6 Key Environmental Issues

This chapter provides an assessment of the key environmental issues associated with constructing and operating the Proposal. Possible impact mitigation and management measures that may be implemented are also identified.

6.1 Overview

This EA describes the Proposal's potential impacts on the surrounding environment, focusing on the key issues in the Director-General's Requirements and issues raised in stakeholder consultation. The issues addressed are:

- marine water quality
- inland water quality
- flora and fauna
- Aboriginal heritage
- non-Aboriginal heritage
- soils and groundwater
- noise and vibration
- air quality
- hazards and risks
- flooding
- environmental risk analysis.

Each of these issues is addressed in a separate section that describes the existing condition and assesses the Proposal's impacts on that issue during construction and operation. The type of assessment was tailored according to the issue and associated level of environmental risk, and included a combination of desktop and field studies to address the Director-General's requirements. Mitigation measures are included where necessary to minimise impacts or clarify Sydney Water's standard practice. These mitigation measures informed the development of the draft Statement of Commitments in Chapter 10.

To provide some context of the environment in which the Proposal will operate, Section 6.2 includes a brief description of the anticipated future environment in the WDURA and AGAs. The chapter concludes with an environmental risk analysis demonstrating relevant issues for the Proposal have been assessed.

The Proposal relies on extending the existing water and wastewater systems in the Illawarra Region, specifically transferring flows to the Wollongong WRP and the Shellharbour WWTP. The Wollongong WRP and Shellharbour WWTP have existing approvals to receive and treat average dry weather flows up to 59 and 20 ML/day respectively (DUAP 2001 and Sydney Water 2003a). The Proposal seeks to potentially increase these capacities to 62.2 and 22.2 ML/day respectively, although this is not expected to be required until some time after 2031. The EA includes some assessment of the impacts of the increased capacities. Sydney Water is not seeking, and the DGRs do not require, this EA to revisit the previous approvals.

6.1.1 Assessment approach

Sydney Water completed desktop reviews for all the environmental issues listed above. Field assessments were also undertaken where it was considered necessary to adequately assess the impacts in accordance with the Director-General's requirements. For some environmental issues, specialist technical assessments were performed and these are attached as Appendix C - I. The technical assessments were prepared for the dual purpose of:

- identifying environmental constraints that could be considered during subsequent detailed design phases; and
- assessing potential environmental impacts to address the Director-General's requirements.

The technical reports identified constraints and developed recommendations to minimise potential impacts associated with those constraints. The recommendations were developed in isolation and did not consider the context of other environmental issues, or engineering and operational limitations. This approach was adopted because the Proposal is currently at a planning stage and will be refined during subsequent detailed design phases that will be staged to meet development timeframes set by the DP&I.

As detailed design of the Proposal progresses, it is possible that refinements will be made to the construction method, location of infrastructure, and means of operating the water and wastewater systems. The design process would consider the mitigation measures described in this chapter, the Statement of Commitments (Chapter 10), and the appropriateness of adopting the recommendations suggested in the technical reports to reduce potential environmental impacts. As many of the recommendations would involve revising either the construction method or location of infrastructure to avoid potential impacts, it is most appropriate that this is considered during the detailed design. Where there are conflicting recommendations between the technical reports, the significance of the impacts associated with each issue would be considered when completing the detailed design. This approach will allow the recommendations to be considered at the time detailed design is undertaken for that stage.

The Proposal has evolved since the technical reports were completed and there are inconsistencies between the description of the Proposal and mitigation measures described in the main body of the EA, and the content and recommendations in the technical reports. The network of pipelines and associated infrastructure was refined after the technical reports for Aboriginal heritage, non-Aboriginal heritage, and soils and groundwater were completed. Sydney Water is seeking approval for a smaller network of pipelines than that assessed in the technical reports, meaning that the technical reports overestimate the extent of impacts. The main body of the EA prevails to the extent of any inconsistency with the technical reports.

This chapter summarises the findings of the environmental investigations undertaken for the Proposal and demonstrates that Sydney Water has a detailed understanding of potential environmental impacts. The assessment accommodates possible changes to the Proposal by assessing maximum impacts along pipeline corridors and within sites. In most instances a larger area than will actually be impacted has been assessed (referred as the Field Assessment area), but there may also be changes that occur outside the Field Assessment area.

To provide some flexibility for site layouts and pipeline alignments, Sydney Water seeks approval for:

- the Proposal to be located anywhere within the Field Assessment Area described below
- the Proposal to be located outside the Field Assessment Area where:
    - changes are consistent with the environmental objectives of the Proposal, and
    - environmental impacts are no greater than those described in this EA, and
    - no additional environmental mitigation measures are required.

Consistency assessments would be undertaken if components of the Proposal are refined during detailed design and modification to the Project Approval would only be sought if the changes are inconsistent and/or the potential impacts are predicted to be greater than those described in this chapter.

6.2 Future environment

The WDURA and AGAs are divided into a number of Precincts to facilitate the staged release of land for development over a period of approximately 40 years. As a result, the environmental and social context in which the Proposal will be developed will differ from that which is currently present.

The landscape in the Proposal area will change significantly as rezoning and development progresses. Land ownership is likely to change from relatively large land holdings, with low density homes and agricultural buildings, to many small land holdings with homes and commercial premises located close to each other. Land use would change from predominantly rural residential, agriculture, and some industrial areas, to varying densities of residential use. Town centres will also be established to complement the existing and proposed residential development. In addition to water related services, infrastructure such as roads, electricity, gas and communications will be substantially expanded as part of the urban development.

The visual character of the area is expected to change over time and progressively become more urbanised. Background noise levels are likely to increase, mainly due to additional traffic and transport and increased residential density. Precinct planning would take into account environmental values of the WDURA and AGAs to minimise environmental impacts. Conservation and parkland areas may be established to minimise impacts on areas of ecological and heritage significance and provide recreational facilities.

Although the exact nature of the future environment is unknown, the assessments have taken into account how the Proposal may potentially impact on the environment. Depending on the changes to the environment that have already occurred when Sydney Water commences construction and operation of the various components of the Proposal, the potential impacts identified in this EA may not necessarily occur. For example some areas of vegetation may have already been cleared by other development related activities, such as constructing or widening roads.

6.3 Marine water quality

This section includes a summary of the *West Dapto Urban Release Area and Adjacent Growth Areas Prediction of Marine Impacts* prepared by Sydney Water in October 2011. The main objective of the study was to address the Director-General's requirements relating to potential impacts of the Proposal on the marine environment. The study focused on impacts to public health, water quality and marine aquatic ecology. The assessment is attached as Appendix C.

6.3.1 Existing environment

The coastline in the Proposal area consists of rocky headlines and sandy beaches (Figure 6-1). The inshore seabed is a mixture of rock, sand, shell and clay, which becomes mostly sand with interspersed rocky reef within two kilometres of the shore. The seabed around Port Kembla WWTP is rocky, with Red Point marking a geological boundary between sandy seabed to the southwest and rock and gravel to the north and east. The shoreline at the Wollongong WRP is a long sandy beach. Fine to medium sand extends offshore to approximately seven metres depth. The offshore seabed is a mixture of rocky reef, sand and clay. A large irregular sandstone reef extends from between seven metres and 21 metres consisting of rocky outcrops and pinnacles, areas of flat rock and sandy patches. Sand extends from the shoreline to beyond the 20 m depth contour. The shoreline near Shellharbour WWTP also comprises sandy beaches interspersed with rocky reef platforms. The rocky shores are popular for swimming, boating and recreational fishing.

As described in Chapters 2 and 3, there will be an increase in population as the WDURA and AGAs are developed. This will increase the volume of effluent (treated wastewater) discharged to the marine environment. Potential impacts have already been assessed under the IWWS and Shellharbour REF (Sydney Water 2003a and DUAP 2001). This EA confirms the previous assessments' findings, and assesses the impacts from the incremental increase in effluent volume beyond that already approved.

Figure 6-1 The coastal environment looking southward to Shellharbour

In normal, dry weather conditions, discharge is from the main Shellharbour WWTP and Wollongong WRP outfalls (see Figure 2-1). The main Shellharbour WWTP outfall is located off Barrack Point, located between Warilla in the North and Bass Point to the South. The outfall is approximately 120 m offshore at approximately eight metres depth. The main Wollongong WRP outfall is located 1,000 m from the shore in water approximately 20 m deep.

In some wet weather events, effluent may also be discharged to the ocean via the existing ocean outfalls at Shellharbour and Port Kembla WWTPs. An emergency overflow is constructed at Shellharbour WWTP to divert flow to Barrack Creek. This provides a ‘controlled’ discharge in emergency situations for example, in the event of a power failure. Port Kembla WWTP receives diverted wastewater from Wollongong WRP in large wet weather events. The Port Kembla WWTP outfall discharges about six metres below sea level on the seaward edge of the Red Point peninsula on which the WWTP is located. The peninsula juts out approximately 1 km from the coast.

It is possible for untreated and partially treated wastewater and urban catchment runoff to reach the marine environment and beaches via stormwater drains in some wet weather events. For wastewater, this is due to the volume of wastewater exceeding the hydraulic capacity of the wastewater pipes at certain points. Figure 6-2 shows the locations where diluted wastewater overflows may occur, that can reach the marine environment via stormwater drains. These are overflow points that already exist in the wastewater system. Although new overflow points will be constructed as part of the Proposal, they are not hydraulically modelled to overflow.

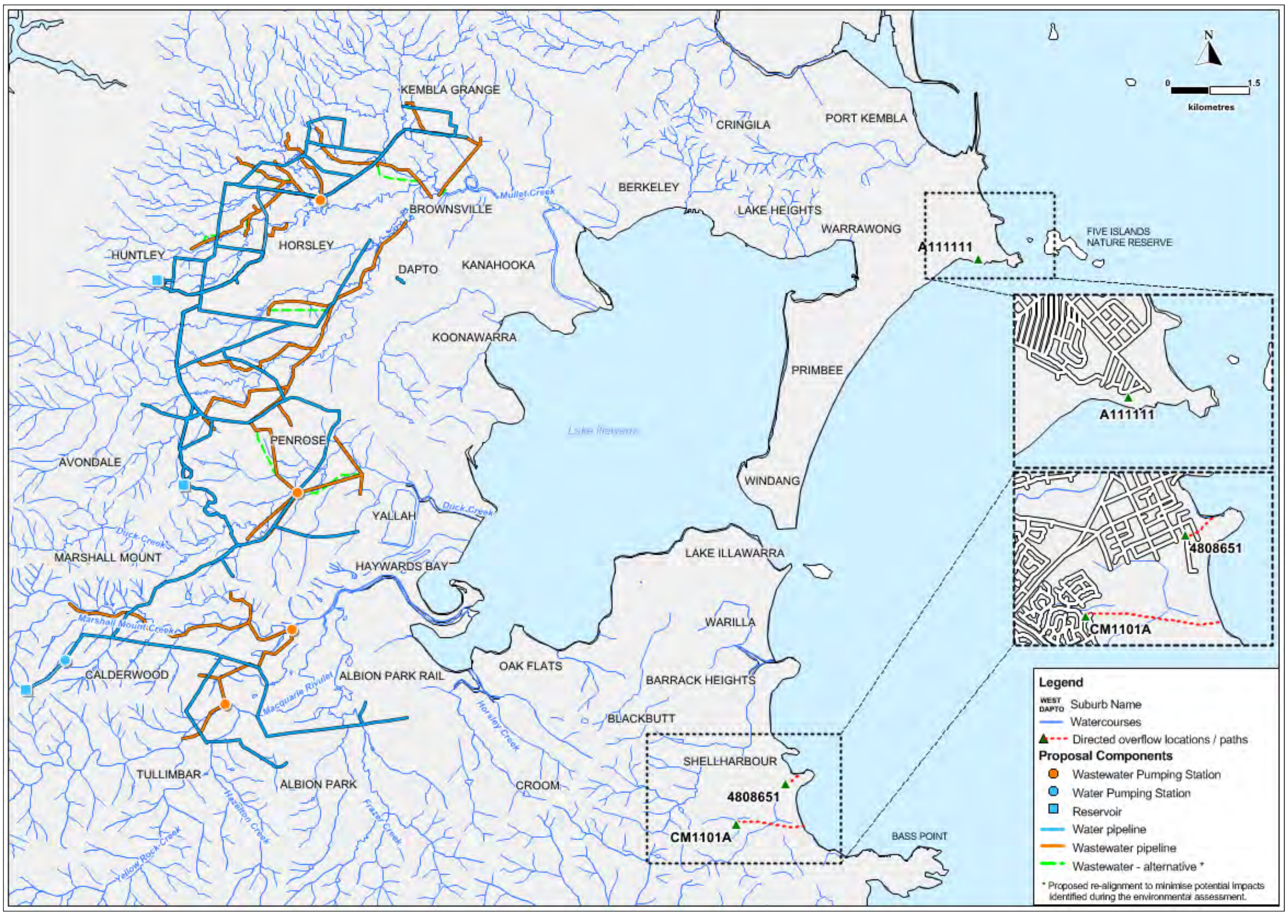


Figure 6-2 Locations of inland overflows that may reach the marine environment and beaches

Water quality

In the Illawarra Region, various land-based discharges can affect coastal water quality, including, WWTPs, industrial sources and stormwater run-off. In addition, naturally occurring events can cause elevated concentrations of substances that can temporarily affect water quality, such as upwellings of nutrient-rich waters that can cause surface algal-blooms (Dela-Cruz et al 2002; Pritchard et al 2003).

Water quality in the Proposal area has improved following implementation of Sydney Water's Illawarra Wastewater Strategy (IWWS) (Sydney Water 1999). The IWWS included:

- cessation of dry weather effluent flow to Port Kembla WWTP
- increased treatment capacity and upgraded treatment technology at Wollongong WRP
- construction of a replacement outfall to discharge effluent outside of the bathing zone.

Water quality monitoring following commissioning of the IWWS confirmed that effluent discharges complied with ANZECC (1992), the relevant water quality guidelines at that time.

Data from a CSIRO monitoring station, together with data collected by Sydney Water indicate that background concentrations of some substances already exceed the current, ANZECC (2000) default trigger values.

The following shows the percentage of samples that exceeded the ANZECC (2000) default trigger values:

- total nitrogen (TN) 93%
- total phosphorus (TP) 6%
- ammonia (22%).

This suggests that the ANZECC (2000) default trigger values may not appropriately describe water quality indicators when applied to the local ambient conditions in the Sydney and Illawarra Region (ie ambient conditions may mean that less stringent levels may be more appropriate). However they have been used in this EA for comparative purposes in the absence of any suitable alternatives.

Aquatic ecology

One of the main objectives of the IWWS was to improve water quality so that aquatic ecosystems were protected. Where potential impacts from this Proposal occur at existing outfalls, this EA draws on the comprehensive studies conducted as part of the IWWS environmental impact assessments and subsequent monitoring results.

Impacts on marine ecological communities and their habitats arise from interactions with contaminants, nutrients and sediments in discharges from streams, stormwater drains and treatment plants, as well as human activity such as fishing. A summary of the existing aquatic ecological environment is provided below, and more detail can be found in Sydney Water (1999 and 2003a).

Habitats

The Illawarra coastline provides a diverse range of marine habitats, including the water column, rocky shores and reefs, sedimentary (sand, mud and clay strata) and artificial habitats such as jettys, pipelines and shipwrecks. These can be broadly divided into hard and soft substrate habitats.

Soft substrate habitats are rich in invertebrate life, such as marine worms, snails, echinoderms and crustaceans, and have a distinctive fish fauna dominated by rays, flatfish, flathead and whiting. This habitat is prevalent near the Wollongong WRP outfall, which lies within a sandy substrate with small patches of clay.

Hard substrates are major habitats for attached algae (eg kelp), a large variety of attached invertebrates (eg barnacles in intertidal and shallow subtidal waters) and sponges. A large variety of reef fish and mobile invertebrates inhabit reef areas. The seafloor around the Shellharbour WWTP outfall is predominantly rocky reef, with barren gullies and interspersed sandy patches (Sydney Water 2003a). The Port Kembla WWTP outfall discharges from a cliff base onto predominantly rocky reef. The outfalls are fairly exposed to ocean conditions. Habitats consist of kelp beds, large boulders and sand channels. Discharge locations are illustrated on Figures 6-3 and 6-4.

Five Islands Nature Reserve and Bass Point Marine Reserve

Offshore and to the north of Red Point (where Port Kembla WWTP discharges) is the Five Islands Nature Reserve, which is an important rookery for seabirds and is used by a large variety of other marine organisms.

The marine environment around Bass Point is the most significant aquatic resource occurring in the local area. Bushrangers Bay, on the eastern edge of Bass Point, has been declared an Aquatic Reserve under the FM Act. The intertidal area supports unique communities of crustacean, mollusc and cnidarian species. The site also has significant recreational and education values due to the diversity and accessibility of marine fauna and flora in both intertidal and subtidal habitats.

Flora and fauna

Marine flora and fauna in the area can be broadly divided into communities:

- associated with soft substrates (eg sediments near the Wollongong WRP outfall)
- associated with rocky reef and intertidal areas (eg the outfalls at Port Kembla and Shellharbour WWTPs)
- within the water column.

Sandy substrates indicative of those near the Wollongong WRP outfall provide habitat for drift algae (ie algae dislodged from the reef) and other macro and micro algae. Fauna in the sandy substrate are often diverse and abundant, including worms, bivalves, crustaceans and occasionally echinoderms.

The Port Kembla WWTP outfall lies in approximately seven metres of water and therefore tides are an important influence on local flora and fauna. In the intertidal habitat there are snails, barnacles, and corraline and other algae. No subtidal biota surveys were conducted for the IWWS at Port Kembla as the conditions were considered unsafe to carry out such work.

Near the Shellharbour WWTP outfall there are subtidal boulders encrusted with hard coralline algae, fields of filamentous and other tufting algae and kelp fields in waters below three metres deep. Fauna included sponges, limpets and gastropods. The intertidal zone community comprises of littorinids (molluscs), barnacles and low-shore algae and sea squirts (Sydney Water 2003a).

Surveys were conducted for the IWWS to record any threatened, endangered or protected fish species under the FM Act. The blue groper and weedy sea dragon were recorded near the Wollongong reefs (the former was common throughout the reef, and the latter was observed in deeper water). A separate study was conducted to establish the extent of the weedy seadragon habitat, which informed the location of the new Wollongong WRP outfall as part of the IWWS (TEL 1999).

Sydney Water (2003) reported that the Shellharbour area supported one threatened species and three species protected under the FM Act. The threatened species was the grey nurse shark and the protected species were the weedy seadragon, eastern blue devil fish and the black rock cod. Based on habitat preferences, it was determined to be unlikely that these species would occur the area near the Shellharbour WWTP outfall.

Public health

The beaches along the Illawarra coastline are commonly used for primary contact activities, such as swimming, diving and surfing. Beachwatch programs conduct routine sampling along Sydney's ocean and harbour beaches to provide beach water quality information. In August 2009, the testing of faecal coliforms as a bacterial indicator ceased. Instead, the National Health and Medical Research Council (NHMRC) advocated enterococci as the single preferred indicator for faecal contamination in recreational waters as they generally survive longer in bathing water and may be detected after most other faecal coliforms have died off. Beachwatch also adopted the NHMRC (2008) guidelines in May 2009. The NHMRC (2008) guidelines recommend that recreational water quality is no longer reported as percent compliance based on microbial data, but as Beach Suitability Grades. The Beach Suitability Grades are determined from a sanitary inspection of the swimming site and an assessment of the Microbial Water Quality. Grades can be Very Good, Good, Fair, Poor or Very Poor. The sanitary inspection identifies potential pollution sources, assesses the risk posed by each and then determines the overall risk at the swimming site, and the microbial water quality is obtained from the 95th percentile of at least 100 enterococci data points collected at the site (WCC 2010b).

Beachwatch monitoring of three beaches at Shellharbour are presented in Table 6-1. For comparison, in 2008-2009 all three sites met the guidelines for faecal coliforms in 100 per cent of samples. Warilla Beach and Shellharbour Beach showed that 100 per cent of samples met the enterococci guidelines. However, 76 per cent of samples taken at Entrance Lagoon Beach complied with the enterococci guidelines (SCC 2010).

Table 6-1 Beachwatch monitoring Shellharbour – Swimming site beach suitability grade (SCC 2010)

Shellharbour swimming site	2009/2010 beach suitability grade
Warilla Beach	Very good
Shellharbour Beach	Very good
Entrance Lagoon Beach	Fair

There are 11 beaches in Wollongong that are also monitored by the Beachwatch program. During the 2009-10 swimming season the beaches were rated as good or very good (Table 6-2). 'Very good' indicates that the water is suitable for swimming almost all the time and the location generally has excellent microbial water quality. 'Good' indicates that the beach generally has good microbial water quality and swimming should only be avoided during and for up to 24 hours after heavy rain at ocean beaches, and up to three days at estuarine sites.

Table 6-2 Beachwatch monitoring Wollongong – Swimming site beach suitability grade (WCC 2010b)

Wollongong beaches	2009/2010 beach suitability grade
Austinmer	Very good
Thirroul	Good
Bulli	Good
Woonona	Very good
Bellambi	Good
Corrimal	Good
North Wollongong	Good
Coniston	Good
Wollongong	Very good
Fishermans	Very good
Port Kembla	Good

6.3.2 Construction impacts

The Proposal will lead to an increase in volume of wastewater to be treated at the existing treatment plants. After treatment, the effluent will be discharged through the existing ocean outfalls. There is no anticipated requirement for any offshore infrastructure to be constructed, and therefore the proposal will not lead to any marine water quality impacts during construction. If the volume of wastewater increases to a point where the capacity of the treatment plants needs to be augmented, then separate impact assessment and approvals will be sought (see Chapter 3).

6.3.3 Operational impacts

The Proposal will lead to an increase in the volume of wastewater to be treated at the existing treatment plants. The Proposal has the potential to impact marine water quality during operations from:

- treated wastewater discharged via ocean outfalls from treatment plants in dry weather
- partially treated or untreated wastewater discharged via ocean outfalls from treatment plants in wet weather
- inland overflows that reach ocean waters during wet weather
- inland overflows that reach ocean beaches environment during wet weather.

Effluent discharged to the marine environment from ocean outfalls during dry weather

Water quality guidelines and indicators

The primary guidelines for assessing water quality impacts are the Australian and New Zealand Guidelines for Fresh and Marine Water Quality, 2000 (ANZECC 2000). The ANZECC (2000) guidelines provide default trigger values as a threshold or as a range of desirable levels needed to protect a particular environmental value, such as water quality, aquatic ecology or recreational use. ANZECC (2000) default trigger values are conservative, they can be used in the absence of site-specific information, but they are not intended to be 'pass/fail' criteria. The guideline concentrations can vary depending on the environmental value they are intended to protect. For example, the ANZECC (2000) default trigger value for ammonia is 20 mg/L for protecting recreational uses of water, and 0.5 mg/L for the protection of 99 per cent of aquatic species. Where a substance lies outside the desirable range for its ANZECC (2000) default trigger value, there may be a risk that the environmental value will not be protected. This may trigger action to address the causes.

There are many substances for which ANZECC (2000) has default trigger values. Not all of them are relevant to this Proposal (eg some metals do not occur in the Shellharbour or Wollongong wastewater but have ANZECC (2000) default trigger values). The ANZECC (2000) default trigger values relevant to the proposal are shown in Table 6-3.

Table 6-3 ANZECC (2000) default trigger values relevant to the Proposal

ANZECC (2000)	ANZECC (2000) – default trigger values
total phosphorus (TP)	25 µg/L
total nitrogen (TN)	120 µg/L
ammonium ion	20 µg/L
Turbidity	0.5 – 10 NTU * (approximately 3 mg/L TSS equivalent)

*ANZECC (2000) uses turbidity as a water quality guideline for marine waters. Sydney Water's treatment plants measure total suspended solids (TSS), therefore, 0.5 – 10NTU (Nephelometric turbidity units) is converted to approximately 3 mg/L after Packman et al. (1999).

Water quality assessment methodology

Sydney Water assessed potential impacts from the Proposal on marine water quality using existing effluent data and a numerical model known as CORMIX. CORMIX has been critically reviewed in scientific literature (eg Jirka and Akar 1991; Jirka and Doneker 1991) and is a preferred model for estimating plume trajectories and dilutions of the OEH and the United States Environment Protection Agency. The numerical model employs a statistical approach. Inputs to the model include randomly selected effluent flow and effluent quality data from 2007 – 2010 (note: data prior to this are not representative of the present levels of treatment), taking into account the population increase to 2048. Inputs to the model also included:

- ocean current speed and direction
- ocean water density
- treatment plant outfall configuration.

The date at which the WDURA and AGA areas will be fully developed is approximately 2048. However, a number of scenarios were modelled, including the expected effluent flow at 2021, the date at which the Project Approval area is projected to be fully developed. The scenarios were compared to the load limits in the EPLs for the Wollongong and Shellharbour wastewater systems. Most of the impact assessment results are presented for 2048, because if the Proposal meets the default trigger values at 2048, then the same conclusions can be made for the 2021 scenario (Project Approval) (Sydney Water 2011b). Under all scenarios, the estimated loads were below the annual load limits in the EPLs.

The methodology assumes that the wastewater composition will remain the same as currently treated. This is considered appropriate, as industrial and commercial customers would be managed to control wastewater composition in accordance with strict Trade Waste Policy requirements.

Once discharged from the treatment plant, effluent mixes with the surrounding seawater. Mixing continues until the density (or salinity) of the effluent and seawater mixture equals that of the surrounding seawater. The distance from the outlet to this point is referred to as the distance to the edge of the initial mixing zone. In the Illawarra Region the average seawater salinity is approximately 35.5 psu, with a standard deviation of approximately 0.25 psu. When the salinity of the effluent and seawater mixture lies in the range 35.5 +/- 0.25 psu, the mixing process is essentially complete. The distance to the edge of the initial mixing zone is not fixed and varies according to the outfall configuration, wastewater flow, current speed and stratification.

At Wollongong WRP, effluent is discharged in waters approximately 1,000 m offshore and 20 m deep, and the edge of the initial mixing zone is generally less than 100 m (see Figure 6-3). At Shellharbour WWTP the water depth is relatively shallow and mixing is not complete when the effluent plume reaches the sea surface and further mixing due to ocean currents takes place. The edge of the initial mixing zone at Shellharbour is approximately 1000 m (see Figure 6-3 and Figure 6-4). Although the initial mixing zones are different shapes and sizes, the volume of effluent in the initial mixing zones for both treatment plants is in proportion to the total volume of effluent discharged by each plant.

