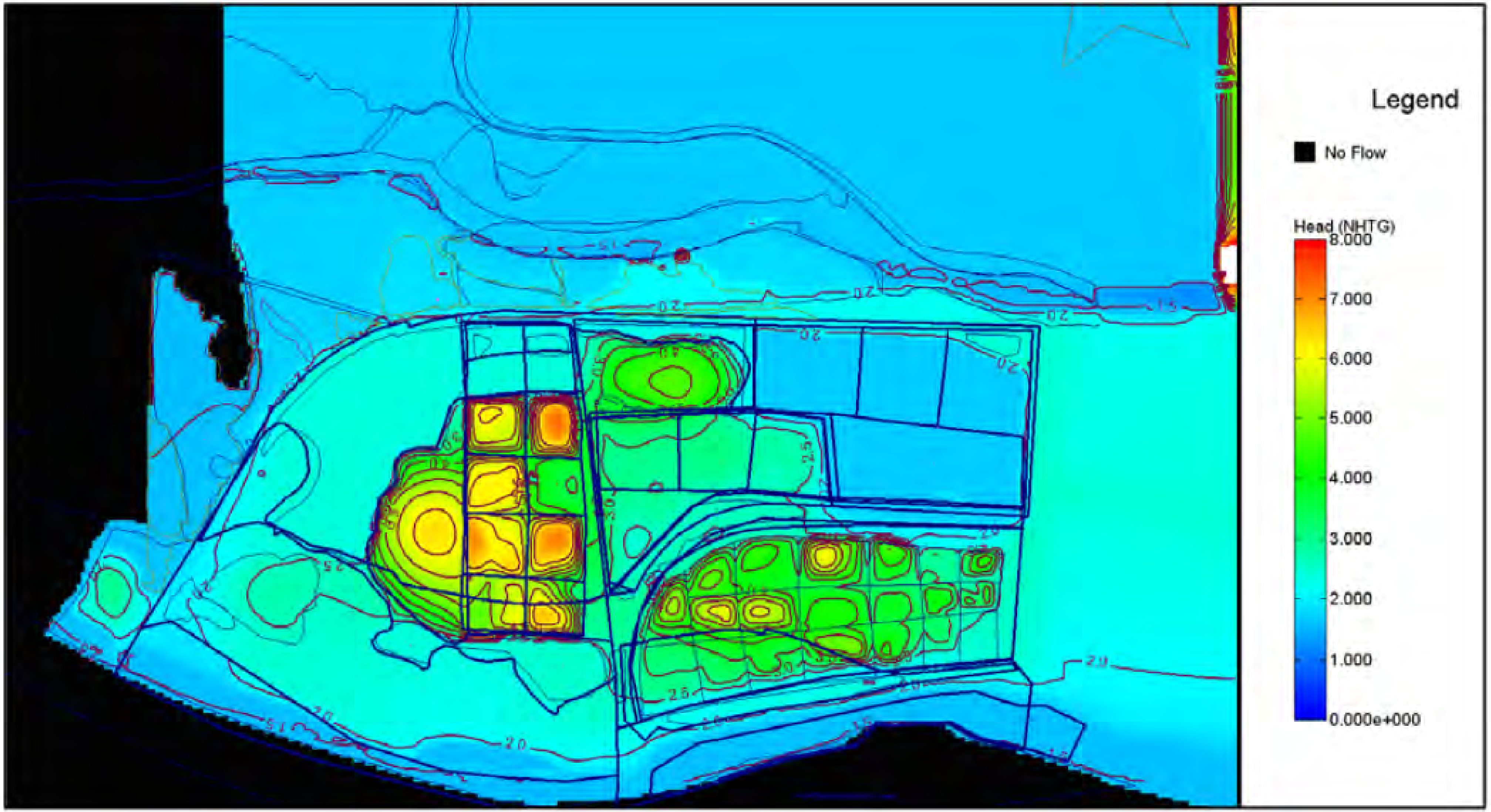


Figure 4 – Existing (Predicted) Groundwater Contours– Fill Aquifer (NHTG contours, Source: Douglas Partners 2013)

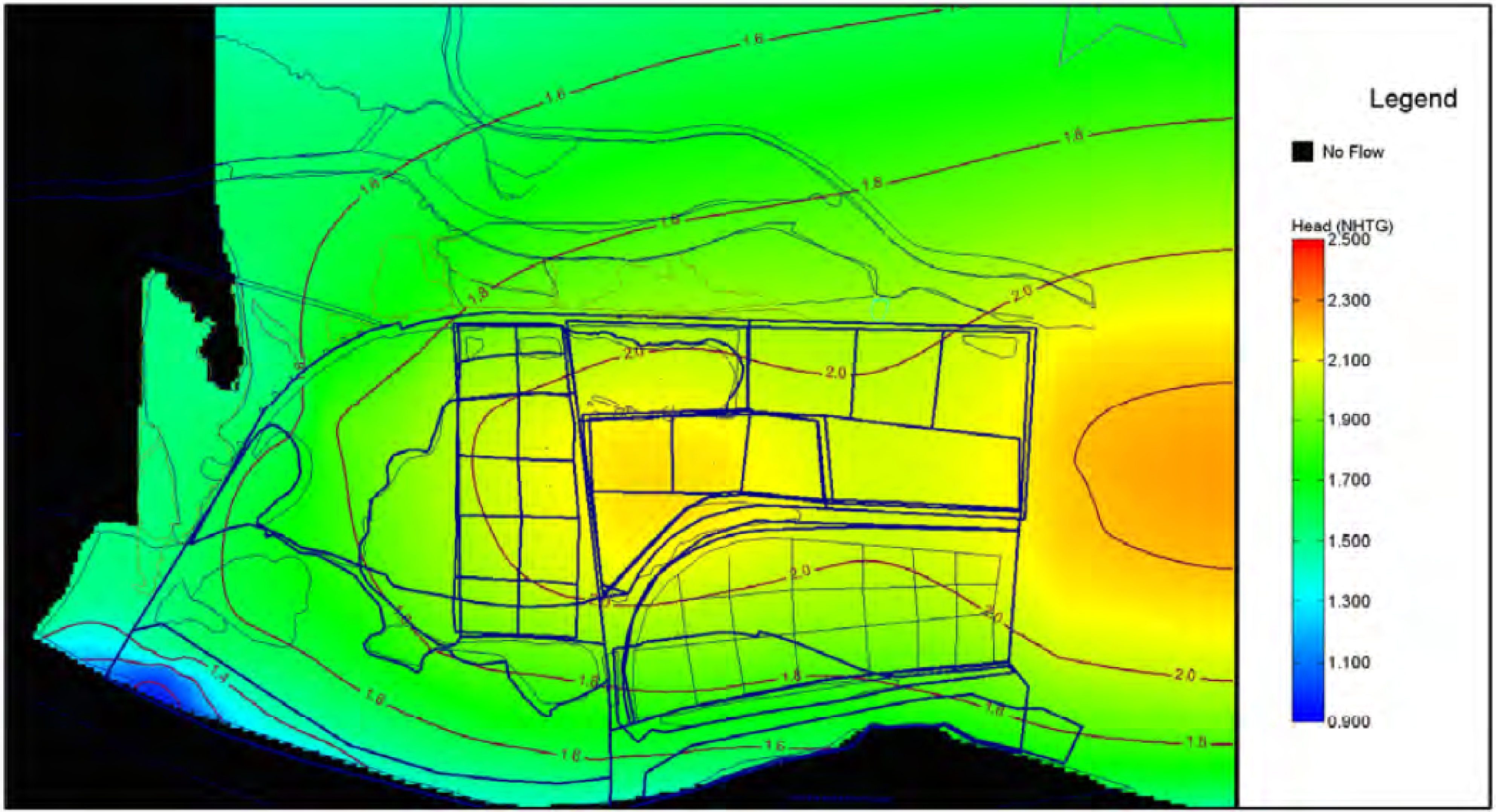


Figure 5 – Existing (Predicted) Groundwater Contours– Estuarine Aquifer (NHTG contours, Source: Douglas Partners 2013)

3. Model Development

3.1. Background

A hydro-salinity model was prepared to determine the hydrology and water quality for Area 2 for both the pre-cap and post-cap scenarios. The model builds on the previous model prepared to assess closure works for Area 1 and 3.

The hydro-salinity model seeks to replicate the hydro-salinity regime of each pond by modelling the following processes:

- Surface water runoff from contributing catchment areas;
- Groundwater inflows into each pond;
- Groundwater outflows from each pond;
- Surface water flows between ponds and from some ponds to receiving waters; and
- Evapotranspiration losses from each pond.

Figure 6 shows key features of the conceptual model. Other features of the model are described below:

- The model runs on a daily time-step and requires daily rainfall and evaporation rates as model inputs.
- The model runs as a continuous simulation and applies a long term (104 year) rainfall record that includes a wide range of embedded dry and wet periods.
- Groundwater flows into and out of ponds have been applied at constant rates, as derived from the MODFLOW Surfact modelling (refer SMEC 2013). The 2013 modelling did not include capping of Area 2. Based on a review of the pre- and post- capping models, the ground water flows to Deep Pond were reduced to 85% of the baseline, in line with previous groundwater flow reductions.
- Water transfers between ponds, demands and sources are effected by transfer rules that are based on stage / discharge relationships derived from survey of the existing pond outlet culverts and other control structures.
- Salt concentrations and loads are tracked throughout the water balance model. Inflow salinity concentrations are required for surface and groundwater sources, based on historic monitoring data.
- Salinity levels in the ponds are tracked on a daily time step, as inflow / outflow to either surface and groundwater, and also through concentration due to evapotranspiration from the ponds.

Further details can be found in the report *'KIWEF SEWPaC SMEC Detailed Review – Revision No. 5'* (SMEC 2013).

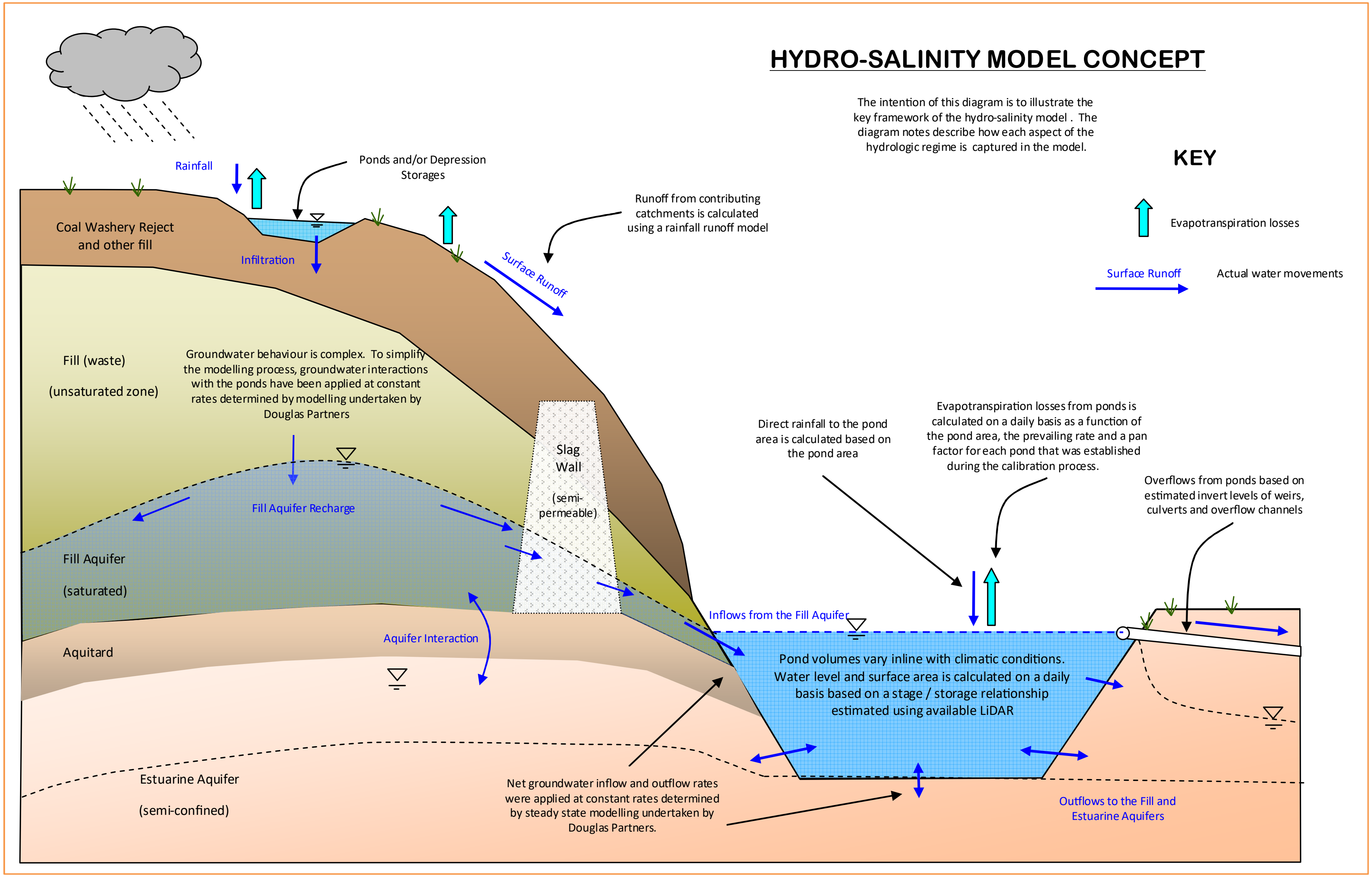


Figure 6 – Hydro-salinity Conceptual Model (SMEC 2013)

3.2. Model Development

In 2013, HDC prepared a response to SEWPaC on the closure works for Area 1 and 3. In that submission, detailed hydro-salinity modelling of the ponds was undertaken and the ponds were shown to:

- Become marginally wetter and fresher;
- Contain water at higher levels for longer periods; and
- Have an increased period in which foraging and breeding habitat are present for the GGBF.

The PDP item 1 requests: a "*quantitative assessment of the changes to the hydrology and water quality of Area 2, and adjacent GGBF habitat and breeding ponds potentially affected by the proposed action*". To undertake this assessment, the hydro-salinity model used in the 2013 submission was updated to reflect changes in the catchment and more recent data, including:

- Commencement, and completion of closure works for Area 1;
- Commencement, and completion of closure works for Area 3;
- Placement of the PWCS T4 Preloading stockpiles (no significant change to catchment boundaries);
- Construction of the NCIG Flyover Modification through Deep Pond and stockpiling over Area 2 (generally only changes to stage-storage of Deep Pond); and
- Roads and Maritime Services (RMS) upgrade of Cormorant Road, including works within Long Pond (generally only changes to stage-storage of Deep Pond).

Validation of the Area 1 and 3 data was not possible due to the changes undertaken in the area surrounding KIWEF that were undertaken by others. Observations of collected data following the completion of the Area 1 and 3 closure works is not inconsistent with the predictions of the model, however the short time frame since completion cannot confirm the modelled outcomes.

3.3. Calibration

The hydrology of the KIWEF is complex, involving deep and shallow estuarine aquifers, a fill aquifer, former filled channels/wetlands, man-made drainage structures (channels, weirs, culverts), tidal movement through slag walls, variable infiltration (variable types of landfill capping materials), and heterogeneous material that can affect water quality. Kooragang Island has also been the subject of recent developments altering water courses and hydrology of the project area.

Water level and water quality modelling of the KIWEF hydrology requires on-going adjustments to improve and validate the model. Since completion of the SMEC 2013 study, additional data has been collected and added to the model, including:

- Four years of additional daily rainfall records from the Bureau of Meteorology (BoM) weather station 61055 (Newcastle Nobby's); and
- Logger data (water level and electrical conductivity) for surface water bodies as provided by HDC for the following ponds over a similar period:
  - BHP Wetlands;
  - Deep Pond A;
  - Easement Pond;
  - Easement Pond South;
  - K2 Pond;
  - Long Pond; and
  - Windmill Road Open Channel.

  NB. No logger data was available for Blue Billed Duck Pond for the post 2013 works.

Locations of each of the loggers are shown on **Figure 7**.

The inclusion of the additional rainfall data and level logger data for surface water bodies over the extended period allowed further refinement of catchment parameters so that a 'best fit' of actual and predicted water level and salinity monitoring data was achieved. Some modification of the following parameters was undertaken to obtain a closer calibration with observed water level and water quality data:

- Refined stage-storage within the KIWEF ponds;
- Adjustments to electrical conductivity (EC) in groundwater and surface water contributions as part of the model calibration (and as validated by surface water grab-samples);
- Adjustments to KIWEF catchments that reflect current conditions including completion of closure works for Area 1 and 3, and catchment modification by other parties; and
- Improvements to the inflows, outflows and connections between ponds, as well as seepage out of Deep Pond north of the rail line, based on an improved understanding of the hydrology and groundwater conceptual model.

Appendix B includes plots illustrating a comparison of the water level and salinity for the respective surface water bodies modelled.

When used to replicate existing conditions, the model results show a close correlation between predicted water levels and salinity, with observations over the calibration period. By modelling the key site processes, the model reproduces existing conditions including the multi-variable processes expected on a complex site such as KIWEF. Application of the model to the proposed capping of Area 2, is considered appropriate based on the reliable calibration achieved.

Figure 7 – Logger locations (Source: RCA 2017)

3.4. Modelled Existing Conditions – Pond Water Level Regime

Within SMEC (2013), Dr Arthur White was consulted to provide expert advice on changes to water levels and identification of thresholds that would be expected to affect the GGBF. Dr White indicated:

- A pond is effected if low water levels occur for a period of four (4) weeks or longer than under existing conditions. Similarly, for wetting regimes, a pond is effected if the ponds have high water levels for a period of six (6) weeks or longer than under existing conditions.
- To define "low" and "high" water level conditions in the ponds, the modelling adopted the 20th percentile and 80th percentile water level values derived from the existing conditions hydro-salinity model. These values are referred to as the **upper/lower bound water level values**, when considering the effects of any change.
- The amount of additional time that the ponds stay dry or wet is of equal importance to GGBF to the frequency of dry or wet conditions.

In the current model, the existing water level regime in Deep Pond is summarised as follows

- 60% of the time Existing Conditions are <u>within</u> the optimum threshold levels;
  - 20% of the time, Existing Conditions are <u>below</u> Lower Bound Water Level Value; and
  - 20% of the time, Existing Conditions are <u>above</u> the Upper Bound Water Level Value.

3.5. Modelled Existing Conditions – Pond Water Quality Regime

Expert advice provided as part of the SMEC (2013) report led to adoption of three key salinity (EC) values for comparison. The values for comparison are shown in **Table 2**:

Table 2 – Salinity Comparison Values for KIWEF Surface Water Bodies

No Chytrid Protection	Chytrid protection threshold [1]	GGBF tadpole health threshold [2]	GGBF Adult health threshold [3]
0 – 1,650 µS/cm	1,650 µS/cm	2,900 µS/cm	4,100 µS/cm

[1] EC below threshold presents increased risk of mortality resulting from Chytrid Fungus.

[2] EC above threshold indicates unsuitability for GGBF tadpole survival.

[3] EC above threshold indicates unsuitability as GGBF adult habitat.

The concentration of salinity in the water is important to GGBF, as at certain levels the salinity provides the GGBF protection against the chytrid fungus, an infectious disease that invades the surface layers of the frog's skin that inhibits the frog's physiology and can lead to the death of individual animals or can spread throughout entire populations. Conditions with too much salinity are also not appropriate, as the GGBF is a freshwater frog species and highly saline conditions will also effect the survivability of the community. An optimum chytrid protection threshold has therefore been identified between 1,650 µS/cm and 2,900 µS/cm, and are referred to as the **threshold levels**.

In the current model, the existing water quality in Deep Pond is summarised as follows

- 42.2% of the time Existing Conditions are <u>within</u> the optimum chytrid protection threshold levels.
  - 49.3% of the time, Existing Conditions are <u>below</u> the optimum chytrid protection threshold level (1,650 µS/cm); and
  - 8.5 % of the time, Existing Conditions are <u>above</u> the optimum chytrid protection threshold level (2,900 µS/cm).

Further details can be found in **Section 5.3** for each pond.

The PDP item 1(a)-(iii) requests, for the pre-capped environment: *Water quality of GGBF habitat and breeding ponds, partitioned by seasonal variation, including the percentage of time that pond water quality is within the optimal range for protection of GGBF's from chytrid fungus.*

The ponds are not considered to have a seasonal partition, as they may be connected during large rainfall events (or prolonged periods of rainfall), but remain separated during drying periods. Observations of the calibration curves (refer to **Appendix B**) during the GGBF Breeding Period (September to March) and Overwintering Period (April to August), typically indicated that water levels decline faster over summer due to higher evaporation.

4. Developed Site Conditions

4.1. Closure Consent

In 2009, HDC prepared and submitted a Closure Plan to the NSW EPA - the Revised Final Landform and Capping Strategy, December 2009 (Revision 4, GHD). The Closure Plan was approved by the NSW EPA, and the KIWEF EPL6437 was surrendered pursuant to a s80 Notice of Surrender of a License under the PoEO Act (dated 8 December 2010).

In general, capping is to be achieved by re-grading the site to 1%, and capping with 500mm of Coal Washery Reject (CWR) to achieve a permeability of 1 x 10^{-7} m/s and a 100mm revegetation layer.

The surrender notice requires a Green and Golden Bell Frog Management Plan to submitted and approved by the EPA. HDC submitted a plan (Green and Golden Bell Frog Management Plan – KIWEF, Golders 2011), which has been approved by the EPA. The surrender notice also requires for measures to maintain, restore and enhance Green and Golden Bell Frog habitat, including movement corridors across the site.

4.2. Developed Site Drainage

The required outcome of capping is to reduce the potential infiltration into the KIWEF wastes, and to slow down the leachate generation into the surrounding waterbodies. Capping works may also

- Reduce shallow saline groundwater inflow into the ponds.

  Previous reports (KI Waste Characterisation and Disposal Practices, June 1991) indicated that the fill aquifer consists of fine CWR material placed by pumping the material mixed with seawater. By decreasing infiltration into the shallow aquifer, the capping works may decrease leachate which is a contributor of salinity into the surrounding ponds; and
- Create fresher conditions in ponds through more frequent surface runoff.

  Currently surface runoff only occurs in large rainfall events with a large percentage of ‘everyday’ rainfall events ponding on the site and infiltrating. Large sections of the site such as the Low Area act as surface water ‘sinks’ with no clear outlet. By improving the site runoff through a 1% draining cap, water that would normally have infiltrated will runoff directly into the ponds.

It is proposed that surface drainage features will typically be the same as that constructed for Area 1 and 3. Typical features will include:

- Channels for stormwater conveyance.
  - Where grades are less than 1%; the channels will be lined;
  - Sized to capture and convey runoff at non-erosive velocities;
  - Facilitate movement corridors for GGBF across the cap;
- No major pipes or culverts are proposed, although some may be required over drainage channels for access;
- Temporary sediment basins sized in accordance with the ‘Blue Book’.
  - Basins lined to prevent infiltration. Whilst not yet designed, it is expected that the basins would provide around 10,000 – 11,000 m^3 of volume across Area 2;
  - Water level in basins maintained through concrete spillway and rock-filled reno mattresses;
  - Rip-rap downstream of basin outlets where erosive flows may occur.

The design of the temporary basins will also consider incorporating suggestions for GGBF beneficial features in line with research undertaken by the University of Newcastle.

The proposed surface water flow-paths post-capping are shown on **Figure 8**. Generally, flows from Area 2 Closure Works are directed toward Deep Pond and therefore any effects to water level and/or salinity levels would be expected to be observed at Deep Pond. The modelling of the predicted capping has therefore focused on the effects to Deep Pond.

The developed site drainage is expected to generally perform in the same manner, under most rainfall conditions, as the capping works will be designed to convey runoff in a controlled manner into, and through, drainage lines and temporary basins, to designated discharge locations.

Groundwater flow paths are likely to remain similar to existing conditions, with flow towards the slag bund-walls and the surrounding ponds, however with a reduced groundwater level and velocity, which is the desired outcome of the proposed capping works.

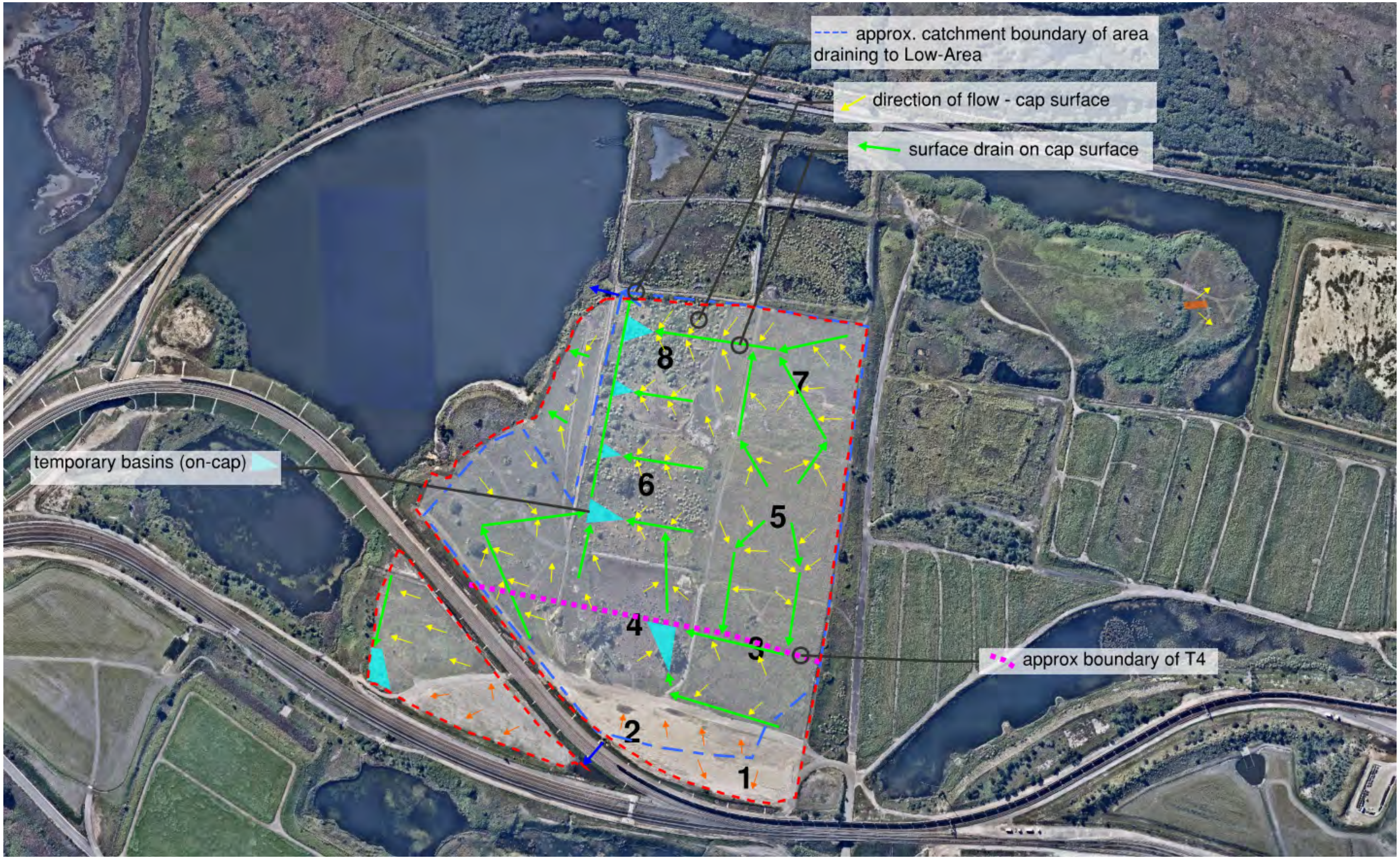


Figure 8 – Developed Site Drainage

5. Model Outcomes - Developed Site

5.1. Standard Cap

Capping and closure works for Area 1 and 3 implemented a 'Standard Cap' strategy, which focussed on:

- Utilising existing site-won material as cap and topsoil to assist in matching pre- and post- surface runoff water quality;
- Matching pre- and post- surface water discharge locations;
- Utilising temporary, but fully lined, sediment basins on the cap surface for water quality control after capping works are complete; and
- Including fully lined surface water drains for stormwater conveyance, and which also facilitate movement corridors for GGBF across the cap.

A standard cap typically involved 500mm of densely compacted CWR or other material, and a 100mm revegetation layer.

The capping works to date have been monitored by HDC through water level and salinity loggers. The data indicates that:

- The capping works have not resulted in any significant change to the salinity or wetting and drying of receiving water bodies;
- The lined surface water drains and temporary lined ponds have likely provided connectivity of existing GGBF foraging and breeding habitat, with GGBF inhabiting the temporary lined ponds and colonising previously uninhabited areas; and
- Water quality in the temporary lined ponds was measured, and is consistent with surface water runoff parameters assumed in the 2013 hydro-salinity model.

5.1.1. Standard Cap Model Results – Pond Water Level Regime

The hydro-salinity model was modified to reflect the entire Area 2 having a Standard Cap. As discussed in **Section 3.4**, long term changes in water levels have been identified as a factor that may affect GGBF habitat. Results of the hydro-salinity model in respect to changes to the time spent within the optimum water level at Deep Pond are provided in **Table 2** below. Further details of the shift in time within the Lower and Upper Bound thresholds are presented in **Appendix C** and illustrated on **Figure 10**, which provide a quantitative overview of the predicted effect on pond hydrology.

Table 2 – Water Level Effects in Deep Pond – Standard Cap

	Percentage of time in optimal Water Level range		Relative change (% shift)
	Existing	Predicted	
Deep Pond (Standard Cap)	60%	55%	-5%

5.1.2. Standard Cap Model Results – Pond Water Quality

As discussed in **Section 3.5**, the concentration of salinity in ponds is important to the GGBF. Changes to the ponds associated with the construction of the Standard Cap have been modelled and the predicted effects on Water Quality are shown in the **Table 3** below. Further details of the shift in time within the Lower and Upper Bound thresholds are presented in **Appendix C,** and illustrated on **Figure 11**, which provides a quantitative overview of the predicted effect on pond hydrology

Table 3 – Water Quality (Salinity) Effects in Deep Pond – Standard Cap

	Percentage of time in optimal Salinity range		Relative change (% shift)
	Existing	Predicted	
Deep Pond (Standard Cap)	42.2%	25.1%	-17.1%

5.1.3. Standard Cap Model Results

Overall the hydro-salinity modelling showed that the construction of a Standard Cap across Area 2 will result in:

- 21.5% of the time the Predicted Conditions are within the Optimum Water Quality range for chytrid protection, 1,650 µS/cm to 2,900 µS/cm (a -17.1% shift from existing).
- 55% of the time, Predicted Conditions are within the optimum water level threshold (a -5% shift from existing).

It is considered that this shift would be a moderate effect to the Deep Pond environment.

5.2. Proposed 'Modified' Cap

Application of the 'Standard Cap' may have a measurable effect on the adjoining water bodies (Deep Pond) by reducing saline groundwater inflows, and increasing fresh water runoff. A 'Modified Cap' is proposed in order to:

- Minimise potential effects of the Area 2 closure works on the receiving water body; and
- Still meet the requirements of the Surrender Notice.

The proposed Area 2 capping works are described in **Table 4**:

Table 4 – Area 2 Capping

Area	Proposed Capping
Low Area ***Modified Cap***	The Low Area (approximately 8.0 Ha, although conservatively modelled as only 7 Ha) does not visibly pond surface water after large rainfall events. It is thought that the rainfall soaks into the weathered upper layer, drains laterally when it encounters the low permeability CWR layer and is likely lost through porous sub-surface slag walls and evapotranspiration. The cap design of the Area 2 Low Area cap has been adjusted to a '**Modified Cap**' to satisfy the requirements of the surrender notice, reflect the current observed site conditions (to the extent possible) and reduce potential effects on ponds through: • Providing storage 'within' the cap: via a thick topsoil, sourced from the existing low-permeability CWR in this area. The material would not be densely compacted, so would offer deep storage of moisture; • Use of a significant vegetative layer (in excess of the Closure Strategy requirements) within the Low Area to maximise evapotranspiration losses; • Use of low permeability layer underneath the vegetative layer to prevent deeper seepage losses into the fill aquifer; and • Where possible provide a drainage layer, above the low permeability layer, to release water that infiltrates through the CWR into surface drains or receiving water bodies.
Remainder of Area 2 ***Standard Cap***	The remainder of Area 2 will likely be capped using a **Standard Cap**. To minimise changes to pond water quality, the cap will include: • Utilisation of the site-won CWR material as cap and/or topsoil to assist in like-for-like runoff;

	• Where possible, direct runoff into the Low Area Cap for 'storage and attenuation'; • Discharge via a sediment basin to receiving waterbodies in a manner similar to Areas 1 and 3

The locations for each cap type are shown on **Figure 9**.

Collectively, the combination of Standard and Modified capping works described in the table above will capture a large portion of Area 2 runoff, reducing the volume of freshwater flushing into Deep Pond through:

- Capturing runoff in a thick layer of existing topsoil / CWR;
- Increasing evapotranspiration to assist in mimicking the existing conditions where there is little runoff from Low Area in everyday rainfall events;
- Reducing infiltration into the fill aquifer through a low permeability layer;
- Capping works will also include an impervious barrier over slag walls, and will prevent these acting as contributors to increased groundwater infiltration; and
- There are very few areas where runoff is directed to ponds other than Deep Pond, thereby limiting potential effects on the other KIWEF water bodies.

The purposeful use of soil moisture storage and vegetation are based on the principles of an 'evapotranspiration-layer, (NSW EPA Environmental Guidelines – Solid Waste Landfills, 2nd Ed. 2016), with the additional security of an underlying low-permeability barrier. The Modified Cap will satisfy the capping requirements outlined in the Closure Plan (GHD 2010) as endorsed by the EPA in the Surrender Notice.

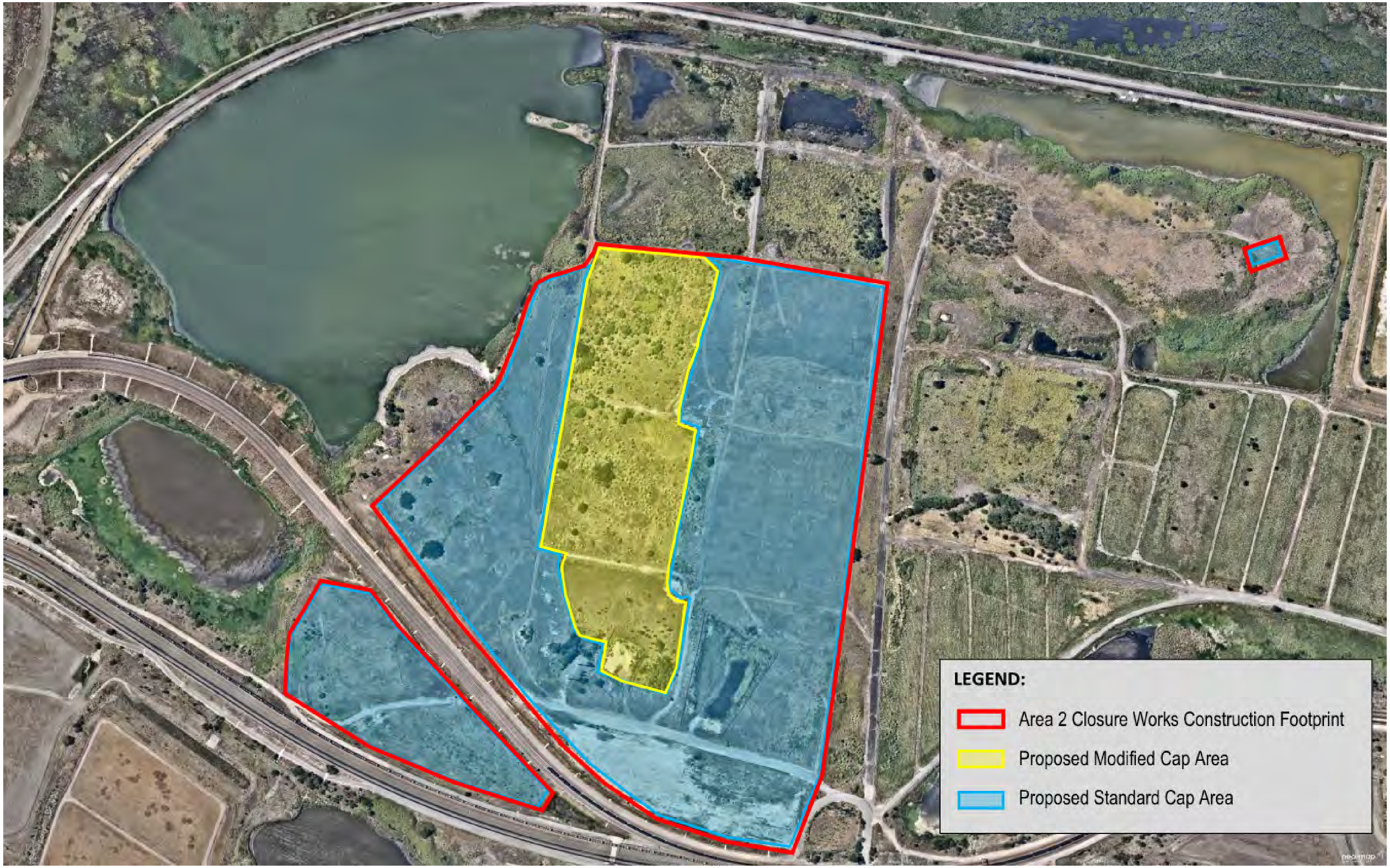


Figure 9 – Location of Cap Types (Aerial image source: NEARMAP)

5.2.1. Modified Cap Model Results – Pond Water Level Regime

The model was used to assess the effects of using a Modified Cap in the low-area, and Standard Cap for the remainder of Area 2. Collectively, this is referred to as the Modified Cap.

As discussed in **Section 3.4**, long term changes in water levels have been identified as a factor that may affect GGBF habitat. Results of the hydro-salinity model in respect to changes to the time spent within the optimum water level at Deep Pond are provided in **Table 5** below. Further details of the shift in time within the Lower and Upper Bound thresholds are presented in **Appendix C**.

Table 5 – Water Level Effects in Deep Pond – Modified Cap

	Percentage of time in optimal Water Level range		Relative change (% shift)
	Existing	Predicted	
Deep Pond (7 ha of Modified Cap)	60%	57%	-3%

A comparison of predicted water levels from using a standard cap versus a modified cap are shown on **Figure 10**.

