Australian Government

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NSW GOVERNMENT

M1 Pacific Motorway extension to Raymond Terrace

Surface Water and Groundwater Quality Working Paper

Transport for NSW | July 2021

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Executive summary

Background

Transport for New South Wales (Transport) proposes to construct the M1 Pacific Motorway extension to Raymond Terrace (the project). Approval is sought under Part 5, Division 5.2 of the *Environmental Planning and Assessment Act 1979* and Part 9, Division 1 of the *Environment Protection and Biodiversity Conservation Act 1999*.

Performance outcomes

This assessment has been prepared to address the Secretary's Environmental Assessment Requirements (SEARs) (SSI 7319) relating to water quality. In addition, the desired performance outcomes for the project in relation to water quality as outlined in the SEARs (SSI 7319) are to:

- Ensure the project is designed, constructed and operated to protect the NSW Water Quality Objectives where they are currently being achieved, and contribute towards achievement of the Water Quality Objectives over time where they are currently not being achieved, including downstream of the project to the extent of the project impact including estuarine and marine waters
- Ensure that the environmental values of nearby, connected and affected water sources, groundwater and dependent ecological systems including estuarine and marine water (if applicable) are maintained (where values are achieved) or improved and maintained (where values are not achieved).

Overview of water quality impacts

Existing surface water quality of waterways and wetlands within the study area generally does not meet the relevant NSW water quality objectives. The waterways and wetlands are typically high in nutrients and heavy metal concentrations and are representative of a catchment that has been impacted by urbanisation, industrial and commercial use and land clearing.

Existing groundwater quality is highly variable and dependent on local geology and geomorphology. Salinity ranges from fresh potable water within the aquifers of the Tomago Sandbeds through to saline beneath the low lying floodplains of the Hunter River.

Surface water and groundwater features classified as sensitive receiving environments within the study areas include various Coastal Wetlands, lower reaches of Purgatory Creek (downstream of the floodgate), Hunter River, Viney Creek, groundwater users, Tomago Sandbeds Catchment Area, Hunter River wetland and the Hunter Estuary Wetlands Ramsar Site downstream of the project.

Surface water quality

Surface water impacts at receiving waterways and wetlands as a result of the project could result from:

- Construction of a viaduct over the Hunter River (and other smaller creeks and minor wetlands)
- Erosion of soils and sediment entering waterways due to construction activities
- Acid sulfate soils (ASS) runoff from construction activities on the floodplain
- Accidental leaks or spills of chemicals and fuels, or the introduction of gross pollutants (rubbish) into waterways from construction activities
- Discharge of water into aquatic receiving environments from temporary sediment basins and permanent water quality basins

- Remediation of contaminated site (former mineral sands processing facility – RZM) which may cause heavy metal contaminants to enter downstream waterways
- Accidental spills of concrete or asphalt waste, altering pH and releasing heavy metals and hydrocarbons to waterways.

An assessment of the likely construction and operational water quality impacts at the Hunter Estuary Wetlands Ramsar site at Kooragang Island has confirmed the project is unlikely to have a significant impact at the Ramsar site.

Groundwater quality

Impacts to groundwater as a result of the project could result from:

- Construction and operation of a new motorway within the Tomago Sandbeds drinking water catchment may impact groundwater quality by infiltration of potential contaminants
- Excavation of temporary sediment basins and permanent water quality basins within areas of high water table introduces a potential pathway for contamination
- Migration of contaminants from the subsoils within the former mineral sands processing facility.

Management measures

To minimise impacts to surface water and groundwater quality during construction, water quality control measures have been incorporated into the design of the project. These include a wide range of typical measures deployed for Transport road construction, bridge construction and soil remediation projects.

Surface water and groundwater management measures would be detailed in a Construction Soil and Water Management Plan. The plan would outline procedures for the management of activities such as bridge construction, stockpiling, excavation and treatment of acid sulfate soils, disturbance of soft soils and saline soils, dewatering, discharging temporary sediment basins and emergency spill response. During operation, the design of the viaduct and bridges minimises ongoing impacts to surface water environments. The control of the source and pathways of existing contaminants at the RZM site shall provide ongoing protection to the receiving surface and groundwaters. A range of permanent water quality treatment measures have been proposed as part of the design including the lining drainage and basins in the Tomago Sandbeds, landscaping, grassed swales, permanent water quality basins and scour protection to avoid erosion and sedimentation impacts.

Conclusion

Following the implementation of the proposed management measures, modelling demonstrated that the project is generally able to either meet the NSW Water Quality Objectives and/or meet existing water quality. Modelling identified some sites and indicators that result in minor exceedances of the NSW Water Quality Objectives or ambient water quality however, is expected to only have minor to negligible impacts on existing surface water and groundwater quality.

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1. Introduction

1.1 Background

Transport for New South Wales (Transport) proposes to construct the M1 Pacific Motorway extension to Raymond Terrace (the project). Approval is sought under Part 5, Division 5.2 of the *Environmental Planning and Assessment Act 1979* (EP&A Act) and Part 9, Division 1 of the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act).

The project would connect the existing M1 Pacific Motorway at Black Hill and the Pacific Highway at Raymond Terrace within the City of Newcastle and Port Stephens Council local government areas (LGAs). The project would provide regional benefits and substantial productivity benefits on a national scale. The project location is shown in **Figure 1-1** within its regional context.

1.2 Project description

The project would include the following key features:

- A 15 kilometre motorway comprised of a four lane divided road (two lanes in each direction)
- Motorway access from the existing road network via four new interchanges at:
  - Black Hill: connection to the M1 Pacific Motorway
  - Tarro: connection and upgrade (six lanes) to the New England Highway between John Renshaw Drive and the existing Tarro interchange at Anderson Drive
  - Tomago: connection to the Pacific Highway and Old Punt Road
  - Raymond Terrace: connection to the Pacific Highway.
- A 2.6 kilometre viaduct over the Hunter River floodplain including new bridge crossings over the Hunter River, the Main North Rail Line and the New England Highway
- Bridge structures over local waterways at Tarro and Raymond Terrace, and an overpass for Masonite Road in Heatherbrae
- Connections and modifications to the adjoining local road network
- Traffic management facilities and features
- Roadside furniture including safety barriers, signage, fauna fencing and crossings and street lighting
- Adjustment of waterways, including at Purgatory Creek at Tarro and tributary of Viney Creek
- Environmental management measures including surface water quality control measures
- Adjustment, protection and/or relocation of existing utilities
- Walking and cycling considerations, allowing for existing and proposed cycleway route access
- Permanent and temporary property adjustments and property access refinements
- Construction activities, including establishment and use of temporary ancillary facilities, temporary access tracks, haul roads, batching plants, temporary wharves, soil treatment and environmental controls.

A detailed project description is provided in Chapter 5 of the environmental impact statement (EIS). The locality of the project is shown in **Figure 1-1**, while an overview of the project is shown in **Figure 1-2**.

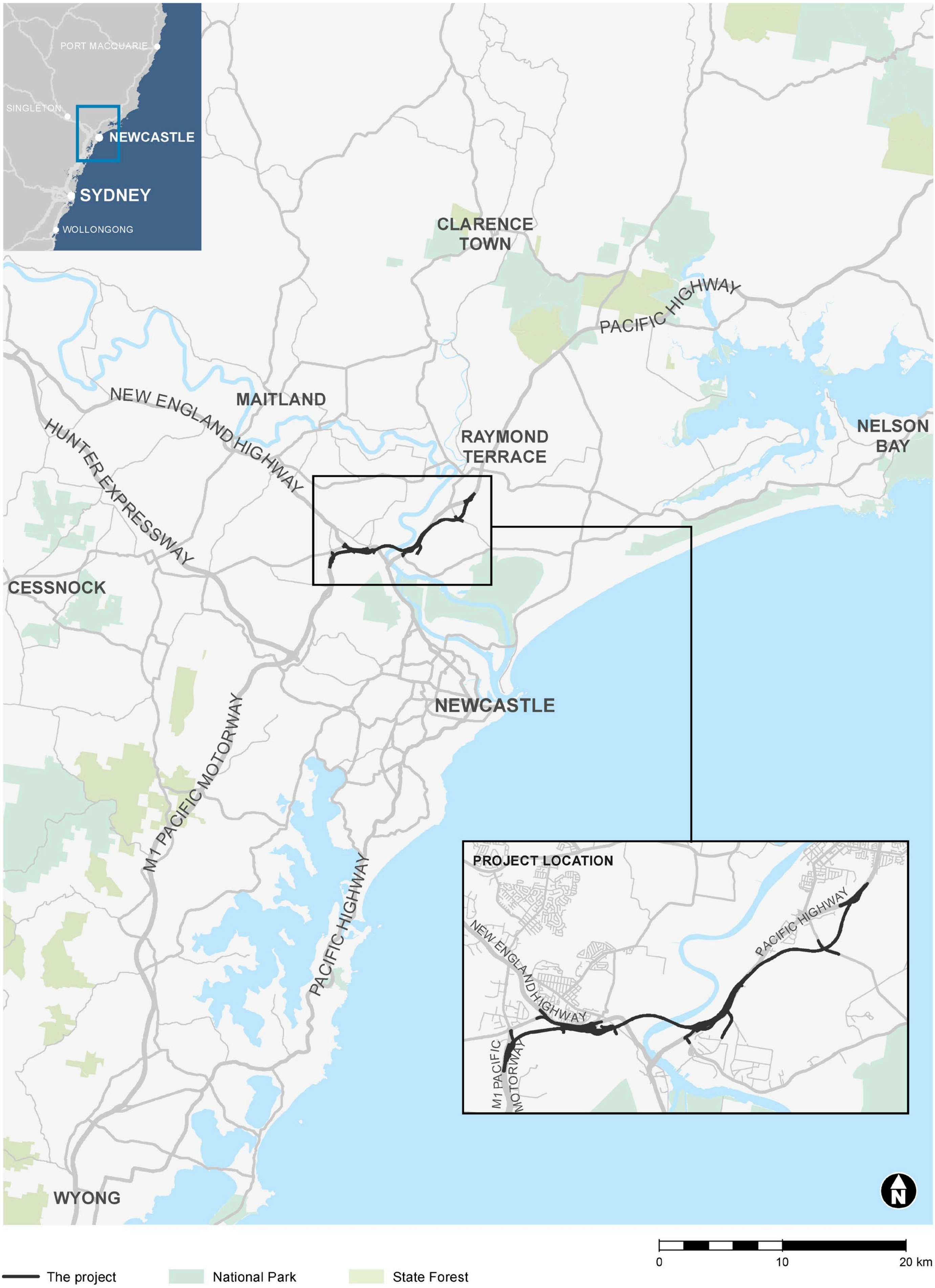

Figure 1-1 Regional context of the project

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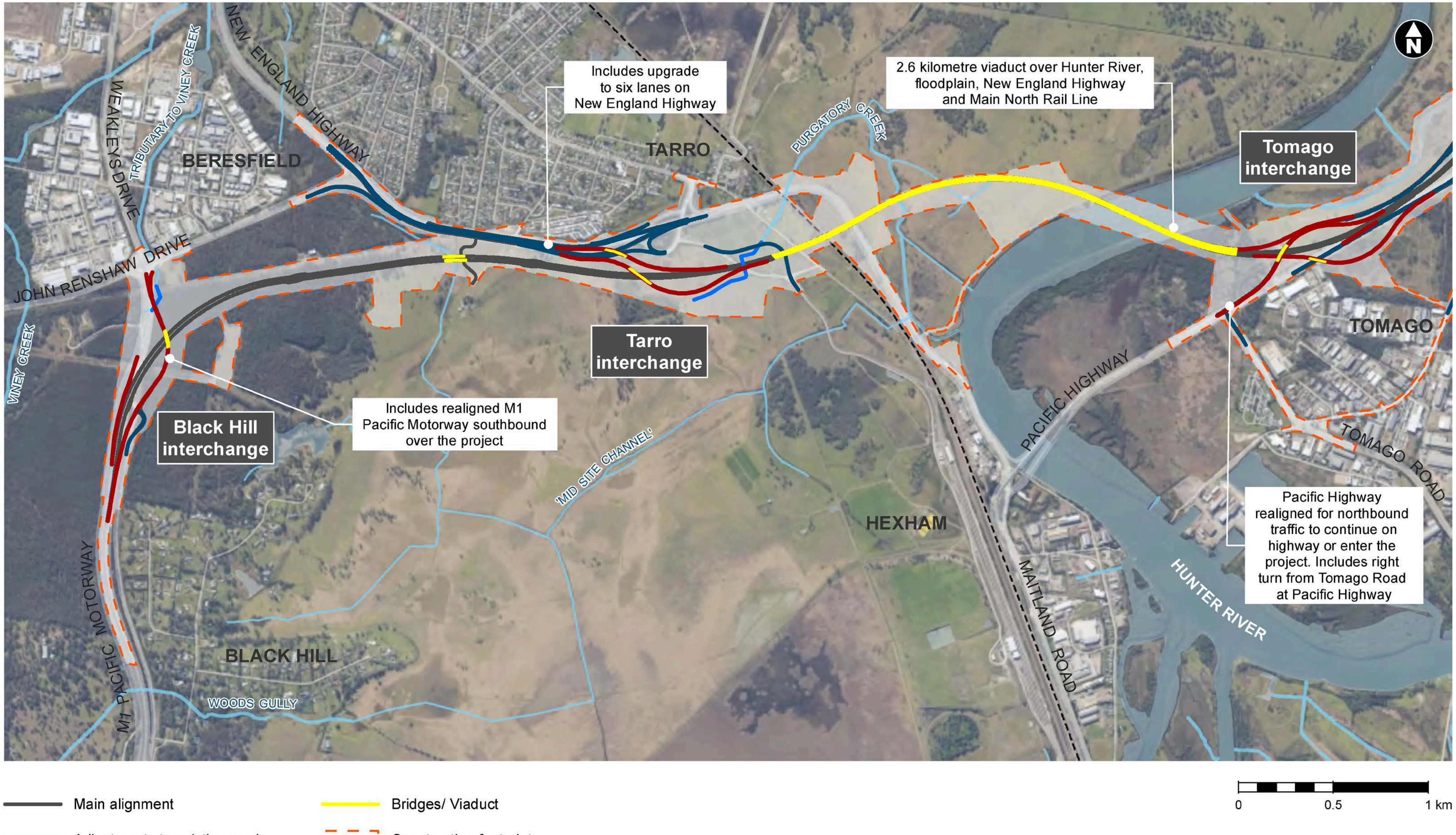

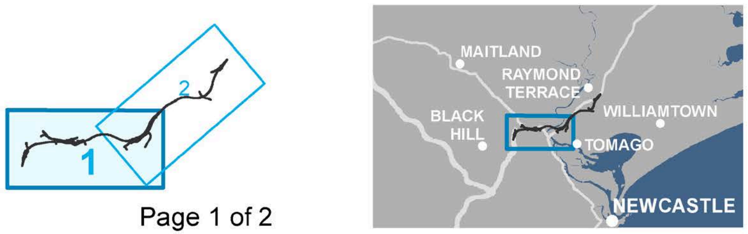

Figure 1-2 Project key features (map 1 of 2)

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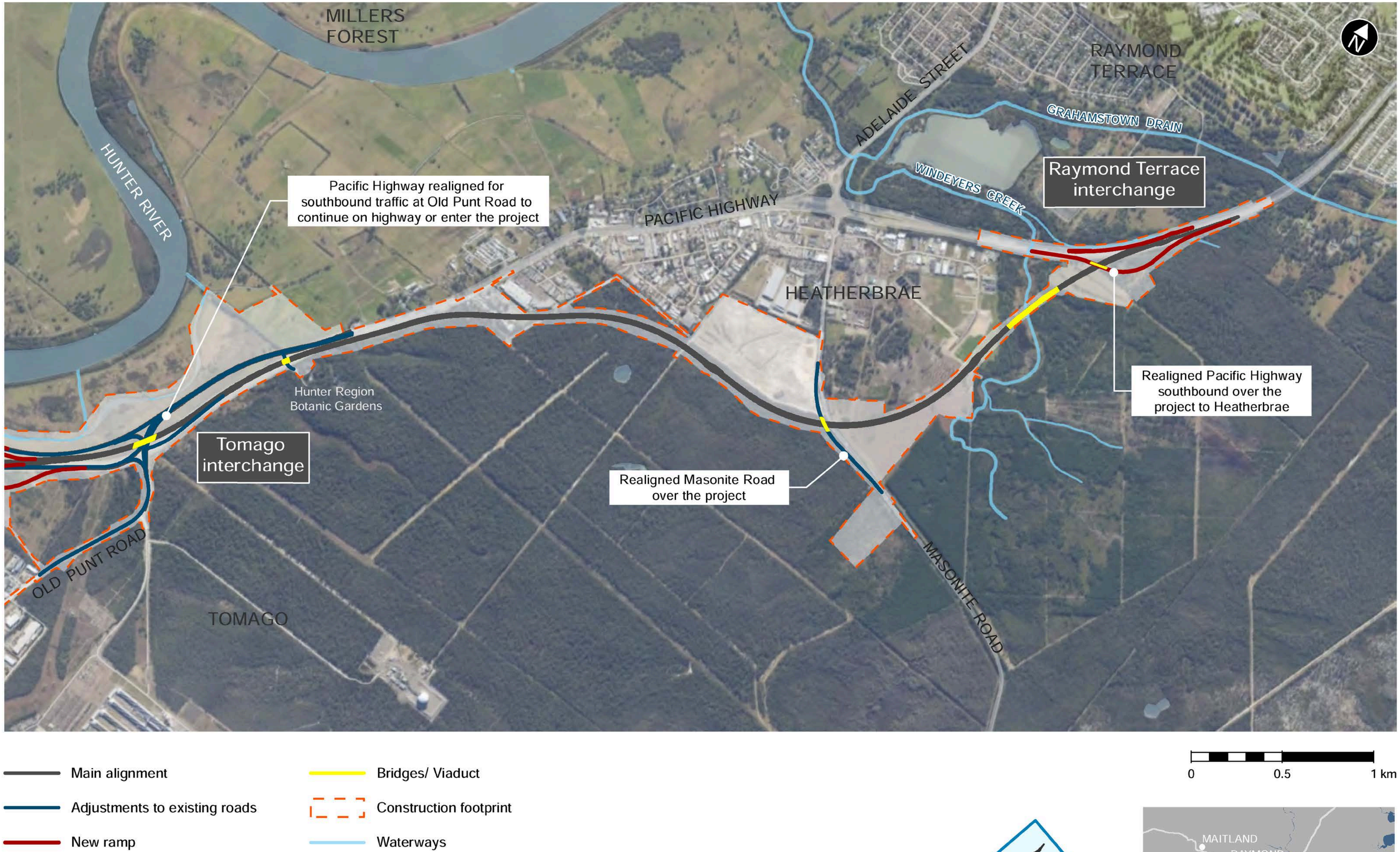

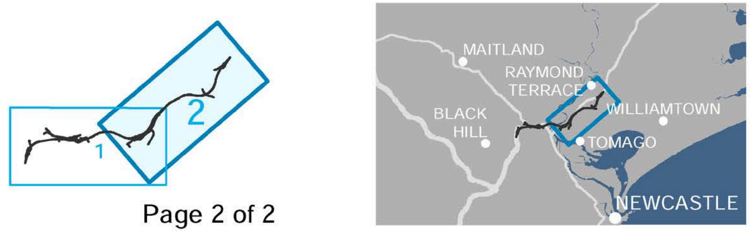

Figure 1-2 Project key features (map 2 of 2)

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1.3 Performance outcomes

The desired performance outcomes for the project relating to water quality are to:

- Ensure the project is designed, constructed and operated to protect the NSW Water Quality Objectives where they are currently being achieved, and contribute towards achievement of the Water Quality Objectives over time where they are currently not being achieved, including downstream of the project to the extent of the project impact including estuarine and marine waters (refer to **Section 6.2.6** and **Section 6.3.4**)
- Ensure that the environmental values of nearby, connected and affected water sources, groundwater and dependent ecological systems including estuarine and marine water (if applicable) are maintained (where values are achieved) or improved and maintained (where values are not achieved) (refer to **Section 6.2.6** and **Section 6.3.4**).

1.4 Secretary's Environmental Assessment Requirements

This assessment forms part of the EIS for the project. The EIS has been prepared under Division 5.2 of the EP&A Act. This assessment has been prepared to address the Secretary's Environmental Assessment Requirements (SEARs) (SSI 7319) relating to water quality and will assist the NSW Minister for Planning and Public Spaces to make a determination on whether or not to approve the project. It provides an assessment of potential impacts of the project on surface water and groundwater quality and outlines proposed management measures.

In 2019 revised SEARs, which included water quality as a key issue were issued for the project. **Table 1-1** outlines the SEARs relevant to this assessment along with a reference to where these are addressed.

Table 1-1 SEARs relevant to surface water and groundwater quality

Secretary's requirement	Where addressed in this report
6. Soils	
5. The Proponent must assess the impacts of the project on soil salinity and how it may affect groundwater resources and hydrology.	Soil salinity risks in the vicinity of the project are discussed in **Section 4.3.2**. Potential impacts on surface water and groundwater associated with soil salinity during construction and operation are discussed in **Section 6.2.1**, **Section 6.2.2**, **Section 6.3.1** and **Section 6.3.2**. The Soils and Contamination Working Paper (Appendix P of the EIS) assesses the impacts of the project on soil salinity.
8. Water – Quality	
1. The proponent must:	
a) state the ambient NSW Water Quality Objectives (NSW WQO) and environmental values for the receiving waters relevant to the project, including the indicators and associated trigger values or criteria for the identified environmental values;	NSW Water Quality Objectives relevant to the project are discussed in **Section 2.3.2**. Nominated environmental values for the receiving waterways relevant to the project are provided in **Table 3-3** and **Table 3-4**. Relevant indicators and associated default guideline values or criteria for the identified environmental values (referred to as Water Quality Objectives in this assessment) are provided in **Table 3-5**.

Secretary's requirement	Where addressed in this report
b) identify and estimate the quality and quantity of all pollutants that may be introduced into the water cycle by source and discharge point and describe the nature and degree of impact that any discharge(s) may have on the receiving environment, including consideration of all pollutants that pose a risk of non-trivial harm to human health and the environment;	Pollutants that may be introduced into the water cycle by source and discharge point during construction are summarised in **Table 6-2** and discussed in detail in **Section 6.2**. Estimated TSS loads discharged from temporary sediment basins during construction, are presented in **Section 5.1.3**. Pollutants that may be introduced into the water cycle by source and discharge point during operation are summarised in **Table 6-9** and discussed in detail in **Section 6.3**. Estimated loads during operation are presented in **Section 5.2.4**. Pollutants which may pose risk to human health and the environment are discussed in **Section 6.2** and **Section 6.3**. Estimated pollutants that may be introduced during construction and operation and the impact on the Ramsar Wetland is discussed in **Section 6.2.6** and **Section 6.3.4**. The risk of pollutants entering groundwater is assessed in **Section 6.2.2** and **Section 6.3.2**.
c) identify the rainfall event that the water quality protection measures will be designed to cope with;	**Section 5.1.3** identifies the rainfall event that the water quality protection measures have been for construction and operation. Temporary sediment basin and permanent water quality basin sizing is provided in **Table 5-2** and **Table 5-9**.
d) assess the significance of any identified impacts including consideration of the relevant ambient water quality outcomes;	Existing surface water quality of receiving waterways is described in **Section 4.6**. Identified impacts to surface water quality from construction are discussed in **Section 6.2**. Identified impacts to surface water quality from operation are discussed in **Section 6.3**. Impact on water quality outcomes are discussed in **Chapter 5** and **Chapter 6**. Specifically, **Section 6.2.6** detail the influence the project on meeting the water quality objectives.
e) demonstrate how construction and operation of the project will, to the extent that the project can influence, ensure that: - where the NSW WQOs for receiving waters are currently being met they will continue to be protected; and - where the NSW WQOs are not currently being met, activities will work toward their achievement over time;	The NSW WQOs refer to the ANZG (2018) and other guidelines to assess compliance as further detailed in **Section 2.3.2**. Existing surface water quality and compliance with ANZG (2018) Water Quality Guideline values is discussed in **Section 4.6** and shown on Figure A-1 of **Appendix A**. Water quality controls and management measures to protect water quality objectives are described in **Chapter 5** and **Chapter 8**. Project influence on meeting objectives during construction and operation is discussed in **Section 6.2.6, Section 6.3.4, Table 6-6** and **Table 6-12**.
f) justify, if required, why the WQOs cannot be maintained or achieved over time;	Discussion about maintaining or achieving WQOs over time is provided in **Section 6.2.6** and **Section 6.3.4**.
g) demonstrate that all practical measures to avoid or minimise water pollution and protect human health and the environment from harm are investigated and implemented;	Construction impacts on surface water and groundwater quality are discussed in **Section 6.2.** Operational impacts on surface water and groundwater quality are discussed in **Section 6.3**. Avoidance of impacts to surface water and groundwater quality is discussed in **Section 6.1**. Water quality controls and management measures to protect human health and the environment are described in **Chapter 5** and **Chapter 8**, with the project's strategy to address construction and operational water quality impacts discussed in **Section 5.1.1** and **Section 5.2.1**.

Secretary's requirement	Where addressed in this report
h) identify sensitive receiving environments (including estuarine and marine waters downstream and the Tomago Sandbeds Catchment Area) and develop a strategy to avoid or minimise impacts on these environments; and	The method for identifying SREs is provided in **Section 3.3.3**, while SREs (which includes Tomago Sandbeds) are discussed in **Section 4.9**. Water quality controls for protecting SREs and the strategy for how these controls were identified are discussed in **Section 5.1** and **Section 5.2**. **Section 6.1** discusses how the project design has avoided and minimised impacts to SREs (including the Tomago Sandbeds Catchment Area). Management measures to avoid and mitigate impacts to SREs and the Tomago Sandbeds are provided in **Chapter 8**.
i) identify proposed monitoring locations, monitoring frequency and indicators of surface and groundwater quality.	Proposed surface water monitoring locations are shown in **Figure 8-1** and shown in **Figure 4-6**. Surface water monitoring frequency is discussed in **Section 8.1.2** and **Section 8.1.3** while monitoring indicators are listed in **Table 8-2**. The proposed groundwater monitoring locations are shown in **Figure 8-1** and detailed further in **Appendix F**. Groundwater monitoring frequency is discussed in **Section 8.1.2** and **Section 8.1.3** while monitoring indicators are listed in **Table 8-3**.
2. The assessment should consider the results of any current water quality studies, as available, in the project catchment.	Sources and existing surface water quality data are discussed in **Section 3.3.1** and **Section 3.3.2**. Existing surface water quality studies are discussed in **Section 4.6** and **Appendix A**. Sources and existing groundwater data are discussed in **Section 3.4**. Existing groundwater quality is discussed in **Section 4.7**.

1.5 Report structure

The report is structured as follows:

- Chapter 1 – Introduces the project with a summary of the project background and assessment objectives
- Chapter 2 – Provides an overview of legislation, policies and guidelines applied to this assessment
- Chapter 3 – Describes the methodology and approach for the assessment
- Chapter 4 – Describes the physical characteristics and existing surface water quality of the environment surrounding the project
- Chapter 5 – Provides a discussion on the water quality controls and modelling that has been incorporated into the concept design for the project
- Chapter 6 – Provides an assessment of the potential impacts to water quality from construction and operation of the project
- Chapter 7 – Provides an assessment of the potential cumulative impacts to water quality from the construction and operation of the project with respect to other projects which are proposed nearby
- Chapter 8 – Provides measures to avoid, mitigate and manage potential impacts to surface water and groundwater and describes the proposed monitoring program
- Chapter 9 – Concludes the key findings and recommendations from the assessment
- References
- Terms and acronyms.

2. Policy and planning setting

2.1 Commonwealth legislation

2.1.1 Environment Protection and Biodiversity Conservation Act 1999

The EPBC Act provides the legal framework to protect and manage Matters of National Environmental Significance (MNES) including nationally and internationally important flora, fauna, ecological communities, cultural heritage and water resources. The project was declared to be a controlled action on 14 January 2019.

The MNES listed in the controlled action declaration relevant to the water quality assessment is the Subtropical and Temperate Coastal Saltmarsh ecological community which is listed as vulnerable under the EPBC Act. Together with state-listed EECs, EECs have been considered in the determination of Sensitive Receiving Environments (SREs) (refer to **Section 4.9**) and potential impact to these EECs have been considered in **Section 6.2** and **Section 6.3**. Impacts relevant to specific EECs are discussed in detail in the Biodiversity Assessment Report (Appendix I of the EIS).

Other MNES which are related to water quality and located within proximity of or are predicted to occur within the study area but have not been declared in the controlled action for the project include:

- The Hunter Estuary Wetlands Ramsar site, comprising the Hunter Wetlands National Park on Kooragang Island and the Hunter Wetlands Centre Australia in Shortland (refer to **Section 4.2.11**). Due to distance of the project from the Hunter Estuary Wetlands Ramsar site areas, no direct impacts are anticipated, however potential indirect impacts to the Hunter Wetlands National Park on Kooragang Island component of the Ramsar site areas are discussed in **Section 6.2.6** and **Section 6.3.4** in accordance with the Significant impact guidelines 1.1 – Matters of National Environmental Significance (Department of the Environment, 2013) and further detailed in the Biodiversity Assessment Report (Appendix I of the EIS)
- Threatened aquatic species including the Black Rock Cod (*Epinephelus daemelii*), listed as vulnerable under the EPBC Act, and the Green Sawfish (*Pristis zijsron*), listed as vulnerable under the EPBC Act, though presumed extinct in NSW. While these species are mapped as potentially occurring within the study area, habitat and water quality within the waterways are not expected to be favourable for these species therefore their presence is considered to be highly unlikely (refer to **Section 4.9.7**).

Despite the low likelihood of impacts and not being declared a controlled action for potential impacts to these MNES, consideration has also been given to them in the determination of Sensitive Receiving Environments (SREs) (refer to **Section 4.9**), and risks to water quality which have potential to impact on any aquatic species are discussed in **Section 6.1** and **Section 6.3**. Impacts to aquatic species and ecological communities have been further addressed in the Biodiversity Assessment Report (Appendix I of the EIS).

2.2 State legislation

2.2.1 Environmental Planning and Assessment Act 1979

The EP&A Act and the Environmental Planning and Assessment Regulation 2000 (the Regulation) provide the framework for development assessment in NSW. The EP&A Act and the Regulation include provisions to ensure that the potential environmental impacts of a development are considered in the decision-making process prior to proceeding to construction. The project is declared State significant infrastructure (SSI) and an EIS has been prepared under Division 5.2 of the EP&A Act. The SEARs have been issued and this report considers those requirements as relevant to surface water and groundwater quality.

Section 5.22 of the EP&A Act specifies that environmental planning instruments, including State Environmental Planning Policies (SEPPs), do not apply to projects that are declared SSI. As such, the Coastal Management SEPP (2018) (Coastal Management SEPP) does not apply, although Coastal Management Areas identified in the Coastal Management SEPP have been considered in the assessment (refer to **Section 2.3.6** for further detail).

Section 5.23 of the EP&A Act states that particular licences, permits and approvals do not apply. Of relevance to this report:

- The requirement for permits under sections 201, 205 or 219 of the *Fisheries Management Act 1994* (FM Act) do not apply (refer to **Section 2.2.4** for further detail)
- The requirements for a water use approval under section 89, a water management work approval under section 90 or an activity approval (other than an aquifer interference approval) under section 91 of the *Water Management Act 2000* (WM Act) do not apply.

2.2.2 Protection of the Environment Operations Act 1997

The *Protection of the Environment Operations Act 1997* (POEO Act) is administered by the Environment Protection Authority (EPA). The POEO Act regulates air and water pollution, noise control and waste management.

Environmental protection licences (EPLs) are issued and administered under the POEO Act to authorise and regulate pollution resulting from scheduled activities. The project is likely to be a scheduled activity as it meets relevant criteria for road construction (under items 35) of Schedule 1 of the POEO Act.

Under the POEO Act, there is a responsibility to ensure that discharge leaving a site meets an agreed water quality standard, including water being discharged from temporary sediment basins and permanent water quality basins after storm events. The water quality controls as presented in **Chapter 5** assist the project in meeting this responsibility.

2.2.3 Water Management Act 2000 and Water Act 1912

The *Water Management Act 2000* (WM Act) and the *Water Act 1912* are the two key pieces of legislation for the management of water in NSW and contain provisions for the licensing of water access and use. Groundwater quality protection is also achieved through consideration of both the objects and principles of the WM Act.

The WM Act and the *Water Act 1912* are administered by the NSW Department of Planning, Industry and Environment (Water) (DPIE (Water)), with WaterNSW as the regulator and DPIE (Water) as the policy maker. The *Water Act 1912* is being progressively phased out and replaced by the WM Act. The applicability of this act to water access and use is discussed in the Hydrology and Flooding Working Paper (Appendix J of the EIS).

The project lies within the following water sources and water sharing plans (refer to **Figure 2-1**):

- Newcastle Water Source of the Water Sharing Plan for the Hunter Unregulated and Alluvial Water Sources 2009 (NSW Government, 2009) (applicable for groundwater and surface water)

- Sydney Basin–North Coast Groundwater Source of the Water Sharing Plan for the North Coast Fractured and Porous Rock Groundwater Sources 2016 (NSW Government, 2016a) (applicable for groundwater)
- Tomago Groundwater Source of the Water Sharing Plan for the North Coast Coastal Sands Groundwater Sources 2016 (NSW Government, 2016b) (applicable for groundwater).

Under the WM Act, all activities that interfere with an aquifer require assessment and approval under the NSW Aquifer Interference Policy. This assessment addresses the potential water quality impacts of the project against the beneficial use components of the NSW Aquifer Interference Policy (discussed further in **Section 2.3.5**).

2.2.4 Fisheries Management Act 1994

The *Fisheries Management Act 1994* (FM Act) provides for the protection of threatened fish and marine vegetation and is administered by NSW Fisheries which are part of the Department of Planning, Industry and Environment (DPIE). The FM Act, in conjunction with the *Biodiversity Conservation Act 2016* (BC Act), aims to conserve, develop and share fisheries resources and conserve marine species, habitats and diversity.

The project would cross an unmapped and unnamed artificial tributary of Viney Creek, Glenrowan Creek, Purgatory Creek, Hunter River and Windeyers Creek, wetlands and drains/drainage channels of the Hunter River. All waterway crossings have been designed with consideration of NSW Fisheries guidelines – Why do Fish need to Cross the Road? Fish Passage Requirements for Waterway Crossings (Fairfull and Witheridge, 2003)) and in consultation with NSW Fisheries staff (S. Carter, pers comm, 24 November 2017) to ensure minimum impact to aquatic habitats and species protected under the FM Act.

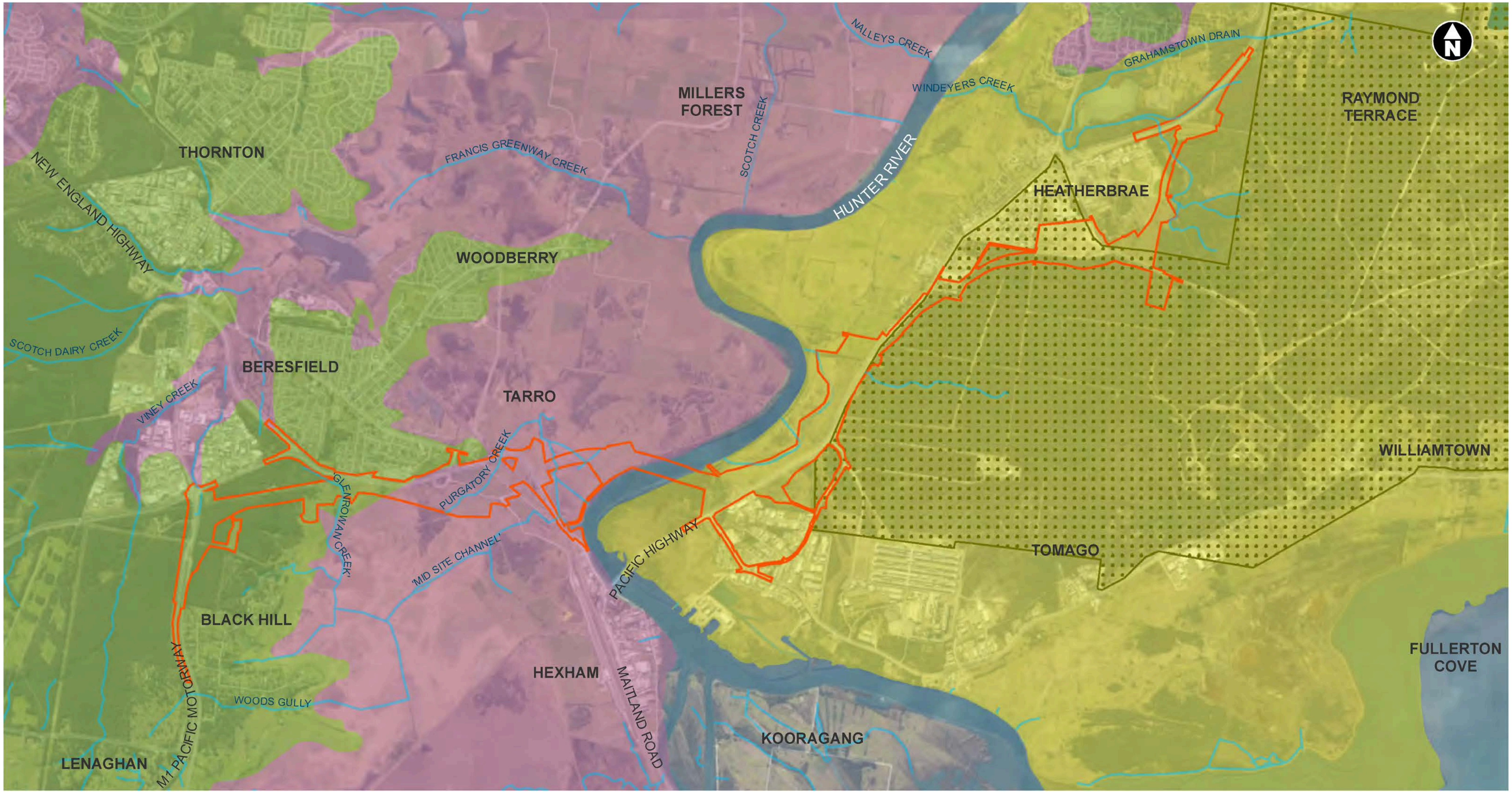
With regard to this project, construction work associated with some waterway crossing structures would require 'dredging' (excavation of water land or removal of material from water land) or 'reclamation' (using material to fill/reclaim or depositing material to construct anything other than water land) as defined under section 198A of the FM Act. In addition, construction and operation of the project would result in the 'temporary or permanent blockage of fish passage within waterways' as defined under section 219 of the FM Act. Assessment of these impacts is detailed in **Section 6.2.1**.

Part 7 of the FM Act relates to the protection of aquatic habitats, including managing dredging and reclamation work within permanently or intermittently flowing waterways, as well as the temporary or permanent blockage of fish passage within a waterway. However, by force of section 5.23 of the EP&A Act, the requirement to obtain permits for these activities (listed under sections 201, 205 or 219 of the FM Act) do not apply for the project.

2.2.5 Hunter Water Act 1991

The *Hunter Water Act 1991* (Hunter Water Act) and associated Hunter Water Regulation 2015 (Hunter Water Regulation) controls activities that can be carried out in special areas. The special area of relevance to the project is the Tomago Sandbeds Catchment Area (refer to **Figure 2-1**).

Clauses in the Hunter Water Regulation which are of relevance include Clause 55(1) of the Act, that requires notification to DPIE prior to work commencing in a special area; Clause 10 that states no pollution of any water in a special area; and Clause 15 of the Act that addresses no engaging in extractive industries in the Tomago Sandbeds Catchment area unless approved by the DPIE.



Construction footprint

Tomago Sandbeds Catchment Area

Waterways

Water sharing plans

Sydney Basin–North Coast Groundwater Source of the *Water Sharing Plan for the North Coast Fractured and Porous Rock Groundwater Sources 2016* (groundwater)

Newcastle Water Source of the *Water Sharing Plan for the Hunter Unregulated and Alluvial Water Sources 2009* (groundwater and surface water)

Tomago Groundwater Source of the *Water Sharing Plan for the North Coast Coastal Sands Groundwater Sources 2016* (groundwater)

0 1.5 3 km

Figure 2-1 Water sharing plan

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2.3 Relevant guidelines

2.3.1 National Water Quality Management Strategy

The National Water Quality Management Strategy (NWQMS) (Australian Government, 2018) is the overarching strategy for managing water quality in Australia and was developed with the objective of achieving sustainable use of the nation's water resources by protecting and enhancing their quality while maintaining economic and social development.

The NWQMS contains all subsequent guidelines and policies related to water quality including:

- The NSW Water Quality and River Flow Objectives (DECCW, 2006) which sets out water quality objectives to sustain current or likely future environmental values for water resources (refer to **Section 2.3.2**)
- The Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZG, 2018) which outlines relevant guidelines related to the water quality objectives (refer to **Section 2.3.3**).

2.3.2 NSW Water Quality and River Flow Objectives

The NSW Water Quality and River Flow Objectives (DECCW, 2006) are the environmental values and long term goals for NSW surface waters. The NSW Water Quality and River Flow Objectives (DECCW, 2006) are in two parts, the NSW Water Quality Objectives (WQOs) and NSW river flow objectives, which are distinct because they relate to different environmental attributes of a waterway that are important for long-term functionality. Project impacts to NSW WQOs nominated for waterways within the project surface water study area have been described and addressed in **Section 6.2.6** and **Section 6.3.4**. NSW river flow objectives have been described and addressed in the Hydrology and Flooding Working Paper (Appendix J of the EIS). From herein, this report will only refer to the NSW WQOs (DECCW, 2006).

The NSW WQOs set out:

- The community's values and uses (i.e. healthy aquatic ecosystems, water suitable for recreation or drinking) for our waterways (e.g. rivers, creeks, lakes and estuaries)
- A range of water quality indicators to assess whether the current condition of the waterway supports these values and uses.

The NSW WQOs consist of three parts: environmental values, water quality indicators and recommended default guideline values (DGVs).

The NSW WQOs identify environmental values for NSW waterways and the associated water quality indicators which relate to these environmental values. The NSW WQOs then refer to ANZG (2018) Water Quality Guidelines and other guidelines to provide DGVs and technical guidance to assess the water quality needed to protect these values.

The environmental values outlined in the NSW WQOs (DECCW, 2006) relevant to the project and nominated for waterways are described in the following section.

Water quality objectives

WQOs are assigned to waterways within a catchment and describe identified or desired uses which are applicable to the waterway. WQOs can relate to maintaining or achieving aquatic ecosystem health, or for public benefit or human health. WQOs require protection from the effects of pollution and waste discharges and provide goals that help select the most appropriate management options (ANZECC/ARMCANZ, 2000a).

The project falls within the lower portion of the Hunter River Catchment (DECCW, 2006). The waterways within this section of the catchment have been categorised and each category has numerous water quality objectives for protection.

WQOs applying to waterway categories within the project study area are outlined in **Section 3.3.4** (refer to **Table 3-3**).

2.3.3 Australian and New Zealand Guidelines for Fresh and Marine Water Quality

The Australian and New Zealand Environment and Conservation Council (ANZECC/ARMCANZ) published Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC/ARMCANZ, 2000a) to provide benchmarks against which to assess the existing water quality of waterways. The guidelines were updated in 2018 to incorporate new science and knowledge developed over the past 20 years (ANZG, 2018).

The ANZG (2018) National Water Quality Guidelines for Fresh and Marine Water Quality (referred to herein as the ANZG (2018) Water Quality Guidelines) have been applied with guidance from the Using the ANZECC Guidelines and Water Quality Objectives in NSW (DEC, 2006) booklet to understand the current health of the waterways in the surface water study area and the ability to support nominated WQOs, particularly the protection of aquatic ecosystems. The ANZG (2018) Water Quality Guidelines provide recommended trigger values which have been considered when describing the existing water quality and key indicators of concern. However, many of the guideline values are still in a draft form. Currently, physical and chemical stressors for aquatic ecosystems for the Southeast Coast (the geographic region relevant to this project) have not yet been completely updated.

The ANZG (2018) Water Quality Guidelines are not intended to directly apply to contaminant concentrations in industrial discharges or stormwater quality (unless stormwater systems are regarded as having relevant community value). They have been derived to apply to the ambient waters that receive effluent or stormwater discharges and protect the water quality objectives they support.

2.3.4 Australian Drinking Water Guidelines

The Australian Drinking Water Guidelines (ADWG) are prepared by the National Health and Medical Research Council for the Australian Government (NHMRC, 2011) and are:

"…intended to provide a framework for good management of drinking water supplies that, if implemented, will assure safety at point of use. The ADWG have been developed after consideration of the best available scientific evidence. They are designed to provide an authoritative reference on what defines safe, good quality water, how it can be achieved and how it can be assured. They are concerned both with safety from a health point of view and with aesthetic quality.

The ADWG are not mandatory standards; however, they provide a basis for determining the quality of water to be supplied to consumers in all parts of Australia. These determinations need to consider the diverse array of regional or local factors, and take into account economic, political and cultural issues, including customer expectations and willingness and ability to pay.

The ADWG are intended for use by the Australian community and all agencies with responsibilities associated with the supply of drinking water, including catchment and water resource managers, drinking water suppliers, water regulators and health authorities."

Given the proximity to the public water supply of the Tomago Sandbeds Catchment Area (administered by Hunter Water Corporation), the drinking water guidelines are relevant in terms of assessing potential impacts on the quality of the water resource. Groundwater quality impacts of the project are discussed in **Section 6.2.2** and **Section 6.3.2**.

2.3.5 NSW Aquifer Interference Policy

The NSW Aquifer Interference Policy (NSW AIP) (DPI, 2012) presents the assessment requirements of interference activities administered by the WM Act. Key components to the policy are:

"All water taken must be properly accounted for. The activity must address minimal impact considerations with respect to water table, water pressure and water quality. Planning for measures in the event that actual impacts are greater than predicted, including making sure there is sufficient monitoring in place."

The NSW AIP outlines minimal impact considerations for water table and groundwater pressure drawdown for high priority Groundwater Dependent Ecosystems (GDEs) (as identified in the WSP), high priority culturally significant sites (as identified in the WSP) and existing groundwater supply bores. Water quality impact considerations are also outlined within the NSW AIP with respect to the beneficial use of the aquifer. The project is assessed against the NSW AIP minimal impact considerations with respect to water quality in **Section 6.2.2** and **Section 6.3.2**.

2.3.6 State Environmental Planning Policy (Coastal Management) 2018

State Environmental Planning Policy (Coastal Management) 2018 (Coastal Management SEPP) updates and consolidates the SEPP 14 (Coastal Wetlands), SEPP 26 (Littoral Rainforests) and SEPP 71 (Coastal Protection) into a single integrated policy. The Coastal Management SEPP aims to promote an integrated and co-ordinated approach to land use planning in the coastal zone in a manner consistent with the objectives of the *Coastal Management Act 2016.*

While the SEPP does not apply to the project because of its declared status as State Significant Infrastructure (refer to **Section 2.2.1**), the sensitivity of areas mapped under the SEPP has been taken into account in this assessment. Coastal Management areas as defined under the Coastal Management SEPP are mapped on **Figure 2-2**.

2.3.7 Managing Urban Stormwater – Soils and Construction

The Managing Urban Stormwater – Soils and Construction series of handbooks are an element of the NSW Government's urban stormwater program specifically applicable to the construction phase of developments. These provide guidance for managing uncontaminated soils in a manner that protects the health, ecology and amenity of urban streams, rivers, estuaries and beaches through better management of stormwater quality.

The handbooks were produced to provide guidelines, principles and recommended minimum design standards for good management practice in erosion and sediment control during the construction phase of a development. The main section of the handbooks is Managing Urban Stormwater – Soils and Construction: Volume 1 (Landcom, 2004) and of particular relevance to the project is Volume 2D Main Road Construction (DECC, 2008b). These volumes are collectively referred to as the 'Blue Book'. The construction management measures proposed in this report (as outlined in **Chapter 8**) are largely based on the guidelines provided in the Blue Book.

2.3.8 Guidelines for Controlled Activities on Waterfront Land

Controlled activities carried out in, on or under waterfront land are regulated by the WM Act. This Act defines waterfront land to include the bed and bank of any river, lake or estuary and all land within 40 metres of the highest bank of the river, lake or estuary. Under section 5.23 of the EP&A Act, an activity approval (including a controlled activity approval) under section 91 of the WM Act is not required for SSI, and so waterfront land has not been considered further in this assessment for water quality.

2.3.9 NSW Wetlands Policy

The NSW Wetlands Policy (DECCW, 2010) replaces the NSW Wetlands Management Policy of 1996 and reflects the development of natural resource management and planning that affect wetlands. The purpose of the NSW Wetland Policy is to complement relevant legislation, including the EP&A Act, *National Parks and Wildlife Act 1974* (NPW Act), FM Act and EPBC Act by:

- Providing a more explicit definition of wetlands, including recognition of their dry phases, to assist the application of legislation to wetlands
- Aiding the decision making when interpreting the provisions of relevant legislation
- Providing direction where legislation lacks a consistent approach.

The approach to the surface water and groundwater assessment has taken into consideration the information outlined in NSW Wetlands Policy with regard to defining wetland environments and identifying impacts on coastal wetlands (Coastal Management SEPP) and other wetlands within proximity of the project.

2.3.10 The NSW State Rivers and Estuaries Policy

NSW State Rivers and Estuaries Policy (NSW Water Resources Council, 1993) establishes the framework for sustainable management of rivers, estuaries and wetlands of NSW. It is based on the “Total Catchment Management” philosophy defined in the *Catchment Management Act 1989*. Since the *Catchment Management Act 1989* has been repealed, this policy is no longer relevant and has therefore not been considered further in this assessment.

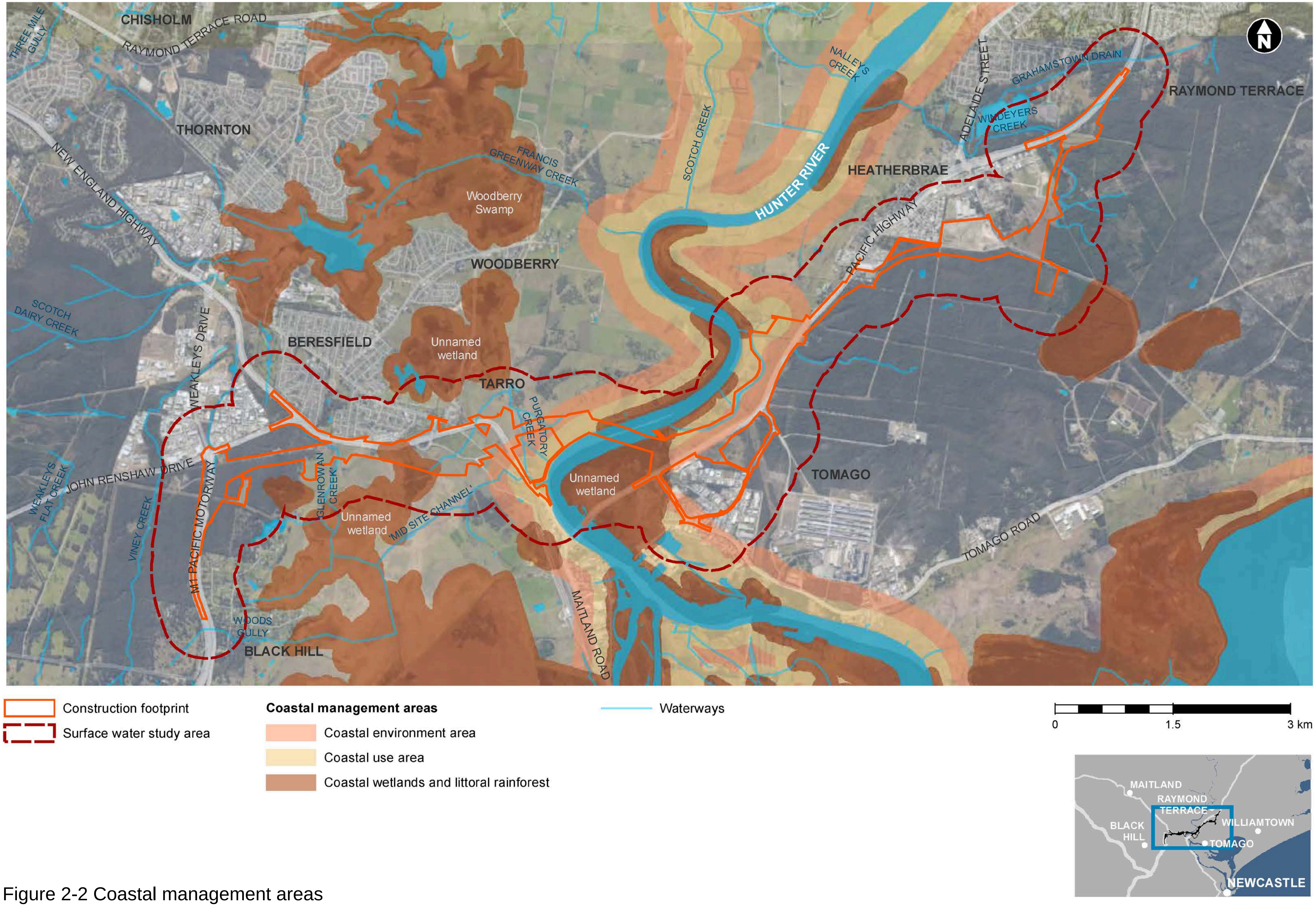

Figure 2-2 Coastal management areas

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3. Assessment methodology

3.1 Overview

The methodology for the assessment of water quality is outlined in the following sections and includes:

- Carrying out a desktop review and analysis to characterise the existing environment and identify potential waterway and aquifer-specific risks
- Incorporation of project specific geotechnical investigations and installation of groundwater monitoring bores
- Site visits and water quality monitoring to support and enhance the findings of the desktop analysis, refine the understanding of potential issues and provide added information to address any knowledge gaps. Surface water quality monitoring for the project was carried out in accordance with the Approved Methods for Sampling and Analysis of Water Pollutants in NSW (DECC, 2008). Groundwater quality monitoring was carried out in accordance with the Approved Methods for Sampling and Analysis of Water Pollutants in NSW (DECC, 2008), the Guideline for Construction Water Quality Monitoring (RTA, 2003b) and the National Water Quality Management Strategy - Australian Guidelines for Water Quality Monitoring and Reporting (ANZECC, 2000b)
- Development of a numerical groundwater model to assess potential groundwater interaction during construction and operation of the project
- Assessment of potential impacts from construction and operation of the project on water quality with reference to the ANZG (2018) Water Quality Guidelines and with regard to the relevant WQOs and environmental values as identified in the DECCW (2006) NSW Water Quality and River Flow Objectives
- Assessment of potential impacts from construction and operation of the project on water quality with reference to the minimal impact considerations of the NSW AIP
- A qualitative assessment of potential cumulative water quality impacts by identifying major projects with a construction program that is likely to overlap with the project construction and/or is within the same water catchment
- Identification of appropriate treatment measures to mitigate the potential impacts to surface water and groundwater quality resulting from construction and operation of the project.

Section 3.3 and **Section 3.4** provide further detail on how surface water and groundwater impacts were assessed.

3.2 Study area

The study areas for the surface water and groundwater quality assessment are shown on **Figure 3-1**.

3.2.1 Surface water

For the purposes of the surface water component of the water quality assessment, the study area (surface water study area) is identified as the project construction and operational footprints and a 500 metre buffer around the project. The surface water study area boundary was adopted to encapsulate a conservative estimate for the maximum distance that sediments and pollutants are likely to be able to mobilise from a point source.

Given the sensitivity of the Hunter Estuary Wetlands Ramsar site area, an assessment was carried out to predict any potential water quality impacts to the Hunter Estuary Wetland Ramsar site at Kooragang Nature

Reserve, despite its location outside the nominated study area. This assessment was carried out using a dilution model to estimate the concentration of key pollutants discharged directly to the Hunter River as a result of the project and predict the concentration that would reach the Hunter Estuary Wetland Ramsar site at Kooragang Nature Reserve, which is located over 5.1 kilometres downstream of the construction footprint. Refer to **Section 6.2** for potential water quality impacts to the wetland during construction and **Section 6.3** for potential impacts during operation. A dilution assessment has not been carried out for the Hunter Wetland Centre in Shortland as there is no pollution pathway to this wetland.

3.2.2 Groundwater

A broader study area was applied for the groundwater assessment and is defined by a two kilometre buffer on the construction footprint (groundwater study area) as shown on **Figure 3-1**.

The groundwater study area boundary was adopted to encapsulate surrounding registered groundwater users in the vicinity of the proposal, including the nearby Hunter Water Corporation Tomago Sandbeds borefield, to increase the amount of bore data available for analysis. While the two kilometre buffer study area was used for analysis relating to existing groundwater users, predicted impacts relating to the project are expected to be localised and limited to the immediate area of the construction footprint.

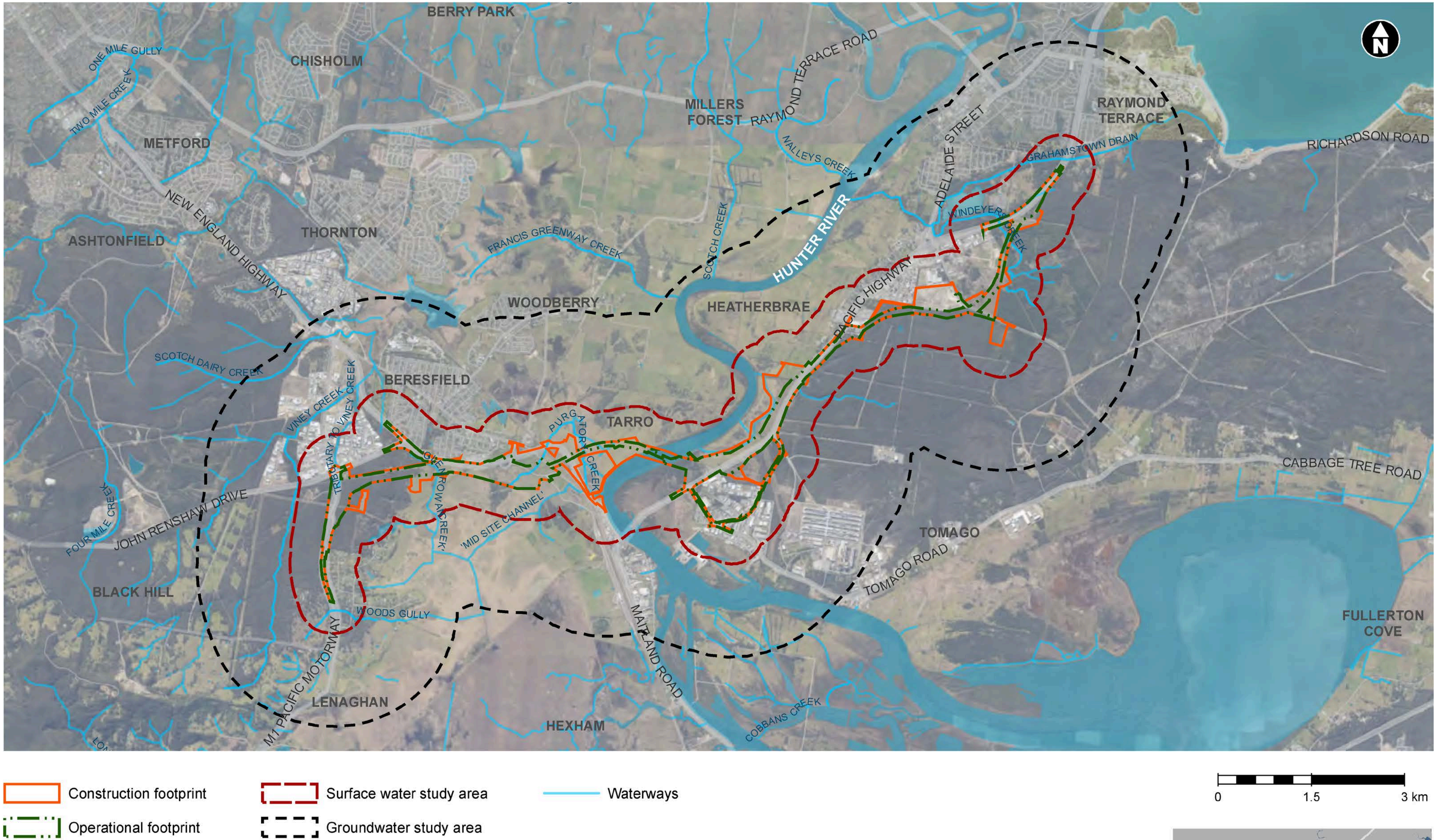

Figure 3-1 Study area - Surface water and groundwater assessment

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3.3 Surface water quality

3.3.1 Desktop assessment

The desktop assessment involved a review of the existing surface water conditions across the study area to assess the likely and potential impacts of the project on surface water quality during construction and operation. The review of information has included review of available literature, water data, background information and land use to aid in interpreting the existing conditions. Literature sources included:

- Changes in fish and crustacean assemblages in tidal creeks of Hexham Swamp following the staged opening of Ironbark Creek floodgates (DPI, 2015)
- Key Fish Habitat Maps (DPI, 2007)
- Preliminary Site Investigation – Contamination and Acid Sulfate Soil Assessment, Proposed M1 Extension to Raymond Terrace (M12RT) Black Hill to Raymond Terrace (Douglas Partners, 2015)
- Soils and Contamination Working Paper, M1 Pacific Motorway extension to Raymond Terrace (Appendix P of the EIS)
- Geotechnical Investigation Factual Report, M1 Pacific Motorway extension to Raymond Terrace, Black Hill to Raymond Terrace (Douglas Partners, 2017)
- BioNet Atlas – the Atlas of NSW Wildlife Threatened Species Profile Database (DPIE, 2020)
- Why do fish need to cross the road? Fish passage requirements for waterway crossings (Fairfull and Witheridge, 2003)
- Tomago Sandbeds Fact Sheet (Hunter Water Corporation, 2019)
- Dam and catchments – Tomago Sandbeds, Hunter Water Corporation (Hunter Water Corporation, 2020)
- Tilligerry Nature Reserve Statement of Management Intent (OEH, 2014)
- Health of the Hunter – Hunter River estuary report card 2016 (OEH, 2017)
- Kooragang Nature Reserve and Hexham Swamp Nature Reserve Plan of Management (Martindale, 1998)
- Water Quality Assessment: Upper Hunter Valley Alliance – Hexham Relief Roads (PB, 2012)
- Woodberry Swamp Hydrologic Study. Rayner et al (2016)
- Hypsometric (area-altitude) analysis of erosional topography. Strahler (1952)
- Water Quality Monitoring Plan: Upper Hunter Valley Alliance – Hexham Relief Roads. (UHVA, 2013a)
- Groundwater and receiving surface water baseline monitoring report, August 2012 to February 2013 – Hexham Relief Roads, Hexham NSW. (UHVA, 2013b) Upper Hunter Valley Alliance (2013)
- Water quality data collected by Hunter Water Corporation, Environment, Energy and Science (EES) Group (formerly the Office of Environment and Heritage (OEH)), Australian Rail Track Corporation (ARTC), and Transport.

3.3.2 Data analysis

Water quality data used in this report is sourced from a variety of stakeholders including Hunter Water Corporation, EES Group (formerly OEH), ARTC and Transport. Each organisation has its own monitoring objectives for their monitoring and as such, data is variable throughout the catchment, spatially and temporarily and also vary in the types of indicators that are monitored. Some organisations have routine monitoring programs while others only monitor water quality for specific projects.

Data used in this water quality assessment is generally from 2011 onwards (with the exception of one site) and is considered most representative of contemporary water quality. Due to the paucity in data, no minimum number of results was applied to the dataset. Therefore, there is variability in the realistic representation of water quality. A summary of the available data used for assessing achievement of WQOs for the protection of environmental values at the various sites in the surface water study area is provided in **Table 3-1**. Monitoring sites are shown on **Figure 4-6**.

Table 3-1 Summary of water quality data

Stakeholder	Monitoring site	Number of samples	Date range
Hunter Water Corporation	Hunter River at Sandgate	63	Jan 2011 – Mar 2016
	Windeyers Creek	184	Jan 2011 – Mar 2016
EES Group/ DPIE	Hunter River (various locations)	109	Aug 2014 – Mar 2015
ARTC	Mid Site Channel	16	Aug 2012 - May 2018
DPIE	Various (pre flood nutrient data)	Single sampling event at 36 sites	Mar 2018
Transport	Project specific (various locations)	7	Jun 2018 – Jul 2020

The methodology for determining water quality exceedance included:

- Collating water quality data into a spreadsheet
- Calculating summary statistics for each site including number of samples, mean, median, maximum and minimum value and the number and percentage of samples outside the guideline range (refer to **Appendix A**)
- Reporting compliance of the data pictorially, through the use of maps and colour coded symbols, for each of the different nominated WQOs (as nominated in **Section 2.3.2** and described in **Section 3.3.4**). The level of compliance has been colour coded with respect to the percentage of samples that achieved WQOs. Colours and rating for compliance are outlined in **Table 3-2**.

Table 3-2 Compliance against water quality objectives

Per cent compliance	Colour and rating
75.1% - 100%	Good
50.1% - 75%	Fair
25.1% - 50%	Poor
0 - 25%	Very poor
Insufficient data	N/A

Non-compliance of WQO is determined as soon as any single indicator fails to meet the relevant guideline.

3.3.3 Identification of sensitive receiving environments

Sensitive receiving environments (SREs) are environments that have a high conservation or community value or support ecosystems/human uses of water that are particularly sensitive to pollution or degradation of water quality. SREs within the surface water study area were identified based on the following considerations:

- Presence of Key Fish Habitat (KFH) based on NSW Fisheries KFH maps (DPI, 2007)
- Presence of threatened aquatic species listed under FM Act and EPBC Act. Likelihood of presence is based on threatened species distribution mapping (DPI, 2016) and database searches including the Protected Matters Search Tool (DAWE, 2020), BioNet Atlas records (DPIE, 2020) and Atlas of Living Australia (ALA) records (ALA, 2020)
- Aquatic habitat field assessment (in accordance with the requirements of DPI (2013))
- Waterway classification (Fairfull and Witheridge, 2003)
- Groundwater and surface water dependent vegetation and fauna communities listed under the BC Act and EPBC Act
- Proximity to a drinking water catchment
- Proximity to protected areas including Ramsar listed wetlands and National Parks
- Proximity to recreational swimming areas.

Additionally, areas mapped as ‘Coastal Wetlands’ within the vicinity of the project under the Coastal Management SEPP are also considered within this assessment to be SREs due to their environmental sensitivity.

The locations identified as SREs are identified in **Section 4.9** and are mapped on **Figure 4-6**.

3.3.4 Identification of water quality criteria

As outlined in **Section 2.3.2**, WQOs were identified for waterways within the surface water study area using the NSW Water Quality Objectives (DECCW, 2006). The relevant water quality objectives endorsed within the surface water study area are provided in **Table 3-3**. Waterways within the surface water study area and their allocated category are provided in **Table 3-4**.

Default guideline values (DGVs), which are nominated for water quality indicators that are associated with the WQOs, have been subsequently identified from relevant guidelines (ANZG, 2018) and the project’s performance for surface water quality have been assessed against these guideline values. These DGVs are the recommended values for protecting the water quality objectives irrespective of existing water quality and river flow conditions in the surface water study area.

WQOs which have been nominated for waterways within the study area and the relevant guidelines used to derive the appropriate DGVs for nominated indicators are detailed in the following sections. DGVs which are associated with indicators for nominated WQOs are provided in **Table 3-5**. Water quality indicators that fall outside these DGVs indicate that the WQO is not being protected.

Table 3-3 NSW Water quality objectives (DGVs) for waterway categories

Category	Environmental Value										
	Aquatic ecosystems	Visual amenity	Secondary contact recreation	Primary contact recreation	Livestock water supply	Irrigation water supply	Homestead water supply	Drinking water at point of supply- disinfection only	Drinking water at point of supply – clarification and disinfection	Drinking water at point of supply - groundwater	Aquatic foods (cooked)
Estuaries – being dominated by saline conditions, estuary has hydraulic and water quality characteristic, and potential problems, that are often very different from those of freshwater systems	X	X	X	X							X
Town water supply sub catchments – streams or groundwater aquifers typically feed into a town's water supply	X	X								X	
Waterways affected by urban development – waterways within urban areas that are often substantially modified and generally carry poor quality stormwater	X	X	X	X							
National Parks, Nature Reserves and State Forests – streams mainly in forested areas including national parks or state forests	X	X	X	X							

Table 3-4 Assigned category for waterways in surface water study area from DECCW mapping

Waterway	Category
Purgatory Creek	Estuaries
Hunter River	Estuaries
Windeyers Creek	Estuaries^
Hexham Swamp	National Parks, Nature Reserves and State Forest
Hunter River (at Raymond Terrace)	Waterways affected by urban development
Grahamstown Drain	Waterways affected by urban development
Tomago Sandbeds	Town water supply sub catchment / aquifers

^ whilst DECCW classify as estuarine it has been classified for this assessment as lowland river as explained **Section 4.2.8**

Protection of aquatic ecosystems

Aquatic ecosystems can range from freshwater to marine and comprise the animals, plants and micro-organisms that live in water and the physical and chemical environment in which they interact. Aquatic ecosystems have been impacted upon by multiple pressures including changes in flow regime, modification or destruction of key habitats, development and poor water quality.

For the purpose of understanding ambient water quality related to aquatic ecosystem health, the ANZG (2018) guidelines for protection of aquatic ecosystems have been applied. Water quality parameters can be divided into those that have a direct toxic effect on organisms and animals (toxicants) and those that indirectly affect ecosystems causing a problem for a specific environmental value (stressors). Toxicants which are relevant to this assessment are primarily heavy metals, while the stressors include nutrients, which consist of nitrogen (total nitrogen (TN), ammonia, oxidised nitrogen (NO_x)) and phosphorus (total phosphorus (TP) and filterable reactive phosphorus (FRP)), turbidity, total suspended solids (TSS), salinity and pH which have the potential to cause degradation of aquatic ecosystems.

Recreational water quality

For the purposes of understanding recreational suitability of a site, the DECCW (2006) guidelines for primary and secondary contact recreation have been applied. For the purposes of this assessment, the number of enterococci coliform units (a type of bacteria) has been used, as there is a direct relationship between the density of enterococci and the risk of gastrointestinal illness associated with swimming in water. The WQOs have guideline criteria for determining microbial water quality of recreational waters, whereby a high density of enterococci indicates water has been contaminated with faecal material from human and/or animal sources (e.g. wastewater overflows, domestic and native animals). The guideline values for recreational waters are provided in **Table 3-5**. It should be noted that there are recommended guidelines for toxicants, however the recommended limits are less conservative than guideline limits recommended for protection of aquatic ecosystem. Therefore, by meeting the latter guideline limits, the recreational guidelines are also being met.

Visual amenity

The aesthetic appearance of a waterbody is important for passive and active recreation. As such, the water should be free from obvious pollution including debris, oil, scum and other matter. Substances producing objectionable colour, odour, taste or turbidity and substances that produce undesirable aquatic life should not be apparent (NHMRC, 2008). The aesthetic quality of a waterway will be compromised if increases of key indicators result in fish deaths, anaerobic conditions, excessive plant growth and visible algal blooms.

Aquatic foods (cooked)

Aquaculture generally involves the production of food for human consumption, and suitable water quality is needed for maintaining viable aquaculture operations. The guidelines primarily relate to toxicant concentrations and reducing the potential for these to accumulate in the tissues of seafood that is likely to be consumed by humans.

The WQOs have been considered in the assessment of existing water quality and potential impacts as a result of the project.

Key water quality indicators and related default guideline values

Key water quality indicators and related DGVs have been nominated for each WQO using the ANZG (2018) Water Quality Guidelines. These values and indicators are provided in **Table 3-5**.

Project performance against these DGVs during project construction and operation is discussed in **Section 6.2.6** and **Section 6.3.4**.

Table 3-5 Water quality indicators and associated default guideline values for water quality objectives nominated to waterways within the surface water study area

Water Quality Objective	Indicator	Default guideline value	
		Lowland rivers	Estuaries
Aquatic ecosystems – maintaining or improving the ecological condition of waterbodies and their riparian zones over the long term	Total phosphorus	0.025 mg/L	0.030 mg/L
	Filterable reactive phosphorus	0.02 mg/L	0.005 mg/L
	Total nitrogen	0.35 mg/L	0.3 mg/L
	Ammonium	0.02 mg/L	0.015 mg/L
	Oxidised nitrogen	0.04 mg/L	0.015 mg/L
	Chlorophyll-a	0.003 mg/L	0.004 mg/L
	pH	6.5 – 8.5	7 – 8.5
	Turbidity	6 – 50 NTU	0.5 – 10 NTU
	Dissolved oxygen	85 – 110 %	80 – 110 %
	Electrical conductivity (EC)	200 – 300 µS/cm	N/A
	Chemical contaminants or toxicants^*	As per ANZG (2018): Arsenic – 0.013 mg/L Cadmium – 0.0002 mg/L, Chromium (VI) –0.001 mg/L Copper – 0.0014 mg/L Nickel – 0.011 mg/L Lead – 0.0034 mg/L Mercury – 0.00006 mg/L Zinc – 0.008 mg/L Benzo(a) pyrene – 0.0001 mg/L TPH – N/A Benzene – 0.95 mg/L, Ethylbenzene – 0.08 mg/L Toluene – 0.18 mg/L	As per ANZG (2018): Arsenic – N/A Cadmium – 0.0007 mg/L Chromium (VI) – 0.0044 mg/L Copper – 0.0013 mg/L Nickel – 0.007 mg/L Lead – 0.004 mg/L Mercury – 0.0001 mg/L Zinc – 0.015 mg/L Benzo(a) pyrene – 0.0001 mg/L TPH – N/A Benzene – 0.0005 mg/L Ethylbenzene – 0.08 mg/L Toluene – 0.18 mg/L
Visual amenity – aesthetic qualities of waters	Visual clarity and colour	Natural visual clarity should not be reduced by more than 20 %. Natural hue of water should not be changed by more than 10 points on the Munsell Scale. The natural reflectance of the water should not be changed by more than 50%.	
	Surface films and debris	Oils and petrochemicals should not be noticeable as a visible film on the water, nor should they be detectable by odour. Waters should be free from floating debris and matter.	
	Nuisance organisms	Macrophytes, phytoplankton scums, filamentous algal mats, blue-green algae, sewage fungus and leeches should not be present in unsightly amounts.	
Secondary contact recreation – maintaining or improving water quality for	Faecal coliforms, enterococci, algae and blue-green algae	Median over bathing season of <230 enterococci per 100 mL (maximum number in any one sample: 450-700 organisms/100 mL) Median over bathing season of < 1000 faecal coliforms per 100 mL, with 4 out of 5 samples < 4000/100 mL Algae – <15000 cells/mL	

Water Quality Objective	Indicator	Default guideline value	
		Lowland rivers	Estuaries
activities such as boating and wading, where there is a low probability of water being swallowed	Nuisance organisms	As per the visual amenity guidelines. Large numbers of midges and aquatic worms are undesirable.	
	Chemical contaminants	Waters containing chemicals that are either toxic or irritating to the skin or mucous membranes are unsuitable for recreation. Toxic substances should not exceed values in Table 9.3 of NHMRC (2008) Guidelines.	
	Visual clarity and colour	As per the visual amenity guidelines.	
	Surface films	As per the visual amenity guidelines.	
Primary contact recreation – maintaining or improving water quality for activities such as swimming where there is a high probability of water being swallowed	Faecal coliforms, enterococci, algae and blue-green algae	Median over bathing season of < 35 enterococci per 100 mL (maximum number in any one sample: 60 – 100 organisms/100 mL) Median over bathing season of < 150 faecal coliforms per 100 mL, with 4 out of 5 samples < 600/100 mL Algae – <15000 cells/mL.	
	Protozoans	Pathogenic free-living protozoans should be absent from bodies of fresh water.	
	Chemical contaminants	Waters containing chemicals that are either toxic or irritating to the skin or mucus membranes are unsuitable for recreation. Toxic substances should not exceed values in Table 9.2 of NHMRC (2008) guidelines.	
	Visual clarity and colour	As per the visual amenity guidelines.	
	Temperature	15°– 35°C for prolonged exposure	
Aquatic foods (cooked) – refers to protecting water quality so that it is suitable for production of aquatic foods for human consumption and aquaculture activities	Algae and blue-green algae	No guidelines is directly applicable, but toxins present in blue-green algae may accumulated in other aquatic organisms.	
	Faecal coliforms	Guideline in water for shellfish: The median faecal coliform concentration should not exceed 14 MPN/100 mL; with no more than 10 per cent of the samples exceeding 43 MPN/100 mL. Standard in edible tissue: Fish destined for human consumption should not exceed a limit of 2.3 MPN E Coli/g of flesh with a standard plate count of 100,000 organisms /g.	
	Toxicants (as applied to aquaculture activities)	Metals: Copper – less than 0.005 mg/L Mercury – less than 0.001 mg/L Zinc – less than 0.005 mg/L. Organochlorines: Chlordane – less than 0.004 mg/L (saltwater production) PCBs – less than 0.002 mg/L.	
	Physico-chemical indicators (as applied to aquaculture activities)	Suspended solids: less than 40 mg/L (freshwater); 10 mg/L (marine) Temperature: less than 2°C change over one hour.	

^ only those indicators where data is available have been reported.
* DGVs for slightly to moderately disturbed ecosystems (95% level of species protection) have been adopted, except for cases where there is a potential for bioaccumulation (i.e. mercury for freshwater and estuarine and cadmium for estuarine) in which the 99% level of species protection have been used.

3.3.5 Site investigations

To supplement existing water quality data provided by external stakeholders, site visits were carried out to monitor surface water quality at nominated project specific sites and visually assess the conditions of the waterways traversed by or in close proximity to the project. Twenty-one monitoring locations were selected with monitoring generally carried out at the project crossing or downstream of potential discharges from the project. Monitoring locations are listed in **Table 3-6** and shown in **Figure 4-6**.

Table 3-6 Project water quality monitoring sites

Site name	Waterway	Location
M12RT1	Glenrowan Creek	Within main alignment
M12RT2	Purgatory Creek	Traverses main alignment
M12RT2a	Purgatory Creek (at crossing/ancillary facility location), east of the New England Highway	Traverses main alignment
M12RT2b	Purgatory Creek (west of Woodlands Close)	Downstream of main alignment
M12RT2c	Purgatory Creek downstream	Downstream of main alignment
M12RT2d	Purgatory Creek downstream at junction with Hunter River	Downstream of main alignment
M12RT3	Hunter River at crossing	Traverses main alignment
M12RT3a	Hunter River midstream	Downstream of main alignment
M12RT3b	Hunter River downstream	Downstream of main alignment
M12RT4	Hunter River Drain (upstream of Hunter River)	Downstream of main alignment
M12RT5	Unnamed tributary of Hunter River Drain (at sediment basin outlets)	Downstream of construction footprint
M12RT6	Windeyers Creek (at the project crossing)	Traverses main alignment
M12RT6a	Windeyers Creek upstream of tributary	Upstream of main alignment
M12RT6b	Downstream of Windeyers Creek crossing and tributary of Windeyers Creek	Downstream of main alignment
M12RT7	Tributary of Windeyers Creek at Crossing	Traverses main alignment
M12RT8	Wetland next to Botanic Gardens	Downstream of construction boundary
M12RT9	Drainage canal, Old Punt Road	Downstream of construction boundary
M12RT10	Grahamstown Drain	Downstream of construction boundary
M12RT11	Inside bend of Hunter River within unnamed Coastal Wetland	Downstream of construction boundary
M12RT11a	Unnamed tributary of Hunter River, flowing through unnamed Coastal Wetland	Downstream of construction boundary
M12RT12	Viney Creek	Downstream of construction boundary

The monitoring dates for each sampling event are provided in **Table 3-7**. Dry weather is classified as less than 20 millimetres of rainfall 24 hours prior to sampling as recorded at the Newcastle University Bureau of Meteorology (BOM) rainfall gauge (#061390). Wet weather sampling is classified as 20 millimetres or more of rainfall recorded at the same gauge 24 hours prior to sampling.

Table 3-7 Monitoring dates and event type (dry/wet)

Monitoring dates	Dry or wet sampling	Rainfall (millimetres)
25-26 June 2018	Dry	0
5-6 February 2019	Dry	0
25-25 February 2020	Dry	0
7-8 May 2020	Dry	0
26-27 May 2020	Wet	33.2
24-25 June 2020	Dry	2
15-16 July 2020	Wet	29

Water quality sampling was carried out where sufficient water was present. In situ parameters including temperature, EC, salinity, oxygen reduction potential (ORP), pH and dissolved oxygen were measured using a calibrated YSI Pro Plus multi-parameters water quality meter. Turbidity was also measured in situ using a Hach turbidimeter.

Measurements were generally collected at the edge of the waterway (so as to not disturb the streambed) between 15 and 30 centimetres below the surface depending on the depth of water. Sampling depth was recorded in the field. For each parameter measured in situ, three replicate measurements were recorded about 10 metres apart. Each parameter was then recorded as the average (arithmetic mean) of the three measures. Individual replicates are also reported to provide an understanding of the variation between individual readings (refer to **Appendix A**).

Grab samples were also collected at each site and sent to the laboratory for analysis. Grab sampling occurred at the same location and depth as in situ monitoring. Grab samples were collected in pre-sterilised laboratory supplied bottles, labelled, stored on ice and sent to a National Association of Testing Authorities (NATA) accredited laboratory for analysis. The analytical suite for laboratory analysis included:

- Total suspended solids
- Turbidity
- Dissolved metals (arsenic, cadmium, chromium, copper, nickel, lead, zinc and mercury)
- Oxidised nitrogen (NO_x)
- Total Kjeldahl Nitrogen (TKN)
- Total nitrogen (TN)
- Total phosphorus (TP)
- Enterococci.

Monitoring Quality Assurance and Quality Control (QA/QC) comprised of calibration of field equipment prior to sampling and laboratory QA/QC at the NATA accredited laboratory where samples were submitted for analysis. Holding times were met for all analytes on all sampling occasions aside from one. Samples submitted for analysis of enterococci and turbidity on 8 May 2020 were not analysed by the laboratory within the required holding times.

3.3.6 Impact assessment methodology

Water quality data monitoring during dry weather (and some wet weather) was carried out to characterise background concentrations and whether the nominated WQOs, as detailed in **Section 2.3.2,** are currently being achieved based on associated DGVs for relevant indicators. This data was collected to supplement data provided by external stakeholders (as summarised in **Table 3-1**). The combined data was used to provide a quantitative and qualitative assessment of impacts from the construction phase of the project. A quantitative assessment of operational impacts to downstream receiving environment has been carried out using modelled data. This is discussed further below.

Assessment of construction impacts

The construction impact assessment involved:

- Identifying unmitigated risks to surface water and groundwater quality from various construction activities
- Identifying potential impacts to downstream waterways and SREs
- Assessing potential impacts to the nominated WQOs of aquatic ecosystems, visual amenity, primary and secondary contact recreation and aquatic foods (cooked) with consideration to the ANZG (2018) Water Quality Guidelines
- Assessment of construction related impacts and changes in water quality to the receiving environment
- A dilution assessment to estimate the concentrations of TSS from temporary sediment basins in the Hunter River and at the downstream Ramsar Wetland (refer to **Appendix D** for more detailed methodology). Flow from all other waterways within the study area are controlled by floodgates and therefore any discharges to these waterways would not reach the Hunter River
- Due to a lack of information regarding flow rates and volumes within local waterways, a dilution assessment for individual waterways could not be carried out. An estimate of the dilution required to meet WQO and ambient water quality has been carried out
- Calculation of TSS annual average loads and maximum TSS discharges from temporary sediment basins during controlled and overflow conditions and assessment against WQOs for turbidity
- Identifying water quality treatment measures to mitigate the impacts of construction in accordance with the Blue Book.

Assessment of operational impacts

The assessment of potential impacts during operation involved:

- Identifying potential unmitigated risks to surface water and groundwater quality from the operation of the project
- Identifying potential impacts to downstream waterways and SREs
- Assessment of increased pollutant loading at each of the SREs or downstream waterways by considering the increase in impervious surfaces within each of their catchments
- Modelling proposed discharges from the project. Pollutant loads of proposed discharges from stormwater runoff were modelled using the eWater Model for Urban Stormwater Improvement Conceptualisation (MUSIC model). The MUSIC model was used to determine surface water pollutant loading from project roads, with a focus on three key indicators: TSS, TP and TN. Further detail on modelling of discharges is provided in **Section 5.2.4**
- Comparing modelled pollutant loading and mean concentrations to existing water quality and nominated WQOs with consideration of ANZG (2018) Water Quality Guidelines, in the context of key areas impacted by the project as detailed in **Section 5.2.4**
- Estimating the concentrations of TSS, TN and TP from permanent water quality basins in the Hunter River and at the downstream Ramsar Wetland (refer to **Appendix D** for more detailed methodology)
- Assessment of operational impacts and changes in water quality to the receiving environment
- Identifying water quality controls to treat project runoff. An iterative process using the MUSIC model was used to identify the water quality controls needed to achieve the required water quality treatment for the project during operation. A combination of permanent water quality basins and swales were identified. Further detail on the operational water quality controls is provided in **Section 5.2**

- Identification of appropriate treatment measures to mitigate the residual impact of the operational phase.