The results of the numerical modelling are presented as the likelihood, (ie probability), that indicators will exceed ANZECC (2000) default trigger values. However, numerical modelling was not undertaken for substances that were below limit of reading (LOR), and where LOR was below ANZECC. Similarly, if it was clear that the ANZECC (2000) default trigger values would be met (based on the maximum concentrations and the dilutions at the edge of the initial mixing zones), then numerical modelling was not carried out.

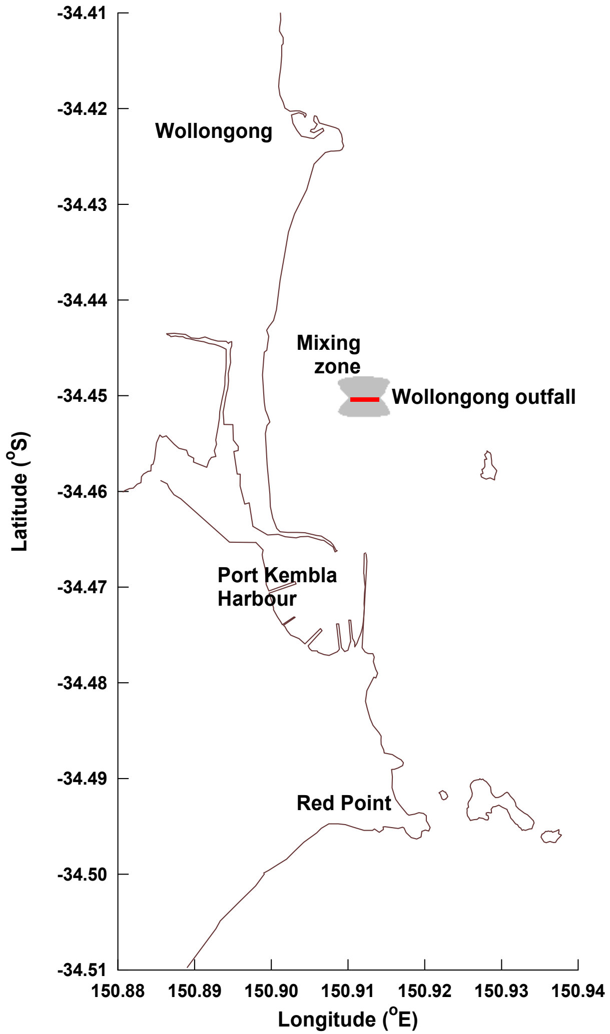


Figure 6-3 Approximate size of the initial mixing zone for Wollongong WRP

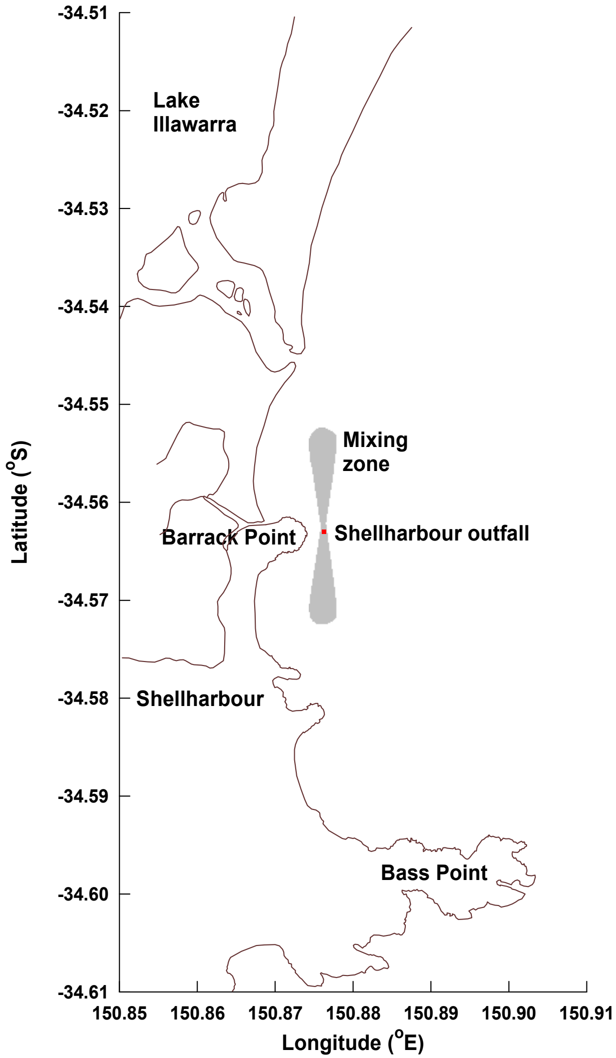
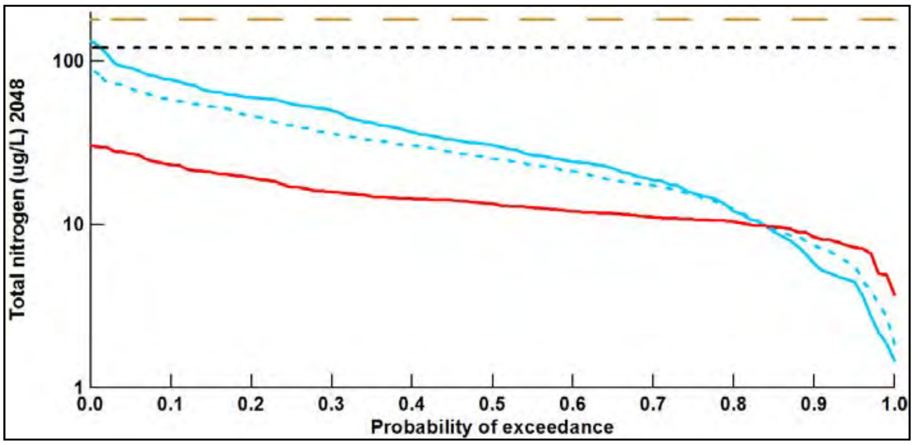


Figure 6-4 Approximate size of the initial mixing zone for Shellharbour WWTP

Water quality assessment

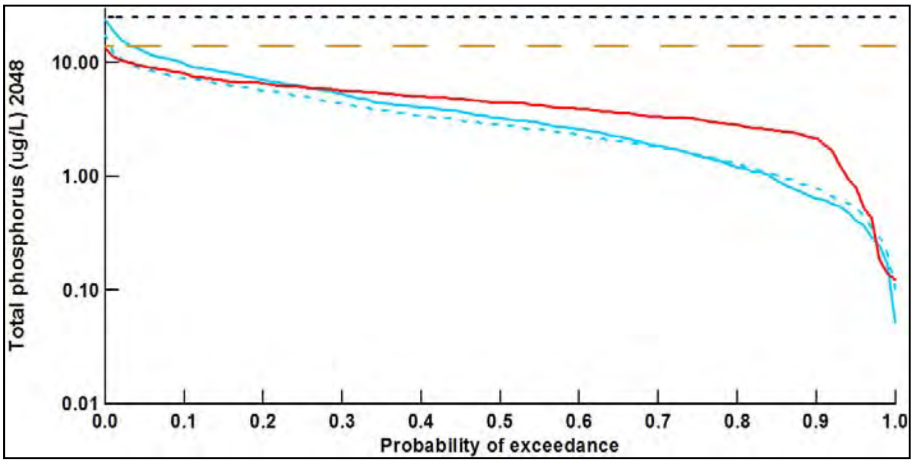
Numerical modelling was undertaken to predict the concentrations of key nutrients and total suspended solids (TSS) at the edge of the mixing zones for Wollongong and Shellharbour treatment plants. The following figures show the likelihood that samples would exceed the default trigger values at 2048, and they also show the ambient (background) concentrations where known.

Figures 6-5 and 6-6 present the results of the numerical modelling for TN and TP at Wollongong and Shellharbour treatment plants. The figures show that the ANZECC (2000) default trigger values are likely to be met at the edge of initial mixing zone at 2048. Figure 6-5 also shows the background concentration of TN already lies well above the ANZECC (2000) default trigger value.



Dashed blue line = TN probability of exceedance Wollongong 30ML/day reuse. Solid blue line = TN probability of exceedance Wollongong 20ML/day reuse. Solid red line - TN probability of exceedance Shellharbour. Dashed black line = ANZECC (2000) default trigger value. Dashed gold line = background level (50th percentile, based on data collected between 2003 and 2007).

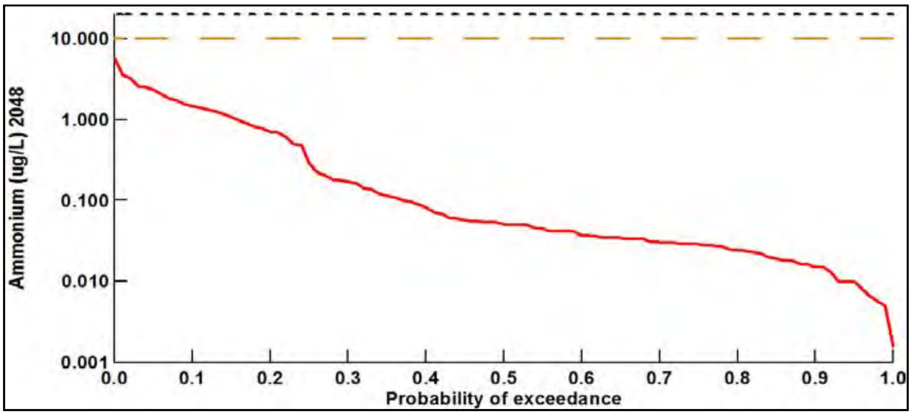
Figure 6-5 Water quality - Probability of exceedance predictions in 2048 for TN at Wollongong and Shellharbour treatment plants at the edge of the initial mixing zones



Dashed blue line = TP probability of exceedance Wollongong 30ML/day reuse. Solid blue line = TP probability of exceedance Wollongong 20ML/day reuse. Solid red line - TP probability of exceedance Shellharbour. Dashed black line = ANZECC (2000) default trigger value. Dashed gold line = background level (50th percentile, based on data collected between 2003 and 2007).

Figure 6-6 Water quality - Probability of exceedance predictions in 2048 for TP at Wollongong and Shellharbour treatment plants at the edge of the initial mixing zones

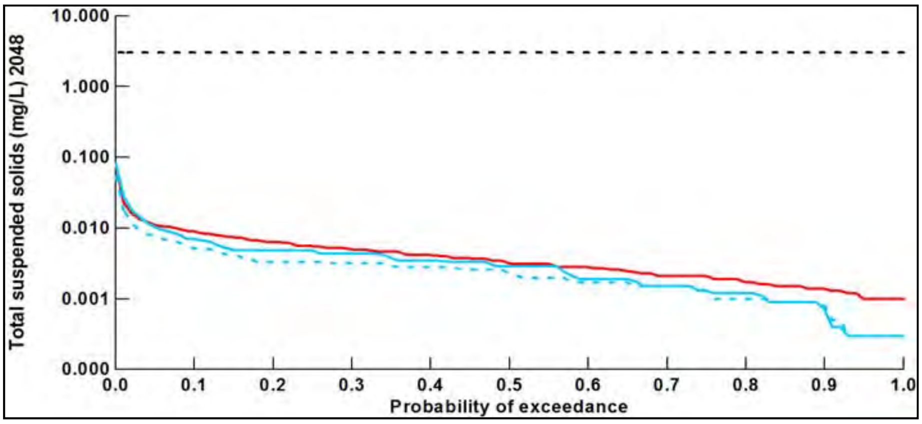
Figure 6-7 shows the results of the numerical modelling for ammonium at Shellharbour at 2048, and shows that the ANZECC (2000) default trigger value is likely to be met at the edge of initial mixing zone. It also shows that the background concentration of ammonium lies close to the ANZECC (2000) default trigger value. There is no licence requirement to monitor ammonium at Wollongong WRP, because of the tertiary treatment employed, which converts ammonia to nitrogen. Therefore, it is predicted that the ANZECC (2000) default trigger value for ammonium will be met at the edge of the Wollongong WRP initial mixing zone at 2048.



Solid red line = ammonium probability of exceedance Shellharbour (µg/L). Dashed black line = ANZECC (2000) default trigger value for marine water quality. Dashed gold line = background level (50th percentile).

Figure 6-7 Water quality - Probability of exceedance predictions in 2048 for ammonium at Shellharbour WWTP at the edge of the initial mixing zone

Numerical modelling was also conducted for TSS, which is used as an approximation for the ANZECC (2000) default trigger value for turbidity (the turbidity guideline of 0.5 to 10 NTU is converted to approximately 3 mg/L for TSS after Packman et al (1999)). Figure 6-8 shows the numerical modelling results for TSS at 2048 for Shellharbour and Wollongong treatment plants. The figure shows that the ANZECC (2000) default trigger value is likely to be met at the edge of the initial mixing zones.



Dashed blue line = TSS probability of exceedance Wollongong 30ML/day reuse. Solid blue line = TSS probability of exceedance Wollongong 20ML/day reuse. Solid red line - TSS probability of exceedance Shellharbour. Dashed black line = ANZECC (2000) default trigger valuesfor marine water quality.

Figure 6-8 Water quality - Probability of exceedance predictions in 2048 for TSS at Wollongong and Shellharbour treatment plants at the edge of the initial mixing zones

Water quality conclusions

Numerical modelling predicts that the relevant ANZECC (2000) default trigger values for the protection of marine water quality will be met at the edge of the initial mixing zones for Wollongong WRP and Shellharbour WWTP at 2048. The background concentration of TN already lies above the ANZECC (2000) default trigger value to protect marine water quality.

Aquatic ecology guidelines and indicators

The ANZECC (2000) guidelines for the protection of 99 per cent of marine species are used to assess potential impacts of the Proposal on aquatic ecology. These default trigger values are the most restrictive of the ANZECC (2000) default trigger values. The *Marine Water Quality Objectives (WQO) for NSW Ocean Waters – South Coast* (DEC, 2005c) are also relevant. The WQO define the environmental values the community places on ocean waters. The WQO list substances and the corresponding concentrations to protect environmental values. They typically defer to the ANZECC (2000) default trigger values for marine water quality.

Aquatic ecology assessment methodology

The numerical modelling methodology used to assess water quality impacts was used to assess impacts on aquatic ecology.

Although tests may not be carried out for all individual substances, potential toxic effects may be identified from testing the 'whole of the effluent'. Some of the results from toxicity tests routinely carried out at Shellharbour WWTP are used to assess any potential toxic effects from this Proposal. In addition, the ocean outfalls potentially impacted by this Proposal are the same as those assessed as part of the IWWS. Therefore this EA draws on the extensive IWWS field studies and post-commissioning studies to assess impacts for this Proposal.

Compared with the relevant ANZECC (2000) default trigger values for the protection of 99 per cent of species, the concentrations of most indicator substances in the effluent are low. If the concentrations in the effluent are below, or close to the ANZECC (2000) default trigger value, then it is likely that the default trigger values will be met at the edge of the initial mixing zones. If the concentrations in the effluent were above the default trigger values, then numerical modelling was undertaken for these substances. Table 6-4 shows the ANZECC (2000) default trigger values for the protection of 99 per cent of species relevant to this Proposal for which numerical modelling was undertaken.

Aquatic ecology assessment (ANZECC 2000)

As described in the water quality assessment methodology section, numerical modelling was not undertaken for substances that were below LOR and where LOR was below the ANZECC (2000) default trigger value, or if it was clear that the ANZECC (2000) default trigger value would be met. Therefore, numerical modelling was conducted for copper, zinc and cobalt at Wollongong WRP. The numerical modelling confirmed that the ANZECC (2000) default trigger values were likely to be met at the edge of initial mixing zone at 2048. Table 6-4 shows the maximum concentrations modelled at the edge of the initial mixing zones at 2048. In April 2004, the requirement to monitor substances at treatment plants was rationalised to only include substances that were detected (ie above LOR). For this reason, there is no licence requirement to monitor zinc and cobalt at Shellharbour WWTP as their concentrations lie below the LOR. Nevertheless, ANZECC (2000) default trigger values for cobalt and zinc will be met at the edge of the initial mixing zone based on concentrations being the same as the LOR, and the dilutions expected at the edge of the initial mixing zone.

Numerical modelling was undertaken to predict the concentration of ammonia at the edge of the mixing zone for Shellharbour WWTP. The results confirmed that the ANZECC (2000) default trigger value is likely to be met at the edge of initial mixing zone. Table 6-4 shows the maximum concentration modelled at the edge of the initial mixing zone at 2048. There is no licence requirement to monitor ammonia at Wollongong WRP. However, as described in the Marine Water Quality Assessment section, it is predicted that the ANZECC (2000) default trigger values for ammonia will be met at the edge of the Wollongong WRP initial mixing zone at 2048.

The model predicts that the Proposal will meet the relevant ANZECC (2000) default trigger values at the edge of the initial mixing zones. However, some substances may exceed the ANZECC (2000) default trigger values *within* the mixing zones.

Table 6-4 Maximum expected dilutions at the edge of the initial mixing zone(s) for the ANZECC (2000) default trigger values for the protection of aquatic ecosystems relevant to the Proposal

ANZECC (2000) protection of 99 per cent of species	ANZECC (2000) default trigger value	Maximum concentration modelled at 2048 at the edge of the initial mixing zone Wollongong WRP	Maximum concentration modelled at 2048 at the edge of the initial mixing zone Shellharbour WWTP
Copper	0.3 µg/L	0.033 µg/L	0.020 µg/L
Zinc	7 µg/L	0.25 µg/L	-
Cobalt	0.005 µg/L	0.004 µg/L	-
Ammonia	500 µg/L	-	9 µg/L

Impacts from within the initial mixing zones at other treatment plants were found to be reversible within a relatively short timeframe. For example, Underwood and Chapman (1996) described the results from a study examining the changes in subtidal habitats when the cliff-face outfall at North Head was turned off and the flows diverted to the deepwater ocean outfalls. Although they raised some issues in terms of whether the habitat was actually stressed by the old discharges or the impacts caused by physical processes, within four months of the cessation of the discharge, the putatively impacted location could not be distinguished from the reference locations. They concluded that "…… this study provides no indication of it (wastewater discharges) being a large ecological problem affecting the distributions and abundances of common sessile fauna and the composition of assemblages in immediately adjacent subtidal rocky habitats" (Underwood and Chapman, 1996). Similar recovery was seen within six months in the intertidal communities near Port Kembla and Bellambi WWTPs when the flow was changed from constant dry weather treatment to infrequent wet weather treatment as part of the IWWS (Sydney Water 2008b). The IWWS monitoring only revealed changes (in the subtidal and intertidal ecosystem assemblages) that were within the limits of natural variability.

Based on previous studies, it is expected that any potential impacts from the WDURA Proposal will likewise be reversible if the treatment plants were to be switched off.

Aquatic ecology assessment (marine water quality objectives)

Of the five marine water quality objectives (WQO) relevant for NSW coastal waters, one seeks to protect aquatic ecosystem values by maintaining or improving the ecological condition of ocean waters and outlined in DEC 2005c. The indicators used to measure progress against this objective include:

- frequency of algal blooms
- levels of nutrients (TN and TP)
- bioaccumulation levels
- levels of toxicants in the water and sediments, such as metals, pesticides, and organochlorines
- turbidity.

The water quality levels deemed necessary to protect this value are based on the ANZECC (2000) guidelines (DEC 2005c). An assessment of how the Proposal contributes towards protecting the value for aquatic ecosystems in normal operation (ie dry weather) is provided below.

Algal blooms

Algal blooms have occurred in the Illawarra Region in the past and are likely to occur in the future. Dela-Cruz et al. (2002) and Pritchard et al. (2003) both concluded that major algal blooms between Port Stephens and Jervis Bay were more likely to result from natural processes such as oceanic upwelling than from point source discharges. However, concentrations of nutrients at the edge of the initial mixing zones are well below the ANZECC (2000) default trigger values and the WQO for the protection of aquatic ecosystems. Therefore the potential for excessive growth of nuisance organisms is much reduced and the Proposal is not likely to be a major contributor to future algal blooms.

Nutrients

Modelled concentrations of TN and TP are predicted to lie below the ANZECC (2000) default trigger values at the edge of the initial mixing zones. This reduces the potential for excessive growth of nuisance organisms, such as macrophytes, phytoplankton scums, filamentous algal mats, blue-green algae and wastewater fungus.

Bioaccumulation

Substances that bioaccumulate are usually attached to fats, oils, and greases (e.g. organics) or attached to particulate matter (for metals). Contaminants are usually adsorbed onto the surface of particulate matter found in water. The high level of treatment at both the Wollongong WRP and at the Shellharbour WWTP effectively eliminates the discharge of particulate matter and hence the discharge of substances that can bioaccumulate.

In addition, modelled concentrations of metals at the edge of the mixing zone are below the ANZECC (2000) default trigger values for the protection of 99 per cent of species. These metals are known to occur naturally in the marine environment. However, it is not possible to determine the relative contributions from the effluent, other anthropogenic sources and natural sources.

Toxicants

In marine waters, copper, lead, zinc and chlorpyrifos (an organophosphate pesticide) are the indicator toxicants used for the aquatic ecology WQO. Numerical modelling based on monitoring results from either Shellharbour or Wollongong treatment plants, shows copper, lead and zinc will meet the indicator levels at the edge of the initial mixing zones. Where monitored, chlorpyrifos is below the LOR and was therefore not numerically modelled. However, it is expected to meet the indicator levels required, based on the maximum concentration being the same as the LOR, and applying the expected dilutions at the edge of the mixing zone.

Copper, lead, zinc, mercury and organochlorines are also WQO indicator toxicants in marine bottom sediments. Organochlorines include chlordane from pesticides. PCBs can originate from sources such as leaking electrical transformers, hazardous waste sites or illegally dumped PCB wastes. No assessment of toxicants in the bottom sediments was deemed necessary for this assessment, because of the high level of treatment at the Wollongong WRP and the Shellharbour WWTP. The treatment levels effectively prevent the discharge to the environment of particulate material that could settle in the marine sediments. Therefore, it is considered extremely unlikely that toxicants attached to particulate matter as part of the WDURA and AGA development will finally end up in sediments.

The impact assessment of the Proposal is based on the existing toxicity testing carried out at Shellharbour WWTP and the numerical modelling conducted for this EA. A toxic impact from the Proposal is unlikely because the concentrations at the edge of the initial mixing zone are much less than the concentrations needed to have a toxic effect.

Turbidity

ANZECC (2000) guidelines state that ‘turbidity is not a very useful indicator in estuarine and marine waters’. In addition, turbidity is not measured in the treatment plant effluent. However, turbidity levels can be estimated using suspended solids. Although the relationship is variable, turbidity (measured as NTU) is approximately one-third of suspended solids (mg/L). ANZECC (2000) does not have a turbidity default trigger value for the protection of aquatic species, but there is one for marine water quality (0.5-10 NTU). The largest modelled concentration of suspended solids at the edge of the initial mixing zone was 0.1 mg/L (approximately 0.03 NTU), which is below the indicator level to meet this objective.

Aquatic ecology conclusions

Based on the current treatment technology and normal operations, the modelling predicts minimal impact on aquatic ecology from the operation of the Proposal (Sydney Water 2011b). The relevant ANZECC (2000) default trigger values for the protection of 99 per cent of species should be met.

Based on the results of the IWWS monitoring and the current high level of treatment at the plants, any potential impacts within the mixing zones are considered to be minor. Based on studies of decommissioned WWTPs, if impacts occur, recovery is expected within a number of months.

In dry weather, the Proposal meets the levels required to achieve the water quality objective to maintain or improve the ecological condition of ocean waters.

Public health guidelines and indicators

ANZECC (2000) guidelines and the DEC (2005c) Marine WQO are relevant for assessing public health issues in the marine environment. For the purpose of public health assessment, this EA refers to the ANZECC (2000) default trigger values for recreation, tainting of fish flesh and aquaculture. An assessment of the proposal against the NHMRC (2008) guidelines has also been made where applicable. The NHMRC (2008) guidelines assist in protecting human health from threats posed by the recreational use of coastal, estuarine and fresh waters. They are not mandatory; rather they are a guideline to develop legislation and standards appropriate for local conditions.

Public health assessment methodology

The numerical modelling methodology used to assess water quality and aquatic ecology was also used to assess potential public health impacts. Compared with the relevant ANZECC (2000) default trigger values for public health, the concentrations of some substances in the effluent are already close to, or below, the ANZECC (2000) default trigger values (eg hydrogen sulphide and TSS). These substances will be sufficiently diluted at the edge of the initial mixing zone to meet the ANZECC (2000) default trigger values, and therefore, only the maximum concentration expected at the edge of the initial mixing zones are presented. For parameters where concentrations in effluent are higher than the ANZECC (2000) default trigger values (eg faecal coliforms and enterococci), the probability of exceedance plots are presented.

In addition, extensive field studies and post-commissioning studies were conducted as part of the IWWS. The ocean outfalls potentially impacted by this Proposal are the same as those assessed as part of the IWWS. Therefore this EA draws on the IWWS assessment and subsequent monitoring, to infer impacts for this Proposal.

Public health assessment (ANZECC 2000)

Table 6-5 shows the relevant ANZECC (2000) default trigger values for the protection of 99 per cent of species relevant to this Proposal for which numerical modelling was conducted. The equivalent NHMRC (2008) guideline is presented for faecal coliforms and enterococci. Table 6-5 also shows the maximum concentrations modelled at the edge of the initial mixing zones at 2048.

