Groundwater Dependent Ecosystems at Tallawarra

Risk Assessment - Update

Prepared for
TRUenergy

19 April 2012

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ACKNOWLEDGEMENTS

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Abbreviations

ABBREVIATION	DESCRIPTION
ANZECC	Australian and New Zealand Environment and Conservation Council
ARMCANZ	Agriculture and Resource Management Council of Australia and New Zealand
ASS	Acid Sulphate Soil
ASSMP	Acid Sulphate Soil Management Plan
CEMP	Construction Environmental Management Plan
DECCW	Department of Environment, Climate Change and Water
DGRs	Director General's Requirements
DoP	Department of Planning
ELA	Eco Logical Australia
EP&A Act	*Environmental Planning and Assessment Act 1979*
EPBC Act	*Environment Protection and Biodiversity Conservation Act 1999*
FM Act	*Fisheries Management Act 1994*
GDE	Groundwater Dependent Ecosystem
POEO Act	*Protection of Environment Operations Act 1997*
TSC Act	*Threatened Species Conservation Act 1995*

Executive Summary

TRUenergy has commissioned Eco Logical Australia (ELA) to undertake further assessment of Groundwater Dependent Ecosystems (GDEs) at Tallawarra. The purpose of this report is to describe and document the presence of GDEs on site and to assess potential impacts to these from the proposed development. The outcomes of this report are presented in a risk assessment framework.

GDEs are defined as ecosystems whose current composition, structure and function are reliant on a supply of groundwater. At Tallawarra, these are predominantly wetland ecosystems concentrated in the southern areas of the site including artificial wetlands in the ash ponds, SEPP 14 wetlands, saltmarsh, forested wetlands and adjacent aquatic ecosystems (seagrass). The precise level of dependency of these ecosystems on groundwater, whilst unquantified, is likely to be determined by the ecosystem type and the availability of suitable quality groundwater.

Groundwater dynamics at Tallawarra are not fully understood, and recent geotechnical investigations have highlighted elevated levels of heavy metals and ammonia in groundwater in the ash ponds exceeding ANZECC/ARMCANZ (2000) guidelines. Elevated levels of arsenic, copper, nickel, zinc and ammonia have been recorded (Coffey 2010b). Heavy metals and ammonia have the potential to have significant negative effects on wetland and aquatic ecosystems.

There are a number of potential impacts to GDEs associated with the proposed development at the Tallawarra site. Many of these apply to terrestrial ecosystems as well as GDEs and are considered in detail in Eco Logical Australia (2011a) and are reviewed in this report. Other impacts apply specifically to GDEs. These include alterations to the groundwater recharge system, contamination and release of acid sulphate soils. These are examined in detail in this report.

Alterations in groundwater recharge may occur as a result of increased area of impervious surfaces and vegetation clearing (Coffey 2010c & 2012). However, broadly, the degree of groundwater dependency of the GDEs is thought to be minimal with higher dependency on the surface water and tidal water. As such, impacts to GDEs from a potentially altered groundwater regime are not expected to be significant.

GDEs may also be impacted by release of contaminants or acid sulphate solids caused by construction however it is difficult to quantify the level of impact.

A risk assessment framework was developed to assess the risk of significant impacts to GDEs from the proposed development at Tallawarra in the absence of specific and determinative information. The risk to GDEs posed by most development actions is low, as impacts can be adequately mitigated and managed. The risk posed by contamination to GDEs has also been assessed as low however this is on the basis of appropriate and adaptive management particularly during construction through a CEMP. Potential risks from coastal hazards, particularly climate change induced sea level rise have also been considered.

Recommended mitigation and management measures are provided.

1 Introduction

TRUenergy commissioned Eco Logical Australia (ELA) in 2010 to undertake further assessment of Groundwater Dependent Ecosystems (GDEs) at Tallawarra. This was an extension of an environmental assessment completed by Eco Logical Australia (ELA) in 2010 which was further informed by information which became available covering groundwater and contamination at the site. The study extended the previous assessment of potential impacts to GDEs by way of a risk assessment and with specific reference to exceedances in heavy metal and ammonia trigger values reported during geotechnical and groundwater contamination investigations (Coffey 2010a, b & c). This current report is an update to the 2010 GDE risk assessment given the groundwater assessment modelling report prepared by Coffey (2012).

The aims of this investigation are to:

- Document the presence of GDEs at the site
- Document the presence of aquatic ecosystems on or adjacent to the site that may have interactions with groundwater (and be considered as groundwater dependent)
- Assess the potential impacts to GDEs and any groundwater related aquatic environments from the proposed development in a risk assessment framework
- Provide recommendations for mitigating and/or managing risks.

This investigation is a desk-top study, and draws on the on-ground ecological assessments undertaken by Eco Logical Australia (2006, 2011a), recent groundwater studies (Coffey 2010a, b, c & 2012) and other existing literature.

1.1 GROUNDWATER DEPENDENT ECOSYSTEMS

Groundwater Dependent Ecosystems (GDEs) are defined as ecosystems whose current composition, structure and function are reliant on a supply of groundwater (Eamus 2009). This reliance may be expressed over a range of timescales from daily to inter-annually, however, it becomes clearly apparent when the supply of groundwater, and/or its quality, is altered for a sufficient length of time that changes in ecological function result. It should be noted that groundwater use does not necessarily equate to groundwater dependence (Dresel et al. 2010).

In Australia, the majority of ecosystems have little dependence on groundwater, although the understanding of the role of groundwater in maintaining ecosystems is generally poor. The exception to this is wetland communities, for which it is thought that most have some dependence on groundwater, ranging from a minor to essential interaction (Hatton and Evans 1998).

GDEs are generally classified into six categories (SCCG 2006, SKM 2001):

- ***Terrestrial vegetation*** – forests and woodland which develop a permanent or seasonal dependence on groundwater, often by extending roots into the water table.
- ***Base flow in streams*** – aquatic and riparian ecosystems that exist in or adjacent to streams fed by groundwater base flow.
- ***Aquifer and cave systems*** – aquatic ecosystems that occupy caves or aquifers. Generally these occur in karst or limestone areas, and the alluvial aquifers along most large rivers.

- ***Wetlands*** – aquatic communities and fringing vegetation that depend on groundwater contribution to lakes and wetlands.
- ***Estuarine and near-shore marine ecosystems*** – various ecosystems including mangroves, saltmarsh and seagrass, and the faunal communities that they support, whose ecological function has some dependence on groundwater discharge.
- ***Terrestrial fauna*** – fauna species assemblages reliant on groundwater for drinking water.

GDEs have varying degrees of dependency on groundwater. These range from total to occasional dependency and include (SCCG 2006, SKM 2001):

- ***Entirely dependent*** – ecosystems where a permanent connection to groundwater is essential, and for which only a slight change in the groundwater regime can have catastrophic consequences.
- ***Highly dependent*** – ecosystems for which moderate changes in the groundwater regime will result in significant changes to ecosystem distribution, health and/or diversity. These ecosystems use both ground- and surface water.
- ***Proportionally dependent*** – ecosystems for which changes in the groundwater regime result in a proportional response to the ecosystem characteristics.
- ***Opportunistically or minimally dependent*** – ecosystems for which the reliance on groundwater is limited to seasonal or climatic variations e.g. end of dry season or drought. These ecosystems use surface water predominantly, however if access to groundwater is prolonged, declines in ecosystem distribution, health and/or diversity are likely.

A final category is also recognised – ***not apparently dependent***. This category acknowledges that some ecosystems, particularly wetland and riparian vegetation, might superficially appear to be groundwater dependent, but in actual fact are dependent entirely on surface flows and/or rainfall.

Various elements of the groundwater regime influence GDEs. These elements include (SKM 2001):

- Flow or flux – the rate and volume of groundwater supply
- Level – the depth below the water table surface
- Pressure (for confined aquifers) – exchange between the head of the aquifer and the groundwater discharge areas
- Quality – the chemical quality of groundwater including pH, salinity and other constituents such as nutrients and contaminants.

1.2 THREATS TO GDES

There are a number of pressures that may threaten GDEs. Threatening processes may act on the ecosystem itself and/or on the groundwater and other hydrologic processes upon which they depend. The main factors that threaten ecological processes in groundwater dependent ecosystems in Australia are listed below (SSCG 2006, DLWC 2002):

- Direct extraction of groundwater
- Reductions in groundwater recharge
- Draining or infilling wetlands
- Clearing wetland and/or riparian vegetation
- Change in land use, particularly those requiring cleaning of native vegetation such as urban development, agricultural and/or forestry
- Commercial, urban, industrial or domestic contamination
- Salinisation

- Activation of acid sulphate soils in coastal areas
- Weed infestation
- Impacts from mining related activities

1.3 LEGISLATIVE FRAMEWORK

Numerous laws and policies are applicable to GDEs in NSW. The most directly applicable are the *Water Management Act 2000* (WMA)[1] and the NSW Groundwater Dependent Ecosystem Policy (2002).

The WMA lists as one of its water management principles that: "water sources, floodplains and dependent ecosystems (including groundwater and wetlands) should be protected and restored and, where possible, land should not be degraded" (Section 5(2)(a)).

The Groundwater Dependent Ecosystem Policy is designed to protect GDEs and ensure the ecosystems and their functioning are protected and (where possible) restored. The policy also provides guidance on how to protect and manage GDEs in a practical sense. It sets out five principles for management of GDEs in NSW:

- The scientific, ecological, aesthetic and economic values of GDEs, and how threats to them may be avoided, should be identified and action taken to ensure that the most vulnerable and the most valuable ecosystems are protected.
- Groundwater extractions should be managed within the sustainable yield of aquifer systems, so that the ecological processes and biodiversity of their dependent ecosystems are retained and/or restored. Management may involve establishment of threshold levels that are critical for ecosystem health and controls on extraction in the proximity of GDEs.
- Priority should be given to ensuring that sufficient groundwater of suitable quality is available at the times when it is needed:
  - for protecting ecosystems which are known to be or are most likely to be groundwater dependent and
  - for GDEs which are under an immediate or high degree of threat from groundwater related activity.
- Where scientific knowledge is lacking, the precautionary principle should be applied to protect groundwater dependent ecosystems. The development of adaptive management systems and research to improve understanding of these ecosystems is essential to their management.
- Planning, approval and management of development, water use and land use activities should aim to minimise adverse impacts on GDEs by:
  - maintaining (where possible) natural patterns of groundwater flow and not disrupting groundwater levels that are critical for ecosystems
  - not polluting or causing adverse changes in groundwater quality
  - rehabilitating degraded groundwater systems where practical.

Other relevant legislation and policy includes:

- *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) – many GDEs and the species they support are protected under the EPBC Act. This may include endangered

[1] Note that as the Tallawarra lands development is being assessed under Part 3A of the EP&A Act, it is exempt from water use, water management and activity approval under the WMA. The Office of Water is consulted in the development of EA requirements and in the proposal's assessment with regard to water management policy.

ecological communities, threatened species and/or migratory species and sites that are listed as Wetlands of International Importance i.e. Ramsar sites.

- *Environment Planning and Assessment Act 1979* (EP&A Act) – requires impacts of development proposals on GDEs to be assessed.
- *Threatened Species Conservation Act 1995* (TSC Act) – many GDEs and the species they support are protected through listing as endangered ecological communities and threatened species.
- *Fisheries Management Act 1994* (FM Act) – many GDEs and the species they support are protected through listing as endangered ecological communities and threatened species
- *Protection of the Environment Operations Act 1997* (POEO Act) – regulates activities that may result in contamination of GDEs though water, air and noise pollution and waste management.
- *SEPP 14 Coastal Wetlands* – aims to preserve and protect coastal wetlands, many of which may be GDEs.
- *NSW Wetlands Policy* – promotes the sustainable conservation, management and wise use of wetlands, many of which may be GDEs.

The *Contaminated Lands Management Act 1997* (CLM Act as amended) enables the Department of Environment, Climate Change and Water (DECCW – previously the EPA) to respond to contamination that it has reason to believe is "significant enough to warrant regulation". The 2003 review of the Act removed the previous concept of "significant risk of harm" and enabled DECCW to declare land to be "significantly contaminated land" for the purposes of regulation.

The planning and development control process under the *Environmental Planning and Assessment Act 1979 (EP&A Act)* also triggers consideration of contamination through State Environmental Planning Policy 55 - Remediation of Land (SEPP55). It aims to ensure that land is not allowed to be put to a use that is inappropriate because of the presence of contamination and prescribes that planning authorities consider contamination issues when they are making rezoning and development decisions.

This report deliberately addresses only the risk of identified contamination under the proposed development scenario on potential GDEs in the locality. Eco Logical Australia is not qualified to provide contamination or remediation advice in regard to the CLM Act or SEPP 55.

2 Tallawarra Lands

2.1 SURFACE AND GROUNDWATER AT TALLAWARRA

The following information concerning the hydrology of the Tallawarra Lands site is summarised from Coffey (2010a, b, c & 2012).

2.1.1 Surface water

In areas north of Yallah Bay Road, surface water is expected to follow the land topography initially, discharging into several unnamed watercourses and farm dams that occupy this area of the site. Some of these watercourses appear to flow into Duck Creek or directly into Lake Illawarra. The area south of Yallah Bay Road is bisected by Duck Creek which flows from the northwest to the east before discharging into Lake Illawarra. Wollingurry Creek and several drains/unnamed watercourses occupy this area of the site and flow into Duck Creek. This area of the site is also occupied by three ash settling ponds which have been mostly filled with ash derived from the former coal fired power station. One of the ponds (Ash Pond 3) in the western portion of this area of the site was only partially filled with ash allowing the remaining unfilled areas to be filled with water.

2.1.2 Groundwater

The depth to groundwater at Tallawarra is likely to vary across the site, increasing in the elevated areas and decreasing in the lower lying areas. Groundwater flow is likely to follow the topography of the land and flow generally towards the east and southeast. In the more elevated areas north of Yallah Bay Road, it is likely that the groundwater will occur in fractures or extremely weathered seams of the Budgong Sandstone. South of Yallah Bay Road, Quaternary estuarine and alluvial sediments underlie most of the site. The water table in this sedimentary aquifer is likely to be relatively shallow, particularly in the lower lying areas.

Groundwater monitoring wells were installed across the Tallawarra site in 2010 and indicate water table depths of 0.6 – 7.09 m below ground level.

2.1.3 Contamination

Coffey Environments recently completed a geotechnical, contamination and groundwater assessment of the Tallawarra lands (Coffey 2010a). With respect to groundwater quality, the assessment identified elevated concentrations of heavy metals (including arsenic, copper, nickel and zinc) and ammonia above the adopted investigation levels for protection of aquatic ecosystems (Coffey 2010b).

Marine water trigger values[2] were considered applicable for investigating chemical concentrations in groundwater at the investigation area, as the receiving body (Duck Creek and Lake Illawarra) is a marine water body.

[2] Australia and New Zealand Environment and Conservation Council (ANZECC) Guidelines for Fresh and Marine Water Quality 2000 (ANZECC 2000)

Elevated concentrations of heavy metals and ammonia were reported in groundwater collected from monitoring wells targeting the ash ponds and were presumed to be from the power station ash and coalwash (Coffey 2010a). It is noted that the some of the contaminant concentrations in groundwater, exceeded trigger values in the NSW DECCW (2009) *Guidelines on the Duty to Report Contamination under the Contaminated Land Management Act 1997* and have since been duly reported and displayed visually in **Figure 1**.

An additional report by Coffey was commissioned to provide a further level of assessment of the significance of the heavy metal and ammonia exceedances recorded in the groundwater (Coffey 2010b). The results of the additional sampling indicate exceedances of heavy metals and ammonia above the adopted investigation levels at background locations, within the ash ponds and inferred down gradient locations.