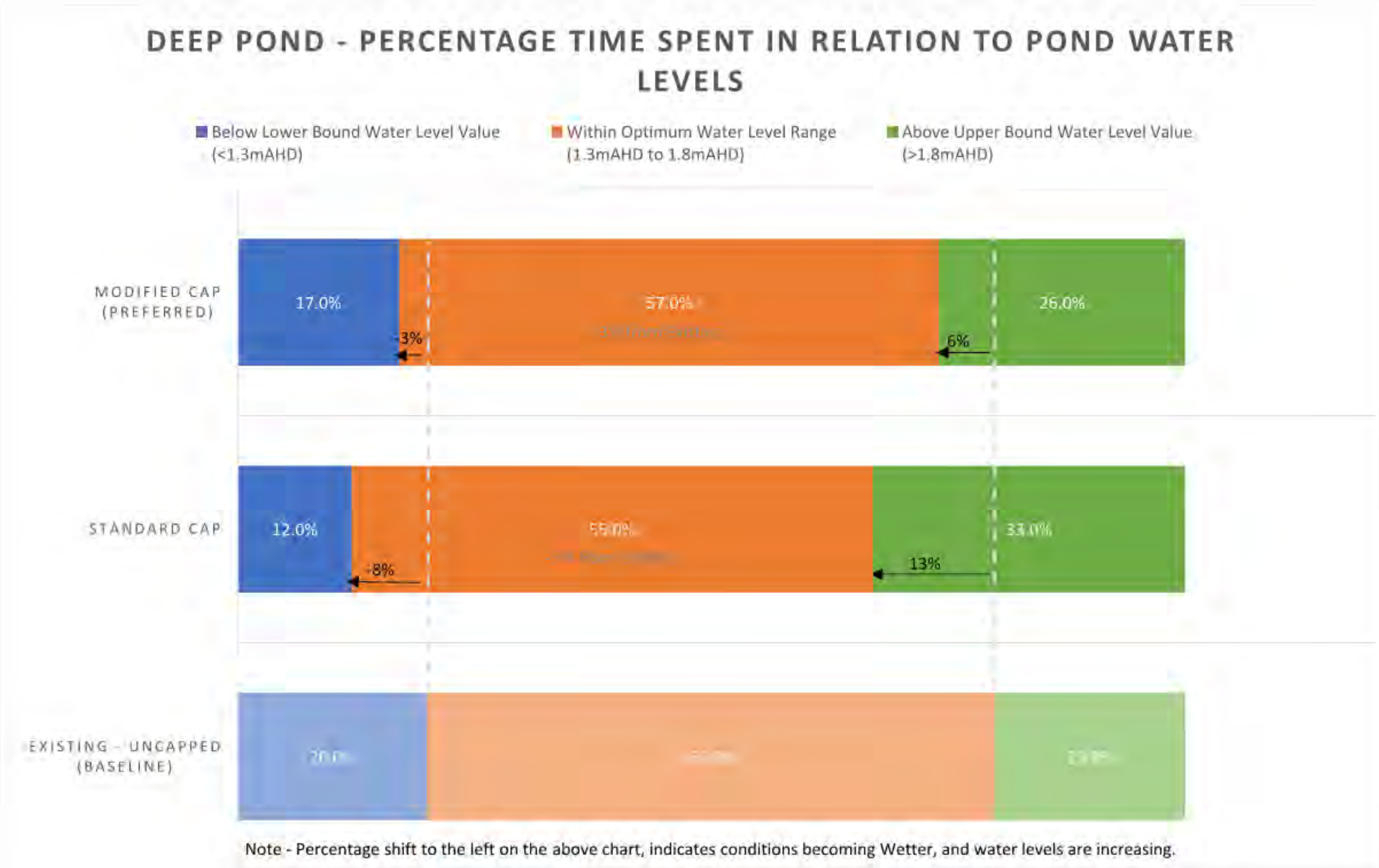
5.2.2. Modified Cap Model Results – Pond Water Quality

As discussed in **Section 3.5**, the concentration of salinity in ponds is important to the GGBF. Changes to the ponds associated with the construction of the Modified Cap have been modelled and the predicted effects on Water Quality are shown in **Table 6**. Further details of the shift in time within the Lower and Upper Bound thresholds are presented in **Appendix C**

Table 6 – Water Quality (Salinity) Effects in Deep Pond – Modified Cap

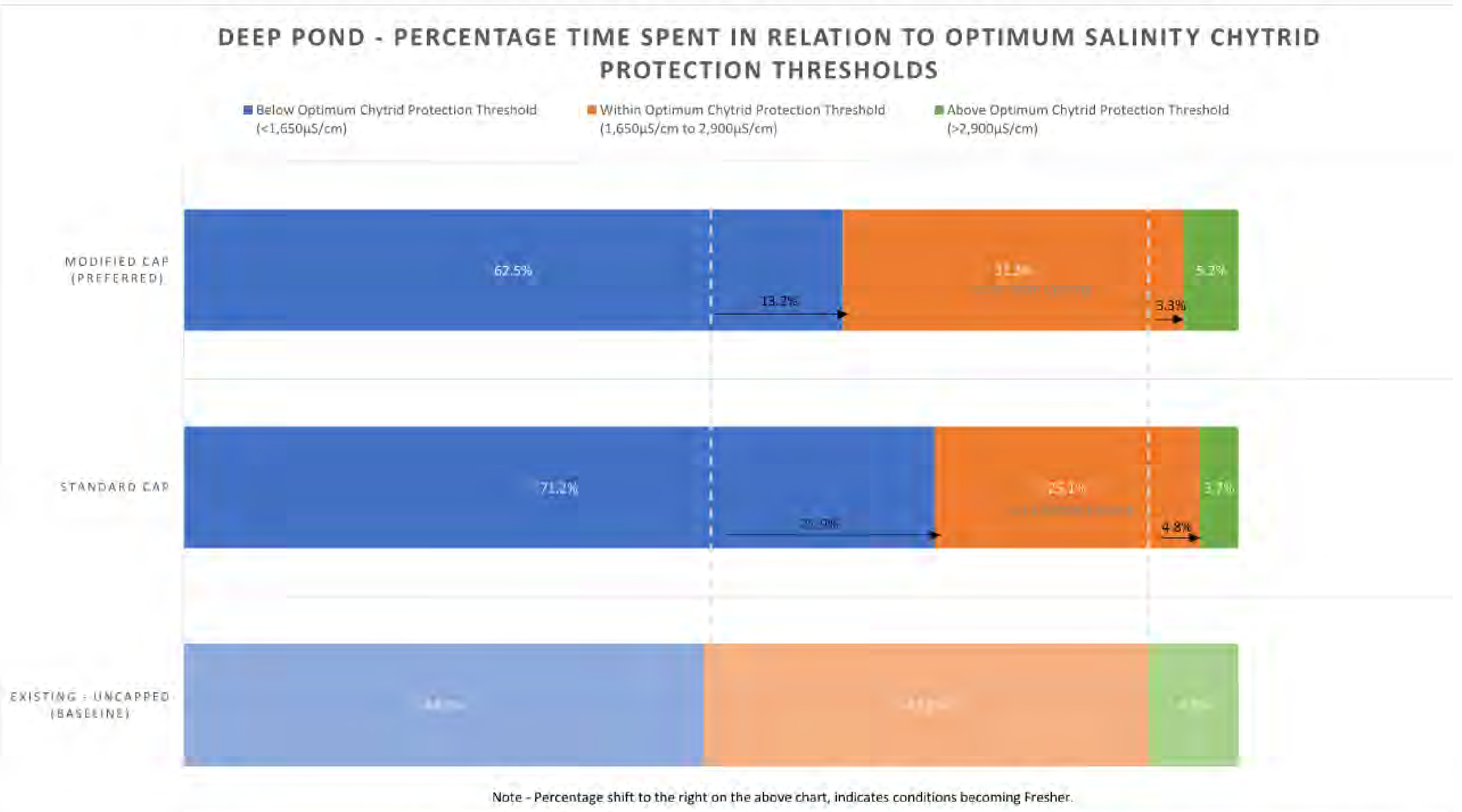
	Percentage of time in optimal Salinity range		Relative change (% shift)
	Existing	Predicted	
Deep Pond (7 ha of Modified Cap)	42.2%	32.3%	-9.9%

A comparison of predicted water quality from using a standard cap versus a modified cap are shown on **Figure 11**.



The above chart illustrates that the implementation of the Modified Capping Design will result in a slight reduction of time in Deep Pond where water levels are below the optimum water level range and a slight increase in time spent above the optimum water level range. The overall effect of the Modified Capping design can be characterised as slightly Wetter in relation to the Existing Uncapped conditions, but are considered to be negligible overall (ie less than 10%).

Figure 10 – Deep Pond – Water Level Effects: Comparison of Cap Types



The above chart illustrates that the implementation of the Modified Capping Design will reduce the percentage of time that salinity levels in Deep Pond are within the optimum chytrid protection thresholds for the GGBF from the Existing Uncapped conditions. However it is important to also note that the Modified Capping Design mitigates the potential impacts to salinity that would otherwise have occurred under a Standard Capping design scenario.

Figure 11 – Deep Pond – Water Quality Effects: Comparison of Cap Types

5.2.3. Modified Cap Model Results

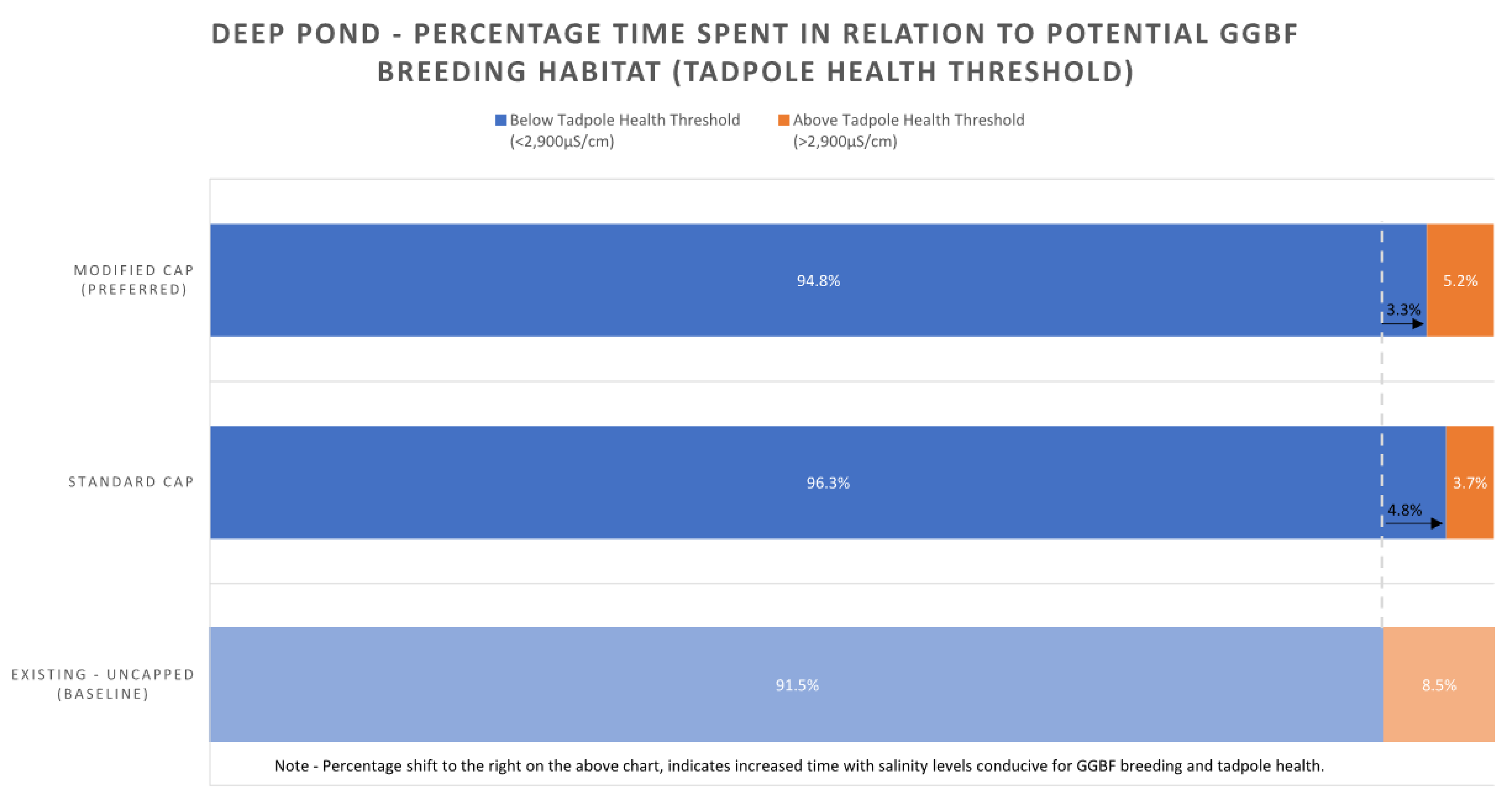
Overall the hydro-salinity modelling showed that the construction of a Modified Cap across Area 2 will result in:

- 32.3% of the time the Predicted Conditions are within the Optimum Water Quality range for chytrid protection, 1,650 µS/cm to 2,900 µS/cm (a -9.9% shift from existing).
- 57% of the time, Predicted Conditions are within the optimum water level threshold (a -3% shift from existing).

It is also noted that the shift in water quality results in an improvement in the time that Deep Pond is in the tadpole heath range, as shown on **Figure 12**.

The modelling confirms the results of the previous modelling undertaken for Areas 1 and 3, indicating that receiving water bodies will be slightly fresher following the capping works. It is however noted that while the receiving waters will be slightly fresher, the overall salinity levels of Deep Pond are predicted to remain within the optimum threshold for approximately 33% of the time. The presence of other ponds surrounding Area 2 will be unchanged as a result of the closure works, and are expected to provide consistent chytrid protection with the existing conditions.

Collectively, the combination of Standard and Modified capping works over Area 2 capping works are not expected to change the hydrology within the surrounding KIWEF ponds in a way would allow migration pathways for the introduction of gambusia.



The above chart illustrates that the implementation of the Modified Capping Design will result in an increase of conditions where salinity levels in Deep Pond are conducive to GGBF breeding and tadpole health, when compared to the Existing Uncapped conditions.

Figure 12 – Deep Pond – Tadpole Health: Comparison of Cap Types

5.3. Cumulative Effects of Areas 1, 2 and 3

SMEC (2013) showed that Area 1 and 3 capping works predominately effected Easement Pond, Windmill Road Open Channel, and Long Pond. The model predicted slightly higher water levels and fresher water conditions in these ponds. The results of the previous modelling (SMEC 2013) are re-produced in **Appendix C**. It is noted that minimal effects were observed within Deep Pond associated with the Areas 1 and 3 works.

The construction of the Area 2 Modified Cap is predicted to have little or no effect on ponds other than Deep Pond, which also predicted conditions in Deep Pond to be slightly wetter (ie water levels are higher) and fresher than the existing conditions.

Table 7 summarises the salinity effects in each pond that was predicted by the SMEC (2013) investigation (for Areas 1 and 3) and the current investigation (for Area 2, Modified Cap).

Table 7 – Cumulative Effect on Salinity (Shift to % of Time spent in optimal salinity range)

Pond	Area 1 & 3 Works	Area 2 Works
BHP Wetlands	Negligible (-0.2%)	Negligible (0.0%)
Blue Billed Duck Pond	Negligible (0.3%)	Negligible (0.1%)
Deep Pond	Negligible (-1.8%)	Minor (-9.9%)
Easement Pond	Minor (-3.9%)	Negligible (0.0%)
Easement Pond South	Negligible (-0.4%)	Negligible (0.0%)
K2 Basin	Negligible (-1.1%)	Negligible (0.0%)
Long Pond	Minor (6.9%)	Negligible (0.0%)
Windmill Rd Open Channel	Minor (13.5%)	Negligible (0.0%)

As per **Table 7**, the previous stages of construction were found to have effects on Easement Pond, Windmill Road Open Channel and Long Pond; while effects associated with the Area 2 works were constrained within Deep Pond. As the modelling observed no overlapping effects between the previous (Areas 1 and 3) and the current (Area 2) proposed works, the effects of the Area 2 Closure Works are considered to be independent of the previous modelled outcomes and will not exacerbate any of the conclusions of the previous investigation.

6. Conclusion

This report provides a quantitative assessment to the predicted changes to the hydrology and water quality of Area 2 and adjacent GGBF habitat, as a result of proposed Area 2 capping works.

The required outcome of capping is to reduce the potential infiltration into the KIWEF wastes, and to slow down the leachate generation into the surrounding waterbodies. Capping works may also

- Reduce shallow saline groundwater inflow into the ponds.
- Create fresher conditions in ponds through more frequent surface runoff.

The post-capping surface drainage in Area 2 will replicate, where possible, the existing surface water drainage directions across Area 2. On the surface of the cap, a number of defined drainage lines (channels) will be created to control the conveyance of stormwater across the cap without damaging the cap. The drainage lines will also convey stormwater to several temporary sediment basins for water quality control. These drainage lines and temporary basins also facilitate GGBF movement across the cap, which is a condition of the surrender notice.

To assess the effect of proposed capping, a site wide water-balance model was used, referred to as a "hydro-salinity model", to determine the inundation regimes and water quality (EC) in the surrounding ponds that are GGBF habitat. The model builds on the model prepared to assess closure works for Area 1 and 3 (SMEC 2013), and considered the following scenarios:

- Existing conditions;
- Standard cap over Area 2: 500mm of densely compacted material with a 100mm revegetation layer. This capping method was used in the previously completed KIWEF Areas 1 and 3; and
- Modified cap over Area 2: a minimum 500mm of loosely placed material (and vegetative layer) to maximise evapotranspiration underlain by a low permeability layer. The Modified Cap would be used in the "low-area" and runoff from other areas (capped using a Standard Cap) directed to the low-area where possible.

The results of the modelling demonstrate that the implementation of the proposed Area 2 Closure Works (under the Modified Cap design) will result in water levels increasing slightly within the receiving water body (Deep Pond), described as slightly 'wetter' than the existing conditions.

- 57% of the time the Predicted Conditions are <u>within</u> the Optimum Water Level range (a -3% shift from existing).

Water quality after capping Area 2 with the proposed Modified Cap will result in:

- 32.3% of the time the Predicted Conditions are <u>within</u> the Optimum Water Quality range for chytrid protection, 1,650 µS/cm to 2,900 µS/cm (a -9.9% shift from existing).
- 94.8% of the time, Predicted Conditions are <u>within</u> the optimum conditions for GGBF breeding (<2,900 µS/cm, Tadpole Health Threshold) (a +3.3% shift from existing).

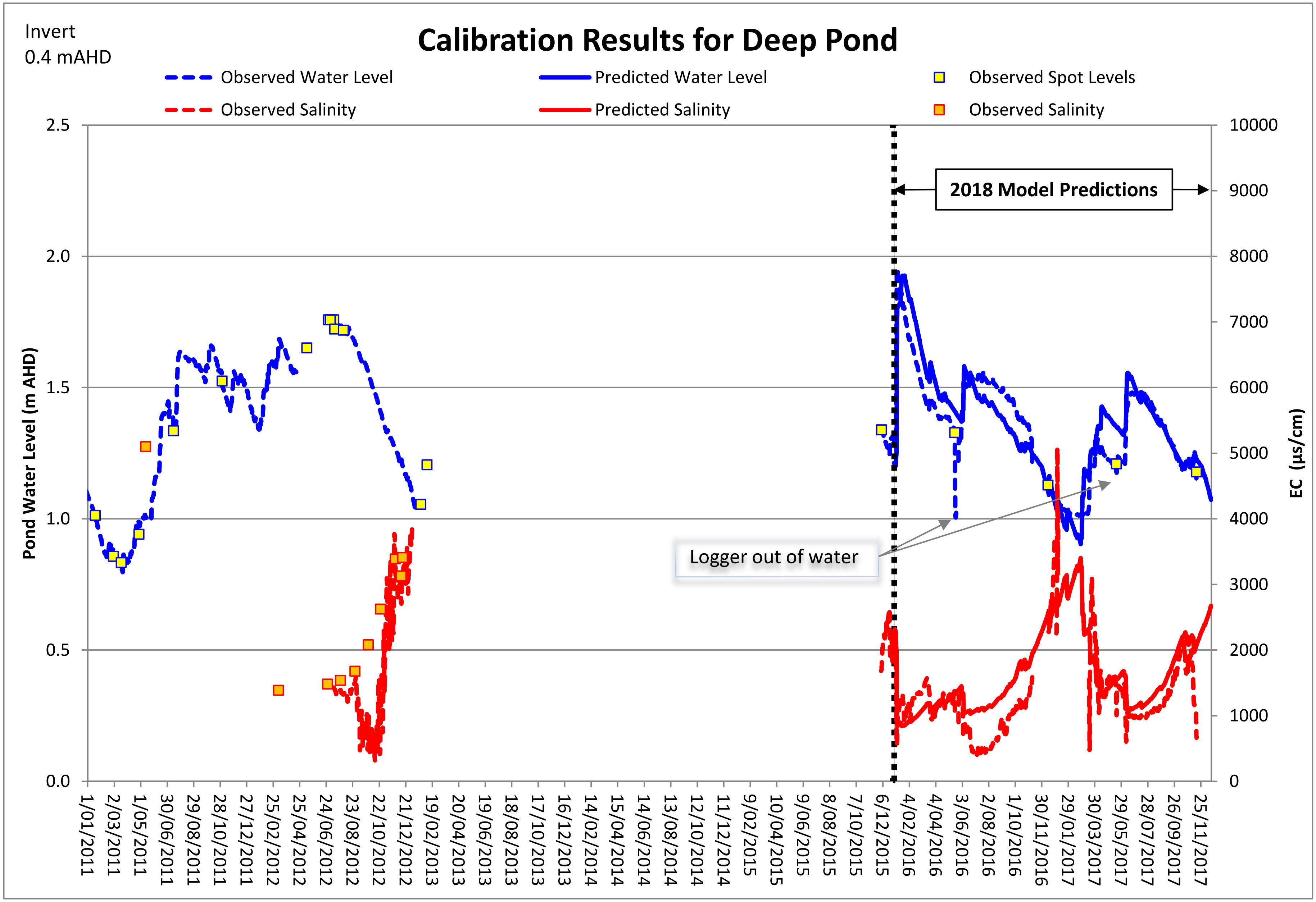
Based on the results of the hydro-salinity modelling, the use of a Modified Cap in the low area and a Standard Cap over the remaining areas is the recommended capping solution for Area 2. The environmental effects associated with the Modified Cap are expected to represent a minor change to the existing conditions.

The cumulative effects of the Area 2 Closure Works were assessed as part of this project and the results were found to be independent of the previous KIWEF Areas 1 and 3 modelled outcomes.

Appendix A Reference Documents

- Douglas Partners (2013), 'Groundwater Modelling KIWEF Landfill Closure Kooragang Island';
- Douglas Partners (2016), 'Report on Qualitative Assessment of Surface Water Impacts, KIWEF Area 2 Closure Works Kooragang Island';
- ERM (2015), 'Kooragang Island Former Waste Emplacement Facility Landfill Closure Works: Site K2, K10 North & K10 South – Response to SEWPaC Requests for Information';
- EMGA Mitchell McLennan (2012) 'T4 Project Environmental Assessment';
- RCA (Nov 2017), 'KIWEF Datalogger Download Monitoring Factual Report – Round 3 (November 2017)';
- RCA (June 2017), 'KIWEF Datalogger Download Monitoring Factual Report – Round 2 (May 2017)';
- RCA (Feb 2017), 'KIWEF Datalogger Download Monitoring Factual Report – Round 1 (December 2016)';
- RCA (Dec 2015), 'Surface Water Data Loggers – Kooragang Island Waste Emplacement Facility (KIWEF)';
- SMEC (November 2016), 'KIWEF Area 2 Geotechnical and Environmental Factual Report – DRAFT;
- SMEC (2017), 'KIWEF Area 2 (Phase 5) Closure Works – Briefing Paper';
- SMEC (2016), 'KIWEF Phase 5 Closure Works – In-Situ Capping Material Information Memorandum'; and
- SMEC (2013), 'KIWEF SEWPaC SMEC Detailed Review – Revision No. 5'.

Appendix B Hydro-Salinity Model Calibration



Invert
0.4 mAHD
Calibration Results for Deep Pond
Observed Water Level
Predicted Water Level
Observed Spot Levels
Observed Salinity
Predicted Salinity
Observed Salinity
2018 Model Predictions
Logger out of water
Pond Water Level (m AHD)
EC (µs/cm)
2.5
2.0
1.5
1.0
0.5
0.0
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
1/01/2011
2/03/2011
1/05/2011
30/06/2011
29/08/2011
28/10/2011
27/12/2011
25/02/2012
25/04/2012
24/06/2012
23/08/2012
22/10/2012
21/12/2012
19/02/2013
20/04/2013
19/06/2013
18/08/2013
17/10/2013
16/12/2013
14/02/2014
15/04/2014
14/06/2014
13/08/2014
12/10/2014
11/12/2014
9/02/2015
10/04/2015
9/06/2015
8/08/2015
7/10/2015
6/12/2015
4/02/2016
4/04/2016
3/06/2016
2/08/2016
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29/05/2017
28/07/2017
26/09/2017
25/11/2017

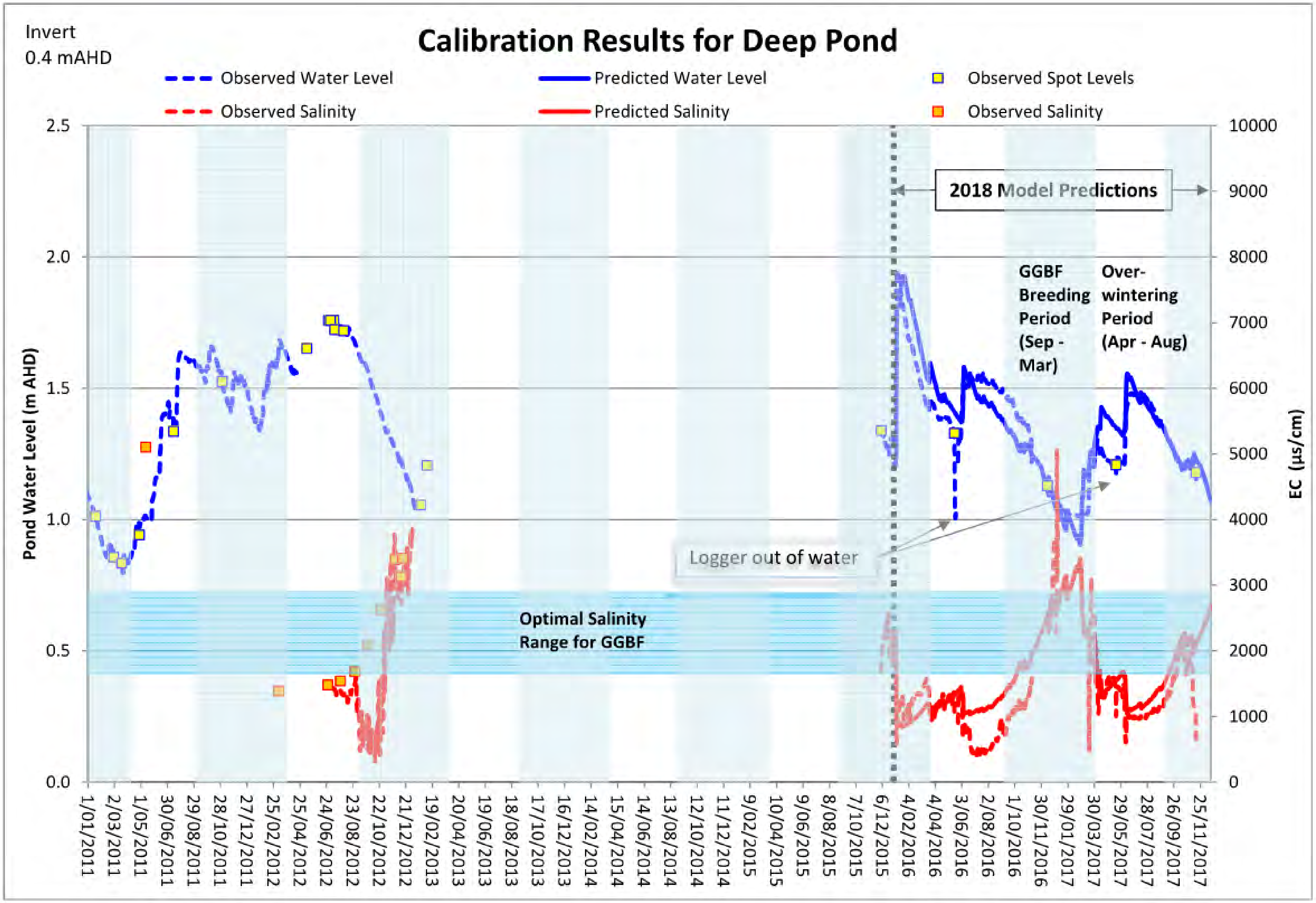
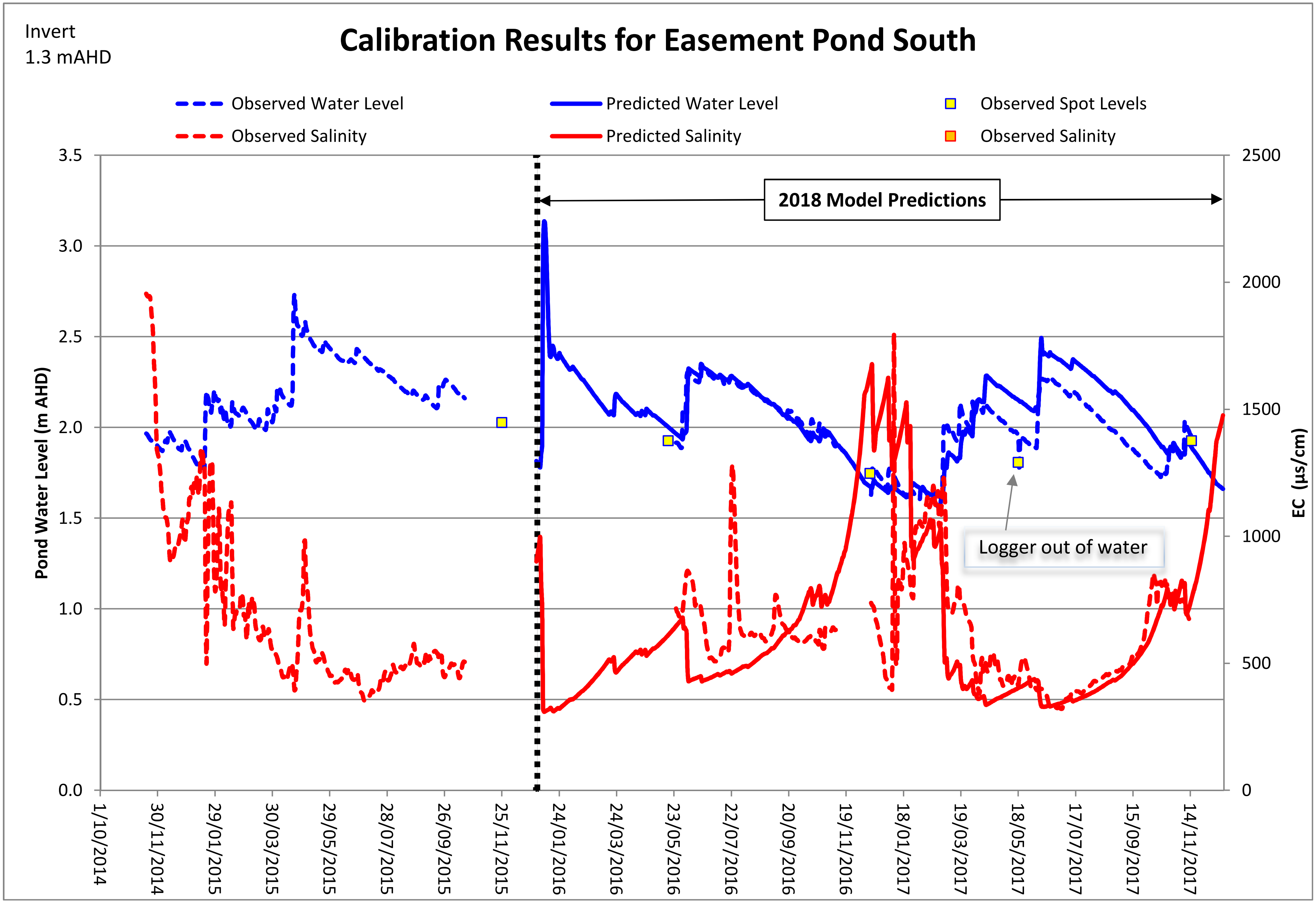


FIGURE - Seasonal Variation (effect of evaporation on water level and salinity)



Invert
1.3 mAHD
Calibration Results for Easement Pond South
Observed Water Level
Predicted Water Level
Observed Spot Levels
Observed Salinity
Predicted Salinity
Observed Salinity
2018 Model Predictions
Logger out of water
Pond Water Level (m AHD)
EC (µs/cm)
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
2500
2000
1500
1000
500
0
1/10/2014
30/11/2014
29/01/2015
30/03/2015
29/05/2015
28/07/2015
26/09/2015
25/11/2015
24/01/2016
24/03/2016
23/05/2016
22/07/2016
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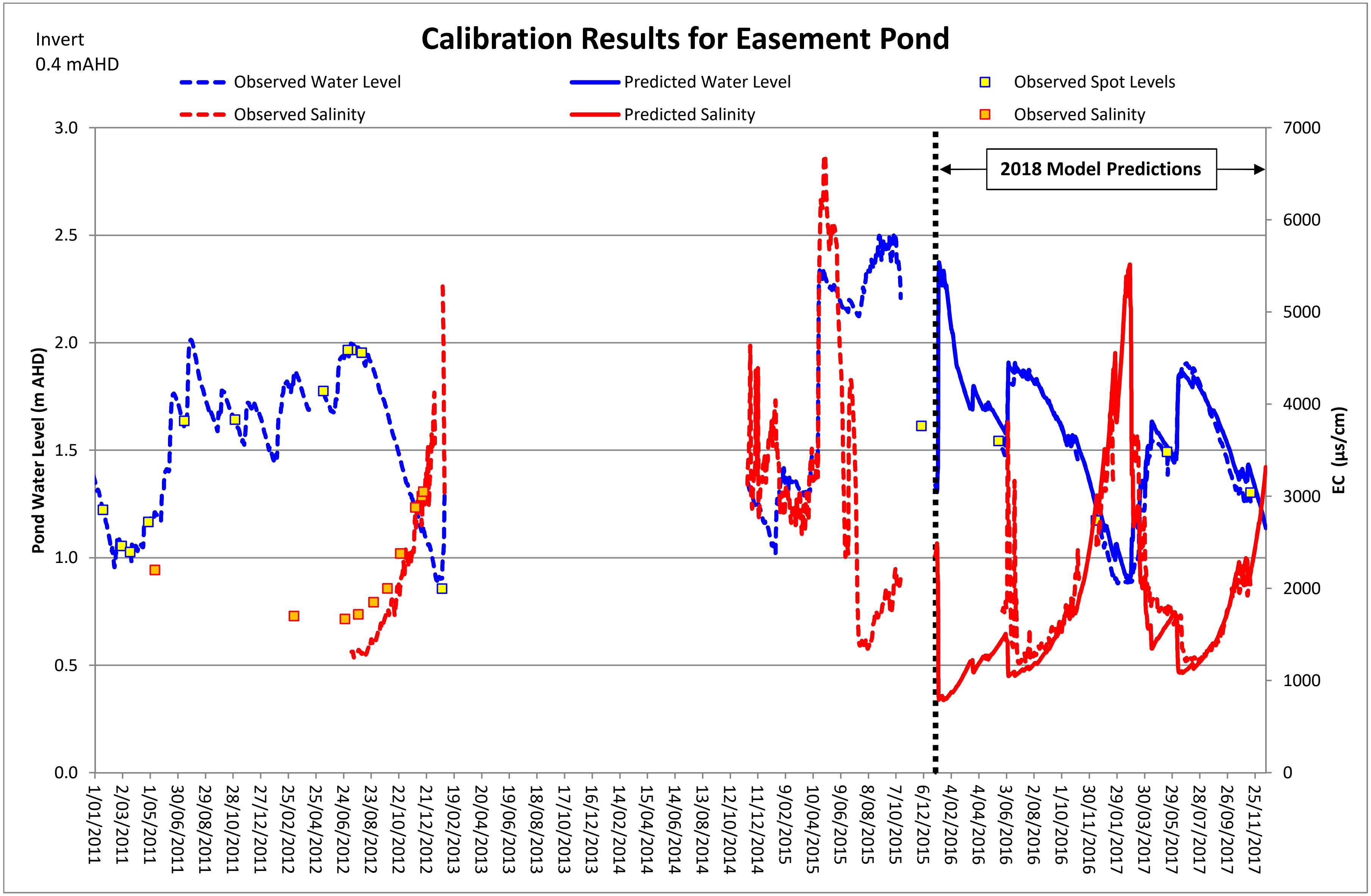
17/07/2017
15/09/2017
14/11/2017



Calibration Results for Easement Pond
Invert
0.4 mAHD
Observed Water Level
Predicted Water Level
Observed Spot Levels
Observed Salinity
Predicted Salinity
Observed Salinity
2018 Model Predictions
Pond Water Level (m AHD)
EC (µs/cm)
3.0
2.5
2.0
1.5
1.0
0.5
0.0
7000
6000
5000
4000
3000
2000
1000
0
1/01/2011
2/03/2011
1/05/2011
30/06/2011
29/08/2011
28/10/2011
27/12/2011
25/02/2012
25/04/2012
24/06/2012
23/08/2012
22/10/2012
21/12/2012
19/02/2013
20/04/2013
19/06/2013
18/08/2013
17/10/2013
16/12/2013
14/02/2014
15/04/2014
14/06/2014
13/08/2014
12/10/2014
11/12/2014
9/02/2015
10/04/2015
9/06/2015
8/08/2015
7/10/2015
6/12/2015
4/02/2016
4/04/2016
3/06/2016
2/08/2016
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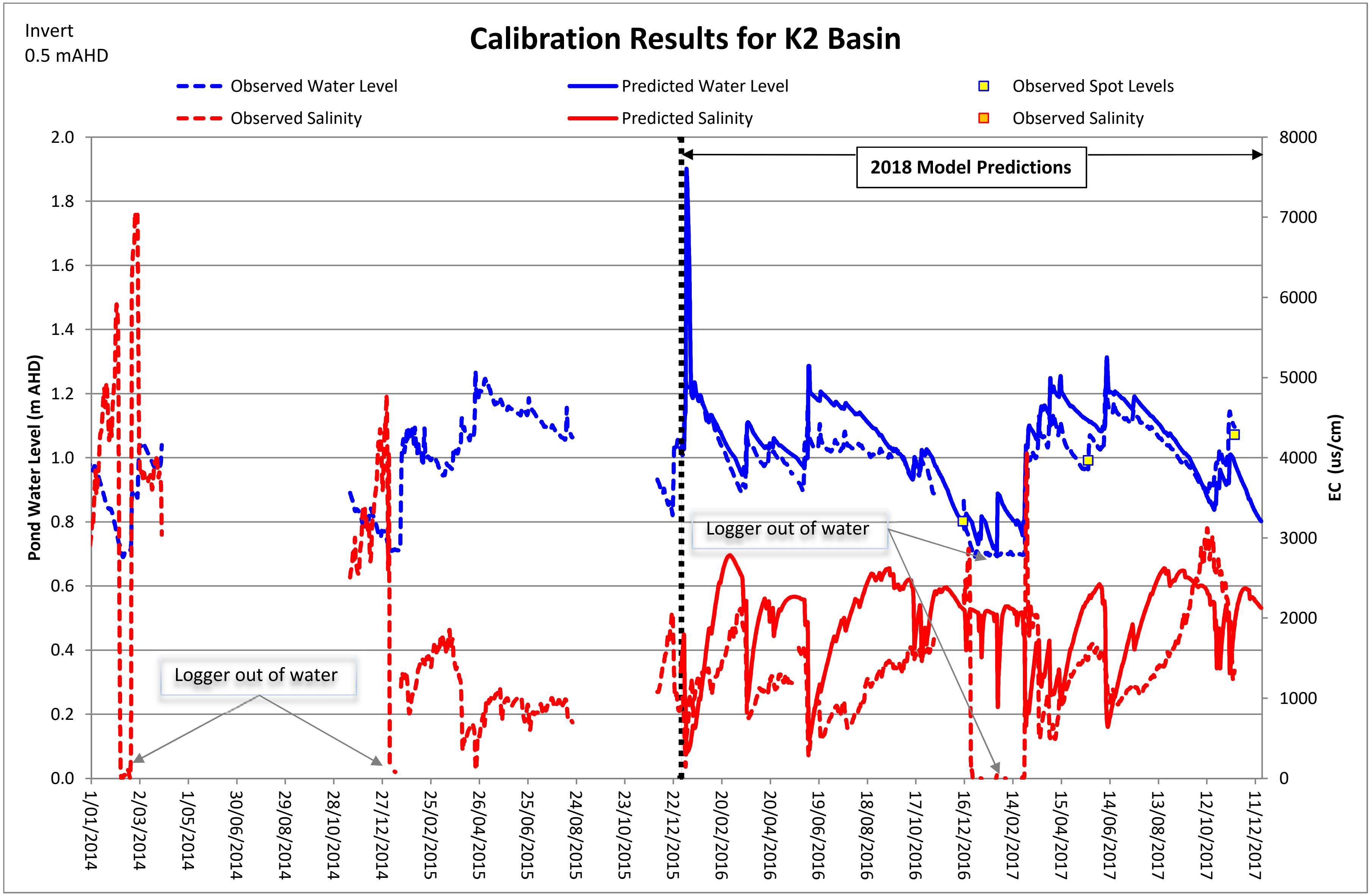
28/07/2017
26/09/2017
25/11/2017