Table 6-5 Maximum expected dilutions at the edge of the initial mixing zone(s) for the ANZECC (2000) and NHMRC (2008) guidelines for public health relevant to the Proposal

Substance	ANZECC (2000) (Aquaculture)	ANZECC (2000) (tainting of fish flesh)	ANZECC (2000) (Primary recreation)	NHMRC (2008)	Maximum concentration modelled at 2048 at the edge of the initial mixing zone Wollongong WRP	Maximum concentration modelled at 2048 at the edge of the initial mixing zone Shellharbour WWTP
Aluminium µg/L	10	-	200	-	1.6	0.7
Copper µg/L	5	1	1000	-	0.033	0.020
Iron µg/L	10	-	300	-	0.85	-
Manganese µg/L	10	-	100	-	0.45	-
Zinc µg/L	5	5	5000	-	0.25	-
Ammonia µg/L		-	10	-	-	9
Hydrogen Sulphide mg/L	2	-	-	-	0.00001	0.00003

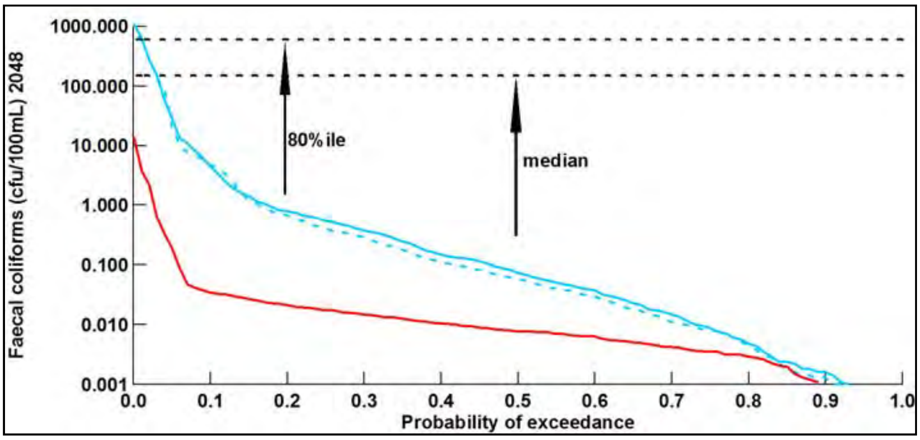
Substance	ANZECC (2000) (Aquaculture)	ANZECC (2000) (tainting of fish flesh)	ANZECC (2000) (Primary recreation)	NHMRC (2008)	Maximum concentration modelled at 2048 at the edge of the initial mixing zone Wollongong WRP	Maximum concentration modelled at 2048 at the edge of the initial mixing zone Shellharbour WWTP
TSS mg/L	10	-	-	-	0.012	0.007
Faecal Coliforms colony forming units / 100 mL	-	-	Median <150 With 4 out of 5 samples < 600	-	< 1	< 1
Enterococci colony forming units / 100 mL	-	-	Median enterococci concentrations should not exceed 35 cfu/100 mL, with a maximum level of 60-100 cfu/100 mL	95th percentile < 40 for category A waters*	< 1	< 1

*These waters have a low susceptibility to faecal coliforms and have more stringent guidelines.

Figures 6-9 and 6-10 show the results of the numerical modelling in more detail for faecal coliforms and enterococci. The arrows indicate where the ANZECC (2000) and NHMRC (2008) guidelines apply. The figures show that the Proposal meets the default trigger values and guidelines at the edge of the initial mixing zones at 2048.

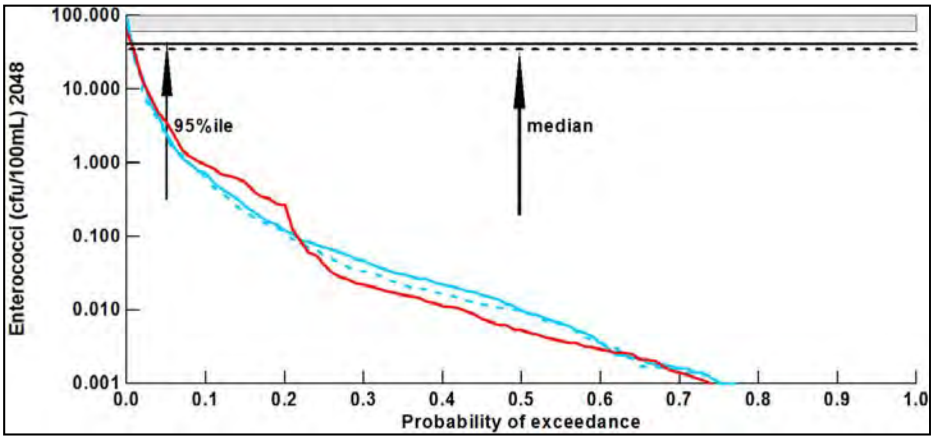
There is no EPA licence requirement to monitor iron, manganese and zinc at Shellharbour WWTP, and therefore there is no effluent data to enable numerical modelling. However, based on the concentrations of metals that are monitored, and the dilutions expected at the edge of the initial mixing zone, it is predicted that the ANZECC (2000) guidelines will be met for these substances at Shellharbour WWTP.

As described in Section 6.3, ammonia is not measured at Wollongong WRP but it is expected that the ANZECC (2000) default trigger value for ammonia will be met at the edge of the Wollongong WRP initial mixing zone at 2048.



Dashed blue line = Faecal coliform probability of exceedance Wollongong WRP 30 ML/day reuse. Solid blue line .- Faecal coliform probability of exceedance Wollongong WRP 20ML/day reuse. Solid red line – Faecal coliform probability of exceedance Shellharbour WWTP. Dashed black lines ANZECC (2000) default trigger value for public health. Arrows median < 150 cfu/q100 mL and 80 %ile < 600 cfu/100 mL for recreation.

Figure 6-9 Public health - Probability of exceedance plot for faecal coliforms at Wollongong and Shellharbour treatment plants at the edge of the initial mixing zones



Dashed blue line = Enterococci probability of exceedance Wollongong WRP 30 ML/day reuse. Solid blue line .- Enterococci probability of exceedance Wollongong WRP 20ML/day reuse. Solid red line – Enterococci probability of exceedance Shellharbour WWTP. Dashed black line ANZECC (2000) guideline, median arrow is where ANZECC default trigger value applies, grey shaded area is ANZECC maximum, <60-100 cfu/100 mL. Black solid line – NHMRC (2008) guideline for public health, 95 %ile arrow are where NHMRC guideline applies.

Figure 6-10 Public health - Probability of exceedance plots for enterococci at Wollongong and Shellharbour treatment plants at the edge of the initial mixing zones

Public Health assessment (Marine water quality objectives)

There are five marine water quality objectives relevant for NSW coastal waters. One relates to aquatic ecology values. The four relevant for public health as follows:

- primary contact recreation - to maintain or improve ocean water quality so that it is suitable for activities such as swimming and other direct water contact sports
- secondary contact recreation - to maintain or improve ocean water quality so that it is suitable for activities such as boating and fishing where there is less bodily contact with the waters
- visual amenity - to maintain or improve ocean water quality so that it looks clean and is free of surface films and debris
- aquatic foods - to maintain or improve ocean water quality for the production of aquatic foods for human consumption (whether derived from aquaculture or recreational, commercial or indigenous fishing).

The water quality required to protect these values is based on the ANZECC (2000) guidelines (DEC 2005c). Each environmental value can have a number of indicators, such as biological, physio-chemical and/or levels of toxicants. An assessment of how the Proposal contributes towards achieving these environmental values in normal operation is provided below.

Primary contact recreation

The primary aim of this value is to protect public health. Indicators to protect this environmental value are:

- levels of faecal coliforms and enterococci bacteria
- visual clarity (an indication of the level of turbidity).

Faecal coliforms and enterococci bacteria indicator were modelled to be below the levels required to protect this value at both Wollongong and Shellharbour treatment plants.

Turbidity levels of 6 NTU or less are the guideline levels to meet this WQO. Using the relationship between TSS and NTU, the maximum TSS expected from the Proposal at the edge of the initial mixing zone is approximately 0.1 mg/L. This translates to approximately 0.3 NTU as a turbidity measure, which is below the level required to achieve the WQO.

Secondary contact recreation

Secondary contact recreation indicators are faecal coliform and enterococci bacteria levels. Because secondary guideline levels are less stringent that those for primary contact recreation (and the Proposal meets the primary recreation guidelines), then the Proposal is assessed to also meet the secondary contact recreation WQO.

Visual amenity

Indicators to protect this environmental value are:

- no noticeable oil and petrochemical film on waters
- no oil or petrochemical odour
- no floating debris or litter
- no macrophytes, phytoplankton scums, filamentous algal mats, blue-green algae and wastewater fungus in unsightly amounts.

The high level of wastewater treatment at Shellharbour and Wollongong treatment plants will effectively eliminate the outfall as a source of floating debris and litter. Oil and grease levels in the wastewater measured between July 2007 and June 2010 were below the LOR, and the LOR is itself three times lower than the ANZECC (2000) default trigger value to protect this value. This reduces the likelihood of visual or odour issues at both treatment plants and this is expected to be the same for the increased volume of wastewater at 2048.

Modelled concentrations of nutrients at the edge of the initial mixing zones are predicted to be below the ANZECC (2000) default trigger values and the WQO for the protection of aquatic ecosystems. Therefore minimising the potential for excessive growth of nuisance organisms.

It is worth noting that aesthetics and visual amenity are subjective and difficult to quantify, and natural events such as storms that stir up bottom sediments can impact this value.

Aquatic foods

Indicators to protect this environmental value are:

- levels of faecal coliforms in the water
- levels of *E. coli* in fish destined for human consumption
- metal and organochlorine toxicants (zinc, mercury, copper, chlordane and PCBs)
- levels of suspended solids
- temperature.

Modelled concentrations of faecal coliforms at the edge of the initial mixing zones were less than the indicator levels to achieve this WQO. Sydney Water does not undertake monitoring of *E. coli* in fish tissue, however, given the very low predicted concentrations of faecal coliforms in the receiving waters, it is very unlikely that this guideline will be exceeded.

Copper is monitored in the effluent at Shellharbour WWTP and was numerically modelled to meet the level required to protect this WQO. The Shellharbour WWTP is not required to monitor for zinc, mercury, chlordane and PCBs in the effluent. It is expected that ANZECC (2000) default trigger values will be met in 2048 at the edge of the initial mixing zone at Shellharbour, based on the modelled dilutions and the results for copper and other metals that are monitored.

The modelled maximum concentrations of copper and zinc at the edge of the Wollongong initial mixing zone were 0.033 and 0.25 µg/L respectively, both below the ANZECC (2000) default trigger values to protect this WQO. Data for mercury, chlordane and PCBs were all close to or below the LOR (median values 0.1, 0.01 and 0.1 µg/L, respectively). Applying the smallest modelled dilution shows these indicator toxicants as at least two orders of magnitude below the guideline water quality criteria to achieve this WQO.

As described in the Primary Contact Recreation section above, modelled concentrations of TSS at the edge of the initial mixing zone were also below the indicator levels required to meet the WQO for aquatic foods. Hourly (or less) temperature data from the Wollongong WRP and the Shellharbour WWTP are not available. However, an analysis indicates that, for the minimum observed dilution of all model scenarios, the temperature of the wastewater would need to be in excess of 1,000 ^{o}C to exceed the indicator value for aquatic foods.

Public health conclusions

The modelling for the Proposal predicts that indicator bacteria and other substances relevant to public health should be below ANZECC (2000) default trigger values (Sydney Water 2011b). The modelling shows the Proposal should contribute towards achieving the environmental values for the Illawarra Region.

The numerical modelling predicts compliance with the guidelines at the edge of the initial mixing zones. Daily Beachwatch monitoring after the IWWS was implemented showed 100 per cent compliance with ANZECC (2000) and the relevant NHMRC guidelines (2008) for beaches either side of the Shellharbour and Wollongong treatment plant outfalls. Because concentrations at the edge of the initial mixing zones for this Proposal are similar to those modelled for the IWWS, continued high levels of public health compliance is expected up to and including the 2048 scenario.

Effluent discharged to the marine environment from ocean outfalls during wet weather

Water quality guidelines and indicators

The ANZECC (2000) guidelines are the relevant guidelines in wet weather as they are in dry. Where more than one ANZECC (2000) guideline exists for a particular substance (eg the concentration varies depending on whether it is to protect recreational use or aquatic species), the most restrictive is applied.

Water quality assessment methodology

In dry weather conditions, effluent from the Proposal will be discharged to the ocean via the ocean outfalls at Shellharbour and Wollongong treatment plants shown in Figure 2-1. In large wet weather events, discharge to the ocean can occur through both the normal ocean outfall at Shellharbour WWTP and an ‘emergency’ outfall that discharges to Barrack Creek (see Figure 2-1). In large wet weather events at Wollongong WRP, flow is diverted to storage tanks at Port Kembla WWTP. If flow is sufficiently large, the capacity of the storage tanks may be exceeded. In this situation the wastewater is treated (up to primary treatment only) and effluent is discharged via the ocean outfall in the cliff face at Red Point (see Figure 2-1).

Wet weather events can vary in duration, magnitude and frequency. Therefore, unlike dry weather flows, it is not possible to assess impacts based on an ‘average’ flow, or on ‘average’ concentrations of substances in the effluent. In wet weather events, stormwater enters the wastewater system, causing some treatment stages at the treatment plants to be partially or completely missed due to the increased flow. In wet weather, effluent can be a combination of flow that has received normal treatment, and flow that has partially or completely missed some treatment steps. Sydney Water uses emission factors for concentrations of substances in effluent that may have missed some treatment steps. Emission factors are estimated concentrations used in the absence of measured data and as set by EPA (Sydney Water 2003b). To compare the Proposal with the ANZECC (2000) default trigger values, this assessment used 2009-2010 wet weather flow data for Port Kembla and Shellharbour WWTPs and the predicted wastewater flow at 2048. Assessment has been made based on emission factors for all of the flow through Port Kembla because there is no data available to determine concentrations of substances in the effluent. At Shellharbour, the assessment is based on a combination of effluent that has received full treatment and effluent to which emission factors are applied.

From the 2009-2010 wet weather data, a number of average recurrence interval (ARI) events were established (Table 6-6). An ARI is the average time interval between rainfall events. For example, an ARI of 12 months is the rainfall that will occur, on average, once every 12 months. The numerical modelling methodology that was used to assess potential impacts from ocean outfalls in dry weather was also used to assess potential impacts from ocean outfall discharges in wet weather.

Table 6-6 Wet weather flow scenarios and compliance with ANZECC (2000) default trigger values

Rainfall average return interval (ARI) (months)	Shellharbour WWTP *	Port Kembla WWTP*
<1	Full treatment	Full treatment at Wollongong WRP
1-3	Full treatment	• approximately 12 events/year • average duration: 14 hours, total volume 15 ML • faecal coliforms, enterococci, ammonia, TP, TN, TSS, aluminium, cobalt, copper, iron, lead, manganese, and zinc exceed ANZECC (2000)
6	Full treatment	• average duration: 21 hours, total volume 47 ML • faecal coliforms, enterococci, ammonia, TP, TN, TSS, aluminium, cobalt, copper, iron, lead, manganese, and zinc exceed ANZECC (2000)
12	• Occurs when flows exceed 5xADWF • Average duration: 4.2 days, total volume 346 ML • TP exceeds ANZECC (2000) in 2% of samples (ie once in 50 years)	• average duration: 27 hours, total volume 85 ML • faecal coliforms, enterococci, ammonia, TP, TN, TSS, aluminium, cobalt, copper, iron, lead, manganese, and zinc exceed ANZECC (2000)
24	• Occurs when flows exceed 7xADWF • Average duration: 7.3 days, total volume 892 ML • TP exceeds ANZECC (2000) in 30% of samples	• average duration: 28 hours, total volume 109 ML • faecal coliforms, enterococci, ammonia, TP, TN, TSS, aluminium, cobalt, copper, iron, lead, manganese, and zinc exceed ANZECC (2000)
48	• Occurs when flows exceed 8xADWF • Average duration: 8 days, total volume 1070 ML • TP exceeds ANZECC (2000) in 45% of samples	• average duration: 53 hours, total volume 228 ML • faecal coliforms, enterococci, ammonia, TP, TN, TSS, aluminium, cobalt, copper, iron, lead, manganese, and zinc exceed ANZECC (2000).

* Based on 2009-2010 wet weather flow data for Port Kembla and Shellharbour WWTPs and the predicted wastewater flow at 2048. Using emission factors for all of the flow through Port Kembla, and a combination of fully treated effluent and effluent to which emission factors are applied at Shellharbour WWTP.

Water quality assessment

In 2009, the volume of effluent discharged to Barrack Creek was 0.8 ML, representing less than 0.0004 per cent of the total effluent flow from Shellharbour WWTP. Effluent discharge through the Port Kembla WWTP outfall during 2009 represented 1.4 per cent of the total volume of effluent discharged from Wollongong WRP and Port Kembla WWTP.

Table 6-6 shows that a number of substances exceed their ANZECC (2000) default trigger value during wet weather events. Table 6-6 only includes substances for which emission factors exist. At Shellharbour WWTP, TP was shown to exceed the ANZECC (2000) default trigger value when wastewater flows exceeded five times the average dry weather flow (ADWF). However, even in rainfall events expected to occur once in four years (when flow is eight times ADWF), events are relatively short-lived and the volume of discharge is comparatively small.

At Port Kembla WWTP, almost any discharge will result in a range of contaminants exceeding the ANZECC (2000) default trigger values. This is because the wastewater is treated to a primary level only, and the dilutions achieved by the outfall are low (a median value of 22:1).

Water quality conclusions

In large wet weather events, numerical modelling predicted that TP may exceed the ANZECC (2000) default trigger values at the edge of the mixing zone at Shellharbour WWTP. Almost any discharge from the Port Kembla WWTP ocean outfall will result in concentrations of most substances being above the ANZECC (2000) default trigger values. This is due to the primary treatment level and low dilutions at the outfall. However, these events are relatively short-lived and infrequent, and any impacts are expected to be minor and reversible.

Aquatic ecology guidelines and indicators

The ANZECC (2000) default trigger values for the protection of 99 per cent of species apply whether the potential impacts on aquatic ecology are from effluent discharged via ocean outfalls in dry or wet weather. Similarly, the DEC (2005c) Water Quality Objectives are also still relevant.

Aquatic ecology assessment methodology

The methodology previously described to assess the potential impacts on marine water quality in wet weather ocean outfalls flows was applied to determine potential aquatic ecological impacts.

Aquatic ecology assessment

Table 6-6 shows that a number of substances were modelled to exceed the ANZECC (2000) default trigger values in wet weather events. Substances that are relevant for the protection of aquatic species were shown to exceed the ANZECC (2000) default trigger values at Port Kembla WWTP (eg copper, ammonia). This is due to the relatively low treatment at Port Kembla WWTP and low dilution achieved at the ocean outfall.

The Proposal is shown to be contributing to the marine WQO environmental values in dry weather. However, in short-lived large wet weather events, the water quality criteria for the protection of the relevant environmental values are unlikely to be met at the edge of the initial mixing zones at Port Kembla WWTP.

Aquatic ecology conclusions

Although a number of substances exceed ANZECC (2000) default trigger values, Table 6-6 shows that these events are relatively short-lived, and they are relatively low volume and infrequent events. The WQO for the protection of aquatic ecosystems will not be met at the edge of the initial mixing zone at Port Kembla WWTP in these events.

However, the IWWS program included an assessment of any subtidal impacts from the short-term discharges from Port Kembla and Belambi WWTPs during wet weather events. Sampling of intertidal communities was undertaken as soon as it was safe to do so after the wet weather event, usually within a few days. Sampling was also undertaken one month after the event. Sample locations were both close to and far away from the discharge location. No differences (beyond natural variation) were seen. Therefore it was concluded that either there was no impact on the intertidal communities associated with the wet weather, or that recovery occurred within a few days (Sydney Water 2008b). Sydney Water (2008b) also concluded that discharges from stormwater drains contributed more to impacts on intertidal rocky foreshore communities than the wet weather discharges from Port Kembla, Shellharbour and Wollongong treatment plants.

Public health guidelines and indicators

The ANZECC (2000) and NHMRC (2008) guidelines for the protection of public health apply whether the potential impacts are from ocean outfalls in dry or wet weather. Similarly, the DEC (2005c) Water Quality Objectives are also still relevant.

Public health assessment methodology

The methodology previously described to assess the potential impacts on water quality and aquatic ecology from ocean outfalls in wet weather was also applied to assess potential public health impacts.

Public health assessment

Table 6-6 shows that a number of substances were modelled to exceed ANZECC (2000) default trigger values in some wet weather events. Substances that are relevant for public health were shown to exceed the ANZECC (2000) and NHMRC (2008) guidelines at Port Kembla WWTP (eg faecal coliforms and ammonia). This is due to the relatively low treatment at Port Kembla WWTP and low dilution achieved at the ocean outfall.

In short-lived, large wet weather events, the water quality criteria for the protection of public health-related environmental values are unlikely to be met at the edge of the initial mixing zone at Port Kembla WWTP.

Public health conclusions

The wet weather events where the relevant ANZECC (2000) default trigger values are modelled to be exceeded are relatively short-lived and infrequent. Any exceedances are likely to occur only in large wet weather events, when primary and secondary recreational contact is unlikely. The NSW Department of Health (DoH) and OEH (2011) advise that swimming should be avoided during, and at least one day after, heavy rain at ocean beaches and at least three days at lagoons, estuaries and rivers. Based on the similar modelling results for this Proposal and the IWWS, it is expected that the current Beachwatch monitoring results for Port Kembla and Fisherman's Beaches (good and very good respectively) will be maintained.

Inland overflows that reach ocean waters during wet weather

Overflows that reach ocean waters - guidelines and indicators

In large wet weather events, some inland wastewater overflows are directed to the marine environment via stormwater drains, and can discharge to the beach or near shore waters (see Figure 6-2). If directed overflows reach oceans waters, it is possible to assess potential impacts against the same ANZECC (2000) and NHMRC (2008) guidelines presented in previous sections for water quality, aquatic ecology and public health. Directed overflows are regulated by OEH in EPLs. OEH limit the number of discharges that can occur from each directed overflow over a ten-year period (see Table 6-7 and 6-8).

Overflows that reach ocean waters - assessment methodology

Three stormwater drains were hydraulically modelled to receive overflows from the Proposal. Two overflows discharge to the beach and there will be no dilution with receiving waters because the wastewater dissipates through the sand. Potential impacts from these directed overflows are considered in the context of public health subsequently. One directed overflow (ID A111111) discharges to ocean water, and the CORMIX model was used to estimate dilutions (Table 6-7).

Table 6-7 Frequency and volume of overflows to ocean waters

Overflow point	Year			Long term targets in EPL (overflows/10 years)
	2009	2021	2048	
Port Kembla Beach (ID A111111)				
overflows/10 years	46*	2	5	40
kL/year	171	35	115	

*SewerFix work is presently underway and is expected to be complete by 2013, at which time the overflow frequency is expected to be 1/10 years.

Overflows that reach ocean waters - assessment

At ten metres from the discharge outlet for direct overflow ID A111111 the average dilution was modelled to be 5:1. This increased to 7:1 at approximately 20 m from the discharge outlet. These dilutions are comparable with the lower end of the wet weather dilutions obtained for discharges through the Port Kembla WWTP outfall and therefore similar compliance with ANZECC (2000) default trigger values is expected (see Table 6-6). For example, faecal coliforms, ammonia, TSS, TN and TP are likely to exceed the ANZECC (2000) default trigger values (and NHMRC (2008) guidelines for enterococci) at the edge of the mixing zone.

Overflows that reach ocean waters - conclusions

The ANZECC (2000) default trigger values for a number of substances will be exceeded at least 20 m from the discharge outlet for directed overflow (ID A111111). However, these events are very infrequent (expected to occur approximately once every two years at 2048), with an average overflow of 230 kL/event. Overflows will only occur in wet weather events, and the risk to public health is reduced, as primary contact (eg swimming) is unlikely to occur at the same time as the overflow. Therefore impacts from this directed overflow are expected to be minimal.

Inland overflows that reach ocean beaches during wet weather

Overflows that reach ocean beaches - guidelines and indicators

Of the three inland directed overflow points impacted by the Proposal, two discharge to the beach, and there will be no dilution with receiving waters, as the wastewater dissipates through the sand (directed overflows ID 4808651 and ID CM1101A see Table 6-8 and Figure 6-2). Potential impacts from these directed overflows are considered in the context of the ANZECC (2000) default trigger values relevant to public health. However, the ANZECC (2000) default trigger value for faecal coliforms requires samples to be collected over the bathing season. It is unlikely that a storm event will last for the bathing season (or longer), so this is not strictly applicable to the wet weather discharges.

Overflows that reach ocean beaches - assessment methodology

Concentrations of contaminants that do not meet the ANZECC (2000) default trigger values in the effluent will not meet these guidelines after discharge to the sand. Therefore, the duration for which wastewater pools in the sand near the stormwater outlet is critical for assessing public health impacts. Darcy's Law (see Freeze and Cherry 1979) and a mass balance analysis were used to estimate the length of time wastewater remains pooled in the sand.

Table 6-8 Frequency and volume of inland overflows to ocean beaches

Overflow point	Year			Long term targets in EPL (overflows/10 years)
	2009	2021	2048	
Shell Harbour Beach (ID 4808651)				
overflows/10 years	2	2	3	45
kL/year	11	14	20	
Shellharbour South Beach (ID CM1101A)				
overflows/10 years	2	2	3	45
kL/year	244	314	472	

Overflows that reach ocean beaches – assessment

Wastewater remains pooled in the sand at the outlet of ID 4808651 up to 14 hours after the cessation of discharge, and for ID CM1101A this is up to 28 hours after the cessation of the discharge. However, it should be noted that values are sensitive to the hydraulic conductivity, which can vary by up to four orders of magnitude for sand.

Overflows that reach ocean beaches - conclusions

Both of the directed overflows lie well below the EPL limits for overflows in any ten year period. However in large wet weather events when these two directed overflows are discharging, indicator bacteria (faecal coliforms and enterococci) may exceed the relevant ANZECC (2000) default trigger values. It is recognised that concentrations of faecal coliforms exceeding 150 cfu/100mL will increase the risk of infection to the public. It is for this reason that the DoH recommends that there is no swimming within 24 hours of heavy rain at ocean beaches and within three days in estuaries or rivers. Similarly, OEH's Beachwatch program advises that people avoid swimming near stormwater drains or wastewater outfalls.

Overall assessment findings

Under normal operations in dry weather, numerical modelling predicts that the Proposal will meet the ANZECC (2000) default trigger values for marine water quality, aquatic ecology and public health at the edge of the initial mixing zones for Wollongong WRP and Shellharbour WWTP. This is because under most flow conditions, wastewater will be fully treated at Wollongong WRP or Shellharbour WWTP.

Extensive field programs were carried out as part of the IWWS upgrades to the Wollongong WRP and Shellharbour WWTP systems. This EA confirms the previous assessments' findings, and assesses the impacts from the incremental increase in effluent volume beyond that already approved. Only small incremental changes in the water quality at the edge of the initial mixing zones were found, which, in many cases, lie within levels of natural variation.

Results from the marine monitoring program for the IWWS failed to find any marine ecological impacts beyond the limits of natural variability from discharges through the new Wollongong WRP outfall or the upgraded Shellharbour WWTP outfall. The primary reason for this is the high level of wastewater treatment and efficient wastewater disposal methods in both systems. Therefore impacts within the initial mixing zones due to the increased effluent flow from the Proposal are not expected.