2.1.4 Hydrology

Based on the results of a preliminary hydrogeological assessment (Coffey 2010c), the following was concluded:

- Groundwater flow south of Duck Creek is to the north east towards Duck Creek, to the east towards Lake Illawarra and to the south east towards Macquarie Rivulet. Groundwater flow north of Duck Creek is radial from the elevated Ash Pond 1 and 2 areas, towards Duck Creek and Lake Illawarra (see **Figure 2**).
- Groundwater flow from the ash ponds to the surrounding environment is assessed as being predominantly vertical flow through the base of the ponds rather than horizontal flow through the bund walls (see **Figures 3, 4 & 5**).
- Vertical hydraulic conductivity values were assessed as similar for the ash material (0.0007 m/day) and alluvial/estuarine sediment (0.0009 m/day).
- The potential volumes of groundwater recharge from the ash ponds were assessed as a total flow of 328 ML/year. In the long term the maximum seepage rate would be limited by the rate of rainfall recharge to the ash.
- During construction excavation it will be important not to create preferential pathways for the groundwater to discharge directly to receptors such as Duck Creek and Lake Illawarra. Mitigation measures would include limiting excavation in ash pond bund walls, and if excavation is to take place, engineering controls such as sheet piles should be used to provide a barrier to groundwater flow.
- Increased hardstand and buildings across the site will locally reduce rainfall recharge.
- Clearing of approximately 27 hectares of vegetation will decrease evapotranspiration rates in the local area and therefore groundwater levels may rise.
- There may be a net increase in groundwater levels within the Ash Pond 2 area due to clearing of trees and a potential decrease in groundwater level within the Ash Pond 3 area due to impermeable surfaces. The amount of change will depend on rainfall recharge rates, evapotranspiration rates, and for Ash Pond 3, the amount of recharge infiltrating from the lake to the groundwater system.
- Development of an impermeable surface on Ash Pond 2 and Ash Pond 3 will result in less rainfall infiltration through the ash material and will also act to minimise the conduit effect of

previous boreholes drilled within the ash ponds. This is considered as a benefit as less groundwater flow from the ash ponds may result. To quantify such changes in groundwater flow numerical groundwater simulation would be required.

2.1.5 Summary from Coffey (2010a, b &c)

The results of the further investigations which are relevant to this GDE risk assessment are listed below:

- All background concentrations exceeded ANZECC/ARMCANZ (2000) Australian and New Zealand Guidelines for Fresh and Marine Water Quality threshold concentrations for all tested contaminants;
- Arsenic, nickel and ammonia concentrations in the Ash Ponds were higher than background levels;
- The highest arsenic concentrations were recorded within the groundwater in the ash ponds and show a decreasing concentration trend downslope of the ash ponds. That the arsenic investigation levels have a low reliability trigger value and are likely to be conservative;
- Copper was recorded at concentrations within background ranges;
- The highest nickel concentrations were recorded within the groundwater in the ash ponds and show a decreasing concentration trend downslope of the ash ponds;
- The highest zinc concentrations were recorded downstream of the ash ponds;
- Based on the concentrations of metals recorded in groundwater within and downslope of the ash ponds, it is likely that the ash, coalwash and/or fill used in the ash ponds contributed to the observed higher metal concentrations in the groundwater.
- The highest ammonia concentrations were recorded in groundwater downslope of the ash ponds;
- These exceedances do not appear to be translating to the receiving surface water environment where concentrations are generally within background ranges (but above trigger levels for arsenic, nickel and zinc).
- Groundwater flows south of Duck Creek is to the north east towards Duck Creek, to the east towards Lake Illawarra and to the south east towards Macquarie Rivulet. Groundwater flow north of Duck Creek is radial from the elevated Ash Pond 1 and 2 area, towards Duck Creek and Lake Illawarra.
- Groundwater flowing (vertically) from the ash ponds is likely to reduce as a result of the development.
- Groundwater flow from the ash ponds to the surrounding environment is assessed as being predominantly vertical flow and decrease as a result of the development of an impermeable surface on ash ponds 2 and 3.

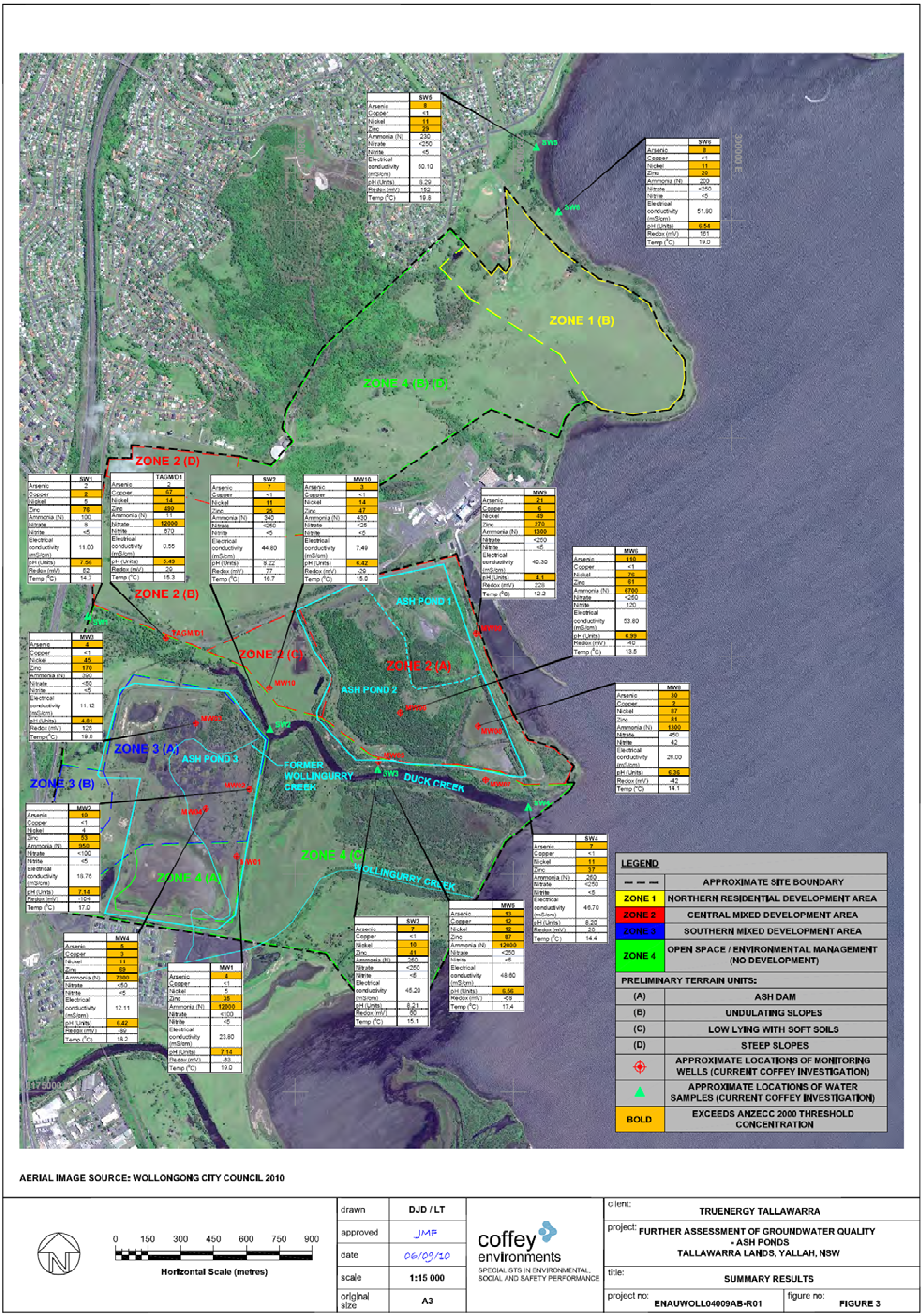


Figure 1: Results of groundwater contamination testing at Tallawarra (Coffey 2010b).

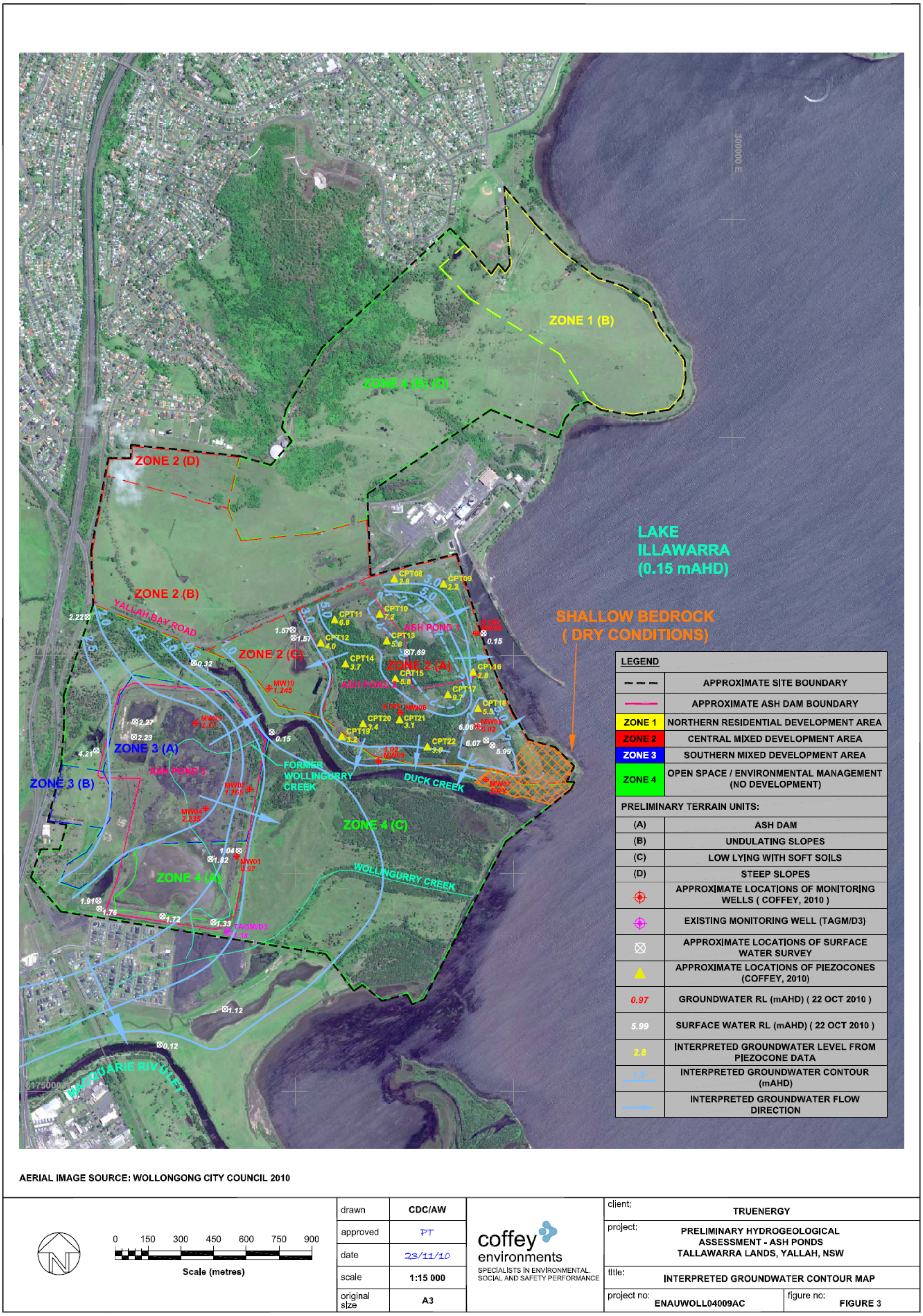


Figure 2: Interpreted groundwater contour map for Tallawarra (Coffey 2010c).

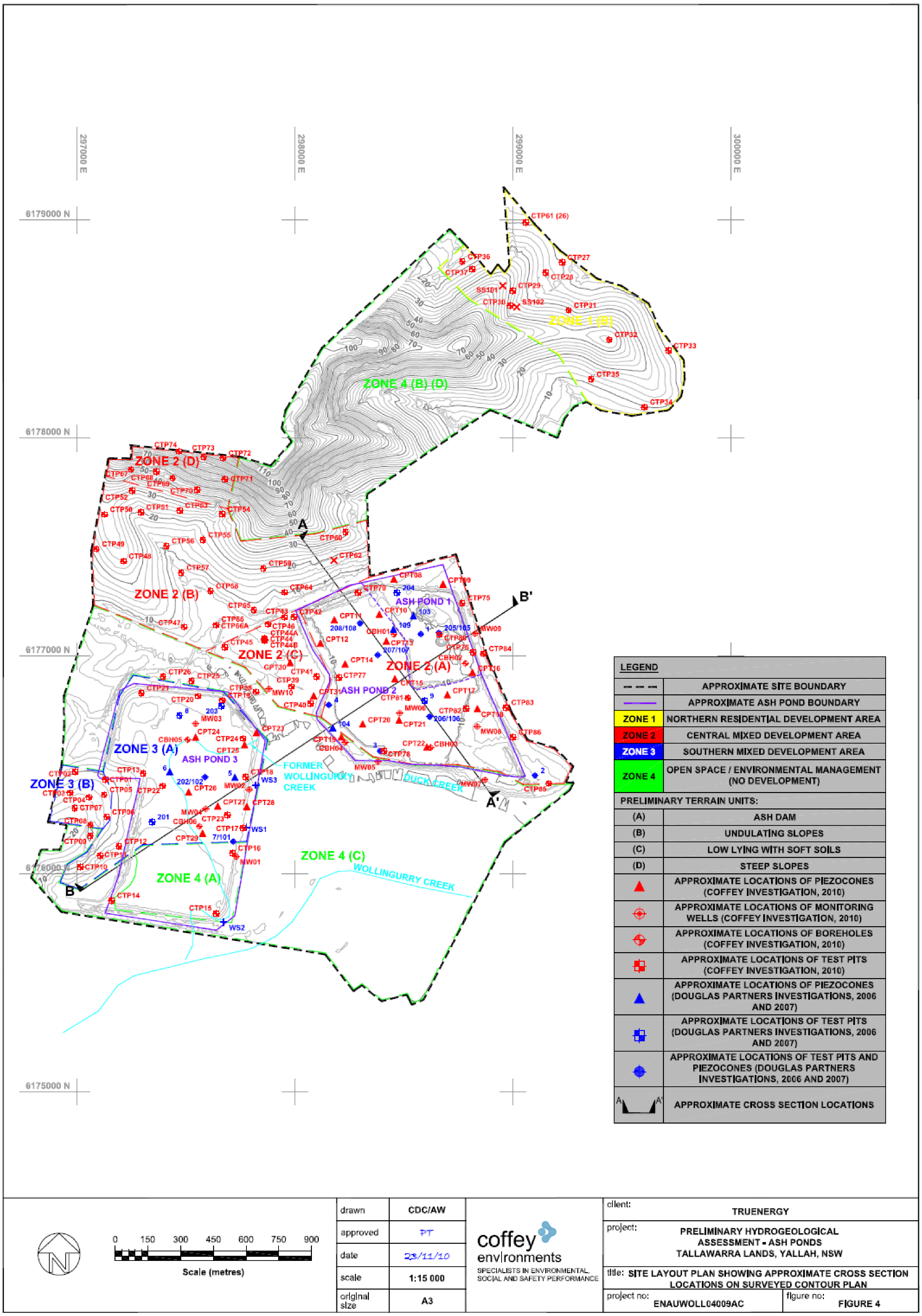


Figure 3: Cross section locations (Coffey 2010c).