Invert
0.5 mAHD
Calibration Results for K2 Basin
Observed Water Level
Predicted Water Level
Observed Spot Levels
Observed Salinity
Predicted Salinity
Observed Salinity
2018 Model Predictions
Logger out of water
Logger out of water
Pond Water Level (m AHD)
EC (us/cm)
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
8000
7000
6000
5000
4000
3000
2000
1000
0
1/01/2014
2/03/2014
1/05/2014
30/06/2014
29/08/2014
28/10/2014
27/12/2014
25/02/2015
26/04/2015
25/06/2015
24/08/2015
23/10/2015
22/12/2015
20/02/2016
20/04/2016
19/06/2016
18/08/2016
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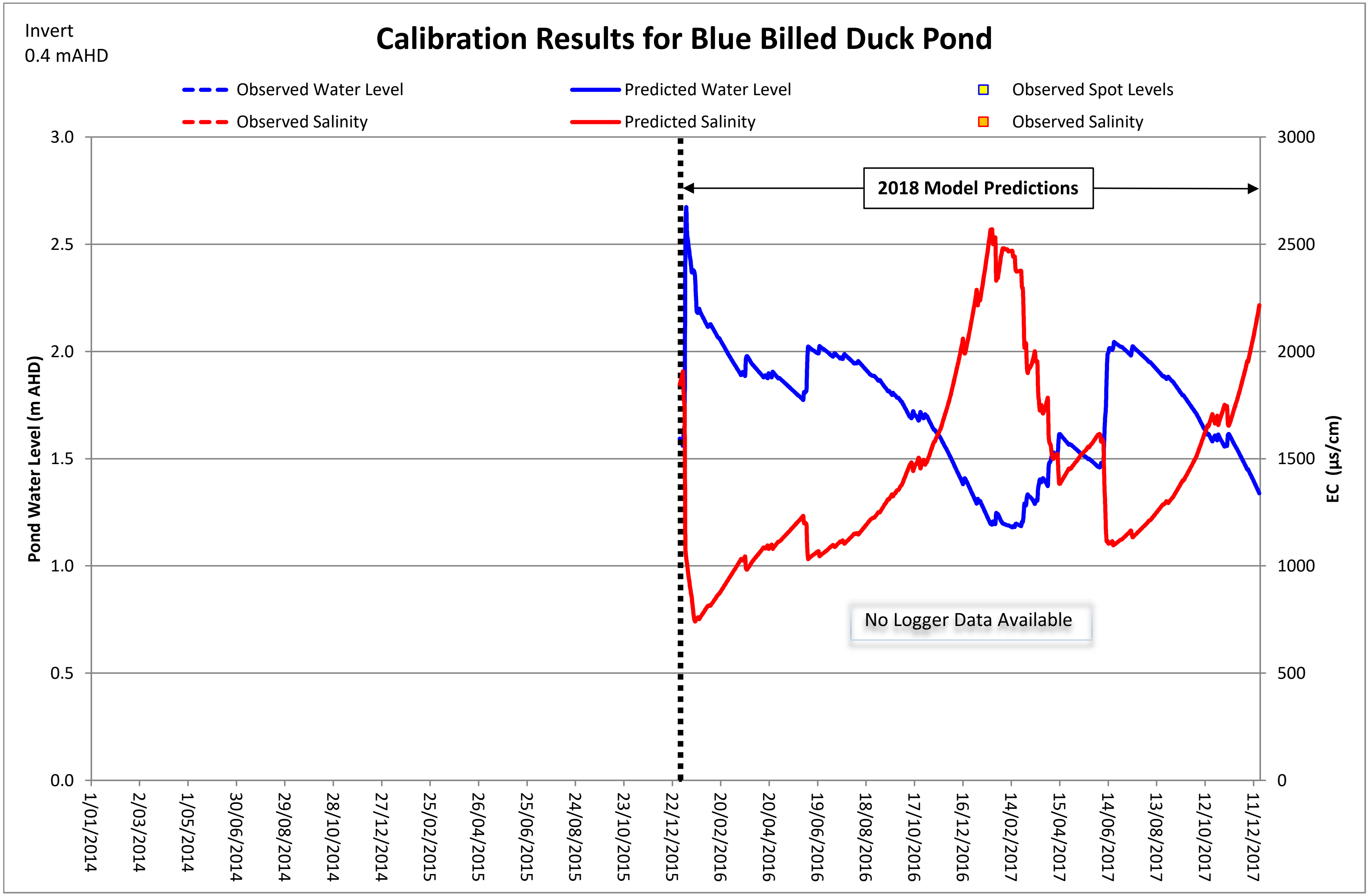
12/10/2017
11/12/2017



Invert
0.4 mAHD
Calibration Results for Blue Billed Duck Pond
Observed Water Level
Predicted Water Level
Observed Spot Levels
Observed Salinity
Predicted Salinity
Observed Salinity
2018 Model Predictions
No Logger Data Available
Pond Water Level (m AHD)
EC (µs/cm)
3.0
2.5
2.0
1.5
1.0
0.5
0.0
3000
2500
2000
1500
1000
500
0
1/01/2014
2/03/2014
1/05/2014
30/06/2014
29/08/2014
28/10/2014
27/12/2014
25/02/2015
26/04/2015
25/06/2015
24/08/2015
23/10/2015
22/12/2015
20/02/2016
20/04/2016
19/06/2016
18/08/2016
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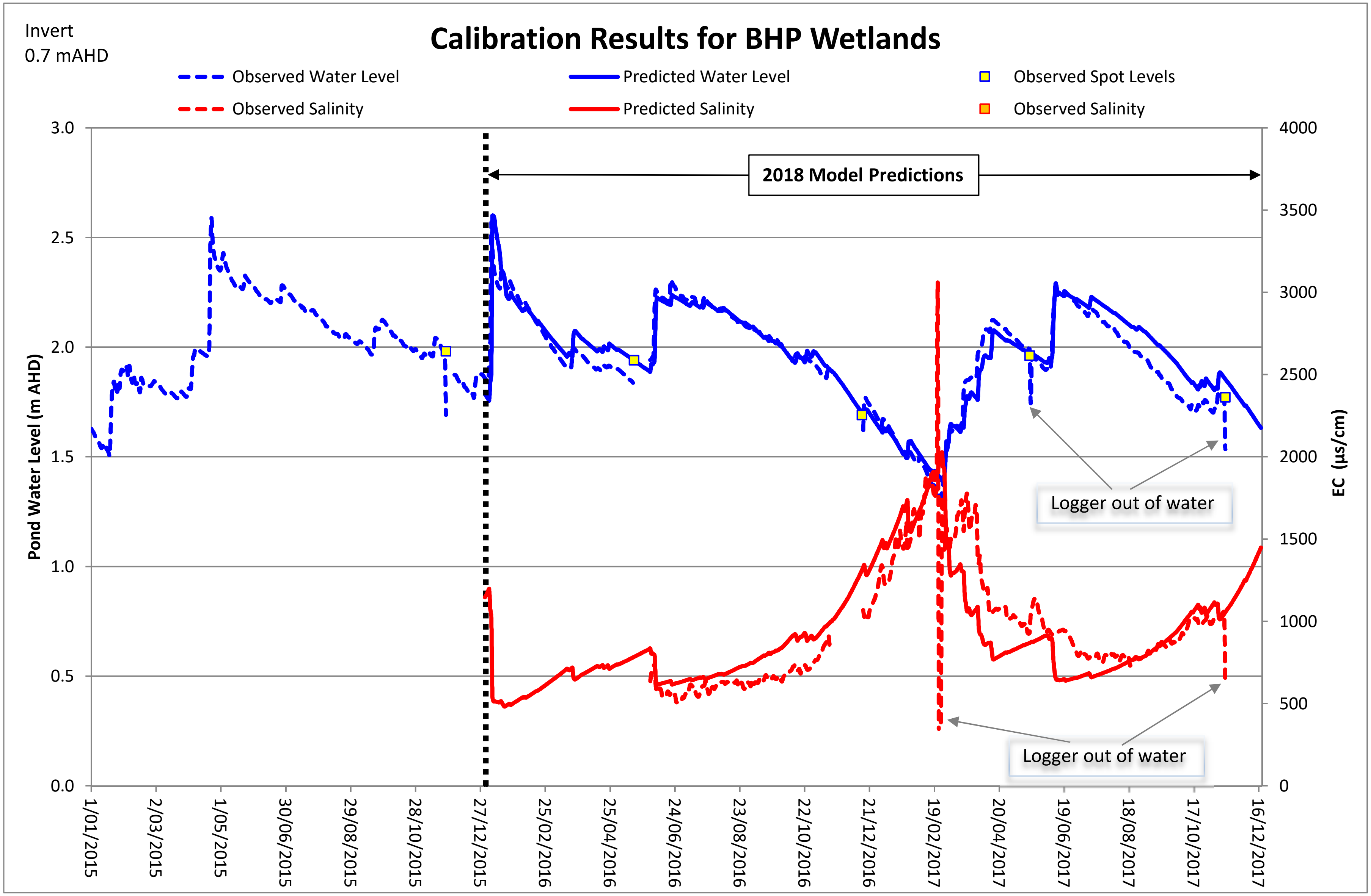
16/12/2016
14/02/2017
15/04/2017
14/06/2017
13/08/2017
12/10/2017
11/12/2017


Invert
0.7 mAHD
Calibration Results for BHP Wetlands
Observed Water Level
Predicted Water Level
Observed Spot Levels
Observed Salinity
Predicted Salinity
Observed Salinity
2018 Model Predictions
Logger out of water
Logger out of water
Pond Water Level (m AHD)
EC (µs/cm)
3.0
2.5
2.0
1.5
1.0
0.5
0.0
4000
3500
3000
2500
2000
1500
1000
500
0
1/01/2015
2/03/2015
1/05/2015
30/06/2015
29/08/2015
28/10/2015
27/12/2015
25/02/2016
25/04/2016
24/06/2016
23/08/2016
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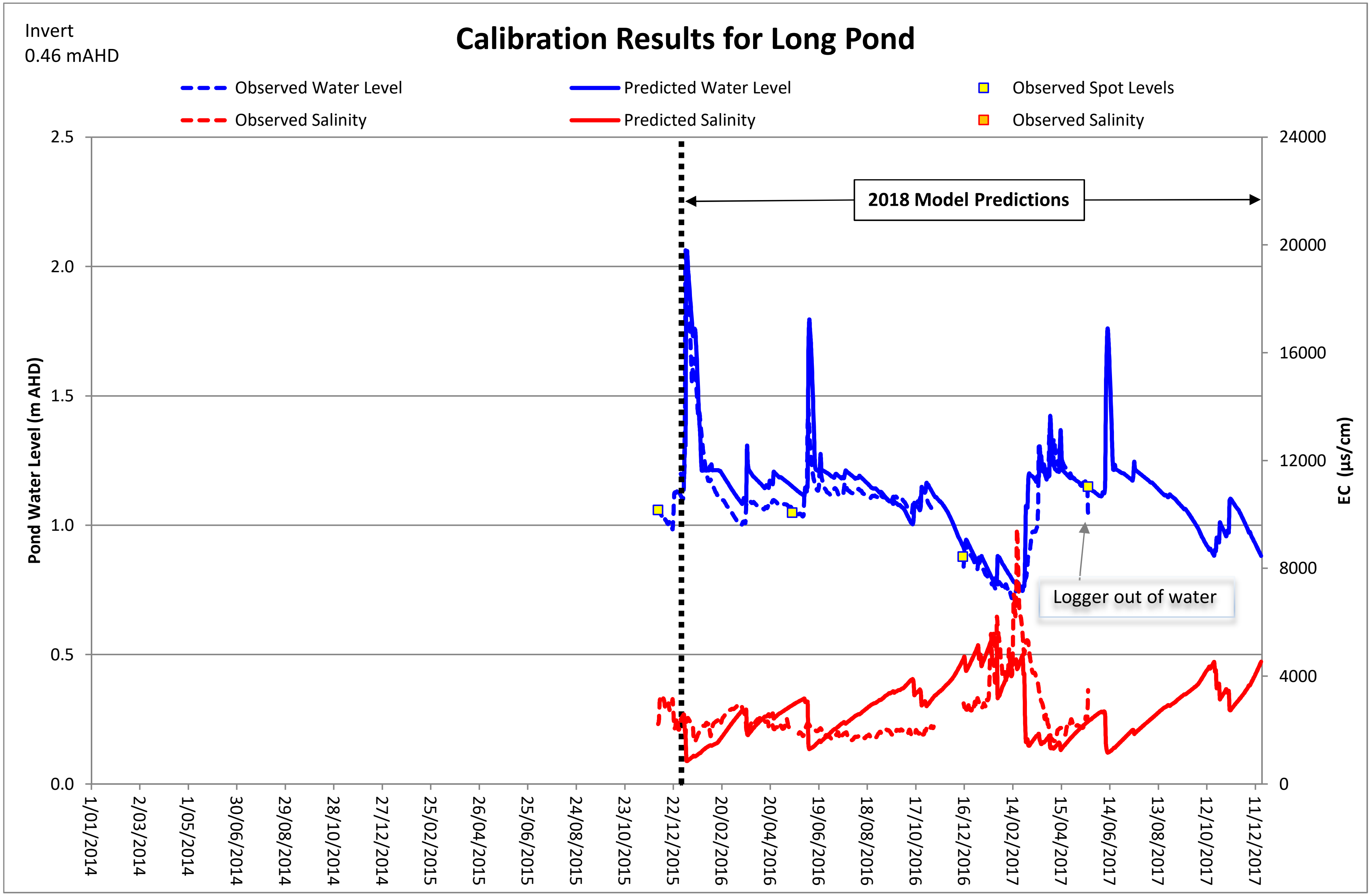
17/10/2017
16/12/2017


Invert
0.46 mAHD
Calibration Results for Long Pond
Observed Water Level
Predicted Water Level
Observed Spot Levels
Observed Salinity
Predicted Salinity
Observed Salinity
2018 Model Predictions
Logger out of water
Pond Water Level (m AHD)
EC (µs/cm)
2.5
2.0
1.5
1.0
0.5
0.0
24000
20000
16000
12000
8000
4000
0
1/01/2014
2/03/2014
1/05/2014
30/06/2014
29/08/2014
28/10/2014
27/12/2014
25/02/2015
26/04/2015
25/06/2015
24/08/2015
23/10/2015
22/12/2015
20/02/2016
20/04/2016
19/06/2016
18/08/2016
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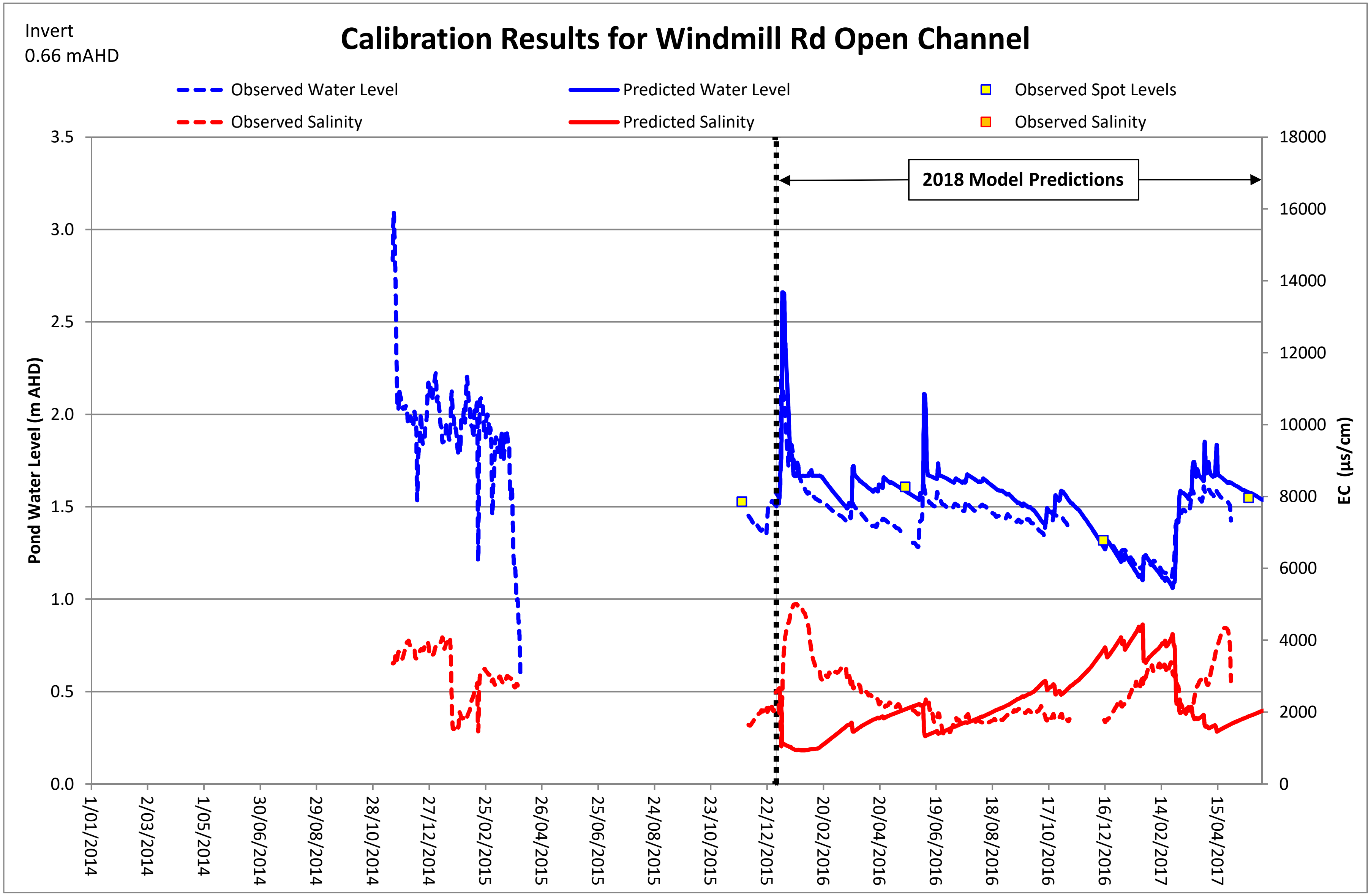
16/12/2016
14/02/2017
15/04/2017
14/06/2017
13/08/2017
12/10/2017
11/12/2017



Invert
0.66 mAHD
Calibration Results for Windmill Rd Open Channel
Observed Water Level
Predicted Water Level
Observed Spot Levels
Observed Salinity
Predicted Salinity
Observed Salinity
2018 Model Predictions
Pond Water Level (m AHD)
EC (µs/cm)
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
1/01/2014
2/03/2014
1/05/2014
30/06/2014
29/08/2014
28/10/2014
27/12/2014
25/02/2015
26/04/2015
25/06/2015
24/08/2015
23/10/2015
22/12/2015
20/02/2016
20/04/2016
19/06/2016
18/08/2016
17/10/2016
16/12/2016
14/02/2017
15/04/2017

Appendix C Hydro-Salinity Model Results

Standard Cap – Water Levels

Table C1 – Water Level Effects in All KIWEF Ponds – Standard Cap

	Percentage of time below the Lower Bound Water Level Value		Relative change (% shift)	Percentage of time greater than the Upper Bound Water Level Value		Relative change (% shift)
	Existing	Predicted		Existing	Predicted	
BHP Wetlands	20%	20%	0%	20%	20%	0%
Blue Billed Duck Pond	20%	20%	0%	20%	20%	0%
Deep Pond	20%	12%	-8%	20%	33%	13%
Easement Pond	20%	20%	0%	20%	20%	0%
Easement Pond South	20%	20%	0%	20%	20%	0%
K2 Basin	20%	20%	0%	20%	20%	0%
Long Pond	20%	20%	0%	20%	20%	0%
Windmill Rd Open Channel	20%	20%	0%	20%	20%	0%

Table C2 – Water Level Effects in All KIWEF Ponds – Standard Cap

	Percentage of time in optimal Water Level range		Relative change (% shift)
	Existing	Predicted	
BHP Wetlands	60%	60%	0%
Blue Billed Duck Pond	60%	60%	0%
Deep Pond	60%	55%	-5%
Easement Pond	60%	60%	0%
Easement Pond South	60%	60%	0%
K2 Basin	60%	60%	0%
Long Pond	60%	60%	0%
Windmill Rd Open Channel	60%	60%	0%

Standard Cap – Water Quality

Table C3 – Water Quality Effects (Salinity) in All KIWEF Ponds – Standard Cap

	Percentage of time below the optimum chytrid protection threshold (<1,650 µS/cm)		Relative change (% shift)	Percentage of time greater than the optimum chytrid protection threshold (>2,900 µS/cm)		Relative change (% shift)
	Existing	Predicted		Existing	Predicted	
BHP Wetlands	92.4	92.4	0.0	0.7	0.7	0.0
Blue Billed Duck Pond	71.9	71.6	-0.3	0.0	0.0	0.0
Deep Pond	49.3	71.2	21.9	8.5	3.7	4.8
Easement Pond	59.1	59.1	0.0	11.7	11.7	0.0
Easement Pond South	98.7	98.7	0.0	0.0	0.0	0.0
K2 Basin	24.7	24.9	0.2	0.9	0.9	0.0
Long Pond	20.1	20.1	0.0	40.9	40.9	0.0
Windmill Rd Open Channel	28.5	28.5	0.0	19.1	19.1	0.0

Table C4 – Water Quality (Salinity) Effects All KIWEF Ponds – Standard Cap

	Percentage of time in optimal Salinity range		Relative change (% shift)
	Existing	Predicted	
BHP Wetlands	6.9%	6.9%	0.0%
Blue Billed Duck Pond	28.1%	28.4%	0.3%
Deep Pond	42.2%	25.1%	-17.1%
Easement Pond	29.2%	29.2%	0.0%
Easement Pond South	1.3%	1.3%	0.0%
K2 Basin	74.4%	74.2%	-0.2%
Long Pond	39.0%	39.0%	0.0%
Windmill Rd Open Channel	52.4%	52.4%	0.0%

Modified Cap – Water Levels

Table C5 – Water Level Effects in All KIWEF Ponds – Modified Cap

	Percentage of time below the Lower Bound Water Level Value		Relative change (% shift)	Percentage of time greater than the Upper Bound Water Level Value		Relative change (% shift)
	Existing	Predicted		Existing	Predicted	
BHP Wetlands	20%	20%	0%	20%	20%	0%
Blue Billed Duck Pond	20%	20%	0%	20%	20%	0%
Deep Pond	20%	17%	-3%	20%	26%	6%
Easement Pond	20%	20%	0%	20%	20%	0%
Easement Pond South	20%	20%	0%	20%	20%	0%
K2 Basin	20%	20%	0%	20%	20%	0%
Long Pond	20%	20%	0%	20%	20%	0%
Windmill Rd Open Channel	20%	20%	0%	20%	20%	0%

Table C6 – Water Level Effects in All KIWEF Ponds – Modified Cap

	Percentage of time in optimal Water Level range		Relative change (% shift)
	Existing	Predicted	
BHP Wetlands	60%	60%	0%
Blue Billed Duck Pond	60%	60%	0%
Deep Pond	60%	57%	-3%
Easement Pond	60%	60%	0%
Easement Pond South	60%	60%	0%
K2 Basin	60%	60%	0%
Long Pond	60%	60%	0%
Windmill Rd Open Channel	60%	60%	0%

Modified Cap – Water Quality

Table C7 – Water Quality Effects (Salinity) in All KIWEF Ponds – Modified Cap

	Percentage of time below the optimum chytrid protection threshold (<1,650 µS/cm)		Relative change (% shift)	Percentage of time greater than the optimum chytrid protection threshold (>2,900 µS/cm)		Relative change (% shift)
	Existing	Predicted		Existing	Predicted	
BHP Wetlands	92.4	92.4	0.0	0.7	0.7	0.0
Blue Billed Duck Pond	71.9	71.8	-0.1	0.0	0.0	0.0
Deep Pond	49.3	62.5	13.2	8.5	5.2	3.3
Easement Pond	59.1	59.1	0.0	11.7	11.7	0.0
Easement Pond South	98.7	98.7	0.0	0.0	0.0	0.0
K2 Basin	24.7	24.7	0.0	0.9	0.9	0.0
Long Pond	20.1	20.1	0.0	40.9	40.9	0.0
Windmill Rd Open Channel	28.5	28.5	0.0	19.1	19.1	0.0

Table C8 – Water Quality (Salinity) Effects All KIWEF Ponds – Modified Cap

	Percentage of time in optimal Salinity range		Relative change (% shift)
	Existing	Predicted	
BHP Wetlands	6.9%	6.9%	0.0%
Blue Billed Duck Pond	28.1%	28.2%	0.1%
Deep Pond	42.2%	32.3%	-9.9%
Easement Pond	29.2%	29.2%	0.0%
Easement Pond South	1.3%	1.3%	0.0%
K2 Basin	74.4%	74.4%	0.0%
Long Pond	39.0%	39.0%	0.0%
Windmill Rd Open Channel	52.4%	52.4%	0.0%

2013 Modelling

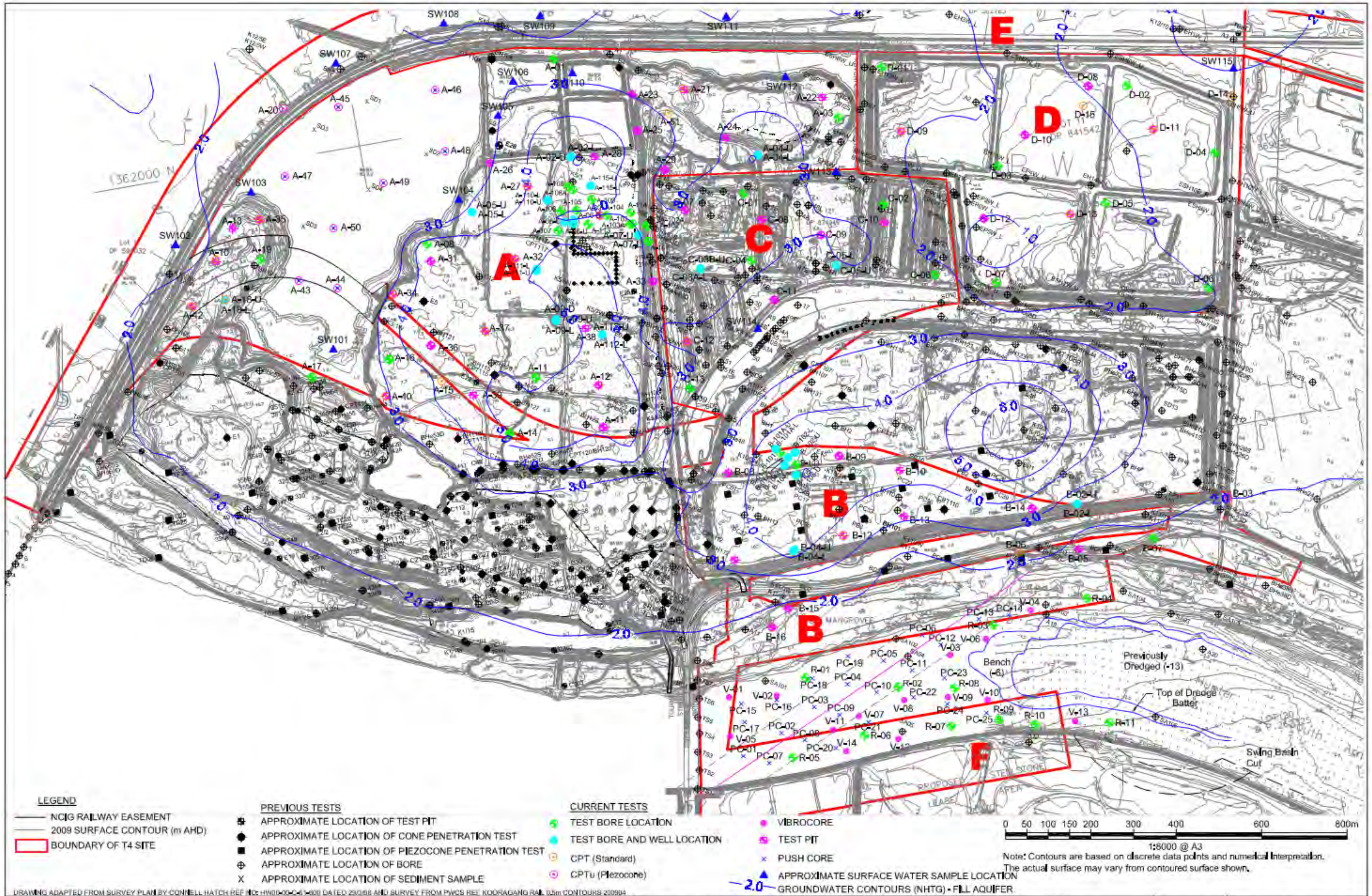
Table C9 – Predicted Water Level Effects from Areas 1 and 3 capping - all KIWEF Ponds (2013 Modelling)

Pond	Percentage of time below the Lower Bound Water Level Value		Relative change (% shift)	Percentage of time greater than the Upper Bound Water Level Value		Relative change (% shift)
	Existing	Predicted		Existing	Predicted	
BHP Wetlands	20%	21%	1%	20%	18%	-2%
Blue Billed Duck Pond	20%	22%	2%	20%	16%	-4%
Deep Pond	20%	19%	-1%	20%	20%	0%
Easement Pond	20%	21%	1%	20%	27%	7%
Easement Pond South	20%	21%	1%	20%	17%	-3%
K2 Basin	20%	22%	2%	20%	19%	-1%
Long Pond	20%	4%	-16%	20%	35%	15%
Windmill Rd Open Channel	20%	1%	-19%	20%	28%	8%

Table C10 –Predicted Water Quality Effects from Areas 1 and 3 capping - all KIWEF Ponds (2013 Modelling)

Pond	Percentage of time below the optimum chytrid protection threshold (<1,650µS/cm)		Relative change (% shift)	Percentage of time greater than the optimum chytrid protection threshold (>2,900µS/cm)		Relative change (% shift)
	Existing	Predicted		Existing	Predicted	
BHP Wetlands	92.6%	92.7%	0.1%	0.2%	0.3%	0.1%
Blue Billed Duck Pond	90.7%	90.4%	-0.3%	0.0%	0.0%	0.0%
Deep Pond	46.4%	48.1%	1.8%	16.6%	16.7%	0.1%
Easement Pond	39.1%	48.9%	9.9%	18.7%	12.8%	-5.9%
Easement Pond South	99.6%	100%	0.4%	0.0%	0.0%	0.0%
K2 Basin	43.8%	46.7%	2.9%	22.3%	20.5%	-1.8%
Long Pond	5.5%	13.4%	7.8%	64.8%	50.0%	-14.8%
Windmill Rd Open Channel	13.7%	7.1%	-6.7%	62.8%	55.9%	-6.9%

Appendix D T4 Groundwater Contours



Douglas Partners — Geotechnics / Environment / Groundwater	CLIENT: Port Waratah Coal Services Limited	TITLE: Groundwater Contours - Fill Aquifer (25 November 2010)	PROJECT No: 49533.02
	OFFICE: Newcastle — DRAWN BY: PLH	Groundwater Assessment	DRAWING No: 5.07
	SCALE: 1:8000@A3 — DATE: 04.11.2011	Proposed Terminal 4 Project, Kooragang Island	REVISION: 3

LEGEND

- NCIG RAILWAY EASEMENT
- 2009 SURFACE CONTOUR (m AHD)
- BOUNDARY OF T4 SITE

PREVIOUS TESTS

- APPROXIMATE LOCATION OF TEST PIT
- APPROXIMATE LOCATION OF CONE PENETRATION TEST
- APPROXIMATE LOCATION OF PIEZOCONE PENETRATION TEST
- APPROXIMATE LOCATION OF BORE
- X APPROXIMATE LOCATION OF SEDIMENT SAMPLE

CURRENT TESTS

- TEST BORE LOCATION
- TEST BORE AND WELL LOCATION
- CPT (Standard)
- CPTu (Piezocone)
- VIBROCORE
- TEST PIT
- × PUSH CORE
- APPROXIMATE SURFACE WATER SAMPLE LOCATION
- 1.4 GROUNDWATER CONTOURS (NHTG) - ESTUARINE AQUIFER

0 50 100 150 200 300 400 600 800m

1:8000 @ A3

Note: Contours are based on discrete data points and numerical interpretation. The actual surface may vary from contoured surface shown.

DRAWING ADAPTED FROM SURVEY PLAN BY CONNELL HATCH REF No: HW00-00-C-01-500 DATED 28/3/08 AND SURVEY FROM PWCS REF KOORAGANG RAIL 0.5m CONTOURS 200804

Douglas Partners
Geotechnics | Environment | Groundwater

CLIENT: Port Waratah Coal Services Limited		TITLE: Groundwater Contours - Estuarine Aquifer (25 November 2010)	PROJECT No: 49533.02
OFFICE: Newcastle	DRAWN BY: PLH	Groundwater Assessment	DRAWING No: 5.08
SCALE: 1:8000@A3	DATE: 04.11.2011	Proposed Terminal 4 Project, Kooragang Island	REVISION: 3

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APPENDIX 6
SUMMARY OF THE IMPACT AND BENEFIT TO THE GREEN AND GOLDEN BELL FROG (LITORIA AUREA) AND ITS HABITAT – UNIVERSITY OF NEWCASTLE

Area 1 and Area 3 Closure Works for Remediation of the former BHP Kooragang Island Waste Emplacement Facility

Summary of the Impact and Benefit to the Green and Golden Bell Frog (*Litoria aurea*) and its Habitat

Prepared for Hunter Development Corporation | April 2018

Area 1 and Area 3 Closure Works for Remediation of the former BHP Kooragang Island Waste Emplacement Facility - Summary of the Impact and Benefit to the Green and Golden Bell Frog (*Litoria aurea*) and its Habitat

Draft

Report Prepared for Hunter Development Corporation | April 2018

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Table of Contents

1. Executive Summary

Hunter Development Corporation (HDC) is undertaking phased closure works of the Kooragang Island Waste Emplacement Facility (KIWEF) on behalf of the State of NSW. Phase 1 has been completed and Phase 2 is currently being assessed as a controlled action under the Commonwealth Environmental Protection and Biodiversity Conservation Act (*EPBC Act 1999*) (Referral 2016/7670). *Litoria aurea* (green and golden bell frog) is listed as vulnerable under the *EPBC Act* and occurs within the footprint of the KIWEF, and adjacent to the area across the rest of Kooragang Island. Several mitigation measures for Phase 1 works were in place to limit impact on the local population and habitat of *L. aurea*.

Phase 1 works involved a process of capping historical waste emplacement areas (Areas 1 and 3), landform reshaping and alteration of surface hydrology resulting in the creation of nine sediment basins within the project footprint. These basins have a temporary (ephemeral) hydroperiod, being disconnected from the groundwater (as a result of capping works to arrest ongoing contamination from historical waste emplacement) and are filled only by surface runoff from rainfall events. *Litoria aurea* has been observed in these sediment basins during annual monitoring of the distribution, density and demography of the local population across Kooragang Island. Thus, in the context of this report, they are considered to be wetlands providing habitat for *L. aurea*.

The presence, breeding and persistence of *L. aurea* within the Phase 1 footprint since completion of closure works may be attributed to a number of landform features that have created suitable artificial habitat for the species. This includes a mosaic of waterbodies with varying hydroperiods to provide opportunities for breeding and over-wintering, good connectivity between waterbodies to allow movement, isolation from groundwater to manage potential contamination and elevation from existing overland surface water flows which could result in invasion of waterbodies by the predatory invasive fish, *Gambusia holbrooki.*

The purpose of this report is to review occupancy of *L. aurea* within the remediated Phase 1 closure works footprint in the context of the broader population across the proposed Port Waratah Coal Services Terminal Four development site (T4 site) using the results of spatial and temporal amphibian surveys conducted over the last four years. The Phase 1 closure footprint resulted in the construction of nine wetlands in the southern section of the T4 site. Subsequent to the construction of the rail embankment that services the Newcastle Coal Infrastructure Group coal loader (NCIG) in 2013, there were no wetlands in the Phase 1 area and recorded occupancy of the area by *L. aurea* was low. The new wetlands have been rapidly occupied by *L. aurea,* and breeding has been recorded at all nine. In all cases, occupancy and breeding occurred within two years of construction and many of the new wetlands were occupied in their first year. The observations of occupancy and breeding by *L. aurea* in the Phase 1 area demonstrates that provision of adequate breeding, foraging and sheltering habitat within this footprint, together with adequate connectivity and the absence of *Gambusia*, has been successful. These observations are evidence that the capping, landform reshaping and alteration of surface hydrology associated with the Phase 1 closure works provide a good model for artificial habitat creation for *L. aurea* at the eastern end of Kooragang Island.

2. Background

Hunter Development Corporation (HDC) is undertaking phased closure works of the Kooragang Island Waste Emplacement Facility (KIWEF) on behalf of the State of NSW (Figure 2-1). These works will arrest leaching of contaminated waste materials into the local environment, including the Hunter River and associated wetlands of high ecological value, and will adequately prepare the land for future industrial re-use. The closure works are undertaken in accordance with EPA Surrender Notices (1111840 and variations 1510956, 1520063) and the Revised Final Landform and Capping Strategy (GHD, 2009).

Environmental effects associated with KIWEF closure works are assessed under the Commonwealth *Environment Protection and Biodiversity Conservation Act, 199*9 (*EPBC Act 1999*). In 2013, the first phase of capping and remediation for Areas 1 and 3 (also known as K2, K10 North and K10 South) was deemed not a controlled action under the *EPBC Act* (Referral 2012/6464) and mitigation measures to manage environmental impacts were conducted in accordance with the KIWEF Capping Strategy (GHD, 2012). In 2016, the Commonwealth Department of the Environment and Energy deemed phase 2 of the closure works (Area 2) as a controlled action (Referral 2016/7670) to be assessed by preliminary documentation (Figure 2-1).

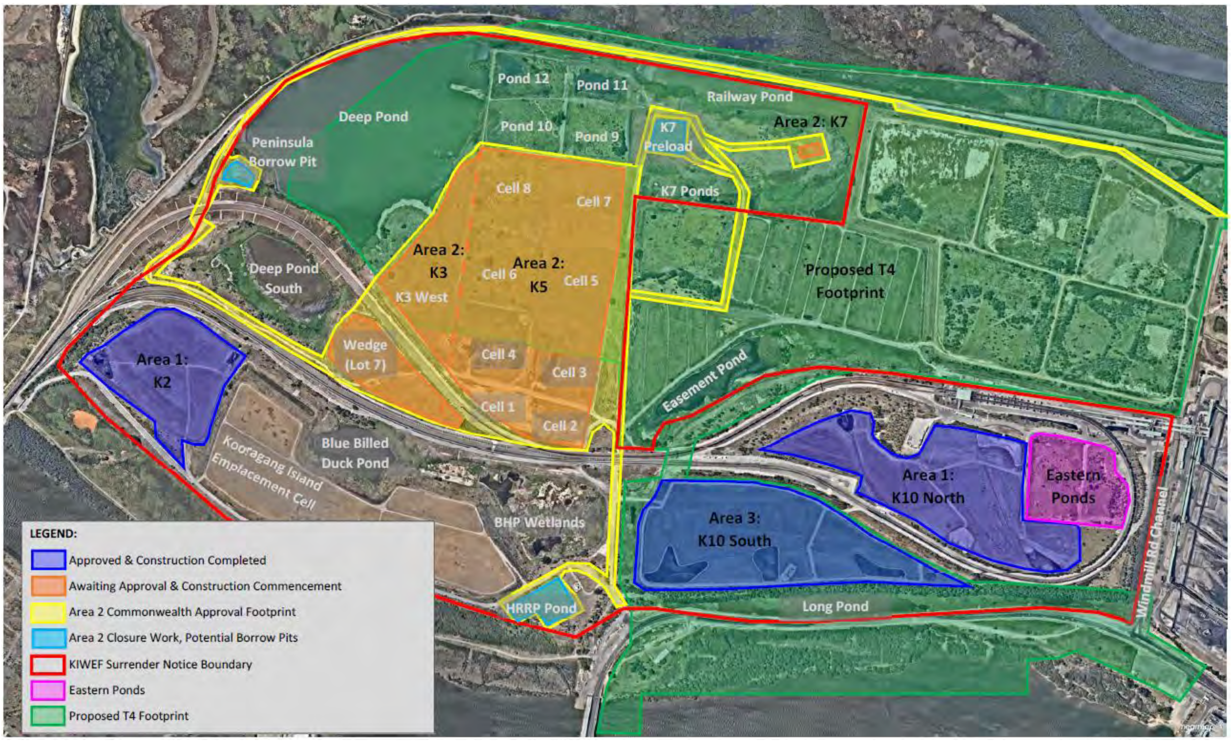

Figure 2-1: Summary of zones and areas within the Kooragang Island KIWEF and 'T4' site. Refer to Figure 2-3 and Table 2-1 for cross referencing of HDC and UoN wetlands reference systems. A high resolution version of this map is shown in Appendix A.

Matters of National Environmental Significance (MNES) under the *EPBC Act* that occur on or adjacent to the KIWEF site and/or may be impacted by closure works include the occurrance and habitat of the vulnerable green and golden bell frog (*L. aurea*). The development of the preliminary documentation package by HDC in support of the referral for Phase 2 (Area 2) closure works requires consideration of the impacts or otherwise of the Phase 1 closure works (Areas 1 and 3) on this population and their habitat, to assist in the effective capping design and mitigation measures of Phase 2 works.

2.1 Objective

The objective of this report is to consider any impacts and benefits of the Phase 1 closure works on the *Litoria aurea* population on Kooragang Island. This has been undertaken by considering the landform elements created by the works and how they enhance habitat for *L. aurea* in terms of a mosaic of aquatic habitats, hydroperiod, connectivity and protection from predation by the invasive fish, *Gambusia*. We use data from replicated annual surveys that employ the methods of visual encounter and mark-recapture surveys to determine the presence, breeding and persistence of *L. aurea* both within the Phase 1 footprint and in the context of the broader habitat across the T4 site.

2.2 *Litoria aurea* habitat on Kooragang Island

Kooragang Island, near Newcastle on the mid-coast of NSW, is home to one of the last remaining strongholds of *L. aurea*, which has declined from most of its previous range across NSW. Waterbodies in this area have varying hydroperiods, governed often by depth, although many are also influenced by the tidal and groundwater regimes characteristic of coastal floodplain environments and are highly variable in size and surface area (Callen, unpubl., 2017). These tidal and groundwater influences provide a salinity signature in some wetlands, and localised climatic variables such as rainfall or high daily evaporation exacerbate the dynamic fluctuations in salinity concentration and hydroperiod in a seasonal manner (Blaxland, 2015). Wetlands that support *L. aurea* on Kooragang Island are a mix of naturally-occurring waterbodies, aquatic environments created as a result of agricultural and industrial development (such as the waste emplacement cells within the KIWEF), and most recently, artificially created compensatory habitat to offset impacts associated with industrial expansion at the eastern end of Kooragang Island.