In some large wet weather events some treatment stages may be partially or fully missed. Numerical modelling predicts that for these events TP concentrations at Shellharbour WWTP will be above the recommended ANZECC (2000) default trigger value. During these events, flows from Wollongong WRP are diverted to Port Kembla WWTP. Only primary treatment occurs and Port Kembla WWTP and a range of contaminants, including bacteria, nutrients, TSS and some metals do not meet the most restrictive ANZECC (2000) default trigger values for marine water quality, recreation or protection of species during these short term events. The ANZECC (2000) guidelines use conservative default trigger values that are not intended to be 'pass/fail' compliance criteria. The volumes and frequency of these events are relatively small, and the results of previous monitoring programs indicate impacts have been shown to be reversible within a short timeframe and system recovery is known to rapidly occur after the cessation of discharges including those associated with wet weather events. In addition, public health impacts to beach waters in the Proposal area are not expected, based on the similarity of modelling results for this Proposal and results of IWWS monitoring.

In large wet weather events, the Proposal may lead to inland overflows reaching ocean waters. However, overflows are very infrequent (expected to occur approximately once every two years at 2048), with an average overflow of 230 kL/event. Any risk to public health is reduced, as primary contact (eg swimming) is unlikely to occur at the same time as the overflow.

In large wet weather events, the Proposal may lead to inland overflows reaching ocean beaches at two locations. Faecal coliforms and enterococci may exceed the ANZECC (2000) and NHMRC (2008) guidelines. However, overflows are infrequent, low volume, and only occur in large wet weather events. It is for this reason that the DoH recommends that there is no swimming within 24 hours of heavy rain at ocean beaches and within three days in estuaries or rivers. Similarly, OEH's Beachwatch program advises that people avoid swimming near stormwater drains or sewage outfalls.

For the majority of time in normal dry weather operations, the Proposal meets the guidelines to achieve the marine water quality objectives for aquatic ecosystems, primary and secondary recreation uses and aquatic foods up to and including 2048.

Many substances monitored in the effluent lie below the limit of reading and the limit of reading is often less than the ANZECC (2000) default trigger values. For many other substances, the concentration of contaminants at the edge of the initial mixing zone was substantially less than the respective guideline. In addition, the routine toxicity testing at Shellharbour WWTP should identify impacts from toxicants tested in the effluent. This includes toxicants for which no specific monitoring is undertaken.

Due to the above, and the high level of treatment processing, it is concluded that the monitoring currently undertaken for the relevant EPLs, together with the existing toxicity testing, continues to be sufficient to enable an understanding of the potential impacts of the Proposal on the marine aquatic environment.

6.4 Inland water quality

Sinclair Knights Merz (SKM) was engaged by Sydney Water to address the Director-General's requirements relating to the potential impacts of the Proposal on inland water quality, aquatic ecology and public health. This section provides a summary of the assessment which is attached as Appendix D.

6.4.1 Existing environment

A number of catchments lie within the Proposal area, including Lake Illawarra catchment (Figure 6-11). Lake Illawarra covers approximately 3500 ha and its catchment area is approximately 270 km^2. It is a shallow saline lagoon, only 4 m deep at its maximum, with about 10 per cent of the Lake less than 1 m deep. It is connected to the ocean by a channel approximately 3.7 km long. In 2007, the Lake Illawarra Authority (LIA) constructed twin breakwaters to maintain the entrance and promote tidal flushing. Prior to 2007 the lake was periodically closed to the ocean.

Water quality in Lake Illawarra sub-catchments is generally poor, due to urban, industrial and agricultural development combined with poor tidal flushing (SKM 2011). According to Wollongong City Council (WCC 2010b), the main pressures include wastewater overflows, urban runoff, on-site sewage management systems, rural runoff, industrial point source discharges, and illegal dumping and litter. Shellharbour City Council (SCC 2010) indicates that agricultural activity could be a major contributor to diffuse pollution, particularly during periods of heavy rain. Rural runoff water often contains soil particles and chemicals such as pesticides, herbicides and fertilisers. Agricultural activities such as dairying also produce large amounts of animal faeces that may be flushed into the waterways during heavy rain.

The Proposal is designed to accommodate the increased wastewater flows from an additional 35,000 lots by 2048. New infrastructure will link into the existing Wollongong and Shellharbour wastewater systems, which transfers wastewater to Wollongong WRP and Shellharbour WWTP. Wastewater systems are designed to include Emergency Release Structures (ERSs) that overflow when the hydraulic capacity of the system is exceeded (eg in large wet weather events) or if there is a malfunction in the system (eg pumping station functional failure). These overflow structures are also known as 'directed' overflows. If directed overflows are not designed into the system, wastewater could back-up in the pipelines causing overflows to occur in residences and businesses, which produces an unacceptable health risk. Generally, directed overflows are designed to flow into stormwater systems or waterways, which ensures that wastewater is rapidly diluted and the potential for human contact with wastewater is minimised.

Wastewater system EPLs set a limit on the frequency that directed overflows can discharge in dry and wet weather, in order to manage potential environmental impacts. The limits are set by OEH.

Hydraulic modelling of the increased wastewater volume as the Proposal is developed can predict the location and frequency of directed overflows over time. Hydraulic modelling shows that 49 of 124 existing directed overflows may be impacted by the Proposal, of which, 22 ultimately discharge to Lake Illawarra. Figure 6-11 shows waterbodies and the 49 directed overflow locations.

Given its importance to the local community, and its central location in the Proposal area, the Lake Illawarra catchment is described below. The condition of the catchment is based on data in the current literature. The available data is sparse, highly variable, and was collected over a number of years and in variable weather (SKM 2011).

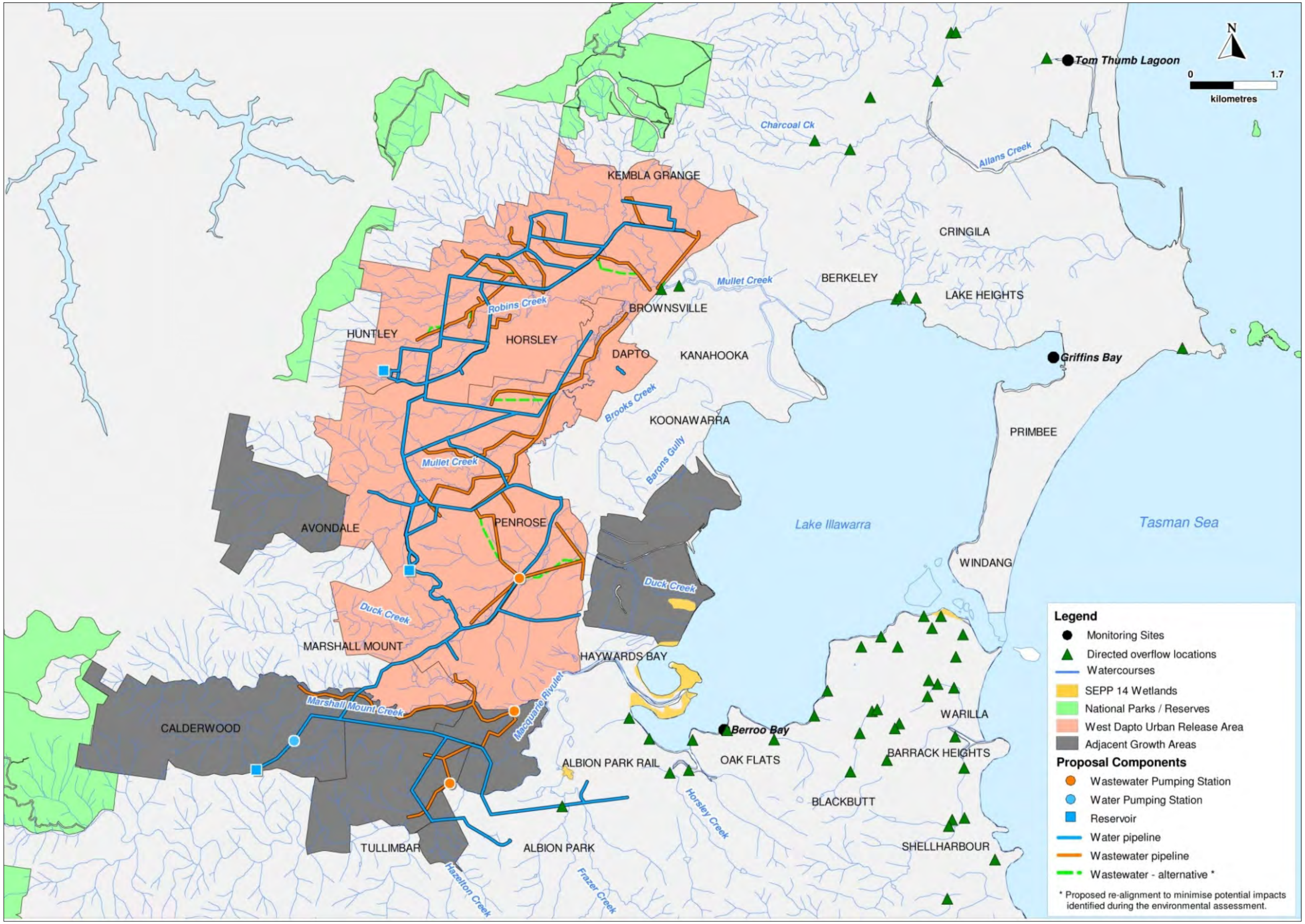


Figure 6-11 Location of waterbodies, and existing directed overflows that may be impacted by the Proposal

Lake Illawarra catchment

There are four sub-catchments of Lake Illawarra that contain directed overflows, which also act as major drainage paths for stormwater across the catchment (LIA 2010) (Figure 6-12). They are listed below, together with their catchment areas:

- Macquarie Rivulet - 109 km^2
- Mullet Creek - 75 km^2
- Horsley and Connor Creek - 9 km^2
- Budjong Creek – 1.5 km^2.

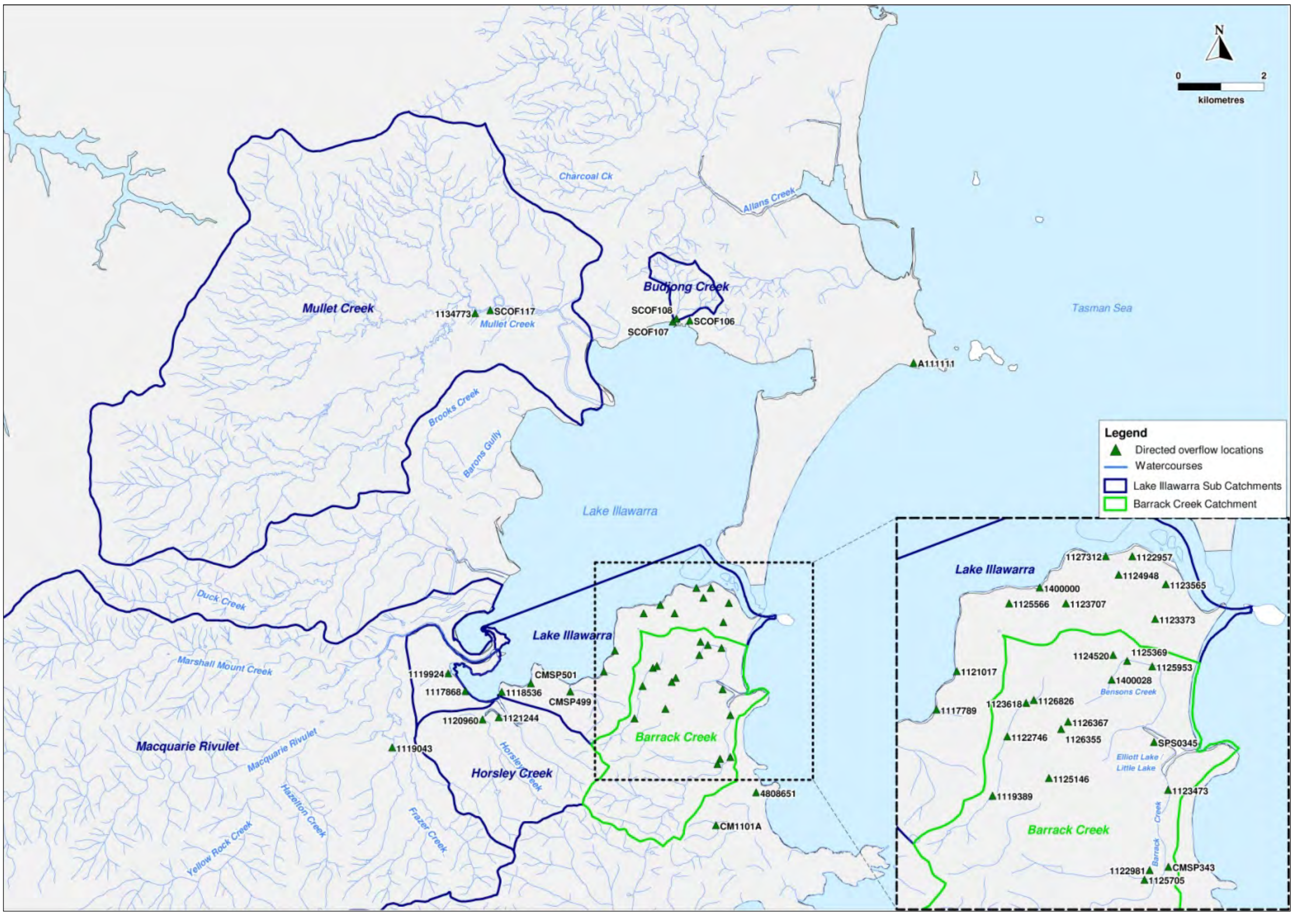


Figure 6-12 Lake Illawarra and Barrack Creek catchments and directed overflows

Water quality

Lake Illawarra has been described by the Healthy Rivers Commission (HRC 2002) as of high conservation value and in need of targeted repair. Water quality is influenced by climactic factors, such as drought conditions that can increase surface water temperatures and can promote algal growth if nutrient levels are also elevated. Intense rainfall events result in a large number of contaminants entering waterways. Land uses near the Lake have recently changed from predominantly rural to urban, particularly in West Dapto, resulting in the clearing of vegetation and changes to hydrology such as increased stormwater discharge of poorer water quality, (LIA 2010). Table 6-9 summarises the general condition of the Lake based on key indicators. As it is an estuarine water body, it is appropriate to compare water quality in the Lake with ANZECC (2000) default trigger values for the protection of estuarine ecosystems, as well as the site-specific trigger values developed by LIA (2010).

Table 6-9 Summary condition of Lake Illawarra based on key indicators

Indicator	Lake Illawarra Authority (2010) 80th percentile	ANZECC (2000) 80th percentile	Comments (results are median data)
Chlorophyll–a (µg/L)	7	4	Generally good. Griffins Bay exceeded (4.6 µg/L). Griffins Bay and Kanahooka data variable (between 0.5 and 60.5 µg/L).
Total phosphorus (TP) (µg/L)	120	30	Generally high due to weathering of basaltic geology underlying the Lake (LIA 2010). All sites within LIA (2010) value. Griffins Bay, Kanahooka and Burroo Bay exceeded ANZECC (2000). 33.95, 39.85 and 57.75 µg/L respectively. TP varies seasonally – directed by catchment inputs (LIA 2010).
Filterable reactive phosphorus (µg/L)	68	5	All sites complied with LIA (2010. High concentrations throughout the Lake, all sites exceed ANZECC (2000). Burroo Bay showed the highest concentration at (25.35 µg/L) which was also highly variable.
Total nitrogen (TN) (µg/L)	720	300	TN varies throughout Lake, and is elevated during summer when rainfall is highest (LIA 2010). Sources include fertiliser, wastewater flows, and decaying matter. All sites complied with LIA (2010) trigger value. Griffins Bay and Burroo Bay exceeded ANZECC (2000) 403 and 374 µg/L respectively.
NOx (µg/L)	40	15	Generally good. All sites met LIA (2010) value. All sites met ANZECC (2000) except South Break Wall (15.65).
Turbidity (NTU)	<6	10	All sites met ANZECC (2000) default trigger value. All sites met LIA (2010) values except Burroo Bay (7.96 NTU).

Studies have shown Macquarie Rivulet to generate the highest nitrogen and phosphorus loads to the Lake (WCC 2009b). Drainage to Macquarie Rivulet has been significantly altered as a consequence of urbanisation (Rienco Consulting 2010). Elevated TN and TP levels may be due to current land use practices and the erosion of the waterways, rather than the impact of stormwater (Thiering et al 1988). WCC (2006a) also describe elevated TN and TP levels in the Mullet Creek catchment, from a number of human activities. No water quality data is available for Horsley and Connor Creek (SKM 2011). Budjong Creek has experienced significant urbanisation over the past 10 to 20 years. Concern about the pollutant load entering Lake Illawarra from the increasing population resulted in the construction of Budjong Creek Wetland. This is an artificial wetland at the outlet of the creek which is estimated to remove approximately 50 per cent of nutrient loads from runoff in the catchment (Critchley 2011 and LIA 2003).

Aquatic ecology

The Lake is listed on the *Directory of Important Wetlands in Australia* (NSW081) (AWD 2010) and is listed under SEPP 14 and Schedule 1 of the Coastal Protection SEPP for protection of conservation values. The shallow nature and saline conditions of Lake Illawarra provide ideal conditions for seagrasses including *Zostera sp.* and *Ruppia sp* (West *et al* 1985). These seagrasses are an important food (eg for waterfowl) and habitat resource. A total of 24 species of waterbirds have been recorded on Lake Illawarra. Whilst no nationally threatened or endangered aquatic species have been recorded within Lake Illawarra, several nationally endangered terrestrial species have been recorded including the Rainforest Vine *Cynanchum elegan,* Rice Flower *Pimelea spicata,* the Little Tern (*Sterna albifrons),* and the Regent Honeyeater (*Xanthomyza Phrygia*). Lake Illawarra may also provide habitat for a large number of vulnerable bird species (SKM 2011).

Lake Illawarra is known to experience algal blooms, particularly when nutrient loads and light availability are conducive to growth. LIA (2010) report both micro-algal and macro-algal blooms. SEPP 14 wetlands within Lake Illawarra are located near the mouth of Macquarie Rivulet and Duck Creeks and also near Bevans Island.

Macquarie Rivulet catchment contains a SEPP 14 listed wetland, and is tidally influenced in its lowest reaches. Brooks Creek (a sub-catchment to Lake Illawarra) drains an almost fully urbanised catchment with more than 70 per cent of the catchment being residential. There are several stormwater outlets along various parts of the creek (WCC 2007a). The limited water quality data that exists indicates elevated nutrient concentrations, particularly nitrogen, which exceeds the ANZECC (2000) default trigger value. This is evident in the fact that Wollongong City Council has identified Brooks Creek as having an extensive aquatic weed problem (WCC 2007a).

Public health

The Lake is an important environmental, recreational and commercial resource, providing habitat for saltmarshes and natural wetlands.

Lake Illawarra is a popular area for swimming, boating, fishing and other recreational activities. The most recent Beachwatch water quality data collected for 2009-2010 by Shellharbour City Council (SCC 2010) found:

- that bacteria levels fluctuated generally in response to rainfall
- that water quality in the entrance lagoon area (widely used for swimming) met the ANZECC (2000) default trigger values for primary contact recreation for most of the period.

When the guidelines were occasionally exceeded due to rainfall, levels were not excessive and posed little risk to human health (SCC 2010).

In the Mullet Creek catchment, WCC (2006a) reported elevated faecal coliforms in parts of Robins, Reed and Mullet Creeks. However, this was thought to be due to stormwater runoff from beef and dairy cattle farms. In the upper reaches of Macquarie Rivulet Catchment, enterococci concentrations met the NHMRC (2008) recreational guidelines for category B classification (category B means that there is a 1 to 5 per cent risk that a healthy adult bather will get gastrointestinal illness, NHMRC 2008).

Other catchments

There are three other catchments that contain directed overflows potentially impacted by the Proposal but which do not discharge to Lake Illawarra:

- Barrack Creek Catchment – 12 km^2 (Table 6-14)
- Allan's Creek Catchment – 42 km^2 (Table 6-15)
- Port Kembla Catchment – 9 km^2 (Table 6-16).

Water quality

Limited water quality data is available for Barrack Creek catchment, which drains to the ocean south of Lake Illawarra. Similarly, no raw water quality was available for analysis for Tom Thumb Lagoon in the Port Kembla catchment, (SKM 2011). Available literature indicates water quality is generally poor in Tom Thumb lagoon, in terms of suspended solids, possibly linked to tidal currents stirring up sediments deposited around the waterway. Nutrient concentrations are high at Tom Thumb lagoon (Figure 6-11) possibly due to leachates from decommissioned landfill sites (WCC 2007a). Faecal coliforms are low, and are not a concern (WCC 2007a). Pressures on the Lagoon include leachates from a former tip, stormwater and effluent from nearby steel works and wastewater discharge at times of high rainfall (Wetland Link 2011).

There are several major tributaries to Allan's Creek catchment, draining escarpment slopes and residential and industrial areas. WCC (2007a) found that dissolved oxygen and nitrite were indicators of concern, especially in the upstream extent of Allan's Creek itself.

Aquatic ecology

The Barrack Creek catchment contains Barrack Swamp (Figure 6-12), which is a freshwater swamp located near Shellharbour WWTP. Whilst limited water quality data is available for Barrack Creek catchment, available data for Bensons Creek suggests water quality is good, with all monitored indicators meeting ANZECC (2000) default trigger values (SKM 2011).

Gurungaty Creek drains the Port Kembla Catchment, which flows into Tom Thumb Lagoon before discharging to the ocean (see Figure 6-13). Tom Thumb Lagoon is an estuarine channel with remnant saltmarsh and tidal mudflats. Approximately 93 per cent of this catchment is used for industrial or industrial related purposes (WCC 2007a). The wetland contains stands of Coastal Saltmarsh and Swamp Oak Floodplain Forest, both of which are listed as endangered ecological communities under the TSC Act. In 2009 there was a sighting of the vulnerable Green and Golden Bell Frog.

Water sampling of tributaries in Allan's Creek catchment showed elevated levels of TN, nitrite, TP and ammonia in several locations (eg Charcoal Creek TN concentrations exceeded the ANZECC (2000) default trigger values fourfold). The ephemeral nature of Jenkins Creek tributary may account for its elevated nutrient concentrations, as sampling only occurred after rainfall events (WCC 2007a).

Further detail of the existing aquatic ecology of the Proposal area is provided in Section 6.5.

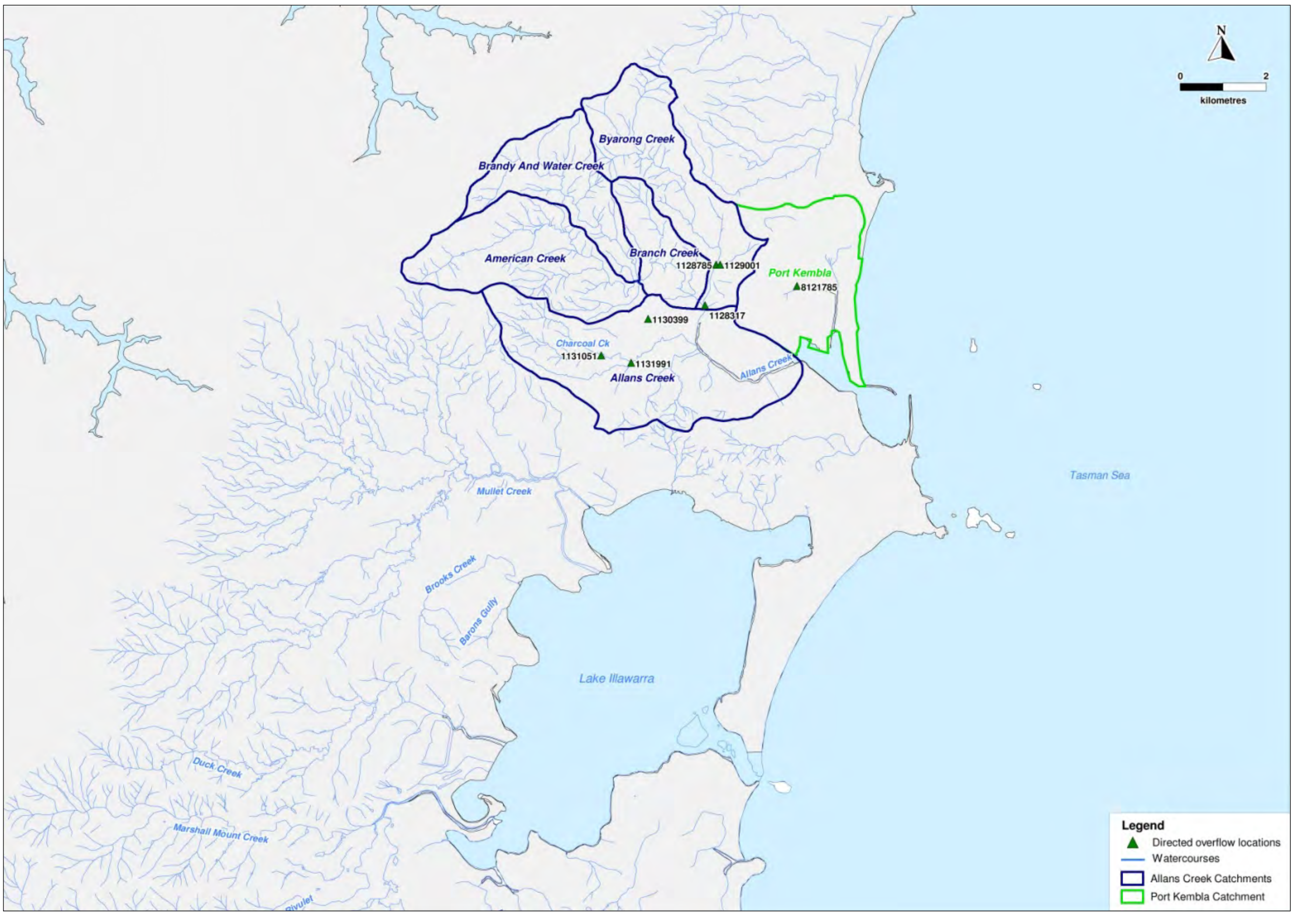


Figure 6-13 Allan's Creek and Port Kembla Catchments and directed overflows

Public health

Barrack Creek catchment is predominantly residential, and contains two major creeks (Barrack and Bensons), which lead to a small estuary known as Little Lake (sometimes known as Elliot Lake) via a system of modified channels. Elliott Lake is a popular location for recreational activities, particularly over the summer period. SCC (2010) reported that for the 2008-2009 and 2009-2010 years, one out of four enterococci samples taken in January and February exceeded the ANZECC (2000) default trigger values.