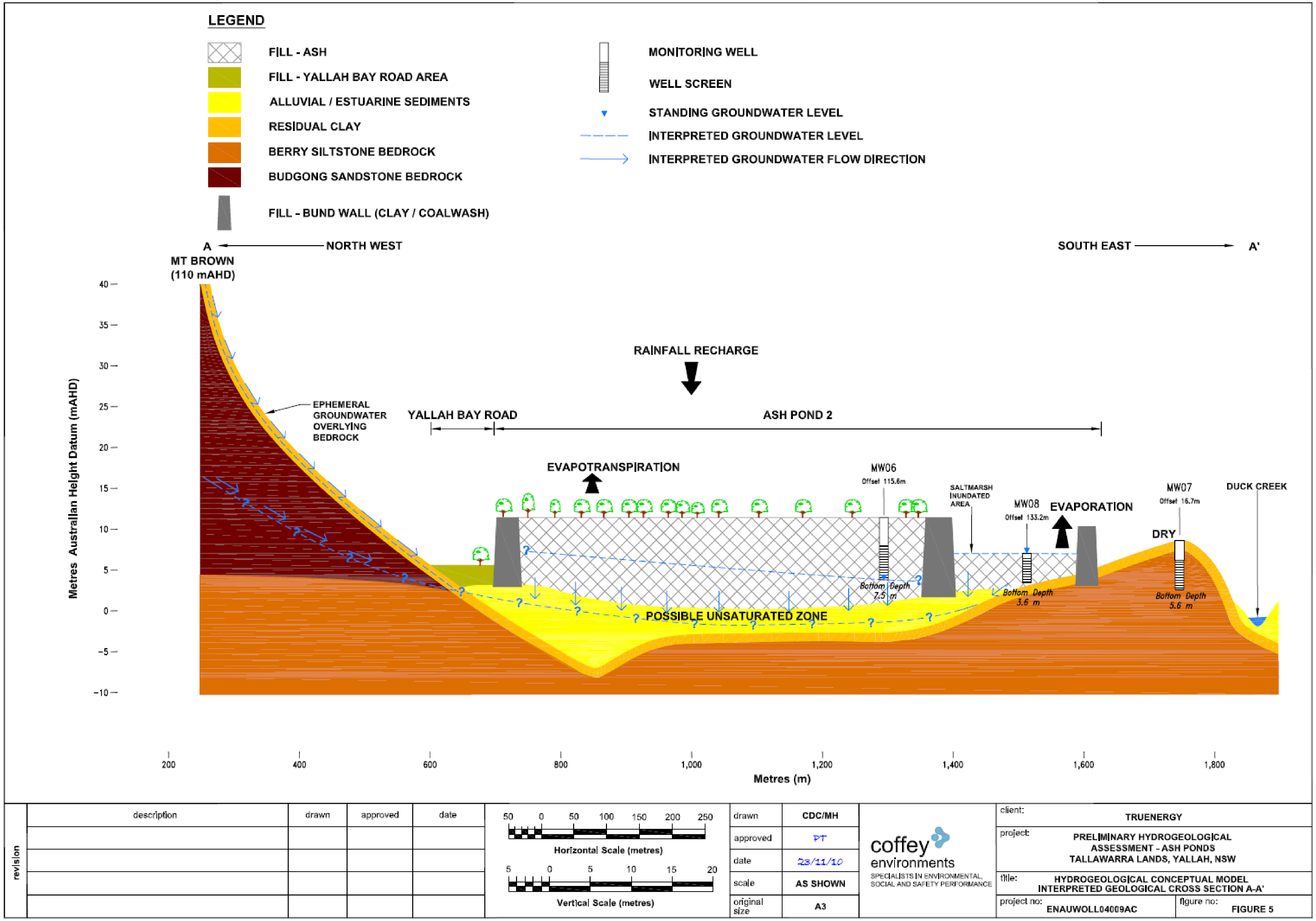


Figure 4: Cross section A-A (Coffey 2010c).

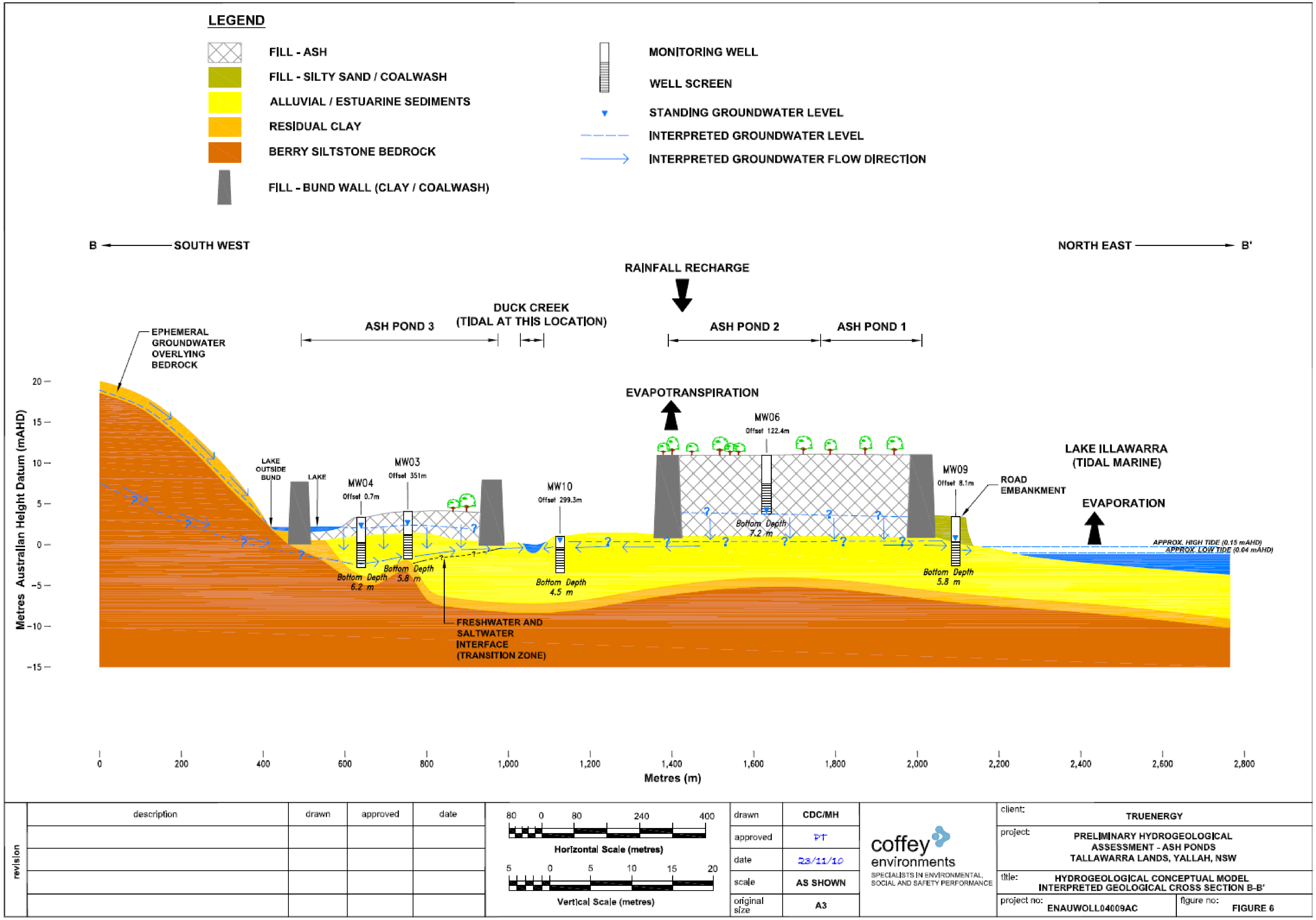


Figure 5: Cross section B-B (Coffey 2010c).

Based on the level of information in Coffey (2010a, b & c), the fate and transport mechanisms for the heavy metals and ammonia are not well understood. It is possible that the transport of contaminants to surface water may be retarded by the presence of clayey subsoils and the bund walls of the ponds. Sampling along Duck Creek has suggested that the elevated metal and ammonia concentrations in groundwater do not appear to be significantly influencing concentrations in this receiving water body. Duck Creek is a much smaller water body than Lake Illawarra and contaminant concentrations should be evident to a greater extent in this system if Duck Creek was receiving substantial influx of groundwater. A possible alternative explanation is that the contaminants are discharging through diffuse groundwater flow into Duck Creek, but the contaminants are moved downstream before they have a chance to concentrate.

Coffey conclude that:

> *The results of this assessment have indicated that background groundwater and surface water have a base load of heavy metals and ammonia, with metal concentrations which exceed the adopted trigger values (ANZECC 2000). Heavy metal and ammonia concentrations in groundwater within and downslope of the ash ponds were generally higher than background concentrations. However, these exceedances do not appear to be translating to the receiving surface water environment where concentrations are generally within background ranges. Based on the age of the ash ponds, it is considered unlikely that there would be significant changes in surface water quality into the future.*

Coffey (2010b p14) recommend that any future disturbance to the ash ponds should take into consideration the groundwater issues and ensure that the disturbances avoid creating preferential pathways for groundwater to discharge directly into the surrounding receiving environment. Mitigation measures suggested include limiting excavation in ash pond bund walls, and if excavation is to take place, engineering controls such as sheet piles to provide a barrier to groundwater flow.

Sediment contamination

Whilst monitoring the chemical and physical properties of the water column can give insight into environmental stress, pollutants can also be present in both sediments and porewaters[3]. Metals are known to preferentially absorb to silts and clays, causing the sediment to become a storage area for pollution. Concern lies in the capacity of this storage, and the possibility of sediments becoming a source rather than a sink of pollutants if the chemicals within the sediment are liberated by altered physical, chemical or biological characteristics of the environment.

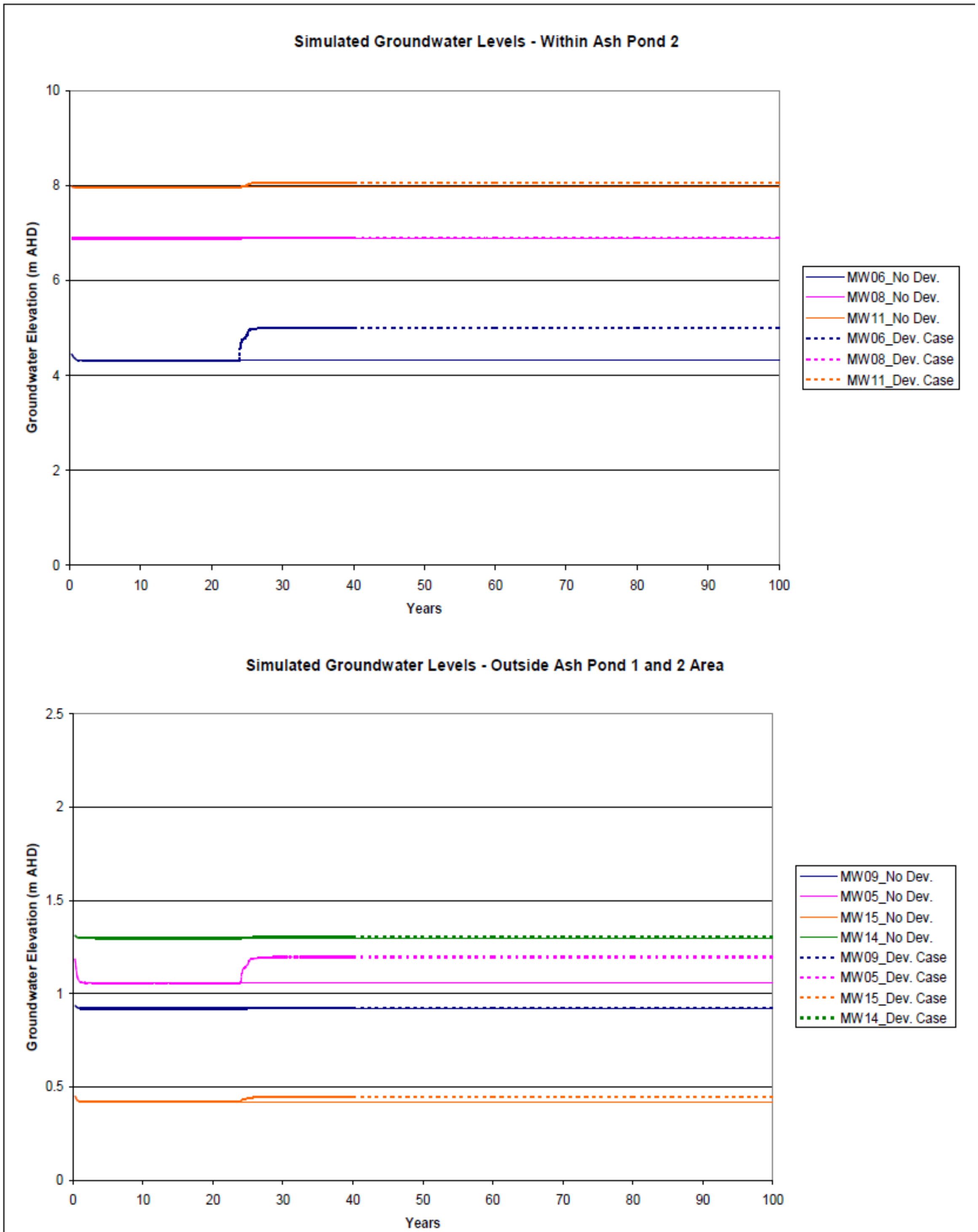
Recent geotechnical investigations by Coffey (2010a & b) did not undertake any sediment testing on the Tallawarra Lands. However, investigations over several years have indicated elevated levels of trace elements in bed sediments of Lake Illawarra (WBM Oceanics 2006). These include zinc, lead, copper, manganese and cadmium and are likely to have come from the highly industrialised northern region and the (now) decommissioned coal fired Tallawarra Power Station and a comprehensive road and freeway system around the lake perimeter. Trace elements can enter the lake via a number of transport mechanisms such as stormwater runoff, groundwater and atmospheric deposition.

[3] Porewater refers to the water that fills the space between the grains of sediment.

2.1.6 Groundwater Modelling

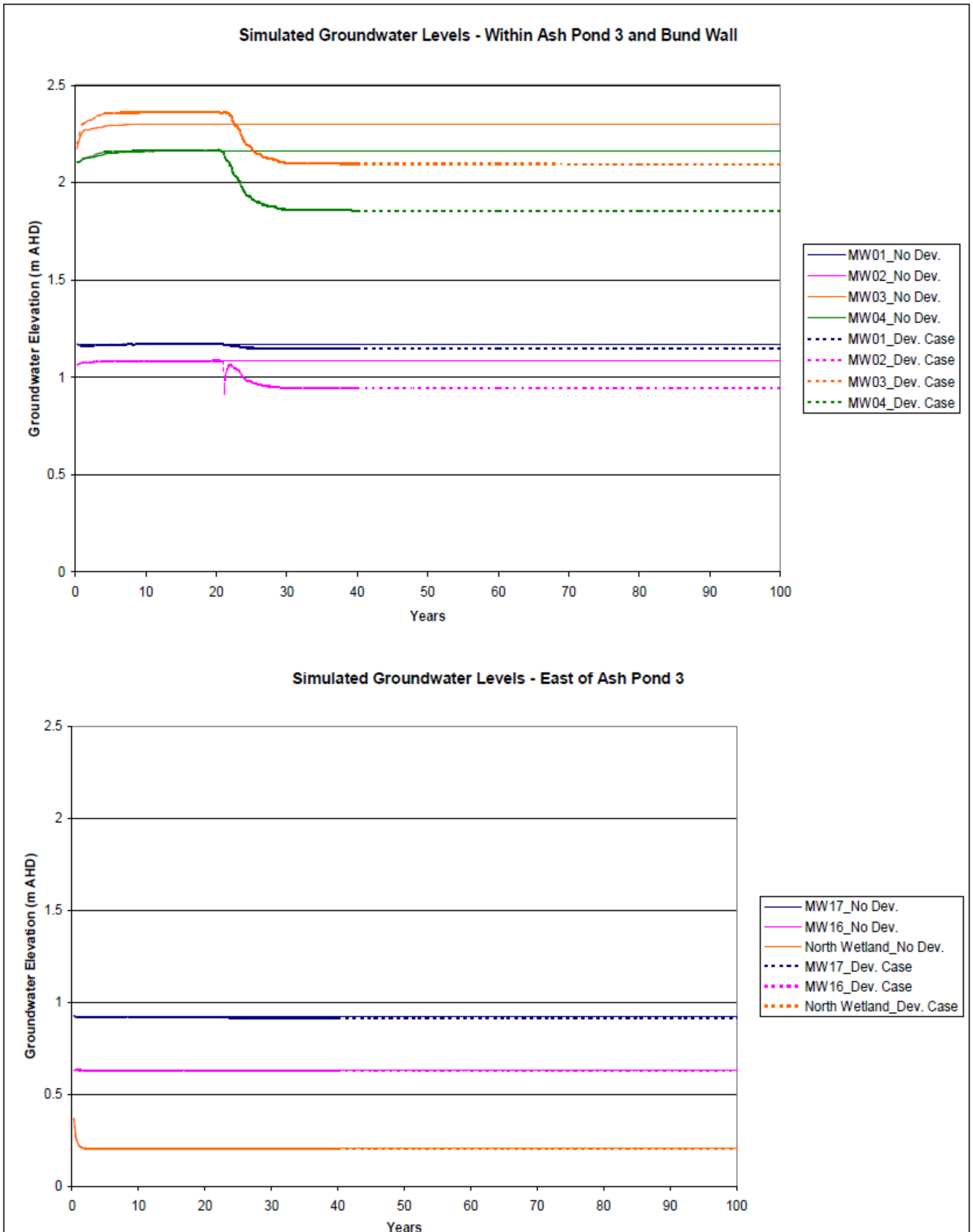
The groundwater modelling assessment completed by Coffey (2012) suggests the following:

