Wallarah 2
COAL PROJECT

# Wallarah 2 Coal Project

## Environmental Impact Statement

April 2013

## Appendix J

Surface Water
Impact Assessment

Hansen Bailey
ENVIRONMENTAL CONSULTANTS

wrm water + environment

# WALLARAH 2 COAL PROJECT SURFACE WATER IMPACT ASSESSMENT

**Hansen Bailey Environmental Consultants**
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For and on behalf of
**WRM Water & Environment Pty Ltd**

**David Newton**
**Director**

# EXECUTIVE SUMMARY

This Surface Water Assessment report presents the results of the assessment of potential impacts on surface water resources due to the proposed Wallarah 2 Coal Project (the Project).

The Project is an underground mining operation that will extract up to 5.0 Million tonnes per annum (Mtpa) of export quality thermal coal by longwall methods at a depth of between 350 m and 690 m below the surface. The proposed underground extraction area lies predominantly beneath Wyong State Forest and adjacent forested hills while a proportion of the extraction area lies deep beneath the Dooralong Valley floodplain which is drained by Jilliby Jilliby Creek, a tributary of the Wyong River which drains to Tuggerah Lake. The primary surface facilities are located to the east of the underground extraction area adjacent to Buttonderry Creek and Wallarah Creek. The mine water management system includes provision for releases of treated mine water to Wallarah Creek.

The Gosford-Wyong Councils Water Authority operates an integrated Water Supply Scheme which collects and stores water from the Wyong River, Jilliby Jilliby Creek and adjoining catchments. The Water Supply Scheme harvests up to about 34,000 ML per year and includes various water storages with a combined capacity of over 200,000 ML.

The water quality of streams draining the area is generally reasonable. Surface waters typically have low to moderate salinity and a pH of approximately 6.6. However, numerous water quality parameters exceed water quality guidelines, particularly for nutrients, zinc and iron.

The potential impacts of the proposed mining operations on surface water resources include:

- Additional water demand from the Gosford-Wyong Councils Water Authority water supply system to meet construction and operational water requirements for the Project;
- Loss of surface water from the water supply catchment system through enhancement of hydraulic connectivity between surface waters and underground aquifers;
- Adverse impacts on the quality of surface runoff draining from the local site catchments to Wallarah Creek and Buttonderry Creek;
- Adverse impacts on downstream water quality associated with possible overflows from the Mine Water Management System;
- Loss of catchment area draining to Buttonderry Creek and Wallarah Creek due to capture of runoff within onsite storages. This could potentially reduce runoff volumes to Buttonderry Creek and Wallarah Creek;
- Interference with flood flows along Wallarah Creek;
- Impacts on the hydrology and water quality of Wallarah Creek associated with the proposed treated water discharge to Wallarah Creek; and
- Flood and geomorphological impacts on the Wyong River, Jilliby Jilliby Creek, Hue Hue Creek and their tributaries associated with ground subsidence caused by undermining these watercourses and their floodplains.

A key component of the methodology for the surface water impact assessment has been the development of a detailed computer model of the mine water balance. The mine water system was simulated on a daily basis over the 28 year life of the Project using 95 different rainfall sequences based on recorded historical data. The model was configured to represent the inflows to and outflows from the mine water management system as well as transfers of water between mine site storages.

Water within the mine water management system, including groundwater inflows to the underground mine and captured surface runoff, will be treated for use at the site to minimise impacts on the Central Coast water supply system. A further objective of the Project's water management strategy is to minimise impacts on the adjacent creek systems. This will be achieved by replacing any intercepted catchment runoff water at the Tooheys Road Site with treated water of a similar or higher quality on an annual average basis.

The results of the water balance model indicate that inflows to the mine water management system are likely to exceed the volumes required for treatment to enable the replacement of environmental flows in Wallarah Creek and site water use. As mining progresses, increasing volumes of underground storage will progressively become available to store groundwater inflows, reducing the volume of water that will need to be pumped out of the underground mine to the surface. However, it is likely that the mine will generate excess water that will need to be removed from the mine water management system.

It is intended that surplus mine water beyond that required to meet mine process water requirements and replenish flows to Wallarah Creek will be treated and discharged to Wallarah Creek. The water treatment process would be designed to ensure that the quality of water being discharged to Wallarah Creek is similar to or better than existing receiving water quality. All brine from the treatment process would be further treated on site to reduce volumes prior to being disposed of in dedicated disposal areas and redundant underground workings. The water management strategy provides for connecting the Project sites to town water supply and reticulated sewer systems. This will allow the potential for variable quantities of discharge to sewer as trade waste in accordance with the requirements and approval of external authorities.

Results of the mine water balance modelling are summarised as follows:

- The maximum external water requirement is 52 ML/a in Year 1.
- Treated water discharges to Wallarah Creek occur intermittently for the life of the Project and peak in Year 7 and remain fairly consistent thereafter. Treated water discharges to Wallarah Creek in Year 7 at the median, 90th percentile and 99th percentile discharge volumes are approximately 250, 370 and 500 ML/a respectively.
- There are no simulated uncontrolled discharges from the Mine Water system for the 99th percentile confidence trace in any year of Project.
- Uncontrolled overflows from the clean water system are generally similar from year to year throughout the Project life. The median, 90th percentile and 99th percentile discharge volumes are approximately 10, 32 and 60 ML/a respectively.
- In the case of an initial brine treatment process step only, after the reverse osmosis water treatment plant, the annual brine concentrate disposal requirement would gradually rise by Year 8 to approximately 25 ML/a (99th percentile confidence trace) and remain fairly consistent thereafter.
- Under an adaptive management scenario involving a full brine treatment process (RO/concentrator/crystalliser/dryer) after the RO water treatment plant up to Year 14, a much smaller volume of treatment plant by-product of less than 5,270 $m^3$/a of salt would be required to be disposed of underground [under median conditions]
- Flow characteristics in Wallarah Creek are impacted for flows less than 10 ML/d. Flows up to 10 ML/d are increased in frequency. For example, a flow of 1 ML/d has increased in frequency from approximately 17% of the time to 30% of the time for an average climate realisation.
- Median salinities in the Mine Water System are expected to range from 1,000 to 8,000 mg/L.

Undermining of a portion of the Jilliby Jilliby Creek catchment has the potential to affect bed levels and sediment transport rates. Inspection of the waterway indicates that the creek is experiencing active bank erosion under existing conditions. An assessment of the hydraulic characteristics of the creek before and after potential subsidence indicates that the main channel drainage system and sediment transport dynamics are unlikely to experience significant adverse impacts due to the Project. The channel is part of a dynamic geomorphic system and is expected to be able to readily adjust to any modified local gradient conditions. An adaptive management approach will be implemented to identify and rehabilitate any adverse impacts.

The Project will not directly harvest water from the catchment of the Gosford-Wyong Water Supply Scheme. However, based on the results of the groundwater impact assessment (MER, 2013), it is expected that post-mining response in the Dooralong Valley floodplain will generate incrementally some additional groundwater storage which would be sourced from regional rainfall recharge, as well as surface runoff. This temporarily diverted water volume would represent less than 1% of the total licensed extraction volume for the area. In practical terms, due to the highly variable nature of surface water flows, it is unlikely that an impact of this magnitude on the flow regime could be detected.

Historical constraints on water supply in the region have been predominantly associated with limited water storage availability. Storages in the lower catchment have a combined total capacity of only 12,445 ML, which is less than 7% of the capacity of the Mangrove Creek Dam (190,000 ML). Completion of the Mardi-Mangrove Link in mid 2012 has provided the necessary infrastructure to pump water to the Mangrove Creek Dam, thereby increasing the yield of the Gosford-Wyong Water Supply Scheme from 40,000 ML/a to 45,600 ML/a (GWCWA, 2007). Since the potential impact of the Project represents less than 0.7% of the current system yield, the Project is unlikely to have a measureable impact on the Gosford-Wyong Water Supply Scheme.

Whilst there will be no defined extraction point or easily measurable extraction volume from the relevant water sources, it is likely that the Project will intercept some volume of surface water through additional groundwater storage, as well as capture of surface runoff at the Buttonderry Site. The Project will increase surface water flows in Wallarah Creek by 42 ML/a on average. Indicative surface water extraction volumes for the various water sources are summarised as follows:

- Tuggerah Lakes Water Source: 20 ML/a from Buttonderry Creek.
- Jilliby Jilliby Creek Water Source: 270 ML/a (Upper limit estimate of increased groundwater storage).
- Central Coast Unregulated Water Source: 30 ML/a (Upper limit estimate of increased groundwater storage).

A detailed Flood Impact Assessment has been undertaken for the Project (G Herman & Associates, 2013). The results of the Flood Impact Assessment indicate virtually no change to flood extents and depths in the Yarramalong Valley. Six dwellings in the Dooralong Valley will experience major adverse flood impacts and a further eleven dwellings will experience moderate adverse impacts. These impacts will be managed on a site-specific basis through the development of Property Subsidence Management Plans and Property Flood Management Plans. Forty-eight of the 103 dwellings in the Yarramalong/Dooralong and Hue Hue study areas that are within or near to the 1% AEP flood extent will be beneficially impacted.

An expanded surface water monitoring and management program will be implemented following approval to identify potential impacts on surface water quality and quantity and take appropriate management action to reduce or eliminate adverse impacts. The program will include water quality sampling of site storages and receiving waters, as well a stream stability monitoring and management program.

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# 1 INTRODUCTION

The Wyong Areas Coal Joint Venture (WACJV) seeks a Development Consent under Division 4.1 in Part 4 of the Environmental Planning and Assessment Act 1979 (EP&A Act) for the Wallarah 2 Coal Project (the Project). This Surface Water Impact Assessment supports 'The Wallarah 2 Coal Project Environmental Impact Statement' (Wallarah 2 EIS) prepared by Hansen Bailey Environmental Consultants to support the application.

This surface water impact assessment has been prepared in accordance with the Director-General's Environmental Assessment Requirements (DGRs) for the Project issued on 12 January 2012 in accordance with the requirements in Part 2 in Schedule 2 to the Environmental Planning & Assessment Regulation 2000 (EP&A Regs).

Development Consent is sought to mine coal via underground longwall methods within the Extraction Area for a period of 28 years. The majority of this coal resource lies beneath the Wyong State Forest and surrounding ranges (including the Jilliby State Conservation Area (SCA)), while a proportion, to be extracted initially, lies beneath a section of the Dooralong Valley and the Hue Hue area. The location of the Project is shown on Figure 1.1.

Key features of the Project include:

- The construction and operation of an underground mining operation extracting up to 5.0 Million tonnes per annum (Mtpa) of export quality thermal coal by longwall methods at a depth of between 350 m and 690 m below the surface within the underground Extraction Area;
- Mining and related activities will occur 24 hours a day 7 days a week for a Project period of 28 years;
- Tooheys Road Site surface facilities on company owned and third party land (subject to a mining lease) between the Motorway Link Road and the F3 Freeway which will include (at least) a rail loop and spur, stockpiles, water and gas management facilities, workshop and offices;
- Buttonderry Site Surface Facilities on company owned land at Hue Hue Road between Sparks Road and the Wyong Shire Council's (WSC) Buttonderry Waste Management Facility. This facility will include (at least) the main personnel access to the mine, main ventilation facilities, offices and employee amenities;
- An inclined tunnel (or "drift") constructed from the coal seam beneath the Buttonderry Site to the surface at the Tooheys Road Site;
- Construction and use of various mining related infrastructure including water management structures, water treatment plant (WTP) (reverse osmosis or similar), generator, second air intake ventilation shaft, boreholes, communications, water discharge point, powerlines, and easements to facilitate connection to the Council water supply system;
- Capture of methane for treatment initially involving flaring as practicable for greenhouse emission management and ultimately for beneficial use of methane such as electricity generation at the Tooheys Road Site;
- Transport of coal by rail to either the Newcastle port for export or to domestic power stations;

- A workforce of approximately 300 full-time company employees (plus an additional 30 contractors); and
- Rehabilitation and closure of the site at cessation of mining operations.

The surface water impact assessment considers the impacts of the Project on the existing surface water hydrology and water quality in the vicinity of and downstream of the Project. The assessment includes a simulation of the water balance for the proposed mine water management system.

The report contains a further seven sections:

- Section 2 provides background information on the characteristics of the existing surface water environment.
- Section 3 provides a summary of the proposed surface water management strategy and water management infrastructure for the mine.
- Section 4 describes the potential impacts of the Project on surface water resources and provides an assessment of the likely magnitude of these impacts.
- Section 5 presents the methodology and results of a numerical simulation of the mine site water balance.
- Section 6 documents the proposed mitigation and management measures to minimise the risk of adverse surface water impacts from the Project.
- Section 7 is a summary of the findings of the surface water impact assessment.
- Section 8 is a list of references.

The report also includes three appendices:

- Appendix A provides detailed water quality monitoring results based on data from the New South Wales Office of Water (NOW) stream gauges in the area of interest.
- Appendix B provides detailed water quality monitoring results from the WACJV surface water quality monitoring program.
- Appendix C is a table which shows where each of the Director General's Requirements relating to surface water is addressed in this report.

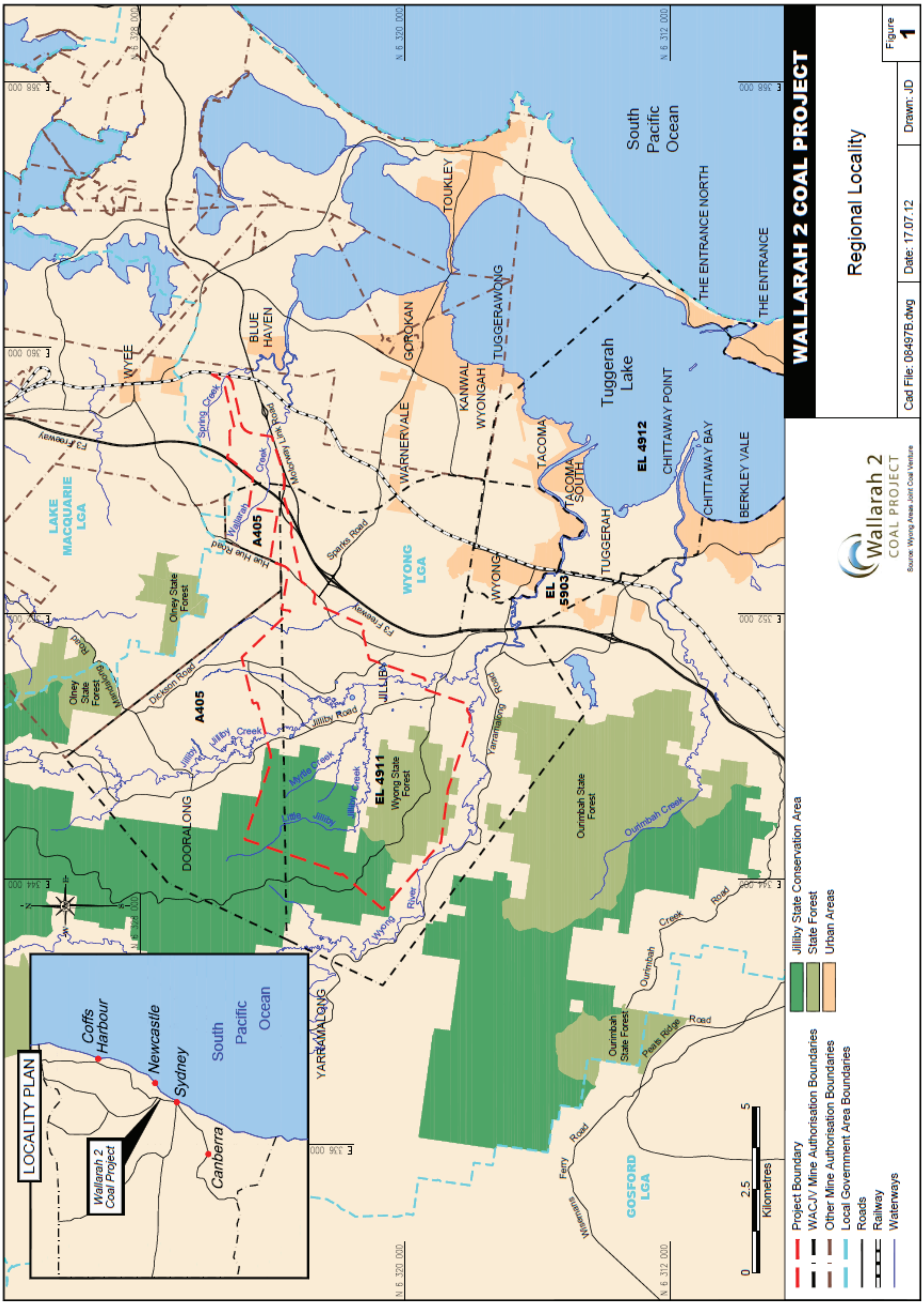


Figure 1.1 Regional Locality

# 2 EXISTING ENVIRONMENT

## 2.1 REGIONAL DRAINAGE NETWORK

The Project is located within the Tuggerah Lakes Basin, which has a total catchment area of approximately 700 $km^2$. The major rivers and tributaries of the catchment include the Wyong River, Jilliby Jilliby Creek and Ourimbah Creek. The catchment includes several water supply storages, including Mardi Dam and Mangrove Creek Dam which are used for irrigation and domestic water storage for urban centres in the lower sections of the Tuggerah Lakes catchment (NSW Government, 2012).

The region is bordered by a series of small eastern flowing streams in the north, the Sugarloaf Ranges in the north west, Watagan Mountains in the west and the Hunter Range in the south and south west (IEC, 2009). The area covers a range of landscapes that include plateaus, ranges, hills, floodplains, estuarine and coastal areas (IEC, 2009).

The character of the region's rivers, creeks and floodplains has been changed dramatically by European settlement, with large areas of land cleared for rural activities. There are still considerable areas (approximately 58%) of State and National Park within the region, however riparian vegetation has only been preserved in the upper reaches. The lower reaches and particularly the floodplain areas have been highly altered with little remnant vegetation existing (IEC, 2009).

Figure 2.1 shows photographs of the main channel along two of the main watercourses in the vicinity of the Project Boundary; Wyong River and Jilliby Jilliby Creek. The proposed mining area predominantly underlies the lower Jilliby Jilliby Creek catchment. The maximum potential impact from subsidence under alluvial land is predicted to occur along lower Jilliby Jilliby Creek. Jilliby Jilliby Creek is a major tributary of the Wyong River with a catchment area of approximately 100 $km^2$. The headwaters of the creek lie in the Olney State Forest, some 36 km upstream of its confluence with the Wyong River (IEC, 2009).

## 2.2 LOCAL DRAINAGE NETWORK

The Project has surface facilities at two primary locations: the Tooheys Road site on the eastern side of the F3 Freeway, and the Buttonderry site on the western side of Hue Hue Road. A small area of disturbance will also be required for construction of a ventilation shaft in the Wyong State Forest.

Figure 2.2 and Figure 2.3 show the local drainage characteristics in the vicinity of the main Project surface facilities, including aerial photography and topographical information. The Tooheys Road site is located within the Wallarah Creek catchment, which is a tributary of Budgewoi Lake. Wallarah Creek to the downstream Project Boundary has a total catchment area of approximately 4 $km^2$. Wallarah Creek flows east and enters Budgewoi Lake approximately 6.6 km downstream of the Tooheys Road site. The Wallarah Creek catchment area to Budgewoi Lake is approximately 45 $km^2$. Figure 2.4 shows photographs of Wallarah Creek at the Tooheys Road site, near the location of a proposed conveyor crossing of the creek.

The Buttonderry Site is located within the Buttonderry Creek catchment, which has a catchment area of approximately 5.4 $km^2$ to the Buttonderry Site. Buttonderry Creek joins Woongarrah and Hue Hue Creeks at the Porters Creek wetland. The Porters Creek wetland has a surface area of approximately 6 $km^2$ and a total catchment of 55 $km^2$. The wetland drains to the Wyong River, which is a tributary of Tuggerah Lake. The confluence of Porters Creek and the Wyong River is approximately 7.6km downstream of the Buttonderry Site. The Wyong River flows east and enters Tuggerah Lake 8.1 km further downstream.


(1)


(2)

**Figure 2.1 Photographs of Main Channels (1) Wyong River at Gracemere, and (2) Jilliby Jilliby Creek at Durren Road**

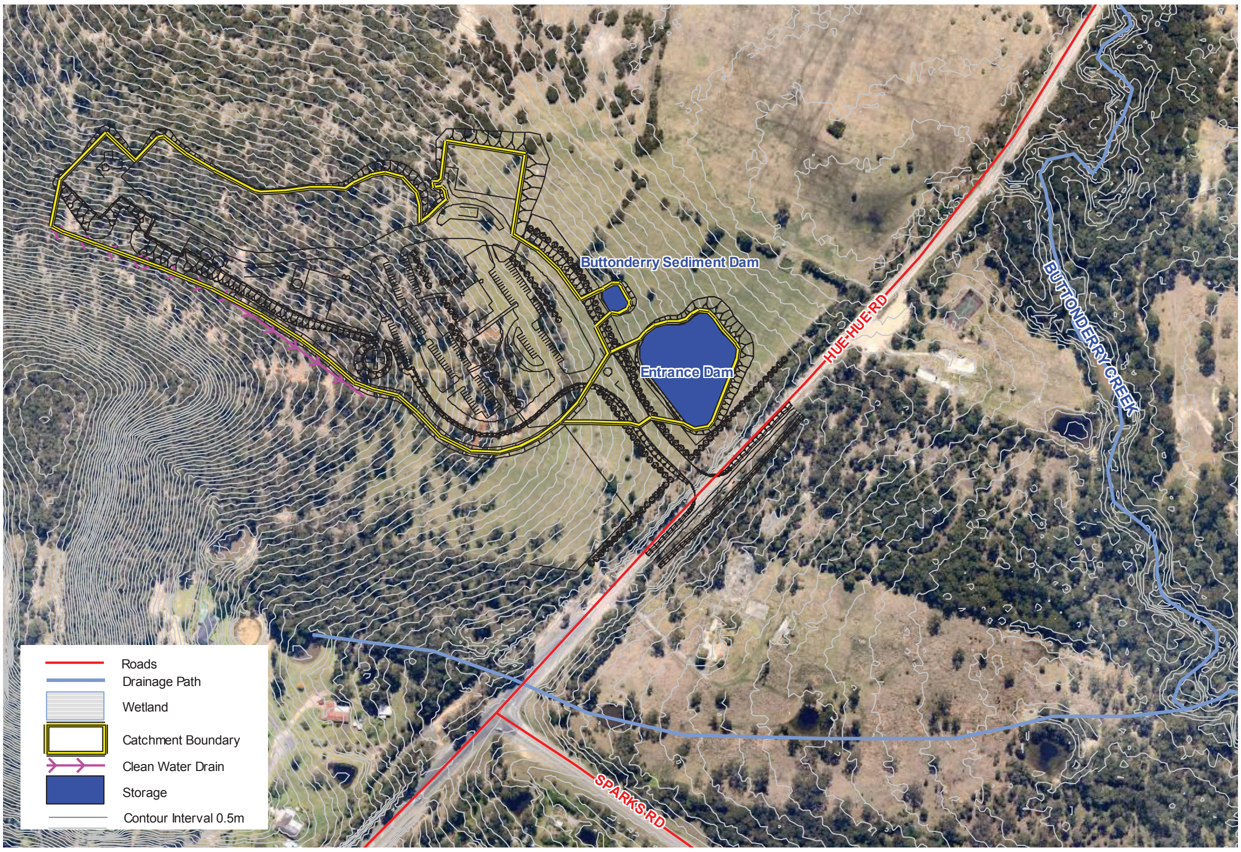


Figure 2.2 Buttonderry Site

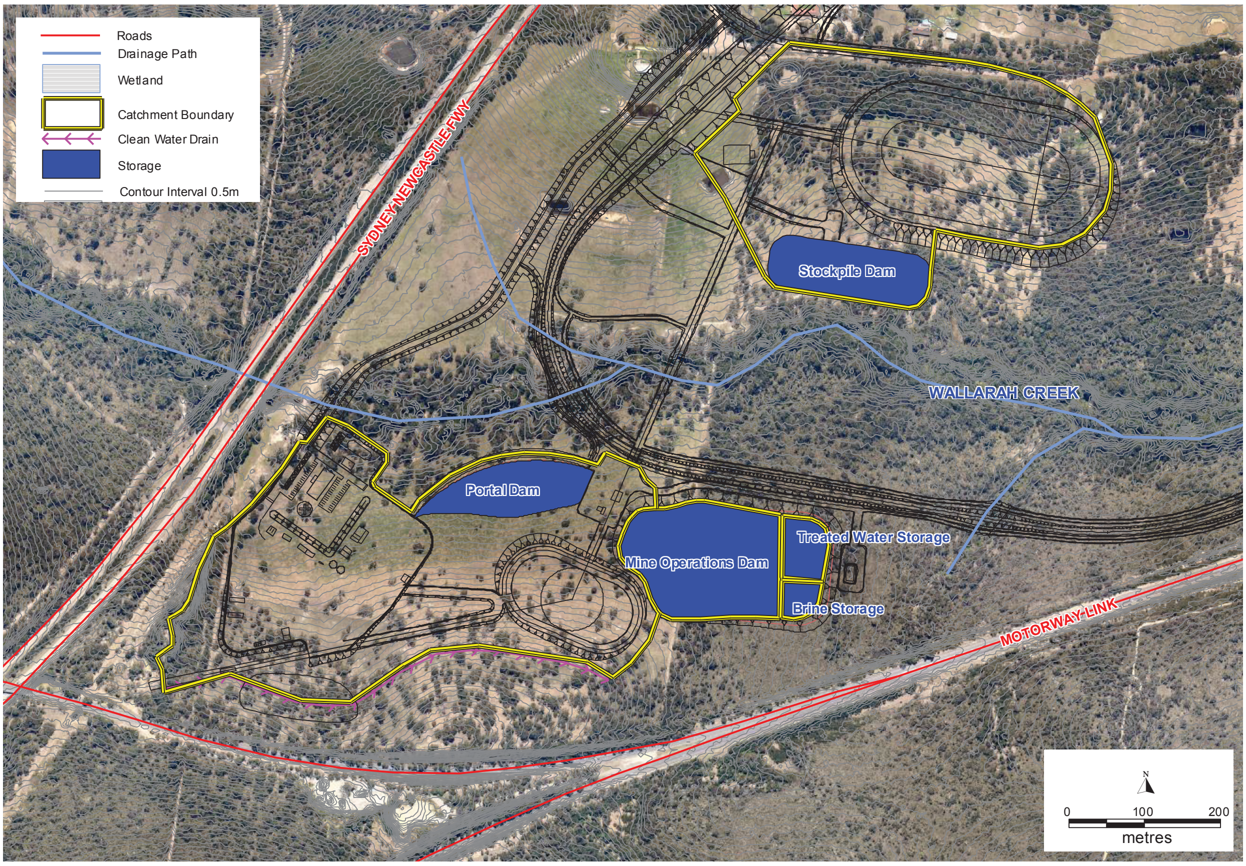


Figure 2.3 Tooheys Road Site

(1)

(2)

Figure 2.4 Photographs showing Wallarah Creek at Tooheys Road Site (1) near proposed conveyor crossing location, and (2) south of proposed Stockpile Dam

## 2.3 STREAM GEOMORPHOLOGY

A detailed description of stream geomorphology within the Project Boundary has been prepared by International Environmental Consultants Pty Ltd (IEC, 2009). A summary of the stream characteristics based on the IEC (2009) report, as well as site inspections undertaken by WACJV and WRM staff are provided below.

### 2.3.1 Upland Streams in the Mining Area

The streams within the proposed mine area have been categorised in terms of Strahler stream order based on 1:25,000 topographic mapping and are shown in Figure 2.5 in relationship to regional surface geology.

Figure 2.5 shows that the western area upland streams are primarily either 1st or 2nd order streams under the Strahler stream ordering system. The exceptions to this are Little Jilliby Jilliby Creek up to its junction with Splash Gully, and the lower reaches of Myrtle Creek which are both 3rd order streams. These 3rd order stream sections are located within areas containing minor to significant valley alluvium and are characterised by relatively lower stream gradients.

As illustrated in Plates 1 to 4 below, the 1st and 2nd order streams are steep, ephemeral drainage lines commonly featuring sandstone boulders, minor areas of alluvium and significant vegetative litter. Alluvial material can include dominant proportions of sandstone rubble and stones.

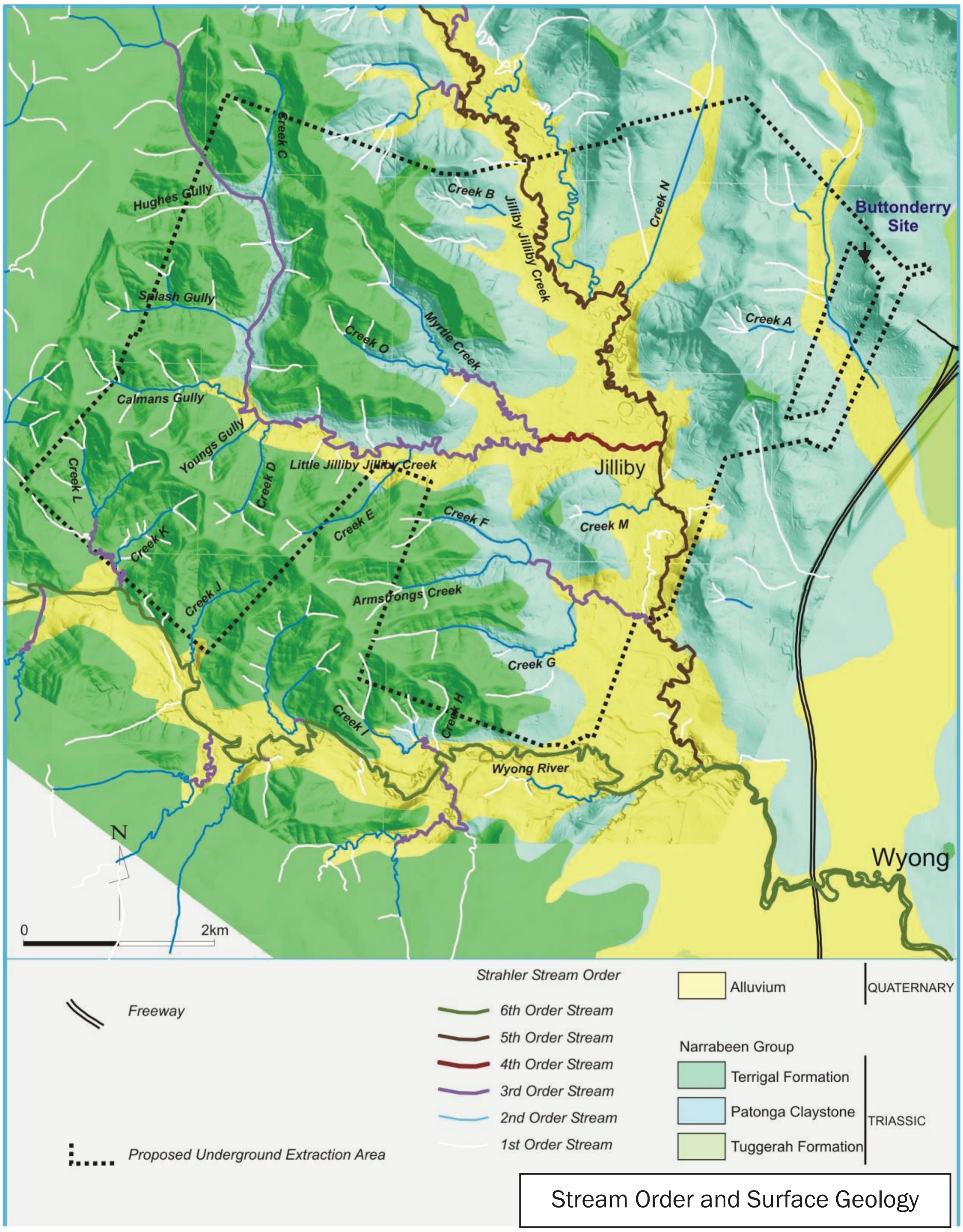


**Figure 2.5 Stream Order and Regional Surface Geology**


**Plates 1 and 2:** Typical 1st order drainage lines in upper slope areas of Wyong SF/Jilliby SCA. Drainage features of 1st order waterways are characterised by steep, v-shaped valleys with sandstone boulders especially near outcrops (Source: WACJV).



**Plates 3 and 4** - Views of typical 2nd order drainage line sections in the Wyong SF/Jilliby SCA (upper Myrtle Creek). These views characterise the more mature phase of drainage features where a gentler stream gradient (see **Plate 4** below) allows alluvium to accumulate in and around the boulders. (Source: OzArk EHM/WACJV)


Plate 4. Low gradient, ephemeral channel in alluvium at lower 2nd order section of Myrtle Creek (0.6° or 1% slope). No water flow was present in the drainage line at the time of inspection. Isolated small to medium sized sandstone boulders are present but are less frequent in these lower sections.

### 2.3.2 Stream Gradients and Landscape Settings Compared to Southern Coalfields

The streams in the vicinity of the W2CP differ considerably from those undermined in the Southern Coalfields.

The alluvial valleys within the Project Boundary feature very sinuous and low gradient streams underlain by deep alluvium within wide unconfined valley formations. The alluvium depth in the Dooralong Valley centre in the mining area is generally from 20m to over 30m and is underlain by the Patonga Claystone fine sedimentary material (aquitards and aquicludes).

The upland streams in the Wyong State Forest/Jilliby SCA are very steep and ephemeral and major pools are absent. There are no massive rock bars which retain permanent major pools and aquatic ecological systems. This is due to the steep terrain as well there being fewer outcroppings of massive sandstones because the units of the Terrigal Formation are thinner, weaker and less resistant than the Hawkesbury Sandstones found elsewhere and are not cliff-forming. The sandstones and siltstone/shales of the Terrigal Formation in the valleys are stress-relieved and well jointed throughout.

In contrast, the Southern Coalfields are characterised by steep canyon-like narrow valleys with significant areas of resistant sandstone defining the creek beds including typical alternating rock bars and major pools. The streams in the Southern Coalfield are notably of lower gradient, extend over less topographic elevation and as rock-lined streams they generally comprise continuous rock bar and pool sequences along their entire lengths.

In addition to the major differences in geology and geomorphology, Figure 2.6 shows the distinctively different stream profiles between the Project Boundary and the Southern Coalfields. The steep profiles typical of 1st and 2nd order upland drainage lines as well as the key alluvial low gradient streams in the Project Boundary are contrasted with those intermediate streams in the Southern Coalfields where mining has occurred.

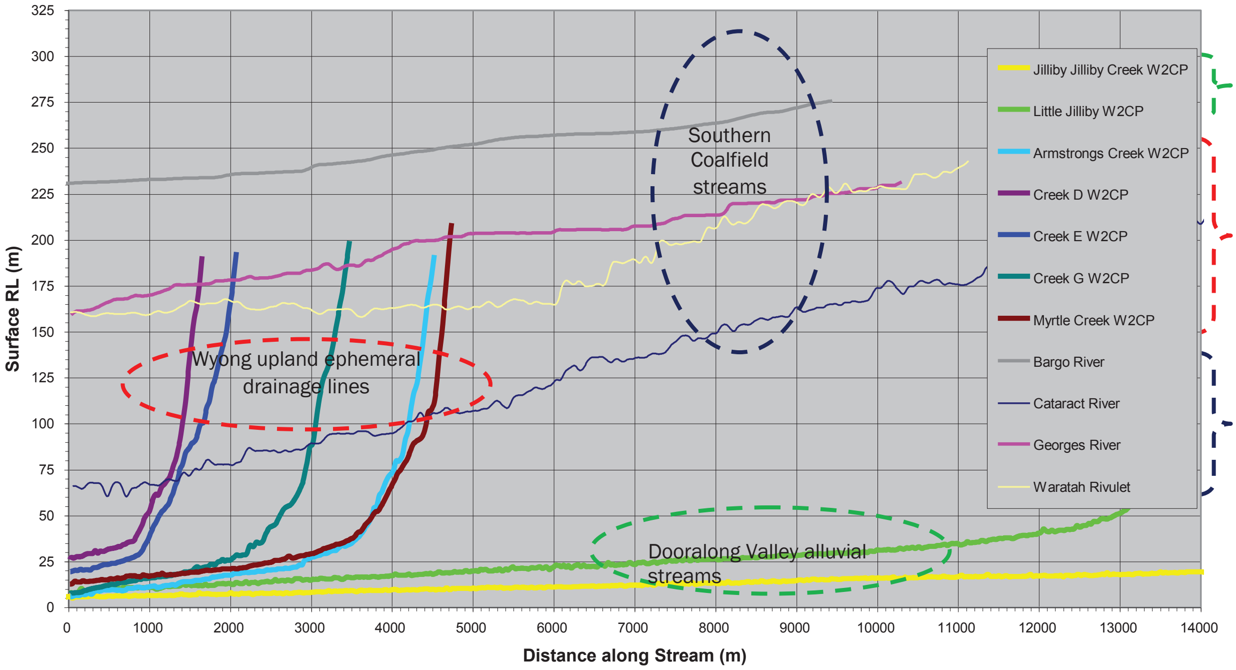


**Figure 2.6 Comparison of stream gradients within the W2CP upland and alluvial areas and those from Southern Coalfields**

### 2.3.3 Sandstone Occurrences in Upland Drainage Lines

Upland drainage lines have been inspected for the purposes of morphological characterisation and to evaluate the potential for sites or conditions of environmental interest. Extensive surveys along upland drainage lines undertaken by archaeological teams recorded grinding groove sites at isolated sandstone outcrops. These sites and the associated drainage lines were revisited. Aquatic ecological surveys, terrestrial ecology field reconnaissance and water sampling activities throughout the upland catchments were also frequently accompanied by geological/geomorphic personnel for information gathering and extensive photographic recording under different conditions.

The field inspections demonstrated that sandstone occurrences in upland ephemeral drainage lines and streams are useful indicators for sites of potential geomorphic and aquatic ecological interest. For example, in the Southern Coalfields, sandstone exposures are associated with rock bar features that could form dams for major pools that form important and persistent aquatic ecological refuges. Other types of sandstone outcrop in drainage lines can provide a potential location for archaeological features such as grinding grooves (provided other conditions are suitable such as suitable adjacent water supply and nearby food sources).

Numerous sandstone strata of varying strength and thickness occur within the Terrigal Formation and uppermost section of the Patonga Formation which underlie the western forested hills in the Extraction Area. To evaluate the potential of the upland drainage lines in the Wyong SF/Jilliby SCA to host sandstone occurrences of environmental interest, four types of “instream” sandstone morphological features (within the drainage channel itself) have been identified:

- **Type A**: Where a sandstone unit exposed in a hillside does not form a bench or prominent feature where it intersects the upland drainage line. Plate 5 shows a Type A example where the drainage line itself does not feature any intact and resistant in situ sandstone unit despite its adjacent presence. Therefore the sandstone bed's recessive condition has no effective in-channel hydrological relevance in such cases.

- Type B: Sandstone units exposed in 1st and 2nd order drainage lines that create a local bench or series of benched outcrops. Plates 6, 7, 8 and 9 show Type B examples. These resistant sandstone units are typically well jointed and fractured but show at least some residual overland seepage over the surface of rock bench. In the forested hills in the Extraction Area, they are not accompanied by any significant water pooling on the upstream side of the outcrop. Whenever pools do occur in the steep upland drainage lines they are ephemeral and typically formed in a small temporary pond composed of an alluvial dam with or without sandstone boulders.
- Type C: Sandstone units which are tabular and exposed as an extended bench top (greater than 3m) or which locally form the floor of the drainage line and may contain temporary water storage in small potholes. Archaeological sites recorded in 1st and 2nd order sections of Myrtle Creek and Little Jilliby Jilliby Creek occur within this type of sandstone exposure. Plates 10 and 11 show Type C sandstone units.
- Type D: Loose sandstone boulders of varying size and density that may choke the drainage line or be more sporadic and which may be accompanied by sandy to pebbly alluvial materials. These are the most frequent type of instream sandstone occurrences throughout the 1st and 2nd order stream sections and can account for up to 75% to 95% or more of the non-alluvial stream sections above the main alluvial valley floors. Plates 12 and 13 show Type D sandstone units.


Plate 6. A strongly jointed sandstone unit exposed in the lower hillside is discontinuous and not exposed or intact in the adjacent 1st order upland drainage line itself. Thus no bench of in situ sandstone is present in the drainage line in this Type A sandstone occurrence. No pool formation evident either above or below the sandstone. This steep drainage line is dominated by sandstone boulders (refer Type D), pebbles and minor quantities of alluvium and significant vegetative litter.


Plate 7. Example of a minor scale Type B sandstone unit exposure in a 1st order drainage line. Such sandstone units are typically well jointed and create a local bench showing overbench seepage. No water pooling is evident.


Plate 8. An additional example of a jointed sandstone at a Type B instream bench exposure showing existing very wide jointing typical in this stress-relieved terrain (Plate 8 above - see prominent jointing crack at left of photo, arrowed). Trickle flow is dominated by overbench seepage with minor seepage flow through joints and cracks. Bench heights are typically from 0.3m to over 1m but can be compound style featuring stepped benches of up to 3 m or more overall depending on the thickness and strength of the exposed sandstone units (refer Plate 9 below).

Plate 9. Example of multi-benched sandstone outcrops (Type B)

Plate 10. Channel bed showing tabular outcrop of resistant sandstone with widely-spaced joints (Type C sandstone occurrence). This location features temporary water storage in shallow potholes and small lateral pond after a rain event. The outcrop (over 6 m wide and 12 m long) is covered in significant leaf litter.


**Plate 11.** This additional example of a Type C sandstone exposure (at Hughes Creek tributary in the upper midsection of the Little Jilliby Jilliby Creek system) shows temporary water storages in closely spaced major joints following rain event. A close jointing pattern in the sandstone outcrop is most common in the upland drainage system and indicates a highly stress-relieved rock condition and a low risk from effects associated with subsidence.



**Plates 12 and 13.** Type D sandstone occurrences of boulder-choked ephemeral drainage line.

In situ sandstone bedrock occurrences in upland drainage lines are generally restricted to isolated well-jointed outcrops forming individual or compound stepped benches (Type B). Sandstone outcrops can also include either widely to closely jointed tabular sections exposed in the bed of the drainage line (Type C) that typically extend for 2 m to 5 m in length but isolated extents of around 15 m have been recorded. Type B and Type C sandstone outcrops in the upland catchments do not tend to act as rock bars for retaining any significant pools as would be more common in the major creeks in the Southern Highlands. Instead, any temporary water storage in the channel zone is localised and tends to be either in minor potholes or in small ponds less than 2 m diameter that are typically formed by stony alluvial dams that deplete within days following runoff events.

Not all exposures of sandstone units at particular contours in the adjacent steep hillside slopes translate to exposure in the creek bed (Type A).

In total, the prominent in situ sandstone exposures (Type B and C) typically account from 1% to up to 4% of the channel length of upland (non-alluvial plain) sections of 1st and 2nd order drainage lines in the Wyong State Forest/Jilliby SCA.

Type D sandstone occurrence involving loose boulders aggregated along or even “choking” the drainage channel is the most common upland drainage channel condition and can account from between 75% to up to 95% of the length of the upland drainage line.

#### 2.3.4 Constructed Drainage Features in Upland Forest Areas

The main forestry roads and trails in the western forested hills of the Extraction Area within Wyong SF/Jilliby SCA are constructed with culverts where they cross drainage lines. While these locations are often overgrown with lantana and it is difficult to make out detail, a “water feature” or pond at the crossing is sometimes evident when viewed from the forestry road as shown in Plate 14. However these conditions are not necessarily typical of the ephemeral drainage channel but instead are artefacts of the culvert design.

Armstrongs Creek has three main arms and is a direct tributary of Jilliby Jilliby Creek. It is a 2nd order stream (drainage line) in its lowest reach along alluvial lands up to the confluence with Jilliby Jilliby Creek. At its headwaters in the east of Wyong State Forest, Armstrongs Creek and its northern and southern arms or tributaries (Creek F and G respectively in Figure 2.5) are all 1st order streams which each pass through separate culverts under Brothers Road forest trail. At each location there are ephemeral ponds below the drainage culvert which act as a plunge pool within a boulder-lined alluvium, as shown in Plates 14 and 15. These semi-persistent ponds do not occur in extended dry periods and are not a rock bar and pool sequence.


**Plate 14** (left) - Creek F (the northern tributary of Armstrongs Creek): Ephemeral pond within alluvium and small loose boulders below culvert in Brothers Road, Wyong State Forest. Looking upstream in the 1st order stream.


**Plate 15** (above) – Creek F: Minor 1st order drainage line of alluvium and small loose boulders below ephemeral pond at culvert in Brothers Road (looking downstream).

### 2.3.5 Implications of Geology and Key Instream Geomorphologic Features

It is important to note that the 3rd order streams roughly correspond with the Patonga Claystone and/or valley alluvium while the steeper 1st and 2nd order streams exist within the relatively resistant sandstones of the Terrigal Formation. Consequently, the gradient of these 1st and 2nd order streams is such that they are too steep for the rock bars with large associated pools to form as distinct from those features that are evident in areas of the Southern Coalfield. All of the upland drainage lines that have been inspected for geological, ecological and archaeological purposes confirm that not one major rock bar and associated pool has been recorded.
On the basis of the extensive field inspections and the gradient of the stream profiles it is concluded that the geomorphology and topography of the area is such that only isolated, small rock benches and no long pools behind rock bars exist within the upland streams in the Extraction Area.

The ephemeral upland streams that exist within the Extraction Area are contained within V-shaped gullies separated by unconfined ridges. This is in contrast to the Southern Coalfield streams which are contained in more U-shaped gorges cut into a plateau. Consequently the stress concentrations that are the driving mechanisms responsible for the upsidence and closure observed in more significant streams such Cataract Gorge, the Georges River and the Waratah Rivulet are likely to be significantly less in the Project Boundary. This would in turn reduce the likely impacts on rock bars and pools in the areas where they may exist.
Evidence of geological jointing and hydrological behaviour in the upland forest areas of the Extraction Area, including recorded conditions of consistent loss of water circulation during drilling in the forest areas, indicates that the ridges that separate the upland streams are stress relieved with open joint systems. This lack of any rock bar controlled drainage lines in the

confined upland valleys reduces the sensitivity to subsidence and valley closure effects and limits the potential impacts upon recorded archaeological sites and aquatic ecological systems. Water quality of major streams in the Project Boundary has been monitored on a monthly basis over the majority of the period since commencement of exploration in 1996 as explained in Section 2.9.

The extensive water quality testing completed in upland streams and geochemical laboratory core testing have confirmed the limited potential for impacts to arise due to enhanced iron staining or related water quality effects following subsidence in upland and valley streams. Further information on the potential for enhanced iron staining is discussed further within the Groundwater Impact Assessment (MER, 2013).

### 2.3.6 Wallarah Creek Stream Characterisation

Wallarah Creek is a 3rd order stream in the locality of the W2CP proposed surface development at Tooheys Road. This section of stream is part of the northern part of the Wallarah Creek catchment which drains to Lake Budgewoi some 6.6 km downstream from the site after its confluence with Spring Creek at Blue Haven nearly 5 km downstream.

At the Tooheys Road site, Wallarah Creek is a stable, low gradient stream that usually resembles a chain of linear ponds with little or no connecting flow in dry periods. The stream flows with low sinuosity within an alluvial zone generally between 10 m and 60 m wide and switches from a well-defined single channel configuration to sections of stable multi-channel flow during higher flow post-rainfall periods. The alluvial zone is well vegetated and stable and features a varying understorey including shrubs, grasses (Lomandra sp.) or bracken fern and an overstorey of mature trees.

An overview of the stream characterisation is provided in Figure 2.7.

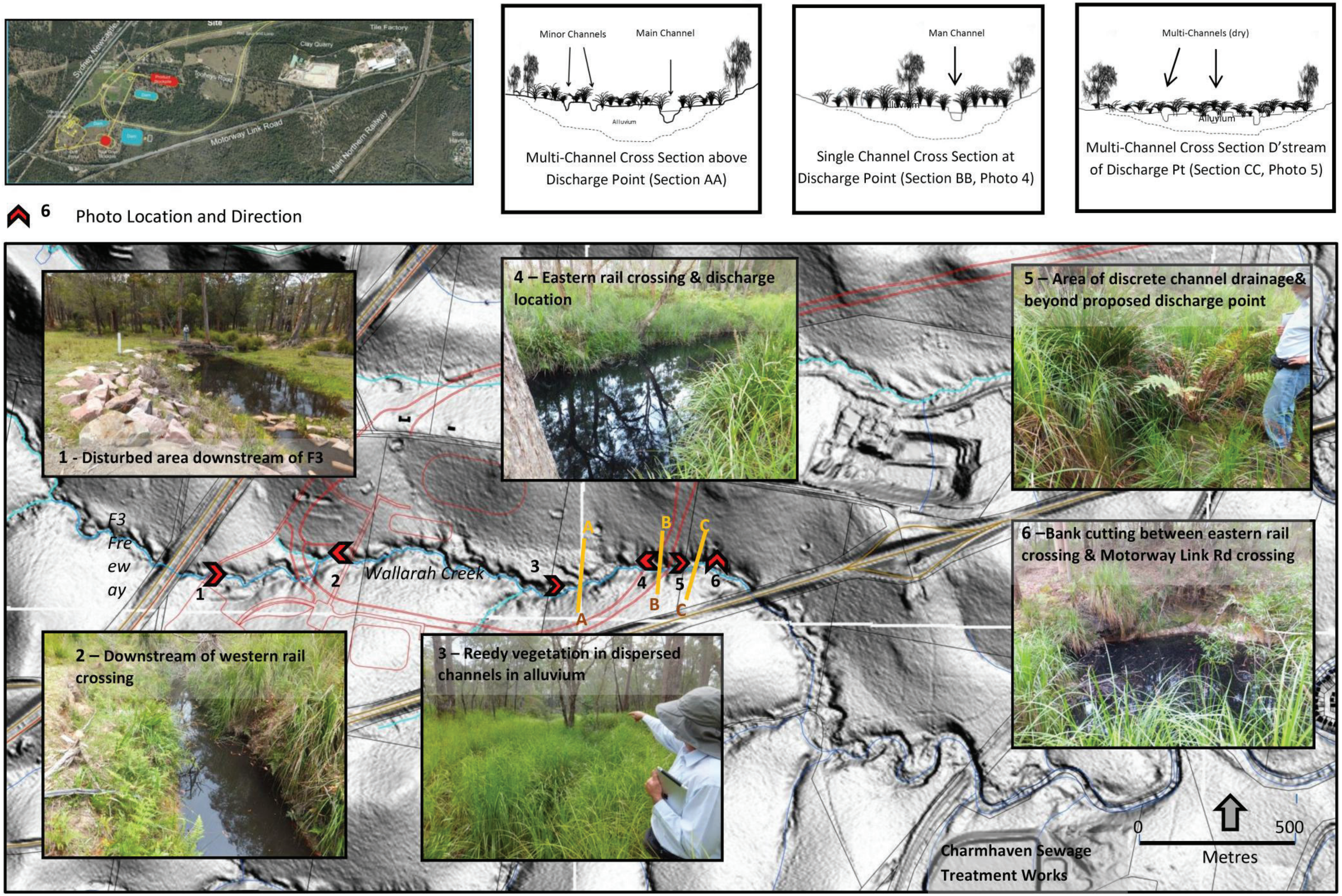


Figure 2.7 Wallarah Creek Characterisation Overview

### 2.3.7 Jilliby Jilliby Creek and Little Jilliby Jilliby Creek

Within the Project Boundary, Jilliby Jilliby Creek is categorised as "Laterally Unconfined Setting, Meandering, Sand" (IEC, 2009). The channel in this area is dominated by sand and becomes deeper than it is upstream. The floodplain is continuous, the channel is symmetrical and trench-like (deep and narrow) with a moderate sinuosity (IEC 2009).

The creek consists of a single, deep narrow channel ranging between 10 m and 20 m wide and approximately 3 m deep. The largely intact riparian vegetation provides lateral stability. The riparian vegetation provides a sustainable source of large woody debris to the creek which provides natural bed controls such as pools and irregular riffle sequences (see Figure 2.8). Some areas of local degradation of river character and behaviour are evident in the Extraction Area. The floodplain topography and aerial images show evidence of historical channel avulsions, resulting in numerous abandoned channels across the floodplain.

A detailed site inspection of the area around the confluence of Jilliby Jilliby Creek and Little Jilliby Jilliby Creek was undertaken in July 2012 to assess channel conditions and any impediments to the readjustment of the channel longitudinal profile following subsidence. Observations from the site inspection are summarised as follows:

- The Jilliby Jilliby Creek waterway (near the confluence of Little Jilliby Jilliby Creek) is heavily wooded on either side of its banks, with significant small and large tree coverage encroaching on the waterway channel (Figure 2.9).
- The waterway channel is deeply incised, at depths of more than 3 m relative to the surrounding natural surface. The banks of the waterway were generally very steep (vertical in some sections), with severe undercutting and slumping evident at several locations (Figure 2.10).
- The creek banks appeared to be heavily supported by local tree root mass along the edge of the channel, with significant erosion evident in areas with no tree coverage (Figure 2.11).
- At the time of the site inspection, the waterway was flowing slowly, at depths of between 0.2 m to 1.0 m.
- The creek bed is primarily comprised of silty sand, with little pebbles/stones evident (Figure 2.12). At a depth of around 0.2 m-0.3 m, there was evidence of a thick layer of decomposed organic matter within the creek bed. This suggests that the top 0.2 m to 0.3 m layer of sand/silt was deposited relatively recently, and indicates significant sediment transport capacity in this section of the creek (Figure 2.13).
- There was no evidence of rock outcrops either in the waterway channel or on the banks.
- Little Jilliby Jilliby Creek has similar characteristics to Jilliby Jilliby Creek, with the following differences:
  - The waterway is less incised (up to around 1.5 m although incised up to 3 m adjacent to the confluence).
  - The flow depth was minimal (around 0.05 m - 0.1 m).
  - Approximately 20 - 30 m upstream of the Jilliby Jilliby Creek and Little Jilliby Jilliby Creek confluence, there was significant evidence of bank erosion actively occurring. At this location, a treefall across Little Jilliby Jilliby Creek had previously occurred, partially damming the creek with leaf matter and deposited sand material.
  - This obstruction was diverting the creek flow towards the peninsula separating the two creeks. Where the flow was diverted, an area of approximately 10 m x 10 m had eroded from the peninsula, causing massive failure of the bank and further vegetation to fall into the waterway. It was estimated that the width of the peninsula between Jilliby Jilliby Creek and Little Jilliby Jilliby Creek has been reduced from 12m to around 2m by this erosive action. It is expected that the next

significant flow event in Little Jilliby Jilliby Creek will likely break through the peninsula, forming a new flow path for the creek (Figure 2.14).

Review of aerial photography shows that the alignment of Jilliby Jilliby Creek has changed over time, with abandoned channels and ox-bow channels evident in a number of locations. Although the cause (natural or man-made) and the timing of these channel alignment adjustments is not known, the active erosion currently occurring near the confluence suggests that this process is naturally occurring to some degree, due to the highly dispersive nature of the bed/bank material.

**Figure 2.8 Photograph showing dominance of large woody debris in main channel**

Figure 2.9 Photograph of Jilliby Jilliby Creek near the confluence of Little Jilliby Jilliby Creek

Figure 2.10 Photograph of bank erosion along Jilliby Jilliby Creek

Figure 2.11 Photograph of Jilliby Jilliby Creek showing erosion of poorly vegetated bank

Figure 2.12 Photograph of Jilliby Jilliby Creek typical bed material

Figure 2.13 Photograph of Jilliby Jilliby Creek showing organic material deposited on creek bed

Figure 2.14 Photograph of active erosion area at confluence of Jilliby Jilliby Creek and Little Jilliby Jilliby Creek

## 2.4 WATER SUPPLY SYSTEM

Gosford City and Wyong Shire Councils have a joint water supply system managed by the Gosford Wyong Councils Water Authority (GWCWA) which serves a current urban population of 285,000 people (GWCWA, 2010). From July 2013, the GWCCWA will become the Central Coast Water Corporation and will manage both the drinking water supply and the regional sewerage system. The present Gosford-Wyong Water Supply Scheme is based on harvesting potable water from four coastal streams: Wyong River, Mangrove Creek, Mooney Mooney Creek and Ourimbah Creek. The Water Supply Scheme surface water infrastructure includes a network of dams, weirs, reservoirs and water treatment plants interconnected by tunnels and pipelines (SKM 2010), as shown in Figure 2.15.

There are three operational dams (Mangrove Creek Dam, Mardi Dam and Mooney Dam) and three operational weirs in the joint water supply system. A summary of the key storages is provided in Table 2.1. There are also two water treatment plants in the Scheme, one located at Somersby in Gosford City and the other at Mardi, in Wyong Shire.

Abstractions from the Wyong River and Ourimbah Creek are transferred to Mardi Dam, which is an off-stream storage. The recently constructed Mardi-Mangrove Link (completed July 2012) links the Wyong River and Ourimbah Creek to Mangrove Creek Dam, via Mardi Dam.

If needed, water can be released from Mangrove Creek Dam to provide sufficient flows down Mangrove Creek. Alternatively, with the advent of the Mardi-Mangrove Creek Dam pipeline, water from the Dam can be released via Boomerang Creek Tunnel and then the pipeline to be transferred to Mardi Dam without requiring routing via the Wyong River as historically has been the case. Water harvested from Wyong River can also be pumped to the larger Mangrove Creek Dam. The Mardi-Mangrove Link can transfer up to 120 ML/d in either direction.

Proposed future development of the water supply system, described in *WaterPlan 2050* (GWCWA, 2007), will progressively raise the annual system yield to 50,000 ML. These works are anticipated to provide sufficient water to satisfy demands until 2050.

Figure 2.16 presents a schematic of the Gosford-Wyong water supply system.

**Table 2.1 GWCWA Water Supply Storages (SKM, 2010)**

| Catchment | Year Built | Catchment Area ($km^2$) | Maximum Capacity (ML) |
|---|---|---|---|
| Mangrove Creek Dam | 1980 | 101 | 190,000 |
| Mardi Dam | 1962 | 2 | 7,400 |
| Mooney Dam | 1961 | 39 | 4,600 |
| Lower Wyong River Weir | 1968 | 355 | 300 |
| Lower Mangrove Creek Weir | 1975 | 140 | 100 |
| Ourimbah Creek Weir | 1978 | 88 | 45 |
| | **Total** | **725** | **202,700** |

Table 2.2 shows the average annual inflows to the water supply system, obtained from *WaterPlan 2050* which indicates an average annual stream flow of 176,300 ML.