2.3 Site context of wetlands occupied by *L. aurea*

The Terminal 4 Industrial Zone ('T4') wetlands are located in the southeast corner of Kooragang Island, bounded by the Port Waratah Coal Service (PWCS) rail line to the west and north, the south arm of the Hunter River (and Cormorant Road) to the south, and Windmill Road (also known as Pacific National Road) to the east (Figures 2-1, 2-2). Although the specific development approval for the proposed Terminal 4 (the proposed expansion of the coal

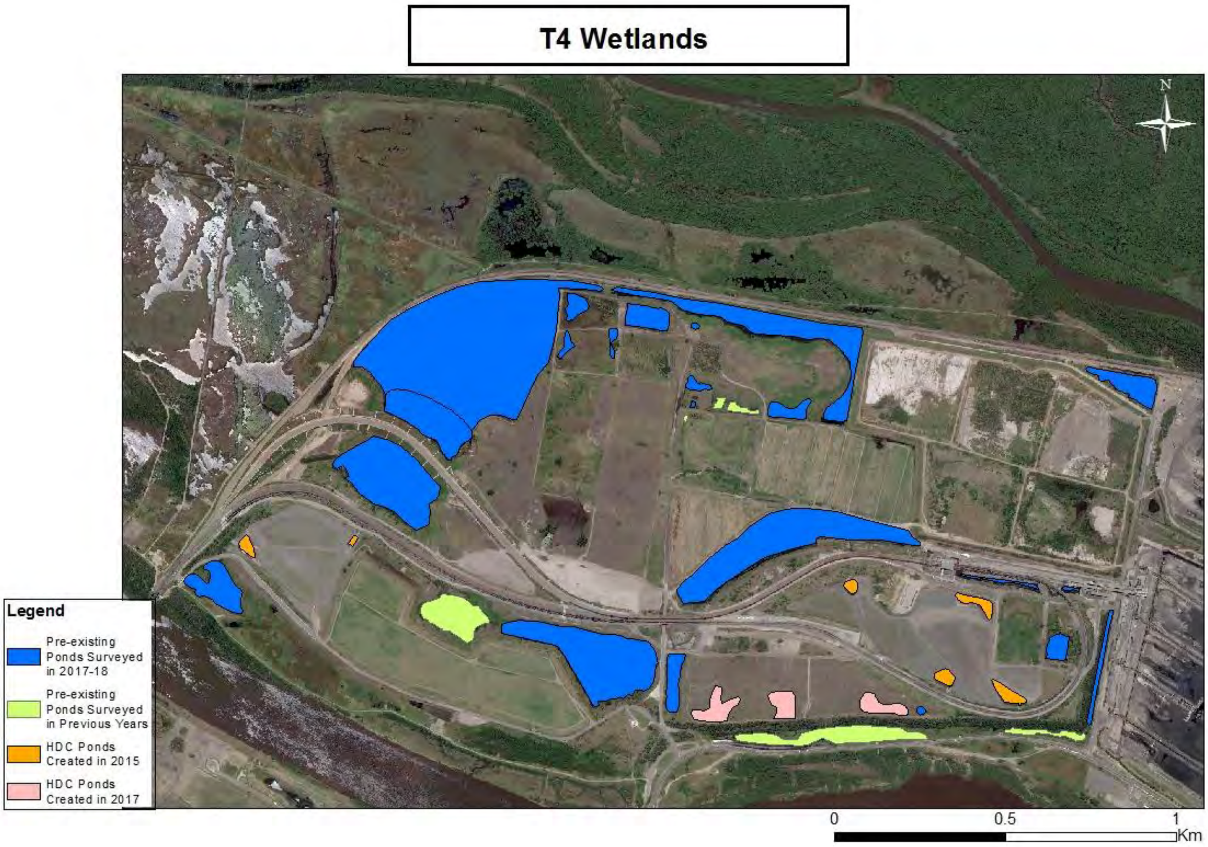

Figure 2-2: T4 wetlands surveyed by UoN as part of long-term research on the *Litoria aurea* population on the island. Top image shows extent of wetlands, group by current survey status and highlighting the nine wetlands constructed by HDC as part of the Phase 1 KIWEF closure works. 'Pre-existing' wetlands are those T4 wetland that were not created during those closure works.

loading facility, currently approved for construction by PWCS) is restricted to a footprint over the north-eastern part of this area (Figure 2-1), the entire site, including the KIWEF, has become commonly referred to as the 'T4 site' and we here use T4 in that context (Figure 2-1, 2-2). The T4 site is approximately 3.2 km^2, with the KIWEF occupying 2 km^2.

The T4 site has a long and varied history. Large parts were used to receive industrial waste, with the Newcastle BHP steel works a major source of that waste (EPA approved Industrial Waste Facility). The repeated rectangular grid structure that can be seen in aerial photographs are the remnants of waste 'cells' that were constructed to receive that waste; the walls of the cells were constructed from rubble to a height of several meters (usually between 4 and 6 metres), and these cells were then filled with the waste. Many, but not all, cells were filled during this phase of the site's use; some of the unfilled cells collected water and subsequently became important wetlands with respect to occupancy by *L. aurea* (e.g. K29, K106, K108) (Figure 2-3).

By the time that T4 ceased being used as a waste disposal site it included numerous wetlands; some on the natural substrate of the floodplain, others that are old industrial works that have become waterlogged, and a few that were constructed explicitly to act as artificial wetlands. As of March 2018, UoN (University of Newcastle) has documented 43 wetlands on T4 that are permanently or intermittently occupied by *L. aurea* (Table 2-1).

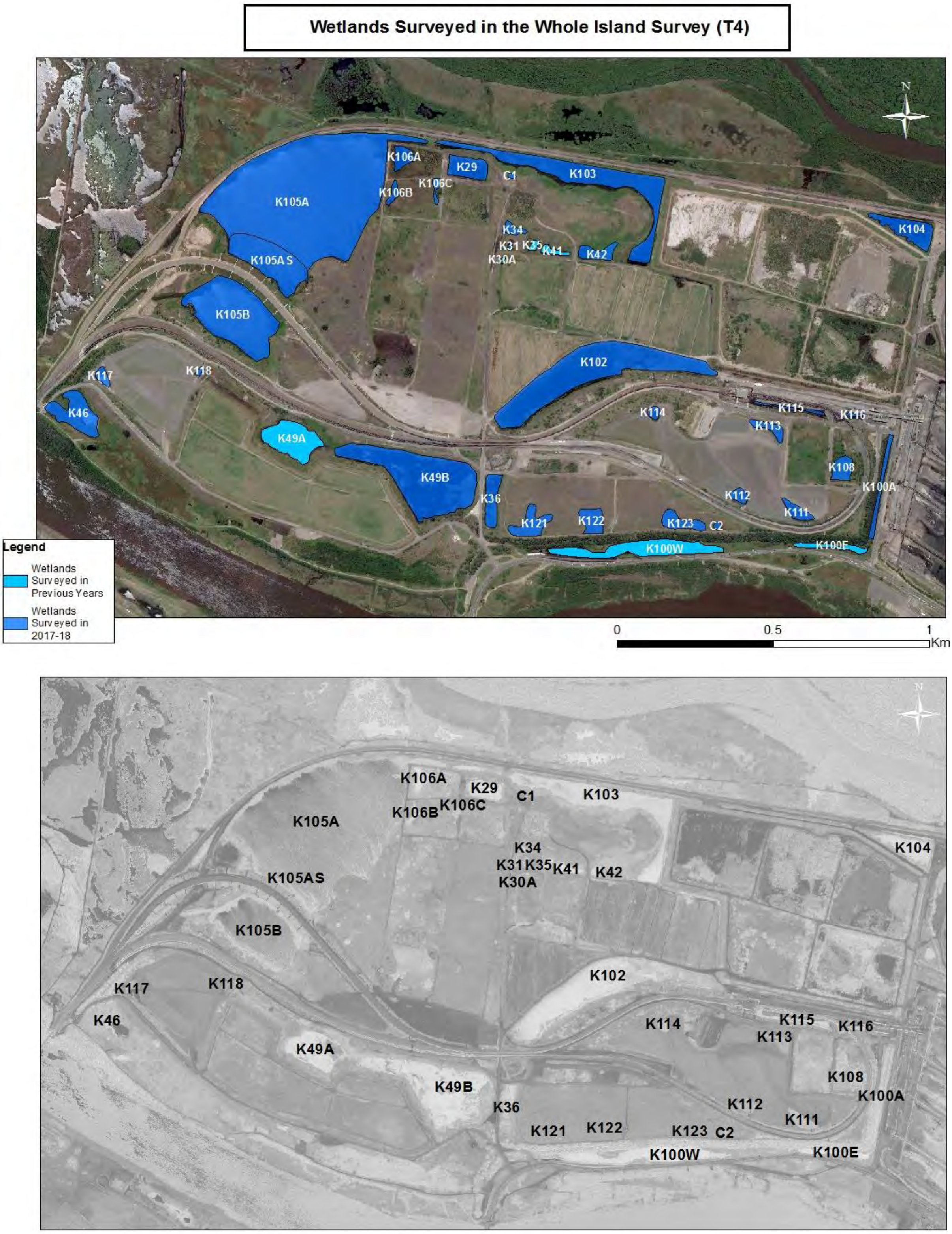

Figure 2-3: UoN wetland numbering system. See Appendix A for high resolution versions of these maps.

UoN #	UoN subregion	KIWEF subregion	Other names	HDC Area	comments
C1	Northern edge	K7	PWCS trial ponds (north)		cluster pond
C2	rail south	K10 South	PWCS trial ponds (south)		cluster pond
K29	Northern edge	K6	Pond 11		holds large numbers of *L. aurea*
K30	Northern edge	K7	K7 ponds		'K30' complex
K30A	Northern edge	K7	K7 ponds		'K30' complex
K31	Northern edge	K7	K7 ponds		'K30' complex
K32	Northern edge	K7	K7 ponds		'K30' complex
K33	Northern edge	K7	K7 ponds		'K30' complex
K34	Northern edge	K7	K7 ponds		'K30' complex
K35	Northern edge	K7	K7 ponds		'K30' complex
K36	South-central	K10	Easement pond south		
K41	Northern edge	K7	K7 ponds		'K30' complex
K42	Northern edge	K7	K7 ponds		'K30' complex
K44	South-west corner	K2	K2 basin		
K46	South-west corner	K2	K2 basin		
K47	South-west corner	K2	K2 basin		
K49A	South-central	K4	Blue-billed duck pond		
K49B	South-central	K4	BHP Wetlands		
K100A	Eastern edge		Windmill Rd channel		
K100E	Southern edge		Long pond		
K100W	Southern edge		Long pond		
K102	South-central		Easement pond		
K103	Northern edge	K7	Railway pond		
K104	North-east corner		Delta pond		holds large numbers of *L. aurea*
K104A	North-east corner				next to rail line, floods in heavy rain
K105A	North-west corner	K4	Deep pond north		
K105AS	North-west corner	K4	Deep pond north		southern edge of K105A
K105B	North-west corner	K4	Deep pond south		
K106A	Northern edge	K6	Pond 12		
K106B	Northern edge	K6	Pond 10		
K106C	Northern edge	K6	Pond 10		
K108	rail-loop	K10 North	Eastern ponds		was permanent, now dry
K111	rail-loop	K10 North	K10N-SB03	1	HDC constructed 2015
K112	rail-loop	K10 North	K10N-SB01	1	HDC constructed 2015
K113	rail-loop	K10 North	K10N-SB02	1	HDC constructed 2015
K114	rail-loop	K10 North	K10N-SB04	1	HDC constructed 2015
K115	rail-loop				NCIG operational pond
K116	rail-loop				NCIG operational pond
K117	South-west corner	K2	K2-SB02	1	HDC constructed 2015
K118	South-west corner	K2	K2-SB01	1	HDC constructed 2015
K121	rail south	K10 South	K10S-SB01	3	HDC constructed 2017
K122	rail south	K10 South	K10S-SB02	3	HDC constructed 2017
K123	rail south	K10 South	K10S-SB03	3	HDC constructed 2017

Table 2-1: UoN wetland numbering system, related to KIWEF designates, HDC Areas, and previous/alternative names.

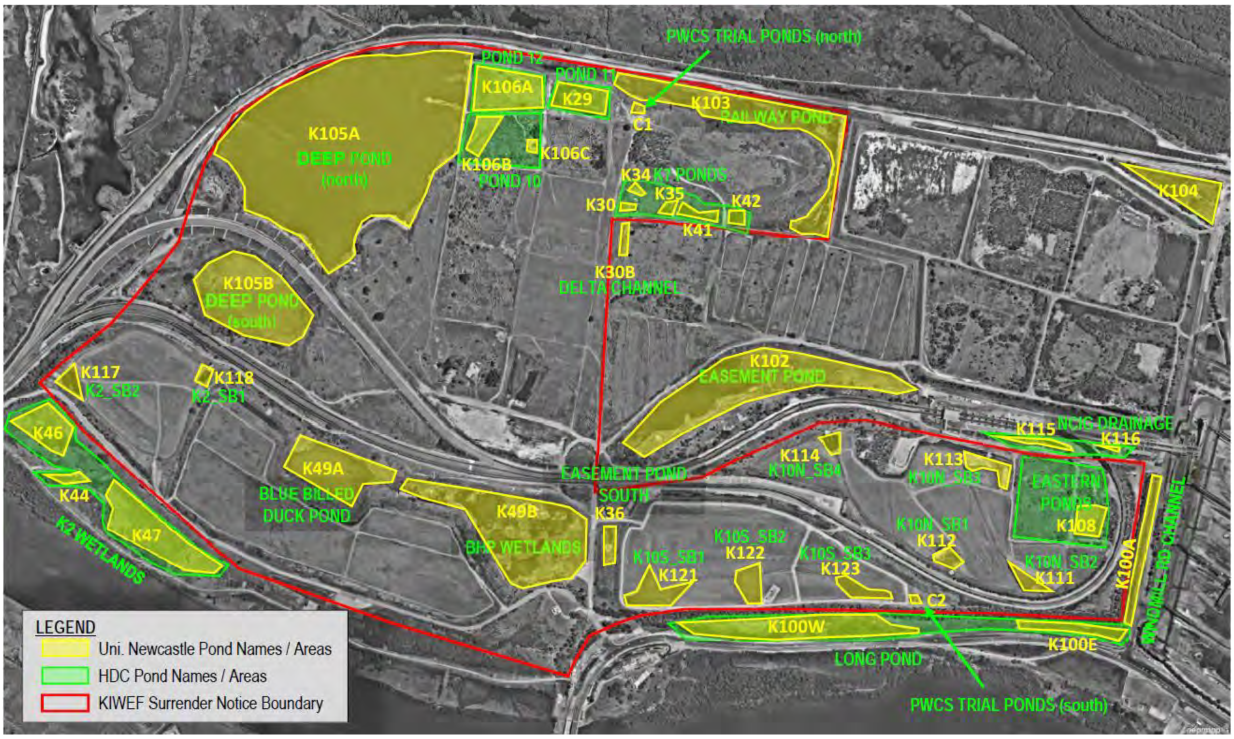

Figure 2-4: HDC and UoN reference systems for wetlands on T4 site. See also Table 2-1.

A subset of these wetlands (29 in 2017/18) are surveyed as part of the annual Kooragang Island *L. aurea* research program, jointly undertaken by key stakeholders in the area, including Hunter Development Corporation (HDC), Newcastle Coal Infrastructure Group (NCIG) and PWCS. PWCS are responsible for a large number of wetlands in the northern and central part of T4. In the south west, HDC is the agent of the State responsible for several wetlands following the change of ownership following the departure of BHP. NCIG actively manage two settlement ponds at the northern edge of the rail loop that contains K10 North (Figures 2-1, 2-2, 2-3, 2-4, 2-5). RMS are responsible for two of the wetlands that lie between the site fence and Cormorant Rd, and NCIG for the wetland that sits between Windmill Rd and the site.

The Area 1 and 3 closure works, which form the footprint for the Phase 1 closure works, are the subject of the current report. In 2015, this resulted in the remediation closure of K10 North and K2 (Figure 2-1) and the subsequent construction of six new wetlands (four within the rail loop and two in the south-west corner)(Area 1). In 2017, K10 South (also referred to as Area 3), south-west of the rail loop, was closed with a further three wetlands created.

Broad spatial patterns of *L. aurea* occupancy within the T4 site can be described by grouping wetlands into three broad regions: northern, central, and southern. K105B and K102 are here designated as comprising a 'central' region, with ponds north and south of these being designated 'northern' and 'southern' respectively.

A more detailed view of spatial variation can be gained by using the history and connectivity of the wetlands within the T4 site to aggregate the waterbodies into eight subregions. These subregions are shown in Figure 2-5 and listed in Table 2-2 (see also Table 2-1). Note that the the 'SW corner' subregions contain the Area 1 and Area 3 closure works which are the focus of this report.

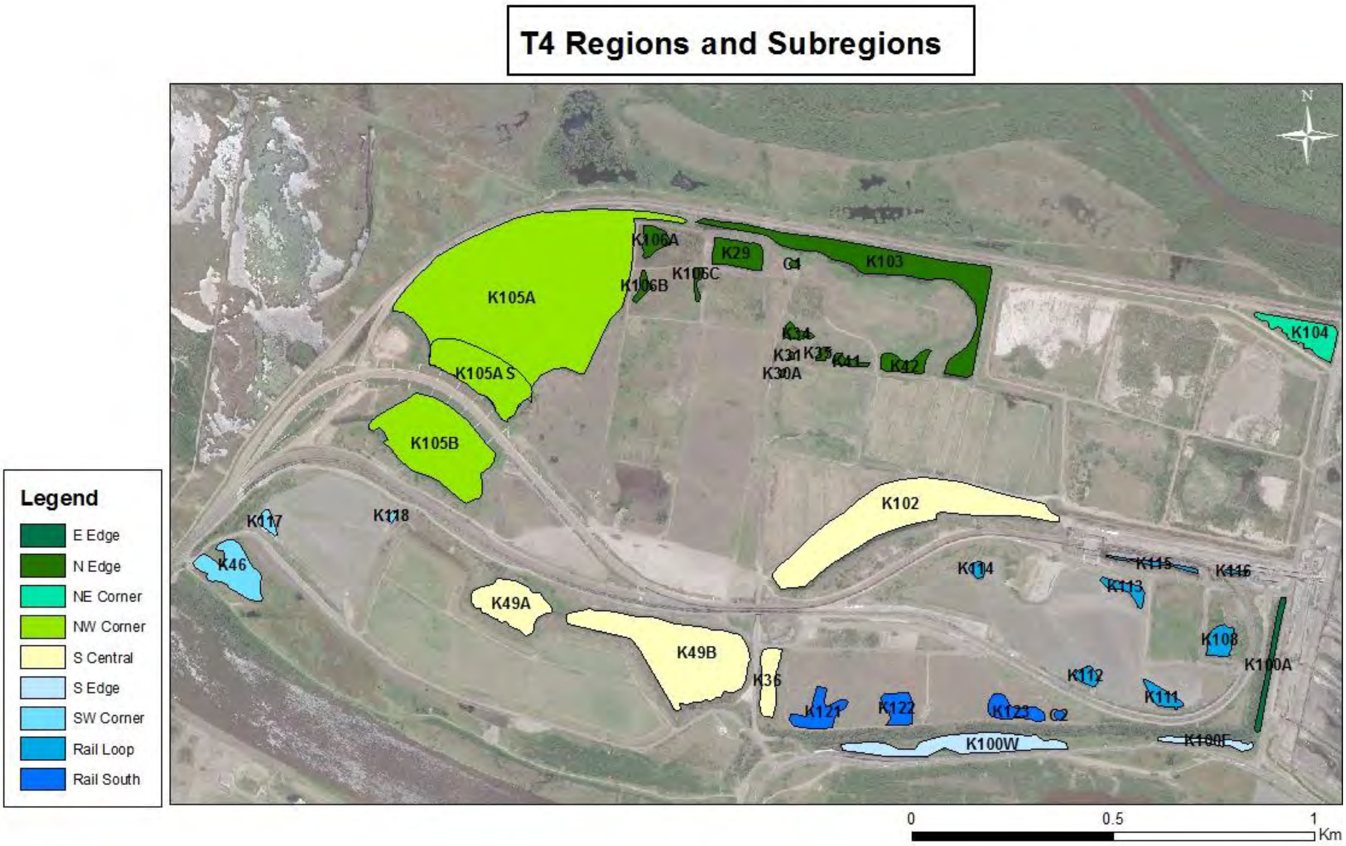

Figure 2-5: Regions and sub-regions of waterbodies within the T4 site used to analyse *L. aurea* occupancy. See Appendix A.

Subregion	Wetlands included	Comments
NE corner	K104	Large, permanent
Northern edge	K29, C1, K103, K106, K30 complex	A mosaic of large permanent, small permanent, and ephemeral wetlands all within 750 m of each other
NW corner	K105A, K105B	A large permanent and a large semi-permanent wetland. Was a single wetland prior to construction of NCIG rail line
South-central	K102, K36, K49A, K49B	A series of large wetlands which have existed for some time. The smallest, K36, is a deep, permanent wetland; the others are semi-permanent
Eastern edge	K100A	A single narrow, well vegetated, permanent wetland between Windmill Road and the T4 site fence
Southern edge	K100E, K100W	Very long, narrow wetland between Comorant Rd and T4 site fence
Rail loop (includes K10N, i.e. the eastern part of Area 1)	K108, K111-4, K115-6	Includes a single large, older wetland (K108), a pair of operational industrial wetlands (K115-6), and four of the wetlands constructed by HDC in 2015 (K111-114).
Rail south (K10S) (Area 3)	C2, K121-3	The three wetlands constructed by HDC in 2017 (K121-123), and the southern 'cluster ponds' constructed by PWCS prior to 2014 (C2).
SW corner (includes K2, I.e. the western part of Area 1)	K44-47, K117-8	Includes three older wetlands (of which K46 is still monitored), and the two wetlands constructed by HDC during closure of the K2 section in 2015 (K117-1118)

Table 2-2: Descriptions and included wetlands of subregions used to analyse *L. aurea* occupancy in this report

3. Methodology

The Conservation Biology Research Group (University of Newcastle) has investigated the *Litoria aurea* population across Kooragang Island, including wetlands on the T4 site. The purpose of this research is to quantify long-term population dynamics across different wetlands on Kooragang, so that the spatial-temporal fluctuations in this significant population can be identified relative to the various land development activities. That information provides an important baseline for conservation management of the species on Kooragang Island. At the same time, the research includes longitudinal studies on marked individuals, which provides fine-scale data on growth, survivorship, and movement across the island, and other relevant data such as breeding activity. The temporal replication and spatial coverage of these surveys exceeds the requirements of the *EPBC Act 1999* guidelines for *L. aurea*.

Wetland surveys are conducted between October and March each year, the time when the activity of *L. aurea* is at its highest. At least two rounds of surveys are conducted each season. Surveys comprise two types:

1. Visual Encounter Surveys (VES): these encompass the majority of surveys and each year are conducted at more than 70% of the wetlands on T4. They require a standardised, non-overlapping visual survey for *L. aurea*, conducted by experienced personnel. In most cases, detected frogs are captured for measurement of demographic traits (size class, sex, etc), but population counts include all detected frogs, whether captured or not.

2. Capture-Mark-Recapture (CMR) surveys: these are intensive surveys at a sub-set of the wetlands and provide an estimate of absolute population size at those wetlands. Combined with the VES this approach enables a robust total population estimate. Those estimates in turn act as a baseline for estimating the size of the bell frog population across Kooragang Island. Within the T4 site, two ponds are the focus of CMR surveys each season: in the last four years, CMR surveys have been conducted at K29 (every year), K108 (2014-15), and K104 (2015-18).

Demographic data (age-class, size, sex, reproductive status) is collected from all captured frogs. This demographic data provides useful information on population turn-over, and also indicates successful breeding via recruitment.

Note that the data analysed here does not include any assessment of the prevalence of the chytrid fungus (*Batrachochytrium dendrobatidis*) in the T4 *L. aurea* population. Infection by chytrid is known to be a key threatening process for *L. aurea*, but fungal loads must be assessed during colder months, which lie outside the scope of the summer field data analysed here.

The data analysed for this report was drawn directly from the annual reports of this ongoing research (Campbell et al. 2015, McHenry et al. 2016, McHenry et al. 2017, McHenry et al. (in prep.)

4. Patterns of wetland occupancy, hydrology, and breeding by *L. aurea*

4.1 Bell frog occupancy

In 2014-15, prior to the construction of the nine wetlands during the Phase 1 closure works (in Areas 1 and 3), the highest densities of *Litoria aurea* (as measured by detection probability) were found in the wetlands in the northern part of the T4 site, particularly K29 and K104 (Table 4-1).

Since the completion of the Area 1 closure works in 2015, detection probability of *L. aurea* has increased across the southern part of T4 (Table 4-1). Occupancy of the south-central, eastern edge, rail-south, and south-west corners has increased from very low levels in 2014-15, a trend which has continued with the completion of the Area 3 works in 2017. These trends can be attributed to increases in the amount of wetland habitat, and improvements in wetland connectivity, across the southern part of T4 as a direct result of the closure works (see detailed discussion of these in sections 4.2 and 4.3 below). Within the rail loop, the construction of four new wetlands resulting from the completion of the Area 1 closure works has apparently offset the drying of a pre-existing wetlands, K108 (which has dried out as a result of factors that are not currently understood).

Detection probablity	2014-15	2015-16	2016-17	2017-18
T4 north	0.36	0.22	0.64	0.14
T4 central	0.00	0.02	0.35	0.17
T4 south	0.05	0.04	0.79	0.11
NE cnr	0.48	0.42	0.57	0.18
N edge	0.39	0.04	0.64	0.13
NW cnr	0.04	0.10	0.71	0.18
S central	0.02	0.01	0.33	0.09
E edge	0.00	0.02	0.98	0.11
rail loop	0.27	0.08	1.65	0.13
rail south	0.00	0.00	0.39	0.10
SW cnr	0.00	0.00	0.12	0.12

Table 4-1: Probability of detection (a measure of density: frogs detected/search effort) of *L. aurea* during Visual Encounter Surveys. The density of *L. aurea* detected in the northern part of T4 is always high, although the detection probability in the southern part has increased across the last four summer seasons.

Because the extent of wetlands in the northern part of T4 is large, the total numbers of *L. aurea* in that part of T4 is high (Table 4-2). Nevertheless, a clear trend is that the proportion of *L. aurea* detected in the southern part of the site has steadily increased each year. In 2014-15, K108 held good numbers but other wetlands across the southern half had very low numbers. Overall, approximately 10% of *L. aurea* detected in VES across the

T4 site were in the southern regions. This proportion has increased to 16% in 2015-16, then to 40% in 2016-17, and 39% in 2017-18.

Search effort	2014-15	2015-16	2016-17	2017-18
T4 north	417	845	1244	2670
T4 central	34	53	116	569
T4 south	363	847	696	2698
NE cnr	87	391	426	629
N edge	274	405	767	1628
NW cnr	56	49	123	781
S central	141	196	174	606
E edge	45	49	56	344
rail loop	59	418	251	948
rail south	6	40	41	463
SW cnr	25	94	140	538

Detected in VES	2014-15	2015-16	2016-17	2017-18
T4 north	151	186	796	385
T4 central	0	1	41	99
T4 south	19	36	552	308
NE cnr	42	165	242	115
N edge	107	16	493	216
NW cnr	2	5	87	141
S central	3	2	58	54
E edge	0	1	55	39
rail loop	16	34	415	119
rail south	0	0	16	46
SW cnr	0	0	17	62

Table 4-2: Search effort for VES (person.minutes) and absolute numbers detected during VES across the wetlands at the T4 site for the last four summer seasons.

Both detection probability (Table 4-1) and absolute numbers detected (Table 4-2) display this trend of increasing *L. aurea* occupancy of the southern part of T4 since the 2014-15 summer season. At a finer spatial scale, both metrics also indicate that *L. aurea* are becoming more evenly distributed across the subregions. In 2014-15, the population was concentrated along the northern edge, the NE corner, and within the rail loop. By 2017-18, densities of *L. aurea* have become much more even across all the subregions (Table 4-1).

Data for the total number of detections (VES and CMR surveys) is shown in Figure 4-1 and reflects the Detected VES numbers. K29 and K104 still have the highest numbers (despite an increase at K29 in 2015-16). These maps show that, although *L. aurea* has not been detected at K108 for the last two years, they have been detected in the created wetlands at Area 1 (K111-114) within the Phase 1 closure footprint. The addition of HDC wetlands in the SW corner (K117-118) has also led to increased numbers in that subregion. In the rail-south subregion a similar trend has been observed since the construction of HDC Area 3 wetlands K121-123.

Note that the data presented here do not constitute absolute population estimates. Absolute estimates of population numbers are made on the basis of search effort, numbers detected, and mark-recapture studies, using robust modelling techniques. That analysis lies outside the scope of this report; instead, our focus is upon the relative distribution of *L. aurea* in different sub-regions of the T4 site within and between years. Thus, for example, the question of whether the number of *L. aurea* in T4 was higher in 2016-17 compared with 2017-18 can only be addressed once the robust modelling for the 2017-18 has been completed.

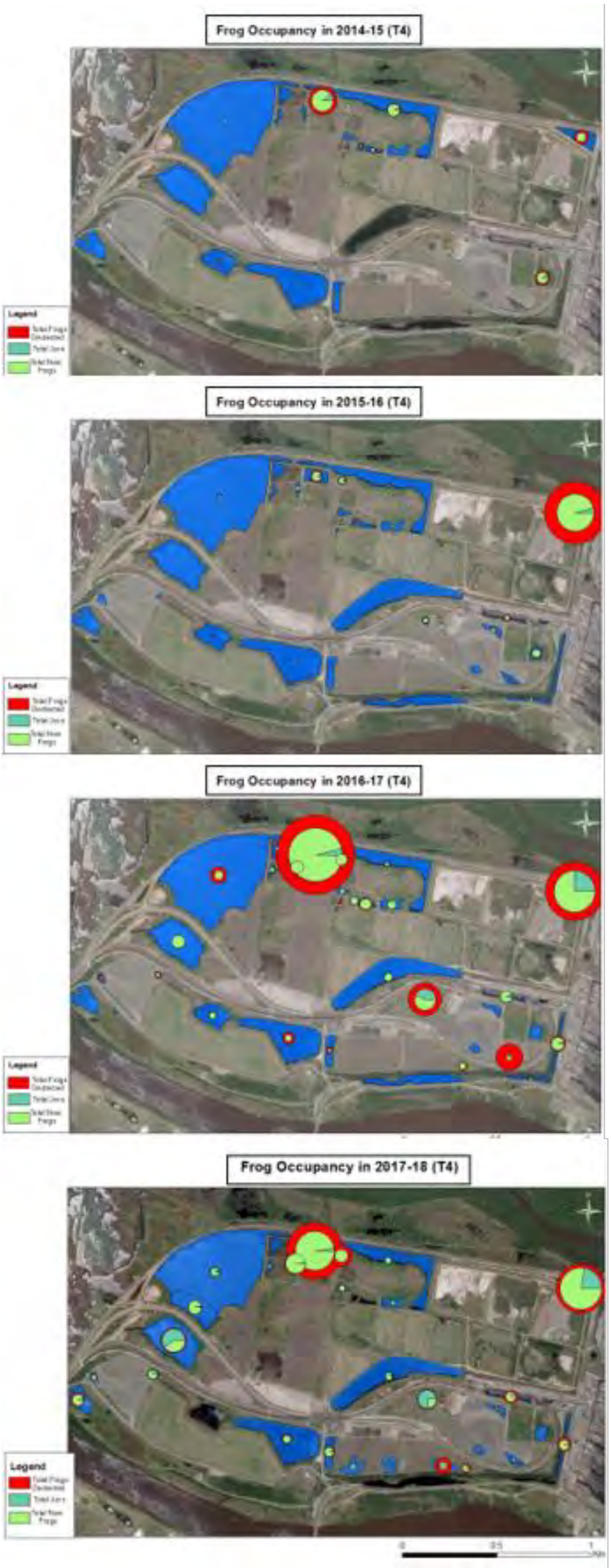

Figure 4-1: Bell frog (*Litoria aurea*) occupancy across the last four summer seasons, shown for each wetland surveyed. Data shows total detections (i.e. VES and CMR data combined). Red circles show total detections. Green inserts show total individuals with snout-vent length (SVL) > 40 mm (i.e. large juveniles and adults), while blue inserts show small juveniles (SVL < 40 mm) that are too small to tag.

High resolution versions of these figures are presented in Appendix C.

4.2 Wetland hydroperiod, occupancy, and breeding:

Across Kooragang Island, *Litoria aurea* adults typically inhabit permanent wetlands through the active season (late spring-summer), and heavy summer rains are the precursor of dispersal to breed in ephemeral areas (Goldingay & Newell, 2005; Hamer, Lane & Mahony, 2008). The species has been observed to spawn in both ephemeral and permanent ponds (Hamer et al; 2002) on Kooragang Island, and similar observations have been made in other populations (Courtice and Grigg, 1975; Goldingay & Newell, 2005). A mosaic of accessible wetlands with varying hydroperiods is thus considered an important requirement for the persistence of *L. aurea* populations.

The contrast in rainfall totals and occurrence over the last three summer seasons has provided important insight into the hydroperiod of the wetlands in the T4 site. High levels of rainfall in January 2016 resulted in widespread flooding and charging of the water table. All wetlands surveyed held water at this time, enabling identification of a number of temporary wetlands, several of which were used by *L .aurea* for breeding (K106A, K106B, K112, K113). This was followed by a relatively dry year in 2016-17, where many of the semi-permanent wetlands dried, but water remained in the permanent and deeper semi-permanent wetlands. The summer season of 2017-18 was exceptionally dry and all the semi-permanent wetlands dried, leaving only a small number of wetlands that can be classed as retaining water even within a drought.

Wetland hydroperiods across the T4 site are illustrated by the pattern of drying during the 2017-18 season (Figure 4-2). Low amounts of winter rainfall meant that water levels were low in many wetlands at the start of the summer, and none of the temporary wetlands (K106A, K106B, K112, K113) held water. By mid-summer (January 2018) several semi-permanent wetlands (K46, K121) had also dried. By the end of the summer (late February 2018) all the semi-permanent and some of the permanent wetlands had dried, including several that had held water through the 2016-17 dry year. This included wetlands which have often held the greatest densities of *L. aurea* (K29, K104). By the end of February 2018, water levels in K105A and K103 were low. Only the artificial cluster ponds (C1, C2), the NCIG operational ponds (K115-116), the K36 and K100A wetlands, the HDC wetlands on the K2 part of Area 1 (K117-118), and one of the new wetlands in Area 3 (K123) retained deep water. The region received heavy rain toward the end of February 2018 (54mm in one day and a total of 104mm for the month), followed by heavy rain at the end of March 2018 (122mm in one day and a monthly total of 169mm) (BOM, 2018), recharged the system (except for K108), with some water sitting even in the most shallow ephemeral wetlands (K106A, K106B).

Wetlands within the T4 site can be categorised according to the amount of time that they retain water (hydroperiod). A course-grained categorisation assigns wetlands on T4 to one of three categories (Table 4-3A, Figure 4-3A), but it is possible to use a finer-grained category system (Table 4-3B, Figure 4-3B). At present, we don't know whether the course-grained or fine-grained system provides the best insight into to *L. aurea* occupancy.

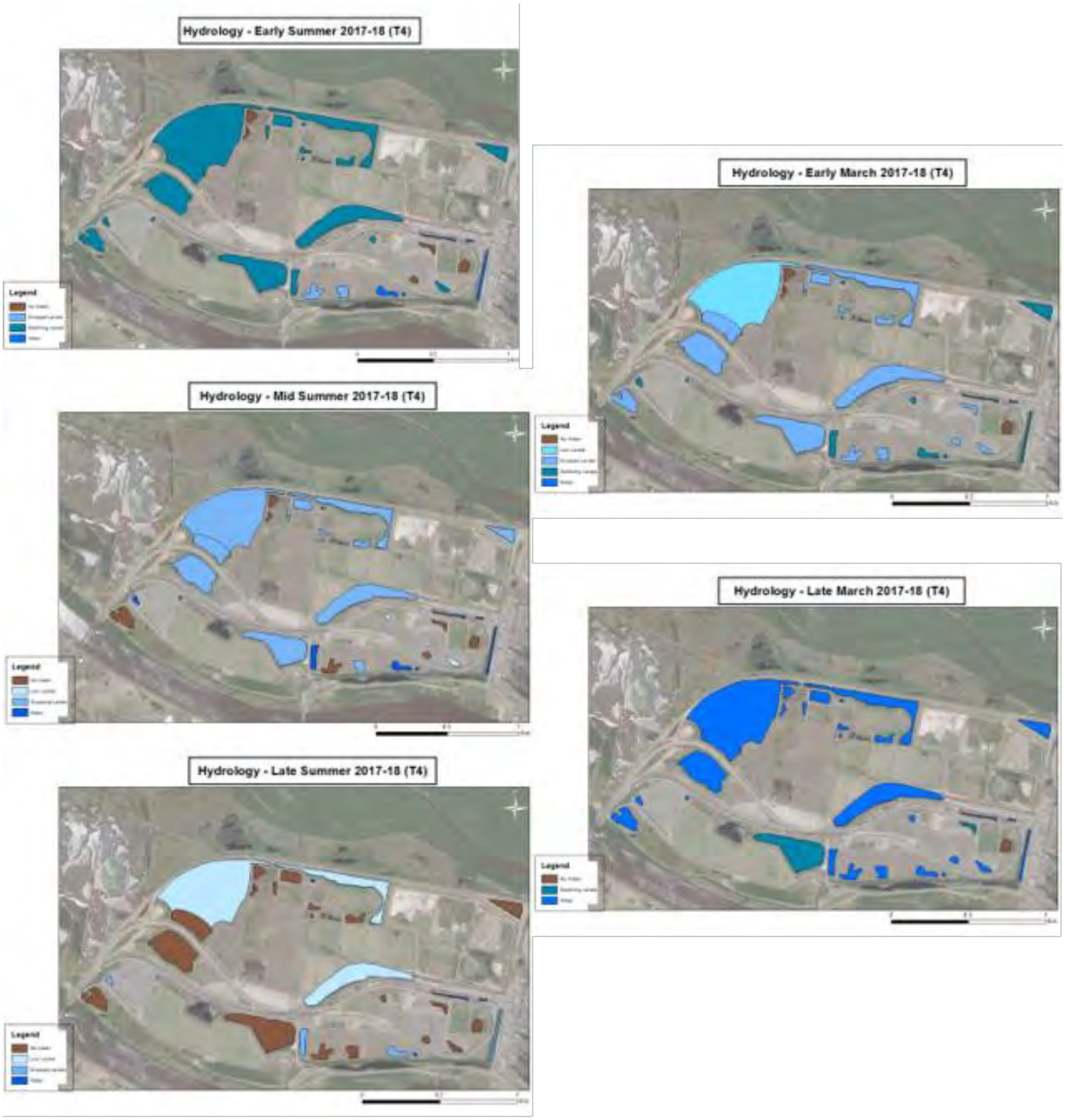

Figure 4-2: Water levels in T4 wetlands over the course of the 2017-18 summer season. High resolution versions of these maps are presented in Appendix B.

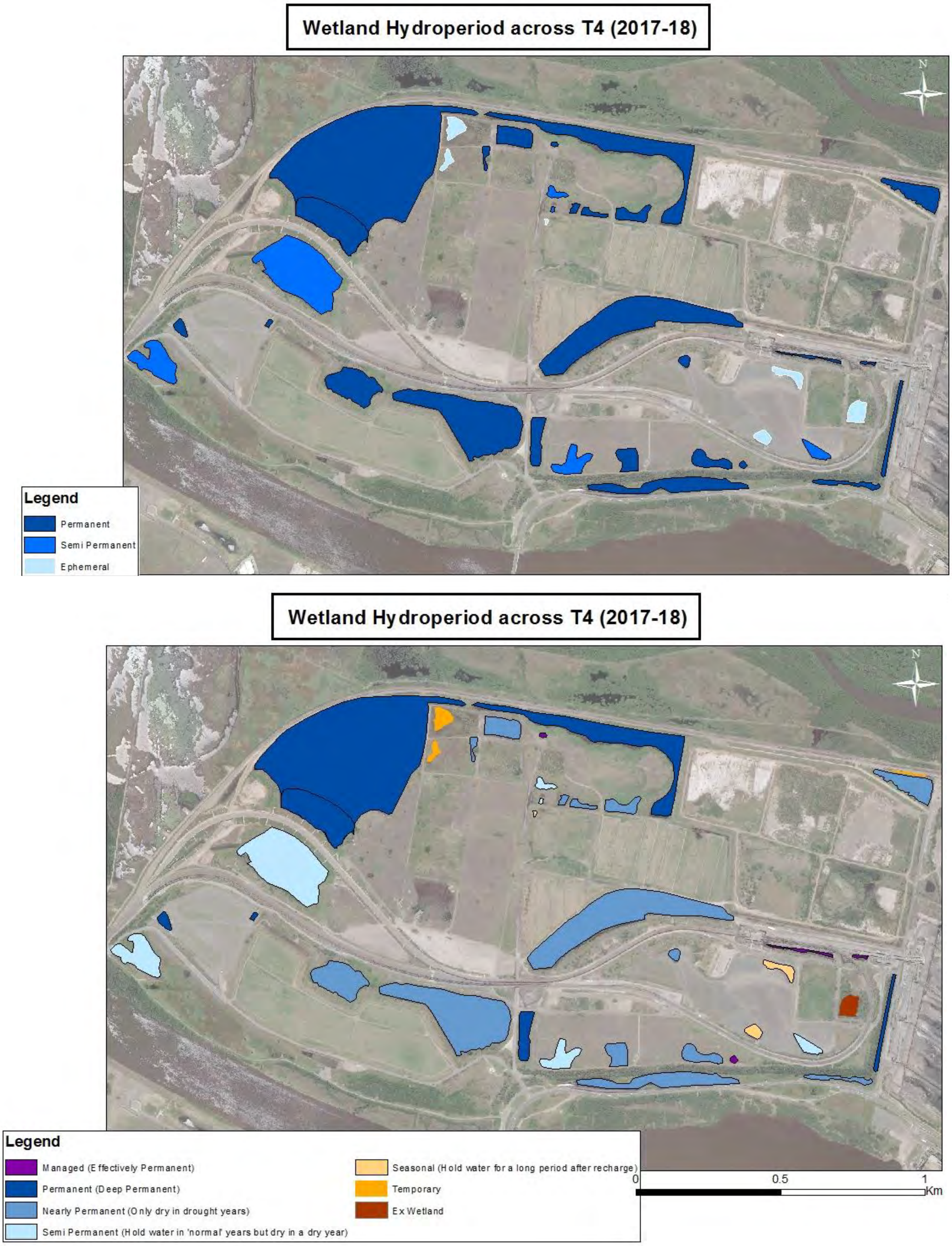

Figure 4-3: Wetland hydroperiod; **(A)** visualised by course-grained (above) and **(B)** fine-grained (below) categories. Hydroperiod is understood to be an important factor in *L. aurea* occupancy and breeding. See text for discussion.