Assessment of cumulative impacts

The assessment of cumulative surface water and groundwater quality impacts involved:

- Identifying major projects with a construction program that are likely to overlap with the project construction and/or is within the same surface water or groundwater catchment as the project (both upstream and downstream)
- Identifying common sensitive receptors with other projects, qualitatively assess likely cumulative impacts and identify management measures during the construction and operation of the project.

3.4 Groundwater quality

3.4.1 Groundwater assessment data

Key sources of data used in the assessment of existing groundwater quality in this assessment were obtained from the BOM (2020) Australian Groundwater Explorer, Hunter Water Corporation and the project's groundwater monitoring bore network. A comprehensive groundwater assessment for the project, including groundwater modelling and assessment of groundwater flow and quantity, is presented in the Hydrology and Flooding Working Paper (Appendix J of the EIS).

BOM (2020) Australian Groundwater Explorer data

Available groundwater salinity data from the BOM's (2020) Australian Groundwater Explorer was reviewed to assess existing bore water salinity. The analysis was restricted to data within the groundwater study area as shown in **Figure 3-1**.

Hunter Water Corporation

Groundwater quality data provided by Hunter Water Corporation (personal communication, 24 March 2016) was reviewed for five Hunter Water Corporation bores installed within the Tomago Sandbeds Catchment Area. While not specifically located within the project study area, the data are considered representative of the areas of Tomago Sandbeds aquifer and drinking water catchment that do fall within the study area. These bores are described below and shown on **Figure 4-42**:

- Bore SK3520 – located 500 metres outside of groundwater study area, near Tomago Road, near Grahamstown Water Treatment Plant
- Bore BL92 – unknown location
- Bore SK4930 – located about one kilometre south of the construction footprint in Heatherbrae
- Bore 40A – located about 300 to 400 metres beyond the construction footprint in Heatherbrae
- Bore SK3535 – located near Masonite Road, near groundwater study area boundary.

Three rounds of groundwater quality sampling results were available for each bore with data available for August and September 2013. Analytes included:

- pH, EC, dissolved oxygen and turbidity
- Biological oxygen demand
- Calcium, magnesium, sulfate, chloride, calcium carbonate
- Dissolved aluminium, arsenic, lead, iron and manganese

- Fluoride
- Ammonia, nitrite, nitrate, total organic nitrogen, total Kjeldahl nitrogen
- Soluble reactive phosphorus and total phosphorus.

Project groundwater monitoring bore network

The project has a groundwater monitoring bore network (refer to **Figure 3-2**) consisting of a total of 20 monitoring bores at 13 locations, comprising six single and seven paired (one deep and one shallow) installations. Paired sites are indicated by suffix A (shallow) and B (deep).

Groundwater monitoring bore details and groundwater quality sampling occurrences are summarised in **Appendix F**. Three groundwater quality monitoring rounds were completed at each project piezometer except for D-PZ-324A (two rounds), D-PZ-324B (two rounds) and D-PZ-616 (one round). Groundwater quality sampling occurred between September 2016 and July 2017.

The monitoring bores were constructed using environmental grade, machine-slotted, Class 18 Polyvinyl chloride (PVC) pipe with threaded connectors. A filter pack, comprising washed and graded sand, was placed to at least 100 millimetres above the top of the PVC screen, and a bentonite seal (using granular bentonite or bentonite grout) was placed above the filter pack to seal the screened section in the target stratum. The wells were completed at the surface with a locked cover and monument. Following completion, the bores were developed by hand bailing.

Groundwater quality data used in this assessment included:

- Field parameters (EC, pH, temperature, oxidation reduction potential and dissolved oxygen)
- Laboratory results from a broad analytical suite consisting of:
  - Major ions and cations
  - Dissolved heavy metals
  - Total dissolved solids (TDS)
  - Nutrients
  - Fluoride
  - Faecal coliforms.

The complete set of laboratory analytes are shown in **Appendix G**.

Construction footprint

Hunter Alluvium and Tomago Coal Measures paired bore location

Hunter Alluvium

Tomago Coal Measures

Tomago Sandbeds

Waterways

0 1 2 km

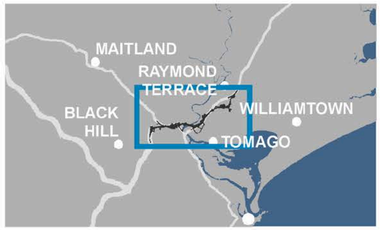

Figure 3-2 Project groundwater monitoring bore network

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3.4.2 Identification of water quality criteria

Criteria for groundwater quality that have been adopted for the project include:

- The NSW AIP (2012) beneficial use categories for in situ groundwater
- The ADWG for groundwater specifically within the Tomago Sandbeds Catchment Area
- Corresponding surface water quality criteria where ground water is to be extracted and discharged.

The criteria are adopted on the basis of groundwater source and are provided in **Table 3-8**, while **Table 3-5** lists the associated water quality indicators and default guideline values.

The NWQM recognises the following beneficial uses, or environmental values:

- Aquatic ecosystems
- Primary industries (irrigation and general water uses, stock drinking water, aquaculture and human consumption of aquatic foods)
- Recreation and aesthetics
- Drinking water
- Industrial water
- Cultural and spiritual values.

No water quality guidelines are provided for the beneficial uses of industrial water or cultural and spiritual values.

Table 3-8 Groundwater sources in groundwater study area and adopted category

Groundwater source	In situ category	Discharge category^
Hunter Alluvium (Hunter floodplain)	Beneficial use criteria – industrial water	Estuarine
Tomago Coal Measures	Beneficial use criteria – industrial water	Lowland River
Tomago Sandbeds	Beneficial use criteria – aquatic ecosystems / drinking water	Lowland River

^ for discharge categories classified as estuarine, the DGVs for toxicants in marine water apply. For discharge categories classified as lowland river the DGVs for toxicants in freshwater water apply.

3.4.3 Impact assessment methodology

Existing baseline groundwater conditions informed by project groundwater and surface water monitoring, regional water quality data and potential groundwater level and flow impacts associated with the project (as detailed in the Hydrology and Flooding Working Paper (Appendix J of the EIS)) have been considered in carrying out the qualitative assessment of potential groundwater quality impacts.

Assessment of construction impacts

The assessment of potential impacts to groundwater quality during construction involved:

- Identifying construction activities with potential to impact on groundwater quality
- Identifying potential risks to groundwater quality from construction activities
- Identifying potential impacts to downstream users and SREs
- Assessment of potential impacts to groundwater quality within the Tomago Sandbeds Catchment Area
- Assessment of potential impacts to the relevant beneficial use of groundwater with consideration of the NSW AIP minimal impact considerations

- Identification of water quality treatment measures or other mitigating measures to manage the potential impacts.

Assessment of operational impacts

The assessment of potential impacts to groundwater quality during project operation involved:

- Identifying operational activities with potential to impact on groundwater quality
- Identifying potential risks to groundwater quality from operational activities
- Identifying potential impacts to downstream users and SREs
- Assessment of potential impacts to groundwater quality within the Tomago Sandbeds Catchment Area
- Assessment of potential impacts to the relevant beneficial use of groundwater with consideration to the NSW Aquifer interference policy minimal impact considerations
- Identification of water quality treatment measures or other mitigating measures to manage the potential impacts.

Assessment of cumulative impacts

Potential groundwater quality impacts arising from the project are expected to be localised to the area of predicted drawdown, mounding, spillage or existing contamination. As such, compounding or cumulative water quality impacts with other proposed projects or developments are not anticipated.

4. Existing environment

4.1 Catchment overview

The project is located in the lower portion of the Hunter River catchment in NSW. The Hunter River catchment is east of the Great Dividing Range, bound by the Manning and Karuah catchments to the north, and by the Lake Macquarie and Hawkesbury-Nepean catchments in the south. The catchment drains a total area of about 22,000 square kilometres. The headwaters of the Hunter River are located in the Liverpool Ranges, which flows generally in a south-easterly direction for about 450 kilometres, before reaching the Tasman Sea at Newcastle. Elevations across the catchment vary from over 1,500 metres above sea level in the mountain ranges, to less than 50 metres above sea level on the floodplains of the lower valley. Four major rivers discharge into the Hunter River along its length – these are Pages River, Goulburn River, Williams River and Paterson River. The lower reaches of the Hunter River form an open, wave-dominated barrier estuary which extends about 64 kilometres inland to its tidal limits at Oakhampton (OEH, 2017). The estuary has two main channel arms (north and south) that diverge about 17 kilometres inland and reconverge before flowing to the mouth. The estuary supports a substantial fishery, particularly for School Prawn (*Metapenaeus macleayi*) and Eastern King Prawn (*Melicertus plebejus*). Commercial fishing occurs from the ocean to Raymond Terrace (about 30 kilometres from the ocean) where School Prawn and Eastern King Prawn (as well as several other species of prawn and squid species which are permitted as ‘by-product’ species in the estuary) are harvested (DPI, 2017).

The Hunter River catchment spans over seven LGAs. The upper catchment is predominantly an agricultural landscape on floodplains dispersed with smaller urban centres. The area surrounding the lower estuary is heavily urbanised with significant industrial, commercial and residential development and a major harbour port near the mouth of the estuary. The water quality of the Hunter River and other waterways within the study area have been substantially affected by industrial development, coal mining (via coal dust particles, coal tar and atmospheric deposition), and agriculture (Swanson, et al, 2017). Land clearing has resulted in erosion and salinity issues within the Hunter River, and the estuary and surrounding wetland systems of the lower Hunter River have also become degraded due to these activities, as well as from surrounding agricultural practices in the upper catchment and the installation of dykes and floodgates that have removed connectivity between wetlands and the main estuary channels (Taylor, et al, 2019).

The project construction and operational footprints intercept waterways within the suburbs of Black Hill, Beresfield, Tarro, Tomago, Heatherbrae and Raymond Terrace. Key waterways, drainage lines and tributaries with the potential to be impacted by the project are described in **Section 4.2** and shown in **Figure 4-4**.

4.1.1 Land use

The project is located within two LGAs; the City of Newcastle LGA in the south east, and Port Stephens Council LGA in the north east. The project construction and operational footprints are in proximity to several urban centres, industrial areas, land utilised for agricultural purposes and water supply areas including the Tomago Sandbeds Catchment Area.

Residential areas within proximity of the project include Black Hill, Tarro, Heatherbrae and Raymond Terrace. Tomago, which is located on the eastern side of the Hunter River, is heavily industrialised with an Aluminium Smelter (Tomago Aluminium) and Forgacs shipyard located within 1.5 kilometres of the eastern bank of the Hunter River Estuary.

The Grahamstown Water Treatment Plant is located about five kilometres east of Tomago and the Hunter River Estuary, on the north-western bank of Fullerton Cove. North east of Tomago, in the northern portion of the suburb of Heatherbrae, the Raymond Terrace Wastewater Treatment Works discharges treated effluent to Grahamstown Drain which subsequently flows to the Hunter River via Windeyers Creek (Hunter Water Corporation, 2020).

A motorway, several highways and roads are also within proximity of the project, including the M1 Pacific Motorway at Black Hill, New England Highway near Tarro, Maitland Road, the Pacific Highway (including Hexham Bridge across the Hunter River), and Tomago Road (refer to **Figure 4-1**).

4.1.2 Topography

The main alignment traverses the lower Hunter River catchment area, which is generally characterised as a low-lying, gently undulating floodplain environment. A review of local topographic mapping (refer to **Figure 4-2**) indicates that the elevation and topography across the study area vary along the main alignment with three distinct areas as follows:

- Western portion: comprising gently sloping ground between reduced level (RL) four metres Australian Height Datum (AHD) and RL 30 metres AHD (with a ridgeline oriented north to south)
- Central portion: comprising low lying, gently undulating floodplains at below RL three metres AHD
- Eastern portion: comprising mildly undulating terrain between RL two metres AHD and 10 metres AHD, with a localised area (possibly fill) next to Masonite Road (western side) of about RL 12 metres AHD.

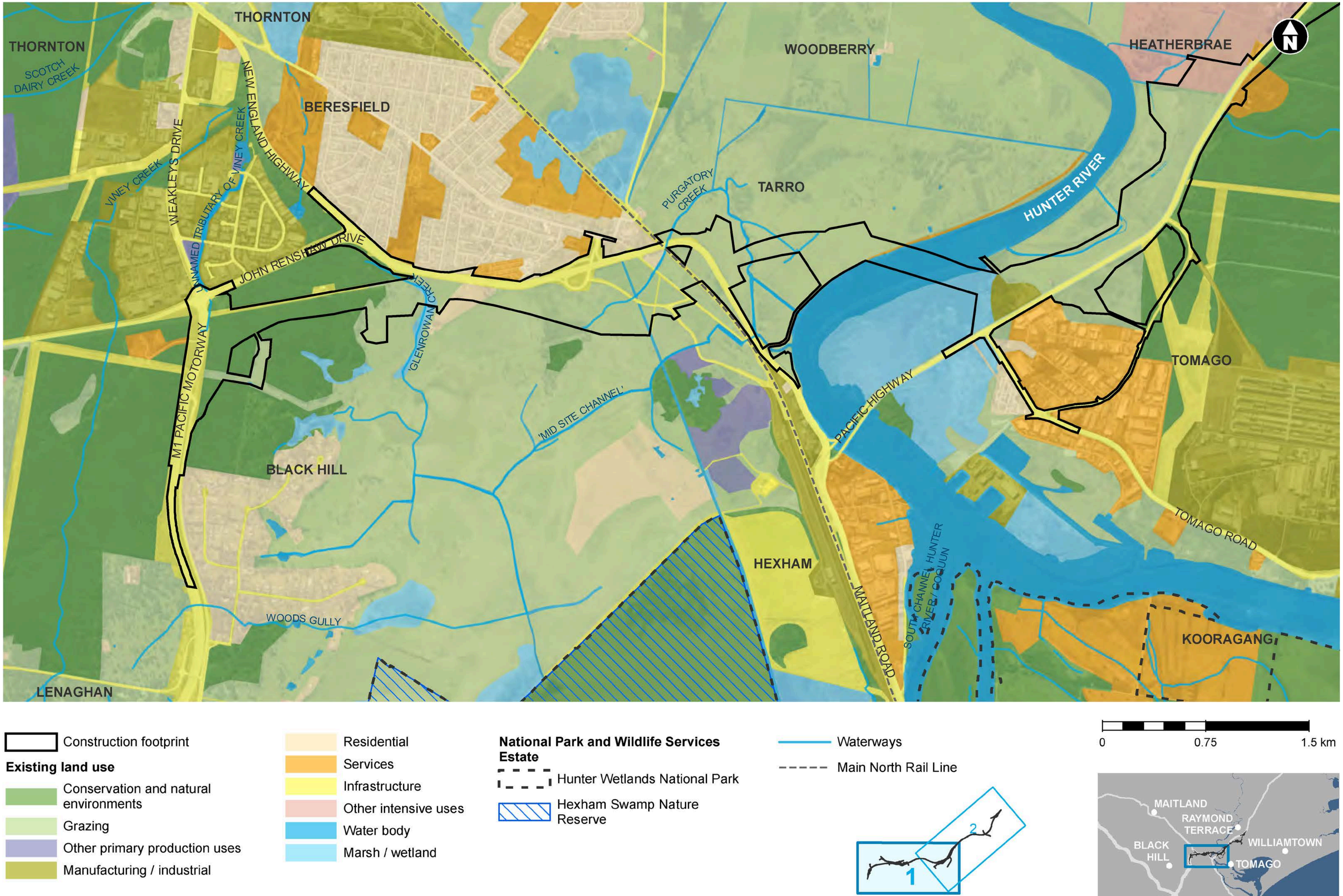

Figure 4-1 Surrounding land use and infrastructure (map 1 of 2)

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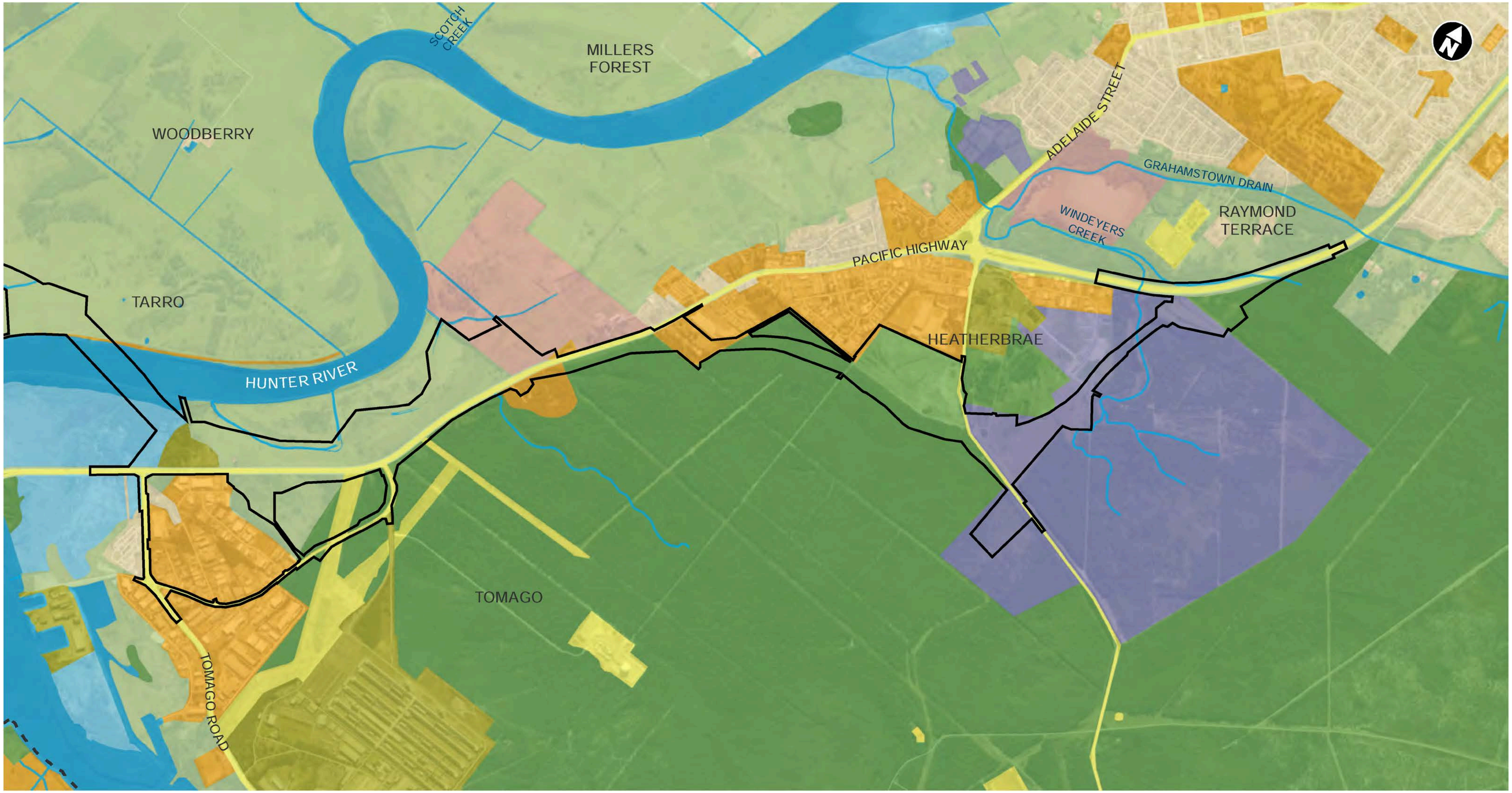

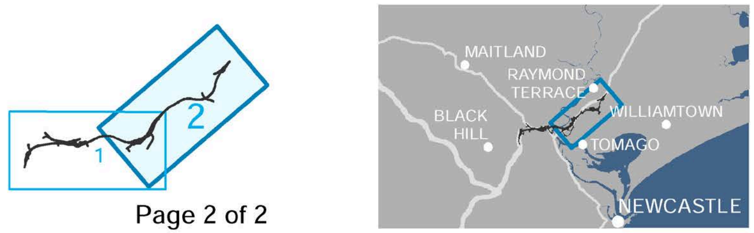

Figure 4-1 Surrounding land use and infrastructure (map 2 of 2)

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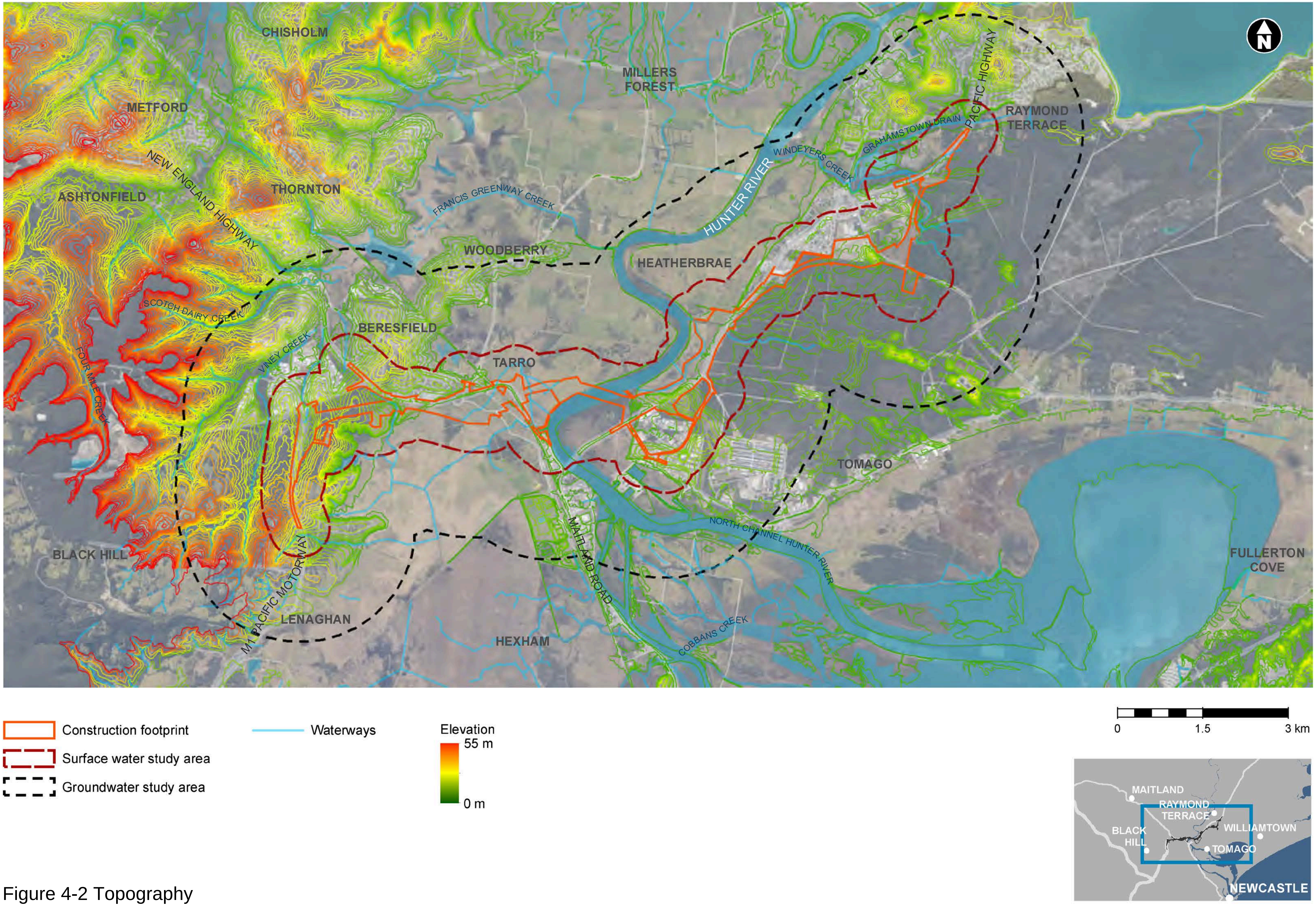

Figure 4-2 Topography

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4.1.3 Climate

The climate of the Lower Hunter River catchment is classified as warm and temperate, generally experiencing mild to hot summers and cool to mild winters. Average maximum temperature approaches 30 degrees in January and average maximum July temperatures are about 18 degrees (BOM, 2020a).

Average annual rainfall is about 1100 millimetres each year. Between 2001 and 2019, the Lower Hunter received the highest average rainfall between February and April and lowest in August, however there also tended to be significant rainfall in June (refer to **Figure 4-3**) (BOM, 2020b).

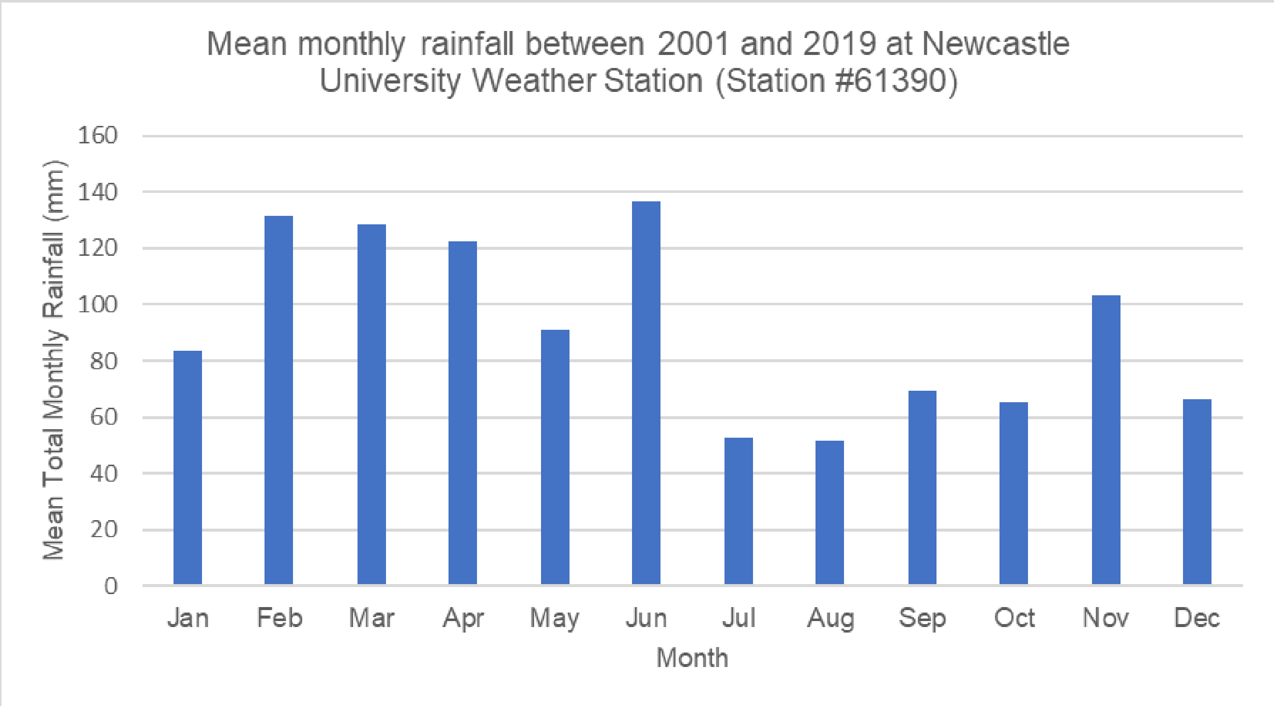

Figure 4-3 Mean total monthly rainfall between January 2001 and December 2019, as recorded by Newcastle University Weather Station (Station #61390) (BOM, 2020b)

4.1.4 Hunter Valley Flood Mitigation Scheme

Following the 1955 flood event, which claimed 14 lives, the Hunter Valley Flood Mitigation Scheme was established by the NSW Government, which has subsequently instigated 160 kilometres of levees, 3.8 kilometres of spillways, 40 kilometres of control banks, 245 floodgates and 120 kilometres of drainage canals (BMT WBM, 2012). The scheme provides flood protection to people, property and infrastructure across the Hunter floodplain. The scheme is still in operation, managed by DPIE, and is subject to periodic maintenance and reviews. The floodgates in the vicinity of the project are shown on **Figure 4-4.**

Importantly, all waterways within the surface water study area which are directly connected to the Hunter River have floodgates installed at the downstream extent (within 200 metres of the confluence with the Hunter River). This has significantly altered tidal processes including tidal flushing, movement of salt water and freshwater between the Hunter River and its tributaries, and potential migration of aquatic species, particularly benthic species, to upstream reaches of waterways. For the purpose of this assessment it is assumed that flow from upstream tributaries would be obstructed by the floodgates which would serve to retain sediment (and associated contaminants).

4.2 Waterways and wetlands

Key waterways, wetlands and drains within the surface water study area are shown on **Figure 2-2**, **Figure 4-4** and **Figure 4-5** and have been described in sections below according to:

- The Strahler stream classification system where waterways are given an order according to the number of additional tributaries associated with each waterway (Strahler, 1952)
- Other key characteristics including natural stream type and relevant features within, or in proximity to the waterway, wetland or drainage feature. A detailed description of stream geomorphology is provided in the Hydrology and Flooding Working Paper (Appendix J of the EIS).

As described in **Section 3.3.5**, water quality monitoring has been carried out along these key waterways and within important wetlands, as well as additional tributaries and drainage lines intercepted by the project or within the surface water study area. Project water quality monitoring sites and selected MUSIC modelled discharge locations (referred to as 'R' sites), as well as Hunter Water Corporation, EES Group and ARTC monitoring sites, are shown on **Figure 4-6**.

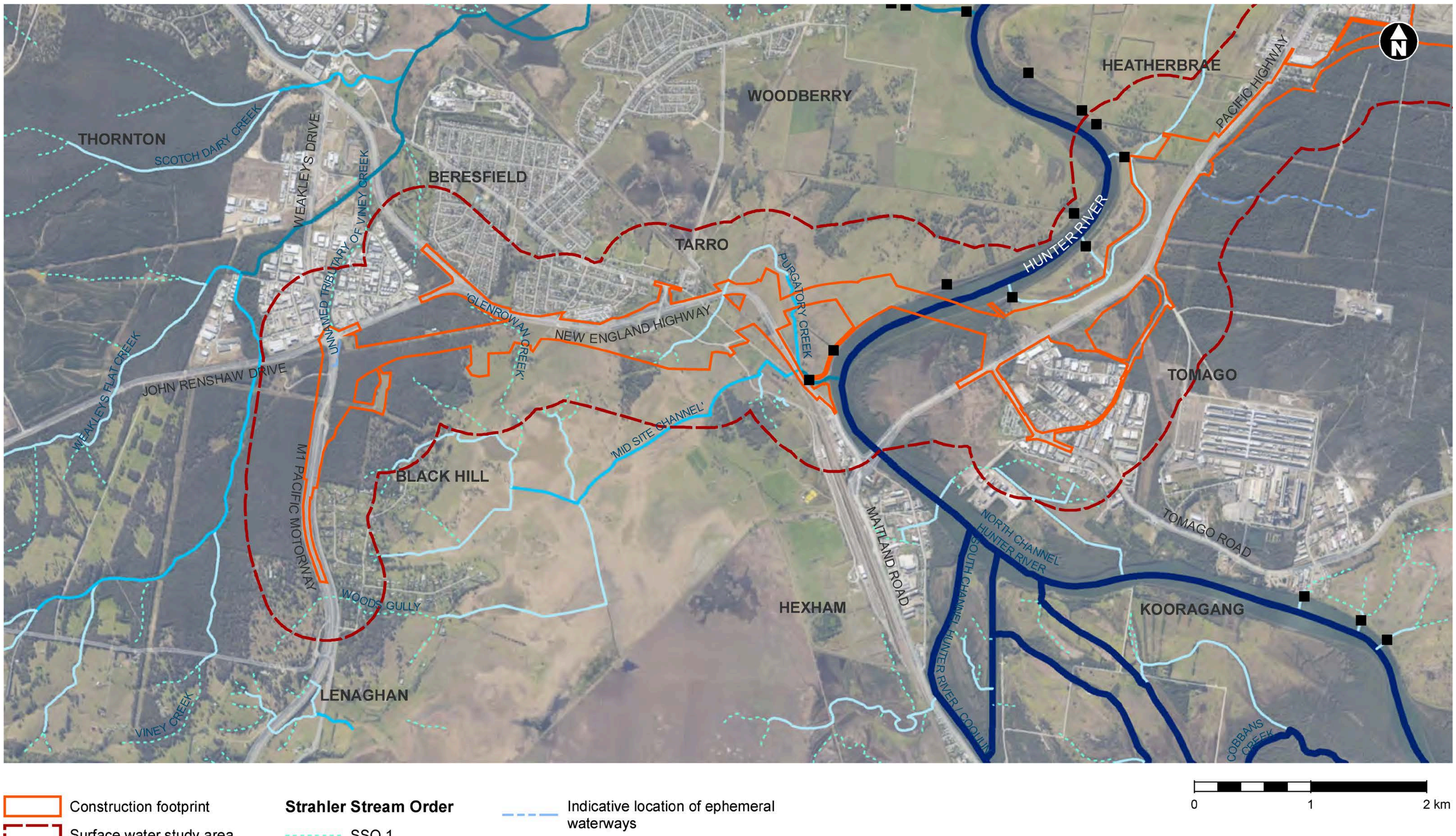

Figure 4-4 Key waterways and drainage features (map 1 of 2)

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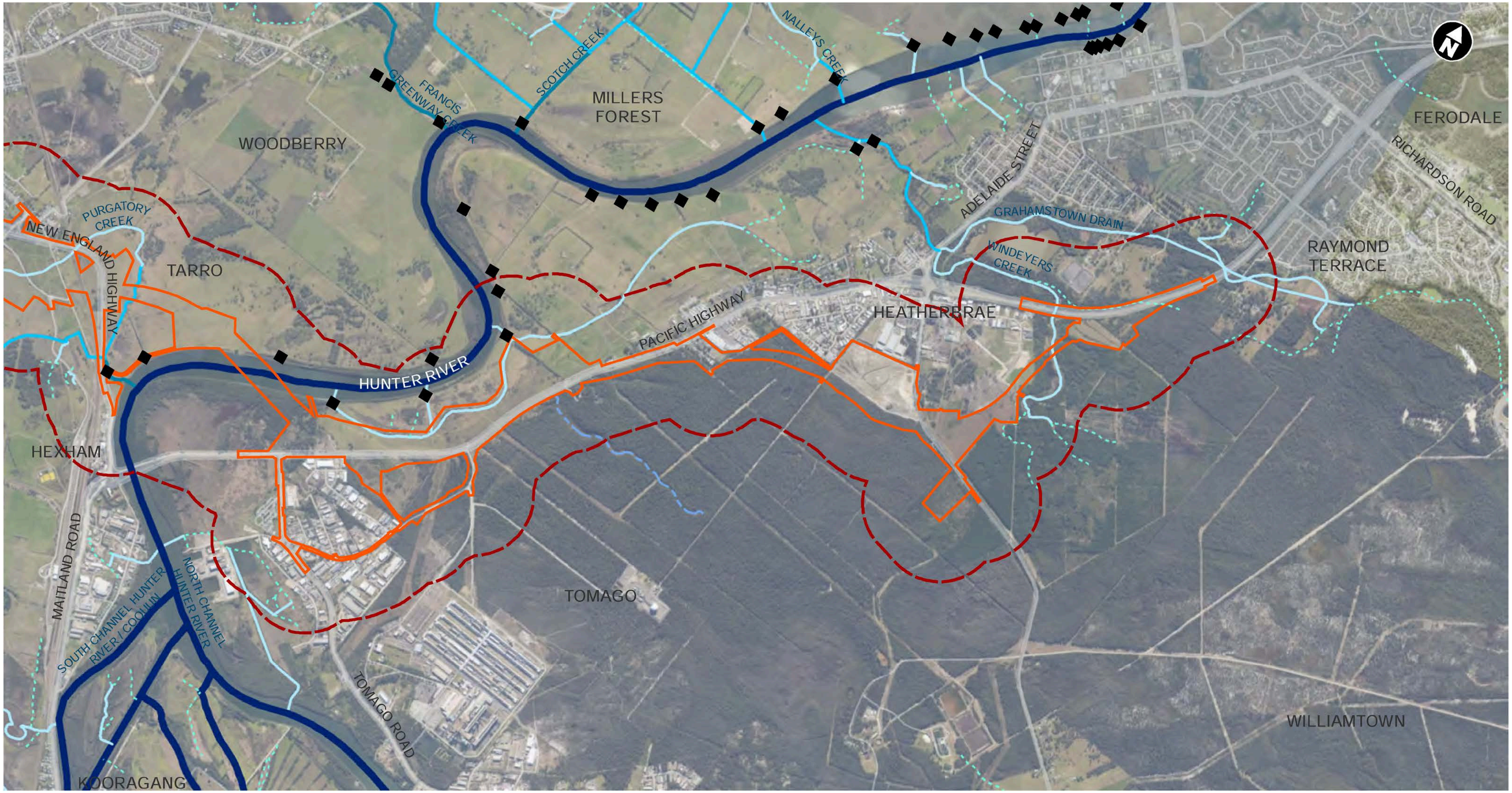

Construction footprint

Surface water study area

Strahler Stream Order

SSO 1

SSO 2

SSO 3

SSO 4

SSO 9

Indicative location of ephemeral waterways

Floodgates

0 1 2 km

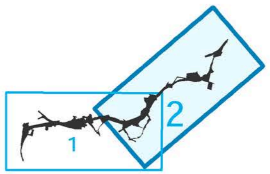

Figure 4 4 Key waterways and drainage features (map 2 of 2)

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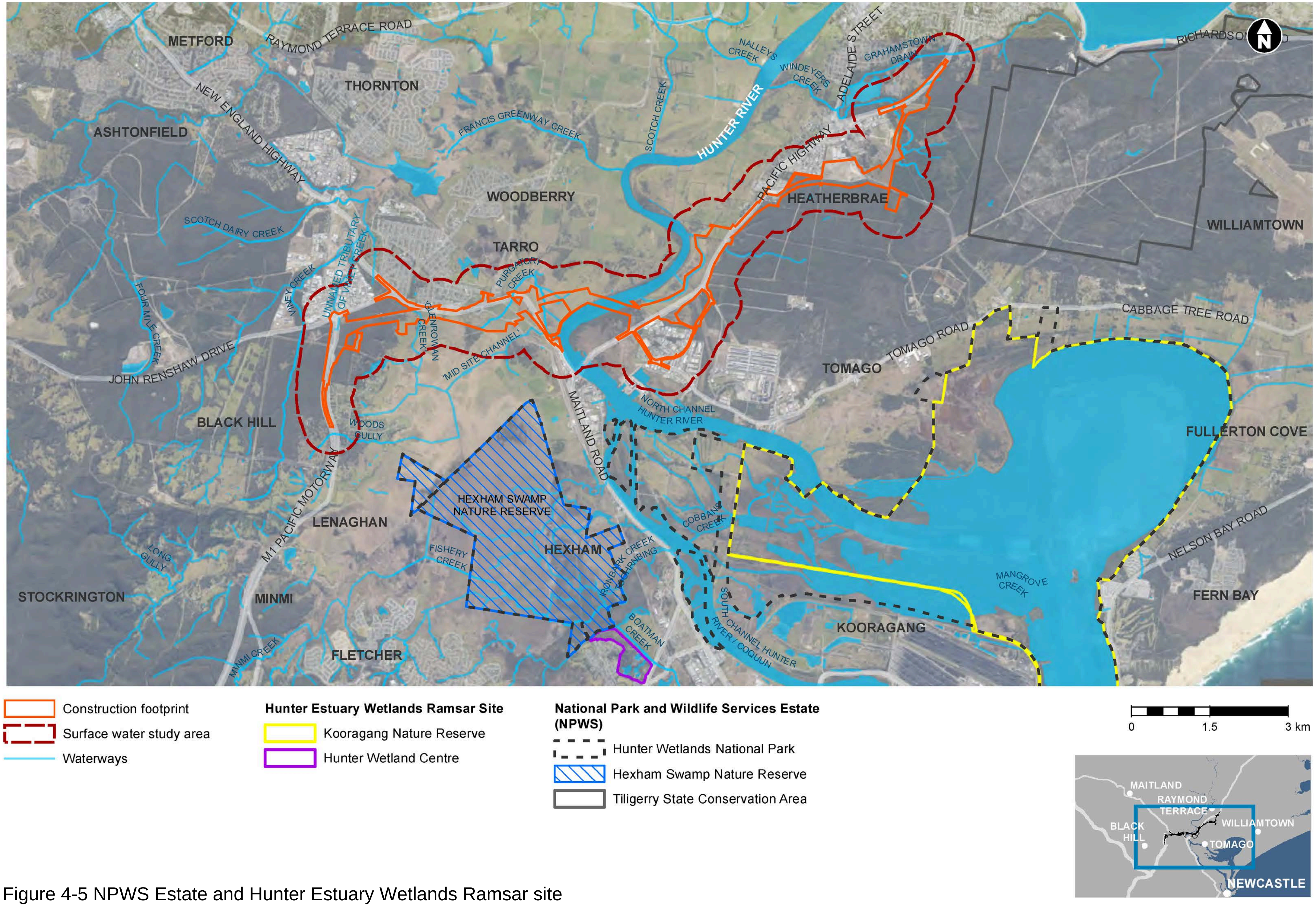

Figure 4-5 NPWS Estate and Hunter Estuary Wetlands Ramsar site

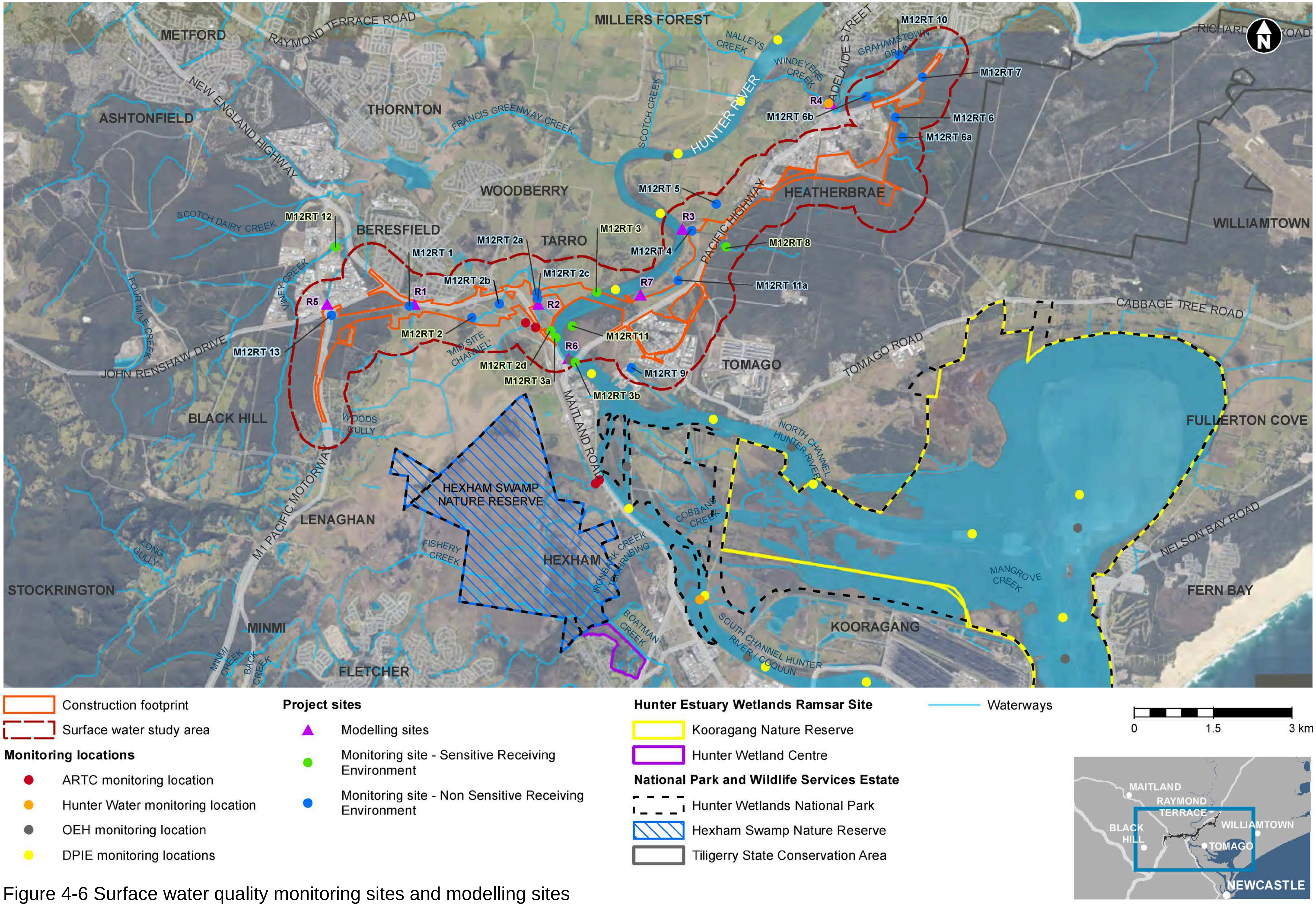

Figure 4-6 Surface water quality monitoring sites and modelling sites

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4.2.1 Viney Creek and Woodberry Swamp Coastal Wetland

Viney Creek is an ephemeral, fourth order stream that flows in a north-easterly direction into Woodberry Swamp. Woodberry Swamp is listed as a Coastal Wetland under the Coastal Management SEPP and is located between Maitland and Hexham. Viney Creek drains a catchment area of 670 hectares with about one fifth of the catchment fully developed (Rayner, et al, 2016). Viney Creek flows through an industrial estate and has several weirs, culverts and bridge structures present along the length of the channel which disrupt flow to Woodberry Swamp (refer to **Photo 4-1** and **Photo 4-2**). There is dense riparian and negligible submergent zone vegetation in the upper reaches of Viney Creek which becomes sparse when the creek flows through the industrial estate.

Photo 4-1 Viney Creek at monitoring site M12RT12 (looking upstream)

Photo 4-2 Viney Creek at monitoring site M12RT12 (looking downstream)

An unmapped and unnamed artificial tributary of Viney Creek within the construction footprint is proposed to be adjusted to accommodate the project. This tributary meets Viney Creek about 1.5 kilometres to the north of the project and drainage from the south western end of the project could discharge into Viney Creek.

Viney Creek has been monitored at one site (M12RT12), downstream of where the unnamed tributary meets Viney Creek. Available water quality data for Viney Creek is discussed in **Section 4.6.1**.

4.2.2 Glenrowan Creek

An unnamed tributary (of Mid Site Channel) is located south of the New England Highway at Tarro. While this creek is not formally named, for ease of identification, this creek will be referred to as Glenrowan Creek for the purposes of this assessment only.

Glenrowan Creek is an ephemeral, first order stream that first flows in an easterly direction for about 500 metres through an undeveloped roadside area (with some sparse vegetation) south of the New England Highway then flows south through cleared farm land near Black Hill (refer to **Photo 4-3** and **Photo 4-4**). The creek during dry weather drains to Mid Site Channel, however during a flood event, there are connections under the rail embankment which allows some hydrological connectivity between the northern and southern floodplains (refer to **Section 4.2.4** for further detail).

Glenrowan Creek drains a predominantly agricultural catchment with modified instream vegetation but also receives runoff from New England Highway and urban runoff from Tarro. Poor water quality recorded during monitoring in the creek is likely to originate from these catchment runoff sources.

Photo 4-3 Glenrowan Creek at monitoring site M12RT1 (looking upstream)

Photo 4-4 Glenrowan Creek at monitoring site M12RT1 (looking downstream)

Twin bridges (B05) are proposed to be built across Glenrowan Creek and the ephemeral waterway would receive runoff from the operation of the project.

Glenrowan Creek has been monitored at one site (M12RT1). Available water quality data for the creek is discussed in **Section 4.6.2**.

4.2.3 Purgatory Creek and unnamed Coastal Wetland

Purgatory Creek is a second order stream that first flows in a north easterly direction under the existing New England Highway, then flows south-east through predominantly cleared farmland to the Hunter River on the eastern side of the New England Highway. Purgatory Creek is ephemeral in its upper reaches, then becomes perennial about 1.5 kilometres upstream of its confluence with Hunter River. About 450 metres upstream of the confluence with Hunter River, a second artificial drainage channel has been dredged to connect another drainage channel (Mid Site Channel) to Purgatory Creek and the Hunter River. Floodgates have been installed on the main Purgatory Creek channel (northern channel) about 30 metres upstream of the confluence with the Hunter River and on the artificial channel about 200 metres from the confluence with the Hunter River (refer to **Figure 4-4** for floodgate locations). Below these floodgates, Purgatory Creek and the Purgatory Creek drainage channel are tidally influenced.

The ephemeral headwaters of Purgatory Creek fall within an area that is listed as 'Coastal Wetland' under the Coastal Management SEPP. The creek drains a low-lying floodplain environment which has been substantially modified to accommodate agricultural land and linear infrastructure (water mains, overhead transmission lines and associated access roads) and control flooding. Upslope of the substantial culverts of the Main North Rail Line and the New England Highway, the waterway has been affected by urban infilling within a registered contaminated site. In places, the creek has been artificially deepened and stabilised with rocks to aid in drainage of the surrounding land, the majority of native riparian vegetation has been removed from the banks and there is negligible submergent zone vegetation (refer to **Photo 4-5** and **Photo 4-6**). The deepening of the channel base for flood conveyance purposes is likely to have resulted in an increased contribution from groundwater which typically has a very high water table beneath the floodplain with saline water quality. Given the limited tidal flow, shallow groundwater is likely to constitute a notable portion of the water in the channel and therefore influence the water quality. Water quality in the creek is also expected to be influenced by surface flows from catchment runoff and by the presence of the floodgates which disrupt flow and prevent tidal flushing. The major sources of pollutants are runoff from the surrounding agricultural land and the New England Highway.

Photo 4-5 Purgatory Creek at monitoring site M12RT2a (looking upstream)

Photo 4-6 Purgatory Creek at monitoring site M12RT2a (looking downstream)

Purgatory Creek is anticipated to receive drainage from the project, and is intercepted by the project at two locations on the western side of the Hunter River. A section of Purgatory Creek upstream is also proposed to be adjusted to accommodate the project. Purgatory Creek has been monitored for the project by Transport at the following locations:

- M12RT2 Purgatory Creek
- M12RT2a Purgatory Creek (at crossing/ancillary facility location), east of the New England Highway
- M12RT2b Purgatory Creek (west of Woodlands Close)
- M12RT2c Purgatory Creek downstream
- M12RT2d Purgatory Creek downstream at junction with Hunter River.

Available water quality data for monitoring sites on Purgatory Creek are discussed in **Section 4.6.3**.

4.2.4 Hexham Swamp Nature Reserve

Hexham Swamp Nature Reserve forms part of the floodplain environment on the southern side of the Hunter River and is part of the Hunter Wetlands National Park. The Hexham Swamp Nature Reserve, and the surrounding wetland area that adjoins the Hexham Swamp Nature Reserve, is classified as Coastal Wetland under the Coastal Management SEPP (refer to **Figure 2-2** and **Figure 4-5**). Hexham Swamp Nature Reserve and the adjoining Coastal Wetland area make up the largest freshwater wetland on the north coast of NSW (Martindale, 1998). The Hexham Swamp Nature Reserve covers an area of about 900 hectares (Martindale, 1998). Hunter Wetlands Centre, which is part of the Hunter Estuary Wetlands Ramsar site, is located to the south of Hexham Swamp Nature Reserve.

The boundary of the Hexham Swamp Nature Reserve is located about two kilometres south of the project. The wetland receives water from tributaries and drainage channels situated to the south-west of the Hunter River and is maintained by rainfall, although flow is minimal. Hexham Swamp Nature Reserve drains to the South Channel of Hunter River via Ironbark Creek which flows north under Maitland Road.

Under normal conditions (when the floodplain is not submerged due to a flood event), surface flow from the construction footprint would not reach the Hexham Swamp Nature Reserve because a disused rail embankment separates the northern floodplain from the southern floodplain and forms the northern boundary of the Hexham Swamp Nature Reserve. However, there are connections under the rail embankment which allows some hydrological connectivity between the northern and southern floodplains, during flood events. The rail embankment is also over topped in the 2% annual exceedance probability

(AEP) flood event and flood modelling shows that the culverts flow back and forth in the 20% AEP event (refer to the Hydrology and Flooding Working Paper (Appendix J of the EIS) for further details).

Notwithstanding, the project construction footprint is located a significant distance from the Hexham Swamp Nature Reserve (about two kilometres) and any water quality impacts associated with the project would be negligible due to flooding from the greater catchment which would provide substantial dilution to any runoff from the project. Therefore, any observable changes to water quality in Hexham Swamp Nature Reserve, during and following a flood event would be representative of the broader catchment pollutant loads and not directly attributable to the project.

Water quality data has not been collected from Hexham Swamp Nature Reserve for the project, however water quality data collected from Hexham Swamp Nature Reserve by PB (2012) is discussed in **Section 4.6.4**. Further, as discussed in **Section 4.2.2**, Glenrowan Creek, which flows toward Hexham Swamp Nature Reserve in high rainfall and is situated in the cleared area south of the construction footprint, has been monitored at monitoring site M12RT1.

4.2.5 Mid Site Channel

Mid Site Channel is an ephemeral, third order, artificial drainage channel located in proximity to the southern portion of the project between Hexham, Tarro and Black Hill. The channel flows in an easterly direction through culverts under the Main North Rail Line and New England Highway, and is governed by floodgates. It discharges to the Hunter River (about 220 metres south of Purgatory Creek) on the eastern side of the existing New England Highway. The majority of native riparian vegetation has been removed from the banks and submergent zone and the creek flows through predominantly cleared farmland. The channel mainly receives water from agricultural pastures near the nearby OAK factory (which holds an existing environmental protection licence), however also drains residential areas in Black Hill to the west. Poor water quality in the waterway is likely to be due to catchment runoff, with the major sources being runoff from the surrounding agricultural land and the New England Highway.

Water quality data has not been collected for Mid Site Channel for the project, however Mid Site Channel was monitored between 2012 and 2018 by ARTC at two locations (refer to **Figure 4-6**). Water quality data for Mid Site Channel is discussed in **Section 4.6.5.**

4.2.6 Hunter River and floodplain

The Hunter River, the ultimate receiving environment for the project, is a ninth order major waterway which forms a tidally influenced estuarine system in its lower reaches (up to 64 kilometres from the mouth of the estuary). On western floodplain where the project is expected to cross the Hunter River Estuary, almost all native bushland and riparian vegetation has been cleared for agricultural grazing land and road infrastructure, however the northern portion of the western riverbank is classified as Coastal Wetland under the Coastal Management SEPP (refer to **Figure 2-2**). The eastern floodplain is extensively vegetated by mangrove forests (refer to **Photo 4-7** and **Photo 4-8**) and is classified as Coastal Wetland under the Coastal Management SEPP (refer to **Figure 2-2**). Other areas which are classified as Coastal Wetlands under the Coastal Management SEPP and fall within the surface water study area are located on the eastern floodplain of the Hunter River near Tomago. One Coastal Wetland is located south east of the construction footprint on the southern side of Masonite Road and the other is located further east on the floodplain north of the North Channel Hunter River (refer to **Figure 2-2**).

The catchment area which drains to the Hunter River Estuary is heavily urbanised with industrial, commercial, agricultural and residential development. Within vicinity of the project, runoff from the surrounding urban centres, major roads including the Maitland Road and the existing Pacific Highway (which crosses Hunter River at Hexham Bridge), and treated wastewater from industry are discharged into Hunter River. The riparian zone of the western bank has been modified as part of levee bank construction for the Hunter Valley Flood Mitigation Scheme which more recently have been rock armoured to prevent scour.

Photo 4-7 Hunter River at monitoring site M12RT3a (looking upstream)

Photo 4-8 Hunter River at monitoring site M12RT3b (looking upstream)

Hunter River and two unnamed drainage lines have been monitored at the following locations:

- M12RT3 Hunter River
- M12RT3a Hunter River midstream
- M12RT3b Hunter River downstream
- M12RT4 Hunter River Drain (upstream at stud farm)
- M12RT5 Hunter River tributary (stud farm).

Additionally, water quality data has been collected by EES Group at 11 sites upstream and downstream of the proposed Hunter River crossing (refer to **Figure 4-6**). Available water quality data for monitoring sites on Hunter River and associated tributaries are discussed in **Section 4.6.6**.

4.2.7 Unnamed Coastal Wetland (east of the Hunter River)

On the eastern side of Hunter River, an unnamed wetland listed as a Coastal Wetland under the Coastal Management SEPP drains a largely greenfield catchment with major sources of runoff from agricultural land, the industrial area of Tomago and Hunter Region Botanic Gardens. Mangrove and wetland vegetation are abundant in this wetland, particularly in the northern area close to the Hunter River (refer to **Photo 4-9** and **Photo 4-10**), and the waterbody is immersed in a dense bed of macrophytes, although the north-eastern area is largely devoid of vegetation and consists of agricultural grassland.

A second order creek (or old oxbow watercourse from the nearby river) is located outside the wetland boundary (about 200 metres) but flows west through the north-eastern portion of the wetland to Hunter River (refer to **Photo 4-11** and **Photo 4-12**). The creek has been regulated by floodgates to control flooding (refer to **Figure 4-4** for floodgate locations).

Photo 4-9 Coastal Wetland (east of the Hunter River) at discontinued monitoring site M12RT11 (looking upstream)

Photo 4-10 Coastal Wetland (east of the Hunter River) at discontinued monitoring site M12RT11 (looking downstream)

Photo 4-11 Unnamed tributary which flows to the Coastal Wetland (east of the Hunter River) at monitoring site M12RT11a (looking upstream)

Photo 4-12 Unnamed tributary which flows to the Coastal Wetland (east of the Hunter River) at monitoring site M12RT11a (looking downstream)

Monitoring for the coastal wetland was initially carried out at monitoring site M12RT11, however due to access constraints and lack of water following the first monitoring event, monitoring at this site was discontinued and moved to a different site about two kilometres north-east on the second order tributary of Hunter River (M12RT11a). Available water quality data for the monitoring site M12RT11a is discussed in **Section 4.6.7**.

4.2.8 Windeyers Creek

Windeyers Creek is a second order stream situated between the urban area of Raymond Terrace and the northern extent of Heatherbrae. The creek's upper catchment is an area used for forestry purposes and flows north through a vegetated wetland area, crosses under the existing Pacific Highway and then flows west toward the Hunter River (refer to **Photo 4-13** and **Photo 4-14**). Tributaries to Windeyers Creek include the Grahamstown Drain, the Raymond Terrace Wastewater Treatment Works (WWTW) ponds and an unnamed first order tributary upstream. Windeyers Creek is considered to be an ephemeral waterway in its upper reaches. It generally holds water for the majority of the time in a series of disconnected ponds due the presence of several artificial barriers (culverts and weirs) along the length of the waterway. The downstream reach of Windeyers Creek is tidal (subject to an auto-tidal floodgate) at the confluence with the Hunter River at Raymond Terrace (refer to **Figure 4-4**). This floodgate is opened during low to medium tides to allow tidal flushing and improve water quality. The lower portion of the creek traverses a largely rural landscape with some riparian vegetation along the banks of the waterway. The lower reaches of the creek are within an area classified as Coastal Wetlands under the Coastal Management (2018) SEPP.

Windeyers Creek has been classified by DECCW (2006) as an estuary, however, the absence of tidal influences in the upper reaches due to the presence of artificial barriers has resulted in Windeyers Creek exhibiting characteristics closer to lowland rivers. Therefore, for the purposes of this water quality assessment, Windeyers Creek has been classified as lowland river and the relevant WQO and DGVs applicable to this category have been applied. The creek receives catchment runoff from the surrounding urban centres of Raymond Terrance and Heatherbrae, as well as from treated effluent from the Raymond Terrace WWTW, which flows to Windeyers Creek via Grahamstown Drain (Hunter Water Corporation, 2020).

Photo 4-13 Windeyers Creek at monitoring site M12RT6 (looking upstream)

Photo 4-14 Windeyers Creek at monitoring site M12RT6 (looking downstream)

Water quality data has been collected for Windeyers Creek and a tributary of Windeyers Creek at the following locations:

- M12RT6a Windeyers Creek upstream of tributary
- M12RT6 Windeyers Creek at the project crossing
- M12RT6b Windeyers Creek downstream of tributary
- M12RT7 Tributary of Windeyers Creek.

Additionally, water quality data has been collected by EES Group from Windeyers Creek at Raymond Terrace (refer to **Figure 4-6**). Available water quality data for monitoring sites on Windeyers Creek and associated tributaries are discussed in **Section 4.6.8**.

4.2.9 Grahamstown Drain

Grahamstown Drain is an artificial drainage channel which flows in a south-westerly direction from Grahamstown Dam to Hunter River via Windeyers Creek. The channel is used to transfer treated effluent (7.3 ML/d) from the Raymond Terrace WWTW to the Hunter River (Hunter Water Corporation, 2020). The drain additionally receives runoff from the surrounding urban parklands and residential area of Raymond Terrace. There is some instream and riparian vegetation along the banks of the channel. Several culverts and bridge structures are present along Grahamstown Drain which disrupt flow to Windeyers Creek which lies downstream (refer to **Photo 4-15** and **Photo 4-16**).

Photo 4-15 Grahamstown Drain at monitoring site M12RT10 (looking upstream)

Photo 4-16 Grahamstown Drain at monitoring site M12RT10 (looking downstream)

Grahamstown Drain has been monitored at one site (M12RT10). Available water quality data for Grahamstown Drain is discussed in **Section 4.6.9**.

4.2.10 Hunter River wetland

A wetland (referred to as the Hunter River wetland for this assessment) is located next to the Hunter Region Botanic Gardens (M12RT8) (refer to **Figure 4-6**). The wetland is a first order, ephemeral freshwater waterbody which is densely vegetated with instream macrophytes and riparian vegetation on the banks (refer to **Photo 4-17** and **Photo 4-18**). To the east of the Hunter River wetland, the catchment is largely undeveloped, vegetated and located on the Tomago Sandbeds which is classified as 'special area' and closed to the public in order protect groundwater quality and water extraction infrastructure (Hunter Water Corporation, 2020). The existing Pacific Highway is located immediately to the west of the Hunter River wetland. Pollutant sources are likely to originate from road runoff which flows toward to the wetland from the highway.

Photo 4-17 Wetland next to Hunter Region Botanic Gardens at monitoring site M12RT8 (looking upstream)

Photo 4-18 Wetland next to Hunter Region Botanic Gardens at monitoring site M12RT8 (looking downstream)

Available water quality data for the wetland next to the Hunter Region Botanic Gardens is discussed in **Section 4.6.6**.

4.2.11 Hunter Estuary Wetlands Ramsar site

The Hunter Estuary Wetlands Ramsar site is part of the Hunter Wetlands National Park and is comprised of two parts:

- The Hunter Wetlands National Park on Kooragang Island (Kooragang Nature Reserve), which was listed under the Ramsar convention in 1984
- The Hunter Wetlands Centre Australia in Shortland (south of the Hexham Swamp Nature Reserve), which was added to the listing in 2002.

Kooragang Nature Reserve includes the island between the North and South Channel of the Hunter River and Fullerton Cove which is located to the north of the North Channel Hunter River. Kooragang Nature Reserve receives flow from the North Channel Hunter River which is tidally influenced. There are also several small inlets and tributaries which flow from the Hunter River through the wetland.

Kooragang Nature Reserve is located in a straight line about 1.9 kilometres south-east of the boundary of the construction footprint however, is located about 5.1 kilometres directly downstream from the project where the new bridge crosses the Hunter River.

The Hunter Wetland Centre lies to the south-west of the South Channel of the Hunter River, next to the southern portion of the Hexham Swamp Nature Reserve. The Hunter Wetland Centre is in a separate sub-catchment to the construction footprint. The Hunter Wetland Centre receives flow from tributaries and drainage channels situated to the south-west of the Hunter River and is maintained by rainfall, although flow is minimal. The Hunter Wetland Centre drains to the South Channel of the Hunter River via Ironbark Creek which flows north under Maitland Road. As mentioned in **Section 4.2.4**, there are floodgates on Ironbark Creek at the confluence with the South Channel of the Hunter River.

Geographically, the Hunter Wetland Centre is about 3.8 kilometres from the project footprint and there are several barriers which obstruct normal flows from reaching the area from the project, including a disused rail embankment on the northern boundary of the Hexham swamp Nature Reserve, and floodgates on Ironbark Creek. Due to substantial distance from the construction footprint and a lack of a pollution pathway, the Hunter Wetland Centre in Shortland is not expected to be directly or indirectly impacted by the project.

Water quality data has not been collected from the Kooragang Nature Reserve or Hunter Wetlands Centre for this assessment, although water quality data collected by EES Group and DPIE have been discussed in **Section 4.6.6**.

4.3 Soil landscapes and characteristics

The project and surrounding area traverse several soil landscapes as shown on **Figure 4-7** and described in **Table 4-1**.

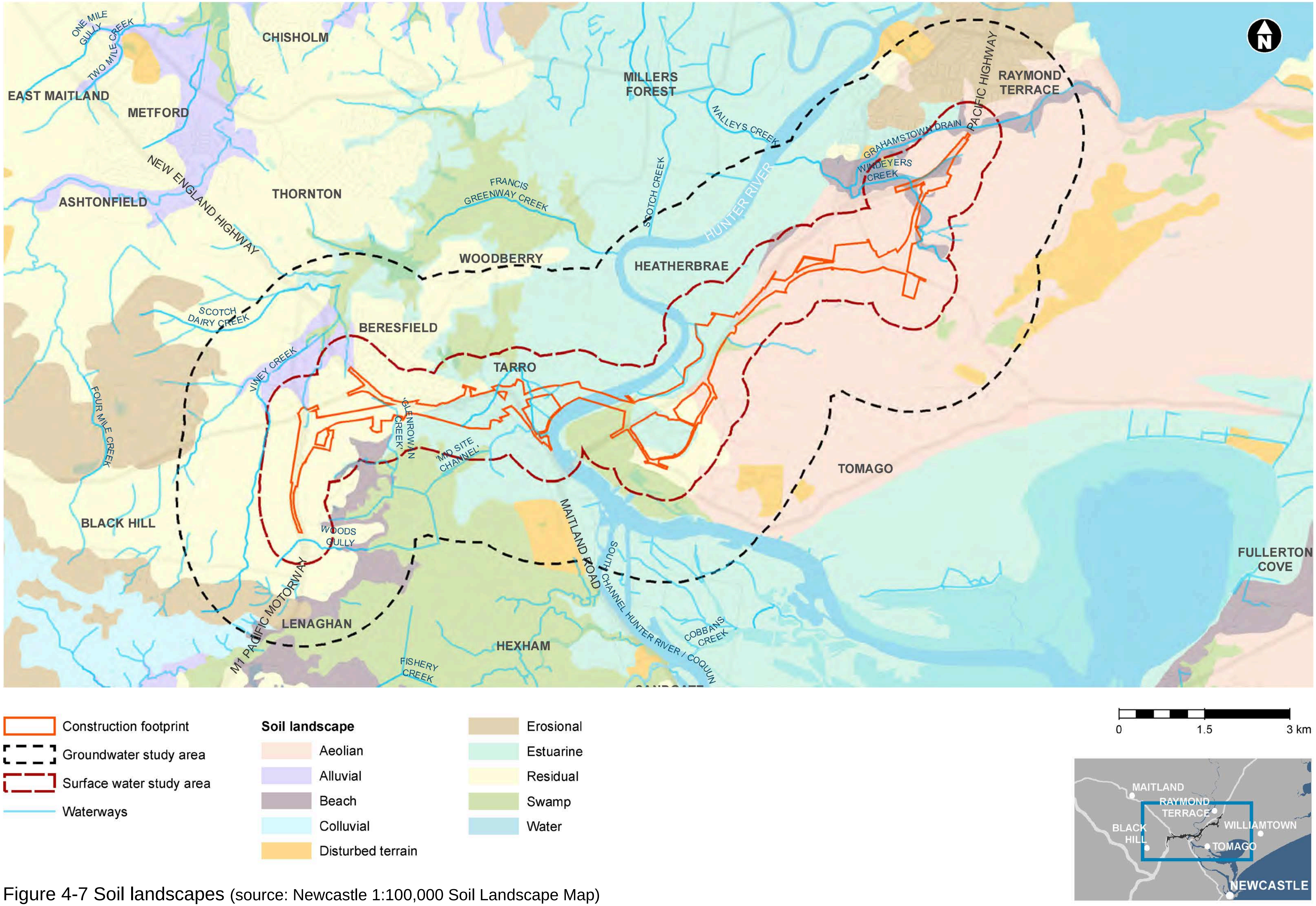

Figure 4-7 Soil landscapes (source: Newcastle 1:100,000 Soil Landscape Map)

Table 4-1 Soil landscapes within the project study area

Soil landscape	Description (taken from Douglas Partners, 2015)
Beresfield soil landscape	The Beresfield soil landscape group comprises undulating low hills and rises on Permian sediments with slopes between thee per cent to 15 per cent and an elevation of 20 metres to 50 metres. Dominant soils comprise brown black loam (topsoils) and yellow brown sandy loam (topsoil), brown plastic mottled clays (subsoil), red brown plastic clays (subsoil) or silty clays (subsoil). Limitations include high foundation hazard, water erosion hazard, seasonal water logging and high run-on on localised low slopes, highly acidic soils of low fertility. Red-brown clays and silty clays are sodic / highly sodic and susceptible to dispersion.
Residual soil of the Hamilton landscape	The Hamilton soil landscape group comprises level to gently undulating well-drained plain on Quaternary aged deposits with slopes less than two per cent and elevations up to 12 metres. Dominant soils comprise brown black loamy sand and pale coarse sand (topsoils) and brown to orange sandy pan (subsoil). Limitations include wind erosion hazard, groundwater pollution hazard, strong acidity, non-cohesive soils.
Millers Forest estuarine landscape	The Millers Forest landscape group comprises extensive alluvial plain on recent sediments with an elevation of six metres to less than three metres and slopes less than one per cent. Dominant soils comprise brown black silty clay loam (topsoils) and brown silty clay (subsoil). Limitations include flood hazard, permanently high water tables, seasonal waterlogging and foundation hazard, low wet bearing strength soils. Brown silty clay subsoils are also limited by sodicity / dispersion, salinity (localised, at depth) and potential acid sulfate soils at depths below 1.5 metres AHD.
Fullerton Cove estuarine landscape	The Fullerton Cove landscape group comprises tidal flats and creeks in tidal inlets and estuaries with slopes less than three per cent and elevation less than three metres. Dominant soils comprise black organic rich peat or saturated saline organic mud. Limitations include flooding, wave erosion hazard and foundation hazard, saturated, saline, potential acid sulfate soils.
Hexham Swamp landscape	The Hexham Swamp landscape group comprises broad, swampy, estuarine backplains on the Hunter delta with slopes less than one per cent and elevation less than two metres. Dominant soils comprise black silty clay loam (topsoil) and plastic clays (subsoil). Limitations include flood hazard, permanently high water tables, seasonal waterlogging, foundation hazard, groundwater pollution hazard, localised tidal inundation, highly plastic potential acid sulfate soils of low fertility. Both topsoils and subsoils are sodic and very highly saline in localised areas.
Tea Gardens Landscape Variant Aeolian landscape	The Tea Gardens landscape group comprises Pleistocene beach ridges on the Tomago coastal plain with slopes less than five per cent, elevations between five metres to eight metres. Dominant soils comprise sandy peat, brown/black to brown /grey loamy sand (topsoil), saturated brown/black coarse sandy clay loam (topsoil), bleached sands (shallow subsoil), massive organic pan (loamy sand to sand), coarse smelly saturated sand. Limitations include permanently high water tables, seasonal waterlogging, groundwater pollution hazard, strongly to extremely acid soils of low fertility and low available water-holding capacity.
Blind Harrys Swamp landscape	The Blind Harrys Swamp landscape group comprises waterlogged swales and deflation areas on sands of the Tomago coastal plain with elevation less than 10 metres and slopes less than two per cent. Dominant soils comprise black organic fibrous peat and saturated brown mottled sand. Limitations include permanently high water tables, foundation hazard, permanently waterlogged, groundwater pollution hazard and strongly acid soils. Sands are also limited by salinity and localised potential acid sulfate soils.
Bobs Farm Beach Landscape	The Bobs Farm variant landscape group comprises low remnant lake shore beach deposits with up to one metre relief, 15 metres in width and 200 metres in length. Dominant soils comprise dark brown loose loamy sands (topsoil) and yellow brown loose coarse beach sand (subsoil). Limitations include flood hazard, high run-on, wind erosion hazard, non-cohesive soils, groundwater pollution hazard, foundation hazard and permanently high water table.

Geotechnical soil domains (Douglas Partners, 2020) are identified in the Soils and Contamination Working Paper (Appendix P of the EIS). Domains B and C represent soft soil areas where the soils consist of unconsolidated and compressible materials. These soft soil areas require specific ground improvement for road construction (specifically around Tarro and Tomago) and are discussed further in Chapter 5 of the EIS. Potential water quality impacts associated with soft soil consolidation are discussed in **Section 6.2.2** and in the Hydrology and Flooding Working Paper (Appendix J of the EIS).

4.3.1 Acid sulfate soils

Acid Sulfate Soils (ASS) is the common name for naturally occurring sediments and soils containing iron sulphides. The exposure of these soils to oxygen by drainage or excavation, oxidises the iron sulphides and generates sulfuric acid. The sulfuric acid can be readily released into the environment, with potential adverse effects on the natural and built environments. The majority of ASS are formed when available sulfate (which occurs widely in seawater, marine sediment, or saturated decaying organic material) reacts with dissolved iron and iron minerals forming iron sulfide minerals, the most common being pyrite. This generally limits their occurrence to deeper marine sediments and low lying sections of coastal floodplains, rivers and creeks where surface elevations are less than about five metres AHD.

Review of the ASS probability mapping (DPIE, 2020) indicates that the southern portion of the project study area, on the southern side of Hunter River, is considered to have a high probability of ASS less than one metre below ground surface. The area immediately next to Hunter River on the northern bank is also considered to have a high probability of ASS less than one metre below ground surface or a high probability of ASS one to three metres below ground surface. The areas north and north-east of Hunter River, in proximity to Heatherbrae and Tomago, have been classified as having a low probability of ASS greater than three metres below ground surface. Probability of ASS occurrence is shown on **Figure 4-8**.

Geotechnical investigations carried out in 2015 and 2016/17 for the project (Douglas Partners, 2015 and Douglas Partners, 2017) indicate that there is a high probability of ASS being present within the low-lying floodplain and swamp areas within the construction footprint, with a low probability of potential ASS in the Tomago Sandbeds (northern parts of the project). Of the 153 samples screened for ASS in 2017, 98 samples returned results indicating potential or actual acid sulfate conditions in 22 locations. These locations are generally located in the floodplain and swamp areas.

An assessment of ASS impacts from the project is provided in the Soils and Contamination Working Paper (Appendix P of the EIS).

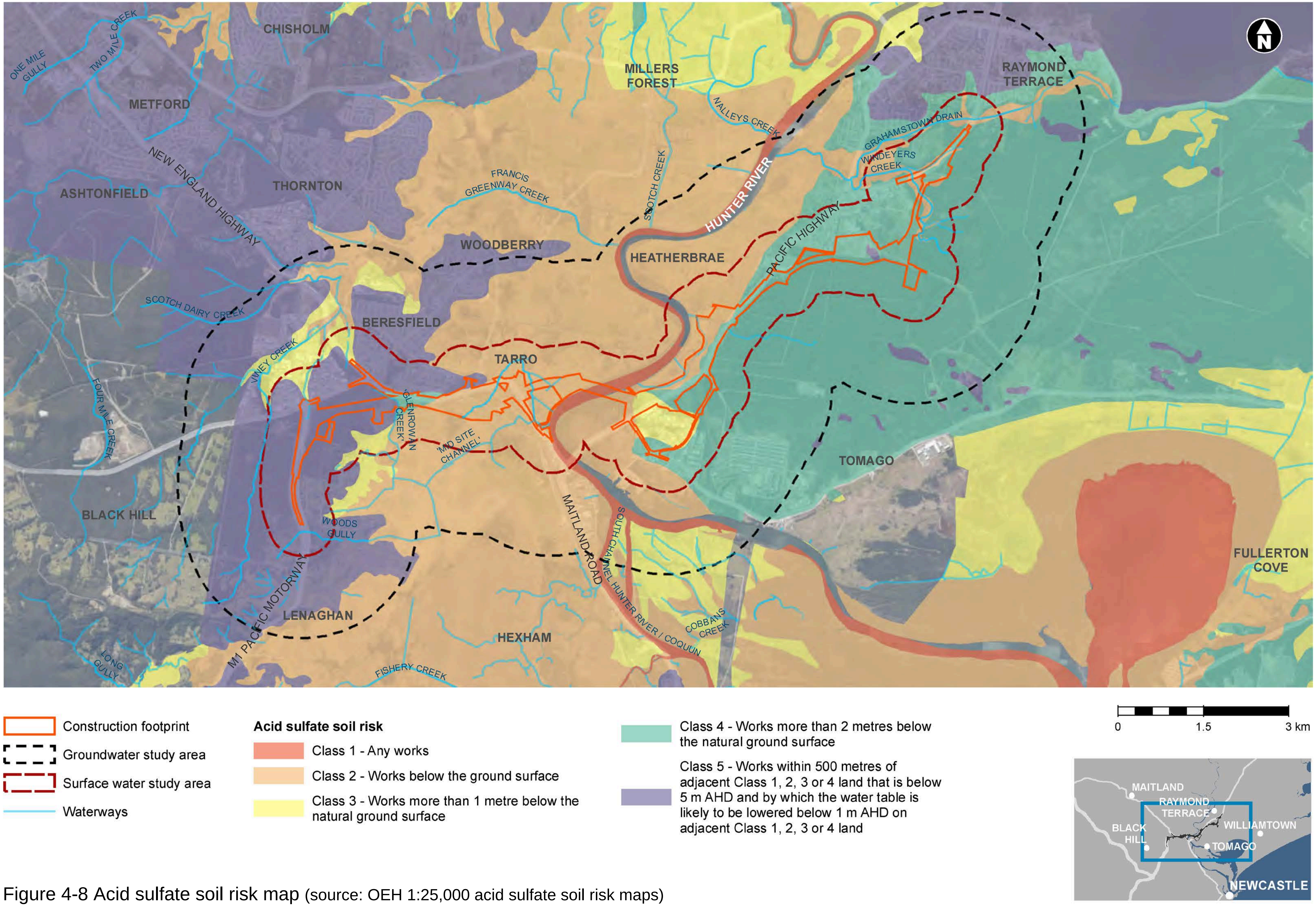

Figure 4-8 Acid sulfate soil risk map (source: OEH 1:25,000 acid sulfate soil risk maps)

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4.3.2 Salinity

Soil salinity is a complex issue relating to salt and water cycles both above and below the ground and is discussed in detail in the Soils and Contamination Working Paper (Appendix P of the EIS). Changes to surface water and groundwater flows and levels can dissolve and mobilise salts and cause their accumulation in other locations. Areas of salinity potential are where soil, geology, topography and groundwater conditions predispose a site to salinity. These areas are most commonly drainage systems or low lying/flat grounds where there is a high potential for the ground to become waterlogged.

High salinity hazards present a risk to surface water quality by creating soils at higher risk of erosion and by increasing instream salinity. Highly saline soils often have high levels of sodium resulting in sodic soils. These soils have poor structure and drainage capacity, are highly dispersive and prone to erosion. This could present a risk for construction as following rainfall these highly erodible soils and contaminants bound to the sediment could be transferred to downstream waterways. Additionally, salts can accumulate on the surface of highly saline soils due to evaporation during dry periods. These salts can be flushed into the waterway via rainfall resulting in more saline waterways. Salinity impacts waterways and other areas relevant to this project in the following ways (DPIE, 2021):

- Farms: Salinity can decrease plant growth and water quality resulting in lower crop yields and degraded stock water supplies. Excess salt affects overall soil health, reducing productivity. It kills plants, leaving bare soil that is prone to erosion
- Wetlands: As salinity increases over time, wetlands become degraded, endangering wetland species and decreasing biodiversity. Where sulfate salts are present, there is an increased risk of acid sulfate soil formation
- Rivers: Increased volume (load) and/or concentration (EC) of salinity in creeks and streams degrades town water supplies, affects irrigated agriculture and horticulture, and adversely impacts on riverine ecosystems
- Drinking water: When a source of drinking water becomes more saline, extensive and expensive treatment may be needed to keep salinity at levels suitable for human use
- Buildings, roads and pipes: Salinity damages infrastructure, shortening its life and increasing maintenance costs.

A review of salinity risk carried out as part of the Soils and Contamination Assessment (detailed in the Soils and Contamination Working Paper (Appendix P of the EIS)) identified several areas with dryland salinity characteristics (observations of saline indicator species to salt outbreaks), including Purgatory Creek between Hexham Bridge and Tomago Road, within creek alignments south of the Hunter River, and along Windeyers Creek*.*

A review of the National Land and Water Resources Audit Dryland Salinity Data Source identified that the majority of the construction footprint lies in an area rated as high hazard or risk of dryland salinity (refer to **Figure 4-9**). Salinity risk has been discussed in **Section 6.2.1** and further detailed in the Soils and Contamination Working Paper (Appendix P of the EIS).

4.4 Hydrogeology

Three main geological units lie along the project as presented on the 1:100,000 scale regional geology map for Newcastle (Newcastle Coalfield Regional Geology, Sheet 9321, NSW Department of Mineral Resources). Geology in the vicinity of the project alignment is presented on **Figure 4-10**. From west to east, these geological units along the alignment include:

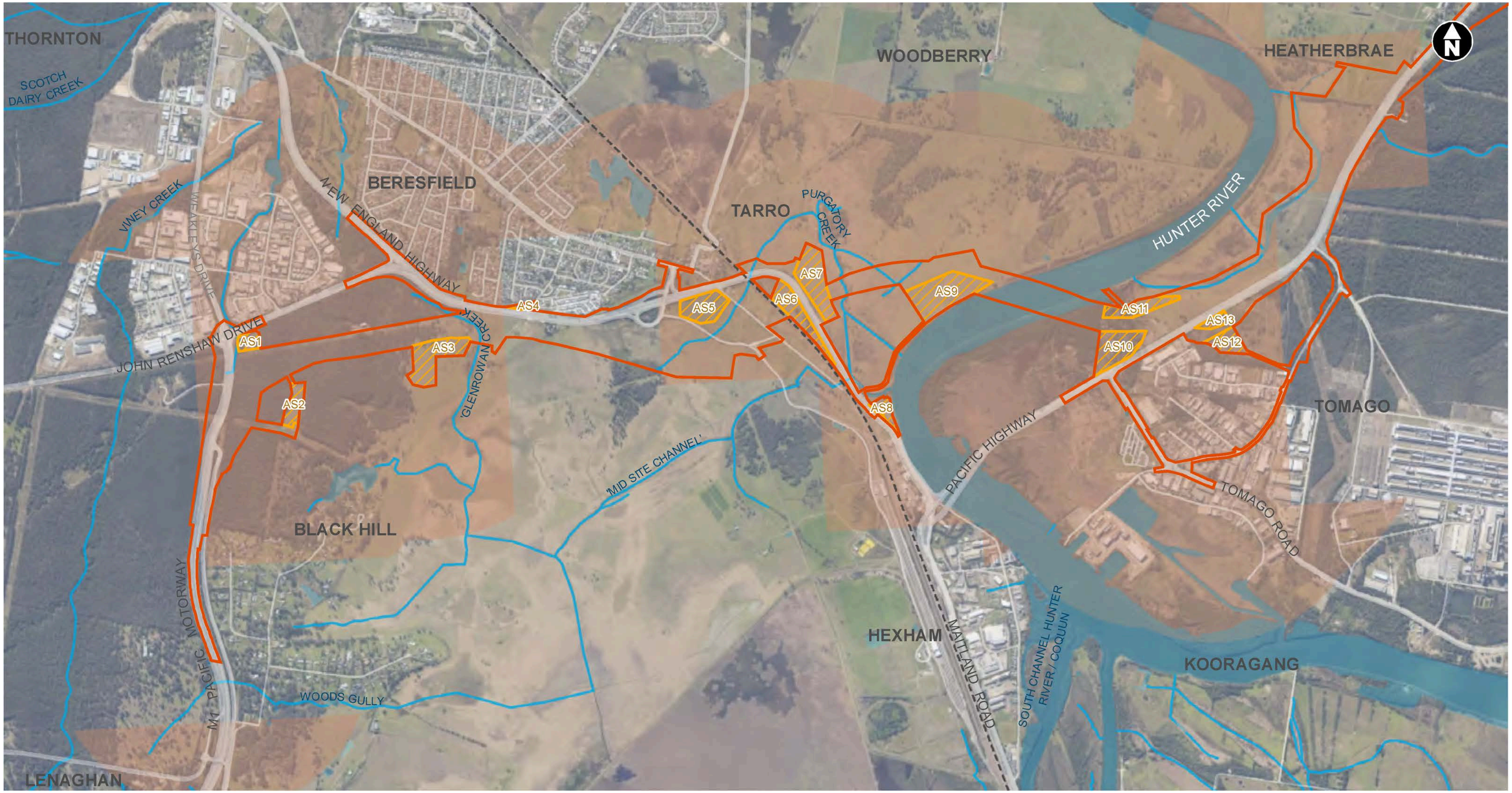
- Permian Tomago Coal Measures of the Singleton Supergroup (Sydney Basin)

- Quaternary alluvium associated with the Hunter River
- Quaternary Coastal Sands.