- Groundwater flow south of Duck Creek is to the north east towards Duck Creek, to the east towards Lake Illawarra and to the south east towards Macquarie Rivulet. Groundwater flow north of Duck Creek is radial from the elevated Ash Pond 1 and 2 area towards Duck Creek and Lake Illawarra;
- The elevated groundwater levels within the ash ponds are above the natural sediment. Groundwater flow from the ash ponds to the surrounding environment is assessed as being predominantly vertical flow through the base of the ponds rather than horizontal flow through the bund walls;
- Movement of groundwater within the ash ponds and the natural alluvial/estuarine sediments is governed by aquifer properties including hydraulic conductivity and effective porosity, and by the hydraulic gradient in the aquifer;
- Calculated aquifer parameters for the ash ponds are: hydraulic conductivity of about 50 m/day, vertical hydraulic conductivity of about 1 m/day, and a specific storage of about 5×10^{-4} m^{-1}, indicating a more compressive aquifer than is typically seen for ash pond sediments in other areas;
- Once groundwater reaches the base of the ash ponds, entry of the groundwater into the underlying alluvial/estuarine clay sediments is controlled by the lower permeability of the clay compared to the ash material. Based on an average horizontal hydraulic conductivity of 0.1 m/day, an average effective porosity of 25% and a hydraulic gradient of 0.001 (see Section 6.2.3), the rate of horizontal groundwater movement within the clay is around 0.0004 m/day or 0.2 m/year. Groundwater discharge from the ash ponds is therefore limited by the aquifer properties of the alluvial/estuarine sediments;
- Modelled 'net' change for groundwater levels (**Figures 6 and 7**) to central and eastern areas of Ash Pond 3 is a small decrease. In the north west of Ash Pond 3, an increase in groundwater levels up to 1.2 m is predicted due to filling of the two borrow ponds in this area. For Ash Pond 2, an increase in groundwater levels of up to 0.6 m is modelled;
- Groundwater arsenic and ammonium concentrations for the "no development" and "development" scenarios were modelled to predict contaminant load and migration over 30 and 100 year periods (**Figures 8 to 11**). It was predicted that for both arsenic and ammonium there is minimal difference in the extent of migration between the no development and development scenarios.
- A conceptual modelling exercise run over 5000 years was used to assess the possibility of contaminant migration as far as the SEPP14 north wetland. For both arsenic and ammonium the north wetland concentrations remain less than laboratory detection limits and monitoring well MW16 remains less than the ANZECC 2000 trigger values.



drawn	CDC	coffey environments SPECIALISTS IN ENVIRONMENTAL, SOCIAL AND SAFETY PERFORMANCE	client:	TRUenergy	
approved	PT		project:	Groundwater Modelling Assessment Modelling Report - Ash Ponds Tallawarra Lands, Yallah, NSW	
date	1 March 2012				
scale	NA		title:	MODELLED HYDROGRAPHS - ASH POND 1 AND 2 AREA	
original size	A4		project no: ENAUWOLL04009AE-R03	figure no:	FIGURE 35

Figure 6: Modelled groundwater levels within and outside Ash Pond 1 & 2 (Coffey 2012).



drawn	CDC	coffey environments SPECIALISTS IN ENVIRONMENTAL, SOCIAL AND SAFETY PERFORMANCE	client:	TRUenergy
approved	PT		project:	Groundwater Modelling Assessment Modelling Report - Ash Ponds Tallawarra Lands, Yallah, NSW
date	1 March 2012			
scale	NA		title:	**MODELLED HYDROGRAPHS - ASH POND 3 AREA**
original size	A4		project no: ENAUWOLL04009AE-R03	figure no: **FIGURE 36**

Figure 7: Modelled groundwater levels within and outside Ash Pond 3 (Coffey 2012).

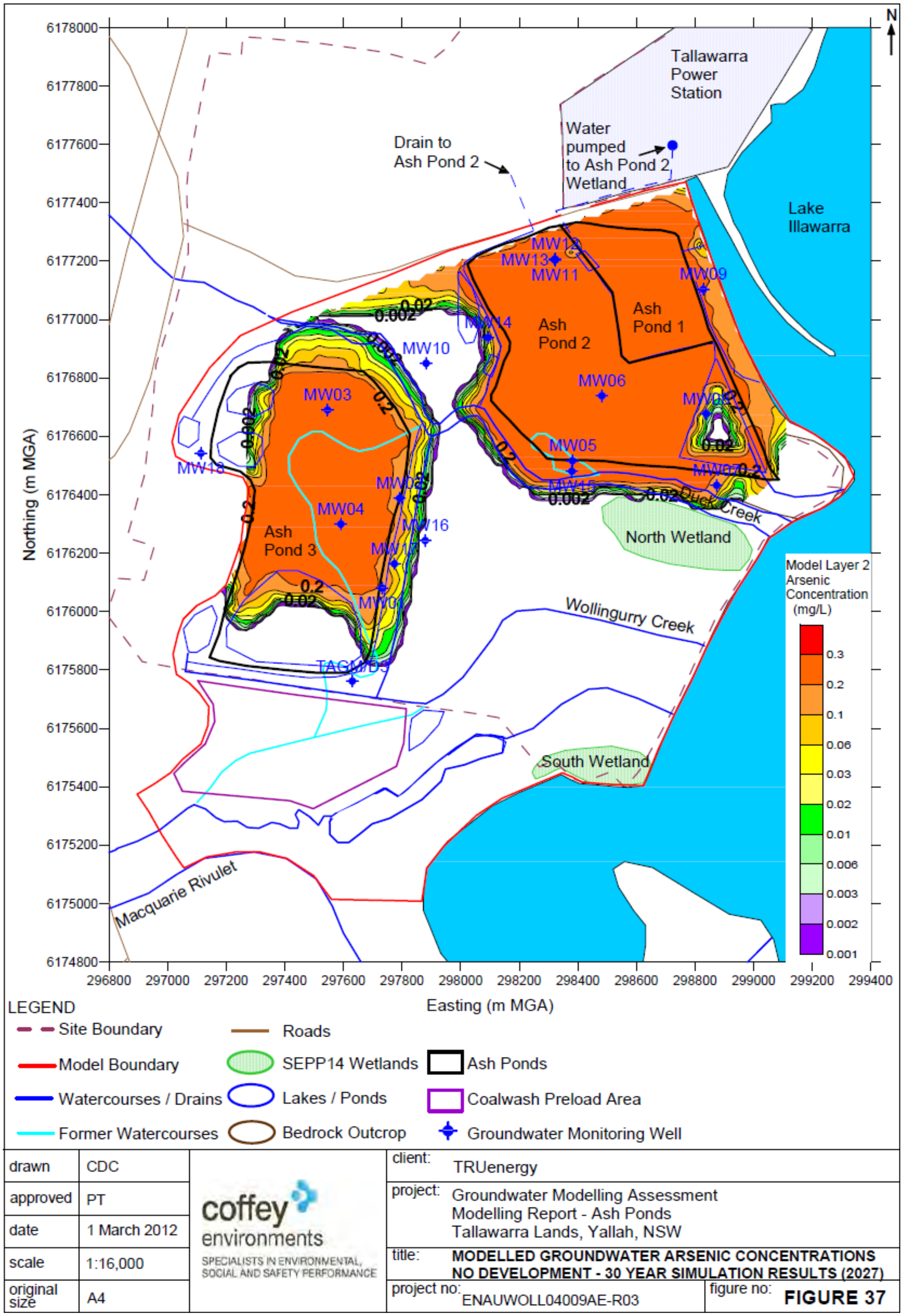


Figure 8: Modelled groundwater arsenic concentration - 30 year simulation – no development (Coffey 2012).

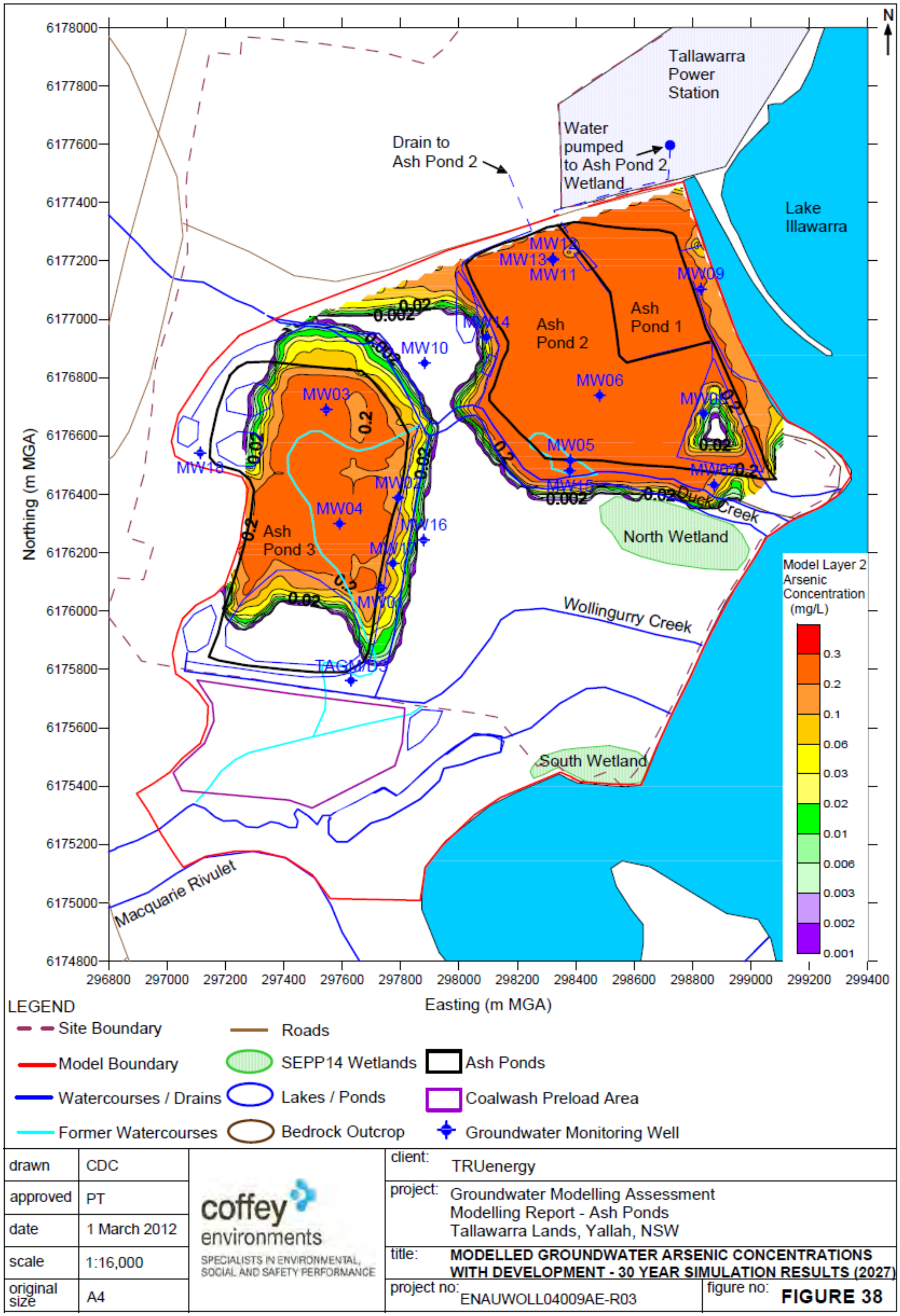


Figure 9: Modelled groundwater arsenic concentration - 30 year simulation – development (Coffey 2012).

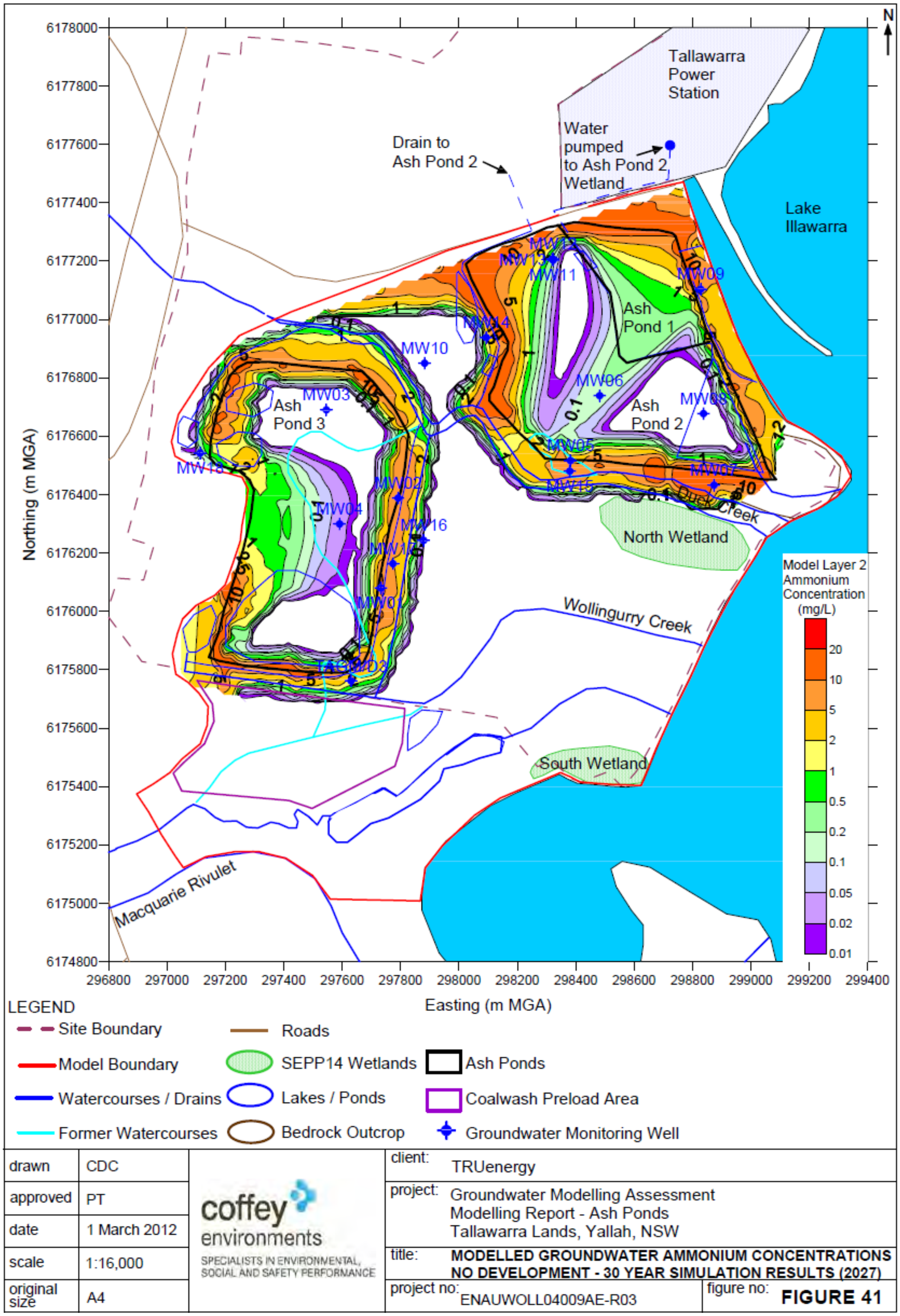


Figure 10: Modelled groundwater ammonia concentration - 30 year simulation – no development (Coffey 2012).