Category	Notes
Permanent	Hold water throughout the year in all but drought
Semi-permanent	Hold water throughout the year in normal conditions
Ephemeral	Hold water only for a period after rainfall events

Table 4-3A: Coarse-grained categorisation of wetland hydroperiod (see Figure 4-3A). The hydroperiod terminology used in the text follows this system.

Category	Notes
Managed (effectively permanent)	Artificial/operational ponds whose water levels can be regulated by deliberate removal or addition of water.
Deep Permanent	Deep wetlands that always hold water
Nearly permanent	Hold water year around, except in drought (e.g. 2017-18)
Semi-permanent	Hold water year around in normal years but not in dry years (e.g. 2016-17)
Ephemeral (seasonal)	Hold water for long periods after rain
Ephemeral (temporary)	Hold water for short periods after rain
Ex-wetland	Wetlands that have previously held water but no longer do so, even after significant rainfall (K108)

Table 4-3B: Wetland hydroperiod on T4, sorted into fine-grained categories (see Figure 4-3B)

A total of nine waterbodies were created within the Phase 1 closure footprint (Areas 1 and 3). Using the 'course-grained' categories (Figure 4-3A, Table 4-3A), five of these are permanent, two are semi-permanent, and two are ephemeral.

Hydroperiod variability across the T4 site appears to be important for maintaining *L. aurea* densities. The northern subregion, which holds the greatest density of *L. aurea*, is a mix of artificial permanent (C1), large permanent (K29, K103), small permanent (K106C, K34-35, K41-42), and small (K30-K33) and large ephemeral wetlands (K106A, K106B). Elsewhere, the large permanent wetlands in the NE and NW corners (K104, K105A, K105B) also have high densities of *L. aurea*. The Area 1 closure works within the rail loop have created a mix of small permanent, small to medium semi-permanent, and ephemeral wetlands. Since 2015 the drying of K108 (which has not been a consequence of the closure works) removed the only large permanent wetland within the rail loop, but this loss of habitat appears to have been offset by the construction of the four wetlands (K111-114) as part of the Area 1 closure, and *L. aurea* occupancy within the rail loop in has remained. The south-central sub-region contains mostly large, permanent wetlands, but lacks ephemeral wetlands; occupancy of these wetlands has historically been at low densities but have increased slightly in the last two seasons (Table 4-1). The rail-south subregion (Area 3) contains a mix of permanent and large semi-permanent wetlands, whist the SW corner contains one large semi-permanent and two small permanent wetlands; in the last two seasons occupancy of these two subregions has increased from very low densities, following construction of wetlands by HDC in Area 1 and Area 3.

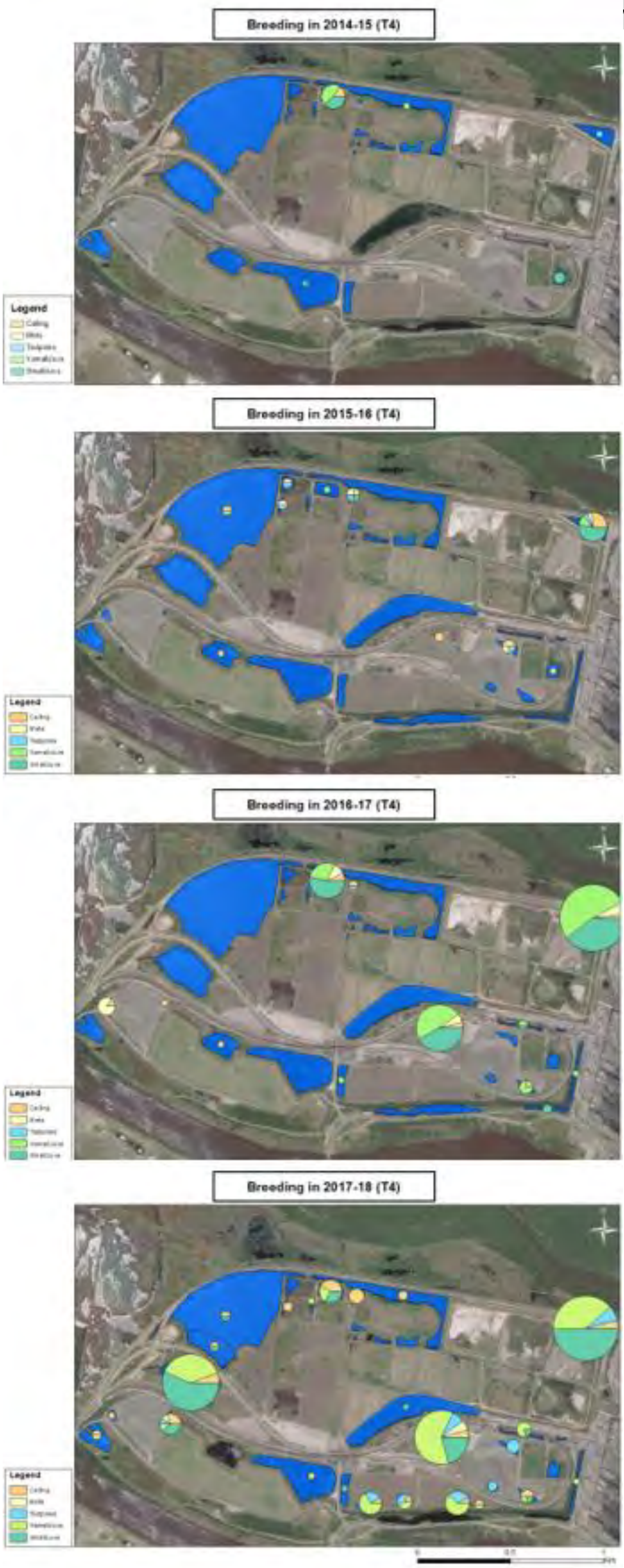

Figure 4-4: Evidence of breeding by *L. aurea* across T4 over the last 4 years. See text for explanation of categories of observed breeding behaviours. High resolution versions of these figures are provided in Appendix D.

Breeding

Hydroperiod variability in a wetland mosaic may improve local population persistence by providing both over-wintering habitat (permanent wetlands) and breeding habitat (often ephemeral wetlands). Observations of wetlands where *L. aurea* tadpole density is highest across Kooragang Island are generally associated with ephemerality (Beranek, pers comm., 2018; Callen, pers comm., 2015).

Evidence for breeding is provided by:

- Calling males
- Tadpoles
- Metamorphs
- Very small (<35 mm SVL) juvenile frogs
- Small (<40 mm SVL) juvenile frogs

Some of these, such as the presence of tadpoles or metamorphs, provide stronger evidence for breeding at a particular wetland than others. The presence of calling males shows an intention to breed but does not demonstrate success. Juvenile frogs are capable of moving between wetlands, although the presence of large numbers of very small juveniles strongly implies a cohort of recruits that have recently metamorphosed. Note that the presence of gravid adult females is required for breeding, but gravid females are able to retain eggs for some time and their presence at a wetland does not necessarily indicate that breeding is imminent.

In 2014-15, evidence of breeding was restricted to a small number of wetlands (K29, K103, and K104) (Figure 4-4). Across the southern T4 wetlands, the presence of small juvenile frogs in K108 and K49B were the only evidence for breeding. Successful breeding in the new HDC wetlands within the rail loop (K113 and K114) (K10 North part of Area 1) occurred in 2015-16. In 2016-17 breeding was detected in HDC rail loop wetlands again (K111 and K114), and in the HDC wetlands in the SW corner (K117-118) (K2 part of Area 1).

In the 2017-18 season, breeding was detected in all of the HDC Area 1 wetlands (K111-K114, K117-118), and in the new Area 3 wetlands (K121-123). As a result, a high proportion of breeding was detected in the southern part of the T4 site (Figure 4-4).

4.3 Wetland connectivity

Occupancy of waterbodies on Kooragang Island has been previously reported as aggregated (Hamer et al; 2002), and as such proximity and connectivity are important considerations in the distribution of the species. Habitat suitability for juvenile dispersal is not well understood, with observations of temporary occurrence around natal ponds (Van De Mortel & Goldingay, 1998) and dispersal over long distances away from these wetlands at the same time scale (Goldingay & Lewis, 1999; Goldingay & Newell, 2005).

The construction of the nine new wetlands in Area 1 and Area 3 has considerably improved connectivity between wetlands in the southern half of T4. Specifically:

- The four wetlands (K111-K114) constructed in the rail loop (K10 North part of Area 1) have improved connectivity between pre-existing wetlands around the edge of the rail loop (K100A, K100W, K100E, K115, K116, K102, C2). Indeed, *Litoria aurea* occupancy of the C2 cluster ponds was only detected following construction of these four new wetlands (Figure 4-4). Previously, these ponds were isolated from other wetlands. They are identical in construction to cluster ponds in the north-west section of T4 that have shown a continuous occupancy by GGBF over five seasons. The only difference in these cluster ponds is proximity to other wetlands, which was the aim of the experiment that led to the construction of these artificial pond habitats.

- The two wetlands (K117, K118) constructed in the south-west corner (K2 part of Area 1) have improved connectivity between the pre-existing wetlands in that sub-region (e.g. K46) and the north-west corner and south-central subregions. *Litoria aurea* occupancy in K46, has increased since the construction of those Area 1 wetlands (Figure 4-4).

- The three wetlands (K121-123) constructed in the rail-south subregion (K10 South, Area 3) have improved connectivity between the rail loop and the wetlands to the west (K36, K49B) and the wetlands along the south edge (K100W).

4.4 Wetlands occupied by *Gambusia*

Gambusia holbrooki is an invasive predatory fish which now has an extensive distribution across eastern Australia. Originally introduced to NSW in the 1920s to reduce mosquito numbers (hence its common name, mosquitofish), *Gambusia* predates small native fish and tadpoles, and is believed to have a negative impact on *L. aurea* populations (Hamer *et al.* 2002). Wetlands that lack *Gambusia*, or where it is present at low densities, are thought to be important for successful breeding by *L. aurea* (Hamer *et al.* 2002), and the elimination of *Gambusia* from drying ephemeral wetlands is one of the factors that links *L. aurea* breeding with wetland hydroperiod.

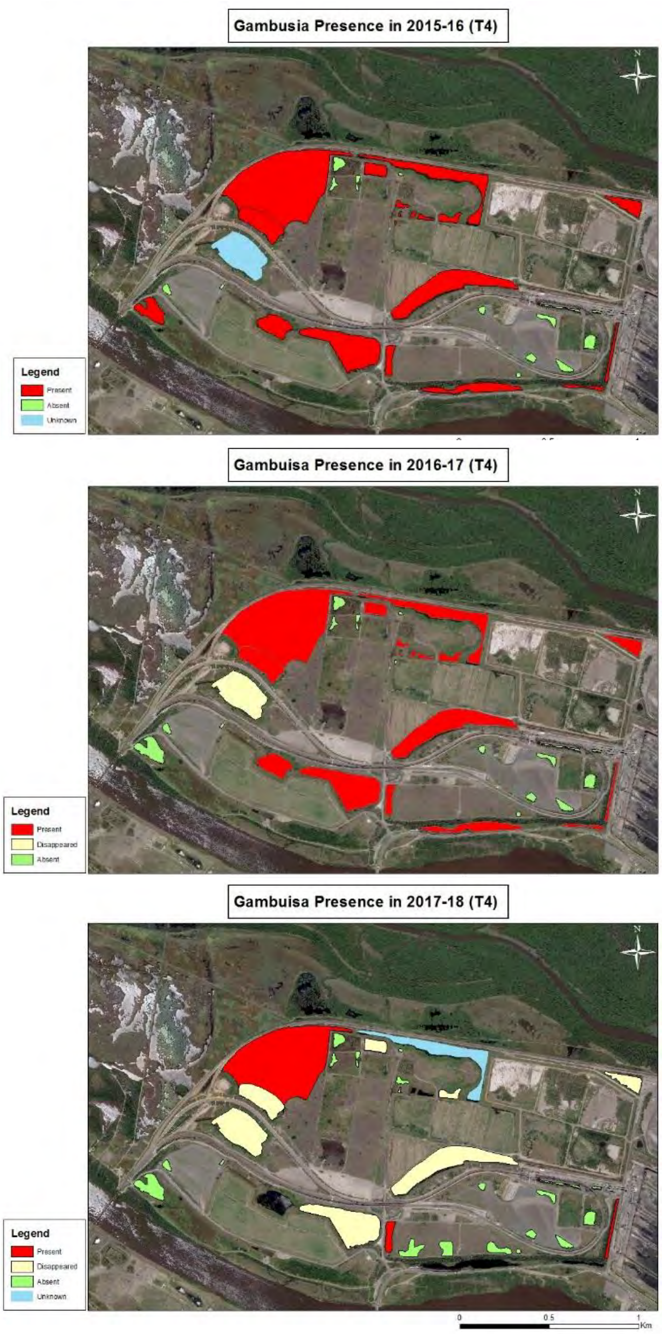

Figure 4-5; *Gambusia* distribution across T4 wetlands for the last three summer seasons. Wetlands are scored according to whether *Gambusia* was present throughout the season, was absent throughout the season, or was present at the start but disappeared during the season. High resolution versions of these maps are provided in Appendix E.

Localised flooding of the Hunter River in 2015 and 2016 facilitated *Gambusia* dispersal across most wetlands on Kooragang Island, and by the end of the 2015-16 summer season only a small number of wetlands were free of *Gambusia*. These included the K106 wetlands (two of which are ephemeral), the two artificial cluster ponds (C1 and C2), and the 6 newly constructed HDC wetlands in Area 1 (K111-114, K117-118) (Phase 1). Within T4, most (four out of five) of the observed breeding events were at those wetlands that lacked *Gambusia*.

Low rainfall in the summer season of 2016-17 led to several semi-permanent wetlands drying completely, and the subsequent elimination of *Gambusia*. In particular, *Gambusia* disappeared from K46 and K105B over the course of that summer season; by the early summer of 2017-18 each of these wetlands had large numbers of adults that were calling, and a large cohort of very small and small juveniles at both wetlands indicate successful breeding after the 2016-17 summer.

Very low levels of water in K104 by the end of the 2016-17 summer season reduced *Gambusia* levels to low densities; the presence of a large cohort of very small and small juveniles at the start of the 2017-18 summer season indicates that breeding occurred in this wetland and suggests that *L. aurea* recruitment can occur in low densities of *Gambusia*.

The drought in the 2017-18 summer season further reduced water levels, eliminating *Gambusia* from many of the wetlands across the T4 site. When the system recharged with the March 2018 rains, *Gambusia* persisted in only a small number of wetlands; K100A, K36, K105A and (probably) K103. The fish were apparently eliminated from all other wetlands, including K104 and K29.

The relationship between *L. aurea* breeding and *Gambusia* can be visualised by counts of wetlands with tadpoles and/or metamorphs observed, and comparing those counts between wetlands where *Gambusia* is present with those where *Gambusia* is absent (Table 4-4, Figure 4-6). No more than 5% of wetlands containing *Gambusia* have *L. aurea* tadpoles or metamorphs. In contrast, at least 25% of wetlands without *Gambusia* have tadpoles or metamorphs recorded.

	Total ponds with	***Gambusia* present**	***Gambusia* absent**
2015-16	tads/mets	1	4
	no tads/mets	19	10
2016-17	tads/mets	1	3
	no tads/mets	17	9
2017-18	tads/mets	0	7
	no tads/mets	3	12

Table 4-4: Pattern of *L. aurea* tadpoles / metamorphs in wetlands with *Gambusia*, vs. wetlands without *Gambusia*

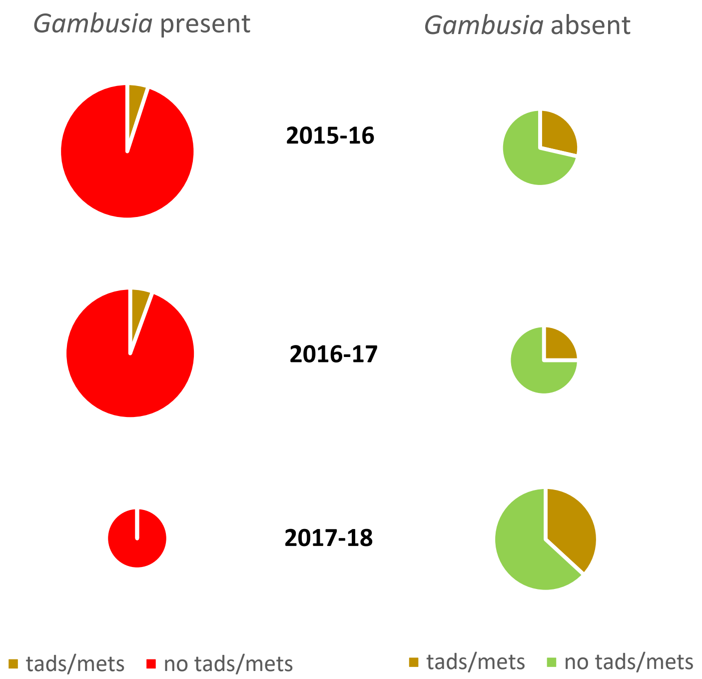

Figure 4-7: The data presented in Table 4-4, visualised graphically. See text for discussion.

5. Conclusion: impacts and benefits of Phase 1 closure works

5.1 Benefits

The long-term research data indicates that the HDC Phase 1 closure works have improved potential population persistence for *L. aurea* by providing suitable habitat area, hydroperiod variability, connectivity and *Gambusia* free wetlands (through elevation and surface hydrology alteration). These elements of habitat have led to increased breeding across T4, and increased *L. aurea* densities in the southern half of the T4 site.

The Terminal 4 site contains the highest numbers of bell frogs on Kooragang Island. Overall GGBF numbers are higher in the northern part of the site, but over the last four years the proportion of frogs detected across the southern part of the site has increased, and the distribution of the frogs has become more even (Table 5-1). Over that same time, breeding behaviour has increased across the southern part of T4. We view all of the trends as being positive for the status of the bell frog population on T4. Furthermore, the observations provide strong evidence of the success of the wetland habitat creation that has occurred in the Phase 1 capping and remediation.

Detected all	2014-15	2015-16	2016-17	2017-18
T4 north	**273**	**883**	**2377**	**1502**
T4 central	**0**	**1**	**55**	**152**
T4 south	**53**	**52**	**568**	**383**
NE cnr	**42**	**824**	**727**	**516**
N edge	**229**	**54**	**1589**	**924**
NW cnr	**2**	**5**	**99**	**202**
S central	**8**	**3**	**73**	**57**
E edge	**0**	**1**	**55**	**41**
rail loop	**45**	**47**	**418**	**139**
rail south	**0**	**0**	**16**	**83**
SW cnr	**0**	**0**	**17**	**75**

Breeding	2014-15	2015-16	2016-17	2017-18
T4 north	11	19	19	31
T4 central	0	0	0	7
T4 south	2	8	20	82
NE cnr	3	5	7	12
N edge	8	12	12	15
NW cnr	0	2	0	10
S central	1	1	3	3
E edge	0	0	2	2
rail loop	1	7	10	33
rail south	0	0	0	33
SW cnr	0	0	4	12

Table 5-1: Summary of GGBF detections (left) and observed breeding (right) across T4 wetlands for the last four seasons. Detections are simply the number of observations of juvenile and adult frogs (including animals that are too small to tag, recaptures of tagged animals, and animals that were seen but not captured). The score for Breeding is based upon observations of calling, tadpoles, metamorphs, very small juveniles, and small juveniles (see preceding section - observations of tadpoles and metamorphs are weighted most, followed by observations of very small juveniles, with calling and small juveniles weighted the least).

The Phase 1 closure works included capping and remediation which altered surface hydrology and created nine lined sediment basins disconnected from the groundwater system to prevent contamination. This has had the effect of creating wetlands with variable hydroperiods to create highly connected wetland mosaics that provide both overwintering habitat (permanent waterbodies) and breeding habitat (ephemeral waterbodies) in close proximity to one another to optimise population persistence. In addition to improved connectivity and hydroperiod variability, the elevation of these sediment basins has reduced the potential for *Gambusia* to invade and occupy wetlands via overland surface water flow during periods of high rainfall, improving *L. aurea* breeding potential by reducing predation risk by this introduced fish.

Of the nine constructed wetlands, six were occupied by *L. aurea* within a year of construction and the other three were occupied by their second year. Individuals have persisted in all of these wetlands following initial occupation whenever water is present. These wetlands, occur in the rail loop, rail south and south-west corner and their construction has coincided with increased numbers of *L.aurea* detected in these subregions. Densities have remained consistent within the rail loop, despite the drying of K108 (formerly a large permanent wetland) since 2015, and it is considered that the presence of the created wetlands (K111-114) has contributed to this consistency. Densities of *L. aurea* in the south-west corner and rail south areas have also increased following construction of HDC wetlands in these areas (2015 and 2017, respectively).

The constructed wetlands contain a mix of small to medium permanent, semi-permanent, and ephemeral wetlands. Ephemeral wetlands are considered to be important breeding habitat for GGBF, and large breeding events have been detected in these following heavy rains (e.g. K113 in 2015-16, 2017-18). Breeding has occurred in all wetlands created as part of the Phase 1 closure works, many within the first year of existence. However, small permanent and semi-permanent wetlands have also been observed to provide breeding habitat in drier years (e .g. K114 and K117 in 2016-17 and the first part of 2017-18), as well as in wetter years (K114 in 2015-16 and late 2017-18).

Connectivity across T4 has improved as a result of the location, size, and wetland type (hydroperiod) of the constructed HDC wetlands. The creation of the nine wetlands within the Phase 1 closure footprint has resulted in improved connectivity of all wetlands across the southern part of T4. This connectivity aids dispersal of *L. aurea* across the area and helps provide the habitat mosaic that appears to be necessary for large persistent populations of GGBF. Prior to the construction of the Area 1 wetlands, the rail loop subregion contained only one wetland (K108) that was occupied by *L. aurea*, in addition to the NCIG operational ponds. The construction of the HDC wetlands in this subregion in 2015 was followed by dispersal of bell frogs across the rail loop, with frogs detected in K111, K113, and K114 in 2015-16, and then to K112 in 2017-18. Adjacent to the rail loop, the 'rail south' region contained a set of small permanent artificial ponds (the "C2 cluster ponds") which appeared to provide suitable habitat. An almost identical set of artificial wetlands in the northern part of the site, the "C1 cluster ponds", have consistently held appreciable numbers of bell frogs since their construction, but prior to 2016 the C2 wetlands have not. The proximity of C1 to wetlands containing bell frogs (K29, K103, K34) led to those cluster ponds being colonised rapidly. Following the construction of the Area 1 wetlands within the rail loop, the C2 cluster ponds were also colonised by *L. aurea* during 2016 and now hold consistent numbers of animals.

Data from the SW corner indicates low numbers of GGBF in this subregion prior to the construction of the western Area 1 wetlands in 2015, despite the presence of the older wetlands K44, K46, and K47. *Litoria aurea* was detected in the newly constructed wetlands

K117 and K118 in late 2016. Subsequently, large numbers of *L. aurea* were detected in K46 in late 2017. In addition to the suitable habitat being provided by K117 and K118, these wetlands appear to have improved connectivity between K46 in the SW corner, and K105B and K49A to the north.

The wetlands created as sediment basins within the Phase 1 closure footprint are free from *Gambusia* and, due to their elevation, are most likely to remain so. Even when flood events (such as January 2016) connect many wetlands across Kooragang Island and thereby allow *Gambusia* to disperse widely, the HDC constructed wetlands are hyrologically isolated from other wetlands and have a very low probability of infestation by *Gambusia*. Access to suitable breeding habitat that is free from high densities of *Gambusia* is widely recognised as an important requirement for recruitment in *L. aurea* (Hamer *et al.* 2002).

Overall, the Phase 1 closure works have improved wetland connectivity across the southern part of T4, have increased the amount of suitable aquatic habitat for occupation by *L. aurea*, and have increased the mix of wetland types in the rail loop, rail south, and SW corner subregions. The nine new wetlands have provided a corridor of suitable habitat across the southern part of the T4 site, connecting established wetlands in the eastern, central, south-western, and north western parts that were previously much more isolated. This has coincided with an increase in densities of *L. aurea* in the southern area of the T4 site, as well as an increase in breeding events in that area. The sustained nature of these events in the southern section of T4 would suggest that the waterbodies created as a result of the Phase 1 closure works have improved *L. aurea* habitat in the south of the site and could be used as a suitable base model for future remediation works across the rest of the T4 site.

5.2 Impacts

There is no evidence of negative impacts upon the Kooragang Island *Litoria aurea* population as a result of the Phase 1 closure works.

Prior to 2015, UoN did not survey the Areas 1 and 3. Information presented as part of the works proposal (HDC response to SEWPaC, 2013) indicates that there were no wetlands in these areas prior to the closure works. As a result, disturbance to important *L. aurea* habitat was minimal. Recorded observations of *L. aurea* were fewer than five individual instances; these areas evidently held some of the lowest densities of *L. aurea* across the T4 site. The probability that the closure works negatively impacted the *L. aurea* population is considered to be low, and there is no data available that suggests any such impact. Any actual impact, even if undetected, must be considered to be more than offset by the measurable benefit of the Stage 1 closure works on the *L. aurea* population.

5.3 Habitat features currently not present in the Stage 1 works

A number of habitat elements remain missing from the Phase 1 closure footprint, mostly associated with the provision of aquatic and terrestrial vegetation to afford protection from predation and prevent desiccation. Although the absence of vegetation is evidently not an impediment for rapid dispersal to, and breeding in, new wetlands (e.g. K121-123 in 2017-18), the planting of low and shallow rooted native vegetation around the waterbodies as well as in terrestrial corridors to allow safe passage between sheltering and breeding wetlands is a cost-effective measure that may improve *L. aurea* survival between breeding seasons. Shallow rooted vegetation should not compromise capping remediation works within the closure footprint. Dispersal is at least partly dependent on connectivity of suitable habitat, and without it, migration and population spread is likely to be limited, as observed at Port Kembla when more than 200 marked individuals failed to disperse to adjacent suitable ponds that were separated by open ground (Goldingay & Newell, 2005).

Additionally, the provision of deep, permanent open wetlands with well vegetated areas improve *L. aurea* survival during very dry years and provide suitable over-wintering habitat for the species. These are conspicuously absent from the rail loop and the rail south sub-regions, especially with the drying of K108 within the rail loop. In the rail south area, permanence is provided by the C2 cluster ponds (comprising small swimming pools constructed on the surface and surrounding by earth mounds to facilitate access by *L. aurea*). This may prove an effective and innovative way of providing permanent wetland water for *L. aurea* without compromising the capping and remediation of future closure works where landfill contamination is an issue.

6. Summary

- The Stage 1 closure works by HDC in Areas 1 and 3 have led to the creation of nine constructed wetlands that provide a large amount of habitat suitable for the green and golden bell frog *Litoria aurea*.
- Prior to the closure works, no suitable wetland habitat existed in those Areas and recorded occupancy by *L. aurea* was low (HDC response to SEWPaC, 2013)
- These nine new wetlands have improved wetland connectivity across the southern part of the Terminal 4 site.
- Between them, the HDC constructed wetlands have a range of hydroperiods. That range, combined with the spatial connectivity of these wetlands, has resulted in an improved habitat mosaic for *L. aurea* in the southern part of T4.
- All of the new wetlands have been occupied by *L. aurea* within two summer seasons of construction. Six of the nine were occupied within a year of construction.
- Prior to 2015, a very high proportion of the *L. aurea* detected in T4 were located in the northern part of the site. Since the construction of the HDC wetlands, the distribution of *L. aurea* across T4 has become more even, and the numbers across the southern part of the site have increased. These patterns can be attributed with confidence to the increase in habitat area and connectivity resulting from the Stage 1 closure works.
- Breeding has occurred in all of the nine of the wetlands constructed during Phase 1. These represent a large proportion of wetlands in T4 that are known breeding locations for *L. aurea*. In 2017-18, tadpoles and metamorphs (the strongest evidence of breeding at a given wetland) were detected at eight wetlands across T4; seven of these were at HDC constructed wetlands in Areas 1 and 3.
- The elevation and construction method of the new wetlands has effectively hydrologically isolated each from the pre-existing wetlands on T4. This will strongly reduce the possibility of the HDC wetlands from becoming infested by the invasive mosquito-fish *Gambusia*. As *Gambusia* are known to reduce successful breeding of *L. aurea* (by predation upon tadpoles), this feature is likely an important factor in the rapid success of the new wetlands as breeding habitat for *L. aurea*. Furthermore, the elevation of these wetlands is likely to provide a *Gambusia*-free habitat even after large flood events (such as January 2016).
- The success of the HDC constructed wetlands in providing habitat for *L. aurea* may serve as a model for construction of new habitat for this species.

7. References

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Appendices

A. Maps showing wetland numbering systems across T4.

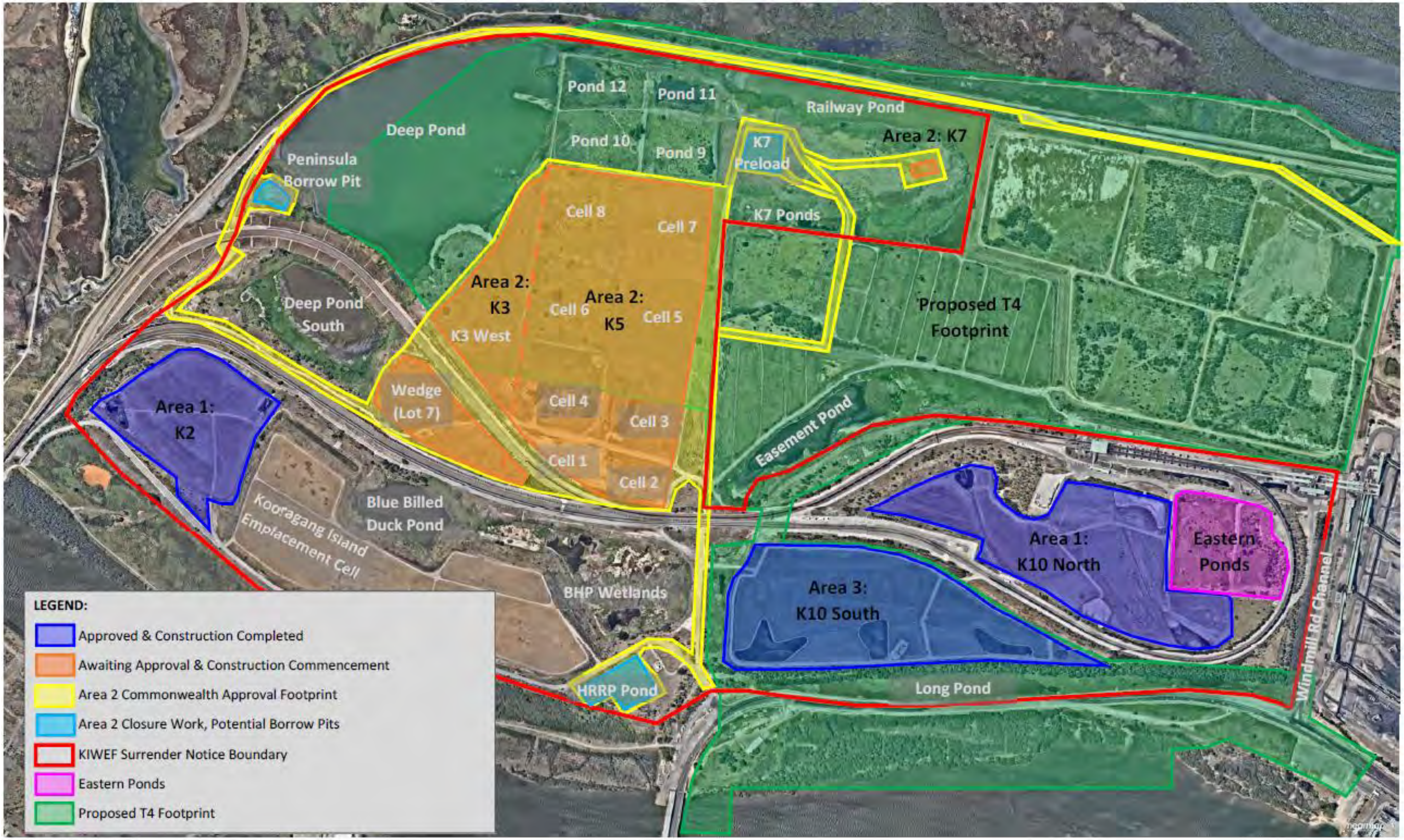
B. Maps showing state of water levels in T4 wetlands, 2017-18 summer season.

C. Maps showing occupancy of T4 wetlands by *L. aurea* for the four summer seasons 2014-2018.

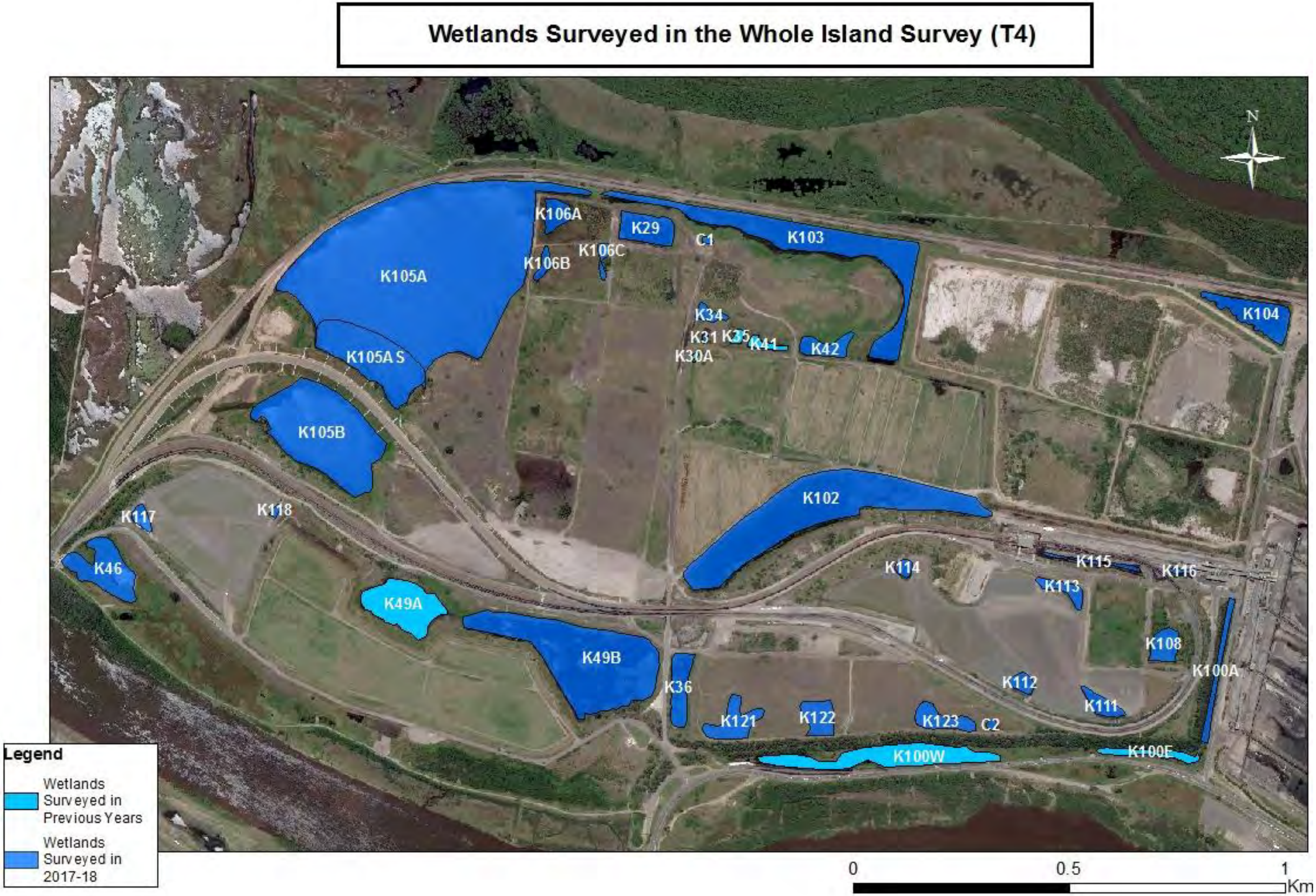
D. Maps showing recorded breeding by *L. aurea* across T4 wetlands for the four summer seasons 2014-2018.