These geological units are host to the three main groundwater systems that are present in the vicinity of the project's construction footprint, including:

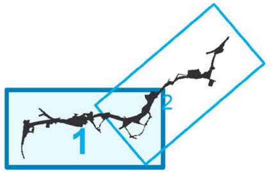
- Tomago Coal Measures
- Hunter Alluvium
- Tomago Sandbeds.

Key characteristics of these three groundwater systems are summarised in **Section 4.4.1**, **Section 4.4.2** and **Section 4.4.3**.



Construction footprint | The project | Waterways | Main North Rail Line | Ancillary facility | High salinity risk areas (DAFF 2020)

0 | 0.75 | 1.5 km



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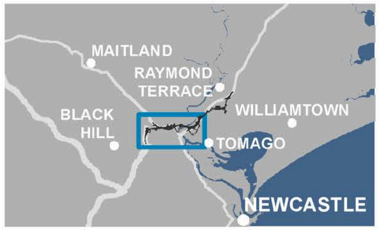

Figure 4-9 High salinity risk areas (map 1 of 2)

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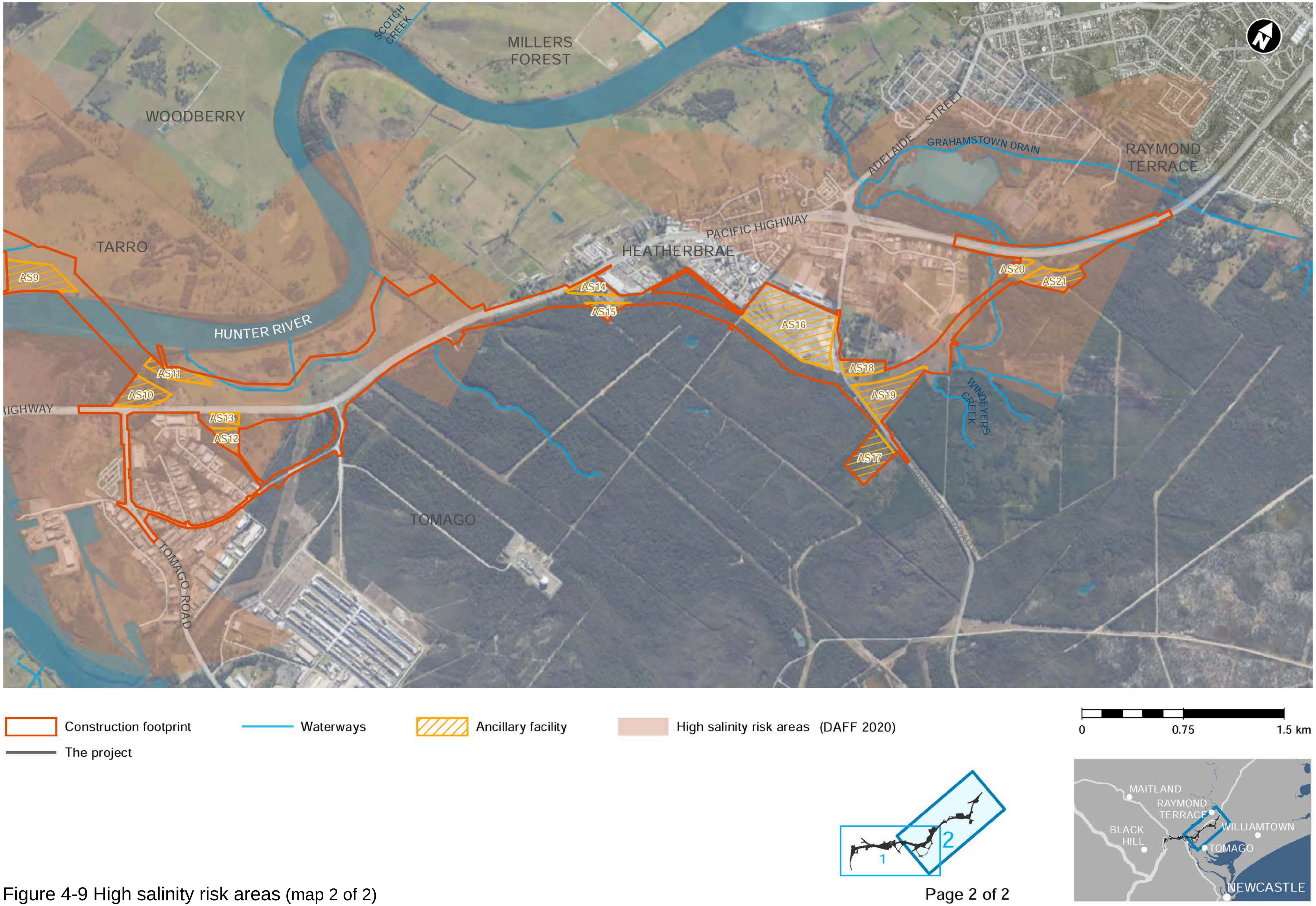

Figure 4-9 High salinity risk areas (map 2 of 2)

Page 2 of 2

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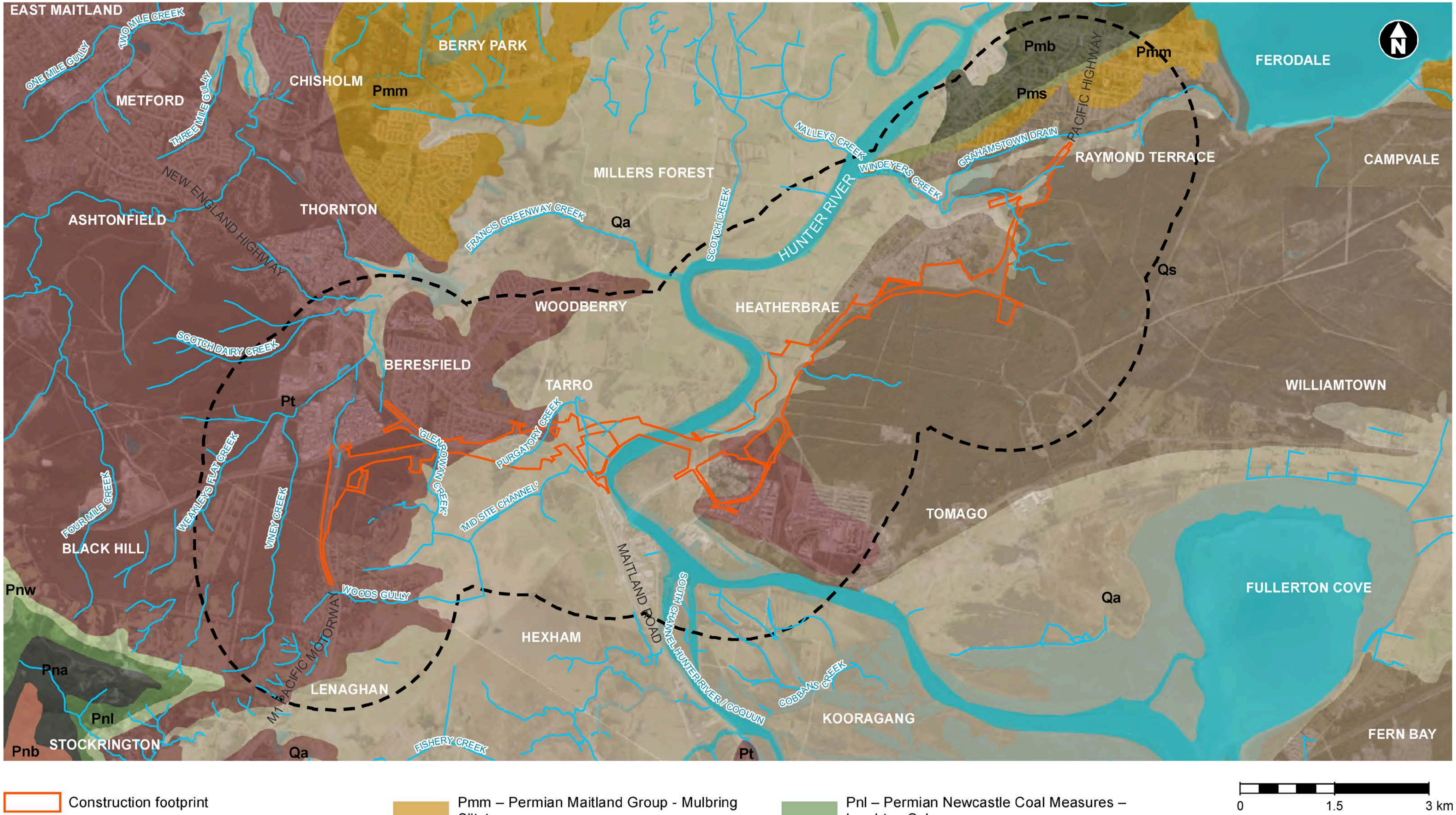

Construction footprint

Groundwater study area

Waterways

Geology

Pmb – Permian Maitland Group - Branxton Formation - Undifferentiated

Pmm – Permian Maitland Group - Mulbring Siltstone

Pms – Permian Maitland Group - Branxton Formation - Muree Sandstone Member

Pna – Permian Newcastle Coal Measures – Adamstown Subgroup

Pnb – Permian Newcastle Coal Measures – Boolaroo Subgroup

Pnl – Permian Newcastle Coal Measures – Lambton Subgroup

Pnw – Permian Newcastle Coal Measures – Waratah Sandstone

Pt - Permian Tomago Coal Measures

Qa - Quaternary Alluvium

Qs - Quaternary Coastal Sand

Water bodies

Figure 4-10 Regional geology (source: Newcastle Coalfield Regional Geology, 1:100,000 map sheet)

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4.4.1 Hunter Alluvium

The indicative extent of Quaternary alluvial in the groundwater study area is shown as unit Qa in **Figure 4-10**. The alluvial deposits commonly comprise sequences of clays, silts, sands and gravels. The deposits are highly heterogeneous and within the floodplain area are likely to be typically of low permeability. More permeable and coarser, sand and gravel materials may be found locally within discontinuous sheets of stringers, or at the base of the alluvial deposits or within paleochannels (basal deposits). The deposits typically are a fining upward sequences of sediments.

In a regional context, the Hunter River floodplain and its associated alluvial groundwater systems form a regional groundwater sink for the surrounding and underlying Permian and Triassic rocks of the Hunter Valley (Kellett, et al, 1987). Groundwater largely flows from the rocks of the Sydney Basin into the Quaternary Alluvium.

In the vicinity of the project, aquifer yields, and water quality are likely to be highly variable due to the generally fine grained nature of the sediments and the salinity of the Hunter River in proximity to the coast.

Groundwater levels are typically very shallow and often express at surface. From project water level monitoring (Hydrology and Flooding Working Paper (Appendix J of the EIS)), indicative standing water levels of the Hunter Alluvium range from 2.4 metres below ground level to 0.2 metres above ground level.

4.4.2 Tomago Sandbeds

Coastal sands are typically unconsolidated sediments comprising estuarine deposits, palaeochannels, dunes or lowland coastal sands. These aquifers are typically unconfined with a high porosity and shallow depth to water table.

In the vicinity of the project, the coastal sands aquifer consists of the Tomago Sandbeds (unit Qs of **Figure 4-10**). The Tomago Sandbeds are of Pleistocene age, consisting of fine to medium grained, well sorted, quartzose beach sand with discontinuous indurated sand layers (Woolley, et al, 1995).

The sandbeds comprise of extensive inner barrier sand ridge deposits extending from Tomago to Port Stephens (to the northeast) and about five to 15 kilometres inland from the present coastline. The Tomago Sandbeds are up to 30 metres thick and are underlain by the Medowie Clay Member. The Tomago Sandbeds are overlain (towards the coast) by the Tilligerry Mud Member and the Stockton Sand Member (Woolley et. al. 1995). The Tomago Sandbeds are locally incised by Holocene age alluvium, particularly around Windeyers Creek near the northern parts of the project and are truncated by the Hunter Alluvium around Tomago.

Since deposition, the inner barrier sand has been subjected to weathering processes and fluctuating water levels that have resulted in the varying colour and induration due to the mobilisation and deposition of iron (oxide and carbonate). This has resulted in the presence of yellow brown to black, indurated, iron cemented (by iron oxyhydroxide) layers. Where present, these cemented layers can be sufficiently continuous and of low permeability to reduce vertical hydraulic conductivity significantly.

The Tomago Sandbeds receive a relatively high percentage of recharge from rainfall runoff and infiltration. DPI Water (2016) have calculated an average infiltration rate of 25 per cent of average annual rainfall for the Tomago Sandbeds.

In the groundwater study area, groundwater levels are relatively shallow. From project water level monitoring (Hydrology and Flooding Working Paper (Appendix J of the EIS)), indicative standing water levels of the Tomago Sandbeds range from 1.6 to 2.7 metres below ground level.

The Tomago Sandbeds are used as a public drinking water supply by Hunter Water Corporation.

4.4.3 Tomago Coal Measures

Hardrock groundwater systems in the area of the construction footprint occur within the Permian Tomago Coal Measures, which outcrop in the western and central portions of the project (unit Pt of **Figure 4-10**).

The coal measures are typically of relatively low permeability, particularly at depth, with the interbedded sandstones and siltstones generally of lower permeability than the coal seams. The permeability of the coal seams relative to the interburden and overburden is enhanced by the presence of cleating and joints within the coal and can produce permeabilities typically an order of magnitude greater than the surrounding formation.

An upper weathered layer can exist in the Permian bedrock, where permeability is enhanced by weathering and un-loading.

Groundwater flow within the deeper Permian formations is conceptualised to generally be controlled by bedding and fracture networks, with variable water quality. A shallow unconfined aquifer can also exist in the weathering zone that is often in hydraulic connection with localised colluvial aquifers and local drainage systems.

Depths to groundwater in the Tomago Coal Measure is variable and is often a reflection of topography (depth to groundwater is greater beneath ridgelines and shallower beneath gullies). From project water level monitoring (Hydrology and Flooding Working Paper (Appendix J of the EIS)), indicative standing water levels of the Tomago Coal Measure range from 6.3 to 16.8 metres below ground level in the vicinity of Black Hill. Beneath the floodplain at Tarro and confined beneath the Hunter Alluvium, potentiometric levels in the Tomago Coal Measures have been measured at 0.3 metres above ground level.

4.5 Groundwater and surface water interactions

The degree and type of interaction between groundwater and surface water is largely dependent on topography, stream geomorphology and the underlying groundwater system. In general, indicative interactions that are anticipated are detailed below. Interactions would be subject to seasonal variation, as the water table rises and falls in response to seasonal changes, and the fluctuations would be accentuated in particularly dry and particularly wet years.

- Hunter Alluvium:
  - The Hunter Alluvial groundwater source occurs beneath the low lying floodplains of the Hunter River. Water levels are typically shallow and often express at surface where ground surface elevations drop below one metre AHD, either seasonally or after high rainfall. Drainages that enter the floodplain (including Viney Creek, the unnamed tributaries to Purgatory Creek and Mid Site Channel) typically transition from ephemeral to perennial as they receive groundwater baseflow concentrations at the lower elevations. The Hunter River is also a point of groundwater discharge. The groundwater surface water interaction is generally one of groundwater discharge to surface water. Wetlands and associated waterways on the floodplain, such as at Tarro and Tomago, are also expected to receive groundwater contribution.
- Tomago Coal Measures:
  - In the west of the groundwater study area, in the vicinity of Black Hill and Beresfield, the area of Tomago Coal Measures groundwater source outcrop/subcrop (**Figure 4-10**) is generally relatively elevated with low order ephemeral drainages (including Viney Creek and its tributary, Glenrowan Creek and unnamed tributaries to Purgatory Creek). These drainages are typically located above the elevation of the shallow water table. Some recharge to groundwater is likely during periods of elevated rainfall and runoff.

- Tomago Sandbeds:
  - On the Tomago Sandbeds, there is a high proportion of rainfall infiltration and very little or no runoff under average conditions as is indicated by a lack of defined drainage channels. Any waterways and surface drainages present, such as the upper reaches of Windeyers Creek, are highly ephemeral with surface flows generally limited to extreme rainfall events. Grahamstown Drain also runs across Tomago Sandbeds, with flows that are artificially maintained by discharge from the Raymond Terrace WWTW. When flowing, waterways and surface drainages are typically sources of groundwater recharge. Wetlands, such as the Hunter River wetland next to the Hunter Region Botanic Gardens, can occur in low lying depressions and swales and these wetlands are maintained by drainage from the aquifers or are windows to the water table where the water table is locally at a higher elevation than ground level.

4.6 Existing surface water quality

This section discusses the existing surface water quality of waterways with the potential to be impacted by the project including Viney Creek, Glenrowan Creek, Purgatory Creek, Hunter River, Windeyers Creek and tributaries of these creeks and rivers, as well as wetland areas within Hexham Swamp Nature Reserve and areas classified as Coastal Wetlands under the Coastal Management SEPP.

The data presented herein was obtained from Hunter Water Corporation, EES Group/DPIE and ARTC and was collected at varying frequencies between 2011 and 2018.This section also incorporates water quality data collected as part of the site investigations discussed in **Section 3.3.4**. The existing water quality is discussed in relation to the ANZG (2018) Water Quality Guidelines default guideline values for the protection of aquatic ecosystems for slightly to moderately disturbed ecosystems (95 per cent level of species protection) except for chemicals that have the potential to bioaccumulate in which the 99 per cent level of species protection has been adopted, as outlined in **Table 3-5**. These values are recommended thresholds for which if an indicator or indicators fall outside of assumes that the environmental value is not being protected. The protection of this WQO provides the most conservative water quality criteria of all nominated WQOs (for indicators relevant to the proposed work). Therefore, by meeting the protection of aquatic ecosystems, all other relevant values will be protected. Outcomes of this assessment are summarised below in **Table 4-2** and Figure A-1 of **Appendix A**.

Table 4-2 Summary of existing water quality compliance with recommended ANZG (2018) thresholds for aquatic ecosystems

Waterway/wetland	Description of water quality (with reference to aquatic ecosystem values)*	
	Wet	Dry
Viney Creek	Very poor	Very poor
Glenrowan Creek	Very poor	
Purgatory Creek	Very poor	Very poor
Hexham Swamp Nature Reserve	Poor	Poor
Mid Site Channel	N/A – no wet weather samples	Very poor
Hunter River main stream	Poor	Very poor
Hunter River Drain and Tributary to Hunter River Drain	Very poor	Very poor
Hunter River wetland	Very poor	Very poor

Waterway/wetland	Description of water quality (with reference to aquatic ecosystem values)*	
	Wet	Dry
Drainage canal, Old Punt Road	Very poor	Very poor
Unnamed Coastal Wetland	N/A – no wet weather samples	Very poor
Windeyers Creek	Very poor	Very poor
Grahamstown Drain	Very poor	Very poor

* **Table 3-2** provides an explanation of water quality compliance ratings

4.6.1 Viney Creek

Viney Creek is a tributary of Weakleys Flat Creek that flows into Woodberry Swamp, a low lying floodplain and wetland area located between Maitland and Hexham. Viney Creek drains an area of 670 hectares with about one fifth of the catchment fully developed (Rayner, et al, 2016). Viney Creek has been monitored during both dry and wet weather and has nominated WQOs of protection of aquatic ecosystems, visual amenity and primary and secondary contact recreation.

The water quality at the time of monitoring during both dry and wet weather conditions is considered 'very poor' with respect to aquatic ecosystems due to elevated nutrients (TN, TP) and zinc concentrations, very low dissolved oxygen concentrations and elevated EC. Nutrient concentrations during both dry and wet weather were generally three times the DGVs for protection of aquatic ecosystems, with TN and TP concentrations increasing slightly following rainfall (refer to **Figure 4-11**). Turbidity was above the upper DGV limit of 50 NTU during wet weather but remained within the DGV range during dry weather (refer to **Figure 4-12**).

During dry weather median dissolved oxygen was very low (median 8.2 per cent saturation) but notably increased following rainfall (median 64 per cent saturation), however still fell outside the DGV range. The low dissolved oxygen levels during dry weather are likely due to the elevated nutrients, stagnant water and proliferation of aquatic macrophytes that can deplete oxygen levels (refer to **Photo 4-19** and **Photo 4-20**). EC for NSW coastal rivers typically ranges between 200-300 µS/cm (ANZG, 2018). Conductivity levels in Viney Creek exceeded this range in both dry and wet weather. Median EC during dry weather was 855 µS/cm, with high concentrations possibly attributable to Viney Creek receiving saline groundwater baseflow during low flow periods. Following rainfall, conductivity decreased (median 610 µS/cm) possibly due to dilution with freshwater runoff, however still exceeded the DGV. Apart from zinc, all other metals were below DGVs during both dry and wet weather (refer to **Figure 4-13**).

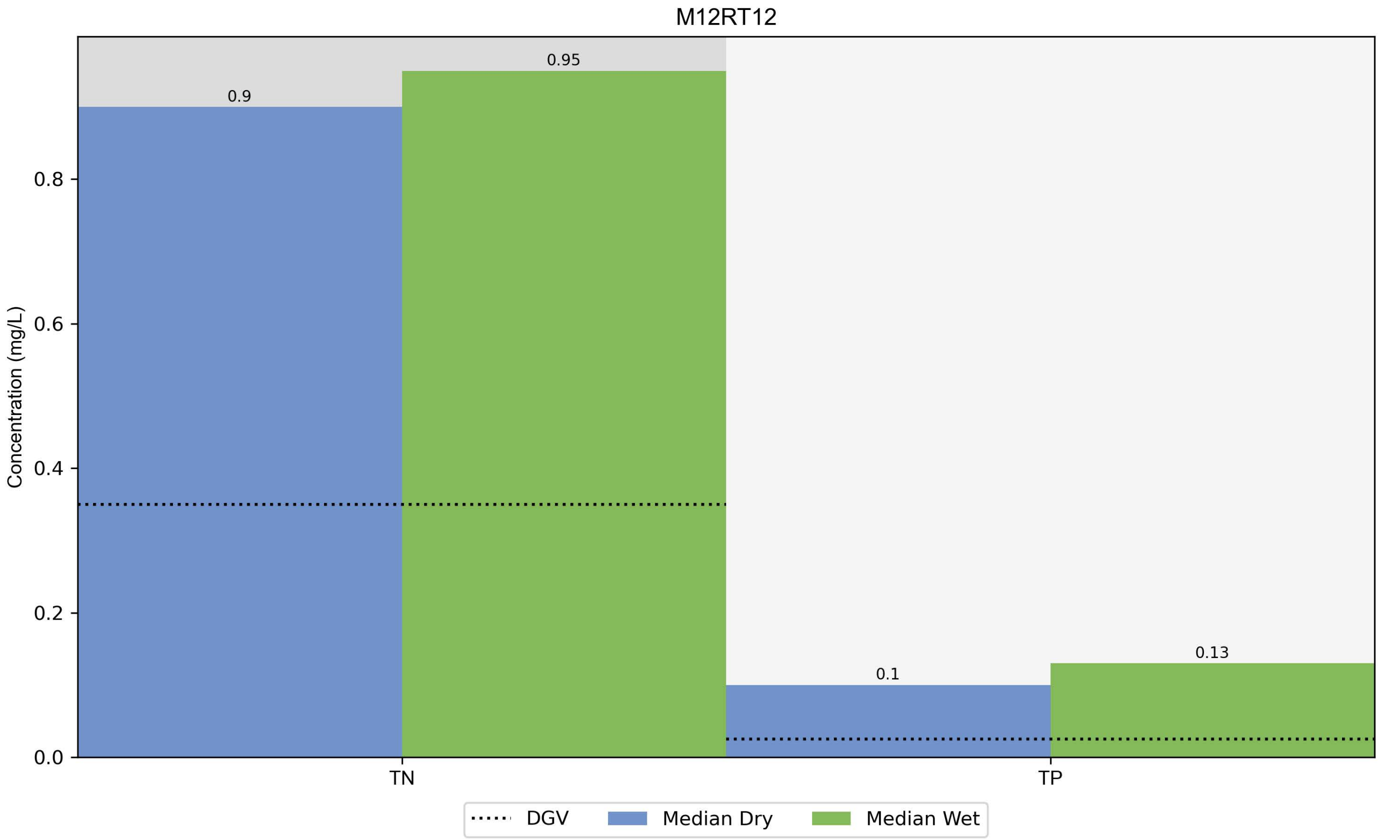


Figure 4-11 Median nutrient concentrations for dry and wet weather at the monitoring site within Viney Creek

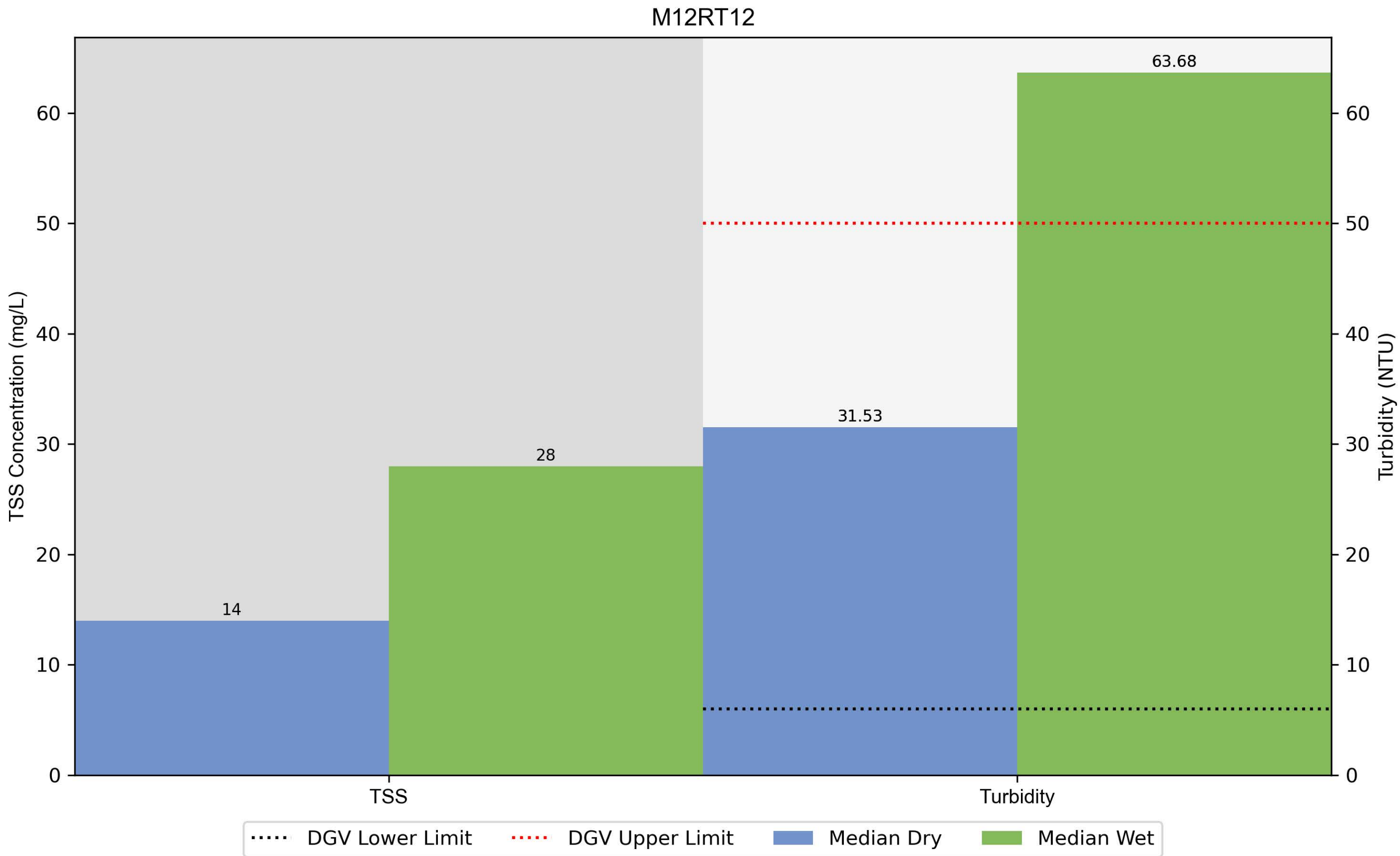


Figure 4-12 Median TSS and Turbidity for dry and wet weather at the monitoring site within Viney Creek

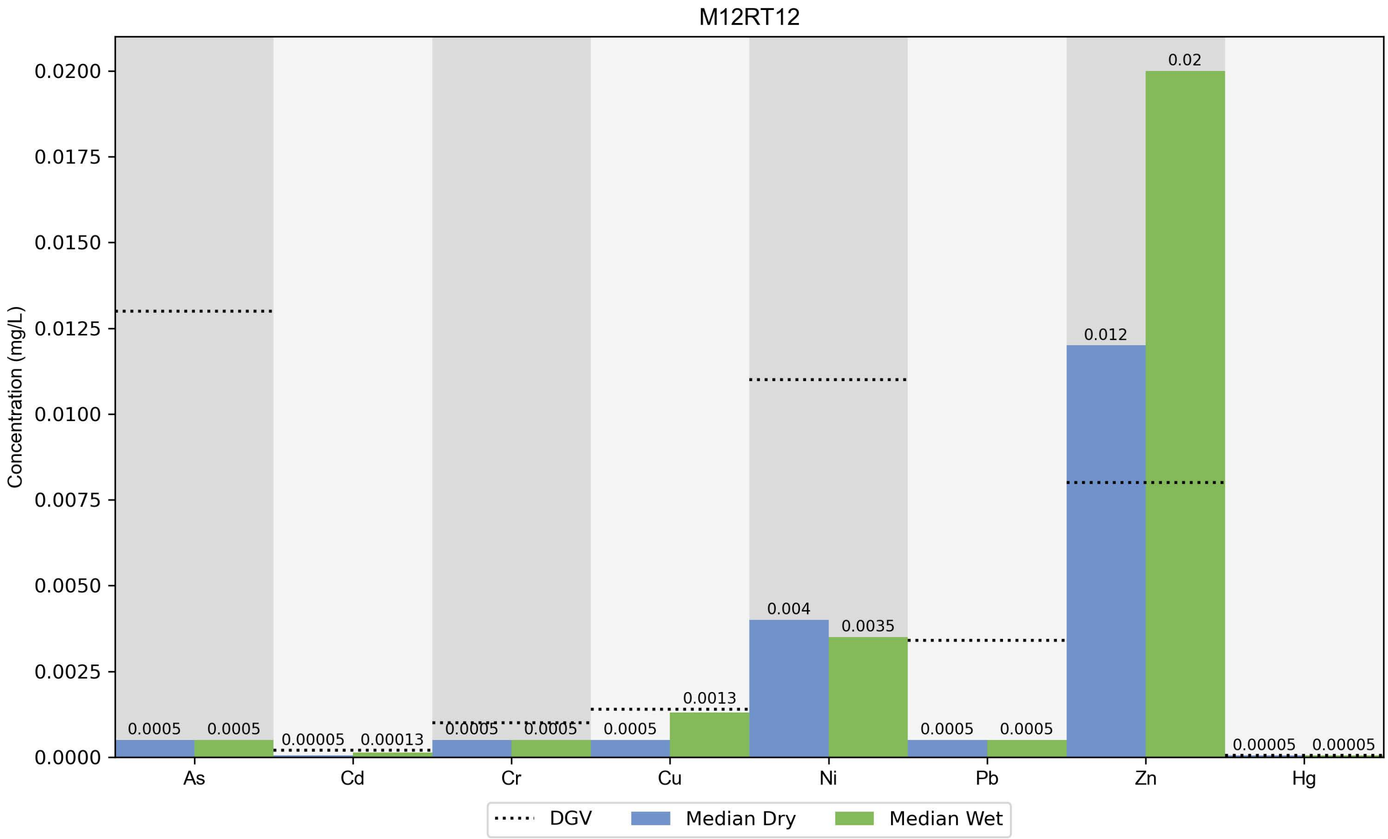


Figure 4-13 Median metals concentrations for dry and wet weather at the monitoring site within Viney Creek

Visual observations over the sampling period infer that that the WQO visual amenity is currently not being protected at Viney Creek. During dry weather the creek emitted an odour, was murky and stagnant with limited transparency. Following rainfall, while there was some flow, the creek was turbid with oily sheens.

The WQO primary contact recreation is not protected in Viney Creek during dry or wet weather and secondary contact recreation following wet weather. Median enterococci of 50 CFU/100mL exceed the recommended threshold of 35 CFU/100mL for primary contact but is below the recommended threshold of 230 CFU/100mL for secondary contact recreation. Following rainfall, median enterococci increased to 1640 CFU/100mL and therefore the WQO for primary or secondary contact recreation was not protected. Enterococci numbers measured indicate sources of faecal pollution particularly following rainfall.

Photo 4-19 Viney Creek during low flow

Photo 4-20 Viney Creek aquatic macrophytes

4.6.2 Glenrowan Creek

Glenrowan Creek (M12RT1) is located to the south of the New England Highway east of John Renshaw Drive draining a largely agricultural catchment, although it also receives stormwater from urban areas to the north via a stormwater drainage pipe under the highway. The creek has the potential to be impacted by the project. The creek is ephemeral and therefore water was not present on all sampling occasions. The waterway is classified as a lowland river and has the nominated WQOs of protection of aquatic ecosystems, visual amenity and primary and secondary recreation assigned to it. Over the sampling periods, three dry weather samples and two wet weather samples were collected. Water quality at the time of sampling (dry and wet) did not meet the DGVs for protection of lowland river aquatic ecosystems for a number of indicators (refer to **Appendix A**). Indicators which met the DGV included pH, turbidity, conductivity and some metals (Cd, Ni, Pb and Hg).

Nutrients (TN and TP) were higher than DGVs during both dry and wet weather. Median total nitrogen concentrations in dry conditions (1.6 mg/L) were more than 4.6 times the DGV and total phosphorus (0.13 mg/L) more than 5.2 times the DGV. Following wet weather, concentrations of nitrogen more than doubled, whereas TP was similar to dry weather concentrations (refer to **Figure 4-14**). The excessive nutrients in Glenrowan Creek are likely the result of anthropogenic non-point sources including fertiliser application and manure from livestock due to the largely agricultural catchment draining to the tributary. Excess nutrients can result in algal blooms and nuisance aquatic vegetation, causing low dissolved oxygen (among other issues), which is apparent at this site (refer to **Photo 4-21**). Turbidity remained within the DGV range during both dry and wet weather (refer to **Figure 4-15**). Dissolved oxygen concentrations were very low (median 17.5 percent) and were outside the DGV lower limit of 85 per cent saturation during dry weather. Following wet weather, median concentrations increased to 67 per cent saturation but were still lower than the DGV range.

Metal concentrations were low and compliant with DGVs, with the exception of copper and zinc, which were 1.5 and two times the DGVs respectively during dry weather. Following wet weather concentrations of copper increased marginally or stayed the same (refer to **Figure 4-16**). However, concentrations of zinc tripled following rainfall which is representative of stormwater runoff from the northern side of the highway.

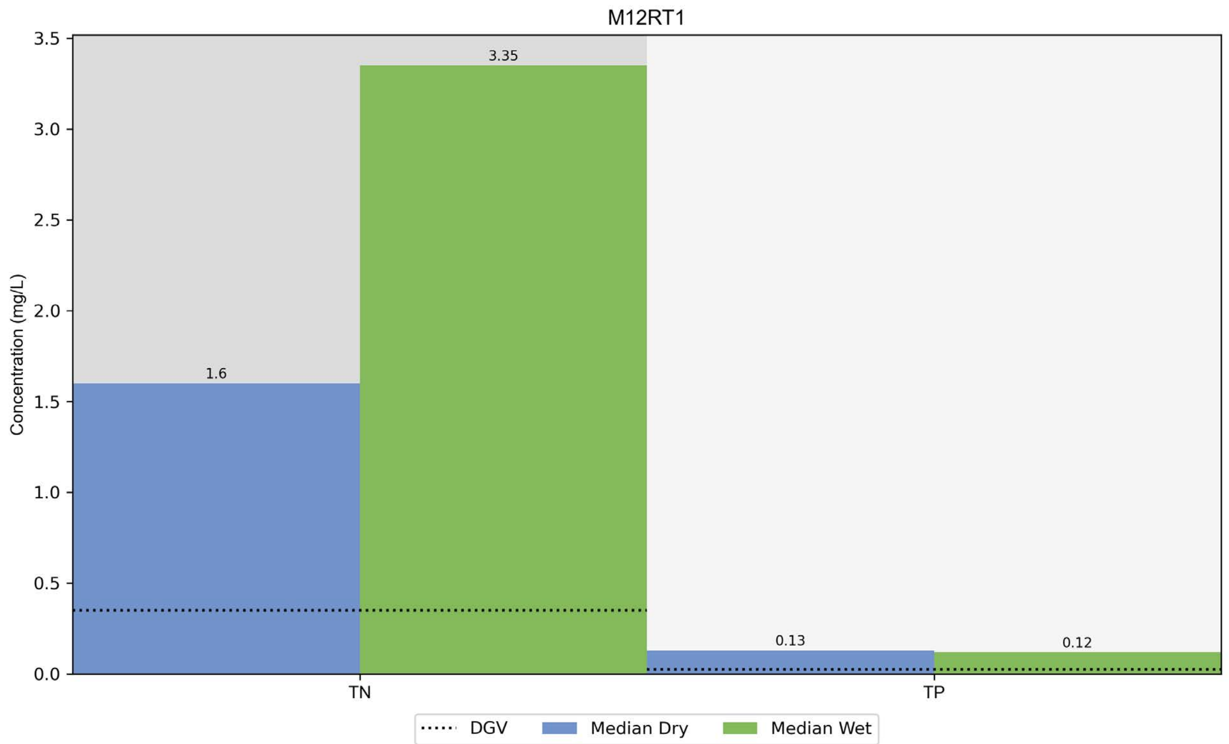


Figure 4-14 Median nutrient concentrations for dry and wet weather at the monitoring site within Glenrowan Creek

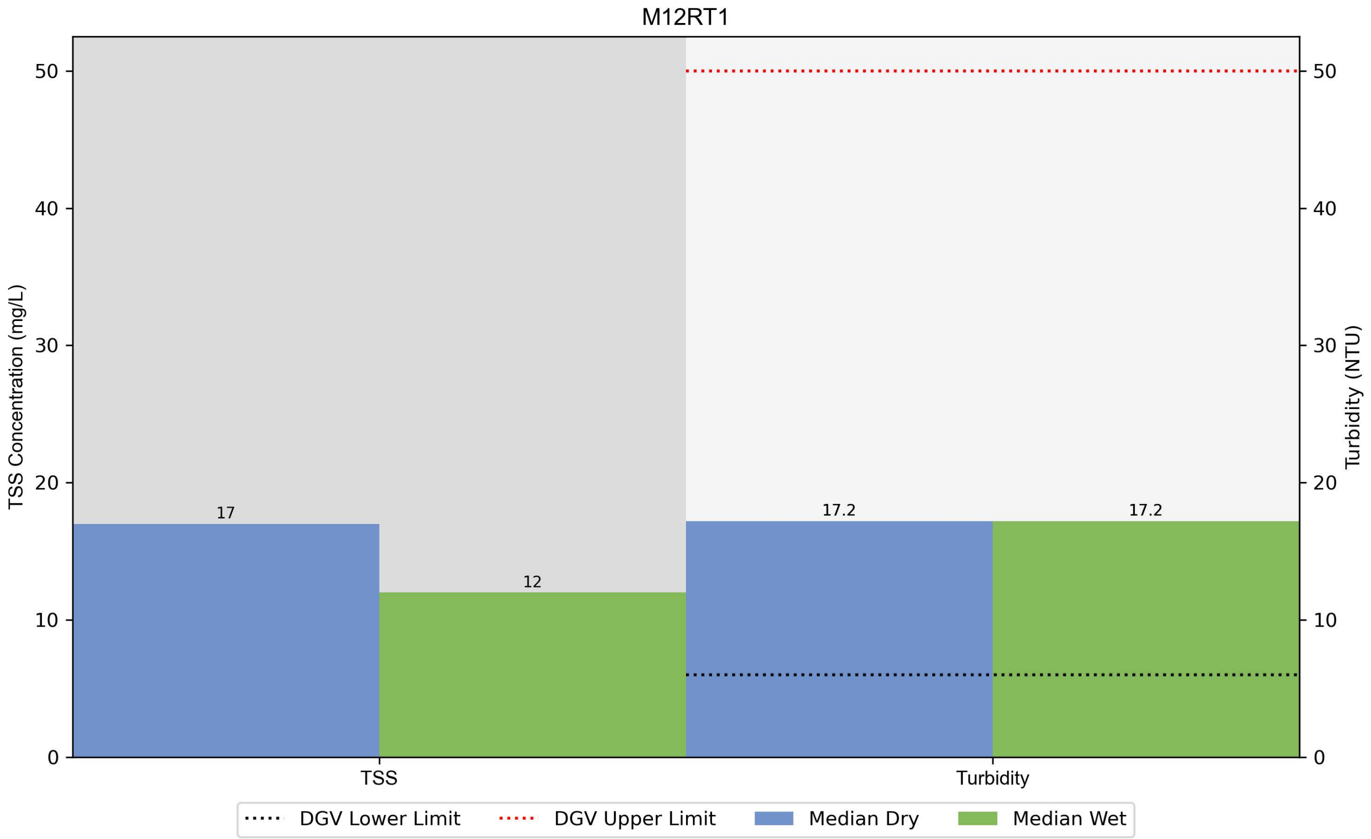


Figure 4-15 Median TSS and Turbidity for dry and wet weather at the monitoring site within Glenrowan Creek

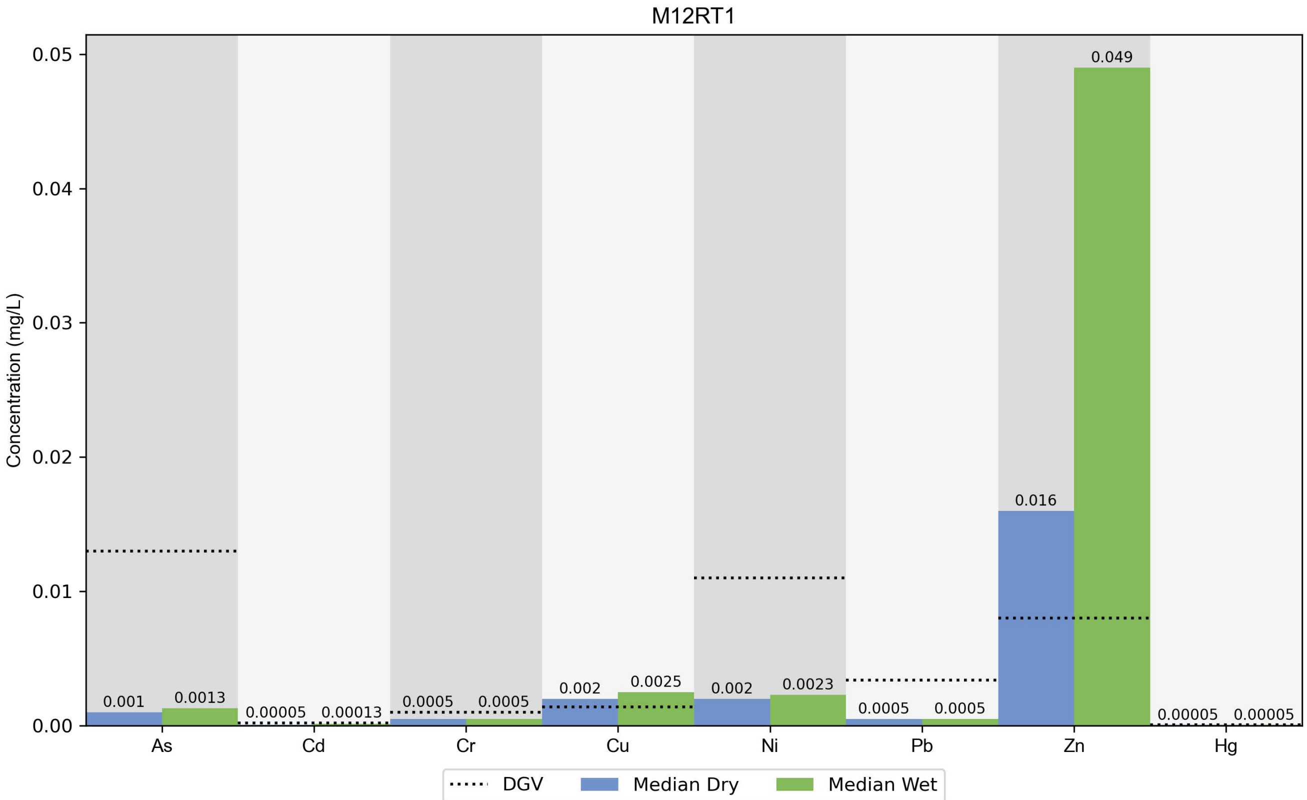


Figure 4-16 Median metal concentrations for dry and wet weather at the monitoring site within Glenrowan Creek

Stormwater is known to contain high levels of zinc which are transported via a drainage pipe that discharges into the tributary (refer to **Photo 4-22**). Overall the water quality could be considered 'very poor' for Glenrowan Creek (refer to Figure A-1 of **Appendix A**) and the WQO of aquatic ecosystems is currently not protected.

Visual observations over the sampling periods infers that the WQO visual amenity is currently not protected at Glenrowan Creek due to the presence of floating debris and nuisance organisms such as algae and aquatic weeds. During dry conditions the water was a translucent brown which became very murky and cloudy following rainfall. Median enterococci was high during both dry (60 CFU/100mL) and wet (2650 CFU/100ml) weather and primary contact recreation is not protected. The WQO secondary contact recreation is currently being met during dry weather. The high number of bacteria is caused by runoff from paddocks containing cattle and horse manure during wet weather or cattle defecation within waterways during dry weather and would pose a risk to recreational health if this site was used for recreational activities.

Photo 4-21 Presence of nuisance organisms at M12RT1

Photo 4-22 Stormwater outlet into M12RT1

4.6.3 Purgatory Creek

Purgatory Creek is a second-order stream, ephemeral in its upper reaches that drains to the Hunter River, the Coastal Wetlands south of the project which flow toward Hexham Swamp Nature Reserve. The creek drains a predominately agricultural catchment and has two floodgates installed in its lower reaches to control flooding (refer to **Figure 4-4**). As described in **Section 4.2.3,** one floodgate is located on Purgatory Creek about 30 metres from the confluence with the Hunter River. The other floodgate is located on the drainage canal between the Hunter River and Purgatory Creek. All monitoring sites (with the exception of M1RT2d) are located upstream of the floodgates. Therefore, the water quality of these sites would not be tidally influenced by water quality in the Hunter River while the gates are closed. Typically the water quality of drains/creeks upstream of floodgates is poorer due to nutrient and toxicant accumulation and low dissolved oxygen. It should be noted however that the conductivity of Purgatory Creek is representative of an estuarine environment and as such the relevant WQOs and guideline criteria for estuarine waterways has been applied. According to DECCW (2006), the nominated WQOs for Purgatory Creek are protection of aquatic ecosystems, visual amenity, primary and secondary contact recreation and aquatic foods (cooked).

Monitoring data from both dry and wet weather sampling indicates that the water quality of Purgatory Creek is 'very poor' and fails to protect the WQO protection of aquatic ecosystems (refer to Figure A-1 of **Appendix A**). WQOs were not met, due predominantly to elevated nutrients and turbidity with median concentrations exceeding DGVs. During dry weather, median total nitrogen concentrations ranged from

5.1 mg/L at the most upstream site (M12RT2) to 0.6 mg/L at the most downstream site (M12RT2c), although M12RT2a did have marginally lower median TN concentrations. Overall, total nitrogen concentrations in Purgatory Creek during dry weather is considerably higher than the DGV of 0.3 mg/L. Similar trends were observed following wet weather with the upstream sites having higher concentrations than the downstream sites, however median TN concentrations at M12RT2 and M12RT2b were lower than median dry weather (refer to **Figure 4-17**), possibly due to the increased stream flow in a typically stagnant section of the creek (refer to **Photo 4-23** and **Photo 4-24**).

Total phosphorus concentrations show a similar trend to total nitrogen during dry weather, with the highest median concentrations of 0.58 mg/L recorded at the most upstream site and median concentrations of 0.27 mg/L recorded at the most downstream site (refer to **Figure 4-17**). Turbidity were also elevated and exceeded the upper DGV of 10 NTU at all sites under wet and dry conditions (refer to **Figure 4-18**). Both pH and dissolved oxygen levels, which were very poor at the most upstream site, did improve at the downstream site. This generally indicates that the water quality of Purgatory Creek improves with distance downstream which is likely attributable to dilution and greater mixing with increased flow. Despite the improved concentrations downstream, Purgatory Creek water quality remains poor and could be considered eutrophic, largely due to the agricultural catchment draining to the creek and limited tidal flushing due to floodgates.

Metal analysis results show that mercury, lead and cadmium were the only metals to remain below the DGVs during dry weather. Median zinc concentrations exceeded the DGV of 0.015 mg/L at M12RT2a and M12RT2c during dry weather and M12RT2b during wet weather. Copper concentrations at the two upstream sites (M12RT2 and M12RT2b) exceeded the DGV during dry and wet weather. At the downstream sites (M12RT2a and M12RT2c), copper was only elevated following wet weather. Median nickel concentrations were generally less than the DGV in Purgatory Creek with the exception of M12RT2 during dry weather and M12RT2b during wet weather. Concentrations for copper and nickel at M12RT2d were only measured during wet weather and were below the DGV. Similar to nutrient concentrations, metal concentrations were highest at the upstream site M12RT2 except following wet weather when concentrations were generally higher downstream (refer to **Figure 4-19**). The downstream sites are also traversed by the New England Highway, Woodlands Close and Main North Rail Line which would receive stormwater runoff containing high concentrations of these toxicants.

Overall, the water quality of Purgatory Creek (M12RT2 – M12RT2d) is ‘very poor’ and infers that the water quality objective of protection of aquatic ecosystems is not protected (refer to Figure A-1 of **Appendix A**).

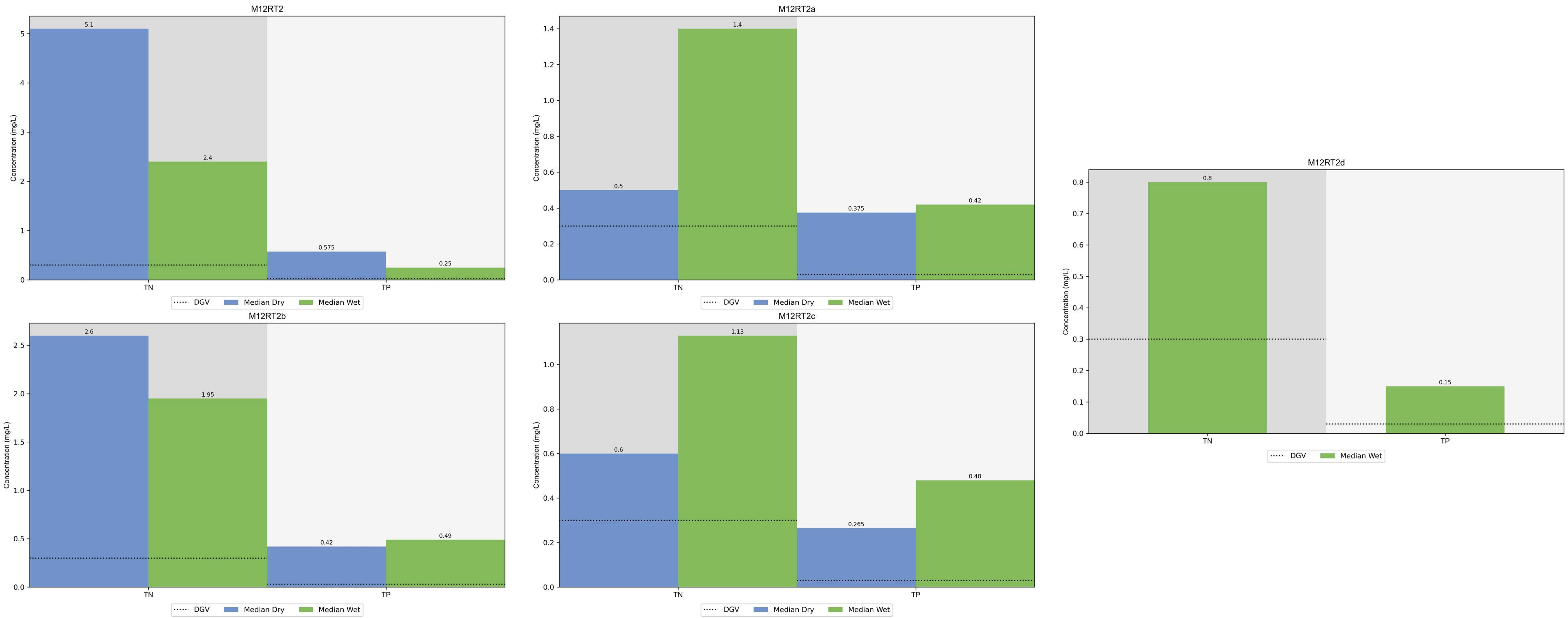


Figure 4-17 Median nutrient concentrations in dry and wet conditions at the five monitoring sites within Purgatory Creek

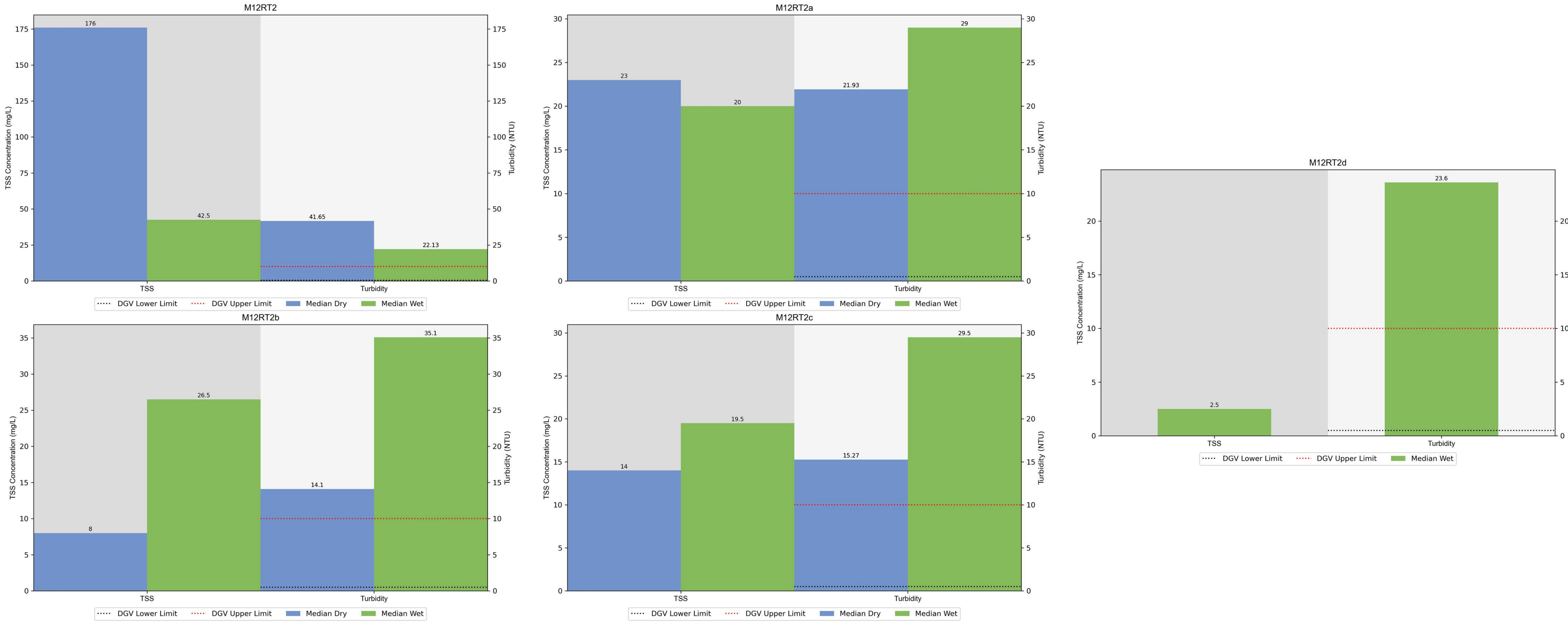


Figure 4-18 Median TSS and Turbidity in dry and wet conditions at the five monitoring sites within Purgatory Creek

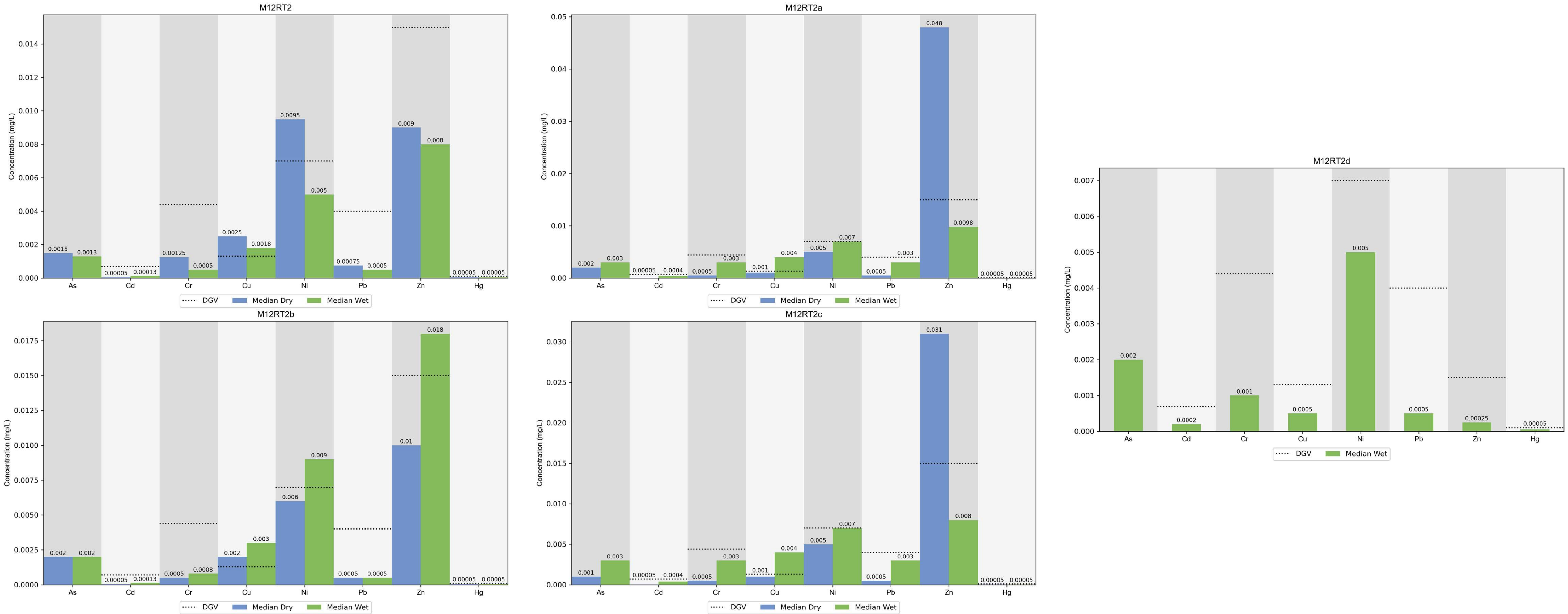


Figure 4-19 Median metal concentrations in dry and wet conditions at the five monitoring sites within Purgatory Creek

The visual appearance of Purgatory Creek varied between sites. Generally, the most upstream site, M12RT2, appeared to have the poorest visual amenity, due to thick turbid brown stagnant water, often covered in aquatic weeds and algae. Cattle faeces were also frequently observed at this site. The other sites while also brown and slightly turbid did have some transparency throughout the water column. These sites were impacted by algae, but at a much lower density than M12RT2. Despite the slightly improved appearance of the creek in downstream reaches, the WQO for protection of visual amenity is currently not being achieved at any site.

Enterococci were generally recorded in low numbers in Purgatory Creek during dry weather with median numbers ranging between 13 CFU/100mL to 47 CFU/100mL, with the WQO for primary contact recreation currently being protected during dry weather at M12RT2, M2RT2b and M12RT2c and the WQO for secondary contact recreation protected at all sites. Following wet weather, median numbers increased significantly ranging between 600 CFU/100mL and 2200 CFU/100mL and therefore the recreation WQOs are currently not being protected. The higher numbers following wet weather would be attributable to runoff from cattle manure.

As Purgatory Creek is categorised as estuarine (DECCW 2008), it has also been assigned the WQO ‘Aquatic Foods’ (cooked) for protection. Current water quality data infers that this objective is rated as ‘very poor’ for all sites except for the most downstream sites M12RT2c, which was rated as ‘poor’. The protection of the WQO is not achieved largely due to elevated zinc levels. Additionally, where data was available, total suspended solids and dissolved oxygen, particularly at the more upstream sites did not meet the relevant DGVs.

Photo 4-23 M12RT2 during dry weather

Photo 4-24 M12RT2 following rainfall

4.6.4 Hexham Swamp Nature Reserve

Hexham Swamp Nature Reserve is a large state recognised wetland identified under the Coastal Management SEPP and lies to the south of the project. The wetland receives water from the west and is maintained by rainfall. It has floodgates to manage saltwater incursions (refer to **Figure 4-4**) and as such it is predominantly a freshwater body of water. As flow is limited there is minimal opportunity for flushing and dilution if contamination of the wetland were to occur (PB, 2012).

There has been no current monitoring of Hexham Swamp Nature Reserve, with the only data available from August and September 2011 (PB, 2012). As the swamp falls into the category National Parks, Nature Reserves and State Forests, the nominated WQOs are for protection include aquatic ecosystems, visual amenity and primary and secondary contact recreation. Due to limited data, only the protection of aquatic ecosystems in Hexham Swamp Nature Reserve could be assessed. Data from PB (2012) indicated that aquatic ecosystem compliance is considered ‘poor’ at the time of collection. This ‘poor’ rating was due to pH and dissolved oxygen being outside acceptable limits and elevated nutrients. At the time of sampling, the swamp was mildly acidic and dissolved oxygen levels were variable with both anoxic and supersaturated levels recorded (PB, 2012). Nutrient concentrations including ammonia, total nitrogen, total phosphorus and filterable reactive phosphorus exceeded the guideline limit inferring that the swamp is eutrophic.

4.6.5 Mid Site Channel

Mid Site Channel is in close proximity to the project and collects water from South East Tarro residential areas and sections of the Coastal Wetland area Mid Site Channel discharges to Purgatory Creek east of the New England Highway (UHVA, 2013a). The water quality of Mid Site Channel was monitored between 2012 and 2018 by ARTC. The nominated WQOs for the channel include protection of aquatic ecosystems, visual amenity, primary and secondary recreation and aquatic foods (cooked).

Water quality results indicate that Mid Site Channel rated ‘very poor’ for protection of aquatic ecosystems due to elevated nutrients and turbidity. The waterway is extremely eutrophic with TP concentrations being almost 10 times the DGV and TN concentration up to 6.5 times the more than the DGV. Metal concentrations were generally low with the exception of zinc, nickel and copper that were recorded in elevated concentrations on occasion.

No visual observations or bacteriological data were recorded by ARTC during their monitoring and therefore it cannot be confirmed if the WQOs protection of visual amenity and recreation are being protected in Mid Site Channel.

Mid Site Channel has also been assigned the WQO ‘Aquatic Foods’ (cooked) for protection. Current water quality data infers that this objective is rated as ‘very poor’ and ‘poor’ for MSC1 and MSC2 respectively. Elevated TSS and zinc concentrations were the main cause of the low ratings.

4.6.6 Hunter River

Hunter River mainstream (estuarine section)

The Hunter Estuary is the tidal portion of the Hunter River. The estuary extends up to the tidal line of the Hunter River at Oakhampton (64 kilometres from the ocean). As such, the portion of the Hunter River that has the potential to be impacted by the project is classified as estuarine and therefore has the WQOs of aquatic ecosystems, visual amenity, primary and secondary contact recreation and aquatic foods (cooked) nominated for protection as identified in **Table 3-3**.

Monitoring along the Hunter River has been carried out by EES Group and Transport, as shown in **Figure 4-6**. Eleven locations were monitored including those on the south and north channels by EES Group, and two of these locations fall within the main alignment. EES Group monitoring also includes a site upstream and downstream of the proposed Hunter River crossing. Transport have also carried out project-specific monitoring at three locations on the river and at two unnamed drainage lines of the Hunter River. While not all sites monitored fall within the construction footprint, the water quality of the Hunter River as a whole has been assessed, particularly as the river is tidal and water quality downstream can influence water quality upstream on an incoming tide.

Monitoring data collected by EES Group between August 2014 and March 2015 at all sites were compared against the relevant DGV for indicators to determine if the WQO for estuarine aquatic ecosystems is currently protected. Aquatic ecosystems is currently protected at one site (Hunter River at Newcastle Harbour, HNT1) and rated ‘good’ with relevant indicators below DGVs at all times. This site is the most downstream located in the Hunter River just before it discharges to the ocean at Stockton Beach where tidal flushing is greatest. All other sites were rated ‘very poor’, with the exception of HNT3 (North Channel Hunter River) which was ‘poor’. The ‘very poor’ and ‘poor’ rating for aquatic ecosystems at the sites was predominantly due to elevated chlorophyll-*a* and total phosphorus concentrations. Total nitrogen concentrations were also elevated at the upstream sites (HNT4-HNT7).

Project specific water quality monitoring has also been carried out by Transport on numerous occasions at the following sites:

- M12RT3 Hunter River (upstream)
- M12RT3a Hunter River (midstream)
- M12RT3b Hunter River (downstream).

Monitoring data from both dry and wet weather sampling indicates that the water quality of the Hunter River itself is generally poor, frequently failing to meet the recommended DGV for numerous indicators for protection of aquatic ecosystems (refer to Figure A-1 of **Appendix A**). Turbidity levels frequently exceeded the upper DGV of 10 NTU (refer to **Figure 4-21**) and nutrients were consistently recorded in high concentrations during both dry and wet weather sampling (refer to **Figure 4-20**). Median nutrient concentrations were highest at the most downstream site, M12RT3b. As sampling was carried out on a receding tide the water quality of this site would be influenced by upstream water quality and inflows from Purgatory Creek. While lower concentrations were recorded at the mid site M12RT3a, this was a single sampling event.

Metal concentrations were generally low, with only copper and zinc median concentrations above recommended DGVs at M12RT3 during dry weather (refer to **Figure 4-22**). Following wet weather, metal concentrations generally decreased. The source of metals in the Hunter River could be attributable to leaching from contaminated soils or from runoff or by-products of industrial activities (OEH, 2017). Dissolved oxygen levels were occasionally below the lower DGV of 80 per cent saturation, particularly at M12RT3b and pH levels were within acceptable range of 7-8.5 on all sampling events (wet and dry). Overall, the Hunter River mainstream has a ‘very poor’ rating. The WQO aquatic ecosystems is currently not protected at these locations in the Hunter River (refer to Figure A-1 of **Appendix A**).

Visual observations over the sampling period infer that that the WQO visual amenity within the Hunter River is generally not met during dry and wet weather. The Hunter River was often observed to be brown and turbid in appearance with an oily sheen. During wet weather sampling, frothing was observed on the surface which is not uncommon following rainfall, potentially due to surfactant chemicals (natural or synthetic) in the water.

The WQO primary contact recreation is currently not protected at M12RT3 and M12RT3b during dry weather due to median numbers of 36 CFU/100mL and 45 CFU/100mL respectively, exceeding the DGV. Only one dry weather sample was collected at M12RT3a, with enterococci of 16 CFU/100mL recorded. The WQO for secondary contact recreation was protected at all sites during dry weather. As expected, enterococci numbers increased following rainfall and were generally more than three times the numbers recorded during dry weather and whilst the WQO for primary contact recreation was not protected, numbers complied with the DGVs for secondary contact recreation.

The Hunter River has also been assigned the WQO aquatic foods (cooked) for protection. The protection of this objective was assessed in the Hunter River mainstream and while most indicators generally complied (>75 per cent of the time) with the relevant guidelines, two indicators, TSS and zinc were consistently higher than the recommended limit for aquatic foods (cooked). Total suspended solid concentrations for protecting aquatic foods (cooked) are recommended to be less than the DGV of 10 mg/L but were frequently higher than this during dry weather. Zinc concentrations were elevated above the DGV of 0.005 mg/L on half of the sampling occasions. Based on these results, this objective is currently not being protected and rated ‘very poor’ (refer to Figure A-1 of **Appendix A**).

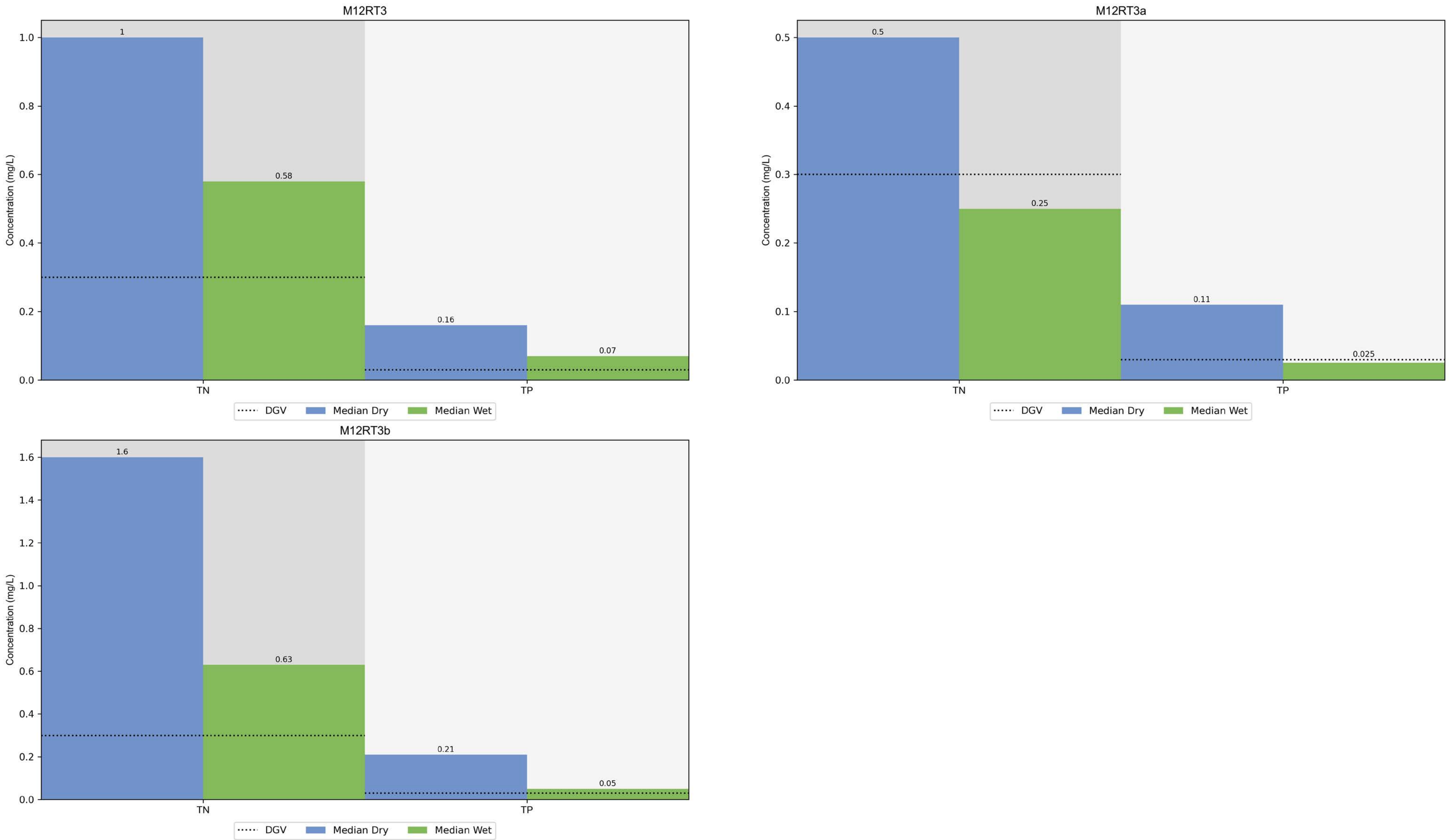


Figure 4-20 Median nutrient concentrations in dry and wet conditions at the three monitoring sites within Hunter River

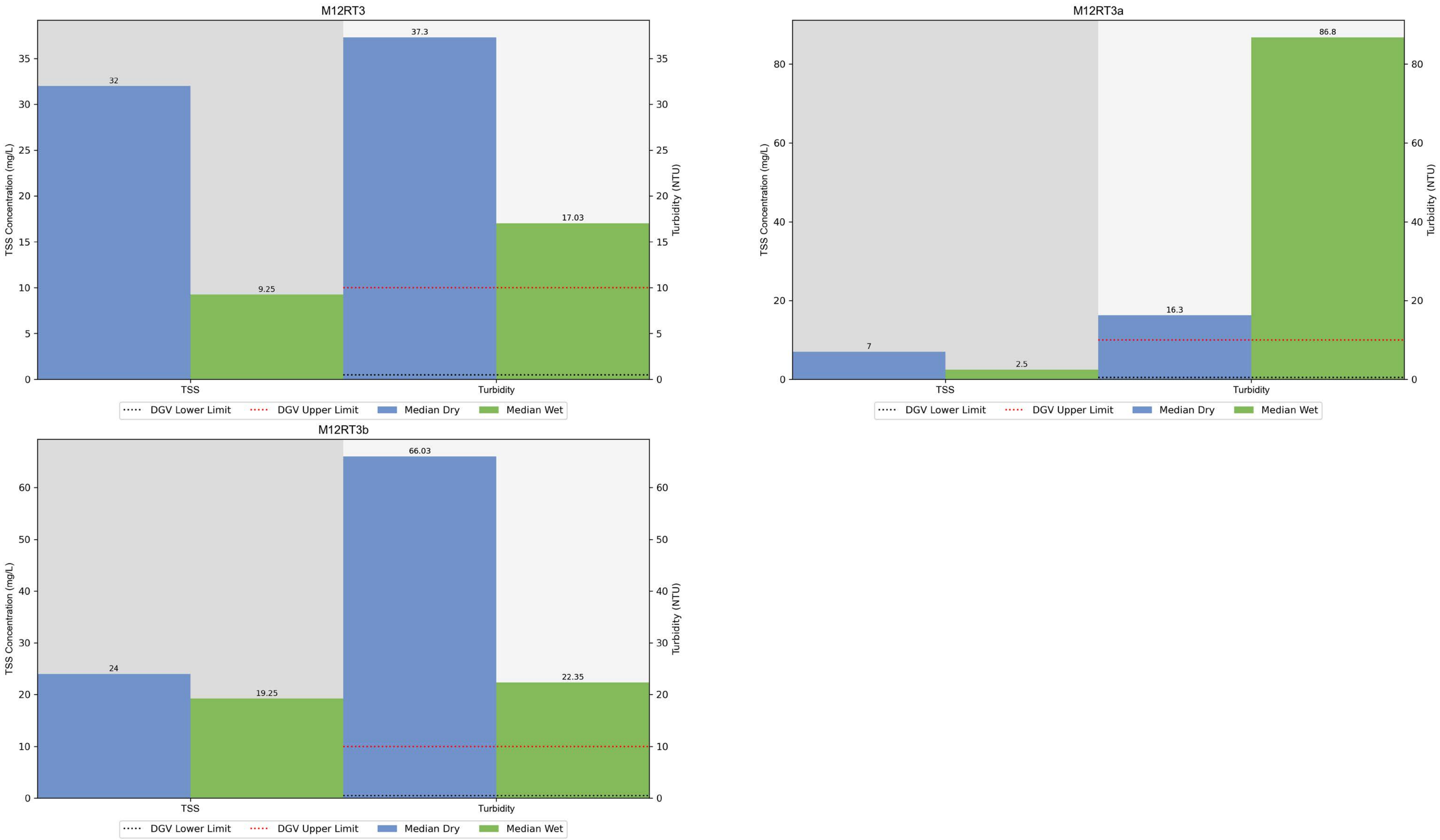


Figure 4-21 Median TSS and Turbidity in dry and wet conditions at the three monitoring sites within Hunter River

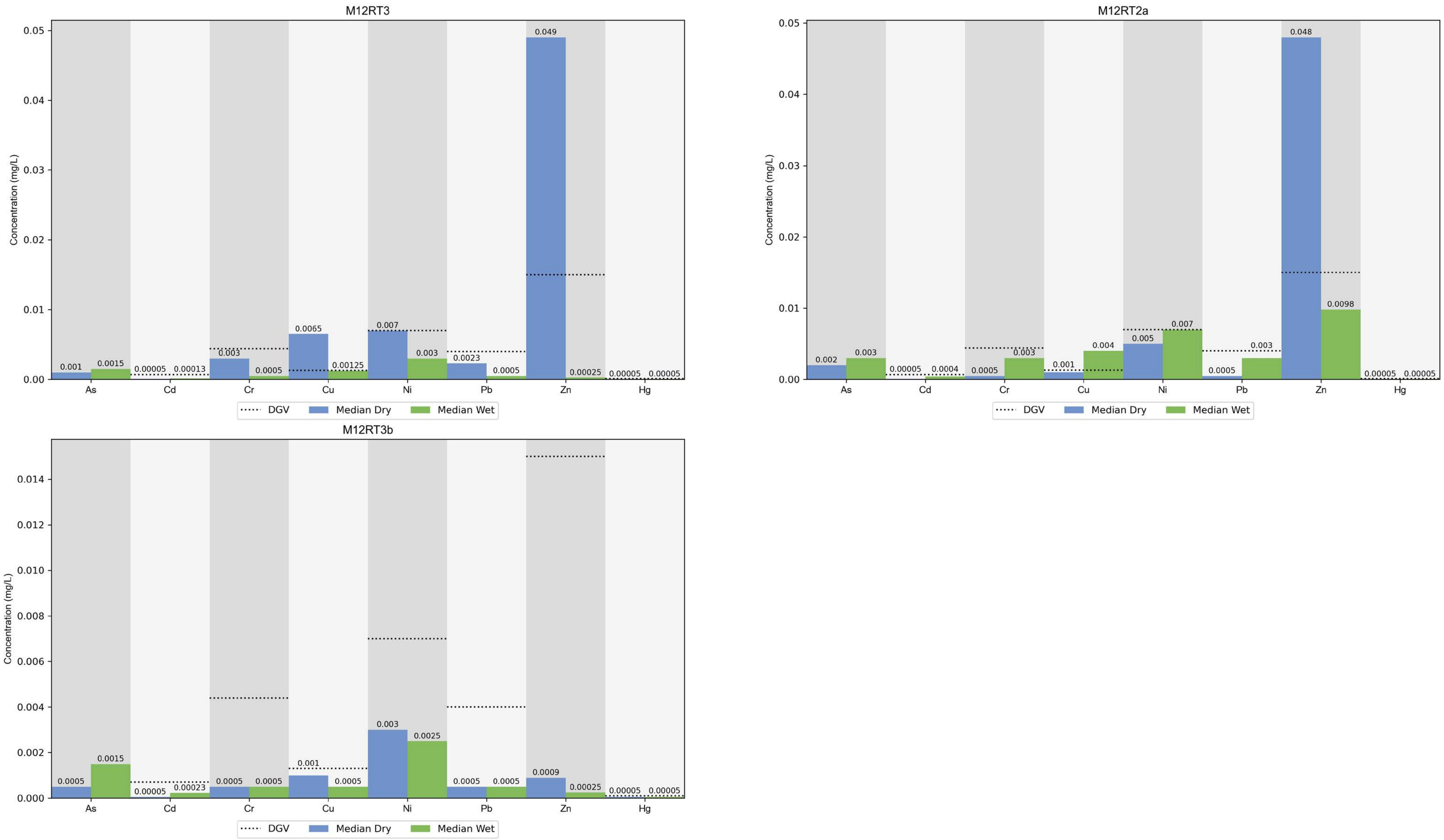


Figure 4-22 Median metal concentrations in dry and wet conditions at the three monitoring sites within Hunter River

Hunter River drains

There are several drains that would typically be tidally influenced by the Hunter River if not controlled by floodgates. Two monitoring sites, M12RT4 and M12RT5, are located on these drains and as such the flow and water quality is not reflective of typical estuarine water quality and natural tidal flows of the Hunter River. The drains are located within a stud farm and have the nominated WQOs of protection of aquatic ecosystems and visual amenity. Despite the disconnection from the Hunter River, the sites are still classified as estuarine with median electrical conductivities ranging between 4163 µS/cm and 7235 µS/cm.

Over the sampling period, up to five dry weather samples and two wet weather samples were collected. Water quality at the time of sampling (dry and wet) did not meet the DGVs for protection of estuarine aquatic ecosystems for a number of indicators and could be considered to exhibit poor water quality (refer to **Appendix A**). The only indicators where median concentrations met the DGVs included pH (during dry weather at both sites and wet weather at M12RT5) and the metals; cadmium, chromium, lead and mercury (refer to **Figure 4-25**). Median turbidity generally exceeded the upper DGV of 10 NTU with concentrations more than two to seven times higher (refer to **Figure 4-24**) and dissolved oxygen concentrations consistently below the DGV. Nutrient concentrations were very high, and while median concentrations were slightly lower at M12RT4, concentrations at both sites were higher than DGVs; between three to 10 times for TN and 14-34 times for TP as shown in **Figure 4-23**. This poor water quality was attributable to the land use surrounding these drains, exacerbated by the low flowing, turbid water that was frequently observed (refer to **Photo 4-25**). The surrounding land use is a stud farm which can lead to nutrient rich runoff from fertilised pastures and from horse faeces. Total phosphorus is very high at these sites due to the inability for horses to digest many types of phosphorus which is subsequently excreted and then washed into waterways. Based on the above-mentioned results, the Hunter River drains have been assigned a ‘very poor’ rating for protection of aquatic ecosystems (refer to Figure A-1 of **Appendix A**).