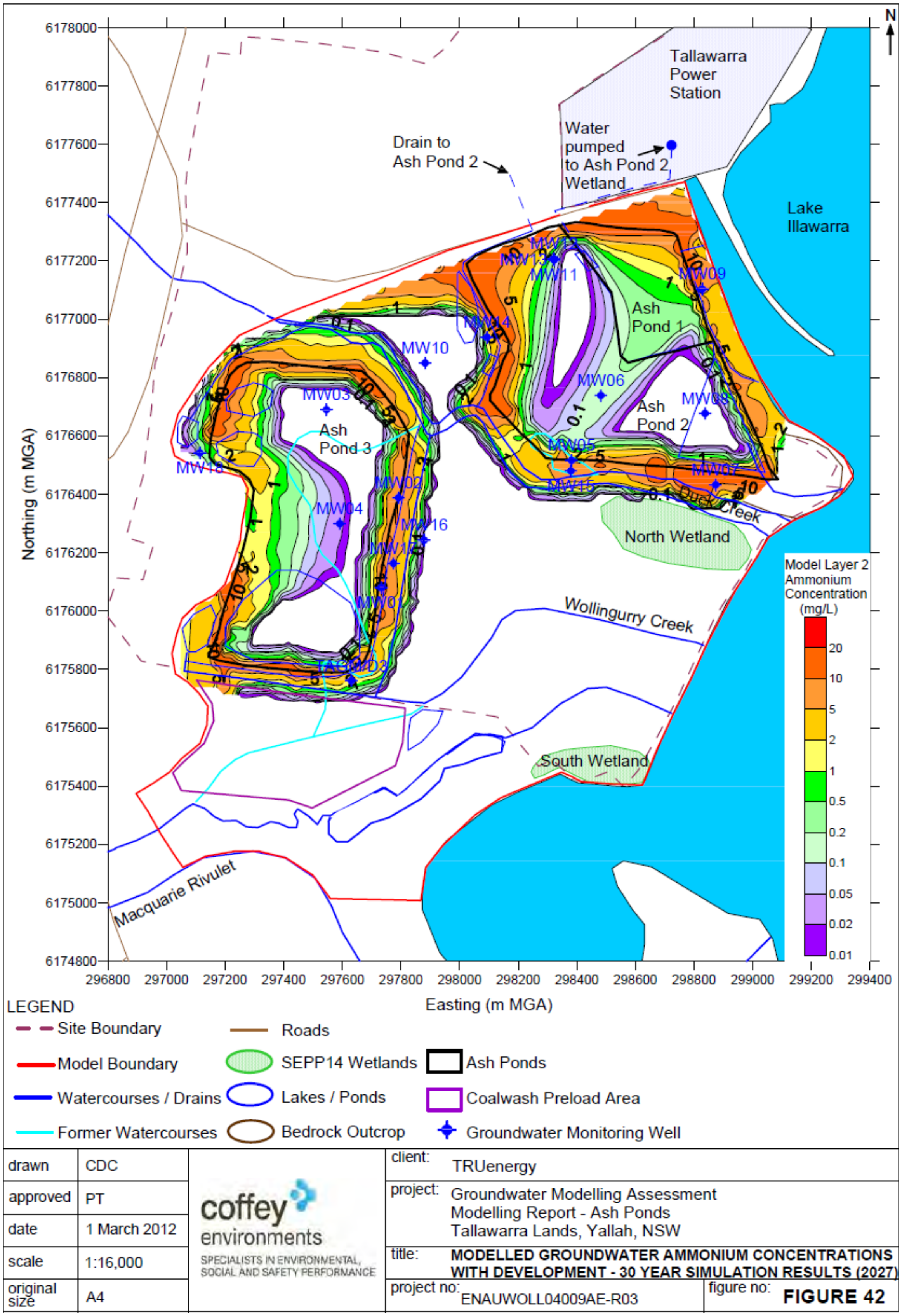


Figure 11: Modelled groundwater ammonia concentration - 30 year simulation –development (Coffey 2012).

2.2 GDES AT TALLAWARRA

There are no known aquifer ecosystems present at the Tallawarra site, so the focus of this assessment is on the terrestrially expressed GDEs, which may include vegetation communities, wetlands, and river baseflow systems. Groundwater use at the site may be through the roots of vegetation directly penetrating sub-surface groundwater, or through the use of groundwater once it has been discharged at the surface. Vegetation communities at Tallawarra are likely to be reliant on water from a variety of sources including rainfall; surface runoff; surface flows in creeks and drains; overbank flow from flooded creeks/drains; marine water from Lake Illawarra; and groundwater. .

There are numerous vegetation communities at Tallawarra that are likely to use groundwater and therefore may be considered potential GDEs. These communities occur predominantly in and around wetlands and are located in the low-lying south-eastern areas of the site where groundwater is closest to the surface (i.e. 1 – 2 m below surface, Coffey 2010a). The ecosystems and assessments of their potential dependency are presented **Table 1** and their location mapped in **Figure 12**.

No formal investigations into the degree of groundwater dependency have been undertaken, and as discussed above, groundwater use does not equate to dependency. The information listed below was reviewed to determine the ecosystems (vegetation classes) on-site that may use and therefore potentially depend on groundwater. These ecosystems are considered to be GDEs for the purposes of this assessment because of the precautionary principal required under the NSW GDE Policy (2002) and based on the following:

- General information about the level of groundwater dependency of various vegetation types (Hatton and Evans 1998)
- Endangered ecological communities' profiles (DECCW 2005), particularly if changes to hydrological regimes are listed as a threat
- On-ground ecological assessments (Eco Logical Australia 2006, 2011a)

Table 1: Potential GDEs present at the Tallawarra study site

ECOSYSTEM	DESCRIPTION OF GROUNDWATER INTERACTION	POTENTIAL DEPENDENCY
Alluvial Swamp Mahogany Forest+	Roots of *Eucalypt* and other tree species may tap into groundwater. All species may rely on groundwater discharged as surface flows, particularly into Duck and Wollingurry Creeks during periods of low surface flow. Alterations to hydrological regimes (both surface and groundwater) threaten this community.	Likely
Coastal Swamp Oak Forest†	Roots of *Casuarina* and other tree species may tap into groundwater. All species may rely on groundwater discharged as surface flows, particularly into Duck and Wollingurry Creeks during periods of low surface flow. Alterations to hydrological regimes (both surface and groundwater) threaten this community.	Likely

ECOSYSTEM	DESCRIPTION OF GROUNDWATER INTERACTION	POTENTIAL DEPENDENCY
Estuarine Alluvial Wetland	All species may rely on groundwater discharged as surface flows, particularly into Duck and Wollingurry Creeks, however dependence is more closely linked to inundation of saline waters. Alterations to hydrological regimes (both surface and groundwater) threaten this community.	Likely
Saltmarsh*	Groundwater volume is one of many interacting factors that influence marsh surface elevation, which is important in maintaining the ecosystem's position within the inter-tidal zone. Uptake of nutrients from groundwater discharge possible. Alterations to hydrological regimes (both surface and groundwater) threaten this community.	Likely but typically more related to tidal movements
Floodplain Wetland^	All species may rely on groundwater discharged as surface flows, particularly into Duck and Wollingurry Creeks during periods of low surface flow. Alterations to hydrological regimes (both surface and groundwater) threaten this community.	Likely
Planted Swamp Oak and Weeds	Roots of *Casuarina* and other tree species may tap into groundwater. All species may rely on groundwater discharged as surface flows, particularly into Duck and Wollingurry Creeks during periods of low surface flow.	Likely
Seagrass	Seagrass within Lake Illawarra is influenced predominantly by marine processes within the lake and by periodic stormwater events (WBM Oceanics Australia 2006).	Possible
SEPP 14 wetlands	SEPP 14 wetlands are comprised of vegetation communities listed above incl. Coastal Swamp Oak Forest, Estuarine Alluvial Wetland and Saltmarsh – see above for degree of dependency.	Likely but will vary with vegetation type
Artificial Wetland	The largest of the artificial wetlands on-site were constructed as ash settling ponds whilst the power station was in use. Other artificial wetlands are farms dams scattered across the property. These are located along drainage lines and are therefore most likely to be fed by rainfall and surface runoff.	Likely

[+] Swamp Sclerophyll Forest on Coastal Floodplains on the NSW North Coast, Sydney Basin & South East Corner Bioregion EEC

[†] Swamp Oak Floodplain Forest on the NSW North Coast, Sydney Basin & South East Corner Bioregion EEC

* Coastal Saltmarsh of the Sydney Basin Bioregion EEC

^ Freshwater Wetland on Coastal Floodplains EEC

Figure 12: Location of potential GDEs at Tallawarra

2.2.1 Aquatic communities

Seagrass and macroalgae beds cover most of the shallow areas (approximately 20%) of Lake Illawarra. The most extensive communities occur along the eastern portion of the lake. A relatively narrower band of seagrass beds occur around the rest of the lake (King 1990). During the 1970-80s there was excessive growth of macroalgae along the foreshore of the lake as a result of increased siltation and excess nitrogen and phosphorus levels from catchment land use (Yassini & Clarke 1986).

There is greater species diversity of benthic fauna and flora in these shallower fringing areas compared to deeper off-shore muddy areas of the lake (King et al. 1997; Aurecon 2009). In 2008, 42 species of benthic invertebrates were recorded within the shallow seagrass communities, compared to 25 species inhabiting the off-shore mud areas within the lake (Aurecon 2009). Historic surveys of the lake have recorded a total of three species of seagrass and 23 species of algae (Yassini and Clarke 1986), 144 species of phytoplankton (Royle 1985; Pacific Power International 1998) and 20 species of zooplankton (Sherman et al. 2000).

Lake Illawarra is an estuarine system, characterised by the interface of fresh and marine waters. Seawater typically has a salinity composition of 35 parts per thousand (ppt). Historic sampling during 1981-2009 show salinity levels in the lake range between 24.3 to 35.9 ppt (Aurecon 2009), which can be explained by variability in historic rainfall, catchment runoff and tidal mixing. Aquatic species inhabiting these waters are tolerant to these fluctuations, with mobile taxa able to follow a preferred niche within the salinity gradient. Freshwater can enter the lake from surface runoff via creeks, direct rainfall and groundwater seepage. Freshwater input transports valuable nutrients that support primary (plant) and secondary (animal) production.

Nutrients, either attached to sediments or dissolved in surface water, are delivered to the estuary during rainfall events and subsequent stream and stormwater flow. Tidal movement also collects nutrients from mangrove and saltmarsh communities, distributing them throughout the lake and exchanging with marine water (Olsen et al. 2006). The combined mechanisms of surface and tidal runoff are likely to outweigh the nutrients delivered via direct groundwater seepage. This is due to the sub-surface soil structure filtering sediments with bonded nutrients. Groundwater does however transport dissolved nutrients through the sub-surface soil into waterbodies (Boulton 1993, Johannes 1980), albeit at a slow rate than surface flow (e.g. groundwater flow at Windang Peninsula in Lake Illawarra was measured to move about 15 m per year through the porous beach sand; Sherman et al. 2000).

Lake Illawarra can be described as an "estuarine and near-shore marine ecosystem" GDE whose ecological function has some dependence on groundwater. Its dependency on groundwater is likely to be "opportunistic or minimal" with its greatest dependence being seawater and freshwater inflow via creeks. Direct groundwater influence would be most prominent during times of drought when surface water flow is greatly reduced. Freshwater input during dry periods would depend on groundwater seepage and stormwater runoff into the streams and lake. Given the slower movement of groundwater, aquatic biota in the lake would also rely on nutrients from fringing vegetation, sediment release and marine water (Nixon 1988). One critical role played by groundwater in Lake Illawarra may be that of dilution. Contributions of both surface water and groundwater keep salinity levels in the lake lower than marine water. However, the diffuse influx of groundwater through the bed of the lake may have a more immediate impact in providing low salinity water to seagrass roots.

2.3 CURRENT CONDITION

The current condition of GDEs at Tallawarra and within adjacent areas of Lake Illawarra is mixed and reflects both current and historical land use on-site and within the catchment. Recent field assessment indicated the following (Eco Logical Australia 2011a):

- Alluvial Swamp Mahogany Forest is in poor condition due to heavy weed infestation from Lantana, Whiskey Grass and Paspalum.
- Coastal Swamp Oak is in poor to very poor condition with some areas dominated by Lantana and other areas by pasture grasses.
- Estuarine Alluvial Wetlands are in very good condition with no weeds species observed.
- Saltmarsh is in moderate condition, with edges dominated by non-native grass species e.g. Paspalum.
- Floodplain Wetlands are in very poor condition.
- Planted Swamp Oak and Weeds are in poor condition with a monoculture of Casuarina and exotic dominated understorey.
- Artificial Wetlands are in moderate to good condition with a mixture of naive and exotic species.

Within Lake Illawarra, monitoring of aquatic communities (in particular seagrass) has indicated that the condition of these ecosystems varies over time. Examination of historical changes in seagrass extent south of Wollingurry Point (in Lake Illawarra adjacent to the Tallawarra site), indicated that the *Zostera capricorni* beds in the south-west of the lake consistently increased in extent from 1987 to 2007 but decreased in 2008 and 2009 (Aurecon 2010).

The current condition of GDEs at the site is a reflection of significant past disturbance particularly in the south and east where a number former ash settling ponds used by the former coal fired Tallawarra Power Station now remain. Extensive vegetation clearance has also occurred across much of the remainder of the site, mostly for grazing purposes, resulting in large areas of exotic grassland. More broadly, the Lake Illawarra catchment is subject to a variety of uses including approximately 23% urban, 40% rural and 37% forested areas (WBM Oceanics 2006). These percentages are likely to change in the near future as there is considerable pressure to develop areas both on the lower slopes of the catchment and around the Lake foreshores.

Aquatic ecosystems within Lake Illawarra have and continue to be subject to a variety of pressures including:

- Contaminated surface sediments
- Foreshore development
- Loss of riparian vegetation
- Pollution from a number sources e.g. the former coal fired Tallawarra Power Station, Port Kembla, Wollongong Golf Course, diffuse pollution via surface runoff
- Sedimentation and erosion
- Sewerage inputs
- Stormwater runoff
- Water quality issues, which lead to periodic algal blooms

The management issues associated with Lake Illawarra and its catchment are shown in the conceptual diagram below (**Figure 13**).

2.3.1 Contaminant levels in biological communities

Understanding of contaminant accumulation in biological communities at Tallawarra is mixed. No investigations have been undertaken within the GDEs on Tallawarra lands to determine the level of heavy metal and other contaminant levels. In contrast, specific investigations have been undertaken in Lake Illawarra since the 1970s to monitor the levels of metal contaminants. The majority of these studies have focused on the soft sediment substrate of the lake floor (e.g. Batley & Chenhall 1995; Chenhall et al. 1994; Chenhall et al. 2004; Ellis & Kanamori 1977; Payne et al. 1997; Roy & Peat 1974). Other studies have investigated air quality, fish, shellfish, saltmarsh and seagrass (e.g. Brown et al. 2004; Carolan 1993; Chenhall et al. 1992; Crisp 1984; Howley 2004; Illawarra Environment Centre 1985; Ohmsen et al. 1995). Combined, these studies have targeted the elements arsenic, copper, nickel, zinc, lead, cobalt, cadmium, rubidium, iron, magnesium, calcium, manganese, and mercury.