E. Maps showing distribution of *Gambusia* across T4 wetlands from 2015-2018.

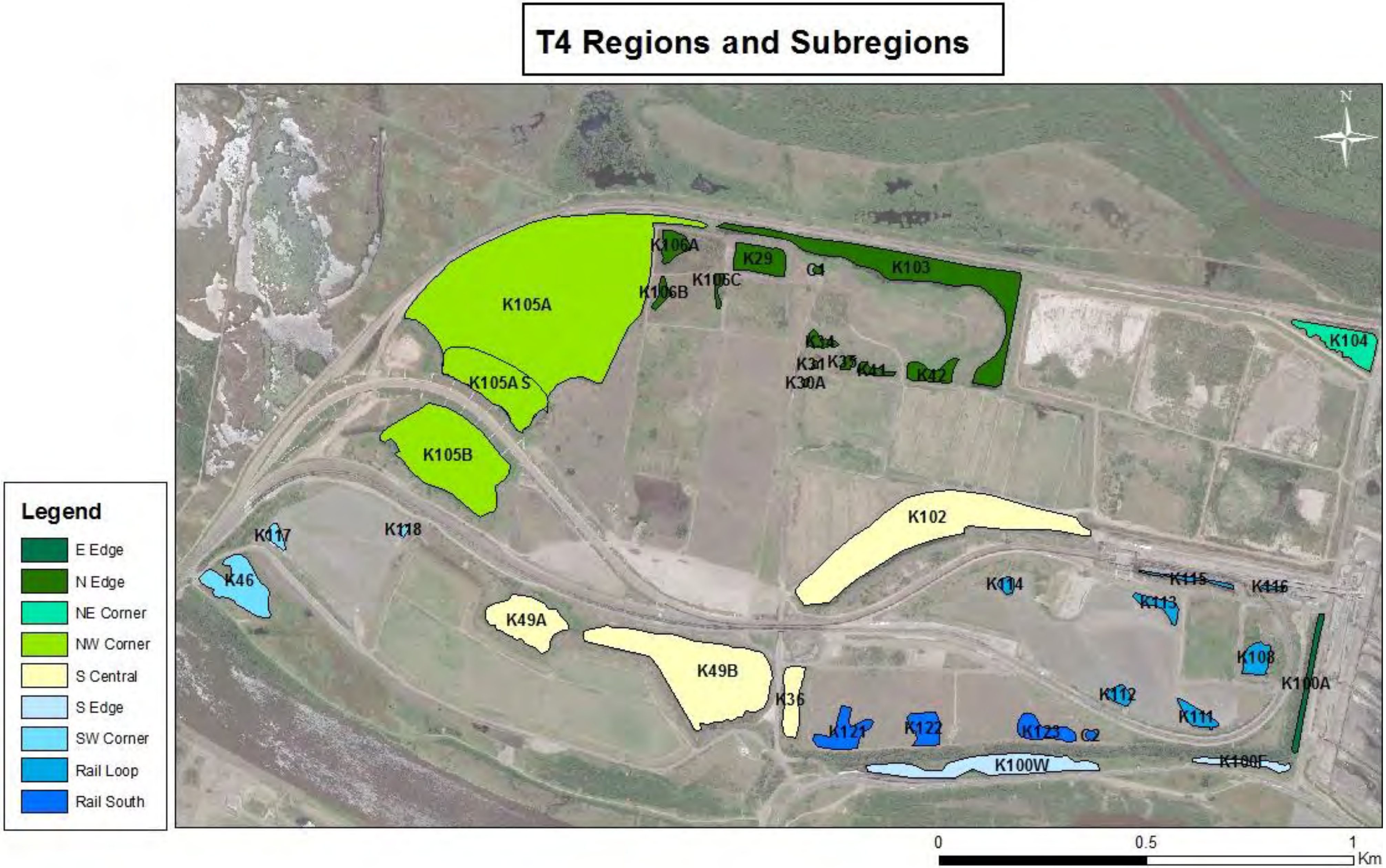
Appendix A: Wetland numbering system



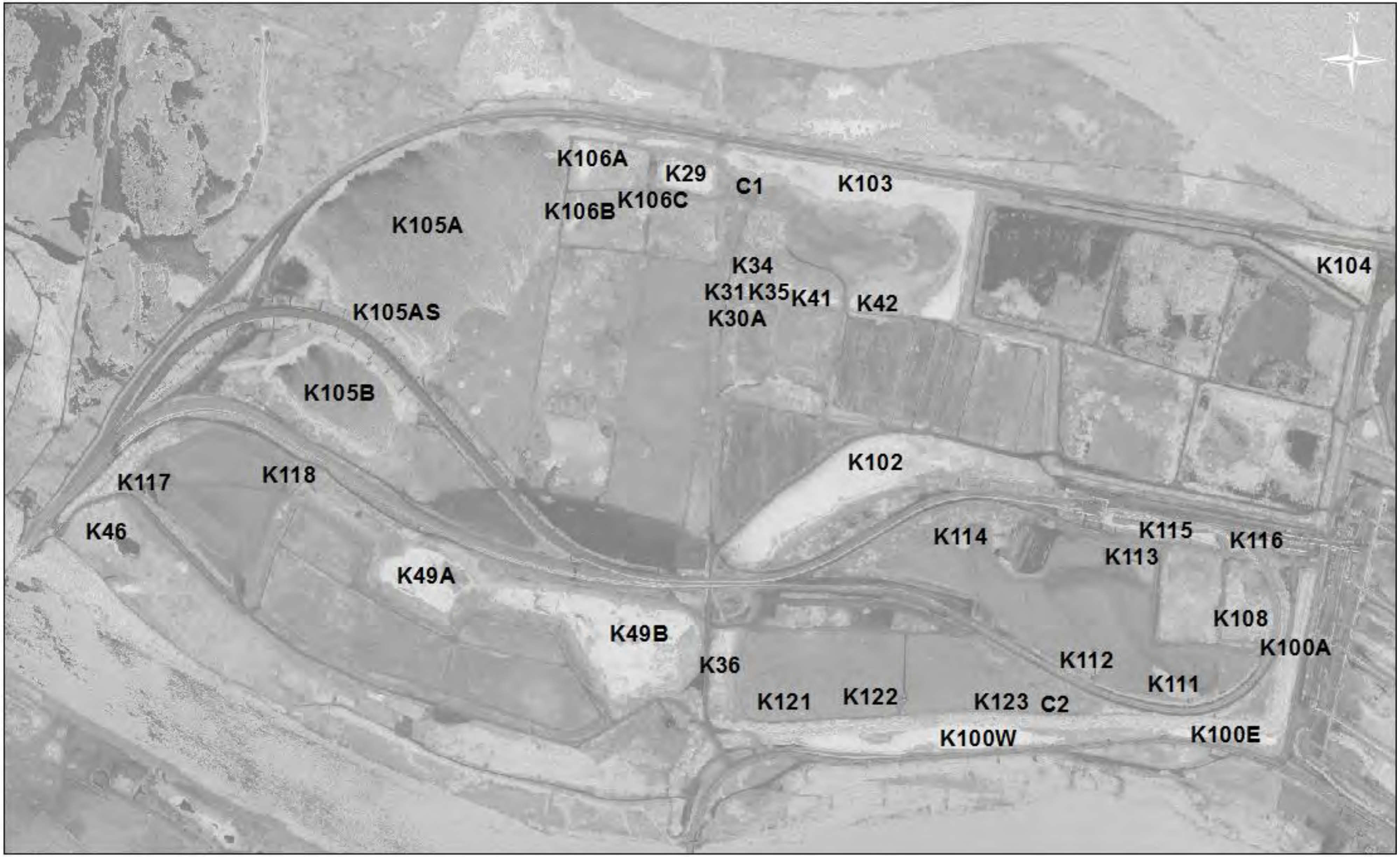
Appendix A: Wetland numbering system



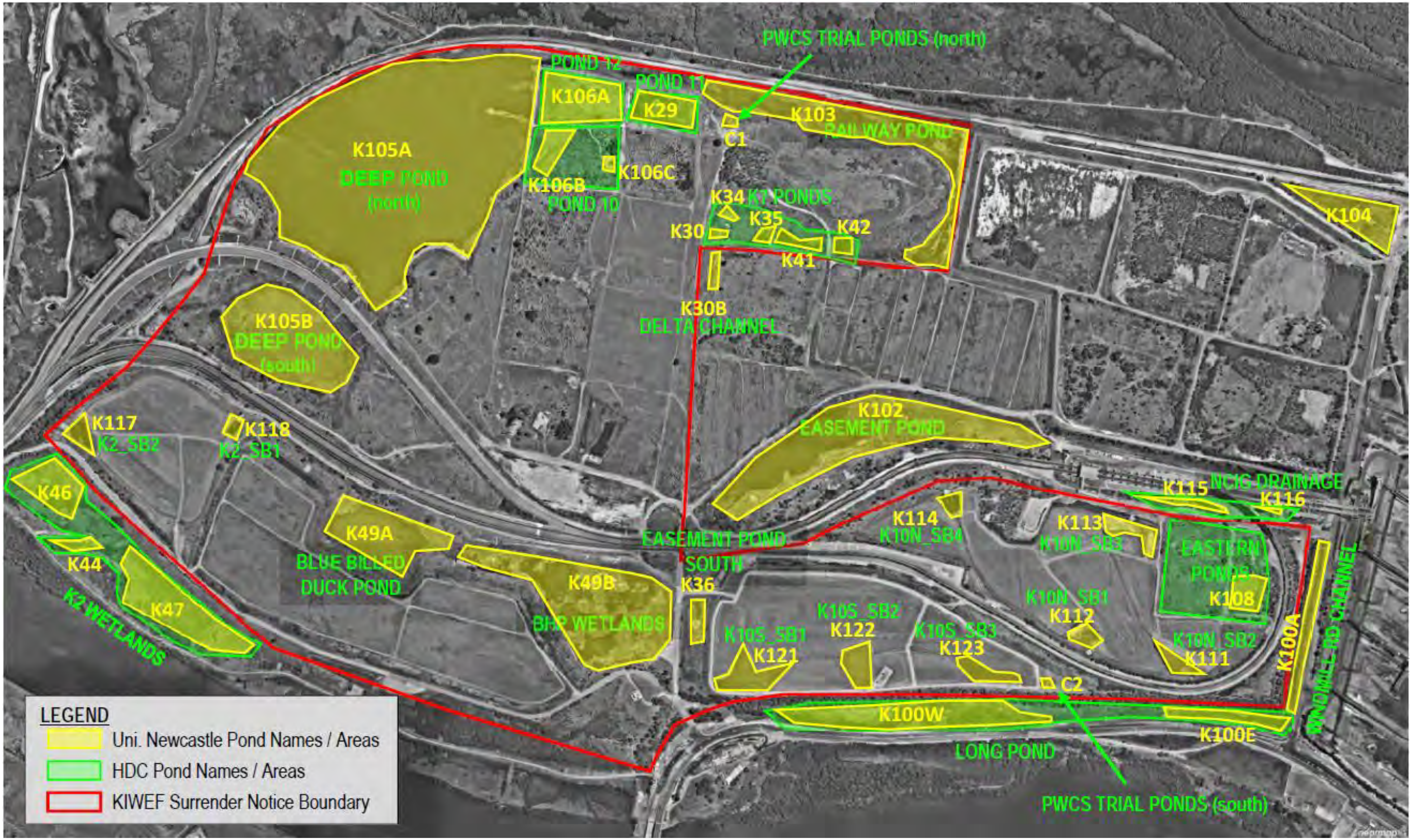
Appendix A: Wetland numbering system



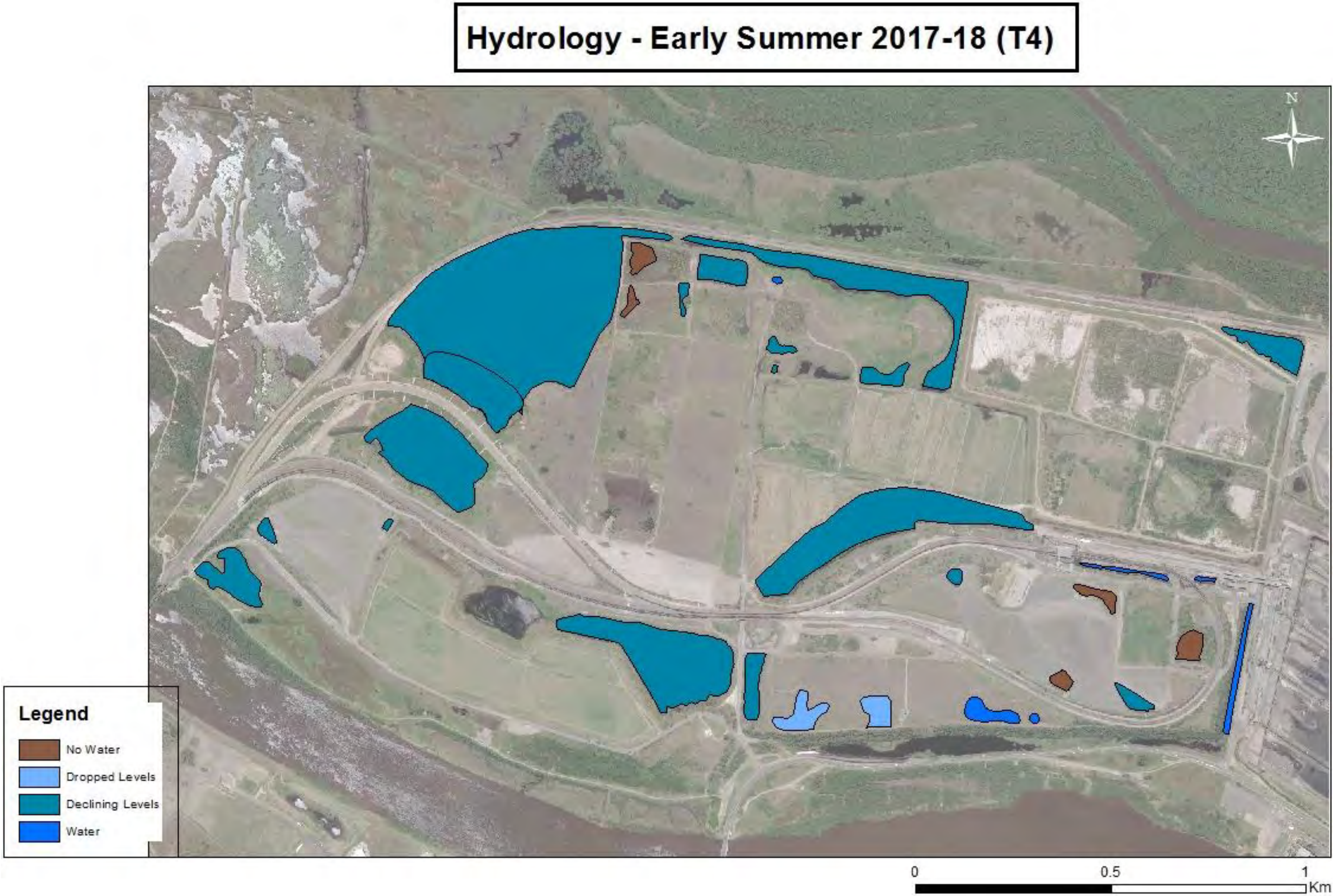
Appendix A: Wetland numbering system



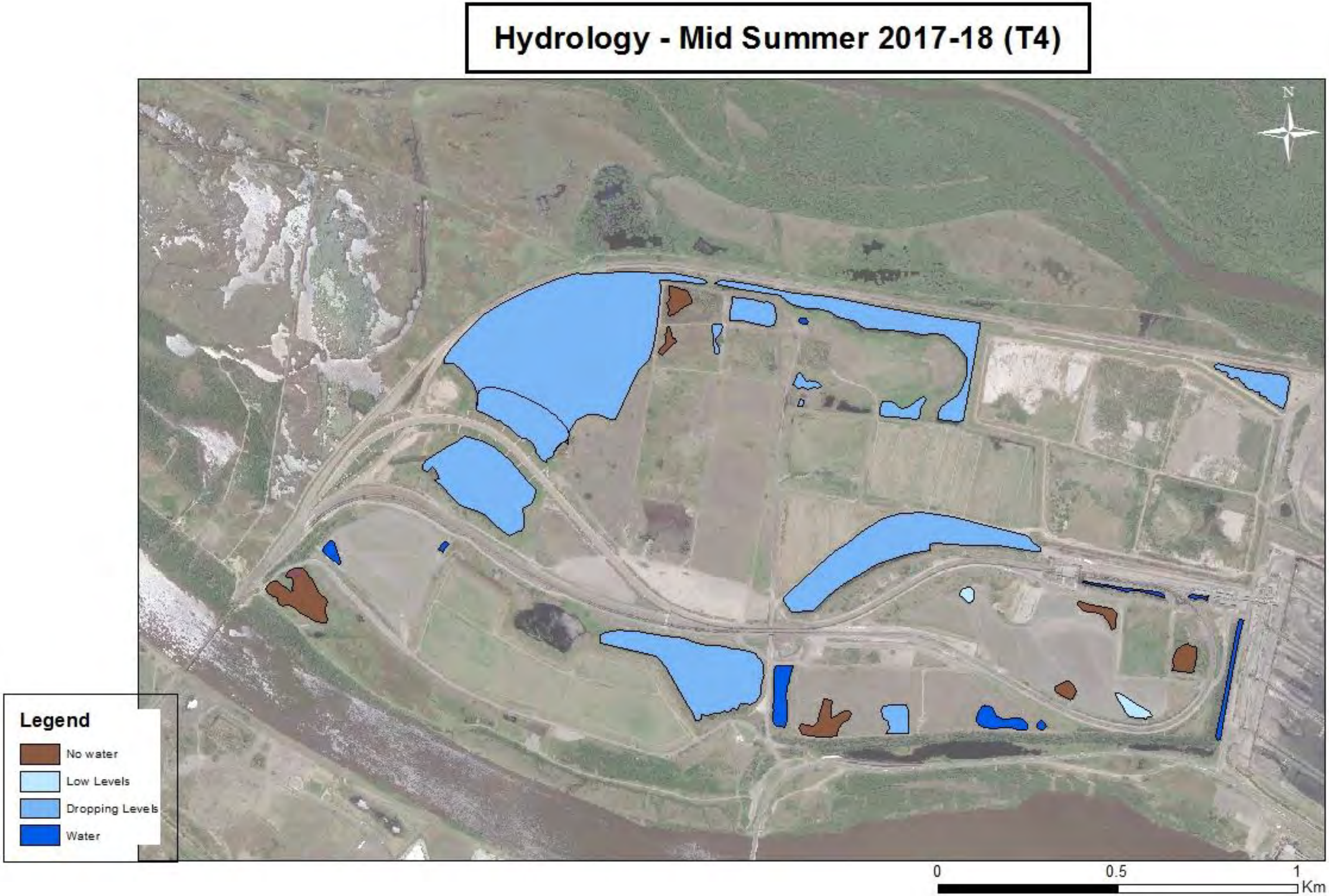
Appendix A: Wetland numbering system



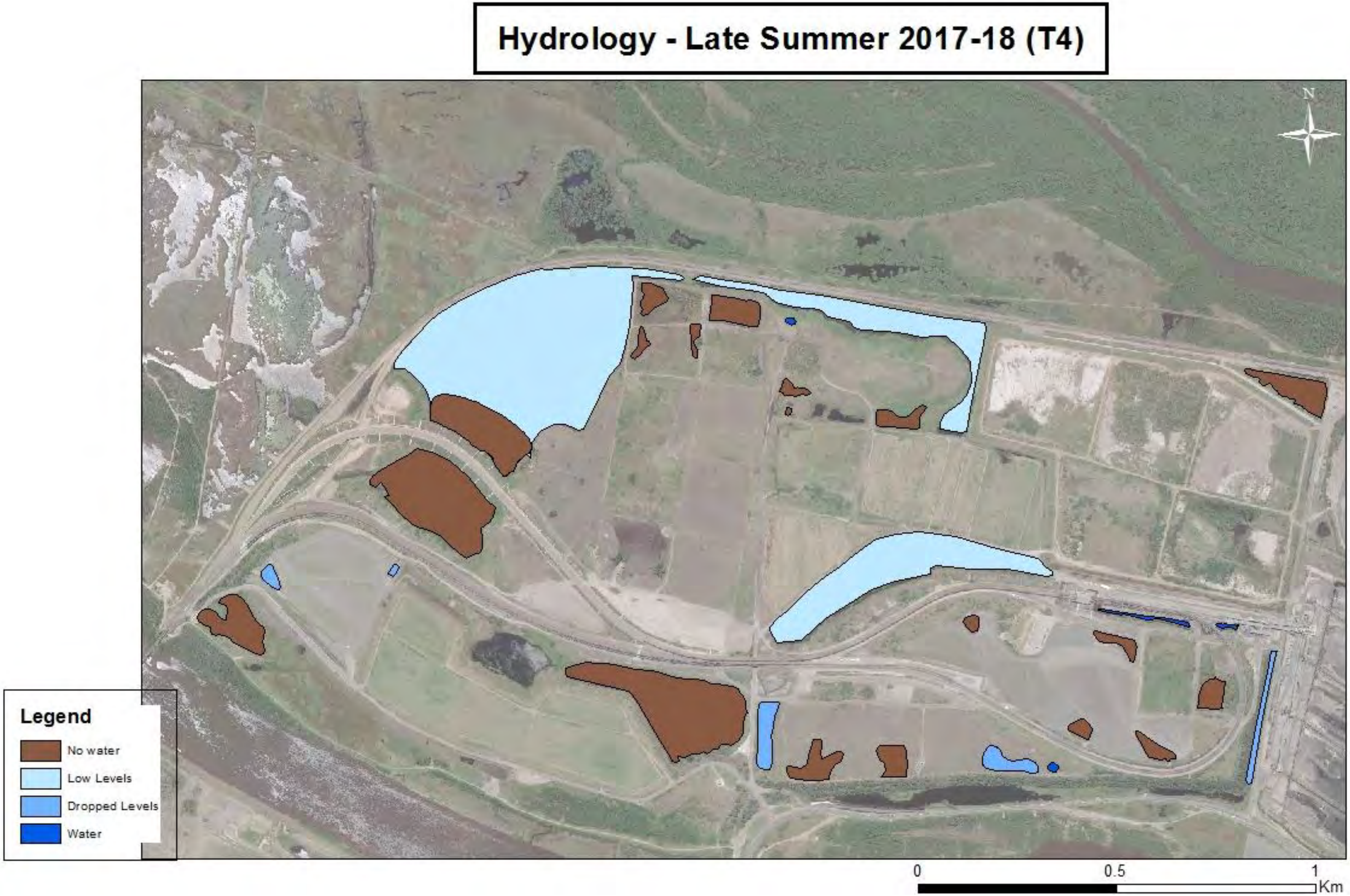
Appendix B: Water levels in T4 wetlands, 2017-2018 summer season



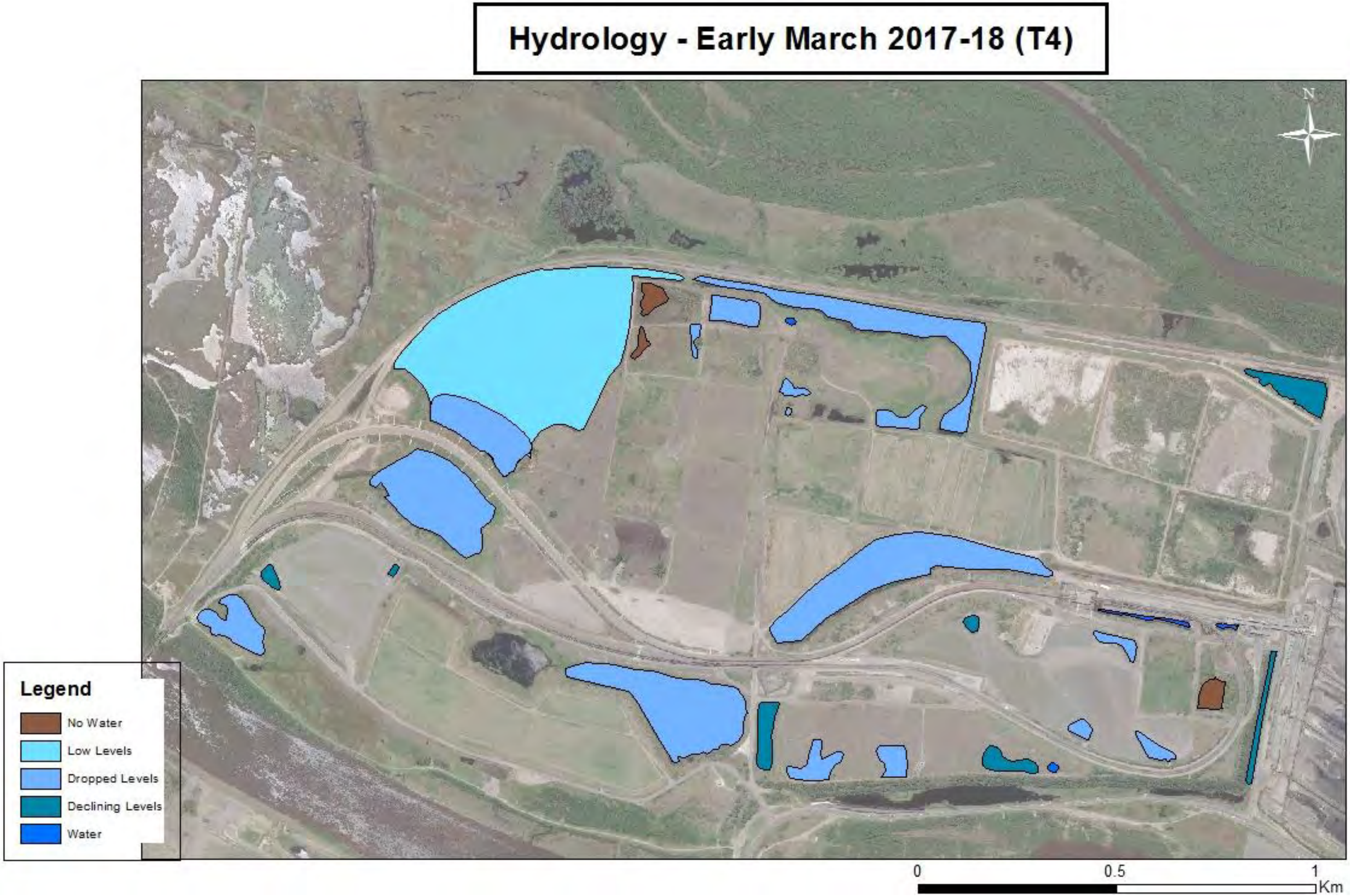
Appendix B: Water levels in T4 wetlands, 2017-2018 summer season



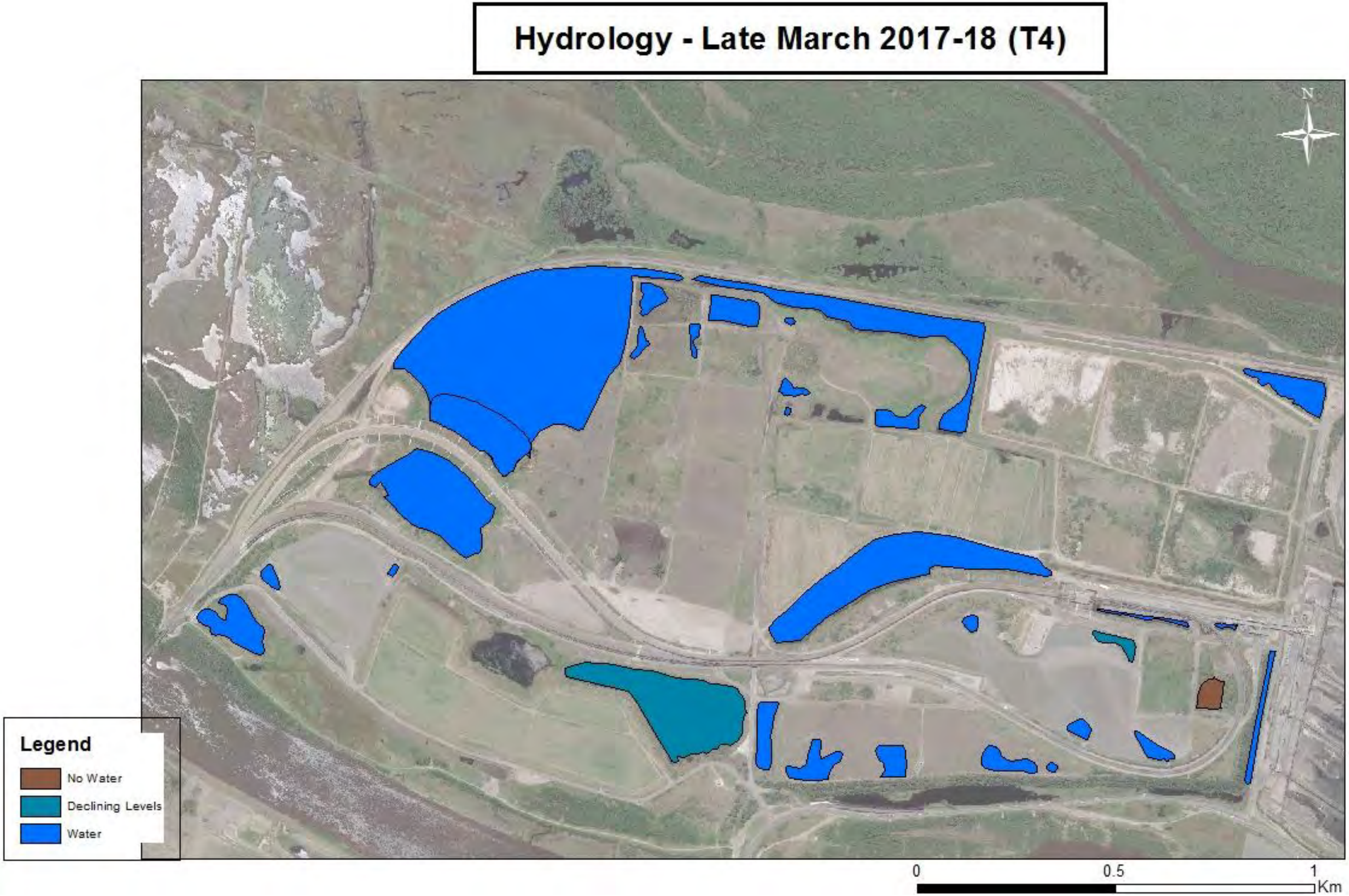
Appendix B: Water levels in T4 wetlands, 2017-2018 summer season



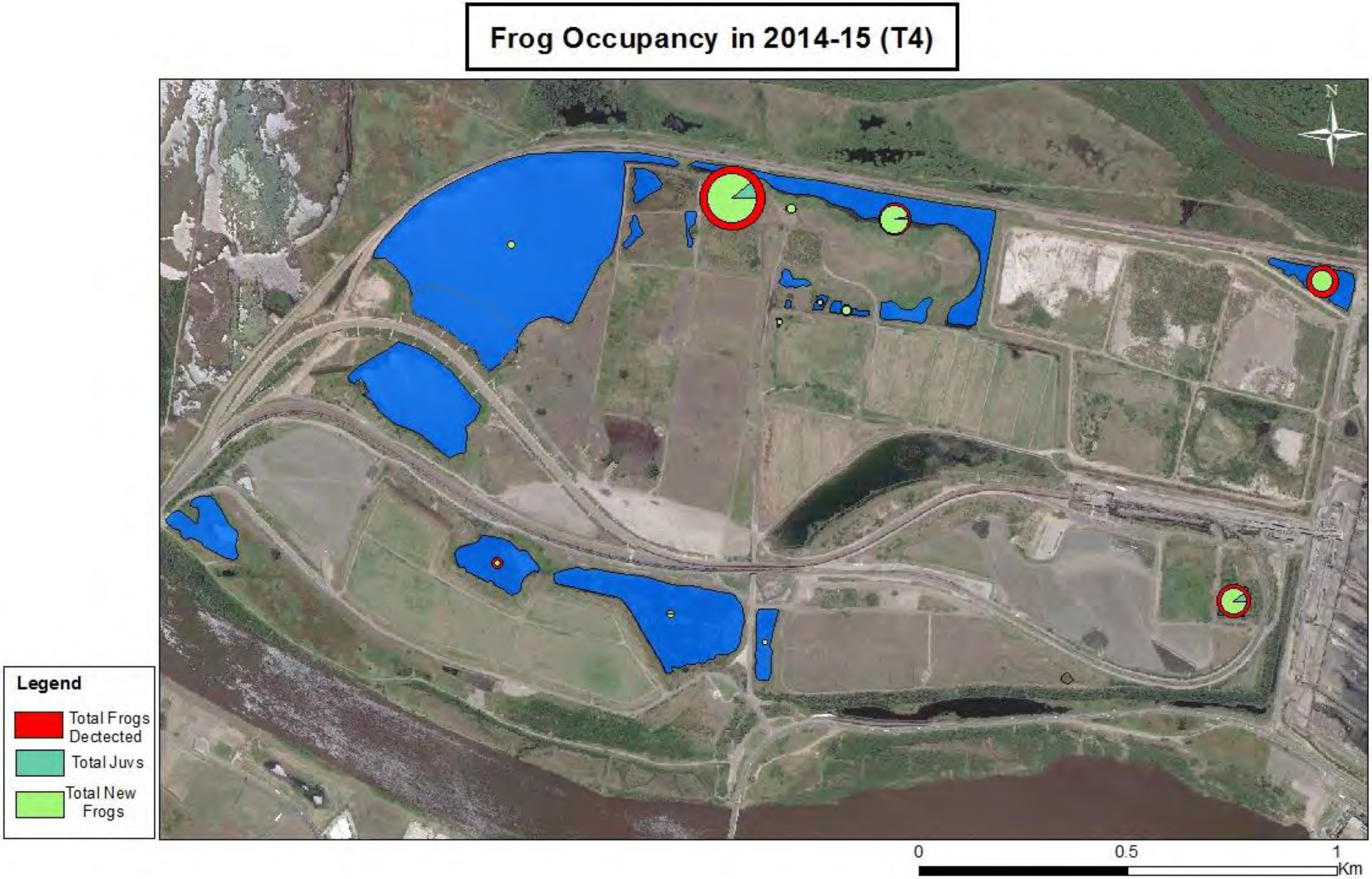
Appendix B: Water levels in T4 wetlands, 2017-2018 summer season



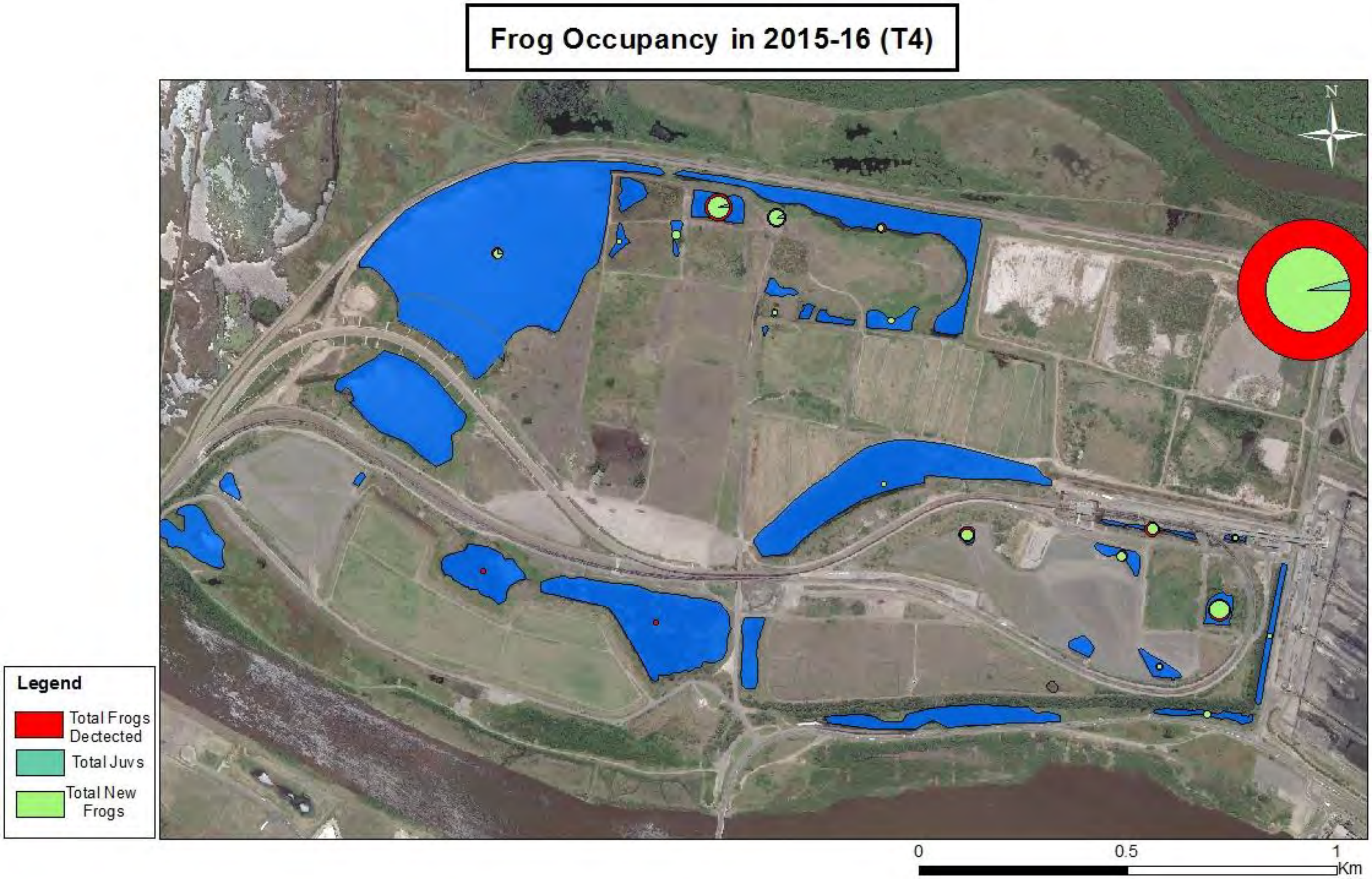
Appendix B: Water levels in T4 wetlands, 2017-2018 summer season



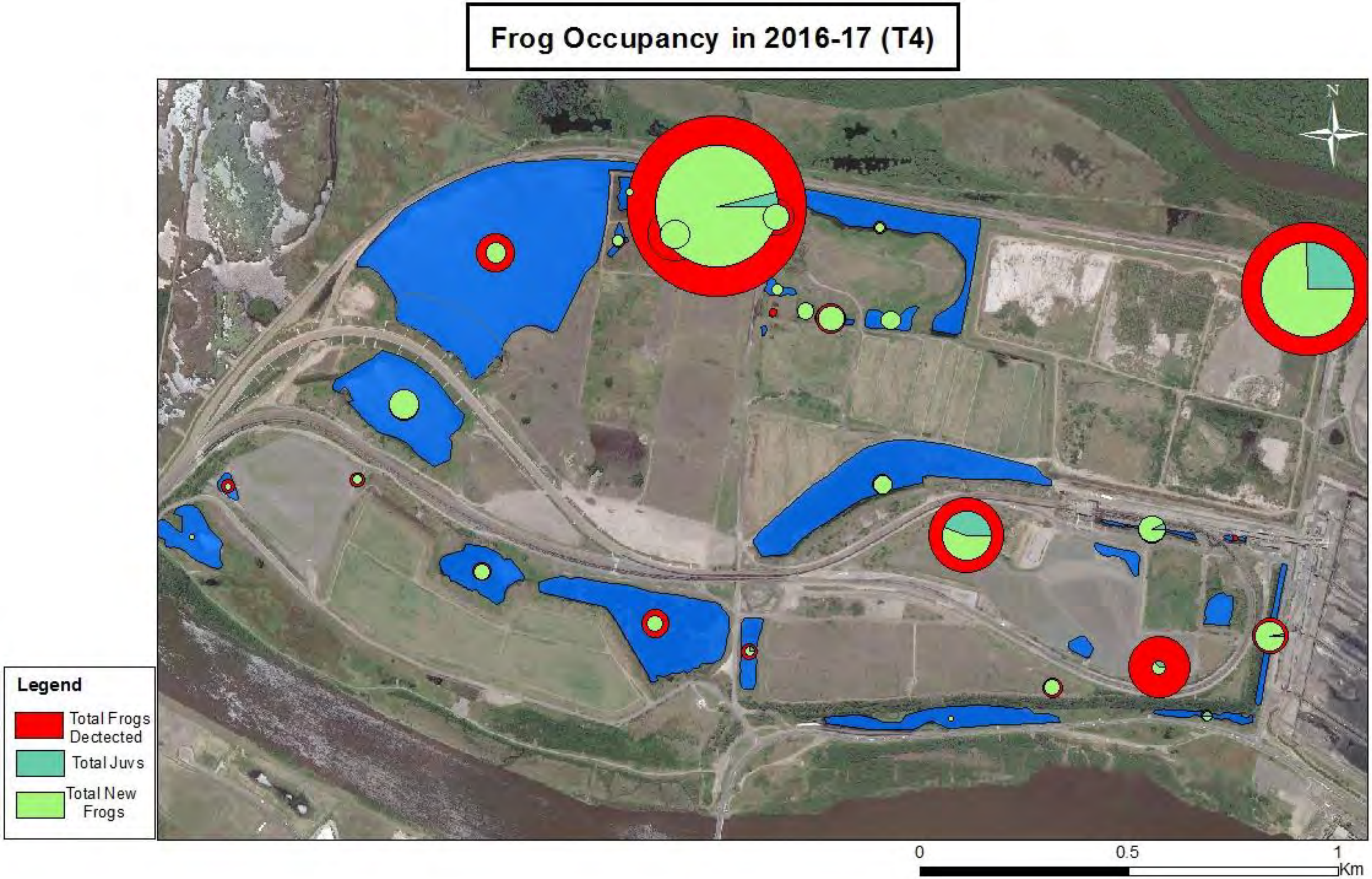
Appendix C: Occupancy of T4 wetlands by *Litoria aurea*, 2014-2018



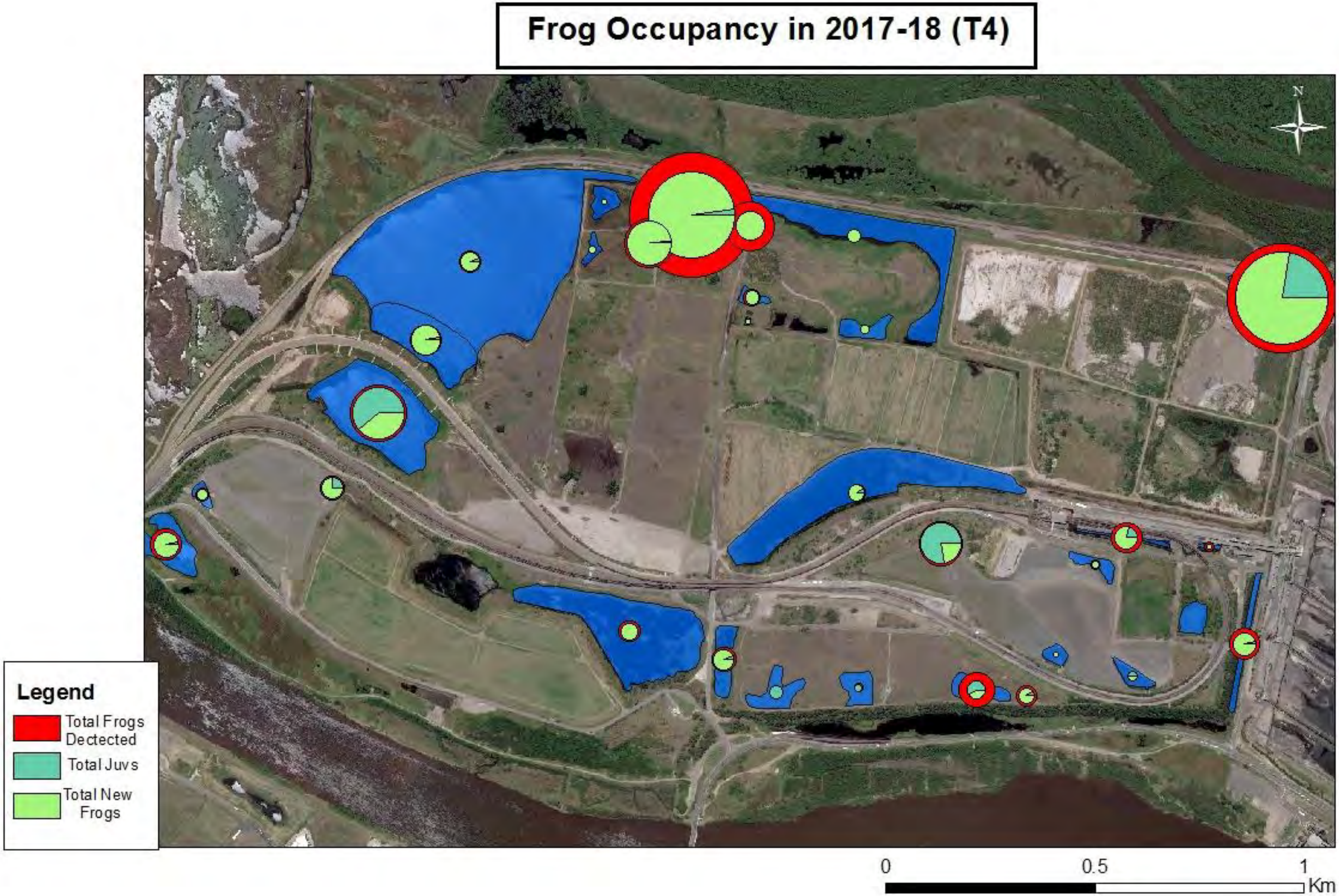
Appendix C: Occupancy of T4 wetlands by *Litoria aurea*, 2014-2018