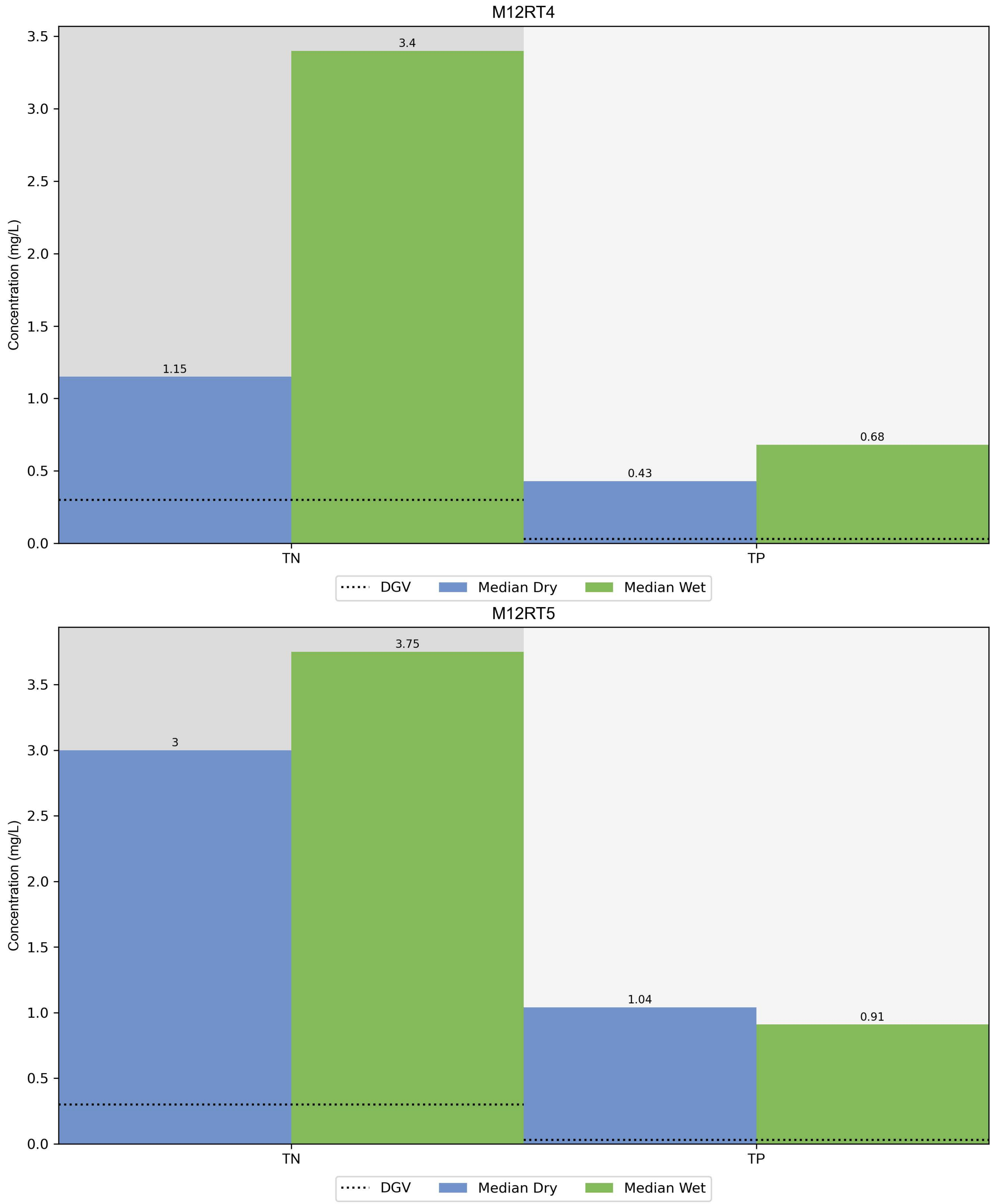


Figure 4-23 Median nutrient concentrations in dry and wet conditions at the two monitoring sites within Hunter River Drain

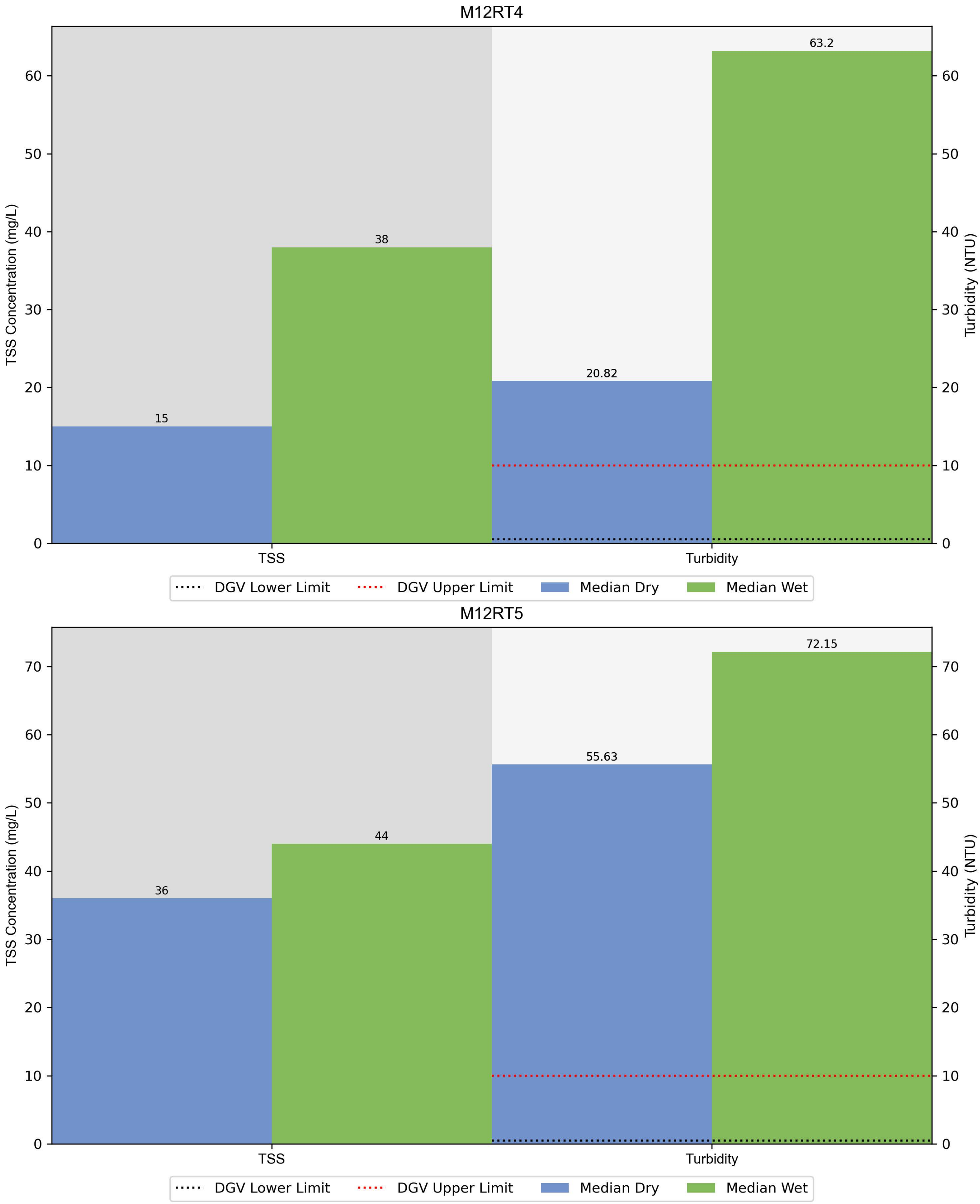
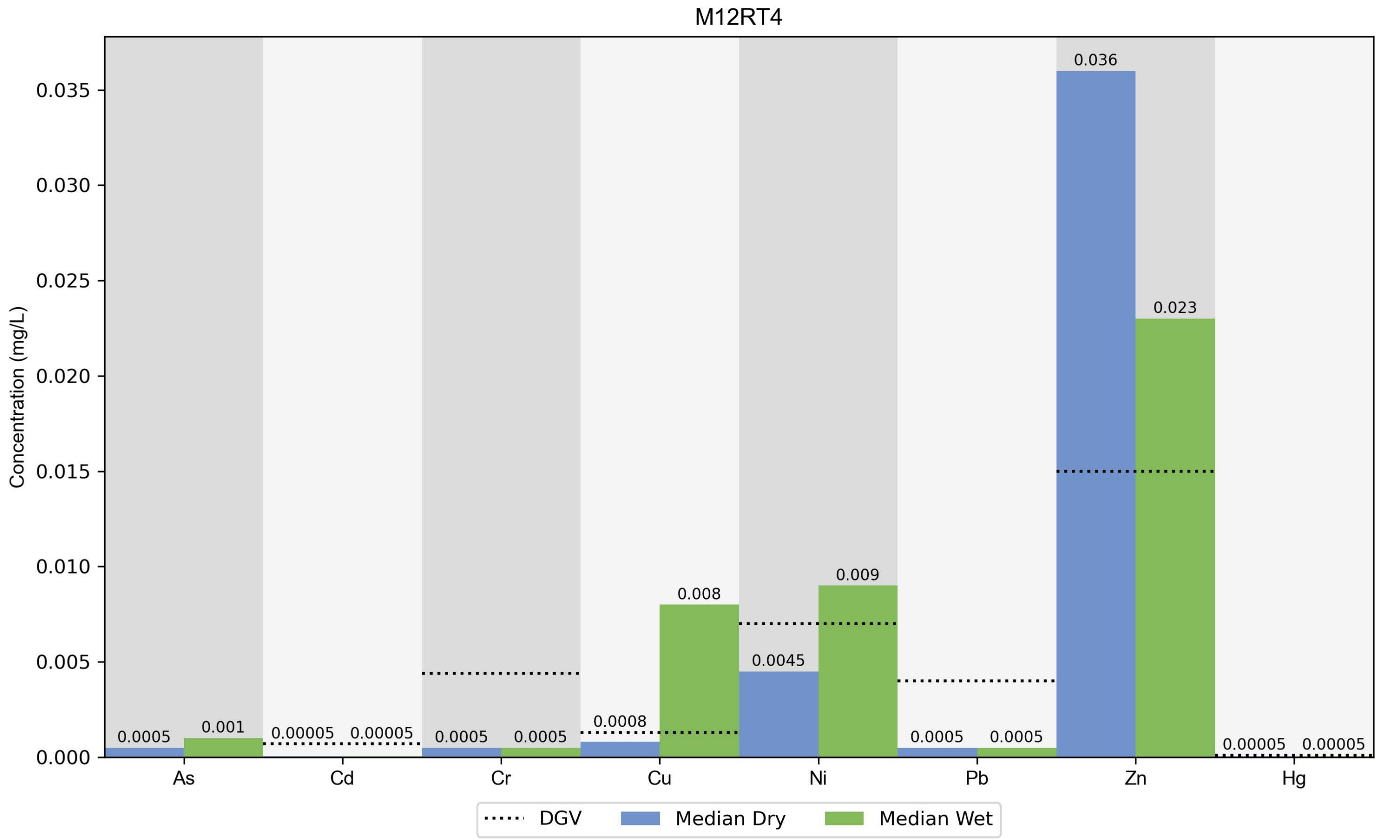


Figure 4-24 Median TSS and Turbidity in dry and wet conditions at the two monitoring sites within Hunter River Drain



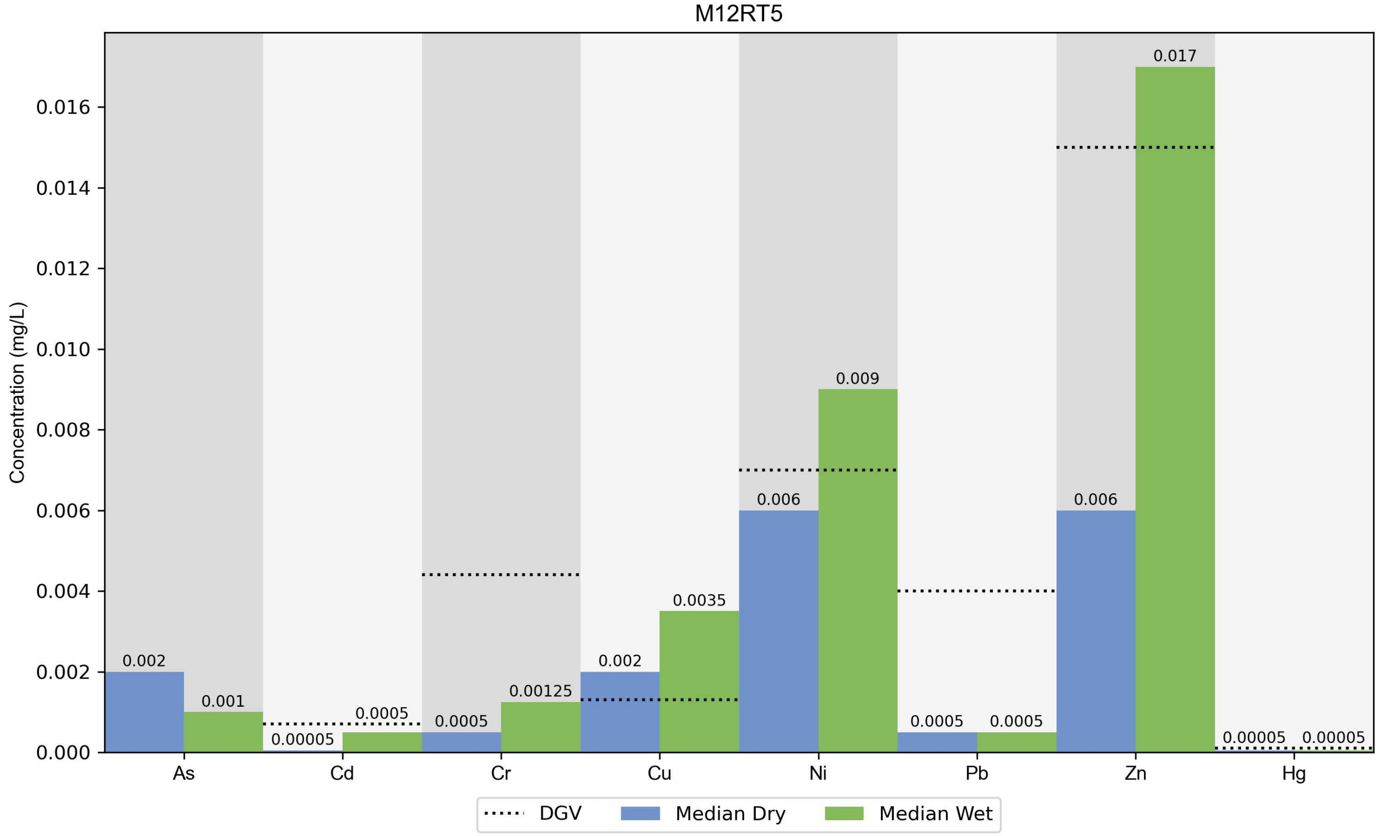


Figure 4-25 Median metal concentrations in dry and wet conditions at the two monitoring sites within Hunter River Drain

Visual observations over the sampling period infer that the WQO visual amenity within the Hunter River Drain is not being protected due to brown muddy turbid water and oily sheens.

Photo 4-25 M12RT4, low flow turbid water

Hunter River wetland

Monitoring of a wetland (referred to as Hunter River wetland, M12RT8) next to the Hunter Region Botanic Gardens has been carried out by Transport.

Monitoring of this wetland has been carried out on one occasion in June 2018 during dry weather. On all other sampling events, including following rainfall events, the wetland was dry and there was insufficient water to conduct sampling (see **Photo 4-26**).

Water quality of the wetland in 2018 during dry weather could be considered 'very poor' and did not meet the DGVs for protection of aquatic ecosystems. Nutrients, both total phosphorus and nitrogen, were higher than the recommended DGVs of 0.025 mg/L and 0.35 mg/L respectively (refer to **Figure 4-26**). pH and dissolved oxygen levels were lower than the minimum DGV ranges. Median Turbidity were below the DGV of 10 NTU (refer to **Figure 4-27**). Metal concentrations were low at the time of sampling, all meeting the relevant species protection limit DGVs with the exception of zinc, which was measured in concentrations three times the DGV (refer to **Figure 4-28**).

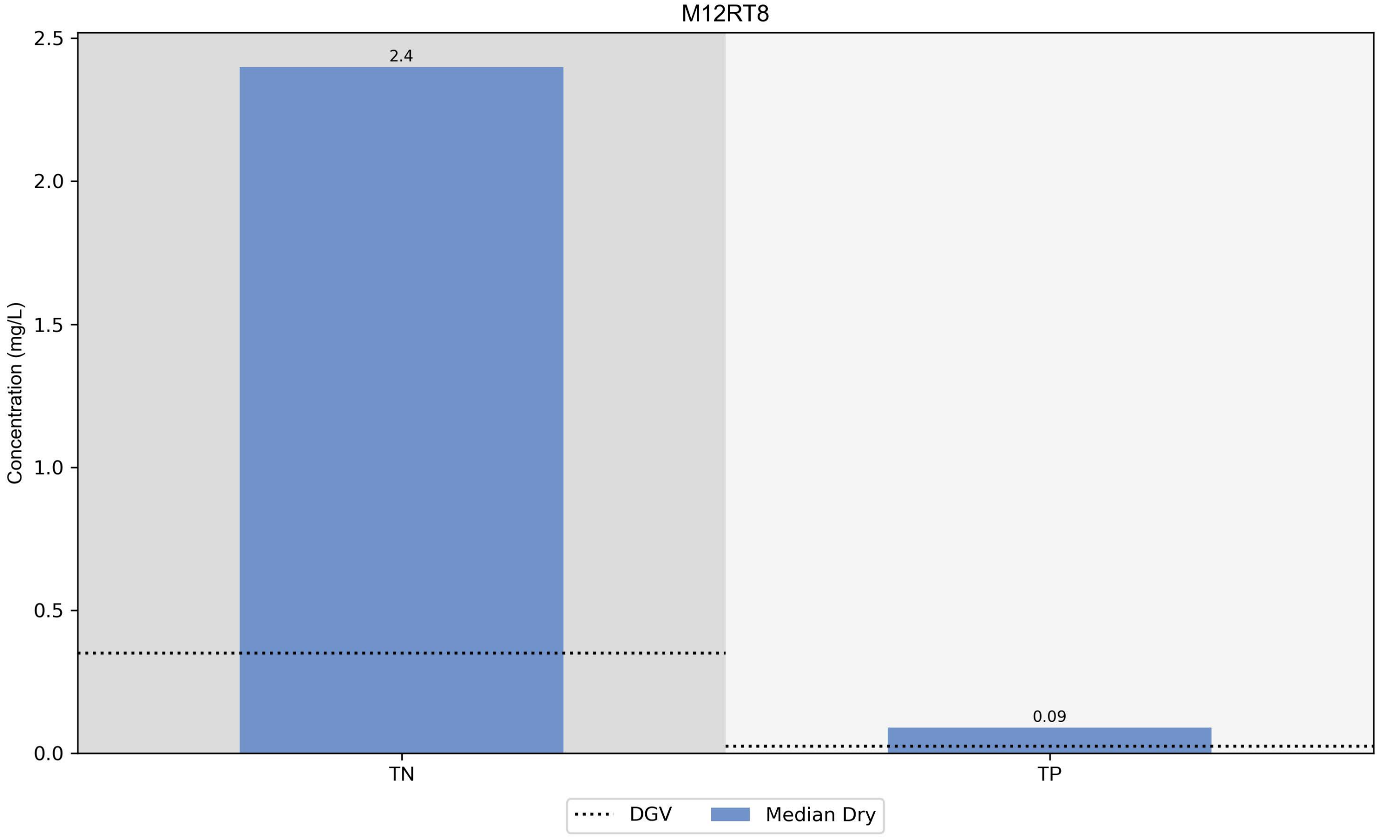


Figure 4-26 Median nutrient concentrations for dry weather at the monitoring site within the Hunter River wetland

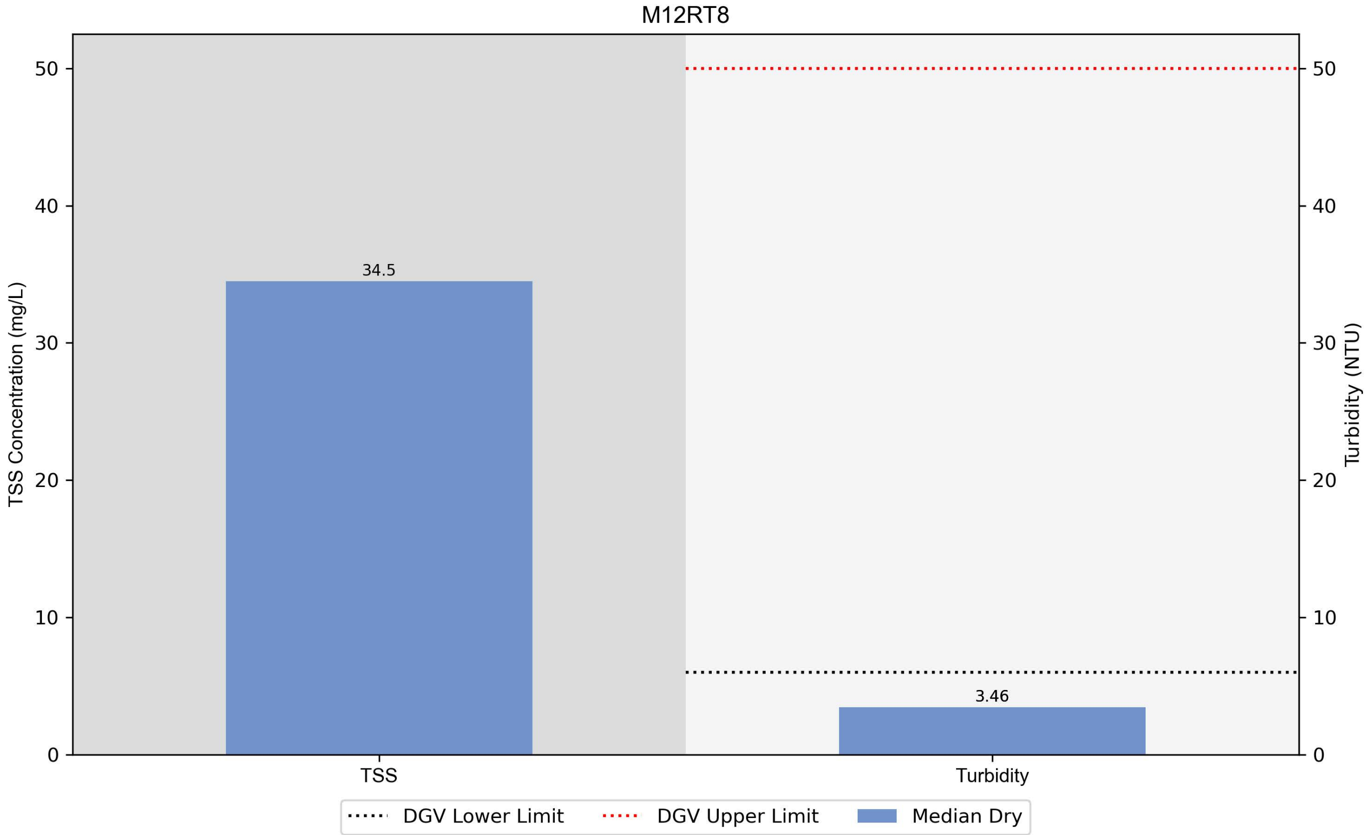


Figure 4-27 Median TSS and Turbidity for dry weather at the monitoring site within the Hunter River wetland

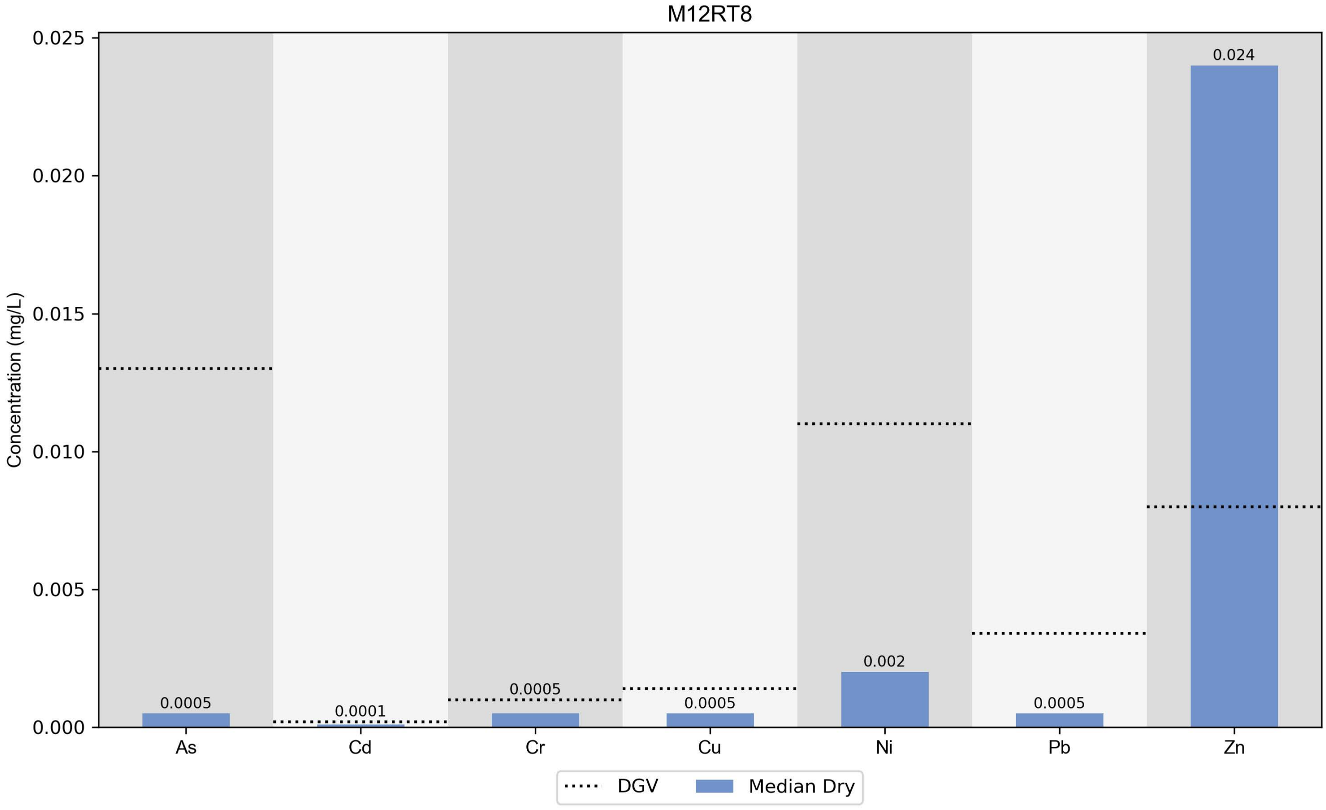


Figure 4-28 Median metal concentrations for dry weather at the monitoring site within the Hunter River wetland

Photo 4-26 M12RT8, Wetland with no water

Drainage canal, Old Punt Road

A drainage canal opposite Old Punt Road, which discharges to the Hunter River, has been monitored by Transport on five occasions during dry weather and twice following rainfall (M12RT9). This site is estuarine and would receive flows from the Hunter River on an incoming tide and discharges to the Hunter River on an ebb tide. The state government endorsed WQOs for this site are protection of aquatic ecosystems, visual amenity, primary and secondary contact recreation and aquatic foods (cooked).

The water quality of this site could be considered ‘very poor' with median concentrations of many indicators failing to meet the recommended DGVs for protection of aquatic ecosystems during dry and wet weather (refer to Figure A-1 of **Appendix A**). Indicators which did meet DGVs included pH and all metals except copper (refer to **Figure 4-31**). Median dissolved oxygen concentrations ranged between 75.8 and 86.7 per cent saturation during dry and wet weather, with median dry weather concentrations falling below the lower DGV of 80 per cent saturation. Median turbidity levels were higher than the upper DGV of 10 NTU during both dry and wet weather, with higher Turbidity recorded during dry weather (refer to **Figure 4-30**). Similar to the Hunter River itself, nutrient concentrations were higher than the recommended DGVs for protection of aquatic ecosystems during both dry and wet weather (refer to **Figure 4-29**), as were concentrations of copper (refer to **Figure 4-31**). This canal drains a largely industrial area which provides little protection to water quality, contributing nutrients and metals to the canal and indirectly to the Hunter River, either from runoff or discharge of organic wastes (refer to **Photo 4-27**).

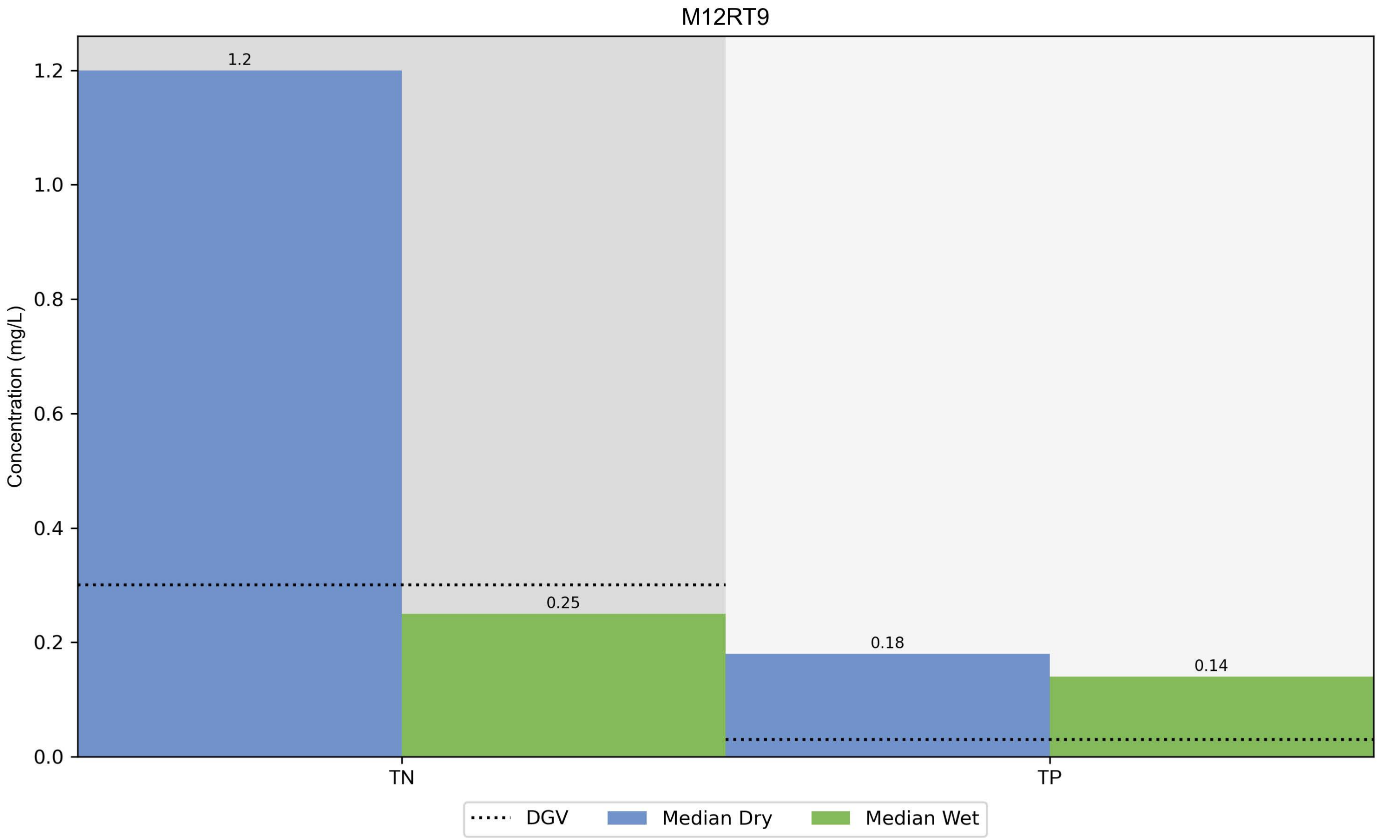


Figure 4-29 Median nutrient concentrations for dry and wet weather at the monitoring site within the drainage canal, Old Punt Road

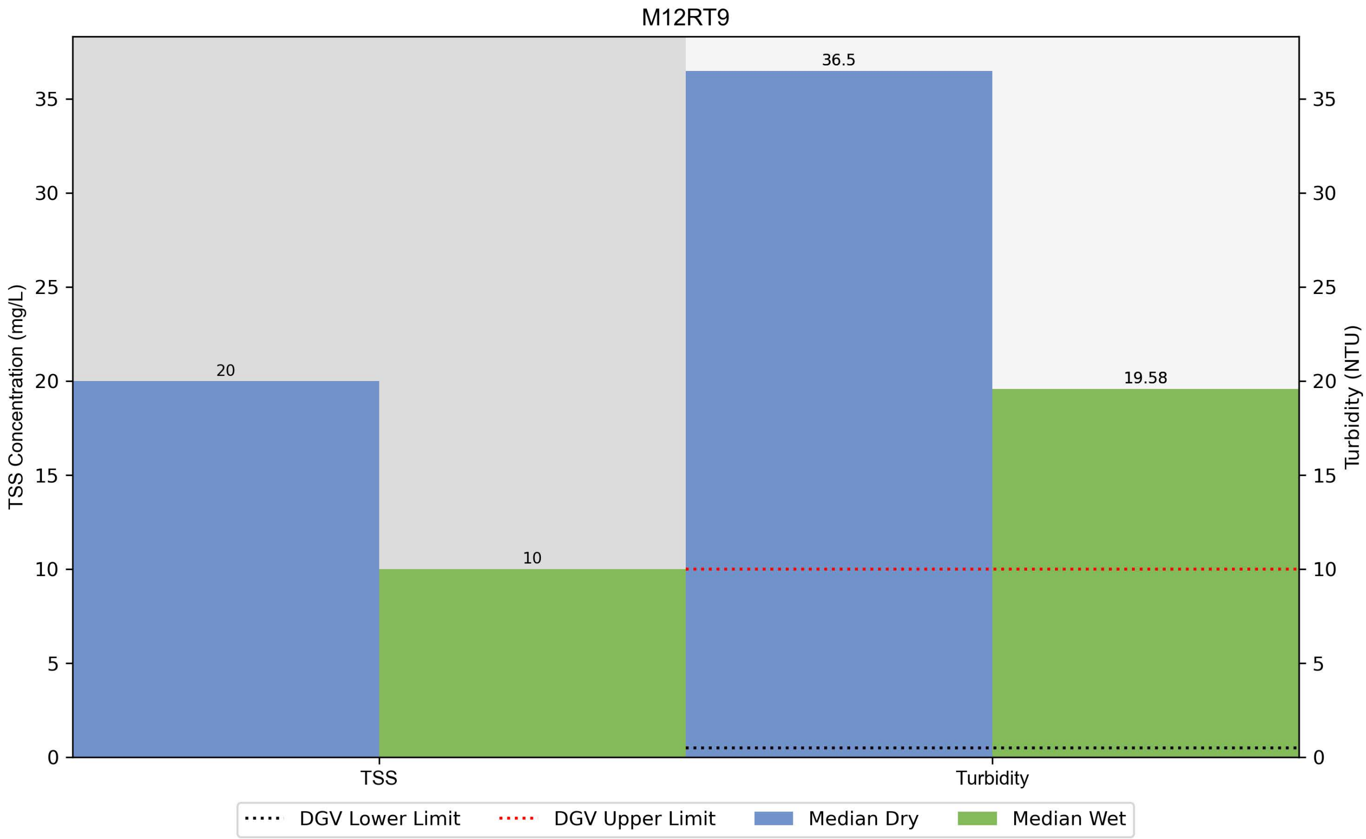


Figure 4-30 Median TSS and Turbidity for dry and wet weather at the monitoring site within the drainage canal, Old Punt Road

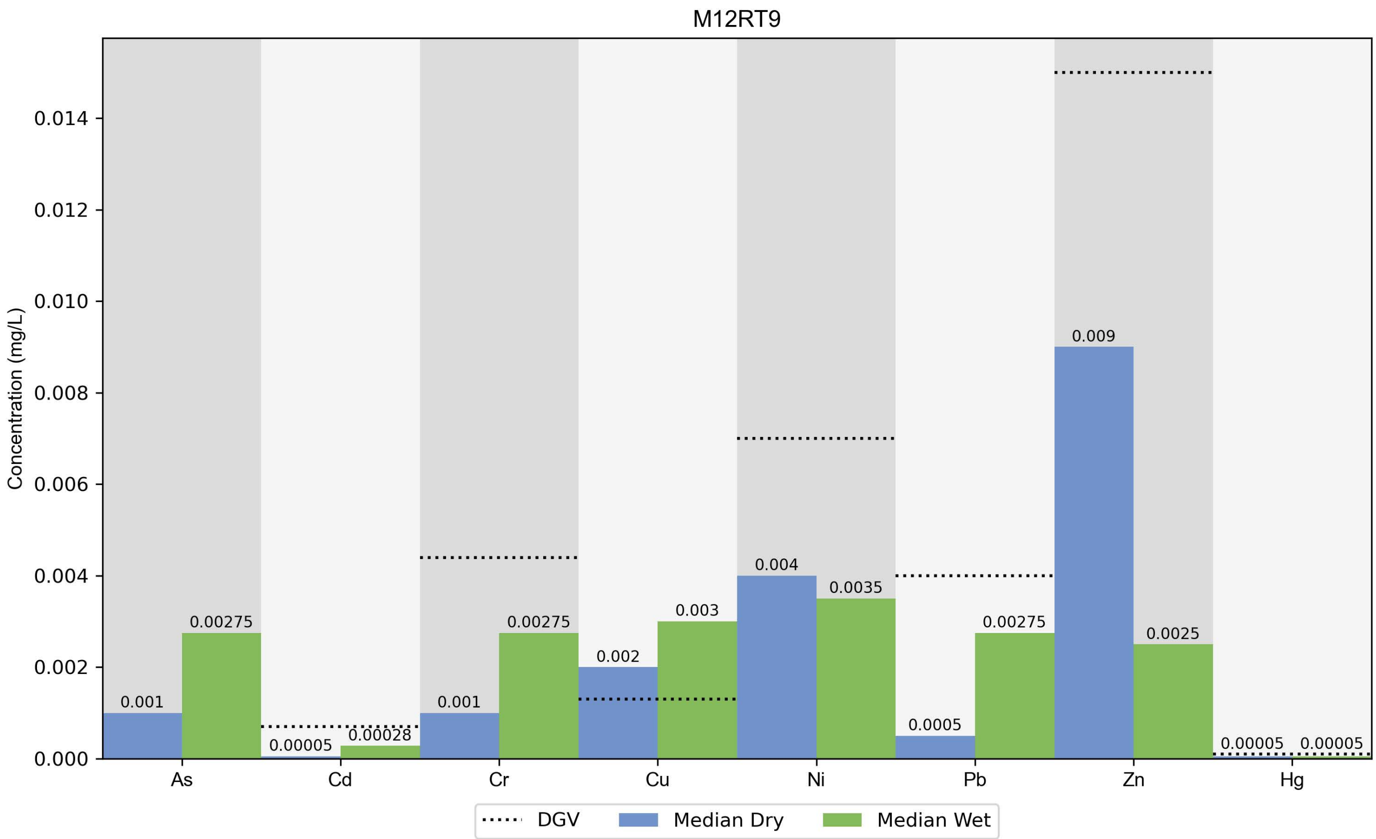


Figure 4-31 Median metal concentrations for dry and wet weather at the monitoring site within the drainage canal, Old Punt Road

Photo 4-27 M12RT9 and surrounding catchment

Visual observations over the sampling period infer that the WQO visual amenity is generally not protected due to turbid brown water which generally becomes more turbid and oily following rainfall.

Based on the few sampling occasions carried out by Transport, enterococci within the canal were recorded in relatively small numbers (median 22 CFU/100mL) during dry weather but increasing to 60 CFU/100mL following wet weather. Therefore, at the time of sampling the WQO for primary contact recreation was protected during dry weather only, and secondary contact recreation during both dry and wet weather.

Water quality at this site also fails to protect the WQO of aquatic foods (cooked) due to elevated total suspended solids on all occasions and elevated zinc and low dissolved oxygen on two and one occasion respectively. As such the overall rating for protection of the WQO is considered 'very poor' (refer to Figure A-1 of **Appendix A**).

4.6.7 Unnamed Coastal Wetland

An unnamed coastal wetland has been monitored at site M12RT11a, as it has the potential to be impacted by drainage from the project, lying within both the construction and operational footprints. As mentioned previously, flow to and from the wetland is controlled by floodgates, located at the downstream extent of the drain connecting the wetland to the Hunter River. Water quality monitoring of this wetland only commenced in February 2020 as the previous site became inaccessible and this site was more closely aligned to the construction footprint. As such, three dry weather and two wet weather sampling events have been carried out. The state government endorsed WQOs for the wetland are protection of estuarine aquatic ecosystems and visual amenity.

The water quality of the wetland could be considered ‘very poor’ and generally did not meet the DGVs for the indicators relevant to protection of aquatic ecosystems for the indicators of dissolved oxygen, turbidity, nutrients and some metals (zinc and copper) during both dry and wet weather. Median dissolved oxygen levels during dry and wet weather sampling ranged between 50-55 percent saturation falling below the lower DGV of 80 per cent saturation. Turbidity ranged between 20-25 NTU exceeding the recommend DGV of 10 NTU (refer to **Figure 4-33**). Similar to other sites located along the drains, nutrients were recorded in high concentrations during both dry and wet weather, however the order of magnitude was not as high as M12RT4 or M12RT5, particularly for total phosphorus, as unlike M12RT4 and M12RT5 which drain a stud farm, this wetland drains a predominantly cattle grazing area (refer to **Figure 4-32**). Zinc and copper concentrations were also higher than the DGVs for protection of aquatic ecosystems, with median zinc concentrations during dry weather higher than any other monitoring sites (refer to **Figure 4-34**). The site drains an agricultural area and zinc could be from farming practices and application of fertilisers which can result in zinc leaching out of the soil leading to further increases in zinc concentrations following rainfall (refer to **Photo 4-28**).

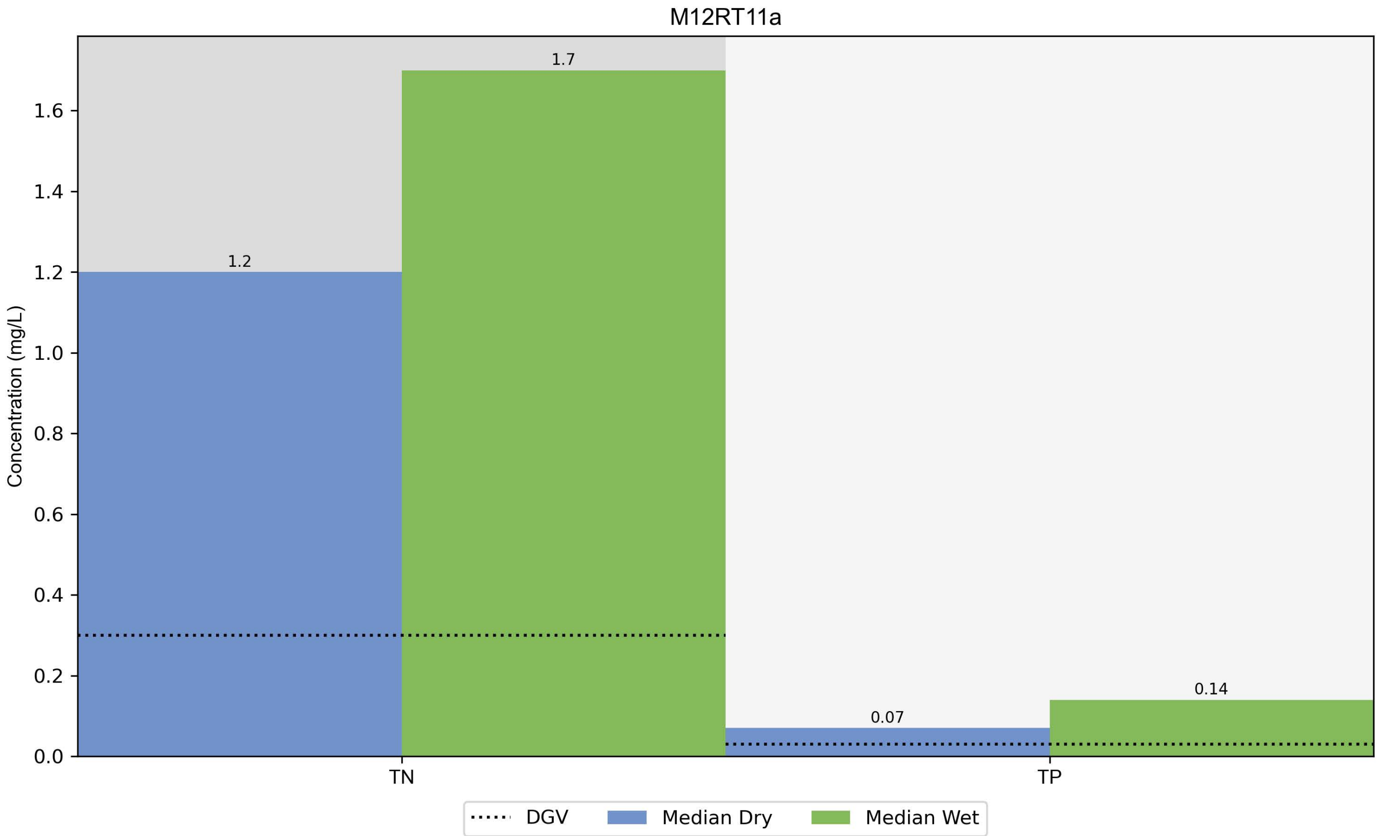


Figure 4-32 Median nutrient concentrations for dry and wet weather at the monitoring site within the Unnamed Coastal Wetland

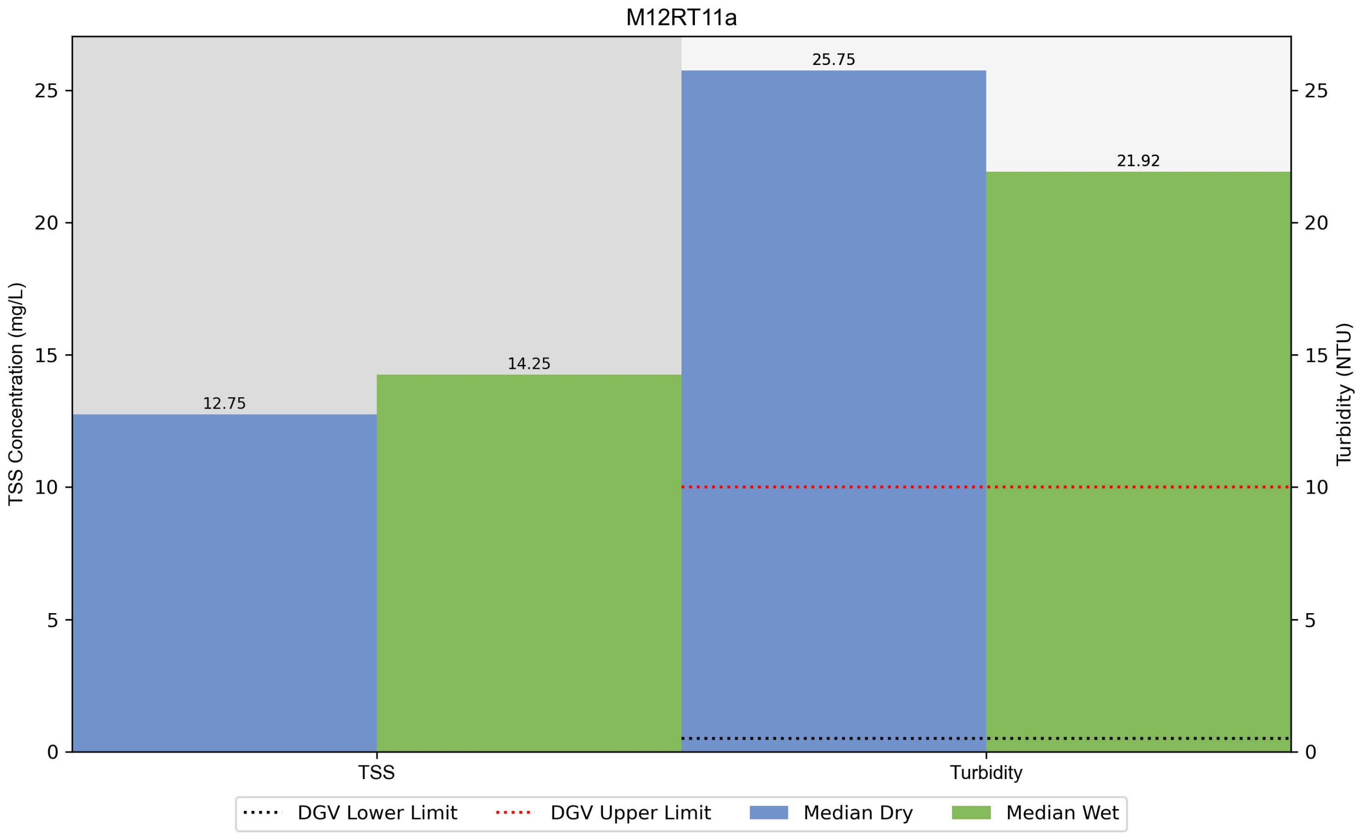


Figure 4-33 Median TSS and Turbidity for dry and wet weather at the monitoring site within the Unnamed Coastal Wetland

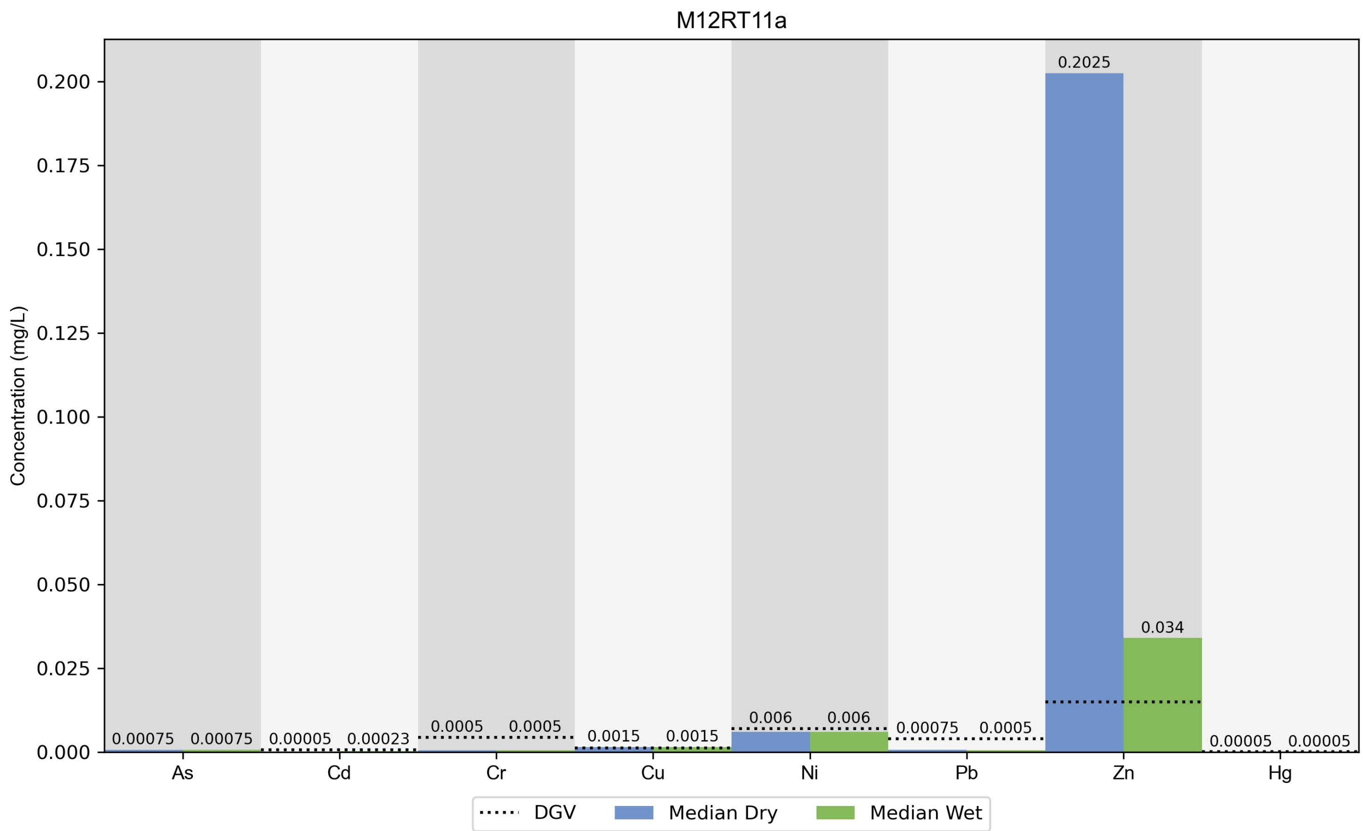


Figure 4-34 Median metal concentrations for dry and wet weather at monitoring site within the Unnamed Coastal Wetland

Visual observations at the time of sampling indicates that the WQO visual amenity is only partially protected. Whilst the water was brown in colour, it was generally transparent. The surface of the water however impacted on the protection of the WQO as it was oily and contained nuisance scums.

Photo 4-28 M12RT11a and surrounding catchment

4.6.8 Windeyers Creek

Windeyers Creek is a second order stream, that flows west between the southern urban areas of Raymond Terrace and the northern region of Heatherbrae. The creek joins the Hunter River south west of its confluence with the Williams River. Windeyers Creek is largely freshwater with a median dry weather EC range between 133 µS/cm and 1047 µS/cm, with the lowest concentrations occurring at the most downstream site.

As discussed in **Section 4.2.8**, there is a floodgate at the downstream extent of Windeyers Creek at the confluence with the Hunter River at Raymond Terrace (refer to **Figure 4-4**). This floodgate is opened during low to medium tides to allow tidal flushing and improve water quality. Water quality is influenced by treated effluent that is discharged to the creek via Grahamstown Drain (Hunter Water Corporation, 2020). The nominated WQOs for Windeyers Creek are protection of aquatic ecosystems, visual amenity, primary and secondary contact recreation and aquatic foods (cooked).

Monitoring of Windeyers Creek and a tributary of Windeyers Creek has been carried out by Transport at the following locations:

- Windeyers Creek upstream of tributary (M12RT6a)
- Windeyers Creek at the project crossing (M12RT6)
- Windeyers Creek downstream of tributary (M12RT6b)
- Tributary of Windeyers Creek (M12RT7).

Additionally, Windeyers Creek at Raymond Terrace was monitored by EES Group between January 2001 and March 2016. During this time, the water quality of Windeyers Creek at Raymond Terrace was poor, due to elevated turbidity and nutrient concentrations. Median NO_x of 0.81 mg/L was more than twenty times the DGV and median TP of 0.185 mg/L more than seven times the DGV for protection of lowland river aquatic ecosystems.

Current monitoring results conclude that Windeyers Creek has a ‘very poor’ protection of aquatic ecosystems largely due to key indicators including TP, total and oxidised nitrogen, pH and dissolved oxygen values high than DGVs (refer to Figure A-1 of **Appendix A**). No samples were below the TP DGV of 0.025 mg/L, with the highest median concentrations recorded at M12RT6a (0.2 mg/L), followed by M12RT6b (0.16 mg/L) during dry weather. Total nitrogen concentrations during dry weather were also higher than DGVs at all times. Median TN concentrations of 2.7 mg/L were recorded at the most upstream site (M12RT6a) which decreased to 1.3 mg/L further downstream at M12RT6b. The tributary flowing into Windeyers Creek, while only sampled on a single occasion, exhibited elevated nutrient concentrations. Two wet weather sampling events were carried out and on both occasions, there was no water present at M12RT6 and M12RT7. Monitoring following rainfall at M12RT6a and M12RT6b showed that nutrient concentrations were lower, although still higher than DGVs (refer to **Figure 4-35**). While Windeyers Creek is influenced by discharges from WWTW via Grahamstown Drain, the likely source of nutrients is from the surrounding catchment as nutrient levels which appear to be diluted with rainwater are low in Grahamstown Drain (refer to **Section 4.2.9**).

For protection of aquatic ecosystems range, the pH levels between 6.5 and 8.5 for lowland rivers are proposed by ANZG 2018. Median concentrations of pH were below the lower DGV on the single sampling event. Dissolved oxygen (per cent saturation) in Windeyers Creek and the tributary of Windeyers Creek were very low and did not meet the lower DGV of 80 per cent saturation. Following wet weather, dissolved oxygen and pH only marginally increased. Despite the low flow and poor water quality, turbidity (refer to **Figure 4-36**) and EC levels generally met their respective DGVs.

Metal concentrations varied within Windeyers Creek and its tributary (refer to **Figure 4-37**). Concentrations of arsenic, cadmium, nickel and mercury were below the DGVs at all sites. Lead concentrations also met DGVs for more than 75 per cent of the time. Zinc concentrations were elevated at all sites, except M12RT6b (dry weather), and were higher than the DGV of 0.008 mg/L with M12RT6a having the highest median concentration in Windeyers Creek. The tributary (M12RT7) which was only sampled on one occasion had very high zinc concentrations. Similarly, chromium concentrations could be considered poor with respect to the DGV with highest concentrations recorded upstream at M12RT6a. Following rainfall, concentrations remained similar or decreased slightly.

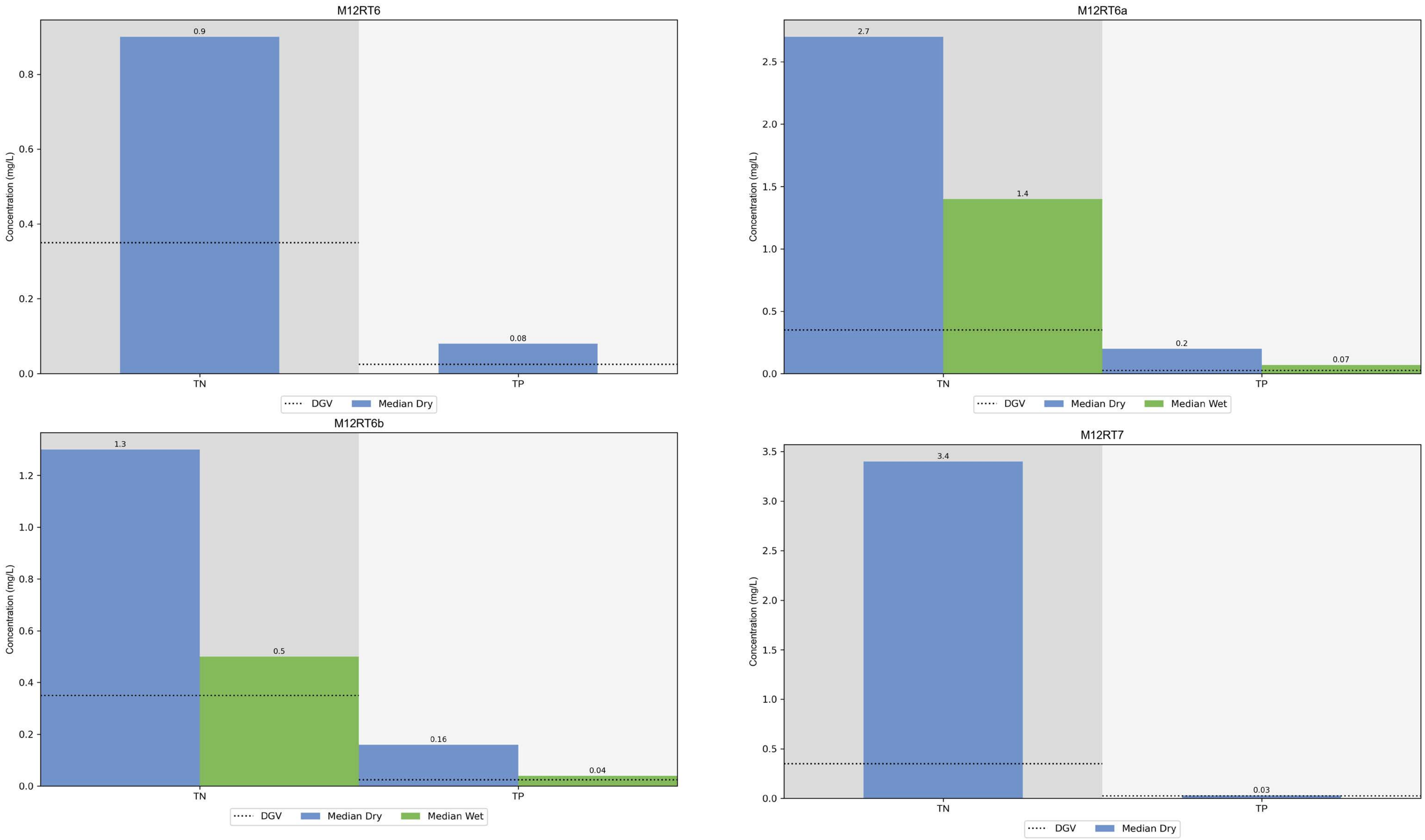


Figure 4-35 Median nutrient concentrations for dry and wet weather at the four monitoring sites within Windeyers Creek and Windeyers Creek tributary

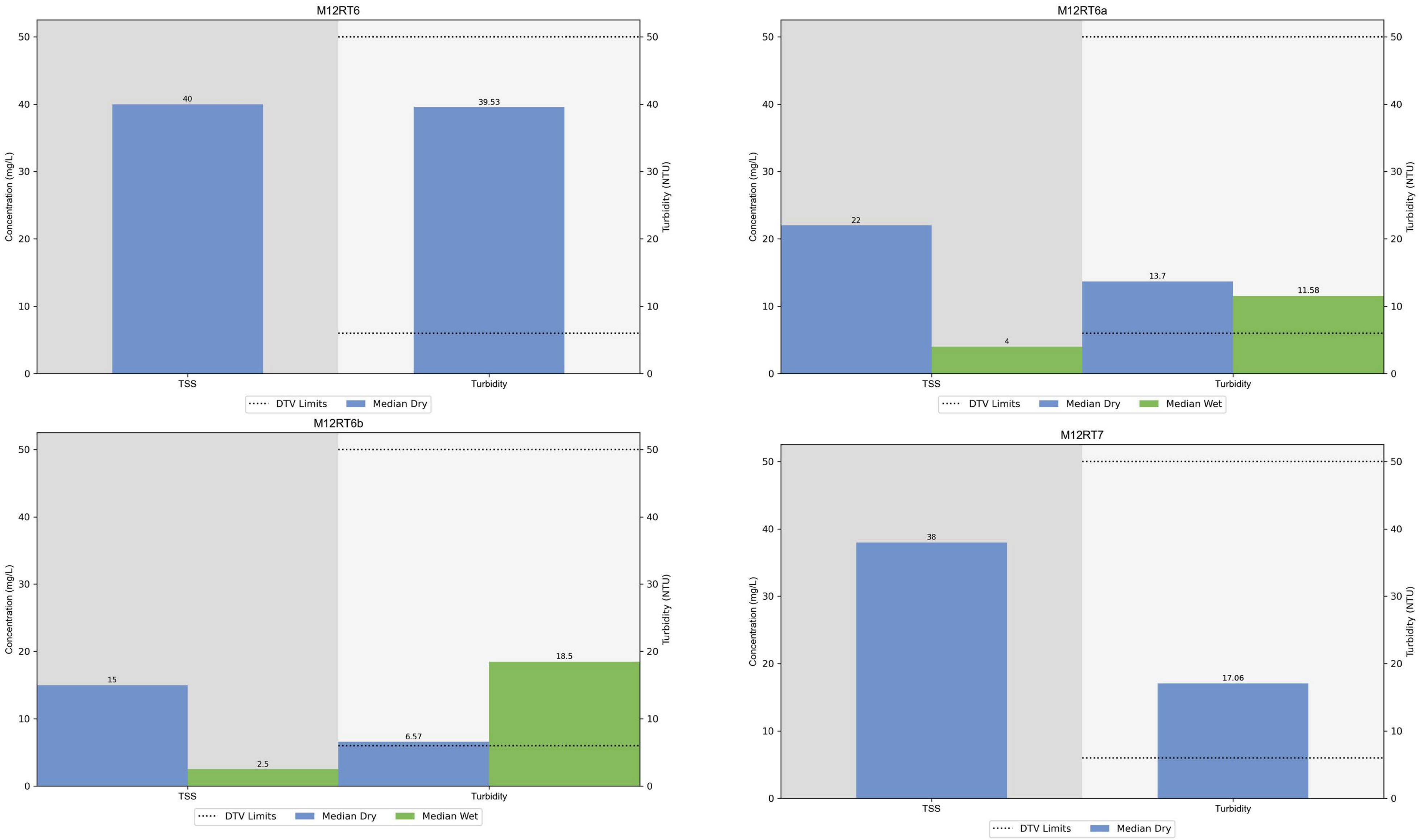


Figure 4-36 Median TSS and Turbidity for dry and wet weather at the four monitoring sites within Windeyers Creek and Windeyers Creek tributary

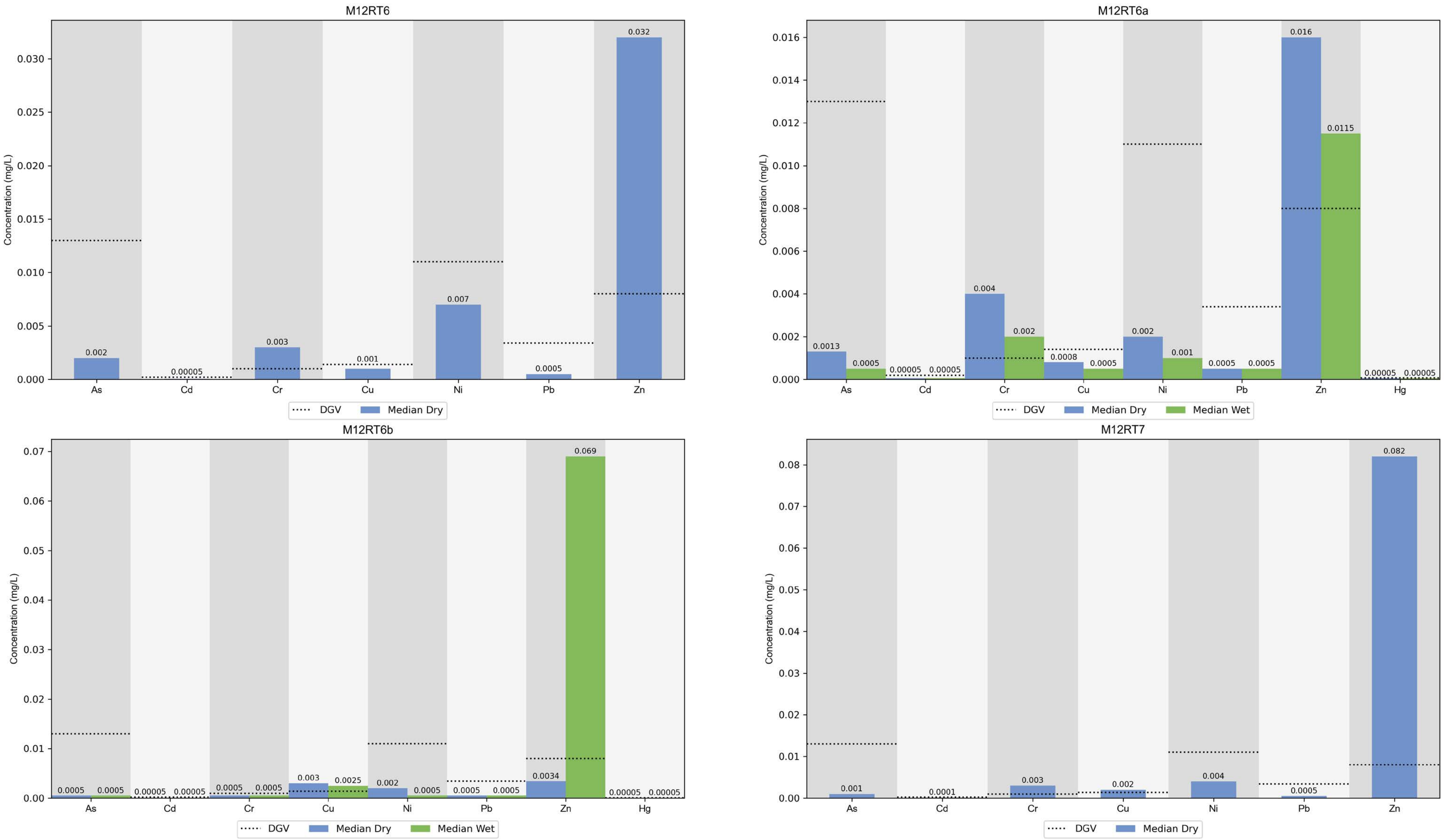


Figure 4-37 Median metal concentrations for dry and wet weather at the four monitoring sites within Windeyers Creek and Windeyers Creek tributary

Overall, Windeyers Creek appears to eutrophic with high nutrient levels and proliferation of aquatic plants and algae resulting in low dissolved oxygen (refer to **Photo 4-29**) which becomes less apparent following rainfall (refer to **Photo 4-30**).

Visual observations at the time of sampling indicate that the WQO visual amenity is generally not protected in Windeyers Creek due to a combination of oily films on the surface and surface coverings of duckweed (which tends to be associated with eutrophic conditions) and algae. Additionally, an odour was present on the majority of sampling occasions.

Enterococci measurements were only available for M12RT6a and M12RT6b due to insufficient water at the other sites. Median dry weather results were higher than the DGV of 35 CFU/100mL and therefore the WQO primary contact recreation is currently not protected. However, the DGV for secondary contact recreation was met and therefore that WQO is currently protected. Following rainfall, Enterococci numbers increased significantly and did not meet DGVs for protection of primary or secondary contact recreation.

Windeyers Creek has also been assigned the WQO aquatic foods (cooked) for protection. Current water quality data infers that protection of this objective is rated as 'very poor'. The WQO is currently not protected across all the sites due to low dissolved oxygen and elevated zinc and total suspended solid concentrations.

Photo 4-29: Windeyers Creek during dry weather

Photo 4-30: Windeyers Creek following rainfall

4.6.9 Grahamstown Drain

Grahamstown Drain is used to transfer water from the Raymond Terrace wastewater treatment works (WWTW) to the Hunter River. The WWTW undergoes secondary treatment (7.3 ML/d) before treated effluent is released to Windeyers Creek via Grahamstown Drain and then the Hunter River (PB, 2012). Monitoring of Grahamstown Drain has been carried out by Transport on five occasions during dry weather and twice following wet weather. This site, M12RT10, is classified as a waterway impacted by urban development and therefore the WQOs of aquatic ecosystems, visual amenity and primary and secondary contact recreation are nominated for protection (DECCW, 2006).

Grahamstown Drain could be considered 'very poor' for the protection of aquatic ecosystems, predominantly due to dissolved oxygen, pH and zinc not meeting recommended DGVs (refer to Figure A-1 of **Appendix A**). Both dissolved oxygen and pH fell below the lower range recommended DGVs. Median DO during dry weather was 16.63 per cent saturation, increasing to only 37.9 per cent saturation following rainfall and pH was 4.88 during dry weather and increased to 5.57 following rainfall. Such low DO and pH could be attributed to seepage and drainage from the surrounding area which is classified as Class 2 (Acid sulfate soils in Class 2 area are likely to be found below the natural ground surface (DPIE, 2020)) and therefore likely to be found just below the ground surface. Acid sulfate soils can contribute to acidic pH and low dissolved oxygen in waterways. Nutrient concentrations were low during dry weather with median concentrations of TP and TN meeting the DGVs for protection of lowland river aquatic ecosystems. Following rainfall, concentrations increased higher than the DGVs (refer to **Figure 4-38** with the likely sources being runoff from the catchment and increased flows to the WWTW, possibly impacting treatment performance, resulting in higher concentrations of nutrients released to the drain. Median turbidity remained within the DGV range for both dry and wet weather events (refer to **Figure 4-39**). Metal concentrations were low during dry and wet weather with the exception of chromium and zinc which had median concentrations above the DGVs (refer to **Figure 4-40**).

The WQO for visual amenity is currently not protected as the surface water was generally observed to be a milky white and containing iron bacteria at the time of sampling.

Enterococci were measured and recorded in low numbers during dry weather (median 15 CFU/100mL) and therefore the WQO of primary and secondary contact recreation are currently protected. Following rainfall, numbers were significantly higher (median 1140 CFU/100mL) and therefore the WQO for primary and secondary contact recreation was not protected.

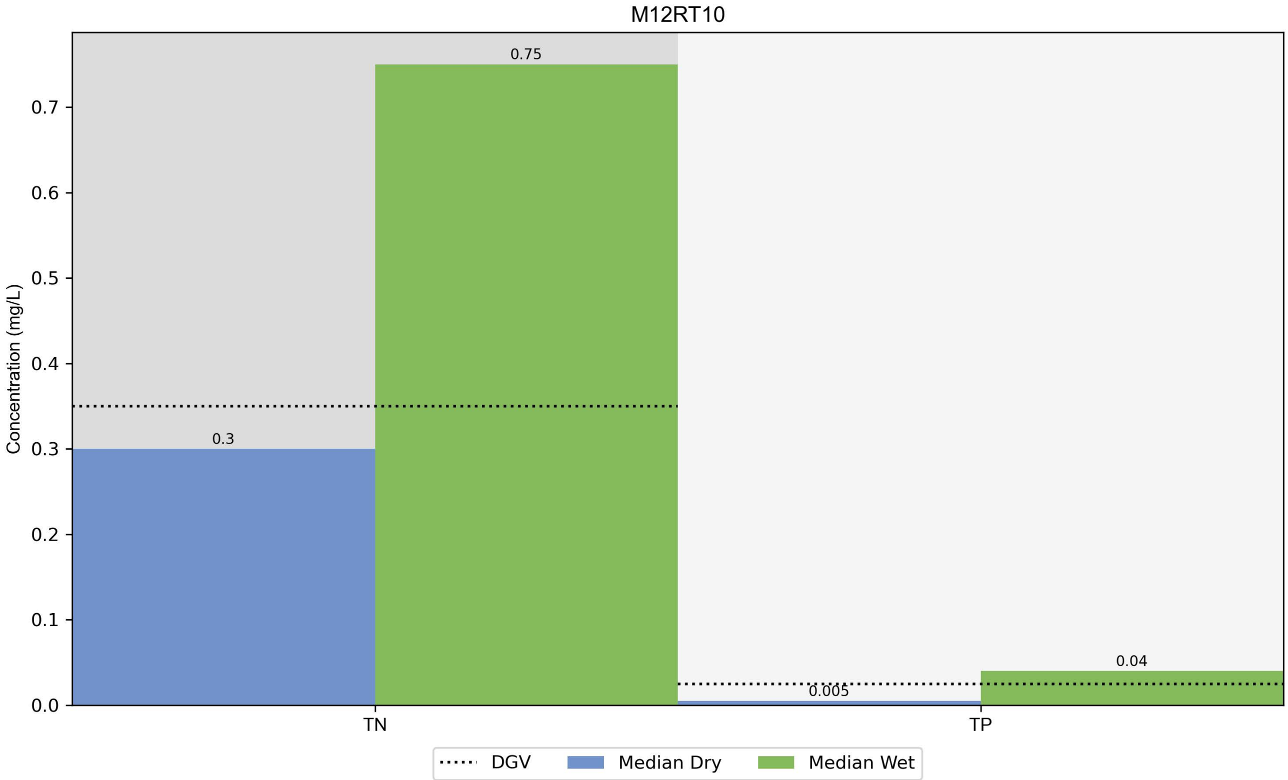


Figure 4-38 Median nutrient concentrations for dry and wet weather at the monitoring site within Grahamstown Drain

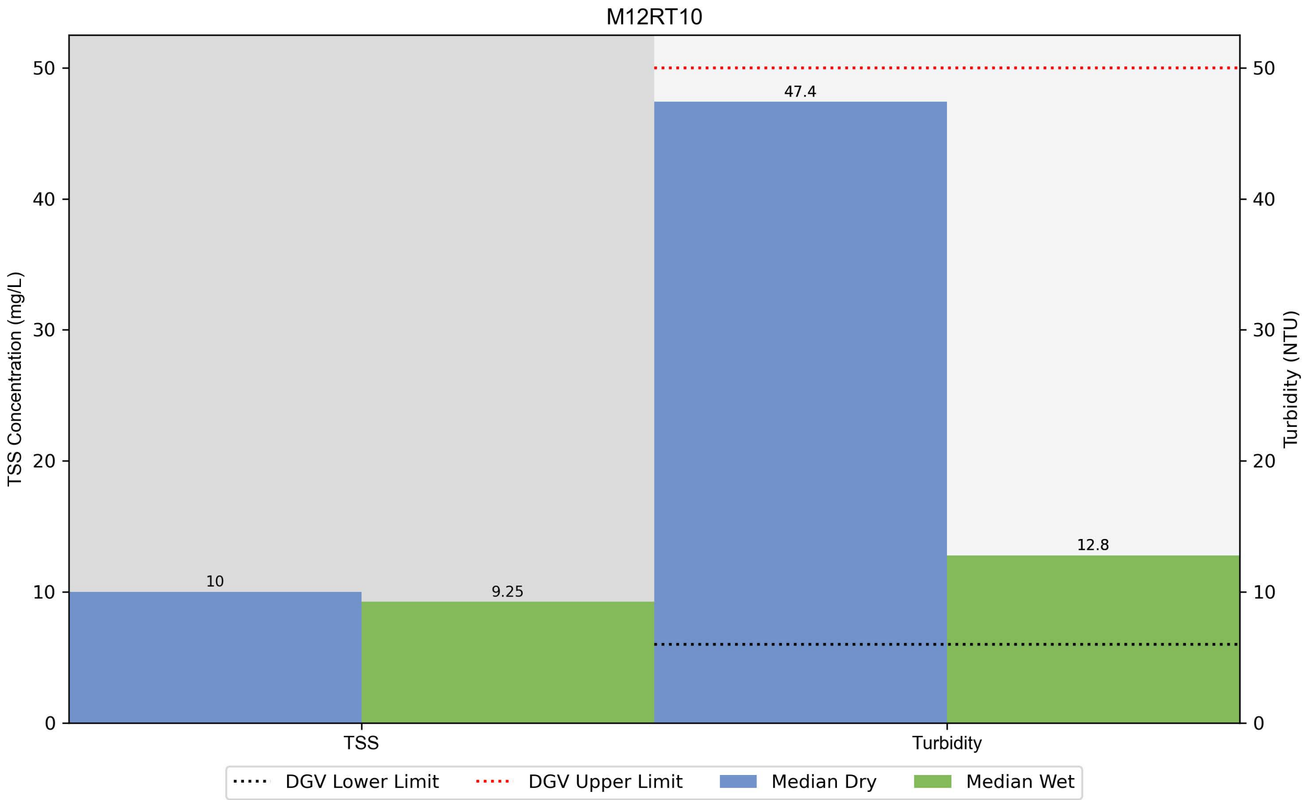


Figure 4-39 Median TSS and Turbidity for dry and wet weather at the monitoring site within Grahamstown Drain

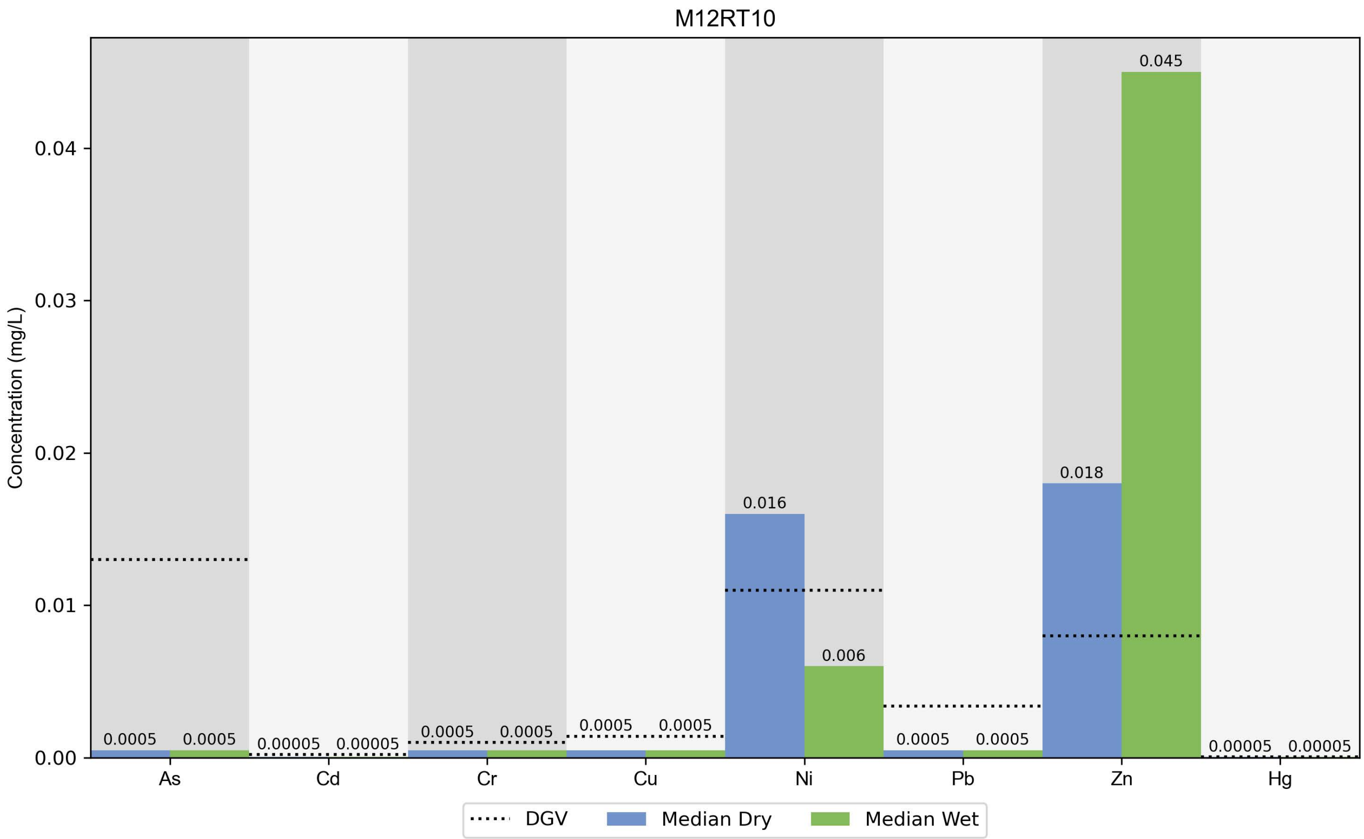


Figure 4-40 Median metal concentrations for dry and wet weather at the monitoring site within Grahamstown Drain

4.7 Existing groundwater quality

This section discusses the existing quality of groundwater in areas with the potential to be impacted by the project. Existing licenced groundwater bores and Hunter Water Corporation bores, as well as groundwater monitoring bores which have been installed for the project are considered.

The groundwater monitoring bores which have been installed for the project are shown on **Figure 3-2**. Details of the installed monitoring bores and comprehensive laboratory chemistry results are provided in **Appendix F** and **Appendix G**, respectively. Median field water quality parameters are also provided in Table G-1 in **Appendix G**. A Piper Diagram showing water quality composition plotting the relative concentrations of major anions and cations is provided in Figure G-1 in **Appendix G**.

Substantial salinity variation occurs along the project with median salinity values ranging from 72 µS/cm in the Tomago Sandbeds up to over 18,000 µS/cm in the Hunter Alluvium. **Figure 4-41** presents median salinity data from project groundwater monitoring bores (a water level monitoring discussion is presented in the Hydrology and Flooding Working Paper (Appendix J of the EIS)). Further discussion on groundwater quality within the different geological units is provided in **Section 4.7.1** to **Section 4.7.3**.

Other groundwater features within the groundwater study area, including existing groundwater bores (BOM, 2020), Hunter Water Corporation bores, and aquatic and terrestrial GDEs, are shown on **Figure 4-42**. A total of 303 existing licensed groundwater bores are registered for the groundwater study area.

Water quality for each of the main groundwater systems is discussed in relation to the ANZG (2018) Water Quality Guidelines default guideline values for the protection of aquatic ecosystems for slightly to moderately disturbed ecosystems (95 per cent level of species protection), as outlined in **Table 3-8**. These values are recommended thresholds for which if an indicator or indicators fall outside of assumes that the environmental value is not being protected. The outcomes of this assessment are summarised in **Table 4-3**. A comprehensive assessment against default guideline values is provided in **Appendix G** and discussed in the following sections.

Table 4-3 Summary of existing water quality comparison against ANZG (2018) DGVs for aquatic ecosystems

Groundwater system	Description of existing water quality (with reference to aquatic ecosystem values)
Hunter Alluvium	Poor (Estuarine)
Tomago Sandbeds	Very poor (Lowland river)
Tomago Coal Measures	Very poor (Lowland river)

* **Table 3-2** provides an explanation of water quality compliance ratings

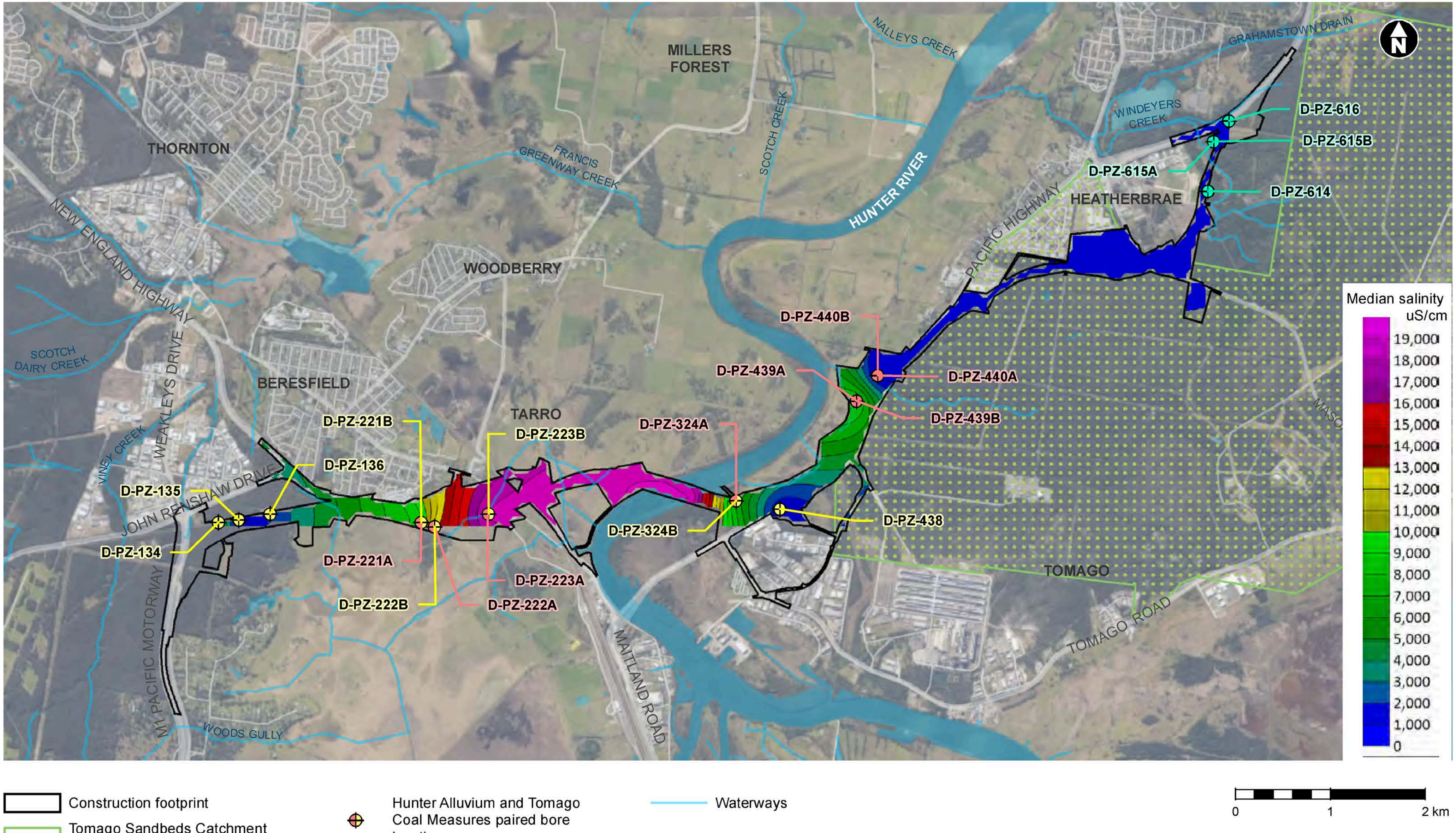


Figure 4-41 Groundwater salinity

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4.7.1 Hunter Alluvium

There are no registered groundwater bores within the groundwater study area with water quality data for the Hunter Alluvium.