WCC (2007a) identified elevated faecal coliforms as a key problem in the Allan's Creek catchment, even in areas not impacted by overflows. The ephemeral nature of the creeks in this catchment may partly account for the high concentrations of indicator substances. In addition, not all sites were considered prime sites for recreational contact.

For Tom Thumb Lagoon (in the Port Kembla catchment), faecal coliform concentrations are low, and are not a concern (WCC 2007a).

6.4.2 Construction impacts

The Proposal has the potential to impact water quality, aquatic ecology and public health in the inland environment during construction and operations. Potential impacts on water quality during construction are discussed further in Section 6.8, soils, geology and groundwater. Potential impacts on aquatic ecology are discussed in Section 6.5, flora and fauna.

6.4.3 Operational impacts

Potential impacts during operation of the Proposal would be from wastewater discharging from directed overflows in dry or wet weather.

Water quality guidelines and indicators

Guidelines for assessing the potential inland aquatic ecology and public health impacts of the Proposal are the:

- *NSW Water Quality Objectives (for the Illawarra Catchment)* (DEC 2006a)
- *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (ANZECC 2000)
- *National Health and Medical Research Council, Guidelines for managing risks in recreational water* (NHMRC 2008).

NSW water quality objectives

The DEC (DEC 2006a) nominated a number of environmental values for the Illawarra Catchment, as well as indicators and guideline levels to protect the environmental value. The relevant values for this study are:

- aquatic ecosystems
- primary and secondary contact recreation
- visual amenity.

Aquatic ecosystems

Aquatic ecosystems comprise the animals, plants and micro-organisms that live in water and the physical and chemical environment in which they interact. There are number of naturally occurring physical and chemical stressors that can cause degradation of aquatic ecosystems. For the purposes of this assessment these include chlorophyll-a, nutrients, dissolved oxygen, pH, salinity and turbidity (suspended solids).

Nutrients in aquatic environments promote the growth of algae and increase turbidity which in turn reduces light and may affect plant growth. Generally excessive nutrient inputs lead to excessive algal growth and formation of nuisance blooms. Nutrients consist of nitrogen (including TN nitrogen, ammonia, oxidised nitrogen) and phosphorus (including total phosphorus and filterable reactive phosphorus). TN is a measure of all nitrogen species found in a water body. Ammonia represents the most reduced form of inorganic nitrogen, as such it is readily taken up by microorganisms. Main sources of ammonia are found to be released during decomposition of organic material by bacteria from human and animal wastes. Oxidised nitrogen represents the level of 'free' nitrogen within the water column. As Lake Illawarra is nitrogen limited, excessive concentrations of oxidised nitrogen and ammonia can lead to promoted algal growth.

Primary and secondary contact recreation

Recreational activities in and around the water are highly valued by the community in the study area, and therefore protection of water for recreational use is necessary. There are two main categories of recreational water use being ‘primary’ and ‘secondary’ contact which refer to types of recreation. Primary contact recreation denotes direct water contact via bodily immersion or submersion with a high potential for ingestion. It includes activities such as swimming, diving and water skiing. Secondary contact recreation denotes some direct contact with water but where ingestions is unlikely and includes activities such as boating, fishing and wading.

Pathogens are the main constituent of wastewater that are likely to impact on the recreational use of local waterways. Pathogens found in both human and animal faeces can increase the risk to public health if the concentrations of this are significant in the overflow. As it is not feasible to monitor pathogenic organisms routinely, indicators organisms including faecal coliforms and enterococci are often used as bacteriological indicators of contamination of water. Bacteriological indicators are used to assess the suitability of water for recreation as they detect faecal contamination of water and hence the likely presence of pathogenic organisms.

Visual amenity

The aesthetic appearance of a waterbody is an important aspect with respect to recreation. The water should be free from obvious pollution, floating debris, oil, scum and other matter. Substances producing objectionable colour, odour, taste or turbidity and substances and conditions that produce undesirable aquatic life should not be apparent (NHMRC 2008). The key aesthetic indicators are transparency, odour, colour and large objects (eg litter).

For each of these values, nationally agreed guidelines and criteria help to determine the water quality that will protect it. The central reference is the *Australian Guidelines for Fresh and Marine Water Quality* (ANZECC 2000). The WQOs and ANZECC (2000) guidelines provide long-term goals for water quality.

ANZECC (2000)

ANZECC (2000) guidelines set default trigger values as a threshold or as a desirable range. They are designed for assessing ambient waters, and are not regulatory, design or discharge standards (DEC 2006b). For this Proposal, the relevant criteria for the protection of aquatic ecosystems are the ANZECC (2000) default trigger values for slightly disturbed ecosystems (see Table 6-10). In accordance with the ANZECCC (2000), LIA developed site specific guidelines for Lake Illawarra (see Table 6-10). They are based on the 80th percentile of existing water quality data (LIA 2010).

Table 6-10 ANZECC (2000) default trigger values for aquatic ecology relevant to this Proposal

Ecosystem Type	Indicator									
	Chl-*a* (µg/L)	TP (µg/L)	FRP (µg/L)	TN (µg/L)	NOx (µg/L)	NH4+ (µg/L)	DO (% sat)	pH	Salinity (µS/cm)	Turbidity (NTU)
Lowland River[1]	3 (5[2])	25	20	350	40	20	85-110	6.5-8.5	125-2200	6-50
Estuaries[1]	4	30	5	300	15	15	80-110	7-8.5	N/A	0.5-10
Lake Illawarra[3]	7.01	120	68	720	40	60	N/A	N/A	N/A	< 6.11

[1]ANZECC (2000) and DEC (2006a), [2] DEC (2006a), [3]LIA (2010).

While ANZECC (2000) provides default trigger values for assessment as concentrations, it is recommended that for more complex water quality issues, indicators such as nutrients should be expressed as loads (SKM 2011). Assessments using loads are considered more robust because they are not influenced by variable factors such as rainfall intensity. Hence a mass balance assessment was used to assess the impact of the Proposal.

NHMRC (2008)

The NHMRC (2008) guidelines assist in protecting human health from threats posed by the recreational use of coastal, estuarine and fresh waters. They are not mandatory, but they are a tool to develop legislation and standards appropriate for local conditions.

The NHMRC (2008) recommend enterococci (rather than faecal coliforms) as the key indicator of microbial quality. As this recommendation to use enterococci is relatively recent, faecal coliform data is still widely collected and enterococci data limited. Also the recommendation to used enterococci as the primary indicator is used on bather illness studies in *marine waters*. Therefore the NHMRC (2008) guidelines for classifications based on enterococci have been applied for determining the suitability of a site for recreation (see Table 6-11) where enterococci data is available. Where enterococci data are not available, the ANZECC (2000) default trigger values and DEC (2006a) guidelines for protection of primary and secondary contact recreation are used for classifications based on faecal coliforms (Table 6-12).

Table 6-11 NHMRC (2008) public health guidelines relevant to this Proposal

Category (based on estimates of probability of gastrointestinal illness)	Microbial water quality assessment category (95^{th} percentile – intestinal enterococci/100mL)
A illness risk <1%	<40
B illness risk 1-5%	41-200
C illness risk 5-10%	201-500
D illness risk >10%	>500

Table 6-12 ANZECC (2000) public health default trigger values and DEC (2006a) water quality objectives relevant to the Proposal

Environmental value	Median faecal coliforms (cfu/100ml)
Primary Contact Recreation	Median <150 (with 4 of 5 samples <600)
Secondary Contact Recreation	Median <1000 (with 4 of 5 samples <4000)

Assessment methodology

SKM (2011) analysed how the volume and frequency of directed overflows changed over time from a 2009 base case due to the WDURA and AGA development at 2021 and 2048. 2021 is the date at which the Project Approval area is expected to be fully developed, and 2048 is the date at which the Proposal will be developed. The analysis was based on 'average' wet weather overflows at each location, and then presented on an overall catchment basis.

The assessment is semi-qualitative, and considers the relative changes in indicator loads over time, and it has limitations over a quantitative assessment. A fully quantitative assessment (typically involving monitoring and numerical modelling) was not considered viable, due to insufficient data regarding quality of the receiving waters, stormwater quality and river hydraulics. The Proposal is highly complex in terms of the variable aspects of each overflow event and location and the impact of different rainfall events and there is uncertainty around ecosystem responses and interpretation. The risk-based methodology is consistent with NHMRC (2008) and ANZECC (2000) guidelines (SKM 2011).

Risk levels are dependent upon the location, volume and frequency of directed wet weather overflows and the sensitivity of the receiving environment. Directed overflows having the potential to impact public health ranked as the highest risk. Directed overflows with low or medium risk due to their location, volume and frequency of discharge ranked lowest.

Of the 49 directed overflows potentially impacted by the Proposal, 10 were shown to have either zero discharge, or very minor increases due to the Proposal. A further three directed overflows discharge to the marine environment and were assessed in the marine water quality Section (6.3). Therefore, 36 directed overflows were subjected to the risk-assessment methodology.

The risk assessment identified 20 directed overflows to progress to a mass balance assessment, based on a notable increase in volume and/or frequency of discharge due to the Proposal. In addition, the risk assessment process prioritised overflows based on the sensitivity of the receiving environment (eg wetlands had a high priority). Figure 6-14 shows the steps in the methodology to determine whether an overflow location would go through to the impact assessment after the mass balance assessment.

The mass balance assessment determined how the loads of key water quality indicators per overflow event change over time. The change over time is presented as change from the 2009 base case to the developed Project Approval area (2021) and the anticipated full development of the Proposal area (2048). Inputs to the mass balance model include average pollutant load from dry weather wastewater and volume of overflow.

The key water quality indicators and assumed concentrations in untreated wastewater are:

- nutrients TN 55 mg/L and TP 10 mg/L
- faecal coliforms 10^7 cfu/100 mL
- TSS 300 mg/L.

Discharge from directed overflows is made up of a combination of wastewater and stormwater that has infiltrated through older parts of wastewater system. The wastewater system includes private wastewater pipelines connecting properties to the Sydney Water pipelines. The proportion of wastewater to stormwater will vary according to the capacity of the wastewater system at each directed overflow point.

The Proposal anticipates expansion of the wastewater system capacity over time to accommodate the increased volume of wastewater resulting from growth. A consequence is that for some directed overflows, even though there may be an increase in discharge frequency and/or volume, there may also be a reduction in the proportion of pollutant load from wastewater as there is proportionally more stormwater in the system.

Compared with the 2009 base case, the mass balance assessment showed an increase in the loads/event at 10 directed overflow locations. These 10 were taken forward to the impact assessment stage. The remaining overflows were not considered to present an impact as a result of WDURA and AGAs due to no increase in event pollutant loads and in some cases, notable decreases in event pollutant loads.

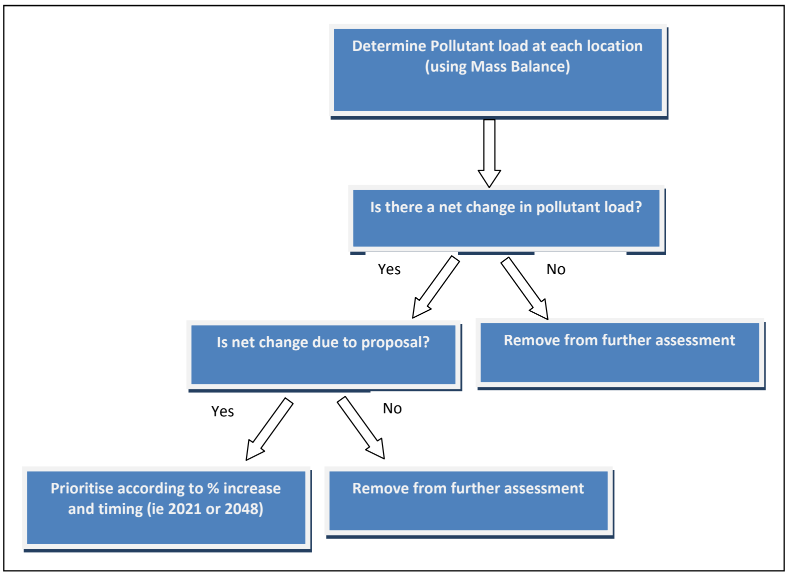


Figure 6-14 Mass balance assessment and categorising overflows to go through to impact assessment

For comparison, an assessment of the annual relative contribution of indicator substances from stormwater was also conducted for each catchment. This was based on a Geographical Information System (GIS) analysis of the number and extent of different land uses in each of the catchments, and their corresponding rainfall coefficients (the percentage of rainfall that appears as stormwater runoff). The concentrations of key pollutants in stormwater were determined for each land use for a median annual local rainfall event[1]. The annual pollutant loads were then calculated by multiplying the annual rainfall, runoff coefficient and stormwater pollutant concentrations for each catchment.

Assessment results - general

Dry weather

Dry weather overflows may occur due to unforeseen blockages in the system (eg tree roots or pipeline collapses) or to failure of pumping stations. In accordance with the Sewage Pumping Station Code of Australia (WSAA 2005), pumping stations are required to have a minimum of 4 hours average dry weather flow (ADWF) storage capacity in the event of a functional failure. Unlike wet weather flows, dry weather flows are low volume, and are not diluted by rainwater and consist primarily of raw wastewater, and contain high concentrations of pathogens, nutrients and putrescible matter. In addition, flows in rivers and waterways will be low in the dry weather, and the possibility of dilution is further reduced. The EPA (EPA 2000a) noted that an independent inquiry determined dry weather overflows of more concern than wet weather flows. Given the relatively high potential impact of dry weather overflows on aquatic ecology and public health, the Proposal is designed with sufficient hydraulic capacity to meet the objective of having no dry weather overflows. This meets the current EPL requirements.

Wet weather

Wet weather overflow points are required in wastewater systems to prevent wastewater backing up in the system. The majority of overflows from wastewater systems occur during or after large wet weather events, as rainfall and runoff finds its way into the system. Rainfall and runoff can inflow into the systems through cracks in pipes and joints, and illegal connections of stormwater downpipes to the wastewater system, or if the system is poorly designed. The new WDURA and AGA wastewater pipelines will minimise opportunities for inflow as they are new (ie yet to deteriorate) and designed to minimise infiltration. It should be noted that it is impractical to design and construct a wastewater system that has no rainwater inflows as most gravity wastewater systems are located in the lowest part of the catchment where rainwater naturally flows and collects. Nevertheless, infiltration of stormwater/rainfall is less likely in the new pipelines to be connected to the existing wastewater system. New ‘leak tight’ sewers, use new materials and welding techniques to reduce the infiltration to an expected 1 per cent of rainfall.

Sydney Water has set system based wet weather overflow frequencies for each of its wastewater systems through EPLs. The long-term wet weather overflow targets for the Wollongong and Shellharbour system EPLs are 40/10 years and 45/10 years respectively. The Proposal has been designed to comply with these targets. Hydraulic modelling indicates that, with the exception of two directed overflows in the Shellharbour system (ID 1123473 and ID 1125953), all of the directed overflow locations would be compliant with their respective EPLs. The two directed overflow locations that may exceed their EPL overflow frequency targets are modelled to be triggered up to 46 and 48 times (in 10 years) between 2031 and 2048 (ID 1123473 and ID 1125953). The need for further works to address performance and impact of these overflows would be addressed closer to this time.

Public health

Overflows are directed to stormwater or creeks and are only likely during or after large wet weather events. This ensures they will be diluted by river flows and catchment runoff and the potential for human contact with wastewater is minimised. Overflows may contain increased volumes of faecal coliforms and enterococci that are a risk to public health, particularly if swimming or other primary

[1] (based on 2000-2010 data from a rainfall gauge at Albion Park).

or secondary recreational activities take place near the discharge locations. However, faecal coliforms and enterococci bacteria typically only survive for 3 days following the overflow, and therefore any risk to public health is temporary. Indeed it is for this reason that DoH recommend that primary contact recreational activities (eg swimming) are avoided for one day at ocean beaches following heavy rain. DoH further advises to avoid swimming near stormwater drains or wastewater outfalls.

Wet weather overflows from the Proposal will not meet the concentrations for faecal coliforms and enterococci recommended in the NHMRC (2008), DEC (2006a) or ANZECC (2000) default trigger values at the point of discharge. However, the assessment employs a risk-based approach for the protection of public health and is consistent with the NHMRC (2008) guidelines for protecting public health in recreational waters.

Impacts have been mitigated during the design process to:

- avoid discharging at new directed overflow locations
- discharge only in large wet weather events
- minimise overflow frequency and comply with the EPL wet weather overflow limits
- only discharge to waterways (in large wet weather events), which will minimise human contact with wastewater.

Aquatic ecology

Overflows of wastewater in large wet weather events contribute to the loads of TN, TP and TSS discharged. Significant increases in TN and TP loads over time can affect aquatic ecosystems by:

- promoting plant biomass, which can reduce the oxygen available to aquatic fauna
- increasing the potential for algal blooms, which can be toxic to aquatic fauna.

Increased TSS loads over time can affect aquatic ecosystems by:

- reducing the light penetration, which can reduce primary production
- increasing the possibility of gill clogging in fish
- smothering benthic organisms and their habitats.

Aquatic plants and seagrasses are a component of shallow lakes and wetlands in the Proposal area. As nutrient loads increase there is the risk that these plants and seagrass will be replaced by algae and phytoplankton, which can reduce the ecological value of a system. Seagrasses are ecologically important and require clear water to grow. Algal blooms and increased turbidity as a result of increased loads, result in less light and subsequently less photosynthetic performance and the potential decline in health of seagrass beds. In addition, there may be aesthetic impacts for recreational water users, such as anaerobic conditions that may have associated odour problems.

Sydney Water is required to maintain the system over time to ensure that its systems based wet weather overflow targets are not exceeded. This ensures that '…the environmental impacts associated with the operation and management of sewer overflows will be properly addressed' (EPA 2000a).

Impact assessment results indicate that the annual contribution of nutrient load from wastewater is small compared with the contribution from stormwater. Compared to current loads from existing land uses in the Barrack's Creek catchment, predicted wet weather overflows in 2048 would be equivalent to approximately:

- 8 per cent of the annual TN load
- 6 per cent of the annual TP load
- >1 per cent of the annual TSS load.

Similar results were found for the Port Kembla catchment, and these were much lower contributions from wastewater in the remaining catchments. Clearly, there are many diffuse and point sources in a catchment that contribute to ambient water quality. According to DEC (2006c), it may not be equitable to require one activity alone to restore ambient water quality for environmental values, unless it is the only activity affecting water quality or it is the greatest impact.

The catchments already receive a considerable nutrient and TSS contribution from stormwater flows. Algal blooms occur and aquatic weeds exist in the Proposal area, however they are not considered significant issues in the catchment. As such, the assimilative capacity of the receiving environment appears to be fairly resilient. It is highly unlikely that these impacts would occur as a direct result of WDURA and AGAs (SKM 2011).

During large wet weather events, the wastewater is unlikely to meet the recommended ANZECC (2000) (or LIA 2010) concentrations for all indicators, as the typical concentrations in wastewater are greater than the guideline limits. Whilst wastewater discharges may exceed the guidelines, the current receiving environment generally assimilates pollutants well (SKM 2011). Concentrations of indicator substances in wastewater overflows will be rapidly diluted by the receiving waterway.

Assessment results – catchment basis

This section presents the results of the risk and mass balance assessment for the ten directed overflows taken forward for impact assessment. The results are presented for each potentially impacted catchment.

Lake Illawarra catchment

Of the 22 directed overflows in this catchment, eight were subjected to mass balance assessment on the basis of risk, and only three were subjected to impact assessment due to an increase in load/event. Table 6-13 summarises the results of the risk assessment and mass balance analysis for three directed overflows in the Lake Illawarra catchment, which were subjected to impact assessment, SCOF107, SCOF117 and 1120960 (see Figure 6-11).

Table 6-13 Summary of impact assessment of directed overflows in the Lake Illawarra catchment

Lake Illawarra catchment (directed overflow ID)	Comments following risk assessment	Comments following mass balance	Percentage change in load/event from 2009		Maximum discharge frequency/ 10 years modeled at 2048 (note all within the EPL limit)
			2021	2048	
Budjong Creek (SCOF107)	Discharges directly to Budjong Creek, which enters Lake Illawarra. Potential impacts on aquatic ecosystems (seagrasses) and public health (boat ramp nearby and recreational area).	Increase in load/event for all indicators between 2009 and 2021. Loads/event continue to marginally increase between 2021 and 2048.	61	76	32
Mullet Creek (SCOF117)	Discharges to Mullet Creek, (which enters Lake Illawarra approximately 4 km downstream). Potential impacts on aquatic ecosystems (wetlands and seagrasses).	Increase in load/event for all indicators between 2009 and 2021. Loads/event continue to marginally increase between 2021 and 2048.	195	241	39
Horsley and Connor Creek (1120960)	Discharges to Horsley Creek, drains to Koona Bay Beach (a popular recreational site). Potential impacts on aquatic ecosystems and public health.	Loads per event *decrease* between 2009 for all key indicators. Between 2021 and 2048, indicator loads/event increase to levels marginally above 2009 levels.	-4	8	38

These overflows will increase in discharge frequency over time. However, hydraulic modelling of the new system configuration showed that all three directed overflows would comply with the long-term wet weather overflow limit set by OEH for the Wollongong system EPL of 40 overflows in 10 years. Any risks to public health will be temporary (due to rapid bacterial die-off) and infrequent (between three and four times a year on average).

At overflow 1120960, there is only a minor increase in the load/event at 2048 compared to the 2009 base case. A load/event *decrease* is predicted at 2021, due to the predicted increase in stormwater dilution within the system. There is an overall increase in nutrient load/event over time at SCOF117 and SCOF107. SCOF117 is the largest overflow in the Wollongong wastewater system and presents the highest risk to receiving waters. However, for comparison, the contribution of nutrient and TSS loads from wet weather overflows as a percentage of stormwater loads was estimated. The loads/event from wastewater are relatively minor compared to stormwater contributions from this sub-catchment.

Increases in loads over time at directed overflow SCOF117 in the Mullet Creek catchment together with stormwater loads may result in an exceedance of the maximum pollutant load that can be assimilated to maintain environmental values (SKM 2011). Compared to current loads from existing land-uses in the Lake Illawarra catchment, predicted wet weather overflows in 2048 would be equivalent to approximately:

- 4 per cent of the annual TN load
- 3 per cent of the annual TP load
- >1 per cent of the annual TSS load.

Based on this, the pollutant contribution from the Proposal would be small compared to the contributions from other sources such as stormwater. Sydney Water would continue to monitor and operate the system to ensure that wet weather overflows comply with the EPL.

Barrack Creek catchment

Of the 17 directed overflows in this catchment, six were subjected to mass balance assessment, and only three were subjected to impact assessment due to an increase in load/event. Table 6-14 summarises the results of the risk assessment and mass balance analysis for three directed overflows in the Barrack Creek catchment that were subjected to impact assessment (1400028, 1125705 and 1122981) (Figure 6-12).

Table 6-14 Summary of impact assessment of directed overflows in the Barrack Creek catchment

Barrack Creek catchment (directed overflow ID)	Comments following risk assessment	Comments following mass balance	Percentage change in load/event from 2009		Maximum discharge frequency/10 years modelled at 2048 (note all within the EPL limit)
			2021	2048	
Barrack Creek 1400028	Discharges via stormwater drains to Bensons Creek, which enters Little Lake. Potential impacts on aquatic ecosystems (seagrasses) and public health (popular summer swimming site).	Minor increases in TSS and faecal coliform loads over time, TN and TP remain relatively constant.	4	12	31
Barrack Creek 1125705	Discharges directly to wetlands near Barrack Creek. Little Lake (1.2 km downstream) contains seagrasses and is a popular summer swimming site.	Increased loads/event for all indicators at 2021. Loads/event continue to marginally increase between 2021 and 2048.	45	62	43
Barrack Creek 1122981	Discharges directly to wetlands near Barrack Creek. Little Lake (1.2 km downstream) contains seagrasses and is a popular summer swimming site.	Increased loads/event for all indicators at 2021. Loads/event remain constant between 2021 and 2048.	29	28	40

Hydraulic modelling of the new system configuration showed that all three directed overflows would comply with the long-term wet weather overflow limit set by OEH for the Shellharbour system EPL, of no more than 45 overflows in a 10 year period.

Barrack Swamp, a freshwater wetland, contains important aquatic ecosystems, including seagrasses. Directed overflows will contribute to increased loads of TSS, TN and TP. Increases in loads over time at directed overflow 1122981 and 1125705 in the Barrack Creek Catchment together with stormwater loads may result in an exceedance of the maximum pollutant load that can be assimilated to maintain environmental values (SKM 2011). The loads/event from wastewater are relatively minor compared to stormwater contributions from this sub-catchment. Compared to current loads from existing land uses in the Barrack Creek catchment, predicted wet weather overflows in 2048 would be equivalent to approximately:

- 14 per cent of the annual TN load
- 10 per cent of the annual TP load
- >1 per cent of the annual TSS load.

Based on this, the pollutant contribution from the Proposal would be small compared to the contributions from other sources such as stormwater. Sydney Water would continue to monitor and operate the system to ensure that wet weather overflows comply with the EPL.

Little Lake is a popular swimming site, especially in the summer months, and it flows to the ocean at Warilla Beach. Shellharbour City Council has launched a stormwater education program to increase awareness of stormwater pollutants, with the aim of improving water quality in Elliot Lake (SCC 2010). Results show that wet weather overflows which may impact Little Lake are infrequent (between three and four times a year on average) and any risks to public health will be temporary, due to rapid bacterial die-off.

Allan's Creek catchment

Of the six directed overflows in this catchment, only three were subjected to impact assessment due to an increase in load/event. Table 6-15 summarises the results of the risk assessment and mass balance analysis for three directed overflows in the Allan's Creek catchment (Figure 6-13) that were subjected to impact assessment (1130399, 1128785 and 1128317).

Table 6-15 Summary of impact assessment of directed overflows in the Allan's Creek catchment

Allan's creek catchment (directed overflow ID)	Comments following risk assessment	Comments following mass balance	Percentage change in load/event from 2009		Maximum discharge frequency/ 10 years modelled at 2048 (note all within the EPL limit)
			2021	2048	
Allan's Creek 1130399	Discharges via Byarong Creek , Brandy and Water Creek before entering Allans Creek and then Port Kembla Harbour. Potential impact on aquatic ecosystems.	Increased loads/event for all indicators at 2021. Loads/event remain constant between 2021 and 2048.	43	43	30*
Allan's Creek 1128785	As above	As above	31	31	31*
Allan's Creek 1128317	Discharges directly into Byarong Creek and then into Allans Creek and Port Kembla Harbour.	Increased loads/event for all indicators at 2021. Loads/event remain constant between 2021 and 2048.	44	44	21

*targeted works to improve current (2009) overflow discharge of 33/10 years.