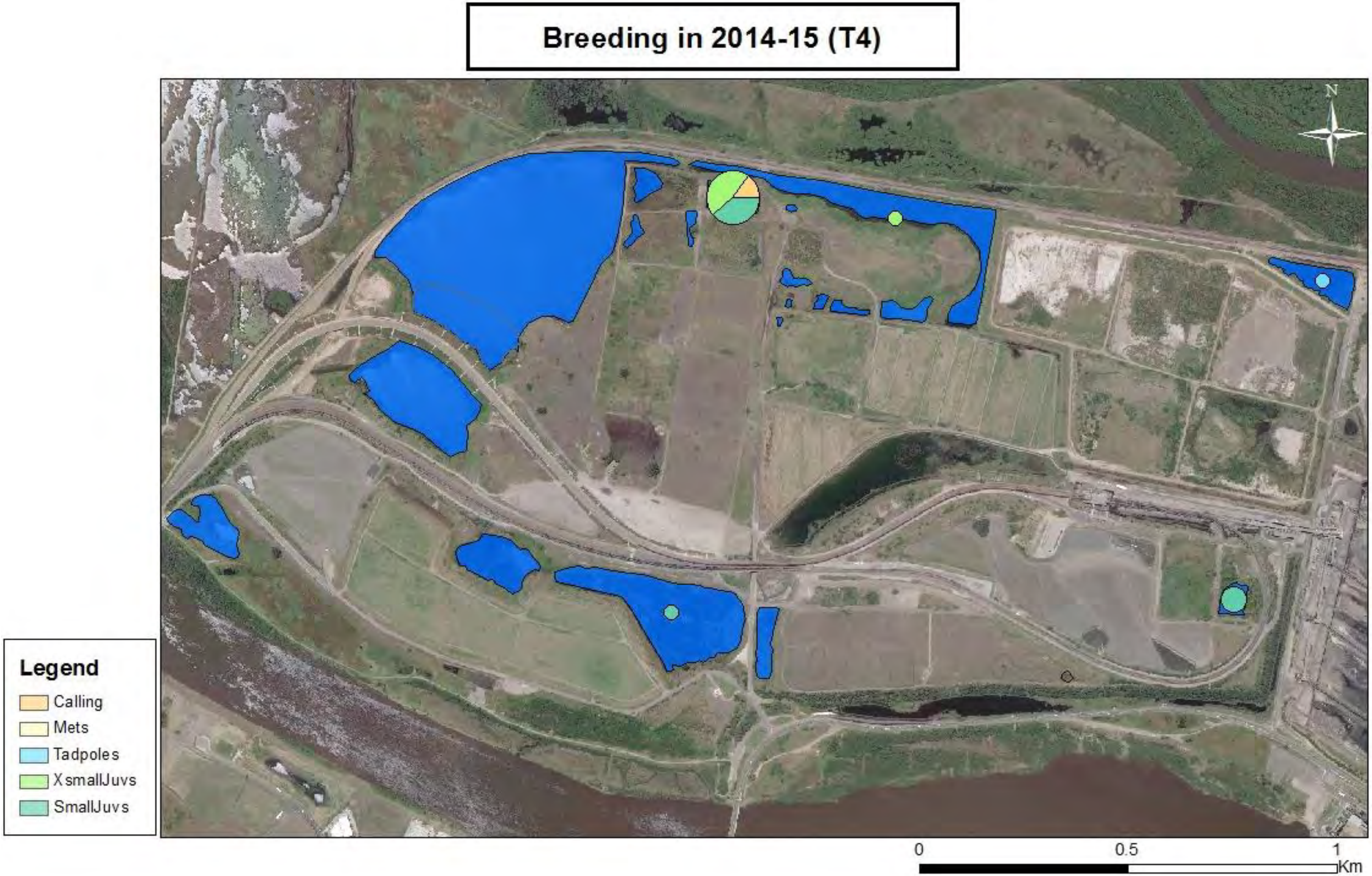
Appendix C: Occupancy of T4 wetlands by *Litoria aurea*, 2014-2018



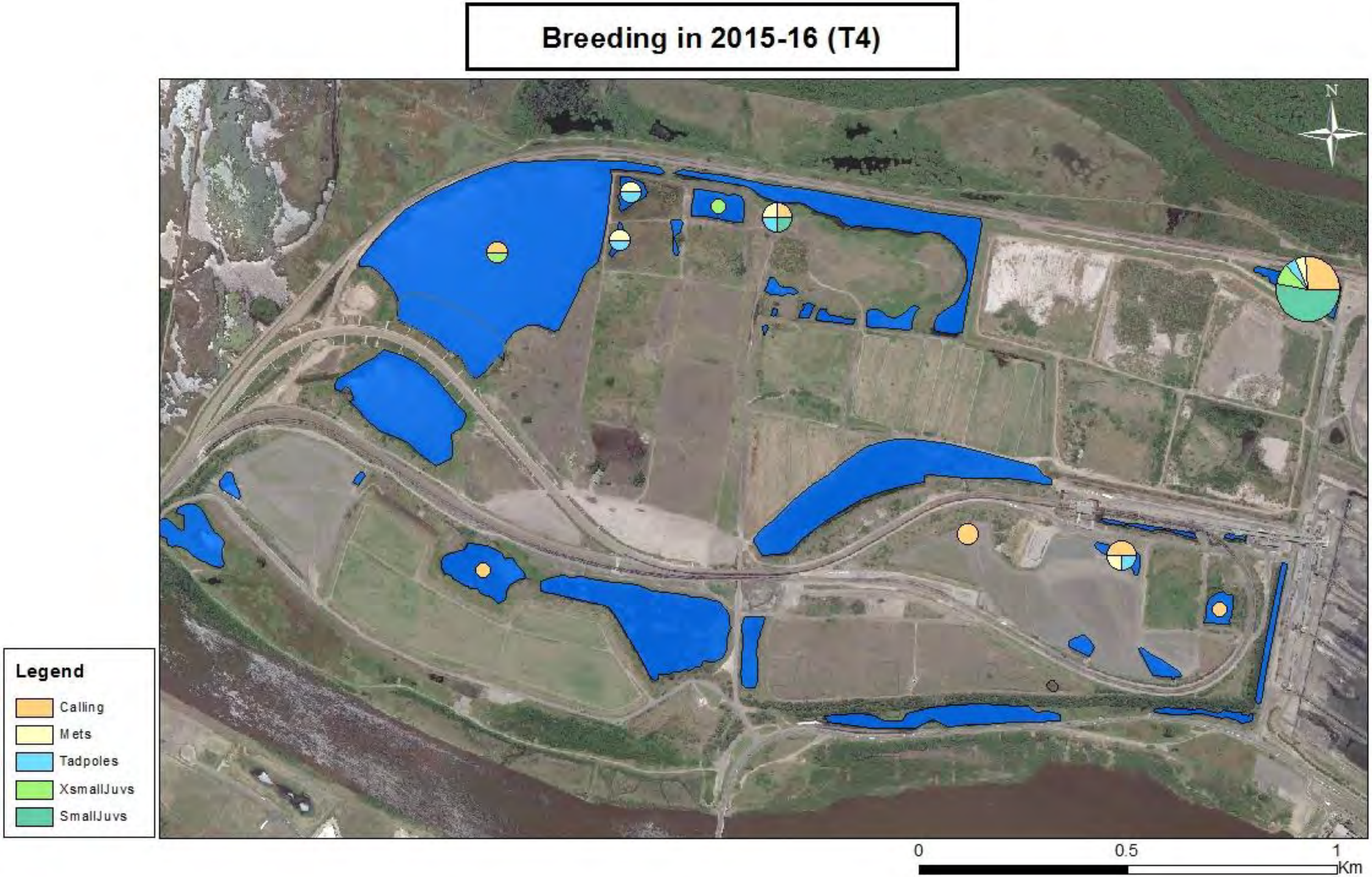
Appendix C: Occupancy of T4 wetlands by *Litoria aurea*, 2014-2018



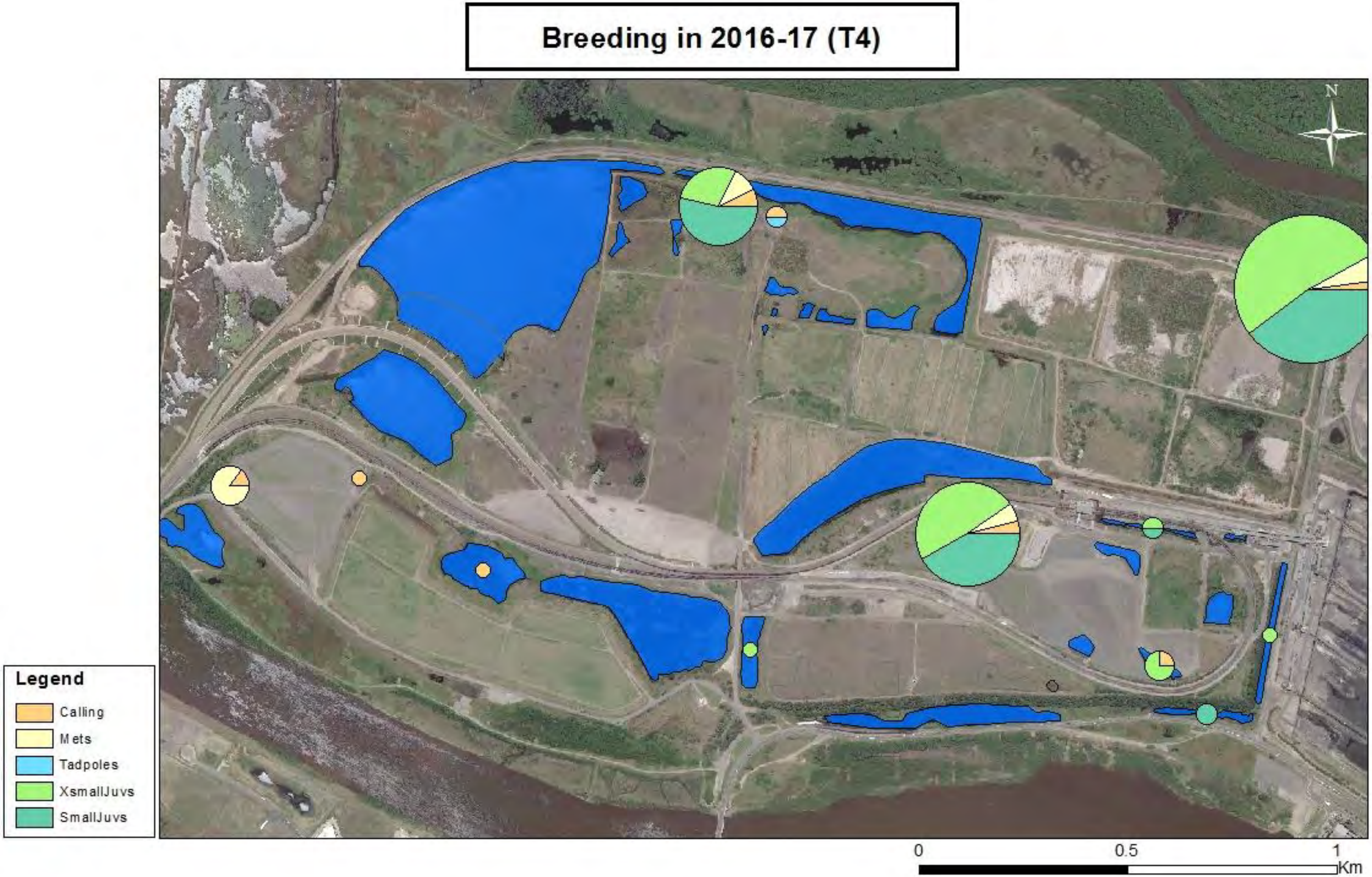
Appendix D: Recorded breeding by *Litoria aurea* across T4 wetlands, 2014-2018



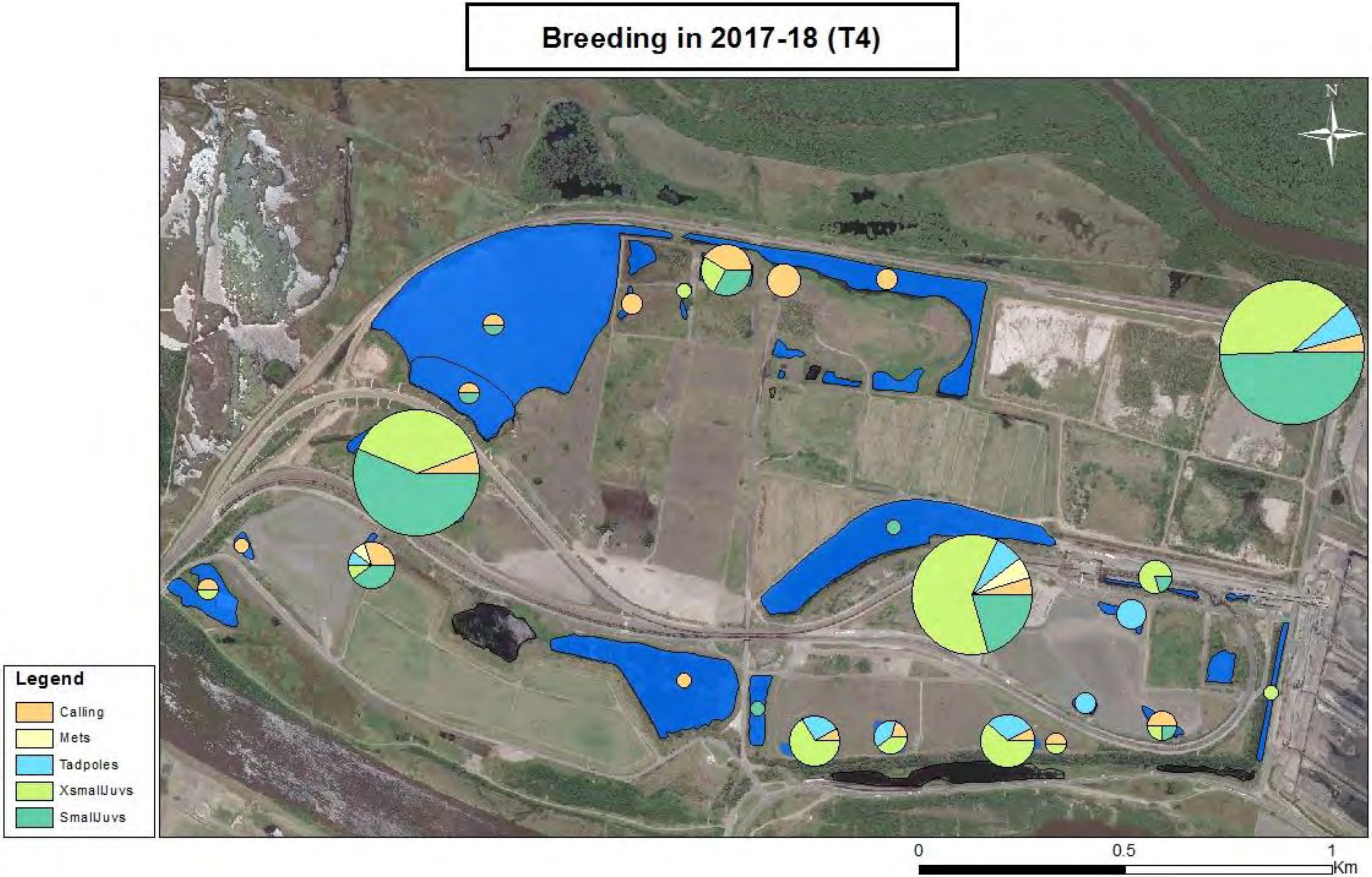
Appendix D: Recorded breeding by *Litoria aurea* across T4 wetlands, 2014-2018



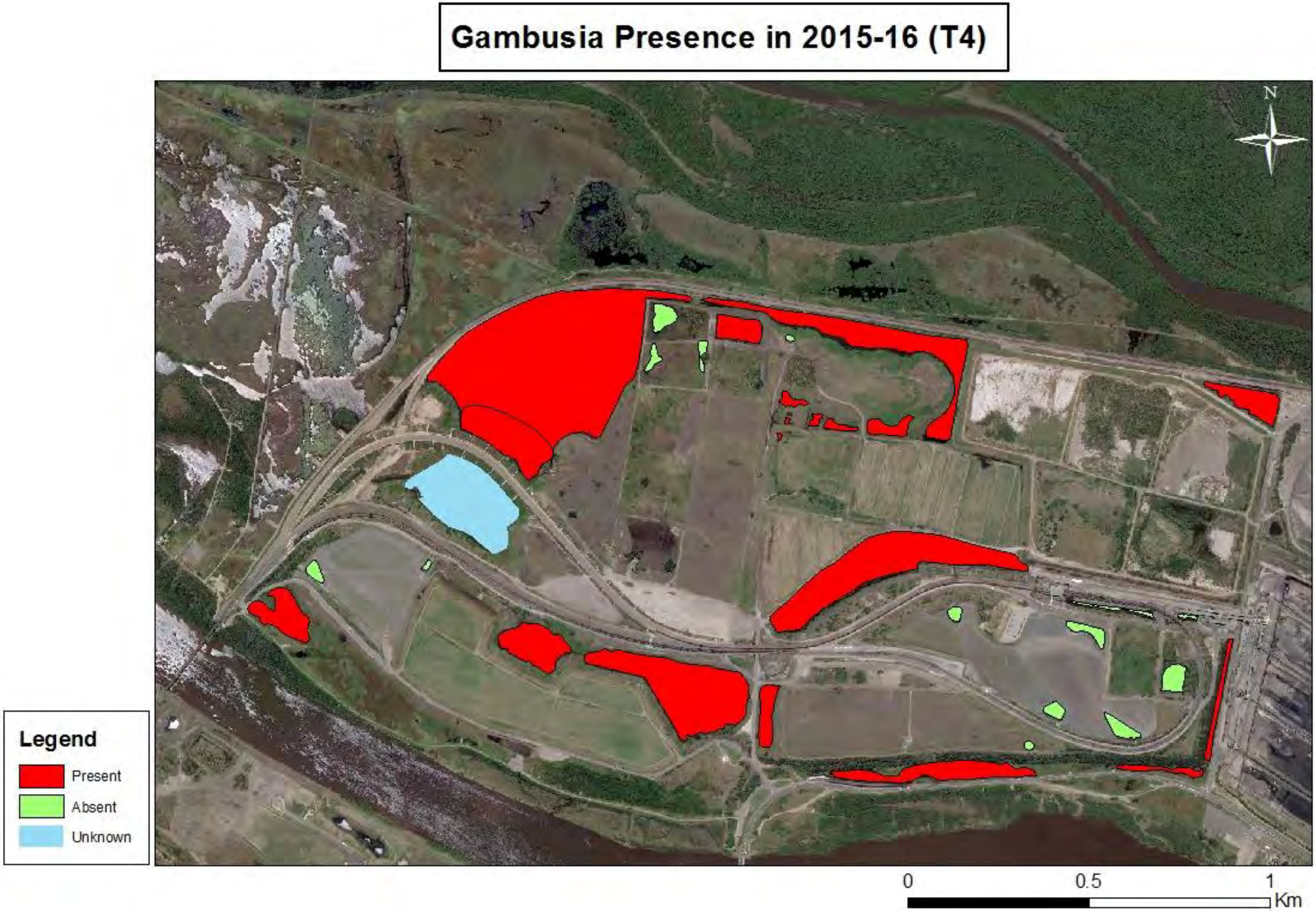
Appendix D: Recorded breeding by *Litoria aurea* across T4 wetlands, 2014-2018



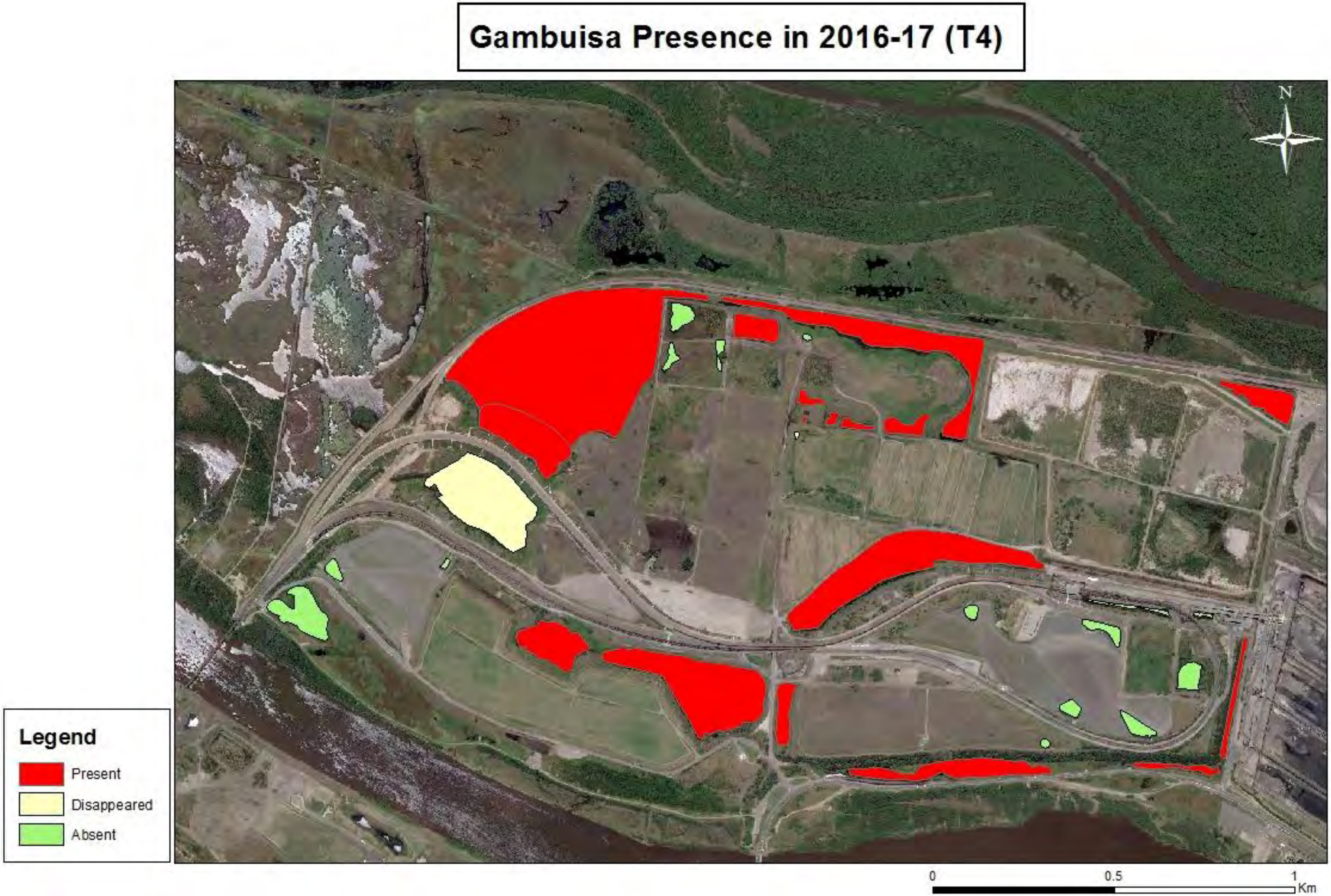
Appendix D: Recorded breeding by *Litoria aurea* across T4 wetlands, 2014-2018



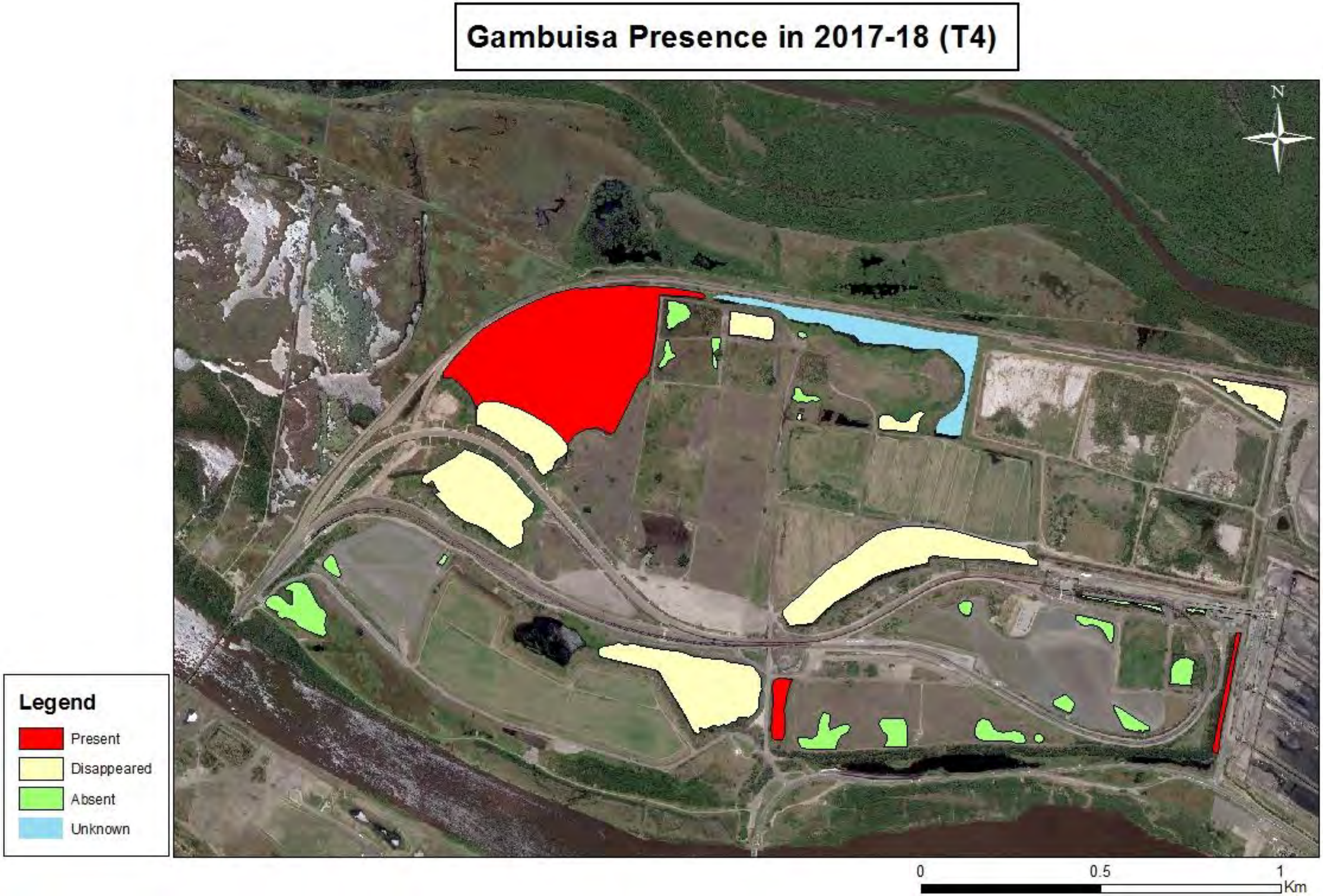
Appendix E: Distribution of *Gambusia* across T4 wetlands, 2015-2018



Appendix E: Distribution of *Gambusia* across T4 wetlands, 2015-2018



Appendix E: Distribution of *Gambusia* across T4 wetlands, 2015-2018



APPENDIX 7
KIWEF AREA 2 STAKEHOLDER CONSULTATION REGISTER

Date	Parties	Method	Topics discussed (related to Area 2 Closure Works)
13 May 2015	HDC Routine Reporting to Port Lessor	Report	HDC submitted Binding Terms Agreement Remediation Works Update Report to Port Lessor. The report provided an update on the progress of adjacent developments (PWCS T4 project) and identified the need for HDC to progress the Area 2 Closure Works. The report also listed HDC's stakeholder consultations throughout the period.
20 July 2015	HDC meeting with NCIG	Meeting	Discussion on current HDC capping works (Area 3) and proposed capping works (Area 2); and NCIG works surrounding rail flyover modification.
11 November 2015	HDC meeting with PWCS	Meeting	Discussion on T4 project and KIWEF capping matters.
17 December 2015	HDC Routine Reporting to Port Lessor	Report	HDC submitted Binding Terms Agreement Remediation Works Update Report to Port Lessor. The report provided an update on the engagement of an approvals consultant for the Area 2 Closure Works and identified key issues to the project.
10 February 2016	HDC meeting with UoN, PWCS and NCIG	Meeting	Progress meeting on GGBF monitoring program across Kooragang and Ash Islands.
16 February 2016	EPA Letter	Letter	EPA issued HDC with a letter acknowledging the completion of the Area 1 capping works in accordance with the requirements of the Surrender Notice.
26 February 2016	HDC Teleconference Port Lessor (& legal counsel)	Teleconference	Update on progress of the HDC remediation projects and Port Lease arrangements.
11 March 2016	GPNSW Letter	Letter	GPNSW issued HDC with a letter providing owners consent for the Area 2 Closure Works.
17 March 2016	HDC submission of ERM Report to DoEE	Deliverable	HDC submission to DoEE of the ERM, KIWEF Area 2 Closure Works EPBC Referral
23 March 2016	HDC meeting with PWCS	Meeting	KIWEF project update and coordination meeting
11 April 2016	HDC Routine Reporting to Port Lessor	Report	HDC submitted Binding Terms Agreement Remediation Works Update Report to Port Lessor. The report documented the submission of the Area 2 Closure Works, EPBC Referral to DoEE; and provided an update on the detailed design works. The report also identified key issues to the delivery of the Area 2 Closure Works
2 May 2016	DoEE Letter	Letter	DoEE issued an Additional Information Request for the Area 2 Closure Works
1 August 2016	HDC meeting with UoN	Meeting	UoN presented the results of the 2015/16 GGBF monitoring period.

Date	Parties	Method	Topics discussed (related to Area 2 Closure Works)
9 August 2016	HDC Routine Reporting to Port Lessor	Report	HDC submitted Binding Terms Agreement Remediation Works Update Report to Port Lessor. The report provided an update on the progress of the Area 2 Closure Works approvals; and confirmed the engagement of a design consultant. The report also updated on key issues to the project and stakeholder consultations.
30 August 2016	HDC Meeting with OEH, NPWS, PoN, BHPB, PWCS, NCIG and UoN	Meeting	Discussion regarding collaboration of GGBF monitoring across Kooragang and Ash Islands and consolidation of various investigations to support the OEH led 'Save Our Species' project for the GGBF.
22 September 2016	HDC submission of ERM Report to DoEE	Deliverable	HDC submission to DoEE of the ERM Response to Request for Information, KIWEF Area 2 Closure Works
10 October 2016	HDC discussion with DoEE	Teleconference	HDC provide DoEE with further details on the current status of the revegetation of the Area 1 capping works completed in 2015, including photo evidence provided via email.
14 October 2016	HDC Routine Reporting to Port Lessor	Report	HDC submitted Binding Terms Agreement Remediation Works Update Report to Port Lessor. The report provided an update on key issues to the Area 2 Closure Works project.
24 October 2016	HDC site visit with Port Lessor	Site Visit	HDC discuss developments on current remedial projects (including the Area 2 works).
30 November 2016	HDC discussion with DoEE	Teleconference	HDC provide DoEE with further detail on the conceptual drainage design (provided via email) for the proposed Area 2 closure works.
2 December 2016	HDC teleconference DoEE	Teleconference	DoEE advised HDC of determination of Area 2 Closure Works to be a Controlled Action.
14 December 2016	HDC site visit with PoN	Site Visit	HDC take Port of Newcastle on a site inspection of the Area 2 Closure Works and present the proposed Area 2 Closure Works strategy. Provide update on approval process and expected construction timings.
17 February 2017	HDC Routine Reporting to Port Lessor	Report	HDC submitted Binding Terms Agreement Remediation Works Update Report to Port Lessor. The report provided an update on the Commonwealth Approval determination; and status of the design projects for the Area 2 Closure works. The report identified HDC's intent to review the available information including results of the SMEC design investigation in terms of the Commonwealth approval process.
20 February 2017	HDC meeting with Port Lessor	Meeting	Regular remediation project update, outlining progress on Closure Works including Area 2 Closure Works and brief update of the HDC review of available Area 2 investigation results.

Date	Parties	Method	Topics discussed (related to Area 2 Closure Works)
6 March 2017	HDC meeting with Port Lessor	Meeting	Following the review of available options to progress the Area 2 Closure Works, HDC provide Port Lessor with detailed briefing of the various approval options available including the potential to rationalise the Area 2 closure strategy.
9 March 2017	HDC site visit with EPA	Site Visit	HDC take the EPA to KIWEF for a walkover of the completed Area 3 capping works. Also discuss the Commonwealth determination of the Area 2 closure works as a Controlled Action and the potential rationalisation.
20 March 2017	HDC meeting with Port Lessor	Meeting	Regular remediation project update, outlining progress on Closure Works including Area 2 Closure Works.
21 March 2017	HDC Briefing Paper to Port Lessor	Deliverable	HDC provide the Port Lessor with a Detailed Briefing Paper, providing the various Closure Options and their approval pathways.
4 April 2017	HDC site visit with Port Lessor	Site Visit	HDC take the Port Lessor to Mayfield and KIWEF sites. HDC presents the proposed Rationalisation Strategy for the Area 2 Closure Works.
10 April 2017	HDC Teleconference Port Lessor (& legal counsel)	Teleconference	Discussion of Area 2 Rationalisation Investigation and its legal implications under the Port Lease.
26 April 2017	HDC Teleconference Port Lessor (& legal counsel)	Teleconference	Discussion of Area 2 Rationalisation Investigation and its legal implications under the Port Lease.
15 May 2017	HDC meeting with Port Lessor	Meeting	Regular remediation project update, outlining progress on Closure Works including Area 2 Closure Works.
30 May 2017	HDC meeting with UoN, PWCS and NCIG	Meeting	UoN presenting the results of the 2016/17 GGBF monitoring period.
22 June 2017	HDC meeting with EPA	Meeting	Update on status of KIWEF Closure Works and Surrender Notice developments
10 July 2017	HDC Teleconference Port Lessor	Teleconference	Regular remediation project update, outlining progress on Area 2 Closure Works approval and design progress. Confirmation of Port Lessors preference to rationalise Area 2 Closure Works.
14 July 2017	HDC Routine Reporting to Port Lessor	Report	HDC submitted Binding Terms Agreement Remediation Works Update Report to Port Lessor. The report documented Port Lessors approval to proceed with the rationalisation of the Area 2 Closure Works following the DoEE determination as a Controlled Action. The report also identified key issues to the project and documented any stakeholder consultations.

Date	Parties	Method	Topics discussed (related to Area 2 Closure Works)
26 July 2017	HDC meeting with PoN and NCIG	Meeting	Meeting to discuss the KIWEF Area 2 project and how HDC can access Lot 7.
3 August 2017	HDC site visit with PoN and PWCS	Site Visit	Site visit to investigate access options to Lot 7 and present update on status of KIWEF Area 2 Closure Works.
21 August 2017	HDC Teleconference Port Lessor	Teleconference	Regular remediation project update, outlining progress on engagement of SMEC to undertake the Rationalisation Investigation.
6 September 2017	HDC meeting with EPA	Meeting	Meeting with senior EPA representatives to discuss the status of ongoing HDC remediation works at Mayfield and KIWEF.
18 September 2017	HDC Teleconference Port Lessor	Teleconference	Regular remediation project update, outlining progress on Area 2 Rationalisation Investigation, including commencement of site activities.
10 October 2017	HDC Teleconference Port Lessor (& legal counsel)	Teleconference	KIWEF Closure Works update, discussion ofand Port Lessors preference for responsibilities on submission of PDP.
23 October 2017	HDC Teleconference Port Lessor	Teleconference	Regular remediation project update, outlining progress on rationalisation investigation site activities.
9 November 2017	HDC Routine Reporting to Port Lessor	Report	HDC submitted Binding Terms Agreement Remediation Works Update Report to Port Lessor. The report provided an update on the progress of the Rationalisation Investigation and the overall approvals process for the Area 2 Closure Works. The report also identified key issues to the project and any stakeholder consultations.
10 November 2017	HDC Teleconference Port Lessor	Teleconference	HDC presenting the findings from the rationalisation investigation, including identified hydrocarbons and the potential for groundwater migration.
20 November 2017	HDC Teleconference Port Lessor	Teleconference	Regular remediation project update, outlining progress on the Area 2 Rationalisation Investigation and update on the Area 2 design process.
21 November 2017	HDC meeting with EPA	Meeting	Presentation of KIWEF Area 2 Rationalisation Investigation findings
22 November 2017	HDC meeting with PoN	Meeting	Presentation of KIWEF Area 2 Rationalisation Investigation findings
29 November 2017	HDC meeting with DoEE	Meeting	Presentation of developments with Area 2 Closure Works including findings of Rationalisation Investigation and proposed strategy going forward.

Date	Parties	Method	Topics discussed (related to Area 2 Closure Works)
6 December 2017	HDC site visit with UoN	Site Visit	Review of successes and deficiencies in the completed capped sites (Areas 1 and 3). Presentation of proposed future capping area (Area 2) and discussion of potential beneficial elements that could be added for GGBF population.
12 December 2017	HDC Teleconference Port Lessor	Teleconference	Regular remediation project update, outlining progress on Closure Works PDP and design, meeting with DoEE. Confirmation of Port Lessors preferred closure strategy.
15 January 2018	HDC Teleconference Port Lessor	Teleconference	Regular remediation project update, outlining progress on Closure Works PDP and design.
24 January 2018	HDC Teleconference Port Lessor (& legal counsel)	Teleconference	Discussion on options to access the wedge area (Lot 7).
25 January 2018	HDC meeting with UoN	Meeting	Meeting to discuss the Area 2 Closure Works and the potential benefits/impacts to the GGBF.
31 January 2018	HDC site visit with PWCS and Daracon	Site Visit	HDC present the proposed Area 2 design to PWCS and Daracon and outline issues particularly in relation to Lot 7 access. Undertake a site visit to determine whether an identified access route to Lot 7 is appropriate for required construction equipment
19 February 2018	HDC Teleconference Port Lessor	Teleconference	Regular remediation project update, outlining progress on Closure Works PDP and design. Confirmation of Port Lessors preferred way forward.
13 February 2018	HDC Routine Reporting to Port Lessor	Report	HDC submitted Binding Terms Agreement Remediation Works Update Report to Port Lessor. The report provided an update on the results of the rationalisation investigation and documented the proposed approvals approach agreed with Port Lessor following recent meetings with DoEE. The report also provided an update on the Area 2 design and how it is being driven by the results of the hydro-salinity modelling works required for the PDP. Finally the report updated on identified key issues to the project and stakeholder consultations.
1 March 2018	HDC meeting with UoN	Meeting	Meeting to discuss potential uses of saline soils to influence water quality salinity levels within surrounding ponds.
13 March 2018	HDC site visit with Port Lessor	Site Visit	HDC presented the Port Lessor with the results of the Area 2 Closure Works hydrosalinity modelling and updated concept design.
13 March 2018	HDC meeting with Port Lessor & Port of Newcastle	Meeting	Discussion on access arrangements to complete the Closure Works for Lot 7

Date	Parties	Method	Topics discussed (related to Area 2 Closure Works)
19 March 2018	HDC teleconference Port Lessor	Teleconference	Regular remediation project update, outlining progress on Closure Works PDP and design. Confirmation of Port Lessors preferred way forward.
21 March 2018	HDC teleconference DoEE	Teleconference	HDC discussed the dynamics of the Area 2 Closure Works under the port Lease arrangements with DoEE. DoEE recommended that the PDP submission be progressed in the name of the Port Lessor as the Entity Taking Action until DoEE issue Draft Conditions of Consent (under S131AA of the Act). At this point the Approval Holder arrangements can be agreed with the correct entity, proposed to be the State during construction and Port of Newcastle following Post-Construction.
21 March 2018	HDC email Port Lessor	Email	HDC notify Port Lessor on the discussion with DoEE and proposed strategy to align the Commonwealth Approval with the dynamics of the Port Lease.
16 April 2018	HDC teleconference Port Lessor	Teleconference	Regular remediation project update, outlining progress on Closure Works PDP, including results of modelling and design.
19 April 2018	HDC, UoN, SMEC, Ramboll	Workshop	KWIEF Area 2 Closure Works Workshop. Discussion with all relevant parties into various factors of the Area 2 Works and how the design can be optimised to address regulator, stakeholder and species requirements.
2 May 2018	HDC, Port Lessor and PoN	Teleconference	Teleconference to discuss progress in accessing Lot 7 (the wedge) and actions to further proceed.
7 May 2018	HDC email PoN	Email	HDC formally notify PoN the status of the Commonwealth Approval process and the intent to for PoN to assume the role of Approval Holder during the Post-Construction phase, to be transferred to PoN under s145B of the EPBC Act on Completion of the works. HDC offered to attend a briefing meeting to outline the scope of the Area 2 closure works, the content of the PDP submission and the commitments that are being put forward.
10 May 2018	HDC email EPA	Email	HDC notify EPA of progress with the Commonwealth Approval, including the results of the modelling and refinements to the Area 2 design. HDC sought to arrange a briefing session with the EPA to outline the project and design and also requested EPA to provide written confirmation that the EPA has no objection to the proposed Area 2 design
21 May 2018	HDC teleconference Port Lessor	Teleconference	Regular remediation project update, Lot 7 access issues and upcoming briefing session.
22 May 2018	HDC teleconference EPA	Teleconference	HDC presented the scope of the proposed Area 2 Closure Works project to EPA. The discussion outlined the scope of the Area 2 Closure Works and confirmed that the approach would be consistent with the Closure Strategy. The EPA confirmed that they had no objection to the works providing they were in accordance with the Closure Strategy.