Hunter Alluvium monitoring bores

Groundwater quality within the Hunter Alluvium is available from eight project monitoring bores (refer **Figure 3-2** and **Appendix G**). Groundwater quality is typically brackish to saline, with median salinity values ranging from 6,587 to 18,199 µS/cm. pH values were typically mildly acidic, with median pH values ranging from pH 5.3 to pH 6.7.

In terms of chemical composition (Figure G-1 in **Appendix G**), groundwater within the Hunter Alluvium is typically sodium-chloride dominant with some sites showing importance of sulfate. Elevated dominance of sulfate can occur where more estuarine sediments prevail and the influence of sea water. Several samples appear to be more sodium-bicarbonate dominant and are likely influenced by groundwater from the Tomago Sandbeds (refer **Section 4.7.2** below).

The relevant WQO for the Hunter Alluvium are estuarine/marine DGVs and estuarine physical and chemical stressors.

The following exceedances of ANZG (2018) estuarine physical and chemical stressors are noted:

- The majority of bores recorded pH values below the lower limit of pH 6.5
- All bores consistently recorded DO concentrations below the lower limit of 80 per cent saturation.

The following exceedances of ANZG (2018) marine water 95 per cent toxicant DGVs are noted:

- Zinc exceeded the DGV of 15 µg/L at D-PZ-223A, D-PZ-324A and D-PZ-439A. The maximum value of 52 µg/L occurred at D-PZ-324A.

4.7.2 Tomago Sandbeds

Only two of the 303 existing registered groundwater bores within the groundwater study area contained salinity data. Both of these bores are located east of the Hunter River, in areas with the geology mapped as Quaternary Sands, and are inferred to be associated with the Tomago Sandbeds. GW061003 and GW023079 had recorded salinities of 500 µS/cm and 810 µS/cm, respectively, indicative of relatively fresh groundwater.

Tomago Sandbeds monitoring bores

Groundwater quality within the Tomago Sandbeds is available from four project monitoring bores (refer **Figure 3-2**, and **Appendix G**). Two of these sites (D-PZ-440 and D-PZ-615) comprise paired piezometer sites with a shallower and a deeper monitoring bore. Groundwater quality is typically fresh, with median salinity values ranging from 72 to 517 µS/cm. pH values were typically mildly acidic, with median pH values ranging from pH 5.4 to pH 6.7.

In terms of chemical composition (Figure G-1 in **Appendix G**), groundwater within the Tomago Sandbeds is typically sodium-bicarbonate dominant. Elevated dominance of bicarbonate can indicate more active recharge with infiltration through the soil profile. Dissolution of carbonate minerals (shell fragments) within the sands may also be a source of bicarbonate.

The relevant WQO for the Tomago Sandbeds are freshwater DGVs, drinking water guidelines, and lowland river physical and chemical stressors.

No exceedances of drinking water guideline values are noted. The following exceedances of ANZG (2018) freshwater 95 per cent toxicant DGVs are noted:

- The DGV for aluminium of 55 µg/L was occasionally exceeded at D-PZ-440A and D-PZ-440B
- The DGV for arsenic of 1 µg/L was exceeded at D-PZ-440A, D-PZ-614, D-PZ-615B and D-PZ-616
- The DGV for chromium of 1 µg/L was exceeded at D-PZ-440B, D-PZ-614, D-PZ-615A, D-PZ-615B and D-PZ-616
- The DGV for copper of 1.4 µg/L was exceeded at D-PZ-614
- The DGV for lead of 3.4 µg/L was exceeded on one occasion at D-PZ-614
- The DGV for zinc of 8 µg/L was exceeded at D-PZ-440A, D-PZ-614, and D-PZ-615B.

The majority of samples were above (or below for pH and dissolved oxygen) the ANZG 2018 lowland rivers physical and chemical stressor guideline values for ammonia, total nitrogen, phosphorous, pH and dissolved oxygen. One sample at D-PZ-615A and D-PZ-614 exceeded the oxidised nitrogen guideline value based on the nitrate result.

Hunter Water Corporation bores

Groundwater quality data for the Hunter Water Corporation bores (refer to **Section 3.4.1**) is summarised in **Table 4-4**. The following key features of groundwater quality are noted:

- No exceedances of drinking water guideline values are noted
- Median aluminium concentrations at all bores exceeded the ANZG (2018) freshwater 95 per cent toxicant DGV of 0.055 mg/L
- Median ammonia concentrations at all bores exceeded the ANZG (2018) lowland rivers physical and chemical stressor guideline value of 0.02 mg/L for ammonia
- Median phosphorus concentration ANZG (2018) lowland rivers physical and chemical stressor guideline value of 0.025 mg/L at 40A
- All samples at all bores had pH and dissolved oxygen below the ANZG (2018) lowland rivers physical and chemical stressor lower guideline limit of 6.5 and 85 percent saturation respectively
- Median pH values ranged from 4.89 to 5.71, moderately acidic
- EC values are indicative of fresh water, with median EC ranging from 169 to 228 µS/cm.

Table 4-4 Median analyte results for Hunter Water Corporation bores

Bore	SK3520	BL92	SK4930	40A	SK3535
Physical parameters					
pH	5.03	5.71	4.89	5.71	5.28
EC (µS/cm)	218	169	222	223	228
DO (% sat)	22.0	27.7	23.0	34.0	20.9
Total hardness (mg/L $CaCO_3$)	36.7	16.3	15.2	32.5	29.9
Metals (dissolved)					
Aluminium (mg/L)	0.31	0.28	0.56	0.16	0.24
Arsenic (µg/L)	0.10	1.55	<0.1	1.90	1.30
Iron (mg/L)	0.71	1.30	0.16	7.40	0.54
Magnesium (mg/L)	4.00	2.20	3.50	5.40	5.10
Manganese (mg/L)	0.02	0.06	0.01	0.05	0.03

Bore	SK3520	BL92	SK4930	40A	SK3535
Nutrients					
Ammonia (mg/L N)	0.18	0.05	0.04	0.06	0.16
Sulfate (mg/L)	30.0	12.0	24.0	28.0	28.5
Total Nitrogen (mg/L N)	0.03	0.03	0.02	0.03	0.03
Total Phosphorous (mg/L P)	0.02	0.01	0.02	0.08	0.01

4.7.3 Tomago Coal Measures

There are no registered groundwater bores within the groundwater study area with water quality data for the Tomago Coal Measures.

Tomago Coal Measures monitoring bores

Groundwater quality within the Tomago Coal Measures is available from eight project monitoring bores (refer **Figure 4-42**, and **Appendix G**). Four of these bores (D-PZ-221B, D-PZ-222B, D-PZ-223B and D-PZ-324B) comprise the deeper monitoring bore of a paired piezometer site, with the corresponding shallower monitoring bore installed in the Hunter Alluvium. Groundwater quality is typically mildly brackish to saline, with median salinity values ranging from 812 to 15,630 µS/cm. pH values were typically mildly to moderately acidic, with median pH values ranging from pH 4.7 to pH 6.4.

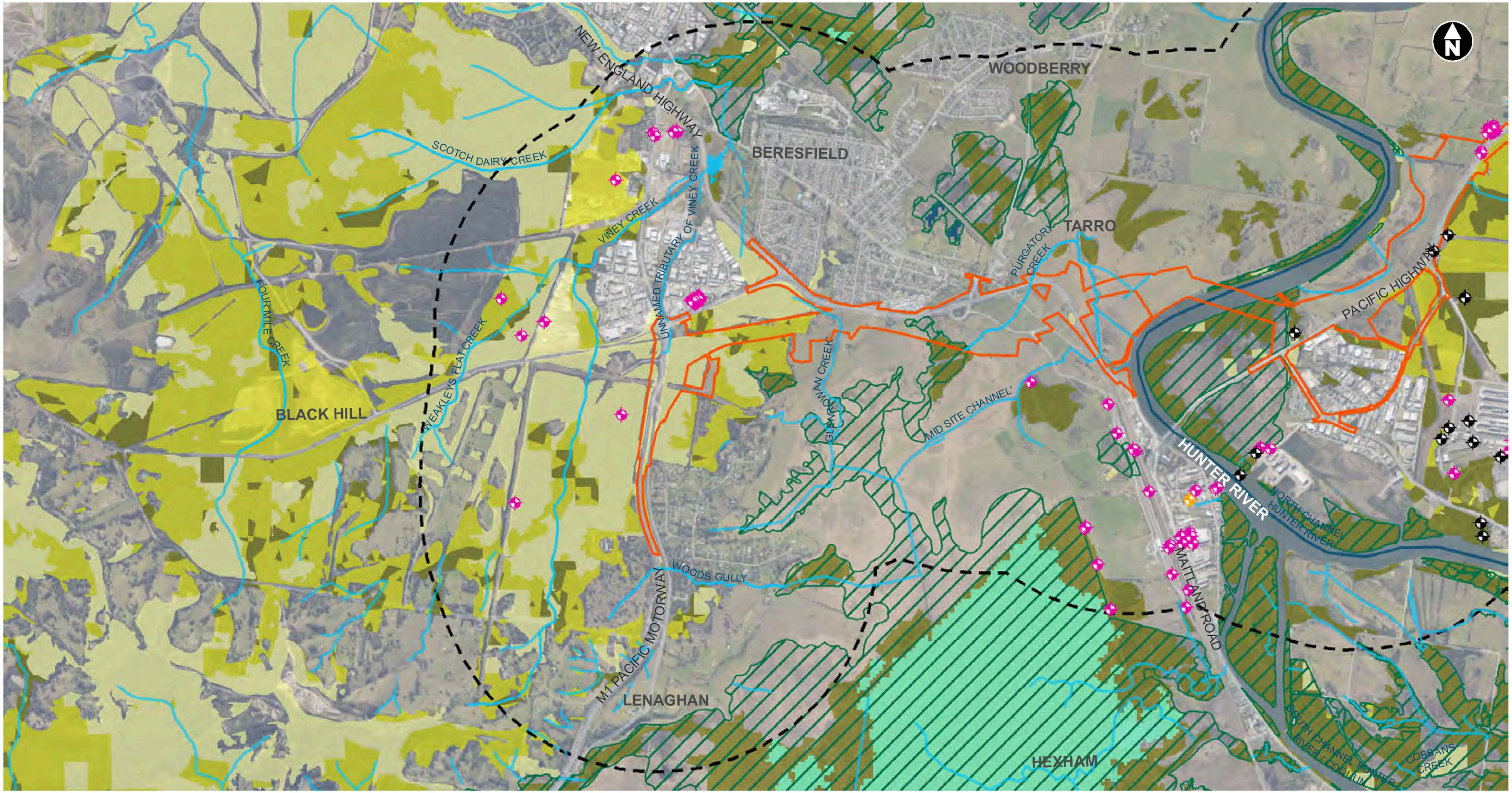
In terms of chemical composition (Figure G-1 in **Appendix G**), groundwater within the Hunter Alluvium is typically sodium-chloride dominant with some sites showing importance of sulfate. Elevated dominance of sulphate can occur where more estuarine sediments prevail and the influence of sea water. Several samples appear to be more sodium-bicarbonate dominant and are likely influenced by groundwater from the Tomago Sandbeds (**Section 4.7.2** below).

The relevant WQO for the Tomago Coal Measures are freshwater DGVs and lowland river physical and chemical stressors.

The following exceedances of ANZG (2018) freshwater 95 per cent DGVs are noted:

- The DGV for aluminium of 55 µg/L was exceeded at consistently at D-PZ-134, D-PZ-135 and D-PZ-324B, and was exceeded occasionally at D-PZ-136 and D-PZ-438
- The DGV for arsenic of 1 µg/L was exceeded consistently at most bores with the exception of D-PZ-438, and D-PZ-223B, which only had one exceedance
- The DGV for cadmium of 0.2 µg/L was exceeded at D-PZ-134, D-PZ-135 and D-PZ324B
- The DGV for copper of 1.4 µg/L was exceeded occasionally at D-PZ-135, D-PZ-136, D-PZ-324B and D-PZ-438
- The DGV for lead was exceeded at D-PZ-324B
- The DGV for manganese of 1900 µg/L was exceeded at D-PZ-223B and D-PZ-324B
- The DGV for nickel of 11 µg/L was exceeded at D-PZ-134, D-PZ-136, D-PZ-223B and D-PZ-324B
- The DGV for zinc 8 µg/L was exceeded all locations except for D-PZ-221B.

All samples were below the ANZG (2018) lowland rivers physical and chemical stressor guideline pH and dissolved oxygen ranges. The majority of samples exceeded this guideline's ammonia and phosphorous guideline values and all samples exceeded the total nitrogen and EC guideline values.

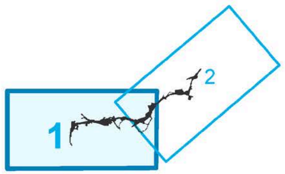


Construction footprint
Groundwater study area
Coastal wetlands
Waterways

High potential GDE
Moderate potential GDE
Low potential GDE
High potential GDE (aquatic)
Moderate potential GDE (aquatic)
Known GDE (aquatic)

BOM GW bores
Dewatering
Irrigation
Monitoring
Unknown

0 1 2 km



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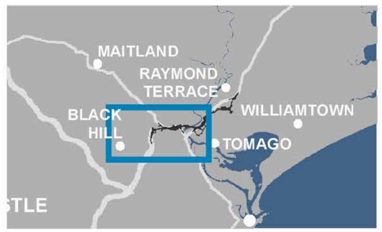

Figure 4-42 Groundwater users and groundwater dependent ecosystems (map 1 of 2)

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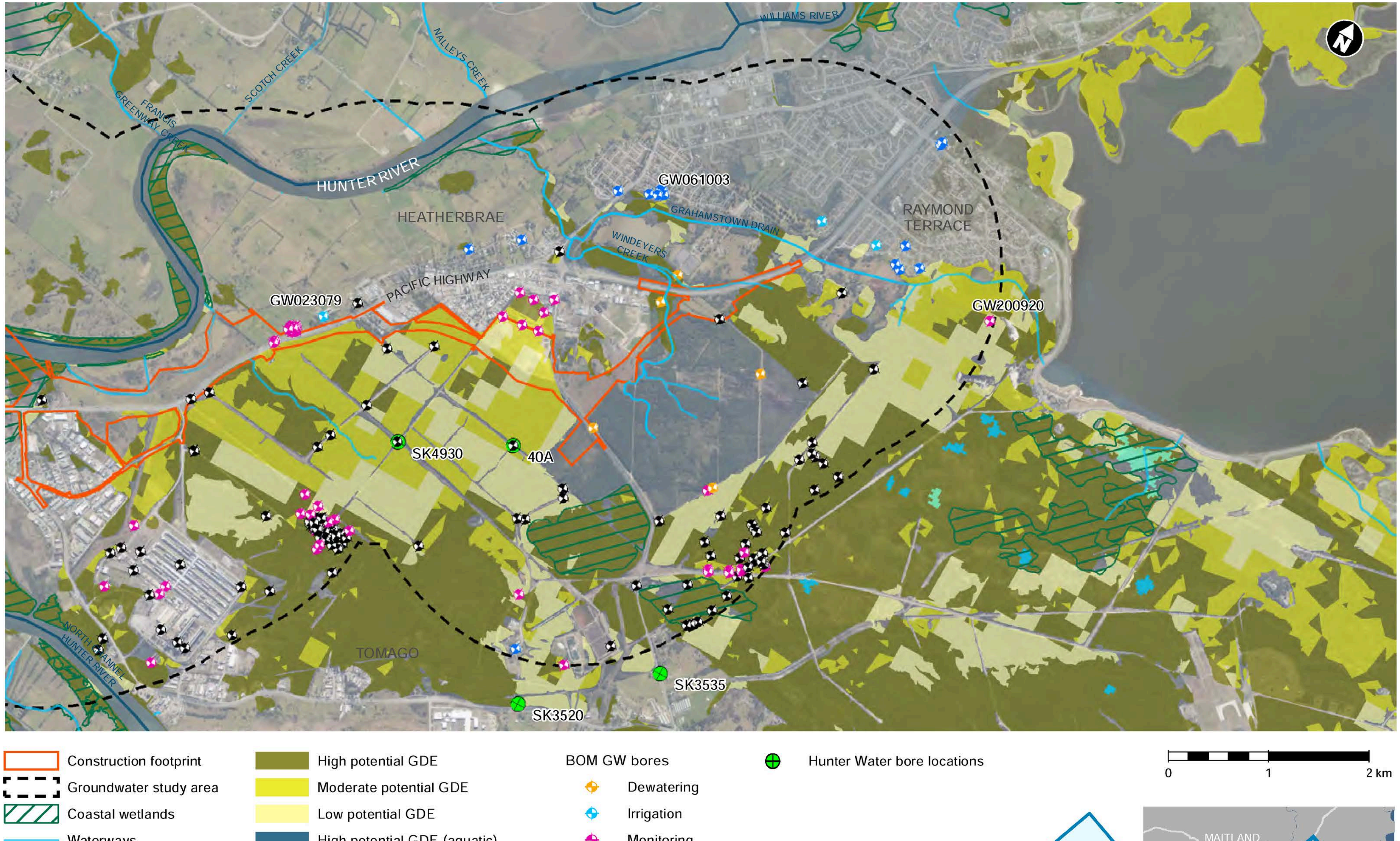

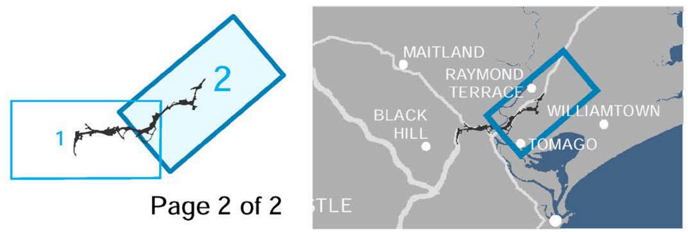

Figure 4-42 Groundwater users and groundwater dependent ecosystems (map 2 of 2)

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4.8 Potential groundwater contamination

Potential areas of soil and groundwater contamination in proximity to the project alignment are discussed in the Soils and Contamination Working Paper (Appendix P of the EIS). In addition to potential for acid sulfate soils and soil salinity risk areas, key areas of potential contamination are noted as follows.

4.8.1 Former mineral sands processing facility

A former mineral sands processing facility is located within the construction footprint in the Tomago area where the Hunter River (B05) bridge adjoins land on the eastern bank of the river. The facility is decommissioned, however the site retains pre-existing contamination in soil and groundwater (see the Soils and Contamination Working Paper (Appendix P of the EIS)).

Transport has carried out several detailed contamination investigations at the facility, between 2012 and 2020. The investigations included preliminary and detailed site investigations (SKM, 2013 and Jacobs, 2016) and a Consolidated Human Health and Ecological Risk Management Report (Jacobs, 2020). More detail on these investigations is provided in the Soils and Contamination Working Paper (Appendix P of the EIS).

The investigations found localised distribution of naturally occurring radioactive materials (NORM) with areas of elevated dose rates relative to surrounds identified on the site surface and at depth. However, concentrations of NORM in both surface water and groundwater were found to comply with all relevant guidelines for drinking water or guidelines for use of the water for livestock or irrigation

Concentrations of metals (cadmium, dissolved copper, dissolved nickel, and dissolved zinc) were detected in surface water and groundwater that exceeded investigation levels (ANZG (2018) fresh water guidelines for 95 per cent ecosystem protection) at locations within and next to the drainage line and at several groundwater investigation well locations.

To ensure that the contaminates identified at the site are controlled to an acceptable level that limits harm to human health and the environment and to facilitate the overlying motorway project, Transport will remediate the former mineral sands processing facility site during construction of the project.

Transport will remediate the site in accordance with the Remediation Action Plan (RAP) described in the Soils and Contamination Working Paper (Appendix P of the EIS). The RAP will address contamination risks and issues associated with NORM, metals and minor hydrocarbon contamination at the site, including areas where metals impacted soils may be interacting with surface water and approved by a NSW EPA accredited site auditor

4.8.2 Per- and poly-fluoroalkyl substances (PFAS)

The EPA is currently investigating potential per- and poly-fluoroalkyl substances (PFAS) contamination at two sites that are situated near the project, as follows:

- Heatherbrae Total Fire Solutions:
  - Total Fire Solutions is investigating the presence of PFAS contamination stemming from the historical use of fire-fighting foams at their Heatherbrae site. Investigations have found PFAS in groundwater, which is not unexpected given the past use of the site. PFAS has also been used in many domestic and industrial products and background levels may be present from these other sources. This site is located at 15 Giggins Road Heatherbrae, about 200 metres north of the construction footprint

- The potential contamination at Heatherbrae is located to the northwest, away from the project alignment, and as such, should not interface with the project groundwater.

- Tarro, Our Lady of Lourdes Primary School:
  - Fire and Rescue NSW (FRNSW) is investigating the presence of PFAS contamination from the historical use of fire-fighting foams at the Our Lady of Lourdes Primary School, Tarro. Firefighting training using PFAS-containing foams occurred at the site for several years, when it was a vacant lot. FRNSW is carrying out a preliminary site investigation and has engaged qualified consultants to carry out PFAS sampling on the school grounds. Preliminary results have identified the presence of PFAS in surface soils. This site is located at Anderson Drive, Tarro, about 300 metres north of the construction footprint
  - Hydraulic gradients beneath the site are anticipated to be in a general north-easterly direction and should direct any potential contamination away from the project.

PFAS contamination is also present at the Williamtown RAAF base. However, this site is located greater than five kilometres from the construction footprint and is situated in a separate groundwater and surface water catchment. NSW Government (2017) management areas associated with this contamination do not encroach upon the groundwater study area.

Areas of potential and known PFAS contamination are located a sufficient distance from the project, with modelled groundwater flow directions from the potential area of contamination at Heatherbrae and Tarro sites is to the north west, away from the project alignment and towards the Hunter River. Predicted groundwater drawdown resulting from temporary construction dewatering for the project (Hydrology and Flooding Working Paper (Appendix J of the EIS)) is also not predicted to interact with the areas of known or potential PFAS contamination. Contaminated groundwater from these sites is therefore considered unlikely to reach the project, and the project activities are not anticipated to influence or capture potential contaminant migration.

4.9 Sensitive Receiving Environments

Based on considerations outlined in **Section 3.3.3** and **Section 4.7**, several state and nationally protected areas (drinking water catchment, national parks and Ramsar listed wetlands), waterways and wetlands, as well as particular groundwater users were identified within the study area and have been classified as SREs. These include:

- Tomago Sandbeds Catchment Area
- Groundwater users within the construction footprint
- Hunter River
- Hunter Estuary Wetlands Ramsar site at Kooragang Nature Reserve
- Six Coastal Wetlands (Coastal Management SEPP) and the Hunter River wetland
- GDEs within the construction footprint and adjacent areas
- Other waterways (not listed above) which have been identified as key fish habitat, including:
  - Viney Creek (M12RT12)
  - Purgatory Creek downstream of the floodgate (M12RT2d).

The above SREs are described in the sections that follow.

4.9.1 Tomago Sandbeds Catchment Area

The Tomago Sandbeds Catchment Area is a designated 'Special Area' in the *Hunter Water Act 1991* and is protected as a public drinking water supply by Hunter Water Corporation (Hunter Water Corporation, 2020c). The Tomago Sandbeds are operated as a backup to Grahamstown Dam, and can provide up to 20 per cent of the Lower Hunter's drinking water. The extent of the catchment area is shown on **Figure 2-1**.

Within the Tomago Sandbeds Catchment Area, Hunter Water Corporation draws water from the Tomago Sandbeds aquifer through a network of more than 500 individual bores covering 100 square kilometres from Lemon Tree Passage west to Tomago. Capture zones are associated with the Hunter Water Corporation borefield, which shows the areas where groundwater is captured as part of Hunter Water Corporation activities. For the purposes of this assessment, the impacts to the Tomago Sandbeds Catchment Area, rather than the capture zone, are assessed, as required by the SEARs.

The aquifer is predominantly comprised of fine sand, typically around 20 metres deep, but reaching up to 50 metres in places. The aquifer receives direct recharge from rainfall. Water levels are generally relatively shallow and typically range between 4.8 metres above sea level when full and 1.8 metres above sea level when low (Hunter Water Corporation, 2020c). Due to the highly permeable nature of the Tomago Sandbeds and shallow depth to water, the aquifer is vulnerable to contamination.

4.9.2 Groundwater users

Existing groundwater bores within a two kilometre radius of the project construction footprint have been extracted from the BOM's Australian Groundwater Explorer (2020). Results are presented on **Figure 4-42** and summarised as follows:

- 303 existing registered bores were identified within two kilometres with the following uses:
  - Monitoring – 144 sites
  - Unknown – 134 sites
  - Water supply – 16 sites
  - Dewatering – six sites
  - Irrigation – three sites.

Of these 303 bores identified, only five bores are located within the construction footprint (GW079605, GW200103, GW079447, GW079591 and GW200102). For all bores within the construction footprint except GW200102 (monitoring purpose), no specific use is recorded. The groundwater users within the project construction footprint have been considered SREs.

4.9.3 Hunter River

As described in **Section 4.2.6**, the Hunter River is a ninth order major river and its lower reaches (where the project is located) form an open, wave dominated barrier estuary which extends about 64 kilometres inland to its tidal limits at Oakhampton.

While the physical condition and water quality of the Hunter River within the study area is generally poor and reflective of the urban, agricultural and industrial land uses within the catchment (refer to **Section 4.6.6**), the waterway is mapped as Type 1 – Major KFH (refer to **Section 4.9.7** and the Biodiversity Assessment Report (Appendix I of the EIS) for further detail) and is additionally accessed as fish grounds for the Estuary Prawn Trawl Fishery. The Estuary Prawn Trawl Fishery targets school prawns and eastern king prawns during the on-season (October to May). The Hunter River also contains oyster leases located near Stockton Bridge about 13 kilometres downstream of the project.

Furthermore, the Hunter River is a focus for secondary contact recreation activities including waterskiing, fishing and boating. Primary contact such as swimming in the study area is not common due to poor water quality and boat traffic.

The Hunter River is considered an SRE.

4.9.4 Hunter Estuary Wetlands Ramsar site

As described in **Section 4.2.11,** the Hunter Wetlands National Park at Kooragang Nature Reserve and the Hunter Wetlands Centre Australia in Shortland together form the Hunter Estuary Wetlands Ramsar site which lies downstream of the project. Kooragang Nature Reserve is about 1.9 kilometres south-east of the boundary of the construction footprint however, is located about 5.1 kilometres directly downstream from the project where the new bridge crosses the Hunter River. Due to the substantial distance from the Kooragang Nature Reserve, no direct impacts are anticipated from the project, however there is potential for indirect impacts if contaminants are mobilised via waterways to the site via surface water runoff or discharge. Potential indirect impacts to Kooragang Nature Reserve has been assessed in this report in **Section 6.2.6** and **Section 6.3.4** and further detailed in the Biodiversity Assessment Report (Appendix I of the EIS).

The Hunter Wetlands Centre Australia in Shortland is located to the south of Hexham Swamp Nature Reserve and a minimum distance of about 3.8 kilometres south of the construction footprint. Due to the substantial distance from the project and several hydrological barriers which obstruct flow from reaching the site (rail embankment at the northern boundary of Hexham Swamp Nature Reserve and floodgates on Ironbark Creek), the Hunter Wetland Centre in Shortland is not expected to be directly or indirectly impacted by the project.

The Kooragang Nature Reserve (part of the Hunter Estuary Wetlands Ramsar site) is considered an SRE.

4.9.5 Important wetlands

Coastal Wetlands (Coastal Management SEPP)

Six areas identified as Coastal Wetlands under the Coastal Management SEPP (refer to **Figure 2-2**) are located within the study area.

Of the six Coastal Wetlands, three are located within the construction footprint, these include:

- South of the existing New England Highway (refer to **Section 4.2.3**)
- On the western banks of the Hunter River (refer to **Section 4.2.6**)
- On the eastern bank of the Hunter River, north of the Pacific Highway (refer to **Section 4.2.7**).

The other three Coastal Wetlands which are outside the construction footprint but within the study area include:

- North of the project in Tarro, separated from the project by Woodberry Road, this wetland is commonly referred to as “Woodberry Swamp” (refer to **Section 4.2.1**)
- In Tomago, located south east of the construction footprint on the southern side of Masonite Road on the northern floodplain of the Hunter River (refer to **Section 4.2.6**)
- In Tomago, located south east on the northern floodplain of the North Channel Hunter River (refer to **Section 4.2.6**).

These Coastal Wetlands are expected to be, in part, supported by groundwater discharge and as such are considered to be groundwater dependent ecosystems.

The Coastal Wetlands (Coastal Management SEPP) are considered SREs.

Hunter River wetland

Although not classified under the Coastal Management SEPP, the Hunter River wetland which is located within the Tomago Sandbeds Catchment Area, has also been considered an important wetland environment due to presence of aquatic and wetland habitat features identified on site (refer to **Figure 2-1** for Tomago Sandbeds Catchment Area and **Figure 4-6** for surface water monitoring site M12RT8 which is located on the Hunter River wetland). This wetland is expected to be supported by groundwater discharge and is therefore considered to be a groundwater dependent ecosystem.

The Hunter River wetland is considered an SRE.

4.9.6 Groundwater Dependent Ecosystems

GDEs are considered to be ecosystems in which the species composition and natural ecological processes are wholly or partially determined by the availability of groundwater (Serov *et al.*,2012).

The BOM's Groundwater Dependent Ecosystem Atlas (BOM, 2020) identifies a number of known and potential GDEs. These communities are shown on **Figure 4-42** and include:

- Known aquatic GDEs:
  - Floodplain wetlands (Hexham Swamp Nature Reserve and surrounding wetlands, Hunter Wetlands National Park)
  - Hunter River.
- High potential terrestrial GDEs:
  - Coastal Floodplain Wetlands on the floodplains of Hunter River (Tarro, Hexham and Tomago)
  - Mangrove Swamps on the margins of the Hunter River
  - Coastal Dune Dry Sclerophyll Forests on the Tomago Sandbeds (Tomago and Heatherbrae).
- Moderate potential terrestrial GDEs:
  - Coastal Dune Dry Sclerophyll Forests on the Tomago Sandbeds (Tomago and Heatherbrae).

It is noted that a number of these potential and known GDEs coincide with the Coastal Wetlands (Coastal Management SEPP) and fall within the construction footprint. GDEs in the vicinity of the project are discussed in detail in the Biodiversity Assessment Report (Appendix I of the EIS) and summarised as follows.

GDEs within the construction footprint and adjacent areas are considered SREs.

4.9.7 Key Fish Habitat

Hunter River and tributaries

Aquatic habitats within the surface water study area include mangroves and saltmarsh, which are associated with the intertidal zone in the Hunter River Estuary, and freshwater wetlands, ephemeral streams and drainage channels that are located on the floodplains and flow toward the Hunter River. As described above, the Hunter River at the proposed crossing and ephemeral waterways on the floodplain have been extensively modified to allow for establishment of agricultural land and to regulate flooding.

Banks of the Hunter River in the vicinity of the project have been stabilised by rock armouring and there is an artificial levee that been built along the length of the west bank.

The waterways on the floodplains have been incised and stabilised to produce artificial drainage channels, and all waterways within the project construction footprint area (which are connected to the Hunter River) are maintained by floodgates that have been installed as part of the Hunter Valley Flood Mitigation Scheme. The installation of floodgates has substantially altered the availability of aquatic habitat within these waterways as the floodgates have disrupted tidal flows and have created a barrier to upstream migration.

Substrate and vegetation

The substrate of the eastern and western floodplain of the Hunter River and intertidal mangrove area near Tomago Sandbeds contains a layer of estuarine mud (0.5 to 1.0 metres) overlying about 20 metres of sand (Hughes *et al.* 1998). Estuarine mud is predominately highly organic fine silt sands over medium grained silty sands with clay lenses and layers of shell (Hughes *et al.* 1998). The substrate in the construction footprint at the edge of the Hunter River is characterised as well bioturbated by crab holes and macroinvertebrate burrowing. The banks of the Hunter River in proximity to the construction footprint are generally lined by mangroves and saltmarsh (DPI, 2000). Instream habitat in the ephemeral freshwater channels is simple, dominated by fine sediments and algae, and a mix of grasses and aquatic macrophytes such as *Typha* sp.

Aquatic habitat at waterways and wetlands that were visited in the study area have been assessed in accordance with the Policy and Guidelines for Fish Habitat Conservation and Management (DPI, 2013) and Fish Passage Requirements for Waterway Crossings (Fairfull and Witheridge, 2003), whereby assessment sites have been classified into KFH “Type” and waterway “Class”.

Outcomes of these aquatic habitat assessment at all sites are detailed in the Biodiversity Assessment Report (Appendix I of the EIS) and have been summarised in **Table 4-5**.

Table 4-5 Summary of aquatic habitat assessment at surface water monitoring sites

Waterway/ wetland	Site name	Strahler stream order (Strahler, 1952)	Mapped as KFH (DPI, 2007)	Threatened aquatic species predicted to occur (DPI, 2016)	KFH type and sensitivity (DPI, 2013)	Waterway class (Fairfull and Witheridge, 2003)	Sensitive Receiving Environment determination
Tributary of Viney Creek	M12RT13	Unmapped at site although is first order about 50 metres downstream where mapping begins	No	No	Not KFH	Class 4 – Unlikely fish habitat	Not a SRE
Viney Creek	M12RT12 Viney Creek	Four	Yes	No	Type 2 – Moderately sensitive KFH	Class 3 – Minimal fish habitat	SRE
Glenrowan Creek	M12RT1 'Glenrowan Creek' at crossing	One	No	No	Not KFH	Class 4 – Unlikely fish habitat	Not a SRE
Purgatory Creek	M12RT2 Purgatory Creek Crossing 1	One	No	No	Not KFH	Class 4 – Unlikely fish habitat	Not a SRE
	M12RT2b Purgatory Creek (west of Woodlands Close)	Two	No	No	Not KFH	Class 4 – Unlikely fish habitat	Not a SRE
	M12RT2a Purgatory Creek (at crossing/ancillary facility location)	Three	Yes	No	Not KFH	Class 3 – Minimal fish habitat	Not a SRE
	M12RT2c Purgatory Creek downstream	Three	Yes	No	Not KFH	Class 3 – Minimal fish habitat	Not a SRE
	M12RT2d Purgatory Creek downstream at junction with Hunter River	Three	Yes	No	Type 1 – Highly sensitive KFH	Class 2 – Moderate fish habitat	SRE

Waterway/ wetland	Site name	Strahler stream order (Strahler, 1952)	Mapped as KFH (DPI, 2007)	Threatened aquatic species predicted to occur (DPI, 2016)	KFH type and sensitivity (DPI, 2013)	Waterway class (Fairfull and Witheridge, 2003)	Sensitive Receiving Environment determination
Hunter River Estuary	M12RT3 Hunter River at crossing	Nine	Yes	Yes – although not expected in this section of the Hunter River	Type 1 – Highly sensitive KFH	Class 1 – Major fish habitat	SRE
	M12RT3a Hunter River midstream	Nine	Yes	Yes – although not expected in this section of the Hunter River	Type 1 – Highly sensitive KFH	Class 1 – Major fish habitat	SRE
	M12RT3b Hunter River downstream	Nine	Yes	Yes – although not expected in this section of the Hunter River	Type 1 – Highly sensitive KFH	Class 1 – Major fish habitat	SRE
Hunter River Drain	M12RT4 Hunter River Drain (upstream of Hunter River)	Two	No	No	Not KFH	Class 3 - Minimal fish habitat	Not a SRE
	M12RT5 Unnamed tributary of Hunter River Drain (at water quality basin outlets)	Two	No	No	Not KFH	Class 4 – Unlikely fish habitat	Not a SRE
Windeyers Creek	M12RT6a Windeyers Creek (Upstream)	Two	No	No	Not KFH	Class 3 - Minimal fish habitat	Not a SRE
	M12RT6 Windeyers Creek (east of Pacific Highway)	Two	No	No	Not KFH	Class 3 - Minimal fish habitat	Not a SRE

Waterway/ wetland	Site name	Strahler stream order (Strahler, 1952)	Mapped as KFH (DPI, 2007)	Threatened aquatic species predicted to occur (DPI, 2016)	KFH type and sensitivity (DPI, 2013)	Waterway class (Fairfull and Witheridge, 2003)	Sensitive Receiving Environment determination
	M12RT6b Downstream of Windeyers Creek and tributary of Windeyers Creek	Two	No	No	Not KFH	Class 3 - Minimal fish habitat	Not a SRE
Tributary of Windeyers Creek	M12RT7 Tributary of Windeyers Creek at crossing	One	No	No	Not KFH	Class 4 – Unlikely fish habitat	Not a SRE
Hunter River wetland	M12RT8 Wetland next to Botanic Gardens	One	No	No	Not KFH	Class 3 - Minimal fish habitat	SRE
Unnamed waterbody	M12RT9 Waterbody opposite Old Punt Road	Two	Yes, however, the waterbody has been artificially built for industrial use. Therefore, according to the KFH guidelines (DPI 2013) which state that urban and artificial ponds are not considered KFH, this waterway has not been considered KFH.	No	Not KFH	Class 3 - Minimal fish habitat	Not a SRE
Grahamstown Drain	M12RT10 Grahamstown Drain	Two	Yes, however because it is second order stream, it does not meet minimum KFH criteria	No	Not KFH	Class 3 – Minimal fish habitat	Not a SRE

Waterway/ wetland	Site name	Strahler stream order (Strahler, 1952)	Mapped as KFH (DPI, 2007)	Threatened aquatic species predicted to occur (DPI, 2016)	KFH type and sensitivity (DPI, 2013)	Waterway class (Fairfull and Witheridge, 2003)	Sensitive Receiving Environment determination
Unnamed Coastal Wetland (Coastal Management SEPP)	M12RT11 Unnamed Coastal Wetland	One	Yes	No	Type 1 – Highly sensitive KFH	Class 1 – Major fish habitat	SRE
	M12RT11a Unnamed tributary of unnamed Coastal Wetland	Two	No	No	Not KFH	Class 3 – Moderate fish habitat	Not a SRE

5. Surface water quality controls

5.1 Construction phase

5.1.1 Construction water quality strategy

Design development has sought to avoid and minimise the water quality impacts of the project as discussed in **Section 6.1**. In addition, the construction water quality strategy for the project has considered:

- The existing land use surrounding the construction footprint and minimising impact on these land uses (including utilities and property owners)
- Landform and topography, which is a key driver for the design of physical controls
- Consideration of all environmental and heritage issues, including where implementation of physical controls may have a negative impact on other areas of environmental importance (for example, the requirement to clear native or protected vegetation or potential to intercept groundwater)
- The presence of the Tomago Sandbeds as a drinking water catchment and Hunter Water Corporation input to the design
- Consideration of footprint and location of temporary and permanent basins so that they use the same footprint where possible. This approach has reduced the need to build additional basins.

The strategy to minimise impacts to water quality during construction, and in particular to SREs, is to provide a combination of water quality treatment measures consisting of erosion control, sediment control, sediment capture and treatment. This strategy is supported by management measures to be implemented during construction as detailed in **Chapter 8**. This also includes the lining of basins located within the Tomago Sandbeds Catchment Area to avoid potential contamination of groundwater.

Erosion and sediment controls are discussed below.

Erosion controls

The primary control for soils is erosion control as this limits the volume of sediments mobilised. This may include, but not be limited to:

- Staged vegetation clearing to limit the exposure of soils, temporary soil stabilisation where practicable (mechanical and soluble)
- Aquatic controls such as in channel coffer dams, floating curtains/booms, sheet piles or temporary rock armouring
- Offsite clean water diversion drains
- Scour protection, including lining of channels and other concentrated flowpaths and check dams
- Enhanced erosion control measures such as temporary binders to stabilise the topsoils.

Sediment controls

The secondary control of soils, is the control of mobilised sediment as this results from a lack of upslope control soils. This may include, but not be limited to:

- Onsite diversion drains to collect impacted run off
- Sediment fences and filters to intercept and filter small volumes of construction runoff
- Level spreaders to convert erosive, concentrated flow into sheet flow
- Scour protection devices

- Inline sediment controls such as sediment fences or filter logs as appropriate for construction activities with low potential for erosion
- Closed loop excavation practices for over water excavation inclusive of physical containment
- Sediment basins, sumps and bunds
- Bunding of equipment and materials when working on waterways.

Water quality management measures that apply to the project in addition to the physical controls listed in this section are discussed in **Chapter 8**.

Further information on the capture and treatment of sediments is provided in **Section 5.1.2.**

5.1.2 Temporary construction sediment basins

One of the main strategies to minimise any impacts to water quality during construction, in particular to SREs, is the use of temporary sediment basins, in addition to other erosion and sediment controls. Temporary sediment basins are proposed to capture and treat runoff from disturbed areas of the construction footprint before discharging into the receiving waterways. Design criteria, basin locations and sizing are discussed further below.

Design criteria

The temporary sediment basins used in the assessment are based on the requirements of:

- Managing Urban Stormwater, *Soils and Construction guidelines,* Volumes 1 (Landcom, 2004) and 2C (DECC, 2008a) (known as the Blue Book)
- Managing Urban Stormwater, *Volume 2D: Main Road Construction* (DECC, 2008b).

The Blue Book criteria have been developed for NSW soils and rainfall. This assessment has adopted the Blue Book criteria when designing construction sediment basins. The impact assessment (**Section 6.2.6**) considers the impacts of the proposed discharges of 50mg/L of TSS from temporary sediment basins to the relevant DGV for the downstream receiving environment.

Temporary construction sediment basin location selection

Temporary sediment basins have been located in areas where they can collect a high proportion of sediment-laden runoff from disturbed areas of the construction site, and where they are accessible for maintenance. The ideal location of the temporary sediment basins is on the downstream side of the construction footprint, but immediately upstream of proposed culvert crossings and receiving environments. Basins have been raised as far as possible without compromising the ability of sediment laden runoff from the construction footprint being able to enter basins. However, in determining locations, consideration has also been given to minimising impacts upon existing or proposed utilities, property owners, heritage curtilages and environmental exclusion zones and existing vegetation.

The flat site topography and the number of cross drainage culverts are such that a large number of basins would be required to treat every section of the construction footprint throughout all stages of construction. In order to minimise the number of temporary sediment basins, and the impact of the construction of these basins on the local natural environment, the Blue Book criteria of ‘minimum 150 cubic metres’ of annual sediment loss was adopted (Blue Book Section 6.3.2, Clause (d) and Appendix M, Clause (54)). This criterion indicates that if the estimated annual soil losses from a disturbed catchment is less than 150 cubic metres, then a temporary sediment basin may not be required subject to other localised erosion and sediment controls being implemented. Alternatively, where constraints identified during detailed design or construction limit the location (or sizing) of a basin, enhanced controls may be considered to assist in obtaining acceptable soil loss and/or performance outcomes such as reducing the contributing catchment area.

Temporary sediment basin sizing

As there are only a very small number of sediment basins (about two per cent of all basins) that are located upstream of non-sensitive receivers, all temporary sediment basins on the project have been sized using the 85th percentile, five day rainfall depth design criteria.

Temporary sediment basins have been sized to provide sufficient volume for settling and storage of sediments. The settling zone volume is estimated using catchment areas and the appropriate design rainfall depth. The storage zone is estimated using the Revised Universal Soil Loss Equation (RUSLE).

The sediment basins have been designed as per the Blue Book classifications and assumed soil parameters. The key design elements that inform the individual sizing of each basin are:

- Catchment areas contributing to the sediment basins (disturbed and undisturbed areas). The required volume of each sediment basin has been determined according to an estimate of the maximum disturbed catchment area that drains to the basin during various stages of the construction. The road formation and earthwork area have been included in the calculation
- The percentage of the total contributing sub-catchment area that is either “cut” or “fill”. These batters/embankment areas generally comprise an area of less than 25 per cent for this project. These sub-catchments generate greater soil losses due to the steeper gradient.

Other design input parameters include soil type, rainfall erosivity (which is a function of local rainfall intensity), soil hydrologic group, volumetric runoff coefficients and soil erodibility. The key site-specific design parameters used to size the sediment basins are listed in below **Table 5-1**.

Table 5-1 M12RT design criteria for sizing the construction temporary sediment basins

Parameter	Value	Comment
Rainfall parameters		
Rainfall depth duration (days)	5 day	5 day is considered appropriate
Rainfall percentile	85th	85th for sensitive areas only
Rainfall depth (mm) – 5 day	38.9 mm	For Newcastle as derived from the Blue Book
Volumetric runoff coefficient, cv	Varies (0.51 to 0.64)	0.64 has been adopted for Group D hydrologic soils of high runoff potential, in the range of 31 mm to 40 mm rainfall depth
Rainfall intensity for 2-year ARI, 6 h duration	10.7 mm/h	10.7 mm/h from the BOM Rainfall Intensity IFD tables
RUSLE parameters		
Soil/sediment type	C, D, or F	Varies along the main alignment
Erodibility, k	Varies k=0.02 to k=0.06	K = 0.05 was adopted as a reasonable value for the typical soils found in this area, however this selection can be further improved at detailed design stage through site specific soil testing
Rainfall erosivity, R	2496	R= 2496 based on the BOM rainfall intensities for the construction footprint
Hydrologic soil group	D	For high runoff potential Reference: Appendix F of the Blue Book
Soil cover, C	1	Corresponding to expected type of activities for the project
Soil conservation practices. P	1.3	Corresponding to expected type of activities for the project

Parameter	Value	Comment
Length slope factors, LS	Variable	Determined separately for main roadway; and steeper embankment areas (cut and fill)
Sediment yield time period (months)	2 to 6 months	4 months can be used as a reasonable period that accounts for the likely maintenance frequency during construction and the removal of captured sediments.

Proposed temporary sediment basins

There are 47 proposed temporary sediment basins. Locations and sizes are presented in **Table 5-2** and shown in Figure I-1 in **Appendix I**. Cells shaded green indicate basins nominated for lining due their location within the Tomago Sandbeds Catchment.

The volume for temporary sediment basins is listed below, however the permanent water quality basin volumes are also provided to demonstrate that for basins to be retained from construction through to operation, the design has adopted the larger of the two volumes. The locations of the temporary sediment basins and permanent water quality basins are indicative only and are subject to change during detailed design or construction.

Table 5-2 Temporary sediment basins

Basin name	Basin code	Type	Construction volume (m^3)	Operational volume (m^3)	Design volume (m^3)
TPB02	B00700M	Construction to operation	990	650	993
TPB01	B00700R(s)	Construction to operation	410	90	414
TPB03	B00920M	Construction to operation	605	150	610
TB01	B00950L(s)	Construction only	360	0	372
TPB04	B01000L(s)	Construction to operation	1725	280	1794
TPB05	B01120L(s)	Construction to operation	185	50	188
TB02	B01550L	Construction only	2360	0	2361
TPB06	B02460L	Construction to operation	3890	1300	3897
TPB07	B02520L(s)	Construction to operation	450	400	175*
TB03	B02700M(s)	Construction only	250	0	254
TPB08	B02700R	Construction to operation	595	210	610
TPB09	B03340M	Construction to operation	380	1250	1255
TB05	B03350L(s)	Construction only	420	0	430
TB04	B03480R	Construction only	900	0	905
TPB10	B03750L(s)	Construction to operation	310	300	321
TPB11	B03800M	Construction to operation	2435	2200	2468
TB06	B04300L	Construction only	575	0	578
TB07	B07000L	Construction only	1485	0	1485
TPB12	B07150L	Construction to operation	150	145	150
TPB13	B07300R	Construction to operation	515	175	515
TPB14	B07500L	Construction to operation	465	295	465

Basin name	Basin code	Type	Construction volume (m³)	Operational volume (m³)	Design volume (m³)
TPB15	B07800R	Construction to operation	180	580	580
TPB16	B08000L	Construction to operation	855	1150	1150
TPB17	B08150L	Construction to operation	730	700	730
TB10	B08360R	Construction only	260	0	269
TPB19	B08980L	Construction to operation	2260	325	2260
TPB18	B09120M	Construction to operation	285	1700	1700
TPB20	B09160M	Construction to operation	190	130	195
TPB21	B09360L	Construction to operation	395	745	745
TPB22	B09440L	Construction to operation	815	1500	1500
TPB23	B10350R	Construction and operation	310	250	319
TPB24	B10400R	Construction and operation	380	1040	1062
TB11	B11000R	Construction only	365	0	372
TB12	B11500R	Construction only	660	0	670
TB13	B11550L	Construction only	325	0	331
TPB25	B11900R	Construction and operation	490	1820	1857
TB14	B11950R	Construction only	375	0	387
TPB26	B12460R	Construction and operation	1320	750	1332
TPB27	B12650R	Construction to operation	425	490	493
TPB28	B13450L	Construction to operation	355	420	421
TPB30	B13850L(s)	Construction to operation	230	70	234
TPB29	B13900L	Construction to operation	325	180	331
TPB31	B14160M	Construction to operation	720	170	729
TPB32	B14400M	Construction to operation	680	230	684
TPB33	B14450M	Construction to operation	615	480	621
TB08	B07450Rb	Construction only	290	0	305
TB09	B07900R	Construction only	431	0	436

* Basin B02520L(s) is located in a severely constrained area. Options to provide a reduced basin size may be developed during detailed design when the construction staging details are finalised
Green shaded cells indicate basins nominated for lining due to their location within the Tomago Sandbeds Catchment. These basins would be lined to avoid contamination of groundwater.

5.1.3 Discharges from sediment basins

The temporary sediment basins have been designed to contain and treat turbid surface runoff from the construction footprint. As discussed in **Section 5.1.2**, sediment basin size design is based on a prescribed site-specific rainfall depth for Newcastle of 38.9 millimetres and must be discharged within five days of the conclusion of the rainfall event.

These basins have been designed in accordance with requirements of the Blue Book described in **Section 5.1.2**.

Frequency of overflows

The basin volumes are not designed to fully contain rainfall runoff from rainfall events exceeding the site-specific design criteria of 38.9 millimetres. Therefore, the basins are designed to overflow if the rainfall exceeds the design criteria, as they are designed in accordance with the Volume 2D Blue Book requirements (DECC NSW 2008). Infrequent rainfall events with depths exceeding the 38.9 millimetre rainfall design criteria have the potential to occur during the construction period.

A review of the daily recorded data for the Newcastle University (BOM station 061390) rain gauge has been carried out to provide an understanding of the likely frequency of basin overflows in design criteria exceeding events. The overflows are considered to be partially controlled as the volume in the basins for runoff generated from the first 38.9 millimetres would still be contained in the basins and treated.

An assessment has been carried out to provide an indication of the likely frequency of overflows from the temporary sediment basins and the likely volume of overflow into the receiving waterways.

The assessment has used rainfall data for a period of 19 years (from 2001 to 2019). The BOM station for this rain gauge was first established in 1998. Data from 1998 to 2000 was not used due to missing data. Based on the review of the recorded rainfall data, some daily rainfall events with depths of over 38.9 millimetres are likely to occur during the construction period, however these are likely to be in the order of up to 70 millimetres and less likely to be in the order of up to 150 millimetres.

The frequency of daily rainfall data exceeding 38.9 millimetres represents the minimum frequency of basin overflows. **Figure 5-1** provides the frequency of basin overflows from 2001 to 2019.

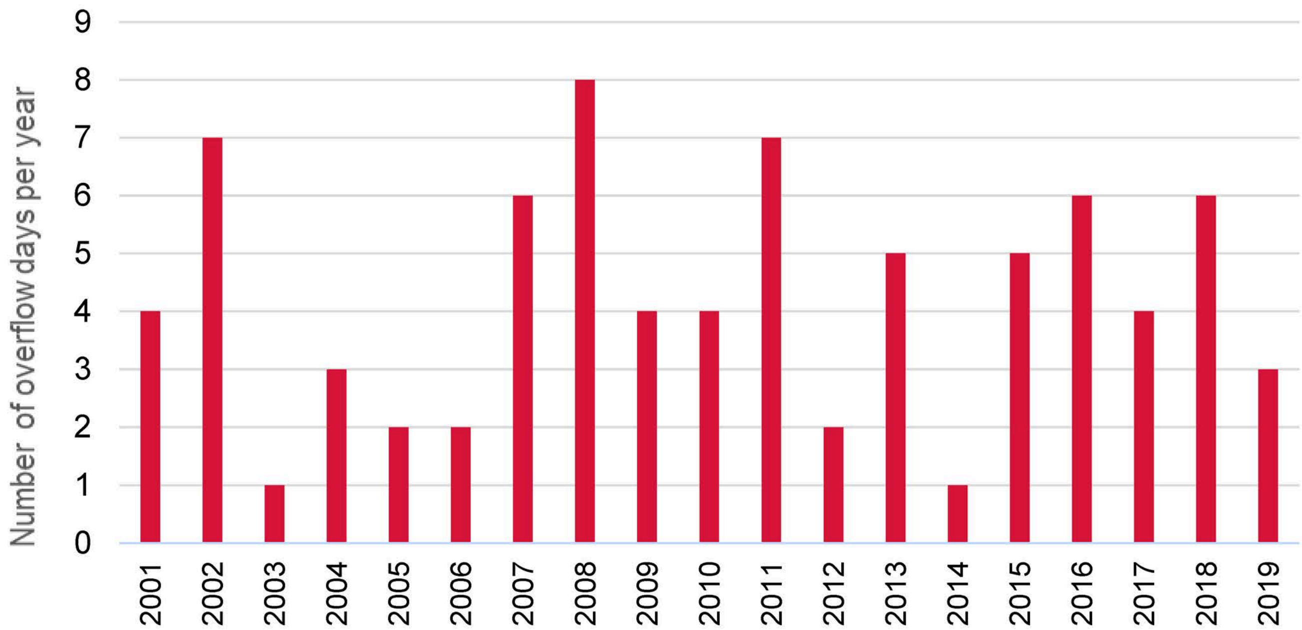


Figure 5-1 Estimated number of overflows from the temporary sediment basins for 2001 to 2019

The minimum average yearly frequency of overflows is approximately four times per year, however a review of the rainfall data for five consecutive days revealed that this frequency is more likely to be seven occurrences per year. The actual frequency during the construction would depend on the rainfall events as dry years would generate a smaller number of overflows.

The frequency of overflows applies to all sediment basins as they are all sized using the same design criteria and input parameters obtained from the Blue Book requirements. However, there are some basins on site where this frequency would be higher than the average seven times per year. These are the basins where the groundwater level is high, which means that when these basins are emptied post treatment and following rainfall events, only a portion of the basin volume can be emptied. Those basins have been identified and an estimate of their increased overflow frequency presented in **Section 5.1.4**.

Sediment discharged from basins

Total suspended solid (TSS) loads discharged from the temporary sediment basins were estimated for seven locations (R1 to R7) during controlled and overflow conditions. The seven locations (R1 to R7) represent the main waterways receiving project impacted water (refer **Figure 4-6**). Under controlled conditions, runoff is collected in the sediment basins and retained for up to five days to reduce TSS concentrations to below 50 mg/L, set in the design criteria by the Blue Book and incorporating anything up to 38.9 millimetres of rainfall. Any rainfall above this was considered to be overflow. Partial treatment of overflow volumes still occurs, as they go through the basin but would unlikely to be retained in the basin long enough to achieve the required TSS concentration of 50 mg/L. Total annual average loads of TSS (see **Table 5-3**) ranged from 104 kilograms per year at R6 – Hunter River to 2974 kilograms per year at R5 - Viney Creek. Lower loads discharged to the Hunter River are due to the smaller number of basins that have a direct connection to the Hunter River, whereas smaller waterways such as Viney Creek have a greater number of basins discharging into it.

Table 5-3 Annual average TSS loads (kg/yr) discharged from sediment basins under controlled conditions

Locations	Controlled discharge from sediment basins
R1-Glenrowan Creek	584
R2-Purgatory Creek	209
R3-Hunter River drain	2734
R4-Windeyers Creek	2066
R5-Viney Creek	2974
R6-Hunter River	104
R7-Unnamed coastal wetland	209

5.1.4 Groundwater interaction

The potential impacts of shallow groundwater on the function of temporary sediment basins have been assessed using modelled groundwater levels and the closest groundwater quality monitoring bore within the same groundwater system. Groundwater levels have been considered at all basin locations to identify any potential issues during the construction phase. Groundwater levels do not exceed the design basin water levels for all basins.

At 30 sediment basins, groundwater levels have been modelled as being above the basin invert, meaning that following construction the basins would fill with groundwater to about the height of the surrounding groundwater level. This has implications for the operation of the basin and for water quality within the basin, but not treatment capability of the basin. An assessment of potential basin water quality resulting from the blending of surface water runoff and local groundwater within the basins has been carried out.

Table 5-4 summarises information on the groundwater levels in comparison to the basin base invert levels of all affected basins and the assessed water quality of the basin. Further detail on the analysis is provided in **Appendix H**. Elevated salinities in discharge water from basins below the water table are likely in these areas, due to the saline nature of the groundwater of the Hunter Alluvium and Tomago Coal Measures.

Four basins (shaded in blue in **Table 5-4**) are recommended for lining due to naturally occurring existing elevated indicative saline levels (refer to **Chapter 8**). It is noted however, that the calculations are conceptual, best estimates and worst--case scenario based on a basin's volume of water being discharged. Ongoing runoff to the basin would then act to further dilute and improve the basin water quality. Green shaded cells indicate basins already nominated for lining due their location within the Tomago Sandbeds Catchment.

Table 5-4 Indicative groundwater levels and water quality at basins during construction

Basin name	Basin code	Basin type	Modelled groundwater level (AHD)	Basin water level RL (metres)	Depth of groundwater above invert (metres)	Indicative blend water quality (µS/cm)*
TB01**	B00950L	Construction only	10.88	10.88	1.63	5,847
TPB04**	B01000L	Construction and operation	11.08	11.08	1.83	5,847
TPB05**	B01120L	Construction and operation	9.73	10.10	0.63	3,726
TPB06**	B02460L	Construction and operation	4.00	4.75	0.75	3,250
TPB09	B03340M	Construction and operation	0.75	0.75	1.80	4,842
TB05	B03350L	Construction only	1.72	2.00	1.22	5,921
TB04	B03480R	Construction only	0.16	0.16	1.76	13,041
TPB10	B03750L	Construction and operation	0.70	0.70	1.95	11,643
TPB11	B03800M	Construction and operation	-0.13	1.05	0.32	2,237
TB06	B04300L	Construction only	-0.07	0.15	1.28	15,543
TPB12	B07150L	Construction and operation	1.53	1.75	1.28	1,864
TPB13	B07300R	Construction and operation	3.38	4.65	0.23	158
TPB14	B07500L	Construction and operation	0.33	1.25	0.58	346
TPB15	B07800R	Construction and operation	4.29	5.35	0.54	292
TPB16	B08000L	Construction and operation	0.55	1.05	1.00	623
TPB17	B08150L	Construction and operation	0.61	1.07	1.04	652
TB10	B08360R	Construction only	1.48	1.75	N/A^	N/A^
TPB19	B08980M	Construction and operation	0.47	0.70	1.27	6,925
TPB18	B09120M	Construction and operation	1.35	1.35	1.60	8,832

Basin name	Basin code	Basin type	Modelled groundwater level (AHD)	Basin water level RL (metres)	Depth of groundwater above invert (metres)	Indicative blend water quality (µS/cm)*
TPB21	B09360L	Construction and operation	0.52	0.70	1.32	317
TPB22	B09440L	Construction and operation	1.53	1.65	1.38	336
TB13	B11550L	Construction only	1.94	2.70	N/A^	N/A^
TB12	B11950R	Construction only	1.99	3.15	0.34	125
TPB26**	B12460R	Construction and operation	1.91	2.40	N/A^	N/A^
TPB27**	B12650R	Construction and operation	1.78	2.10	1.18	273
TPB28**	B13450L	Construction and operation	2.59	3.25	0.34	206
TPB30**	B13850L	Construction and operation	1.40	2.84	0.06	51
TPB29**	B13900L	Construction and operation	1.41	2.49	0.43	54
TPB31**	B14160M	Construction and operation	1.43	2.60	0.33	53
TPB32**	B14400M	Construction and operation	1.48	1.55	1.43	185

* Indicative water quality blend is based on groundwater modelling, nearest groundwater bore within same groundwater system and monitoring data. Note that this assessment does not consider seasonal fluctuations. Assumes that runoff has an EC of 50 µS/cm on the Tomago Sandbeds and Tomago Coal Measures, and EC of 150 µS/cm on the Hunter Alluvial groundwater system.
** Indicates that basin discharges into a waterway classified as a lowland river under the ANZG (2018) guidelines.
^ N/A refers to basins within the Tomago Sandbeds Catchment Area that are lined. Depth of groundwater and water quality blend is therefore not applicable.
Blue shading indicated basins that are in areas that exceed the nominated salinity level of 7500 µS/cm. These basins are nominated for lining.
Green shaded cells indicate basins already nominated for lining due their location within the Tomago Sandbeds Catchment. These basins would be lined to avoid contamination of groundwater.

If the basin is emptied within five days after a storm event, it will be emptied down to the groundwater level only (with the exception of basins where no emptying is possible, as discussed in **Section 5.1.3**).

During construction, groundwater would not have an impact on the basin's treatment capability, allowing it to operate as intended. However, basins experiencing groundwater inflows may overflow more frequently (as discussed in the subsequent section).

Overflows from basins that are affected by high groundwater levels

Several sediment basins are located in areas where the groundwater level is relatively high. These basins are surrounded by very shallow groundwater where less than 50 per cent of their capacity can be emptied. Some of these basins have no emptying capacity as the groundwater level is at the same level as the surface water in the basin.

These basins can only be emptied down to the groundwater level and therefore would overflow more frequently. An assessment has been carried out to review the basin volume of water that cannot be emptied so that the increased frequency of overflow can be determined. **Table 5-5** provides the list of sediment basins expected to overflow more frequently. **Table 5-6** provides a list of sediment basins where over 50 per cent of capacity cannot be emptied.

Table 5-5 Increased frequency of overflows from sediment basins with high groundwater levels

Basin name	Basin code	Annual overflow frequency
TPB06*	B02460L	12
TPB14	B07500L	10
TPB27	B12650R	14
TPB28	B13450L	11

* Basin TPB06 is proposed to be lined to avoid saline groundwater discharge to surface waterways (refer to **Chapter 8**). Lining would reduce the annual overflow frequency as it would prohibit groundwater inflows.

Table 5-6 Percentage volume of sediment basins that cannot be emptied

Basin name	Basin code	Percent of basin volume that cannot be emptied due to high groundwater levels
TB01	B00950L	100%
TPB04	B01000L	100%
TPB05	B01120L	63%
TPB09	B03340M	61%
TB05	B03350L	74%
TB04	B03480R	96%
TPB10	B03750L(s)	85%
TB06	B04300L	79%
TPB16	B08000L	57%
TPB17	B08150L	60%
TPB18	B09120M	100%
TPB21	B09360L	83%
TPB22	B09440L	88%
TPB32	B14400M	67%

5.2 Operational phase

5.2.1 Operational water quality strategy

The ANZECC Guidelines (ANZECC/ARMCANZ, 2000a) (now ANZG, 2018) indicate that several physical-chemical and toxicant parameters need to be controlled to maintain the required protection level for aquatic ecosystems during the operational phase of the project (refer to **Section 2.3.3**). These parameters include nutrients (total phosphorus and nitrogen), suspended solids, oils and greases, petroleum hydrocarbons and several heavy metals including copper, lead, zinc, cadmium and chromium which are commonly found in stormwater runoff from roads.

The provision of operational water quality treatment controls for road pavement runoff have been determined by four factors:

- The environmental sensitivity of the receiving waterways assessed as part of this environmental assessment process
- The annual average daily traffic (AADT) loading
- Design criteria (refer to section below) and planning requirements such as the SEARs (refer to **Section 3.3.4**)
- Consideration and balancing of all environmental issues, particularly where implementation of water quality treatment measures may have a negative impact on other items of environmental importance, such as biodiversity and sensitive receiving environments.

As such, the main strategy to minimise impacts to water quality during operation, in particular to SREs, is the provision of a water quality treatment sequence consisting of permanent water quality basins (further detailed in **Section 5.2.2**) and grassed swales (further detailed in **Section 5.2.3**). Rainfall runoff and accidental spills (such as petroleum hydrocarbons) within the footprint of the road would be captured and treated through these swales and basins. Specific aspects of the operational water quality strategy includes:

- Permanent water quality basins and swales, which where practicable, capture and treat runoff from the main alignment
- Use of grassed swales as appropriate to reduce the operational footprint and optimise water quality basin size
- Accidental spill containment of minimum 20,000 litres provided at basins that are located within 500 metres of aquatic environmentally sensitive areas, except for at the Tomago Sandbeds Catchment Area where the minimum containment volume is 30,000 litres. All permanent water quality basins that discharge to SREs provide spill containment by default through an underflow baffle arrangement located at the outlet side of the basin that capable of capturing accidental spills such as hydrocarbons in dry weather as well as during small to moderate storm events
- Water quality controls for all roads with high traffic volumes where practicable. Water quality treatment for local roads and access ramps with lower traffic volumes and low speed is not warranted due to minimal pollutant loads. Water quality controls have not been identified to treat runoff from existing road pavements that are not affected or modified by the project
- Directing pavement runoff from the viaduct to water quality treatment control measures prior to discharging into the Hunter River
- Lining of basins and swales located within the Tomago Sandbeds Catchment Area so that road impacted run off is treated before it interacts with soils or is allowed to discharge. This helps reduce the potential risk to groundwater and is in accordance with Hunter Water Corporation requirements.

5.2.2 Permanent water quality basin designs

Design criteria

The NSW Office of Environment and Heritage design target for water quality, as described in Managing Urban Stormwater – Council Handbook (EPA, 1997), have been used to preliminarily guide the project design criteria for the sizing of permanent water quality basins. These criteria are listed in **Table 5-7**.

Table 5-7 Design criteria

Pollutant	Minimum reduction of the annual average loads*
Total suspended solids (TSS)	80%
Total phosphorus (TP)	45%
Total nitrogen (TN)	45%

* In comparison to average annual loads if the proposed permanent water quality basins were not implemented. These criteria are not the criteria by which the project is assessed, rather the criteria that have informed the basin design. Assessment criteria are discussed in **Section 3.3.4**.

Permanent water quality basin location selection

The locations of permanent water quality basins were identified in relation to the main alignment and drainage discharge points. Where possible, the locations of temporary sediment basins and permanent water quality basins have been consolidated so that the construction phase temporary basins can be converted into permanent basins following completion of construction and stabilisation of the site. This would minimise the need to construct additional basins at different locations for the project and would minimise total drainage infrastructure

Catchments associated with the project were identified by considering the roadway and the proposed pipe drainage network. The location of these project catchments inform the location of the proposed controls. The total catchment area associated with the project was divided into two sub-catchments – the impervious road catchment (all impervious elements), and the pervious road side catchment (generally batter slopes and unsealed embankments).

Permanent water quality basin sizing

Water quality modelling in the MUSIC model was carried out to derive pollutant loads and pollutant concentrations from the project, specifically TSS, TN and TP. Together with the project's WQOs and targets, these loads and concentrations were used iteratively in the model to determine the size of the proposed controls.

Rainfall inputs and event mean concentrations

The assessment utilised a MUSIC model to quantify stormwater quality outputs. The project MUSIC model used recorded data from the pluviograph (1 hour rainfall data or smaller increments) local to the project (Newcastle BOM Station 061390).

Appropriate event mean concentrations (EMCs) for the proposed sealed road pavement and revegetated areas for TSS, TN and TP were used in the MUSIC model. The MUSIC model provides recommended EMCs for sealed roads and revegetated batters. These default parameters are appropriate to use, however, the following sources were also used for typical concentrations:

- CRC for Catchment Hydrology (1999), Urban Stormwater Quality, A Statistical Overview
- CRC for Catchment Hydrology and Monash University (2004), Stormwater Flow and Quality and the Effectiveness of Non-Proprietary Stormwater Treatment Measures, A review and Gap Analysis.

The recommended EMCs for the proposed pavement and for the roadside pervious areas are outlined in **Table 5-8**.

Table 5-8 Typical stormwater runoff concentrations for operational phase in mg/L

Pollutant concentration (mg/L)	TSS		TP		TN	
	Event (wet)	Base (dry)	Event (wet)	Base (dry)	Event (wet)	Base (dry)
Road pavement – impervious	270	15.8	0.5	0.14	2.19	1.29
Roadside vegetated batters – pervious	89	14.1	0.22	0.06	2.0	0.89
Existing open space – pervious	79	7.9	0.079	0.03	0.84	0.72

Proposed permanent water quality basin locations

There are 39 proposed permanent water quality basins. Locations and sizes are presented in **Table 5-9** and are shown on Figure I-2 in **Appendix I**. Green shaded cells indicate basins nominated for lining due their location within the Tomago Sandbeds Catchment.

Table 5-9 Permanent water quality basins

Basin name	Basin code	Type	Construction volume (m^3)	Operational volume (m^3)	3D modelled volume (m^3)
PB01	B00560M(s)*	Operation only	0	800	809
PB03	B00700M	Construction and operation	990	650	993
PB02	B00700R(s)	Construction and operation	410	90	414
PB04	B00920M	Construction and operation	605	150	610
PB05	B01000L(s)	Construction and operation	1725	280	1794
PB06	B01120L	Construction to operation	185	50	180
PB07	B02460L	Construction and operation	3890	1300	3897
PB08	B02520L(s)	Construction and operation	450	400	175**
PB09	B02700R	Construction and operation	595	210	610
PB10	B03340M	Construction and operation	380	1250	1255
PB11	B03440M	Operation only	0	350	350
PB12	B03750L	Construction and operation	310	300	321
PB13	B03800M	Construction and operation	2435	2200	2468
PB14	B05700L	Operation only	0	1450	1466
PB15	B06100L	Operation only	0	60	64
PB16	B07005L	Operation only	0	295	300
PB18	B07300M	Operation only	0	530	545
PB17	B07150L	Construction and operation	150	150	150
PB19	B07300R	Construction and operation	515	175	515
PB20	B07500L	Construction and operation	465	295	465
PB21	B07800R	Construction and operation	180	580	580
PB22	B08000L	Construction and operation	855	1150	1150

Basin name	Basin code	Type	Construction volume (m^3)	Operational volume (m^3)	3D modelled volume (m^3)
PB23	B08150L	Construction and operation	730	700	730
PB25	B08980L	Construction and operation	2260	325	2260
PB24	B09120M	Construction and operation	285	1700	1700
PB26	B09160	Construction and operation	190	130	195
PB27	B09360L	Construction and operation	395	745	745
PB28	B09440L	Construction and operation	815	1500	1500
PB29	B10350R	Construction and operation	310	250	319
PB30	B10400R	Construction and operation	380	1040	1062
PB31	B11900R	Construction and operation	490	1820	1857
PB32	B12460R	Construction and operation	1320	750	1332
PB33	B12650R	Construction and operation	425	490	493
PB34	B13450L	Construction and operation	355	420	421
PB36	B13850L(s)	Construction and operation	230	70	234
PB35	B13900L	Construction and operation	325	180	331
PB37	B14160M	Construction and operation	720	170	729
PB38	B14400M	Construction and operation	680	230	684
PB39	B14450M	Construction and operation	615	480	621

* B0560M(s) denotes that the sediment basin is at about Stn. 560 on the control string. The L, M or R indicates that it is on the left, right or middle of the main alignment looking at increasing chainages. The (s) denotes a basin located on a road other than the new Pacific Highway, i.e. a 'side' road
** Basin B02520L(s) is located in a severely constrained area. Options to provide a reduced basin size will need to be developed during detailed design when the construction staging details are finalised based on the final detailed design.
Green shaded cells indicate basins nominated for lining due their location within the Tomago Sandbeds Catchment. These basins would be lined to avoid contamination of groundwater.

5.2.3 Grassed swales

Grassed swales were incorporated into the project design to support the function of the water quality basins. While swales alone may not achieve all of the water quality criteria for the project, the swales allow basin sizes to be reduced, therefore reducing the operational footprint. **Table 5-10** lists basins which have been reduced in size due to the operation of a swale or number of swales. In total, the swales on the project have resulted a reduction of about 2000 cubic metres across 12 water quality basins. This is considered a conservative assessment, and the actual reductions gained by grassed swales are likely to be larger for low to moderate flows due to the high effectiveness of the swales.

Green shaded cells indicate swales nominated for lining due their location within the Tomago Sandbeds Catchment.

Table 5-10 Reduction of permanent basin volumes utilising swales

Basin name	Basin code	Swale length proposed (m)	Volume before swale (m^3)	Volume after swale (m^3)	Basin volume reduction
PB01	B00560M(s)	25	1050	800	24%
PB10	B03340M	426, 82*	1800	1250	31%

Basin name	Basin code	Swale length proposed (m)	Volume before swale (m^3)	Volume after swale (m^3)	Basin volume reduction
PB15	B06100L	35	150	60	60%
PB18	B07300M	130	550	480	6%
PB19	B07300R(s)	120	530	480	3%
PB24	B09120M	105	530	500	6%
PB27	B09360L	68	850	800	6%
PB30	B10400R	300	1250	1040	17%
PB33	B12650R	114	860	490	43%
PB34	B13450L	156	550	420	24%
PB35	B13900L	108, 68*	450	315	30%
PB38	B14400M	245, 240*	780	680	13%

* Multiple lengths denote multiple swales
Green shaded cells indicate swales nominated for lining due their location within the Tomago Sandbeds Catchment. These swales would be lined to avoid contamination of groundwater

5.2.4 Discharges from water quality basins

The MUSIC model developed for the project has been used to quantify pollutant loads for existing and proposed conditions. The MUSIC model has also been applied during the concept design to determine the sizes of the permanent water quality controls and measure the proposed water quality against the WQO.

When carrying out MUSIC modelling, the catchment draining to an individual control measure was identified by considering the formation of the proposed carriageway and the proposed pipe drainage network. The total catchment area was then divided into sub catchments according to the different land use characteristics of the 'impervious road catchment' area, and the batter slope or 'pervious roadside' area. Appropriate rainfall and other key input parameters such as event mean concentrations and soil permeability were then used.

There are scattered areas along the project where additional water quality treatment occurs that has not been included in the water quality model. These areas are typically landscaped batters and vegetated median areas where sheet flow surface runoff is treated as it travels over these areas. This means that the real outcomes are anticipated to be better than the modelled outcomes (that is, that the modelling is conservative).

The permanent water quality basins have been designed to comply with design criteria outlined in Managing Urban Stormwater – Council Handbook (EPA, 1997) and described in **Section 5.2.2**. These design criteria involve a percentage load reduction on the estimated unmitigated pollutant loads generated from the project only. They do not consider existing conditions, rather they are load-based targets

Total suspended solid, total phosphorus and total nitrogen loads discharged from the permanent water quality basins were estimated using the MUSIC water quality model for seven locations (R1 to R7) during the operational phase. The seven locations (R1 to R7) represent the main waterways receiving project impacted water (refer **Figure 4-6**). Road pavement surface runoff is collected in the water quality basins for treatment to reduce concentrations and loads. The residual annual average pollutant loads for each of the R1 to R7 locations are provided in **Table 5-11**. Lower loads discharged to the Hunter River are due to the smaller number of basins that have a direct connection to the Hunter River, where as smaller waterways such as Viney Creek have a greater number of basins discharging into it.

Road pavement surface runoff is collected in the water quality basins and retained up until the next storm event during which volume displacement occurs and the treated water leaves the basin. This process which is repeated provides hydraulic residence time for the collected runoff to start the treatment process of reducing concentrations and loads. TSS and particulate bound pollutants such as TP and heavy metals settle at the base of the basin and additional chemical and biological processes occur in the basin to reduce other pollutants such as TN.

Table 5-11 Annual average TSS, TP and TN loads (kg/yr) discharged from water quality basins under controlled conditions

Locations	TSS	TP	TN
R1-Glenrowan Creek	231	0.48	3.1
R2-Purgatory Creek	2,200	4.47	28.4
R3-Hunter River drain	2,260	4.11	22.7
R4-Windeyers Creek	2,270	5.39	39.2
R5-Viney Creek	1,950	4.38	39.7
R6-Hunter River	128	0.36	3.9
R7-Unnamed coastal wetland	606	2.09	14.3

5.2.5 Groundwater interaction

Groundwater levels have been considered at all permanent water quality basin locations to identify any potential issues during the operational phase. This assessment has been carried out using modelled groundwater levels and the closest groundwater quality monitoring bore within the same groundwater system. For 25 basins during operation, groundwater levels have been assessed as being above the basin invert.

Four basins (shaded in blue) are recommended for lining due to elevated indicative saline levels. **Table 5-12** summarises information on the groundwater levels in comparison to the basins base invert levels of all affected basins. Green shaded cells indicate basins already nominated for lining due their location within the Tomago Sandbeds Catchment. Further detail on the analysis is provided in **Appendix H**.

Table 5-12 Indicative groundwater levels and quality at the proposed water quality basins during operation

Basin name	Basin code	Basin type	Modelled groundwater level (mAHD)	Basin water level (mAHD)	Depth of groundwater above invert (m)	Indicative blend water quality (µS/cm)*
PB05**	B01000L	Construction and operation	11.08	11.085	1.83	5,847
PB06**	B01120L	Construction and operation	9.73	10.10	0.63	3,726
PB07**	B02460L	Construction and operation	4.00	4.75	0.75	3,250
PB10	B03340M	Construction and operation	0.75	1.2	1.80	4,842
PB12	B03750L	Construction and operation	0.70	0.85	1.95	11,643
PB13	B03800M	Construction and operation	-0.13	1.05	0.32	2,237

Basin name	Basin code	Basin type	Modelled groundwater level (mAHD)	Basin water level (mAHD)	Depth of groundwater above invert (m)	Indicative blend water quality (µS/cm)*
PB14	B05700L	Operation only	0.04	0.19	1.35	16,886
PB15	B06100L	Operation only	0.12	0.55	0.82	11,976
PB17	B07150L	Construction and operation	1.53	1.75	1.28	1,864
PB19	B07300R	Construction and operation	3.38	4.65	0.23	158
PB20	B07500L	Construction and operation	0.33	1.25	0.58	346
PB21	B07800R	Construction and operation	4.29	5.35	0.54	292
PB22	B08000L	Construction and operation	0.55	1.05	1.00	623
PB23	B08150L	Construction and operation	0.61	1.07	1.04	652
PB25	B08980M	Construction and operation	0.47	0.70	1.27	6,925
PB24	B09120M	Construction and operation	1.35	1.35	1.60	8,832
PB27	B09360L	Construction and operation	0.52	0.70	1.32	317
PB28	B09440L	Construction and operation	1.53	1.65	1.38	336
PB32**	B12460R	Construction and operation	1.91	2.40	N/A^	N/A^
PB33**	B12650R	Construction and operation	1.78	2.10	1.18	273
PB34**	B13450L	Construction and operation	2.59	3.25	0.34	206
PB36**	B13850L	Construction and operation	1.40	2.84	0.06	51
PB35**	B13900L	Construction and operation	1.41	2.49	0.43	54
PB37**	B14160M	Construction and operation	1.43	2.60	0.33	53
PB38**	B14400M	Construction and operation	1.48	1.55	1.43	185

* Indicative water quality blend is based on groundwater modelling, nearest groundwater bore within same groundwater system and monitoring data. Note that this assessment does not consider seasonal fluctuations and is based on a small sample size for groundwater monitoring. Assumes that runoff has an EC of 50 µS/cm on the Tomago Sandbeds and Tomago Coal Measures, and EC of 150 µS/cm on the Hunter Alluvial groundwater system.
** Indicates that basin discharges into a waterway classified as a lowland river under the ANZG (2018) guidelines.
^ N/A refers to basins within the Tomago Sandbeds Catchment Area that are lined. Depth of groundwater and water quality blend is therefore not applicable.
Blue shading indicated basins that are in areas that exceed the nominated salinity level of 7500 µS/cm
Green shaded cells indicate basins already nominated for lining due their location within the Tomago Sandbeds Catchment. These basins would be lined to avoid contamination of groundwater

When the basin water level is above the local groundwater level, water from the basin may slowly exfiltrate and feed the groundwater depending on the soil permeability rates. The water level in the basin may reduce slightly over prolonged dry weather, however, base flow and small storm events would compensate for those losses so the permanent water level would remain at the groundwater levels and the basin would continue to work as intended. Sediment basins are designed based on retention times (flow duration from inlet to outlet) and sediment settling velocities when full. As such the level of groundwater within the basin would have no impact on the water quality treatment capabilities of the basin.

The key outcomes of this groundwater and basins assessment are:

- The groundwater level would be below the surface water level for all basins
- For 25 basins, the groundwater level may be above the basin invert level, i.e. above the base of the basin
- As the groundwater level would not be above the surface water level of the basin, continuous drawdown and impact on the groundwater levels would not occur
- Lining would be implemented for basins and swales located in the Tomago Sandbeds Catchment Area
- Lining is recommended for where indicative basin blend water quality is greater than 7500 µS/cm (refer to **Chapter 8**).

6. Assessment of potential impacts

6.1 Impacts avoided and minimised

The concept design for the project was developed using a multi-disciplinary process that identified and assessed routes against a range of engineering, environmental, social, land-use and economic criteria. This process (as described in Chapter 4 of the EIS) ultimately determined that the project alignment represented the best balance after a multi-criteria analysis of all known constraints and opportunities.

As a result of project development, the alignment has been shifted to be closer to the New England Highway and other existing infrastructure corridors, crossing the Hunter River 1.4 kilometres north of the original crossing and minimising the overlap with the Hunter River floodplain. As a result of route optioneering and the design development, the project has avoided:

- Minimise the extent of the project located within the flood plain and its soft soils to limit ongoing complex surface water and groundwater interactions
- Substantial water quality impacts arising from substantial increases in flooding behaviour, flows and afflux associated with an large embankment across the Hunter River floodplain
- Permanent drawdown of the various groundwater resources during operation as a result of design interface lowering the groundwater.

Project design has sought to minimise impacts to water quality. In summary, the project has minimised water quality impacts through:

- Application of a strategy to minimise impacts to the Tomago Sandbeds Catchment Area. This strategy has included lining water quality controls within the Tomago Sandbeds Catchment Area during construction and operation to avoid infiltration of untreated water into the Tomago Sandbeds aquifer and ensuring runoff is treated in water quality basins prior to discharge (refer to **Section 5.1.1** and **Section 5.2.1**)
- Minimising vegetation clearance and disturbance of previously undisturbed areas by placing the project within or adjacent to development corridors
- Minimising disturbance of sediments on the Hunter River floodplain by crossing the floodplain with a 2.6 kilometre viaduct instead of an embankment
- Construction water quality controls to reduce water quality impacts during construction, including impacts on SREs and downstream estuarine and marine waters (refer to **Section 5.1**)
- Operational water quality controls (comprising permanent water quality basins and grassed swales) to reduce water quality impacts during operation, including impacts on SREs and downstream estuarine and marine waters (refer to **Section 5.2**)
- Lining select temporary and permanent basins with the potential to discharge water with elevated salinity into receiving environments (refer to **Section 6.2.1**).

6.2 Construction impacts

Construction of the project presents a risk of degradation of downstream surface water and groundwater quality if management measures are not implemented, monitored and maintained throughout the construction phase. Construction phase impacts to surface water and groundwater are discussed in **Section 6.2.1** and **Section 6.2.2**, respectively.

6.2.1 Surface water quality

Construction activities have the potential to cause surface water quality impacts. Road and bridge construction work have the potential to impact on receiving waterways and wetlands within the construction footprint. Importantly, construction activities which are considered to be the highest risk to water quality are:

- **Bridge work**: Involving instream work, including dredging, piling, as well as construction and use of temporary instream work platforms, bridges and wharfs, vegetation clearing in the riparian zones of creeks, concrete work, steel work and dewatering. Bridges which are proposed to be constructed over or within proximity of waterways and wetlands include:
  - A 2.6 kilometre viaduct over Hunter River and areas classified as Coastal Wetlands (Coastal Management SEPP)
  - Bridges across minor waterways including Glenrowan Creek (B02) and Windeyers Creek (B11); and
  - A bridge within proximity of the Hunter river wetland (B09).
- **Drainage work**: Including excavation and soft soil compaction, vegetation clearing on the streambed and banks, instream work, including streambed levelling for installation of culverts and temporary creek diversions, installation of drainage culverts, pipes and pits, construction of table drains and swales, and dewatering.

Other construction activities with the potential to impact specific waterways include but are not limited to:

- **Site establishment and access tracks**: Involving movement and use of vehicles across exposed earth, excavation, vegetation clearing and mulching, and transport of materials to and from site
- **Ancillary facilities**: Activities occurring at ancillary facilities include movement and use of vehicles across exposed earth, stockpiling, vegetation clearing and mulching, batching plants, crushing plants, precast facilities, transport of materials to and from site and establishment of water quality controls (temporary sediment basins and permanent water quality basins)
- **Earthworks**: Activities including cut and fill of existing soils, importing materials to work areas, and stockpiling soils and treatment of soils
- **Excavation and relocation of utilities**: Utilities would need to be relocated, adjusted or protected where they may be affected by project construction, particularly in areas where ground disturbance is required
- **Waterway adjustments**: Involving excavation, vegetation clearing in the riparian zones of creeks , and instream work, including streambed levelling for installation of culverts and new channel alignments
- **Construction discharges and dewatering**: Involving dewatering of excavations and as a result of soil consolidation activities
- **Site restoration**: Restoration and landscaping of disturbed areas (including ancillary facilities and construction access roads) where required.