Most studies found either greater than trace amounts, or point source concentrations of copper, lead and zinc. Other elements with raised levels common across these studies include cadmium and nickel. Although trace metals levels can be attributed to a variety of sources (e.g. combustion of petrol and domestic effluent), the major source of metal contamination is from the Port Kembla industrial complex (Chenhall et al. 1994; Chenhall et al. 2004; Payne et al. 1997) and the former Tallawarra power station (Carolan 1993; Howley 2004; Payne et al. 1997). It is likely that these metals have entered the lake via a variety of pathways, including metal-bearing ash, and the erosion and sedimentation of contaminated soils (Chenhall et al. 2004; Payne et al. 1997). Knowledge gaps include limited research of the 'bioavailability' of metals in the sediment and the ability of transfer through the food web in Lake Illawarra (Morrison & West 2004).

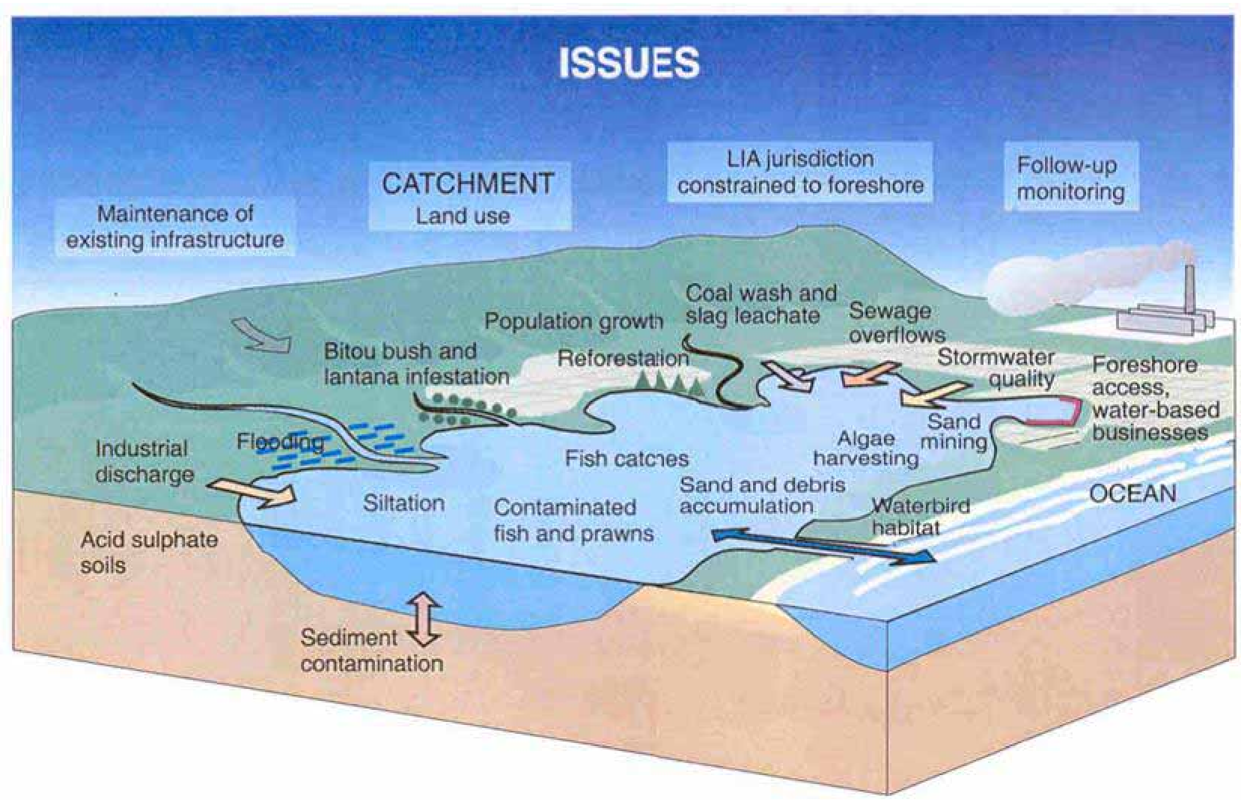


Figure 13: Conceptual diagram of issues in Lake Illawarra and catchment (Sherman 1999).

2.4 PROPOSED DEVELOPMENT

The development proposal involves the establishment of a number of land uses throughout the study area. These include:

- Residential development in the north east of the site along the Lake Illawarra Foreshore.
- Residential development, a local centre and an employment zone in the central–western parts of the site, north of Duck Creek and Yallah Bay Road.
- An employment area and tourism facility in the central–eastern parts of the site.
- An employment precinct, primary school, retirement village and residential development in the south west of the site.
- Significant dedication of various parts of the site for environmental and open space purposes:
    - Provision of a significant environmental corridor for Duck Creek.
    - A large environmental reserve in the south east incorporating two SEPP 14 wetlands.
    - Conservation of two artificial wetlands in the south west for incorporation into open space areas.
    - An environmental reserve on the upper slopes of Mount Brown.
    - An environmental reserve on the central western boundary.
    - Provision of riparian zones for affected waterways.
    - Large areas of open space reserves.

The concept plan application is supported by various studies and assessments including:

1. A Landscape Masterplan (Corkery Consulting, 2010)
2. Water Sensitive Urban Design (WBM BMT, 2010)
3. Riparian Management (ELA 2011b)
4. Vegetation Management (ELA 2011c)

3 Potential Impacts

There are a number of potential impacts to GDEs associated with the proposed development at the Tallawarra Lands site. Many of these apply to terrestrial ecosystems as well as GDEs and are considered in detail in Eco Logical Australia (2011a) and are briefly outlined below. Other impacts apply specifically to GDEs (such as alterations to the groundwater system and contamination) and are discussed in detail below.

3.1 GENERAL IMPACTS

Eco Logical Australia (2011a) provides a thorough evaluation of the anticipated impacts to the ecological values of the Tallawarra Lands site. The approach to the proposal mirrors DECCW policy to avoid impacts, then mitigate (to minimise impacts) and if required to offset any anticipated residual impacts. This evaluation of impacts (both direct and indirect) is reviewed briefly below, with specific consideration of GDEs.

Vegetation clearance – across the site, there will be 51.63 ha of vegetation cleared. This clearance is predominantly planted vegetation (i.e. non-natural) and highly degraded vegetation (such as weeds). Of this clearance 26.36 ha may conform to a GDE classification, however 97% of this clearance is of non-natural vegetation including 3.96 ha of Artificial Wetland and 21.69 ha of Planted Swamp Oak and Weeds. **Table 2** shows the evaluation of vegetation clearance (modified from Eco Logical Australia 2011a) specifically for potential GDE vegetation types. Note, seagrass is not shown in this table as it is only found off the site and no clearance is proposed (and has also not been mapped by this study).

Table 2: Vegetation clearance of GDEs.

	Alluvial Swamp Mahogany Forest	Coastal Swamp Oak Forest	Saltmarsh	Estuarine Alluvial Wetland	Floodplain Wetland (FW)	Artificial Wetland	Planted Swamp Oak and Weeds	Total
Total within study area (ha)	17.34	32.12	7.61	2.24	24.23	21.89	25.66	**131.09**
Total clearance (ha)	0.00	0.54	0.17	0.00	0.00	3.96	21.69	**26.36**
Total retained (ha)	17.34	31.58	7.44	2.24	24.23	17.93	3.97	**104.73**
% cleared	0.00	1.68	2.23	0.00	0.00	18.09	84.53	**20.11**
% retained	100.00	98.32	97.77	100.00	100.00	81.91	15.47	**79.89**

Note: Yellow columns represent endangered ecological communities listed on the TSC Act

Loss of fauna habitat – many of the GDEs provide habitat for species such as frogs and shorebirds. Clearing, filling or altering GDEs' character may result in loss of habitat for these species. The direct impact to this habitat generally conforms to the vegetation retention and clearance detailed above and in **Table 2**. Alteration to habitat character may be from indirect impacts such as hydrological changes, sedimentation, erosion and disturbance which are discussed below.

Loss of aquatic habitat – there are no direct impacts to aquatic habitat anticipated from the proposed development as these habitats are located off-site, within Lake Illawarra (including the estuarine portions of Duck Creek) and no direct works are proposed in these areas. There is the potential for indirect impacts to these areas and these are discussed further below.

Hydrological changes – there is the potential for indirect impacts to GDEs through hydrological changes (for both groundwater and surface waters) resulting from the changes in landuse proposed by the development as well as impacts to riparian vegetation. This includes changes to the character of the land surface (degree of pervious surface and topography) and changes to the hydrological regime including water use and discharge, evapotranspiration, water quality, periodicity and level of flows. The predevelopment hydrological regime is sought to be maintained by implementing a Water Sensitive Urban Design (WSUD) approach that aims to meet the following objectives:

1. Promote sustainable water resources management;
2. Protect ecological habitats from water pollution;
3. Protect watercourses, wetlands, groundwater and riparian corridors from water pollution;
4. Protect watercourses from increased erosion and sedimentation;
5. Integrate the management of stormwater, water supply, wastewater and flooding;
6. Conserve potable water to achieve more efficient use of water resources; and
7. Integrate water management into the landscape.

Runoff, sedimentation and erosion – indirect impacts associated with construction, maintenance and alterations to land use patterns. Potential impacts from these factors are proposed to be mitigated and managed by the preparation of a Construction Environmental Management Plan (CEMP) incorporating a Soil and Water Management Plan (SWMP). These actions will seek to ensure all potential sources of impact (runoff or sediments) are identified and appropriately treated during both construction and maintenance. Treatment actions should include stabilisation, entrapment and rehabilitation within the development footprint. Further to this is the retention and improvement of riparian areas documented in a riparian assessment and vegetation management plan by Eco Logical Australia (2011b & 2011c). This will occur through the dedication of riparian buffer areas and the revegetation of these areas to assist with the facilitation of functional waterways.

Edge effects and weed invasion – currently observed across the site, with the potential to increase. The development proposes to mitigate these potential impacts through the implementation of a vegetation management plan (Eco Logical Australia 2011c). This plan will manage all noxious weeds across the entire site along with specific environmental weeds of concern. In addition is the proposed revegetation of significant areas of the site to assist with riparian management as well as vegetation community and habitat viability.

Increased disturbance to fauna and/or predation – proximity to future residential development and recreational use has the potential to increase these impacts to fauna associated with GDEs. Measures aimed at mitigating such impacts have been proposed (Eco Logical Australia 2011a) including appropriate urban and landscape design, restrictions on trail use and recommendations for sensitive construction techniques for landscaping elements and usage.

Fragmentation – reduced connectivity between GDEs. Design of the Concept Plan was guided by the retention and protection of high value ecological assets. Connectivity is also provided by the provision of riparian and habitat corridors which will be improved under the vegetation management plan (Eco Logical Australia 2011c) through weed control and extensive revegetation works.

Wildfire – accidental fire during construction/maintenance and/or via arson. Mitigation measures proposed include the development of a Bushfire Management Plan along with the development of a Construction Environmental Management Plan.

3.2 GROUNDWATER-SPECIFIC IMPACTS

3.2.1 Altered groundwater recharge

Alterations in groundwater recharge may occur as a result of an increase in impervious surfaces (changes to recharge) and vegetation clearing (changes to evapotranspiration). Coffey (2010c) have advised that there may be a net increase in groundwater levels within the Ash Pond 2 area due to the clearing of trees and a potential decrease in groundwater levels within the Ash Pond 3 area due to there being more impermeable surfaces. This is supported by the modeling assessment presented in Coffey (2012). The extent of change at these locations will depend on rainfall recharge rates, evapotranspiration rates, and for Ash Pond 3, the amount of recharge infiltrating from the lake to the groundwater system. Development of an impermeable surface on Ash Pond 2 and Ash Pond 3 will result in less rainfall infiltration through the ash material and less groundwater flow from the ash ponds may result.

The degree of groundwater dependency of the GDEs is also worth considering when assessing impacts from a potentially altered groundwater regime. Broadly, the degree of groundwater dependency is thought to be minimal with higher dependency on the surface water and tidal water dynamics. As such, impacts to GDEs from a potentially altered groundwater regime are not expected to be significant.

3.2.2 Contamination

Contaminant pathways

Contaminants that affect the health of GDEs include metals, organometals, organic compounds (e.g. pesticides, industrial chemicals), and nutrients such as ammonia, nitrate, nitrite and phosphates (CSIRO 2005). Sherman et al. (2000) identify numerous paths in which contaminants can enter GDEs in and around Lake Illawarra:

- Catchment runoff delivers nutrient and pollution loads as suspended solids or in dissolved form. Sediment is sourced from erosion in upslope areas before travelling down creeks into the lake. Sediments may be stored in valleys, creek beds and wetlands for some time and later resuspended during flushing rainfall events.
- Stormwater runoff delivers nutrients and other contaminants from urban areas to wetlands, creeks and the lake. Runoff may include animal faeces, litter, chemical residues (e.g. paints, detergents, oil, grease and pesticides) from residential and industrial areas. Stormwater enters the waterways through numerous drains, many of which have been improved to trap rubbish and larger debris. In some areas, constructed wetlands have been built to further reduce sediment and nutrient concentrations before runoff enters Lake Illawarra.
- Sewage overflows may occur as a result of wet weather, pipe blockages and pump failures. In addition, some sewage may leak out from the pipe network.
- Contaminated groundwater plumes can infiltrate the aquifer and slowly seep down and across the geological structure. The speed, distance and direction travelled varies with geological type and pressure gradients, with more porous soils (e.g. sand) allowing faster infiltration than

compact soils (e.g. clay); and low-pressure fractures creating a 'downhill' path. Contaminants can migrate from the pollution source via the groundwater as a sub-surface plume and may enter GDEs by way of direct uptake by plant roots (e.g. Swamp Oak forests) and/or discharge into waterbodies (e.g. **Figure 14**);

- Atmospheric deposition of contaminants can occur when dust and aerosols either fall or are washed out of the air (e.g. from Port Kembla steel works and copper smelter, and the former operation of the coal fired power station at Tallawarra, 1954-1989).

It is likely that the majority of these sources of contamination continue today.

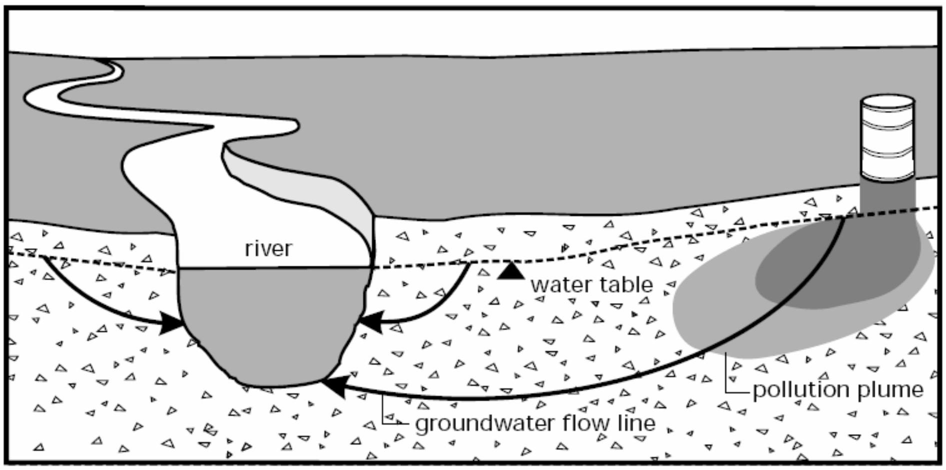


Figure 14: Example of contaminated groundwater impacting a river via infiltration through the sub-surface geology (image DLWC 2002).