Overflows are modelled to increase in frequency over time. However, hydraulic modelling of the new system configuration showed that all three directed overflows would comply with the long-term wet weather overflow limit set by OEH for the Wollongong system EPL of no more than 40 overflows in a 10 year period. System maintenance planned to occur before 2016, will lead to a reduction in the frequency of overflows at 1130399 and 1128785 compared with the 2009 case. This will lead to a reduction in the average number of overflows/year at these locations. Whilst none of the three directed overflows are deemed to be popular recreational sites, public health risks are minimised by these reductions.

Directed overflows will contribute to increased loads of TSS, TN and TP. The loads/event from wastewater are relatively minor compared to stormwater contributions from this sub-catchment.

Compared to current loads from existing land uses in the Allan's Creek catchment, predicted wet weather overflows in 2048 would be equivalent to approximately:

- 1 per cent of the annual TN load
- 1 per cent of the annual TP load
- >1 per cent of the annual TSS load.

Due to the assimilative capacity of the receiving environment, additional pollutant loads are unlikely to have harmful effects on aquatic ecosystems or on the water quality downstream in Port Kembla harbour.

Wollongong catchment

There is only one directed overflow in this catchment. This directed overflow (8121785 on Figure 6-13) was taken through the risk, mass balance and impact assessment stages. Hydraulic modelling of the new system configuration showed that directed overflow 8121785 will meet the long term wet weather overflow limit of no more than 40 overflows in a 10 year period in the Wollongong system EPL (see Table 6-16).

Table 6-16 Summary of impact assessment of directed overflows in the Wollongong catchment

Wollongong catchment (directed overflow ID)	Comments following risk assessment	Comments following mass balance	Percentage change in load/event from 2009		Maximum discharge frequency/10 years modeled at 2048 (note within the EPL limit)
			2021	2048	
Wollongong 8121785	Potential impact on aquatic ecosystems, discharges into Tom Thumb Lagoon which contains an endangered ecological community and wetlands.	Increased loads/event for all indicators at 2021. Loads/event remain constant between 2021 and 2048.	19	19	34

Wet weather overflows are infrequent (an average of 3.4 times a year) and risks to public health will be temporary, due to rapid bacterial die-off. Tom Thumb lagoon has been considerably modified over the last several decades. Although it is used by the local community as a foot and bicycle commuter corridor (WCC 2007b), it is not deemed to be a popular primary or secondary recreational site. Therefore risks to human health are further reduced. Restoration and rehabilitation works have been conducted by Council and volunteer initiatives for over 15 years (Wetland Link 2011).

Directed overflows will contribute to increased loads of TSS, TN and TP. Tom Thumb Lagoon and wetlands currently assimilate pollutant loads from stormwater and existing wastewater overflows. Additional loads as a result of the Proposal are expected to be readily assimilated. The loads/event from wastewater are relatively minor compared to stormwater contributions from this sub-catchment. Compared to loads from existing land-uses in the Port Kembla catchment, predicted wet weather overflows in 2048 would be equivalent to approximately:

- 11 per cent of the annual TN load
- 7 per cent of the annual TP load
- >1 per cent of the annual TSS load.

Overall assessment findings

The EA found that potential impacts during operation of the Proposal would be mainly from wastewater discharging from directed overflows in wet weather. Directed overflow points are designed in the system to prevent wastewater backing up in the system, during or after large wet weather events. Overflows are directed to stormwater or creeks to ensure they will be diluted by river flows and catchment runoff and the potential for human contact with wastewater is minimised. Wet weather overflows from the Proposal would be discrete and infrequent events that would last for a relatively short period of time.

The impact assessment employed a risk-based approach for the protection of public health and is consistent with the NHMRC (2008) guidelines for protecting public health in recreational waters. The impact assessment concluded that during and directly after extreme events the NHMRC (2008), DEC (2006a) or ANZECC (2000) recommended default trigger values for pathogens are unlikely to be met at the point of discharge, but any potential risk to public health would be temporary, as pathogens only live for a relatively short time. It is for this reason that DoH recommend that primary contact recreational activities (eg swimming) are avoided for one day at ocean beaches, and three days in estuaries and rivers. DoH further advises to avoid swimming near stormwater drains or wastewater outfalls. Based on these findings it is considered that overall the impact to human health from the Proposal would not be significant.

The impact assessment determined that the annual contribution of nutrient load from wastewater is small compared with the contribution from stormwater. During large wet weather events, the wastewater is unlikely to meet the recommended ANZECC (2000) default trigger values, or the LIA 2010 concentrations for nutrients or TSS. However, whilst wastewater discharges may exceed the guidelines, the current receiving environment generally assimilates pollutants well (SKM 2011). Indicator substances in wastewater overflows will be rapidly diluted by the receiving waterway. It is considered that overall the impact to water quality and aquatic ecology from the Proposal would not be significant.

The Proposal has been designed to meet a target of zero overflows in dry weather. Sydney Water is required to maintain the system over time to ensure that the frequency of overflows specified in system EPLs is not exceeded. This ensures that '…the environmental impacts associated with the operation and management of sewer overflows will be properly addressed' (EPA, 2000).

In wet weather, all but two of directed overflows potentially impacted by the Proposal would be compliant with their respective EPL targets. Two directed overflows in Shellharbour may exceed their EPL targets, between 2031 and 2048. The overflow performance at these sites over the longer term will be monitored. These overflow points may require upgrading in the future to maintain the overflow frequency within the EPL limits.

6.5 Flora and fauna

Overview

Eco Logical Australia was engaged to prepare a flora, fauna and ecological assessment for the Proposal. The *West Dapto Water and Wastewater Servicing – Flora, Fauna and Ecological Assessment* (ELA, 2011), which is attached as Appendix E, concluded that the Proposal would not have a significant impact on threatened species, populations or endangered ecological communities.

The assessment was prepared in accordance with the *Draft Guidelines for Threatened Species Assessment* (DEC & DPI 2005). The guidelines identify factors that must be considered when surveying and assessing impacts on threatened species, populations or ecological communities or their habitats for development assessed under the former Part 3A of the EP&A Act. Table 6-17 sets out the sections of the EA that address these guidelines.

Table 6-17 Consistency with DEC & DPI (2005) guidelines for threatened species assessment

DEC &DPI Requirement	Section
Preliminary assessment	6.5.1
Field survey and assessment	6.5.1
Evaluation of impacts	6.5.2
Avoid, mitigate and then offset	6.5.2
Key thresholds	6.5.2

The assessment (ELA 2011) included:

- a desktop assessment and literature review
- a field assessment of land potentially impacted by the Proposal (between May and August 2011)
- an assessment of impacts and the significance of these impacts
- development of mitigation measures including the consideration of offsets for the clearing of native vegetation consistent with the 'maintain or improve' principles.

Field assessments were conducted for the overall proposal with an emphasis on the Project Approval area. A detailed description of the methodologies used is provided in Appendix E. Assessments of significance were also conducted for threatened species, populations and communities potentially impacted by the Proposal.

This section addresses potential impacts of the Proposal on terrestrial flora and fauna in accordance with the Director-General's Requirements and all relevant legislation and guidelines. Potential impacts on threatened species, populations, ecological communities and/or critical habitat have been considered and assessed with reference to the *Illawarra Escarpment and Coastal Plain – bioregional assessment* (NPWS 2002). Potential impacts on riparian areas (including aquatic flora, fauna and fish passage) have been considered and assessed with reference to the *Wollongong Riparian Corridor Management S*tudy (DIPNR 2004).

As discussed in Section 6.1, the network of pipelines and associated infrastructure has been refined since the ecological assessment was finalised, and therefore some impacts and recommendations discussed in the ELA assessment are not relevant to the Proposal described in Chapter 3.

6.5.1 Existing environment

The Proposal area is situated in the central Illawarra Region, on the coastal plain generally west of Lake Illawarra. Large areas of native vegetation on the coastal plain have been previously cleared, firstly by European settlers for agricultural purposes, and more recently for residential and commercial development. The current landscape is a fragmented mosaic of bushland, urban development, and rural and/or rural residential areas. No National Parks or other land reserved under the NPW Act are located within the Proposal area.

Vegetation communities

Native vegetation exists throughout much of the Proposal area as isolated remnant communities of varying size and condition, with the majority subject to horse and/or cattle grazing and weed infestation. Of the approximately 800 ha of land assessed in the field assessment area, 16 ha contains remnant native vegetation. This vegetation is generally in a disturbed state and in low to moderate condition (ELA 2011). Some remnants in good condition occur in the southern part of the Proposal area where horse and/or cattle grazing has been restricted or denied (e.g. Yallah TAFE area; TruEnergy substation, Yallah; Calderwood foothills). Roadside vegetation is predominantly cleared grassland with occasional remnant native trees.

Vegetation communities identified in the desktop assessment were verified during the field assessment. Eight BioMetric Vegetation Types (BVTs) (DECCW 2009b) were recognised across the Proposal area (Table 6-18). Figures 6-15 and 6-16 indicate the locations of the BVTs in the Proposal area.

Threatened ecological communities

Five of the BVTs are recognised as components of four endangered ecological communities (EEC) listed under the NSW *Threatened Species Conservation Act 1995* (TSC Act). The relationship between the BVTs and the EEC is provided in Table 6-18.

No threatened ecological communities listed under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) are present within the Proposal area.

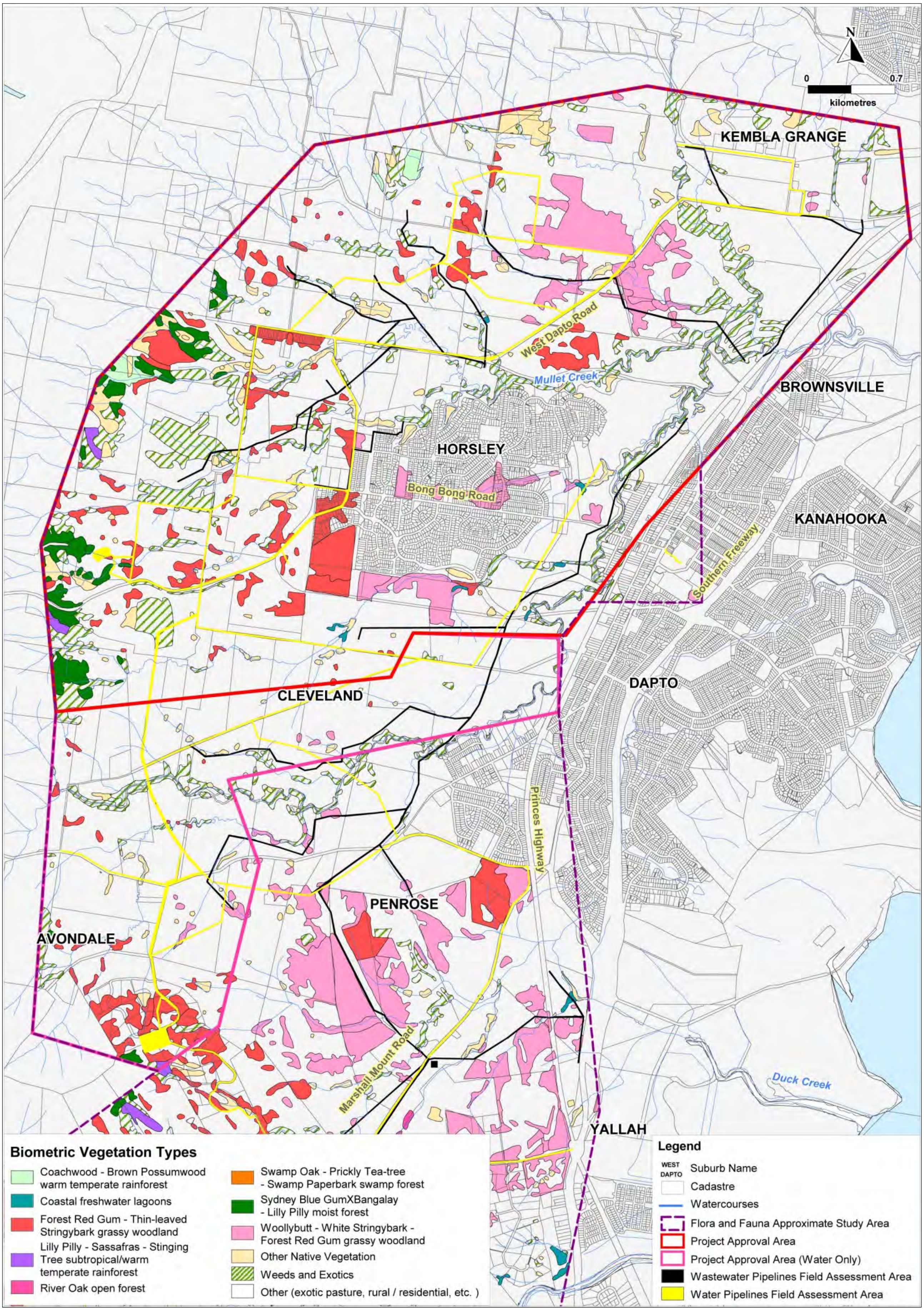


Figure 6-15 BioMetric Vegetation Types of the northern Proposal area (including the Project Approval area) (DECCW 2009b)

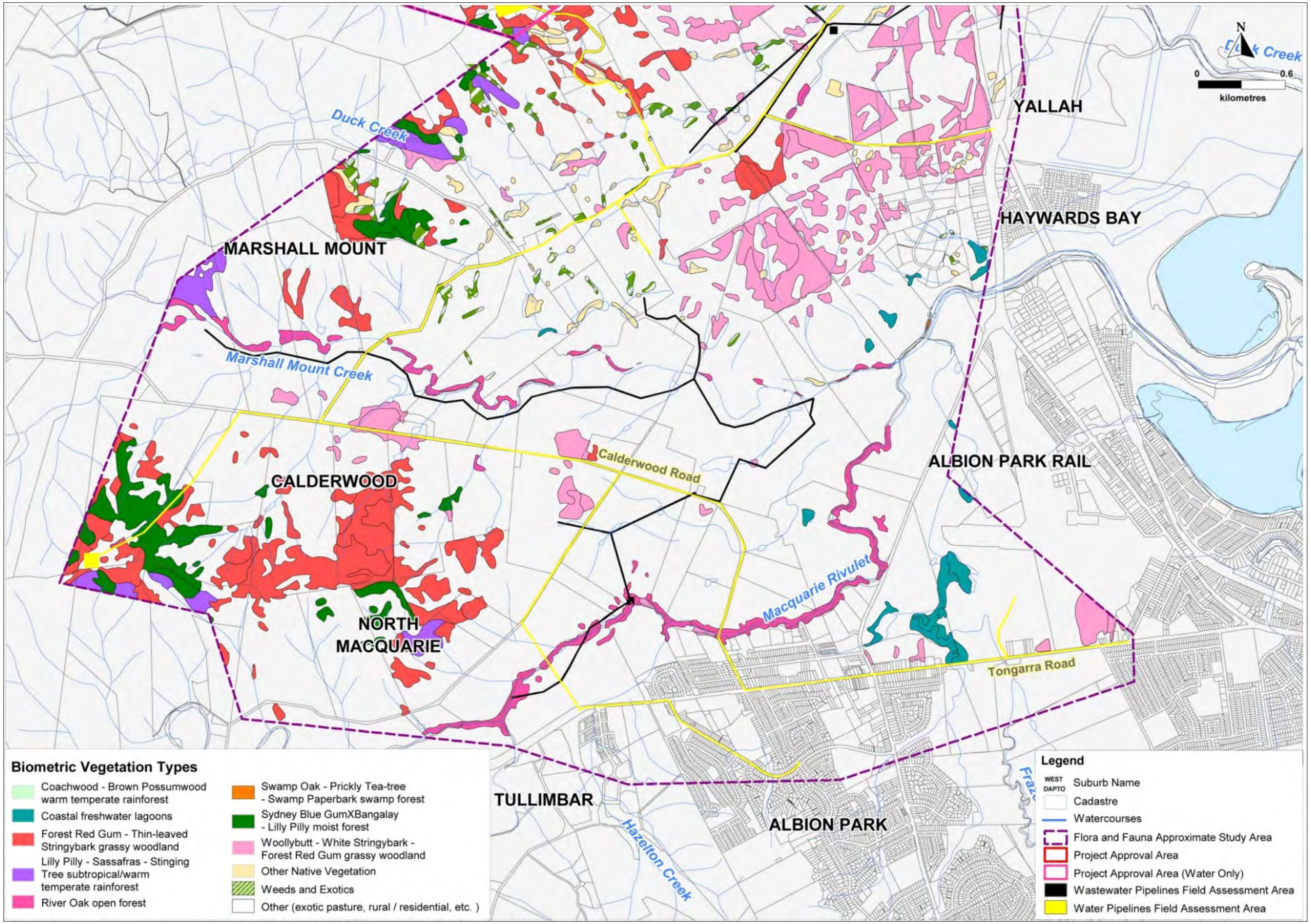


Figure 6-16 BioMetric Vegetation Types of the southern Proposal area (DECCW 2009b)

Table 6-18 Relationships between vegetation classifications in the Proposal area

BioMetric Vegetation Type (Consistent with DECCW 2009b)	Native Vegetation of the Illawarra (NPWS 2002)	SCIVI Map Units (Tozer et al 2006)	Endangered Ecological Community[1]
Coachwood - Brown Possumwood warm temperate rainforest in sheltered gullies of the Illawarra Escarpment, southern Sydney Basin (SR528)	Coachwood Warm Temperate Rainforest (MU 2)	Budderoo Temperate Rainforest (RF314)	No
Forest Red Gum - Thin-leaved Stringybark grassy woodland on coastal lowlands, southern Sydney Basin (SR545)	Coastal Grassy Red Gum Forest (MU 23)	South Coast Grassy Woodland (GW p34)	Yes – Illawarra Lowland Grassy Woodlands
Woollybutt - White Stringybark - Forest Red Gum grassy woodland on coastal lowlands, southern Sydney Basin and South East Corner (SR662)	Lowland Woollybutt-Melaleuca Forest (MU 24)	Illawarra Lowland Woodland (GW p3)	Yes – Illawarra Lowland Grassy Woodlands
Swamp Oak - Prickly Tea-tree - Swamp Paperbark swamp forest on coastal floodplains, Sydney Basin and South East Corner (SR649)	Coastal Swamp Oak Forest (MU 36)	Floodplain Swamp Forest (FoW p105)	Yes – Swamp Oak Floodplain Forest
Coastal freshwater lagoons of the Sydney Basin and South East Corner (SR536)	Floodplain Wetland (MU 54)	Coastal Freshwater Lagoon (part) (FrW p313)	Yes – Freshwater Wetlands on Coastal Floodplains
Lilly Pilly - Sassafras - Stinging Tree subtropical/warm temperate rainforest on moist fertile lowlands, southern Sydney Basin (SR568)	Lowland Dry-Subtropical Rainforest (MU 4)	Sub-tropical Dry Rainforest	Yes – Illawarra Sub-tropical Rainforest
Sydney Blue GumXBangalay - Lilly Pilly moist forest in gullies and on sheltered slopes, southern Sydney Basin (SR652)	Moist Box-Red Gum Foothills Forest (MU 13)	Warm Temperate Layered Forest	No
River Oak open forest of major streams, Sydney Basin and South East Corner (SR606)	Riparian River Oak Forest (MU 37)	Riverbank Forest (FoW p32)	No

[1] As listed under the NSW *Threatened Species Conservation Act 1995.*

Threatened flora

The desktop assessment and literature review identified 27 threatened flora species previously recorded within 10 km of the Proposal area. Those species considered either as ‘known’, ‘likely’ or ‘potentially’ occurring within the Proposal area are listed in Table 6-19. Field assessments were undertaken to identify the presence of these species.

An assessment of the likelihood of each threatened species being present within the field assessment area was undertaken (Appendix E). This included an assessment of the conservation status (under both State and Commonwealth legislation), habitat requirements and vegetation community associations of these species.

The only threatened flora species recorded during the field assessment was an endangered population of *Lespedeza juncea* subsp. *sericea* found along Marshall Mount Road. Threatened flora species known to occur in the Proposal area but not found during the field assessment include *Chorizema parviflorum, Cynanchum elegans* and *Pterostylis gibbosa.*

Table 6-19 Migratory and threatened species, populations and ecological communities within the Proposal area

Scientific Name	Common name	Conservation status		Likelihood of occurrence
		TSC Act	EPBC Act	
Ecological communities				
Illawarra Sub-tropical Rainforest		Endangered	-	Known
Illawarra Lowland Grassy Woodlands		Endangered	-	Known
Swamp Oak Floodplain Forest		Endangered	-	Known
Coastal Saltmarsh		Endangered	-	Known
River-flat Eucalypt Forest on Coastal Floodplains		Endangered	-	Potential
Flora				
Chorizema parviflorum	Chorizema parviflorum population in the Wollongong LGA	Endangered Population		Known
Cynanchum elegans	White-flowered Wax Plant	Endangered	Endangered	Known
Daphnandra sp. C Illawarra EPBC Act as Daphnandra johnsonii	Illawarra Socketwood	Endangered	Endangered	Potential
Irenepharsus trypherus	Illawarra Irene	Endangered	Endangered	Potential
Lespedeza juncea subsp. *sericea*	*Lespedeza juncea* subsp. sericea population in Wollongong LGA	Endangered Population	-	Known
Pterostylis gibbosa	Illawarra Greenhood Orchid	Endangered	Endangered	Known
Solanum celatum	Nightshade	Endangered	-	Potential
Zieria granulate	Hill Zieria	Endangered	Endangered	Potential
Birds				
Ardea alba	Great Egret, White Egret	-	Migratory	Likely
Ardea ibis	Cattle Egret	-	Migratory	Known
Merops ornatus	Rainbow Bee-eater	-	Migratory	Likely
Lathamus discolor	Swift Parrot	Endangered	Endangered & migratory	Potential
Monarcha melanopsis	Black-faced Monarch	Vulnerable	-	Potential
Ninox connivens	Barking Owl	Vulnerable	-	Potential
Ninox strenua	Powerful Owl	Vulnerable	-	Potential
Rhipidura rufifrons	Rufous Fantail	-	Migratory	Potential
Hirundapus caudacutus	White-throated Needletail	-	Migratory	Potential
Mammals				
Chalinolobus dwyeri	Large-eared Pied Bat	Vulnerable	Vulnerable	Potential
Falsistrellus tasmaniensis	Eastern False Pipistrelle	Vulnerable	-	Known
Miniopterus australis	Little Bent-wing Bat	Vulnerable	-	Known
Miniopterus schreibersii oceanensis	Eastern Bent-wing Bat	Vulnerable	-	Known
Mormopterus norfolkensis	Eastern Free-tail Bat	Vulnerable	-	Known
Myotis macropus	Large-footed Myotis	Vulnerable	-	Known
Pteropus poliocephalus	Grey-headed Flying-fox	Vulnerable	Vulnerable	Known
Saccolaimus flaviventris	Yellow-bellied Sheath-tail bat	Vulnerable	-	Known
Scoteanax rueppellii	Greater Broad-nosed Bat	Vulnerable	-	Known

Noxious weeds

Five noxious weeds, categorised as Class 4 under the *Noxious Weeds Act 1993*, were recorded during the field surveys. These were: Lantana (*Lantana sp*), African Boxthorn (*Lycium ferocissimum*), Prickly Pear (*Opuntia sp.*), African Lovegrass (*Eragrostis curvula*), and Bridal Creeper (*Asparagus asparagoides*).

Fauna habitats

Fauna habitats in the Proposal area are limited to woodland and forest remnants, grasslands, hollow-bearing trees, coarse woody debris (fallen dead timber), rocky areas, dense shrub thickets, and both disused and in use anthropogenic structures (i.e. houses, sheds, dams etc.).

Larger forest remnants that are not grazed provide habitat for reptiles, ground-dwelling and arboreal mammals and micro-bats. Migration between remnants is restricted due to limited vegetation connectivity and availability of fallen timber to provide refuge and shelter sites. Smaller remnants, paddock trees and riparian vegetation can connect larger forest remnants or habitat areas by acting as stepping-stones for wildlife movement. In those areas where woodland is present and grazing is less intense, coarse woody debris such as fallen timber and logs provide nesting and shelter resources for wildlife. Lantana infestations are common in unmanaged remnants and provide a sheltering resource for ground mammals and small passerine birds.

Some remnants of relatively intact BVTs occur as isolated patches of vegetation in a generally cleared landscape (refer to Figures 6-15 and 6-16), including:

- Forest Red Gum - Thin-leaved Stringybark grassy woodland
- Woollybutt - White Stringybark - Forest Red Gum grassy woodland
- Sydney Blue GumXBangalay - Lilly Pilly moist forest
- River Oak open forest.

These remnants are likely to provide primary habitat for common native fauna and/or highly mobile species, including threatened micro-bats. They are also likely to provide valuable stepping-stone and/or refuge habitat for species dispersing between larger areas of remnant vegetation.

Hollow-bearing trees are present within many of the woodland remnants of the field assessment area. These trees are an important habitat feature for avifauna, arboreal mammals, micro-bats, reptiles and amphibians.

Riparian corridors generally occur as eroded and largely cleared creeks within farmland and provide limited habitat for fauna. These corridors provide some suitable habitat for common amphibians, aquatic reptiles and to a limited extent, wetland birds. However, they are highly disturbed, with most occurring within grazing paddocks on private property.

A few small farm dams occur or partially occur within the field assessment area. These are small, open bodies of water in grazing paddocks that have little or no emergent or surrounding vegetation. Their value to wildlife is minimal due to the lack of any sheltering or foraging habitat.

No critical habitats are listed at either State or Commonwealth level within the field assessment area.

Threatened and migratory fauna

The desktop assessment and literature review identified 83 threatened fauna and 40 migratory species previously recorded within 10 km of the Proposal area. Those considered either 'known', 'likely' or 'potentially' occurring within the Proposal area are listed in Table 6-19. Field surveys were undertaken to identify the presence of and habitat availability for these species.

An assessment of the likelihood of each species being present within the field assessment area was undertaken. This included an assessment of the conservation status (under both State and Commonwealth legislation), habitat requirements and vegetation community associations of these species (Appendix E). Outcomes were considered in the impact assessment (refer Section 6.5.2).