Waterways and wetlands with the potential to be impacted by these various construction activities are presented in **Table 6-1**.

Table 6-1 Waterways and wetlands with the potential to be impacted by construction activities

Waterway or wetland	Construction activities									
	Bridge work	Drainage work	Site establishment and access tracks	Ancillary facilities	Earthworks	Road construction work	Excavation and relocation of utilities	Waterway adjustment	Construction discharges and dewatering	Site restoration
Unnamed tributary of Viney Creek			✓	✓	✓	✓	✓	✓	✓	✓
Glenrowan Creek and wetland near the twin bridge (B02) between Black Hill and Tarro	✓		✓	✓	✓	✓	✓		✓	✓
Unnamed Coastal Wetland (Coastal Management SEPP) south of New England Highway		✓	✓	✓	✓	✓	✓		✓	✓
Purgatory Creek	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Hunter River	✓	✓	✓	✓		✓			✓	✓
Unnamed Coastal Wetland (Coastal Management SEPP) east of Hunter River	✓	✓	✓	✓	✓	✓			✓	✓
Hunter River wetland	✓	✓	✓	✓	✓	✓		✓	✓	
Tomago Sandbeds (near Masonite Road)		✓	✓	✓	✓	✓	✓	✓		✓
Windeyers Creek	✓	✓	✓	✓	✓	✓			✓	✓
Tributary of Windeyers Creek		✓	✓	✓	✓	✓	✓		✓	✓

The construction activities described above may result in potential release of pollutants described in **Table 6-2**. Work within waterways (comprising bridge work, drainage work and waterway adjustments etc.) is considered to be the construction activity with the highest risk to surface water quality as it is located in a dynamic and fluid setting with minimal buffer area for control.

Pollutant-specific impacts are described in the sections that follow.

Table 6-2 Potential construction pollutant sources that may impact on surface water quality

Pollutant	Potential source of pollutant from construction activities
Erosion and sedimentation	• Instream work, including dredging and piling, streambed levelling for installation of culverts and temporary creek diversions • Vegetation clearing in waterways and riparian zone • Movement and use of vehicles across exposed earth • Cut and fill earthwork • Excavation • Transport of materials to and from site • Relocation of utilities, including under boring and trenching • Stockpiling • Waterway adjustments • Dewatering temporary sediment basins • Site restoration including landscaping.
Sulfuric acid	Disturbance of ASS from: • Excavation • Dredging • ASS treatment.
Salts	Disturbance of saline soils from: • Excavation • Cut and fill earthwork • Dewatering.
Concrete waste	• Release of concrete liquid by-products with high pH from concrete installation or batching plants / precast facilities.
Oils and fuels	Release of oils and fuels from: • Vehicle movements • Spills and leaks from construction plant and equipment • Dewatering temporary sediment basins.
Heavy metals, polycyclic aromatic hydrocarbons (PAHs) and other hydrocarbons	Release or exposure of heavy metals and PAHs from: • Asphalt works (batching, transport, laying, milling • Contaminated site remediation • Concrete works • Vegetation clearing and mulching • Spills.
Tannin leachate	Release of tannin leachate from: • Mulching and stockpiling of cleared vegetation.
Dust and litter	Release of dust and litter during: • Use of construction sites by construction workers • Material transport • Stockpiling • Concrete work • Rock crushing and blasting • Demolition.

Erosion and sedimentation

While highly erodible soils are generally not located within the construction footprint, there is still a risk of erosion and sedimentation from the following activities:

- **Instream work, including dredging and piling, streambed levelling and alteration of banks for installation of culverts and temporary creek diversions**: Carrying out instream works would result in disturbance of sediment during piling or dredging activities, or may destabilise the streambed and river banks when altering channel structure. This may result in potential sedimentation of downstream environment which can cause increased turbidity that can be detrimental to aquatic life, result in algal blooms and can reduce visual amenity
- **Vegetation clearing in waterways and the riparian zone (comprising bridge work, drainage work and waterway adjustments)**: Vegetation clearing within and near waterways may result in mobilisation of instream sediments, destabilisation of riverbanks and potential bank collapse, and/or erosion of exposed top soils via wind or runoff. Mobilised soils or sediments may result in increased turbidity within waterways which can be detrimental to aquatic life, result in algal blooms and can reduce visual amenity
- **Cut and fill earthwork**: Cut and fill earthwork are required along the main alignment due to the undulating topography. In areas of cut, there is a risk of erosion and sedimentation from potential destabilisation of the landform. In areas of fill, soils and landform have the potential to become eroded during rainfall events, resulting in sedimentation of downstream waterways through mass movement of soils. There is a risk of erosion and sedimentation from potential destabilisation at the large cut proposed at Black Hill and from smaller cuts at the Tomago interchange. Areas of fill around Purgatory Creek, Hunter River Drain and tributary to the Hunter River Drain also pose a risk to downstream water quality during rainfall events
- **Excavation**: Excavation has the potential to transport loose sediment to downstream waterways if able to mobilise via wind and runoff. Excavation is required for establishing access tracks, road construction activities, piling activities, building bridge abutments, constructing drainage infrastructure and adjusting waterway channel alignments along the entirety of the project
- **Movement and use of heavy vehicles across exposed earth**: Operation of heavy machinery can disturb soils, particularly in areas where vegetation has been removed or topsoil has been stripped. This increases the potential for erosion and sedimentation in downstream receiving environments, particularly those near access tracks, ancillary facilities and areas where construction vehicles, plant and equipment would be used
- **Transport of materials to and from site**: Excavated material, as well as material brought to site to be used in construction, would need to be transported to and from site via access tracks which has the potential be lost from the vehicle if not appropriately secured. This could result in sedimentation to downstream waterways if able to mobilise via wind or runoff. Material transport poses the highest risk to waterways that are near or crossed by access tracks and waterways in proximity to ancillary facilities or construction sites
- **Stockpiling**: Excavated material would require stockpiling before being crushed and reused or transported offsite. High rainfall events and high winds during construction can erode stockpiled areas and disturbed areas with exposed soils which can be transported downstream. This can result in increased turbidity, lower dissolved oxygen and increased nutrients which may exacerbate algal blooms and aquatic weed growth. Stockpiles are proposed at all ancillary facilities within the project construction footprint

- **Relocation of utilities**: A number of utilities are located within the construction footprint and may need to be relocated, adjusted or protected where they have the potential to be impacted by project construction, particularly where excavation is required. Relocation would involve soil disturbance from trenching and underboring, and disturbance of soil by machinery and could increase the potential for soil erosion. More significant utilities located near waterways that may be relocated include:
  - Electrical facilities at John Renshaw Drive which would need to be relocated near the unnamed tributary, within Coastal Wetland areas at the Tarro interchange and within coastal use and coastal environment areas at Tarro
  - Sewer relocation near a tributary of Windeyers Creek
  - Gas relocation within coastal environmental areas and an unnamed drainage line near Tomago and Heatherbrae
  - Watermain relocation at Purgatory Creek.
- **Construction dewatering and discharges**: Dewatering discharge from construction (either from excavations or wick drains) can result in water that turbid. This water would be directed into temporary sediment basins to minimise impacts
- **Site restoration**: Minor earthwork are required during landscaping and site restoration activities that could result in the erosion of disturbed soils that have not yet stabilised, with potential for sediment to be transported downstream by wind or runoff. Impacts associated with landscaping and site restoration would be temporary as stabilisation and revegetation would act to prevent future soil erosion.

While sediment-laden runoff and pollutants from erosion and sedimentation have the potential to temporarily reduce downstream water quality, they are unlikely to cause major or long term impacts to the overall condition of the surrounding waterways, as erosion and sedimentation will be managed with the implementation of erosion and sediment controls (as detailed in **Chapter 5**). Further to this, additional environmental management measures outlined in **Chapter 8** will be implemented to avoid and/or manage erosion and sedimentation impacts from construction activities.

An assessment of the likely quantities of sediment generated by the project during construction against WQO has been carried out and is documented in **Section 6.2.6**.

Sulfuric acid

Vegetation clearing, excavation, dredging, piling, general ground disturbance and streambed levelling can result in moderate water quality impacts due to the potential to disturb ASS and subsequently mobilise poor water quality to downstream waterways.

Within the construction footprint, there is a high potential for encountering ASS in sediments within the Hunter River and on the floodplains, between Tarro and Tomago, on the eastern side of the project in Heatherbrae and Raymond Terrace and at Windeyers Creek (refer to **Figure 4-8**). The waterways at risk of being impacted by disturbance of ASS are the Hunter River and Windeyers Creek due to the excavation required for bridge construction, and Purgatory Creek due to disturbance for creek adjustment. Of lower risk are the Viney Creek tributary and the unnamed tributaries and drainage canals.

The key contaminants of concern for disturbance of ASS are sulfuric acid and heavy metals. Exposure of ASS during construction can pose a risk if not appropriately managed and may lead to oxidation and cause acid leachate formation. This could occur in situ or in excavated stockpiles during construction. Acid leachate may contain elevated heavy metals that can be transferred to downstream waterways following rainfall, directly impacting aquatic life and water supply quality. Acid leachates can cause corrosion of construction materials such as concrete, iron and steel. Treatment of identified ASS introduces additional risk with the movement of chemicals and treated materials around the construction footprint. Therefore the potential to reuse treated ASS should be considered where feasible.

All excavated materials currently mapped as ASS shall be investigated and where required, treated before reuse or disposal. Treatment of ASS can comprise of neutralisation using lime or other neutralising agents.

While ASS treatment would be confirmed following finalisation of construction design, it would include implementation of an ASS management plan prepared in accordance with the Acid Sulfate Soil Manual (ASSMAC, 1998 or similar recognised guidance, establishing designated treatment areas, lime dosing prior to disturbance, transfer of soil to treatment area and leaving it until such time as soil testing confirms its acceptable for reuse or transferred offsite. These measures and treatment measures as outlined in the Soils and Contamination Working Paper (Appendix P of the EIS), would substantially reduce the risk to surface or ground water quality. As such, acid sulfate soil disturbance, if managed correctly, is not likely to result in a significant impact to water quality.

Salts

Saline soils are known to occur within the construction footprint at Black Hill, Tarro, Tomago, Heatherbrae and Raymond Terrace. Saline soils present a risk to downstream waterways if they are exposed and leach high concentrations of salt into runoff. Saline soils can alter the salinity of the waterways which can alter instream biodiversity and ecosystem function. However, risk of this impact is low as the receiving environment has habituated to catchment geology and saline impacted surface water flows. The projects surface water and ground water quality controls and management measures will be implemented to minimise the development of excessive saline water flows.

Concrete waste

Concrete work, including batching, pre-casting and in-situ pouring are required for building all water crossing structures, roads, and drainage infrastructure along the alignment. Concrete work can result in concrete dust, concrete slurries or washout water entering downstream waters. Concrete by-products are alkaline, with a pH of around 12, and therefore have the potential to alter the pH of downstream watercourses which can be harmful to aquatic life that are sensitive to changes in water quality.

The main areas at risk from potential mobilisation of concrete waste are waterways which are in proximity to ancillary facilities where concrete batch plants and precast facilities would be located. However, the risk of transportation of concrete waste to waterways is considered low as water quality controls and management measures will be implemented to ensure no runoff is mobilised downstream prior to being captured and treated in temporary sediment basins.

Oils, fuels, polycyclic aromatic hydrocarbons and heavy metals

Mobilisation of oils and/or fuels from leaks and spills or discharged from temporary sediment basins may lead to the introduction of hydrocarbons and heavy metals into the waterways which may be harmful to aquatic life and could reduce visual amenity.

Release or exposure of PAH from asphalt can be toxic to aquatic life. Dewatering of surface water features for the establishment of the construction footprint and access tracks may mobilise poor quality water with high toxicant concentrations, including PAHs to downstream receiving environments.

Heavy metals have potential to be introduced into waterways from construction activities if mobilised by wind or stormwater runoff. Potential sources include:

- Steel cuttings from steel works required for road and bridge construction
- Given the mangrove systems in the vicinity of the construction footprint, changes in physico-chemical conditions may trigger release of accumulated trace metals from mangroves
- Concrete waste may contain elevated concentrations of chromium
- Other heavy metals associated with waste materials from contaminated site remediation.

With the implementation of the environmental management measures described in **Chapter 8**, the release or exposure of oils, fuels and PAH, if managed correctly, is not likely to result in a significant impact to surface water quality.

Tannin leachate

Tannins can cause dark coloured water to be discharged into downstream waterways from mulching and stockpiling of cleared vegetation. This could alter the instream pH and reduce visibility and light penetration in the water column. Tannins could also increase biochemical oxygen demand, which could decrease instream dissolved oxygen concentrations which can impact on aquatic ecosystems and lead to fish kills.

With the implementation of the environmental management measures described in the Biodiversity Assessment Report (Appendix I of the EIS), tannin leachate, if managed correctly, is not likely to result in a significant impact to water quality.

Dust and litter

Dust generated from concrete work, rock crushing and blasting may contain heavy metals which could be harmful to aquatic life. Dust associated with demolition of buildings and infrastructure may contain contaminants such as concrete, asbestos, or other pollutants which may be harmful to aquatic ecosystems if mobilised to downstream environments.

Mobilisation of litter to waterways may lead to the introduction of gross pollutants, hydrocarbons and heavy metals into the waterways which may be harmful to aquatic life and reduce visual amenity.

With the implementation of the environmental management measures described in **Chapter 8**, dust and litter, if managed correctly, are not likely to result in a significant impact to water quality.

6.2.2 Groundwater quality

The main activities with potential for groundwater quality impacts during construction include:

- Temporary construction dewatering may result in dewatered discharge of unknown quality to be managed and also result in localised lowering of the water table with potential to oxidise ASS material or impact GDEs. Dewatering discharge is assessed in **Section 6.2.1**
- Soft soil consolidation causing in mounding of water table, which can result in potential for mobilisation of salts within soil profile
- Operation of unlined temporary sediment basins and potential to introduce contaminants into groundwater via a new migration pathway
- Construction activities resulting in mobilisation of areas of existing or potential groundwater contamination (notably the former mineral sands processing facility).

Water quality impacts to the Tomago Sandbeds Catchment Area, as a result of project activities, are also a specific consideration due to aquifer use as public drinking water supply.

It is noted that no specific groundwater quality impacts are anticipated as a result of access tracks or ancillary facility work.

Potential impacts associated with importation of unsuitable soils or other fill materials are discussed in the Soils and Contamination Working Paper (Appendix P of the EIS).

Temporary construction dewatering – acid sulfate soil risk

Temporary construction dewatering would be required where excavations occur below the water table. As discussed in the Hydrology and Flooding Working Paper (Appendix J of the EIS), shallow excavations, such as for culverts and minor utilities, or for the adjustment of the Viney Creek tributary alignment, are not anticipated to require substantial dewatering.

Key activities that have been assessed as requiring more substantial dewatering include, but are not limited to the following:

- Excavation for large utility works
- Excavation of temporary and permanent basins – 36 basins require excavation below the water table
- Excavations for bridge and viaduct piers – at four sites including a tributary to Mid Site Channel in Tarro, the Hunter River viaduct, an overbridge at Tomago interchange, and Windeyers Creek
- Excavations for the Purgatory Creek adjustment.

Temporary construction dewatering has the potential to lower groundwater levels in areas of high ASS risk, exposing sulphide minerals in soil to oxygen, creating acidic conditions. This is especially relevant in the low lying floodplain areas next to the Hunter River in Tarro and Tomago and Windeyers Creek (refer to **Figure 4-8**).

An assessment of volumetric dewatering requirements, associated groundwater level drawdown and impacts associated with temporary construction dewatering are provided in the Hydrology and Flooding Working Paper (Appendix J of the EIS). Predicted drawdowns due to temporary construction dewatering are typically of limited extent and short duration.

Utility work excavation durations are unknown due to requirements of working within an operational utility network and could be exposed for longer durations. Following active dewatering, modelled groundwater recovery durations are of the order of 30 days, however as the period of active dewatering is over represented in the groundwater model due to the applied model stress period (refer Hydrology and Flooding Working Paper (Appendix J of the EIS)), then so is the recovery. It is anticipated that timeframes for the full recovery of the water table at individual dewatering locations would be similar to the duration of dewatering (typically two to 10 days).

The rate of oxidation of sulfide minerals in soil is controlled by a number of factors, with the key factors being the rate of oxygen diffusion through the soil and the initial pH of the soil, where the rate of oxidation significantly increased below pH 4 (Ward, et al, 2004). The rate of oxygen diffusion is a function of the soil permeability. Given the generally fine grained nature of potential ASS sediments, particularly on the Hunter River floodplain, permeability is typically low and therefore the rate of oxygen diffusion and release of any generated acid, is also low. However, excavated materials have a higher risk of generating acid drainage due to being disturbed and aerated during excavation and stockpiling.

From Table G-1 in **Appendix G** the typical pH values of shallow groundwater in areas of high ASS risk on the Hunter River floodplain ranges from pH 5.27 to 6.65, which indicates that these initial pH conditions are not favourable for rapid oxidation.

Given the relatively short durations of dewatering, the typically low permeability of the high risk ASS materials and the elevated initial pH conditions, acid generation resulting from short term dewatering is expected to be minor. Any potential for oxidation is likely to be limited to oxidation within the exposed faces in the excavation, and the volume of acid generated is not expected to be significant.

Excavated ASS material will be buffered and stored to avoid the risk of excavated materials generating acid drainage, while dewatering discharge will be monitored and managed in accordance with the Construction Soil and Water Management Plan and Acid Sulfate Soils Management Plan, under the project Construction Environmental Management Plan (CEMP) (refer to **Chapter 8**).

Soft soil consolidation activities – soil salinity risk and acid sulfate soil risk

Soft soil consolidation activities can raise groundwater levels, which can increase soil salinity risk by potentially mobilising salts accumulated in unsaturated soils. This can result in elevated shallow groundwater salinity. Lowered groundwater levels also have potential to result in generation of ASS.

The main construction activity that substantially raises groundwater levels is use of surcharge embankments to facilitate soft soil consolidation for the project. Surcharge embankments can create mounding effects (elevated groundwater levels up gradient of the embankment) and shadowing effects (reduced groundwater levels down gradient of the embankment). Mounding occurs as the consolidation induced by the surcharge embankment reduces hydraulic conductivity in the sediments below the embankments, reducing the ability for groundwater to pass from one side of the embankment to the other. As soft soil consolidation is proposed as occurring within areas of high salinity risk (refer to **Figure 4-9**), the potential for salt mobilisation associated with increased water levels was assessed.

At Tarro, predicted shadowing was found to very localised and negligible (less than 0.05 metres), with predicted mounding also localised and minor (less than 0.3 metres. At the Tomago soft soil consolidation area, mounding of up to 0.2 metres is predicted by groundwater modelling over most of the upstream area of consolidation, increasing up to 0.8 metres in the central areas. Shadowing effects at the Tomago soft soil consolidation area are very localised and minor (less than 0.1 metre). An assessment of water levels and associated groundwater impacts associated with soft soil consolidation is provided in the Hydrology and Flooding Working Paper (Appendix J of the EIS).

At Tarro, the predicted mounding is considered to be minor. The degree of mounding of 0.2 metres is considered to be well within season fluctuations and is in an area where there is frequent surface expression of groundwater. As such the unsaturated zone is not subject to salt accumulation and the rise in water level would have little effect from a salinity risk quality perspective.

At Tomago, the magnitude of the predicted mounding is more substantial; however, as discussed in the Hydrology and Flooding Working Paper (Appendix J of the EIS), the assessment of potential mounding at Tomago is very conservative and unlikely to be realised to the magnitude predicted by the groundwater model. The greatest magnitude of predicted mounding (up to 0.8 metres increase in water levels) is predicted within the highly permeable Tomago Sandbeds that are subject to frequent flushing by infiltrating rainfall. As such, the unsaturated zone is not subject to substantial salt accumulation and the rise in water level would have little effect from a salinity risk perspective. It is also noted that the level of mounding, at its highest point, is still about two metres below ground surface and as such is not expected to result in noticeable surface effects or impacts to other groundwater users.

Lowered groundwater water levels as a result of soft soil consolidation is predicted to be negligible and well within the range of seasonal groundwater fluctuation. Accordingly, there is no significant risk of acid generation as a result of oxidation of ASS due to groundwater shadowing.

Operation of unlined sediment basins – groundwater contamination risk

Sediment basins that are unlined and which are excavated below the water table, have the potential to expose local groundwater to any contaminants in the basin water. When full or partially full, water levels in the basins would be above that of the surrounding water table and the basins have potential to act as temporary groundwater recharge points, dependant on local soil conditions. With runoff from the construction footprint entering the basins there is potential for spills or contaminants to also enter the basin with subsequent migration to groundwater impacting on groundwater quality.

During construction, key risks from contaminants relate to hydrocarbon storage and the operation of mobile plant (leaks and spills). Hydrocarbon spills will be managed by site protocols and any spills will be cleaned up in the short term. In the event of any hydrocarbon spills substantial enough to make it to a water quality basin, the spills would be obvious on the surface of the basins and allow rapid clean up based on site management protocols, and so minimising the potential for groundwater contamination.

Most non-spill related contaminants likely to enter the basin would be associated with suspended sediment. Sediment would settle out in the water quality basin and impact on groundwater is expected to be negligible.

The potential for spills during construction will be minimised through application of the construction surface water quality strategy as detailed in **Section 5.1.1**. Options to further reduce the likelihood of potential contaminants entering the groundwater through basins would be investigated during detailed design (refer to **Chapter 8**).

Mobilisation of areas of existing or potential groundwater contamination

Construction dewatering and associated drawdown is not anticipated to interact with areas of existing known contamination. Drawdown is not predicted in areas of known contamination and is not predicted to encroach on the former mineral sands processing facility or known PFAS areas at Tarro or Heatherbrae.

Impacts to Tomago Sandbeds Catchment Area

Temporary sediment basins within the Tomago Sandbeds Catchment Area will be lined to avoid potential for any contamination to occur.

Accordingly, no impacts to water quality are anticipated within the Tomago Sandbeds Catchment Area as a result of construction.

NSW AIP minimal impact considerations – groundwater quality

With consideration for project and adjacent water quality data, an assessment of the productivity of the various groundwater sources in the vicinity of the project, with respect to the NSW AIP (2012), is provided in **Table 6-3**.

Table 6-3 Water source type and productivity

Water source	Type	Productivity
Newcastle Water Source	Alluvial	Less productive (variable yields and high salinity)
Sydney Basin–North Coast Groundwater Source	Porous rock	Less productive (variable yields and high salinity)
Tomago Groundwater Source	Coastal sands	Highly productive

An assessment of potential construction impacts against groundwater quality considerations of the NSW AIP is presented on **Table 6-4**. This table summarises the outcomes of the impact assessment carried out in **Section 6.2.2**. For the water source types and productivity outlined on **Table 6-3**, the project construction meets the level 1 NSW AIP minimal impact considerations with respect to water quality.

Table 6-4 NSW AIP level 1 minimal impact considerations – construction groundwater quality

Water source	Consideration	Assessment
Highly productive coastal sands water sources	Any change in the groundwater quality should not lower the beneficial use category of the groundwater source beyond 40m from the activity.	Meets consideration. The project construction is not anticipated to have a detrimental impact on water quality or lower the beneficial use of the coastal sands water source.

Water source	Consideration	Assessment
Less productive alluvial water sources	a) Any change in the groundwater quality should not lower the beneficial use category of the groundwater source beyond 40m from the activity; and b) No increase of more than 1% per activity in long-term average salinity in a highly connected surface water source at the nearest point to the activity. c) No mining activity to be below the natural ground surface within 200m laterally from the top of high bank or 100m vertically beneath (or the three dimensional extent of the alluvial material - whichever is the lesser distance) of a highly connected surface water source that is defined as a "reliable water supply".	a) Meets consideration. The project construction is not anticipated to have a detrimental impact on water quality or lower the beneficial use of the alluvial water source beyond 40m from the construction footprint. b) Meets consideration. The project construction is not anticipated to have a detrimental impact on water quality or result in an increase in the long term average salinity of the alluvial water source. c) Not applicable.
Less productive porous and fractured rock water sources	Any change in the groundwater quality should not lower the beneficial use category of the groundwater source beyond 40m from the activity.	Meets consideration. The project construction is not anticipated to have a detrimental impact on water quality or lower the beneficial use of the porous and fractured rock water source.

6.2.3 Surface water reuse

Non-potable (low quality) water is required for a number of construction activities such as dust suppression, and earthwork compaction. While water sources will be confirmed during detailed design, there is the potential to source this water from temporary sediment basins, which as described in **Section 6.2.1**, may comprise of surface runoff as well as groundwater. Water in basins may be acidic, saline or turbid depending on its source (as discussed in **Section 6.2.1**). Where possible, acidic water would be treated to reduce acidity, while turbid water would be treated through normal operation of the temporary basins. However, water with elevated salinity (greater than 7500µS/cm) would be reused in applications where there is minimal risk of harm to biodiversity, infrastructure, existing soils or entry into waterways (such as compaction of elevated formations, dust suppression etc) and where the salinity is commensurate with existing soil and groundwater conditions.

With the appropriate sizing of the sediment basins to allow for treatment of runoff and implementation of other management measures (including sediment basin water quality checks prior to reuse), reuse of this water for construction activities would not pose a risk to downstream surface water and groundwater quality including any risks to ecosystems and human health.

6.2.4 Coastal Management Areas

As identified in **Section 4.9.3** and **Figure 2-2**, the construction footprint, including the main alignment and ancillary facilities, are located within Coastal Management Areas as defined in the Coastal Management SEPP which has been considered throughout this assessment. These include areas classified as Coastal Wetlands, Coastal Wetlands Proximity Area, Coastal Environment Area or Coastal Use Area. It is specified in the Coastal Management SEPP that work carried out within these areas should be designed to avoid, minimise or mitigate any adverse impacts on the integrity and reliance of the biophysical, hydrological or ecological environment of the wetland, adjacent wetland, coastal environment area or coastal use area. Impacts to visual amenity of the areas should also be avoided or minimised.

Table 6-5 outlines the Coastal Management Areas that would be cleared for use during construction of the project.

Table 6-5 Coastal Management Areas (Coastal Management SEPP) that would be cleared or occupied for use during construction

Coastal Management Area category	Area to be cleared for use	Project features that would occupy the area
Coastal Wetlands	16.5 ha	• Main alignment (western side of Hunter River) • Hunter River crossing (the viaduct) • Main alignment (eastern side of Hunter River) • Ancillary facility 10 (AS10) • Ancillary facility 11 (AS11)
Coastal Wetlands Proximity Area	28.3 ha	• Main alignment (western side of Hunter River) • Ancillary facility 9 (AS9) • Hunter River crossing (the viaduct) • Main alignment (eastern side of Hunter River) • Ancillary facility 10 (AS10) • Ancillary facility 11 (AS11)
Coastal Use Area	46.8 ha	• Ancillary facility 6 (AS6) • Ancillary facility 7 (AS7) • Ancillary facility 8 (AS8) • Ancillary facility 9 (AS9) • Hunter River crossing (the viaduct) • Ancillary facility 10 (AS10) • Ancillary facility 11 (AS11)
Coastal Environment Area	140 ha	• Ancillary facility 6 (AS6) • Ancillary facility 7 (AS7) • Ancillary facility 8 (AS8) • Ancillary facility 9 (AS9) • Hunter River crossing (the viaduct) • Ancillary facility 10 (AS10) • Ancillary facility 11 (AS11) • Ancillary facility 13 (AS13)

The majority of the mapped 'Coastal Management Areas' which fall within the construction footprint have already been cleared for agricultural purposes, and any remnant wetland vegetation within the mapped areas is in poor condition (refer to the Biodiversity Assessment Report (Appendix I of the EIS) for further information). The mapped areas are therefore not expected to function as important wetland environments and clearance of vegetation from these areas would not result in a significant impact to their ecological function. The exception to the existing poor condition of the impacted wetlands is the area on the eastern bank of the Hunter River that contains substantial patches of mature Grey Mangrove low closed forest, however as the construction footprint in this area has been reduced as far as practical and the disturbed area shall be stabilised and rehabilitated to preworks condition prior to demobilisation, the temporary impacts to this wider section of Mangrove Forest and associated Coastal Wetland area is not expected to be significant.

Water quality impacts from construction activities on coastal management areas are unlikely because management measures and controls will be implemented to ensure that pollutants are sufficiently captured in temporary sediment basins for treatment. Further, excavated material from areas where there is potential for ASS would be transferred to an ASS treatment area where it would be treated prior to being reused onsite or disposed of at an appropriate waste facility. Ancillary facilities, instream work platforms and wharves would be rehabilitated as far as practicable prior to demobilisation.

The unnamed Coastal Wetland which is located on the eastern bank of the Hunter River is in good condition and it is known to include a number of threatened ecological community types and functions as an estuarine habitat (refer to the Biodiversity Assessment Report (Appendix I of the EIS) for further information). While clearance in this section is unlikely to significantly disrupt the ecological processes of the wetland, there is potential for changes to the local biophysical and hydrological conditions during construction due to increased risk of erosion of disturbed soils and potential for overland flow. It is considered unlikely that these impacts would occur due to the establishment of erosion and sediment controls.

6.2.5 Basin discharge

Project construction would result in discharge of water from temporary sediment basins.

The primary aim of the temporary sediment basins is to capture sediment as nutrients and metals are typically bound to sediments in a dissolved (and often harmful) state. By capturing sediments (and subsequently nutrients and toxicants) via temporary sediment basins, the risk to downstream water quality would be reduced.

As discussed in **Section 5.1.3**, sediment basins have been designed to capture and release runoff so that sediments and other contaminants are reduced before entering downstream waterways. However, it is possible that under large rainfall events, temporary sediment basins would be overtopped and water would be discharged to downstream waterways (overflow discharge). Overflow discharge is likely to result in high turbidity and subsequently elevated levels of nutrients which are bound to the sediment. Indirect impacts that could result include low dissolved oxygen levels and increased algal activity if nutrient levels increase to a level that is conducive to algal blooms.

Environmental impact of discharge from basins is of greatest concern where they discharge directly to the SREs of the Hunter River and the downstream Ramsar wetlands. Ambient turbidity modelled at the Hunter River and Ramsar wetlands (refer to **Section 6.3.4**) indicates that impacts are unlikely to be significant. All other construction discharges would be into smaller modified waterways that are controlled by floodgates and therefore sediment and associated contaminants would likely be deposited in the disturbed waterways upstream of the floodgates and not reach the Hunter River.

Thirty of the 47 temporary sediment basins listed in **Table 5-4** would interact with the groundwater table. For the majority of the basins, modelled EC of discharge is similar to the receiving environment. However, there are a number of basins (see **Table 5-4**) where modelled conductivity would exceed background concentrations and the ANZG (2018) lowland river guidelines. Discharge from these basins would be into Glenrowan Creek and the tributary of Viney Creek and has the potential to impact on biota due to the modelled increased salinity. Given the temporary nature of dewatering (i.e. only for a short period during construction), timing of discharge during rainfall events where there is greater dilution it is unlikely to have long term impacts on the salinity of the affected waterways, and is not expected to have a significant impact on water quality.

To continue to protect the WQO from saline dewatering, four basins are proposed to be lined where the EC of discharge could exceed 7500 µs/cm. Basins proposed to be lined are listed in **Chapter 8** and include TB04, TB06, TPB10 and TPB18. Further investigations will be carried out in detailed design to confirm salinity thresholds for lining or other treatment options (see **Chapter 8**).

ANZG (2018) Water Quality Guidelines recommended water quality discharges have a pH between 6.5 and 8.5 to ensure protection of lowland river aquatic ecosystems, or between pH 7 and 8.5 for protection of estuarine aquatic ecosystems. pH of water will be managed during construction and tested prior to discharge to unsure it falls within these limits so that there is no impact to the pH of downstream waterways.

6.2.6 Discharge assessment

Background

Assessment of project construction discharges against WQOs

The WQOs and DGVs, as defined in **Section 3.3.4**, are currently not being met for most sites and parameters. Pollutant loading of the receiving environment with respect to nutrients and toxicants would be reduced by limiting discharge concentrations of TSS to which nutrients and toxicants are typically bound, however it is likely that minor levels of pollutants would be present in the construction discharges.

Pollutant loading into waterways from temporary basin discharges has been calculated for turbidity and compared against the DGV for protection of aquatic ecosystems (refer **Table 6-6**).

Representative waterways have been assessed to verify if they comply with the relevant WQO DGV or, to determine if the outcomes of the project construction activities work towards their achievement over time.

Proposed calculated turbidity that is lower than the ambient DGV is shaded dark green to highlight that the WQO is being met at the receiving waterway. The compliant discharge is considered unlikely to cause significant harm to the waterway and a brief discussion on the relevant default WQO(s) is provided below in **Table 6-7**.

Proposed calculated turbidity that does not meet the DVG, but is generally lower than the existing ambient median values (determined by onsite monitoring) is shaded light green as it is contributing to achievement of the WQO DGV of the receiving waterway over time. The discharge is generally an improvement on the existing ambient water quality and is unlikely to cause significant harm to the waterway and a brief discussion on the relevant default WQO(s) is provided below in **Table 6-7**.

Proposed calculated turbidity that exceeds the WQO DGV and existing ambient water quality are shaded red in **Table 6-6**. These representative locations are assessed in further detail in **Table 6-7.**

Table 6-6 Comparisons of calculated turbidity discharged from sediment basins during construction against existing conditions and guideline values

Waterway	Ecosystem turbidity guideline values (NTU)	Existing median turbidity values (NTU) (Dry)	Existing range of turbidity values (NTU) (Dry)	Proposed calculated turbidity (NTU)	Further discussion required (see Table 6-7)
R1-Glenrowan Creek	6-50	17.2	5.8-57.7	33 Achieves WQO DGV	No
R2-Purgatory Creek	0.5-10	14.1 – 41.65	4-115	92	Yes
R3-Hunter River drain	0.5-10	20.82 – 55.63	6-551	82	Yes

Waterway	Ecosystem turbidity guideline values (NTU)	Existing median turbidity values (NTU) (Dry)	Existing range of turbidity values (NTU) (Dry)	Proposed calculated turbidity (NTU)	Further discussion required (see Table 6-7)
R4-Windeyers Creek	6-50	6.57 – 39.53	5.01-71.2	12 Achieves WQO DGV	No
R5-Viney Creek	6-50	31.58	20-58	67	Yes
R6-Hunter River	0.5-10	37.3 – 66.03	18-776	48 Contributes towards achieving WQO over time	No
R7- Unnamed coastal wetland	0.5-10	25.75	9-33	48	Yes

Table 6-7 Project impact on water quality objectives during construction

Waterway	Relevant site specific WQO					Assessment of project impact during construction against all WQOs
	Aquatic ecosystems	Visual amenity	Secondary contact recreation	Primary contact recreation	Aquatic foods (cooked)	
R1 – Glenrowan Creek (Lowland river)	✓	✓	✓	✓	NA	The proposed quality of the construction water discharge from basins at this waterway complies with the turbidity DGV and continues to protect aquatic ecosystems WQO. Construction basin discharges are unlikely to have a significant impact on water quality. A brief discussion on the WQO is provided below. Aquatic ecosystems - Turbidity of discharges from temporary sediment basins to Glenrowan Creek will comply with the DGV for the protection of aquatic ecosystems (lowland river) WQO. Electrical conductivity (EC), however, is expected to be slightly elevated above the DGV for protection of lowland river aquatic ecosystems as the sediment basin may interact with the saline groundwater table in this location, causing discharges to not meet the WQO. The impact of the potentially slightly elevated EC is considered to be negligible as the existing receiving environment is disturbed (refer to **Section 4.2.2** and **Section 4.6.2**) and is anticipated to be habituated to the existing inputs. Despite the discharges from the temporary sediment basins not meeting the DGV for EC, the temporary nature of the discharge is unlikely to reduce existing water quality or impact aquatic ecosystems over time. Visual amenity - Turbidity of discharges will comply with the DGV and hence protect visual amenity. Construction discharges are expected to meet the WQO for visual amenity as turbidity levels are expected to be below the DGV and therefore visual clarity is not expected to be reduced. Primary and secondary contact - Secondary contact is possible due to landowner access and ongoing asset maintenance, however primary contact is considered highly unlikely due to the nature of the waterway as a shallow drainage channel within grazing land. Construction discharges are not anticipated to generate or consolidate enterococci. Additionally, since the turbidity of the discharges will be low, algal blooms are not anticipated. Concentrations of metals and toxicants that are hazardous to human health are not expected as they would be bound to sediment captured within the sediment basin. As the project would not generate any additional enterococci and is not expected to produce excessive sediment, the project is not anticipated to impact on the achievement of the relevant WQO DGV.

Waterway	Relevant site specific WQO					Assessment of project impact during construction against all WQOs
	Aquatic ecosystems	Visual amenity	Secondary contact recreation	Primary contact recreation	Aquatic foods (cooked)	
R2 – Purgatory Creek (Estuarine)	✓	✓	✓	✓	NA	The proposed turbidity of the construction water discharge from basins at this waterway does not comply with the DGV or the median turbidity in the existing environment. Further assessment is provided below. The existing water quality and receiving environment at Purgatory Creek is presented in **Section 4.2.3** and **Section 4.6.3** where it is shown to be highly disturbed. Ongoing maintenance (flood conveyance) and surrounding livestock grazing land uses are anticipated to result in ongoing impacts to water quality and the aquatic environment. The range of values identified during site monitoring (<115 NTU) display the disturbed and variable condition of the waterway. The impacts of the surrounding land use on water quality in Purgatory Creek are evident in the water quality measured to date (**Section 4.6.3**). Without changes in surrounding land use it is unlikely that Purgatory Creek will meet WQO's over time. Flood gates at the downstream end of the creek alter surface flows by containing flows within the creek channel and hence increase residence time to aid sediment settlement within the confines of the disturbed environment. The proposed turbidity is calculated to require a dilution of 2.2 to meet the existing median ambient water quality and it is assumed that discharge inputs would generally occur during/after rainfall events where catchment surface water would be adequate to provide sufficient dilution. It is noted that the proposed calculated turbidity is lower that the upper limit of the existing environment and following dilution, the short term construction discharge is anticipated to be generally in accordance with the existing surface water and is unlikely to significantly impact on the receiving disturbed environment. A brief discussion on the WQO is provided below. Aquatic ecosystems - Turbidity in Purgatory Creek will not meet the DGV for protection of aquatic ecosystems (estuarine), however existing conditions do not comply with the DGV for turbidity. Due to surrounding land use, Purgatory Creek is not likely to meet the WQO over time and the proposed discharges (temporary for construction discharges) are unlikely to have a significant impact to existing water quality or aquatic ecosystems over time. Visual amenity - Existing water quality in Purgatory Creek does not meet the WQO for visual amenity due to high turbidity that reduces visual clarity. As stated above, turbidity of discharges to Purgatory Creek from the temporary sediment basins are within the range of existing turbidity experienced within Purgatory Creek and all discharges would be temporary in nature. Discharges are therefore not expected to result in further degradation of visual amenity.

Waterway	Relevant site specific WQO					Assessment of project impact during construction against all WQOs
	Aquatic ecosystems	Visual amenity	Secondary contact recreation	Primary contact recreation	Aquatic foods (cooked)	
						Primary and secondary contact - Secondary contact is possible due to landowner access and ongoing asset maintenance, however primary contact recreation is considered highly unlikely as it is a shallow modified drainage channel that is situated within private farmland. Construction discharges is not anticipated to generate or consolidate enterococci. Additionally, since the turbidity of the discharges will be low, algal blooms are not anticipated. Concentrations of metals and toxicants that are hazardous to human health are not expected as they would be bound to sediment captured within the sediment basin. As the project would not generate any additional enterococci and would not produce excessive sediment, the project is considered unlikely to have a significant impact to secondary contact values.
R3 – Hunter River Drain (Estuarine)	✓	✓	✓	✓	NA	The existing water quality and receiving environment at Hunter River Drain (not a natural waterway) is presented in **Section 4.2.6** and **Section 4.6.6** where it is shown to be highly disturbed (as per WQO supporting information). Ongoing maintenance (flood conveyance) and surrounding agricultural land uses are anticipated to result in ongoing impacts to water quality and aquatic environment impacts. The range of values identified during site monitoring (<551 NTU) display the disturbed and variable condition of the drain. Flood gates at the downstream end of the creek alter surface flows by containing low and medium flows within the creek channel and therefore increase residence time to aid sediment settlement within the confines of the disturbed environment. The proposed quality of the construction water discharge from basins at this waterway does not comply with the DGV or the median turbidity of the existing environment. The impacts of the surrounding land use on water quality in the Hunter River Drain are evident in the water quality measured to date (**Section 4.6.6**). Without changes in surrounding land use it is unlikely the Hunter River Drain will meet WQO's over time. The proposed turbidity is calculated to require a dilution of 1.5 to meet the existing median ambient water quality and it is assumed that discharges would generally occur during/after rainfall events where catchment surface water would be adequate to provide sufficient dilution. It is noted that the proposed calculated turbidity is lower that the upper limit of the existing environment and following dilution, the short term construction discharge is anticipated to be generally in accordance with the existing surface water and is unlikely to significantly impact on the receiving disturbed environment. A discussion on the WQO is provided below.

Waterway	Relevant site specific WQO					Assessment of project impact during construction against all WQOs
	Aquatic ecosystems	Visual amenity	Secondary contact recreation	Primary contact recreation	Aquatic foods (cooked)	
						Aquatic ecosystems – Discharges from temporary sediment basins to Hunter River Drain will not meet the turbidity DGVs for protection of aquatic ecosystems (estuarine), however existing conditions within the waterway are often found to be highly turbid. Despite the sediment basin discharges not meeting DGVs, the temporary nature of the discharge is unlikely to reduce existing water quality or impact aquatic ecosystems over time. Visual amenity - Existing water quality in Hunter River Drain does not meet the WQO for visual amenity due to high turbidity levels that reduce visual clarity. Turbidity of discharges to Hunter River Drain from the temporary sediment basins are within the range of existing turbidity experienced within Hunter River Drain and discharges would be temporary in nature, therefore it is not expected to significantly impact visual amenity. Primary and secondary contact - Secondary contact is possible due to private land owner access and ongoing asset maintenance, however, primary contact is considered highly unlikely as it is a drainage channel that receives degraded runoff from a stud farm. Discharges from the temporary sediment basin would not contribute any bacterial constituents, however elevated turbidity would mean that the discharges could contain contaminants that could be hazardous to human health and therefore would continue to not meet these.
R4 – Windeyers Creek (Lowland river)	✓	✓	✓	✓	NA	The proposed turbidity of the construction water discharge from basins at this waterway complies with the DGV and continues to protect WQOs. A brief discussion on the WQO is provided below. Aquatic ecosystems - Turbidity associated with discharge from temporary sediment basins to Windeyers Creek will comply with the DGV for the protection of aquatic ecosystems (lowland river) WQO. Contaminants such as heavy metals or toxicants which are bound to sediments are unlikely to be elevated in basin discharge due to deposition of sediments prior to discharge. The discharge into the aquatic environment is unlikely to have significant impact to the aquatic ecosystem. Visual amenity - Proposed turbidity would meet the WQO for visual amenity as turbidity levels are expected to be below the DGV and therefore visual clarity is not expected to be reduced.

Waterway	Relevant site specific WQO					Assessment of project impact during construction against all WQOs
	Aquatic ecosystems	Visual amenity	Secondary contact recreation	Primary contact recreation	Aquatic foods (cooked)	
						Primary and secondary contact - Secondary contact is possible due to public access, although primary contact recreation is considered highly unlikely. WQO for primary and secondary contact would be met for recreation, as sediment basin discharges are not expected to generate bacteria (i.e. enterococci) that would result in the deterioration of recreational water quality. Additionally, since the turbidity of the waterway will be low, additional algal blooms are not anticipated.
R5 – Viney Creek (Lowland river)	✓	✓	✓	✓	NA	The proposed turbidity at this waterway does not comply with the DGV or the median turbidity of the existing environment. Further assessment is provided below. The existing water quality and receiving environment at Viney Creek is presented in **Section 4.2.1** and **Section 4.6.1** where it is shown to be disturbed and modified due to complete alteration for its passage through a light industrial precinct. Ongoing maintenance (flood conveyance) and surrounding light industrial land uses are anticipated to result in ongoing impacts to water quality and aquatic environment impacts. A dam constructed within the channel of the creek alter surface flows by containing low and medium flows within the dam, however the dam increases residence time to aid sediment settlement within the confines of the disturbed environment. The proposed turbidity is calculated to require a dilution of 1.3 to meet the existing median ambient water quality and it is assumed that discharges would generally occur during/after rainfall events where catchment surface water would be adequate to provide sufficient dilution. It is noted that the proposed turbidity is slightly higher that the upper limit of the existing environment however following dilution, the short term construction impact is anticipated to be generally in accordance with the existing surface water and is unlikely to significantly impact on the receiving disturbed environment. With the proposed attenuation, construction discharges would work towards achievement of the WQO DGV over time and are unlikely to have a significant impact on water quality. Aquatic ecosystems - Proposed turbidity in Viney Creek is marginally higher that the ambient DGV, however the diluted turbidity would generally correspond with the existing water quality. The existing aquatic ecosystems are habituated to existing water quality and therefore the diluted discharges are unlikely to have significant impact to the aquatic ecosystem and would not hinder the long-term achievement of this WQO.

Waterway	Relevant site specific WQO					Assessment of project impact during construction against all WQOs
	Aquatic ecosystems	Visual amenity	Secondary contact recreation	Primary contact recreation	Aquatic foods (cooked)	
						Visual amenity - Turbidity would not meet the WQO, however the proposed turbidity is only slightly above the DGV and existing turbidity levels and therefore significant changes to the clarity of the waterway are not expected. Discharges are therefore not expected to hinder the long term achievement of the WQO. Primary and secondary contact - Secondary contact with the water is possible due to its accessibility by the public and its ongoing of maintenance for flood conveyance through the industrial area, however primary contact is unlikely due to shallow water and access limitation due to dense reed growth. Construction discharges are not anticipated to generate or consolidate enterococci, and as the modelled turbidity output is lower than the existing range, the project is unlikely to have a significant impact to secondary contact values.
R6 – Hunter River (Estuarine)	✓	✓	✓	✓	✓	The proposed turbidity at this waterway does not comply with the DGV, however calculated turbidity levels are generally lower than existing ambient turbidity levels. Hence the construction basin discharges are unlikely to have a significant impact on water quality and are working towards achieving the WQO over time. A discussion on the WQO is provided below. Aquatic ecosystems – The proposed turbidity is generally consistent with the existing background levels and with the high levels of dilution available in the tidal Hunter River, the minor volumes of construction basins discharges are unlikely to impact water quality in the Hunter River. As the aquatic ecosystems present within the river are habituated to the proposed discharge levels and are well under the existing range in the river (<776 NTU), the proposed discharges are unlikely to have a significant impact on the aquatic ecosystems of the Hunter River Visual amenity – The proposed turbidity of discharges to Hunter River are below the median value of turbidity experienced within the waterway and all discharges would be temporary in nature. Discharges are therefore expected to be working towards improving visual amenity. Primary and secondary contact – The most probable primary recreational contact with water across the project will be in the Hunter River as it is infrequently used for water sports (skiing, paddling etc) Secondary contact is highly probable due to activities such as shore and boat fishing. The WQOs of primary and secondary contact recreation are currently not being met due to high turbidity and nutrient levels and suspended sediments may contain elevated concentrations of metals and toxicants that are hazardous to human health. Construction discharges would not contribute to conditions favouring the growth of or

Waterway	Relevant site specific WQO					Assessment of project impact during construction against all WQOs
	Aquatic ecosystems	Visual amenity	Secondary contact recreation	Primary contact recreation	Aquatic foods (cooked)	
						introducing bacteria (i.e. enterococci) to the waterway. Discharges therefore would work toward meeting these WQOs and improving existing conditions. <u>Aquatic foods (cooked)</u> - The WQO of aquatic foods (cooked) is currently not being met due to elevated NTU and other contaminant levels above the DGV. The discharges from the temporary sediment basins would comply with the low land river DGV. Additionally, due to the temporary nature of construction, the basin discharges are unlikely to hinder the long-term achievement of this WQO.
R7 – Unnamed coastal wetland (Estuarine)	✓	✓	✓	✓	NA	The proposed turbidity at this waterway does not comply with the DGV and exceeds the existing median background levels. Further assessment is provided below. The existing water quality and receiving environment is presented in **Section 4.2.7** and **Section 4.6.7**. Surrounding livestock grazing land uses are anticipated to result in ongoing impacts to water quality and the aquatic environment. The proposed turbidity calculated to require a dilution of 1.8 to meet the existing ambient water quality and it is assumed that discharges would generally occur during/after rainfall events where catchment surface water would be adequate to provide sufficient dilution. Additionally, the wetland is expected to receive ongoing groundwater inputs from the adjacent Hunter River and upgradient Tomago Sands aquifer and these inputs can also be expected to express as surface water in the channel resulting in further dilution. When the dilution factor is applied to the, the short duration discharges are unlikely to have a significant impact on the receiving aquatic ecosystem. A brief discussion on the WQO is provided below. <u>Aquatic ecosystems</u> - The wetland and channelised watercourse at the site reflects a wetland of low to moderate condition that is affected by livestock grazing, various underground and overhead utility installations and the flood levee bank that separates the wetland form the adjacent Hunter River. The aquatic ecosystems at the site have become habituated to the modified conditions and are anticipated to be resilient to further modified inputs over the construction period. The site is expected to receive ongoing groundwater inputs from the adjacent Hunter River and upgradient Tomago Sands aquifer and these inputs can be expected to consistently resupply the channel with water for dilution. When the dilution factor is applied to the waterway inputs from construction basins are

Waterway	Relevant site specific WQO					Assessment of project impact during construction against all WQOs
	Aquatic ecosystems	Visual amenity	Secondary contact recreation	Primary contact recreation	Aquatic foods (cooked)	
						unlikely to have a significant impact on the receiving aquatic ecosystem and work towards meeting the water quality objectives over time. Visual amenity - Existing water quality of the unnamed tributary does not meet the estuarine WQO for visual amenity due to elevated turbidity that reduces visual clarity, Diluted turbidity is anticipated to be generally consistent with the range of turbidity experienced within the waterway and temporary in nature. Discharges are therefore not expected to degrade the waterway further than existing conditions and are expected to work towards meeting the lowland river WQO over time. Primary and secondary contact – Secondary contact with surface water is possible due to access to the site for asset maintenance. Primary contact is highly unlikely due to shallow water at the site Whilst construction discharges would not contribute to conditions conducive to the growth of bacteria (i.e. enterococci) in the waterway, discharges could contribute sediment and therefore toxicants that may result in WQO not being met.

When the calculated project pollutant loading from basin discharges is considered against the WQO DGV and/or compared with pollutant loading from the wider catchments, impacts to ambient water quality due to the project are unlikely to be significant.

Assessment of project construction discharges on Hunter Estuary Wetlands Ramsar site

As detailed in **Section 2.1.1**, the Hunter Estuary Wetlands Ramsar site comprises the Hunter Wetlands National Park at Kooragang Nature Reserve and the Hunter Wetland Centre at Shortland. Due to substantial distance from the project, it is expected that there would be no direct impacts on either section of the Hunter Estuary Wetlands Ramsar site. However, there is potential for indirect impacts to the Kooragang Nature Reserve from construction discharges to the Hunter River. Potential indirect impacts to the Hunter Estuary Wetlands Ramsar site were considered and highlighted in an assessment of significance required under the EPBC Act referral guidelines as described in the Biodiversity Assessment Report (Appendix I of the EIS), but was not declared a controlled action for the project by the delegate for the Australian Minister for the Environment. No pollution pathway is expected for the Hunter Wetland Centre at Shortland, therefore the following assessment only relates to the Hunter Estuary Ramsar Wetland at Kooragang Nature Reserve.

Hunter Estuary Wetlands Ramsar site at Kooragang Nature Reserve is about 5.1 kilometres downstream of the construction footprint along the Hunter River. During the project construction, only three temporary sediment basins (TB07, TPB12 and TPB13) on the eastern side of the Hunter River have the potential to discharge directly into the river, travelling downstream to the Hunter Estuary Wetlands Ramsar site at Kooragang Nature Reserve. These basins have a direct flow path to the Hunter River (without obstruction by floodgates). It is assumed that discharges from all other temporary sediment basins would not reach the Hunter River without additional retention behind flood gates and therefore not included in this assessment.

A dilution model was used to simulate concentrations of TSS that could be discharged from the basins and transported downstream (refer **Appendix D** for additional information and **Section 5.1.3** which discusses high flow events during which basins would overflow without treatment). The dilution model estimated concentrations that would enter the river and subsequently the Hunter Estuary Wetlands Ramsar site at Kooragang Nature Reserve from both controlled (50 mg/L) and overflow releases, with TSS concentration from overflow releases modelled under three different scenarios: 150 mg/L, 250 mg/L and 500 mg/L release concentrations from basins. The model considered existing TSS concentrations during wet weather and volume of water in the Hunter River upstream of the discharge and downstream of the discharge (i.e. with the addition of the basin discharge). Results for TSS were converted to turbidity using the results of the linear regression (refer to **Appendix C**).

The results of the dilution assessment are presented in Figure D-1 (refer to **Appendix D**) and indicate that:

- Controlled discharges of 50 mg/L (or turbidity of 37.3 NTU) from the sediment basins results in an estimated turbidity (following dilution) in the Hunter River at the Hunter Estuary Wetlands Ramsar site at Kooragang Nature Reserve of 8.4 NTU, compared to median wet weather concentration of 8.36 NTU upstream of the discharge. This complies with the WQO for the Ramsar site
- Overflow discharges from the project of 150 mg/L (or turbidity of 179.94 NTU) from sediment basins generally resulted in an estimated turbidity less than 10 NTU (following dilution) at the Hunter Estuary Wetlands Ramsar site at Kooragang Island, compared to median wet weather concentration of 8.36 NTU upstream of the discharge. This complies with the WQO for the Ramsar site.
  However over the modelled time period between 1998 and 2010, there would have been five rainfall events that would have resulted in turbidity greater than 10 NTU (between 10.2 NTU and 12.84 NTU) which exceed the recommended upper limit of 10 NTU and would not meet the WQO. During this time, streamflow in the Hunter River was very low (less than 250 ML/d) and representative of drought conditions providing little dilution
- Overflow discharges from the project of 250 mg/L (or turbidity of 304.5 NTU) generally resulted in an estimated turbidity of less than 10 NTU (following dilution) at the Hunter Estuary Wetlands Ramsar site at Kooragang Nature Reserve (between 8.36 and 12.93 NTU), compared to median wet weather concentration of 8.36 NTU upstream of the discharge. This complies with the WQO for the Ramsar site.

Over the modelled time period (1998-2010) there would have been nine rainfall events that would have resulted in turbidity greater than 10 NTU (between 10.48 NTU and 12.93 NTU) which exceed the recommended guideline and would not have met the WQO. During this time, streamflow in the Hunter River was very low (generally less than 362 ML/d) and representative of drought conditions providing little dilution

- Overflow discharges of 500 mg/L (or turbidity of 638 NTU) meet the WQO at the Hunter Estuary Wetlands Ramsar site at Kooragang Island, except when there is a high rainfall event under low flow conditions. During these times, the guidelines are exceeded. These Overflow discharges from the project generally resulted in an estimated turbidity of less than 10 NTU (following dilution) at the Hunter Estuary Wetlands Ramsar site at Kooragang Nature Reserve (between 8.36 and 17.8 NTU), compared to median wet weather concentration of 8.36 NTU upstream of the discharge which complies with the WQO for the Ramsar site. Over the modelled time period (between 1998 and 2010) there would have been 15 rainfall events that would have resulted in turbidity greater than 10 NTU (between 10.4 NTU and 17.8 NTU) which exceed the WQO. As previously determined, streamflow in the Hunter River was low (less than 1100 ML/d) providing little dilution.

In summary, the Hunter River generally provides sufficient dilution of the basin discharges into the Hunter River so that water flowing to the Hunter Estuary Wetlands Ramsar site at Kooragang Island, as a result of controlled construction discharges, meets the DGV for turbidity. As controlled discharges from temporary sediment basins would not contribute additional sediment to the wetland, it is expected that nutrient and toxicant concentrations would also not increase as a result of discharges as these are typically bound to sediment. The WQO is met due to the dilution of the Hunter River with the relatively small contribution of water from basin discharges. There is the small possibility that overflow discharges could occur, however these are unlikely to present any long term risk to the health of the Hunter Estuary Wetlands Ramsar site at Kooragang Nature Reserve as they would be temporary, largely dependent on current streamflow within the Hunter River and modelled turbidity is not significantly higher than the recommended guideline limits.

6.3 Operational impacts

Prior to the end of construction, disturbed areas would be completely stabilised with sealed operational surfaces, completed landscaping and in channel scour protection. Potential water quality impacts to waterways would therefore be limited to the accidental spills associated with vehicle accidents and road use, and stormwater runoff from new impervious surfaces. Surface water and groundwater quality impacts are discussed in **Section 6.3.1** and **Section 6.3.2**, respectively.

6.3.1 Surface water quality

The main operational risks with the potential to cause surface water quality impacts include:

- **Accidental spills**: Involving discharge of spills directly into waterways (should spill event happen on a bridge) or via runoff into the drainage system. Spills may include heavy metals, oils and/or fuels. This may result in transportation of dust, litter, or poor-quality runoff to downstream receiving environments from road use by vehicles or from car accidents
- **Stormwater runoff**: Involving untreated stormwater from impervious surfaces which are not conveyed to treatment systems. This may result in surface runoff that may cause erosion and sedimentation of downstream receiving environments, or may contain elevated levels of pollutants from new impervious surfaces which are not conveyed to treatment systems

- **Permanent basin discharges**: Involving overflow discharges from water quality basins following a rainfall event and dewatering of unlined basins with groundwater interaction which could result in water with elevated salinity being discharged to receiving environments.

Waterways and wetlands with the potential to be impacted by these operational risks are presented in **Table 6-8** and a summary of pollutants and sources associated with operation are presented in **Table 6-9**. Further pollutant specific discussion is provided in the following sections.

Table 6-8 Waterways and wetlands with the potential to be impacted by operational water quality risks

Waterways or wetland	Operational water quality risks		
	Accidental spill	Stormwater runoff	Permanent basin overflows of elevated saline water
Unnamed tributary of Viney Creek	✓	✓	✓*
Glenrowan Creek and wetland near the twin bridge (B02) between Black Hill and Tarro	✓	✓	✓*
Unnamed Coastal Wetland (Coastal Management SEPP) south of New England Highway	✓	✓	
Purgatory Creek	✓	✓	
Hunter River	✓	✓	
Unnamed Coastal Wetland (Coastal Management SEPP) east of Hunter River	✓	✓	
Hunter River wetland	✓	✓	
Tomago Sandbeds (near Masonite Road)	✓^	✓	
Windeyers Creek	✓	✓	
Tributary of Windeyers Creek	✓	✓	

* These waterways/wetlands are considered lowland river environments. These environments will receive saline discharge (<7500 µS/cm). Windeyers Creek is not ticked for intrusion of elevated saline water, as indicative blends of water quality from basins are not saline (refer to **Table 5-12**).
^ The event of an accidental spill in this area is considered highly unlikely as all road pavements in the drinking water catchment areas, drain to water quality basins which have spill containment of 30,000 litres and are lined.

Table 6-9 Potential operational pollutants and impacts on surface water quality

Pollutant	Potential source of pollutant from operation of project	Potential surface water quality impacts
Sediment	• Sedimentation of downstream receiving environment as a result of surface runoff from project	• Erosion and downstream sedimentation can result in increased turbidity and poor water clarity, impacting visual amenity and potentially leading to smothering of aquatic ecosystems due to clogging fish gills or decrease trophic interactions due to reduced visibility • Mobilised sediments may also contain high concentrations of nutrients which can lead to algal blooms and subsequently result in reduced light penetration that limits the growth of aquatic and estuarine vegetation. Algal blooms may also result in a reduction of dissolved oxygen content of the water which can lead to the creation of 'dead zones' where aquatic life cannot survive

Pollutant	Potential source of pollutant from operation of project	Potential surface water quality impacts
		• Mobilised sediments may contain elevated concentrations of metals and other contaminants, which can negatively impact aquatic life.
Saline groundwater	• Overflows of saline groundwater from unlined basins with groundwater interaction	• Dewatering of basins with groundwater interaction can result in discharge of water of higher salinity than the receiving environment which can impact on instream biota that cannot tolerate higher salinity • Over the operation of the project this could result in receiving waterway become more and more saline and possibly not meet the nominated WQO.
Heavy metals	• Poor-quality runoff to downstream receiving environments from car accidents or spills • Stormwater which may contain elevated levels of pollutants, from new impervious surfaces which are not conveyed to treatment system	• Increased concentrations of heavy metals and hydrocarbons (either directly transported to a waterway or attached to sediments) which are toxic to aquatic biota
Oils and fuels	• Transportation of oils and/or fuels from spills or leaks associated with road use by vehicles	• Increased concentrations of hydrocarbons in downstream waterways which can decrease dissolved oxygen levels and result in fish kills • Oily films may accumulate on the surface of the water and reduce visual amenity • Excessive biochemical oxygen demand as a result of oxidation of hydrocarbons and reduction of metals leading to depletion of dissolved oxygen in the water. This may cause the death of aquatic organisms and result in the release of nutrients and heavy metals bound to the bed sediments due to anoxic conditions.
Dust and litter	• Transportation of dust, litter associated with road use by vehicles	• Gross pollutants (litter) may result in increased levels of nutrients and toxicants which may be harmful to aquatic life and could reduce visual amenity.

Sediment

Sediment is most likely to be generated by the project during operation when surface runoff enters downstream receiving environments, causing erosion and sedimentation impacts. Sediment-laden runoff has the potential to temporarily reduce downstream water quality, particularly directly after a rainfall event. This is unlikely to cause major or long term impacts to the overall conditions of the surrounding waterways, as erosion and sedimentation will be managed with the implementation of erosion and sediment controls as detailed in **Section 5.2**.

Saline groundwater

During the operation, the project has the potential to impact on the downstream environment from occasional discharge of water from permanent water quality basin following rainfall. Overflows from permanent water quality basins with groundwater interaction can result in discharge of water that is more saline than the receiving environment during rainfall events. While permanent water quality basins are not subject to a dewatering regime during operation, surface water runoff during and following rainfall may result in permanent water quality basins to overtop and discharge into receiving environments. Thirteen permanent basins would interact with groundwater as detailed in **Section 5.2.5**.

The risk of overflows that are more saline than the receiving environment is highest at basins which would discharge into lowland rivers (Glenrowan Creek and the tributary of Viney Creek) that typically have lower salinity concentrations than groundwater. This discharge, if prolonged and regular, presents a risk to the long term health of these waterways which over time may become more and more saline. Increased salinity may impact on biota that are unable to tolerate higher salinities. However, discharge is expected to be limited to occasional rainfall events where basin capacity is exceeded. This is due to the design of the basin and gradual impermeability of the basins from the settlement of fine particles which reduces the interaction between groundwater and surface water.

Basins most likely to result in elevated saline water discharges are PB12, PB14, PB15 and PB24 (as outlined in **Table 5-12**), where the indicative blend of water quality is expected to exceed 7500 µS/cm. Over the operation of the project this could result in receiving waterway become more saline and possibly not meeting the nominated WQO. To minimise the impacts of saline groundwater on receiving waterways, these four basins have been recommended for lining to avoid groundwater ingress to the basin water and therefore any overflows. As such, the risk of water quality impacts from operation of the project are low, not expected to be significant.

Potential impacts to surface water quality would be reduced through the implementation of adequate project design and management measures as discussed above and as detailed in **Section 5.2.5** and **Chapter 8**.

Heavy metals, oils and fuels

During rainfall events, increased concentrations of heavy metals and hydrocarbons can be mobilised downstream in runoff. Oils and fuels can also be mobilised downstream from spill events or leaks. While mobilisation downstream is most likely during rainfall events, spills following vehicle accidents can still result in transportation of pollutants to downstream environments in dry weather. These pollutants (either directly transported to a waterway or attached to sediments) can severely damage the ecology of waterways and terrestrial ecosystems, as they can be toxic to aquatic biota, result in fish kills and reduce visual amenity.

Stormwater quality management for road runoff includes managing the export of suspended solids and associated contaminants – namely heavy metals, nutrients and organic compounds (Austroads, 2001). Pollutants such as nutrients, heavy metals and hydrocarbons are usually attached to fine sediments (RTA, 2003a). To minimise water quality impacts from stormwater runoff and spills, the project has been designed to include permanent water quality controls, including vegetated swales and permanent water quality basins. Due to these controls, risk of potential changes to water quality within downstream waterways and wetlands would be minimised. Stormwater runoff from the project is not expected to have a significant impact on water quality during operation.

There is sufficient opportunity for any spill event to be contained near the project within the project water quality basins which include underflow baffles, with additional spill containment capacity at the Tomago Sandbeds Catchment Area (refer to **Section 5.2** for further detail). As such, potential risk of poor water quality mobilising to downstream waterways from spills is negligible and would be sufficiently managed through proposed design and management measures.

Dust and litter

Project operation would generate litter and transport dust as part of road use by vehicles. Gross pollutants may result in increased levels of nutrients and toxicants which may be harmful to aquatic life and reduce visual amenity in receiving waterways and wetlands. With the implementation of the environmental management measures described in **Chapter 8**, dust and litter, if managed correctly, are not likely to result in a significant impact to water quality.

6.3.2 Groundwater quality

The main potential groundwater quality impacts during operation include:

- Permanent lowering of the water table and associated potential for oxidation of PASS material
- Mounding of water table associated with soft soil consolidation, resulting in mobilisation of salts from the soil profile
- Operation of unlined permanent water quality basins and potential to introduce contaminants into groundwater via a new migration pathway.

Permanent lowering of water table – acid sulfate soil risk

No long term lowering of the water table is anticipated as a result of operation of the Project. Once temporary dewatering activities are finished, recovery of the water table at individual dewatering locations is expected to occur within the same time frame for which dewatering was carried out (typically 2 to 10 days). In the vicinity of the Purgatory Creek adjustment, no long term reduction in water levels in the vicinity of the adjusted channel is anticipated. Accordingly, project operation is not expected to result in the oxidation of PASS material.

Mounding of water table – soil salinity risk

The long term mounding of the water table due to the consolidation of soft soil is commensurate with that predicted during construction, with minor mounding predicted at Tarro and more substantial mounding predicted at Tomago. As such, and similar to construction, no significant impacts, with respect to groundwater quality or soil salinity risk are anticipated.

Operation of unlined permanent water quality basins – groundwater contamination risk

Permanent water quality basins that are unlined and which are excavated below the water table, have the potential to expose local groundwater to any contaminants in the basin water. When full or partially full, water levels in the basins would be above that of the surrounding water table and the basins would act as temporary groundwater recharge basins. With runoff from the operational footprint entering the basins there is a risk that spills or contaminants could also enter the basin with subsequent migration to groundwater potentially impacting on groundwater quality.

The design of the permanent water quality basins incorporates several features to account for potential spills and the minimisation of accidental discharge or migration to groundwater (refer to **Section 5.2.1**). All permanent basins provide spill containment by an underflow baffle arrangement that would contain hydrocarbon spills in dry weather as well as during small to moderate storm events. From a groundwater quality perspective, hydrocarbon spills would float on the surface of the basins, be released to the atmosphere through volatilisation and minimise the potential for migration to groundwater.

Most non-spill related contaminants likely to enter the basin would be associated with suspended sediment or road particulate in runoff water. These particulates would settle out in the water quality basin and impacts of these contaminants on groundwater is expected to be negligible.

Given that unlined water quality basins would be generally located in areas of relatively low permeability soils (Hunter Alluvium and Tomago Coal Measures) the potential for contaminant migration, and potential impacts, would be substantially reduced.

There would be sufficient opportunity for any spill event to be contained near the project within the proposed swales and water quality basins that would enable remedial measures to be implemented, where required.

Impacts to Tomago Sandbeds Catchment Area

The area most sensitive to groundwater contamination is the Tomago Sandbeds Catchment Area. The project has been designed to minimise and avoid impacts to the Tomago Sandbeds Catchment Area by conveying captured surface water in a sealed pipe network that drains into lined water quality basins ensuring all runoff is treated in basins (as discussed in **Section 5.2.1** and **Section 6.1**) prior to discharge and potential exposure to groundwater. Risk to groundwater contamination at the Tomago Sandbeds Catchment Area from the project is therefore considered to be minimal.

Further, groundwater modelling and particle tracking, carried out to identify borefield capture zones for the Hunter Water Corporation borefield and assess the risk of potential for contaminants to enter the water supply (SKM, 2012), shows that the majority of project construction and operational activities are outside of the modelled well head capture zones. The main alignment traverses the nominal well head management area, delineated by a 200 metre buffer on the predicted 70 year travel time capture zones, west of the Masonite Road. There are no permanent water quality basins located within the borefield capture zones.

NSW AIP minimal impact considerations – groundwater quality

An assessment of potential operational impacts against groundwater quality considerations of the NSW AIP (2012) is presented on **Table 6-10**. This table summarises the outcomes of the impact assessment carried out in **Section 6.3.2**. For the water source types and productivity outlined on **Table 6-3**, the project operation meets the level 1 NSW AIP (2012) minimal impact considerations with respect to water quality.

Table 6-10 NSW AIP (2012) level 1 minimal impact considerations – operational groundwater quality

Water source	Consideration	Assessment
Highly productive coastal sands water sources	Any change in the groundwater quality should not lower the beneficial use category of the groundwater source beyond 40m from the activity.	Meets consideration. The project operation is not anticipated to have a detrimental impact on water quality or to lower the beneficial use of the coastal sands water source.
Less productive alluvial water sources	a) Any change in the groundwater quality should not lower the beneficial use category of the groundwater source beyond 40m from the activity; and b) No increase of more than 1% per activity in long-term average salinity in a highly connected surface water source at the nearest point to the activity c) No mining activity to be below the natural ground surface within 200m laterally from the top of high bank or 100m vertically beneath (or the three dimensional extent of the alluvial material - whichever is the lesser distance) of a highly connected surface water source that is defined as a “reliable water supply”.	a) Meets consideration. The project operation is not anticipated to have a detrimental impact on water quality or to lower the beneficial use of the alluvial water source b) Meets consideration. The project operation is not anticipated to result in an increase in the long term average salinity of the alluvial water source c) Not applicable.
Less productive porous and fractured rock water sources	Any change in the groundwater quality should not lower the beneficial use category of the groundwater source beyond 40m from the activity.	Meets consideration. The project operation is not anticipated to have a detrimental impact on water quality or to lower the beneficial use of the porous and fractured rock water source.

6.3.3 Coastal Management Areas

The operational footprint is expected to be smaller than the construction footprint, therefore there is opportunity for revegetation of several of the Coastal Management Areas which would be cleared and occupied during construction. Revegetation would be in accordance with the project Urban Design Strategy (refer to Appendix O of the EIS). **Table 6-11** outlines the Coastal Management Areas that would be permanently occupied by the project during operation.

Table 6-11 Coastal Management Areas (Coastal Management SEPP) that would be cleared or occupied for use during operation

Coastal Management Area category	Area to be permanently occupied by project footprint
Coastal Wetlands	16.2 ha
Coastal Wetlands Proximity Area	22.6 ha
Coastal Use Area	15.3 ha
Coastal Environment Area	78.2 ha

Considering the existing roads (New England Highway and Pacific Highway) which traverse the Coastal Management Areas (and which the main alignment generally follows), the permanent occupation of these areas for the project is not expected to significantly impact on the functionality or visual amenity of the wetlands more than is already occurring. In particular, only two areas of wetland and floodplain vegetation are required to be permanently cleared and occupied from areas classified as ‘Coastal Wetland’ in the project operational footprint. These are:

- Wetland vegetation within the unnamed Coastal Wetland (south of the existing New England Highway) would be permanently cleared for the main alignment (western side of Hunter River) and the Tarro interchange. It is suggested in the Biodiversity Assessment Report (Appendix I of the EIS) that this vegetation is in poor condition and that the wetland is not considered to be significant aquatic habitat as it is situated within cleared farmland area
- Freshwater wetland and floodplain vegetation within the unnamed Coastal Wetland (east of the Hunter River) would be permanently cleared for the eastern bridge abutment of the Hunter River viaduct, the main alignment and the realignment of northbound Pacific Highway. While this vegetation is considered to be in moderate condition, the vegetation to be cleared is located on the fringes of the mangrove forest patch and it is suggested that most of the habitat has been previously disturbed, with some areas representing regrowth following clearing and grazing (refer to the Biodiversity Assessment Report (Appendix I of the EIS) for further details).

To further minimise impacts to the wetlands, the project design has ensured wetland fragmentation is minimised as much as practicable with the main alignment only permanently occupying fringe areas of the wetlands and only requiring clearance and occupation of a small amount of the wetland relative to its size. As such, the permanent occupation of the main alignment is not expected to result in any significant impacts to the Coastal Wetland areas listed under the Coastal Management SEPP.

Potential impacts to the Coastal Management Areas during operation of the project would therefore be limited to indirect impacts which would be related to changes to local hydrology at Purgatory Creek and road runoff during project operation.

Purgatory Creek adjustment

The headwaters of Purgatory Creek are situated in the Coastal Wetland south of New England Highway near Tarro. The permanent adjustment of Purgatory Creek has the potential to result in a change in local hydrology for the area which may lead to changes in water quality such as build-up of contaminants in the wetland environment due to reduced flow or barriers to flow and therefore less flushing. The risk of this impact is considered low, and not significant, however, as the project design has ensured the revised operational drainage capacity is generally maintained at pre-works condition.

Road runoff

Road runoff to permanent water quality basins and subsequent discharge to downstream environments has the potential to result in deposition of sediment in wetlands or may introduce elevated levels of hydrocarbons, heavy metals or other contaminants such as litter to the wetland environment. In particular, a permanent water quality basin (PB13) has been proposed within the Coastal Wetland Proximity Area south of the New England Highway near Tarro, however since this environment already experiences runoff from existing roads, it is not expected to result in a substantial increase in volume of runoff flowing to the downstream environment. As such, road runoff from the project is not expected to have a significant impact on Coastal Management Areas during operation.

6.3.4 Discharge assessment

Assessment of project operational discharges against WQOs

While an improvement to existing water quality is anticipated for some indicators at modelled locations, water quality remains unlikely to meet the ANZG (2018) Water Quality Guidelines and nominated objectives in the short term. **Table 6-12** provides the expected concentrations of key pollutants from permanent water quality basin discharges against the DGVs for protection of aquatic ecosystems and existing water quality. The modelled median concentrations proposed in the discharge were compared against the WQOs DGV and against the existing background median values.

Representative waterways have been assessed to verify if they comply with the relevant WQO DGV or, to determine if the outcomes of the project construction activities work towards their achievement over time.

Proposed modelled water quality that is lower than the ambient DGV is shaded dark green to highlight that the WQO is being protected. The compliant water quality is considered unlikely to cause significant harm to the waterway and a brief discussion on the relevant default WQO(s) is provided below in **Table 6-13**.

Proposed modelled water quality that do not meet the DVG, but is generally lower than the existing ambient median values (determined by onsite monitoring) is shaded light green as it is contributing to achievement of the WQO DGV over time. The water quality is generally an improvement on the existing ambient water quality and is unlikely to cause significant harm to the waterway and a brief discussion on the relevant default WQO(s) is provided below in **Table 6-13**.

Proposed modelled water quality that exceeds the WQO DGV and existing ambient water quality are shaded red in **Table 6-12**. These representative locations are assessed in further detail in **Table 6-13.**

A dilution assessment for the Hunter River and the Hunter Estuary Wetlands Ramsar site is provided separately below.

A detailed summary of the modelling results are presented in **Table 6-13** and analysis is further detailed in **Appendix C, Appendix D** and **Appendix E**.

Table 6-12 Comparison of modelling water quality during operation with existing water quality and project water quality objectives

Waterway classification	Indicator	DGV aquatic ecosystem	Existing median concentrations when dry	Existing range concentrations when dry	Modelled project median value and comparison against aquatic ecosystems WQO	Further discussion required (see Table 6-13)
R1 – Glenrowan Creek (Lowland river)	Turbidity	6-50 NTU	17.2	5.84 – 57.7	26.8 Complies with WQO DGV	No
	TN	0.35 mg/L	1.6	0.5 – 1.6	0.69 Contributes towards achieving WQO over time	No
	TP	0.025 mg/L	0.13	0.03 – 0.29	0.105 Contributes towards achieving WQO over time	No
R2 – Purgatory Creek (Estuarine)	Turbidity	0.5-10 NTU	14.1 – 41.65	2.26 – 115	62.67	Yes
	TN	0.3 mg/L	0.5 - 5.1	0.5 –6.5	0.47 Contributes towards achieving WQO over time	No
	TP	0.03 mg/L	0.27 – 0.58	0.02 – 0.81	0.07 Contributes towards achieving WQO over time	No
R3 – Hunter River Drain (Estuarine)	Turbidity	0.5-10 NTU	20.82 – 55.63	5.95 – 551	38.13 Contributes towards achieving WQO over time	No
	TN	0.3 mg/L	1.15 – 3	0.6 – 5.1	0.28 Complies with WQO DGV	No
	TP	0.03 mg/L	0.43 – 1.04	0.16 – 1.36	0.05 Contributes towards achieving WQO over time	No
R4 – Windeyers Creek (Lowland River)	Turbidity	6-50 NTU	6.57 – 39.53	5.01 – 71.2	9.32 Complies with WQO DGV	No
	TN	0.35 mg/L	0.9 – 2.7	0.6 – 3.8	0.51 Contributes towards achieving WQO over time	No

Waterway classification	Indicator	DGV aquatic ecosystem	Existing median concentrations when dry	Existing range concentrations when dry	Modelled project median value and comparison against aquatic ecosystems WQO	Further discussion required (see Table 6-13)
	TP	0.025 mg/L	0.08 – 0.2	0.03 – 0.32	0.068 Contributes towards achieving WQO over time	No
R5 – Viney Creek (Lowland River)	Turbidity	6-50 NTU	31.58	19.7 – 57.7	55.25	Yes
	TN	0.35 mg/L	0.9	0.5 – 0.9	0.59 Contributes towards achieving WQO over time	No
	TP	0.025 mg/L	0.1	0.07 – 0.11	0.083 Contributes towards achieving WQO over time	No
R6 – Hunter River (Estuarine)	Turbidity	0.5-10 NTU	37.3 – 66.03	14.8 – 776	22.96 Contributes towards achieving WQO over time	No
	TN	0.3 mg/L	1 – 1.6	0.3 – 3.1	1.34 Contributes towards achieving WQO over time	No
	TP	0.03 mg/L	0.16 – 0.21	0.06 – 0.68	0.121 Contributes towards achieving WQO over time	No
R7 – Unnamed Coastal Wetland (Estuarine)	Turbidity	0.5-10 NTU	25.75	12.1 – 32.7	29.34	Yes
	TN	0.3 mg/L	1.2	0.5 – 1.8	0.67 Contributes towards achieving WQO over time	No
	TP	0.03 mg/L	0.07	0.07 – 0.09	0.093	Yes

Where a range is presented for the monitoring results it shows the range of the monitoring points on that stream. Some streams only have one monitoring point and therefore have a single data point not a range.

Table 6-13 Project impact on water quality objectives during operation

Waterway	Relevant site specific WQO applied to the assessment					Assessment of project impact during construction
	Aquatic ecosystems	Visual amenity	Secondary contact recreation	Primary contact recreation	Aquatic foods (cooked)	
R1 – Glenrowan Creek (Lowland river)	✓	✓	✓	✓	NA	The proposed water quality at this waterway complies with the DGV for turbidity and contributes toward the achieving the WQO over time for TN and TP. Therefore, discharges during operation of the project are unlikely to have a significant impact on water quality. A brief discussion on the WQO is provided below. <u>Aquatic ecosystems</u> – Proposed water quality has lower levels of contaminates then either the WQO or the existing environment and are unlikely to have a significant impact on the receiving aquatic ecosystem. <u>Visual amenity</u> - The project would meet the WQO for visual amenity with turbidity levels expected to be below the DGV. Visual clarity is therefore not expected to be reduced. <u>Primary and secondary contact</u> – Secondary contact may be possible for public access and maintenance of assets however primary contact is unlikely due to shallow water and degraded water quality. The project would meet the WQO secondary recreation as operation of the project is not expected to increase bacterial counts that would result in the deterioration of recreational water quality. Additionally, metal and toxicant concentrations are expected to be captured with sediment and therefore are unlikely to be in concentrations that are hazardous to human health.
R2 – Purgatory Creek (Estuarine)	✓	✓	✓	✓	NA	The proposed water quality at this waterway does not comply with the DGVs for turbidity, however TN and TP however are modelled to be less than existing background and hence contribute to achieving the WQO over time. Further assessment is provided below. The existing water quality and receiving environment at Purgatory Creek is presented in **Section 4.2.3** and **Section 4.6.3** where it is shown to be highly disturbed. Ongoing maintenance (flood conveyance) and surrounding livestock grazing land uses are anticipated to result in ongoing impacts to water quality and the aquatic

Waterway	Relevant site specific WQO applied to the assessment					Assessment of project impact during construction
	Aquatic ecosystems	Visual amenity	Secondary contact recreation	Primary contact recreation	Aquatic foods (cooked)	
						environment. The range of values identified during site monitoring (<115 NTU) display the disturbed and variable condition of the waterway. Flood gates at the downstream end of the creek alter surface flows by containing low and medium flows within the creek channel and hence increase residence time to aid sediment settlement within the confines of the disturbed environment. The proposed turbidity is calculated to require a dilution of 6.2 to meet the existing median ambient water quality and as the operational basins passively discharge only during rainfall events that overtop the designed capacity, it is assumed that there would be would be adequate water within the catchment to provide sufficient dilution. It is noted that the proposed modelled water quality indicators are lower that the upper value of the existing ambient quality and following dilution, infrequent operational discharge is anticipated to be generally in accordance with the existing surface water and is unlikely to significantly impact on the receiving disturbed environment. Aquatic ecosystems – Turbidity in at Purgatory Creek will not meet the turbidity DGV for protection of aquatic ecosystems, however existing conditions do not comply. Proposed TN and TP levels are less that existing background. Due to the existing water quality, the receiving aquatic ecosystem is habituated to degraded conditions. As the operational basins passively discharge during rainfall (only) the discharge into the diluted creek is anticipated to reflect the existing variable water quality habitat and is unlikely to have significant impact to the aquatic ecosystem. Visual amenity –Existing turbidity levels do not meet the WQO. The sporadic addition of discharge water during rainfall events that generally complies with the existing turbidity range during rain fall events is unlikely to significantly impact on the visual amenity of the water. Primary and secondary contact - Secondary contact is possible due to landowner access and ongoing asset maintenance, however primary contact recreation is considered highly unlikely as it is a shallow modified drainage

Waterway	Relevant site specific WQO applied to the assessment					Assessment of project impact during construction
	Aquatic ecosystems	Visual amenity	Secondary contact recreation	Primary contact recreation	Aquatic foods (cooked)	
						channel that is situated within private farmland. Construction discharges shall not generate or consolidate enterococci and as the turbidity of the discharges will be consistent with existing conditions, increased algal blooms are not anticipated. The project is unlikely to significantly impact on secondary contact values.
R3 – Hunter River Drain (Estuarine)	✓	✓	✓	✓	NA	The proposed water quality at this drain complies with the WQO DGV for TN. Turbidity and TP do not meet the WQO DGV however are lower than the existing environment and hence contribute toward achieving the WQO over time. Therefore, discharges during operation of the project are unlikely to have a significant impact on water quality. A brief discussion on the WQO is provided below. Aquatic ecosystems – Discharges to the Hunter River Drain from the operation of the project would not meet the WQO for aquatic ecosystems (estuarine) due to elevated turbidity and TP concentrations. Noting that the drain is not a natural waterway, significant impacts to aquatic ecosystems are unlikely. Visual amenity - The proposed water quality generally consistent with the existing ambient condition and is unlikely to significantly impact on visual amenity. Primary and secondary contact – Secondary contact is possible due to landowner access for flood conveyance management and ongoing asset maintenance, however primary contact recreation is considered highly unlikely as it is a shallow modified drainage channel that is situated within private farmland. Construction discharges shall not generate or consolidate enterococci and as the turbidity of the discharges will be consistent with existing conditions, increased algal blooms are not anticipated. The project is unlikely to significantly impact on secondary contact values.
R4 – Windeyers Creek (Lowland river)	✓	✓	✓	✓	NA	The proposed water quality at this waterway complies with the DGV for turbidity and contributes toward achieving the DGV over time for nutrients. Discharges from permanent basins are unlikely to have a significant impact on water quality.