Table 2.2 GWCWA Water Supply System Inflows (GWCWA, 2007)

| Catchment | Catchment Area ($km^2$) | Average Annual Streamflow (ML) | Average Annual Streamflow ($ML/km^2/year$) |
|---|---|---|---|
| Lower Wyong River Weir | 355 | 84,500 | 238 |
| Ourimbah Creek Weir | 88 | 26,400 | 300 |
| Mooney Dam | 39 | 16,800 | 431 |
| Mangrove Creek Dam | 101 | 18,600 | 184 |
| Mangrove Creek Weir (excluding Mangrove Creek Dam catchment) | 140 | 30,000 | 214 |
| **TOTAL** | **725** | **176,300** | |

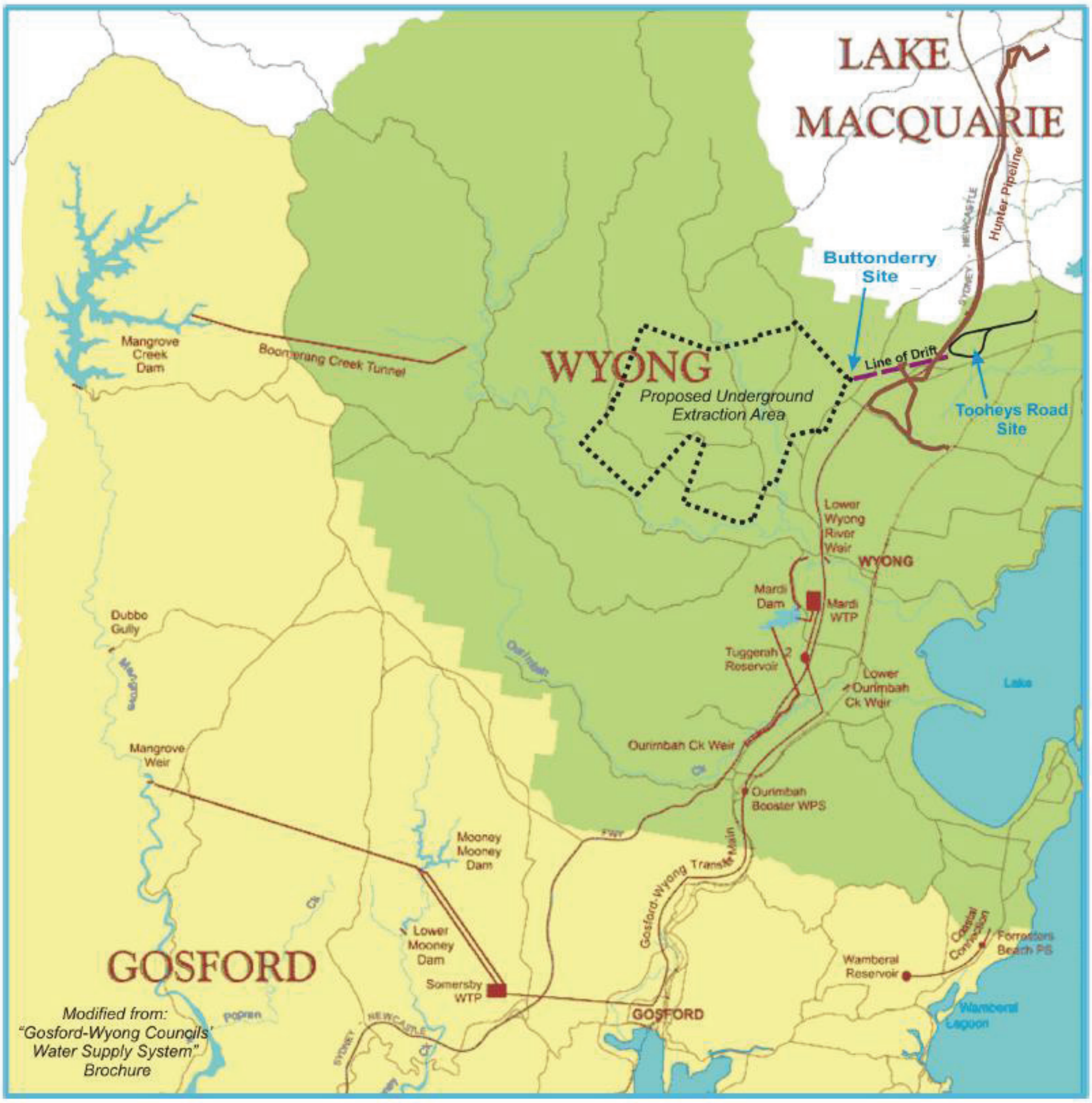


Figure 2.15 Location of the Project within the Water Supply Catchment (Base Source: GWCWA)

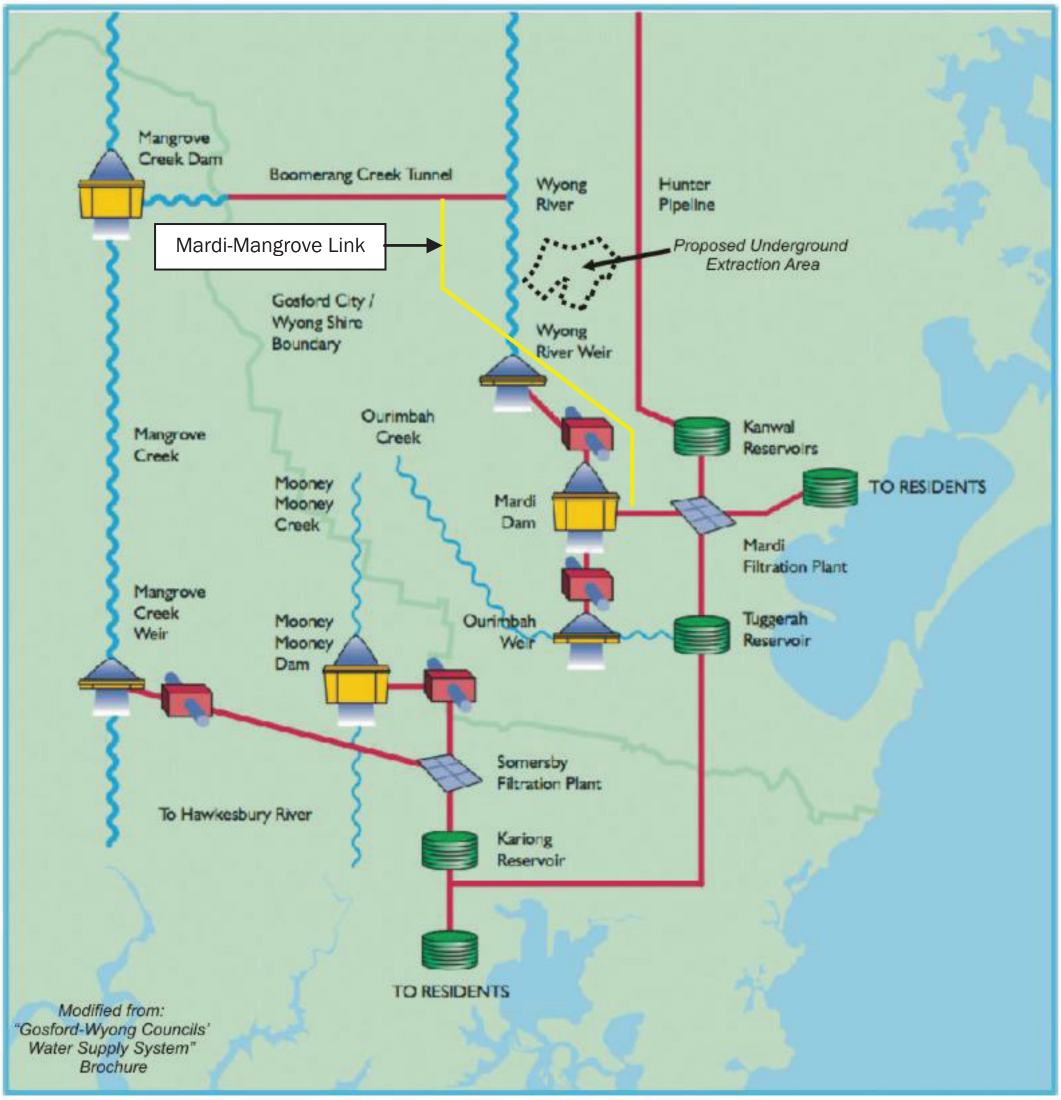


Figure 2.16 Gosford-Wyong Water Supply System (Base Source: GWCWA)

## 2.5 WATER SHARING PLANS

### 2.5.1 Overview

Water Sharing Plans (WSPs) are detailed legal instruments which provide certainty of access for environmental health and for all licensed water users (DPI 2004a). River flows are divided into flow classes. A portion of the water within each flow class is reserved for the environment and both annual and daily limits are set on the water which can be extracted. WSPs relevant to the Project include:

- Water Sharing Plan for the Central Coast Unregulated Water Sources, and
- Water Sharing Plan for the Jilliby Jilliby Creek Water Source.

### 2.5.2 Jilliby Jilliby Creek Water Source

Jilliby Jilliby Creek is naturally variable, changing frequently from flood to drought. The DNR (now Department of Primary Industries (DPI) Office of Water (NOW)) considers Jilliby Jilliby Creek to be a stressed river. This means that relative to the natural flows in the water source, the potential demand for extraction by water users is high (DPI 2004a). The Jilliby Jilliby Creek WSP commenced in 2004 and was revised in July 2009 following public consultation in late 2008 and early 2009. At the commencement of the Jilliby Jilliby Creek Water Source WSP in July 2004, there were 27 water access licences. Of these, 23 were for irrigation, one for farming purposes, one for industrial and two for domestic and stock purposes. The total water volume for all categories of licences from the water source at the commencement of the plan was approximately 1,016 ML/year.

The Jilliby Jilliby Creek WSP applies only to the surface water resources occurring on land shown on the plan at Schedule 2 of the Jilliby Jilliby Creek WSP (which includes Jilliby Jilliby Creek itself and any lakes and wetlands in the water source area). The WSP does not include any water contained within the aquifers underlying the water source. Management of the long-term water extraction in the Jilliby Jilliby Creek Water Source is undertaken within the Tuggerah Lakes Extraction Management Unit.

### 2.5.3 Central Coast Unregulated Water Source

The Central Coast Unregulated Water Source WSP commenced on 1 August 2009 and includes the Central Coast unregulated rivers and creeks but excludes Ourimbah and Jilliby Jilliby Creek as WSPs already exist for these creeks. In total, there are five water sources covered by the WSP: the Brisbane Water Water Source, the Mooney Mooney Creek Water Source, the Mangrove Creek Water Source, the Wyong River Water Source and the Tuggerah Lakes Water Source. The availability of water to be taken from these water sources and the management of the long-term average annual extraction limit in these water sources is undertaken in the Tuggerah Lakes Extraction Management Unit and the Gosford Extraction Management Unit.

The Wyong River Water Source, which could potentially be impacted indirectly by the Project, has the following licensed water use:

- Total surface water entitlement: 38,782 ML/year (10% used for irrigation purposes, 89% used for town water supply purposes).
- 94 surface water licences.
- Peak Daily Demand = 79.9 ML/day.
- Makes up 78.6 % of the total Tuggerah Lakes Extraction Management Unit entitlement.

The Wyong River water source, the WSP for the Central Coast Unregulated Water Sources only applies to the surface water resources of Wyong River itself and any lakes and wetlands in the water source area. However, the WSP does not include any water contained within the aquifers underlying the water source, including alluvial sediments.

The Tuggerah Lakes Water Source, which could also potentially be impacted indirectly by the Project, has the following licensed water use:

- Total surface water entitlement: 20 ML/year (75% used for irrigation purposes).
- 1 surface water licence.
- Peak Daily Demand = 0.1 ML/day.
- Makes up 0.04 % of the total Tuggerah Lakes Extraction Management Unit entitlement.

### 2.5.4 GWCWA Entitlemenhts

GWCWA presently has the following water entitlements from the water supply system catchments:

- 34,600 ML/year from Wyong River and Jilliby Jilliby Creek,

- 8,400 ML/year from Ourimbah Creek,
- 47,900 ML/year from Mangrove Creek, and
- 17,900 ML/year from Mooney Mooney Creek.

Note however that actual extractions are limited by the water sharing plans to a total of 36,750 ML/year.

## 2.6 RAINFALL AND EVAPORATION

Table 2.3 shows summary details of Bureau of Meteorology (BoM) rainfall recording stations with a significant period of record in the vicinity of the Project.

**Table 2.3 Bureau of Meteorology Rainfall Stations**

| Station No. | Station Name | Elevation | Lat (°S) | Long (°E) | Distance from Site | | Opened | Closed |
|---|---|---|---|---|---|---|---|---|
| | | | | | Tooheys Rd | Buttonderry | | |
| 061082 | Wyee (Wyee Farms Rd) | 40m | 33.18 | 151.44 | 4 km NW | 5 km NE | 1899 | - |
| 061012 | Cooranbong (Avondale) | 10m | 33.09 | 151.46 | 14 km N | 15 km NE | 1903 | - |

In order to extend the rainfall dataset for the water balance calculations, a synthetic rainfall dataset was also obtained for a location near the Project from the Queensland Climate Change Centre of Excellence Data Drill service (Jeffrey et al. 2001). The Data Drill "*accesses grids of data derived by interpolating the Bureau of Meteorology's station records. Interpolations are calculated by splining and kriging techniques. The data in the Data Drill are all synthetic; there are no original meteorological station data left in the calculated grid fields. However, the Data Drill does have the advantage of being available for any set of coordinates in Australia*" (QCCCE, 2012). The key advantage of adopting the Data Drill data is that it has been adjusted to remove accumulated totals over multiple days and to fill periods of missing data using rainfall from nearby stations.

A comparison of mean monthly rainfalls for Data Drill and BoM rainfall stations over the period 1904-2008 is presented in Table 2.4. Table 2.5 shows mean monthly evaporation recorded at the Cessnock (Nulkaba) station which is located approximately 40 km north of the Project Boundary and at the Peats Ridge (Waratah Road) station, located about 23 km southwest of the Project Boundary.

Table 2.5 also shows interpolated pan evaporation and Morton's Lake evaporation (Morton, 1983) obtained from the Data Drill service for the Project Boundary. Mean annual rainfall is about 15% lower than mean annual evaporation. Figure 2.17 shows the annual distribution of monthly rainfall and evaporation. The evaporation pattern indicates higher evaporation in the warmer months and less evaporation in the colder months. The rainfall pattern shows most rainfall occurring at the end of summer and during spring. During autumn and early winter, mean monthly rainfall is higher than mean monthly evaporation.

Table 2.4 Mean Monthly Rainfall (1904-2008)

| Month | Wyee (Wyee Farms Rd) - #061082 | Cooranbong (Avondale) - #061012[a] | Data Drill |
|---|---|---|---|
| Jan | 112.1 | 109.4 | 109.9 |
| Feb | 134.1 | 132.3 | 130.5 |
| Mar | 134.1 | 126.3 | 133.2 |
| Apr | 128.4 | 121.0 | 126.0 |
| May | 113.3 | 98.2 | 112.1 |
| Jun | 109.9 | 102.2 | 111.2 |
| Jul | 75.5 | 70.0 | 75.6 |
| Aug | 65.0 | 60.4 | 64.8 |
| Sep | 68.6 | 59.8 | 67.3 |
| Oct | 72.4 | 67.9 | 71.4 |
| Nov | 80.8 | 79.9 | 79.7 |
| Dec | 99.3 | 99.9 | 97.9 |
| **Total** | **1,192** | **1,135** | **1,180** |

Note: [a] Significant period of missing data during 1934-1943.

Table 2.5 Mean Monthly Evaporation [mm/month]

| Month | Peats Ridge (Waratah Road) (1981 to 2012) | Cessnock (Nulkaba) (1973-2012) | Pan Evaporation [a] (1889-2011) | Morton's Lake Evaporation [a] (1889-2011) |
|---|---|---|---|---|
| Jan | 143 | 177 | 176.1 | 179.4 |
| Feb | 116 | 138 | 141.6 | 146.6 |
| Mar | 105 | 121 | 125.9 | 132.2 |
| Apr | 78 | 84 | 93.7 | 91.0 |
| May | 56 | 59 | 67.3 | 59.5 |
| Jun | 48 | 45 | 56.1 | 41.7 |
| Jul | 53 | 53 | 65.3 | 49.5 |
| Aug | 78 | 78 | 90.1 | 74.6 |
| Sep | 102 | 105 | 116.8 | 104.1 |
| Oct | 124 | 133 | 145.6 | 139.1 |
| Nov | 129 | 150 | 158.4 | 159.0 |
| Dec | 146 | 177 | 185.3 | 181.4 |
| **Total (mm/y)** | **1,177** | **1,319** | **1,422** | **1,358** |

[a] Obtained from SILO Data Drill

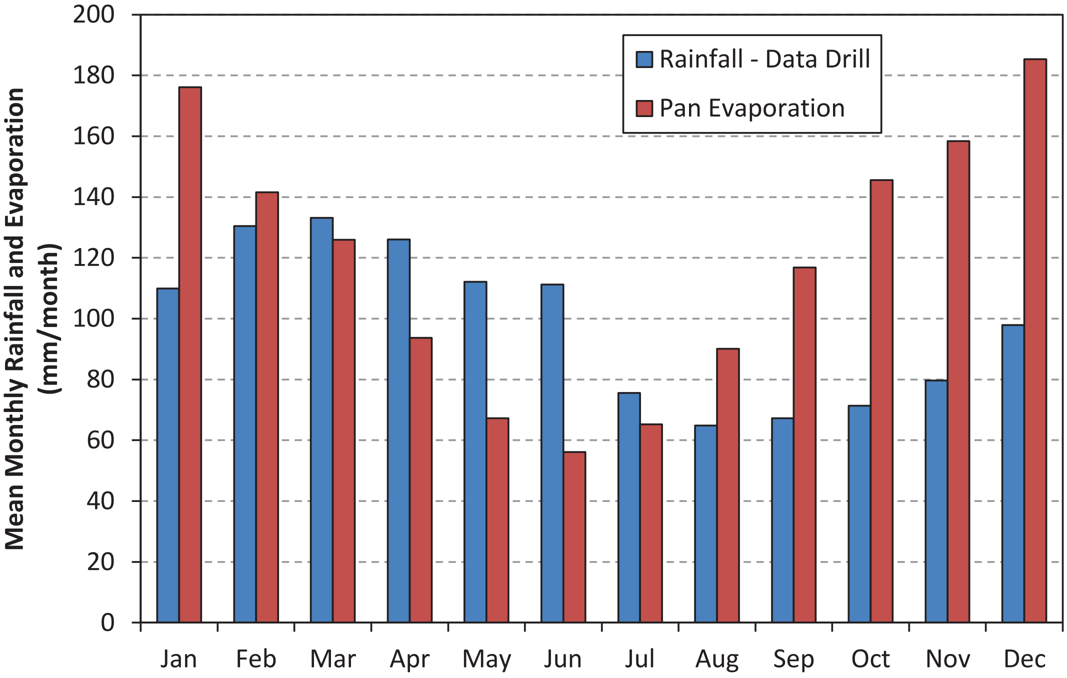


Figure 2.17 Distribution of Monthly Rainfall and Pan Evaporation

## 2.7 STREAMFLOW

Figure 2.18 shows the locations of New South Wales Office of Water (NOW) stream gauging stations in the vicinity of the Project Boundary. A summary of these stations is provided in Table 2.6.

Table 2.6 NOW Stream Gauging Stations

| Station No. | Station Name | Catchment Area ($km^2$) | Opened | Closed |
|---|---|---|---|---|
| 211006 | Wallarah Creek at Warnervale | 9 | 1965 | 1976 |
| 211009 | Wyong River at Gracemere | 236 | 1972 | - |
| 211010 | Jilliby Jilliby Creek U/S of the Wyong River | 92 | 1972 | - |

Figure 2.19 shows the recorded flow-duration relationship for streamflow recorded at Wallarah Creek at Warnervale (#211006) for the period of record 1965 to 1976. This gauge (now closed) is located approximately 2 km downstream of the Tooheys Road site. During the period of record, Wallarah Creek was ephemeral, with a median ($50^{th}$ percentile) flow rate of approximately 0.25 ML/d. The $10^{th}$ percentile flow rate is approximately 4 ML/d. That is, 10% of all recorded daily flows exceeded 4 ML/d over the period of record.

Figure 2.19 shows the recorded flow-duration relationship for streamflow recorded at Wyong River at Gracemere (#211009) for the period of record 1972 to 2009. During the period of record, Wyong River was perennial, with a median ($50^{th}$ percentile) flow rate of greater than 30 ML/d.

Figure 2.19 shows the recorded flow-duration relationship for streamflow recorded at Jilliby Jilliby Creek U/S of the Wyong River (#211010) for the period of record 1972 to 2009. During the period of record, Jilliby Jilliby Creek was ephemeral, with a median (50th percentile) flow rate of approximately 5 ML/d.

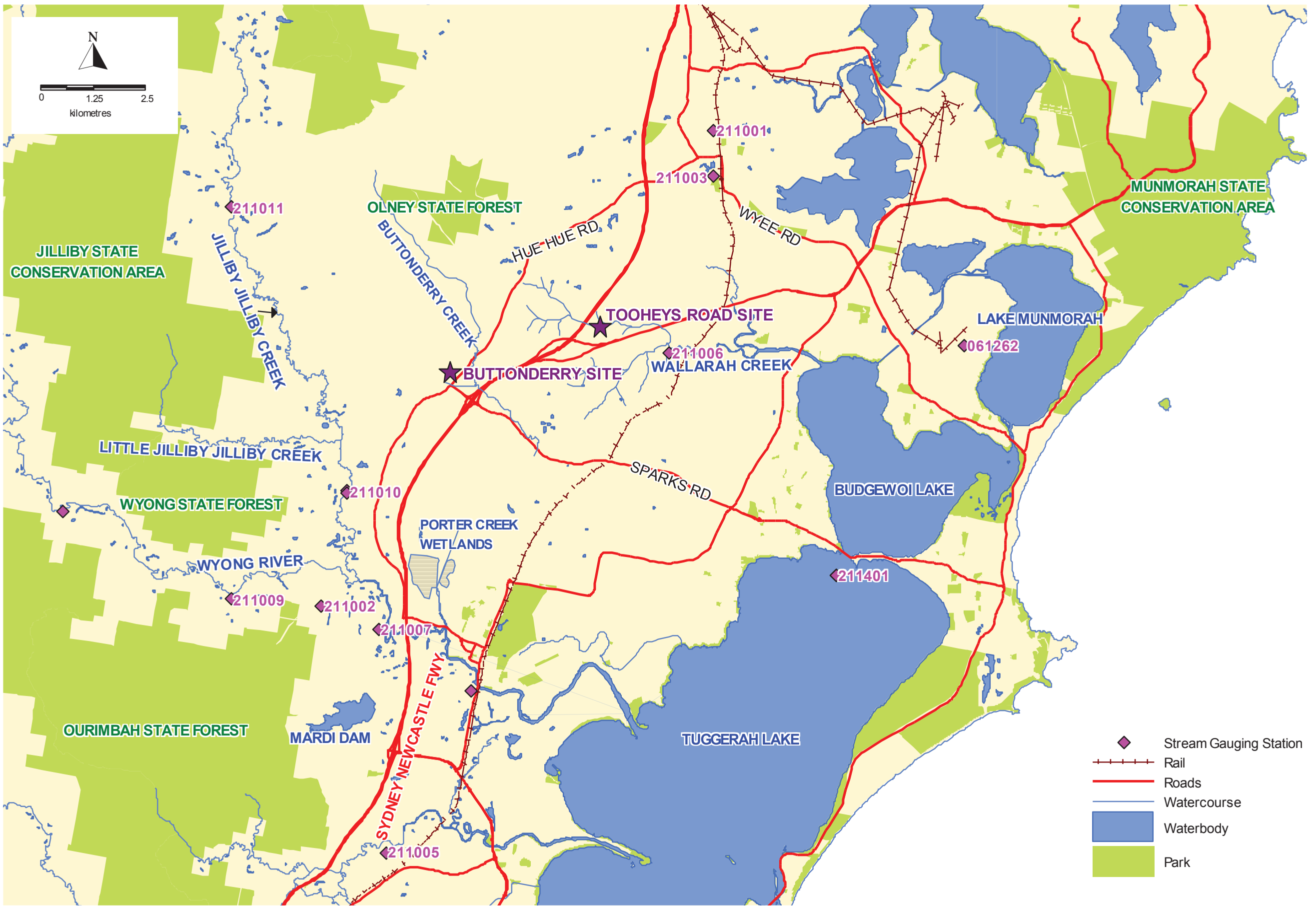


Figure 2.18 NOW Stream Gauging Locations

A summary of the historical information for rainfall and streamflow in Wallarah Creek, Wyong River and Jilliby Jilliby Creek is presented in Table 2.7, Table 2.8 and Table 2.9 respectively. An estimate of the volumetric runoff coefficient for each year is also presented. Rainfall data has been taken from BoM rainfall stations within or closest to each catchment. The estimated volumetric runoff coefficients for the Wyong River (17%) and Jilliby Jilliby Creek (24%) are relatively high. The estimated volumetric runoff coefficient of 36% for Wallarah Creek is very high for a catchment without significant impervious areas. It is possible that this high runoff coefficient is an artefact of the rating curve at the Wallarah Creek gauge. However, it is noted that the period of available data (1966 to 1976) includes some very wet years.

Based on these results, the average annual streamflow from the Jilliby Jilliby Creek catchment is 248 mm, which is equivalent to 248 ML per km$^2$ per year. The Jilliby Jilliby Creek catchment thus contributes, on average, approximately 24,800 ML of streamflow per year to the catchment of the Gosford-Wyong Water Supply Scheme. This represents about 14% of total streamflow in the Gosford-Wyong Water Supply Scheme.

Table 2.7 Historical Streamflow Data, Wallarah Creek at Warnervale (#211006)

| Year | Rainfall (mm) | Streamflow (ML) | Streamflow (mm) | Volumetric Runoff Coefficient (%) |
|---|---|---|---|---|
| 1966 | 908 | 814 | 90.4 | 10 |
| 1967 | 1,742 | 7,762 | 862.4 | 50 |
| 1968 | 911 | 1,577 | 175.2 | 19 |
| 1969 | 1,353 | 3,692 | 410.3 | 30 |
| 1970 | 915 | 1,359 | 151.0 | 17 |
| 1971 | 1,232 | 4,326 | 480.7 | 39 |
| 1972 | 1,357 | 4,986 | 554.0 | 41 |
| 1973 | 1,185 | 2,379 | 264.4 | 22 |
| 1974 | 1,545 | 7,424 | 824.9 | 53 |
| 1975 | 1,377 | 6,405 | 711.6 | 52 |
| | Average | 4,072 | | 36% |

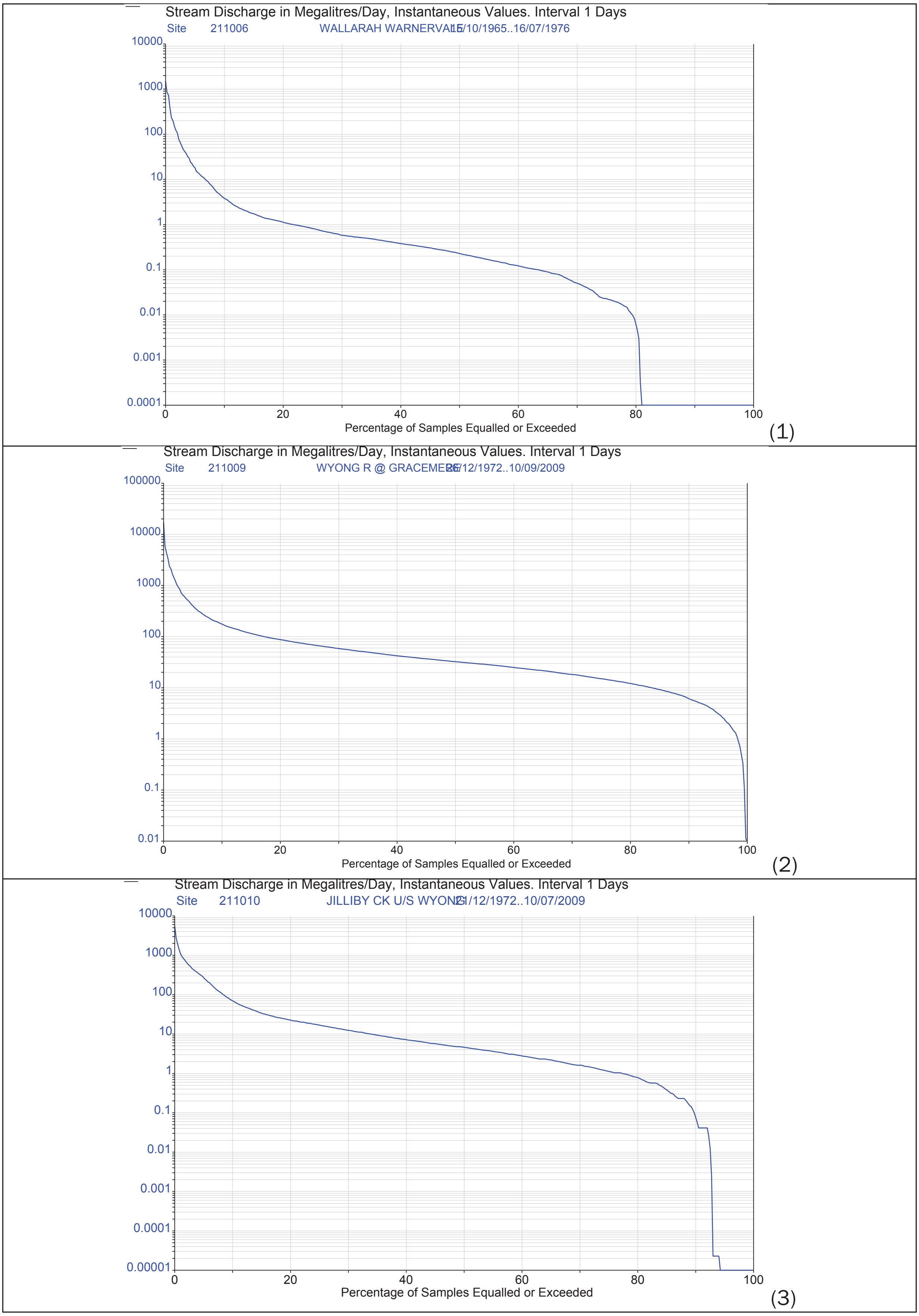


**Figure 2.19 Flow Duration Curves for (1) Wallarah Creek at Warnervale, (2) Wyong River at Gracemere, and (3) Jilliby Jilliby Creek U/S Wyong River**

Table 2.8 Historical Summary of Wyong River at Gracemere (#211009)

| Year | Rainfall (mm) | Streamflow (ML) | Streamflow (mm) | Volumetric Runoff Coefficient (%) |
|---|---|---|---|---|
| 1974 | 1,465 | 151,200 | 641 | 44 |
| 1975 | 1,407 | 72,130 | 306 | 22 |
| 1977 | 1,101 | 104,800 | 444 | 40 |
| 1979 | 605 | 15,730 | 67 | 11 |
| 1980 | 807 | 6,666 | 28 | 4 |
| 1981 | 1,439 | 82,630 | 350 | 24 |
| 1982 | 772 | 28,240 | 120 | 15 |
| 1983 | 1,045 | 22,580 | 96 | 9 |
| 1984 | 1,283 | 64,740 | 274 | 21 |
| 1985 | 1,100 | 60,460 | 256 | 23 |
| 1986 | 1,183 | 45,450 | 193 | 16 |
| 1987 | 1,195 | 35,600 | 151 | 13 |
| 1993 | 698 | 11,860 | 50 | 7 |
| 1994 | 638 | 12,990 | 55 | 9 |
| 1995 | 976 | 24,860 | 105 | 11 |
| 1996 | 918 | 19,500 | 83 | 9 |
| 1997 | 813 | 12,590 | 53 | 7 |
| 1998 | 1,163 | 50,100 | 212 | 18 |
| 1999 | 1,215 | 27,410 | 116 | 10 |
| 2000 | 814 | 19,070 | 81 | 10 |
| 2001 | 703 | 49,260 | 209 | 30 |
| 2002 | 1,025 | 22,980 | 97 | 10 |
| 2003 | 359 | 12,040 | 51 | 14 |
| 2004 | 924 | 13,270 | 56 | 6 |
| 2005 | 852 | 8,813 | 37 | 4 |
| 2006 | 760 | 4,106 | 17 | 2 |
| 2007 | 1,681 | 76,920 | 326 | 19 |
| | Average | 39,071 | | 17% |

Table 2.9 Historical Summary of Jilliby Jilliby Creek U/S Wyong River (#211010)

| Year | Rainfall (mm) | Streamflow (ML) | Streamflow (mm) | Volumetric Runoff Coefficient (%) |
|---|---|---|---|---|
| 1974 | 1,465 | 57,190 | 622 | 42 |
| 1975 | 1,407 | 38,020 | 413 | 29 |
| 1976 | 1,441 | 59,450 | 646 | 45 |
| 1977 | 1,101 | 34,670 | 377 | 34 |
| 1978 | 1,464 | 38,550 | 419 | 29 |
| 1979 | 605 | 5,163 | 56 | 9 |
| 1980 | 807 | 1,108 | 12 | 1 |
| 1981 | 1,439 | 44,460 | 483 | 34 |
| 1982 | 772 | 11,110 | 121 | 16 |
| 1983 | 1,045 | 13,370 | 145 | 14 |
| 1984 | 1,283 | 27,420 | 298 | 23 |
| 1985 | 1,100 | 23,320 | 253 | 23 |
| 1986 | 1,183 | 17,080 | 186 | 16 |
| 1987 | 1,195 | 8,490 | 92 | 8 |
| 1988 | 1,771 | 42,020 | 457 | 26 |
| 1989 | 1,514 | 55,650 | 605 | 40 |
| 1990 | 1,857 | 66,340 | 721 | 39 |
| 1991 | 745 | 5,056 | 55 | 7 |
| 1993 | 698 | 1,428 | 16 | 2 |
| 1994 | 638 | 4,855 | 53 | 8 |
| 1995 | 976 | 11,120 | 121 | 12 |
| 1996 | 918 | 8,188 | 89 | 10 |
| 1997 | 813 | 3,928 | 43 | 5 |
| 1998 | 1,163 | 30,340 | 330 | 28 |
| 1999 | 1,215 | 19,870 | 216 | 18 |
| 2000 | 814 | 6,327 | 69 | 8 |
| 2001 | 703 | 18,770 | 204 | 29 |
| 2002 | 750 | 10,790 | 117 | 16 |
| 2003 | 359 | 6,255 | 68 | 19 |
| 2004 | 387 | 3,800 | 41 | 11 |
| 2006 | 760 | 2,125 | 23 | 3 |
| 2007 | 1,681 | 25,490 | 277 | 16 |
| 2008 | 1,482 | 36,240 | 394 | 27 |
| 2009 | 800 | 36,238 | 394 | 49 |
| | **Average** | **22,532** | | **24%** |

## 2.8 BASEFLOW

An analysis of baseflow in the Wyong River and Jilliby Jilliby Creek was undertaken as part of the Wyong Water Study (SKM, 2010). The results of the baseflow analysis indicate that baseflow comprises 14% to 28% of measured streamflow across the region. During dry periods, the proportion of baseflow may increase to 100% of recorded streamflow (SKM, 2010).

## 2.9 WATER QUALITY

### 2.9.1 Regional Water Quality

Water quality data has been sourced from the NOW for two locations (shown in Figure 2.18):

- Wyong River at Gracemere (Station No. 211009) – opened in 1972; and
- Jilliby Jilliby Creek upstream of Wyong River (Station No. 211010) – opened in 1972.

The available water quality data is summarised in Appendix A and compared to the trigger values in the Australia and New Zealand Environment Conservation Council (ANZECC) water quality guidelines (ANZECC, 2000), shown in Table 2.10. Instances of exceedances of the protection trigger values for either the ecosystem, irrigation, recreational or livestock drinking water have been recorded for pH, electrical conductivity (EC), turbidity, total iron and total phosphorus, but all other constituents are below trigger levels. Further details are presented in Appendix A.

Table 2.10 Water Quality Trigger Values (ANZECC, 2000)

| Parameter | Unit | Trigger Value | | | |
|---|---|---|---|---|---|
| | | Irrigation | Livestock drinking | Eco-system*[d] | Recreational |
| pH | pH | 6.0 - 9.0 | - | 6.5 - 8.5 | 6.5 - 8.5 |
| EC (uncompensated) | µS/cm | 1,000 *[a] | - | - | - |
| EC (25C) | µS/cm | - | - | 125 – 2,200 | - |
| DO (% Saturation) | | - | - | 85-110 | - |
| Total Dissolved Solids (TDS) | mg/L | - | 2,000*[a] | - | 1,000 |
| Turbidity | NTU | - | - | 6-50 | - |
| Calcium (Ca) | mg/L | - | 1,000 | - | - |
| Sodium (Na) | mg/L | 115*[c] | | - | 300 |
| Magnesium (Mg) | mg/L | - | 2,000*[b] | - | - |
| Sulphate as SO4 | mg/L | - | 1,000 | - | 400 |
| Chloride as Cl | mg/L | 175*[c] | - | - | 400 |
| Arsenic | mg/L | 0.1*[f] | 0.5 | 0.013*[ae] | 0.05 |
| Barium | mg/L | | - | - | 1 |
| Cadmium | mg/L | 0.01*[f] | 0.01 | 0.0002*[e] | 0.005 |
| Chromium | mg/L | 0.1*[f] | 1 | 0.001*[e] | 0.05 |
| Copper | mg/L | 0.2*[f] | 0.4*[a] | 0.0014*[e] | 1 |
| Iron | mg/L | 0.2*[f] | - | - | 0.3 |
| Lead | mg/L | 2*[f] | 0.1 | 0.0034*[e] | 0.05 |
| Manganese | mg/L | 0.2*[f] | - | 1.9*[e] | 0.1 |
| Nickel | mg/L | 0.2*[f] | 1 | 0.011*[e] | 0.1 |
| Zinc (Zn) | mg/L | 2*[f] | 20 | 0.008*[e] | 5 |
| Mercury | mg/L | 0.002*[f] | 0.002 | 0.0006*[e] | 0.001 |
| Ammonia | mg/L | - | - | 0.02 | - |
| Total phosphorus (Total P) | mg/L | 0.05*[f] | - | 0.025 | - |
| Total nitrogen (Total N) | mg/L | 5 | - | 0.35 | - |
| Nitrate-N | mg/L | - | 400 | 0.7 | 10 |
| Nitrite-N | mg/L | | 30 | | 1 |

Notes: - No Trigger Value recommended.
*[a] Lowest recommended value.
*[b] Cattle (insufficient information on other livestock)
*[c] Sensitive crops
*[d] Lowland River
*[e] 95% of species protected
*[f] Long term Trigger Value

### 2.9.2 Baseline Water Quality Monitoring

Baseline surface water quality monitoring at 13 sites has been undertaken by WACJV from 2006 to date. Figure 2.20 shows the baseline surface water monitoring locations. Sampling has been undertaken on a monthly basis for salinity, pH, temperature, Dissolved Oxygen, Total Suspended Solids (TSS) and Total Dissolved Solids (TDS) as well as a number of metals and organic compounds. Results are summarised in Table 2.11.

Comparison of the recorded baseline monitoring data at Wallarah Creek (monitoring locations W6 and W12) with ANZECC trigger values has been undertaken and is shown in Appendix B. Ecosystem protection trigger values used in the comparison are for Lowland Rivers with a level of protection of 95% of species. If ANZECC indicated a range of trigger values, the lowest value has been used for comparison. Review of this information indicates the recorded surface water quality in Wallarah Creek in the vicinity of the Tooheys Road Site is:

- Slightly acidic, with pH ranging from 5.7 to 7.3 with a median pH value of approximately 6.3;
- Fresh, with ECs ranging from 120 to 680 µS/cm, with a median value between 200 and 392 µS/cm;
- Below the ANZECC trigger values for TDS, calcium, magnesium, sulphate, arsenic, barium, chromium, copper, lead, nickel and mercury.
- Mostly below the sodium ANZECC trigger value for irrigation purposes, but has exceeded the irrigation trigger value on several occasions. The sodium recreation trigger value has not been exceeded.
- Mostly below the chloride ANZECC trigger value for irrigation purposes, but has exceeded the irrigation trigger value on several occasions. The chloride recreation trigger value has not been exceeded;
- Mostly below the manganese ANZECC trigger value for recreation purposes, but has exceeded the recreation trigger value on several occasions. The manganese irrigation and ecosystem trigger values have not been exceeded;
- Exceeds the zinc ANZECC trigger values for ecosystem protection on numerous occasions. The zinc irrigation, recreation and livestock trigger values have not been exceeded;
- Exceeds the iron ANZECC trigger values for irrigation and recreation on numerous occasions;
- Exceeds the ammonia ANZECC trigger value for ecosystem protection on numerous occasions; and
- Exceeds the total phosphorus ANZECC trigger value for irrigation and ecosystem protection on numerous occasions.
- Exceeds the cadmium ANZECC trigger value for ecosystem protection on numerous occasions. The cadmium livestock and recreation trigger values have not been exceeded.
- Exceeds the nitrite + nitrate (Total N) ANZECC trigger value for ecosystem protection on one occasion. The nitrite + nitrate (Total N) ANZECC trigger value for irrigation has not been exceeded.

Surface water quality in Buttonderry Creek is characterised as follows:

- Water quality is generally similar to Wallarah Creek although slightly higher concentrations of some pollutants are observed;
- pH ranges from 5.9 to 6.8 with a median pH value of approximately 6.5;
- ECs ranging from 137 to 702 µS/cm, with a median value of 371 µS/cm;
- Calcium, sulphate and manganese concentrations are higher than Wallarah Creek;
- Ammonia and total phosphorus concentrations are higher than Wallarah Creek and exceed the ANZECC trigger value for ecosystem protection.

### 2.9.3 Groundwater Quality

The results of groundwater quality sampling in the vicinity of the Project indicate that groundwater is fresh to brackish, with an indicative TDS concentration ranging from 1,800 to 7,500 mg/L and pH values from 6.3 to 7.6 (MER, 2013).

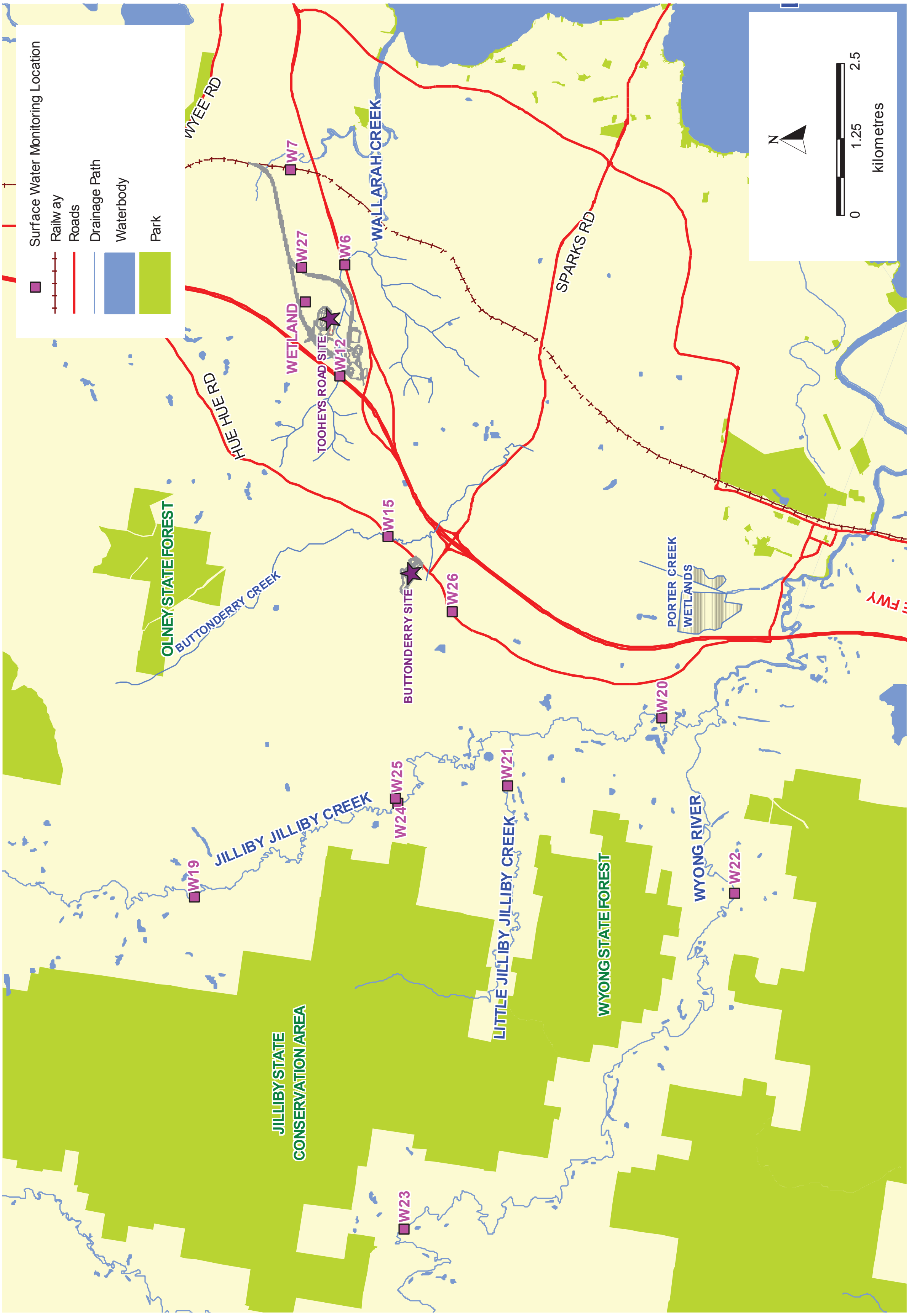


Figure 2.20 Baseline Surface Water Quality Monitoring Locations

wrm water + environment

Table 2.11 Surface Water Quality Monitoring Baseline Data (2006 to 2012)

| Water Quality Parameter | | Sampling Site | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Wyong River | | Jilliby Jilliby Creek | | | | | Hue Hue Creek | Buttonderry Creek | Spring Creek & Tributaries | | | Wallarah Creek | |
| | | W22 | W23 | W19 | W20 | W21 | W24 | W25 | W26 | W15 | Wetland | W27 | W7 | W6 | W12 |
| pH | 10%ile | 6.1 | 6.1 | 6.1 | 6.2 | 6.2 | 6.1 | 6.2 | 5.6 | 5.9 | 5.0 | 4.6 | 5.3 | 5.9 | 5.8 |
| | Median | 6.6 | 6.6 | 6.6 | 6.7 | 6.6 | 6.7 | 6.6 | 6.3 | 6.5 | 5.5 | 5.0 | 5.9 | 6.4 | 6.3 |
| | 90%ile | 7.2 | 7.1 | 7.1 | 7.1 | 7.1 | 7.1 | 7.0 | 7.0 | 6.8 | 6.4 | 5.9 | 6.8 | 6.8 | 6.7 |
| | N | 66 | 64 | 55 | 57 | 56 | 54 | 62 | 53 | 53 | 22 | 32 | 35 | 57 | 30 |
| Electrical Conductivity (µS/cm) | 10%ile | 207 | 176 | 332 | 295 | 378 | 323 | 284 | 288 | 137 | 201 | 144 | 202 | 171 | 162 |
| | Median | 236 | 225 | 403 | 397 | 483 | 411 | 417 | 446 | 371 | 268 | 253 | 250 | 392 | 200 |
| | 90%ile | 270 | 259 | 465 | 511 | 568 | 478 | 538 | 788 | 702 | 377 | 447 | 351 | 516 | 276 |
| | N | 67 | 65 | 56 | 58 | 57 | 55 | 63 | 55 | 54 | 22 | 34 | 36 | 58 | 31 |
| Dissolved Oxygen (mg/L) | 10%ile | 5.1 | 4.2 | 3.5 | 4.1 | 3.4 | 3.4 | 2.1 | 3.6 | 2.6 | 3.4 | 3.3 | 4.5 | 2.6 | 4.0 |
| | Median | 6.4 | 5.7 | 4.7 | 5.7 | 4.8 | 5.1 | 3.5 | 4.5 | 3.6 | 5.0 | 5.7 | 6.7 | 4.2 | 5.8 |
| | 90%ile | 8.4 | 7.9 | 7.0 | 7.2 | 6.2 | 7.1 | 5.1 | 6.4 | 5.4 | 6.4 | 7.5 | 7.7 | 6.4 | 7.1 |
| | N | 65 | 64 | 55 | 56 | 55 | 53 | 62 | 52 | 52 | 21 | 32 | 33 | 57 | 29 |
| Dissolved Oxygen (%Saturation) | 10%ile | 56.8 | 43.9 | 36.9 | 43.8 | 36.2 | 33.9 | 23.1 | 37.0 | 27.0 | 33.3 | 36.2 | 40.4 | 27.9 | 41.8 |
| | Median | 67.0 | 61.9 | 49.4 | 58.8 | 49.4 | 51.2 | 36.8 | 45.2 | 34.9 | 46.0 | 54.0 | 63.3 | 44.6 | 52.0 |
| | 90%ile | 81.9 | 73.3 | 63.7 | 71.7 | 62.8 | 64.3 | 50.9 | 60.8 | 52.5 | 61.4 | 72.2 | 73.0 | 67.8 | 66.0 |
| | N | 64 | 64 | 54 | 56 | 54 | 52 | 61 | 50 | 50 | 21 | 32 | 34 | 57 | 28 |
| Total Dissolved Solids (mg/L) | 10%ile | 112 | 105 | 191 | 166 | 205 | 191 | 172 | 215 | 103 | 123 | 118 | 117 | 148 | 101 |
| | Median | 133 | 128 | 225 | 237 | 272 | 227 | 244 | 286 | 275 | 202 | 222 | 155 | 240 | 144 |
| | 90%ile | 153 | 151 | 262 | 291 | 316 | 279 | 300 | 437 | 433 | 296 | 313 | 190 | 322 | 213 |
| | N | 69 | 68 | 58 | 60 | 58 | 56 | 65 | 56 | 51 | 23 | 33 | 36 | 61 | 37 |
| Total Suspended Solids (mg/L) | 10%ile | 3 | 3 | 5 | 5 | 6 | 4 | 7 | 8 | 8 | 7 | 6 | 7 | 9 | 12 |
| | Median | 6 | 5 | 8 | 10 | 8 | 10 | 12 | 14 | 17 | 10 | 23 | 12 | 12 | 20 |
| | 90%ile | 10 | 10 | 24 | 37 | 15 | 21 | 24 | 22 | 47 | 22 | 47 | 30 | 24 | 50 |
| | N | 70 | 70 | 60 | 62 | 60 | 59 | 66 | 56 | 57 | 23 | 35 | 36 | 63 | 34 |
| Calcium (mg/L) | 10%ile | 3 | 3 | 4 | 4 | 6 | 4 | 4 | 3 | 4 | 2 | 2 | 1.4 | 4 | 5.8 |
| | Median | 4 | 4 | 5 | 5 | 8 | 5 | 5 | 5 | 16 | 3 | 3 | 2 | 6.5 | 9.5 |
| | 90%ile | 4 | 4 | 6 | 6 | 8 | 6.6 | 7 | 10 | 24 | 4 | 5 | 3 | 13.6 | 18.8 |
| | N | 71 | 71 | 61 | 63 | 61 | 60 | 68 | 57 | 56 | 24 | 36 | 37 | 64 | 34 |
| Sodium (mg/L) | 10%ile | 24.2 | 23 | 42 | 44.6 | 53 | 39 | 38 | 40 | 18.4 | 27 | 28 | 28 | 29 | 18 |
| | Median | 28 | 27 | 55 | 59 | 65 | 54 | 54 | 59 | 65.5 | 41.5 | 43 | 40 | 54 | 23 |
| | 90%ile | 32 | 31 | 61 | 70 | 72.4 | 60.6 | 70 | 113.6 | 92.4 | 54.6 | 64 | 52.2 | 81.4 | 30.8 |
| | N | 71 | 71 | 61 | 63 | 61 | 60 | 68 | 57 | 56 | 24 | 37 | 37 | 64 | 34 |
| Magnesium (mg/L) | 10%ile | 5 | 5 | 8 | 8 | 9.2 | 7 | 7 | 6 | 4 | 4 | 4 | 3 | 4 | 3 |
| | Median | 6 | 6 | 10 | 10 | 12 | 9 | 9 | 10 | 10 | 5.5 | 6 | 4 | 7 | 3.5 |
| | 90%ile | 7 | 7 | 11 | 12 | 13 | 11.6 | 11 | 19 | 14 | 8.6 | 10.2 | 6 | 9.8 | 4 |
| | N | 71 | 71 | 61 | 63 | 61 | 60 | 68 | 57 | 56 | 24 | 37 | 37 | 64 | 34 |
| Potassium (mg/L) | 10%ile | 3 | 3 | 3 | 4 | 4 | 3 | 4 | 3 | 5 | 2 | 2 | 2 | 2 | 3 |
| | Median | 4 | 3 | 4 | 5 | 5 | 4 | 5.5 | 4 | 7 | 3 | 3 | 2 | 3 | 3.5 |
| | 90%ile | 4 | 4 | 5 | 6 | 6 | 6 | 8 | 5 | 10 | 4 | 4 | 3 | 3 | 5 |
| | N | 71 | 71 | 61 | 63 | 61 | 60 | 68 | 57 | 56 | 22 | 37 | 37 | 64 | 34 |
| Sulphate (mg/L) | 10%ile | 3.9 | 3.0 | 2.8 | 4.0 | 6.0 | 3.0 | 2.8 | 3.1 | 5.0 | 0.5 | 0.5 | 7.4 | 3.0 | 1.8 |
| | Median | 5.0 | 5.0 | 8.0 | 9.0 | 10.0 | 7.1 | 7.5 | 11.0 | 26.0 | 6.0 | 6.5 | 12.0 | 14.0 | 7.0 |
| | 90%ile | 7.0 | 7.0 | 12.4 | 14.0 | 15.1 | 12.0 | 13.0 | 17.4 | 48.8 | 15.7 | 18.8 | 16.2 | 19.9 | 10.9 |
| | N | 71 | 71 | 61 | 63 | 61 | 60 | 68 | 57 | 56 | 24 | 36 | 37 | 64 | 34 |
| Chloride (mg/L) | 10%ile | 45.3 | 44.3 | 74.8 | 82.6 | 93.4 | 68.0 | 64.1 | 69.6 | 40.1 | 52.9 | 55.2 | 44.9 | 45.9 | 24.6 |
| | Median | 54.5 | 52.2 | 100.0 | 103.0 | 113.0 | 95.0 | 95.0 | 117.0 | 86.0 | 72.9 | 76.0 | 61.0 | 98.0 | 32.0 |
| | 90%ile | 65.4 | 63.0 | 112.4 | 125.0 | 134.0 | 112.6 | 124.4 | 230.6 | 125.4 | 105.8 | 116.4 | 77.2 | 141.8 | 37.8 |
| | N | 71 | 71 | 61 | 63 | 61 | 60 | 67 | 56 | 56 | 24 | 37 | 37 | 64 | 34 |
| Arsenic (mg/L) | 10%ile | 0.0005 | 0.0005 | 0.0005 | 0.0005 | 0.0005 | 0.0005 | 0.0005 | 0.0005 | 0.0005 | 0.0005 | 0.0005 | 0.0005 | 0.0005 | 0.0005 |
| | Median | 0.0005 | 0.0005 | 0.0005 | 0.0005 | 0.0005 | 0.0005 | 0.0010 | 0.0005 | 0.0020 | 0.0005 | 0.0005 | 0.0005 | 0.0005 | 0.0005 |
| | 90%ile | 0.0005 | 0.0005 | 0.0005 | 0.0005 | 0.0005 | 0.0005 | 0.0020 | 0.0010 | 0.0020 | 0.0010 | 0.0010 | 0.0005 | 0.0005 | 0.0005 |
| | N | 62 | 62 | 59 | 59 | 59 | 58 | 66 | 52 | 51 | 22 | 32 | 31 | 60 | 30 |
| Barium (mg/L) | 10%ile | 0.04 | 0.04 | 0.04 | 0.03 | 0.06 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.02 | 0.03 | 0.05 |
| | Median | 0.05 | 0.05 | 0.11 | 0.07 | 0.11 | 0.07 | 0.04 | 0.05 | 0.06 | 0.07 | 0.04 | 0.03 | 0.06 | 0.07 |
| | 90%ile | 0.15 | 0.15 | 0.15 | 0.15 | 0.17 | 0.14 | 0.14 | 0.15 | 0.14 | 0.16 | 0.15 | 0.12 | 0.15 | 0.17 |
| | N | 65 | 65 | 56 | 58 | 56 | 55 | 63 | 52 | 51 | 22 | 35 | 34 | 59 | 32 |

| Water Quality Parameter | | Sampling Site | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Wyong River | | Jilliby Jilliby Creek | | | | | Hue Hue Creek | Buttonderry Creek | Spring Creek & Tributaries | | | Wallarah Creek | |
| | | W22 | W23 | W19 | W20 | W21 | W24 | W25 | W26 | W15 | Wetland | W27 | W7 | W6 | W12 |
| Cadmium (mg/L) | 10%ile | 0.00005 | 0.00005 | 0.00005 | 0.00005 | 0.00005 | 0.00005 | 0.00005 | 0.00005 | 0.00005 | 0.00005 | 0.00005 | 0.00005 | 0.00005 | 0.00005 |
| | Median | 0.00005 | 0.00005 | 0.00005 | 0.00005 | 0.00005 | 0.00005 | 0.00005 | 0.00005 | 0.00005 | 0.00005 | 0.00005 | 0.00005 | 0.00005 | 0.00005 |
| | 90%ile | 0.0001 | 0.00005 | 6E-05 | 0.0001 | 0.00005 | 0.00005 | 0.0001 | 0.0001 | 0.0002 | 0.0003 | 0.0002 | 0.0002 | 0.0001 | 0.00034 |
| | N | 61 | 61 | 57 | 57 | 57 | 55 | 61 | 51 | 50 | 21 | 31 | 31 | 59 | 29 |
| Chromium (mg/L) | 10%ile | 0.0005 | 0.0005 | 0.0005 | 0.0005 | 0.0005 | 0.0005 | 0.0005 | 0.0005 | 0.0005 | 0.0005 | 0.0005 | 0.0005 | 0.0005 | 0.0005 |
| | Median | 0.0005 | 0.0005 | 0.0005 | 0.0005 | 0.0005 | 0.0005 | 0.0005 | 0.0005 | 0.0005 | 0.00075 | 0.0005 | 0.0005 | 0.0005 | 0.0005 |
| | 90%ile | 0.0005 | 0.0005 | 0.0005 | 0.0005 | 0.0005 | 0.0005 | 0.0005 | 0.001 | 0.002 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 |
| | N | 62 | 62 | 58 | 58 | 58 | 57 | 62 | 53 | 51 | 22 | 33 | 32 | 60 | 31 |
| Copper (mg/L) | 10%ile | 0.0005 | 0.0005 | 0.0005 | 0.0005 | 0.0005 | 0.0005 | 0.001 | 0.001 | 0.002 | 0.002 | 0.001 | 0.0006 | 0.001 | 0.004 |
| | Median | 0.001 | 0.0005 | 0.001 | 0.001 | 0.0005 | 0.001 | 0.002 | 0.002 | 0.004 | 0.002 | 0.002 | 0.002 | 0.002 | 0.005 |
| | 90%ile | 0.001 | 0.001 | 0.002 | 0.003 | 0.002 | 0.002 | 0.003 | 0.004 | 0.005 | 0.003 | 0.003 | 0.003 | 0.003 | 0.008 |
| | N | 63 | 63 | 59 | 61 | 59 | 59 | 67 | 56 | 54 | 23 | 35 | 36 | 63 | 33 |
| Lead (mg/L) | 10%ile | 0.0005 | 0.0005 | 0.0005 | 0.0005 | 0.0005 | 0.0005 | 0.0005 | 0.0005 | 0.0005 | 0.0005 | 0.0005 | 0.0005 | 0.0005 | 0.0007 |
| | Median | 0.0005 | 0.0005 | 0.0005 | 0.0005 | 0.0005 | 0.0005 | 0.0005 | 0.0005 | 0.0005 | 0.0005 | 0.0005 | 0.0005 | 0.0005 | 0.001 |
| | 90%ile | 0.0005 | 0.0005 | 0.0005 | 0.0005 | 0.0005 | 0.0005 | 0.0005 | 0.0005 | 0.001 | 0.001 | 0.001 | 0.001 | 0.0008 | 0.002 |
| | N | 62 | 62 | 58 | 58 | 58 | 56 | 61 | 52 | 50 | 22 | 33 | 31 | 60 | 32 |
| Manganese (mg/L) | 10%ile | 0.1 | 0.1034 | 0.1754 | 0.1116 | 0.1468 | 0.129 | 0.2018 | 0.034 | 0.041 | 0.0184 | 0.026 | 0.0178 | 0.0286 | 0.0114 |
| | Median | 0.1375 | 0.1525 | 0.3025 | 0.19 | 0.2835 | 0.214 | 0.3395 | 0.067 | 0.107 | 0.031 | 0.041 | 0.034 | 0.0605 | 0.0205 |
| | 90%ile | 0.206 | 0.228 | 0.6546 | 0.408 | 0.5628 | 0.7452 | 0.595 | 0.1672 | 0.5058 | 0.0714 | 0.0852 | 0.0678 | 0.105 | 0.0418 |
| | N | 64 | 64 | 56 | 58 | 56 | 55 | 62 | 52 | 50 | 22 | 35 | 34 | 58 | 32 |
| Nickel (mg/L) | 10%ile | 0.001 | 0.0005 | 0.002 | 0.002 | 0.001 | 0.002 | 0.002 | 0.002 | 0.003 | 0.002 | 0.001 | 0.0005 | 0.0005 | 0.002 |
| | Median | 0.001 | 0.001 | 0.002 | 0.002 | 0.002 | 0.002 | 0.002 | 0.002 | 0.004 | 0.002 | 0.002 | 0.001 | 0.001 | 0.002 |
| | 90%ile | 0.002 | 0.002 | 0.003 | 0.003 | 0.003 | 0.003 | 0.003 | 0.003 | 0.005 | 0.004 | 0.0034 | 0.002 | 0.002 | 0.003 |
| | N | 64 | 63 | 60 | 62 | 59 | 59 | 67 | 56 | 55 | 23 | 36 | 35 | 61 | 33 |
| Zinc (mg/L) | 10%ile | 0.0088 | 0.008 | 0.012 | 0.014 | 0.0206 | 0.0126 | 0.0112 | 0.017 | 0.0188 | 0.0366 | 0.0348 | 0.0262 | 0.0156 | 0.0356 |
| | Median | 0.038 | 0.037 | 0.0465 | 0.054 | 0.055 | 0.04 | 0.0425 | 0.055 | 0.054 | 0.076 | 0.0695 | 0.061 | 0.056 | 0.063 |
| | 90%ile | 0.0814 | 0.072 | 0.078 | 0.085 | 0.0916 | 0.09 | 0.0774 | 0.1032 | 0.1046 | 0.111 | 0.121 | 0.0894 | 0.097 | 0.099 |
| | N | 67 | 66 | 60 | 61 | 59 | 58 | 66 | 55 | 54 | 23 | 36 | 36 | 63 | 33 |
| Iron (mg/L) | 10%ile | 0.96 | 0.96 | 1.17 | 1.38 | 1.462 | 1.12 | 1.13 | 0.774 | 0.606 | 1.056 | 0.76 | 0.566 | 0.696 | 0.526 |
| | Median | 1.82 | 1.67 | 2.03 | 2.035 | 2 | 1.7 | 1.56 | 1.245 | 1.07 | 1.5 | 1.08 | 0.86 | 1.31 | 0.685 |
| | 90%ile | 2.768 | 2.634 | 3.218 | 2.77 | 3.204 | 2.536 | 2.09 | 1.596 | 2.034 | 2.28 | 1.938 | 1.24 | 1.764 | 1.124 |
| | N | 65 | 65 | 56 | 58 | 56 | 55 | 63 | 52 | 51 | 22 | 35 | 34 | 59 | 32 |
| Mercury (mg/L) | 10%ile | 0.00005 | 0.00005 | 0.00005 | 0.00005 | 0.00005 | 0.00005 | 0.00005 | 0.00005 | 0.00005 | 0.00005 | 0.00005 | 0.00005 | 0.00005 | 0.00005 |
| | Median | 0.00005 | 0.00005 | 0.00005 | 0.00005 | 0.00005 | 0.00005 | 0.00005 | 0.00005 | 0.00005 | 0.00005 | 0.00005 | 0.00005 | 0.00005 | 0.00005 |
| | 90%ile | 0.00005 | 0.00005 | 0.00005 | 0.00005 | 0.00005 | 0.00005 | 0.00005 | 0.00005 | 0.00005 | 0.00005 | 0.00005 | 0.00005 | 0.00005 | 0.00005 |
| | N | 61 | 61 | 57 | 57 | 57 | 55 | 60 | 51 | 49 | 22 | 31 | 30 | 59 | 29 |
| Ammonia (mg/L) | 10%ile | 0.01 | 0.02 | 0.022 | 0.02 | 0.0428 | 0.02 | 0.02 | 0.007 | 0.02 | 0.005 | 0.005 | 0.005 | 0.005 | 0.005 |
| | Median | 0.03 | 0.032 | 0.05 | 0.04 | 0.091 | 0.064 | 0.085 | 0.022 | 0.046 | 0.005 | 0.015 | 0.005 | 0.02 | 0.016 |
| | 90%ile | 0.0574 | 0.06 | 0.1102 | 0.084 | 0.182 | 0.156 | 0.24 | 0.06 | 0.1184 | 0.0212 | 0.03 | 0.038 | 0.06 | 0.04 |
| | N | 70 | 69 | 61 | 64 | 62 | 60 | 68 | 57 | 54 | 24 | 35 | 35 | 64 | 32 |
| Nitrate and Nitrite (mg/L) | 10%ile | 0.108 | 0.101 | 0.056 | 0.058 | 0.037 | 0.028 | 0.012 | 0.005 | 0.017 | 0.005 | 0.005 | 0.005 | 0.005 | 0.011 |
| | Median | 0.240 | 0.270 | 0.100 | 0.120 | 0.120 | 0.080 | 0.060 | 0.021 | 0.050 | 0.018 | 0.020 | 0.015 | 0.030 | 0.030 |
| | 90%ile | 0.420 | 0.461 | 0.132 | 0.184 | 0.165 | 0.151 | 0.198 | 0.056 | 0.114 | 0.040 | 0.036 | 0.032 | 0.052 | 0.078 |
| | N | 71 | 71 | 61 | 63 | 61 | 60 | 69 | 56 | 56 | 24 | 36 | 37 | 64 | 34 |
| Kjedahl Nitrogen as N | 10%ile | 0.3 | 0.3 | 0.3 | 0.3 | 0.4 | 0.4 | 0.7 | 0.7 | 0.9 | 0.6 | 0.6 | 0.1 | 0.4 | 0.6 |
| | Median | 0.5 | 0.5 | 0.5 | 0.6 | 0.6 | 0.7 | 1.1 | 1.0 | 1.4 | 1.0 | 1.0 | 0.4 | 0.7 | 0.8 |
| | 90%ile | 0.7 | 0.7 | 0.9 | 1.0 | 0.9 | 1.2 | 2.3 | 1.6 | 2.1 | 1.6 | 1.6 | 0.8 | 1.0 | 1.0 |
| | N | 71 | 71 | 61 | 63 | 61 | 60 | 68 | 57 | 56 | 24 | 37 | 37 | 63 | 34 |
| Total Phosphorus as P | 10%ile | 0.02 | 0.005 | 0.042 | 0.08 | 0.02 | 0.06 | 0.17 | 0.05 | 0.07 | 0.028 | 0.005 | 0.005 | 0.03 | 0.03 |
| | Median | 0.05 | 0.04 | 0.08 | 0.13 | 0.06 | 0.13 | 0.295 | 0.09 | 0.13 | 0.085 | 0.04 | 0.05 | 0.07 | 0.07 |
| | 90%ile | 0.1 | 0.1 | 0.14 | 0.23 | 0.124 | 0.266 | 0.71 | 0.162 | 0.19 | 0.138 | 0.13 | 0.106 | 0.1 | 0.136 |
| | N | 70 | 69 | 61 | 63 | 61 | 60 | 68 | 57 | 56 | 24 | 36 | 35 | 63 | 34 |

N = Number of samples

Note: Analytes analysed in a concentration below the detection limit were replaced for the calculation of the 95% UCL with half of the detection limit.