Date	Parties	Method	Topics discussed (related to Area 2 Closure Works)
25 May 2018	HDC Meeting Port Lessor	Meeting	HDC presented the scope of the proposed Area 2 Closure Works project to Port Lessor. The presentation was focussed on the changes from previous capping strategies and the reasoning behind the changes. The presentation also highlighted the proposed construction and post-construction conditions; including who would hold the responsibilities to comply with the conditions and how they would be transferred following completion of the construction activities. Port Lessor confirmed HDC can commence consultation with other key stakeholders.
31 May 2018	HDC meeting PoN	Meeting	HDC presented the scope of the proposed Area 2 Closure Works project to Port of Newcastle. The presentation was focussed on the proposed cap design and ongoing post-construction monitoring and maintenance obligations. The process for transfer of the commonwealth approval to PoN following construction completion and the timings for PoN input into the process was also discussed.
4 June 2018	HDC report provided to Port Lessor	Memorandum	HDC provided Briefing Paper for the Treasurer. The briefing paper outlined the Commonwealth Approval process and the proposed strategy for the Commonwealth Approval holder.
5 June 2018	HDC meeting PWCS	Meeting	HDC presented an overview of the proposed Area 2 Closure Works project to Port Waratah Coal Services. The presentation provided an update on the status of the Area 2 Approval Process and discussed features of the Closure Works and how they integrate with the already approved T4 project. PWCS provided an update on the T4 approval status and other works packages related to the Kooragang Island site.

APPENDIX 8
ENVIRONMENTAL MANAGEMENT PLAN SUB PLANS(REVEGETATION AND WATER QUALITY)

Annex A

Revegetation Management Plan

Revegetation Management Plan	
Objective	To comply with State and Federal approvals requirements and related conditions To provide a post construction environment that is revegetated to stabilise the capping surface; and planted with species known to be favoured by GGBF..
Targets	The capped surface is stabilised and vegetated within 12 months of construction completion. Provide a revegetated capped surface that includes species of flora known to be favoured by GGBF.
Key Documents	**State Documents** NSW EPA (2010), Approval of the Surrender of a Licence – License 6437, (Ref: 1111840, and as varied by notice number 1510956 and 1520063) Golders (2011), KIWEF Closure Works, Green and Golden Bell Frog Management Plan (Ref: 117623029-001-R-Rev0) GHD (2009), Report on KIWEF, Revised Final Landform and Capping Strategy (Ref: 22/14371/85882 R4) ERM (2016), Review of Environmental Factors, KIWEF Area 2 Closure Works (Ref: 0320327-Review of Environmental Factors) **Commonwealth Documents** ERM (2015), KIWEF Area 2 Closure Works, EPBC Referral (Ref: 0320327_Final) ERM (2016), Response to Request for Information, KIWEF Area 2 Closure Works (Ref: 0320327-Response to Request for Information) Ramboll (2018), EPBC Referral, Preliminary Documentation Package – KIWEF Area 2 Closure Works (Ref: 318000395)
Sections of Key Documents Relevant to Revegetation	**State Approval Documents and Sections** The commitments for Revegetation under the State Approval documents are summarised within the following key documents and the respective relevant sections: • NSW EPA (2010), Approval of the Surrender of a Licence – License 6437 [condition 4a] • ERM (2016), Review of Environmental Factors, KIWEF Area 2 Closure Works [Sections 2.1.2, and 8] **Commonwealth Approval Documents and Sections** The commitments for Revegetation under the Commonwealth Approval documents are summarised within the following key documents and the respective relevant sections: • ERM (2015), KIWEF Area 2 Closure Works, EPBC Referral [Section 5] • ERM (2016), Response to Request for Information, KIWEF Area 2 Closure Works [Section 8] • Ramboll (2018), EPBC Referral, Preliminary Documentation Package – KIWEF Area 2 Closure Works [Section 7.4 and 12]

Mitigation Measures and Controls	**Commitments under State Approval documents**
	The EPA Approval of the Surrender of a Licence (as varied), includes the requirement to comply with the following commitments:
	• Condition 4a) By 30 June 2017, the licensee shall complete implementation of the final landform and capping strategy as detailed in the documents titled:
	    o Hunter Development Corporation - Report on KIWEF - Revised Final Landform and Capping Strategy - August 2009 - Revision 2, prepared by GHD, ("the Landform and Capping Strategy");
	    o 'Green and Golden Bell Frog Management Plan – Kooragang Island Waste Emplacement Facility Closure Works' dated 19 April 2011 and prepared by Golder Associates;

Revegetation Management Plan	
	o 'Materials Management Plan - Kooragang Island Waste Emplacement Facility' dated November 2012 prepared by RCA Australia. Section 2.1.2 of the Review of Environmental Factors requires: • The closure works include the importation of a regrowth material to be sourced from an area that is demonstrated to be low in nutrients and assessed as having a low risk of containing Chytrid Fungus (to the extent possible). Section 8 of the KIWEF Area 2 Review of Environmental Factors; and Section 5.3 of the GGBF Management Plan requires that: • As part of the rehabilitation and revegetation plan for the KIWEF site, open stormwater infrastructure across the KWIEF site may be planted with species known to be favoured by GGBF. This revegetation and rehabilitation strategy will include a 2m wide buffer on either side of the stormwater drains. The intention is to provide movement corridors for GGBF across the site. • The capped areas will ideally be designed to shed water to table drains, which, in a similar manner to other stormwater infrastructure, will be vegetated with species known to be favourable to GGBFs. • Drainage culverts will, where practicable, be vegetated and lined with rocks and objects that may provide temporary frog refuge, in the event that a frog seeks to traverse the future capped area of KIWEF. Section 8 of the KIWEF Area 2 Review of Environmental Factors; and Section 7.4 of the Final Landform and Capping Strategy calls up the mitigation measures within the GHD (2010) Flora and Fauna Impact Assessment which require: • Habitat features such as woody debris that may be utilised by fauna within the construction area would be retained and set-aside during the construction period for reinstatement at completion of works. • The site wide joint monitoring of the GGBF population should be continued seasonally, where feasible, from the next breeding season (spring 2009) to help best manage the population and determine if any adverse impacts have resulted from any works/modifications to GGBF habitat across Kooragang Island, before and after the emplacement closure works. General mitigation measures to be considered include: • Care should be taken that any noxious weeds occurring on the site are not further dispersed as a result of the Proposal. A follow up Weed Control Program may be necessary to control the encroachment of these species into surrounding areas. The landowner has a legal responsibility to control and suppress these species on their property under the Noxious Weeds Act 1995. The Weed Control Program should be remove weeds by physical means and avoid the use of herbicides • Stockpiling of soil that may contain seeds of exotic species shall be stockpiled away from adjacent vegetation or drainage lines where they could be spread during rainfall events. • Placement of soil stockpiles away from vegetated areas. • Utilising existing disturbed corridors such as cleared areas, roads, tracks and existing easements, where possible for set up of equipment, stockpile areas and site facilities

	• Bitou Bush and Crofton Weed would be managed by following the Local Noxious Weed Control Plans (NCC 2006). It is recommended that the plants be removed by physical removal, as herbicides may impact GGBFs and their habitat.
	• Plant and equipment brought on to site must be cleaned and free of deleterious material, mud and other material that may harbour weed seeds
	• Works associated with the closure of the KIWEF must only occur within the closure works area (project footprint); and must be restricted to the extent required to satisfy the Surrender Notice requirements
	• All disturbed surfaces will be revegetated within 1 month of final land forming and in compliance with the landscaping plans.
	• Any capping materials that are imported from outside the KIWEF facility must be sourced from an area that is assessed as having a low risk of containing Chytrid Fungus. The Chytrid Assessment Process will follow the below procedure:
	  o The contractor is to demonstrate that suitable risk assessment has been undertaken by an appropriately qualified and experienced ecologist on all imported capping and revegetation materials to demonstrate that it contains a low risk of containing chytrid. Risk assessment should consider as a minimum:
	    ▪ Material not sourced from known, suspected or likely amphibian habitat areas;
	    ▪ Material unlikely to have had contact with amphibians and no amphibians present in material; and
	    ▪ Material stored in a dry location prior to transport.
	• Topsoil to be used for surface layers must be sourced from within KIWEF to the extent possible and will otherwise be assessed as low in nutrients and having a low risk of containing Chytrid Fungus to be protective of adjacent MNES habitat;
	• Design of erosion and sediment controls must be in accordance with environmental protection standards for sensitive environments, such as (but not limited to) 'Managing Urban Stormwater – Soils and Construction' (Landcom, 2004); and
	• Upon completion of works, the works area will be rehabilitated with vegetation species known to be favoured by GGBF.
	Chapter 7 of Revised Final Landform and Capping Strategy requires the final landform to include "topsoil 100mm thick using stockpiled surface soils or imported topsoil and revegetate the disturbed area".
	Section 7.4 of the Final Landform and Capping Strategy Flora and Fauna Impact Assessment requires that:
	• Provenance native plant stock would be used for rehabilitation of the disturbed areas to maintain the genetic integrity of the vegetation communities present on site.
	• Revegetation of the capped areas following soil/capping material placement, should be in accordance with a Revegetation and Restoration Plan.
	• Restore and rehabilitate wetland communities disturbed by the capping works in accordance with a Revegetation and Restoration Plan.
	Section 5.3 of the GGBF Management Plan requires that:
	• As part of the rehabilitation and revegetation plan for the KIWEF site, open stormwater infrastructure across the KIWEF site may be planted with species known to be favoured by GGBFs. This revegetation and rehabilitation strategy will include a 2 metre wide vegetation buffer on either side of the stormwater drains. The intention of these areas is to provide movement corridors for GGBFs across the site.
	• The capped areas will ideally be designed to shed water to table drains, which, in a similar manner to other stormwater infrastructure, will be vegetated with species known to be favourable to GGBFs.
	• Drainage culverts will, where practicable, be vegetated and lined with rocks and objects that may provide temporary frog refuge, in the event that a frog seeks to traverse the future capped area of KIWEF.
	
	Commitments under Commonwealth Approval documents
	In addition to the State measures described above, the implementation of the following additional measures have been committed to within the Commonwealth Approval process.

Revegetation Management Plan	
	Section 5 of the KIWEF Area 2 EPBC Referral outlines the same measures as described under the KIWEF Area 2, Review of Environmental Factors documents described above. Section 8.1 of the Response to Request for Information, KIWEF Area 2 Closure Works described the Contractor maintenance period and revegetation requirements, which include: • Prior to the Construction Completion dates the Contractor was required to seed the vegetation layer above the capping layer. The contractor was then required to maintain possession of the site for a further 3 months to ensure that the caps integrity was maintained and the surrounding environment protected. • The maintenance period also required the contractor to reseed areas of the cap with sparse vegetation coverage. Section 7.4 of the KIWEF Area 2 Preliminary Documentation Package outlines key attributes that may be incorporated into the Area 2 Closure Works design that were developed in collaboration with researchers at the University of Newcastle. These attributes are considered to represent the conditions that would be favourable to the GGBF: <u>Aquatic vegetation:</u> • Selection of reeds that provide good habitat cover such as Typha, Bolboshoenus, Phragmites, and Juncus; • A mixed community is preferable to single species stands; • GGBF prefer wetlands with sections of open water. Water depth should be deep enough to prevent Typha spreading across the entire pond area; the reeds should be mainly at the edge of ponds; • Substrate at edges should be suitable for reed growth (i.e. not too many pebbles, sandbags, etc.); • Areas of low blanketing vegetation are also desirable for GGBF breeding, for example, Paspalum grass and Shoenoplectus rush; • Establishing aquatic plants with planting after Closure Works: will maximise structural suitability of wetland to immigrating GGBF as soon as construction is completed. <u>Terrestrial vegetation:</u> • Stabilise new works with sterile millet (or other suitable cover crop); • Retain seed bank in fill taken from site (to be reused); • Avoid large tree species (as roots may potentially compromise the cap); • Allow terrestrial species to re-colonise Drainage culverts will, where practicable, be vegetated and lined with rocks and objects that may provide temporary frog refuge, in the event that a frog seeks to traverse the future capped area of KIWEF. Section 12 of the KIWEF Area 2 Preliminary Documentation Package, includes the incorporation of key attributes described under Section 7.4, within the design; and outlined the monitoring requirements (refer to Monitoring and Reporting section below).
Performance Criteria	Establish adequate vegetation coverage across the closure area. Where vegetation regrowth is sparse (ie less than 50% growth) in areas of greater than 10m2, the performance criteria will be considered to have failed and contingency measures are required. No deep-rooted vegetation (ie large shrubs or trees) on top of capped surface
Contingency Measures	Where Vegetation Coverage has been identified to be insufficient, the area will be reseeded. Where deep-rooted vegetation is identified on top of capped surface. The vegetation will be removed (mechanically where possible)

Revegetation Management Plan	
Responsibilities	The Contractor is responsible for undertaking the work, monitoring and maintenance of all elements of the revegetation management plan, until the completion of the construction maintenance period (indicatively 3 months post construction completion). The State (or its agent) is responsible for the monitoring and maintenance of all elements of the revegetation management plan and any rectification works, following the completion of the construction maintenance period.
Timeframe	Monthly monitoring and maintenance will continue for the duration of the construction works; and the construction maintenance period. The Post Construction monitoring and maintenance will continue (on a biannual basis) in accordance with the requirements of the Surrender Notice (or as superseded by new instruments directed by the EPA).
Monitoring & Reporting	Section 12 of the KIWEF Area 2 Preliminary Documentation Package, describes the monitoring and reporting requirements for Revegetation of the capped site, which includes: • Vegetation establishment will be visually monitored monthly during the construction works and construction maintenance period to identify any areas where vegetation is failing to establish. Should vegetation not establish within the construction maintenance period then targeted seeding and/or planting would be undertaken. • Biannual cap inspections will be undertaken following the construction maintenance period in accordance with the Surrender Notice (or as superseded by new instruments directed by the EPA), to ensure the cap surface remains stable and that vegetation roots do not have the opportunity to compromise the cap integrity.

Annex B

Water Quality Management Plan

Water Quality Management Plan	
Objective	To comply with State and Federal approval requirements. To manage water discharged from the construction works satisfactorily.
Targets	No significant sediment impacts to the surrounding environment and waterways from the construction works. To satisfy all water quality monitoring requirements under relevant approvals and licences.
Key Documents	**State Documents** NSW EPA (2010), Approval of the Surrender of a Licence – Licence 6437, (Ref: 1111840, and as varied by notice number 1510956 and 1520063). GHD (2009), Report on KIWEF, Revised Final Landform and Capping Strategy (Ref: 22/14371/85882 R4) ERM (2016), Review of Environmental Factors, KIWEF Area 2 Closure Works (Ref: 0320327-Review of Environmental Factors) **Commonwealth Documents** ERM (2015), KIWEF Area 2 Closure Works, EPBC Referral (Ref: 0320327_Final) ERM (2016), Response to Request for Information, KIWEF Area 2 Closure Works (Ref: 0320327-Response to Request for Information) Ramboll (2018), EPBC Referral, Preliminary Documentation Package – KIWEF Area 2 Closure Works (Ref: 318000395)
Sections of Key Documents Relevant to Water Quality	**State Approval Commitments** The commitments around Water Quality that were included within the State Approval documents are summarised within the following key documents and the respective relevant sections: • NSW EPA (2010), Approval of the Surrender of a Licence – License 6437 [condition 4d, 5c, 5d, and 5f, please note the groundwater and surface water monitoring required under conditions 5c, 5d and 5f are described in Section B1] • ERM (2016), Review of Environmental Factors, KIWEF Area 2 Closure Works [Sections 7.1 and 8] **Commonwealth Approval Documents and Sections** The commitments to manage Water Quality under the Commonwealth Approval documents are summarised within the following key documents and the respective relevant sections: • ERM (2015), KIWEF Area 2 Closure Works, EPBC Referral [Sections 4 and 5] • ERM (2016), Response to Request for Information, KIWEF Area 2 Closure Works [Section 5.1] • Ramboll (2018), EPBC Referral, Preliminary Documentation Package – KIWEF Area 2 Closure Works [Section 7.1 and 12]
Controls	**Commitments under State Approval documents** The EPA Approval of the Surrender of a Licence (as varied), includes the requirement to comply with the following commitments: • Condition 4d) The licensee shall implement, maintain and operate erosion and sedimentation controls during the final capping process to ensure that there is no sedimentation of waterways. • Condition 5c) The licensee shall undertake the groundwater monitoring program outlined in Table 1, 2 and 3 of the Surrender Notice. Monitoring locations are those groundwater bores identified in both the fill and natural aquifers as shown on the map attached to the Surrender Notice. • Condition 5d) The licensee shall undertake the surface water monitoring program outlined in Table 4 of the Surrender Notice. Monitoring locations are those groundwater bores identified in both the fill and natural aquifers as shown on the map attached to the Surrender Notice.

Water Quality Management Plan	
	• Condition 5f) If any samples collected from monitoring locations listed in Condition 5c) and 5d) show an increase in pollutant concentration at the boundary of the lands to which the Surrender License applies, HDC must commence capping works within 2 months of receiving the data. Capping works are to commence regardless of the progress of the T4 project unless otherwise agreed in writing by the EPA. *The key methods, locations, frequency, and duration of the monitoring program, investigation triggers, contingency measures and corrective actions are described in Section B1 of this Water Quality Management Plan.* Section 8 of the KIWEF Area 2 Review of Environmental Factors includes the following commitments: • That appropriate erosion and sediment control structures will be installed at least 30 metres upslope of known and potential GGBF habitat. These erosion and sediment control structures will be regularly inspected and maintained, particularly after significant rainfall events. This is also required under Section 5.1 of GGBF Management Plan. • The establishment of erosion and sedimentation controls and construction of sedimentation basins as required. This is also a requirement under Chapter 7 of the Final Landform and Capping Strategy • Adequate run-off, erosion and sedimentation controls should be in place during construction, particularly in areas where run-off has the potential to impact on nearby waterways, surrounding native vegetation, EEC regrowth, and existing drainage line and dam areas. This is also a requirement under Section 7.4 of the Final Landform and Capping Strategy, Flora and Fauna Impact Assessment • Development of an Erosion and Sedimentation Control Plan covering the works associated with the Proposal. Erosion and sediment controls are to be installed prior to construction, and maintained throughout construction, to minimise sediment entering the adjacent waterbodies, EECs and SEPP 14 wetland areas. This is also a requirement under Section 7.4 of the Final Landform and Capping Strategy, Flora and Fauna Impact Assessment General Mitigation measures described within the KIWEF Area 2 Review of Environmental Factors and Final Landform and Capping Strategy include: • Progressive erosion and sediment control plans (ESCPs) will be developed and implemented prior to the commencement of topsoil stripping and earthworks. • The development of ESCPs will be guided by the Blue Book and other guidelines where required. • Particular attention will be paid to the design criteria for sediment fences, catch drains, diversion drains, sandbags and similar controls. • Permanent drainage to be installed as early in the program as possible. • All water to be discharged in accordance with legislation. • Top soil/mulch stockpiles to be not greater than 2.0m in height. All stockpiles will be located clear of watercourses and drainage works. • Wastewater management facilities shall only be provided through proprietary storage and pump out systems. • All disturbed surfaces will be revegetated within 1 month of final land forming and in compliance with the landscaping plans. • Erosion and Sediment Control devices are to be maintained when their capacity has been reduced by 25%. • Toolbox talks will be conducted for employees and subcontractors on the requirements of the Erosion and Sediment Control Plan. • The Erosion and Sediment Control Plan is to be maintained and up to date for the current site conditions. • All temporary ESC works will be removed immediately prior to final completion and all surfaces will be returned to pre-existing condition. Surface water from capping areas is to be controlled by capture and retention in purpose-built sediment basins that provide retention of design runoff events. Erosion and sediment control will be designed, installed and managed as follows:

Water Quality Management Plan	
	• Design according to the environmental protection standards for sensitive environments based on Managing Urban Stormwater - Soils and Construction, (Landcom, 2004), as well as documents from other States and internationally (such as “International Erosion Control Association – Australasia”); • Construction of lined sediment basins, before clearing land from where runoff may be sourced; and • Basins to be retained post construction, where practicable and in consultation with adjacent land stakeholders. **Commitments under Commonwealth Approval documents** In addition to the State measures described above, the implementation of the following additional measures have been committed to within the Commonwealth Approval process. Section 4 of the KIWEF Area 2 EPBC Referral requires • The potential for indirect impacts to wetlands through sedimentation will be managed through the implementation of erosion and sediment control measures appropriate for sensitive environments. • The installation of hydro-salinity monitoring devises has been undertaken and will be monitored throughout the duration of capping with any identified significant changes in pond hydro-salinity attributable to the proposed activity to be investigated and mitigation measures explored. Section 5 of the EPBC Referral outlines the same measures as described under the KIWEF Area 2, Review of Environmental Factors documents described above. Section 5.1 of the KIWEF Area 2, EPBC Referral Response to RFI requires that: • The installation of hydro-salinity monitoring devices has been undertaken and will be monitored throughout the duration of capping with any identified significant changes in pond and hydro-salinity attributable to the proposed activity to be investigated and mitigation measures explored. • An adaptive response approach will be undertaken for GGBF habitat should salinity measure outside the range of comparison limits. Primarily when an impact to the population is observed a further detailed investigation will be undertaken aimed to fully understand reasons for the change. Section 7.1 of the KIWEF Area 2 Preliminary Documentation Package outlines the KIWEF Annual Surrender Notice Monitoring and the Continuous Data logging. Further details on the specific monitoring requirements of each program are provided in Section B1 and B2 respectively of this Water Quality Management Plan. Section 12 of the KIWEF Area 2 Preliminary Documentation Package, confirms: • Water monitoring at the KIWEF is undertaken consistently with the requirements of the Surrender Notice, which will be undertaken annually until the Surrender Notice is relinquished or as directed by the EPA. There are 50 monitoring wells and five surface water monitoring locations listed under the Surrender Notice • Thirteen monitoring points have been established in ponds across KIWEF to collect data for Salinity (electrical conductivity), Water level and Temperature. • Salinity trends will be compared against the GGBF population trends. Should a pattern be identified and a direct correlation be validated by a qualified ecologist, an appropriate management trigger and response will be developed

Water Quality Management Plan	
Performance Criteria	Discharge quality must comply with Performance Criteria: • TSS: < 50mg/Lt (~Turbidity 30NTU). • pH: Between 6.5 and 8.5. • Otherwise able to be demonstrated not to have caused pollution of waters. Performance Criteria for the KIWEF Annual Water Monitoring and Continuous Data Logging are detailed under Section B1 and Section B2 of this Water Quality Management Plan.
Contingency Measures	If Water Quality performance criteria is not suitable for discharge, other management measures must be implemented prior to discharge. These may include such things as: • If this cannot be achieved though natural settling, then the trapped sediment laden water is to be flocculated with gypsum applied at a rate of approx. 40kg/100m^3. • Dosing with appropriate buffers to neutralise water; • Other mitigation measures deemed appropriate. Contingency Measures for the KIWEF Annual Water Monitoring and Continuous Data Logging are detailed under Section B1 and Section B2 of this Water Quality Management Plan.
Responsibilities	**Construction and Maintenance Period** The Contractor is responsible for undertaking the work, monitoring and maintenance of all elements of the water quality management plan (except for the KIWEF Annual Water Monitoring described under Section B1; and the KIWEF Continuous Data Logging described under Section B2) until the completion of the construction maintenance period (indicatively 3 months post construction completion). The State (or its agent) is responsible for the monitoring described under the KIWEF Annual Water Monitoring described under Section B1; and the KIWEF Continuous Data Logging described under Section B2. **Post Construction and Maintenance Period** The State (or its agent) is responsible for the monitoring and maintenance of all elements of the water quality management plan and any rectification works, following the completion of the construction maintenance period.
Timeframe	Construction Water Quality and Erosion Sediment Controls will be maintained and monitored throughout the duration of site works. The KIWEF Annual Water Monitoring Program will be undertaken annually until the Surrender Notice is relinquished or as directed by the EPA. The Continuous Monitoring of Pond Water Quality Parameters will continue for 2 years post-construction. The Post Construction monitoring and maintenance will continue (on a biannual basis) in accordance with the requirements of the Surrender Notice (or as superseded by new instruments directed by the EPA).

Water Quality Management Plan	
Monitoring and Reporting	Daily visual monitoring by site supervisors. Weekly inspections to be documented on a Weekly Environmental Inspection Checklist. Maintenance activities for ESCPs shall be documented. All water quality data including quantity, quality and dates of water release will be maintained within the project records. The results of the KIWEF Annual Water Monitoring program are compared against historical analytical results, national groundwater investigation levels (NEPM and ANZECC). Discussion of the actions and contingency measures under this program is included in Section B1 of this Water Quality Management Plan. Data collected during the Continuous Monitoring of Pond Water Quality Parameters (temperature, water level and salinity concentration), are compared to established salinity threshold for chytrid protection. Discussion of the actions and contingency measures under this program is included in Section B2 of this Water Quality Management Plan. Biannual cap inspections will be undertaken following the construction maintenance period in accordance with the Surrender Notice (or as superseded by new instruments directed by the EPA), to ensure the cap surface remains stable. This will include inspection of any water quality features to determine whether they are functioning correctly, or if any rectification woks are necessary.

KIWEF Annual Water Quality Monitoring	
Objective	To satisfy all water quality monitoring requirements under NSW EPA Surrender Notice.
Targets	To submit an Annual Monitoring report to the EPA as specified under the Surrender Notice.
Key Documents	**State Documents** NSW EPA (2010), Approval of the Surrender of a Licence – License 6437, (Ref: 1111840, as varied by notice number 1510956 and 1520063). **Commonwealth Documents** Ramboll (2018), EPBC Referral, Preliminary Documentation Package – KIWEF Area 2 Closure Works (Ref: 318000395)
Sections of Key Documents Relevant to KIWEF Annual Water Quality Monitoring	**State Approval Commitments** The EPA Approval of the Surrender of a Licence (as varied), includes the requirement to comply with the following commitments: • Condition 5c) The licensee shall undertake the groundwater monitoring program outlined in Table 1, 2 and 3 of the Surrender Notice. Monitoring locations are those groundwater bores identified in both the fill and natural aquifers as shown on the map attached to the Surrender Notice.

Table 1 – Deep Estuarine Wells being K5/5S, K5/6S, K7/2N, K9/2E, K9/3N, K9/4W, K11/1S, K11/2W, K11/3W, K12/1E, K12/3N, K12/4N, K12/7E, K12/9E and K12/10

Pollutant	Units of Measure	Frequency	Sampling Method
Ammonia	mg/L	Every 12 months	Grab sample
Phenols[1]	mg/L	Every 12 months	Grab sample
Cyanide (Total, WAD and free)	mg/L	Every 12 months	Grab sample
Chromium (hexavalent)	mg/L	Every 12 months	Grab sample
Molybdenum (dissolved)[2]	mg/L	Every 12 months	Grab sample
Lead (dissolved)[3]	mg/L	Every 12 months	Grab sample
Total PAHs	mg/L	Every 12 months	Grab sample
Conductivity	mg/L	Every 12 months	Grab sample
pH	pH	Every 12 months	Grab sample

[1] Not required to be analysed at wells K5/5S, K9/2E, K9/4W

[2] Not required to be analysed at wells K5/5S, K5/6S, K7/2N, K9/4W

[3] Not required to be analysed at wells K5/5S, K5/6S, K7/2N, K9/2E, K9/4W

KIWEF Annual Water Quality Monitoring

Table 2 – Shallow Estuarine Wells being K3/1W, K5/6NN, K7/2S, K7/4S, K8/5W, K9/2W, K9/3S, K9/4E, K10/2NN, K11/1, K11/2E, K11/3E, K12/1W, K12/3W, K12/6, K12/7, K12/9, K12/10E, BHe29s, GHD02, E61D, 336B, 334B

Pollutant	Units of Measure	Frequency	Sampling Method
Ammonia	mg/L	Every 12 months	Grab sample
Phenols[4]	mg/L	Every 12 months	Grab sample
Cyanide (Total, WAD and free)	mg/L	Every 12 months	Grab sample
Chromium (hexavalent)	mg/L	Every 12 months	Grab sample
Molybdenum (dissolved)[5]	mg/L	Every 12 months	Grab sample
Lead (dissolved)[6]	mg/L	Every 12 months	Grab sample
Total PAHs	mg/L	Every 12 months	Grab sample
Conductivity	mg/L	Every 12 months	Grab sample
pH	pH	Every 12 months	Grab sample

[4] Not required to be analysed at wells K7/4S, K8/3W, K9/2W, K9/4E, K10/2NN

[5] Not required to be analysed at wells K5/6NN, K7/2S, K9/4E

[6] Not required to be analysed at wells K5/6NN, K7/2S, K9/4E, K7/4S, K9/2W, K9/4E

Table 3 – Fill Wells being K5/4, K5/5N, K5/6N, K7/4N, K8/5E, K10/2, K10/2N, K7/1, GHD01, E61S, 336A, 344A

Pollutant	Units of Measure	Frequency	Sampling Method
Ammonia	mg/L	Every 12 months	Grab sample
Phenols[7]	mg/L	Every 12 months	Grab sample
Cyanide (Total[8], WAD and free)	mg/L	Every 12 months	Grab sample
Chromium (hexavalent)	mg/L	Every 12 months	Grab sample
Molybdenum (dissolved)[9]	mg/L	Every 12 months	Grab sample
Lead (dissolved)[10]	mg/L	Every 12 months	Grab sample
Total PAHs	mg/L	Every 12 months	Grab sample
Conductivity	mg/L	Every 12 months	Grab sample
pH	pH	Every 12 months	Grab sample

[7] Not required to be analysed at wells K5/4, K5/5N, K7/4N, K8/5E, K10/2, K10/2N

[8] Not required to be analysed at wells K5/5N, K10/2, K10/2N

[9] Not required to be analysed at wells K5/4, K5/5N, K5/6N

[10] Not required to be analysed at wells K5/4, K5/5N, K5/6N, K7/4N

KIWEF Annual Water Quality Monitoring

- Condition 5d – The licensee shall undertake the surface water monitoring program outlined in Table 4 of the Surrender Notice. Monitoring locations are those groundwater bores identified in both the fill and natural aquifers as shown on the map attached to the Surrender Notice.

Table 4– Surface Water Monitoring at Locations KS2/1, KS1/3, K10/1, KS7/1, KS12/6

Pollutant	Units of Measure	Frequency	Sampling Method
Ammonia	mg/L	Every 12 months	Grab sample
Phenols	mg/L	Every 12 months	Grab sample
Cyanide (Total, WAD and free)	mg/L	Every 12 months	Grab sample
Chromium (hexavalent)	mg/L	Every 12 months	Grab sample
Molybdenum (dissolved)	mg/L	Every 12 months	Grab sample
Lead (dissolved)	mg/L	Every 12 months	Grab sample
Total PAHs	mg/L	Every 12 months	Grab sample
Conductivity	mg/L	Every 12 months	Grab sample
pH	pH	Every 12 months	Grab sample

- Condition 5f – If any samples collected from monitoring locations listed in Condition 5c) and 5d) show an increase in pollutant concentration at the boundary of the lands to which the Surrender License applies, HDC must commence capping works within 2 months of receiving the data. Capping works are to commence regardless of the progress of the T4 project unless otherwise agreed in writing by the EPA.

Commonwealth Approval Commitments

Section 7.1 of the KIWEF Area 2 Preliminary Documentation Package outlines the KIWEF Annual Surrender Notice Monitoring, which requires:

- Water monitoring at the KIWEF is undertaken consistently with the requirements of the Surrender Notice which will be undertaken annually until the Surrender Notice is relinquished or as directed by the EPA. There are fifty monitoring wells and five surface water monitoring locations listed under the Surrender Notice.

Scope of Monitoring

Fifty (50) Groundwater monitoring locations and five (5) surface water monitoring locations (refer to **Figure 1**) located across and surrounding the KIWEF facility were selected in consultation with the NSW EPA.

The Groundwater monitoring wells have been installed to target one of three aquifers present at Kooragang Island, including the Fill Aquifer, Shallow Estuarine Aquifer and the Deep Estuarine Aquifer.

The Surface Water monitoring locations were selected within various ponds within and surrounding the KIWEF.

KIWEF Annual Water Quality Monitoring	
Sampling Methods	**Groundwater Sampling** • The methodology for collection of samples is to be consistent with best industry practice, DECCW guidelines as well as AS 4482.1-2005, AS 4482.2-1999 and ASNZS 5667.11:1998. Please explicitly state if any departure is proposed and reasons behind any recommended departures. • Wells are to be dipped with an Interface Probe to record water levels and the presence of any phase separated hydrocarbons. • The purging (until parameters stabilise if using low-flow sampling techniques or three well volumes if bailing) and sampling of Groundwater locations is to be undertaking using equipment and methods that will minimise the disturbance of sediment within the well wherever possible. Previous sampling events have used Micro-Purge sampling equipment, with disposable bailers available as a back-up option. Note dedicated Micro-Purge tubing has been left within the wells at many locations. • All samples collected for dissolved metal analysis should be filtered in the field. • Sampling parameters are to reflect those specified in the Surrender Notice **Surface Water Sampling** • The methodology for collection of samples is to be consistent with best industry practice, DECCW guidelines as well as AS 4482.1-2005, AS 4482.2-1999 and ASNZS 5667.11:1998. Please explicitly state if any departure is proposed and reasons behind any recommended departures. • Grab samples are to be collected using a dedicated laboratory supplied non-preserved sample bottle attached to a telescopic arm (or similar); • Samples to be collected away from the edge of the water body (minimum 1m to avoid sediment disturbance); and where possible from a depth of 20cm below the surface (to reduce the potential of collecting organic materials); • Reusable equipment (eg telescopic arm) are to be decontaminated between sampling locations; • Sample bottles attached to telescopic arm are to be replaced between each sample location.
Sampling Frequency and Duration	Sampling is to be undertaken on an Annual basis (nominally between March and May) each year until the Surrender Notice is relinquished or as superseded by new instruments directed by the EPA.
Investigation Triggers	Results collected during the KIWEF Annual Water Quality Monitoring are assessed against: • the National Environmental Protection (Assessment of Site Contamination) Measure (2013), Groundwater Investigation Levels for Marine Waters in slight to moderately disturbed environments; • The Australian and New Zealand Environment Conservation Council and the Agriculture and Resource Management Council of Australia and New Zealand (ANZECC/ARMCANZ), Australia and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC, 2000), 95% Protection Level for Marine Environments in slightly to moderately disturbed systems; and • Historical analytical data from previous KIWEF monitoring
Reporting	An annual report that includes the results from the water sampling will be prepared and submitted to the EPA in accordance with the Surrender Notice requirements.
Contingency Actions	The results of the Water Quality monitoring are managed in accordance with Surrender notice and are administered through the provision of an Annual report to the NSW EPA.
Contingency Measures	Should management measures be determined to be necessary they may include such things as: • Further confirmatory investigation sampling and analysis.

KIWEF Annual Water Quality Monitoring	
	• Installation of additional monitoring locations to delineate the area influenced by the result observed, potentially also to identify the source. • Immediate capping of the site, in accordance with condition 5f) of the Surrender Notice. • Other measure deemed appropriate by a suitably experienced person or appropriate stakeholder.

Section B2 – KIWEF Continuous Data Logging

KIWEF Continuous Data Logging	
Objective	To satisfy Commonwealth Approval requirements for continuous monitoring of pond locations for salinity concentrations.
Key Documents	**State Documents** N/A **Commonwealth Documents** Ramboll (2018), EPBC Referral, Preliminary Documentation Package – KIWEF Area 2 Closure Works (Ref: 318000395)
State and Commonwealth Approval Commitments	**State Approval Commitments** N/A **Commonwealth Approval Commitments** Section 4 of the KIWEF Area 2 EPBC Referral requires • The installation of hydro-salinity monitoring devises has been undertaken and will be monitored throughout the duration of capping with any identified significant changes in pond hydro-salinity attributable to the proposed activity to be investigated and mitigation measures explored. Section 5.1 of the KIWEF Area 2, EPBC Referral Response to RFI requires that • The installation of hydro-salinity monitoring devices has been undertaken and will be monitored throughout the duration of capping with any identified significant changes in pond and hydro-salinity attributable to the proposed activity to be investigated and mitigation measures explored. • An adaptive response approach will be undertaken for GGBF habitat should salinity measure outside the range of comparison limits. Primarily when an impact to the population is observed a further detailed investigation will be undertaken aimed to fully understand reasons for the change. Section 7.1 of the KIWEF Area 2 Preliminary Documentation Package outlines the KIWEF Annual Surrender Notice Monitoring, which requires: • Thirteen monitoring points have been established in ponds across KIWEF to collect data for salinity (electrical conductivity), water level and temperature. • The loggers were installed in December 2015 to record the water parameters in 20-minute increments, and are typically downloaded every 6 months (nominally in November and May of each year). • Monitoring is to continue for an additional two years following completion of the Area 2 Closure Works. • The data would be considered against the water quality threshold values (for chytrid protection) and the results of the GGBF population monitoring.
Scope of Monitoring	Thirteen (13) pond monitoring locations were chosen throughout the KIWEF (refer to **Figure 2**). Data loggers are installed beneath the water level and above the sediment layer at the 13 monitoring locations to continuously take readings of salinity concentration, water level, and temperature. The data loggers are set to record the conditions in 20-minute increments. A dedicated barometric pressure logger is also set up onsite (also recording

<table>
<tr><th colspan="2">KIWEF Continuous Data Logging</th></tr>
<tr><td></td><td>20-minute intervals) to allow for compensation of the water level data (to account for variations in atmospheric pressure) and provide accurate readings of water levels in the KIWEF ponds.</td></tr>
<tr><td>Sampling Methods</td><td>Data Logger Download
Collect the specifics for each of the units including (but not limited too) – water to sediment depth, top of pipe to water height, top of pipe to datalogger height, water level above datalogger, datalogger recording interval.
Download the data off all (13) of the Levelogger units. Prior to reinstalling the Levelogger units, the units should be confirmed to be programmed to record water level, temperature and EC data at 20-minute intervals.
Download the data of the Barologger unit. Prior to reinstalling, the Barologger should be confirmed to record at 20-minute intervals.
Correct the water level data for each unit, using the downloaded Barologger data.</td></tr>
<tr><td>Download Frequency and Duration</td><td>The dataloggers are downloaded every 6 months (nominally in November and May of each year). Continuous monitoring using the dataloggers would carry on for an additional two years following completion of the Area 2 Closure Works.</td></tr>
<tr><td>Investigation Triggers</td><td>Salinity results downloaded from the dataloggers will be compared to established salinity threshold for chytrid protection (shown below):
Suggested Salinity Comparison Values for KIWEF Surface Water Bodies
<table>
<tr><th>No Chytrid Protection</th><th>Chytrid protection threshold[1]</th><th>GGBF tadpole health threshold[2] (μS/cm)</th><th>GGBF Adult health threshold [3] (μS/cm)</th></tr>
<tr><td>0 – 1,650 μS/cm</td><td>1,650 μS/cm</td><td>2,900 μS/cm</td><td>4,100 μS/cm</td></tr>
</table>
1. EC below threshold presents increased risk of mortality resulting from Chytrid Fungus.
2. EC above threshold indicates unsuitability for GGBF tadpole survival.
3. EC above threshold indicates unsuitability as GGBF adult habitat.

The threshold values will be plotted alongside the salinity concentration data for ease of observation.</td></tr>
<tr><td>Reporting</td><td>A Factual Report will be prepared following each download event. The Factual Report should:
Include a summary of the works completed,
Update the Data Logger location data,
Provide a figure of the KIWEF Logger locations
Provide charts of the barometric corrected water level and EC data. The charts should also illustrate the established chytrid protection thresholds (refer to the above table) and daily rainfall totals.
The results of the Factual Datalogger Report will be considered in conjunction with the Annual GGBF population monitoring program.</td></tr>
<tr><td>Contingency Actions</td><td>Actions to remedy a shift in observed salinity levels:
Review any actions being taken in the immediate surroundings in the proceeding 12 – 24 months, to identify whether the Area 2 works are the cause of the change;</td></tr>
</table>

KIWEF Continuous Data Logging	
	• Review GGBF population modelling to identify if the changes in salinity has effected the GGBF population.
Contingency Measures	The measures will be developed following the completion of the review process outlined under the Contingency Actions section and consultation with relevant stakeholders. If triggered, the State will engage a suitably qualified expert in hydro-salinity processes to establish an appropriate mechanism to adjust salinity dynamics, if it has been shown that significant changes are attributable to the capping works.