Waterway	Relevant site specific WQO applied to the assessment					Assessment of project impact during construction
	Aquatic ecosystems	Visual amenity	Secondary contact recreation	Primary contact recreation	Aquatic foods (cooked)	
						A brief discussion on the WQO is provided below. Aquatic ecosystems – As the proposed water quality meet the WQO or are better than the existing background levels, the operation of the project is unlikely to significantly impact on the receiving aquatic ecosystems. Visual amenity - The proposed water quality is generally consistent with the existing ambient turbidity and are unlikely to significantly impact on visual amenity Primary and secondary contact - Secondary contact is possible due to open public access to surrounding open spaces and access for maintenance for drainage from WWTP, however primary contact recreation is considered highly unlikely due to shallow water and poor water quality. Operational discharges shall not generate or consolidate enterococci and as the turbidity of the discharges will be consistent with existing conditions, increased algal blooms are not anticipated. The project is unlikely to significantly impact on secondary contact values.
R5 – Viney Creek (Lowland river)	✓	✓	✓	✓	✓	The proposed water quality at this waterway does not meet the WQO or existing background levels for turbidity. TN and TP are lower than ambient conditions and therefore work towards improving water quality and meeting the WQO over time. Further detailed assessment is provided below. The existing water quality and receiving environment at Viney Creek is presented in **Section 4.2.1** and **Section 4.6.1** where it is shown to be disturbed and modified due to complete alteration for its passage through a light industrial precinct. Ongoing maintenance (flood conveyance) and surrounding light industrial land uses are anticipated to result in ongoing impacts to water quality and aquatic environment impacts. A dam constructed within the channel of the creek alters surface flows by containing low and medium flows within the dam, however the dam increases residence time to aid sediment settlement within the confines of the disturbed environment. The proposed turbidity discharged from basins is calculated to require a dilution of 1.1 to meet the existing median ambient water quality and as the operational basins passively discharge only during rainfall events that overtop the

Waterway	Relevant site specific WQO applied to the assessment					Assessment of project impact during construction
	Aquatic ecosystems	Visual amenity	Secondary contact recreation	Primary contact recreation	Aquatic foods (cooked)	
						designed capacity, it is assumed that there would be would be adequate water within the catchment to provide sufficient dilution. It is noted that the proposed modelled discharge is slightly higher in turbidity that the upper limit of the existing environment and following dilution, infrequent operational discharge is anticipated to be generally in accordance with the existing surface water and is unlikely to significantly impact on the receiving disturbed environment. The Aquatic foods (cooked) WQO would not apply to this waterway as there is no commercial fishery and no recreational fishing was identified during project consultation nor in background information reviewed for the EIS. Aquatic ecosystems - Proposed turbidity in Viney Creek is marginally higher that the ambient DGV and TN and TP are lower existing conditions, however the diluted turbidity corresponds with the existing water quality. The existing aquatic ecosystems is habituated to existing water quality and therefore the proposed impacts to water quality are considered unlikely to have significant impact to the aquatic ecosystem Visual amenity - The proposed water quality is generally consistent with the existing ambient water quality and is unlikely to significantly impact on visual amenity Primary and secondary contact - Secondary contact with the water is possible due to its accessibility by the public and its ongoing of maintenance for flood conveyance through the industrial area, however primary contact is unlikely due to shallow water and access limitation due to dense reed growth. Operational discharges shall not generate or consolidate enterococci, and as the modelled turbidity output is lower than the existing range, the project is unlikely to have a significant impact to secondary contact values.
R6 – Hunter River (Estuarine)	✓	✓	✓	✓	✓	The proposed water quality at this waterway would not meet the WQO however as it is lower that both the existing median and range values, the proposed discharges contributes toward the achieving the DGV over time. Discharges from permanent basins are unlikely to have a significant impact on water quality.

Waterway	Relevant site specific WQO applied to the assessment					Assessment of project impact during construction
	Aquatic ecosystems	Visual amenity	Secondary contact recreation	Primary contact recreation	Aquatic foods (cooked)	
						In the Hunter River, dilution modelling was carried out which indicated that there is sufficient dilution provided by river flows so that basin discharges would not result in any long term changes in water quality (refer to **Section 6.2.6**). A brief discussion on the WQOs is provided below. Aquatic ecosystems - The existing water quality of the Hunter River does not meet the WQO DGV and is highly variable due to land uses in the catchment and the tidal influence, however the significant water volumes in the river and associated dilution from upstream and downstream sources support the existing aquatic ecosystems described in **Section 4.2.6** and **Section 4.6.6**. The existing aquatic ecosystems (such as a lack of seagrass, but broad areas of mangrove forest) reflect the variable turbidity in the surface water quality and the aquatic ecosystems are habituated to the existing conditions. The infrequent operational discharges (point load) from the project are lower than the existing turbidity range and far lower than the existing upper limit observed onsite and are unlikely to have a significant impact on the SRE aquatic ecosystem. Proposed operational nutrient discharge is also well under the existing median and range and is unlikely to significantly impact the aquatic ecosystems Visual amenity - The proposed ambient water quality are generally better than the existing ambient quality and is unlikely to significantly impact on visual amenity Primary and secondary contact - The most probable primary recreational contact with water across the project will be in the Hunter River as it is infrequently used for water sports (skiing, paddling etc) Secondary contact is highly probable due to activities such as shore and boat fishing. The WQOs of primary and secondary contact recreation are currently not being met due to high turbidity and nutrient levels and suspended sediments may contain elevated concentrations of metals and toxicants that are hazardous to human health. Permanent operational discharges would not contribute to conditions favouring the growth of or introducing bacteria (i.e. enterococci) to the waterway. Discharges therefore would work toward meeting these WQOs and are unlikely to have a significant impact to primary and secondary contact values.

Waterway	Relevant site specific WQO applied to the assessment					Assessment of project impact during construction
	Aquatic ecosystems	Visual amenity	Secondary contact recreation	Primary contact recreation	Aquatic foods (cooked)	
						<u>Aquatic foods (cooked)</u> - The WQO of aquatic foods (cooked) is currently not being met due to elevated NTU and other contaminates levels above the DGV. The discharges from the permanent water quality basins would improve the background water quality. Additionally, with the large volume of dilution available, the basin discharges are unlikely to hinder the long-term achievement of this WQO and are unlikely to have a significant impact on aquatic food values.
R7 – Unnamed coastal wetland (Estuarine)	✓	✓	✓	✓	✓	The proposed turbidity of the water quality at this waterway does not comply with the DGV and exceeds the existing median background levels for both turbidity and TP. TN is below the existing environment is unlikely to have a significant impact on water quality. The Aquatic foods (cooked) WQO would not apply to this waterway as there is no commercial fishery and no recreational fishing was identified during project consultation nor in background information reviewed for the EIS. Further assessment on turbidity and TP is provided below. The existing water quality and receiving environment is presented in **Section 4.2.7** and **Section 4.6.7**. Surrounding livestock grazing land uses are anticipated to result in ongoing impacts to water quality and the aquatic environment. The proposed turbidity is modelled to require a dilution of 1.1 for turbidity and 1.3 for TN to meet ambient median background water quality. As the operational basins passively discharge only during rainfall events that overtop the designed capacity, it is assumed that there would be adequate surface water within the catchment to provide sufficient dilution. Additionally, the wetland is expected to receive ongoing groundwater inputs from the adjacent Hunter River and upgradient Tomago Sands aquifer and these inputs can also be expected to express as surface water in the channel that may provide further dilution. The infrequent diluted permanent operational discharge is anticipated to be generally in accordance with the existing surface water and is unlikely to significantly impact on the receiving water quality.

Waterway	Relevant site specific WQO applied to the assessment					Assessment of project impact during construction
	Aquatic ecosystems	Visual amenity	Secondary contact recreation	Primary contact recreation	Aquatic foods (cooked)	
						A brief discussion on the WQOs is provided below. Aquatic ecosystems - The wetland and channelized watercourse at the site presents as a wetland of low to moderate condition that is affected by livestock grazing, various underground and overhead utility installations and the flood levee bank that separates the wetland form the adjacent Hunter River. The disturbed aquatic ecosystems at the site have become habituated to the modified water quality and flow conditions. The proposed water quality is within the range(s) identified during site monitoring and the diluted discharges are unlikely to have a significant impact on the receiving aquatic ecosystem. Visual amenity - Existing water quality of the unnamed tributary does not meet the estuarine WQO for visual amenity due to elevated turbidity that reduces visual clarity, Diluted turbidity is anticipated to be generally consistent with the range of turbidity experienced within the waterway and are unlikely to have a significant impact on visual amenity. Primary and secondary contact – Secondary contact with surface water is possible due to access of the site for asset maintenance. Primary contact is unlikely due to shallow water at the site. Permanent operational discharges would not contribute to conditions favouring the growth of or introducing bacteria (i.e. enterococci) to the waterway. Discharges therefore would work toward meeting these WQOs and are unlikely to have a significant impact to secondary contact values.

The operation of the project is not expected to impact on achieving the WQOs of primary and secondary contact recreation with the key indicators of concern relevant to these objectives being pathogens, algae and toxicants. This is because the operation of the project would not result in an increase in bacteriological indicators. Additionally, increased algal numbers are not anticipated as there would be a reduction in nutrients entering the water via project runoff. It would be expected that a corresponding decrease in toxicants would also be observed into downstream waterway which could have posed a risk to human health. Therefore, operation of the project does not pose a significant risk to human health and the environment.

Assessment of project operational discharge on Hunter Estuary Wetlands Ramsar site

The operation of the project has the potential to impact on the Hunter Estuary Wetlands Ramsar site at Kooragang Nature Reserve as a result of discharges from water quality basins which have the potential to increase the TSS, TN and TP concentrations entering the wetland. Potential indirect impacts to the Hunter Estuary Wetlands Ramsar site were considered and highlighted in an assessment of significance was required under the EPBC Act referral guidelines as described in the Biodiversity Assessment Report for the project (Appendix I of the EIS), but was not declared in the controlled action for the project by the delegate for the Australian Minister for the Environment.

To gain an understanding of the impact operation of the project could have on the Hunter Estuary Wetlands Ramsar site at Kooragang Island, a dilution model was simulated to estimate TSS/turbidity, TN and TP concentrations discharged directly into the Hunter River. There are five water permanent water quality basins (PB14, PB15, PB17, PB18 and PB19) that discharge directly to the Hunter River, two on the western side and three on the eastern side of the river. It is assumed that discharges from all other permanent water quality basins would not reach the Hunter River and therefore not included in this assessment.

Estimated concentrations and volumes from each of the five water quality basins was provided from the MUSIC model. This information, together with existing streamflow and median dry weather concentrations in the Hunter River were used to model the concentrations at the discharge and at the downstream Hunter Estuary Wetlands Ramsar site at Kooragang Nature Reserve (refer **Appendix D** for more information). Results for TSS were converted to turbidity using the results of the linear regression (refer **Appendix C**).

The results of the dilution assessment are presented in Figure D-2 to Figure D-8 (refer to **Appendix D**) and indicate that:

- The combined volume of water discharged from the five water quality basins is only a small proportion of the overall flow in the Hunter River upstream (Figure D-2). Over the modelling period (1998 to 2010) there would have been 826 occasions where the permanent basins would have discharged. While the estimated maximum discharge volume was 16 ML/d, the volume was typically much smaller, with 70 percent of the overflows contributing less than 0.1 ML/d to the Hunter River. In comparison, flow in the Hunter River ranged between 13.07 ML/d and 223,921 ML/d
- Discharges from the basins would not meet the WQO however turbidity levels are already elevated within the Hunter River. As such, basin discharges would result in a negligible change to turbidity levels at the Hunter Estuary Wetland Ramsar site at Kooragang Nature Reserve (Figure D-3). Modelling, however, shows that turbidity levels from the basin are generally lower (range 11-46 NTU) than existing concentrations (43 NTU) and that discharge concentrations would only require a dilution of one to five times to meet the WQO, which is easily available in the Hunter River (Figure D-4). As the basins present such a small proportion of the overall volume of water in the Hunter River, their better quality does not influence the overall levels of turbidity in the Hunter River downstream of the discharges. Therefore the project itself would not impact on sediment levels entering the Hunter Estuary Wetland Ramsar site at Kooragang Nature Reserve, which would remain unchanged during project operation. Due to the existing high turbidity in the Hunter River, the WQO for turbidity would continue to not be met at the Hunter Estuary Wetlands Ramsar site at Kooragang Nature Reserve
- Total nitrogen concentrations are currently elevated in the Hunter River (median 1.15 mg/L during dry weather) and do not meet the WQO (0.3 mg/L). Total nitrogen concentrations discharged from the basins (combined) ranges between 0.62 mg/L and 1.96 mg/L and require a dilution of between two and seven times for the discharge to meet the WQO, which is available under all flow conditions in the Hunter River (Figure D-5). Given the small contribution of discharge from the basins to the Hunter River, TN remains relatively unchanged between the existing conditions and downstream of the discharge. Concentrations are estimated to be lower at the Hunter Estuary Wetlands Ramsar site at

Kooragang Nature Reserve due to decay (Figure D-6). Project operation and operational discharges would not increase TN concentrations in the Hunter River. While concentrations decrease at the Hunter Estuary Wetlands Ramsar site at Kooragang Island, the WQO for TN is still not met due to existing conditions

- Similar to TN, TP concentrations are currently elevated in the Hunter River (median 0.18 mg/L during dry weather) and do not meet the WQO (0.03 mg/L). Total phosphorus concentrations discharged from the basins (combined) ranges between 0.09 mg/L and 0.19 mg/L and require a dilution of between three and six times for the discharge to meet the WQO, which is available under all flow conditions in the Hunter River (Figure D-7). Given the small contribution of discharge from the basins to the Hunter River, TP remains relatively unchanged between the existing conditions and downstream of the discharge. Concentrations are estimated to be lower at the Hunter Estuary Wetlands Ramsar site at Kooragang Nature Reserve due to decay (Figure D-8). Project operation and operational discharges would not increase TP concentrations in the Hunter River. While concentrations decrease at the Hunter Estuary Wetlands Ramsar site at Kooragang Island, the WQO for TP is still not met due to existing conditions.

In summary, the Hunter River would provide sufficient dilution of the basin discharges so that the basin discharges meet the WQO and do not contribute to higher turbidity, TN or TP at the Hunter Estuary Wetland Ramsar site at Kooragang Nature Reserve. The project is not expected to result in any significant impacts to water quality at the Hunter Estuary Wetland Ramsar site at Kooragang Nature Reserve. However, due to existing elevated levels of turbidity, TN and TP the WQO would continue to not be met at the Hunter Estuary Wetlands Ramsar site at Kooragang Nature Reserve, irrespective of the minor contribution of basin discharges which are generally of better quality than what is currently in the Hunter River.

7. Cumulative impacts

Cumulative water quality impacts may arise from the interaction of construction and operation activities of the project, and other approved or proposed projects in the area. When considered in isolation, specific project impacts may be considered minor. These minor impacts may, however, be more substantial, when the impact of multiple projects on the same receivers is considered.

This chapter provides an assessment of cumulative surface water quality impacts based on the most current and publicly available information for projects (within the vicinity of the proposed project) that are in varying stages of delivery and planning. In many instances this is a high-level qualitative assessment.

Cumulative impacts with respect to groundwater are not anticipated. Potential water quality impacts, if any, are expected to be localised to the area of predicted drawdown, mounding, spillage or existing contamination. As such, compounding or cumulative water quality impacts with other operations or proposed developments are not anticipated.

Potential cumulative impacts to surface water quality with respect to nearby projects are summarised in **Table 7-1**.

Table 7-1 Assessment of potential cumulative impacts for relevant identified projects

Project (approval status)	Relevance in consideration of cumulative impacts	Potential cumulative impacts
Black Hill Hunter Business Park (In planning)	• Located south of John Renshaw Drive and west of M1 Pacific Motorway • Likely to be some overlap in construction program, meaning likelihood of concurrent (simultaneous) construction and operation.	Construction and operation of the Black Hill Hunter Business Park (part of the Emerging Black Hill Precinct) is likely to have some overlap with the construction of the project. During timeframes where construction activities are concurrent, there is potential for minor surface water quality impacts to Viney Creek which flows through the centre of the Black Hill Hunter Business Park development site, and the unnamed tributary of Viney Creek which is located on the north eastern corner of the proposed site. Due to the extent of clearing required for the construction of the Black Hill Hunter Business Park, there is potential for increased erosion and sedimentation and subsequent downstream water quality impact to Viney Creek and the unnamed tributary to Viney Creek. The project is also likely to require construction discharges to these creeks. However, it is expected that construction activities and discharges associated with the development would be managed to avoid downstream water quality impacts and erosion and sedimentation. During operation, it is expected that cumulative impacts to surface water quality of Viney Creek and the tributary of Viney Creek would be negligible as the Black Hill Hunter Business Park development would ensure the landscape is stabilised and design will have incorporated water detention and bio-detention basins to adequately capture runoff. Additionally, the Black Hill Hunter Business Park development is expected to have a 'Green Buffer Zone' along the perimeter of the project boundary which would reduce sediment being transported to Viney Creek and the tributary of Viney Creek.

Project (approval status)	Relevance in consideration of cumulative impacts	Potential cumulative impacts
Kinross Industrial Heatherbrae/ Weathertex (Approved)	• Located within the project's construction footprint on Masonite Road, Heatherbrae • Likely to be some overlap in construction program, meaning likelihood of concurrent (simultaneous) construction and operation.	This development is proposed on land identified for AS16, AS18 and AS19. If the site is developed prior to or during project construction, this ancillary facility would be unavailable to the project for use. Should construction take place concurrently, there is potential for construction runoff to be discharged into the nearby receiving waterway, Windeyers Creek, which may result in elevated levels of heavy metals, hydrocarbons or other contaminants such as litter that may impact aquatic ecosystem health. Further, due to its location within the Tomago Sandbeds Catchment Area, there is potential for earthwork and excavation to result in changes to drinking water quality. It is expected, however, that construction activities associated with the development would be managed to avoid impacts to the Tomago Sandbeds and construction discharges would be designed and implemented in accordance with standard practices and guidelines to ensure minimal water quality impacts (Landcom, 2004; DECC, 2008a; DECC, 2008b). Once operational, it is expected that cumulative impacts to water quality of Windeyers Creek or the Tomago Sandbeds would be negligible as drainage structures and water quality control measures for runoff would be designed to ensure minimal downstream impacts and compliance with licenced discharges.
Newcastle Power Station (in planning)	• Located within the project's construction footprint at Tomago near Old Punt Road • Potential to be consecutive (back to back) construction and concurrent (simultaneous) operation.	AGL propose to construct a 250 megawatt (MW) gas fired power station at Tomago, with gas pipelines and electricity transmission lines. Construction of the power station is due to commence in 2021 with the power station expected to be operational in 2022. The site for the proposed power station is located between the Pacific Highway and Old Punt Road, north of the Tomago industrial area (AGL, 2019). The power station would be located next to AS12 and AS13 and immediately next to where the main alignment is proposed to cross near the Tomago interchange. Consideration of the project has been given in the siting and layout of the power station. Due to its location at the most western extent of the Tomago Sandbeds Catchment Area, there is potential for earthwork and excavation to result in changes to drinking water quality. It is expected, however, that construction activities associated with the gas fired power station development would be managed to avoid impacts to the Tomago Sandbeds and construction discharges would be designed and implemented in accordance with standard practices and guidelines to ensure minimal water quality impacts (Landcom, 2004; DECC, 2008a; DECC, 2008b). Cumulative impacts to water quality of Tomago Sandbeds would be negligible as drainage structures and water quality control measures for runoff would be designed to ensure minimal impacts and compliance with licenced discharges.

Project (approval status)	Relevance in consideration of cumulative impacts	Potential cumulative impacts
Pacific Highway improvements at Hexham (Hexham Straight) (in planning)	• Located about one kilometre south of the project at Hexham • Potential to be consecutive (back to back) construction and concurrent (simultaneous) operation.	This road project is currently in planning. The Hexham Straight project is located along the Pacific Highway (Maitland Road) at Hexham, between Sandgate and Hexham Bridge, south of the construction footprint. The proposed scope of the Hexham Straight project involves the addition of an extra lane in both directions of the Pacific Highway, removal of the existing bridges and construction of two new bridges at Ironbark Creek, adjustments to connecting roads as well as substantial utility relocation. Due to the differing time frames involved, it is not expected there would be any cumulative surface water quality impacts during construction. During operation, it is expected that cumulative impacts to surface water quality of the Hunter River would be negligible as, similar to the proposed project, Transport would employ rehabilitation efforts (in line with relevant guidelines) to ensure the disturbed landscape is stabilised. Design of the Hexham Straight project will have additionally incorporated permanent water quality basins to adequately capture runoff.
Lower Hunter Freight Corridor (in planning)	• Investigation area includes Hexham.	The Transport Lower Hunter Freight Corridor (LHFC) website (TfNSW, 2018) indicates that in 2018 preliminary investigations were being carried out to assess options for a dedicated freight rail line between Fassifern and Hexham. No options were available on the website to review. An investigation areas figure between Fassifern and Hexham was available. As corridor options and environmental assessment are not available for the LHFC, the level of impact surface water quality of downstream receiving environments generated by this project is currently unknown. Consequently, cumulative impacts associated with the construction or operation of the project is unknown.
Hunter Gas Pipeline (approved)	• Intersects the project at Tomago	This project would cross the main alignment at Tomago. Construction is planned between 2023 and 2028, therefore due to the differing time frames involved, no cumulative impacts to surface water quality are anticipated during construction. During operation, since the project is likely to consist of a buried pipeline, no cumulative surface water impacts are anticipated.

7.1 Cumulative impact summary

Overall, the project would have minor cumulative surface water quality impacts associated with both construction and operation. Where any minor impacts occur, they are likely to be either highly localised, temporary and/or readily assimilated into existing waterways. No cumulative groundwater impacts are expected.

8. Environmental management measures

The key water quality objective for the project is to ensure downstream waterways, groundwater and sensitive receiving environments are protected against the potential impacts associated with the construction and operation of the project.

The following management measures detailed in **Table 8-1** have been developed to specifically manage potential impacts which have been predicted as a result of the proposed work. These measures should be incorporated into relevant Environmental Management Plans (EMPs) during construction and operations.

The environmental management measures should be read in conjunction with those outlined in the Hydrology and Flooding Working Paper (Appendix J of the EIS), Biodiversity Assessment Report (Appendix I of the EIS), and Soils and Contamination Working Paper (Appendix P of the EIS). With the implementation of these recommended management measures, it is expected that the construction and operational impacts of the project are manageable and residual impacts would be minimal.

Table 8-1 Environmental management measures

Impact	Reference	Management measure	Responsibility	Timing
General	WQ01	A Construction Soils and Water Management Plan (CSWMP) would be developed as a sub plan of the CEMP and will outline measures to manage soil and water quality impacts associated with the construction work, including contaminated land. The CSWMP would include but not be limited to: • Measures to minimise/manage erosion and sediment transport both within the construction footprint and offsite including requirements for the preparation of erosion and sediment control plans (ESCP) for all progressive stages of construction and the implementation of erosion and sediment control measures • Erosion and sediment control measures, which will be implemented and maintained in accordance with Managing Urban Stormwater – Soils and Construction, Volume 1 (Landcom 2004) and Volume 2D (DECC, 2008) • Measures to manage stockpiles including locations, separation of waste types, sediment controls and stabilisation in accordance with the Stockpile Site Management Guideline (Roads and Maritime Services, 2015). • Procedures for dewatering (including waterways, wetlands and excavations and temporary sediment basins) including relevant discharge criteria. • Concrete waste management procedures • Measures to manage accidental spills including the requirement to maintain materials such as spill kits, an emergency spill response procedure and regular visual water quality checks when working near waterways • Measures to manage tannin leachate and potential saline soils • Controls for sensitive receiving environments which may include but not be limited to identification of 'no go' zones for construction plant and equipment (where applicable).	Contractor	Prior to construction/ construction/ operation
	WQ02	A soil conservation specialist will be engaged for the duration of construction of the project to provide advice on the planning and implementation of erosion and sediment control including review of the CSWMP and ESCP.	Transport / Contractor	Prior to construction/ construction/ operation
Water reuse	WQ03	A water reuse strategy will be developed as part of the CEMP for both construction and operational phases of the project to reduce reliance on potable water. Any water from sediment basins will be checked to ensure compliance with ANZG (2018) Water Quality Guidelines prior to reuse.	Contractor	Detailed design/ prior to construction/ construction

Impact	Reference	Management measure	Responsibility	Timing
Discharge of saline groundwater to drinking catchment	WQ04	Basins and swales within the Tomago Sandbeds drawdown area will be lined during construction and operation.	Contractor	Detailed design
Discharge of saline groundwater to surface waterways	WQ05	Basins TB04, TB06, TPB10 (PB12), TPB18 (PB24), PB14 and PB15 shall be further investigated to confirm requirement for lining to avoid discharge of saline groundwater to surface waterways during construction and operation.	Transport	Detailed design
Surface water quality and groundwater quality impacts	WQ06	A water quality monitoring program will be developed in accordance with the Guidelines for Construction Water Quality Monitoring (RTA, 2003b). The program will monitor surface water quality and groundwater quality during construction and during operation.	Transport / Contractor	Prior to construction/ construction/ operation

8.1 Water quality monitoring program

A surface water and groundwater monitoring program will be implemented as an environmental management measure to observe any changes in surface water and groundwater quality that may be attributable to the project and inform appropriate management responses.

The monitoring program will include collection of pre-construction data to build upon baseline water quality data that has been collected for this assessment. The pre-construction data will be used for comparison to construction and operational monitoring data to characterise and inform an appropriate response to any impacts from the project. An outline of each stage of the monitoring program (pre-construction, construction, operational) is provided in **Section 8.1.2** and **Section 8.1.3** and describes the location and frequency of monitoring during these periods.

The surface water and groundwater quality indicators to be monitored are common to all stages of the monitoring program and are outlined in **Table 8-2** and **Table 8-3**.

Monitoring would be carried out in accordance with the following guidelines:

- Guideline for Construction Water Quality Monitoring (RTA, 2003b)
- Australian Guidelines for Water Quality Monitoring and Reporting (ANZECC/ARMCANZ, 2000b).

8.1.1 Monitoring locations

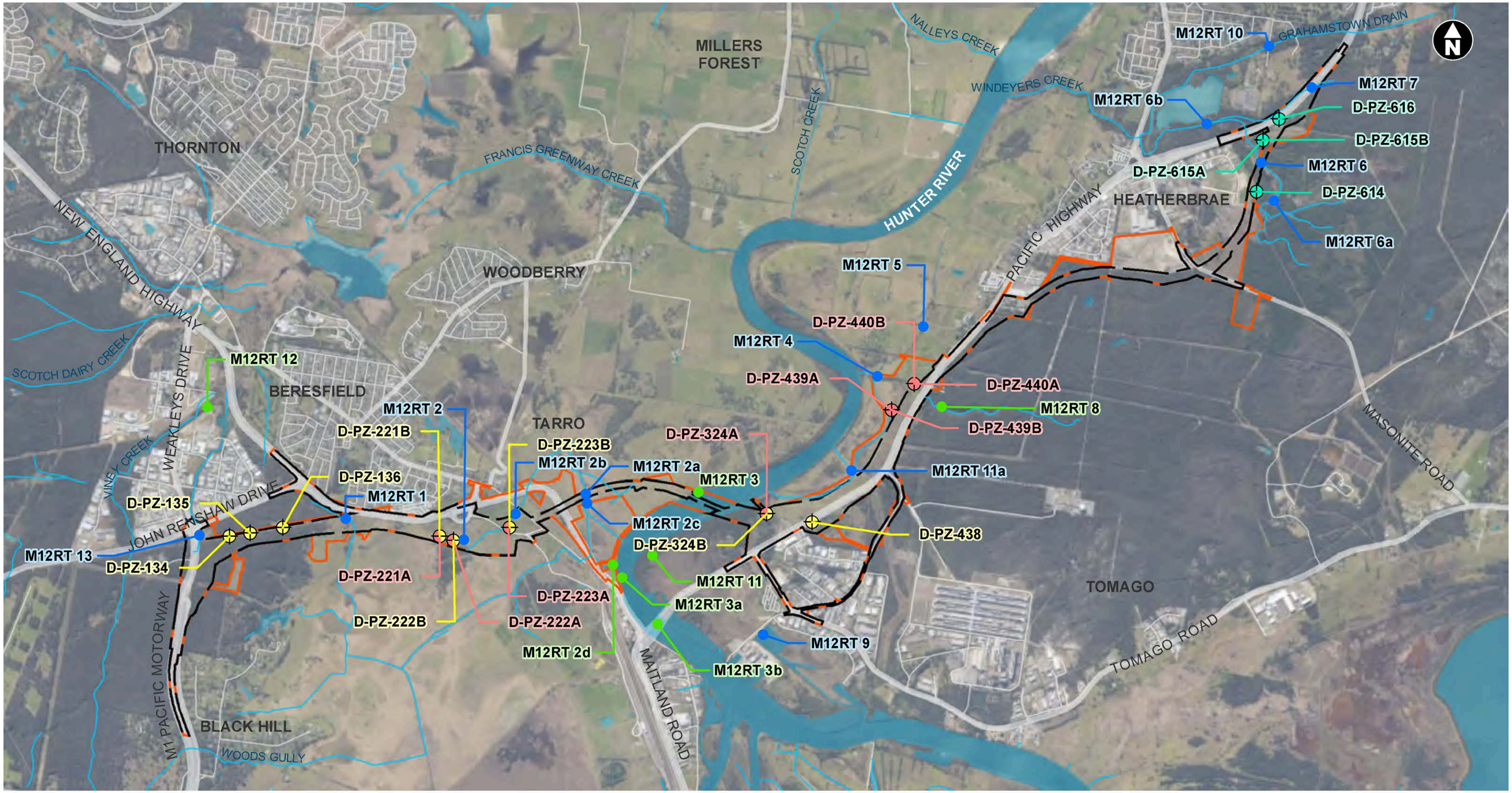
Monitoring locations for surface water and groundwater quality during pre-construction, construction and operation are shown in **Figure 8-1**.

The proposed surface water monitoring program would aim to continue monitoring these sites, however, the location of monitoring sites may be refined during detailed design based on site design and location of proposed water quality controls. Monitoring site locations which are expected to become unavailable after construction due to creek adjustment work (i.e. M12RT2, M12RT2b) would be reconsidered and relocated downstream to ensure changes in water quality associated with the adjustment work is captured. Site M12RT7 is also likely to be relocated downstream due to being currently situated in the construction footprint.

The proposed groundwater monitoring program would continue monitoring these existing monitoring network of 20 bores. However, the necessity for some of the monitoring sites may be rationalised during detailed design based on site design and anticipated impacts. It is also likely during detailed design that additional groundwater investigations would be required, that will likely result in further monitoring bores being installed to target specific elements or areas of risk during construction, such as confirming groundwater level and quality at water quality basin locations.

Before construction all available groundwater monitoring locations would be reviewed and rationalised as required. Additional sites may be identified before construction as an outcome of detailed site investigation. Where applicable, sentinel monitoring locations, situated between high risk activities and sensitive receptors may also considered.

Additional sites, reference and control sites (i.e. up and downstream of the project) will be identified before construction. These sites are useful in determining impacts of a disturbance or pollution event.



Construction footprint

Operational footprint

Groundwater monitoring locations

- Hunter Alluvium and Tomago Coal Measures paired bore location
- Hunter Alluvium
- Tomago Coal Measures
- Tomago Sandbeds

Surface water monitoring locations

- Monitoring site - Sensitive Receiving Environment
- Monitoring site - Non Sensitive Receiving Environment

Waterways

0 1 2 km

Figure 8-1 Surface water and groundwater monitoring locations

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8.1.2 Surface water quality monitoring program

The proposed surface water quality monitoring program will aim to continue monitoring the sites shown on.

The location, frequency and indicators of the surface water quality monitoring program is presented in **Table 8-2**.

Table 8-2 Location, frequency and indicators for surface water quality monitoring

	Additional baseline data[1]	Construction phase	Operational phase
Location	As per **Figure 8-1**[2]		
Frequency	Quarterly (wet and dry[3]) for a minimum of six months prior to construction	Quarterly (wet and dry[3]) for the duration of construction	Quarterly (wet and dry) for a period of 12 months during operation of the project (i.e. 12 months post construction)
Indicators	• Field parameters (electrical conductivity, pH, turbidity, dissolved oxygen and temperature) • Visible oil and grease[4] • Total dissolved solids and TSS • Total nitrogen • Total phosphorus • Dissolved metals (arsenic, cadmium, chromium, copper, lead, mercury, nickel, zinc, iron and manganese)		

1. In addition to the existing baseline data described in **Section 4.6**
2. As described above, the necessity for some of the monitoring sites may be rationalised during detailed design. As a result, the locations shown in **Figure 8-1** are indicative only and are subject to change
3. A wet weather event is classified as 20 millimetres or more of rain within 24 hours, as recorded at the Newcastle University BOM rainfall gauge (#061390). Sampling would occur within 24 hours of the rain event. If rainfall events are regularly less than 20 mm, opportunistic wet weather monitoring would be carried out to ensure that some wet weather data is collected
4. If oil and grease visible, sample to be assessed for total petroleum hydrocarbons

8.1.3 Groundwater quality monitoring program

The location, frequency and indicators of the groundwater quality monitoring program are presented in **Table 8-3**.

Table 8-3 Location, frequency and indicators for groundwater quality monitoring

	Additional baseline data[1]	Construction phase	Operational phase
Location	As per **Figure 8-1**[2]		
Frequency	Two monthly for at least 12 months prior to construction	Quarterly for the duration of construction	Quarterly for a period of 12 months during operation of the project (i.e. 12 months post construction)
Indicators	• Field parameters (electrical conductivity, pH, turbidity, dissolved oxygen and temperature) • Total dissolved solids • Major ions (sodium, magnesium, calcium, chloride, bicarbonate/carbonate and sulfate)[3] • Nutrients (ammonia, nitrate, TN, TP)[3] • Dissolved metals (aluminium, arsenic, cadmium, chromium, copper, iron, lead, manganese, mercury, nickel and zinc)[3]		

1. In addition to the existing baseline data described in **Section 4.7**
2. As described above, the necessity for some of the monitoring sites may be rationalised during detailed design. As a result, the locations shown in **Figure 8-1** are indicative only and are subject to change

9. Conclusion

The project lies entirely within the lower portion of the Hunter River Catchment which is a heavily modified. The assessment of existing surface water quality data and project specific monitoring of waterways and wetlands relevant to the project found that they exhibit poor water quality with elevated nutrient levels and heavy metals. Existing waterways currently do not meet the ANZG (2018) Water Quality Guidelines for protection of nominated WQOs.

Groundwater within the study area is highly variable. The best quality groundwater is associated with the Tomago Sandbeds that contain fresh groundwater, although several exceedances of ANZG (2018) Water Quality Guidelines for protection of nominated WQOs are noted east of the project. Groundwater within the Hunter Alluvium and Tomago Coal Measures are typically saline with numerous exceedances of ANZG (2018) Water Quality Guidelines for protection of nominated WQOs noted.

During construction and operation of the project, control measures typical to Transport projects shall be implemented. The result of these controls is that the ambient surface and groundwater quality shall meet the DGVs for some NSW Water Quality Objectives, or be better than existing water quality and therefore work towards achieving the WQOs over time. There are some occasions when the project would result in minor exceedances of current ambient water quality, however, it is expected that sufficient dilution will be available so that there is no significant impact to surface water quality.

The project construction and operation is not anticipated to have any detrimental impact on groundwater quality or to lower the beneficial use of the groundwater source in the vicinity of the project.

The assessment of the likely construction and operational water quality impacts at the Hunter Estuary Wetlands Ramsar site at Kooragang Island has confirmed the project is not likely to present any long term risk to the health of the site.

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Terms and acronyms

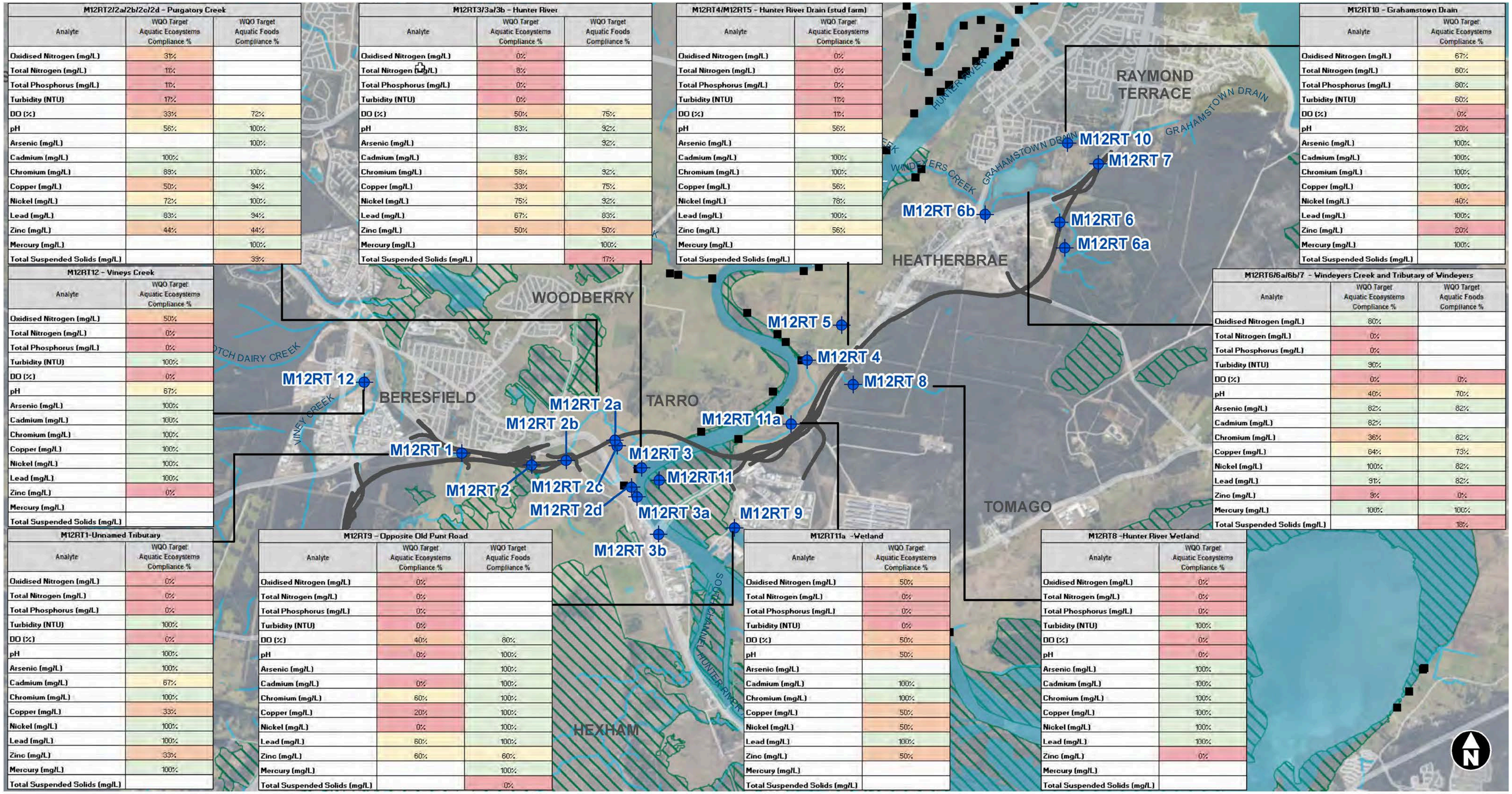
Term / Acronym	Description
AADT	Annual average daily traffic
AHD	Australian Height Datum
ALA	Atlas of Living Australia
Ammonia	The most reduced form of inorganic nitrogen available, and is preferentially utilised by plants and aquatic micro-organisms and comprise of un-ionised ammonia (NH3) and ionised ammonia (NH4+). The main sources of ammonia in aquatic ecosystems are found to be from human and animal wastes and by release during the decomposition of organic material by bacteria
ANZECC / ARMCANZ	Australian and New Zealand Environment and Conservation Council (ANZECC) & Agriculture and Resource Management Council of Australia and New Zealand (ARMCANZ)
ANZG (2018) Water Quality Guidelines	Australian and New Zealand Guidelines for Fresh and Marine Water Quality (2018)
Aquatic ecology	Flora and fauna that live in or on water for all or a substantial part of the lifespan.
Aquifer	Under the WMA 2000 an aquifer is a geological structure or formation, or an artificial landfill, that is permeated with water or is capable of being permeated with water. More generally, the term 'aquifer' is commonly understood to mean a groundwater system that is sufficiently permeable to allow water to move within it, and which can yield productive volumes of groundwater.
ASS	Acid Sulfate Soil
BC Act	*Biodiversity Conservation Act 1999*
BOD	Biological oxygen demand
BOM	Bureau of Meteorology (Australian Government)
CEMP	Construction Environmental Management Plan
Chlorophyll-*a*	An estimate of the biomass of microscopic plants such as phytoplankton in a waterway
Coastal Management SEPP	State Environmental Planning Policy (Coastal Management) 2018
Culvert	An enclosed channel for conveying water below a road
DAWE	Department of Agriculture, Water and the Environment
DECCW	Department of Environment, Climate Change and Water
DECC	Department of Environment and Climate Change
Dissolved Oxygen	A measure of the amount of dissolved oxygen in water
DPI	Department of Primary Industries
DPIE	Department of Planning, Industry and Environment
DPIE (Water)	Department of Planning, Industry and Environment (Water)
DGV	Default Guideline Values
Ecosystem	A functional unit of energy transfer and nutrient cycling in a given place. It includes all relationships within the biotic community and between the biotic components of the system.

Term / Acronym	Description
EES Group	Environment, Energy and Science Group, a part of the NSW Department of Planning, Industry and Environment
EIS	Environmental Impact Statement
Electrical conductivity (EC)	The measure of a material's ability to accommodate the transport of an electric charge
EMC	Event mean concentration
Environmental values	Environmental values are particular values or uses of the environment that are important for a healthy ecosystem or for public benefit or health. They are values that require protection from the effects of pollution and waste discharges and provide goals that help in the selection of the most appropriate management options (ANZECC/ARMCANZ, 2000a)
EPA	NSW Environment Protection Authority
EP&A Act	*Environmental Planning and Assessment Act 1979*
EPBC Act	*Environment Protection and Biodiversity Conservation Act 1999*
Ephemeral creek	A creek that only exists for a short duration of time following rainfall
EPL	Environmental Protection Licence
Erosion	A natural process where wind and water detaches a soil particle and provides energy to move the particle
FM Act	*Fisheries Management Act 1994*
FRP	Filterable reactive phosphorus
GDE	Groundwater dependent ecosystem
Geomorphology	The study of shaping of the landscape by water, wind and other processes. Commonly used to describe the condition of stream as they are shaped by erosion and/or accretion of sediments.
Groundwater	Groundwater is all water that occurs beneath the ground surface in the saturated zone. A groundwater system is any type of saturated geological formation that can yield anywhere from low to high volumes of water. For the purposes of this NSW AIP the term aquifer has the same meaning as groundwater system and includes low yielding and saline systems.
Habitat	The habitat where a species, population or ecological community lives (whether permanently, periodically or occasionally). Habitats are measurable and can be determined by flora and physical components.
Heavy metals	Metals and metalloids present in total or dissolved forms that may be directly toxic to instream organisms
Impact	Influence or effect exerted by a project or other activity on the natural, built and community environment
Interchange	A grade separation of two or more roads with one or more interconnecting carriageways
KFH	Key Fish Habitat
LGA	Local Government Area
Median	The middle value of a set of data.
Metals	Occur naturally at trace levels in the environment. This category includes the elements of arsenic, cadmium, copper, chromium, iron, lead, manganese, mercury, nickel, selenium and zinc.

Term / Acronym	Description
mg/L	Milligrams per litre
MNES	Matters of National Environmental Significance
MUSIC model	eWater Model for Urban Stormwater Improvement Conceptualisation
NATA	National Association of Testing Authorities
NHRMC	National Health and Medical Research Council
NO_x	Oxidised nitrogen, which represents the level of free nitrogen within the water column that is immediately available to plants
NPW Act	*National Parks and Wildlife Act 1974*
NSW	New South Wales
NSW AIP	NSW Aquifer Interference Policy
NTU	Nephelometric Turbidity Unit
Nutrients	Nutrients in aquatic environments promote the growth of algae and increase turbidity which in turn reduces light and may affect aquatic plat growth.
NWQMS	National Water Quality Management Strategy
OEH	The former Office of Environment and Heritage, which is now the Environment, Energy and Science Group (EES Group)
Oxidised nitrogen	Represents the level of free nitrogen within the water column that is readily available to plants.
PASS	Potential Acid Sulfate Soils
pH	A measure of the acidity or alkalinity of a substance
POEO Act	*Protection of the Environment Operations Act 1997*
PVC	Polyvinyl Chloride
QA/QC	Quality Assurance and Quality Control
RL	Reduced level
RTA	Roads and Traffic Authority
RUSLE	Revised Universal Soil Loss Equation
Scour	The erosion of material by the action of flow water
SEAR	Secretary's Environmental Assessment Requirements
Sediment	Material, both mineral and organic, that is being or has been moved from its site of origin by the action of wind, water or gravity and comes to rest either above or below water level
Sedimentation	Deposition of sediment usually by water
Study area (surface water)	The surface water study area is identified as the construction and operational footprints and a 500 metre buffer around the project alignment.
Study area (groundwater)	The groundwater study area is identified the construction and operational footprints and a 2000 metre (2 kilometre) buffer around the project alignment.
SRE	Sensitive Receiving Environments
SSI	State significant infrastructure

Term / Acronym	Description
Stockpile	Temporarily stored materials such as soil, sand, gravel and spoil/waste
Stream order	A classification systems which assigns an ‘order’ to waterways according to the number of additional tributaries associated with each waterway, to provide a measure of system complexity
Surface water	Water flowing or held in streams, rivers and other wetlands in the landscape
Swale	A shallow, grass-lined drainage channel
Terrestrial	Living or growing on land (i.e. terrestrial flora or fauna)
The Blue Book	*Managing Urban Stormwater – Soils and Construction* series of handbooks includes two main sections which are of particular relevance to the project. These are *Managing Urban Stormwater – Soils and Construction*: *Volume 1* (Landcom, 2004), and *Volume 2D Main Road Construction* (DECC, 2008b).
The project	Refers to the construction and operation of the M1 Pacific Motorway extension to Raymond Terrace
TKN	Total Kjeldahl Nitrogen
TN	Total nitrogen, which is measure of all the nitrogen species found in a waterbody including ammonia, oxidised nitrogen and total organic nitrogen
TP	Total phosphorus, which is a measure of dissolved phosphorus in the waterbody. There are two forms of dissolved phosphorus, these are organic phosphorus produced from the decay of plant and animal material and inorganic orthophosphates which is released through the breakdown of rock and then transported into the waterbody
Tributary	A river or stream flowing into a larger river or lake
Transport	Transport for New South Wales
TDS	Total dissolved solids
TSS	Total suspended solids
UHVA	Upper Hunter Valley Alliance
Wetland	Wetlands are areas of land that are wet by surface water or groundwater, or both, for long enough periods that the plants and animals in them are adapted to, and depend on, moist conditions for at least part of their lifecycle. They include areas that are inundated cyclically, intermittently or permanently with fresh, brackish or saline water, which is generally still or slow moving except in distributary channels such as tidal creeks which may have higher peak flows. Wetlands may be constructed for the purposes of removing pollutants from runoff.
WM Act	*Water Management Act 2000*
WQO	Water Quality Objective

Appendix A. Median water quality results



M12RT2/2a/2b/2c/2d – Purgatory Creek		
Analyte	WQO Target Aquatic Ecosystems Compliance %	WQO Target Aquatic Foods Compliance %
Oxidised Nitrogen (mg/L)	31%	
Total Nitrogen (mg/L)	11%	
Total Phosphorus (mg/L)	11%	
Turbidity (NTU)	17%	
DO (%)	33%	72%
pH	56%	100%
Arsenic (mg/L)		100%
Cadmium (mg/L)	100%	
Chromium (mg/L)	89%	100%
Copper (mg/L)	50%	94%
Nickel (mg/L)	72%	100%
Lead (mg/L)	83%	94%
Zinc (mg/L)	44%	44%
Mercury (mg/L)		100%
Total Suspended Solids (mg/L)		33%

M12RT3/3a/3b – Hunter River		
Analyte	WQO Target Aquatic Ecosystems Compliance %	WQO Target Aquatic Foods Compliance %
Oxidised Nitrogen (mg/L)	0%	
Total Nitrogen (mg/L)	8%	
Total Phosphorus (mg/L)	0%	
Turbidity (NTU)	0%	
DO (%)	50%	75%
pH	83%	92%
Arsenic (mg/L)		92%
Cadmium (mg/L)	83%	
Chromium (mg/L)	58%	92%
Copper (mg/L)	33%	75%
Nickel (mg/L)	75%	92%
Lead (mg/L)	67%	83%
Zinc (mg/L)	50%	50%
Mercury (mg/L)		100%
Total Suspended Solids (mg/L)		17%

M12RT4/M12RT5 – Hunter River Drain (stud farm)	
Analyte	WQO Target Aquatic Ecosystems Compliance %
Oxidised Nitrogen (mg/L)	0%
Total Nitrogen (mg/L)	0%
Total Phosphorus (mg/L)	0%
Turbidity (NTU)	11%
DO (%)	11%
pH	56%
Arsenic (mg/L)	
Cadmium (mg/L)	100%
Chromium (mg/L)	100%
Copper (mg/L)	56%
Nickel (mg/L)	78%
Lead (mg/L)	100%
Zinc (mg/L)	56%
Mercury (mg/L)	
Total Suspended Solids (mg/L)	

M12RT10 – Grahamstown Drain	
Analyte	WQO Target Aquatic Ecosystems Compliance %
Oxidised Nitrogen (mg/L)	67%
Total Nitrogen (mg/L)	60%
Total Phosphorus (mg/L)	80%
Turbidity (NTU)	60%
DO (%)	0%
pH	20%
Arsenic (mg/L)	100%
Cadmium (mg/L)	100%
Chromium (mg/L)	100%
Copper (mg/L)	100%
Nickel (mg/L)	40%
Lead (mg/L)	100%
Zinc (mg/L)	20%
Mercury (mg/L)	100%
Total Suspended Solids (mg/L)	

M12RT12 – Vineys Creek	
Analyte	WQO Target Aquatic Ecosystems Compliance %
Oxidised Nitrogen (mg/L)	50%
Total Nitrogen (mg/L)	0%
Total Phosphorus (mg/L)	0%
Turbidity (NTU)	100%
DO (%)	0%
pH	67%
Arsenic (mg/L)	100%
Cadmium (mg/L)	100%
Chromium (mg/L)	100%
Copper (mg/L)	100%
Nickel (mg/L)	100%
Lead (mg/L)	100%
Zinc (mg/L)	0%
Mercury (mg/L)	
Total Suspended Solids (mg/L)	

M12RT6/6a/6b/7 – Windeyers Creek and Tributary of Windeyers		
Analyte	WQO Target Aquatic Ecosystems Compliance %	WQO Target Aquatic Foods Compliance %
Oxidised Nitrogen (mg/L)	80%	
Total Nitrogen (mg/L)	0%	
Total Phosphorus (mg/L)	0%	
Turbidity (NTU)	90%	
DO (%)	0%	0%
pH	40%	70%
Arsenic (mg/L)	82%	82%
Cadmium (mg/L)	82%	
Chromium (mg/L)	36%	82%
Copper (mg/L)	64%	73%
Nickel (mg/L)	100%	82%
Lead (mg/L)	91%	82%
Zinc (mg/L)	9%	0%
Mercury (mg/L)	100%	100%
Total Suspended Solids (mg/L)		18%

M12RT1-Unnamed Tributary	
Analyte	WQO Target Aquatic Ecosystems Compliance %
Oxidised Nitrogen (mg/L)	0%
Total Nitrogen (mg/L)	0%
Total Phosphorus (mg/L)	0%
Turbidity (NTU)	100%
DO (%)	0%
pH	100%
Arsenic (mg/L)	100%
Cadmium (mg/L)	67%
Chromium (mg/L)	100%
Copper (mg/L)	33%
Nickel (mg/L)	100%
Lead (mg/L)	100%
Zinc (mg/L)	33%
Mercury (mg/L)	100%
Total Suspended Solids (mg/L)	

M12RT9 – Opposite Old Punt Road		
Analyte	WQO Target Aquatic Ecosystems Compliance %	WQO Target Aquatic Foods Compliance %
Oxidised Nitrogen (mg/L)	0%	
Total Nitrogen (mg/L)	0%	
Total Phosphorus (mg/L)	0%	
Turbidity (NTU)	0%	
DO (%)	40%	80%
pH	0%	100%
Arsenic (mg/L)		100%
Cadmium (mg/L)	0%	100%
Chromium (mg/L)	60%	100%
Copper (mg/L)	20%	100%
Nickel (mg/L)	0%	100%
Lead (mg/L)	60%	100%
Zinc (mg/L)	60%	60%
Mercury (mg/L)		100%
Total Suspended Solids (mg/L)		0%

M12RT11a –Wetland	
Analyte	WQO Target Aquatic Ecosystems Compliance %
Oxidised Nitrogen (mg/L)	50%
Total Nitrogen (mg/L)	0%
Total Phosphorus (mg/L)	0%
Turbidity (NTU)	0%
DO (%)	50%
pH	50%
Arsenic (mg/L)	
Cadmium (mg/L)	100%
Chromium (mg/L)	100%
Copper (mg/L)	50%
Nickel (mg/L)	50%
Lead (mg/L)	100%
Zinc (mg/L)	50%
Mercury (mg/L)	
Total Suspended Solids (mg/L)	

M12RT8 –Hunter River Wetland	
Analyte	WQO Target Aquatic Ecosystems Compliance %
Oxidised Nitrogen (mg/L)	0%
Total Nitrogen (mg/L)	0%
Total Phosphorus (mg/L)	0%
Turbidity (NTU)	100%
DO (%)	0%
pH	0%
Arsenic (mg/L)	100%
Cadmium (mg/L)	100%
Chromium (mg/L)	100%
Copper (mg/L)	100%
Nickel (mg/L)	100%
Lead (mg/L)	100%
Zinc (mg/L)	0%
Mercury (mg/L)	
Total Suspended Solids (mg/L)	

The project
Water quality monitoring sites
Floodgates
Coastal wetlands (Coastal Management SEPP)
Waterways

0 1.5 3 km

Figure A-1 Summary of compliance with ANZG (2018) Water Quality Guidelines

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Table A-1 Median Water Quality Results Viney Creek (bolded text denotes an exceedance of guideline)

Analyte	Median M12RT12		Aquatic Ecosystem guideline (lowland river)
	Dry (n=3)	Wet (n=2)	
pH	7.11	7.29	6.5-8.5
Dissolved oxygen (% saturation)	**8.2**	**64**	85-110
Turbidity (NTU)	31.53	**63.68**	6-50
Total Suspended solids (mg/L)	14	28	No guideline
Electrical conductivity (µS/cm)	**855**	**610**	200-300
Oxidised Nitrogen (mg/L)	**0.12**	**0.11**	0.04
Total nitrogen (mg/L)	**0.9**	**0.95**	0.35
Total phosphorus (mg/L)	**0.1**	**0.13**	0.025
Arsenic (mg/L)	0.0005	0.0005	0.013
Cadmium (mg/L)	0.00005	0.00013	0.0002
Chromium (mg/L)	0.0005	0.0005	0.001
Copper (mg/L)	0.0005	0.0013	0.0014
Nickel (mg/L)	0.004	0.0035	0.011
Lead (mg/L)	0.0005	0.0005	0.0034
Zinc (mg/L)	**0.012**	**0.02**	0.008
Mercury (mg/L)	0.00005	0.00005	0.00006
Enterococci (CFU/100mL)*	**50**	**1640**	<35 primary contact <230 secondary contact

*DECCW (2006)

Table A-2 Median Water Quality Results Glenrowan Creek (bolded text denotes an exceedance of guideline)

Analyte	M12RT1 (median)		Aquatic ecosystem guideline (lowland river)
	Dry (n=3)	Wet (n=2)	
pH	6.9	7.04	6.5-8.5
Dissolved oxygen (% saturation)	**17.8**	**67.05**	85-110
Turbidity (NTU)	17.2	17.2	6-50
Total suspended solids (mg/L)	17	12	No guideline
Electrical conductivity (µs/cm)	266	285	200-300
Oxidised Nitrogen (mg/L)	**0.09**	**2**	0.04
Total nitrogen (mg/L)	**1.6**	**3.35**	0.35
Total phosphorus (mg/L)	**0.13**	**0.12**	0.025
Arsenic (mg/L)	0.001	0.0013	0.013
Cadmium (mg/L)	0.00005	0.00013	0.0002
Chromium (mg/L)	0.0005	0.0005	0.001
Copper (mg/L)	**0.002**	**0.0025**	0.0014
Nickel (mg/L)	0.002	0.0023	0.011
Lead (mg/L)	0.0005	0.0005	0.0034
Zinc (mg/L)	**0.016**	**0.049**	0.008
Mercury (mg/L)	0.00005	0.00005	0.00006
Enterococci (CFU/100mL)*	**60**	**2650**	<35 primary contact <230 secondary contact

*DECCW (2006)

Table A-3 Median Water Quality Results Purgatory Creek (bolded text denotes an exceedance of guideline)

Analyte	M12RT2		M12RT2b		M12RT2a		M12RT2c		M12RT2d^	Aquatic ecosystem guideline (estuarine)
	Dry (n=4)	Wet (n=2)	Dry (n=3)	Wet (n=2)	Dry (n=5)	Wet (n=2)	Dry (n=5)	Wet (n=2)	Wet (n=2)	
pH	**6.56**	7.17	7.16	7.58	7.34	7.02	8.24	7.4	7.9	7-8.5
Dissolved oxygen (% saturation)	**63.15**	**45.2**	**79.23**	**76.28**	**72.87**	**22.7**	97.07	80.43	101.1	80-110
Turbidity (NTU)	**41.65**	**22.13**	**14.1**	**35.10**	**21.93**	**29**	**15.27**	**29.5**	**23.6**	**0.5-10**
Total Suspended solids (mg/L)	176	42.5	8	26.5	23	20	14	19.5	2.5	No guideline
Electrical conductivity (µs/cm)	760	370	3183	4080	7623	1611	6133	5370	15643	No guideline
Oxidised Nitrogen (mg/L)	**0.09**	**0.02**	**0.03**	**0.06**	**0.13**	**0.04**	**0.05**	**0.06**	**0.2**	**0.015**
Total nitrogen (mg/L)	**5.1**	**2.4**	**2.6**	**1.95**	**0.5**	**1.4**	**0.6**	**1.13**	**0.8**	**0.3**
Total phosphorus (mg/L)	**0.58**	**0.25**	**0.42**	**0.49**	**0.38**	**0.42**	**0.27**	**0.48**	**0.15**	**0.03**
Arsenic (mg/L)	0.0015	0.0013	0.002	0.002	0.002	0.003	0.001	0.003	0.002	No guideline
Cadmium (mg/L)	0.00005	0.00013	0.00005	0.00013	0.00005	0.0004	0.00005	0.0004	0.0002	0.0007
Chromium (mg/L)	0.00125	0.0005	0.0005	0.0008	0.0005	**0.003**	0.0005	**0.003**	0.001	0.0044
Copper (mg/L)	**0.0025**	**0.0018**	**0.002**	**0.003**	0.001	**0.004**	0.001	**0.004**	0.0005	0.0013
Nickel (mg/L)	**0.0095**	0.005	0.006	**0.009**	0.005	0.007	0.005	0.007	0.005	0.007
Lead (mg/L)	0.00075	0.0005	0.0005	0.0005	0.0005	0.003	0.0005	0.003	0.0005	0.004
Zinc (mg/L)	0.009	0.008	0.01	**0.018**	**0.048**	0.0098	**0.031**	0.008	0.00025	0.015
Mercury (mg/L)	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.0001
Enterococci (CFU/100mL)*	16	**1595**	33	**2150**	**47**	**2200**	13	**1615**	**600**	<35 primary contact <230 secondary contact

^ - no dry weather sampling carried out at this site
*DECCW (2006)

Table A-4 Median Water Quality Results Hunter River (mainstream) (bolded text denotes an exceedance of guideline)

Analyte	M12RT3		M12RT3a		M12RT3b		Aquatic Ecosystem guideline (estuarine)
	Dry (n=5)	Wet (n=2)	Dry (n=1)	Wet (n=1)	Dry (n=5)	Wet (n=2)	
pH	7.69	7.88	7.78	7.9	7.29	7.99	7-8.5
Dissolved oxygen (% saturation)	**88.77**	107.2	91.37	86.8	**77.33**	83.5	80-110
Turbidity (NTU)	**37.3**	**17.03**	**16.3**	**86.8**	**66.03**	**22.35**	0.5-10
Total Suspended solids (mg/L)	32	9.25	7	2.5	24	19.25	No guideline
Electrical conductivity (µs/cm)	3990	24070	25786	22807	3356	26140	No guideline
Oxidised Nitrogen (mg/L)	**0.37**	**0.29**	**0.26**	**0.2**	**0.6**	**0.29**	0.015
Total nitrogen (mg/L)	**1**	**0.58**	**0.5**	**0.25**	**1.6**	**0.63**	0.3
Total phosphorus (mg/L)	**0.16**	**0.07**	**0.11**	0.025	**0.21**	**0.05**	0.03
Arsenic (mg/L)	0.001	0.0015	0.0005	0.002	0.0005	0.0015	No guideline
Cadmium (mg/L)	0.00005	**0.00013**	0.00005	0.0002	0.00005	**0.00023**	0.0007
Chromium (mg/L)	0.003	0.0005	0.0005	0.0005	0.0005	0.0005	0.0044
Copper (mg/L)	**0.0065**	0.00125	0.001	0.0005	0.001	0.0005	0.0013
Nickel (mg/L)	0.007	0.003	0.001	0.004	0.003	0.0025	0.007
Lead (mg/L)	0.0023	0.0005	0.0005	0.0005	0.0005	0.0005	0.004
Zinc (mg/L)	0.049	0.00025	0.0003	0.00025	0.0009	0.00025	0.015
Mercury (mg/L)	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.0001
Enterococci (CFU/100mL)*	**36**	**88**	16	**170**	**45**	**197**	<35 primary contact <230 secondary contact

* DECCW (2006)

Table A-5 Median Water Quality Results Hunter River Drains (bolded text denotes an exceedance of guideline)

Analyte	M12RT4		M12RT5		Aquatic Ecosystem guideline (estuarine)
	Dry (n=5)	Wet (n=1)	Dry	Wet (n=2)	
pH	7.14	**6.65**	7.6	7.44	7-8.5
Dissolved oxygen (% saturation)	**58.65**	**44.9**	**16.6**	**45.3**	80-110
Turbidity (NTU)	**20.82**	**63.2**	**55.63**	**72.15**	0.5-10
Total Suspended solids (mg/L)	15	38	36	44	No guideline
Electrical conductivity (µS/cm)	7235	4697	4163	1050	No guideline
Oxidised Nitrogen (mg/L)	**0.15**	**0.77**	**0.1**	**0.61**	0.015
Total nitrogen (mg/L)	**1.15**	**3.4**	**3**	**3.75**	0.3
Total phosphorus (mg/L)	**0.43**	**0.68**	**1.04**	**0.91**	0.03
Arsenic (mg/L)	0.0005	0.001	0.002	0.001	No guideline
Cadmium (mg/L)	0.00005	0.00005	0.00005	0.0005	0.0007
Chromium (mg/L)	0.0005	0.0005	0.0005	0.00125	0.0044
Copper (mg/L)	0.0008	**0.008**	**0.002**	**0.0035**	0.0013
Nickel (mg/L)	0.0045	**0.009**	0.006	**0.009**	0.007
Lead (mg/L)	0.0005	0.0005	0.0005	0.0005	0.004
Zinc (mg/L)	**0.036**	**0.023**	0.006	**0.017**	0.015
Mercury (mg/L)	0.00005	0.00005	0.00005	0.00005	0.0001
Enterococci (CFU/100mL)*	**44**	**8000**	**965**	**4600**	<35 primary contact <230 secondary contact

* DECCW (2006)

Table A-6 Median Water Quality Results Hunter River wetland (bolded text denotes an exceedance of guideline)

Analyte	M12RT8		Aquatic Ecosystem guideline (lowland river)
	Dry (n=1)	Wet (n=2)	
pH	**4.35**	No data - dry	6.5-8.5
Dissolved oxygen (% saturation)	**34.5**	-	85-110
Turbidity (NTU)	3.46	-	6-50
Total Suspended solids (mg/L)	2.5	-	No guideline
Electrical conductivity (µs/cm)	240	-	200-300
Oxidised Nitrogen (mg/L)	**1.3**	-	0.04
Total nitrogen (mg/L)	**2.4**	-	0.35
Total phosphorus (mg/L)	**0.09**	-	0.025
Arsenic (mg/L)	0.0005	-	0.013
Cadmium (mg/L)	0.0001	-	0.0002
Chromium (mg/L)	0.0005	-	0.001
Copper (mg/L)	0.0005	-	0.0014
Nickel (mg/L)	0.002	-	0.011
Lead (mg/L)	0.0005	-	0.0034
Zinc (mg/L)	**0.024**	-	0.008
Mercury (mg/L)	No data	-	0.00006
Enterococci (CFU/100mL)*	No data	-	<35 primary contact <230 secondary contact

* DECCW (2006)

Table A-7 Median Water Quality Results Drainage Canal, Old Punt Road (bolded text denotes an exceedance of guideline)

Analyte	M12RT9		Aquatic Ecosystem guideline (estuarine)
	Dry (n=5)	Wet (n=2)	
pH	7.66	7.34	7-8.5
Dissolved oxygen (% saturation)	**75.8**	86.7	80-110
Turbidity (NTU)	**36.5**	**19.58**	0.5-10
Total Suspended solids (mg/L)	20	10	No guideline
Electrical conductivity (µs/cm)	5043	13370	No guideline
Oxidised Nitrogen (mg/L)	**0.32**	**0.21**	0.015
Total nitrogen (mg/L)	**1.2**	0.25	0.3
Total phosphorus (mg/L)	**0.18**	**0.14**	0.03
Arsenic (mg/L)	0.001	0.00275	No guideline
Cadmium (mg/L)	0.00005	0.00028	0.0007
Chromium (mg/L)	0.001	0.00275	0.0044
Copper (mg/L)	**0.002**	**0.003**	0.0013
Nickel (mg/L)	0.004	0.0035	0.007
Lead (mg/L)	0.0005	0.00275	0.004
Zinc (mg/L)	0.009	0.0025	0.015
Mercury (mg/L)	0.00005	0.00005	0.00006
Enterococci (CFU/100mL)*	22	**60**	<35 primary contact <230 secondary contact

* DECCW (2006)

Table A-8 Median Water Quality Results Unnamed Coastal Wetland (bolded text denotes an exceedance of guideline)

Analyte	M12RT11		Aquatic Ecosystem guideline (estuarine)
	Dry (n=3)	Wet (n=2)	
pH	7.58	7.52	7-8.5
Dissolved oxygen (% saturation)	**50.98**	**54.9**	80-110
Turbidity (NTU)	**25.75**	**21.92**	0.5-10
Total Suspended solids (mg/L)	12.75	14.25	No guideline
Electrical conductivity (µs/cm)	10378	13060	No guideline
Oxidised Nitrogen (mg/L)	**0.03**	**0.09**	0.015
Total nitrogen (mg/L)	**1.2**	**1.7**	0.3
Total phosphorus (mg/L)	**0.07**	**0.14**	0.03
Arsenic (mg/L)	0.00075	0.00075	No guideline
Cadmium (mg/L)	0.00005	0.00023	0.0007
Chromium (mg/L)	0.0005	0.0005	0.0044
Copper (mg/L)	**0.0015**	**0.0015**	0.0013
Nickel (mg/L)	0.006	0.006	0.007
Lead (mg/L)	0.00075	0.0005	0.004
Zinc (mg/L)	**0.2025**	**0.034**	0.015
Mercury (mg/L)	0.00005	0.00005	0.0001
Enterococci (CFU/100mL)*	**39**	**2950**	<35 primary contact <230 secondary contact

* DECCW (2006) guideline

Table A-9 Median Water Quality Results Windeyers Creek (bolded text denotes an exceedance of guideline)

Analyte	M12RT6a		M12RT6		M12RT6b		M12RT7		Aquatic Ecosystem guideline (lowland river)
	Dry (n=4)	Wet (n=2)	Dry (n=1)	Wet (n=1)	Dry (n=5)	Wet (n=2)	Dry (n=1)	Wet (n=1)	
pH	**6.6**	**6.76**	**4.42**	ND - dry	**6.52**	**6.9**	**4.61**	ND - dry	6.5-8.5
Dissolved oxygen (% saturation)	**15.03**	**23.28**	**17.1**	-	**11.2**	**42.57**	**28.9**	-	85-110
Turbidity (NTU)	**13.7**	**11.58**	**39.53**	-	6.57	**18.5**	**17.06**	-	6-50
Total Suspended solids (mg/L)	22	4	40	-	15	2.5	38	-	No guideline
Electrical conductivity (µs/cm)	489	550	1047	-	133	70	351	-	200-300
Oxidised Nitrogen (mg/L)	0.01	**0.02**	0.005	-	0.01	**0.16**	**1.85**	-	0.04
Total nitrogen (mg/L)	**2.7**	**1.4**	**0.9**	-	**1.3**	**0.5**	**3.4**	-	0.35
Total phosphorus (mg/L)	**0.2**	**0.07**	**0.08**	-	**0.16**	**0.04**	0.03	-	0.025
Arsenic (mg/L)	0.0013	0.0005	0.002	-	0.0005	0.0005	0.0005	-	0.013
Cadmium (mg/L)	0.00005	0.00005	0.00005	-	0.00005	0.00005	0.0001	-	0.0002
Chromium (mg/L)	0.004	0.002	0.003	-	0.0005	0.0005	0.003	-	0.001
Copper (mg/L)	0.0008	0.0005	0.001	-	**0.003**	**0.0025**	**0.002**	-	0.0014
Nickel (mg/L)	0.002	0.001	0.007	-	0.002	0.0005	0.004	-	0.011
Lead (mg/L)	0.0005	0.0005	0.0005	-	0.0005	0.0005	0.0005	-	0.0034
Zinc (mg/L)	**0.016**	0.0115	**0.032**	-	0.0034	**0.069**	**0.082**	-	0.008
Mercury (mg/L)	0.00005	0.00005	No data	-	0.00005	0.00005	No data	-	0.00006
Enterococci (CFU/100mL)*	**62**	**627**	No data	-	**78**	**2705**	No data	-	<35 primary contact <230 secondary contact

* DECCW (2006)

Table A-10 Median Water Quality Results Grahamstown Drain (bolded text denotes an exceedance of guideline)

Analyte	M12RT10		Aquatic Ecosystem guideline (lowland river)
	Dry (n=5)	Wet (n=2)	
pH	**4.88**	**5.57**	6.5-8.5
Dissolved oxygen (% saturation)	**16.63**	**37.9**	85-110
Turbidity (NTU)	47.4	12.8	6-50
Total Suspended solids (mg/L)	10	9.25	No guideline
Electrical conductivity (µs/cm)	**553**	260	200-300
Oxidised Nitrogen (mg/L)	0.02	**0.32**	0.04
Total nitrogen (mg/L)	**0.3**	**0.75**	0.35
Total phosphorus (mg/L)	0.005	**0.04**	0.025
Arsenic (mg/L)	0.0005	0.0005	0.013
Cadmium (mg/L)	0.00005	0.00005	0.0002
Chromium (mg/L)	**0.0005**	**0.0005**	0.0001
Copper (mg/L)	0.0005	0.0005	0.0014
Nickel (mg/L)	**0.016**	0.006	0.011
Lead (mg/L)	0.0005	0.0005	0.0034
Zinc (mg/L)	**0.018**	**0.045**	0.008
Mercury (mg/L)	0.00005	0.00005	0.00006
Enterococci (CFU/100mL)*	15	**1140**	<35 primary contact <230 secondary contact

* DECCW (2006)

Appendix B. Mean concentrations from operational basins (not located upstream of main waterway locations R1-R7)

Table B-1 Mean basin outlet concentrations at permanent basins

Operational basin code	TSS (mg/L)	TP (mg/L)	TN (mg/L)
B02460L	22.2	0.05	0.393
B02520	52.5	0.109	0.705
B03340M	36.7	0.093	0.771
B03440M	32.6	0.075	0.516
B03800M	36	0.083	0.56
B07300M	53.9	0.19	1.96
B07300R	35.3	0.111	1.15
B07500L	47.2	0.103	0.721
B07800R	50.1	0.102	0.693
B08000L	51.1	0.106	0.701
B08150L	15.6	0.093	0.625
B10350R	29.3	0.056	0.289
B10400R	7.2	0.014	0.094
B11900R	22.2	0.041	0.228
B12460R	21.8	0.042	0.236
B12650R	32.4	0.072	0.529

Appendix C. Comparison of existing and predicted discharge concentrations and associated turbidity/TSS correlation plots

The DECCW (2006) water quality objectives and the ANZG (2018) guidelines for protection of aquatic ecosystems only provide a guideline limit for turbidity, not total suspended solids (TSS). The MUSIC modelling and subsequent sediment basin design and discharge concentrations are only modelled and reported for TSS. To understand if the project is having an impact on achieving WQOs it is necessary to convert the estimated TSS concentrations to turbidity. To do this, a linear regression analyses is required that involves developing a linear regression model between turbidity and total suspended solids. The monitoring program sampled for both turbidity and total suspended solids (TSS) at all monitoring locations and this data will be used for the regression analyses.

As shown in the following charts, monitoring data were plotted in Microsoft Excel from which a linear regression was derived for conversion of all recorded TSS values to turbidity values. For the purposes of this assessment, the dependent Y variable is turbidity and the independent variable X is total suspended solids. The strength of the relationship can be assessed based on the correlation of determination (R^2), whereby an R^2 value close to 1 indicates that there is strong correlation between TSS and turbidity. This linear regression model produced a correlation equation which was used to convert modelled TSS discharge concentrations to turbidity. It should be noted that a linear regression model was produced for each of the R1 to R7 locations, the results of which are presented below. It should be noted that the number of data points used in the correlation is limited to the number of dry weather sampling events (up to five in total) which results in a high level of uncertainty.

Table C-1 MUSIC modelling concentrations from the project at R1 and existing water quality for Glenrowan Creek (M12RT1)

Indicator	Existing (median) water quality at M12RT1		With project estimate (treated)	ANZG (2018)
	Dry	Wet	Mean discharge concentration at R1	
TSS (mg/L)	17	12	50.5	No guideline
Turbidity (NTU)	17.2	17.2	26.8^	6-50
TN (mg/L)	1.6	3.35	0.69	0.35
TP (mg/L)	0.13	0.12	0.105	0.025

^ correlated value ($y = 0.5964x - 3.3528, R^2 = 0.9703$). See below:

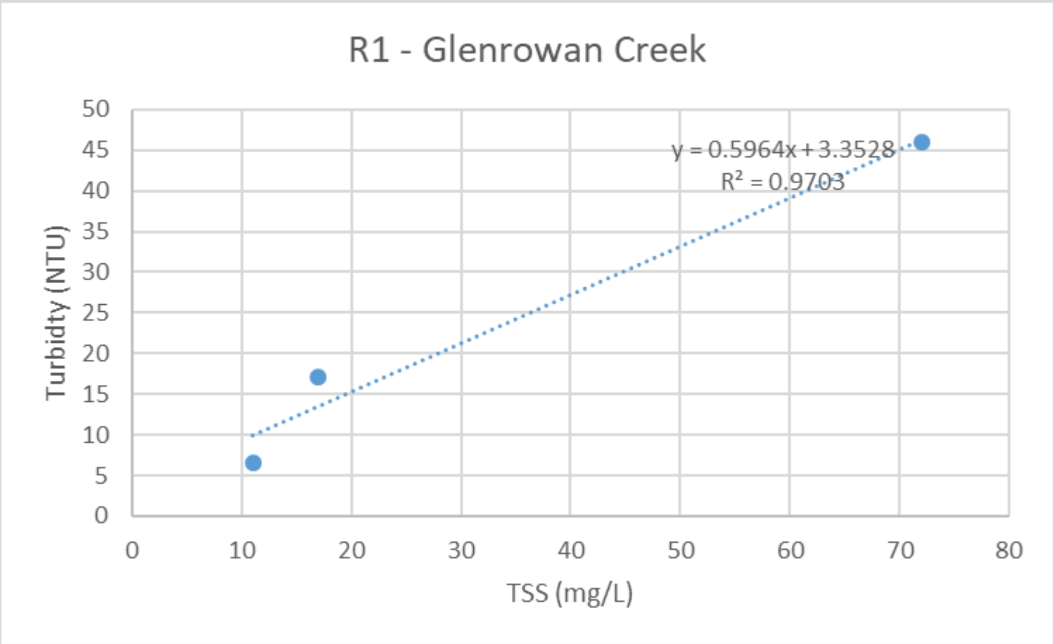


Figure C-1: Linear relationship between turbidity and TSS for Glenrowan Creek

Table C-2 MUSIC modelling concentrations from the project at R2 and existing water quality for Purgatory Creek

Indicator	Existing (median) water quality for Purgatory Creek								With project estimate (treated)	ANZG (2018)
	M12RT2 (Dry)	M12RT2 (Wet)	M12RT2b (Dry)	M12RT2b (Wet)	M12RT2a (Dry)	M12RT2a (Wet)	M12RT2c (Dry)	M12RT2c (Wet)	Mean discharge concentration at R2	
TSS (mg/L)	176	42.5	8	26.5	23	20	14	19.5	33.5	No guideline
Turbidity (NTU)	41.65	22.13	14.1	35.1	21.93	29	15.27	29.5	62.67^	0.5-10
TN (mg/L)	5.1	2.4	2.6	1.95	0.5	1.4	0.6	1.13	0.47	0.3
TP (mg/L)	0.58	0.25	0.42	0.49	0.38	0.42	0.27	0.48	0.07	0.03

^ correlated value ($y = 1.7808x + 3.0031, R^2 = 0.9464$). See below:

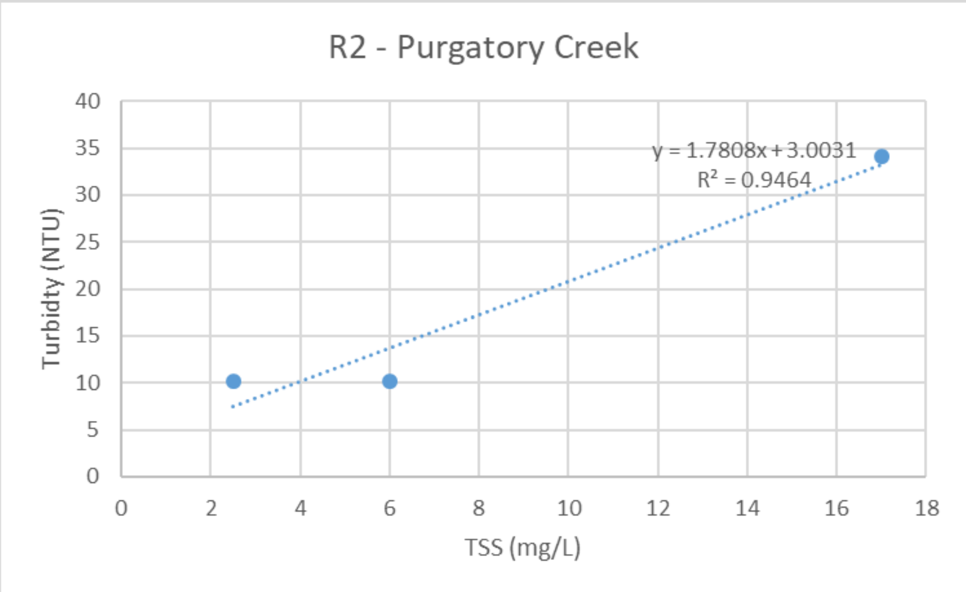


Figure C-2 Linear relationship between turbidity and TSS for sites on Purgatory Creek

Table C-3 MUSIC modelling concentrations from the project at R3 and existing water quality for Hunter River Drains

Indicator	Existing (median) water quality for Hunter River drains				With project estimate (treated)	ANZG (2018)
	M12RT4 (Dry)	M12RT4 (Wet)	M12RT5 (Dry)	M12RT5 (Wet)	Mean discharge concentration at R3	
TSS (mg/L)	15	38	36	44	26	No guideline
Turbidity (NTU)	20.82	63.2	55.63	72.15	38.13^	0.5-10
TN (mg/L)	1.15	3.4	3	3.75	0.28	0.3
TP (mg/L)	0.43	0.68	1.04	0.91	0.05	0.03

^correlated value ($y = 1.8355x - 9.5978, R^2 = 0.9996$). See below:

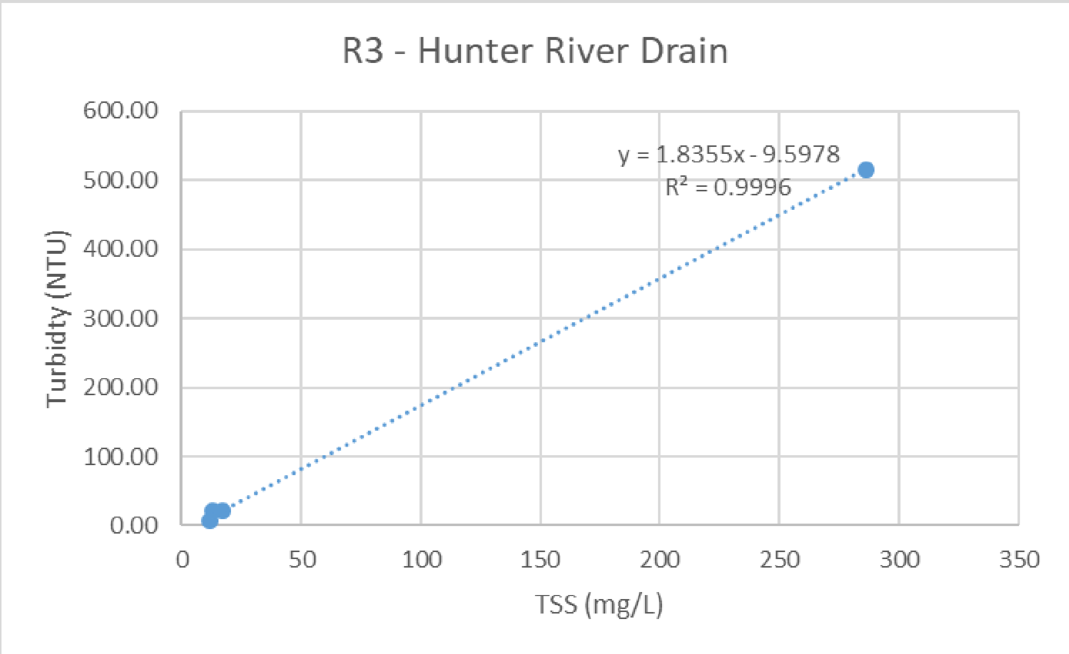


Figure C-3 Linear relationship between turbidity and TSS for Hunter River Drain

Table C-4 MUSIC modelling concentrations from the project at R4 and existing water quality for Windeyers Creek

Indicator	Existing median water quality for Windeyers Creek						With project estimate (treated)	ANZG (2018)
	M12RT 6a (Dry)	M12RT 6a (Wet)	M12RT6 (Dry)	M12RT6 (Wet)	M12RT 6b (Dry)	M12RT 6b (Wet)	Mean discharge concentration at R4	
TSS (mg/L)	22	4	40	ND	15	2.5	29.8	No guideline
Turbidity (NTU)	13.7	11.58	39.53	ND	6.57	18.5	9.32^	6-50
TN (mg/L)	2.7	1.4	0.9	ND	1.3	0.5	0.51	0.35
TP (mg/L)	0.2	0.07	0.08	ND	0.16	0.04	0.068	0.025

^ correlated value ($y = 0.135x + 5.2968, R^2 = 0.6425$). See below.