# 3 PROPOSED WATER MANAGEMENT STRATEGY AND INFRASTRUCTURE

## 3.1 OVERVIEW

The strategy for the management of water for the Project is based on the separation of runoff from undisturbed catchments (clean water) from water that potentially has elevated levels of suspended sediment, salt and other pollutants due to contact with coal or disturbed areas (mine water). Mine water includes groundwater inflows pumped from the underground operations, as well as surface runoff from the coal stockpiles and other disturbed areas. A key objective for the operation of the mine water management system is to minimise the risk of untreated mine water being released to receiving waters. The site will also generate runoff that is unlikely to have high salt concentrations, such as roof and carpark runoff, and may be suitable for release from the site after treatment in sedimentation dams to reduce concentrations of suspended sediment.

Figure 2.2 and Figure 2.3 show indicative locations of key water management infrastructure at the Buttonderry Site and Tooheys Road Site and underground areas respectively. The main components of water-related infrastructure include:

- A Stockpile Dam which collects runoff from the product coal stockpile;
- A Portal Dam which collects runoff from the raw coal stockpile, offices and workshop area;
- A Mine Operations Dam (MOD) to store water pumped out of the underground. The MOD will also store runoff water pumped from the Portal Dam and Stockpile Dam;
- A water treatment plant (WTP) to treat excess mine water from the MOD and supply treated water to the site surface and underground demands;
- A Treated Water Storage to store raffinate from the WTP for reuse. This storage is likely to be a cell in the MOD (separate from the higher salinity mine water);
- A Brine Water Storage to store the concentrated byproduct from the WTP for storage prior to disposal underground or for further treatment through a Brine Treatment Plant;
- Sediment traps and drainage channels to collect and treat runoff from the rail loop and access road;
- Clean water drains to divert runoff from undisturbed catchments around areas disturbed by mining/infrastructure;
- Discharge infrastructure for releases of treated water to Wallarah Creek;
- An Entrance Dam to store water for the Buttonderry Site demands;
- A sediment dam to collect and treat runoff from the Buttonderry buildings, paved and hardstand areas; and
- An underground mine water storage sump.

The Project also includes the construction and operation of a water supply pipeline to import water for onsite demands that cannot be met through recycling of water captured onsite.

Details of the site water management strategy are provided below. Further information on proposed mine site storages, including indicative storage sizes and pumping rules are provided in Section 5.

## 3.2 WATER MANAGEMENT STRATEGY

The proposed water management strategy is based on treatment of mine water for use on site, with releases of treated water to Wallarah Creek as required. Mine water would be treated using a combined reverse osmosis (RO) plant with a capacity of up to 3 ML/day (including backwash recycle). The net capacity (WTP mine water inflow less total backflush volumes) is 2.7 ML/d. At certain times during the operational phase of the Project, a brine water treatment plant will be utilised to produce a partly dried mixed salt solid waste product for disposal underground. It is likely that use of the brine treatment plant will be implemented during the initial years of the Project and continue until at least the end of Project year 14 in parallel with the completion of LW11N. In this period, a salt waste stream from a full brine treatment plant would be transported underground for permanent disposal in a dedicated two-heading development sump at a rate of about 0.76% by volume of water treatment plant gross input. The period after Year 14 will involve a simplified brine treatment whereby a concentrated brine waste stream would be pumped direct to underground voids for disposal at a rate of about 2.4% of water treatment plant gross input.

This water management strategy outlining brine and salt underground disposal options represents a worst case scenario for assessment purposes in this Water Impact Statement. It provides stakeholders and approval authorities with certainty that the Project will be able to sustainably cater for environmentally sound water management and underground disposal of relevant waste streams.

WACJV is committed to finalising the detailed water management strategy in cooperation with key stakeholders including Wyong Council, the Central Coast Water Authority, NSW Office of Environment and Heritage, NSW Environment Protection Authority and NSW Office of Water.

The final water management strategy may (subject to agreements and relevant approvals) involve mine dewatering and water treatment (mainly to provide sufficient recycled water for underground mining purposes) and to enable a combination of:

- Discharge of suitably treated water to Wallarah Creek under terms of an Environmental Protection Licence, and
- Providing trade waste effluent of sediment settled brine and/or mine water to sewer for ultimate disposal to ocean waters.

WACJV may also be able to be a potential provider of treated clean water for beneficial industrial and non-potable purposes to local authorities and businesses. The final water management strategy would be dependent on agreements and further approvals by external parties.

## 3.3 WATER TREATMENT INFRASTRUCTURE

### 3.3.1 Overview

To assist with water (and salt) management for the W2CP, a site specifically designed combined RO and brine water treatment plant with a capacity of up to 3 ML/day (or 2.7 ML/d net) will be installed. The WTP enables production of treated water for beneficial use and/or environmental release. As the raw water extracted from the Mine Operations Dam is a blend of mine-site surface water and groundwater, it is anticipated to be brackish i.e. the salinity will range from 2,000-8,000 mg/L total dissolved solids (TDS). Therefore, the WTP will employ a desalination process to remove excess salts.

As with any desalination process, a significant amount of brine by-product is produced at the WTP (~10% of the mine water inflow to the WTP). Occasionally at inland desalination sites, WTP brine can be disposed of directly without further processing. However, to reduce the volumes of water and waste products to be managed or disposed underground, the brine will be further processed to significantly lower volume of waste product. The Brine Treatment Plant will predominantly use a thermal process to produce a Distilled Water (to be blended with the treated water from the WTP) and a partly dried mixed salt (which has been reduced to less than <10% of the volume of the brine).

The following diagram provides a high level overview of the Water Treatment Plant and Brine Treatment Plant.

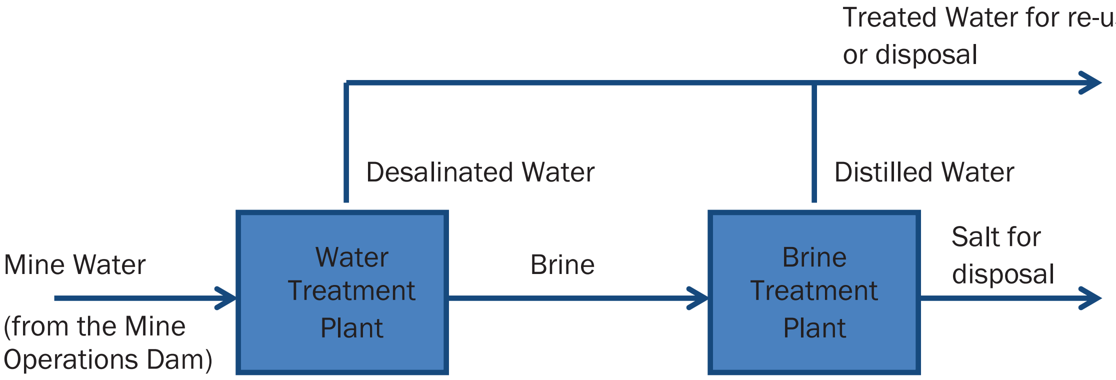


**Figure 3.1 Water Treatment Plant and Brine Treatment Plant – High Level Overview**

The following sections provide a more detailed description of each plant.

### 3.3.2 Water Treatment Plant

The Water Treatment Plant for the W2CP has been designed for site specific conditions based upon the modelled inputs and outputs produced both underground and around surface hardstand facilities. It employs the following main process units: disc filtration, membrane filtration, ion exchange (IX) and reverse osmosis (RO) system, as shown in Figure 3.2. The disc filtration process is utilised to predominantly remove “fine solids” (i.e. which are in the order of micrometers in size) and the membrane filtration system (i.e. microfiltration or ultrafiltration) is utilised to predominantly remove colloidal solids (i.e. which are in the order of nanometers in size). The inclusion of disc filtration and membrane filtration protects downstream units particularly the RO process. The ion exchange system will be of the weak acid cation type and is used to remove scale forming multivalent ions (e.g. hardness). In doing this, the recovery (i.e. volume of desalinated treated water) is increased and therefore the volume of brine produced is reduced. The desalination process utilised is RO which uses membranes to separate the brackish water into Desalinated Water and Brine (often referred to as RO reject). The Desalinated Water is blended with other internal WTP process streams to ensure it is “stabilised” (i.e. not overly aggressive or scale-forming). It is noted that the process also requires two dams or dam segments for normal operation: the Treated Water Storage to store treated water and the Brine Dam to provide buffering for the downstream Brine Treatment Plant process.

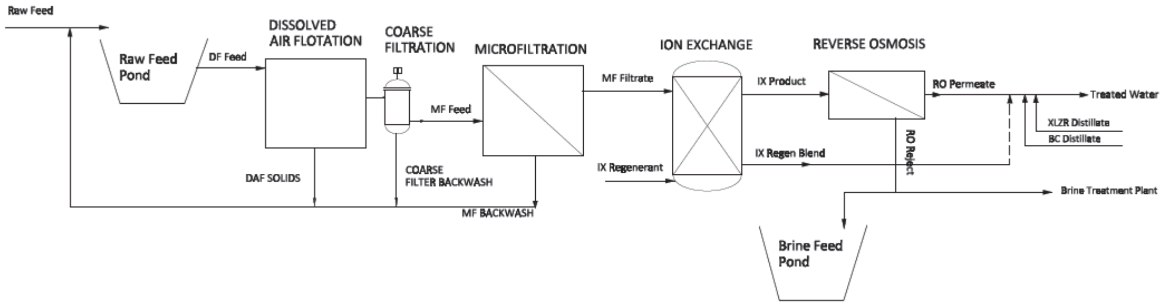


Figure 3.2 Water Treatment Plant Concept Flow Diagram (Source: Salt Water Strategics Pty Ltd, 2013)

### 3.3.3 Brine Treatment Plant

The Brine Treatment Plant employs the following main process units: Brine Concentrator, Brine Crystalliser and Belt Filter, as shown in Figure 3.3. The Brine Concentrator is a thermal process which separates the Brine via distillation into Concentrated Brine (~20% the volume of Brine) and distilled water. The process will be of the falling film type which helps avoid excessive scaling and can be electrically driven via a compressor. The brine crystalliser is also a thermal process which separates the Concentrated Brine via distillation into a Salt Slurry (~30% of the Concentrate Brine volume) and distilled water. The process will employ a forced circulation crystalliser which uses a high circulation rate to avoid excessive scaling and can also be electrically driven via a compressor. The distilled water from the above processes is blended with the WTP Desalinated Water to produced Treated Water. The Salt Slurry from the Brine Crystalliser is sent to a proprietary filter press which dewaters and dries the Salt Slurry to form a partly dried salt mixture ("Salt") of approximately 95% w/w solids which can be readily disposed of.

The detailed operation of this Underground Disposal Assessment Scenario is described below.

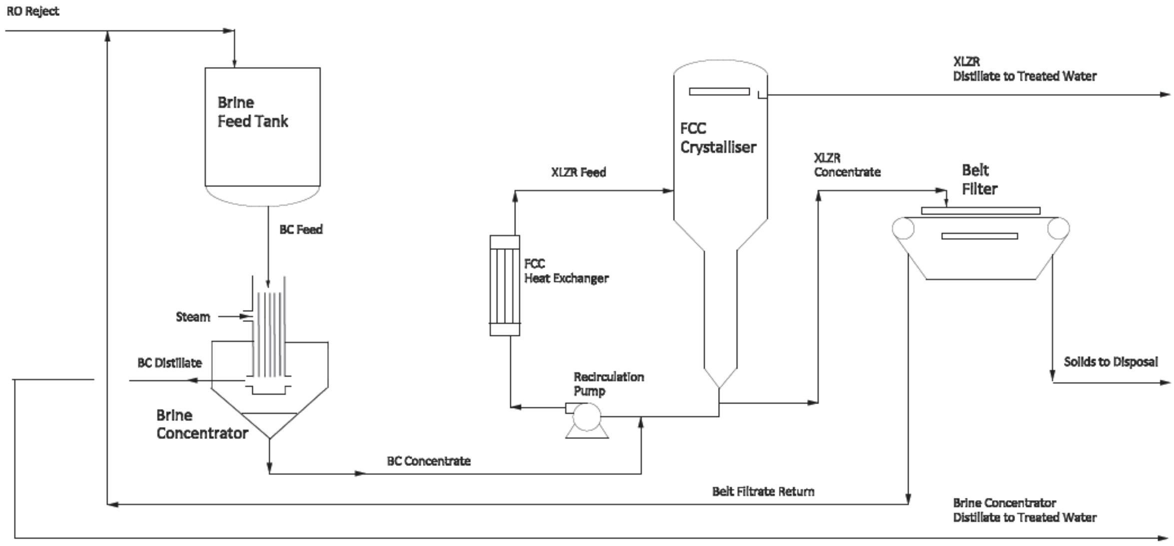


Figure 3.3 Brine Treatment Plant Concept Flow Diagram (Source: Salt Water Strategics Pty Ltd, 2013)

## 3.4 SALT, BRINE AND MINE WATER UNDERGROUND DISPOSAL ASSESSMENT SCENARIO

This assessment scenario would involve WACJV installing a RO Water Treatment Plant and Brine Treatment Plant with a 3.0 ML/d capacity (2.7 M/d net capacity) designed specifically for the W2CP that will produce a semi solid salt final waste product at least until the end of LWN11 (Project Year 14).

Beyond Project Year 14 WACJV will generally have the option to revert to brine concentrate waste product disposal instead of the more labour intensive semi solid salt waste product.

To assist with the management of mine water, brine and salt within the underground workings under this water management strategy, the following storages would be constructed:

- A two heading development to provide a sump with 72 ML capacity which would provide for a dedicated semi-solid salt disposal area until the completion of LW 11N extraction, and
- A three heading development to provide a 120 ML sump for the emergency storage of up to seven (7) weeks of maximum mine water inflow should the MOD be consistently full of surface runoff water due to a prolonged period of high rainfall.

It is projected that the need for mine dewatering will gradually increase to a rate of up to 2.5 ML/d over the first 6-8 Project Years. This assessment provides that the dewatering capacity from the emergency underground sump would be enabled up to 3.5 ML/d following temporary storage during wet periods on the surface as determined by the climate model.

With these mechanisms in place, LW 1N-11N would be extracted, during which time virtually all intercepted mine inflows would be pumped from the mine for full treatment, with the partly dried mixed salt solid waste product from the process being permanently disposed of in the dedicated salt disposal area.

Once these initial longwall blocks are completed, mining operations will move to the southeast area of the mine to extract LW 1S-10S. During this time virtually all intercepted mine inflows will also be pumped from the mine for treatment on the surface. If the decision is made at the completion of LW 11N (Project Year 14) to revert to the production of a brine concentrate only instead of salt, the concentrate produced during the extraction of LW 1S-10S will be contained in the first set of northeast cascading sumps, i.e. connected sumps at the end of LW 1N-6N.

On the completion of the southeast longwall blocks, operations will move to the southwest area of the mine to extract LW 1SW-10SW. During this time virtually all intercepted mine inflow water will again be pumped from the mine. The concentrate that will be produced during the extraction of LW 1SW-10SW will be contained in the remaining northeast cascading sumps, i.e. sumps 7N-11N. Once the southwest blocks have been extracted, all brine concentrate in the northeast cascading sumps would then be drained to the southeast cascading sumps.

Extraction of remaining longwall blocks in the north (LW 12N-26N) will then commence. At this time it would be possible to reduce the mine dewatering rate to 1 to 1.5 ML/d and drain the remaining mine water to the southeast and southwest goaf areas.

The production rate of salt and brine waste products for underground disposal are shown in Table 3.1. Details of the site water balance modelling used to estimate the values shown in Table 3.1 are provided in Section 5. The waste product streams highlighted are these used for the purposes of waste disposal modelling in the relevant areas.

Table 3.1 Waste Product for Underground Disposal

| Project Year | Water Treatment Plant Net Inflow (Median) ML/year | Concentrated Brine Flow (Median) ML/year | Salt (Median) m³/year |
|---|---|---|---|
| 1 | 0 | 0.0 | 0 |
| 2 | 169 | 4.4 | 1270 |
| 3 | 232 | 6.0 | 1750 |
| 4 | 303 | 7.9 | 2280 |
| 5 | 434 | 11.3 | 3270 |
| 6 | 546 | 14.2 | 4110 |
| 7 | 629 | 16.4 | 4740 |
| 8 | 677 | 17.6 | 5100 |
| 9 | 669 | 17.4 | 5040 |
| 10 | 699 | 18.2 | 5270 |
| 11 | 688 | 17.9 | 5180 |
| 12 | 675 | 17.6 | 5090 |
| 13 | 648 | 16.9 | 4880 |
| 14 | 612 | 15.9 | 4610 |
| 15 | 635 | 16.5 | 4790 |
| 16 | 632 | 16.5 | 4760 |
| 17 | 606 | 15.8 | 4570 |
| 18 | 653 | 17.0 | 4920 |
| 19 | 663 | 17.3 | 5000 |
| 20 | 693 | 18.0 | 5220 |
| 21 | 712 | 18.5 | 5370 |
| 22 | 709 | 18.5 | 5340 |
| 23 | 720 | 18.7 | 5430 |
| 24 | 709 | 18.5 | 5340 |
| 25 | 683 | 17.8 | 5150 |
| 26 | 688 | 17.9 | 5180 |
| 27 | 683 | 17.8 | 5150 |
| 28 | 688 | 17.9 | 5180 |

Shaded data in bold indicates proposed annual waste product to be disposed in the manner and location outlined above.

# 4 IMPACT ASSESSMENT

## 4.1 POTENTIAL IMPACTS

The potential impacts of the proposed mining operations on surface water resources include:

- Additional water demand from the municipal water supply system to meet construction and operational water requirements for the Project;
- Loss of surface water from the Gosford-Wyong Water Supply Scheme through enhancement of hydraulic connectivity between surface waters and underground aquifers;
- Adverse impacts on the quality of surface runoff draining from the local site catchments to Wallarah Creek and Buttonderry Creek;
- Adverse impacts on downstream water quality associated with possible overflows from the Mine Water Management System;
- Loss of catchment area draining to Buttonderry Creek and Wallarah Creek due to capture of runoff within onsite storages. This could potentially reduce runoff volumes to Buttonderry Creek and Wallarah Creek;
- Interference with flood flows along Wallarah Creek and watercourses affected by subsidence, such as Jilliby Jilliby Creek;
- Impacts on the hydrology and water quality of Wallarah Creek associated with the proposed discharge of treated water to Wallarah Creek; and
- Flood and geomorphological impacts on the Wyong River, Jilliby Jilliby Creek, Hue Hue Creek and their tributaries associated with ground subsidence due to coal extraction beneath or near these watercourses and their floodplains.

An assessment of each of these potential impacts of the Project is provided in the following sections.

## 4.2 MINE SITE WATER REQUIREMENTS

The maximum annual water demands for operations during the life of the mine, including water for construction, underground use, coal processing and dust suppression, is approximately 450 ML/a. Further details on the site water management system and water demands are provided in Section 5. Accounting for predicted annual groundwater inflows and surface runoff, the maximum estimated water requirement to be met from external sources over the life of the Project is approximately 52 ML/a. The peak external water requirement is predicted to occur during the construction phase (Year 1). Once mining commences, the groundwater inflows are greater than site water requirements. The percentage of groundwater inflows retained within the goaf for storage increases over the project life as goaf areas are continuously increased.

The first priority source of water to satisfy mine site water demands at the Tooheys Road Site will be the Treated Water Storage. The WTP sources feed water from the MOD, which stores water transferred from the underground, and runoff water directed from the Stockpile Dam and Portal

Dam. Underground dewatering includes groundwater inflows as well as water recycled from underground activities.

Water for outside use at the Buttonderry site will be sourced from the Entrance Dam at the Buttonderry Site. Potable quality water for internal use will be sourced from external water sources.

The external water source requirement is therefore minimised by the recycling of mine site water and prioritising the use of water treated onsite. Since the quantity of water available from onsite sources will be dependent on rainfall, water balance modelling was undertaken to estimate the required volume of makeup water for a range of climatic conditions. Full details of the water balance modelling are provided in Section 5.

The results of the water balance modelling show that the maximum external water requirement is 52 ML/a in Year 1. It is proposed to obtain this shortfall in water, as well as all potable water required for the site (approximately 10 to 20 ML/a) from the GWCWA town water system. It is noted that after Year 4 of the Project, the mine is expected to have excess water and will rely on the town water system for potable water supply at the Buttonderry Site only.

The maximum Project external makeup water requirement represents a very small fraction of the current licensed town water supply volume for the Central Coast Unregulated Water Source WSP (approximately 34,500 ML/a) and will have a negligible impact on water availability in the GWCWA town water system.

## 4.3 LOSS OF CATCHMENT AREA

### 4.3.1 Active Mining Operations

During active mining operations, the mine water management system will capture runoff from areas that would have previously flowed to either Buttonderry Creek or Wallarah Creek at the Buttonderry Site and Tooheys Road Sites respectively. The captured catchment area will remain essentially constant once mining commences. A key objective of the Project water management strategy is to minimise impact of the Project on the adjacent creek systems. This is discussed further in Section 5.

Table 4.1 shows the catchment area captured within the mine water management system during the Project life. The total catchment area draining to the mine water management system is approximately 43.3 ha. At the Tooheys Road Site, the captured catchment represents about 9% of the Wallarah Creek catchment to the downstream limit of the Project Boundary. The proposed water management strategy at the Tooheys Road site (refer to Section 5) has been designed to minimise the impact on the flows in Wallarah Creek. On average, the mine water management system captures approximately 150 ML/a from the Wallarah Creek catchment. However, clean water discharges from the WTP to Wallarah Creek will exceed the captured runoff volume, resulting in a net increase in flow in Wallarah Creek. Further details are provided in Section 4.5.2.

At the Buttonderry Site, the captured catchment represents about 1% of the Buttonderry Creek catchment to the downstream limit of the Project Boundary. Note that at the Buttonderry Site the dams are sediment dams which overflow “clean” category water to Buttonderry Creek during periods of rainfall, reducing the volume of water lost from the natural catchment. The average captured runoff volume for the Buttonderry Site is approximately 30 ML/a. However, the net captured runoff volume is lower due to clean water overflows.

Buttonderry Creek drains to the Porters Creek wetland, which has a total catchment area of approximately 55 $km^2$. The captured catchment area at the Buttonderry Site (7.4 ha) represents approximately 0.1% of the contributing catchment area. Hence, if all runoff from the captured catchment area was retained, the reduction in runoff volume draining to Porters Creek Wetland would be about 0.1%. Note however that overflows from the Buttonderry Entrance Dam will occur during significant rainfall events. Hence, the reduction in runoff volume draining to Porters Creek Wetland will be less than 0.1% and in practical terms will be undetectable.

Construction of the western ventilation shaft will result in a very small (less than 1 ha) disturbance area within the catchment of Jilliby Jilliby Creek. This represents less than 0.01% of the Jilliby Jilliby Creek catchment area and will have no measureable impact on runoff volume.

**Table 4.1 Estimated Catchment Area Captured Within Site Storages**

| Site | Captured Catchment Area (ha) | Proportion of Creek Catchment Area to D/S Project Boundary [a] |
|---|---|---|
| Buttonderry | 7.4 | 1.1 % |
| Tooheys Road | 35.9 | 9.3 % |
| **Total** | **43.3** | |

Notes: [a] At Buttonderry Site, Buttonderry Creek. At Tooheys Road Site, Wallarah Creek.

### 4.3.2 Final Landform

It is proposed that on completion of mining, the Tooheys Road Site will be rehabilitated to a condition that is suitable for ongoing use as an industrial site. The pollution control structures such as drains and sediment dams will be required for the future industrial use of the site. Therefore, the post-mining captured catchment area will be similar to that during mining operations (see Table 4.1).

Post-mining, it is proposed that the Buttonderry Site will be rehabilitated and revegetated to provide additional conservation areas to further enhance the ecological offsets for the Project. The post-mining captured catchment area will be negligible.

## 4.4 UNCONTROLLED OFFSITE DISCHARGES

A key objective for the operation of the mine water management system is to minimise the risk of untreated mine water being released to receiving waters. Review of the water balance model results indicates that there are no simulated uncontrolled discharges from the mine water management system to Wallarah Creek in any year of the Project. On this basis, the risk of adverse environmental impact from uncontrolled discharge to Wallarah Creek is considered negligible. Full details of the water balance modelling methodology and results are provided in Section 5.

Figure 4.1 shows uncontrolled discharges on an annual basis from the Entrance Dam on the Buttonderry Site. Since there is no coal handling at the Buttonderry Site, the primary potential pollutant will be suspended sediment and runoff will be suitable for release after treatment of sediment within this dam. Review of the water balance model results indicates the following:

- Uncontrolled discharges from the Entrance Dam are relatively constant throughout the Project life;
- The median uncontrolled discharge reaches a maximum of about 20 ML/a;

- The 90th percentile uncontrolled discharge is approximately 40 ML/a; and
- The 99th percentile uncontrolled discharge is approximately 67 ML/a.

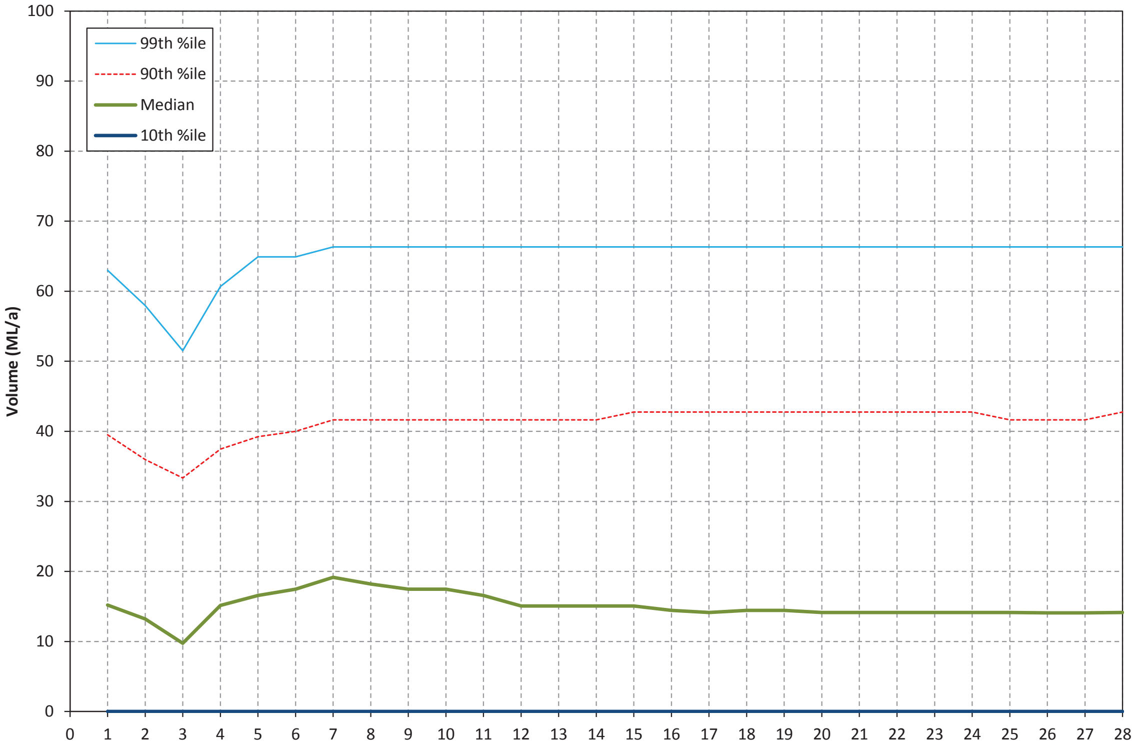


Figure 4.1 Entrance Dam Uncontrolled Discharges to Buttonderry Creek

## 4.5 IMPACTS OF CONTROLLED RELEASES TO WALLARAH CREEK TRIBUTARY

### 4.5.1 Overview

At the Tooheys Road Site, it is proposed to discharge some proportion of treated water from the WTP to a tributary of Wallarah Creek. The proposed discharge location for treated water at the Tooheys Road Site is shown in Figure 4.2.

Controlled discharges of treated water from the Tooheys Road Site to the tributary of Wallarah Creek have the following potential impacts:

- Impacts on the total flow volume in Wallarah Creek;
- Impacts on the Wallarah Creek flow regime (change in the frequency of high, medium and low flows);
- Impacts on stream condition, including bank erosion; and
- Water quality impacts.

These potential impacts are discussed in the following sections.

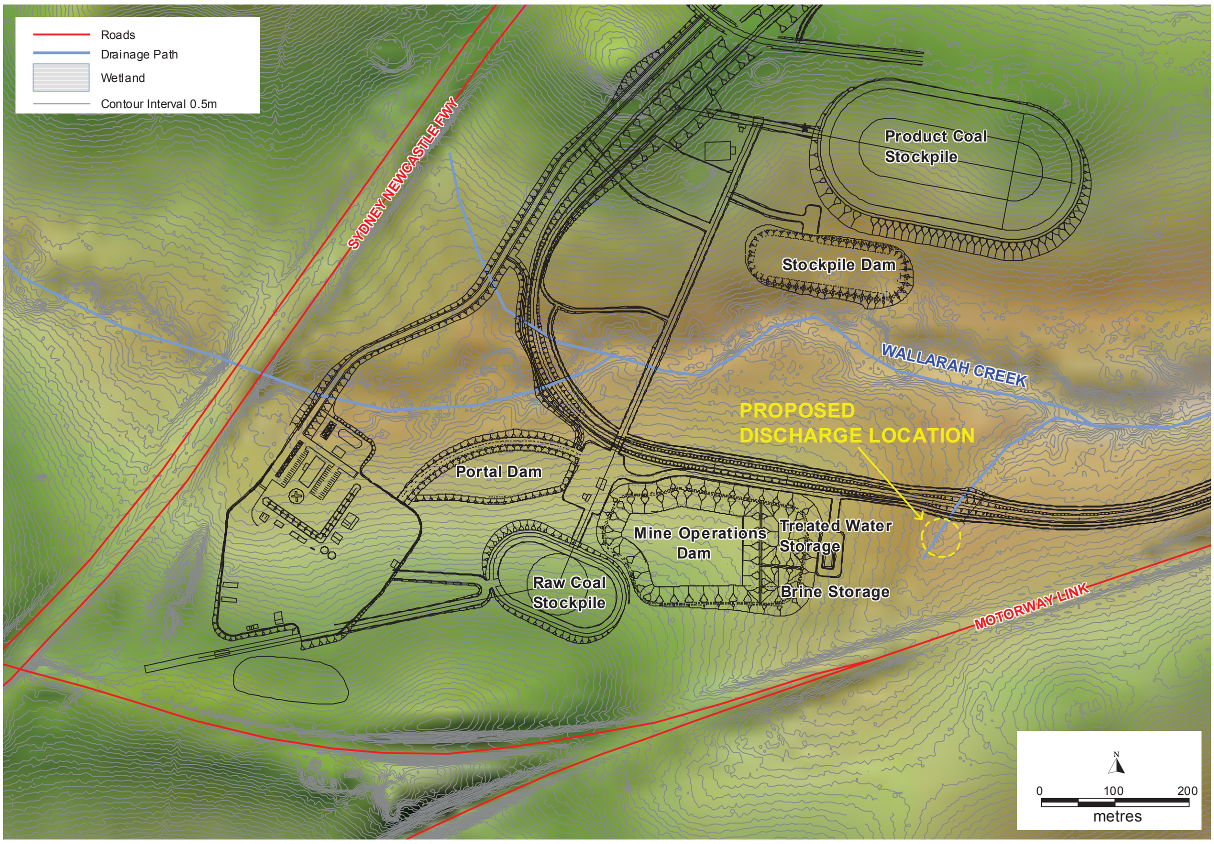


Figure 4.2 Proposed Discharge Location

### 4.5.2 Wallarah Creek Flow Volume

Table 4.2 shows the net impact on flow volumes in Wallarah Creek. Results are shown for three different climate sequences over the mine life; dry (below average rainfall), average (average rainfall) and wet (above average rainfall). Under the adopted model assumptions, the results show that the Project will increase flow volumes in Wallarah Creek by about 3%. This is equivalent to an average annual increase of approximately 42 ML/a over the Project life.

Table 4.2 Net Impact of Mine Water Management System on Wallarah Creek Flow Volumes Over Project Life

| Realisation | Total Rainfall (mm) | Pre-mining Total Flow (ML) | Captured Runoff Volume (ML) | WTP Discharge Volume (ML) | Net Wallarah Ck Flow (ML) | % Increase / Decrease |
|---|---|---|---|---|---|---|
| "Dry" | 31,343 | 42,504 | 3,924 | 5,129 | 43,709 | + 3% |
| "Average" | 33,143 | 48,351 | 4,496 | 5,791 | 49,646 | + 3% |
| "Wet" | 35,071 | 51,214 | 4,589 | 6,068 | 52,693 | + 3% |

### 4.5.3 Flow Regime

The discharge of treated water to the tributary of Wallarah Creek will also affect the frequency of different flow rates within Wallarah Creek. Event runoff will be captured in the mine water management system during storm events and then slowly released as treated water over the subsequent days or weeks.

Figure 4.3 shows the simulated flow duration relationship for Wallarah Creek at the downstream limit of the Project Boundary for the pre-mining and during mining case, for the duration of the Project. The results are presented for a 28 year climate sequence with average total rainfall. The assessment of the discharge of treated water shows the following:

- There are negligible impacts on the frequency of flows greater than 10 ML/d in Wallarah Creek; and
- The frequencies of low flows up to 10 ML/d are increased. For example, for the pre-mining case, a flow of 1 ML/d occurred approximately 17 % of the time, whereas during mining it occurs approximately 30 % of the time.

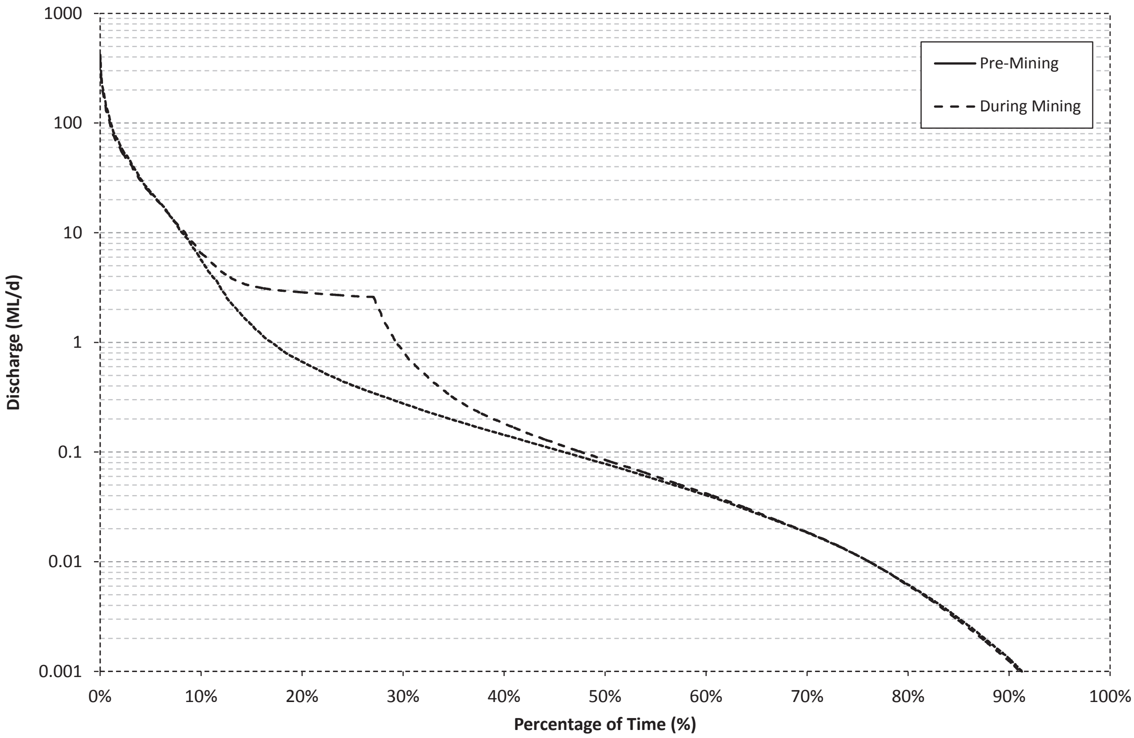


Figure 4.3 Wallarah Creek Flow Duration Relationship, 'Average' Climate Realisation

The mine water balance (see Section 5) indicates that the maximum controlled discharges occur in Year 7, which would represent the worst case for impacts on the Wallarah Creek flow regime. Figure 4.4 shows the simulated flow duration relationship for Wallarah Creek at the downstream limit of the Project Boundary for the pre-mining and during mining case for Year 7 only. The results indicate the following:

- There are negligible impacts on the frequency of flows greater than 10 ML/d in Wallarah Creek; and
- The frequencies of low flows up to 10 ML/d are increased. For example, for the pre-mining case, a flow of 1 ML/d occurred approximately 25 % of the time, whereas during mining it occurs approximately 43 % of the time.

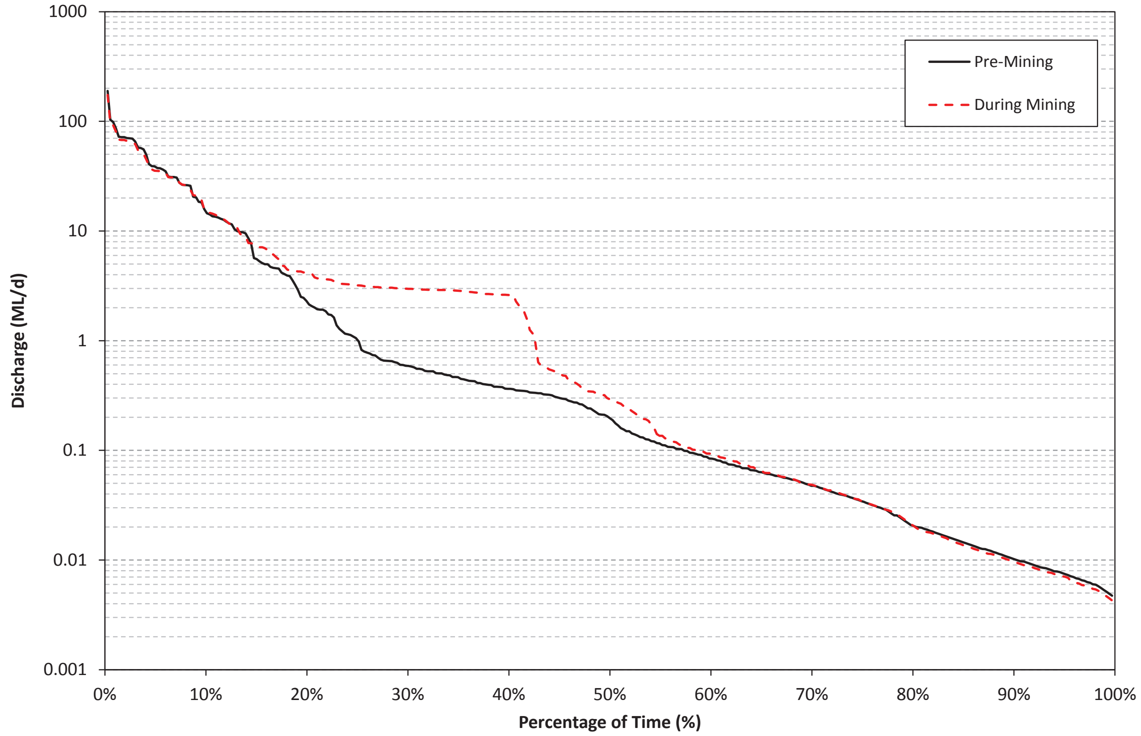


**Figure 4.4 Wallarah Creek Flow Duration Relationship (Year 7 only), Average Rainfall**

### 4.5.4 Stream Condition

The expected flow rate of the treated water to be discharged will be less than 3 ML/d (35 L/s). Historical flow information indicates that Wallarah Creek is an ephemeral watercourse, and hence, it is likely that treated water discharges may occur at times when there is no natural flow in Wallarah Creek.

Figure 4.5 and Figure 4.6 show cross sections of the discharge tributary to Wallarah Creek, as well as Wallarah Creek just downstream of the discharge tributary. The water level of a treated water discharge of 35 L/s (assuming a velocity of 0.5 m/s) is shown on the figures. A discharge of this magnitude is much smaller than each of the channels' bank full capacity. Therefore, the discharges are unlikely to impact the bank stability of Wallarah Creek.

Based on the relatively low flow rate of treated water discharge and the good condition of bank vegetation (see Figure 2.4), it is unlikely that these flows would result in adverse hydraulic impacts, such as increased bed and bank erosion. Note also that whilst the treated water discharge will alter the flow-duration relationship of Wallarah Creek, the creek will remain ephemeral and will still experience a similar frequency of zero to very low flow events.

Due to the negligible impact on erosion, the discharges of treated water will not alter the geomorphology of Wallarah Creek. The Ecological Impact Assessment for the Project has determined that riparian vegetation and aquatic habitats near the Tooheys Road Site will not be adversely affected by the discharges (Cumberland Ecology, 2013).

Appropriate erosion controls measures, such as an energy dissipation device at the discharge point and channel bed protection over a short downstream length, will be implemented to minimise scour erosion at the point of release.

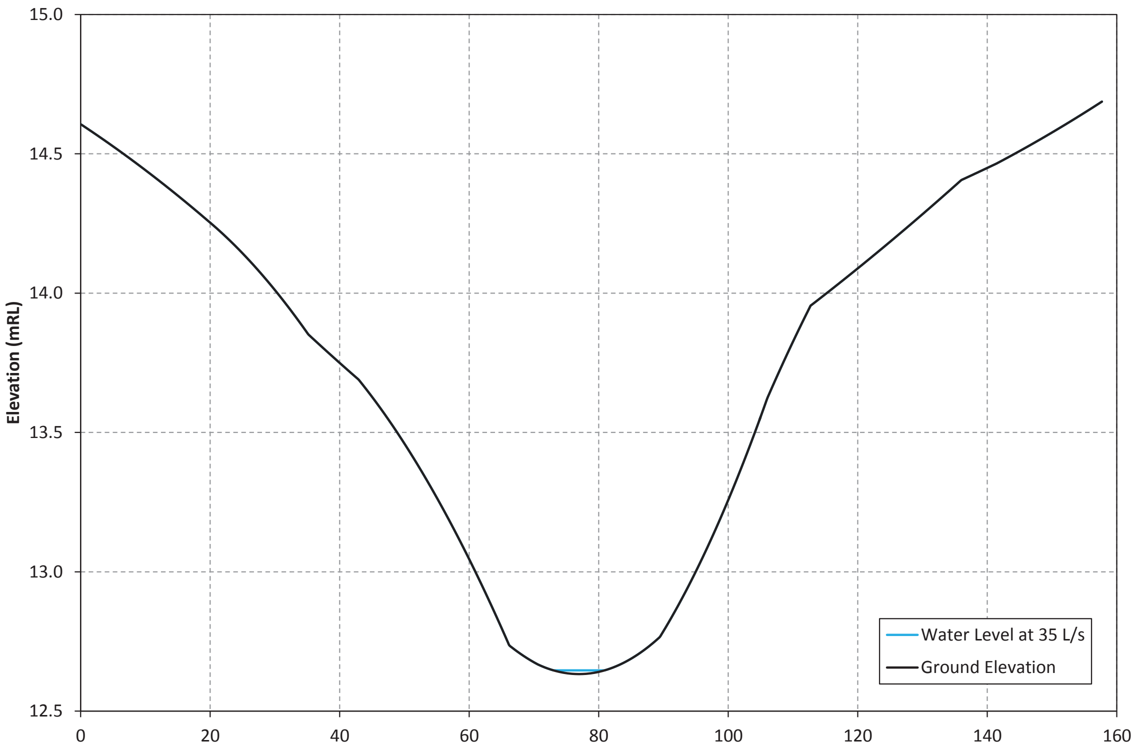


Figure 4.5 Wallarah Creek Tributary at Discharge Location – Cross Section

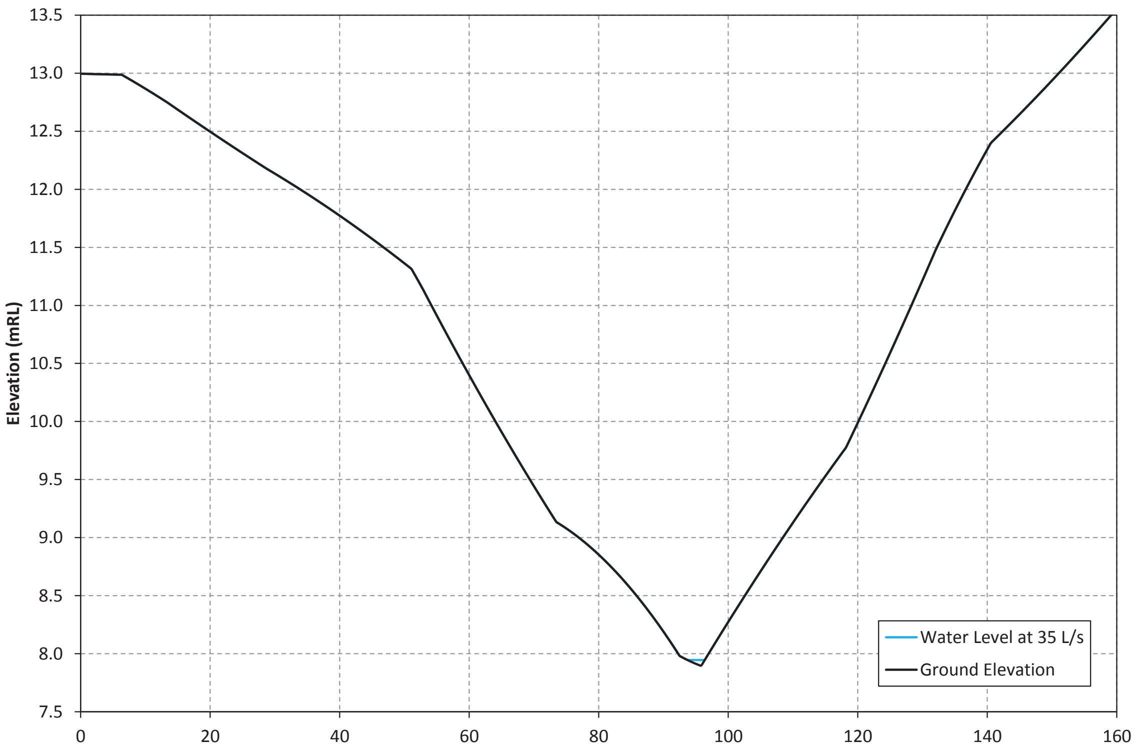


Figure 4.6 Wallarah Creek downstream of Discharge Tributary – Cross Section

### 4.5.5 Impacts on Water Quality

The WTP will treat mine waters to a water quality which is consistent with existing water quality within Wallarah Creek. Baseline water quality monitoring has been undertaken in Wallarah Creek and is presented in Section 2.9.2. Detailed design of the WTP will be undertaken to ensure that discharge water quality is compatible with existing environmental values for Wallarah Creek to ensure minimal impacts. Table 4.3 shows a comparison of Wallarah Creek water quality and the expected WTP treated water quality (Salt Water Strategics Pty Ltd, 2013). All parameters are similar to existing receiving water quality in Wallarah Creek, with the exception of Barium. The ANZECC (2000) recreational water quality trigger value for Barium is 1 mg/L.

**Table 4.3 Comparison of Wallarah Creek (W6) Discharge Point Water Quality and WTP Treated Water Quality (Salt Water Strategics Pty Ltd, 2013)**

| Site Parameters | Units | W6 | Treated Water |
|---|---|---|---|
| Temperature | °C | 18.6 | 15 – 25 |
| pH | | 6.58 | 6.5 – 8.5 |
| Dissolved Oxygen | % saturation | 53 | >60% saturation |
| Conductivity at 25 °C | µS/cm | 445 | < 450 |
| Total Dissolved Solids | mg/L | 281 | < 300 |
| Suspended Solids | mg/L | 37 | < 5 |
| Calcium | mg/L as ion | 12 | 5 – 15 |
| Magnesium | mg/L as ion | 8 | 2 – 5 |
| Sodium | mg/L as ion | 70 | < 70 |
| Potassium | mg/L as ion | 3 | < 1 |
| Alkalinity | mg/L as $CaCO_3$ | 34 | <20 |
| Sulphate | mg/L as ion | 19 | < 1 |
| Chloride | mg/L as ion | 121 | < 120 |
| Iron | mg/L as ion | 1.36 | < 0.3 |
| Arsenic | mg/L as ion | 0.001 | < 0.001 |
| Barium | mg/L as ion | 0.102 | 0.5 – 3.0 |
| Cadmium | mg/L as ion | 0.0002 | < 0.0002 |
| Chromium | mg/L as ion | 0.0009 | < 0.0009 |
| Copper | mg/L as ion | 0.005 | < 0.02 |
| Manganese | mg/L as ion | 0.073 | < 0.073 |
| Nickel | mg/L as ion | 0.001 | < 0.001 |
| Lead | mg/L as ion | 0.001 | < 0.001 |
| Zinc | mg/L as ion | 0.072 | < 0.072 |
| Mercury | mg/L as ion | 0.0001 | < 0.001 |
| Ammonia | mg/L as N | 0.0562 | < 0.05 |
| Nitrite and Nitrate | mg/L as N | 0.0550 | < 0.05 |
| Total Kjeldahl Nitrogen | mg/L as N | 0.8815 | < 0.1 |
| Total Phosphorous | mg/L as ion | 0.0846 | <0.02 |
| Reactive Phosphorous | mg/L as ion | 0.0276 | < 0.02 |
| Oil and Grease | mg/L | 2.8 | ND |
| Faecal Coliforms | CFU/100 mL | 2216 | ND |

Note: The above represents the 95% upper confidence limit of the average concentration of analytes, and where a range is specified, values may vary due to WTP feed water variations.
ND: No data.

## 4.6 LOSS OF SURFACE WATER IN THE WATER SUPPLY CATCHMENT

### 4.6.1 Estimated Impacts

The Project will not directly harvest water from the catchment of the Gosford-Wyong Water Supply Scheme. However, subsidence, particularly in the Jilliby Jilliby Creek catchment, has the potential to affect the yield of surface water from the catchment through:

- Altered drainage patterns and efficiency; and
- Increase or reduction in groundwater recharge.

The main channels along Jilliby Jilliby Creek and to a lesser extent Little Jilliby Jilliby Creek will be affected by subsidence, however based on the hydraulic characteristics of these waterways, it is likely that drainage impacts along these watercourses will be limited to greater flow depths and some additional ponding (expected to be temporary) within the main channel. Further assessment of the impacts on the hydraulic characteristics of Jilliby Jillby Creek is provided in Section 4.9.

The combination of subsidence and changes in water table levels across the floodplain of Jilliby Jilliby Creek will potentially reduce the drainage efficiency of the floodplain, leading to possible increased wet areas and surface ponding during wet weather (MER, 2013). As a consequence, slightly increased infiltration and evaporation may occur across the subsided floodplain. Through appropriate land management practices, such as the construction of remedial drainage infrastructure, the change in surface drainage efficiency is unlikely to result in a measurable reduction in total surface water volumes draining to the Gosford-Wyong Water Supply Scheme. Note that the total potential subsidence area of approximately 37 $km^2$ represents about 5% of the total catchment area contributing to the Gosford-Wyong Water Supply Scheme. Approximately 29 $km^2$ of the potential subsidence area is located beneath the Jilliby Jilliby Creek catchment, which represents about 30% of the catchment area. A further 4.2 $km^2$ is located in the catchment of Hue Hue Creek and the remaining 3.8 $km^2$ is located in the direct catchment of the Wyong River.

Flow in upland drainage paths is highly ephemeral and significant loss of surface flow through surface cracking along drainage paths in upland areas is not anticipated (IEC, 2009; MER, 2013).

An analysis of the impacts of subsidence on baseflows to surface drainage paths has been completed as part of the groundwater impact assessment (MER, 2013). The results of this analysis (MER, 2013) show that subsidence will have no measureable impact on baseflows.

Subsidence has the potential to impact surface water resources if subsidence leads to enhanced hydraulic connectivity between the shallow and deeper groundwater aquifers. The results of a detailed investigation of groundwater impacts (MER, 2013) indicate that connective cracking to deeper aquifers is avoided and hence shallow groundwater resources will not freely drain down to the mined panels. Some additional groundwater storage, estimated to reach a maximum annual volume of the order of 270 ML over the mine life, will be created by the subsidence process and this additional volume would be sourced from regional rainfall recharge, as well as surface runoff (MER, 2013). Assuming that this process results in an equivalent volume reduction in surface water, this would represent a potential maximum annual water loss of less than 30% of the total licensed volume for the Jilliby Jilliby Creek Water Source and less than 1% of the surface water entitlement for the Central Coast Unregulated Water Source. In practical terms, due to the highly variable nature of surface water flows, it is unlikely that an impact of this magnitude could be detected within the system.

A quantitative assessment has been undertaken of the impacts of the temporary leakage from surface drainage systems to subsided shallow alluvial as the groundwater table re-equilibrates. A rainfall-runoff model (AWBM, Boughton 1993) of the catchment was developed and calibrated to recorded streamflow data. The model separately simulates surface runoff and baseflow catchment responses to allow an assessment to be made of the potential impacts of the loss of surface runoff.

The rainfall-runoff model was calibrated to recorded streamflow data at Jilliby Jilliby Creek upstream of Wyong River (Station No. 211010). Data at this station has been recorded since December 1972. The location of the stream monitoring station is shown in Figure 2.18. The monitoring station has a catchment area of approximately 94 $km^2$.

Figure 4.7 shows the calibration results as a flow duration relationship for the observed and simulated discharges. The total runoff over the period for the observed and simulated data sets was 9,024 mm and 9,019 mm respectively. The calibrated AWBM model parameters were adopted for the impact assessment of surface runoff leakage losses to subsided panels.

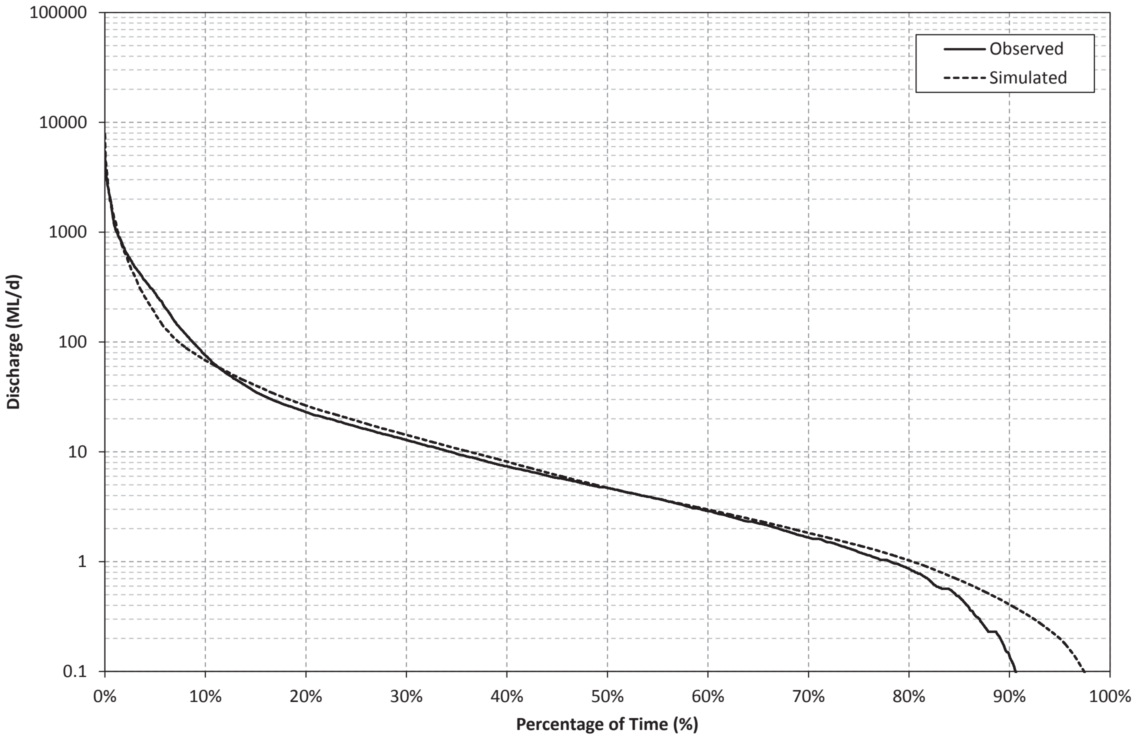


**Figure 4.7 AWBM Calibration of Jilliby Jilliby Creek U/S Wyong (#211010) – Flow Duration Relationship (1972 – 2012)**

The loss of surface runoff was simulated as an initial loss of surface flows. The value of the initial loss was selected to match the estimated upper limit total loss of 270 ML/a (MER, 2013). The adopted initial loss was 0.06mm/d (6 ML/d), which was subtracted from the estimated daily surface runoff. If surface runoff was less than the adopted initial loss, surface runoff was set to zero. It was assumed that impacts to baseflow were negligible (MER, 2013).