Contaminant impacts - general

Direct quantification of contaminate impacts is difficult. It depends on knowledge of the contaminant; its location, concentration and bioavailability[4]; and ambient conditions at the site. Furthermore, contaminants are usually partitioned between sediments, groundwater, porewater and surface water in varying concentrations, which affects their bioavailability and toxicity. In fluvial systems, external factors including storms, floods and the daily fluctuations of tides and temperature influence the release and relative toxicity of contaminants.

Heavy Metal contamination of ecosystems is a worldwide issue. Impacts may persist for lifetimes and can be transferred through the food web into larger migratory species, potentially ending in human consumption (Closs et al. 2004). Jones et al. (2009) reviewed the potential impacts of elevated levels of heavy metals on wetland biota, with the following results:

- *Microalgae* – effects of aluminium, copper and zinc have received the most attention in the literature. The effects depend entirely on the bioavailability of metals, however elevated levels may cause changes in algal community composition and/or reductions in species richness and abundance.

[4] A measure of how exposed biological elements are to contaminants.

- *Aquatic vegetation (emergent and submerged)* – while there is little research available, aluminium, copper and iron are believed to affect aquatic vegetation the most. Elevated levels are likely to reduce photosynthesis and growth and affect other internal mechanisms. The community-wide effects are likely to result in the loss of sensitive species and associated dominance of tolerant species.

- *Fringing vegetation* - while there is little research available, elevated heavy metal levels have been shown to interfere with cell division in plant roots, decrease root respiration, increase cell wall rigidity and interfere with the uptake and use of other trace elements and water. Tolerance of vegetation to different metals is species specific.

- *Invertebrates* – are thought to be particularly sensitive to lead and zinc. Sensitivity varies greatly between taxa, but overall reductions in species richness, abundance and a change in community composition is likely. Tolerant taxa include some species of chironomids (flies), leptocerids (caddis flies) and hemipterans (true bugs).

- *Waterbirds* – limited information. Waterbirds are at the top of the food chain and therefore bioaccumulation of metals (in particular copper and lead) is a potential issue. High metal levels may affect reproduction and survival of birds associated with contaminated wetlands.

- *Amphibians* – depending on the species present can be a good indicator of water quality. High metal levels are known to affect reproduction and tadpole survival/formation. Current frog surveys are not tailored to meet a monitoring objective but may establish a baseline.

- *Fish* - The impacts of heavy metals on fish (incl. accumulation) have been widely studied, due to the potential human health effects associated with consumption of contaminated fish. While specific impacts depend on the fish species, the heavy metal in question, and the length and degree of exposure, there are several common themes. In general, heavy metals will accumulate in fish tissues, where they eventually lead to impaired metabolic functioning, growth and reproduction. Extreme impacts may result in death. Copper is thought to be one of the most toxic heavy metals to fish.

Ammonia is made up of nitrogen and hydrogen and is a key component of many fertilizers. It is highly soluble in water, however it is considered both a non-persistent and a non-cumulative toxicant (ANZECC 2000). In addition to increasing the nutrient load of the surrounding environment, high levels of ammonia may have an inhibitory effect on plants. Experimental investigations into the impacts of ammonia on wetland vegetation revealed that high concentrations inhibited growth of plants such as *Juncus* sp. and *Typha* sp. (Clarke and Baldwin 2002).

Phytoplankton and aquatic vascular plants are more tolerant of elevated ammonia compared to invertebrates, with fish being the most sensitive (ANZECC 2000). Acute toxicity to fishes may cause loss of equilibrium; hyper-excitability; increased breathing rate, cardiac output and oxygen uptake; and, in extreme cases, convulsions coma and death. Chronic effects of ammonia include a reduction in hatching success, reduction in growth rate and morphological development, and pathological changes in gill, liver and kidney tissue.

Contaminant impacts - Tallawarra

With the information available, it is difficult to quantitatively assess the current impact of contaminants on GDEs at the Tallawarra site. However, from the basis of the investigations completed to date by ELA, Coffey and others, it does not appear as though the groundwater contamination found in the former ash pond areas has adversely compromised the GDEs found at the site, particularly the more natural values in the south east (SEPP 14 wetlands, Saltmarsh and Forested Wetlands) along with the aquatic values found in Lake Illawarra.

As discussed above, impacts are directly related to the bioavailability of contaminants to biota. Whilst Coffey (2010a, b, c & 2012) provides information about the level of groundwater contamination across parts of the site and predictions on its potential migration (assuming certain management scenarios), there are several large unknown factors. These include:

- Extent to which groundwater contaminants are available to these biota.
- Level of contamination in untested areas of the site, in particular the south-eastern regions where GDEs are concentrated.
- Level of sediment contamination.
- If sediment contamination levels are elevated, how available these are to biota.
- The degree of impact in an already contaminated environment.
- The degree of effect (if any) the proposed development may have on these factors.

Given that the former coal fired power station has stopped burning coal and discharging ash and coal wash, it is unlikely that the total concentration of contaminants across the site will increase. However, the contaminants currently contained within groundwater (and potentially sediments) of the Tallawarra site may be disturbed either during construction and/or through future use of the site. This, in turn, may increase their bioavailability and lead to impacts to GDEs.

Advice from Coffey (Manuel Fernandez, pers comm. 2010) is that release of contaminants from groundwater during construction is unlikely so long as a construction environmental management plan (CEMP) is developed and implemented to ensure best practise construction (see Section 5.2). In this instance, impacts to GDEs from contaminants are unlikely. However to date, this has not been thoroughly investigated. It must also be noted that there is uncertainty regarding the extent of contaminants and their bioavailability across the site. Such uncertainty increases the risk of inadequate controls and consequent impacts to GDEs, particularly since wetlands act as sinks for sediments and any attached contaminants.

Currently, there is insufficient knowledge of contamination across the site and how this may be affected during construction to definitively determine the likely impacts of contaminants to GDEs and the aquatic environment. A precautionary approach is therefore recommended. To achieve this, a risk assessment approach is presented later in this report along with recommendations for mitigation and management.

3.2.3 Acid sulphate soil activation

Acid sulphate soils (ASS) occur naturally in both coastal (tidal) and inland or upland (freshwater) settings. Left undisturbed, these soils are harmless, but when disturbed (e.g. during construction) or drained (e.g. with groundwater extraction), the sulphides within the soil react with the oxygen in the air, forming sulphuric acid. This acid, together with associated toxic elements such as heavy metals and other contaminants can have significant environmental impacts such as:

- Death of fish, crustaceans, annelid worms, shellfish and oysters
- Exacerbation of fish diseases
- Changes to aquatic plant communities as a result of plant death and/or reduced productivity

Coffey (2010a) investigations highlighted that ASS are present in the southern parts of the Tallawarra site with current/former lower lying alluvial/estuarine environments. In particular, the sewage pump site at the southern end of the site is likely to require specific ASS management during construction.

Development within these areas will most likely require filling to raise ground levels to resolve flooding and other issues and therefore significant disturbance to underlying acid sulfate soils (if any) is unlikely. Small scale construction in areas with ASS that do not requiring fill e.g. recreational facilities in open space areas, are also unlikely to result in significant impacts provided the works are implemented in strict adherence to an Acid Sulphate Soil Management Plan (ASSMP). Further geotechnical investigations may be required during the development of this plan.

3.3 POTENTIAL COASTAL HAZARD IMPACTS

Given the adjacency to Lake Illawarra of the majority of the GDEs identified at the Tallawarra Lands site, consideration of potential coastal hazards is relevant. Worley Parsons (2010) identified that “the Tallawarra Lands may be subject to a range of coastal hazards”, including:

- Coastal inundation – that which may be associated with tides, storm surge, wave set-up and sea level rise. Climate change induced sea level rise has the potential to have the most severe impact with modelling by Worley Parsons (2010) showing almost complete inundation of the south east corner of the Tallawarra Lands site, where the bulk of the natural GDEs are located (see **Figure 15**). GDE response (such as ecosystem migration) to this inundation (given that it is likely to be over ~40 to 900 years is not well understood;

- Foreshore erosion – such as through extreme storm events (non climate change related) and boat wash. This was not considered likely to have a significant impact due to the nature of the waterway including bathymetry as well as shoreline;

- Shoreline recession – a long time frame process of shoreline movement generally considered associated with sea level rise; and

- Climate change – additional impacts such as an increase in the frequency and intensity of storm events, rainfall and windspeeds and resultant flow-on impacts from these effects. The resolution of climate modelling makes these changes difficult to accurately quantify (Worley Parsons 2010).

Predicted coastal inundation areas are illustrated for Tallawarra in **Figure 15**, demonstrating the dominance of coastal processes on GDEs at Tallawarra.

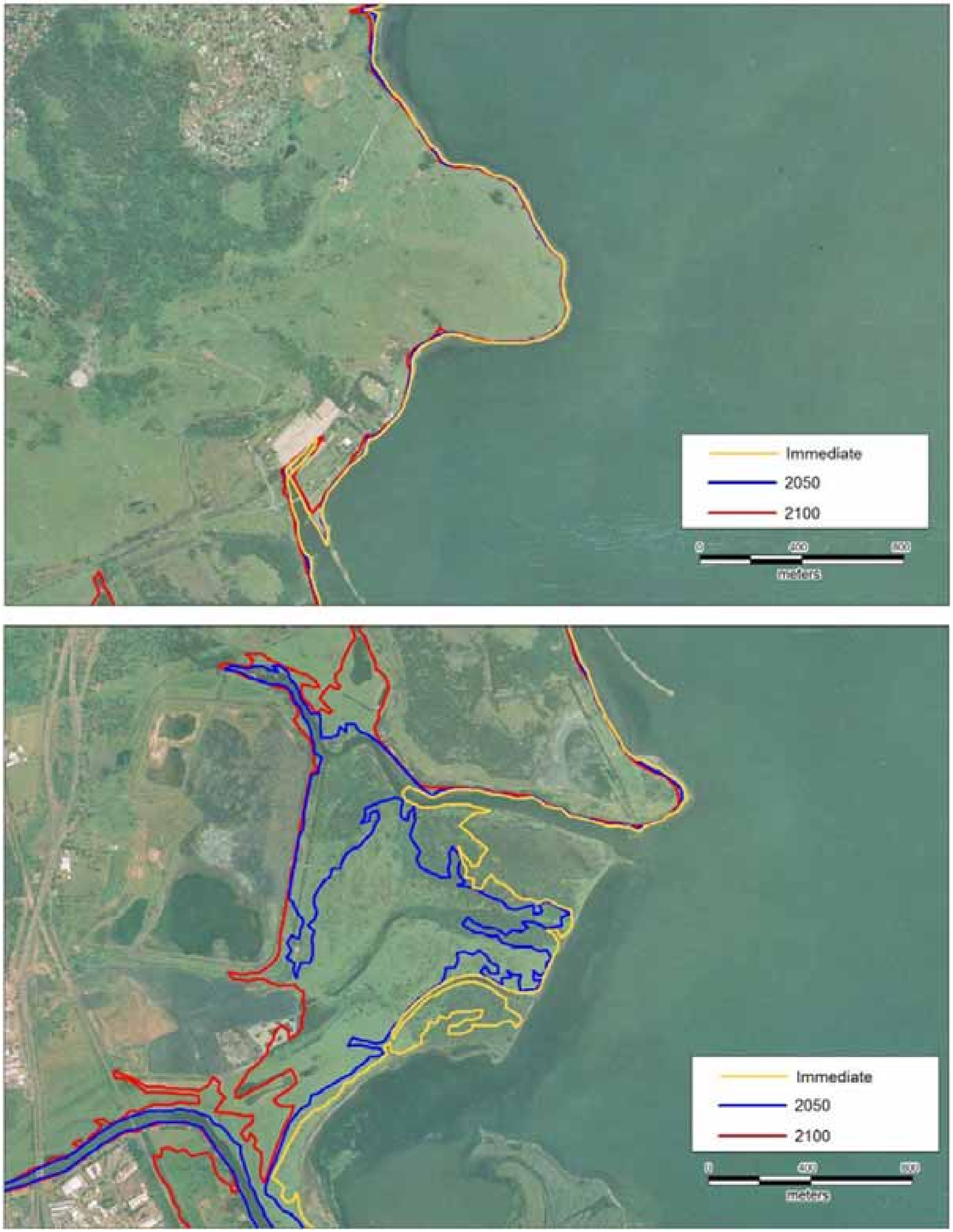


Figure 15: Coastal inundation lines for Tallawarra Lands (Worley Parsons 2010).

4 Risk Assessment

4.1 RISK ASSESSMENT METHODS

This risk framework has been prepared to assess the potential impact of the proposal on potential GDEs found at Tallawarra (see Section 2.1.6). For each potential GDE the following has been assessed:

1. Likely level of groundwater dependency
2. Potential impact from the proposal (as currently understood, see above for details)
3. Residual risk level

Definitions of terms used are provided in **Table 3**. Both the level of dependency (1) and the potential impact (2) have been estimated based on professional judgement and the data compiled for each GDE. The residual risk level (3) was generated by comparing likelihood of occurrence (1) and the potential impact (2), as per **Table 4**. Priority refers to the level of priority for further consideration/investigation into risk level and management options.

4.2 RISK ASSESSMENT ASSUMPTIONS AND LIMITATIONS

Table 3: Description of terms

TERM	DESCRIPTION
1. LEVEL OF DEPENDENCY *as per SCCG (2006), SKM (2001)*	
ENTIRELY	Ecosystems for which only a slight change in the groundwater regime will have catastrophic consequences
HIGHLY	Ecosystems for which moderate changes in the groundwater regime will result in significant changes to ecosystem distribution, health and/or diversity
PROPORTIONALLY	Ecosystems for which changes in the groundwater regime result in a proportional response to the ecosystem characteristics
MINIMALLY	Ecosystems use surface water predominantly, however if access to groundwater is prolonged, declines in ecosystem distribution, health and/or diversity are likely
NOT APPARENTLY	Ecosystems superficially appear to be groundwater dependent, but in actual fact are dependent entirely on surface flows and/or rainfall
2. POTENTIAL IMPACT LEVELS	
HIGH IMPACT	Highly Detrimental – Major negative impacts. Impacts with serious, long-term and possibly irreversible effects leading to serious damage, degradation or loss of entire ecosystem. Requires a major re-scope of concept, design, location and justification.
MODERATE IMPACT	Moderately Detrimental – Moderate negative impact. Impacts may be short, medium or long-term. Impacts will most likely respond to management actions.
LOW IMPACT	Slightly Detrimental – Minimal negative impact, probably short-term, able to be managed or mitigated and will not cause substantial detrimental effects. May be confined to a small area

TERM	DESCRIPTION
NO IMPACT	Neutral – No discernable or predicted negative impacts

Table 4: Risk Matrix

MATRIX	2. POTENTIAL IMPACTS		
1. DEPENDENCY	**LOW**	**MODERATE**	**HIGH**
Entirely	**M**	**H**	**E**
Highly	**M**	**H**	**E**
Proportionally	**L**	**M**	**H**
Minimally	**L**	**L**	**M**
Not apparently	**NA**	**NA**	**NA**

3. DESCRIPTION OF RISK LEVEL CATEGORIES		PRIORITY
E	Extreme - Impacts are most likely to result in significant impacts on threatened species, populations or ecological communities. Impacts unlikely to be adequately offset, instead seek to avoid impacts to the maximum extent practicable.	High Priority
H	High - Potential impacts which could result in significant effect on threatened species, populations or ecological communities or cause other legislative risk. Impacts would require significant offsets.	High Priority
M	Moderate - Potential impacts which require improved levels of control and/or where higher level management input is required to ensure adequate risk prevention, reporting and investigation. Impacts would require offsets.	Medium Priority
L	Low - Potential impacts which can be prevented and/or managed by applying standard management controls. Offsets generally not required.	Low Priority
NA	Not applicable – ecosystem is not a GDE and therefore risks are not applicable in this assessment.	No Priority

The risk assessment has been based on the following assumptions[5]:

- The current site layout assessed in Eco Logical Australia (2011a) applies.
- No remediation is planned for the contaminated areas i.e. all contaminated material will remain in situ and will be entirely covered by fill material in most areas.
- No groundwater extraction or insertion is proposed as part of the development.