Micro-bats

The desktop assessment identified eight threatened micro-bat species within the Proposal area. Of these, the following seven threatened micro-bat species were recorded during the field assessment:

- Little Bent-wing Bat (*Miniopterus australis*)
- Eastern Bent-wing Bat (*Miniopterus schreibersii oceanensis*)
- Eastern Free-tail Bat (*Mormopterus norfolkensis*)
- Eastern False Pipistrelle (*Falsistrellus tasmaniensis*)
- Large-footed Myotis (*Myotis macropus*)
- Yellow-bellied Sheath-tail Bat (*Saccolaimus flaviventris*)
- Greater Broad-nosed Bat (*Scoteanax rueppellii*).

The Large-eared Pied bat (*Chalinolobus dwyeri)* was identified as having potential to occur within the Proposal area from the desktop assessment, however none were recorded during the field assessment.

Fruit-bats

The Grey-headed Flying Fox (*Pteropus poliocephalus*) is considered likely to utilise the Proposal area for foraging, with a closed camp located to the west of Farmborough Heights (less than 1 km north of the Proposal area). This species was not recorded during the field assessment.

Birds

Given the large number of tree hollows in the woodland areas of the Proposal area, there is potential for threatened bird species to occur. Whilst none were recorded during the field assessment, three were identified as potentially occurring within the Proposal area, including the Swift Parrot (*Lathamus discolor*), Barking Owl (*Ninox connivens*) and Powerful Owl (*Ninox strenua*). The Swift Parrot is listed as an 'endangered' species under the TSC Act and EPBC Act, and both Owls are listed as vulnerable species under the TSC Act, but not listed under the EPBC Act.

One migratory bird species listed under the EPBC Act was recorded within the Proposal area during the field assessment; Cattle Egret (*Ardea ibis*). Two migratory bird species were considered likely to occur; Great Egret (*Ardea alba*) and Rainbow Bee-eater (*Merops ornatus*). Two others were considered to have the potential to occur; Rufous Fantail (*Rhipidura rufifrons*) and Swift Parrot (also listed as endangered). The latter four species were not recorded during the field assessment.

Creeks and riparian corridors

Major creeks that drain the Proposal area include Sheaffes Creek, Dapto Creek, Robins Creek, Mullet Creek, Duck Creek, Marshall Mount Creek and Macquarie Rivulet. These creeks are within the catchment of Lake Illawarra. Steep rainforest creeks on the Illawarra Escarpment flow across the alluvial plains into lowland creeks before entering the estuarine waters of Lake Illawarra.

The *Riparian Corridor Management Study* (RCMS) (DIPNR 2004) mapped creeks or watercourses in the Wollongong LGA according to their riparian and aquatic habitat value to establish protection buffers for different creek or watercourse categories. Mapping of the 'top of bank' was undertaken to further define the spatial extent of the riparian corridors within the field assessment area.

Field inspections of representative riparian/pipeline intersect sites were undertaken in the Proposal area and watercourses were grouped into the following three categories based on the RCMS (DIPNR 2004):

- Category 1 – *Environmental Corridor.* Provides biodiversity linkages ideally between one key destination and another (for example between the coast and the escarpment)
- Category 2 – *Terrestrial and Aquatic Habitat*. Provides basic habitat and preserves the natural features of a watercourse
- Category 3 – *Bank Stability and Water Quality*. Has limited (if any) habitat value but contributes to the overall basic health of a catchment.

Within each group, watercourses were further subdivided into "cleared" and "uncleared" zones based on the characteristics of land immediately adjacent to the riparian zone. A rapid assessment of riparian condition was applied to 21 representative sites. An additional 77 sites were visited to verify the representative nature of the assessed sites. Following field validation, the remainder of the field assessment area was assessed using aerial photographs to determine the likely condition and impact of each riparian/pipeline intersect.

This process resulted in pipeline alignments being refined to minimise potential impacts (refer to Section 6.5.2) and informed the anticipated method for crossing watercourses detailed in Figure 6-17 and Figure 6-18.

Aquatic habitat

Aquatic habitats are the in-stream features that form pools, runs and riffles of flowing creeks and rivers and still-water bodies such as dams and lakes. These habitats may range from permanent water with large catchments on low-lying land, to ephemeral creeks near the escarpment that only flow after local rainfall.

In-stream habitat values can be assessed by describing and rating several common physical and biotic features, including:

- hydrology – stream type and modifications to channel
- physical form – bank slope and erosion
- water quality and habitat – connectivity, habitat variety, turbidity, wetted width, depth, substrate variety, velocity, aquatic flora richness and abundance, and in-stream woody debris
- fish – potential habitat
- other fauna – opportunistic sightings of significant waterbird and frog habitats.

Assessment of aquatic habitats in the Proposal area involved field inspections of representative sites, field validation and the use of aerial photographs to determine the likely condition and potential impact at each riparian/pipeline intersect. The results of the assessment informed the anticipated method for crossing watercourses as detailed in Figures 6-17 and 6-18.

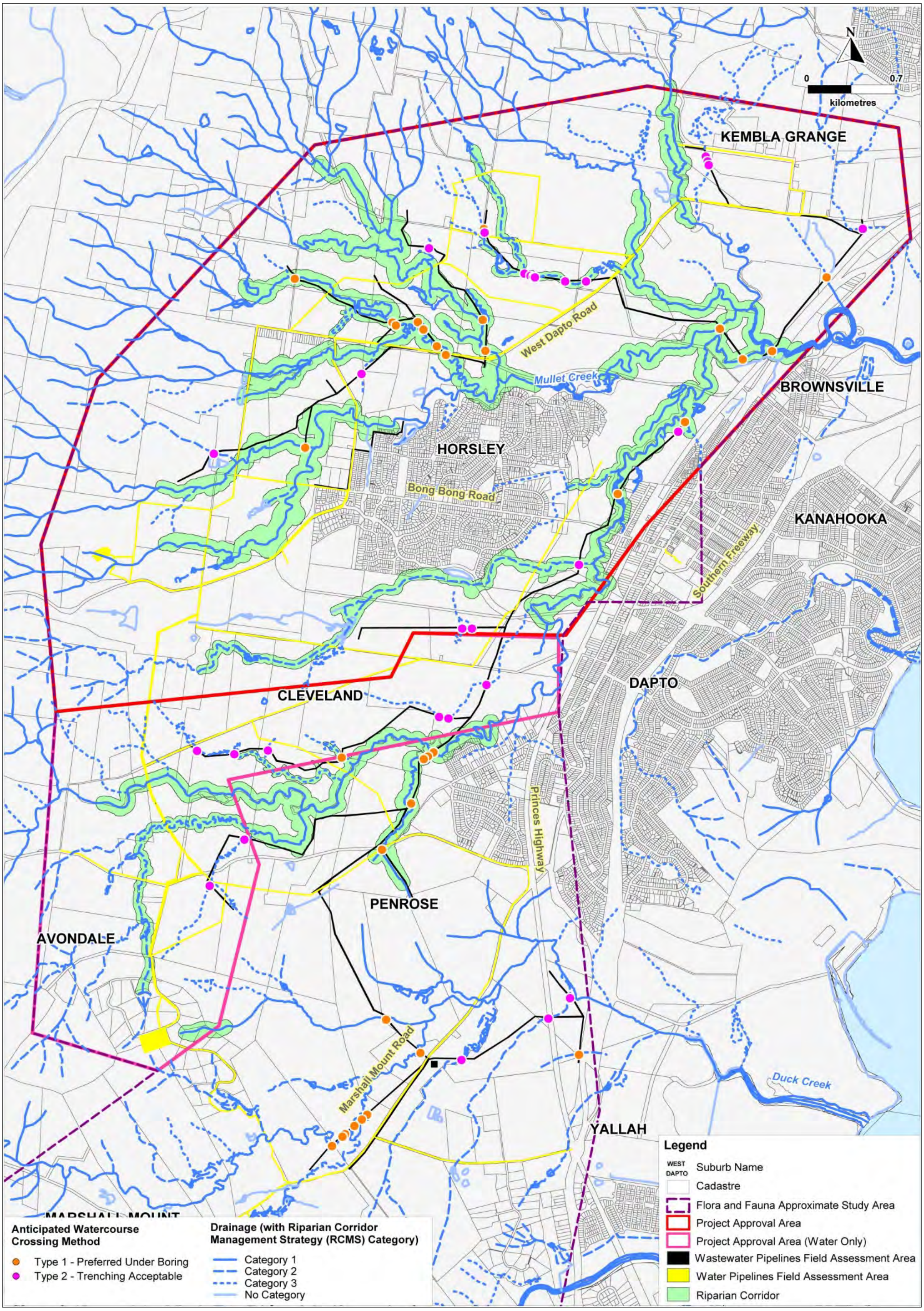


Figure 6-17 Anticipated watercourse crossing methods (wastewater) – north

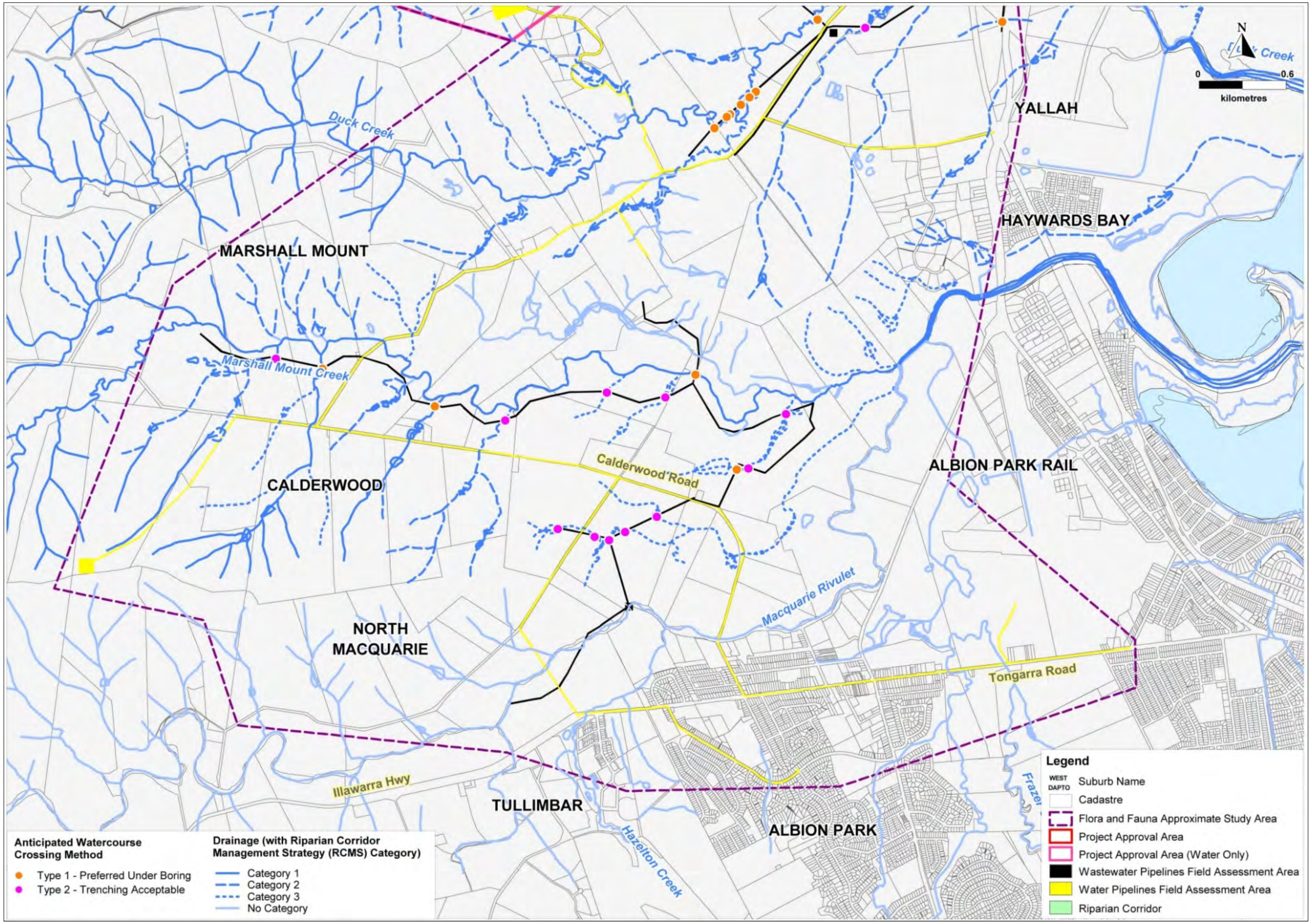


Figure 6-18 Anticipated watercourse crossing methods (wastewater) – south

Groundwater Dependent Ecosystems

Groundwater Dependent Ecosystems (GDEs) are defined as ecosystems whose current composition, structure and function are reliant on a supply of groundwater as opposed to relying on surface watering from overland flows.

GDEs in the Proposal area are confined to riparian vegetation that may utilise groundwater-fed base flows of creeks and freshwater wetlands positioned on low-lying ground close to shallow aquifers. BVTs occurring in the Proposal area that may be classed as potential GDEs include:

- Swamp Oak - Prickly Tea-tree - Swamp Paperbark swamp forest on coastal floodplains, Sydney Basin and South East Corner
- Coastal freshwater lagoons of the Sydney Basin and South East Corner
- River Oak open forest of major streams, Sydney Basin and South East Corner.

Other vegetation types that may be GDEs have been mapped by NPWS (2002), but do not have a BVT equivalent, include:

- artificial wetlands
- estuarine alluvial wetland
- estuarine lagoons and channels
- weeds and exotics (in the riparian zone).

6.5.2 Construction impacts and mitigation measures

The potential impacts of constructing the Proposal are likely to be limited to:

- removing native vegetation at 14 specific locations in the Proposal area (including four locations in the Project Approval area)
- removing hollow-bearing trees.

The mitigation and rehabilitation measures proposed at the end of this section will ensure any potentially long term impacts of construction are minimised.

Vegetation impacts

The Proposal will require the removal of native vegetation at specific locations to allow for construction to occur. Avoiding the need to clear native vegetation has been a primary objective of the Proposal. Where practicable, it is proposed to locate the majority of water pipelines within existing or proposed road corridors, and wastewater pipelines, reservoirs and pumping stations in areas of lower conservation value such as cleared land and exotic pastures.

Initial pipeline alignments in the Proposal area have been adjusted to avoid vegetation communities confirmed in the initial field assessment. Remaining locations that may be directly impacted in the Project Approval area (four locations) have been discussed in this section. Alternate pipeline alignments and/or construction methodologies are proposed to further avoid and/or minimise potential direct impacts in the remaining Proposal area. These areas would be subject to specific consideration during the detailed design process as discussed in Section 3.4.1.

Of the approximately 800 ha of land assessed, 16 ha contains remnant native vegetation. Up to 3.38 ha of the remnant native vegetation has the potential to be directly impacted at 14 separate locations (refer to Figure 6-19 and Figure 6-20). Four of the direct impact areas (totalling 1.28 ha) are located in the Project Approval area. The remaining 10 direct impact areas (totalling 2.10 ha) are located in the remaining Proposal area. Table 6-20 provides a breakdown of potential direct impact in terms of vegetation type impacted and the proposed infrastructure involved in the Project Approval area and remaining Proposal area. One endangered ecological community, Illawarra Lowland Grassy Woodland (ILGW), has the potential to be directly impacted.

As detailed design of the infrastructure progresses, pipeline alignments and/or infrastructure will be positioned, wherever technically feasible, to further avoid and/or minimise direct impacts on native vegetation. Further investigations will be undertaken and this will involve consultation with planning authorities such as councils to confirm the location of road corridors. This means the ultimate extent of direct impact may be less than that indicated in Table 6-20. Potential direct impacts of the Proposal are considered to be negligible as they are limited in number and total area, and temporary in nature due to the restoration mitigation measures proposed.

Table 6-20 Breakdown of the area of vegetation impacted in potential direct impact areas

Vegetation type	Area	Potential direct impact area (ha)				
		Wastewater pipelines	Water pipelines	Pumping station	Reservoirs	Total
Illawarra Lowland Grassy Woodlands EEC	Project Approval	0.15	0.47	0.0	0.34	0.96
	Remaining Proposal	0.44	0.65	0.0	0.04	1.13
	Total ILGW EEC	0.59	1.12	0.00	0.38	2.09
Other native vegetation	Project Approval	0.0	0.0	0.0	0.32	0.32
	Remaining Proposal	0.36	0.36	0.25	0	0.97
	Total Other Native Vegetation	0.36	0.36	0.25	0.32	1.29
Total native vegetation	Project Approval	**0.15**	**0.47**	**0.0**	**0.66**	**1.28**
	Remaining Proposal	**0.80**	**1.01**	**0.25**	**0.04**	**2.10**
Total	Proposal	**0.95**	**1.48**	**0.25**	**0.7**	**3.38**

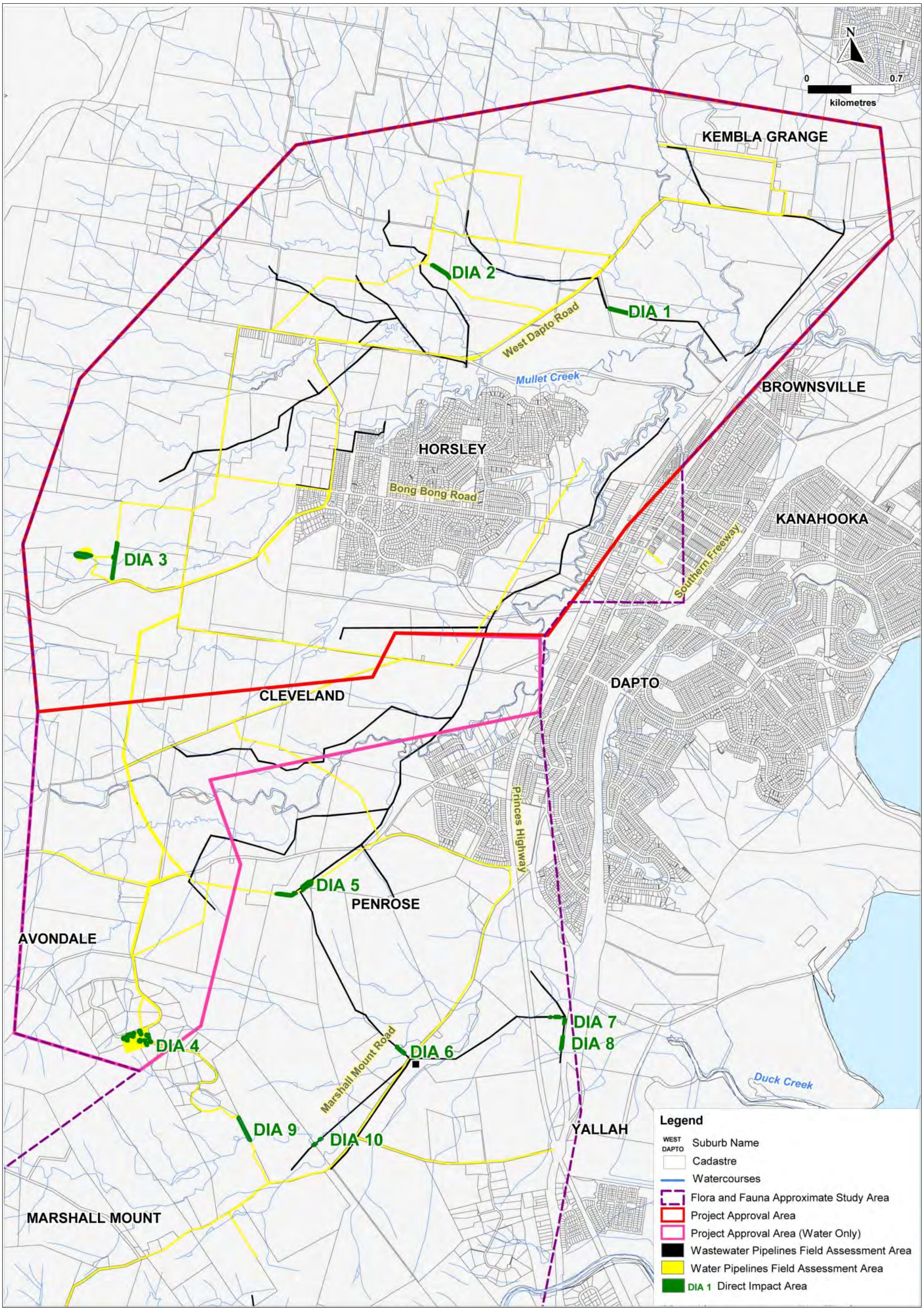


Figure 6-19 Direct impacts on vegetation communities expected from the Proposal (north including Project Approval area)

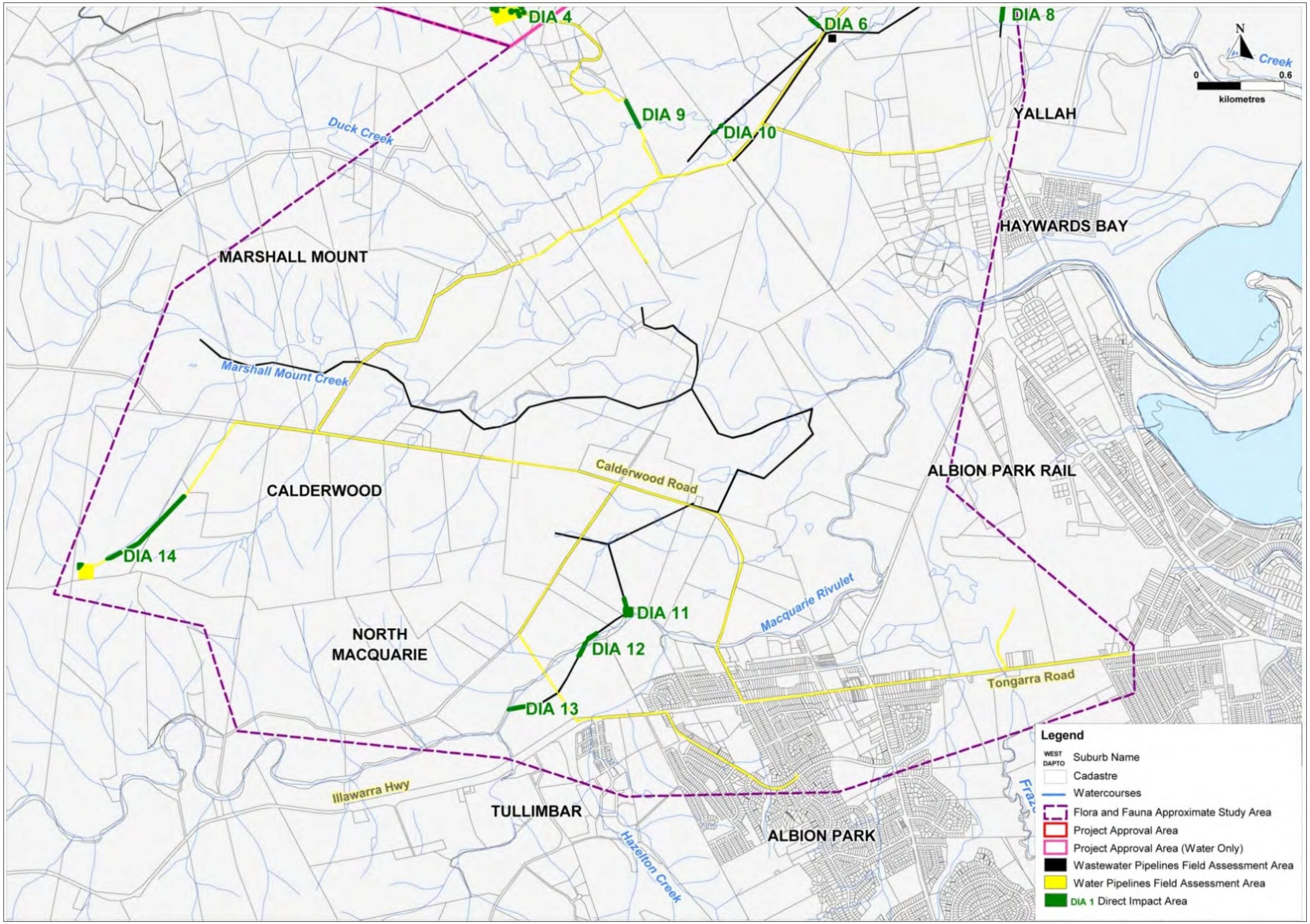


Figure 6-20 Direct impacts on vegetation communities expected from the Proposal (south)

Water pipelines

Water pipeline alignments generally follow existing or future road corridors. The alignment of future roads was provided by Wollongong City Council. Of the estimated 3.38 ha of native vegetation directly impacted by the Proposal, over half this area is in the water pipeline/road corridors. Of the estimated 1.28 ha directly impacted in the Project Approval area, 0.47 ha is in the water pipeline/road corridors. These potential direct impacts are considered to be shared infrastructure impacts as vegetation removal would be a combined impact from the construction of the roadways along with water pipelines. As water pipelines would only be constructed in these locations to follow future road corridors, there is potential for the pipeline alignments to move with changes to road corridors. Consultation will be undertaken with Council during the detailed design process to confirm the locations of future road corridors.

The direct impact areas within the water pipeline/road corridors in the Project Approval area are shown in detail in Figure 6-21 and Figure 6-22 and are described below:

- Sheaffes Road, Kembla Grange (Direct Impact Area 2) - At this site, impacts to vegetation would include the potential to remove 0.17 ha of ILGW EEC including up to seven hollow-bearing trees (Figure 6-21). This is considered to be a 'worst case' scenario as it assumes that all vegetation within the proposed road corridor would be cleared. The impact at this site would be reduced or avoided if Council re-aligns the road corridor to avoid this vegetation. This process could potentially reduce the area of ILGW EEC that would be impacted in this shared infrastructure corridor.
- Bong Bong Road, Avondale (Direct Impact Area 3) - Water pipelines at this location have been confined to existing tracks and cleared exotic pastures. One arm of the water pipeline would impact on approximately 0.3 ha of ILGW (Figure 6-22).