Figure 4.8 shows the long term (1889 to 2012) simulated flow duration relationship (surface runoff plus baseflow) for the pre-mining and post-mining case. Review of the results indicates that the impacts on the flow duration relationship in Jilliby Jilliby Creek are negligible.

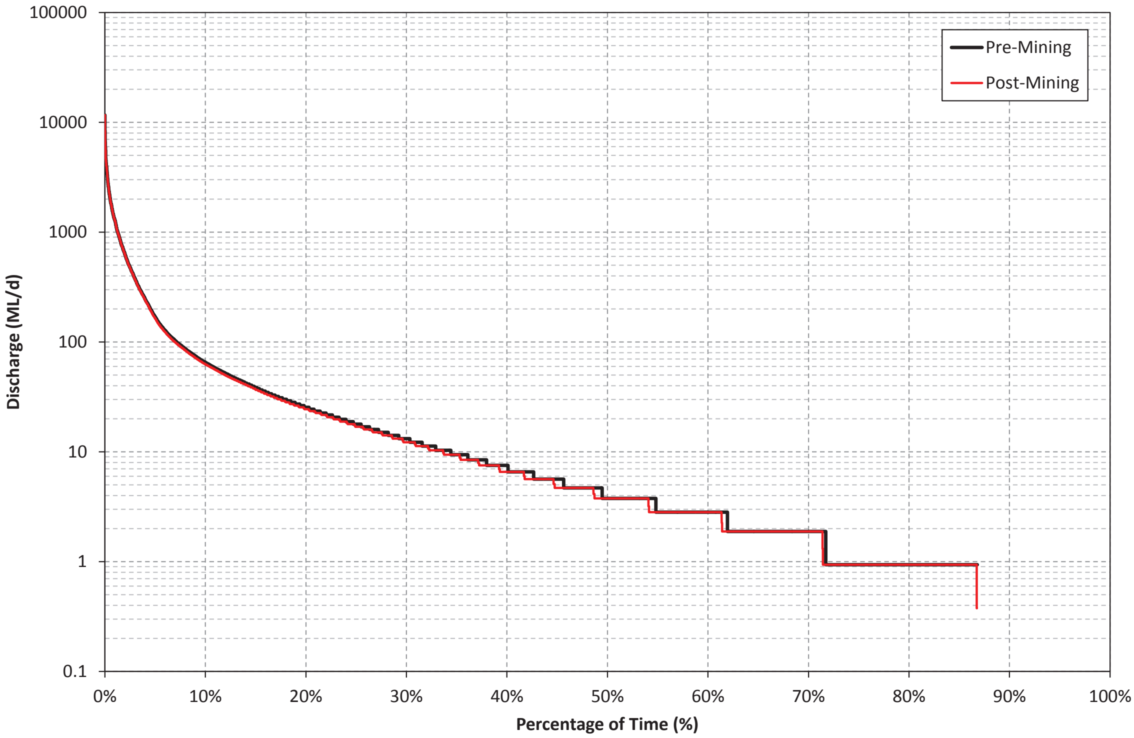


**Figure 4.8 Post-Mining Impacts on Jilliby Jilliby Creek U/S Wyong (#211010) – Flow Duration Relationship (1889 – 2012)**

Historical constraints on water supply in the region have been predominantly associated with limited water storage availability. Storages in the lower catchment (see Table 2.1) have a combined total capacity of only 12,445 ML, which is less than 7 % of the capacity of the Mangrove Creek Dam (190,000 ML). Note also that the Mangrove Creek Dam has a relatively small catchment area (101 $km^2$) which generates average annual runoff of approximately 18,600 ML (see Section 2.4). On this basis, without any extractions, it would take, on average, about 10 years for the dam to fill.

Completion of the Mardi-Mangrove Link in mid 2012 has provided the necessary infrastructure to pump water to the Mangrove Creek Dam, thereby increasing the yield of the Gosford-Wyong Water Supply Scheme from 40,000 ML/a to 45,600 ML/a (GWCWA, 2007). The potential impacts of the Project represent less than 0.7 % of the current system yield. Hence, the Project is unlikely to have a measureable impact on the Gosford-Wyong Water Supply Scheme.

Collection and onsite use of surface runoff from disturbed areas and discharges of treated water from the Water Treatment Plant will impact surface runoff volumes in Wallarah Creek (see Section 4.5.2). Flow volumes to Wallarah Creek will be increased by an average of approximately 42 ML/a. The Buttonderry Site will capture, on average, approximately 30 ML/a from site runoff. However, approximately 10 ML/a of clean water will overflow from the Entrance Dam at the Buttonderry site (see Section 4.4), resulting in a net average capture of 20 ML/a. Wallarah Creek and Buttonderry Creek are part of the Tuggerah Lakes Water Source.

Both Buttonderry Creek and Wallarah Creek are outside of the Water Supply Scheme catchment.

### 4.6.2 Surface Water Licensing Requirements

Whilst there will be no defined extraction point or easily measurable extraction volume from the relevant water sources, it is likely that the Project will intercept some volume of water, as estimated above. On this basis, indicative surface water extraction volumes for the various water sources are summarised as follows:

- Tuggerah Lakes Water Source: 20 ML/a from Buttonderry Creek;
- Jilliby Jilliby Creek Water Source: 270 ML/a (Upper limit estimate of potential loss of surface water from increased groundwater storage); and
- Central Coast Unregulated Water Source: 30 ML/a (Upper limit estimate of potential loss of surface water from increased groundwater storage).

Licensed discharge of treated water to Wallarah Creek is predicted to increase flow volumes.

## 4.7 HARVESTABLE RIGHTS AT TOOHEYS ROAD AND BUTTONDERRY SITES

### 4.7.1 Overview

The water management system for the Project has been designed to minimise the capture of clean runoff wherever possible. Clean water diversion drains are proposed to divert clean water runoff that would have drained into mine water storages. Sediment dams are solely for the capture, containment and recirculation of mine affected water consistent with best management practice to prevent the contamination of a water source. These types of dams are “excluded works” and are exempt from the requirement for water supply works approvals and Water Access Licences (WAL). Therefore, water from disturbed areas captured in these dams does not require a WAL.

### 4.7.2 Harvestable Rights

The maximum harvestable right dam calculator (DPIOW, 2012) provides a harvestable right multiplier value of 0.11ML/ha for the Project. Table 4.4 shows the harvestable right for the two Project sites.

Table 4.4 WACJV Harvestable Rights

| Site | Land Holdings (ha) | Harvestable Right (ML) |
|---|---|---|
| Buttonderry | 83 | 9 |
| Tooheys Road | 354 | 39 |
| **Total** | **437** | **48** |

### 4.7.3 Water Access Licences

Some residual undisturbed catchment will drain to mine water storages which may require a WAL. It has been assumed that collection of water from undisturbed catchment draining to the Portal Dam, Stockpile Dam and Entrance Dam (all of which generally store mine affected water with the exception of the Entrance Dam) may require a WAL. Figure 5.2 and Figure 5.3 show the clean water catchment areas draining to these storages.

The intercepted average and maximum annual runoff has been estimated using average and maximum annual rainfalls at Wyee (#061082) of 1,192 mm and 2,031 mm respectively. A volumetric runoff coefficient of 0.092 has been used based on the runoff coefficient utilised for harvestable rights calculations at Wallarah (10% of runoff = 0.11 ML/ha = 11 mm runoff. 100% of runoff = 110mm. Volumetric runoff coefficient = 110 mm /1,192 mm = 9.2%).

Table 4.5 shows the estimated average and maximum volume of clean water runoff captured within the water management system over the life of the Project.

Review of the results indicates that the maximum clean water take at the Buttonderry and Tooheys Road sites do not exceed the harvestable right. On this basis, no WALs are expected to be required for the Tooheys Road and Buttonderry sites.

**Table 4.5 WACJV Clean Water Take**

| Storage | Natural Catchment Area (ha) | Average Water Take (ML) | Maximum Water Take (ML) | WAL Requirement |
|---|---|---|---|---|
| Buttonderry (Entrance Dam) | 0.3 | 0.3 | 0.6 | 0 |
| Tooheys Road (MOD, Portal Dam, Stockpile Dam) | 12.21 | 13.4 | 22.9 | 0 |
| **Total** | **12.51** | **13.8** | **23.4** | **0** |

## 4.8 FLOOD IMPACT ASSESSMENT

### 4.8.1 Wyong River Catchment

A detailed Flood Impact Assessment has been undertaken for the Project (G Herman & Associates, 2013). The current mine plan was developed over a number of iterations to eliminate flood impacts from almost all of the Yarramalong Valley, which is drained by the Wyong River. Longwall layouts were also improved to minimise the overall impacts in the Dooralong Valley, drained by Jilliby Jilliby Creek, and along Hue Hue Creek.

The results of the Flood Impact Assessment indicate virtually no change to flood extents and depths in the Yarramalong Valley. Six dwellings in the Dooralong Valley will experience major adverse flood impacts and a further eleven dwellings will experience moderate adverse impacts. These impacts will be managed on a site-specific basis through the development of Property Flood Management Plans. Forty-eight of the 103 dwellings in the Yarramalong/Dooralong and Hue Hue study areas that are within or near to the 1 % AEP flood extent will be beneficially impacted.

### 4.8.2 Wallarah Creek Catchment

A flood study of Wallarah Creek has been undertaken by ERM (ERM, 2002). Results of the flood study show that:

- The 100-year ARI (1 % AEP) flood extent of Wallarah Creek will not infringe on the proposed location of surface operations for the Project.
- The culvert crossing the F3-Pacific Highway Link Road acts as a hydraulic control for Wallarah Creek, creating a storage area behind the road embankment, however this pond does not infringe on the area proposed for surface operations.

Figure 4.9 shows the 100 year ARI flood extent of Wallarah Creek in the vicinity of the Tooheys Road Site. Detailed design of site infrastructure will provide adequate flow capacity for road and conveyor crossings to ensure no offsite impacts on flood levels and will also ensure that mine infrastructure is not affected by flooding.

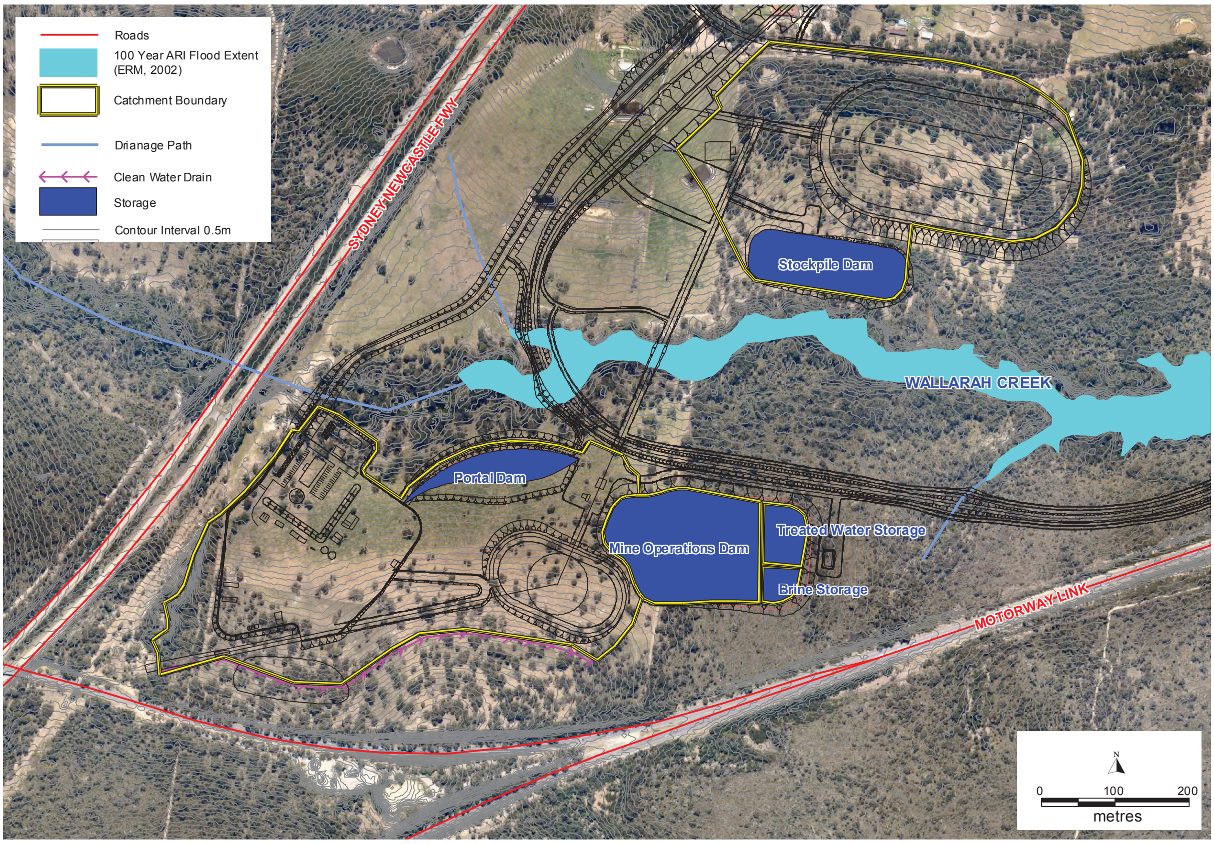


Figure 4.9 Wallarah Creek 100 year ARI Flood Extent (ERM, 2002)

## 4.9 STREAM GEOMORPHOLOGY

### 4.9.1 Overview

A detailed assessment of potential impacts of mining subsidence associated with the Project on stream geomorphology has been undertaken by International Environmental Consultants Pty Ltd (IEC, 2009). A summary of the findings of that study include:

- Major impacts on creek stability and water quality are not anticipated along Little Jilliby Jilliby Creek. The greatest potential subsidence impacts in this creek are in the upper reaches which are presently in excellent condition and will recover quickly from any impact.
- Subsidence impacts along Jilliby Jilliby Creek are expected to be relatively uniform (except near the confluence of Little Jilliby Jilliby Creek), which will limit changes in flow velocity and erosion potential.
- Increased ponding and flow velocity may occur at some locations along Jilliby Jilliby Creek. The proposed monitoring and management program will ensure that remediation works, if required, will be completed before significant water quality or channel stability problems occur.

- Overall, the geomorphological impacts on Jilliby Jilliby Creek and Little Jilliby Jilliby Creek will be minor, or will be manageable through the implementation of mitigation measures and rehabilitation works (see Section 6.4.3).
- The Wyong River may be subject to up to 150 mm of subsidence at some locations, however this is considered to be negligible and will not have any measureable adverse impact on the river or water supply system.

### 4.9.2 Assessment of Impacts on In-stream Erosion

Subsidence beneath the alluvial floodplains of Jilliby Jilliby Creek and Little Jilliby Jilliby Creek has the potential to alter the sediment transport characteristics along these watercourses. The primary risk areas include:

- The area of differential subsidence immediately upstream of the confluence of Jilliby Jilliby Creek and Little Jilliby Jilliby Creek (see Figure 4.10). Subsidence modelling indicates potential subsidence of the order of 1 m immediately upstream of the confluence between Jilliby Jilliby Creek and Little Jilliby Jilliby Creek. However, no subsidence will occur above the main headings located just downstream of the confluence. The relative change in bed level may cause some minor “damming” of low flows along Jilliby Jilliby Creek. Based on the height of the creek banks, it is likely that any ponding would be predominantly confined to the main channel. These impacts will reduce over time as the channel bed readjusts to the altered topography.
- Near the upstream limit of the Extraction Area where bed gradients may be increased due to the transition between subsided and unsubsided bed profiles.

A HECRAS hydraulic model was used to assess the impacts of potential subsidence on erosion potential along Jilliby Jilliby Creek and Little Jilliby Jilliby Creek. The model was based on the same channel cross-sections used in the flood impact assessment (G Herman & Associates, 2013). The locations of cross-sections used to develop the model are shown in Figure 4.11. Some additional cross-sections (identified with a letter subscript in Figure 4.11) were added into the hydraulic model to improve the representation of Little Jilliby Jilliby Creek. The model was run with discharges selected to approximate bankfull flow conditions, which are often regarded as representing the channel forming flow rate.

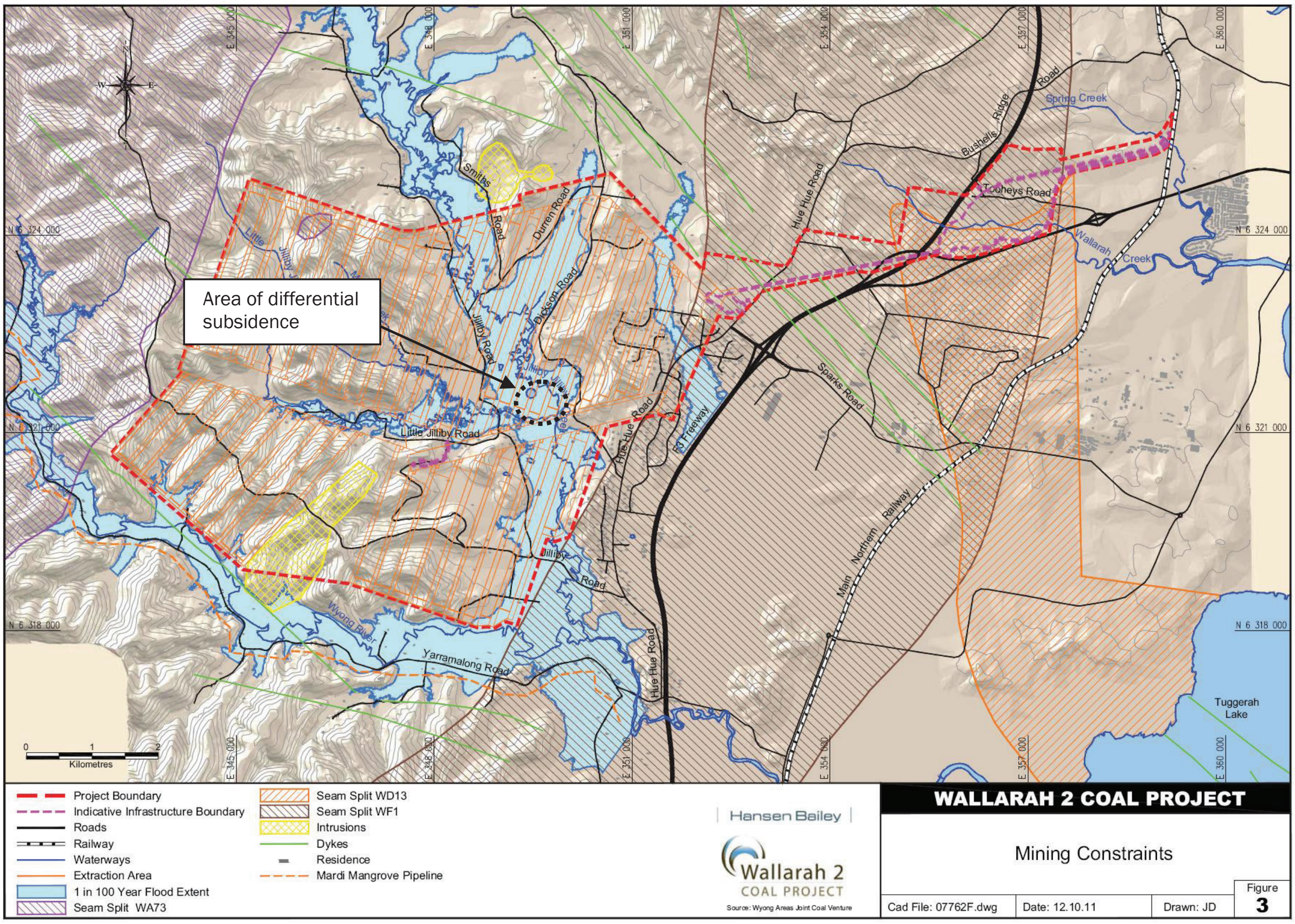


Figure 4.10 Area of Differential Subsidence near Little Jilliby Jilliby Creek Confluence

The following assumptions were adopted in the development of the HECRAS model:

- Downstream boundary condition of normal depth with hydraulic gradient = 0.0012 m/m.
- Manning's n = 0.07.

Several flow change locations were adopted in the hydraulic model to represent the increase of bankfull discharge as catchment areas increase. Table 4.6 shows the design discharges adopted in the hydraulic model to indicate bankfull flow conditions. The bankfull capacity for Jilliby Jilliby Creek downstream of the confluence with Little Jilliby Jilliby Creek is approximately 35 $m^3/s$, which is less than the 2 year average recurrence interval flow rate.

Table 4.6 Adopted Design Discharge

| Reach | Location | Design Discharge ($m^3/s$) |
|---|---|---|
| Jilliby Jilliby Creek | XS 51 | 15 |
| | XS 38 | 20 |
| | XS 24 | 35 |
| Little Jilliby Jilliby Creek | XS 29b | 5 |
| | XS 26 | 15 |
| | XS 10 | 20 |

Figure 4.12 shows the longitudinal channel bed profile and modelled water surface level of Jilliby Jilliby Creek for bankfull flow conditions. Figure 4.13 and Figure 4.14 show longitudinal profile plots of flow velocity and stream power respectively. The results of the hydraulic model show:

- Flow velocities will generally be reduced, with a potential minor increase in flow velocity upstream of XS 45 and downstream side of the main headings (XS22). The range of post-subsidence velocities is similar to pre-subsidence.
- General reductions in stream power, with a small increase upstream of XS 45 and around XS22.
- Potential for minor ponding (less than 1 m depth) along the channel bed around XS20, XS26 and XS28.

Figure 4.15 shows the longitudinal channel bed profile and modelled water surface level of Little Jilliby Jilliby Creek for bankfull flow conditions. Figure 4.16 and Figure 4.17 show longitudinal profile plots of flow velocity and stream power respectively. The results of the hydraulic model show:

- Flow velocities are generally similar, with a potential minor increase in flow velocity near XS 28f, XS 28b, XS 28, XS 16a, XS 12, XS 04 and XS 01. The range of post-subsidence velocities is slightly higher than pre-subsidence.
- Stream powers along Little Jilliby Jilliby Creek are slightly higher than pre-subsidence, noticeably near XS 28f, XS 28b, XS 28, XS 16a, XS 12, XS 04 and XS 01.
- Potential for minor ponding (less than 1 m depth) along the channel bed around XS 26c.

The results of the hydraulic modelling indicate that key hydraulic parameters for subsided conditions are generally within the range of pre-subsidence values. There is the potential for reduced sediment transport in reaches where bed gradients have been reduced and increased sediment transport where gradients have been increased. Based on the existing dynamic nature of the main channel, particularly in the lower reaches of Jilliby Jilliby Creek and Little Jilliby Jilliby Creek, it is likely that impacts of subsidence on the creek channel will be difficult to separate from the existing natural variability in vegetation and bed and bank condition. Ongoing monitoring of subsidence and possible associated impacts will be undertaken throughout the Project to identify and correct any observed impacts. A stream stability monitoring and management program will be developed following development approval to address subsidence impacts. Further details of the proposed program are provided in Section 6.4.3.

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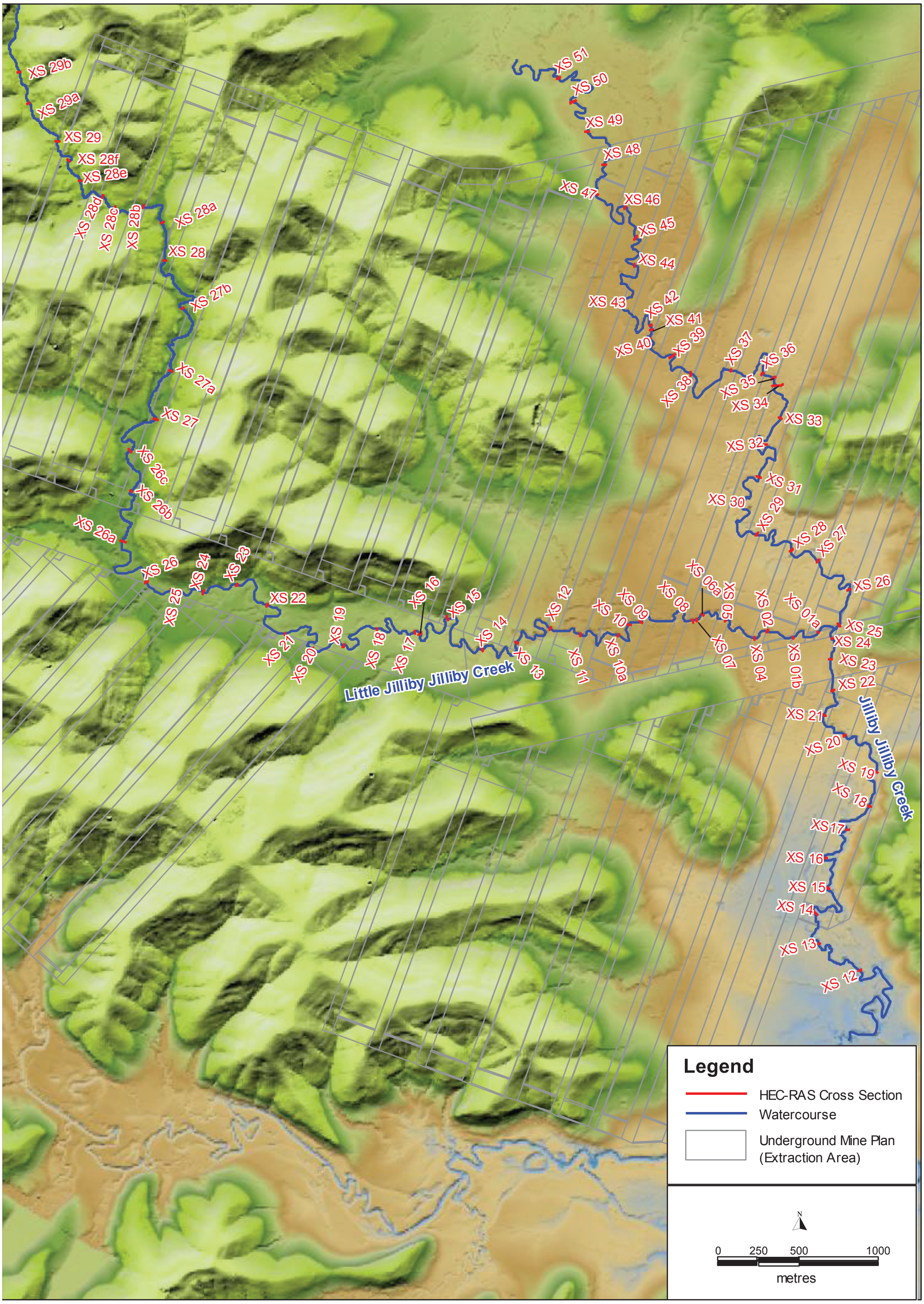


Figure 4.11 HECRAS Model Cross-section Locations

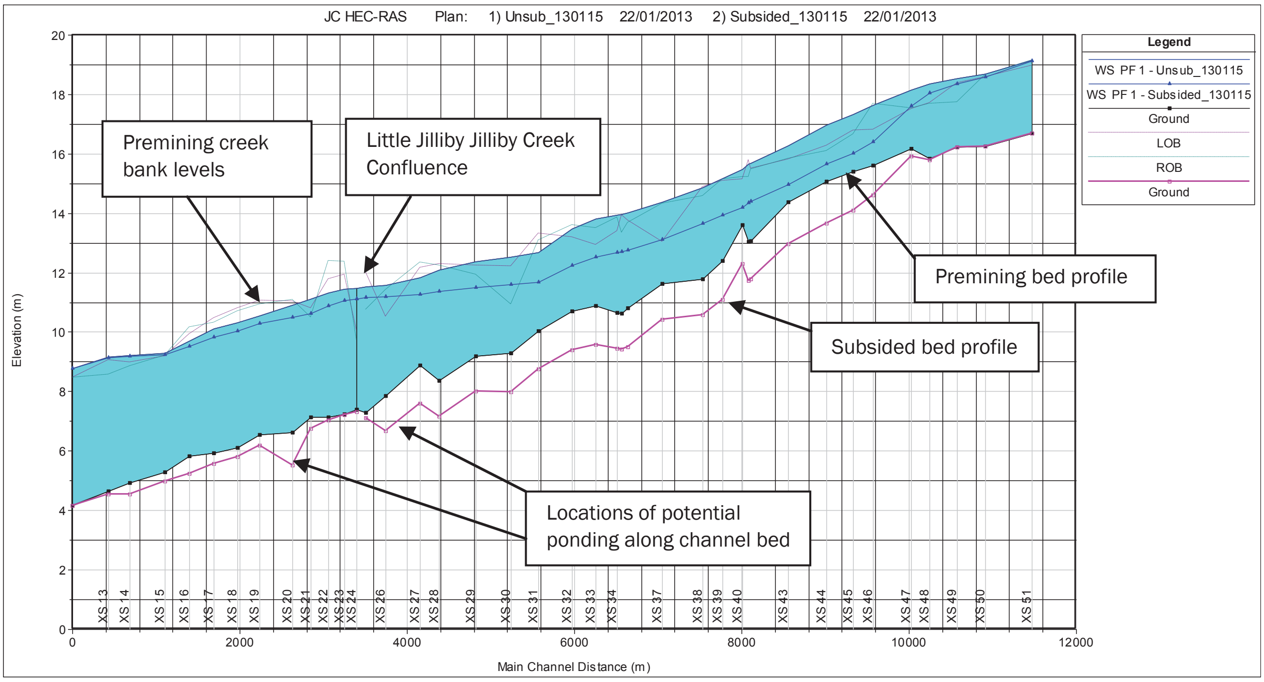


Figure 4.12 Longitudinal Section of Jilliby Jilliby Creek Upstream and Downstream of Little Jilliby Jilliby Creek Confluence, Bed and Water Levels, Pre and Post Subsidence, Bankfull Flow Conditions

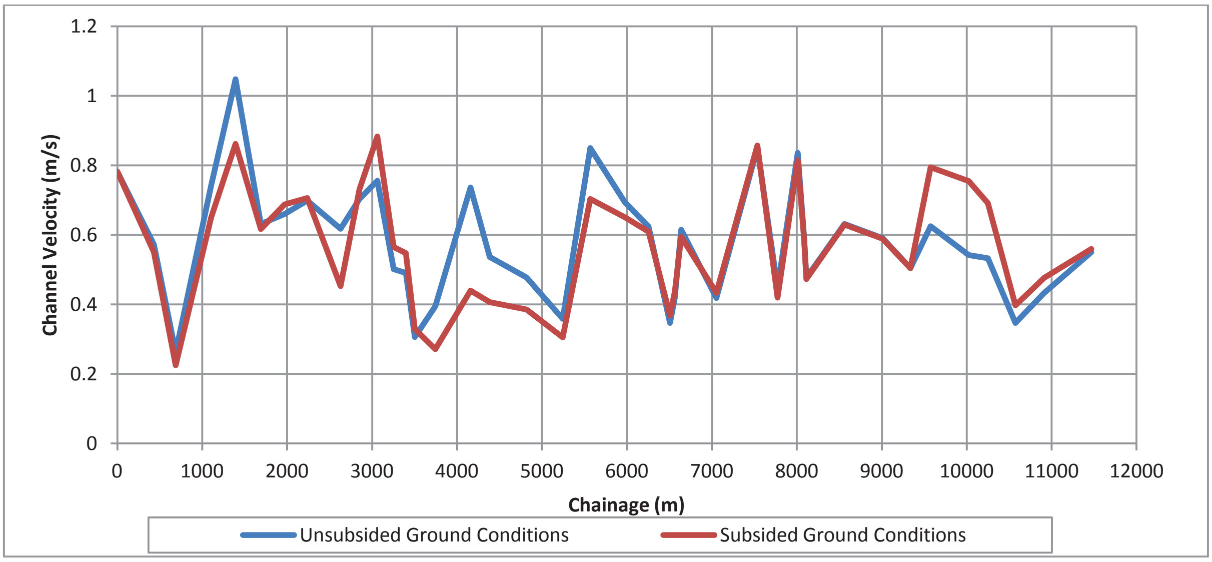


Figure 4.13 Longitudinal Section of Jilliby Jilliby Creek, Velocities, Pre and Post Subsidence, Bankfull Flow Conditions

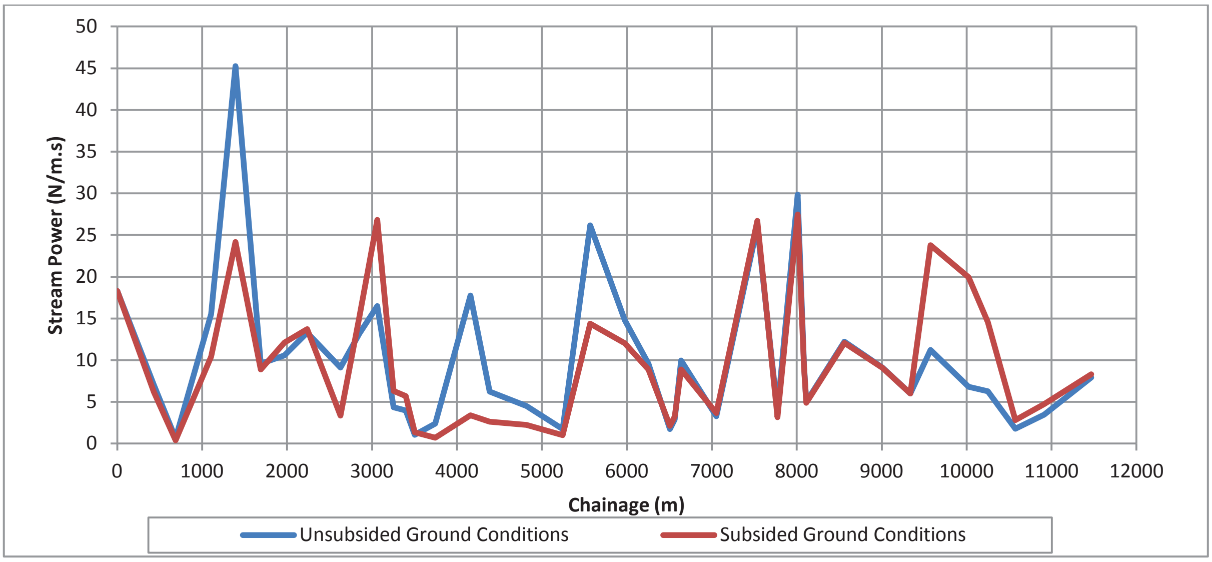


Figure 4.14 Longitudinal Section of Jilliby Jilliby Creek, Stream Power, Pre and Post Subsidence, Bankfull Flow Conditions

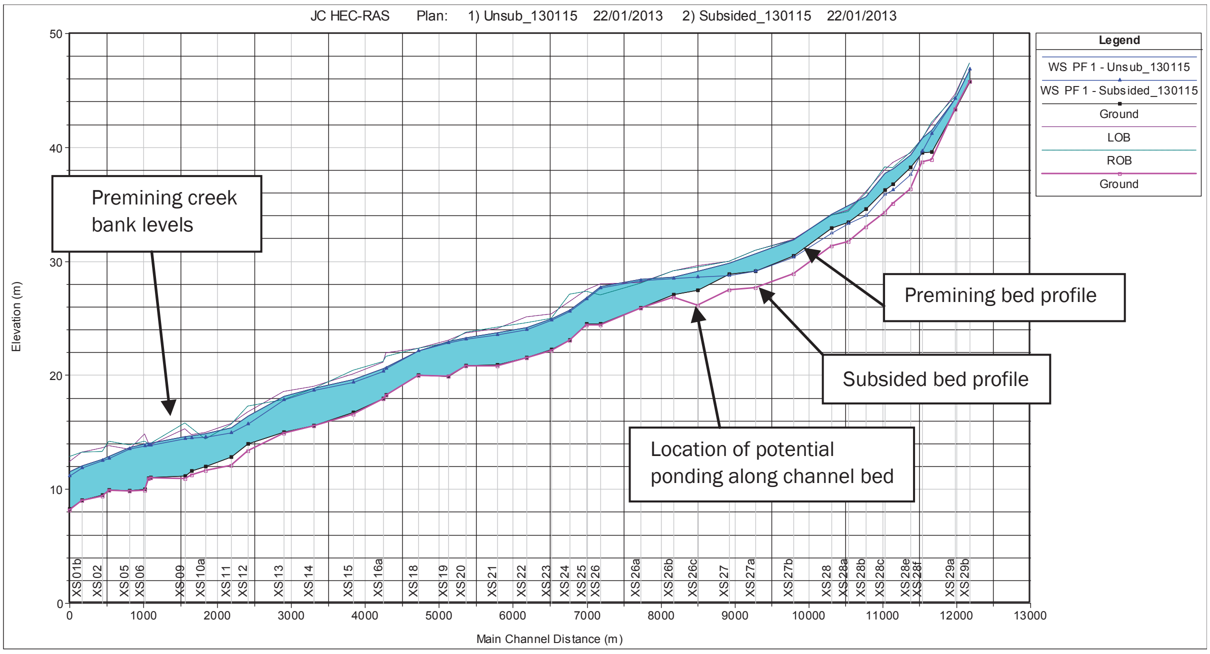


Figure 4.15 Longitudinal Section of Little Jilliby Jilliby Creek Upstream and Downstream of Jilliby Jilliby Creek Confluence, Bed and Water Levels, Pre and Post Subsidence, Bankfull Flow Conditions

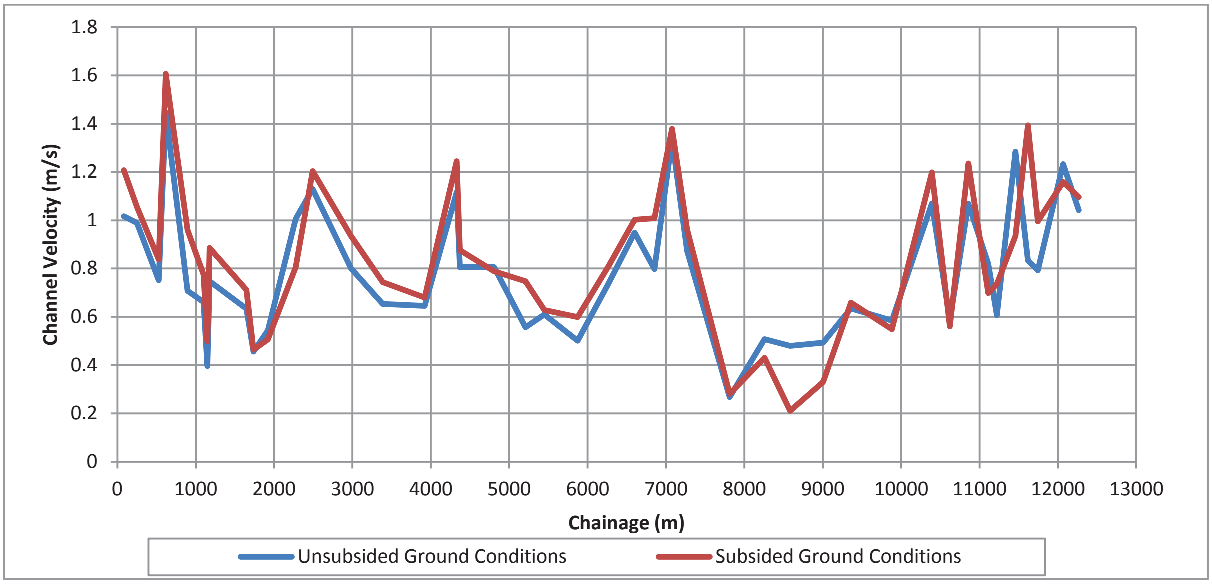


Figure 4.16 Longitudinal Section of Little Jilliby Jilliby Creek, Velocities, Pre and Post Subsidence, Bankfull Flow Conditions

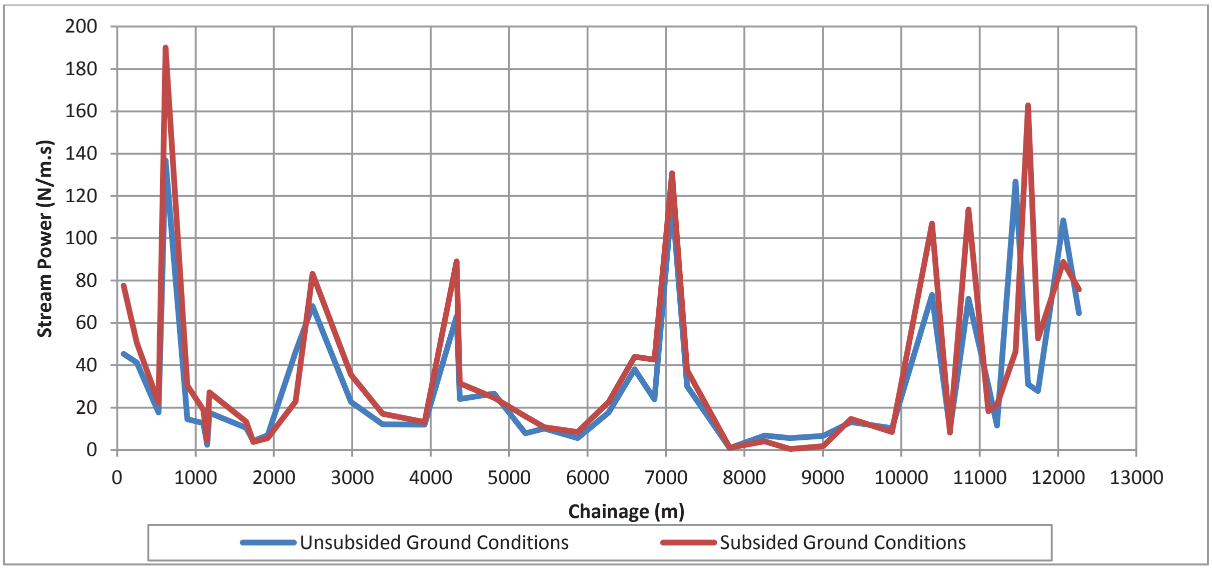


Figure 4.17 Longitudinal Section of Little Jilliby Jilliby Creek, Stream Power, Pre and Post Subsidence, Bankfull Flow Conditions

# 5 MINE WATER BALANCE

## 5.1 OVERVIEW

The GoldSim software (developed by GoldSim Technology Group) was used to simulate the water balance of the mine on a daily basis over the 28 year life of the Project. The model was configured to represent the inflows to and outflows from the mine water management system shown in Table 5.1, as well as transfers of water between mine site storages. Details of the model configuration, input data and results are provided in the following sections.

Table 5.1 Simulated Inflows and Outflows to Mine Water Management System

| Inflows | Outflows |
|---|---|
| Direct rainfall on water surface of storages | Evaporation from water surface of storages |
| Catchment runoff | Surface water demands (including dust suppression) |
| Groundwater inflows to Underground | Underground water demand |
| Raw water supply from External Source | Treated water discharge to Wallarah Creek |
| | Brine/Salt and groundwater storage in goaf/sumps |
| | Offsite spills from storages |

## 5.2 SIMULATION METHODOLOGY

To assess the performance of the water management system under a range of climatic conditions, water balance modelling was undertaken using a set of ninety-five, 28 year rainfall sequences, extracted from recorded historical data. The first rainfall sequence commences on 1/1/1889. The second commenced on 1/1/1890 and so on.

The water balance model was configured to represent the changing characteristics of the conceptual water management system over the 28 year mine life, including the construction period, varying groundwater inflow rates and varying underground void space. The model was then run for the 95 historical sequences, with a nominal starting year of 2014, to assess the performance of the water management system (storage level, pumped volumes, etc.) under the different climate scenarios.

## 5.3 WATER MANAGEMENT SYSTEM LAYOUT

### 5.3.1 Water Storages

The proposed water management system comprises two sites; the Buttonderry Site and Tooheys Road Site. The layout of each site is shown in Figure 2.2 and Figure 2.3. No coal handling is proposed to occur at the Buttonderry Site. The site water management system will also include a water storage sump within the underground mine.

Tooheys Road Site
The MOD is the main mine water storage on the surface and receives underground dewatering, as well as water transferred from the Stockpile Dam and Portal Dam, which are maintained empty if possible. The MOD supplies water to the WTP. Treated water is either discharged to Wallarah Creek, or used to top up the Treated Water Storage which supplies the Tooheys Road Site and underground demands. Water from an external source (town water supply) is used as a last priority to supplement the Tooheys Road and underground demands.

Buttonderry Site
Runoff from the Buttonderry Site is captured in the Sediment Dam, which spills to the Entrance Dam. The Entrance Dam supplies water to the Buttonderry Site demands as a first priority. In the adopted model configuration, any shortfall in Buttonderry Site demands is met by treated water from an external source.

Both Buttonderry and Tooheys Rd sites will be connected to town water supply for potable supply needs, and to the reticulated sewer system for general effluent disposal.

The proposed capacities of the water storages are listed in Table 5.2. The proposed water management system is shown schematically in Figure 5.1. The assumed staging of storages is as follows:

- Buttonderry Sediment Dam and the Entrance Dam are available from the commencement of the Project.
- Portal Dam, Stockpile Dam, MOD, Treated Water Storage and Brine Storage become available at the end of Year 1.

Table 5.2 Storage Capacities

| Storage | Capacity (ML) |
|---|---|
| Tooheys Road Site | |
| MOD | 180 |
| Portal Dam | 30 |
| Stockpile Dam | 20 |
| Treated Water Storage | 20 |
| Underground Sump | 120 |
| Brine Storage | 9 |
| Buttonderry Site | |
| Entrance Dam | 10 |
| Sediment Dam | 1 |

The brine storage is a component of the water treatment plant operations and is not shown explicitly in the water management system schematic.

Sizing of the mine water storages (Portal Dam, Stockpile Dam and MOD) has been based on achieving no uncontrolled discharge (spills) to the receiving environment for the period of historical climate record. This method of sizing takes into account prolonged wet periods in which water accumulated on site as well as large (historical) storm events.

For comparison purposes, the MOD dam capacity has been compared to the 100 year Average Recurrence Interval (ARI) 72 hour duration design storm event at the Project site, as follows:

- 100 year ARI, 72 hour duration design storm event depth: 453.6 mm
- Volumetric runoff coefficient: 1.0 (100% rainfall runoff)
- MOD catchment area: 5.39 ha
- Runoff volume: 24 ML

The MOD is operated at a Maximum Operating Level (MOL) of 155 ML (refer Section 5.9 for detailed operating rules), which gives a storm 'buffer' volume of 25 ML. This indicates that the runoff from a 100 year ARI 72 hour duration design storm event would be contained within this storm 'buffer' volume.

For comparison purposes, the Buttonderry Sediment Dam, Entrance Dam, Tooheys Road Portal Dam and Stockpile Dam capacities have been compared to the 'Managing Urban Stormwater: Soils and Construction' sediment dam sizing guidelines (DECC, 2008) (previously known as the Blue Book). The following is of note:

- Duration of disturbance >3 years;
- 'Sensitive' receiving environment;
- Type F sediment retention basin;
- Volumetric runoff coefficient: 1.0 (100% rainfall runoff)
- Catchment areas as per Table 5.6.

Table 5.3 presents the results of the sediment retention basin capacity comparison. The Buttonderry Sediment Dam and Entrance Dam have been assessed as a combined system. The results indicate that the proposed capacities of the Portal Dam, Stockpile Dam and Buttonderry dams exceed the Blue Book guidelines capacity requirements.

**Table 5.3 Type F Sediment Retention Basin Sizing (comparison purposes only)**

| Storage | Sediment Retention Basin Size (ML) | Proposed Storage Size (ML) |
|---|---|---|
| Tooheys Road Site | | |
| Portal Dam | 22 | 30 |
| Stockpile Dam | 18 | 20 |
| Buttonderry Site | | |
| Entrance Dam + Sediment Dam | 10 | 11 |

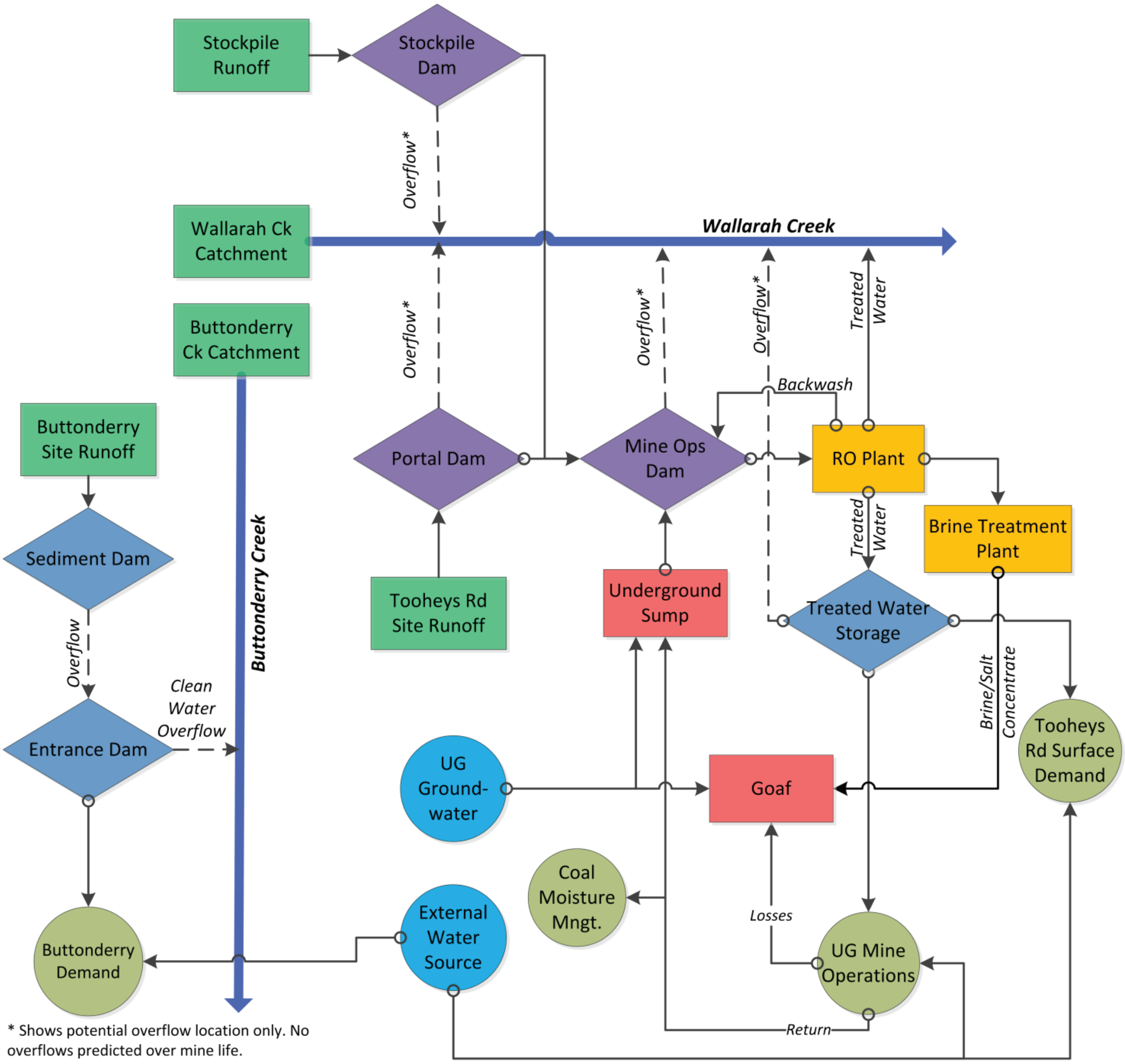


Figure 5.1 Water Management System Schematic

## 5.4 CATCHMENT RUNOFF

### 5.4.1 Adopted Rainfall-Runoff Model

The AWBM model (Boughton, 1993) was used to estimate runoff volumes from onsite catchments, based on available rainfall and evaporation data. AWBM is a saturated overland flow model which allows for variable source areas of surface runoff. The model uses daily rainfall and estimates of catchment evapotranspiration to calculate daily values of runoff using a daily water balance of soil moisture. The model has a baseflow component which simulates the recharge and discharge of a shallow groundwater store. Runoff depth calculated by the AWBM model is converted into runoff volume by multiplying by the contributing catchment area. The various parameters of the AWBM model are shown in Table 5.4.

Table 5.4 Summary of AWBM Model Parameters

| Parameter Specification | Description |
|---|---|
| Partial Area Fractions | Parameters A1, A2 & A3. Fraction of catchment area represented by surface storages No. 1, 2 & 3. |
| Soil Store Capacities | Parameter C1, C2 & C3. Soil moisture storage capacities for smallest store (No. 1), middle store (No. 2) and largest store (No. 3). |
| Base Flow Index | Parameter BFI. Proportion of runoff directed to baseflow store. |
| Daily Baseflow Recession Constant | Parameter $K_b$. Rate at which water discharges from baseflow store. |

### 5.4.2 Catchment Land Use Classifications

To estimate catchment runoff inflows to the mine water management system, separate AWBM model parameters were developed for the following catchment types:

- Natural/Undisturbed;
- Roads/Industrial/Hardstand; and
- Stockpile.

Figure 5.2 and Figure 5.3 show the land use classifications adopted for the catchment runoff volume estimation at the Buttonderry Site and Tooheys Road Site respectively. A summary of this information is provided in Table 5.5 and Table 5.6.

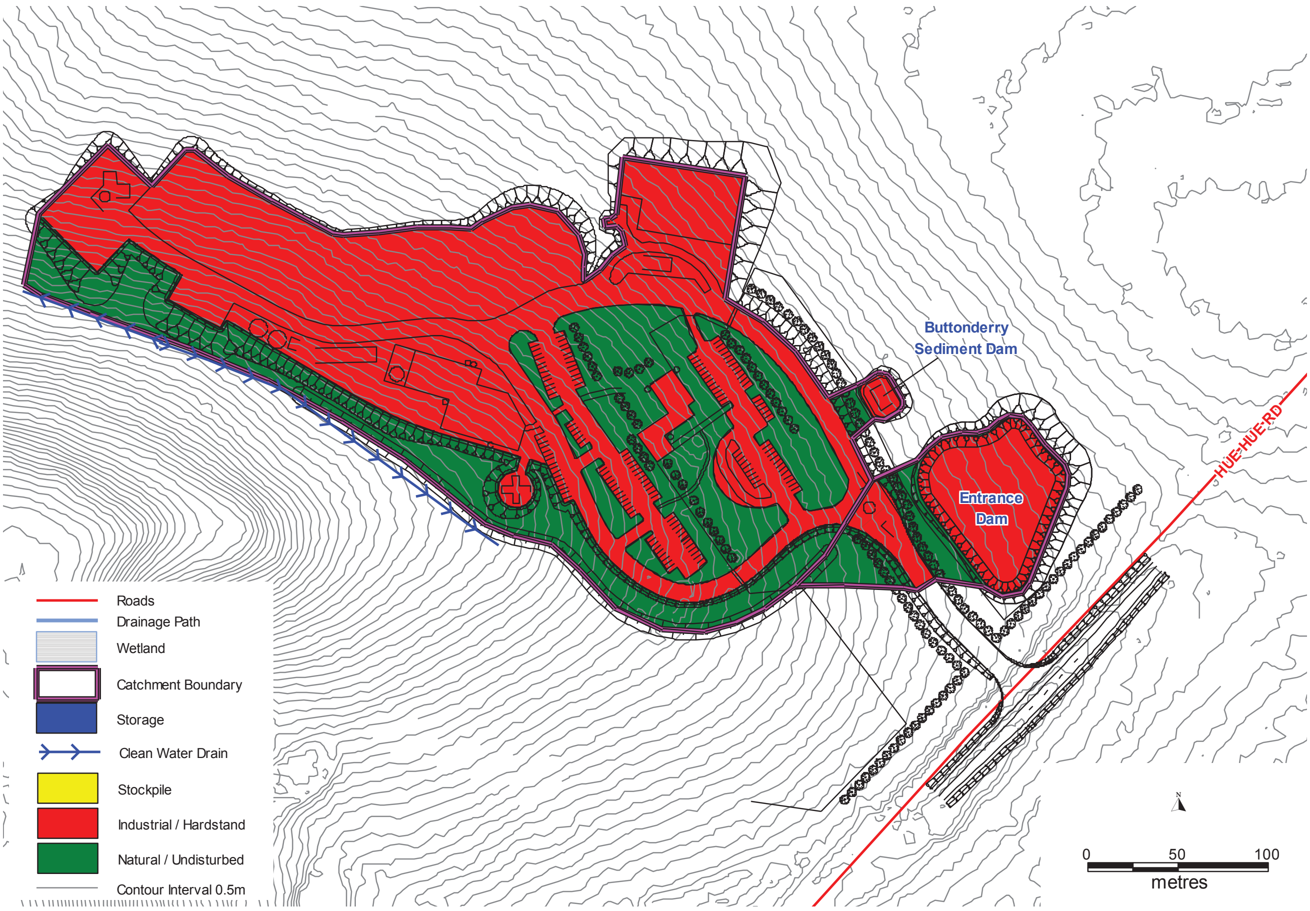


Figure 5.2 Buttonderry Site – Land Use Classifications

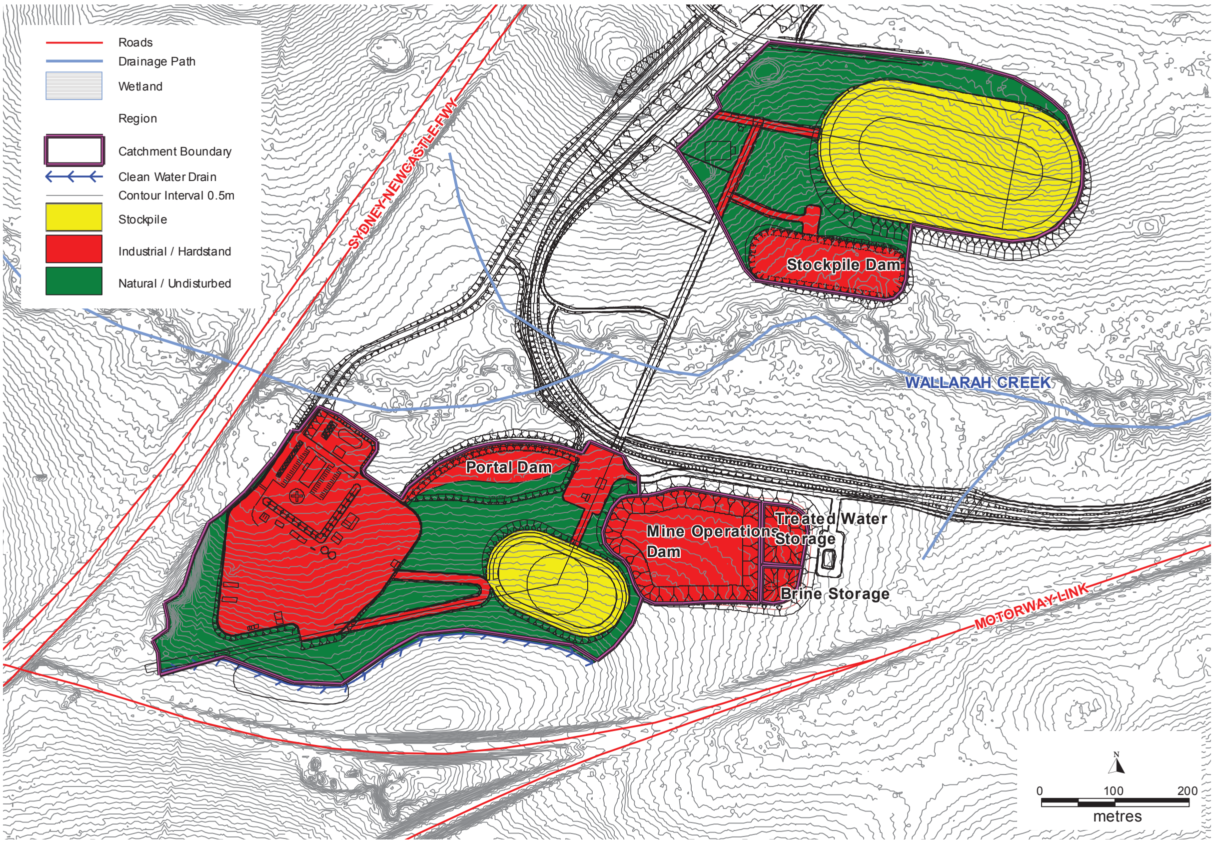


Figure 5.3 Tooheys Road Site – Land Use Classifications

Table 5.5 Land Use Classifications, Buttonderry Site – Year 1

| Storage | Captured Catchment Area (ha) | | | |
|---|---|---|---|---|
| | Natural | Stockpile | Industrial | Total |
| Buttonderry Site | | | | |
| Entrance Dam | 0.30 | 0 | 0.61 | 0.91 |
| Sediment Dam | 2.37 | 0 | 4.12 | 6.49 |
| **Total** | **2.67** | **0** | **4.73** | **7.4** |

Table 5.6 Land Use Classifications – Years 2 to 28

| Storage | Captured Catchment Area (ha) | | | |
|---|---|---|---|---|
| | Natural | Stockpile | Industrial | Total |
| Tooheys Road Site | | | | |
| MOD | 0 | 0 | 5.39 | 5.39 |
| Portal Dam | 7.10 | 1.95 | 7.55 | 16.60 |
| Stockpile Dam | 5.11 | 6.06 | 2.07 | 13.24 |
| Treated Water Storage [a] | 0 | 0 | 0.85 | 0.85 |
| Buttonderry Site | | | | |
| Entrance Dam | 0.30 | 0 | 0.61 | 0.91 |
| Sediment Dam | 2.37 | 0 | 4.12 | 6.49 |
| **Total** | **14.88** | **8.01** | **20.59** | **43.48** |

Notes: [a] Cell within MOD

### 5.4.3 AWBM Parameter Calibration

Parameters for natural catchment areas were based on model calibration to local runoff data from Wallarah Creek which has been obtained from NOW. Parameters for industrial and stockpile areas have been adopted from previous water balance investigations for the Project (Parsons Brinckerhoff, 2011).