[5] Should circumstances change, and make any of the listed assumptions incorrect, the results of the risk assessment may require revision.

- Management and mitigation measures listed in Eco Logical Australia (2011a, b & c) and this report are implemented and are effective in minimising impacts i.e. this assessment considers residual risk after all management and mitigation measures have been implemented.

The limitations of this risk assessment include:

- The study being a desk-top assessment only and based primarily on the results of investigations undertaken for the Part 3A assessment.
- Groundwater hydrology of the site is not fully understood.
- Groundwater contaminant levels within the south-eastern portion of the site where GDEs are concentrated have not been directly tested.
- Contaminant levels within sediments are not known.
- It is unknown whether contaminants will be mobilized during construction and if so, whether standard construction controls will effectively mitigate / manage this to prevent impacts to GDEs.
- There is no information on how bioavailable contaminants are.
- No formal investigations into the dependency of ecosystems on groundwater at the site have been undertaken. All wetland vegetation is assumed to be groundwater dependent to some degree (see section 2.1.6 for further details).

4.3 RISK ASSESSMENT

Risk of significant impacts to GDEs at Tallawarra from the proposed development are presented in **Table 5** below. Risks are presented for various GDE types and are grouped by potential impact (as discussed above).

Table 5: Risk assessment

GDE	DEPENDENCY	POTENTIAL IMPACT	RISK LEVEL	COMMENT
Vegetation clearance				
Forested wetlands (EEC)	Proportional	Low	Low	
Forested wetlands (non-EEC)	Proportional	High	High	While the proposed development is considered high risk for this GDE type given the high level of vegetation clearance, it is not considered a high risk more broadly. Non-EEC forested wetlands are primarily poor condition mono-specific planted Casuarina stands, which have little habitat value. Loss of this GDE is not likely to have significant biodiversity implications.
Estuarine wetlands incl. saltmarsh	Proportional	Low	Low	
Artificial wetlands	Proportional	Low	Low	
Aquatic ecosystems	Minimal	No	Low	
Loss of fauna habitat				
Forested wetlands (EEC)	Proportional	Low	Low	
Forested wetlands (non-EEC)	Proportional	Low	Low	Not considered key fauna habitat (Eco Logical Aust 2011a)
Estuarine wetlands incl. saltmarsh	Proportional	Low	Low	
Artificial wetlands	Proportional	Low	Low	
Aquatic ecosystems	Minimal	No	Low	
Loss of aquatic habitat				
Forested wetlands (EEC)	Proportional	NA	NA	No direct impact to aquatic habitat is proposed as part of

GDE	DEPENDENCY	POTENTIAL IMPACT	RISK LEVEL	COMMENT
Forested wetlands (non-EEC)	Proportional	NA	NA	the development.
Estuarine wetlands incl. saltmarsh	Proportional	No	Low	
Artificial wetlands	Proportional	No	Low	
Aquatic ecosystems	Minimal	No	Low	
Hydrological changes – general				
Forested wetlands (EEC)	Proportional	Low	Low	WSUD measures aiming to maintain pre-development hydrological regime will be implemented.
Forested wetlands (non-EEC)	Proportional	Low	Low	
Estuarine wetlands incl. saltmarsh	Proportional	Low	Low	
Artificial wetlands	Proportional	Low	Low	
Aquatic ecosystems	Minimal	Low	Low	
Runoff, sediment and erosion				
Forested wetlands (EEC)	Proportional	Low	Low	Potential impacts from these factors will be avoided, mitigated and managed by the preparation of a Construction Environmental Management Plan (CEMP) incorporating a Soil and Water Management Plan (SWMP). Retention and improvement of riparian areas documented in a riparian assessment and vegetation management plan by Eco Logical Australia (2011b & c) will also mitigate impacts.
Forested wetlands (non-EEC)	Proportional	Low	Low	
Estuarine wetlands incl. saltmarsh	Proportional	Low	Low	
Artificial wetlands	Proportional	Low	Low	
Aquatic ecosystems	Minimal	Low	Low	
Edge effects and weed invasion				
Forested wetlands (EEC)	Proportional	Low	Low	Potential impacts will be avoided and mitigated through the implementation of a vegetation management plan (Eco Logical Australia 2011c).
Forested wetlands (non-EEC)	Proportional	Low	Low	
Estuarine wetlands incl. saltmarsh	Proportional	Low	Low	
Artificial wetlands	Proportional	Low	Low	
Aquatic ecosystems	Minimal	No	Low	

GDE	DEPENDENCY	POTENTIAL IMPACT	RISK LEVEL	COMMENT
Increased disturbance to fauna and/or predation				
Forested wetlands (EEC)	Proportional	Low	Low	Measures aimed at mitigating impacts have been proposed (Eco Logical Australia 2011a) and include appropriate urban and landscape design, restrictions on trail use and recommendations for sensitive construction techniques of landscaping elements and usage.
Forested wetlands (non-EEC)	Proportional	Low	Low	
Estuarine wetlands incl. saltmarsh	Proportional	Low	Low	
Artificial wetlands	Proportional	Low	Low	
Aquatic ecosystems	Minimal	Low	Low	
Fragmentation				
Forested wetlands (EEC)	Proportional	Low	Low	Concept design specifically aims to reduce fragmentation and riparian and habitat corridor improvement will occur with the implementation of a vegetation management plan (Eco Logical Australia 2011c) that incorporates significant revegetation and restoration.
Forested wetlands (non-EEC)	Proportional	Low	Low	
Estuarine wetlands incl. saltmarsh	Proportional	Low	Low	
Artificial wetlands	Proportional	Low	Low	
Aquatic ecosystems	Minimal	No	Low	
Wildfire				
Forested wetlands (EEC)	Proportional	Low	Low	Mitigation measures include the development of a Bushfire Management Plan along with the development of a Construction Environmental Management Plan.
Forested wetlands (non-EEC)	Proportional	Low	Low	
Estuarine wetlands incl. saltmarsh	Proportional	Low	Low	
Artificial wetlands	Proportional	Low	Low	
Aquatic ecosystems	Minimal	No	Low	
Reduced groundwater recharge				
Forested wetlands (EEC)	Proportional	Low	Low	Coffey (2010c & 2012) indicate that impacts are likely to be negligible to most natural GDEs and minor to the artificial wetlands.
Forested wetlands (non-EEC)	Proportional	Low	Low	
Estuarine wetlands incl. saltmarsh	Proportional	Low	Low	
Artificial wetlands	Proportional	Moderate	Moderate	

GDE	DEPENDENCY	POTENTIAL IMPACT	RISK LEVEL	COMMENT
Aquatic ecosystems	Minimal	Low	Low	
Contamination				
Forested wetlands (EEC)	Proportional	Low	Low	Coffey (2012) has modelled the potential contaminant migration for both the development and no-development scenarios and outlines that there is minimal difference between the two scenarios. It is also noted that the potential impact level assigned is based on the assumption that best practise construction controls (i.e. through a CEMP) are implemented to avoid, mitigate and manage these matters.
Forested wetlands (non-EEC)	Proportional	Low	Low	
Estuarine wetlands incl. saltmarsh	Proportional	Low	Low	
Artificial wetlands	Proportional	Moderate	Moderate	
Aquatic ecosystems	Minimal	Low	Low	
Acid sulphate soil activation				
Forested wetlands (EEC)	Proportional	Low	Low	An Acid Sulphate Soil Management Plan must be developed for any development which may disturb ASS. Additional geotechnical investigation may be required to develop this plan.
Forested wetlands (non-EEC)	Proportional	Low	Low	
Estuarine wetlands incl. saltmarsh	Proportional	Low	Low	
Artificial wetlands	Proportional	Moderate	Moderate	
Aquatic ecosystems	Minimal	Low	Low	
Coastal Hazard Impacts				
Forested wetlands (EEC)	Proportional	Moderate - high	Moderate – high	The primary potential impact is climate change induced sea level rise and various ancillary related impacts such as erosion and recession. Potential impacts may be able to be avoided, mitigated and managed with engineering controls. However there is significant uncertainty regarding the climate change modelling and the environmental response to climate change induced changes (i.e. potential ecosystem migration).
Forested wetlands (non-EEC)	Proportional	Moderate – high	Moderate – high	
Estuarine wetlands incl. saltmarsh	Proportional	Moderate – high	Moderate – high	
Artificial wetlands	Proportional	Low	Low	
Aquatic ecosystems	Minimal	Moderate	Low	

4.4 AUDIT AGAINST GDE POLICY PRINCIPLES

The following table outlines the NSW GDE Policy principles and how the proposed development at Tallawarra is consistent with these.

Table 6: Application of GDE Policy principles at Tallawarra

PRINCIPLE	APPLICATION AT TALLAWARRA
The scientific, ecological, aesthetic and economic values of GDEs, and how threats to them may be avoided, should be identified and action taken to ensure that the most vulnerable and the most valuable ecosystems are protected.	This risk assessment has identified the values and threats to GDEs at the Tallawarra site. Recommendations are outlined in Section 5 below to ensure the most vulnerable and the most valuable ecosystems are protected.
Groundwater extractions should be managed within the sustainable yield of aquifer systems, so that the ecological processes and biodiversity of their dependent ecosystems are retained and/or restored. Management may involve establishment of threshold levels that are critical for ecosystem health and controls on extraction in the proximity of GDEs.	No groundwater extraction is proposed for the Tallawarra development.
Priority should be given to ensuring that sufficient groundwater of suitable quality is available at the times when it is needed: • for protecting ecosystems which are known to be or are most likely to be groundwater dependent and • for GDEs which are under an immediate or high degree of threat from groundwater related activity.	The development proposal has been designed to retain and enhance the GDEs (and other vegetation) with the highest biodiversity values e.g. EECs, important fauna habitats, aquatic habitat etc. There is little threat from groundwater related activity (see risk assessment results above) as a number of mitigation and management controls will be implemented prior to the proposed development commencing.
Where scientific knowledge is lacking, the precautionary principle should be applied to protect groundwater dependent ecosystems. The development of adaptive management systems and research to improve understanding of these ecosystems is essential to their management.	Coffey (2010a, b, c & 2012) provides a raft of information regarding the groundwater contamination matter and the potential impact to contaminated groundwater from the proposed development. Whilst this work provides some confidence that the development is of low risk to the GDEs it is reliant on appropriate management such as through a CEMP (Section 5). There is also significant uncertainty regarding the potential impacts from climate change.

PRINCIPLE	APPLICATION AT TALLAWARRA
Planning, approval and management of development, water use and land use activities should aim to minimise adverse impacts on GDEs by: • maintaining (where possible) natural patterns of groundwater flow and not disrupting groundwater levels that are critical for ecosystems • not polluting or causing adverse changes in groundwater quality • rehabilitating degraded groundwater systems where practical.	Preliminary calculations by Coffey (2010c) indicate that it is likely that groundwater levels will decrease in Ash Pond 3 and increase in Ash Pond 2. It is also noted that groundwater infiltration will decrease in both ash ponds as a result of the development of impermeable surfaces (Coffey 2010c). There is a risk that groundwater contaminants will be released during construction. There are several mitigation measures proposed (below) to reduce the risk of this occurrence. Rehabilitation of groundwater systems will be explored if and when it becomes necessary.

5 Conclusions & Recommendations

This assessment, along with ELA (2011a) has demonstrated that known and potential impacts to GDEs as a result of the proposed development are unlikely to change groundwater regimes such that GDEs would be significantly impacted.

Coffey (2010c) have advised that there may be a net increase in groundwater levels in the Ash Pond 2 area due to clearing of trees and a subsequent reduction in evapotranspiration, and a reduction in groundwater level around Ash Pond 3 because of an increase in impermeable surfaces. The change at these locations will depend on rainfall recharge rates, evapotranspiration rates, and for Ash Pond 3, the amount of recharge infiltrating from the lake to the groundwater system. Development of an impermeable surface on Ash Pond 2 and Ash Pond 3 will result in less rainfall infiltration through the ash material and less groundwater flow from the ash ponds may result. Modelling presented in Coffey (2012) indicates that post-development groundwater levels at Ash Pond 3 may be 0.4 m lower than current levels, while at Ash Pond 2 there may be a 0.6 m increase in level.

Direct impacts to GDEs are unlikely to be significant as the impacts (i.e. vegetation clearance) are predominately restricted to non-natural elements such as artificial wetlands and planted swamp oak vegetation. That is, excluding contamination matters, impacts to GDEs from the proposed development are unlikely to be significant.

The matter of contamination at Tallawarra Lands and its potential impact on GDEs is difficult to quantify. There is a history of contamination in the sediments of Lake Illawarra which has been documented in studies from the 1970s (Section 2.3.1). In addition, background concentrations of heavy metals and ammonia from “control sites” at Tallawarra Lands exceed ANZECC/ARMCANZ (2000) guidelines. Yet given this, there has been no recorded impact to the Tallawarra GDEs from the existing contamination and further, the GDEs appear to be continuing to provide various ecosystem functions, such as waterbird habitat in the artificial wetlands of former ash pond 3 and seemingly healthy estuarine wetland functions in the SEPP14 wetlands and saltmarsh in the south east corner of the site.

While the risk to GDEs from contamination is difficult to quantify, the development is unlikely to exacerbate contamination issues provided that appropriate mitigation and management measures are implemented (i.e. through a CEMP) and that an ongoing adaptive management framework be established. The modelling assessment provided in Coffey (2012) provides some reassurance of this. Mitigation and management recommendations are provided in Section 5.2 below.

On this basis, any impacts to the GDEs (from contamination or direct development impacts) are not expected to be significant. However, there is a significant underlying threat to most of the GDEs on site from climate change effects, primarily sea level rise.

5.1 RECOMMENDATIONS FOR MITIGATION AND MANAGEMENT

In addition to those mitigation measures outlined by Coffey (2010c & 2012), to protect the GDEs of the study area the following management and mitigation measures are recommended:

1. Preparation of Construction Environmental Management Plan (CEMP) incorporating a Soil and Water Management Plan (SWMP).

2. Inclusion (in the CEMP) of additional mitigation or management measures following collation of further information including:

    a. Review of likely construction techniques, requirements and interaction with contaminated lands;

    b. Results and outcomes of any further groundwater or sediment contaminant investigation, contaminant bioavailability assessment, benthic sediment sampling or ecotoxicity testing (if any);

    c. Incorporation of relevant mitigation measures into ongoing operation plans.

3. Review of measures in the CEMP by experts in contamination management whilst giving due regard to the proposed construction type, location and other details.

4. Ensure the CEMP and ongoing operation plans allow for adaptive management.

5. Implement the Vegetation Management Plan and riparian corridor rehabilitation and improvement works detailed in Eco Logical Australia (2011b & c).

6. Implementation of WSUD measures aiming to maintain pre-development hydrological regime. These are detailed in BMT WBM (2010).

7. Develop and implement an Acid Sulphate Soil Management Plan for all development activities that may involve disturbance of ASS. Further geotechnical investigations into ASS extent may be required to support this plan.

5.2 APPROVALS

The DGRs for the Tallawarra Part 3A assessment include:

> *3(f) – The EA shall provide details on the presence and distribution of Groundwater Dependent Ecosystems (GDEs) in the vicinity of the site and identify any potential impacts on GDEs as a result of the proposal.*

This report fulfils the requirements of the DGRs of the DoP for the Tallawarra Lands Part 3A Concept Plan application. It is recommended that this report be appended to Eco Logical Australia (2011a) and included in the Part 3A application package submitted to DoP. Results of additional studies should also be included when available (where relevant).

ELA are also aware that the groundwater contamination has been reported to DECCW as required under the Contaminated Lands Act (Manuel Fernandez pers comm. 2010). The results of their (DECCW) assessment may have implications for the management of contaminants at the Tallawarra site and therefore impacts to GDEs. The outcomes of this report should be considered in the context of any advice from / requirements of DECCW when this is received.

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