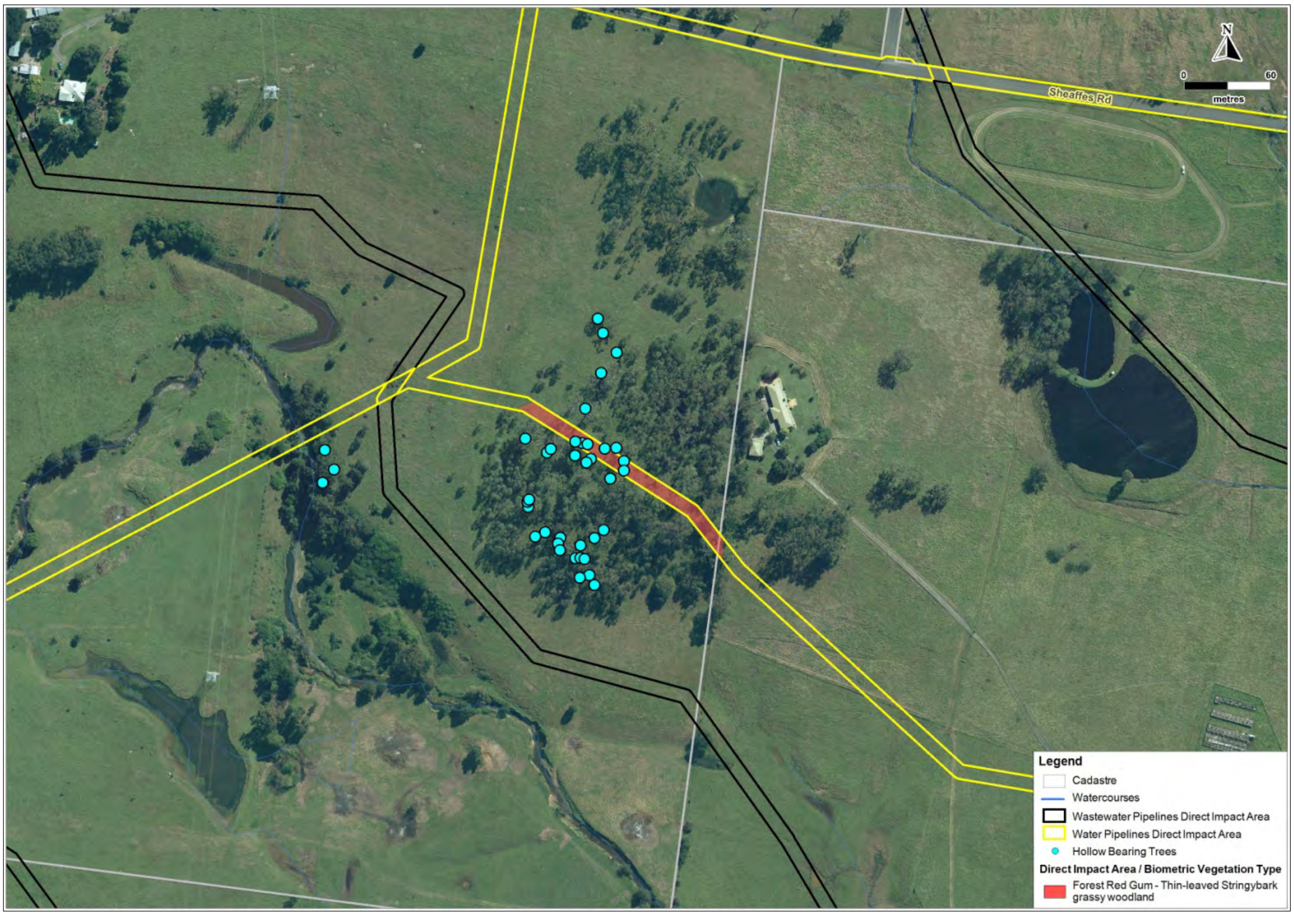


Figure 6-21 Direct Impact Area 2, Sheaffes Road, Kembla Grange

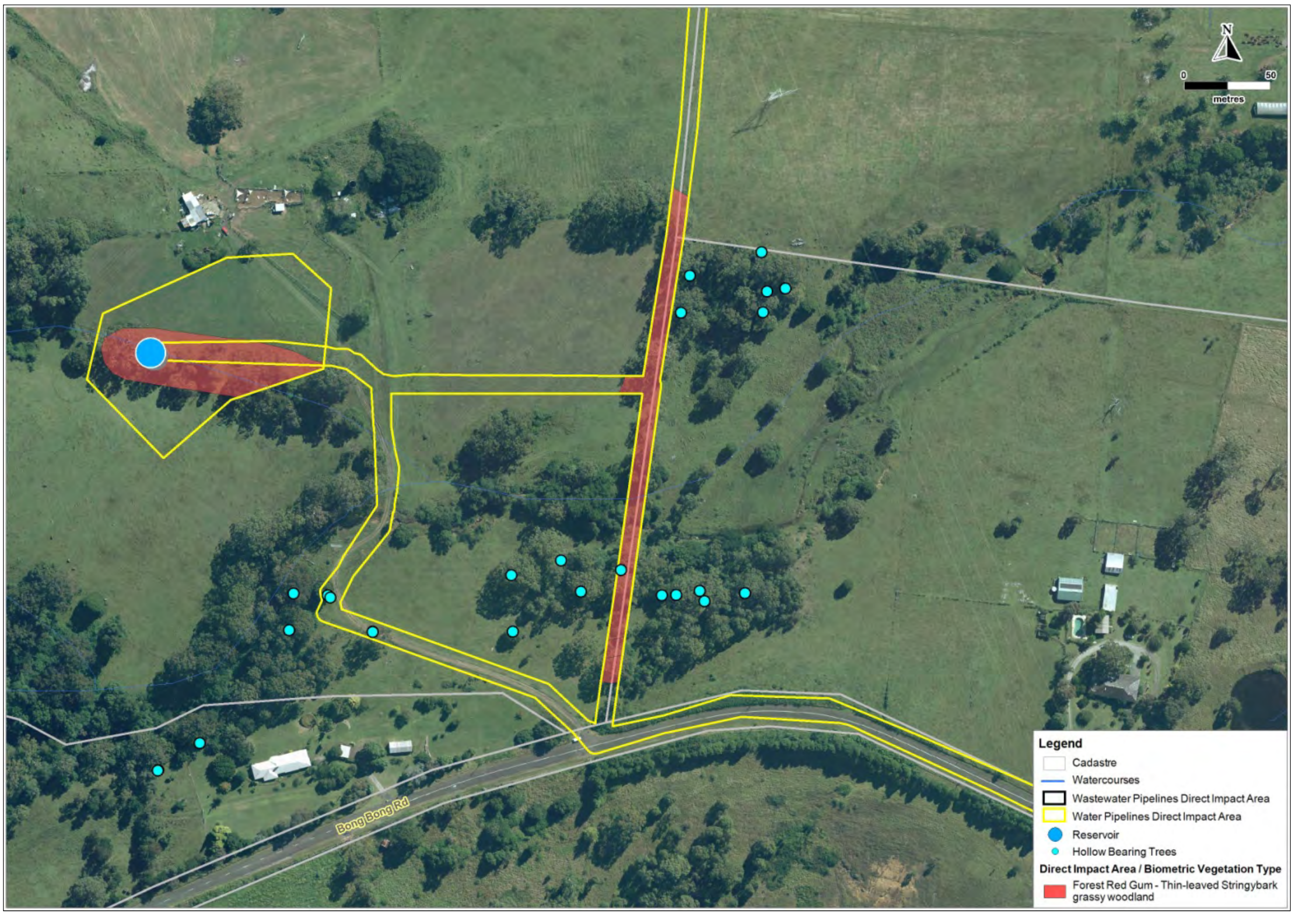


Figure 6-22 Direct Impact Area 3, Bong Bong Road, Avondale

Reservoir construction

In general, the direct impact of reservoir construction has been conservatively estimated for the Proposal. The 0.7 ha potential direct impact area attributable to reservoir construction in Table 6-20 is based on clearing all existing native vegetation from each reservoir property. It is more likely that vegetation clearing would be limited to small areas of the reservoir sites and avoided wherever possible. Up to 0.34 ha of ILGW and three hollow-bearing trees could be impacted to construct the Avondale Reservoir at Direct Impact Area 3 (Figure 6-22). This was estimated conservatively, and the reservoir is likely to directly impact only the north eastern portion of the property without impacting the existing vegetation occupying the southern portion of the property.

Marshall Mount Reservoir, Marshall Mount (Direct Impact Area 4) is currently maintained as cleared open space with 16 remnant Forest Red Gum (*Eucalyptus tereticornis*) trees recorded onsite (Figure 6-23). Given the scattered nature of the trees, the absence of an understorey and the managed nature of the site (i.e. exotic lawn grasses), vegetation is not considered to form part of the ILGW EEC. A worst case scenario has been assessed and this would clear approximately 0.32 ha of native vegetation and potentially result in the loss of up to eight hollow-bearing trees. Reservoir construction would likely only directly impact vegetation occupying the central area of the property, without impacting the vegetation closer to the property boundary. The extent of tree removal will be confirmed during the detailed design process.

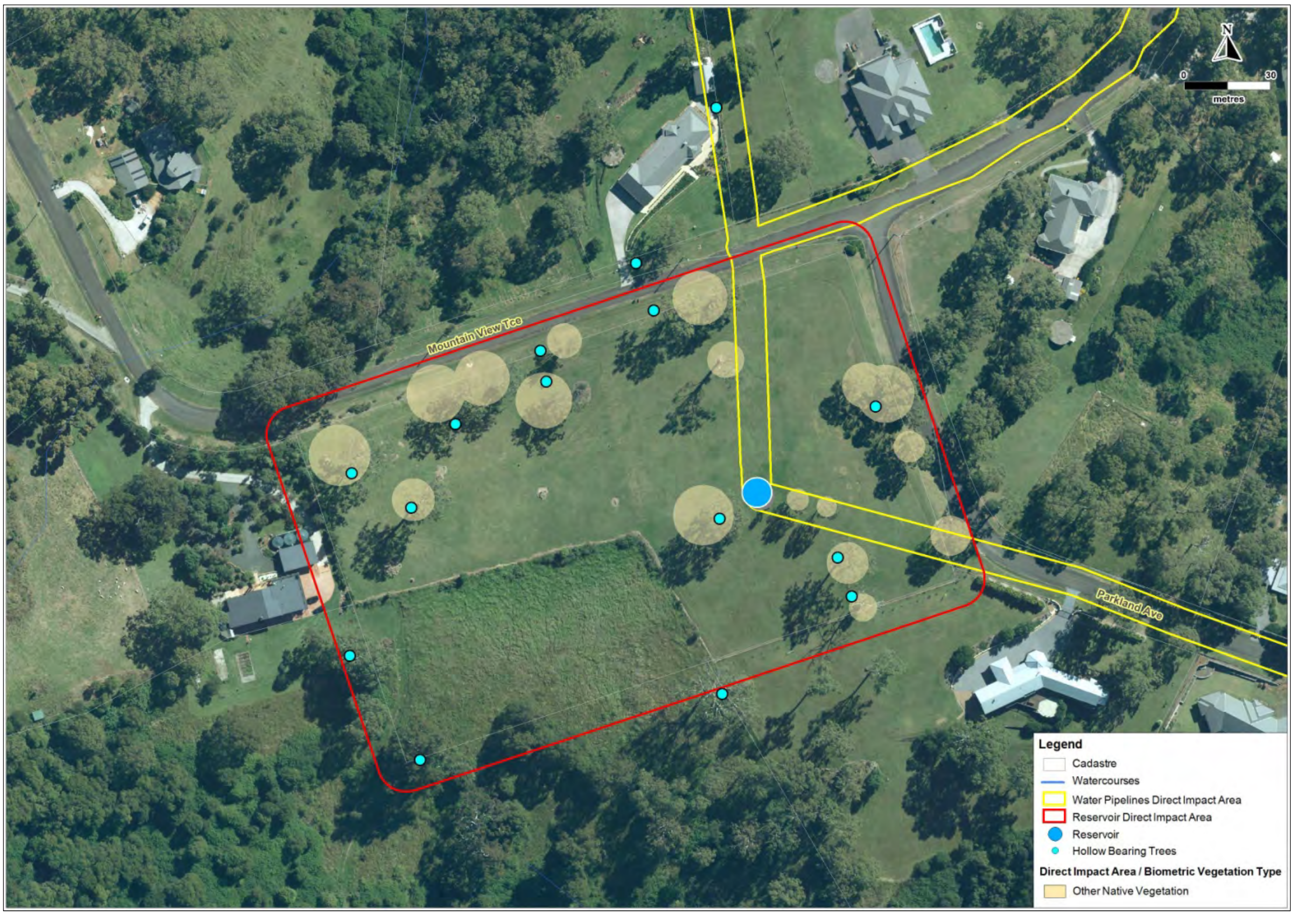


Figure 6-23 Direct Impact Area 4, Marshall Mount Reservoir, Mountain View Terrace, Marshall Mount

Wastewater pipelines

In the case of the wastewater pipeline alignments, direct impacts on native vegetation may be unavoidable due to engineering and/or hydraulic design constraints. The alignment at Darkes Road, Kembla Grange (Fgure 6-24) is the only location in the Project Approval area where direct impacts are unavoidable. Mitigation measures will be developed and implemented to minimise the extent of clearing at this location. The wastewater pipeline alignment shown on Figure 6-24 was placed at this location to avoid the dense remnant ILGW EEC surrounding Sheaffes Creek. An area of approximately 0.15 ha of highly modified ILGW EEC primarily consisting of exotic lawn grasses, with little to no native understorey, would be impacted in this area. The removal of remnant trees that are part of the EEC would be avoided where possible.

Figure 6-24 Direct Impact Area 1, Darkes Road, Kembla Grange

Threatened species and ecological communities

Assessments of the potential effects of constructing the Proposal on each threatened species and ecological community recorded in the Proposal area, have been completed in accordance with *Appendix 3* of the *Draft Guidelines for Threatened Species Assessment* (DEC & DPI 2005) and are attached to the specialist study (Appendix E). These assessments concluded that the Proposal is unlikely to have a significant effect on threatened species, populations or ecological communities, or their habitats.

Matters of national environmental significance (matters of NES) relevant to the Proposal were confined to migratory avifauna species. Impact assessments for all matters of NES in accordance with *Matters of National Environmental Significance – Significant Impact Guidelines 1.1* (DEWHA 2009) have been completed and are included in the specialist study (Appendix E). The assessments determined that there is unlikely to be significant impact on matters of NES and therefore a referral to the Commonwealth is not required (ELA 2011).

Endangered ecological communities

The Assessment of Significance undertaken for ILGW EEC concluded that the potential removal of up to 2.09 ha of the EEC for the Proposal would not have a significant impact on the EEC and is considered to be minor in proportion to the total extent of ILGW in the local area (Appendix E). Furthermore, the extent of vegetation removal has been assessed as a ‘worst-case’ scenario and is likely to be reduced during the detailed design process.

Threatened flora

The only threatened flora species recorded within the Proposal area during the field assessment, was an endangered population of *Lespedeza juncea* subsp. *sericea*, along Marshall Mount Road (outside the Project Approval area). The proposed pipeline location has been aligned to avoid impact to the threatened population. The mitigation and management measures proposed at the end of this section will further safeguard this population.

Other threatened flora species known to occur in the immediate area and targeted during the survey period include *Chorizema parviflorum, Cynanchum elegans* and *Pterostylis gibbosa,* though none were recorded in the field assessment area.

As no direct or indirect impacts are anticipated to this population or these species from the Proposal, it was not necessary to undertake an Assessment of Significance (ELA 2011).

Threatened fauna

The Proposal has the potential to directly impact up to 3.38 ha of native vegetation, consisting of approximately 2.09 ha of ILGW EEC and 1.29 ha of other vegetation. Impacts on fauna from direct loss or modifying the habitat are likely to be minimal as vegetation adjoining the direct impact area would provide similar sheltering, nesting or foraging opportunities. The exception is the loss of hollow-bearing trees, where hollow-dwelling fauna may be reliant on a particular hollow for breeding, nesting or sheltering purposes.

The species most likely to be impacted by the Proposal are hollow dependent micro-bat species. The potential direct impact on this habitat resource has been estimated to be 18 hollow-bearing trees across the Project Approval area. This potential direct impact is associated with the proposed water pipeline alignment and Marshall Mount Reservoir, where clearing was estimated based on worst case scenarios. Impacts to hollow-bearing trees along the water pipeline alignment would only be incurred if the roads are constructed and all trees within the road corridor are required to be removed, meaning that potential impacts are likely to be shared with future roadways.

Assessments of Significance were undertaken for hollow-dependant threatened fauna including the seven microchiropteran bat species known to occur within the Proposal area, one megachiropteran bat and two owl species with the potential to occur in the Proposal area (Appendix E). The Assessments of Significance concluded that the potential removal of the hollow-bearing trees will not have a significant impact on these species (Appendix E). The mitigation measures proposed at the end of this section will ensure that any direct impact on these species will be minimised.

Assessments of Significance were undertaken for non-hollow dependant threatened fauna species known to occur within the Proposal area (including the Swift Parrot (*Lathamus discolour*), Great Egret (*Ardea alba*) and Cattle Egret (*Ardea ibis*)) concluded that due to little or no potential habitat loss in the Proposal area for these species, no significant impacts to the species are likely (Appendix E).

Recovery plans

Of the threatened species, populations and ecological communities with the potential to be impacted by the Proposal, Recovery Plans exist for only the Powerful Owl and Barking Owl. These plans have been considered during the Assessment of Significance process for these species (ELA 2011).

Impacts and key threatening processes

The Proposal has the potential to contribute to a number of key threatening processes listed under the TSC Act and/or the EPBC Act, both directly and indirectly. These include:

- clearing of native vegetation (leading to habitat fragmentation and barrier effects)
- removal of dead wood and dead trees
- loss of hollow-bearing trees (leading to increased isolation of hollow-dependent fauna)
- invasion and establishment of weeds (various species including exotic perennial grasses)
- alteration of the natural flow regimes of rivers, streams, floodplains and wetlands.

These processes were considered when preparing the Assessments of Significance for threatened species, populations and ecological communities (Appendix E).

Threat Abatement Plans

There are no Threat Abatement Plans relevant to the Proposal.

Habitat fragmentation and isolation

The Proposal will be constructed in a largely cleared landscape with patches of vegetation occurring amongst farmland and/or rural residential properties. The Proposal may clear or partially clear some of these patches, which generally have minimal wildlife value in themselves but may provide stepping-stone habitat between larger areas of better quality vegetation. Further fragmentation of these stepping-stone habitat patches could have implications for fauna moving between larger, better quality habitat areas. However, due to the limited number and spatial distribution of the potential direct impact areas, these implications are unlikely to be significant.

Many of the wider ranging threatened fauna are unlikely to be impacted by the removal of small patches of woodland, due to the amount of similar habitats for nesting, roosting and foraging in the immediate area.

As well as direct impacts to native fauna, the loss of hollow-bearing trees has the potential to further isolate fauna species that are dependent on hollows for roosting or nesting. Due to the limited number of hollow-bearing trees (18) to potentially be removed in the Project Approval area, there is unlikely to be a significant impact on hollow-dependent fauna.

Weed infestation

A number of noxious weeds and listed exotic species occur within the Proposal area and these have the potential to spread through disturbance activities and the introduction of weed seed to less disturbed areas. The majority, if not all of the field assessment area has been subject to previous disturbance, most of it experiencing high levels of disturbance. Construction activities are not likely to significantly increase weed levels. Mitigation measures provided at the end of this section will help minimise the spread of exotic species and pathogenic fungi during construction and post construction works.

Cumulative effects

The potential impacts of vegetation removal and habitat loss as a result of the Proposal have been considered in the context of the cumulative effects of the development of the WDURA and AGAs. The landscape of the WDURA and AGAs is likely to change significantly over the next 30 to 40 years, with much of the land being developed for housing, commercial and community service needs and related infrastructure (refer Section 6.2). This is likely to have a considerable cumulative effect on biodiversity of the region.

The potential direct impacts of the Proposal on flora and fauna have been limited to 14 isolated locations. When considered in terms of the impact mitigation and management measures proposed and the native vegetation and/or habitat immediately adjoining and/or nearby to these locations, the Proposal is unlikely to make a significant contribution to the cumulative effects of development of the WDURA and AGAs.

Riparian and aquatic ecology impacts

The proposed pipeline alignments have been designed to avoid sensitive riparian and aquatic environments wherever possible. This has been achieved through desktop studies during the design phase and field assessment by a specialist aquatic ecologist to confirm alignment adjustments to avoid sensitive environments.

Due to the extensive network of pipelines and the equally extensive network of watercourses, there are numerous locations where the pipelines will cross watercourses. Crossings for water infrastructure will generally be co-located with roads and/or bridge alignments and the construction method of the road/bridge would influence the method used to construct the pipe across the watercourse. Wastewater pipelines generally cannot be co-located with roads and/or bridges due to engineering and/or hydraulic design constraints. Crossings for wastewater infrastructure are therefore the focus of this assessment.

The two main wastewater pipeline construction methods used in crossing watercourses are trenching and under boring. Trenching directly impacts on the in-stream environment. Under boring may require the establishment of launch and receiving pads at either end of the bore, but does not directly impact on the in-stream environment.

A representative number of Category 1, 2 and 3 streams from the DIPNR (2004) *Riparian Corridor Management Study* were assessed in the field. Riparian and aquatic habitat was scored at each location. The results of this assessment showed a relationship between the stream category and aquatic and riparian habitat quality (ELA 2011). The anticipated spatial application of the two construction or watercourse crossing methods in the Proposal area is detailed in Figures 17 and 18 and potential impacts were assessed based on the assumption that these methods would be implemented.

During the detailed design process (Section 3.4.1), the construction methodology for each creek crossing will be determined based on a number of risk factors. Under boring is anticipated for most Category 1 stream crossings and high risk areas that cannot be avoided (ground conditions permitting). As such, the Proposal is unlikely to have a significant impact on moderate-good quality aquatic habitat. Where possible, the entry and exit points for under boring would be located outside the top of bank. Under boring would reduce the risk of erosion and sedimentation and avoid the need for creek diversions, therefore, avoiding potential impacts on water quality and connectivity of flow or fish passage in these streams.

Where practicable, watercourses would only be trenched if they are minor, shallow, ephemeral, highly disturbed creeks. Potential impacts from trenching include risk of erosion and sedimentation and associated impacts to water quality and temporary impacts to water flow and fish passage. Trenching would only be undertaken in minor streams (Category 2 and 3) that are generally in very poor condition, many being drainage lines with no riparian habitat. Mitigation measures would be implemented to minimise soil erosion and sedimentation and temporary diversion or partial bunding of these minor streams to allow for connectivity of flows and fish passage. Therefore, direct impacts from trenching are unlikely to be significant.

Construction of the Proposal has the potential to indirectly impact aquatic ecology. Indirect impacts as a result of soil erosion and sedimentation due to excavation and the removal of vegetation may occur during construction. Erosion can lead to the degradation of soil substrates. Sedimentation can smother riparian and aquatic vegetation and lead to eutrophication. Construction management measures for the Proposal include the use of sediment controls to minimise this potential impact. None of the proposed construction methods are likely to substantially impact connectivity of flows or fish passage.

Fuels and chemicals entering aquatic ecosystems can result in toxic levels of contaminants and cause fish kills and other impacts on waterway health. Potential impacts from spillage of fuels and chemicals into waterways will be minimised through appropriate storage, handling and disposal of these materials.

Mitigation measures

Pre-construction

Identifying opportunities to avoid the direct impacts of vegetation removal and habitat loss has been a primary objective of the flora, fauna and ecological assessment. Initial pipeline alignments were adjusted to avoid vegetation communities confirmed in the initial field assessment. This initial adjustment process reduced the potential direct impact area from 17.5 ha to the current 3.38 ha detailed in Table 6-20.

The following principles would be applied during detailed design to further minimise potential impacts on flora and fauna where practically and technically feasible:

- configure pipeline alignments to avoid impacts to native riparian vegetation
- place alignments outside the ‘top of bank’ where pipelines run parallel to watercourses. This approach reduces the number of creek crossings, prevents changes in erosion processes during high flows and allows for the potential establishment of riparian vegetation
- co-locate alignments with existing infrastructure (e.g. utilise road and/or bridge crossings) where pipelines cross a watercourse (whilst recognising technical constraints)
- coordinate water pipeline watercourse crossings to occur during the roadway/bridge construction to minimise the duration of impacts on riparian corridors
- locate permanent access tracks required for maintenance purposes outside riparian corridors

- avoid or underbore farm dams and coastal freshwater lagoons
- utilise existing and/or proposed future road alignments for water pipeline alignments so that construction impacts are shared and/or minimised through geographic consolidation
- align pipelines to have the least impact to native vegetation and to avoid significant hollow-bearing trees
- design infrastructure to avoid native vegetation (e.g. at reservoir locations)
- consider construction methods that avoid and/or minimise impacts (e.g. under boring instead of open trenching).

Construction management measures

Where feasible, appropriate management measures will be used to minimise impacts to flora and fauna. Construction management measures may include:

- limiting the extent of the direct pipeline construction impact to a maximum width of 10 m through native vegetation
- protecting and physically delineating areas of native vegetation that are to be protected. Retained trees would be protected and managed in accordance with the *Australian Standard 4970-2009 Protection of Trees on Development Sites*.
- protecting hollow-bearing trees. Where impacts cannot be avoided, an inventory of those trees to be removed would be taken and suitable mitigation measures implemented (eg. placing the cut tree and any other fauna habitat elements in suitable adjacent habitat and/or installing nesting boxes in nearby trees as an offset for the removal of hollow-bearing trees).
- seeking specialist advice prior to and during native vegetation removal (to mark any hollow-bearing trees, check vegetation for fauna prior to removal, carry out any necessary fauna rescue)
- locating and managing soil stockpiles appropriately
- locating construction facilities and vehicle turning areas in already cleared areas
- removing noxious weeds, managing Class 4 noxious weeds in accordance with management plans published by the Council and decreasing barriers for movement of native fauna where possible.
- temporarily diverting, or partially bunding minor streams during trenching to allow for connectivity of flows and fish passage.

Rehabilitation

Rehabilitation of all construction sites and disturbed surfaces is a central part of the construction process. All construction sites and locations will be appropriately stabilised and/or rehabilitated post-construction. Site specific rehabilitation measures would be developed during the detailed design process and may include maintenance and monitoring programs (refer to Section 3.4.1). The following areas will take priority in terms of rehabilitation:

- the direct impact locations as shown on Figures 6-17 and 6-18 and impacted areas of ILGW EEC
- riparian corridors where native vegetation communities are directly impacted.

Biodiversity offsets

Vegetation removal has been conservatively estimated and biodiversity impacts may be further reduced by refining the Proposal during detailed design as described in Section 3.4.1. Once the extent of native vegetation to be impacted by the Proposal has been confirmed, consideration would be given to offsetting impacts to achieve an improve or maintain outcome.

The Proposal would involve works within shared infrastructure corridors and in these instances, if offsets are considered appropriate they would be proportional to the impact of Sydney Water's activities.