Streamflow data was recorded at Wallarah Creek at Warnervale (Station No. 211006) for the period October 1965 to July 1976. The location of the historical monitoring station is shown in Figure 2.18. The monitoring station had a catchment area of approximately 9 $km^2$.

Figure 5.4 shows the calibration results as monthly runoff volume for observed and simulated discharges. Figure 5.5 shows the cumulative runoff over the recorded period for the observed and simulated discharges. Figure 5.6 shows the flow duration relationship for the observed and simulated discharges. Review of the calibration results indicates good agreement with the observed discharges on a monthly volume and cumulative basis. The flow duration curve shows good agreement for discharges greater than 0.1 ML/d, however the simulated discharges deviate from the observed discharges below this value (the model predicts slightly longer periods of flow below 0.1 ML/d).

The adopted AWBM model parameters and volumetric runoff coefficients for the three catchment types are shown in Table 5.7.

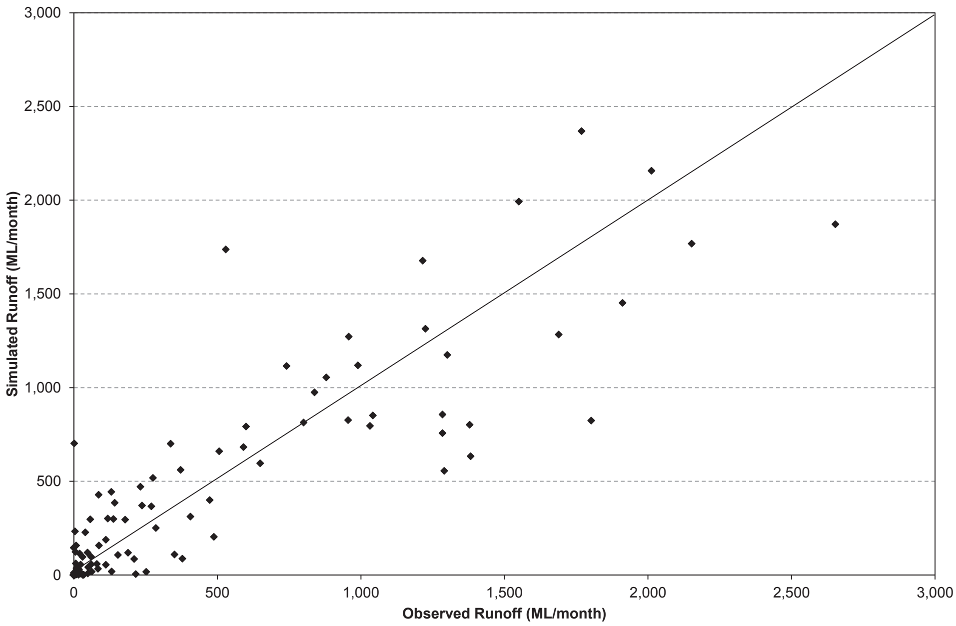


Figure 5.4 Natural Catchment AWBM Calibration, Monthly Runoff – Simulated vs. Observed

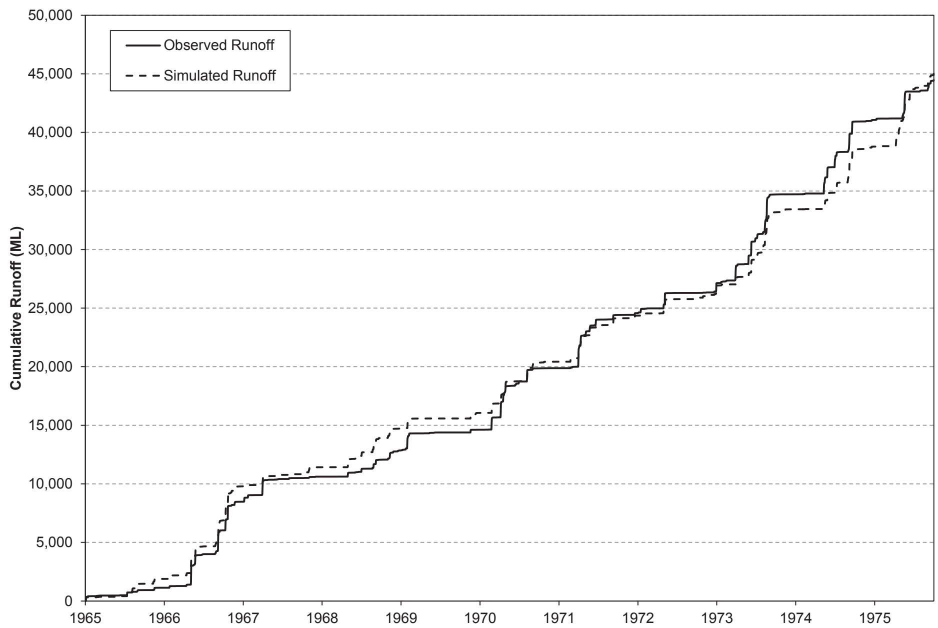


Figure 5.5 Natural Catchment AWBM Calibration, Cumulative Runoff – Simulated vs. Observed

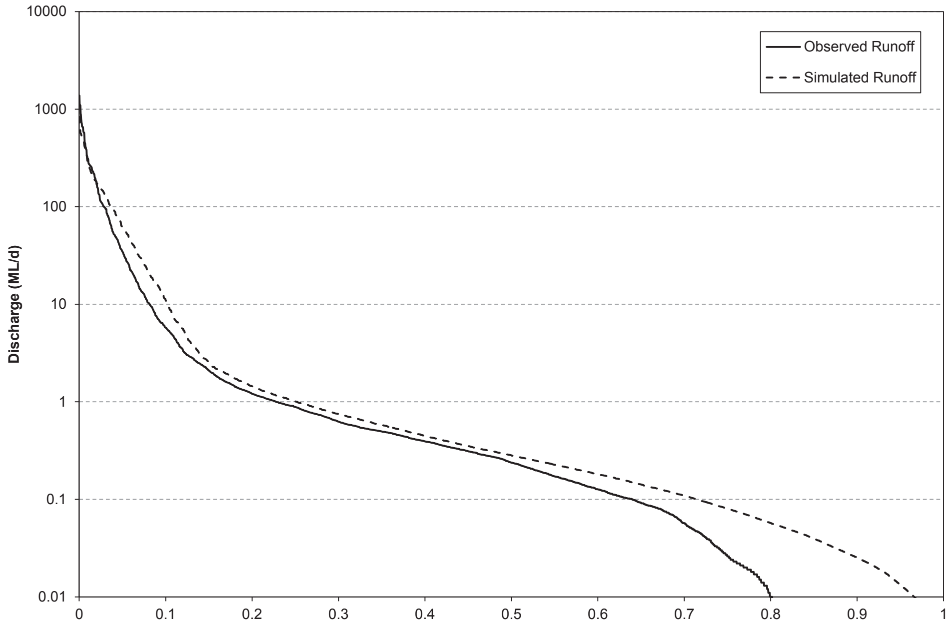


**Figure 5.6 Natural Catchment AWBM Calibration, Flow Duration Relationship – Simulated vs. Observed**

**Table 5.7 AWBM Parameters**

| Parameter | Natural/Undisturbed | Roads/Industrial/ Hardstand | Stockpile |
|---|---|---|---|
| A1 | 0.134 | 0.134 | 0.1 |
| A2 | 0.433 | 0.433 | 0.9 |
| C1 | 50 | 2.6 | 5.0 |
| C2 | 70 | 26.7 | 50.0 |
| C3 | 180 | 53.3 | 0 |
| BFI | 0.04 | 0 | 0.5 |
| Kb | 0.96 | 1 | 0.98 |
| Ks | 0.2 | 0 | 0 |
| Long-term Runoff Coefficient (%) | 36% | 51% | 46% |

## 5.5 WATER QUALITY

The water balance model also included a salt balance to provide an indication of the expected water quality in storages within the mine water management system. Each catchment type has been assigned a runoff salinity as presented in Table 5.8. The adopted salinities were based on available baseline water quality data as well as experience from similar operations, such as Mandalong Coal Mine (Centennial Coal, 2012).

Table 5.8 Adopted Water Quality

| Source | Total Dissolved Solids (mg/L) |
|---|---|
| Catchment Runoff | |
| Natural*1 | 300 |
| Industrial | 1,500 |
| Stockpile | 4,000 |
| Groundwater*2 | 7,000 |
| External Supply Source*3 | 200 |

Notes: *1 – Based on baseline surface water quality monitoring at Wallarah Creek, refer Section 2.9.2.
*2 – Upper limit of groundwater salinity estimate, refer Section 2.9.3.
*3 – Estimate of drinking water quality (NRW, 2007).

## 5.6 WATER DEMANDS

Estimated water demands for the Tooheys Road Site and Buttonderry Site provided by WACJV are shown in Table 5.9. These estimated demands were adopted for the water balance model.

Table 5.9 Water Demand Summary (ML/a)

| Project Year | Tooheys Road Site | | | | | | Buttonderry Site | | | Total |
|---|---|---|---|---|---|---|---|---|---|---|
| | Construction | Mine Use Surface | Net Mine Use UG*1 | Coal Handling | Product Coal Moisture | Total | Construct -ion | Mine Use Surface | Total | |
| 1 | 30 | 5 | 0 | 0 | 0 | 35 | 15 | 10 | 25 | 60 |
| 2 | 30 | 5 | 0 | 0 | 0 | 35 | 25 | 15 | 40 | 75 |
| 3 | 30 | 5 | 2 | 0 | 2 | 39 | 30 | 15 | 45 | 84 |
| 4 | 0 | 10 | 40 | 5 | 50 | 105 | 0 | 30 | 30 | 135 |
| 5 | 0 | 10 | 70 | 15 | 88 | 183 | 0 | 30 | 30 | 213 |
| 6 | 0 | 10 | 100 | 25 | 125 | 260 | 0 | 30 | 30 | 290 |
| 7 | 0 | 10 | 128 | 35 | 160 | 333 | 0 | 30 | 30 | 363 |
| 8 | 0 | 10 | 160 | 50 | 200 | 420 | 0 | 30 | 30 | 450 |
| 9 | 0 | 10 | 160 | 50 | 200 | 420 | 0 | 30 | 30 | 450 |
| 10 | 0 | 10 | 160 | 50 | 200 | 420 | 0 | 30 | 30 | 450 |
| 11 | 0 | 10 | 160 | 50 | 200 | 420 | 0 | 30 | 30 | 450 |
| 12 | 0 | 10 | 160 | 50 | 200 | 420 | 0 | 30 | 30 | 450 |
| 13 | 0 | 10 | 160 | 50 | 200 | 420 | 0 | 30 | 30 | 450 |
| 14 | 0 | 10 | 160 | 50 | 200 | 420 | 0 | 30 | 30 | 450 |
| 15 | 0 | 10 | 160 | 50 | 200 | 420 | 0 | 30 | 30 | 450 |
| 16 | 0 | 10 | 160 | 50 | 200 | 420 | 0 | 30 | 30 | 450 |
| 17 | 0 | 10 | 160 | 50 | 200 | 420 | 0 | 30 | 30 | 450 |
| 18 | 0 | 10 | 160 | 50 | 200 | 420 | 0 | 30 | 30 | 450 |
| 19 | 0 | 10 | 160 | 50 | 200 | 420 | 0 | 30 | 30 | 450 |
| 20 | 0 | 10 | 160 | 50 | 200 | 420 | 0 | 30 | 30 | 450 |
| 21 | 0 | 10 | 160 | 50 | 200 | 420 | 0 | 30 | 30 | 450 |
| 22 | 0 | 10 | 160 | 50 | 200 | 420 | 0 | 30 | 30 | 450 |
| 23 | 0 | 10 | 160 | 50 | 200 | 420 | 0 | 30 | 30 | 450 |
| 24 | 0 | 10 | 160 | 50 | 200 | 420 | 0 | 30 | 30 | 450 |
| 25 | 0 | 10 | 160 | 50 | 200 | 420 | 0 | 30 | 30 | 450 |
| 26 | 0 | 10 | 160 | 50 | 200 | 420 | 0 | 30 | 30 | 450 |
| 27 | 0 | 10 | 160 | 50 | 200 | 420 | 0 | 30 | 30 | 450 |
| 28 | 0 | 10 | 160 | 50 | 200 | 420 | 0 | 30 | 30 | 450 |

Notes: *1 Net underground water losses. Based on 40% loss of underground water demand (Parsons Brinckerhoff, 2011).

## 5.7 GROUNDWATER INFLOWS TO UNDERGROUND

Gross groundwater inflows to the underground operations have been provided by Mackie Environmental Research (MER, 2013). The gross groundwater inflow rates are shown in Figure 5.7 and summarised in Table 5.10.

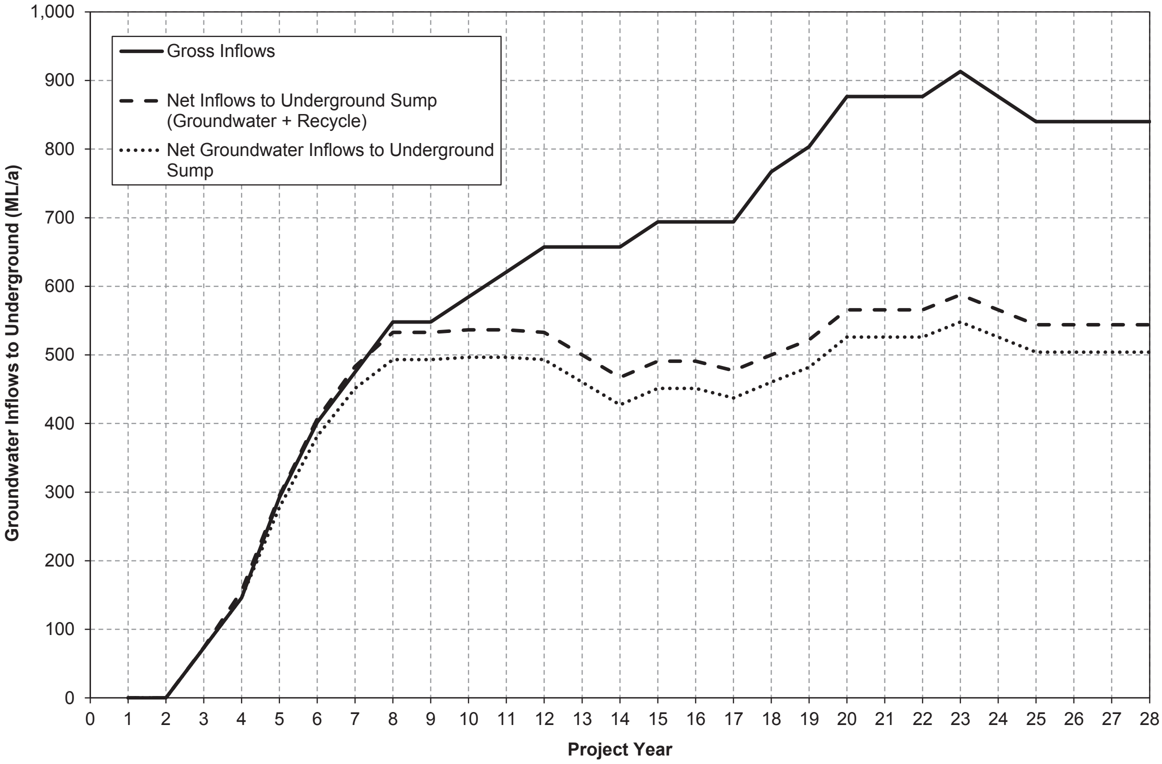


Figure 5.7 Groundwater Inflow Rates to Underground (MER, 2013)

Table 5.10 Gross Groundwater Inflow Rates to Underground (MER, 2013)

| Year | Average Groundwater Inflow (ML/d) | Year | Average Groundwater Inflow (ML/d) |
|---|---|---|---|
| 1 | 0.0 | 15 | 1.9 |
| 2 | 0.2 | 16 | 1.9 |
| 3 | 0.4 | 17 | 2.1 |
| 4 | 0.8 | 18 | 2.2 |
| 5 | 1.1 | 19 | 2.4 |
| 6 | 1.3 | 20 | 2.4 |
| 7 | 1.5 | 21 | 2.4 |
| 8 | 1.5 | 22 | 2.5 |
| 9 | 1.6 | 23 | 2.4 |
| 10 | 1.7 | 24 | 2.3 |
| 11 | 1.8 | 25 | 2.3 |
| 12 | 1.8 | 26 | 2.3 |
| 13 | 1.8 | 27 | 2.3 |
| 14 | 1.9 | 28 | 2.2 |

## 5.8 MINE VOID SPACE

The underground mine plan will progressively generate large volumes of mine void space which will become available for water storage as mining proceeds. The water balance model has accounted for this void space as an annual diversion of groundwater inflows directly to the mine void. This water bypasses the underground sump and is not dewatered to the surface operations. For the purposes of conservatism, it is assumed that the water losses which occur during underground operations are also retained in the goaf for storage with some lost as evaporation in mine ventilation. A conservative estimate of the volumes available for mine water storage provided by WACJV is shown in Table 5.11. Net groundwater inflows to the water balance model are shown in Figure 5.7.

**Table 5.11 Underground Operations Summary (ML/d)**

| Year | Groundwater Inflows (Gross) | % of Gross Groundwater Inflows Retained in Mine Goaf | Underground Operations | | | Product Coal Moisture | Total Water to Goaf (GW x % + UG Loss) | Total Water to Underground (UG Recycle - Prod Coal Moist + (1-%)xGW Inflows) |
|---|---|---|---|---|---|---|---|---|
| | | | Total UG Use | Total UG recycle | Total UG Loss | | | |
| 1 | 0 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 2 | 0 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 3 | 0.2 | 0.00 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.20 |
| 4 | 0.4 | 0.00 | 0.27 | 0.16 | 0.11 | 0.14 | 0.11 | 0.43 |
| 5 | 0.8 | 0.05 | 0.48 | 0.29 | 0.19 | 0.24 | 0.23 | 0.81 |
| 6 | 1.1 | 0.05 | 0.68 | 0.41 | 0.27 | 0.34 | 0.33 | 1.11 |
| 7 | 1.3 | 0.05 | 0.88 | 0.53 | 0.35 | 0.44 | 0.42 | 1.32 |
| 8 | 1.5 | 0.10 | 1.10 | 0.66 | 0.44 | 0.55 | 0.59 | 1.47 |
| 9 | 1.5 | 0.10 | 1.10 | 0.66 | 0.44 | 0.55 | 0.59 | 1.47 |
| 10 | 1.6 | 0.15 | 1.10 | 0.66 | 0.44 | 0.55 | 0.68 | 1.47 |
| 11 | 1.7 | 0.20 | 1.10 | 0.66 | 0.44 | 0.55 | 0.78 | 1.47 |
| 12 | 1.8 | 0.25 | 1.10 | 0.66 | 0.44 | 0.55 | 0.89 | 1.46 |
| 13 | 1.8 | 0.30 | 1.10 | 0.66 | 0.44 | 0.55 | 0.98 | 1.37 |
| 14 | 1.8 | 0.35 | 1.10 | 0.66 | 0.44 | 0.55 | 1.07 | 1.28 |
| 15 | 1.9 | 0.35 | 1.10 | 0.66 | 0.44 | 0.55 | 1.10 | 1.34 |
| 16 | 1.9 | 0.35 | 1.10 | 0.66 | 0.44 | 0.55 | 1.10 | 1.34 |
| 17 | 1.9 | 0.37 | 1.10 | 0.66 | 0.44 | 0.55 | 1.14 | 1.31 |
| 18 | 2.1 | 0.40 | 1.10 | 0.66 | 0.44 | 0.55 | 1.28 | 1.37 |
| 19 | 2.2 | 0.40 | 1.10 | 0.66 | 0.44 | 0.55 | 1.32 | 1.43 |
| 20 | 2.4 | 0.40 | 1.10 | 0.66 | 0.44 | 0.55 | 1.40 | 1.55 |
| 21 | 2.4 | 0.40 | 1.10 | 0.66 | 0.44 | 0.55 | 1.40 | 1.55 |
| 22 | 2.4 | 0.40 | 1.10 | 0.66 | 0.44 | 0.55 | 1.40 | 1.55 |
| 23 | 2.5 | 0.40 | 1.10 | 0.66 | 0.44 | 0.55 | 1.44 | 1.61 |
| 24 | 2.4 | 0.40 | 1.10 | 0.66 | 0.44 | 0.55 | 1.40 | 1.55 |
| 25 | 2.3 | 0.40 | 1.10 | 0.66 | 0.44 | 0.55 | 1.36 | 1.49 |
| 26 | 2.3 | 0.40 | 1.10 | 0.66 | 0.44 | 0.55 | 1.36 | 1.49 |
| 27 | 2.3 | 0.40 | 1.10 | 0.66 | 0.44 | 0.55 | 1.36 | 1.49 |
| 28 | 2.3 | 0.40 | 1.10 | 0.66 | 0.44 | 0.55 | 1.36 | 1.49 |

## 5.9 OPERATING RULES

The operational strategy for the mine's water management system is represented in the water balance model as a set of pumping rules that describe interactions between the various water storages. Table 5.12 provides a summary of the adopted model operating rules for the water balance model. Figure 5.1 shows a schematic of the mine water management system.

Table 5.12 Water Balance Model Operating Rules

| Item | Node Name | Operating Rules |
|---|---|---|
| *1.0* | *Water Sources* | |
| 1.1 | External Water Source | ▪ Supplies to Tooheys Road Surface Demand, Underground Mine Use and Buttonderry Demand as required. |
| 1.2 | Groundwater inflows | ▪ Inflows to Underground Operations.<br>▪ Portion of inflows lost to goaf |
| *2.0* | *Water Demands* | ▪ Supplied from the following locations in order of priority: |
| 2.1 | Tooheys Road Surface & Underground Demand | ▫ Treated Water Storage<br>▫ External Water Source |
| 2.2 | Buttonderry Demand | ▪ Potable water component supplied from External Water Source.<br>▪ All other demands supplied from the following locations:<br>▫ Entrance Dam<br>▫ External Water Source |
| 2.3 | Product Coal Moisture Management | ▪ Inherent loss from Underground Operations return water to increase coal moisture content from in-situ to meet product coal specification. |
| *3.0* | *Underground Operations* | ▪ Dewatering to MOD at the following rates: |
| 3.1 | Underground Operations | ▫ MOD < 100 ML: 3.5 ML/d<br>▫ MOD >100 ML, <155 ML: 1 ML/d<br>▫ MOD >155 ML: 0 ML/d<br>▪ Receives return from underground mine use, minus product coal moisture losses<br>▪ Portion of return water lost to goaf storage<br>▪ Receives groundwater inflows |

| Item | Node Name | Operating Rules |
|---|---|---|
| *4.0* | *Water Storages* | |
| 4.1 | MOD | ▪ Primary saline water storage dam<br>▪ Maximum Operating Level at a nominal 155 ML capacity<br>▪ Supplies to the WTP when above 5 ML or when TWS is less than 5 ML<br>▪ Receives pumped transfers from the following locations:<br>▫ Underground Operations<br>▫ Portal Dam<br>▫ Stockpile Dam<br>▫ RO Plant backwash<br>▪ Treated Storage water overflows (if they occur) to Wallarah Creek |
| 4.2 | Portal Dam | ▪ Pump transfers to Mine Operations Dam to maintain empty<br>▪ Storage overflows to Wallarah Creek |
| 4.3 | Stockpile Dam | ▪ Pump transfers to Mine Operations Dam to maintain empty<br>▪ Storage overflows to Wallarah Creek |
| 4.4 | Treated Water Storage (TWS) | ▪ Receives treated water from WTP as required<br>▪ Supplies to Tooheys Road Surface & Underground Demands, and Buttonderry Demand<br>▪ Storage overflows to Wallarah Creek |
| 4.5 | Entrance Dam | ▪ Supplies to Buttonderry Demand as required<br>▪ Receives storage overflows from Buttonderry Sediment Dam<br>▪ Storage overflows to Buttonderry Creek |
| 4.6 | Buttonderry Sediment Dam | ▪ Storage overflows to Entrance Dam |
| *5.0* | *Water Treatment Operations* | |
| 5.1 | WTP | ▪ Supplied from the MOD when above MOL<br>▪ Discharges to Wallarah Creek when TWS storage is greater than 50 %<br>▪ Treated water quality to meet receiving water quality objectives. Remainder of salts directed to brine concentrate stream<br>▪ Treated water directed to Treated Water Storage at a rate of 97% of net (not including backwash) WTP inflow<br>▪ Brine disposed to goaf at a rate of 2.6% net WTP inflow<br>▪ Backwash recycle directed to MOD |
| *6.0* | *Receiving Waters* | |
| 6.1 | Wallarah Creek | ▪ Receives treated water discharge from WTP<br>▪ Receives storage overflows (if they were to occur) from the following locations:<br>▫ MOD<br>▫ Treated Water Storage<br>▫ Portal Dam<br>▫ Stockpile Dam |
| 6.2 | Buttonderry Creek | ▪ Receives storage overflows from the following locations:<br>▫ Entrance Dam |

### 5.9.1 Sample WTP Behaviour

Figure 5.9 shows a sample of the simulation of the WTP during Year 16 operations under one climate realisation. The figure illustrates that early in the year, any inflows to the MOD are immediately sent to the WTP to meet site demands, which are supplemented with pipeline water (external water requirement). A storm event occurs which causes a sudden increase in volume in the MOD. The WTP is operated to maintain the TWS at 10 ML, and discharge any excess treated water to Wallarah Creek until the MOD volume is reduced below 5 ML. This takes several months. After the MOD water volume has been sufficiently reduced, the WTP is operated once again to meet site demands.

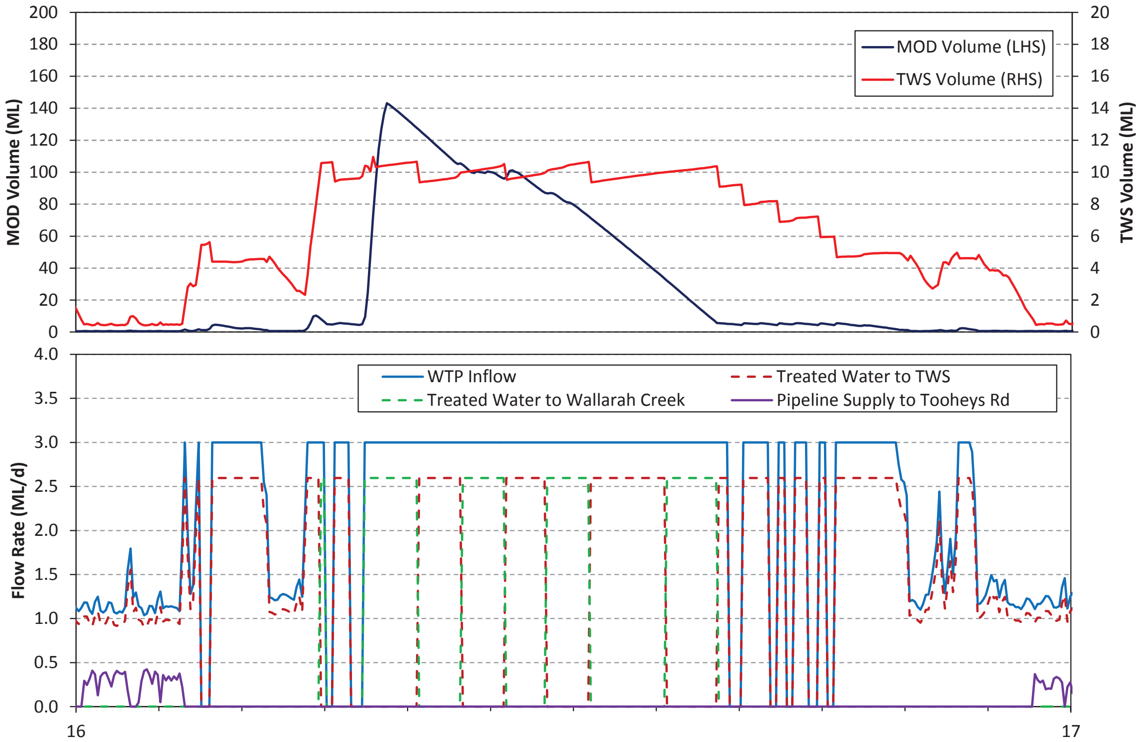


Figure 5.8 Sample of simulated WTP behaviour for Year 16 (one realisation)

## 5.10 PUMP CAPACITIES

Table 5.13 shows the maximum pump capacities adopted in the water balance modelling.

Table 5.13 Adopted Pump Capacities - Maximum

| Pump From | Pump To | Pump rate | |
|---|---|---|---|
| | | ML/d | L/s |
| Stockpile Dam | MOD | 10 | 115 |
| Portal Dam | MOD | 10 | 115 |
| Underground Sump | MOD | 3.5 | 40 |
| MOD | WTP | 3 | 35 |
| WTP | Treated Water Storage | 2.6 | 30 |
| WTP | Wallarah Creek | 2.6 | 30 |
| WTP | Goaf | 0.1 | 1.1 |
| WTP | MOD | 0.3 | 3.5 |

## 5.11 WATER BALANCE MODEL RESULTS

### 5.11.1 Overview

Results from the water balance modelling are presented in the following sections. The 10%, median, 90% and 99% confidence intervals are presented. The 10% confidence interval represents the value on each day of the simulation, at which 10% of all simulations are lower; it does not represent one continuous realisation. In the same way the 99% confidence interval represents the 99% highest value on each day of the simulation, it does not represent one realisation of an extremely wet period.

### 5.11.2 Water Balance Summary

The predicted overall average annual site water balance is summarised in Table 5.14. Results are shown for Years 1, 5, 8 and 22. These results provide an indication of the components of the site water balance for various stages of mine development over this climate sequence. Note that the difference between total inflows and total outflows represents the change in the volume of water storage onsite.

In summary, the following observations can be made on the average annual water balance over the Project life:

**Outflows**

- Total water demand ranges between 66 ML/a and 290 ML/a.
- Total evaporation loss from storages ranges between approximately 5 ML/a and 90 ML/a.
- Controlled discharges to Wallarah Creek range between approximately 0 ML/a and 230 ML/a.
- Total water to goaf, including brine concentrate, groundwater and underground operations losses ranges between approximately 0 ML/a and 530 ML/a.

**Inflows**

- Rainfall and runoff yield contributes between approximately 40 ML/a to 280 ML/a.
- Net groundwater inflows to underground contributes between approximately 0 ML/a and 880 ML/a.
- Required external water supply at a maximum of 40 ML/a to 50 ML/a during the construction period.

Table 5.14 Project Average Annual Water Balance

| | Year 1 | Year 5 | Year 8 | Year 22 |
|---|---|---|---|---|
| **Water Inputs (ML/a)** | | | | |
| Rainfall/Runoff Yield | | | | |
| *Mine Water System* | *0* | *222* | *228* | *225* |
| *Clean Water System* | *43* | *52* | *53* | *53* |
| Total | 43 | 274 | 282 | 278 |
| Groundwater Inflows to Underground | 0 | 292 | 548 | 876 |
| External Water Source | 47 | 13 | 13 | 13 |
| **Gross Water Inputs** | **90** | **580** | **842** | **1,167** |
| **Water Outputs (ML/a)** | | | | |
| Evaporation from Storages | | | | |
| *Mine Water System* | *0* | *76* | *76* | *77* |
| *Clean Water System* | *6* | *18* | *18* | *18* |
| Total | 6 | 93 | 94 | 94 |
| Dam Overflows (offsite) | | | | |
| *Mine Water System* | *0* | *0* | *0* | *0* |
| *Clean Water System* | *19* | *19* | *20* | *19* |
| Total | 19 | 19 | 20 | 19 |
| Treated Water Discharge to Wallarah Creek | 0 | 223 | 204 | 232 |
| Water to Goaf*1 | 0 | 98 | 235 | 532 |
| Buttonderry Site Demands | 25 | 30 | 30 | 30 |
| Toohey's Road Site Demands | 35 | 112 | 260 | 260 |
| **Gross Water Outputs** | **84** | **576** | **843** | **1,167** |
| **Water Balance (ML/a)** | | | | |
| **Change in Storage Volumes** | **6** | **4** | **-1** | **0** |
| **Gross Water Balance (deficit)** | **0** | **0** | **0** | **0** |

Notes: *1 – Includes Underground Operation losses, diverted groundwater inflows and brine solids. Totals may not be precise due to rounding of model outputs.

### 5.11.3 Makeup Water Requirements

Figure 5.9 shows the range of annual volumes of makeup water required from an External Source, based on the maximum, minimum and average for each year of operation from the 95 climate scenarios. Review of the results indicates that the maximum external water requirement is 52 ML/a in Year 1. After Year 4 the makeup water requirement peaks in Year 14 at 49ML/a and reduces to 20ML/a for the 99th percentile confidence trace.

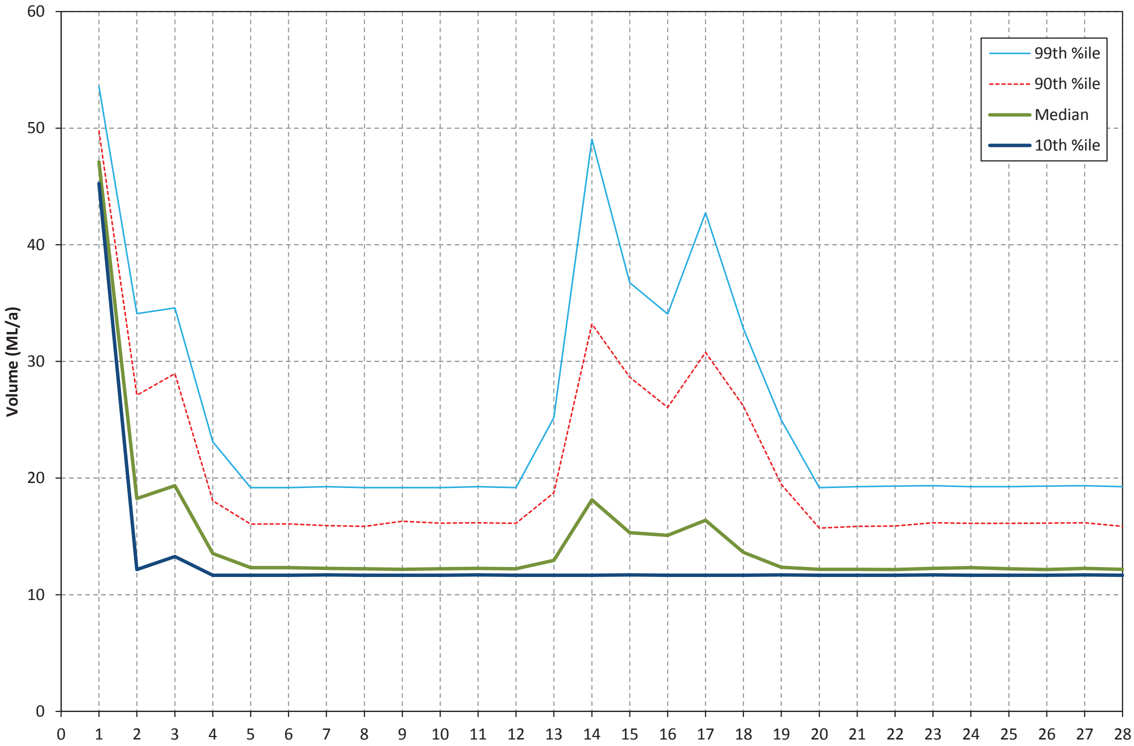


Figure 5.9 Annual Volume of Makeup Water Requirements from External Source

### 5.11.4 Storage Behaviour – MOD

Figure 5.10 shows a summary of the simulated stored volume in the Mine Operations Dam (MOD), based on the distribution of model results from the 95 climate sequences over the mine life. Review of the results indicates the following:

- The MOD is operational at the end of the first year of the Project;
- The median confidence trace shows the MOD volume is between 5 ML and 20 ML for the duration of the Project life;
- Maximum ($99^{th}$ percentile) volumes increase during years 1 to 7, reaching a maximum of approximately 175 ML which is consistent from Year 8 onwards.

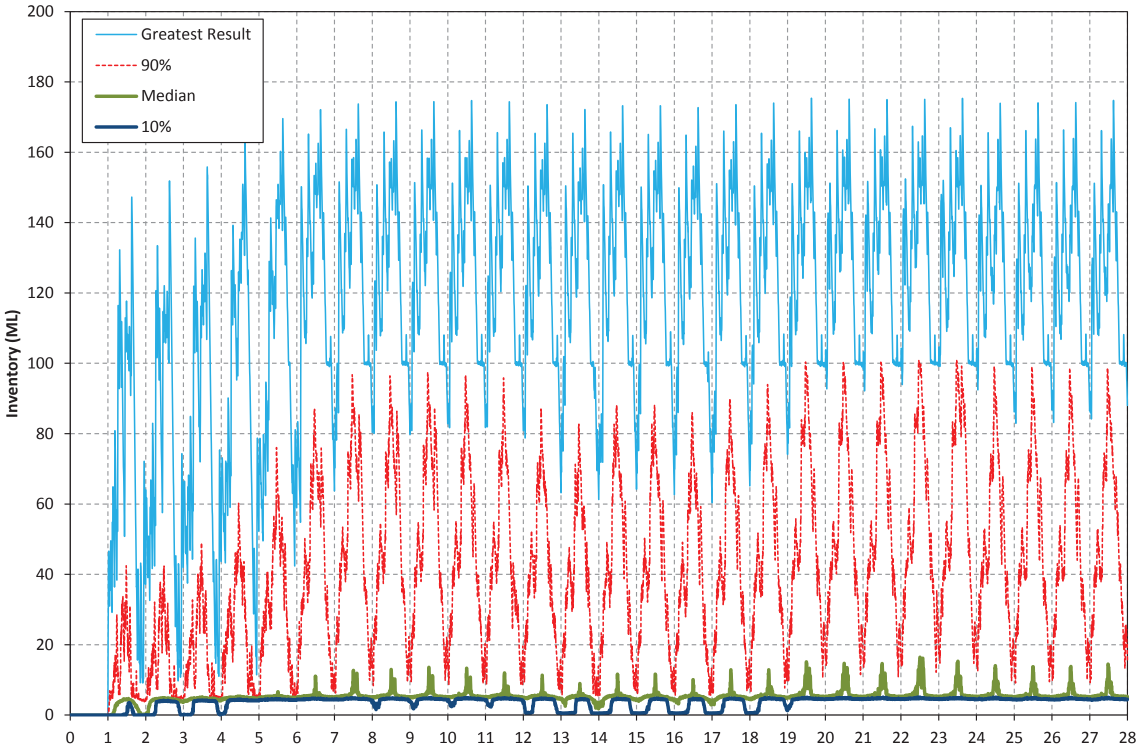


**Figure 5.10 MOD Stored Inventory, Summary of 95 Climate Sequences**

### 5.11.5 Storage Behaviour – Underground Sump

Figure 5.11 shows a summary of the simulated stored volume in the Underground Sump, based on the distribution of model results from the 95 climate sequences over the mine life. Review of the results indicates that the underground sump is maintained close to empty for the 90th percentile results in each year. The 99th percentile results indicate some accumulation of water; and show that the period from Year 19 to 24 is the critical period for mine water storage, however in practice this period would be managed by diverting extra water to the permanent underground voids in any periods when the sumps approached full capacity. This is consistent with the increased net groundwater inflows, as shown in Figure 5.7.

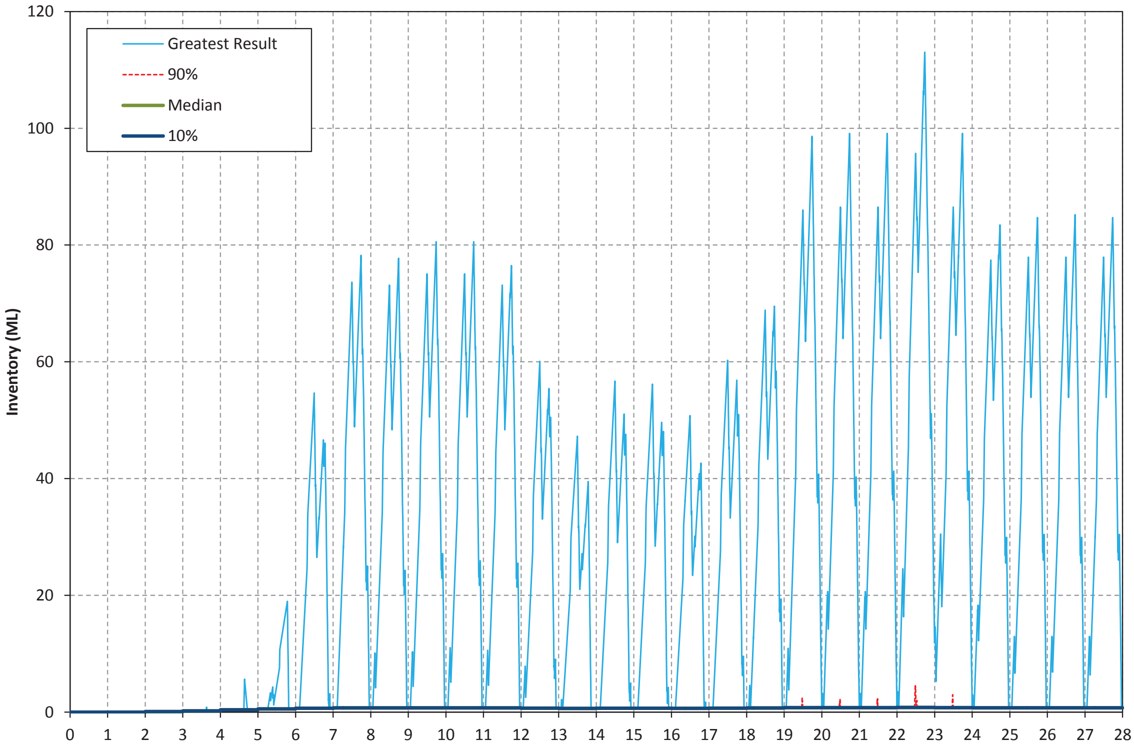


**Figure 5.11 Underground Sump Stored Inventory, Summary of 95 Climate Sequences**

### 5.11.6 WTP Net Inflows, Treated Water Outflows and Utilisation

Figure 5.12 shows a summary of the net WTP inflows (i.e. not including backwash recycle volumes), based on the distribution of model results from the 95 climate sequences over the mine life. A summary of total treated water outflows from the WTP on an annual basis are shown in Figure 5.13 and the WTP utilization (as days per year) is shown in Figure 5.14. Review of the results indicates the following:

- Net WTP inflows increase steadily in the first 8 years of mine life, and remain fairly consistent thereafter. From Year 8 to 28, in any given year:
  - The 10th percentile WTP net inflows are approximately 500 to 600 ML/a;
  - The median WTP net inflows are approximately 700 ML/a; and
  - The 99th percentile WTP net inflows are approximately 950 ML/a.
- Similarly, the WTP treated water outflows increase steadily in the first 8 years of mine life, and remain fairly consistent thereafter. From Year 8 to 28, in any given year:
  - The 10th percentile WTP treated water outflows are approximately 500 to 600 ML/a;
  - The median WTP treated water outflows are approximately 600 to 700 ML/a; and
  - The 99th percentile WTP treated water outflows are approximately 900 ML/a.
- During Years 8 to 28, the WTP utilisation ranges between approximately 220 days per year (10th percentile) to 365 days per year (99th percentile).

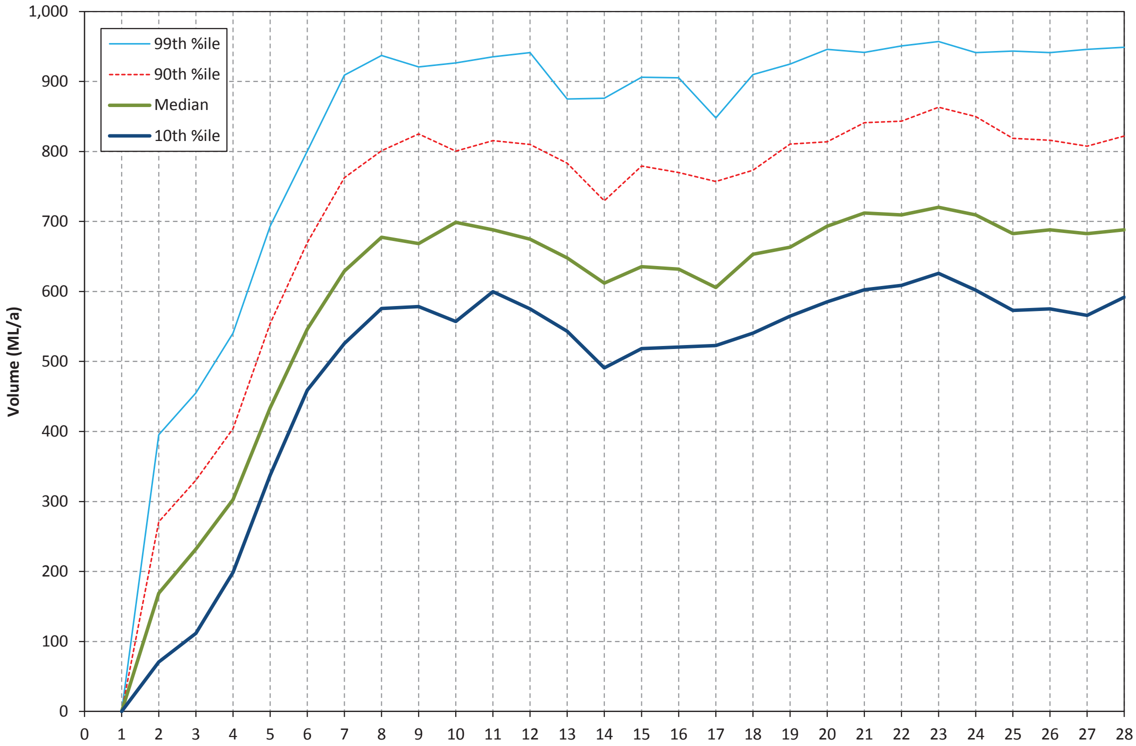


Figure 5.12 WTP Net Inflows, Summary of 95 Climate Sequences

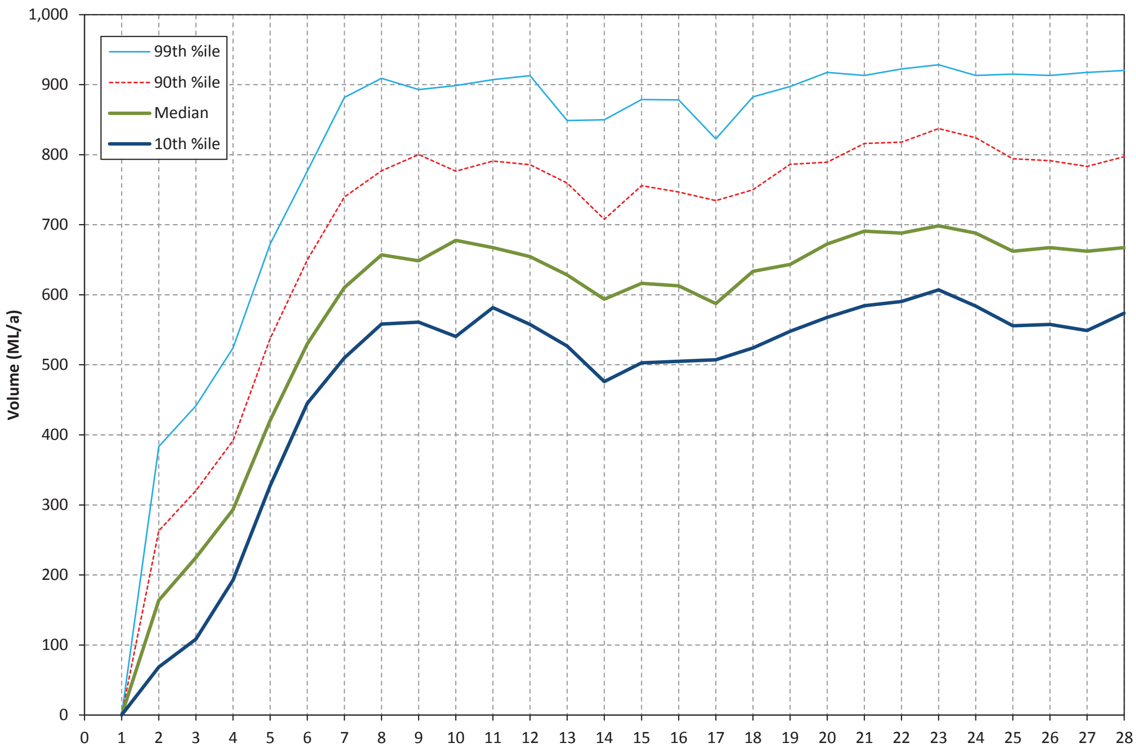


Figure 5.13 WTP Treated Water Outflows, Summary of 95 Climate Sequences

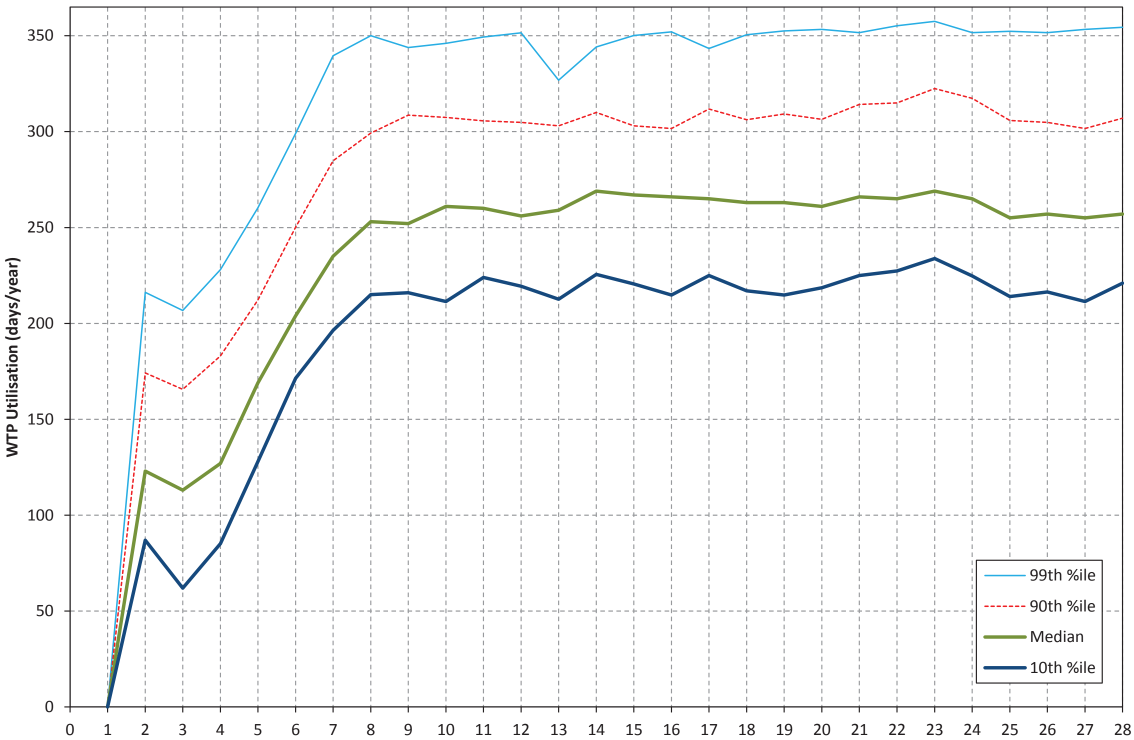


Figure 5.14 WTP Utilisation, Summary of 95 Climate Sequences

### 5.11.7 Controlled Discharges

Figure 5.15 shows the annual volumes of treated water from the WTP which are discharged to Wallarah Creek, based on the distribution of model results from the 95 climate sequences over the mine life. Review of the results indicates the following:

- On average, treated water discharges to Wallarah Creek occur for the life of the Project; and
- Discharges increase up to Year 7, and remain fairly consistent thereafter, ranging from 50 to 500 ML/a.

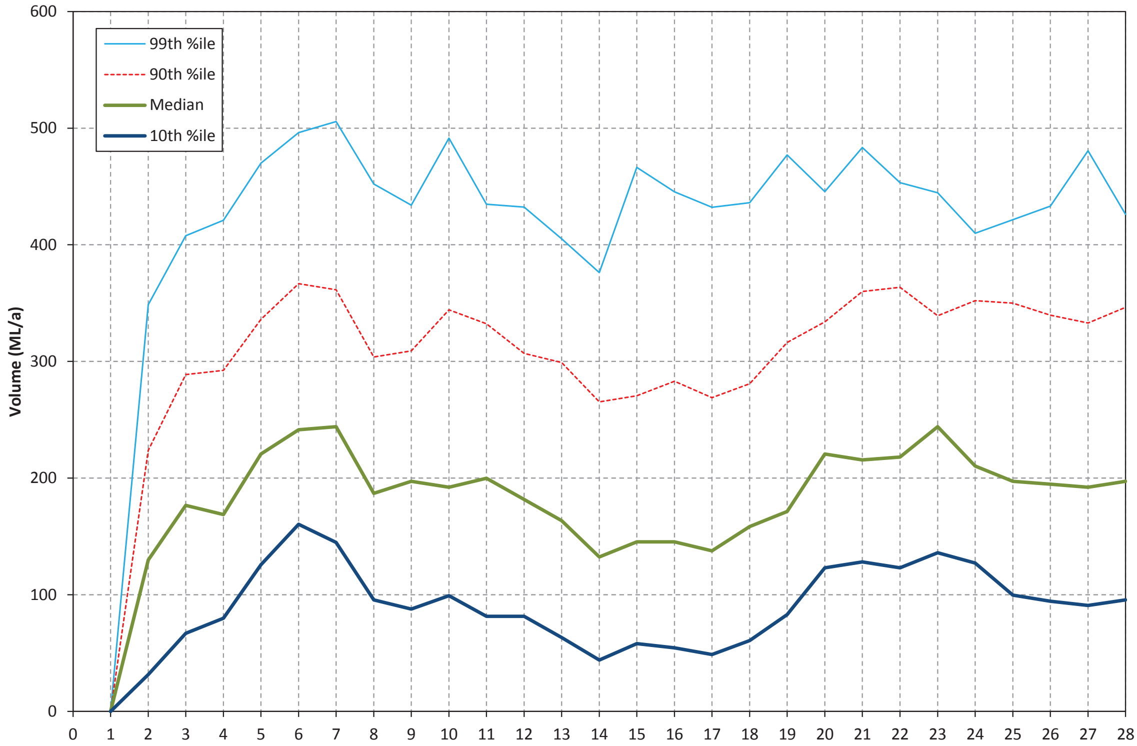


**Figure 5.15 WTP Treated Water Discharges to Wallarah Creek, Summary of 95 Climate Sequences**

### 5.11.8 Uncontrolled Overflows

The water balance model results show that there are no simulated uncontrolled discharges from the mine water system for the 99th percentile confidence trace in any year of the Project life.

Figure 5.16 shows the annual volumes of overflows from the Buttonderry Entrance Dam, which collects runoff from roofs and carparks at the Buttonderry Site. Based on the distribution of model results from the 95 climate sequences over the mine life:

- Uncontrolled discharges from the Buttonderry Entrance Dam are similar from year to year throughout the Project life;
- The median uncontrolled discharge is approximately 15 ML/a;
- The 90th percentile uncontrolled discharge is approximately 40 ML/a; and
- The 99th percentile uncontrolled discharge is approximately 67 ML/a.

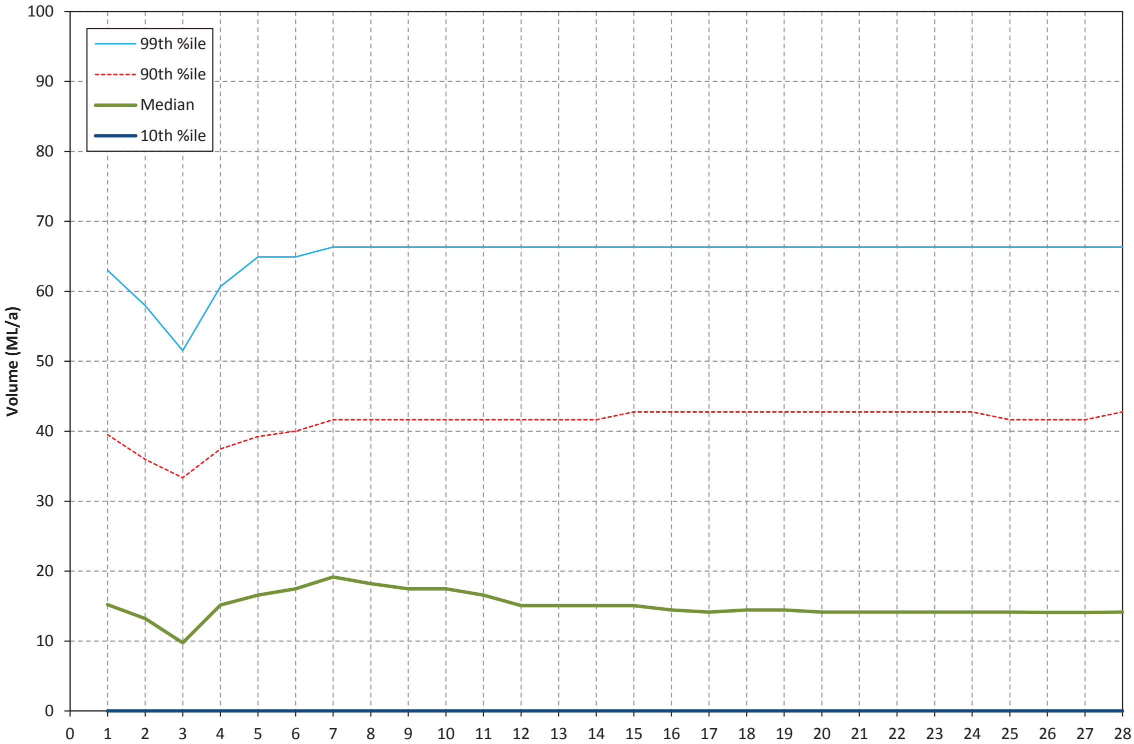


Figure 5.16 Buttonderry Entrance Dam Overflows, Summary of 95 Climate Sequences

### 5.11.9 Concentrated Brine Disposal Requirements

Figure 5.17 and Table 5.15 show the annual volumes of concentrated brine which would require disposal, including the 99th percentile, 90th percentile and median for each year of operation from the 95 climate scenarios. Review of the results indicates the following:

- In the case of only an initial brine treatment process step after the reverse osmosis water treatment plant, the annual brine concentrate disposal requirement would gradually rise by Year 8 to approximately 25 ML/a (99th percentile confidence trace) and remain fairly consistent thereafter.
- Under an adaptive management scenario involving a full brine treatment process (RO/concentrator/crystalliser/dryer) after the RO water treatment plant up to Year 14, a much smaller volume of treatment plant by-product of less than 5,270 $m^3$/a of salt would be required to be disposed of underground [under median conditions].

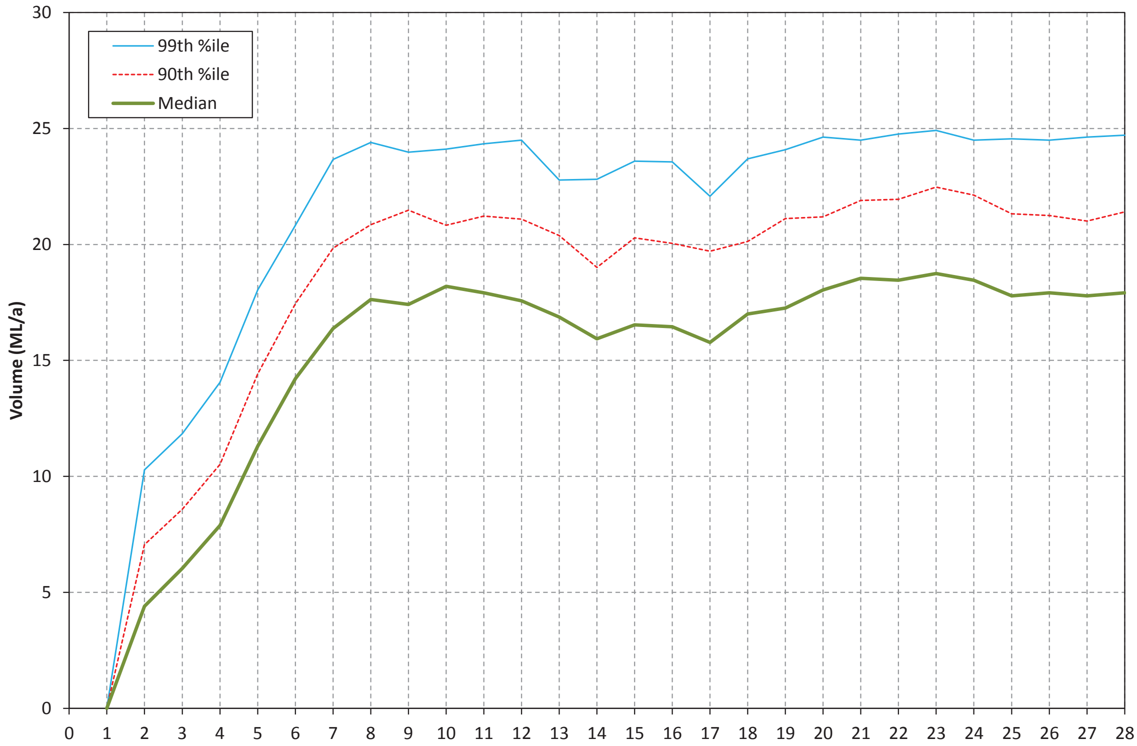


Figure 5.17 Annual Concentrated Brine Disposal Requirements[1], Summary of 95 Climate Sequences

[1] In the case of only a brine concentrator step rather than full brine treatment plant installed after the RO water treatment plant

Table 5.15 Concentrated Brine Disposal Requirements, Summary of 95 Climate Sequences (ML/a)

| Year | Median | 90%ile | 99%ile |
|---|---|---|---|
| 1 | 0.0 | 0.0 | 0.0 |
| 2 | 4.4 | 7.1 | 10.3 |
| 3 | 6.0 | 8.6 | 11.8 |
| 4 | 7.9 | 10.5 | 14.1 |
| 5 | 11.3 | 14.4 | 18.0 |
| 6 | 14.2 | 17.4 | 20.8 |
| 7 | 16.4 | 19.8 | 23.7 |
| 8 | 17.6 | 20.9 | 24.4 |
| 9 | 17.4 | 21.5 | 24.0 |
| 10 | 18.2 | 20.8 | 24.1 |
| 11 | 17.9 | 21.2 | 24.3 |
| 12 | 17.6 | 21.1 | 24.5 |
| 13 | 16.9 | 20.4 | 22.8 |
| 14 | 15.9 | 19.0 | 22.8 |
| 15 | 16.5 | 20.3 | 23.6 |
| 16 | 16.5 | 20.0 | 23.6 |
| 17 | 15.8 | 19.7 | 22.1 |
| 18 | 17.0 | 20.1 | 23.7 |
| 19 | 17.3 | 21.1 | 24.1 |
| 20 | 18.0 | 21.2 | 24.6 |
| 21 | 18.5 | 21.9 | 24.5 |
| 22 | 18.5 | 21.9 | 24.8 |
| 23 | 18.7 | 22.5 | 24.9 |
| 24 | 18.5 | 22.1 | 24.5 |
| 25 | 17.8 | 21.3 | 24.6 |
| 26 | 17.9 | 21.2 | 24.5 |
| 27 | 17.8 | 21.0 | 24.6 |
| 28 | 17.9 | 21.4 | 24.7 |
| **Total** | **428.4** | **518.6** | **604.3** |

### 5.11.10 Wallarah Creek Flow Characteristics

Figure 5.18 shows the flow duration relationship for Wallarah Creek at the downstream Project Boundary for the pre-mining and during mining case. The results are presented for the 28 year realisation with the average cumulative rainfall. Figure 5.19 and Figure 5.20 show the Wallarah Creek flow duration relationship for the $10^{th}$ percentile and $90^{th}$ percentile cumulative rainfall which represent dry and wet 28 year realisations respectively. Review of the results indicates the following:

- Results for the average, wet and dry climate scenarios show similar outcomes. There are negligible impacts on the frequency of flows greater than 10 ML/d in Wallarah Creek; and
- The frequencies of low flows up to 10 ML/d are increased. For example, for the pre-mining case, a flow of 1 ML/d occurred approximately 17 % of the time, whereas during mining it occurs approximately 30 % of the time.

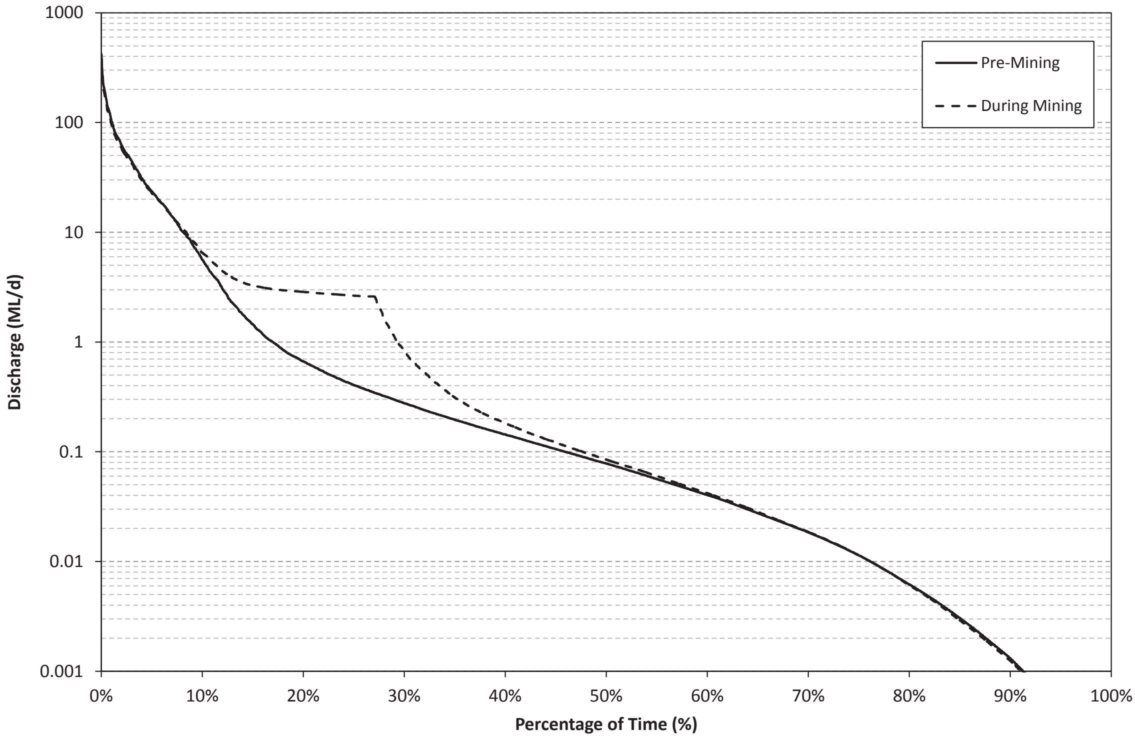


Figure 5.18 Wallarah Creek Flow Duration Relationship, 'Average' Climate Realisation

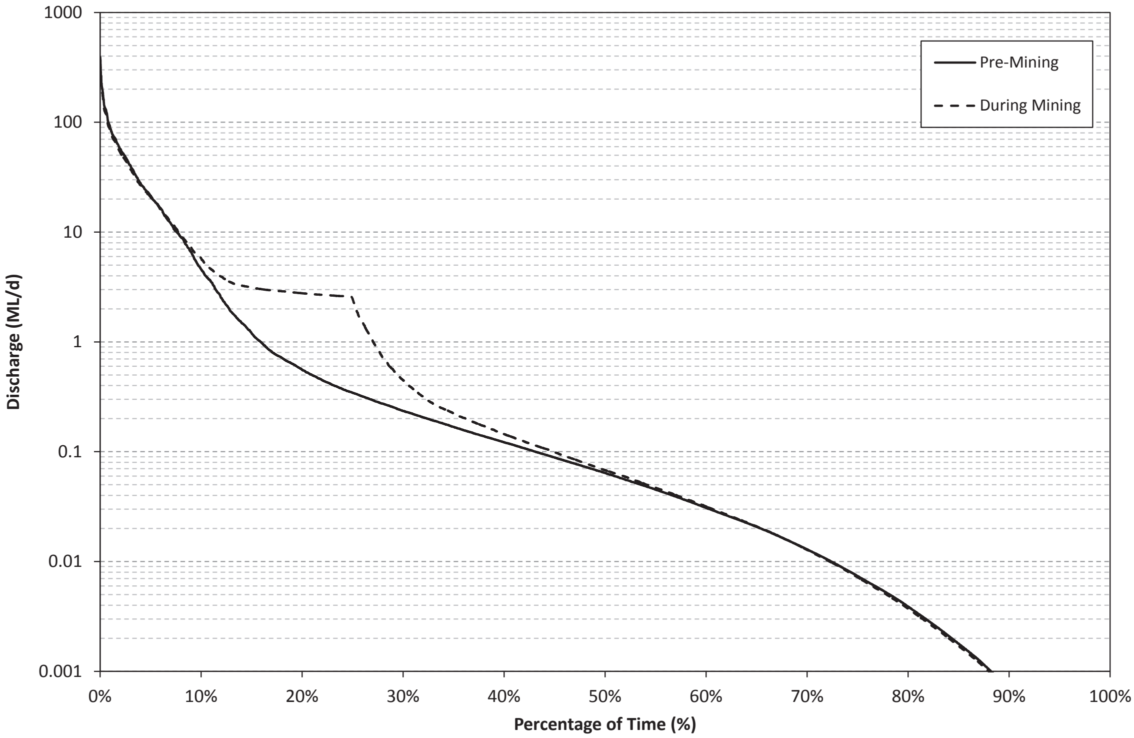


Figure 5.19 Wallarah Creek Flow Duration Relationship, 'Dry' Climate Realisation

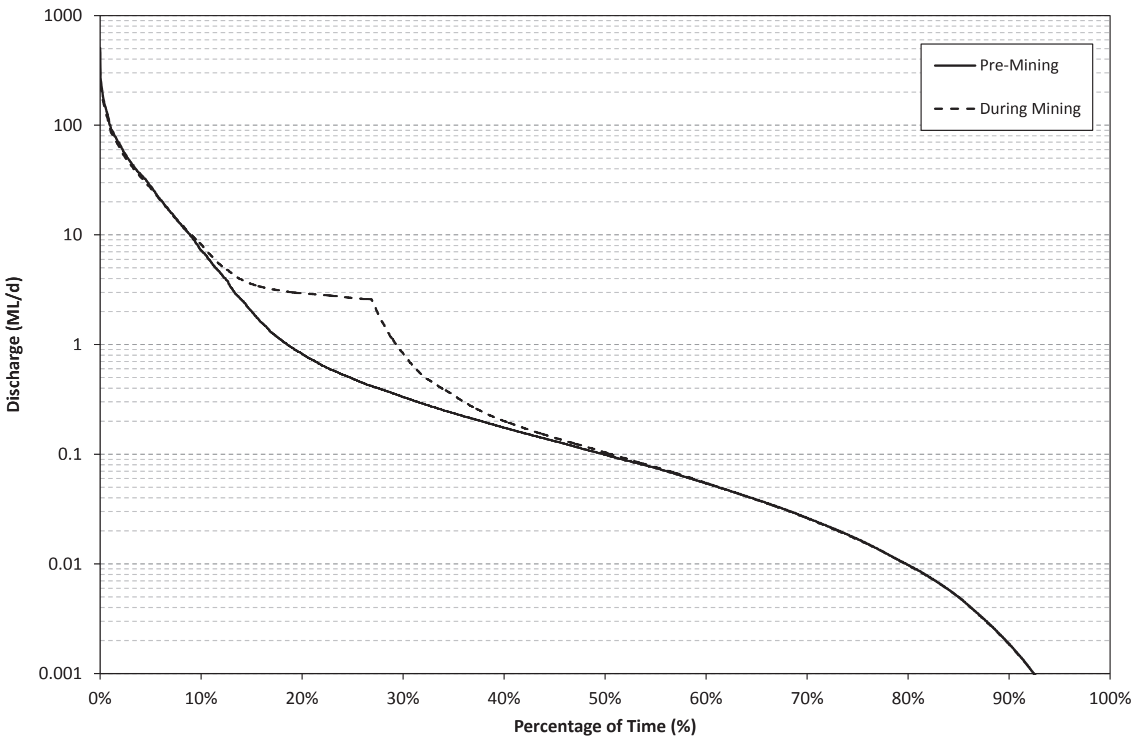


Figure 5.20 Wallarah Creek Flow Duration Relationship, 'Wet' Climate Realisation

### 5.11.11 Stored Water Quality

Figure 5.21 shows the median stored water salinity for the mine water management system. Review of the results indicates the following the following median water qualities:

- MOD: 4,500 –8,000 mg/L
- Stockpile Dam: 3,000 mg/L – 7,000 mg/L
- Portal Dam: 1,000 mg/L - 6,000 mg/L

The spike in MOD water quality in the early years of the Project is a model artefact caused by a very small volume of water in the storage.

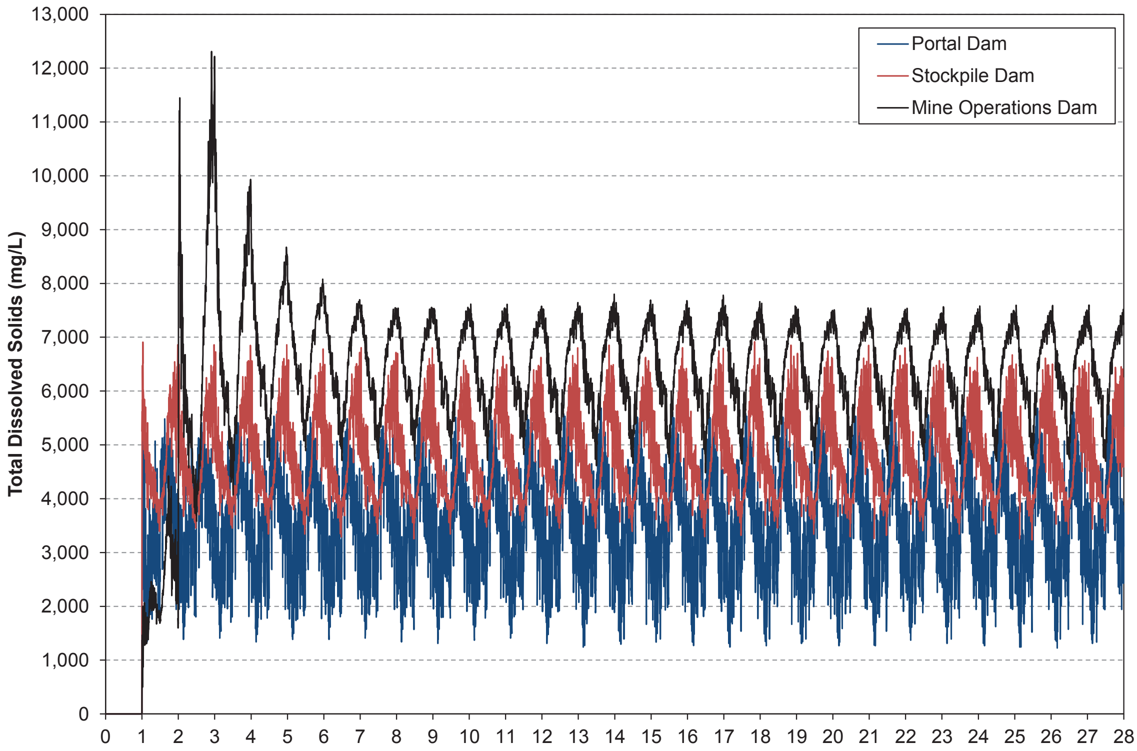


**Figure 5.21 Median Stored Water Quality, Mine Water System**

## 5.12 MINE WATER BALANCE SUMMARY

Results of the mine water balance are summarised as follows:

- The maximum external water requirement is 52 ML/a in Year 1.
- Treated water discharges to Wallarah Creek occur for the life of the Project and increase up to Year 7, remaining fairly consistent thereafter, ranging from 50 to 500 ML/a.
- There are no simulated uncontrolled discharges from the Mine Water system for the 99$^{th}$ percentile confidence trace in any year of Project life.
- Uncontrolled overflows from the clean water system are generally similar from year to year throughout the Project life. The median, 90$^{th}$ percentile and 99$^{th}$ percentile discharge volumes are approximately 15, 40 and 67 ML/a respectively.
- In the case of only an initial brine treatment process step after the reverse osmosis water treatment plant, the annual brine concentrate disposal requirement would gradually rise

by Year 8 to approximately 25 ML/a (99th percentile confidence trace) and remain fairly consistent thereafter.

- Under an adaptive management scenario involving a full brine treatment process (concentrator/crystalliser/dryer) after the RO water treatment plant up to Year 14, a much smaller volume of treatment plant by-product of less than 5, 270 $m^3$/a of salt would be required to be disposed of underground [under median conditions]
- Flow characteristics in Wallarah Creek are impacted for flows less than 10 ML/d. Flows of 1 ML/d are increased in frequency from approximately 17% to 30% for an average climate realisation.
- Median salinities in the Mine Water System range from 1,000 to 8,000 mg/L.

# 6 MITIGATION AND MANAGEMENT MEASURES

## 6.1 OVERVIEW

The impacts of the Project on surface water resources will be mitigated through the implementation of the following measures:

- A mine site water management system to control the flow and storage of water of different qualities across the site;
- A sediment control plan to reduce sediment loads from disturbed area runoff;
- A surface water monitoring program post-approval to continually assess environmental impacts and ensure that the site water management system is meeting its objectives of minimal impact on receiving waters; and
- Property Flood Management Plans to document proposed mitigation measures for dwellings with adverse flood impacts due to subsidence.

An overview of each of these management measures are provided in the following sections.

## 6.2 MINE WATER MANAGEMENT SYSTEM

A key objective of the mine water management system will be to minimise the risk of uncontrolled discharges from mine site storages. To achieve this objective, operation of the mine water management system will be based on the following principles:

- Diversion of clean surface water runoff away from areas disturbed by mining activities;
- Operation of the mine water management system to ensure no uncontrolled releases of mine water from the site;
- Collection of potentially sediment-affected runoff in sediment dams for treatment prior to discharge from site or reuse in the mine water management system;
- Maximising the availability of permanent underground storage capacity;
- Transfer of mine water (groundwater inflows) to the MOD for reuse as a water supply;Collection of contaminated water from industrial areas for treatment in an oil and grease separator prior to recycling in the mine water management system; Minimisation of fresh water usage by recycling water from the mine water system before taking additional water from the mine's external supply source; and
- Provision for treated water discharge to Wallarah Creek and connection of the Project sites to town water and reticulated sewer systems. This will allow the potential for variable quantities of discharge to sewer as trade waste in accordance with the requirements and approval of external authorities.

Key components of proposed water management infrastructure for the Buttonderry Site and Tooheys Road Site are shown in Figure 2.2 and Figure 2.3 respectively. Details of the operation of the mine water management system are provided in Section 5.9.

## 6.3 SEDIMENT AND EROSION CONTROL PLAN

The design of sediment control measures for the Project will be based on the principle of ensuring that runoff from disturbed areas is separated from clean area runoff and collected in sediment dams for treatment. Design of proposed erosion and sediment control measures will be based on the recommended design standards in the following guidelines:

- Managing Urban Stormwater, Soils and Construction, (Landcom, 2004); and
- Managing Urban Stormwater, Soils and Construction, Volume 2E Mine and Quarries (DECC, 2008).

Sediment dam sizes and locations will be determined as part of detailed design and follow the principles above. In addition to the water management infrastructure discussed in Section 3, a number of small sediment traps will be required to treat runoff from the rail loop.

The treated water discharge point to the tributary of Wallarah Creek will also be designed with adequate dissipation of concentrated flows to ensure that bed and bank erosion does not occur at the discharge location or downstream along the Wallarah Creek tributary.

## 6.4 SURFACE WATER MONITORING PROGRAM

### 6.4.1 Overview

The surface water monitoring program for the Project will consist of two main components:

- A surface water quality monitoring program, and
- A stream stability monitoring and management program.

Further information on these monitoring programs is provided below.

### 6.4.2 Water Quality Monitoring

Monitoring of surface water quality both within and external to the Project boundary will form a key component of the surface water management system. Monitoring of upstream, onsite and downstream water quality will assist in demonstrating that the site water management system is effective in meeting its objective of no adverse impact on receiving water quality and will allow for early detection of any impacts and appropriate corrective action.

Table 6.1 shows the proposed water quality monitoring program for water storages onsite. All samples should be collected in a manner consistent with the *Approved Method for Sampling and Analysis of Water Pollutants in NSW* (DEC, 2004).

The surface water monitoring program will also include onsite monitoring of key climate parameters including wind speed and direction, as well as pluviometer measurement of rainfall.

**Table 6.1 Site Surface Water Monitoring Program**

| Storage | Water Level | Water Quality | | |
|---|---|---|---|---|
| | | pH, EC and TSS | | Comprehensive Analysis |
| | | Quarterly | Monthly | Annually |
| Tooheys Road Site | | | | |
| MOD | Daily | | ✓ [a] | ✓ |
| Portal Dam | Weekly [a] | | ✓ [a] | ✓ |
| Stockpile Dam | Weekly [a] | | ✓ [a] | ✓ |
| Treated Water Storage | Weekly [a] | | ✓ [a] | ✓ |
| Underground Sump | Weekly [a] | | ✓ [a] | ✓ |
| Buttonderry Site | | | | |
| Entrance Dam | Weekly | ✓ | | ✓ |
| Sediment Dam | - | ✓ | | ✓ |

[a] Additional observation to be taken when onsite daily rainfall exceeds 25 mm

Based on the baseline monitoring undertaken in Wallarah Creek during 2006 to 2012 (Table 2.11), environmental protection limits are proposed as 'end-of-pipe' limits for discharge water, shown in Table 6.2.

**Table 6.2 Proposed Discharge Environmental Protection Limits**

| Water Quality Parameter | Unit | Proposed Limit |
|---|---|---|
| Electrical conductivity | µS/cm | 400 (upper) |
| pH | ph units | 6.0 (lower)<br>7.5 (upper) |
| Total suspended solids | mg/L | 40 |

Figure 6.1 shows proposed stream monitoring locations, which are based on the baseline water quality monitoring locations. Details of the proposed monitoring locations, including sample collection frequency and key water quality parameters to be monitored, are shown in Table 6.3. The following monitoring locations have been added to the existing program:

- BD1 – Buttonderry Creek at Sydney Newcastle Freeway. Downstream of all Buttonderry Site disturbance.
- WTP – Release point from the WTP to Wallarah Creek.

Table 6.3 Receiving Waters Surface Water Monitoring Program: Post Approval

| Monitoring Point | Watercourse | Water Quality | | | Comment |
|---|---|---|---|---|---|
| | | pH, EC and TSS | | Comprehensive Analysis | |
| | | Weekly [a] | Monthly | | |
| WTP | Wallarah Creek Tributary | ✓ | | Monthly for first 12 months, then annual | Release point from WTP |
| W12 | Wallarah Creek | | ✓ | Monthly for first 12 months, then annual | Upstream of site disturbance |
| W6 | Wallarah Creek | | ✓ | Monthly for first 12 months, then annual | Downstream of site disturbance |
| Wetland | Spring Creek Tributary | | ✓ | Annual | Wetland adjacent to site |
| W27 | Spring Creek Tributary | | ✓ | Annual | Downstream of site disturbance |
| W7 | Spring Creek | | ✓ | Annual | Downstream of site disturbance |
| W15 | Buttonderry Creek | | ✓ | Annual | Upstream of site disturbance |
| BD1 | Buttonderry Creek | | ✓ | Annual | Downstream of site disturbance |
| W22 | Wyong River | | ✓ | Annual | Adjacent to underground mine |
| W23 | Wyong River | | ✓ | Annual | Upstream of mine |
| W19 | Jilliby Jilliby Creek | | ✓ | Annual | Upstream of underground mine |
| W20 | Jilliby Jilliby Creek | | ✓ | Annual | Downstream of underground mine |
| W21 | Jilliby Jilliby Creek | | ✓ | Annual | Above underground mine |
| W24 | Jilliby Jilliby Creek | | ✓ | Annual | Above underground mine |
| W25 | Jilliby Jilliby Creek | | ✓ | Annual | Above underground mine |
| W26 | Hue Hue Creek | | ✓ | Annual | Above underground mine |

[a] Sample prior, during and following releases to Wallarah Creek

wrm water+environment

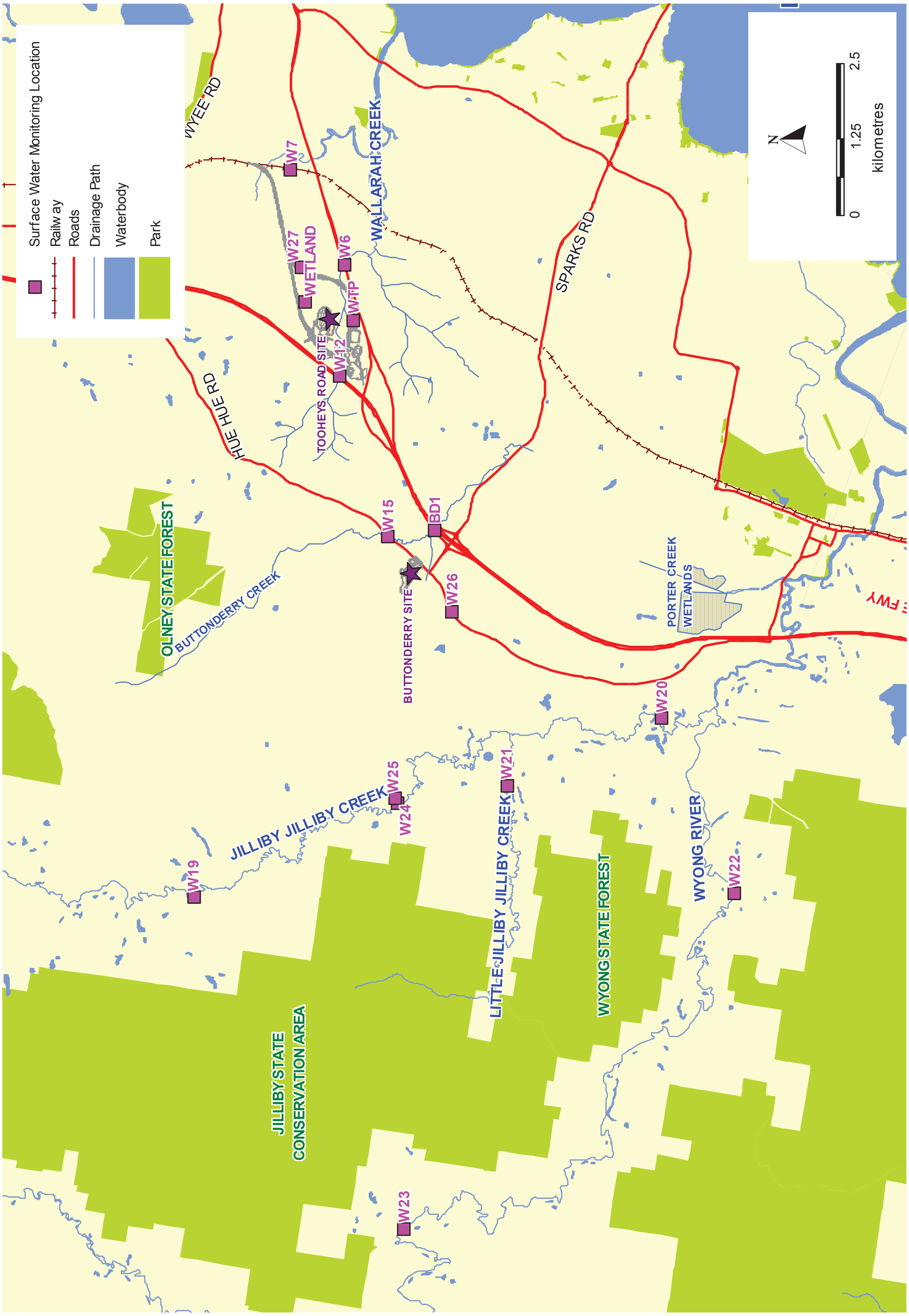


Figure 6.1 Surface Water Monitoring Locations



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### 6.4.3 Stream Stability Monitoring and Management Program

A stream stability monitoring and management program will be undertaken in conjunction with the subsidence management and monitoring process. The program will include:

- A baseline ground survey of nominated creek cross-sections in areas of expected subsidence prior to undermining as part of the Subsidence Management Plan process;
- Development of specific measurable trigger levels (in consultation with NOW and local landholders) to enable subsidence monitoring to identify and possible unforseen impacts to the stream system;
- Ongoing monitoring of the stream system prior to, during and after mining beneath the sections of the creek;
- A walkover assessment of key areas, particularly around the confluence of Jilliby Jilliby Creek and Little Jilliby Jilliby Creek, identifying areas of water ponding, active bed and/or bank erosion and qualitative assessment of the condition of riparian and floodplain vegetation;
- Collection of photographs of creek channel and floodplain conditions;
- Preparation of a report documenting the results of each assessment with recommendations for any mitigation works that may be required. This report will specifically require a Trigger Action Response Plan (TARP) to be prepared to set aside a process for management of any unforseen impacts to the system.

Initially, a quarterly timeframe is considered appropriate for each field assessment supplemented with an additional inspection after any significant flow event. The area of investigation will be modified as mining progresses to target areas of active subsidence. Once subsidence has stabilised, the frequency of assessments of the stabilised area may be reduced to annual or after major flood events and eventually discontinued when a stable final landform has been confirmed.

Although subsidence effects and impacts have been assessed on a worst case basis to provide a high level of conservatism, given the dynamic nature of fluvial systems it is appropriate that an adaptive management approach is proposed for the management of stream stability, in consultation with NOW, other relevant authorities and riparian landowners. The proposed monitoring program will enable impacts to be identified and managed on a case-by-case basis. However, these works would be carefully planned to ensure that they are targeted towards actual subsidence impacts, rather than naturally occurring variability in the stream.

A key element of the proposed remediation approach will be the use of “soft” engineering techniques that will aim to minimise soil and vegetation disturbance by using low impact construction methods and natural materials. Given the dominant role of vegetation in maintaining bank stability in the alluvial reaches, it is possible that bank and vegetation disturbance associated with poorly planned remedial works could represent a higher risk to stream stability than subsidence. Where bed controls are considered necessary, the preferred approach will be to try and replicate natural channel features using, for example, large woody debris which already plays a significant role in bed control (see Figure 6.2).

It will be over 15 years into the proposed mine project operations before upland stream sections in the western forested hills would potentially be affected by subsidence. Prior to mining in these areas, detailed reviews of all potential impacts will be required as part of the statutory Subsidence Management Plan / Extraction Plan process. These will be based on site-specific subsidence data, verified models and environmental monitoring data that will have been accumulated during mining and all significant risks and impacts addressed by appropriate mitigation or control.

Figure 6.2 Example of Bed Control by Large Woody Debris for Pre-Mining Conditions

## 6.5 PROPERTY FLOOD MANAGEMENT PLANS

Prior to undermining of an area, a detailed site-specific flood assessment will be undertaken to estimate flood impacts and identify any adverse impacts on existing dwellings. Property Flood Management Plans will be developed which will identify measures to ensure that any adverse flood impacts are adequately managed. Options available to mitigate against flood impacts on dwellings would include construction of individual flood levees, raising houses in-situ and relocating or reconstructing houses on higher ground within the affected properties. Further details are provided in the flood impact assessment report (G Herman & Associates, 2013).

## 6.6 RESIDUAL IMPACTS

Whilst the proposed mitigation measures will limit the surface water impacts of the Project, some residual impacts will occur. These residual impacts will include:

- Small reductions in the catchment area draining to Wallarah Creek (9%) and Buttonderry Creek (1%).
- A small increase, of the order of 3% in total flow volumes in Wallarah Creek.
- Increased frequency of flows to Wallarah Creek less than 10 ML/d.

- Potential changes to the longitudinal and lateral profiles of Jilliby Jilliby Creek caused by subsidence. The impacts of subsidence would be monitored and managed to maintain stability of the creek channel.
- It is possible that undermining of Jilliby Jilliby Creek may generate some additional groundwater storage which would be sourced from regional rainfall recharge, as well as surface runoff. The diverted water volume would represent less than 1% of the total licensed extraction volume for the area. In practical terms, due to the highly variable nature of surface water flows, it is unlikely that an impact of this magnitude could be detected. Hence, the Project is unlikely to have a measureable impact on the Gosford-Wyong Water Supply Scheme or entitlements under WSPs.
- Virtually no changes will occur to flood extents and depths in the Yarramalong Valley as a result of mine subsidence. Negligible subsidence (less than 0.15 m) is predicted under short stretches of the main channel of the Wyong River and minor subsidence is predicted in three small backwater areas.

# 7 SUMMARY OF FINDINGS

The findings of the assessment of surface water impacts for the proposed Wallarah 2 Coal Project may be summarised as follows:

- With the exception of the first 3-4 years of the Project, there is a net water make from mining operations.
- The maximum makeup water requirement for the Project from the town water supply system will be of the order of 52 ML/a during the initial construction phase of the Project.
- The proposed water management system will ensure the separation of clean and mine water on the site and no uncontrolled discharges from the Mine Water System.
- Treated water discharges to Wallarah Creek occur for the life of the Project and are generally consistent from Year 10 to 28, ranging from approximately 50 to 500 ML/a.
- Concentrated brine disposal volumes are generally consistent ranging from 18 to 25 ML/a. For scenarios involving further brine treatment steps then the volume of waste material (such as near-solid salt) to be disposed of underground would be substantially less.
- Flow characteristics in Wallarah Creek are impacted for flows less than 10 ML/d. Flows of 1 ML/d are increased in frequency from approximately 17% to 30% for an average climate realisation.
- Subsidence of Jilliby Jilliby Creek and Little Jilliby Jilliby Creek will be monitored to quantify changes in surface levels and an adaptive management strategy put in place to manage impacts on surface water flows and stream stability.
- It is possible that undermining of Jilliby Jilliby Creek may generate some additional groundwater storage which would be sourced from regional rainfall recharge, as well as surface runoff. The diverted water volume would represent less than 1 % of the total licensed extraction volume for the area. In practical terms, due to the highly variable nature of surface water flows, it is unlikely that an impact of this magnitude could be detected. Hence, the Project is unlikely to have a measureable impact on the Gosford-Wyong Water Supply Scheme.
- Detailed design of infrastructure will be undertaken to ensure that the Project does not significantly affect flood behaviour along Wallarah Creek for flood events up to the 100 years Average Recurrence Interval event.
- The results of the Flood Impact Assessment indicate virtually no change to flood extents and depths in the Yarramalong Valley. Six dwellings in the Dooralong Valley will experience major adverse flood impacts and a further eleven dwellings will experience moderate adverse impacts. These impacts will be managed on a site-specific basis through the development of Property Flood Management Plans. Forty-eight of the 103 dwellings in the Yarramalong/Dooralong and Hue Hue study areas that are within or near to the 1% AEP flood extent will be beneficially impacted.

# 8 REFERENCES


| | |
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# APPENDIX A

NEW SOUTH WALES OFFICE OF WATER (NOW)
SURFACE WATER QUALITY MONITORING RESULTS

Table A 1 – NSW Office of Water (NOW) Surface Water Quality Monitoring Summary

| Water Quality Parameter | | Sampling Site | |
|---|---|---|---|
| | | Wyong Creek | Jilliby Jilliby Creek |
| | | #211009 | #211010 |
| **pH** | 10%ile | 6.5 | 6.3 |
| | Median | 6.8 | 6.7 |
| | 90%ile | 7.2 | 7.2 |
| | N | 204 | 56 |
| **Electrical Conductivity (µS/cm)** | 10%ile | 171 | 237 |
| | Median | 236 | 440 |
| | 90%ile | 282 | 549 |
| | N | 346 | 73 |
| **Turbidity (NTU)** | 10%ile | 3 | 4 |
| | Median | 8 | 10 |
| | 90%ile | 15 | 35 |
| | N | 297 | 56 |
| **Calcium (mg/L)** | 10%ile | 2.3 | 3.4 |
| | Median | 3.2 | 4.5 |
| | 90%ile | 4.3 | 6.6 |
| | N | 69 | 3 |
| **Sodium (mg/L)** | 10%ile | 23.7 | 6.5 |
| | Median | 31.0 | 7.3 |
| | 90%ile | 35.9 | 10.2 |
| | N | 69 | 3 |
| **Magnesium (mg/L)** | 10%ile | 4.7 | 6.6 |
| | Median | 6.2 | 10.2 |
| | 90%ile | 8.3 | 13 |
| | N | 69 | 3 |
| **Potassium (mg/L)** | 10%ile | 1.8 | 2.5 |
| | Median | 2.4 | 3.0 |
| | 90%ile | 3.5 | 4.0 |
| | N | 69 | 3 |
| **Sulphate (mg/L)** | 10%ile | 3.4 | 6.5 |
| | Median | 5.3 | 7.3 |
| | 90%ile | 7.4 | 10.2 |
| | N | 70 | 3 |
| **Chloride (mg/L)** | 10%ile | 44.4 | 61.7 |
| | Median | 59.3 | 103.5 |
| | 90%ile | 70.1 | 104.1 |
| | N | 70 | 3 |
| **Cadmium (mg/L)** | 10%ile | 0 | - |
| | Median | 0 | - |
| | 90%ile | 0.032 | - |
| | N | 10 | - |
| **Chromium (mg/L)** | 10%ile | 0 | - |
| | Median | 0 | - |
| | 90%ile | 0.04 | - |
| | N | 12 | - |
| **Copper (mg/L)** | 10%ile | 0 | - |
| | Median | 0.0020 | - |
| | 90%ile | 0.0088 | - |

| Water Quality Parameter | | Sampling Site | |
|---|---|---|---|
| | | Wyong Creek | Jilliby Jilliby Creek |
| | | #211009 | #211010 |
| | N | 12 | - |
| Lead (mg/L) | 10%ile | 0 | - |
| | Median | 0.0045 | - |
| | 90%ile | 0.0083 | - |
| | N | 10 | - |
| Manganese (mg/L) | 10%ile | 0.066 | - |
| | Median | 0.135 | - |
| | 90%ile | 0.174 | - |
| | N | 12 | - |
| Zinc (mg/L) | 10%ile | 0 | - |
| | Median | 0 | - |
| | 90%ile | 0.2 | - |
| | N | 33 | - |
| Total Iron (mg/L) | 10%ile | 0.2 | - |
| | Median | 0.8 | - |
| | 90%ile | 2.4 | - |
| | N | 63 | - |
| Mercury (mg/L) | 10%ile | 0.0 | - |
| | Median | 0 | - |
| | 90%ile | 0.0 | - |
| | N | 4 | - |
| Ammonia (mg/L) | 10%ile | 0 | - |
| | Median | 0.01 | - |
| | 90%ile | 0.08 | - |
| | N | 14 | - |
| Nitrate and Nitrite (mg/L) | 10%ile | 0.07 | 0.122 |
| | Median | 0.15 | 0.170 |
| | 90%ile | 0.38 | 0.346 |
| | N | 100 | 3 |
| Total Phosphorus as P (mg/L) | 10%ile | 0.015 | 0.082 |
| | Median | 0.030 | 0.088 |
| | 90%ile | 0.067 | 0.094 |
| | N | 295 | 2 |

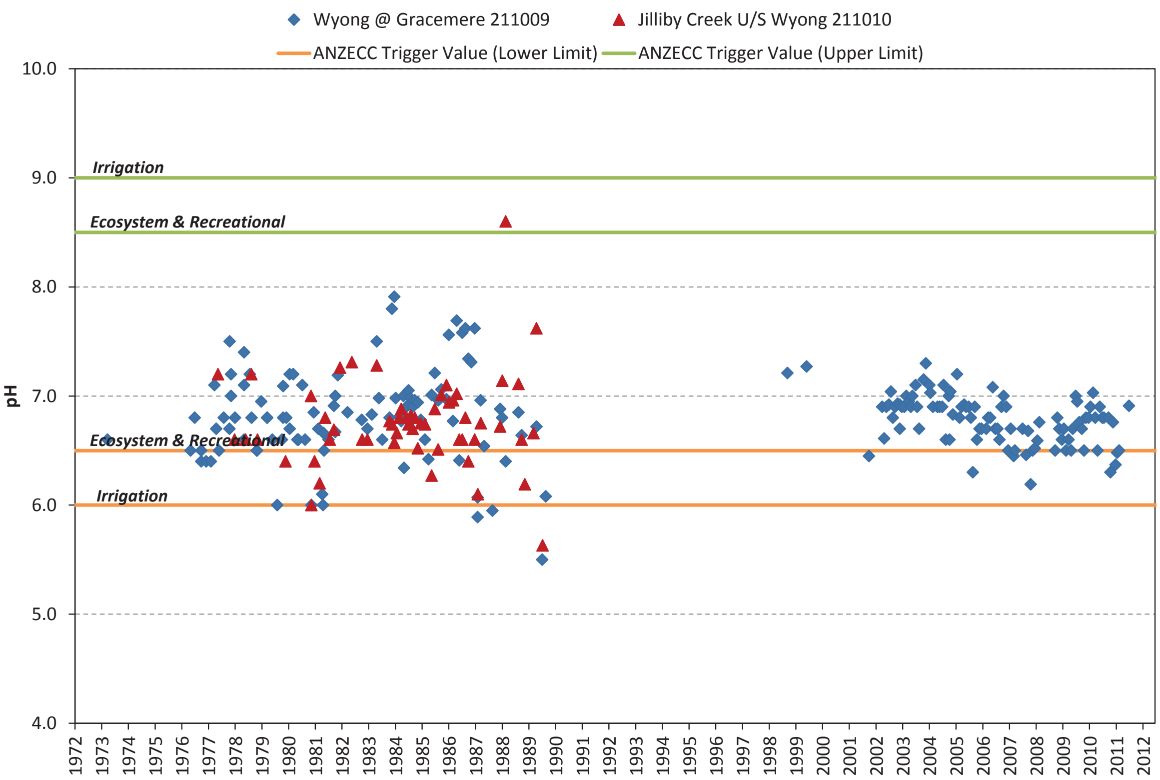


Figure A 1 – NOW Surface Water Quality Monitoring - pH

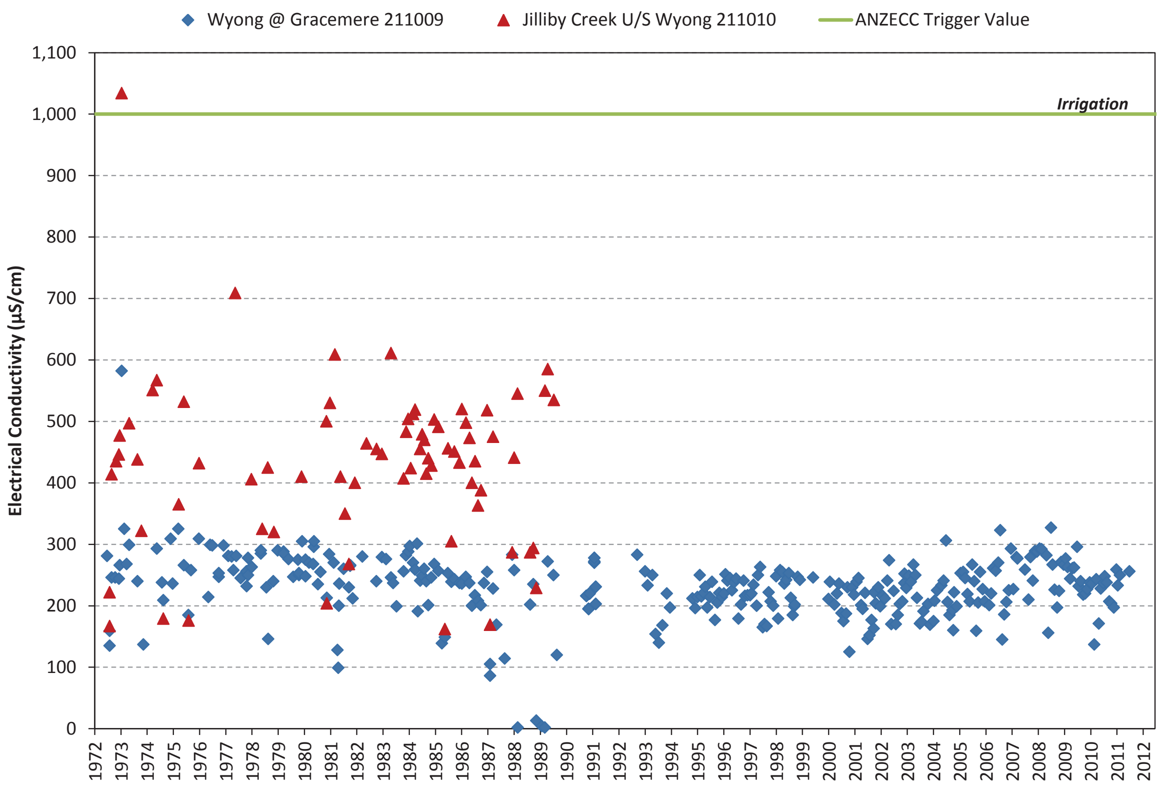


Figure A 2 – NOW Surface Water Quality Monitoring – Electrical Conductivity

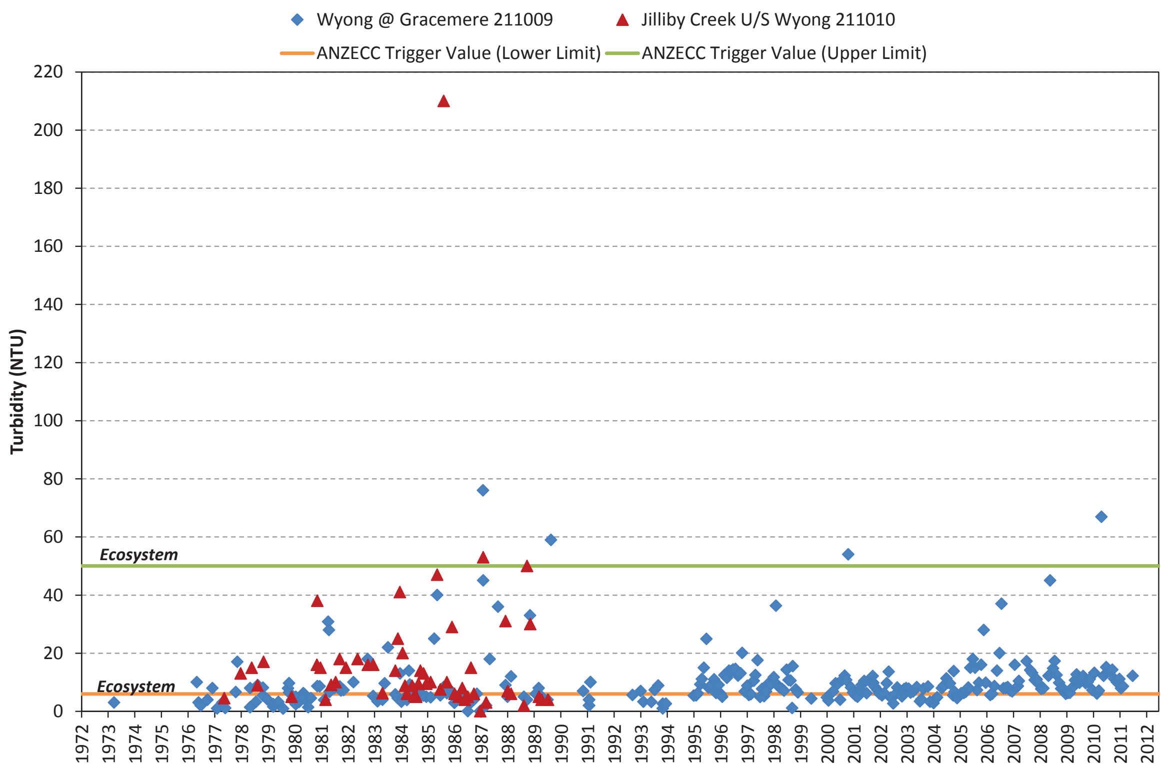


Figure A 3 – NOW Surface Water Quality Monitoring – Turbidity

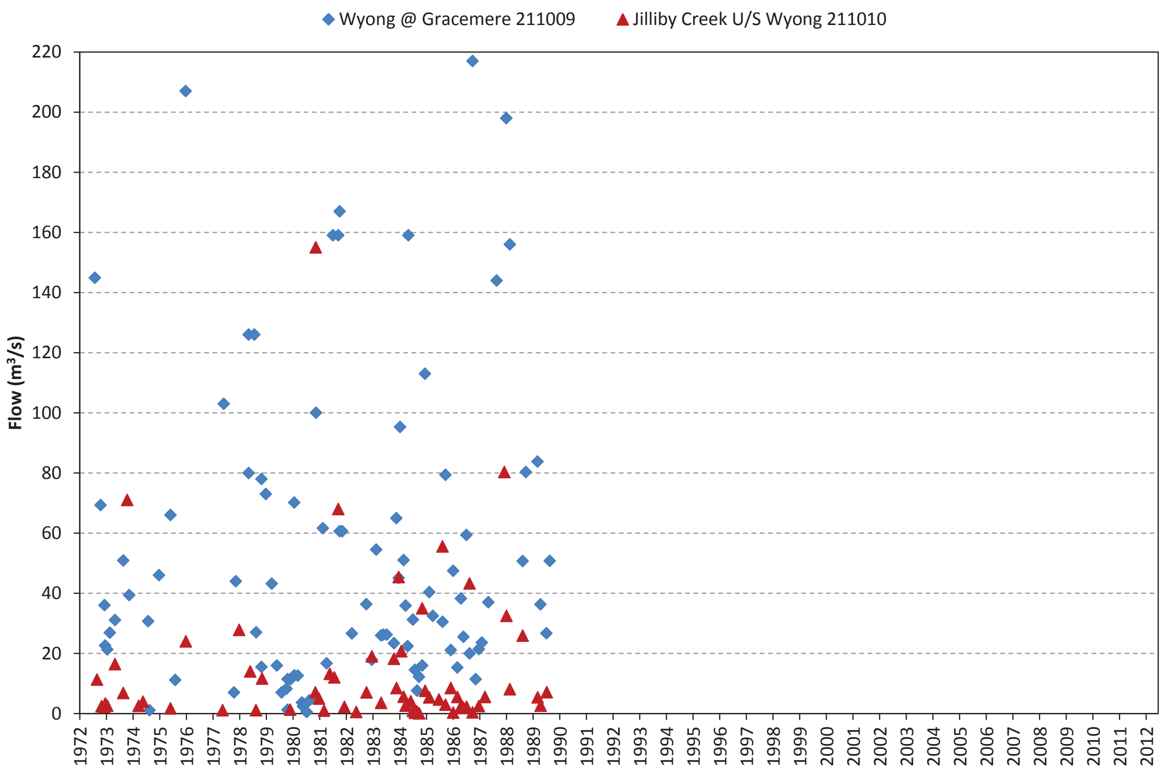


Figure A 4 – NOW Surface Water Quality Monitoring – Flow

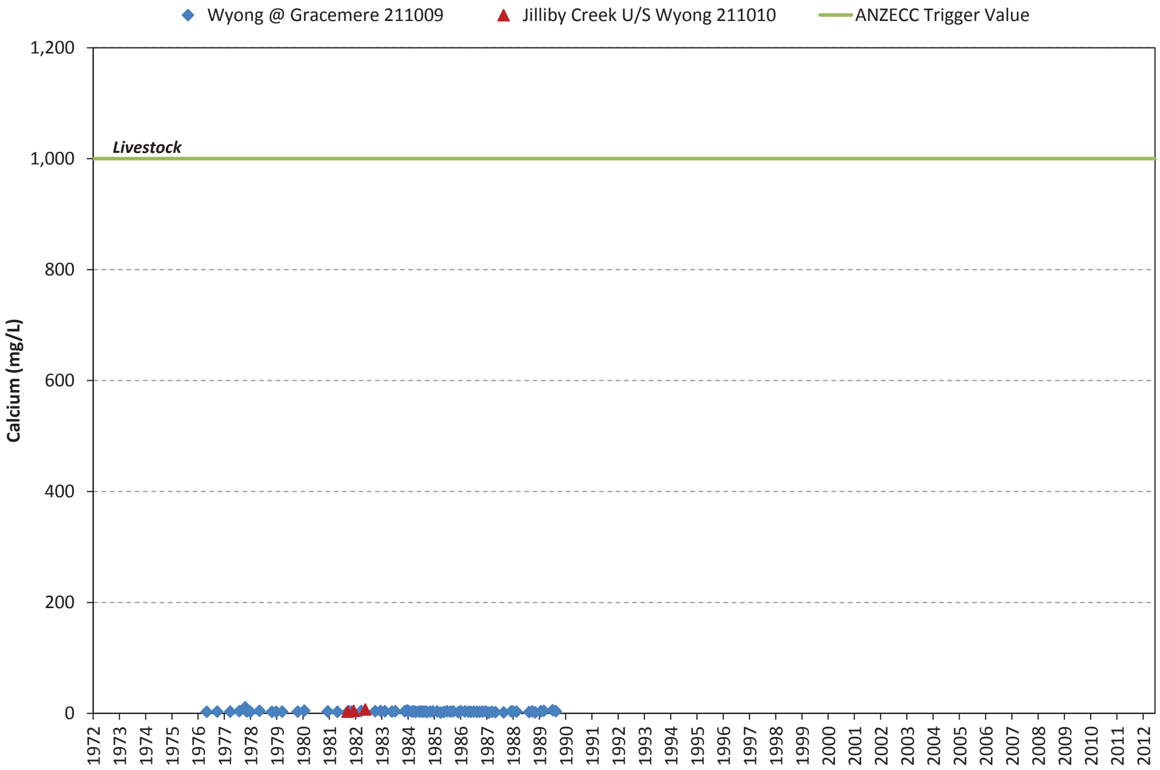


Figure A 5 – NOW Surface Water Quality Monitoring – Calcium

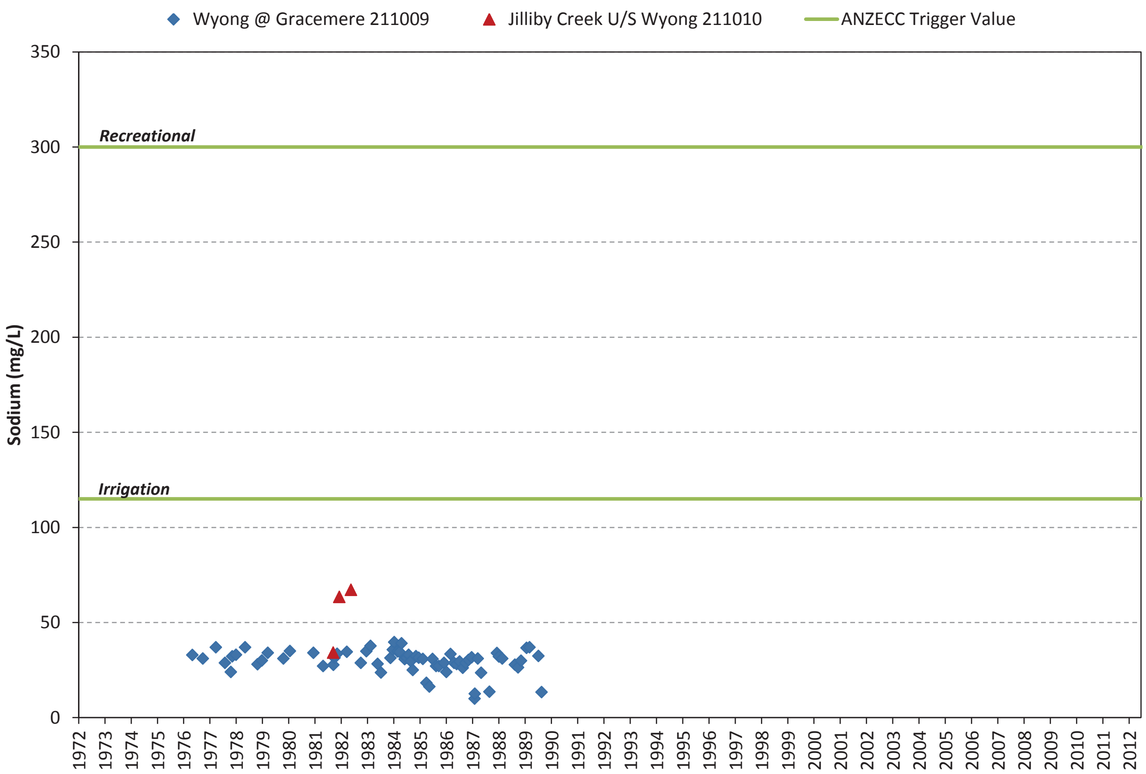


Figure A 6 – NOW Surface Water Quality Monitoring – Sodium

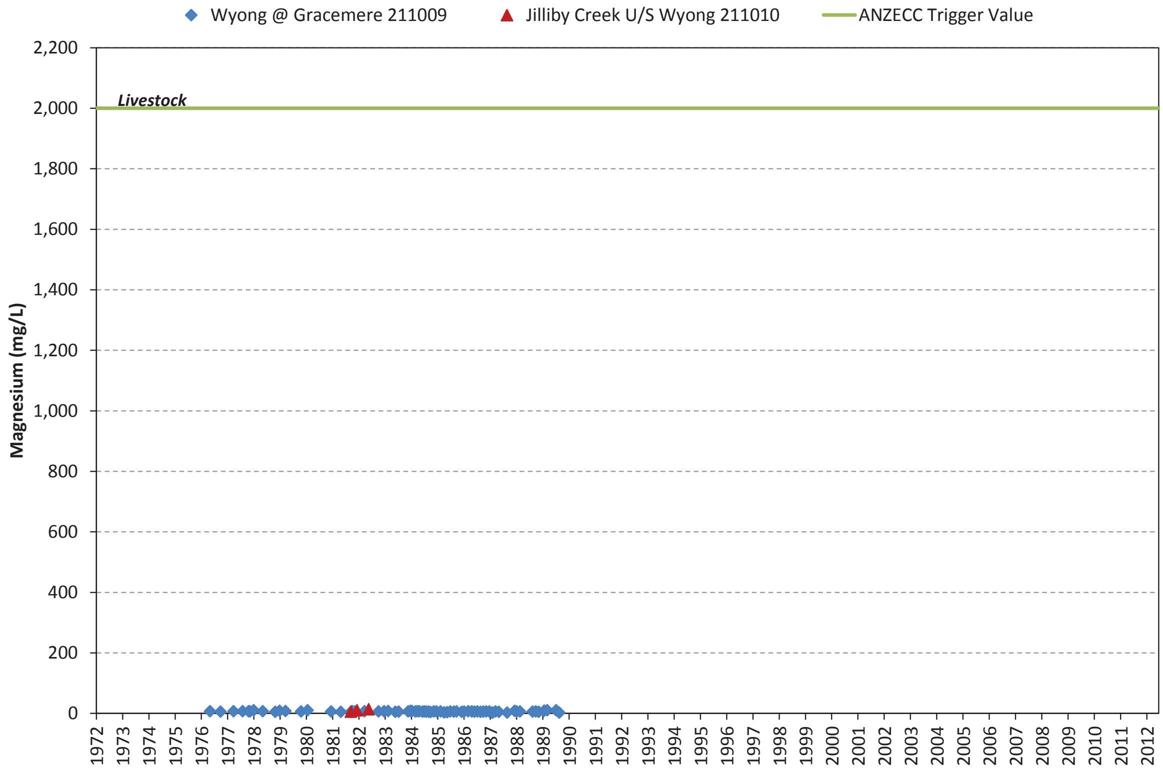


Figure A 7 – NOW Surface Water Quality Monitoring – Magnesium

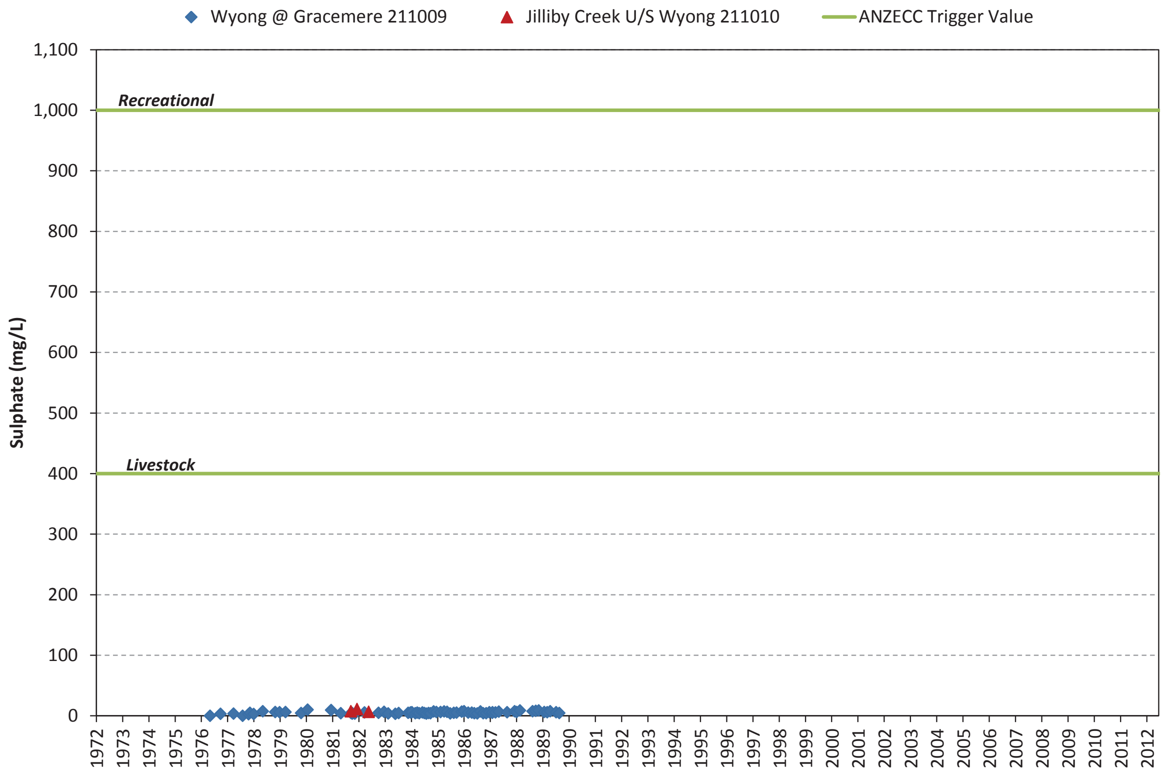


Figure A 8 – NOW Surface Water Quality Monitoring – Sulphate

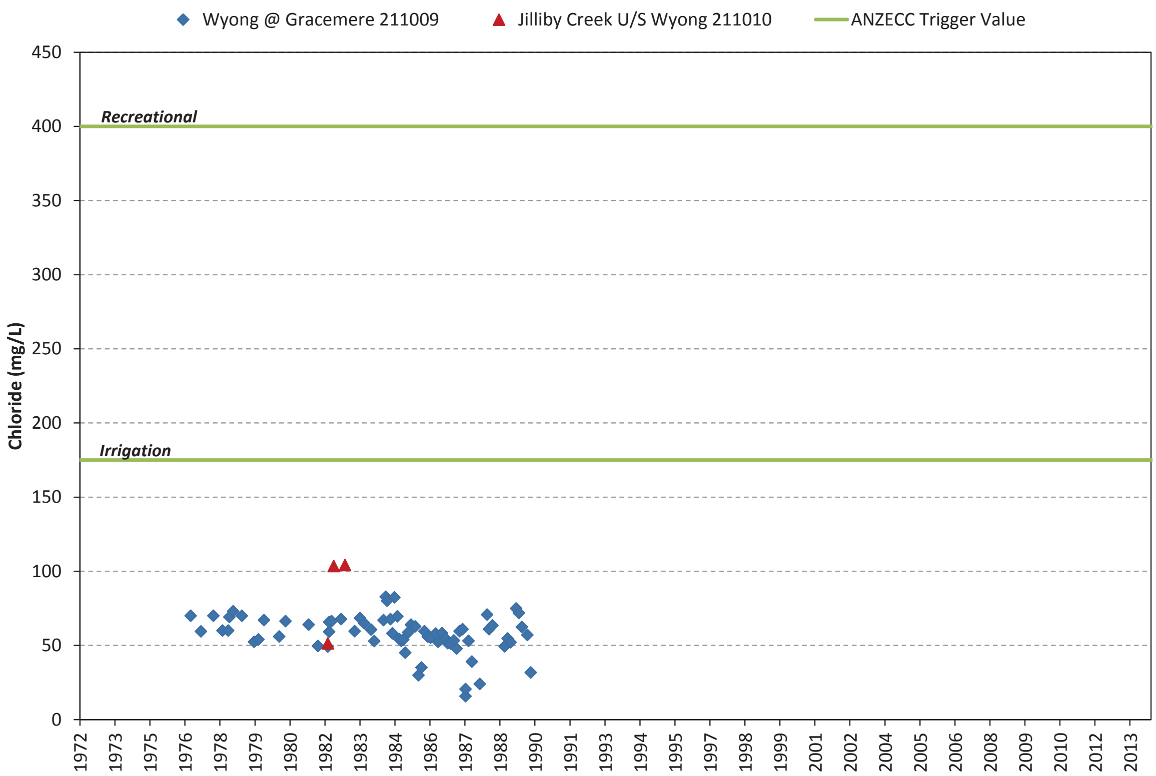


Figure A 9 – NOW Surface Water Quality Monitoring – Chloride

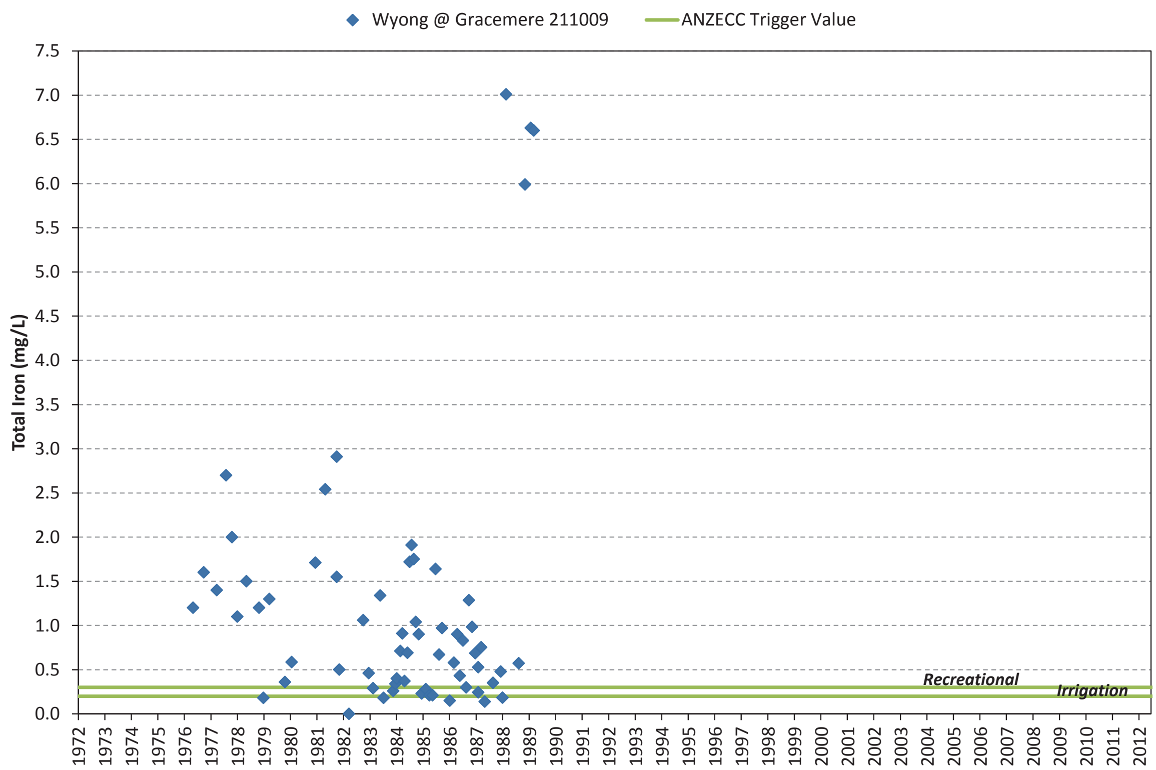


Figure A 10 – NOW Surface Water Quality Monitoring – Total Iron

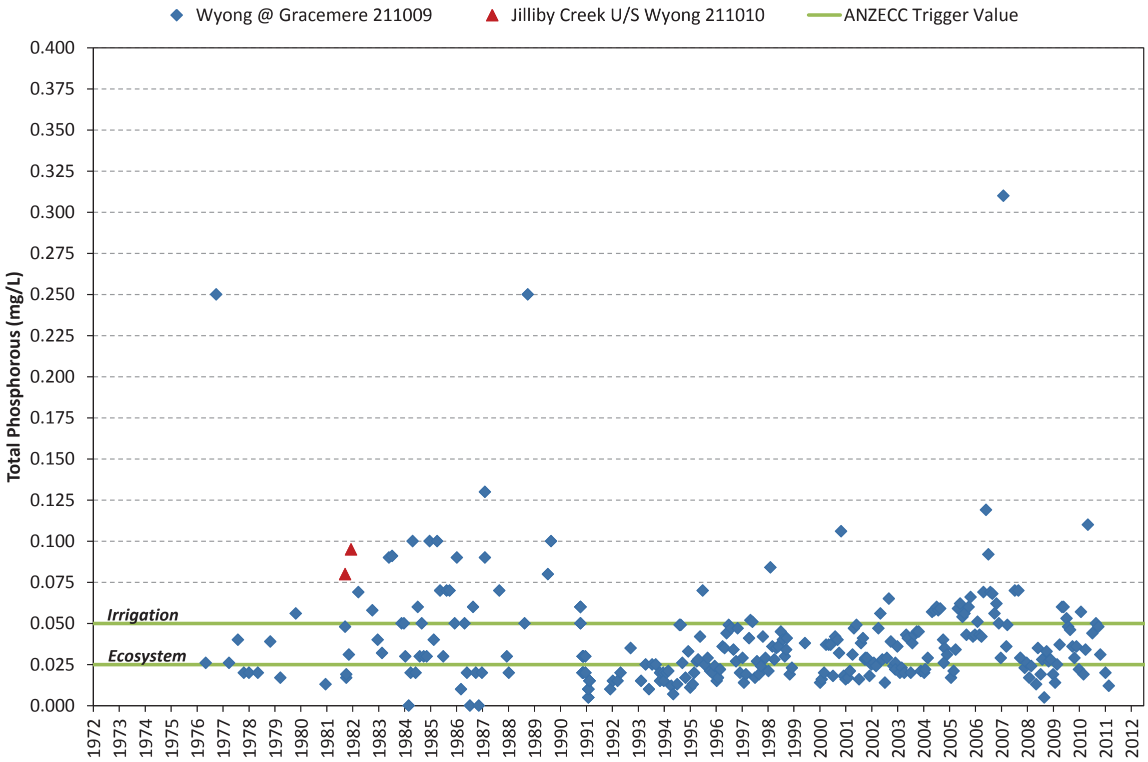


Figure A 11 – NOW Surface Water Quality Monitoring – Total Phosphorus

# APPENDIX B

## W2CP BASELINE SURFACE WATER QUALITY MONITORING RESULTS – WALLARAH CREEK

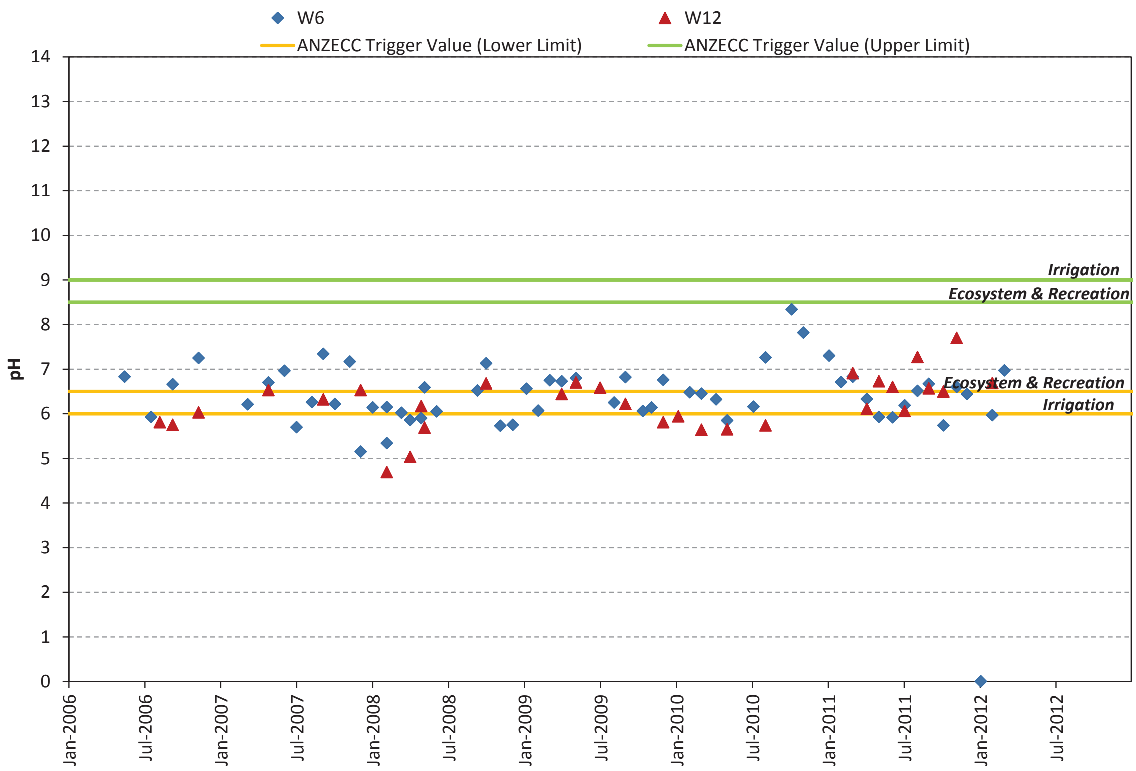


Figure B 1 – Baseline Surface Water Quality Monitoring – pH

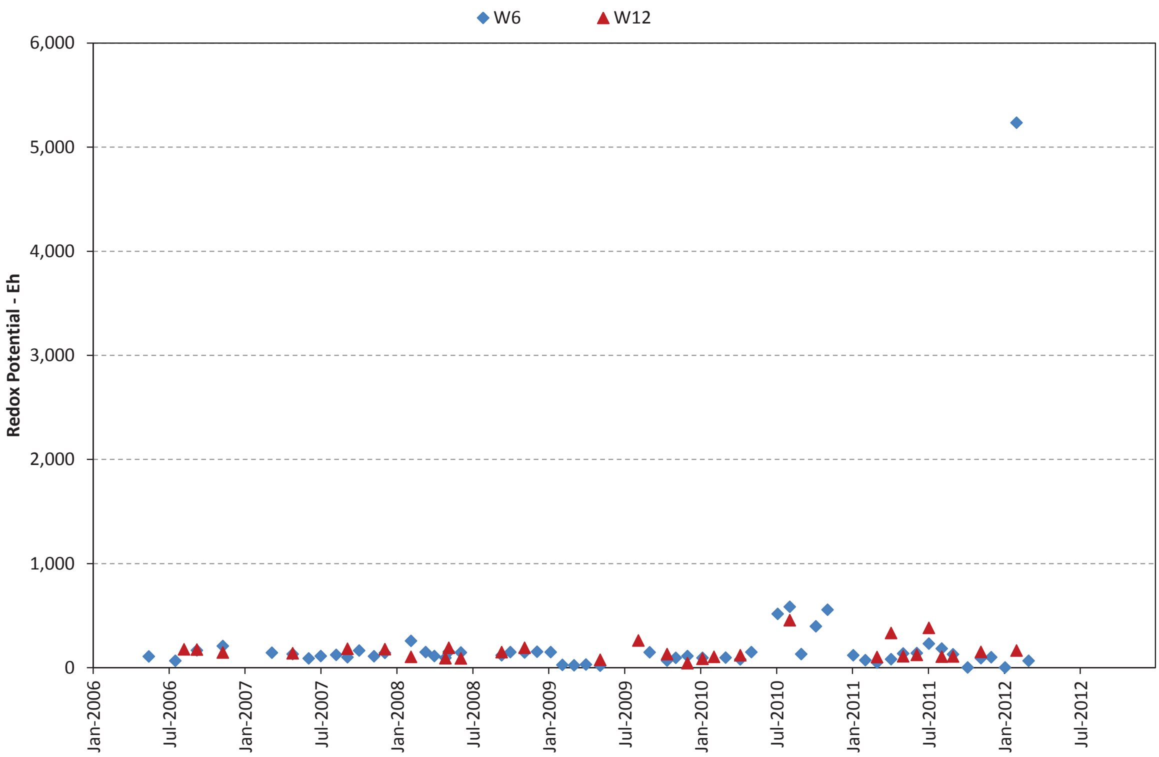


Figure B 2 – Baseline Surface Water Quality Monitoring – Redox Potential

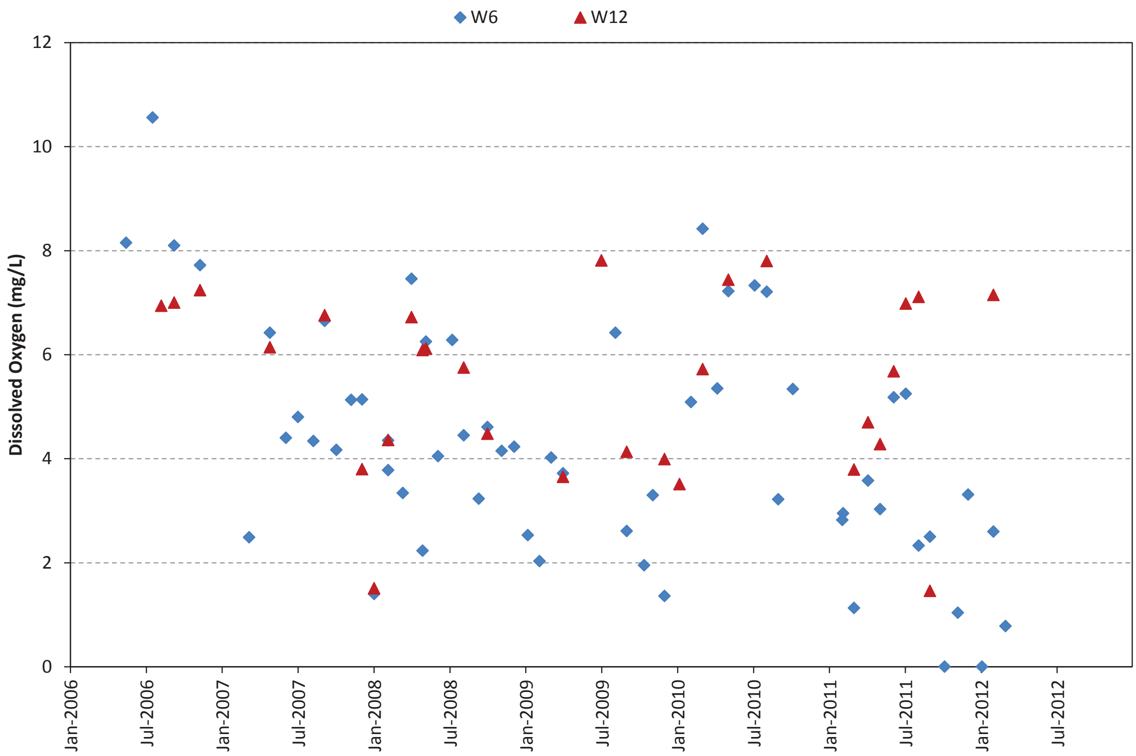


Figure B 3 – Baseline Surface Water Quality Monitoring – Dissolved Oxygen

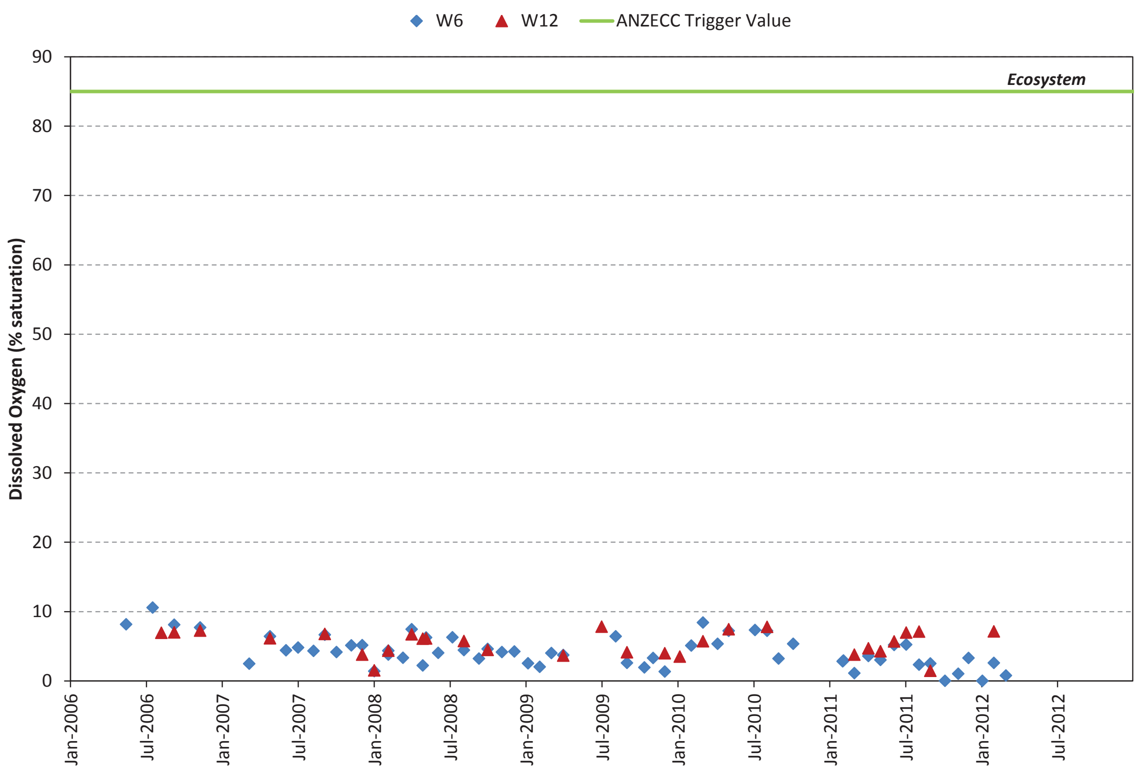


Figure B 4 – Baseline Surface Water Quality Monitoring – Dissolved Oxygen

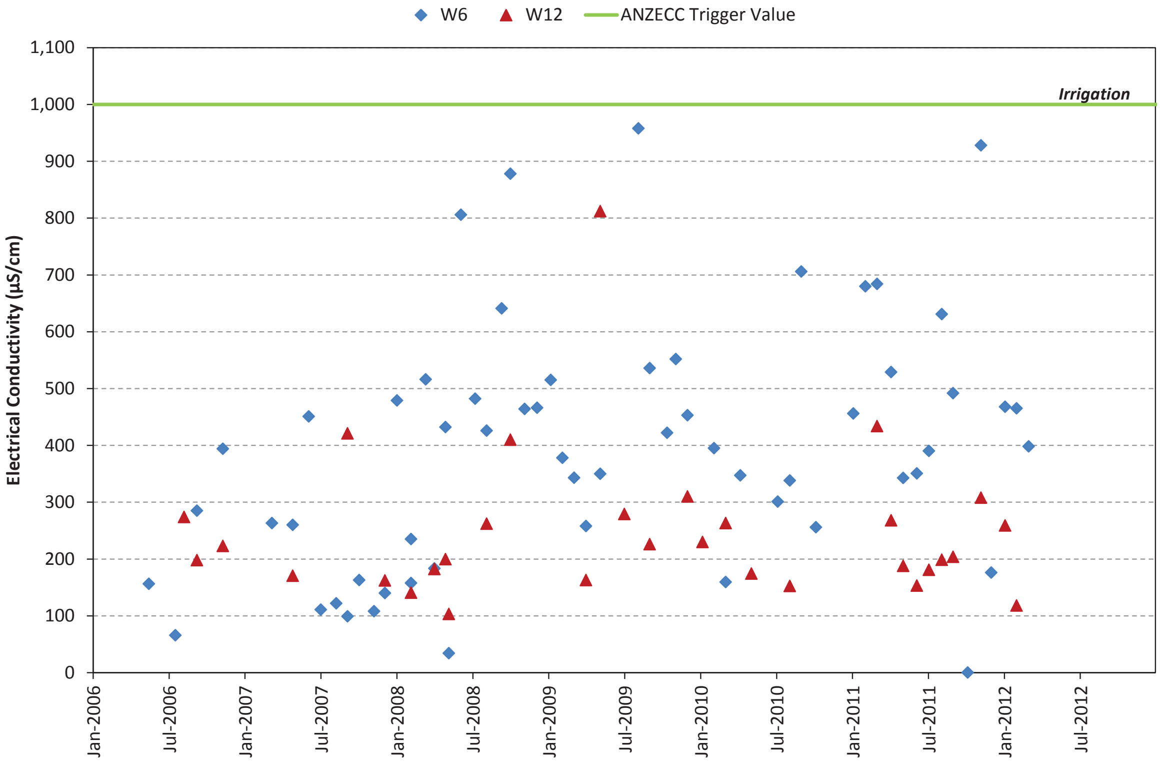


Figure B 5 – Baseline Surface Water Quality Monitoring – Electrical Conductivity

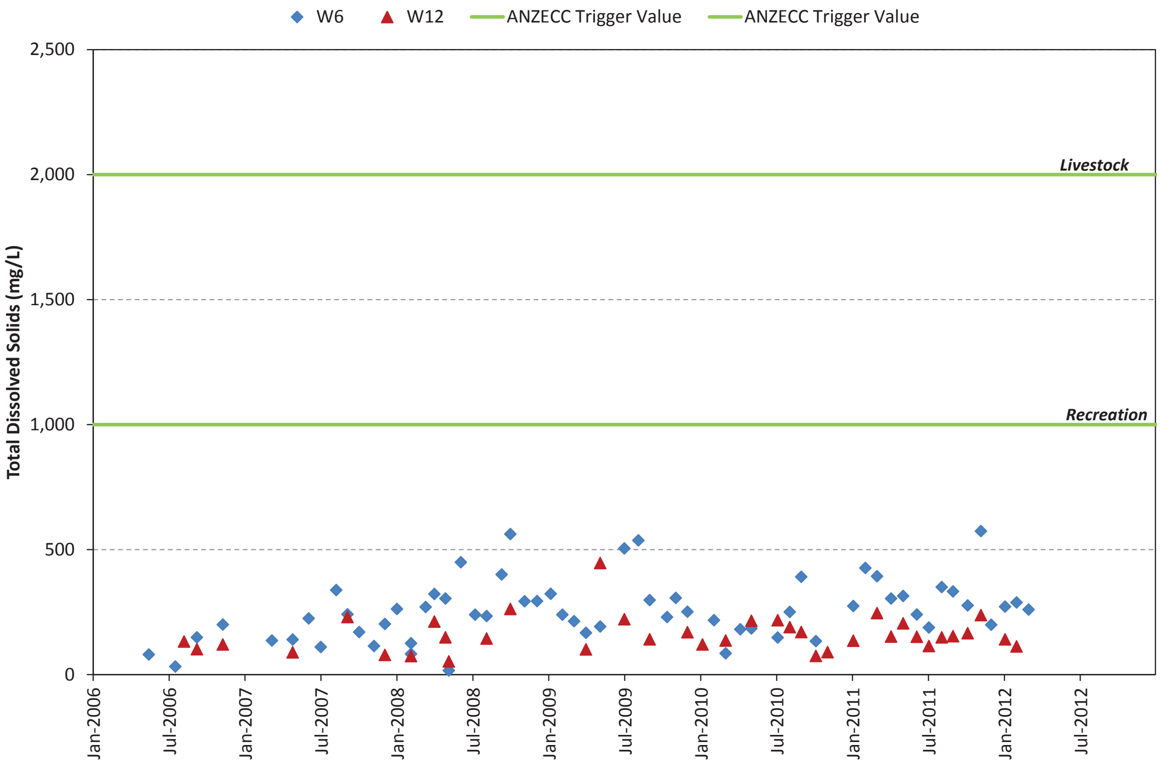


Figure B 6 – Baseline Surface Water Quality Monitoring – Total Dissolved Solids

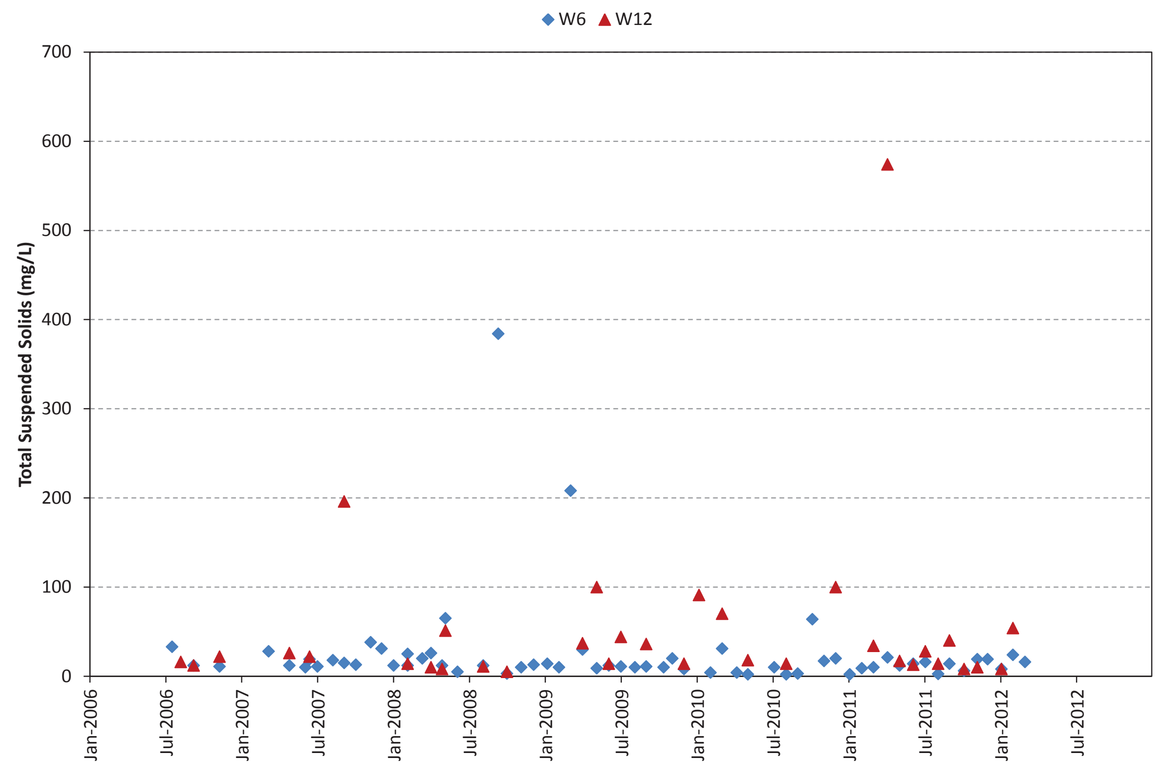


Figure B 7 – Baseline Surface Water Quality Monitoring – Total Suspended Solids

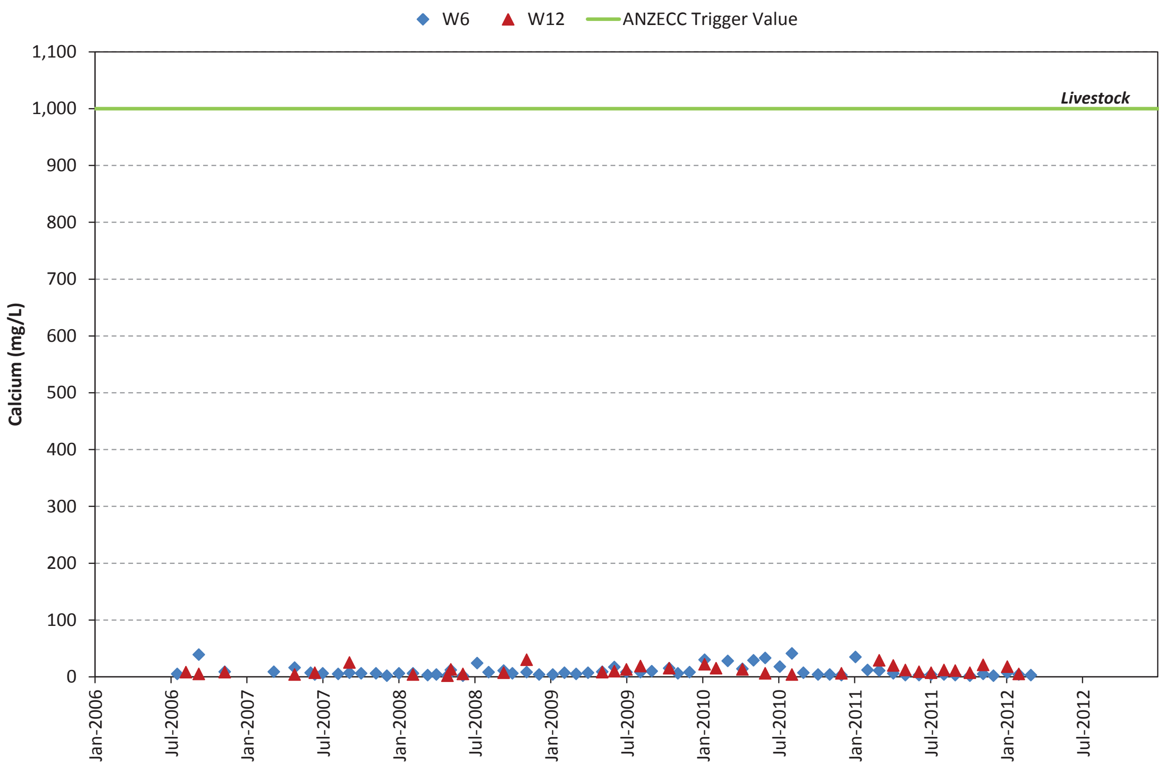


Figure B 8 – Baseline Surface Water Quality Monitoring – Calcium

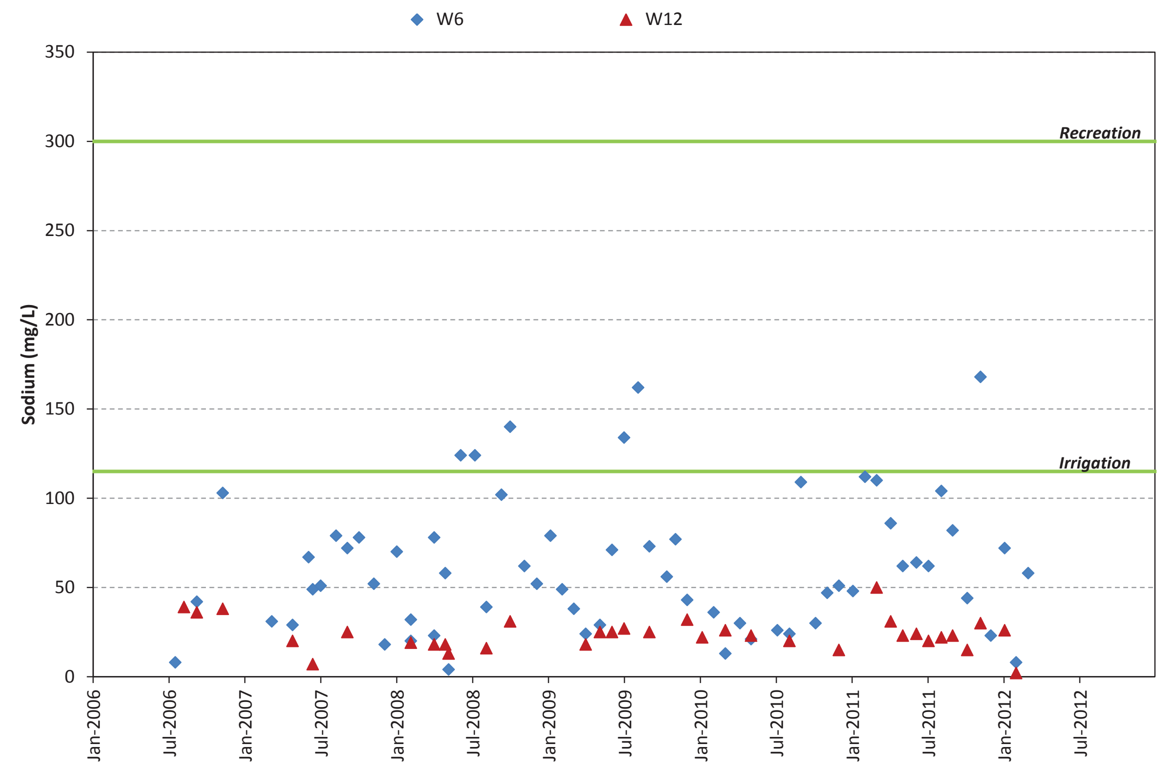


Figure B 9 – Baseline Surface Water Quality Monitoring – Sodium

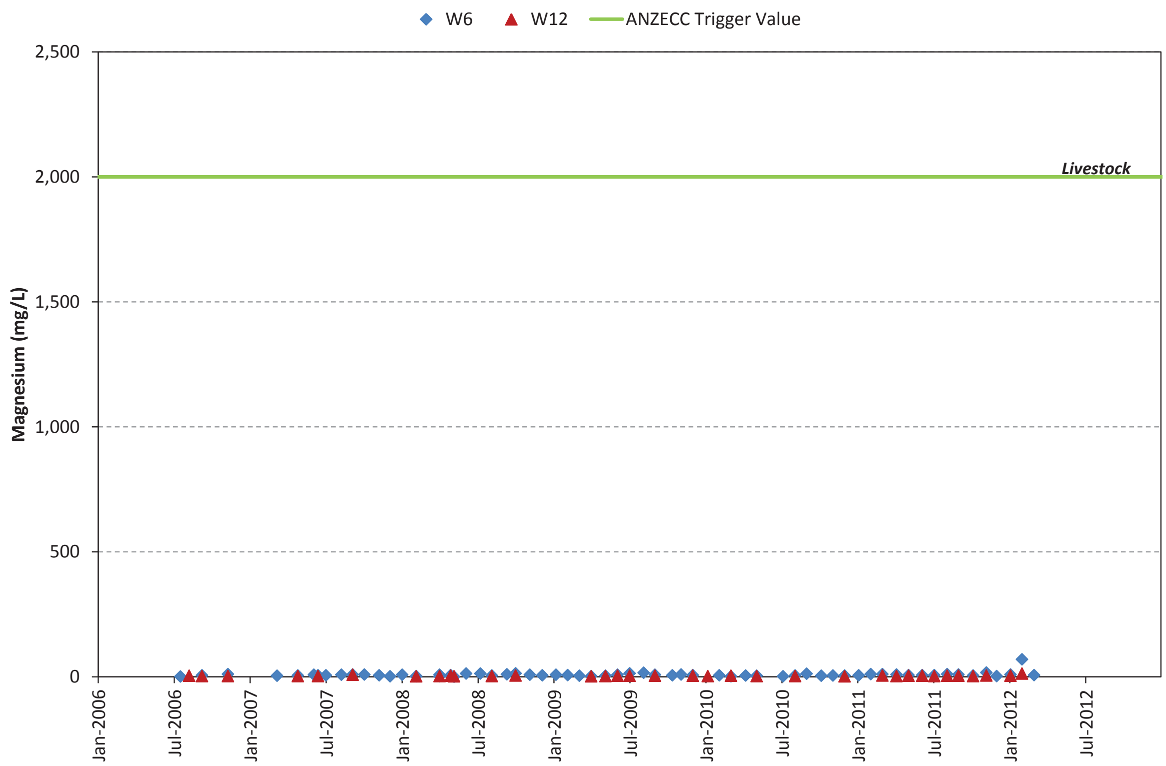


Figure B 10 – Baseline Surface Water Quality Monitoring – Magnesium

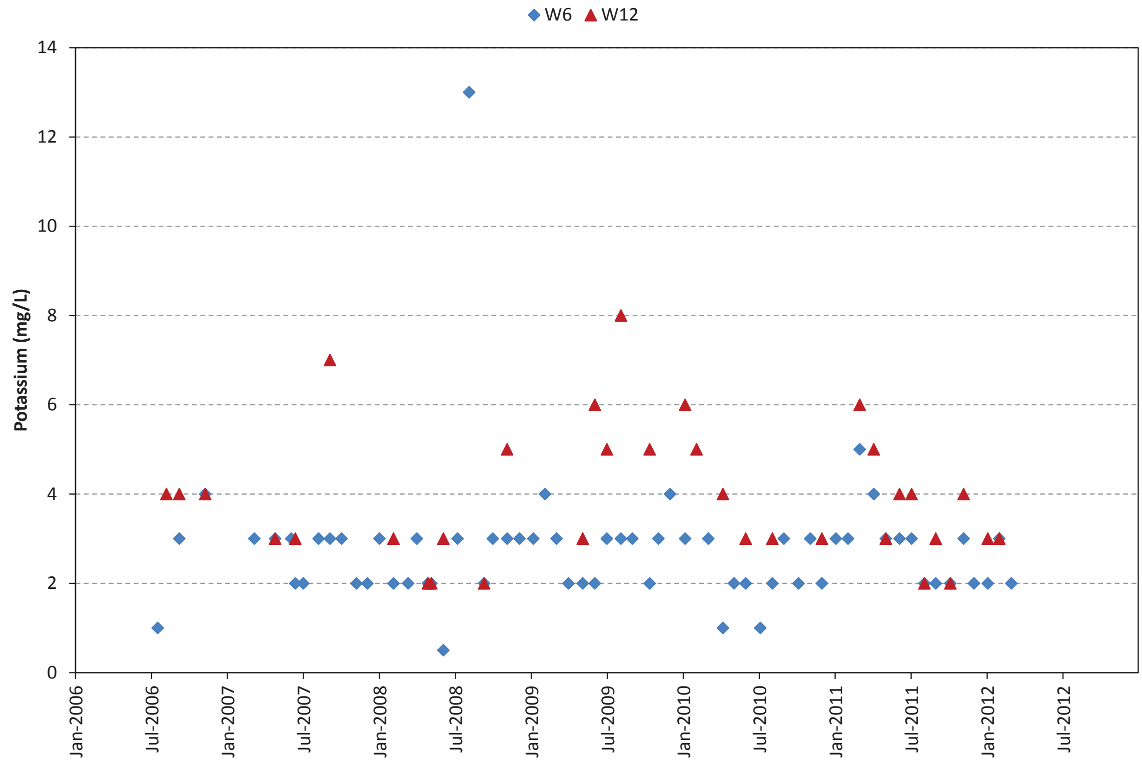


Figure B 11 – Baseline Surface Water Quality Monitoring – Potassium

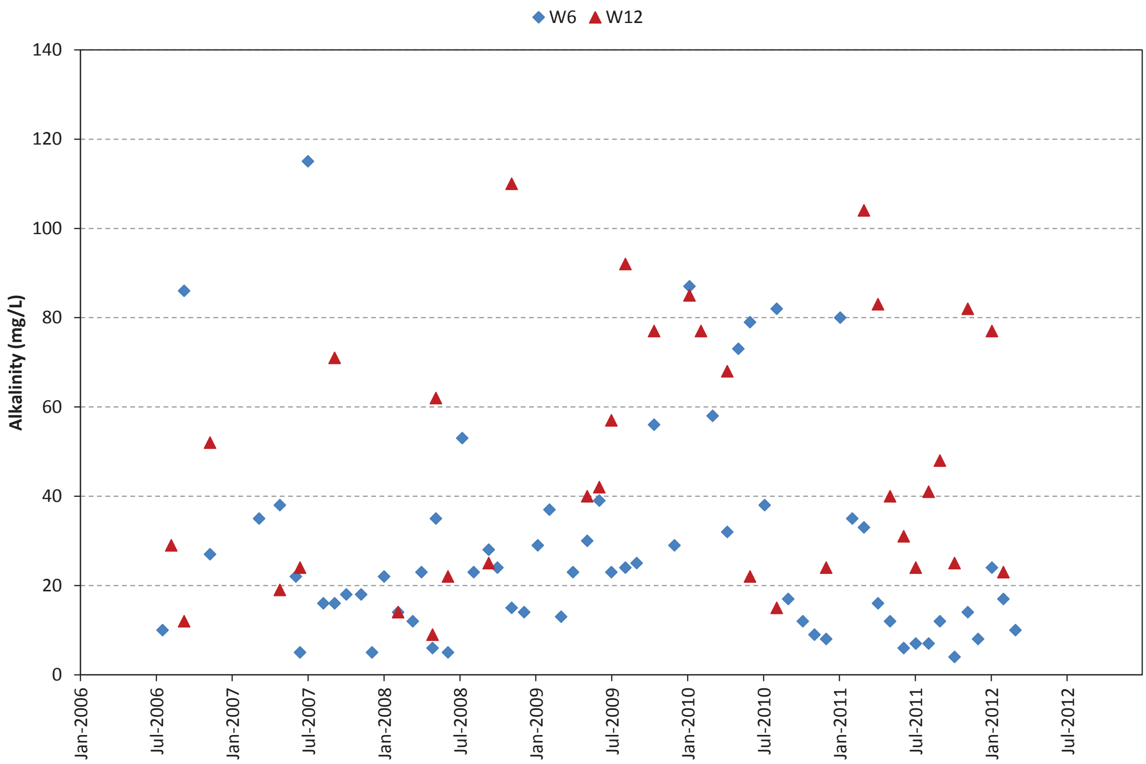


Figure B 12 – Baseline Surface Water Quality Monitoring – Alkalinity

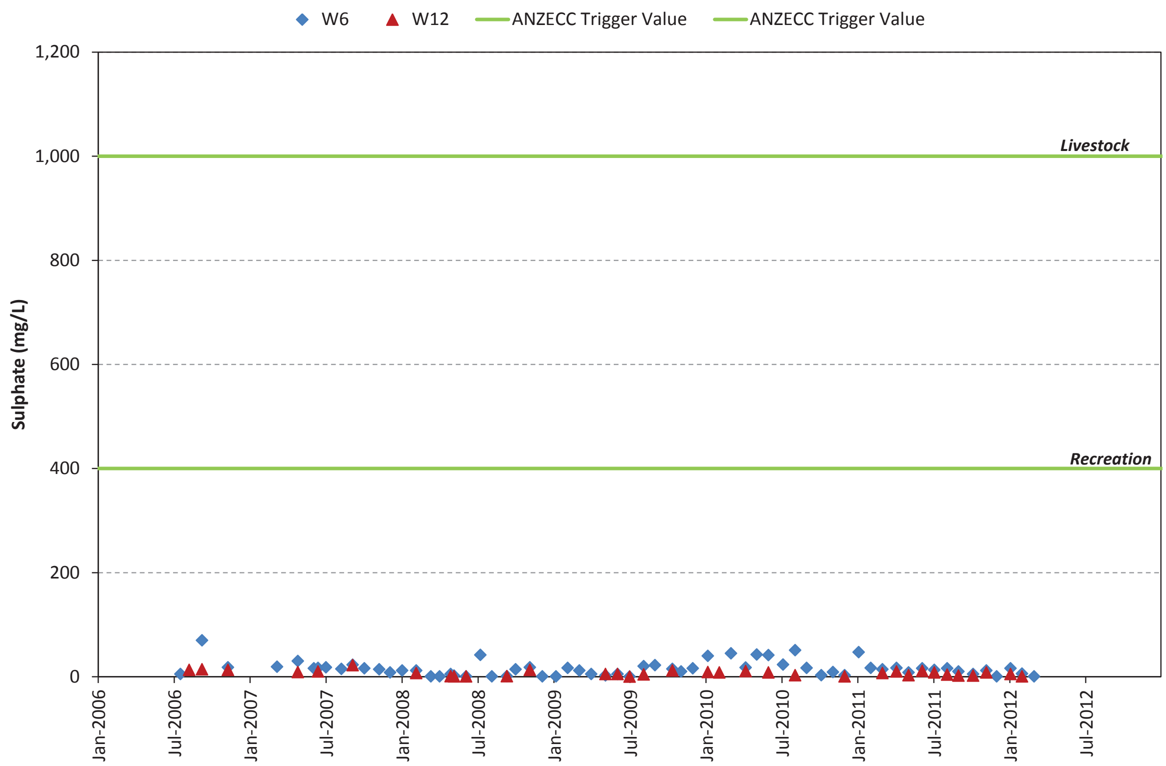


Figure B 13 – Baseline Surface Water Quality Monitoring – Sulphate

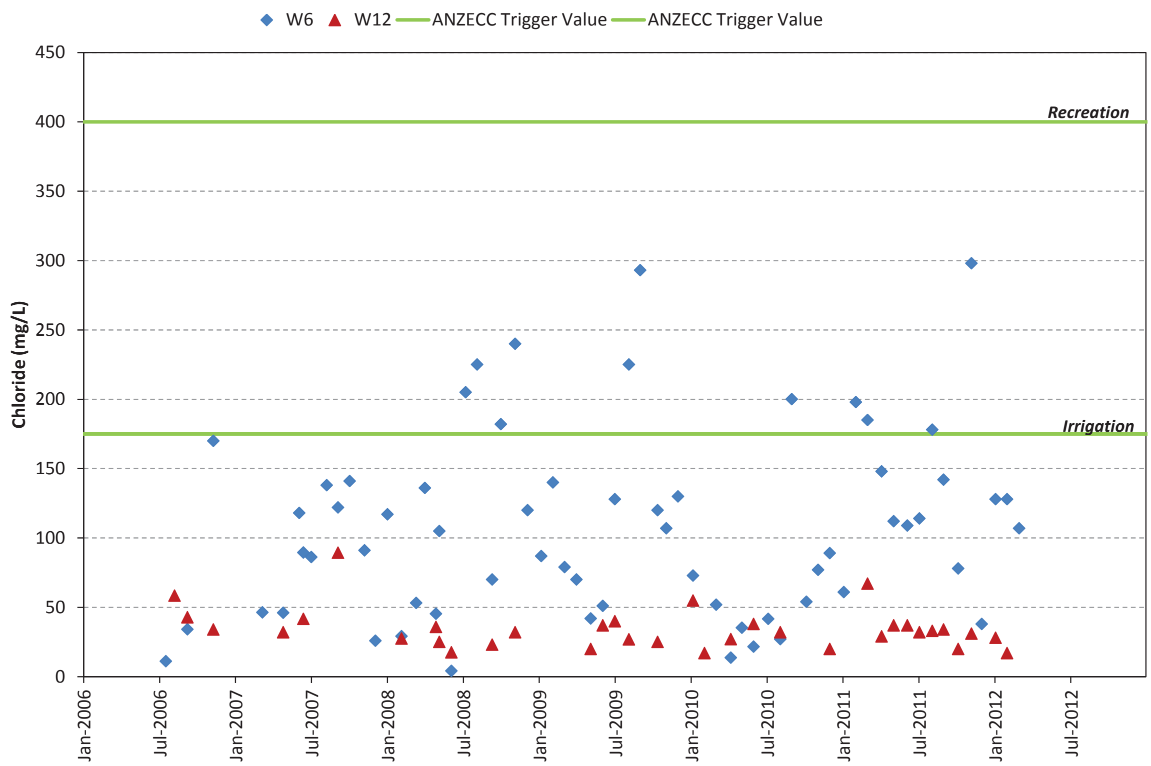


Figure B 14 – Baseline Surface Water Quality Monitoring – Chloride

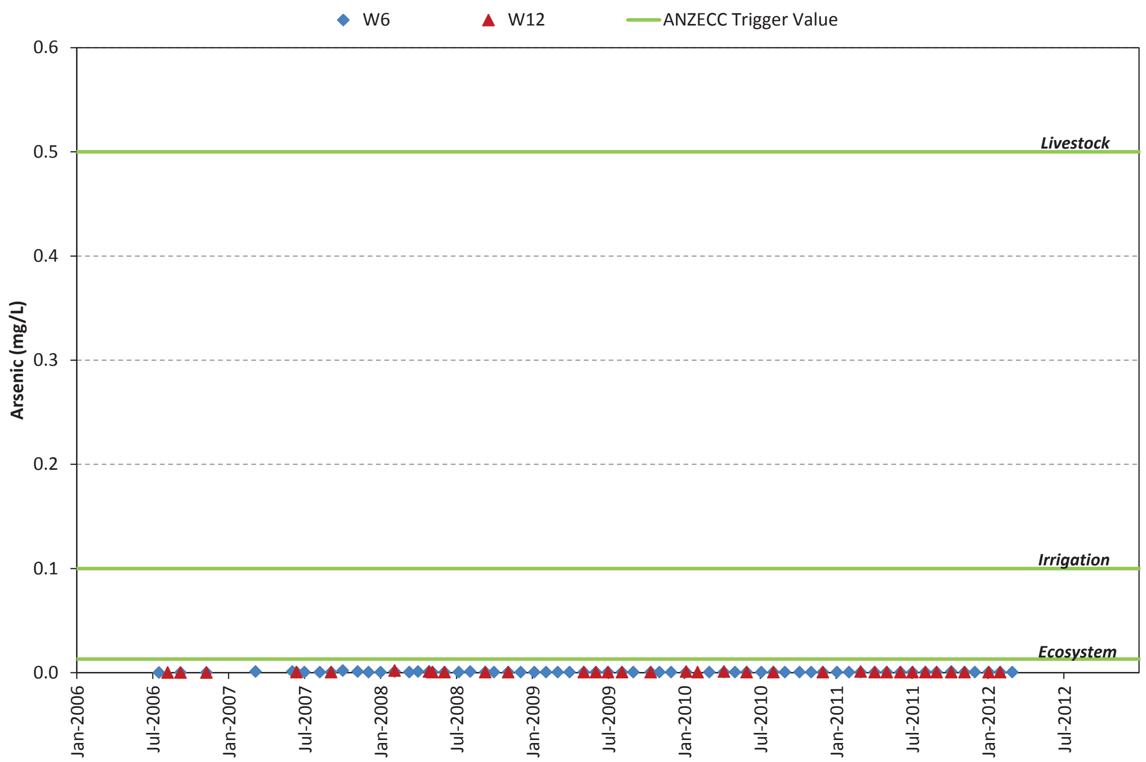


Figure B 15 – Baseline Surface Water Quality Monitoring – Arsenic

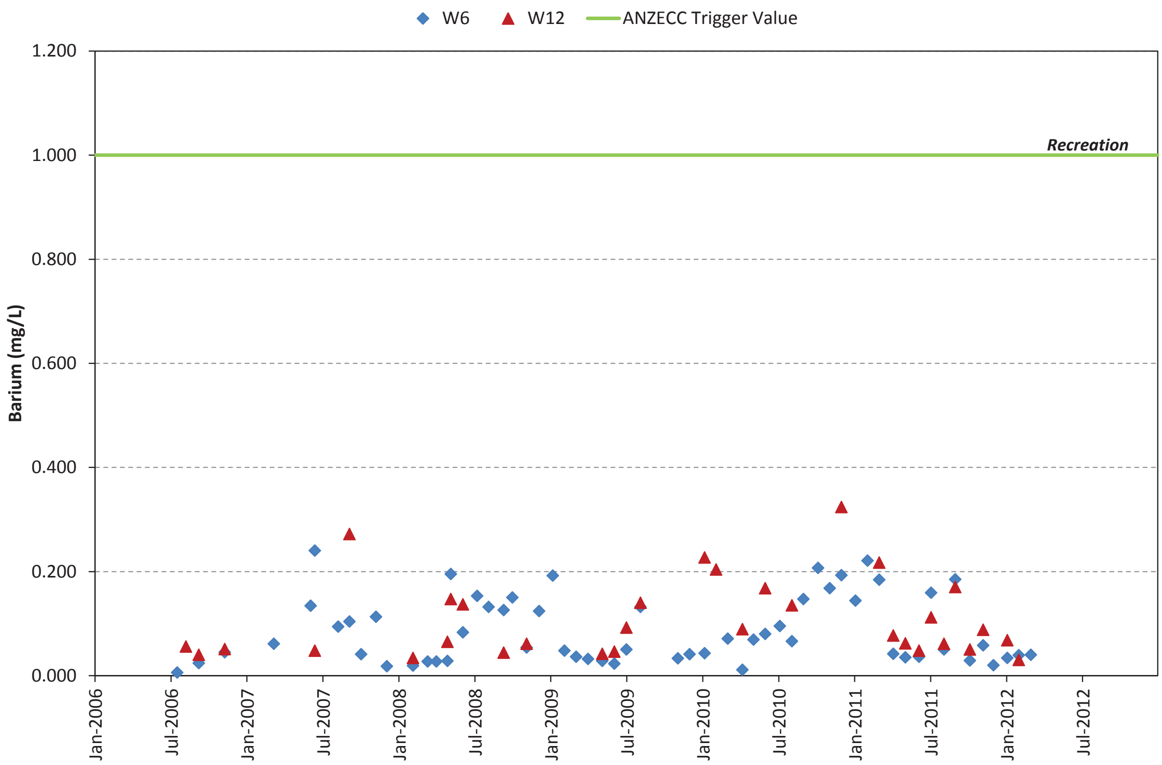


Figure B 16 – Baseline Surface Water Quality Monitoring – Barium

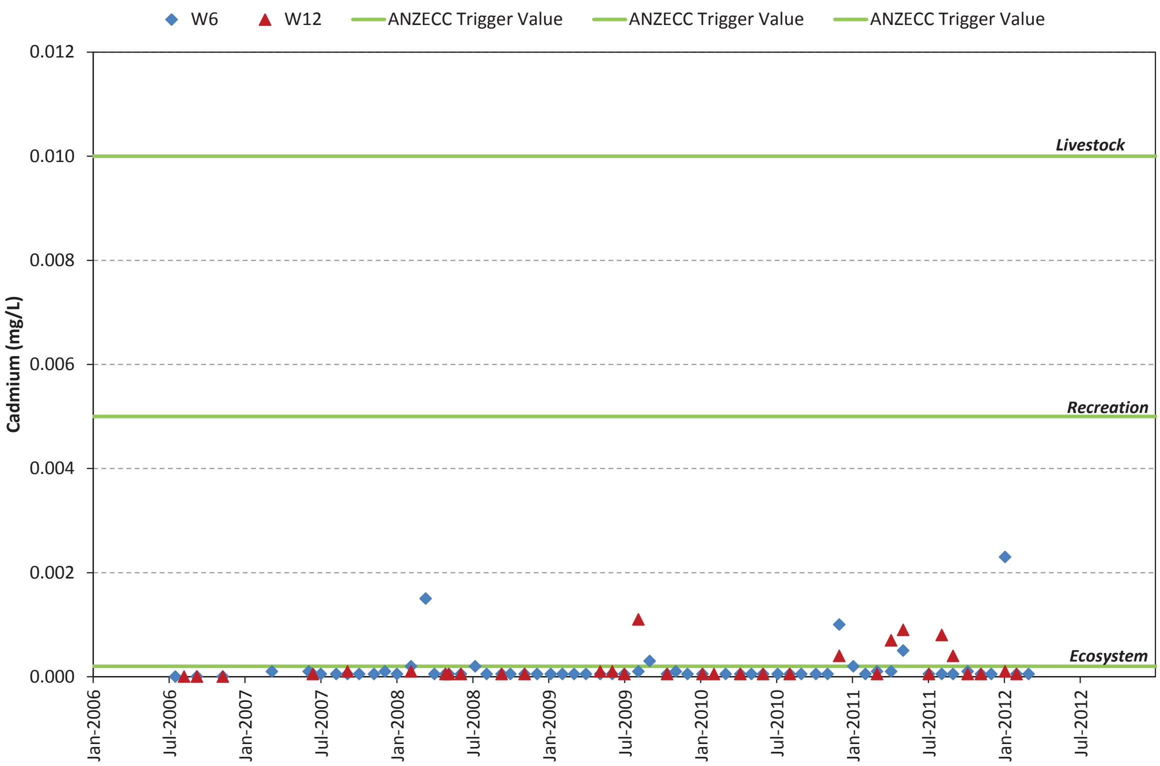


Figure B 17 – Baseline Surface Water Quality Monitoring – Cadmium

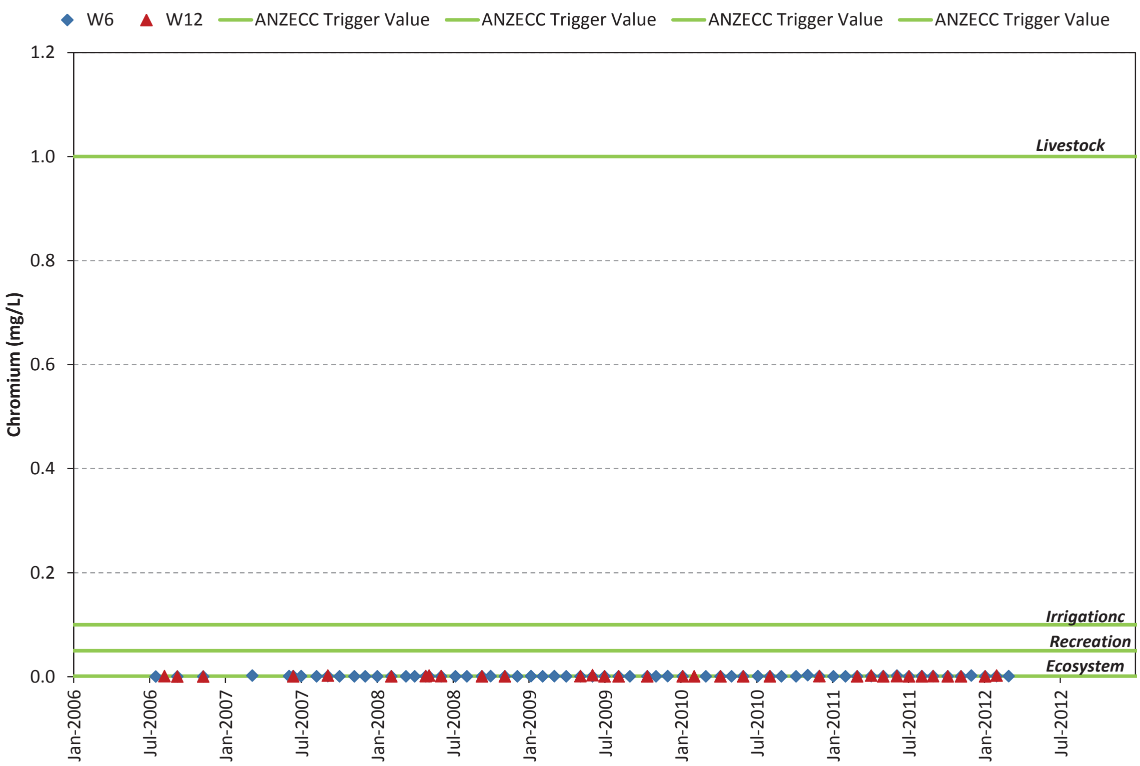


Figure B 18 – Baseline Surface Water Quality Monitoring – Chromium

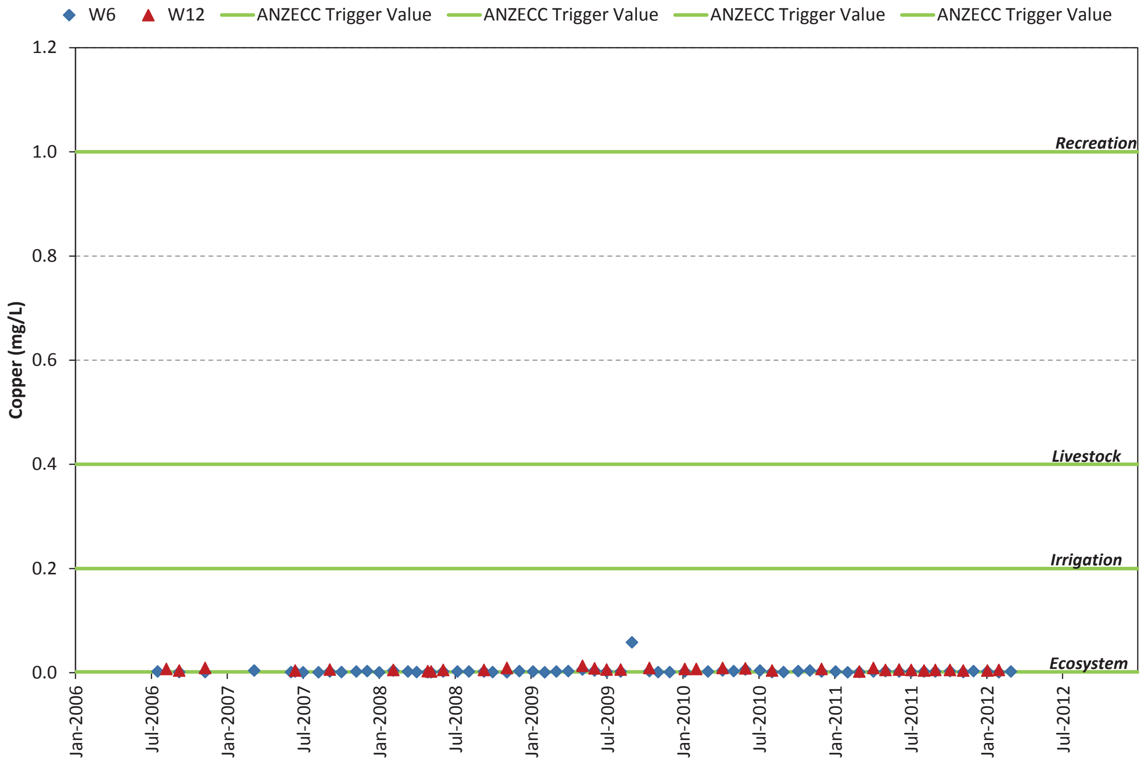


Figure B 19 – Baseline Surface Water Quality Monitoring – Copper

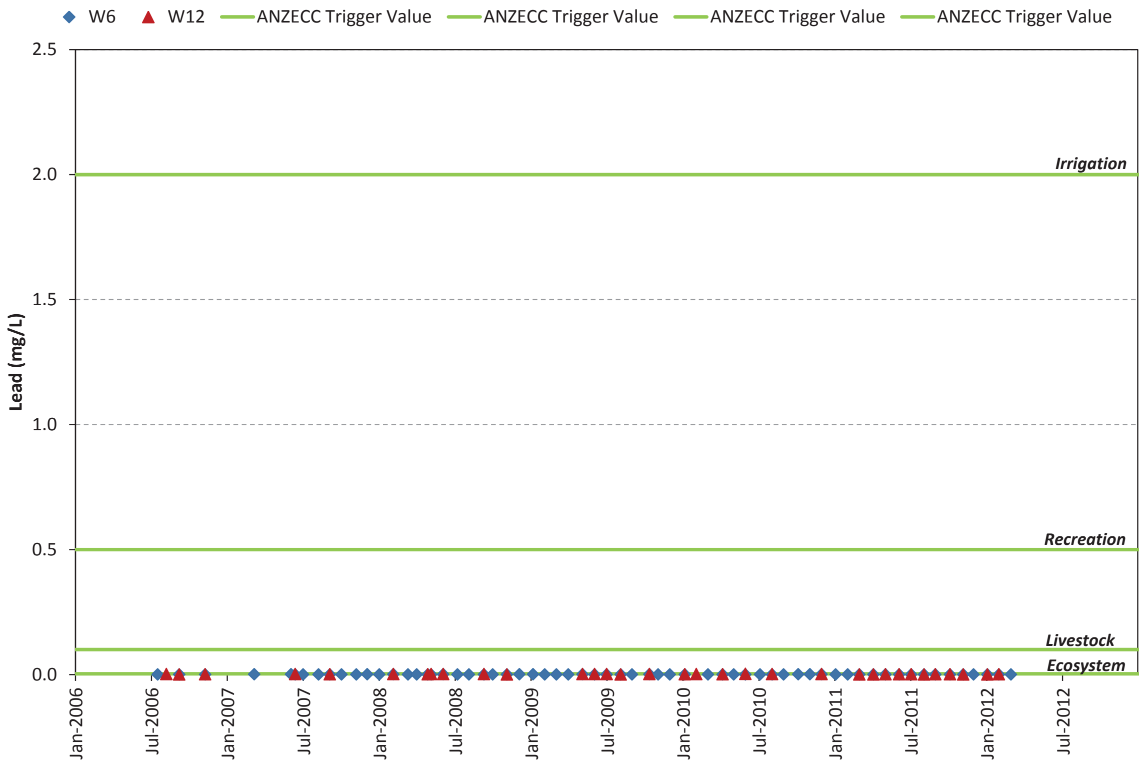


Figure B 20 – Baseline Surface Water Quality Monitoring – Lead

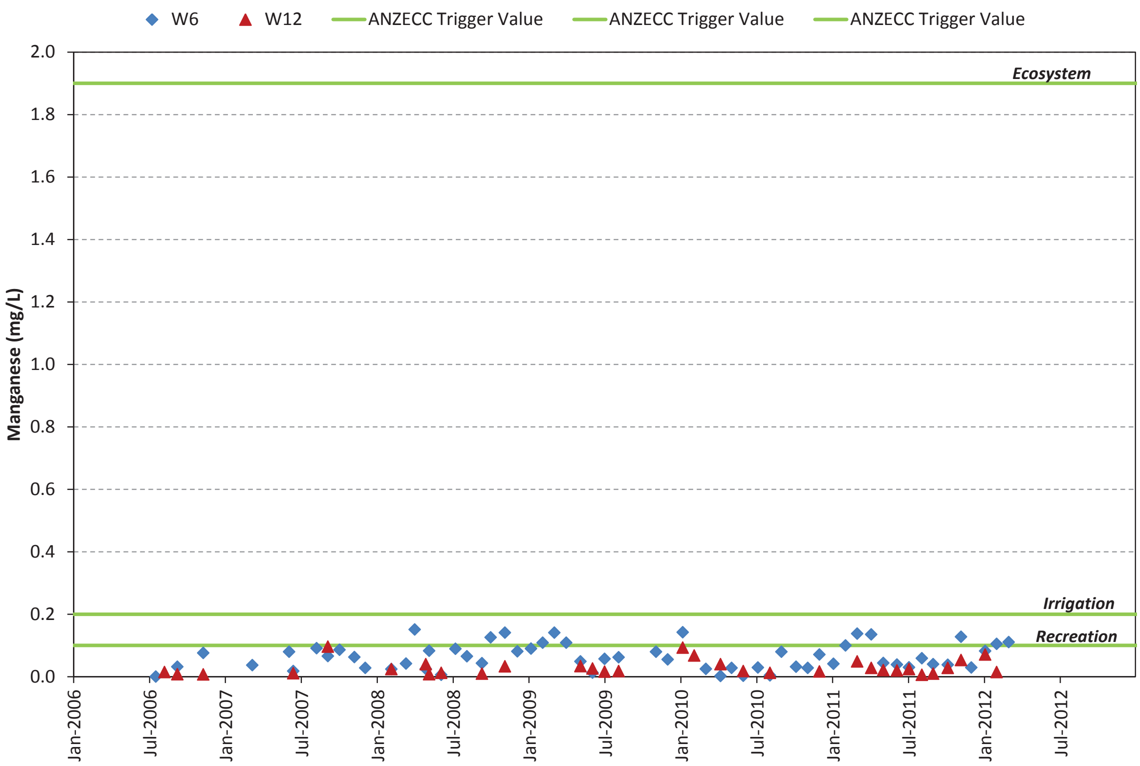


Figure B 21 – Baseline Surface Water Quality Monitoring – Manganese

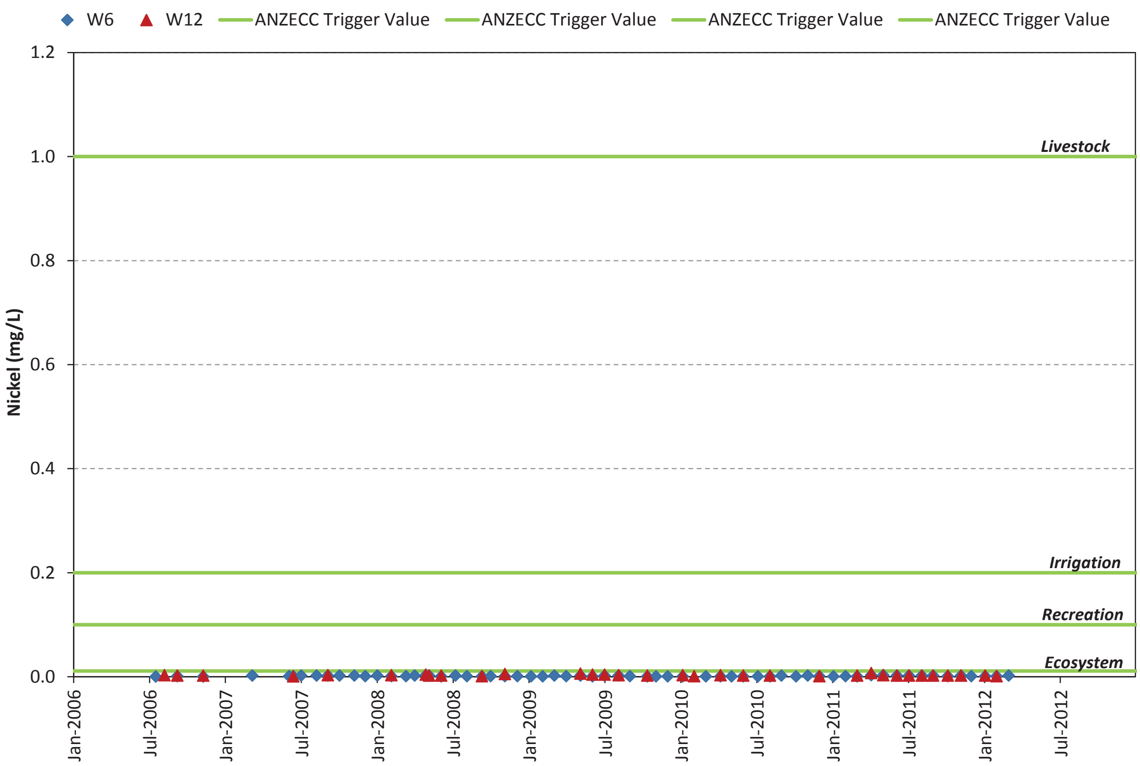


Figure B 22 – Baseline Surface Water Quality Monitoring – Nickel

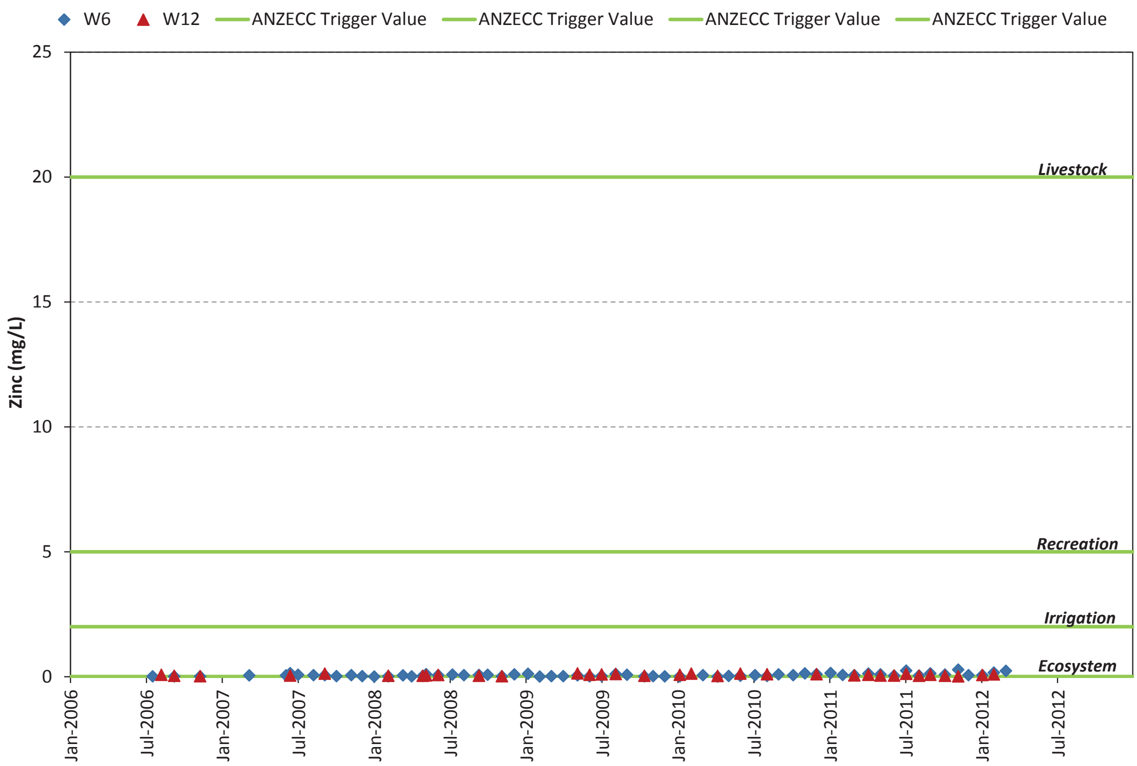


Figure B 23 – Baseline Surface Water Quality Monitoring – Zinc

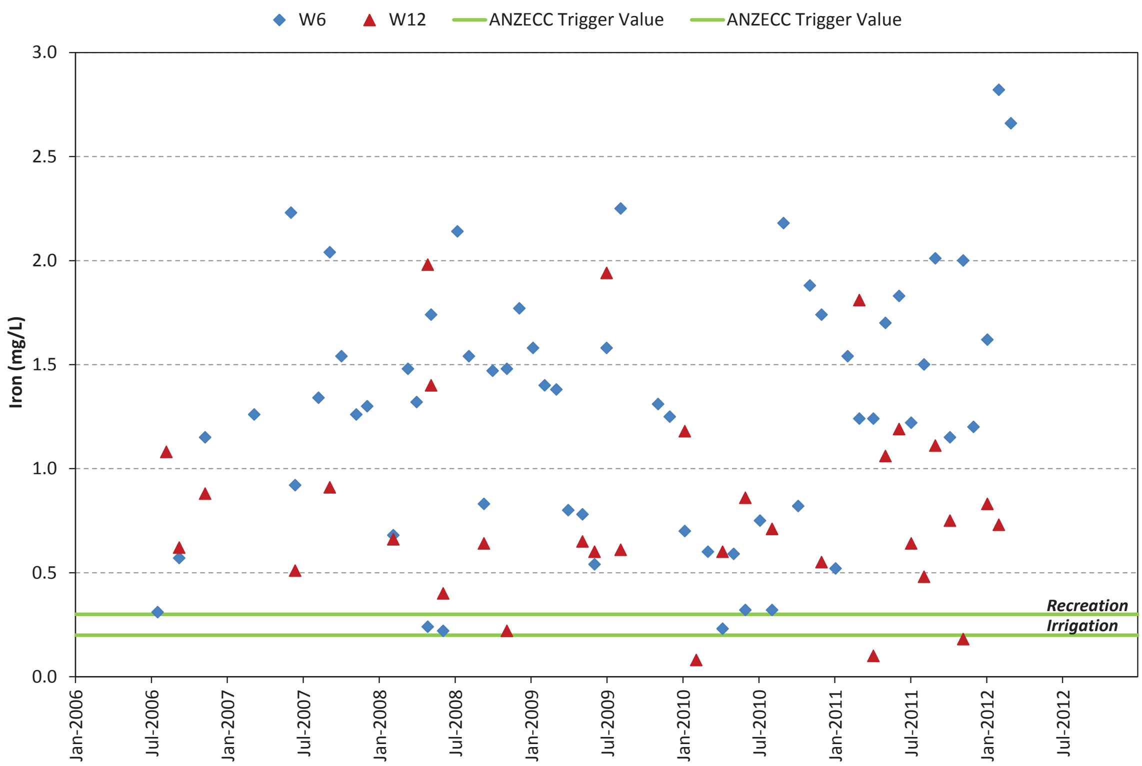


Figure B 24 – Baseline Surface Water Quality Monitoring – Iron

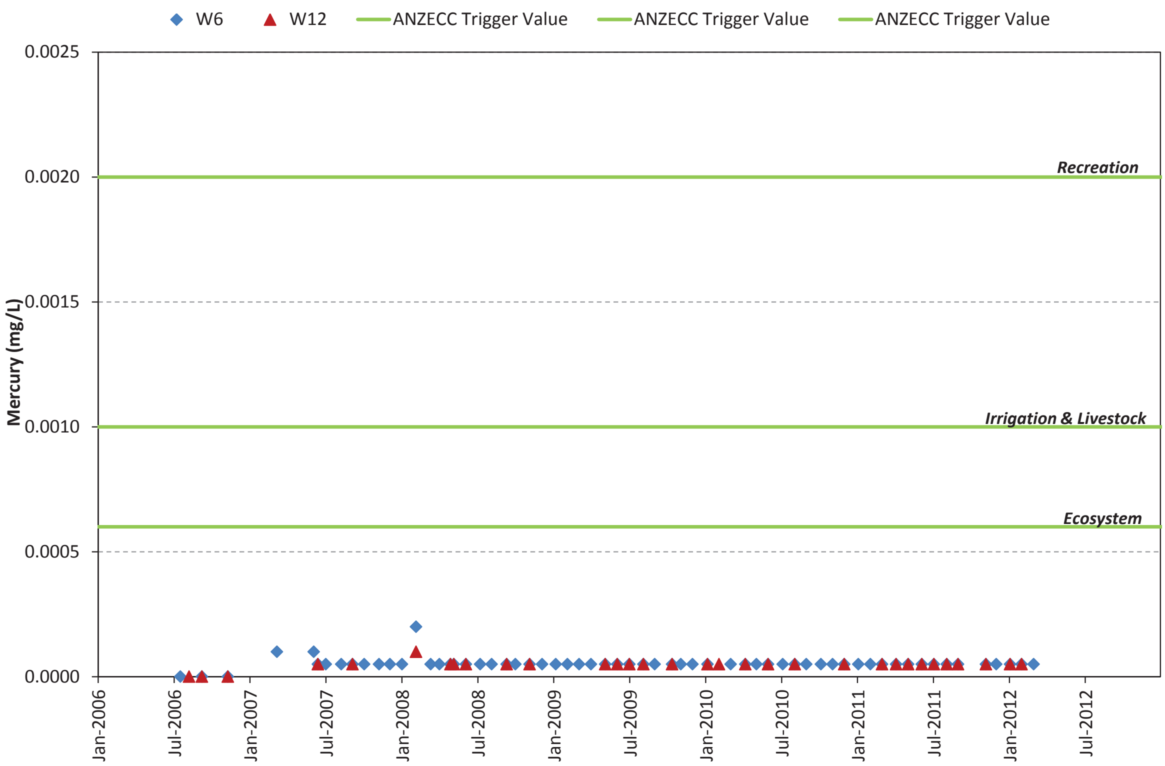


Figure B 25 – Baseline Surface Water Quality Monitoring – Mercury

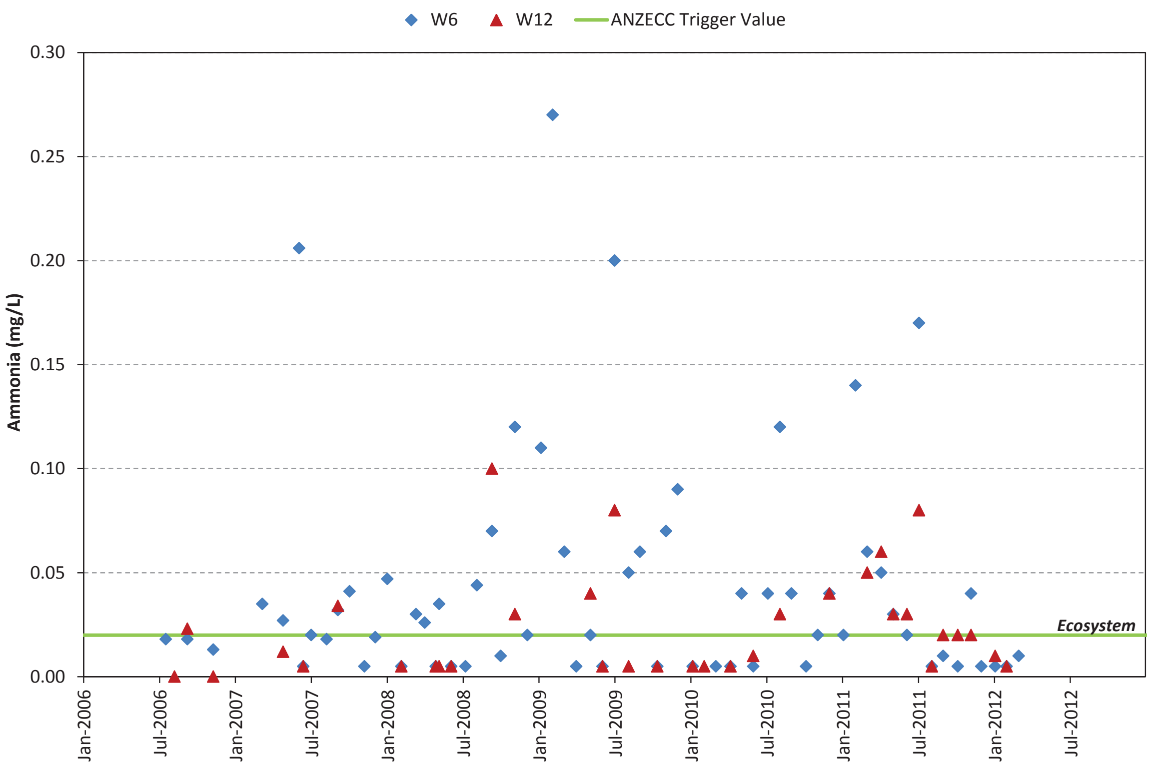


Figure B 26 – Baseline Surface Water Quality Monitoring – Ammonia

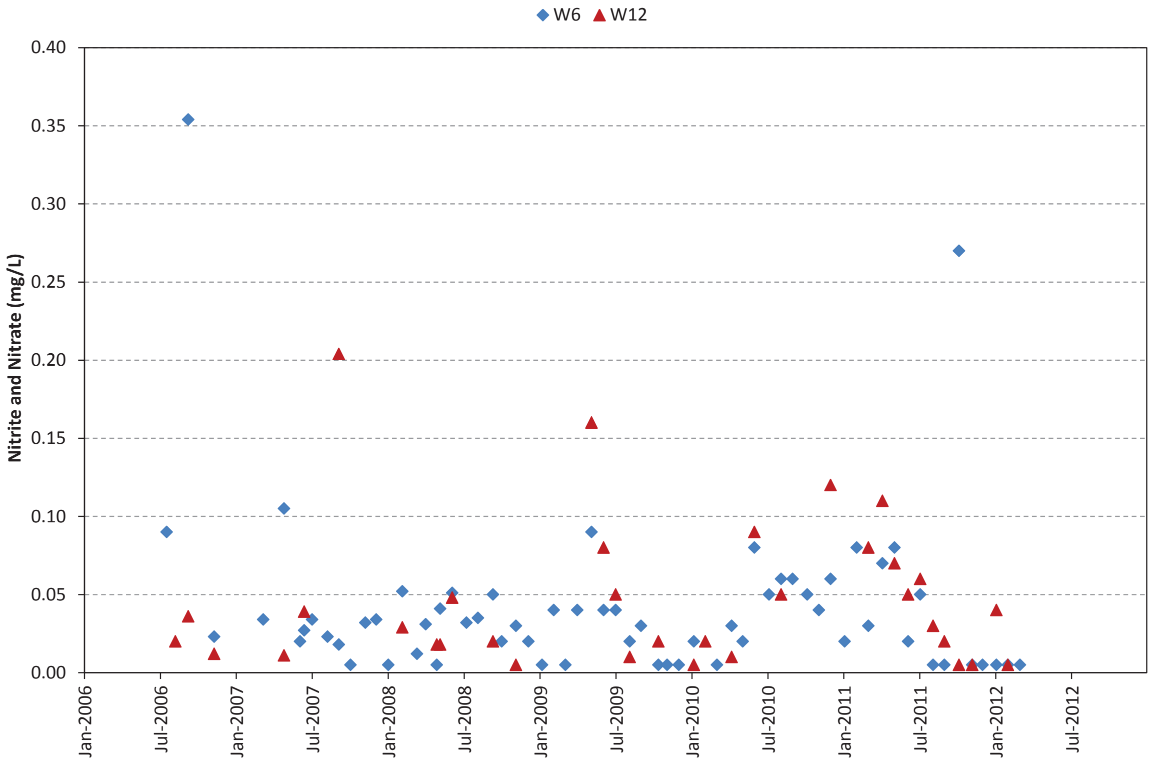


Figure B 27 – Baseline Surface Water Quality Monitoring – Nitrite and Nitrate

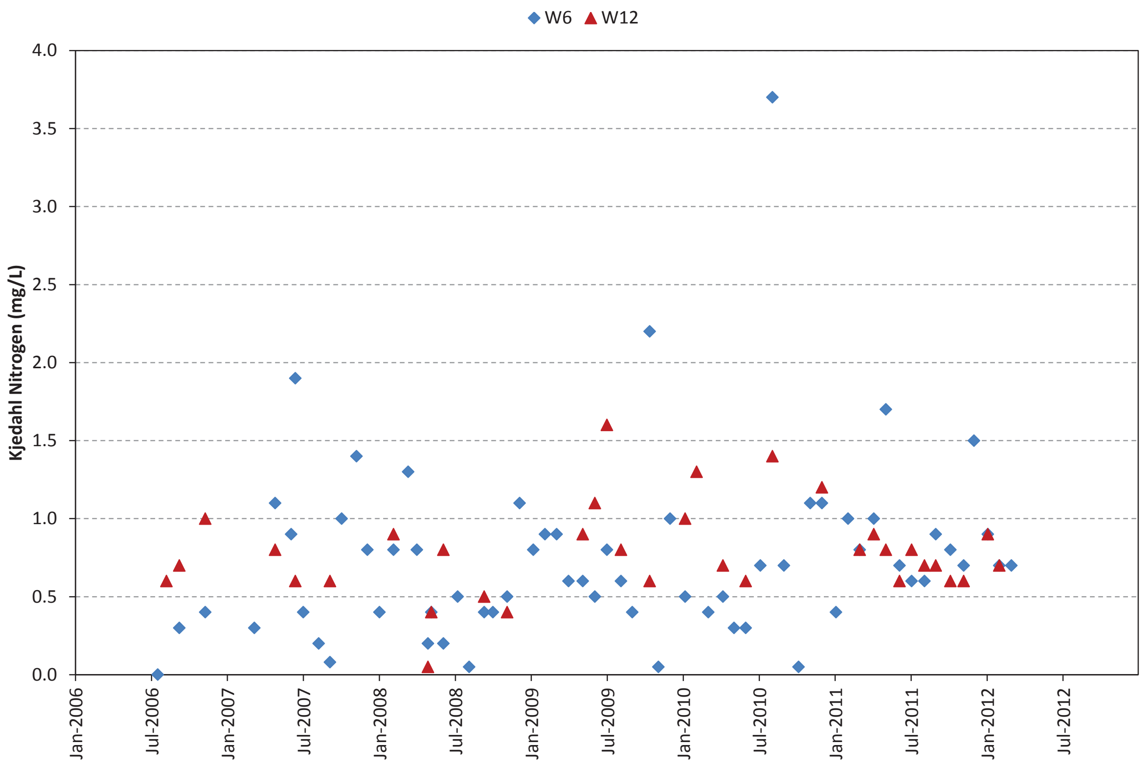


Figure B 28 – Baseline Surface Water Quality Monitoring – Kjedahl Nitrogen

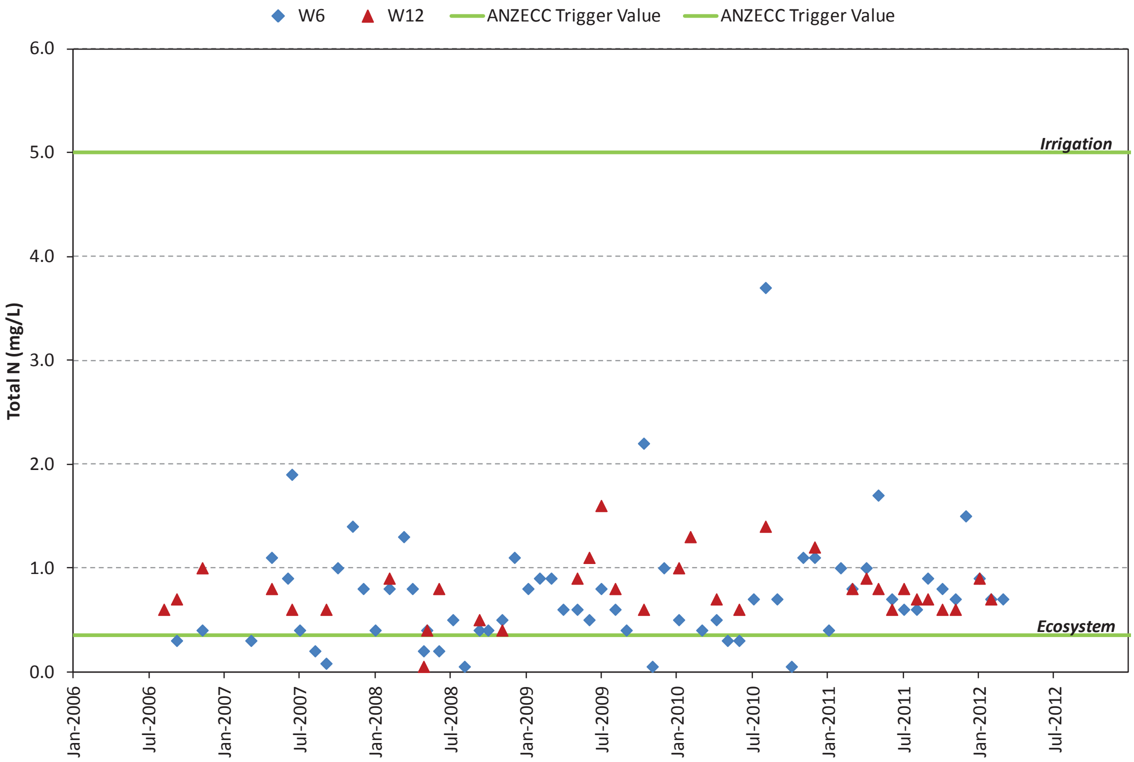


Figure B 29 – Baseline Surface Water Quality Monitoring – Total Nitrogen

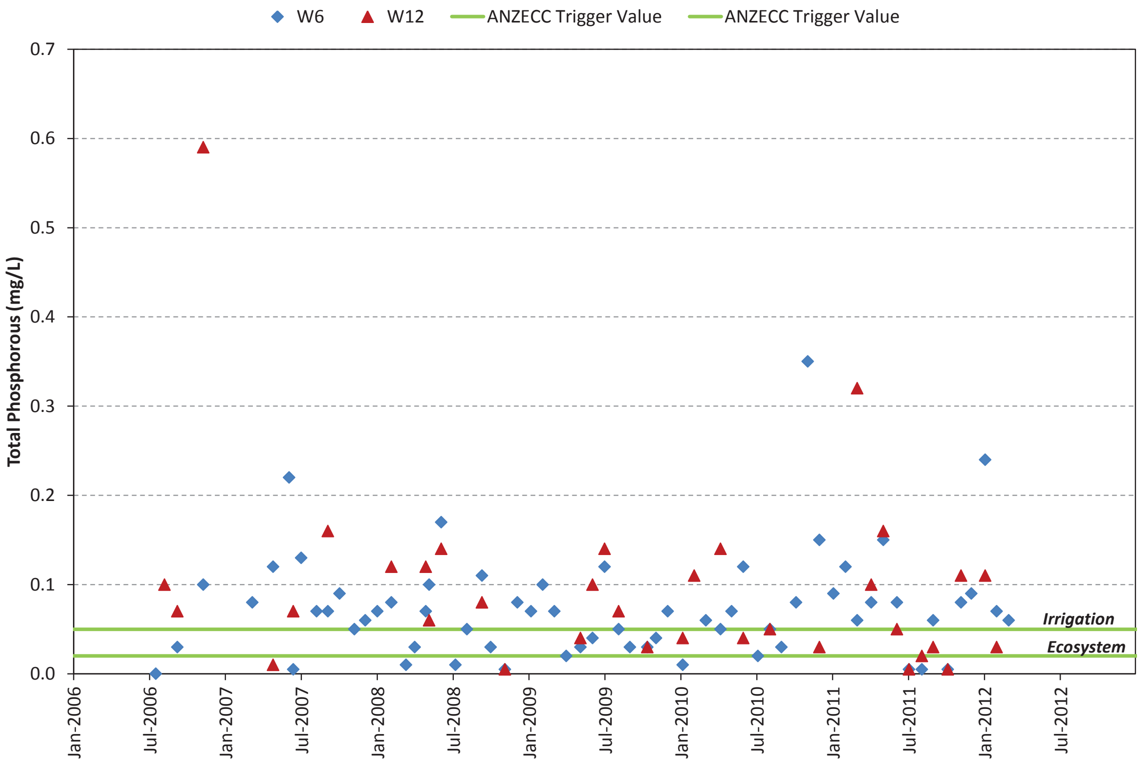


Figure B 30 – Baseline Surface Water Quality Monitoring – Total Phosphorus

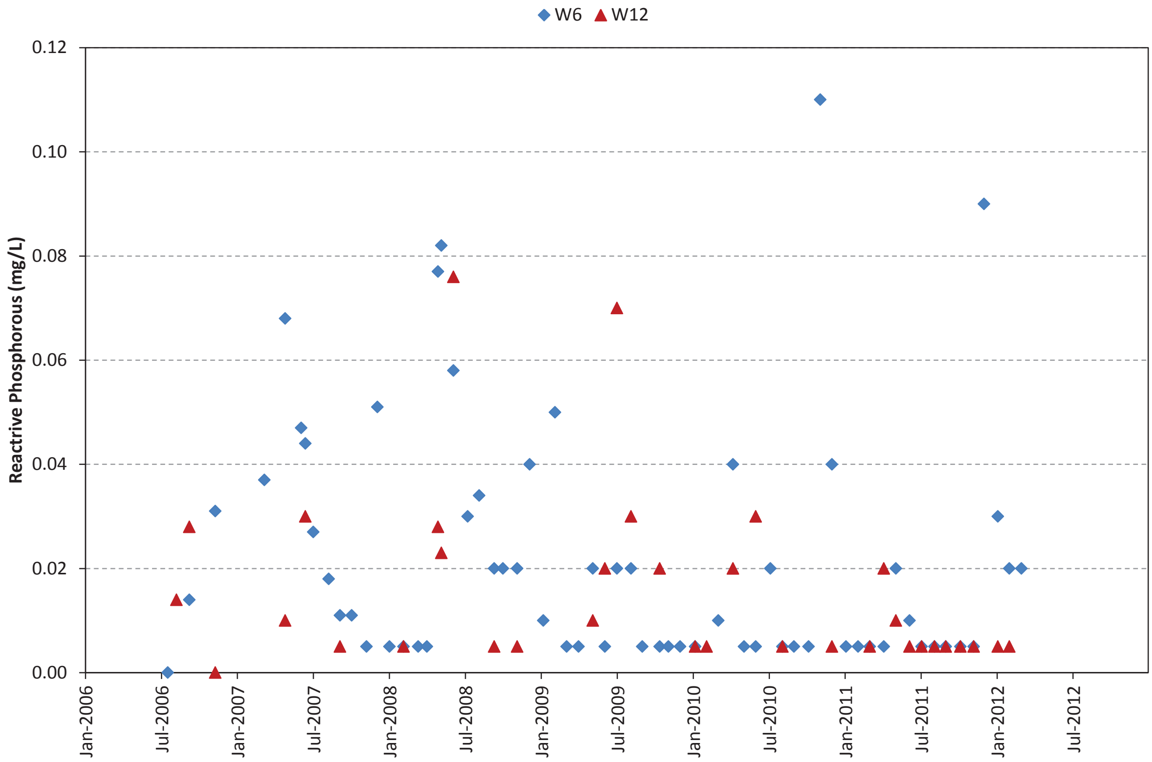


Figure B 31 – Baseline Surface Water Quality Monitoring – Reactive Phosphorous

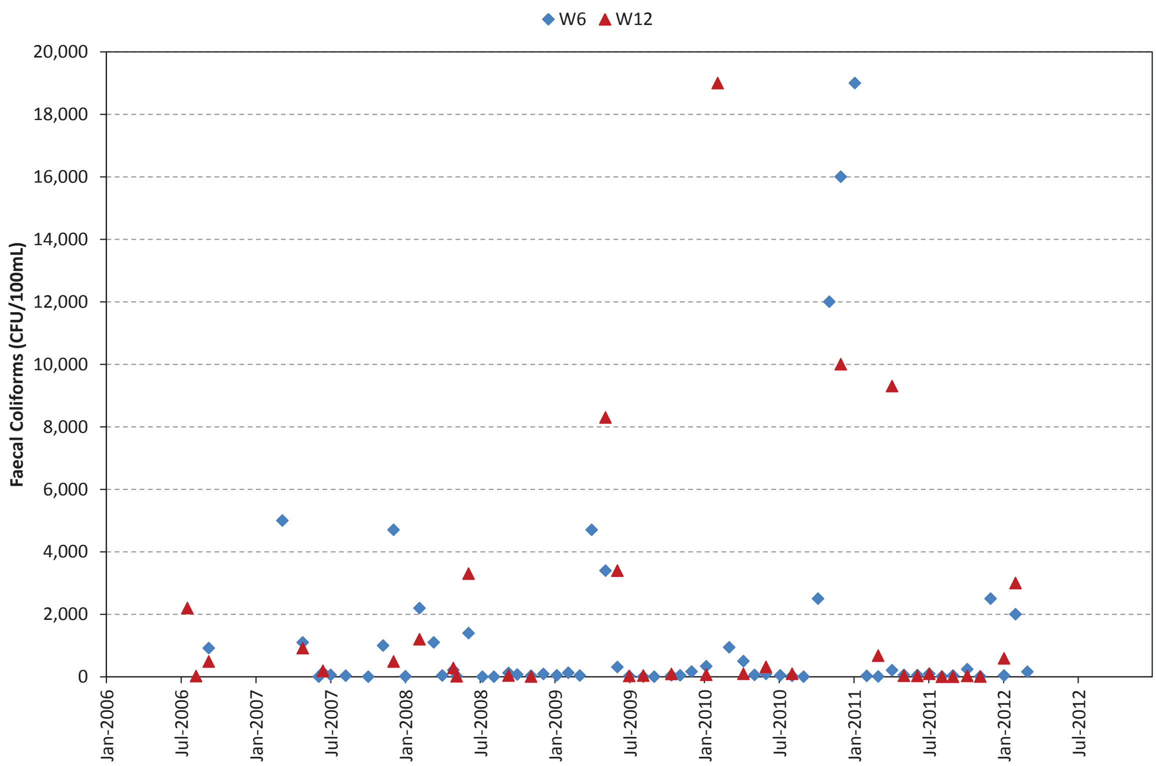


Figure B 32 – Baseline Surface Water Quality Monitoring – Faecal Coliforms

# APPENDIX C

## DIRECTOR GENERAL'S REQUIREMENTS

## Wallarah 2 Coal Project EIS – Director General's Requirements

| Ref | Issue | Relevant Section of Surface Water Impact Assessment |
|---|---|---|
| 9. | • **Water Resources -** including:<br>○ detailed assessment of potential impacts on the quality and quantity of existing surface and ground water resources, including:<br>– detailed modelling of potential groundwater impacts;<br>– impacts on riparian, ecological, geo-morphological and hydrological values of watercourses, including environmental flows;<br>○ a detailed assessment of the potential impacts of the project on:<br>– the quantity and quality of regional water supplies, and in particular the supply of water to the Gosford-Wyong Water Supply Scheme;<br>– regional water supply infrastructure; and<br>– affected licensed water users and basic landholder rights (including downstream water users);<br>○ a detailed site water balance, including a description of site water demands, water disposal methods (inclusive of volume and frequency of any water discharges), water supply infrastructure and water storage structures;<br>○ identification of any licensing requirements or other approvals under the Water Act 1912 and/or Water Management Act 2000;<br>○ demonstration that water for the construction and operation of the development can be obtained from an appropriately authorised and reliable supply in accordance with the operating rules of any relevant Water Sharing Plan (WSP) or water source embargo;<br>○ a description of the measures proposed to ensure the development can operate in accordance with the requirements of any relevant WSP;<br>○ a detailed description of the proposed water management system (including sewage), water monitoring program and other measures to mitigate surface and groundwater impacts; and<br>○ a detailed flood impact assessment, which identifies impacts on local and regional flood regimes and resultant impacts on agricultural land use, transport, services, habitability and public safety, including any measures proposed to mitigate potential flood impacts; | Section 4.5<br>Section 4.8 (Geomorphology)<br>Section 4.6<br>Section 5<br>Section 4.6.2<br>Section 4.2<br>Section 4.6<br>Section 6<br>See Flood Impact Assessment |
| 42. | The Department has significant concerns about the potential impacts from subsidence of waterways in the catchments overlying the proposed mine site.<br>These include loss of water from the creeks into the unconsolidated alluvium, draining the alluvium and changes in stream slope, leading to erosion and excessive ponding.<br>To fully assess the potential impacts the DPI would require:<br>• a full assessment of the subsidence profiles in relation to longitudinal surveys of the creeks systems, identifying areas that may create instability due to slope changes or blockages to natural low water flows;<br>• an assessment of the stability of the creek beds to ensure water loss does not occur;<br>• fully assess the potential for the mine site to be "zero discharge " in relation to groundwater make from the mine and from stormwater collected on surface facilities. | Section 4.9<br>Section 4.9<br>See Groundwater Impact Assessment<br>Section 5 |

| Ref | Issue | Relevant Section of Surface Water Impact Assessment |
|---|---|---|
| 44. | The Office of Water restates its primary requirements as they relate to the equitable sharing of water to all users, including environmental water requirements. These requirements include:<br>• Minimal interaction between the mining operation and the maintenance of minimum and base flows in Jilliby Jilliby Creek and its tributaries and the Wyong River.<br>• Demonstration of minimal risk of interconnection between the mining operation and the alluvial groundwater system connected to the above water sources.<br>• Formation of an appropriate adaptive mining plan which may respond to any inadvertent or unpredicted groundwater impact.<br>• Demonstration that the water sharing arrangements in force to the Jilliby Jilliby Creek and Wyong River water sources will be protected throughout both the life time of any mining operation which is conducted, and the subsequent post-mining period.<br>These requirements should be demonstrated by rigorous analysis of existing and potential surface/ground water interactions both during mine life and into the post-mining period. This must be accompanied by adequate demonstration that the equity of water sharing arrangements in the Jilliby Jilliby Creek and Wyong River water sources will be maintained and environmental water requirements protected, both in terms of maintenance of minimum and base flows and water quality in both water sources. | Section 4.6 |
| 46. | <u>A. Relevant Legislation</u><br>The proposal will require the following approvals under legislation administered by THE NSW Office of Water:<br>• an access licence under the *Water Management Act 2000* (WMA) will be required for any incidental take of surface water from the Jilliby Jilliby Creek catchment.<br>*Note: Any proposal to* access *water from this source must be through purchase* of *existing entitlements and be subject to the rules* of *transfer outlined in the Water Sharing Plan for the Jilliby Jilliby Creek Water Source 2003 (WSPJJCWS).* | Section 4.6.2 |
| 47. | • an access licence under the *Water Management Act 2000* (WMA) will be required for any incidental take of surface water from the Wyong River.<br>*Note: Any proposal to access water from this source must be through purchase* of *existing entitlements and be subject to the rules* of *transfer outlined in the Water Sharing Plan for the Central Coast Unregulated Water Sources 2009 (WSPCCUWS).* | Section 4.6.2 |
| 51. | <u>B. Relevant Policies</u><br>The proposal must address the relevant NSW State Government natural resource management policies, including:<br>• NSW State Rivers and Estuaries Policy<br>• NSW Wetlands Management Policy<br>• NSW Flood Prone Land Policy<br>• NSW Groundwater Policy Framework Document – General<br>• NSW Groundwater Quantity Management Policy<br>• NSW Groundwater Quality Protection Policy<br>• NSW Groundwater Dependent Ecosystem Policy | Section 4 |

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| 52. | <u>C. Statutory Requirements</u><br>The proposal must address the relevant rules of the following water sharing plan, where applicable:<br>• Water Sharing Plan for the Jilliby Jilliby Creek Water Source 2003 (WSPJJCWS);<br>• Water Sharing Plan for the Central Coast Unregulated Water Sources 2009 (WSPCCUWS). | Section 4.6 |
| 53. | <u>D. Relevant Guidelines</u><br>The NSW Office of Water has adopted the following publications as best practice management in the area of stream rehabilitation, groundwater modelling and management of flood liable land:<br>• Cook, Nicholas. 2004. Geomorphic Categorisation of the streams within the Central Coast Catchment Management Board Area. NSW Department of Infrastructure Planning and Natural Resources, Hunter Region. ISBN 0 7347 5412 4 *(Note: This document can be provided by the NSW Office of Water upon request)*<br>• Land and Water Resources Research and Development Corporation. 2000. Rehabilitation Manual for Australian Streams. ISBN 064276030 6.<br>• Middlemis, Hugh. 2001. Groundwater - Groundwater flow modelling guideline. Murray Darling Basin Commission. ISBN 1876830166.<br>• NSW Government. 2005. Floodplain Development Manual. ISBN 073475476 O. | Section 4, Section 6 |
| 66. | 1. <u>Surface Water Impacts</u><br>• details of the existing surface water users (both licensed and stock and domestic users) within the area of the proposal and any potential impacts on these users, including the environment (environmental flows)<br>Note: Gosford Wyong Joint Water Supply Authority is a major water user in the Wyong River catchment. The proposal must detail measures to be put in place to ensure that this water supply is not negatively impacted upon by the proposal. | Section 2.5, Section 4 |
| 67. | • details of potential impacts on surface water features as a result of mine subsidence, including the potential for loss of surface water to the groundwater system and the potential for reversal of surface flows, for individual longwall panels and cumulative risk over the mine life | Section 4.6, Section 4.9 |
| 69. | • a fluvial geomorphic assessment which specifically details the risk of initiation of bed and bank erosion, change in channel slope or plan form, for individual longwall panels and cumulative risk over the mine life | Section 4.9 |
| 71. | • details of a proposed subsidence monitoring program for impact on surface water features, with trigger levels for response actions and remedial measures | Section 6.4 |
| 72. | 2. <u>Water Balance</u><br>• a site-specific water balance, covering both surface and groundwater, must be provided, which includes: sources of water supply location and design specifications for all clean water diversions details of internal drainage of the contaminated water circuit details in regard to any mine water storage proposed for the development discussion of proposed monitoring programs and reporting procedures description of the integrated water management system, including an assessment of the water management system under a range of conditions (including 10%, 50% and 90% wet years, and severe storm events) | Section 5 |

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| 73. | <u>F. Secondary Issue - Flooding</u><br>The primary objective of the *NSW Flood Prone Land Policy* is to reduce the impact of flooding and flood liability on individual owners and occupiers of flood prone property and to reduce private and public losses resulting from floods. The policy also highlights the primary responsibility for floodplain risk management rests with councils, which are provided with financial and technical support by the State Government.<br>Although THE NSW Office of Water has no direct statutory role with regard to flood impacts in the determination of this mining proposal, the possible effects on the flooding behaviour of the catchments of Jilliby Jilliby Creek and Wyong River are important considerations in relation to impacts on surface water features and the mine water balance. The following comments are offered in this regard.<br>The mining proposal may, if approved, result in landform changes in the catchments of Wyong River and Jilliby Jilliby Creek through mine subsidence. These changes in the landform, especially in the floodplain, have the potential to alter the flooding characteristics of the catchment. These possible changes to the landform may take place for at least the proposed mine life of 42 years.<br>The proponent should be required to undertake a study to assist in the determination of the effects of the mining proposal on flood prone property. Any flood study required should be in line with the provisions set down in the state government's Floodplain Development Manual.<br>The flood study should include, but not be limited to, ecological impacts of flooding, such as: an assessment of the impact of change of flood level and flow characteristics on ecological communities, especially riparian vegetation, wetlands, groundwater dependent ecosystems, floodplains and not only focus on threatened ecological communities. It should also include an assessment of the impact of change of flood level and flow characteristics on geomorphic stability of watercourses. | See Flood Impact Assessment |
| 79. | This year (2011) has seen the connection of a pipeline allowing water to be pumped from the Wyong River weir to Mangrove Dam, providing greater security to the Central Coast's water supply. The Australian Drinking Water Guidelines have just been updated. These changes and the provision of more details about water management will require comprehensive documentation within the EIS itself. The EIS should include, and not be limited to addressing the following matters. | Section 2.4 |
| 80. | It is noted that the proposed extraction area represents about 5% of the surface area of the local water supply catchment area. The EIS should quantify the volume of water flowing through the waterways, especially Wyong River and Jilliby Creek. The surface area of the catchment feeding into these waterways, and their respective water flows are what is at risk should there be any adverse effects. They should be clearly identified. | Section 2.4, 2.7 |
| 81. | It is expected the EIS will address the ability of the project to meet the required outcomes of the various water management strategies. | Section 4 |
| 82. | It is noted that water will be carted on site until the facilities are connected to town water. The EIS should confirm there is no intent to have direct potable reuse. The EIS should confirm the use of carted water and how the water supply will comply with NSW Health Private Water Supply Guidelines. Similarly, wastewater management strategies should be clearly described for the period prior to connection to town sewerage system, and any additional systems that will be in place after this connection. | Section 4.2 |
| 83. | The EIS should quantify the likely volumes and chemical characteristics, including contaminants, in water taken from the mine. The EIS should describe how it will be treated, the quality of this treated water, and health risk assessments relevant to the planned uses of this water. | Section 2.9, 5.11 |

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| 84. | In the Background Document p32, undertakings are made to protect surface water flows. The EIS should address the effectiveness of these undertakings and design. | Section 4.9 |
| 85. | The EIS should demonstrate that water treatment processes (extracted water and surface facility wastewater), and stormwater management will comply with applicable guidelines to prevent impacts on the environment and on human health. | Section 4 |
| 217. | 5. Provide details of how waste will be handled and managed onsite to minimise pollution, including:<br>a) Stockpile location and management | |
| 218. | b) Erosion, sediment and leachate control including measures to be implemented to minimise erosion, leachate and sediment mobilisation at the site during works. The EIS should show the location of each measure to be implemented. The Proponent should consider measures such as:<br>• Sediment traps<br>• Diversion banks<br>• Sediment fences<br>• Bunds (earth, hay, mulch)<br>• Geofabric liners<br>• Other control measures as appropriate | Section 6.3 |
| 219. | The Proponent should also provide details of:<br>• how leachate from stockpiled waste material will be kept separate from stormwater runoff;<br>• treatment of leachate through a wastewater treatment plant (if applicable); and<br>• any proposed transport and disposal of leachate off-site. | Section 3 |
| 231. | **Flooding and coastal erosion**<br>The EIS should include an assessment of the following referring to the relevant guidelines in Attachment 2:<br>1. Whether the proposal is consistent with any floodplain risk management plans. | See Flood Impact Assessment |
| 232. | 2. Whether the proposal is compatible with the flood hazard of the land. | See Flood Impact Assessment |
| 233. | 3. Whether the proposal will significantly adversely affect flood behaviour resulting in detrimental increases in the potential flood affectation of other development or properties. | See Flood Impact Assessment |
| 234. | 4. Whether the proposal will significantly adversely affect the environment or cause avoidable erosion, siltation, destruction of riparian vegetation or a reduction in the stability of river banks or watercourses. | Section 4.9 |
| 235. | 5. Whether the proposal incorporates appropriate measures to manage risk to life from flood. | See Flood Impact Assessment |
| 236. | 6. Whether the proposal is likely to result in unsustainable social and economic costs to the community as a consequence of flooding. | See Flood Impact Assessment |

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| 242. | **Water**<br>Describe Proposal<br>1. Describe the proposal including position of any intakes and discharges, volumes: water quality and frequency of all water discharges. | Section 3, Section 4 |
| 243. | 2. Demonstrate that all practical options to avoid discharge have been implemented and environmental impact minimised where discharge is necessary. | Section 3, Section 4 |
| 244. | 3. Where relevant include a water balance for the development including water requirements (quantity, quality and source(s)) and proposed storm and wastewater disposal, including type, volumes, proposed treatment and management methods and re-use options. | Section 5 |
| 245. | Background Conditions<br>4. Describe existing surface and groundwater quality. An assessment needs to be undertaken for any water resource likely to be affected by the proposal. | Section 2 |
| 246. | Proponents are generally only expected to source available data and information. However, proponents of relatively large and/or high risk developments may be required to collect some ambient water quality / river flow / groundwater data to enable a suitable level of impact assessment. Issues to include In the description of the receiving waters could also include, for example:<br>o water chemistry<br>o a description of receiving water processes circulation and mixing characteristics and hydrodynamic regimes<br>o lake or estuary flushing characteristics<br>o sensitive ecosystems or species conservation values<br>o specific human uses (e.g. fishing, proximity to recreation areas)<br>o a description of any impacts from existing industry or activities on water quality<br>o a description of the condition of the local catchment e.g. erosion, soils, vegetation cover, etc<br>o an outline of baseline groundwater information, including, for example depth to watertable, flow direction and gradient, groundwater quality, reliance on groundwater by surrounding users and by the environment<br>o historic river flow data | Section 2 |
| 247. | 5. State the Water Quality Objectives for the receiving waters relevant to the proposal. These refer to the community's agreed environmental values and human uses endorsed by the NSW Government as goals for ambient waters (http://www:environment.nsw.gov.au/ieo/index.htm). Where groundwater may be impacted the assessment should identify appropriate groundwater environmental values. | Section 2.9 |
| 248. | 6. State the indicators and associated trigger values or criteria for the identified environmental values. This information should be sourced from the ANZECC (2000) Guidelines for Fresh and Marine Water Quality (http://www.mincos.gov.au/publications/Australian_and_new_zealand_guidelines_for_fresh_and_marine_water_quality). | Section 2.9 |
| 249. | 7. State any locally specific objectives, criteria or targets which have been endorsed by the NSW Government. | Section 2.9 |

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| 250. | <u>Impact Assessment</u><br>8. Describe the nature and degree of impact that any proposed discharges will have on the receiving environment.<br>• Depending on the nature, scale and/or risk of the proposal, this could include specific requirements to consider impacts on, for example:<br>o water circulation, current patterns, water chemistry and other appropriate characteristics such as clarity, temperature, nutrient and toxicants<br>o changes to hydrology (including drainage patterns, surface runoff yield, flow regimes, and groundwater)<br>o disturbance of acid sulphate soils and potential acid sulfate soils<br>o stream bank stability and impacts on macro invertebrates | Section 4 |
| 251. | • Depending on the nature, scale and/or risk of the proposal, modelling, monitoring, or both, may need to be undertaken to assess the potential impact of discharges on the receiving environment. If modelling is required to assess the potential impact of any discharge(s), this could include, for example:<br>o a range of scenarios that encompass any variations in discharge quality and quantity as well as the relevant range of environmental conditions of the receiving waters. The scenarios could describe a set of worst-case conditions and typical conditions to ensure that both acute and chronic impacts are assessed<br>o assumptions used in the modelling, including identification and discussion of the limitations and assumptions to ensure full consideration of all factors, including uncertainty in predictions. | Section 4 |
| 253. | 9. Assess impacts against the relevant ambient water quality outcomes. Demonstrate how the proposal will be designed and operated to:<br>o protect the Water Quality Objectives for receiving waters where they are currently being achieved: and<br>o contribute towards achievement of the Water Quality Objectives over time where they are hot currently being achieved | Section 4 |
| 254. | 10. Where a discharge is proposed that includes a mixing zone, the proposal should demonstrate how wastewater discharged to waterways will ensure the ANZECC (2000) water quality, criteria for relevant chemical and non-chemical parameters are met at the edge of the initial mixing zone of the discharge, and that any impacts in the initial mixing zone are demonstrated to be reversible. | Section 4 |
| 256. | 12. Describe how stormwater will be managed both during and after construction. | Section 6 |
| 257. | <u>Monitoring</u><br>13. Describe how predicted impacts will be monitored and assessed over time.<br>• For relatively large and/or high risk developments, proponents should develop a water quality and aquatic ecosystem monitoring program to monitor the responses for each component or process that affects the Water Quality Objectives that includes, for example:<br>o adequate data for evaluating compliance with water quality standards and/or Water Quality Objectives<br>o measurement of pollutants identified or expected to be present in any discharge<br>• Water quality monitoring should be undertaken in accordance with the *Approved Methods for the Sampling and Analysis of Water Pollutant in NSW (2004)* (http://www.environment.nsw.gov.au/resources/legislation/approvedmethods-water.pdf). | Section 6 |

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| 260. | Council's most significant concerns are in respect to the serious risk posed by any large scale extractive industry within the Dooralong and Yarramalong Valleys to the security of the Central Coast region's water supply. In addition, Council has grave concerns relating to the potential irreparable environmental damage which may be created by the proposed coal mine, including the failure of creek systems and resultant impact on flora and fauna. | Section 4 |
| 262. | Issues:<br>• The proposed mine is in a major water supply catchment.<br>• It is directly under water supply streams and infrastructure.<br>• Water resources on the Central Coast are very limited and any loss of water resources/supply will affect the ability to supply the growing population.<br>• Potential for negative impacts on the water sources and the town water supply.<br>• Disruption of aquifers feeding water supply streams.<br>• Water quality may be impacted.<br>• Significant dependence on surface water and groundwater by residents and agriculture in the extraction area.<br>What is needed:<br>• Ground water modelling.<br>• Surface water modelling.<br>• Assessment of impacts on water/groundwater quality and quantity.<br>• Independent interpretation of methodology and results.<br>• Extensive baseline data.<br>• Establishment of a rigorous monitoring and evaluation program over the life and following closure of the mine to identify the impact of the mine on the town water supply with a linked mitigation / compensation program for any negative impacts. | Section 4, Section 5, Section 6 |
| 267. | Issues:<br>• There will be significant impacts by the development on roads/water/sewer and telecommunication services.<br>• The development offers opportunities for upgrading of road/water/sewer and telecommunications services.<br>• It is important that the development be closely linked to commuter services, such as, nearby rail stations and providing alternative access, such as, cycle ways, so that car and truck access is minimised.<br>• Opportunity for the use of tertiary treated effluent from Council's treatment plants.<br>What is needed:<br>• Transport study clearly defining proposed access systems both for construction and maintenance as well as commuter access.<br>• Analysis of impacts of haulage on the long term performance of Council's roads (pavements). The analysis should include impacts of haulage routes with regard to environmental capacity (refer to RTA Guide to Traffic Generating Developments). | |

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| | • Detailed water balance during construction and over the full lifetime of the project.<br>• Clarification of the use of and the amounts required of Council recycled effluent.<br>• Clarification of the potential provision by the development of water for domestic use.<br>• Power requirements including the potential impact of providing electricity, gas and other forms of power.<br>• Details of proposals for engineering services to be fed back into systems, such as, the provision of potable water, methane gas, environmentally sustainable energy production (eg. wind power or solar). | Section 5 |
| 271. | Issues:<br>• Local creeks flood rapidly.<br>• There is generally poor access for residences in the area of proposed extraction.<br>• There is the likelihood of increased flooding for some properties due to subsidence.<br>What is needed:<br>• Before and after subsidence flood modelling.<br>• Compensation programs for impacts arising.<br>• Emergency evacuation programs for flood affected properties.<br>• Extensive baseline data. | See Flood Impact Assessment |
| 278. | The EIS must outline the interaction between the proposed mining activities and the existing environment and include a comprehensive description of the following activities and their impacts, as follows:<br>• underground mine entries, and the scheduling and layouts of long walls; | |
| 282. | • water management. | Section 3, Section 4, Section 5 |
| 291. | The following significant issues relating to subsidence impacts/management for the Wallarah No 2 proposal have been identified by ORE: | |
| 293. | 3. A significant number of properties/structures located in flood prone areas are proposed to be undermined. Properties / structures already affected by flooding may be subject to greater flood impacts and properties/structures not previously affected by flooding may be impacted by flooding as a result of the proposed mining. In addressing this issue, the proponent will have significant challenges with respect to community issues, identification of all affected features, selection of appropriate mine design and development of effective management strategies. | See Flood Impact Assessment |
| 294. | 4. There are identified watercourses, catchment areas and aquifers that may be affected by subsidence which provide or may provide water to the population centre of Wyong. A detailed and rigorous assessment of the potential impacts to water resources as a result of subsidence will be necessary. | Section 4 |