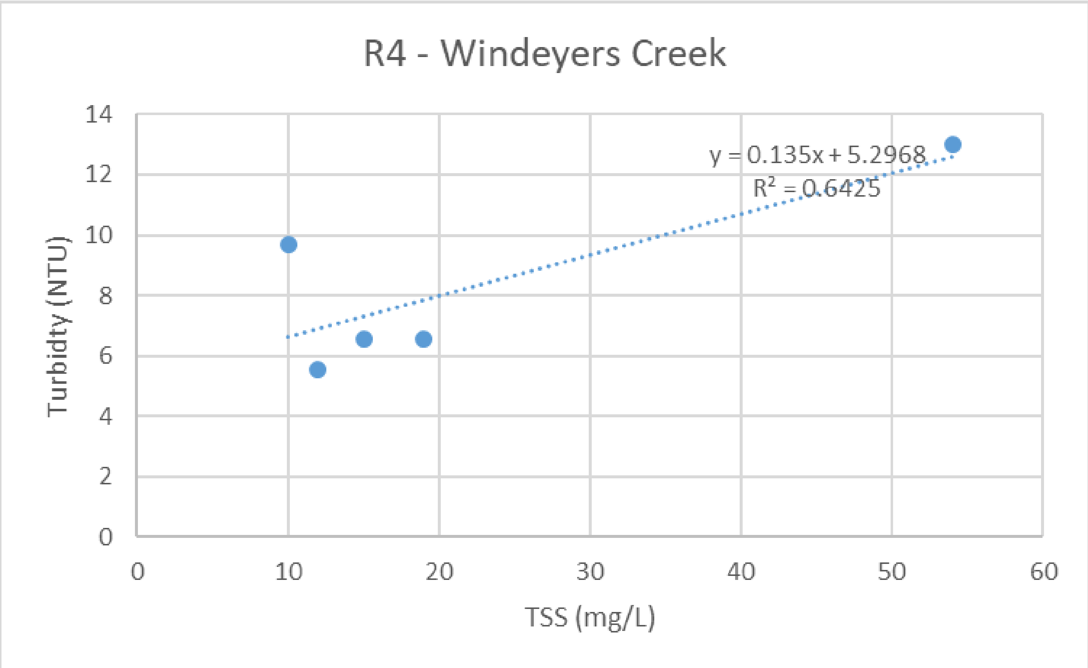


Figure C-4 Linear relationship between turbidity and TSS for sites on Windeyers Creek

Table C-5 MUSIC modelling concentrations from the project at R5 and existing water quality for Viney Creek (M12RT12)

Indicator	Existing (median) water quality at M12RT12		With project estimate (treated)	ANZG (2018)
	Dry	Wet	Mean discharge concentration at R5	
TSS (mg/L)	14	28	38.2	No guideline
Turbidity (NTU)	31.58	63.68	55.25^	6-50
TN (mg/L)	0.9	0.95	0.59	0.35
TP (mg/L)	0.1	0.13	0.083	0.025

^ correlated value ($y = 0.9558x + 18.734, R^2 = 0.9961$). See below:

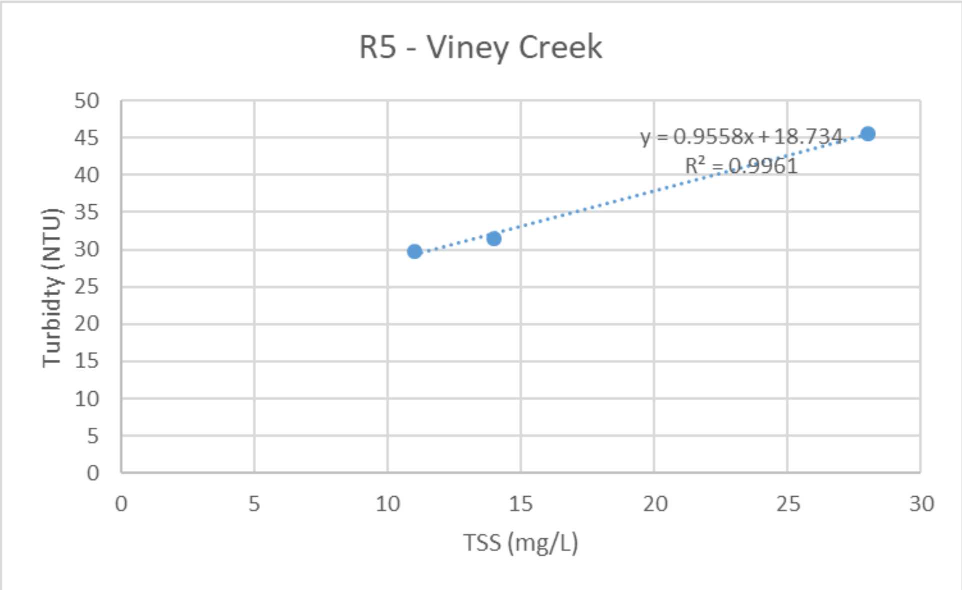


Figure C-5 Linear relationship between turbidity and TSS for Viney Creek

Table C-6 MUSIC modelling concentrations from the project at R6 and existing water quality for Hunter River (mainstream)

Indicator	Existing (median) water quality for Hunter River (mainstream)				With project estimate (treated)	ANZG (2018)
	M12RT3 (Dry)	M12RT3 (Wet)	M12RT3b (Dry)	M12RT3b (Wet)	Mean discharge concentration at R6	
TSS (mg/L)	32	9.25	24	19.25	30.5	No guideline
Turbidity (NTU)	37.3	17.03	66.03	22.35	22.96^	0.5-10
TN (mg/L)	1	0.58	1.6	0.63	1.34	0.3
TP (mg/L)	0.16	0.07	0.21	0.05	0.121	0.03

^ correlated value ($y = 1.3049x - 16.844, R^2 = 0.8898$). See below:

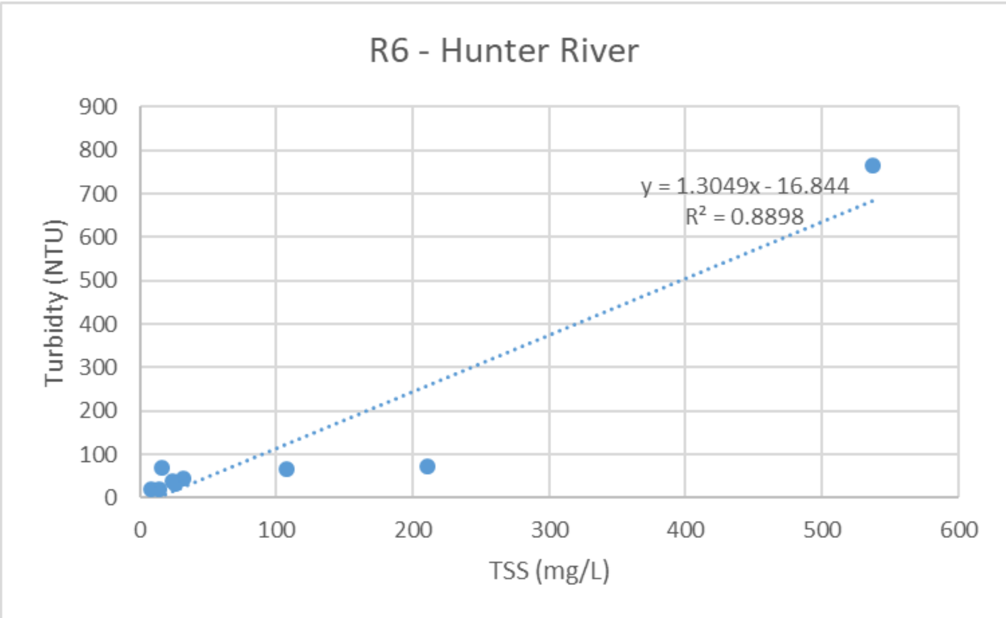


Figure C-6 Linear relationship between turbidity and TSS for sites on Hunter River

Table C-7 MUSIC modelling concentrations from the project at R7 and existing water quality for an unnamed coastal wetland

Indicator	Existing (median) water quality at M12RT11a		With project estimate (treated)	ANZG (2018)
	Dry	Wet	Mean discharge concentration at R7	
TSS (mg/L)	12.75	14.25	18.7	No guideline
Turbidity (NTU)	25.75	21.92	29.34^	0.5-10
TN (mg/L)	1.2	1.7	0.67	0.3
TP (mg/L)	0.07	0.14	0.093	0.03

^ correlated value ($y = 0.6029x + 18.063, R^2 = 1$)

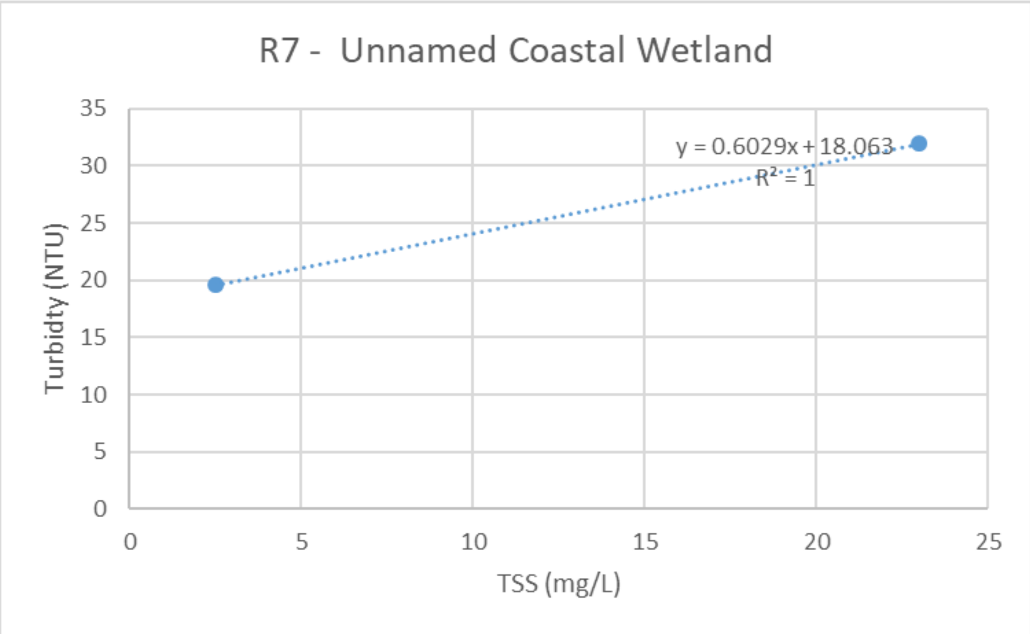


Figure C-7 Linear relationship between turbidity and TSS for Unnamed Coastal Wetland

Appendix D. Dilution assessment

A dilution assessment was carried out in order to understand the potential impact that discharges from the project could have on the Hunter River, and subsequently the Hunter Estuary Wetlands Ramsar site at Kooragang Nature Reserve (located about 5.12 kilometres downstream of the project construction footprint boundary).

A water quality dilution model was used to simulate concentrations, loads and dilution requirements associated with discharges directly into the Hunter River from sediment basins during construction and water quality basins during operation of the project. The model was generated for total suspended solids, total nitrogen and total phosphorus as these indicators are comparable to the MUSIC modelling results.

The model is a spreadsheet model based on the dilution equation:

$$c1v1 + c2v2 = c3v3$$

Where: *c* is concentration; *v* is volume and 1, 2 and 3 refer to sources of water (where 1 is volume of water in the Hunter River upstream of discharge, 2 is volume of water discharged from the basin and 3 is combined volume of water downstream (i.e. Hunter River volume (v1) plus basin volume (v2)). For calculation of nutrients, a decay function was nested within the model after the initial mixing of basin discharge with Hunter River flows to simulate biological update of nutrients which was approximated using first order kinetics. The effects of density differences due to salinity, stratification and tidal influences have not been considered within the model.

Dilution requirements for discharge from the basins to meet a water quality objective (WQO) and the available dilution in the Hunter River were calculated using a number of equations (detailed below). The adopted WQOs were in accordance with ANZG (2018) protection of estuarine aquatic ecosystems and were:

- Turbidity 0.5-10 NTU with the upper limit adopted based on ambient water quality of the Hunter River
- TN 0.3 mg/L
- TP 0.03 mg/L.

Equation 1 – dilution requirement for discharge to meet water quality objectives*

$$Sreq = \frac{Cdis - Cwqo}{Cwqo - Camb}$$

Where Sreq = dilution requirement

Cdis = Discharge concentration (or the concentration of combined disgorge from multiple basins)

Cwqo = Water Quality Objective

Camb = ambient median concentration in the Hunter River (wet weather for construction and dry weather for operation)

*if Camb is equal to or greater than Cwqo, Sreq is calculated as Cdis ÷Cwqo

Equation 2 – Available dilution in the receiving environment

$$Savail = \frac{Qdis + Qamb}{Qdis}$$

Where Savail = dilution available in the ambient receiving environment

Qdis = Combined daily flow from the basins

Qamb = flow in the Hunter River upstream of the discharge point.

Inputs to the model included:

Temporary basins (B0700L, B07150 and B07300R) which discharge directly into the Hunter River:

- Outlet flow rates estimated using indicative daily runoff based on a daily rainfall estimation, yield (assumed runoff coefficient) and construction catchment area for each basin (daily time step, period of record 01/07/1998 – 31/05/2010)
- TSS concentrations of 50 mg/L for controlled flows or 150 mg/L/ 250 mg/L/ 500 mg/L for overflow discharges. A range of TSS concentrations was used for overflow discharges as a sensitivity test of potential impact to the Hunter River as the concentration of TSS in overflow discharges is not known and will likely vary depending on the rainfall event. Concentrations were altered between 'controlled flows' and 'overflow discharges' based on rainfall of greater than 38.9 millimetres over five days.

Permanent basins ((B05700L, B06100L, B07150L, B07300R, B07300M) which discharge directly into the Hunter River:

- Outflow rates estimated via MUSIC modelling (daily time step, period of record 01/07/1998 – 31/05/2010)
- TSS, TN and TP concentrations based upon MUSIC modelling results.

Hunter River (upstream of work area):

- Mean Daily Flows from gauges 210064 (Hunter River at Greta) and 210010 (Williams River at Glen Martin) were retrieved from Water NSW (realtimetimedata.waternsw.com.au) and combined for the period of record 01/07/1998 – 31/05/2010. The complete flow series used regardless of the quality rating of the data – 23% of data from gauge 210064 and 15% of data from gauge 210010 were rated as estimates or unknown reliability
- TSS, TN and TP concentrations were median values based upon monitoring data collected at three Hunter River sites (M12RT3, M12RT3a and M12RT3b) sites. Concentration estimates were used for dry conditions as basins would typically be released after a rainfall event.

TSS concentrations were converted to turbidity estimates using an empirically derived formula to allow comparison with WQOs.

Results of the dilution assessment for construction and operation are provided below:

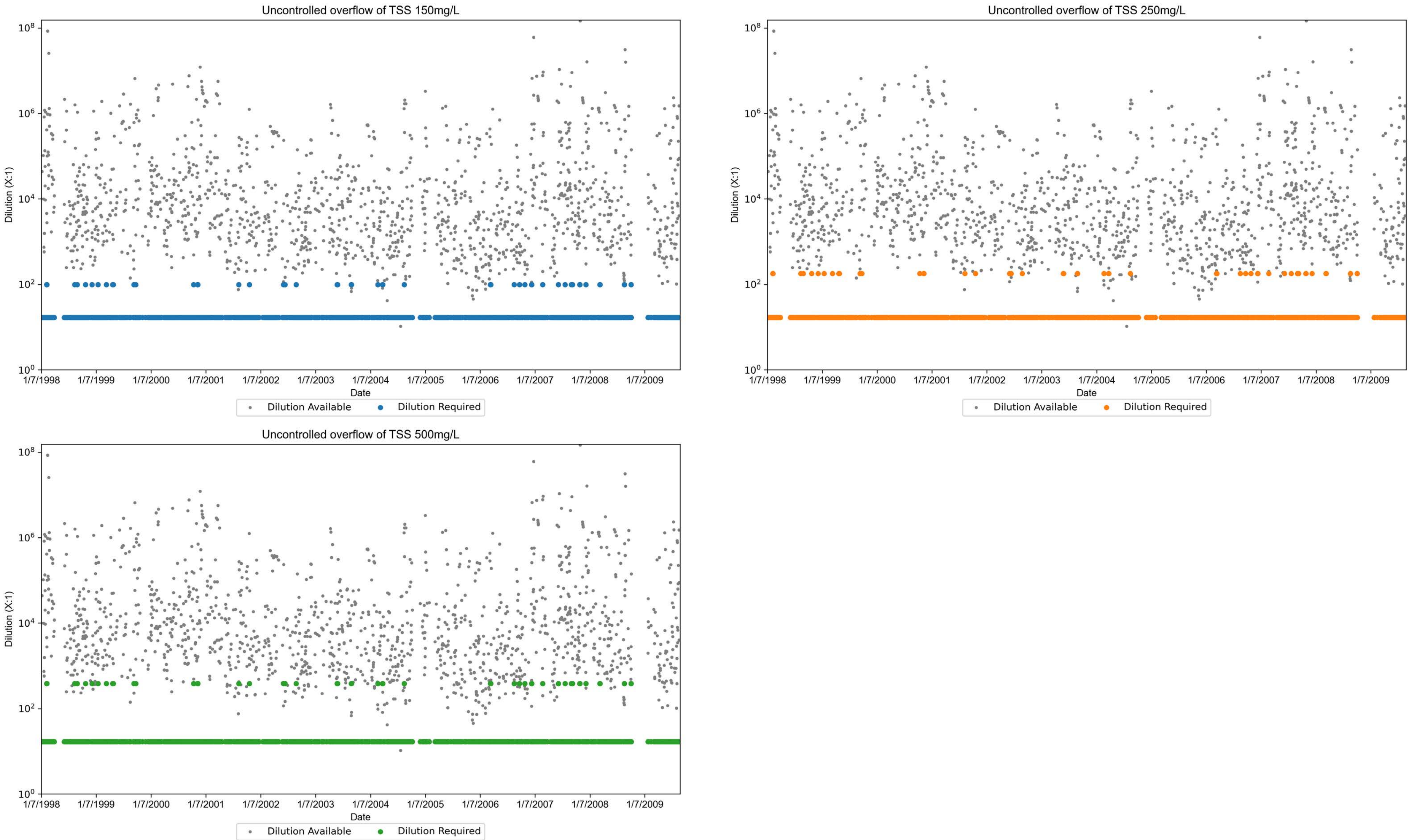


Figure D-1 Construction phase – Dilution required for overflow TSS discharges to meet WQO

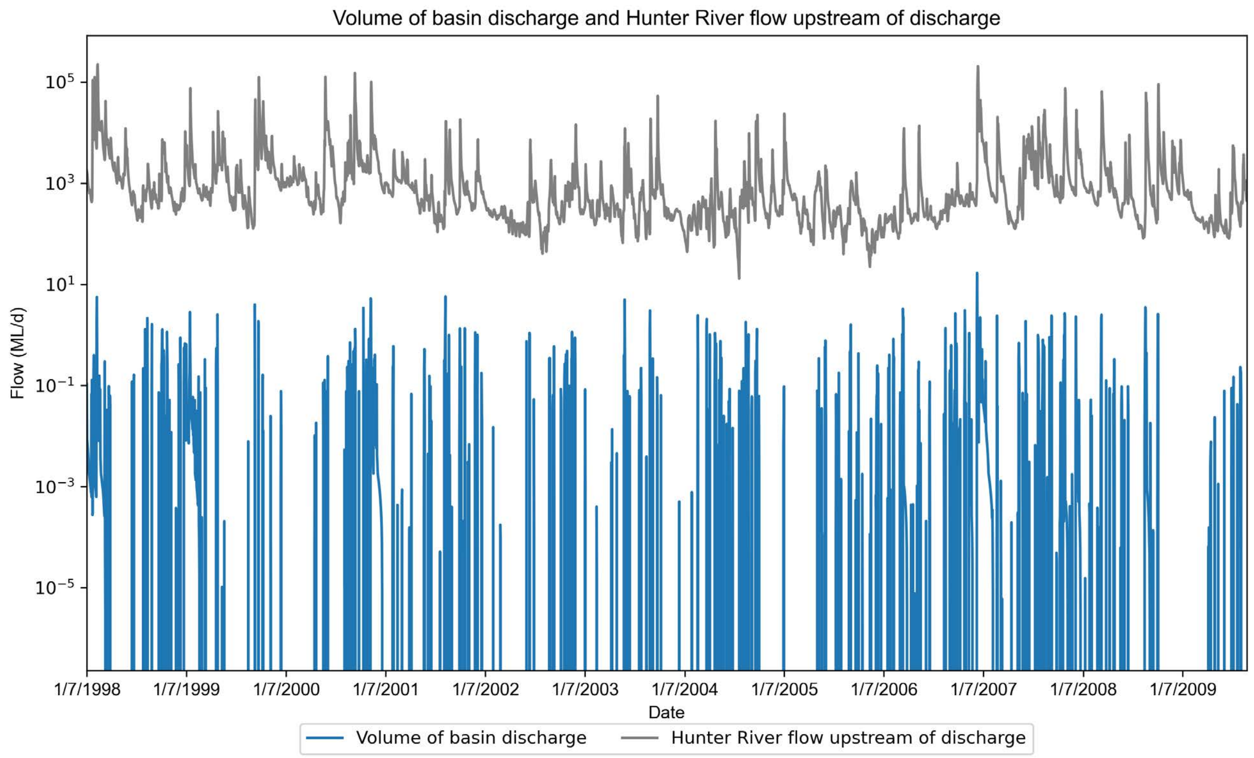


Figure D-2 Operational phase – Combined basin discharge volume compared to flow in Hunter River

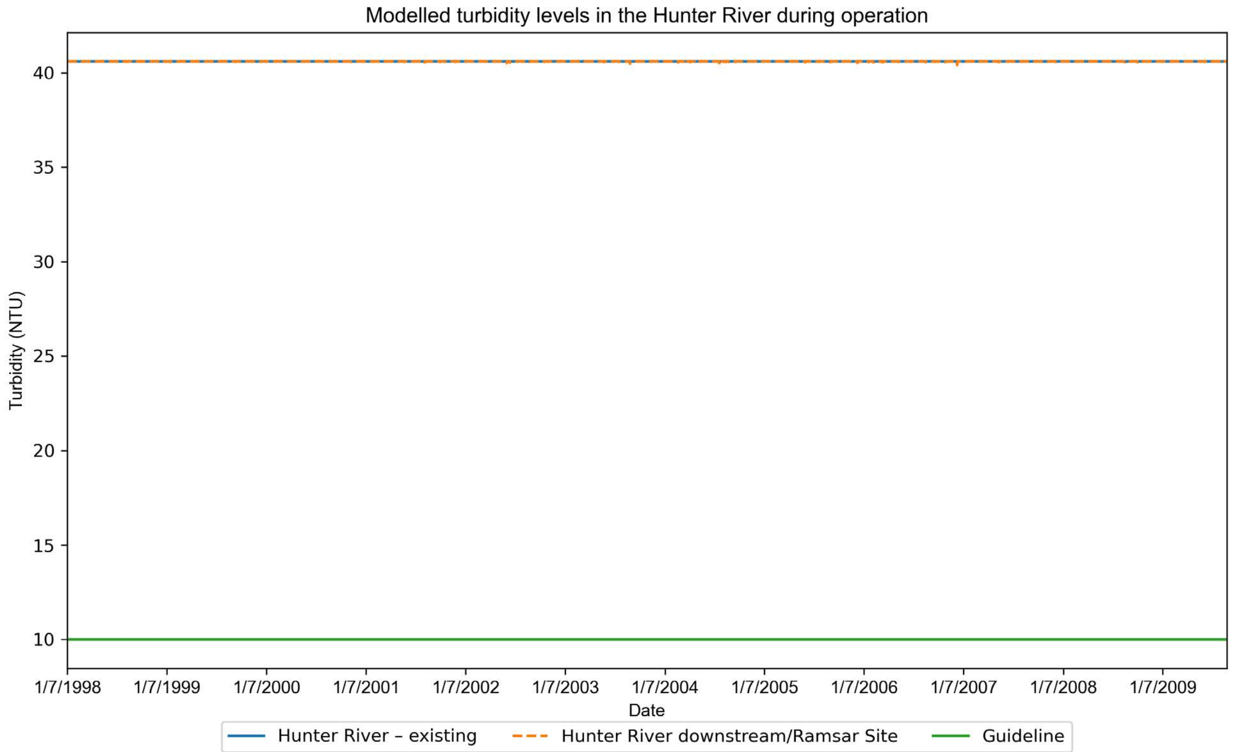


Figure D-3 Operational phase – Existing turbidity in the Hunter River and modelled turbidity at the Hunter Estuary Wetland Ramsar site at Kooragang Nature Reserve

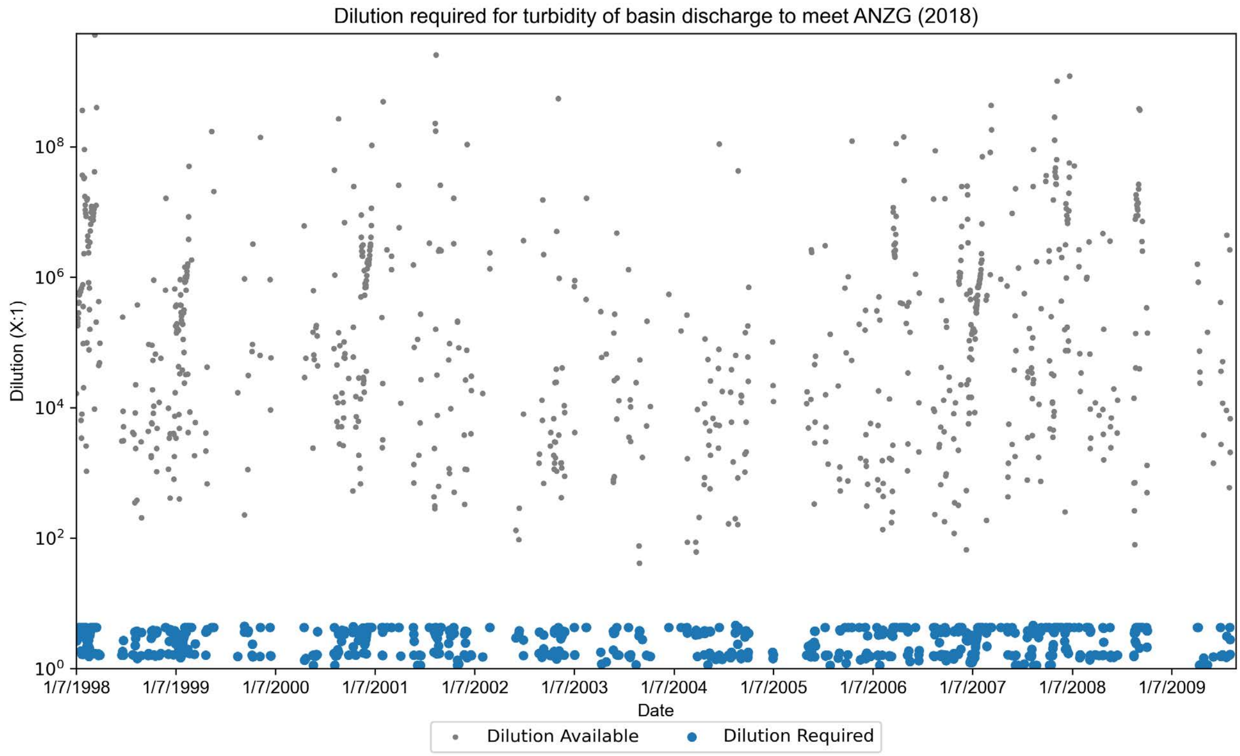


Figure D-4 Operational phase – Required dilution for Turbidity in combined permanent basins to meet ANZG (2018)

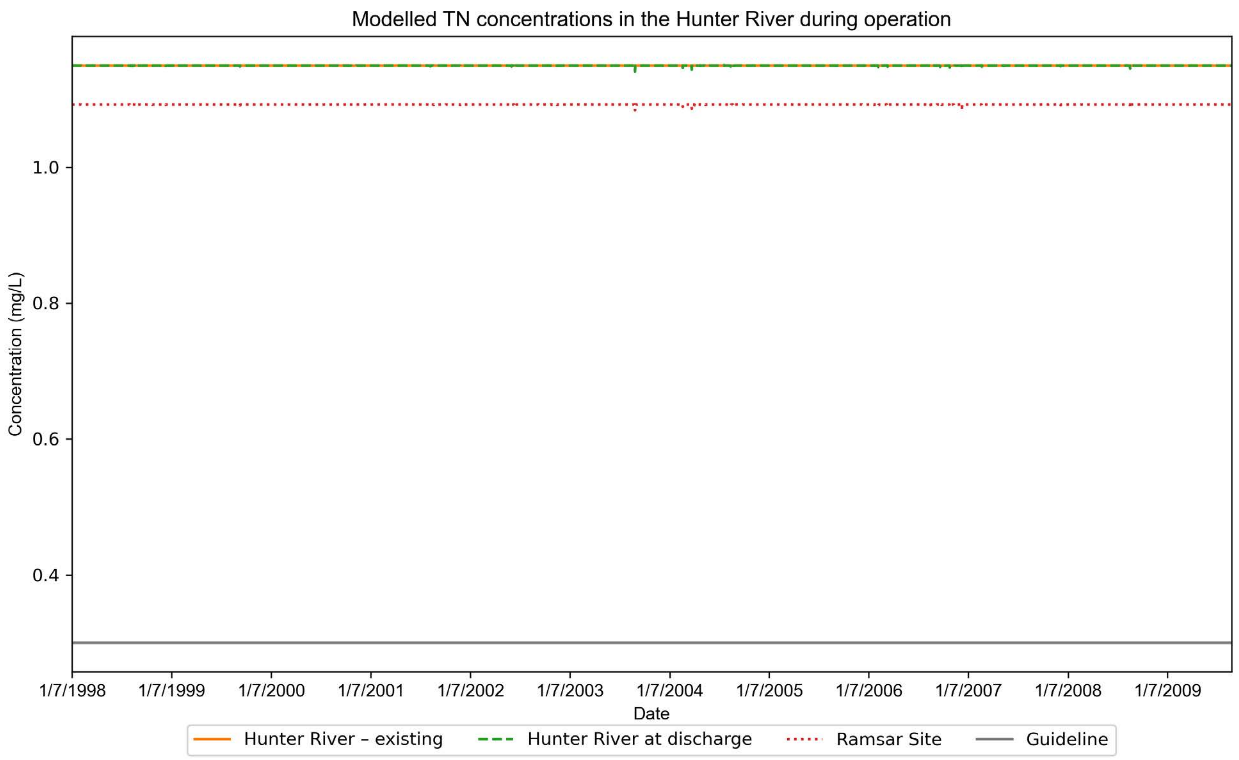


Figure D-5 Operational phase – Existing TN in the Hunter River and modelled TN at the discharge and Hunter Estuary Wetland Ramsar site at Kooragang Nature Reserve

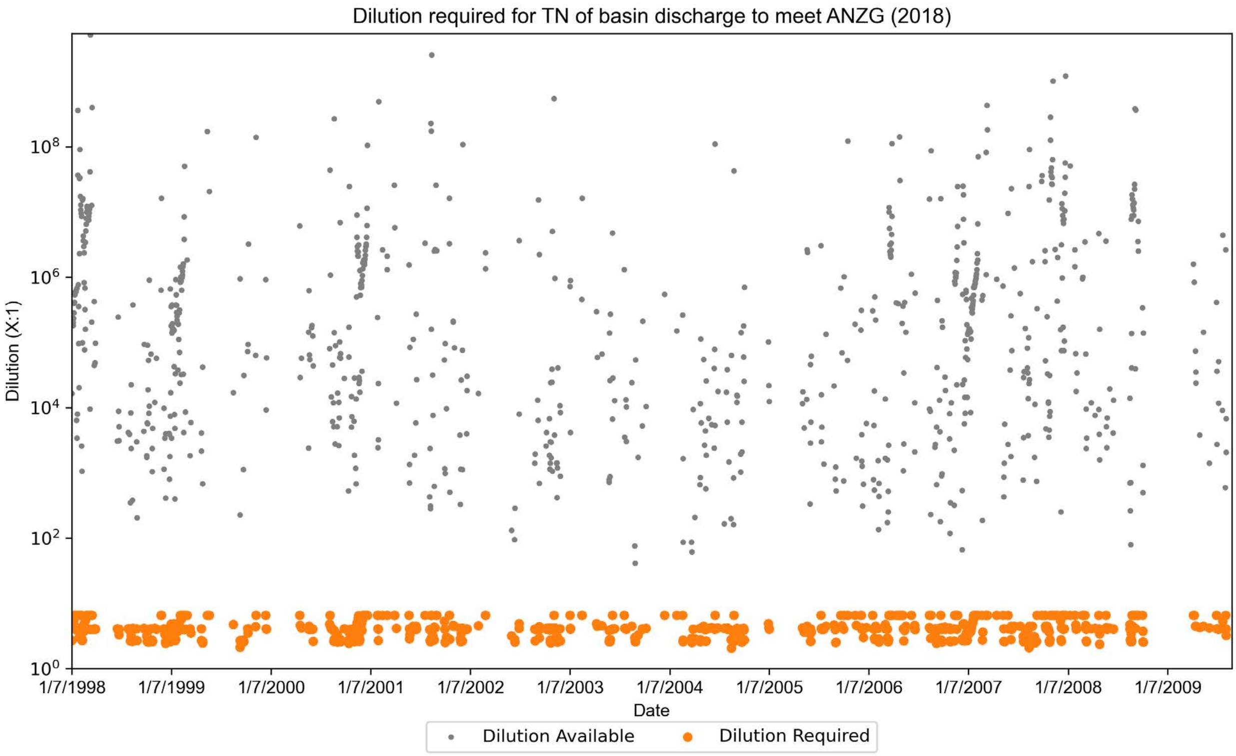


Figure D-6 Operational phase – Required dilution for TN concentrations in combined permanent basins to meet ANZG (2018)

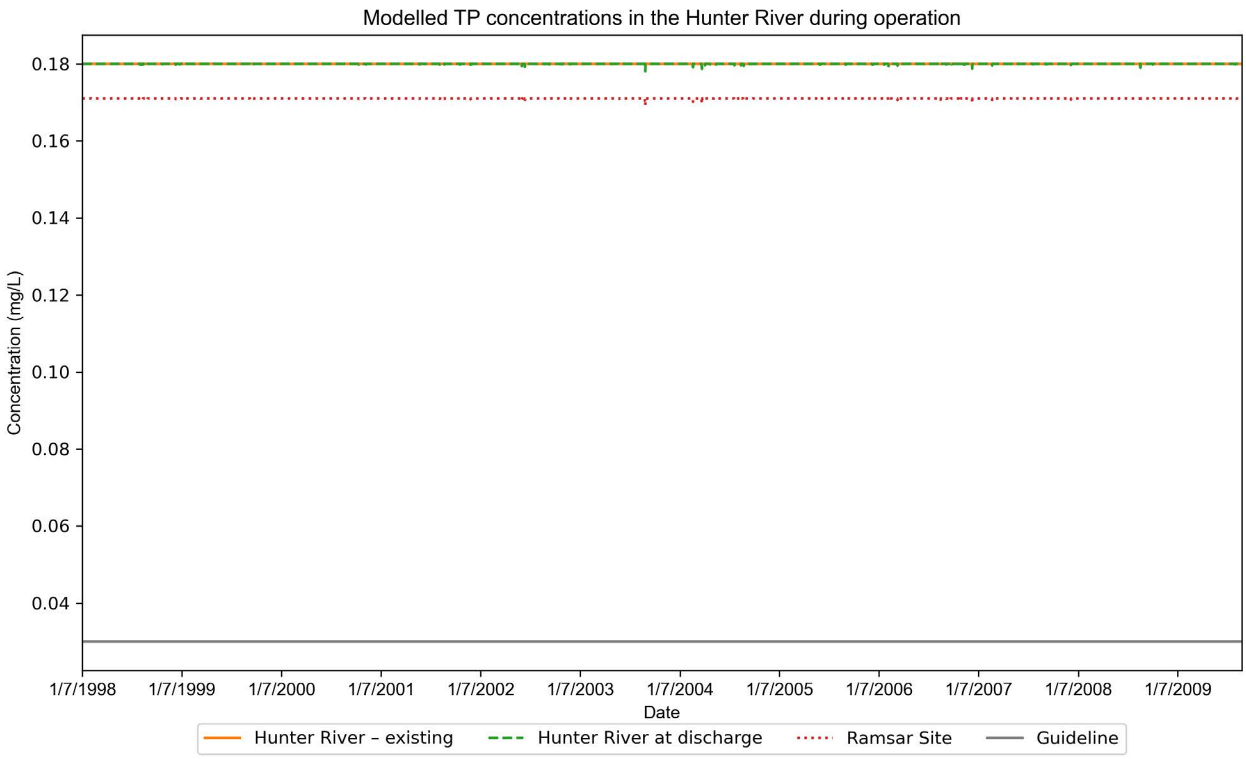


Figure D-7 Operational phase – Existing TP in the Hunter River and modelled TP at the discharge and Hunter Estuary Wetland Ramsar site at Kooragang Nature Reserve

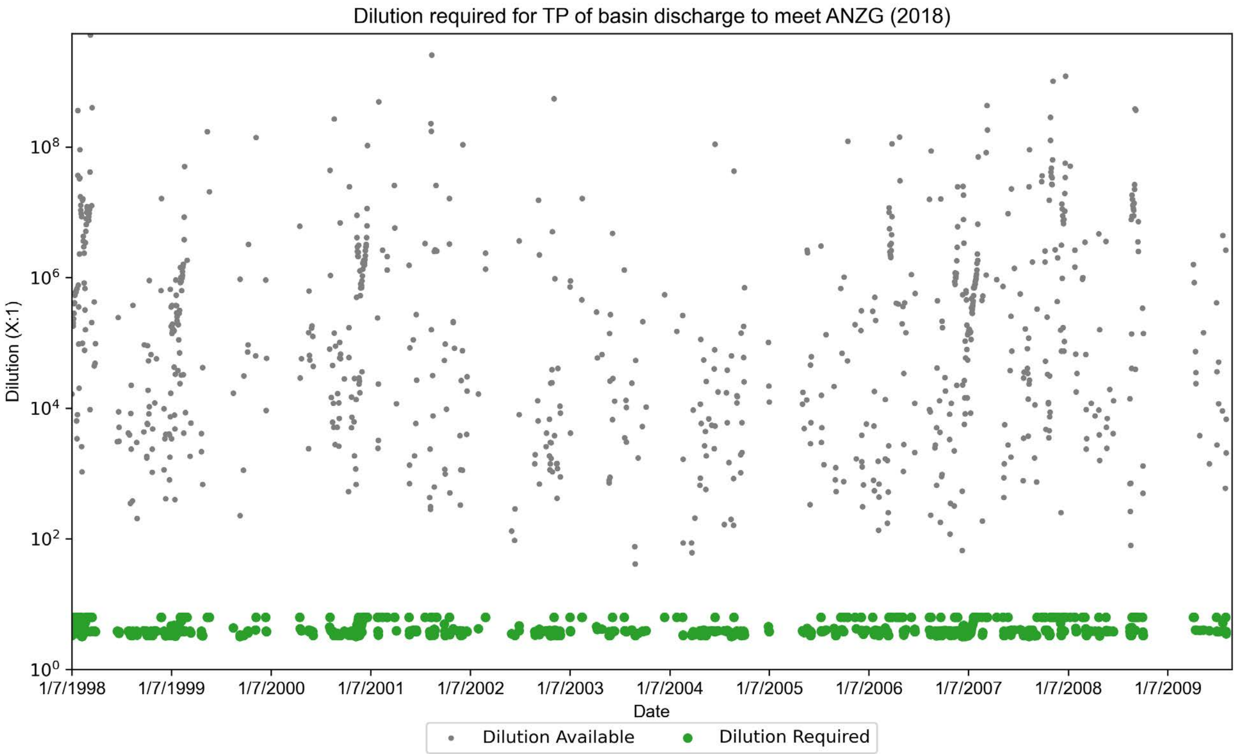


Figure D-8 Operational phase – Required dilution for TP concentrations in combined permanent basins to meet ANZG (2018)

Appendix E Comparison of operational water quality with existing water quality and water quality objectives

MUSIC modelling was carried out to understand the potential change in water quality from the operation of the project. The modelling considered the proposed water quality controls for the project to gain an appreciation of how effective these would be in meeting the WQOs and/or background concentrations. It should be noted the MUSIC modelling produces mean concentrations during a rainfall event. This water quality would typically be poorer than the water quality of the receiving waterway which has predominantly been sampled during dry weather. To gain an appreciation of how discharge from basins would compare to downstream water quality following rainfall, two wet weather sampling events were carried out. A comparison between recorded and predicted modelled concentrations from the project was carried out to provide an understanding of any potential impacts.

The recorded concentrations were measured at seven locations which are provided in **Figure 4-6**. At each of these seven locations, the project's proposed basins that are located upstream of these monitoring locations were identified. The modelled concentrations at the downstream end of each basin which represent the treated runoff from the road pavement area and batters were derived from the MUSIC model. The mean concentration from these basins at each of the seven monitoring locations was then compared against the recorded concentration values.

The nominated seven locations receive runoff from 23 of the 39 permanent basins. The concentrations from all the proposed basins are generally similar as they have all been sized to reduce annual average pollutant loads by the same percentage. This means that the compliance of the modelled concentrations at the seven locations is representative of the project. The results of the modelled concentrations from the remaining basins are provided in **Appendix B**.

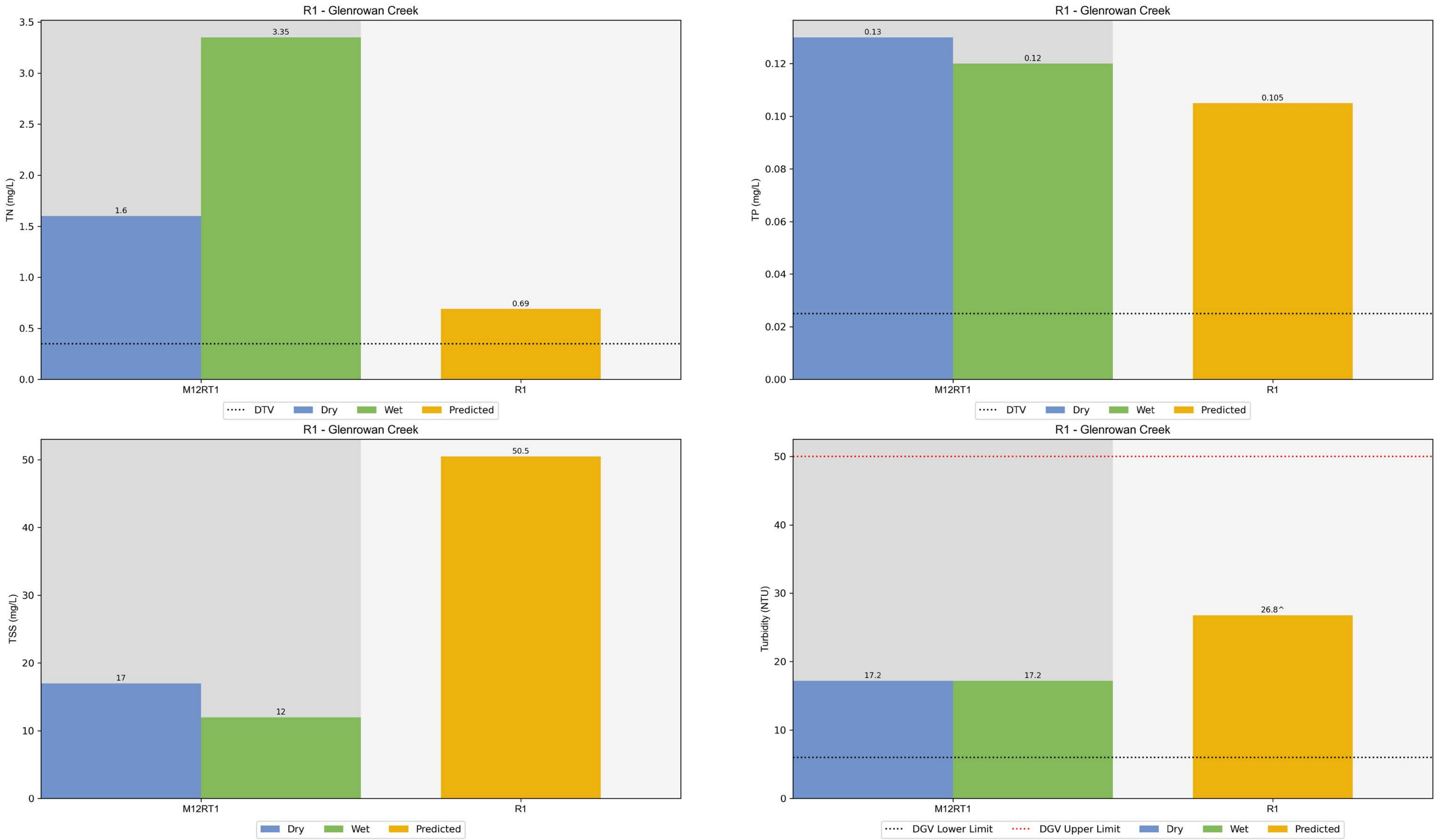
As ANZG (2018) do not recommend a guideline limit for TSS, laboratory analysed TSS and turbidity values were collated to determine a correlation between with two indicators. This correlation is presented in **Appendix C** and has resulted in a conversion equation specific to each location that has been applied to the modelled TSS value to convert it to a turbidity reading. It should be noted that the number of data points used in the correlation is limited to the number of dry weather sampling events (up to five in total).

R1

MUSIC modelling at R1 has predicted concentrations of TSS, turbidity, TN and TP that would be discharged into Glenrowan Creek (M12RT1) from one permanent water quality basin (refer to **Appendix C**). The basin is located upstream of R1.

Concentrations of total suspended solids generated from the operation of the project are estimated to be 50.5 mg/L which is higher than concentrations currently recorded in Glenrowan Creek during both dry and wet weather. The correlated Turbidity for the operation of the project is 26.8 NTU which is also higher than background concentrations. While the project would contribute higher turbidity, the estimated concentration remains within the recommended ANZG (2018) guideline limit of 6-50 NTU.

Concentrations of TN and TP generated by the operation of the project and subsequently discharged into Glenrowan Creek are expected to be lower than the median concentrations for TN and TP recorded during both dry and wet weather. Estimated concentrations of TN would be reduced to less than half the current concentrations recorded during dry weather and more than one quarter the concentrations recorded following rainfall. Estimated TP concentrations would be slightly less than existing water quality during dry and wet weather. Despite the low concentrations of TN and TP discharged from the project, concentrations do not meet the ANZG (2018) recommended limits for protection of aquatic ecosystems. These guidelines are targets to achieve, and by discharging better water quality than is currently within Glenrowan Creek, the project is working towards achieving the WQOs. Modelling results together with existing water quality for the Glenrowan Creek are displayed in Figure E-1 and detailed in **Appendix C**.



^ correlated value ($y = 0.667x - 2.2549, R^2 = 0.9949$) (refer to **Appendix C**)

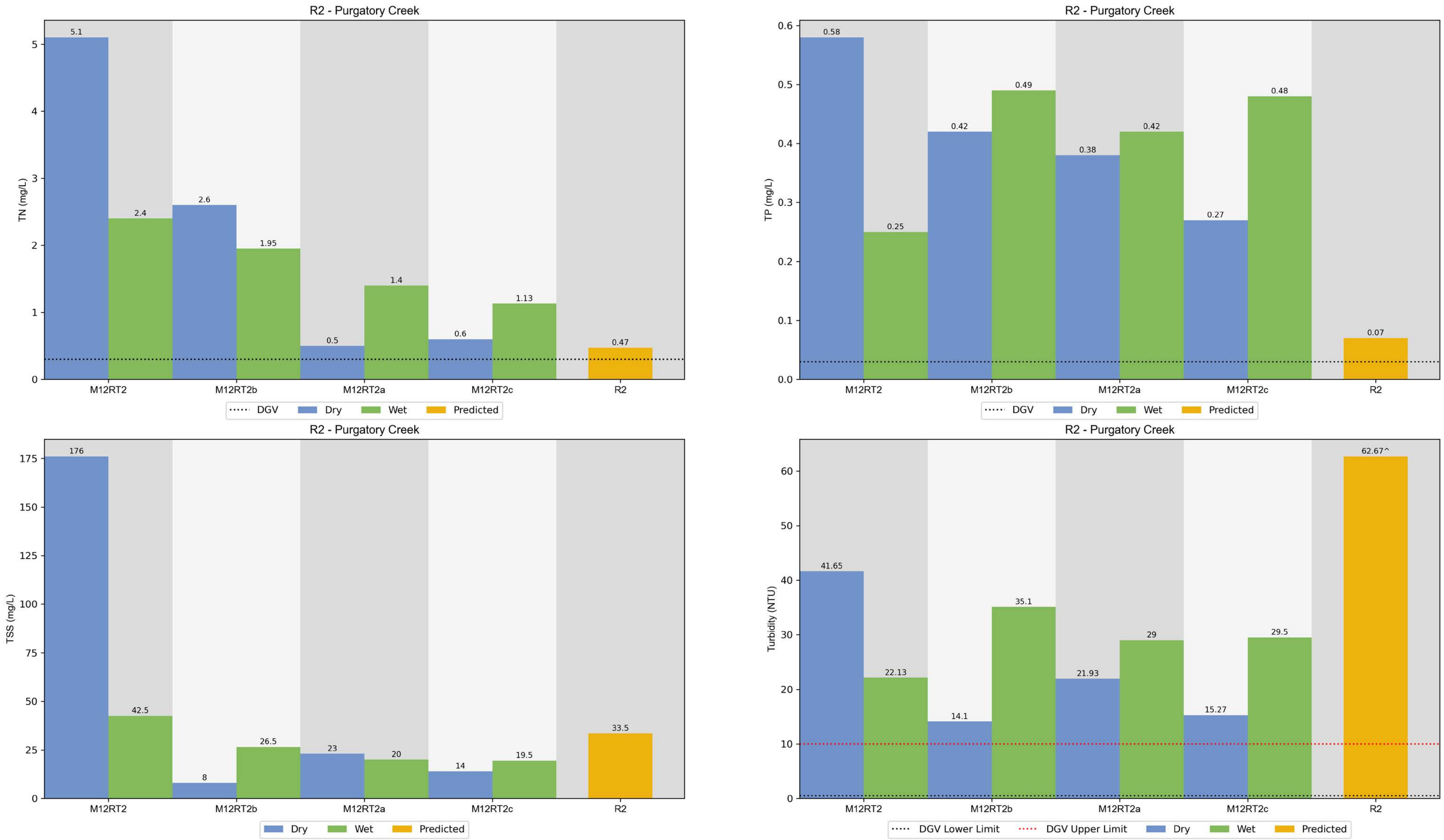
Figure E-1 MUSIC modelling concentrations from the project at R1 and existing water quality for Glenrowan Creek

R2

R2 is located on Purgatory Creek downstream of the monitoring locations M12RT2, M12RT2b, M12RT2a and M12RT2c. MUSIC modelling has predicted discharge concentrations at this location from two permanent water quality basins located upstream. Modelling results together with existing water quality for Purgatory Creek are displayed in Figure E-2 and detailed in **Appendix C**.

Concentrations of total suspended solids generated from the operation of the project and subsequently discharged into Purgatory Creek are estimated to be 33.5 mg/L which is higher than concentrations generally recorded during dry and wet weather in Purgatory Creek with the exception of the most upstream site (M12RT2). The correlated turbidity value of 62.67 NTU is generally double the turbidity recorded during wet weather in Purgatory Creek and up to four times greater than dry weather turbidity. The estimated concentration also exceeds the recommended upper limit of 10 NTU for protection of estuarine aquatic ecosystems.

Despite the likelihood of higher than existing TSS concentrations entering Purgatory Creek from the project, associated nutrient concentrations are greatly reduced compared to background levels. MUSIC modelled TN concentrations of 0.47 mg/L, while about 1.5 times the recommended guideline limit are up to ten times less than median dry weather concentrations and up to five times less than wet weather concentrations recorded throughout Purgatory Creek. Similarly, MUSIC modelled TP concentrations of 0.07 mg/L also exceed the recommended guideline limit, however, are up to eight and seven times less than median dry and wet weather concentrations respectively. Therefore, the lower TN and TP concentrations generated from the project work towards achieving the WQOs.



^ correlated value $y = 1.8647x + 1.0104, R^2 = 0.8571$) (refer to **Appendix C**)

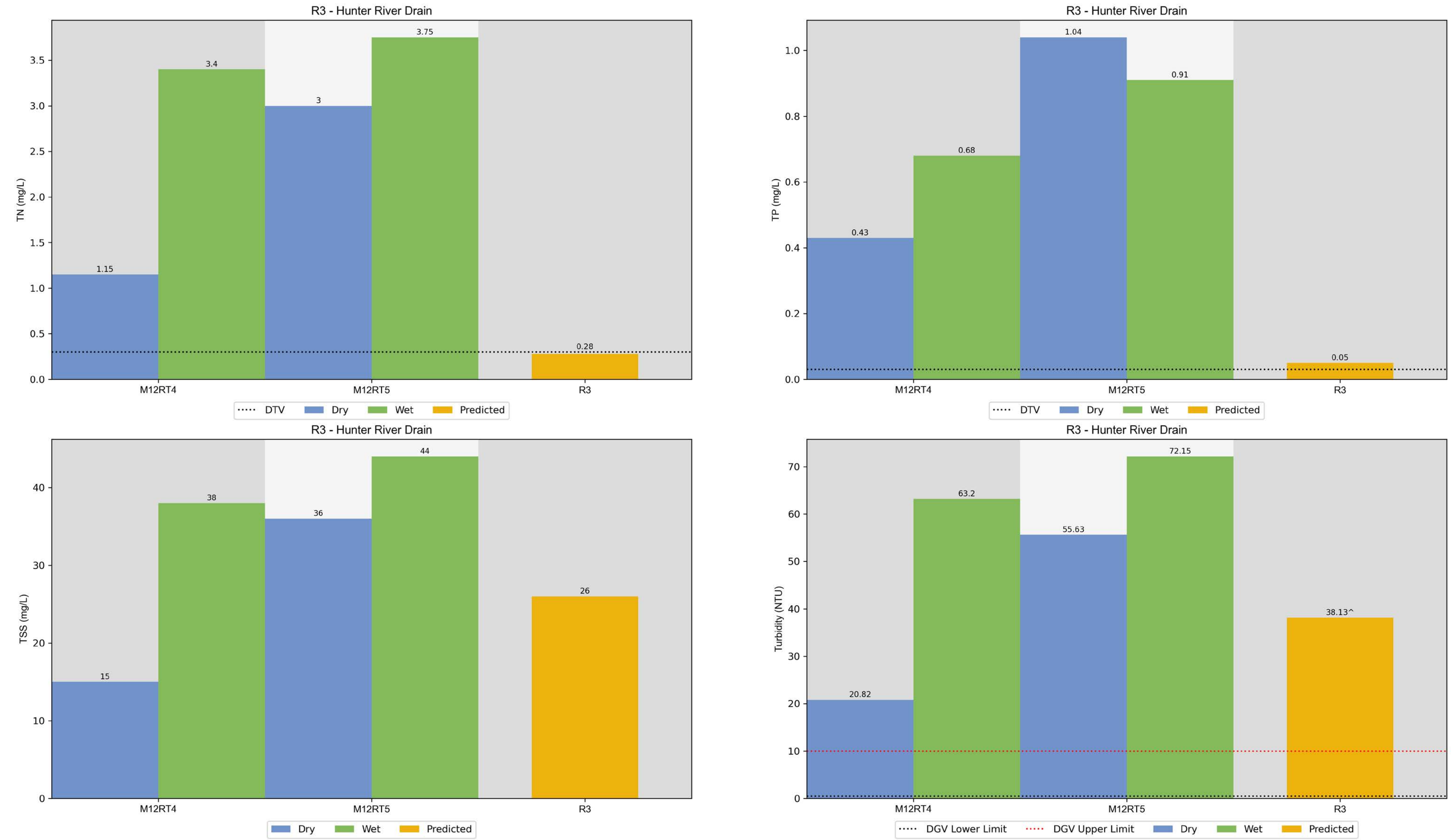
Figure E-2 MUSIC modelling concentrations from the project at R2 and existing water quality for Purgatory Creek

R3

R3 is located at the downstream end of the Hunter River drain before it discharges into the Hunter River. The monitoring sites M12RT4 and M12RT5 are located upstream of R3. MUSIC modelling has predicted discharge concentrations at this location from five permanent water quality basins located upstream. Modelling results together with existing water quality for Hunter River drains are displayed in Figure E-3 and detailed in **Appendix C**.

Total suspended solid concentrations discharged into Hunter River Drain as a result of the project are estimated to be 26 mg/L, which is currently less than median concentrations recorded in dry weather at M12RT5 and median concentrations recorded during wet weather at both M12RT4 and M12RT5. The correlated turbidity discharge value of 38.13 NTU is also less than recorded turbidity levels in the Hunter River drain with the exception of median dry weather turbidity at M12RT4. Despite the expected lower turbidity runoff from the project, estimated levels would still exceed the upper limit of 10 NTU.

Existing nutrient concentrations in the Hunter River drain are very high and considerably higher than the guideline limits, particularly for total phosphorus. MUSIC modelling has estimated low nutrient concentration in runoff from the project. Total nitrogen concentrations estimated at 0.28 mg/L would be less than the recommended limit of 0.3 mg/L and therefore would comply with the ANZG (2018) Water Quality Guidelines. Total phosphorus concentrations are significantly lower in the project runoff when compared to existing water quality, however are still slightly higher than the recommended limit of 0.03 mg/L. Therefore, the lower TN and TP concentrations generated from the project work towards achieving the WQOs.



^correlated value ($y = 1.8488x - 13.543, R^2 = 0.999$) (refer to **Appendix C**)

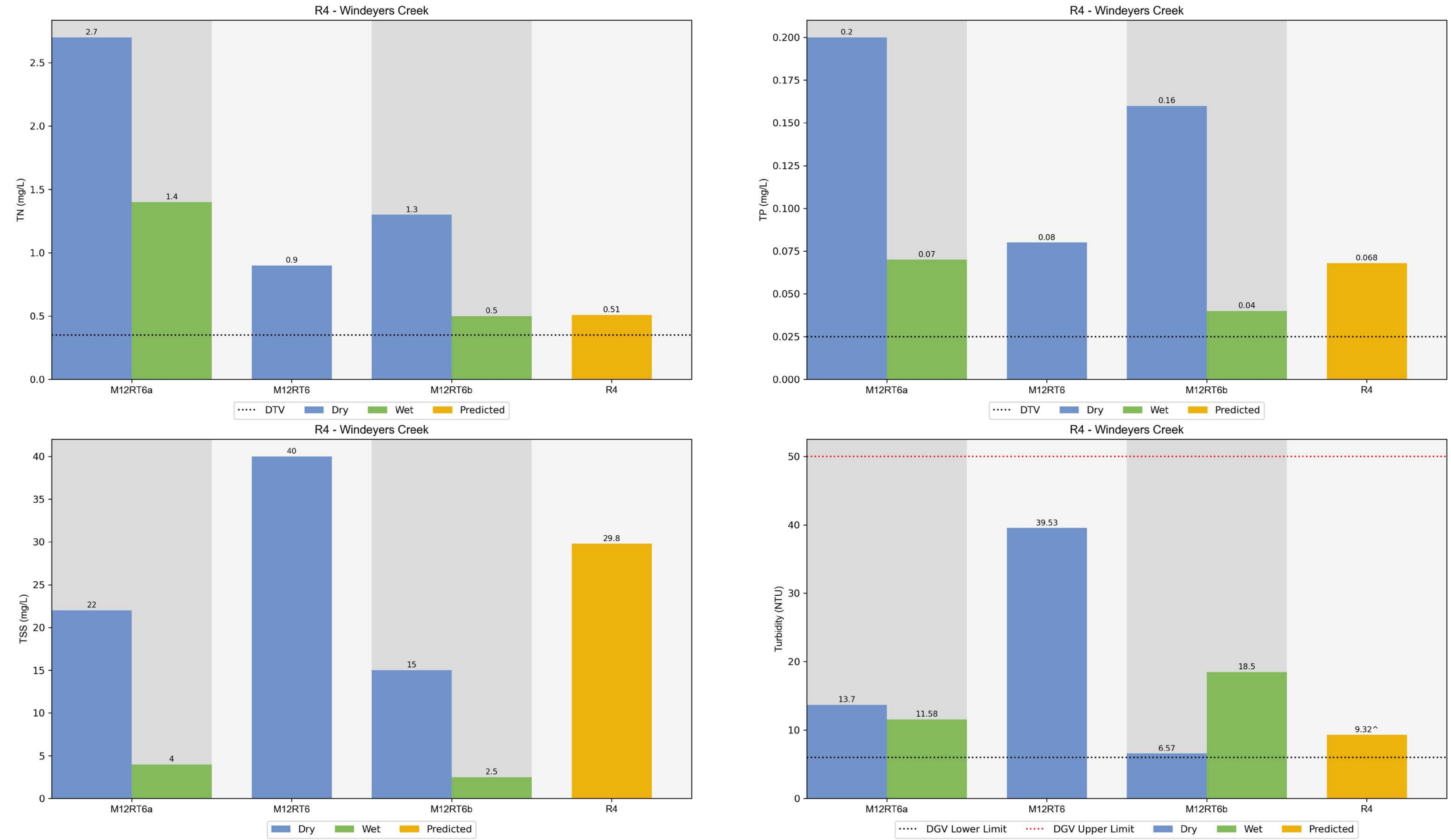
Figure E-3 MUSIC modelling concentrations from the project at R3 and existing water quality for Hunter River Drain

R4

R4 is located on Windeyers Creek downstream of the monitoring sites M12RT6, M12RT6a and M12RT6b. MUSIC modelling has predicted discharge concentrations at this location from six permanent water quality basins located upstream. Modelling results together with existing water quality for Windeyers Creek are displayed in Figure E-4 and detailed in **Appendix C**.

Concentrations of total suspended solids generated from the operation of the project and subsequently discharged into Windeyers Creek are estimated to be 29.8 mg/L which is higher than TSS currently recorded at M12RT6a and M1RT6b during both dry and wet weather, but lower than M12RT6 which was only monitored on one occasion. The correlated turbidity value of 9.32 NTU is lower than turbidity recorded at M12RT6a during dry and wet weather and M12RT6b during wet weather. The estimated turbidity value is also within the recommended guidelines for protection of lowland river aquatic ecosystems.

Concentrations of TN and TP generated by the operation of the project and subsequently discharged into Windeyers Creek are expected to be lower than the median concentrations for TN and TP recorded during dry at all sites and following rainfall at M12RT6a. Estimated concentrations of TN from the project would be reduced by more than half the current concentrations recorded during dry weather at M12RT6a and M12RT6b and slightly less at M12RT6. Concentrations following wet weather are noticeably less than M12RT6a but similar to concentrations recorded at M12RT6b. Similarly, estimated TP concentrations would be slightly less than existing TP concentrations during dry and wet weather at all sites except M12RT6b after rainfall. Despite the low concentrations of TN and TP discharged from the project, concentrations do not meet the ANZG (2018) recommended limits for protection of aquatic ecosystems but is generally better than existing water quality in Windeyers Creek and therefore work towards achieving the WQOs.



^ correlated value ($y = 0.1266x + 6.2284, R^2 = 0.5886$) (refer **Appendix C**)

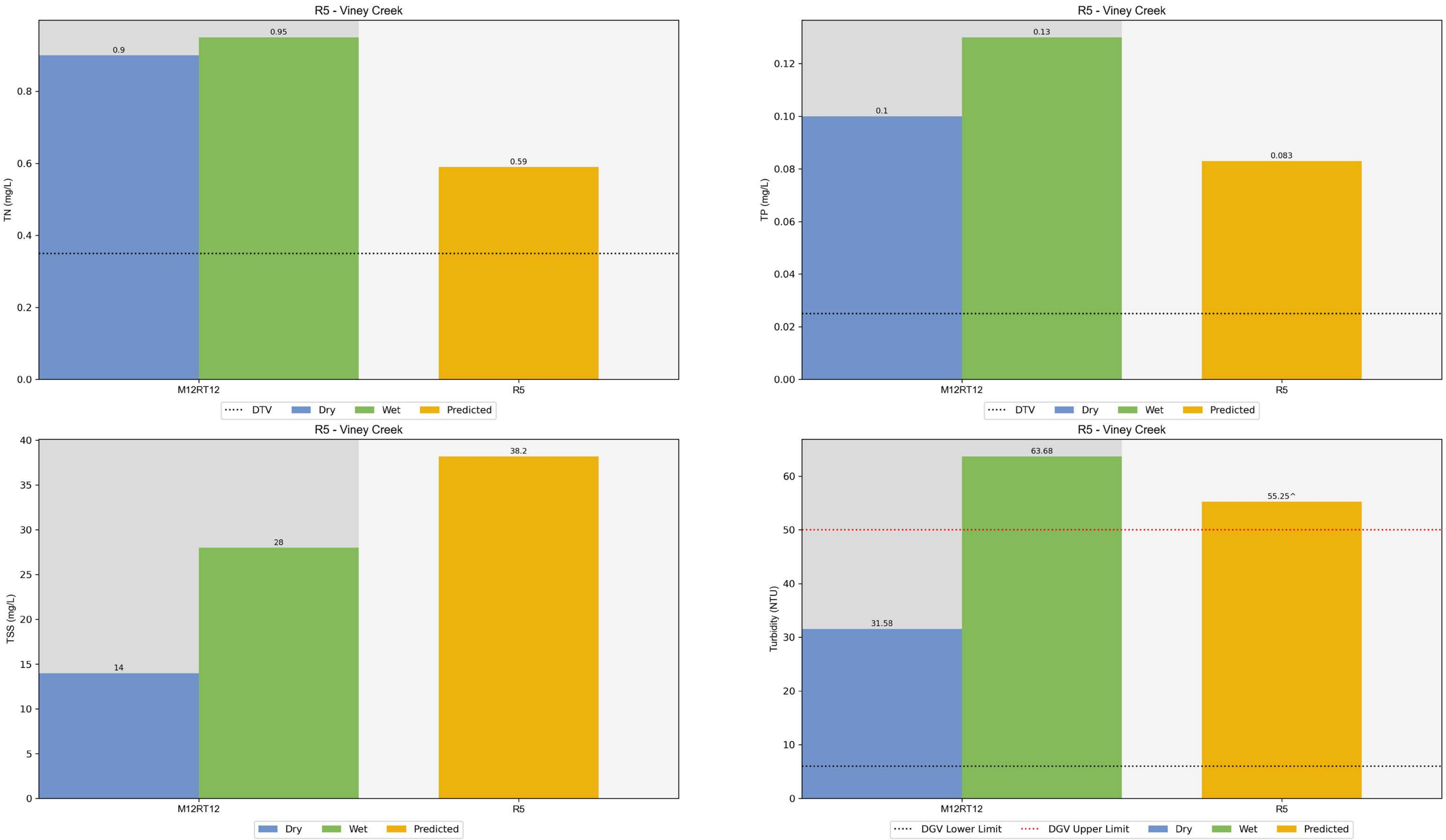
Figure E-4 MUSIC modelling concentrations from the project at R4 and existing water quality for Windeyers Creek

R5

R5 is located on Viney Creek upstream of the monitoring site M12RT12. MUSIC modelling has predicted discharge concentrations at this location from six permanent water quality basins located upstream. Modelling results together with existing water quality for Viney Creek are displayed in Figure E-5 and detailed in **Appendix C**.

Total suspended solid concentrations estimated in project runoff are higher than existing concentrations recorded in Viney Creek during both dry and wet weather. The correlated turbidity value of 55.25 NTU is higher than dry weather turbidity in Viney Creek, but lower than the measured turbidity following rainfall. The project estimated turbidity also complies with the recommended ANZG (2018) guidelines for protection of lowland river aquatic ecosystems.

Concentrations of TN and TP generated by the operation of the project and subsequently discharged into Viney Creek are expected to be lower than the median concentrations for TN and TP recorded during both dry and wet weather. Estimated concentrations of TN would be almost half the current concentrations recorded during dry weather and wet weather and estimated TP concentrations would be slightly less than an existing water quality during dry and wet weather. Despite the lower concentrations of TN and TP discharged from the project, concentrations do not meet the ANZG (2018) recommended limits for protection of aquatic ecosystems, but by discharging better water quality than is currently within Viney Creek the project is working towards achieving the WQOs.



^ correlated value ($y = 0.1593x + 25.519, R^2 = 0.2194$) (refer to **Appendix C**)

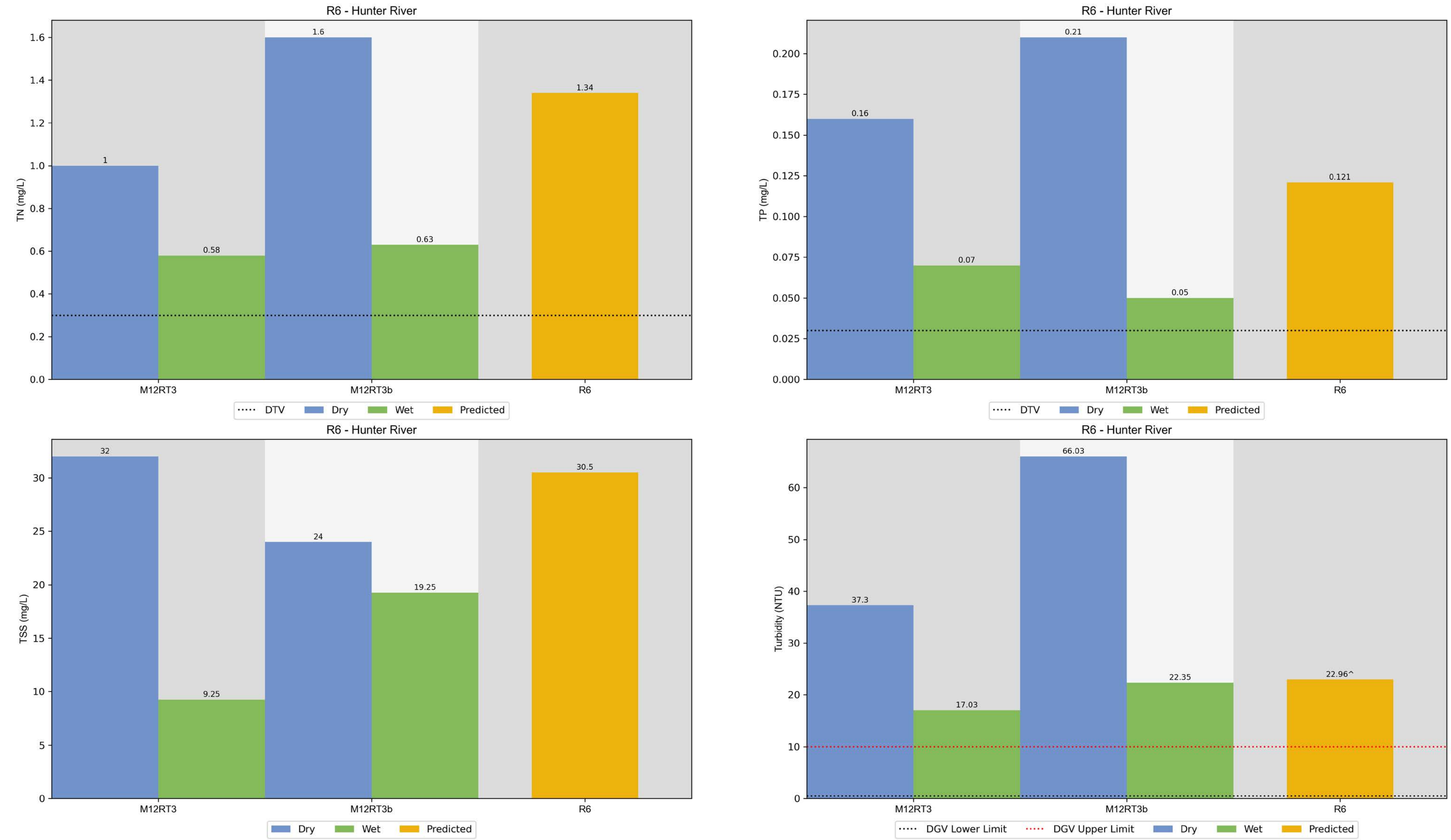
Figure E-5 MUSIC modelling concentrations from the project at R5 and existing water quality for Viney Creek

R6

R6 is located on the Hunter River downstream of the viaduct, between monitoring sites M12RT3 and M12RT3b. MUSIC modelling has predicted discharge concentrations at this location from one permanent water quality basin located upstream. Modelling results together with existing water quality for Hunter River are displayed in Figure E-6 and detailed in **Appendix C**.

The project is estimated to discharge treated runoff with TSS concentrations of 30.5 mg/L into the mainstream Hunter River which is higher than existing TSS concentrations recorded during dry weather at M12RT3b and both M12RT3 and M12RT3b during wet weather. The correlated turbidity of 22.96 NTU estimated in the project runoff is less than turbidity recorded at both sites during dry weather, but higher than turbidity at both sites during wet weather. The correlated turbidity exceeds the recommended upper limit of 10 NTU for protection of estuarine aquatic ecosystems.

Total nitrogen and total phosphorus concentrations generated from the project are estimated to be higher than existing concentrations recorded in the Hunter River at M12RT3 (dry and wet weather) and M12RT3b (wet weather). The estimated discharge concentrations are also notably higher than the recommended limit of 0.3 mg/L for TN and 0.03 mg/L for TP. While pollutant loadings from the project are expected to be slightly higher than existing concentrations, the project is unlikely to hinder the long-term achievement of the nominated WQOs due to substantial tidal movement in this part of the Hunter River and sufficient dilution provided by upstream flows as demonstrated in **Section 6.3.4**.



^ correlated value ($y = 1.3357x - 29.411, R^2 = 0.9043$) (refer to **Appendix C**)

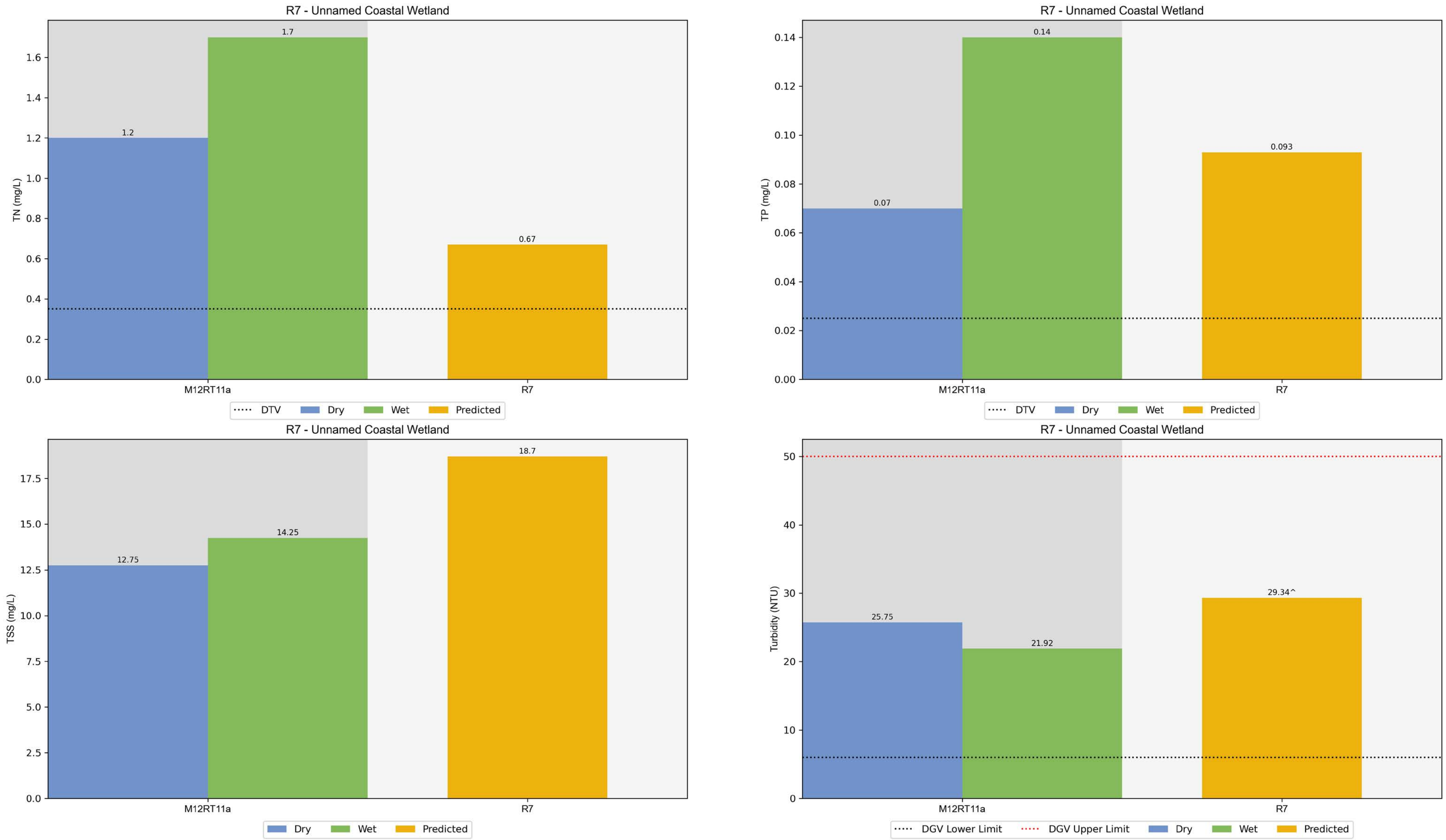
Figure E-6 MUSIC modelling concentrations from the project at R6 and existing water quality for Hunter River (mainstream)

R7

R7 is located on a drainage line of the Hunter River near monitoring site M12RT11a. MUSIC modelling has predicted discharge concentrations at this location from two permanent water quality basins located upstream. Modelling results together with existing water quality for the unnamed Coastal Wetland (Coastal Management SEPP) (M12RT11a) are displayed in Figure E-7 and detailed in **Appendix C**.

Concentrations of total suspended solids generated from the operation of the project are estimated to be 18.7 mg/L which is slightly higher than TSS recorded in the unnamed Coastal Wetland (Coastal Management SEPP) during both dry and wet weather. The correlated Turbidity for the operation of the project is 29.34 NTU which is slightly higher than background turbidity and exceeds the recommended upper limit of 10 NTU for protection of estuarine aquatic ecosystems.

Concentrations of TN generated by the operation of the project and subsequently discharged into the unnamed Coastal Wetland (Coastal Management SEPP) are expected to be less than concentrations currently recorded during both dry and wet weather. Total phosphorus concentrations generated from project runoff are slightly higher than existing dry weather concentrations in the wetland, but less than wet weather concentrations. The project estimated concentrations currently do not meet the recommended limits for protection of lowland river aquatic ecosystems but are generally lower than existing concentrations and therefore work towards achieving the WQOs.



^ correlated value ($y = 1.039x - 0.1976, R^2 = 1$) (refer to **Appendix C**)

Figure E-7 MUSIC modelling concentrations from the project at R7 and existing water quality for an Unnamed Coastal Wetland

Appendix F. Groundwater monitoring sites and groundwater quality sampling occurrences

Table F-1 Project groundwater monitoring bore details

Location	Easting	Northing	Ground level (mAHD)	Total depth (mbTOC)	Screened interval (mbgl)	Screened lithology[1]	Interpreted screened hydrogeological unit
D-PZ-134	372642	6368469	22.48	18.92	11.8 - 17.8	Sandstone (PT)	Tomago Coal Measures
D-PZ-135	372853	6368499	16.11	13.35	6.1 - 12.1	Sandstone / Siltstone (PT)	Tomago Coal Measures
D-PZ-136	373183	6368558	21.22	18.60	12.0 - 18.0	Sandstone / Siltstone (PT)	Tomago Coal Measures
D-PZ-221A	374772	6368470	0.65	5.02	1.5 - 4.5	Sandy clay / Clayey sand (QA)	Hunter Alluvium
D-PZ-221B	374772	6368470	0.65	15.31	11.5 - 14.5	Sandstone / Siltstone (PT)	Tomago Coal Measures
D-PZ-222A	374910	6368425	0.53	3.70	0.5 - 2.5	Clay (QA)	Hunter Alluvium
D-PZ-222B	374910	6368425	0.53	13.84	9.5 - 12.5	Sandstone / Siltstone (PT)	Tomago Coal Measures
D-PZ-223A	375480	6368559	0.83	6.10	2.0 - 5.0	Clay / Silty Clay (QA)	Hunter Alluvium
D-PZ-223B	375480	6368559	0.83	13.80	7.0 - 13.0	Carbonaceous claystone/ sandstone (PT)	Tomago Coal Measures
D-PZ-324A	378085	6368698	1.58	3.55	1.0 -2.5	Clay / sand (QA)	Hunter Alluvium
D-PZ-324B	378085	6368698	1.58	9.82	6.0 – 9.0	Sandstone (PT)	Tomago Coal Measures
D-PZ-438	378543	6368611	7.12	10.65	7.0 – 10.0	Sandstone (PT)	Tomago Coal Measures
D-PZ-439A	379350	6369744	0.75	3.82	2.0 - 3.0	Clayey silt (QA)	Hunter Alluvium
D-PZ-439B	379350	6369744	0.75	10.03	4.0 - 10.0	Clayey silt / silty clay (QA)	Hunter Alluvium
D-PZ-440A	379577	6370011	1.25	4.05	0.5 - 3.0	Clay / clayey sand (QA/QS)	Hunter Alluvium
D-PZ-440B	379577	6370011	1.25	8.51	5.0 - 8.0	Sand (QS)	Hunter Alluvium
D-PZ-614	383045	6371950	6.17	6.23	3.5 - 5.0	Sand (QS)	Tomago Sandbeds
D-PZ-615A	383108	6372474	3.62	6.05	2.5 - 4.0	Sand (QS)	Tomago Sandbeds
D-PZ-615B	383108	6372474	3.62	8.0	5.0 - 8.0	Sand (QS)	Tomago Sandbeds
D-PZ-616	383271	6372687	2.14	9.03	7.0 - 10.0	Sand (QS)	Tomago Sandbeds

Notes 1 PT= Permian Tomago Coal Measures; QA = Quaternary Alluvium; QS = Quaternary Sand

Table F-2 Groundwater quality sampling occurrences

Location	2016				2017						
	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul
D-PZ-134	✓	-	-	-	-	-	✓	-	-	-	✓
D-PZ-135	✓	-	-	-	-	-	✓	-	-	-	✓
D-PZ-136	✓	-	-	-	-	-	✓	-	-	-	✓
D-PZ-221A	-	-	✓	-	-	-	✓	-	-	-	✓
D-PZ-221B	-	-	✓	-	-	-	✓	-	-	-	✓
D-PZ-222A	✓	-	-	-	-	-	✓	-	-	-	✓
D-PZ-222B	✓	-	-	-	-	-	✓	-	-	-	✓
D-PZ-223A	✓	-	-	-	-	-	✓	-	-	-	✓
D-PZ-223B	✓	-	-	-	-	-	✓	-	-	-	✓
D-PZ-324A	-	-	-	-	-	-	✓	-	-	-	✓
D-PZ-324B	-	-	-	-	-	-	✓	-	-	-	✓
D-PZ-438	✓	-	-	-	-	-	✓	-	-	-	✓
D-PZ-439A	-	-	✓	-	-	-	✓	-	-	-	✓
D-PZ-439B	-	-	✓	-	-	-	✓	-	-	-	✓
D-PZ-440A	-	-	✓	-	-	-	✓	-	-	-	✓
D-PZ-440B	-	-	✓	-	-	-	✓	-	-	-	✓
D-PZ-614	-	-	✓	-	-	-	✓	-	-	-	✓
D-PZ-615A	-	-	✓	-	-	-	✓	-	-	-	✓
D-PZ-615B	-	-	✓	-	-	-	✓	-	-	-	✓
D-PZ-616	-	-	✓	-	-	-	-	-	-	-	-

Appendix G. Groundwater quality results

Field_ID	Sampling round	Exchangeable Potassium, K (Filtered)	Aluminium (Filtered)	Arsenic (Filtered)	Boron (Filtered)	Cadmium (Filtered)	Chromium (III+VI) (Filtered)	Copper (Filtered)	Iron (Filtered)	Lead (Filtered)	Magnesium (Filtered)	Manganese (Filtered)	Mercury (Filtered)	Nickel (Filtered)	Zinc (Filtered)	Potassium - Dissolved (Filtered)	Total Alkalinity as CaCO3	Ammonia	Bicarbonate Alkalinity as CaCO3	Calcium (Filtered)	Carbonate Alkalinity as CO3	Chloride	Fluoride	Hydroxide	Ionic Balance	Nitrate (as N)	Nitrogen (Total)	Phosphorus	Sodium (Filtered)	Sulphate	Total Dissolved Solids	Faecal Coliforms	pH	Electrical conductivity (at 25deg)	Temp	Redox	DO
			Metals													Inorganics																Biological	Field parameters				
		mg/L	mg/L	µg/L	µg/L	µg/L	µg/L	µg/L	mg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	µg/L	%	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	CFU/100ml or MPN/100ml	pH units	µS/cm	Degrees C	mV	ppm
EQL		0.5	0.01	1	5	0.1	1	1	0.01	1	500	5	0.05	1	1		5	0.005	5	0.5	5	1	0.1	5000		0.005	0.1	0.05	0.5	1	5						
ANZECC 2000 lowland rivers physical and chemical stressors																		0.02								0.04	0.35	0.025					6.5-8.5	200 - 300			
ADWG 2018 Aesthetic								1000	0.3			100			3000			0.5				250							180	250	600						
ADWG 2018 Health				10	4000	2		2000		10		500	1	20									1.5			11.29											
ANZG (2018) Freshwater 95% toxicant DGVs			0.055	13	940	0.2	3.1	1.4	700	3.4		1900	0.6	11	8																						
D-PZ-134	Sep-16	19	0.37	6	34	1.1	<1	1	11	<1	140,000	270	<0.05	160	180	-	42	0.53	42	25	<5	1700	-	<5000	23	<0.005	1.7	0.8	1500	38	3300	<10	6.08	4462	18.1	131.8	3.17
D-PZ-135	Sep-16	8	0.2	3	39	0.2	<1	<1	6.6	<1	25,000	370	<0.05	10	85	-	33	0.55	33	9.6	<5	380	-	<5000	16	0.006	1.5	0.6	320	35	900	<10	6.78	1557	18.4	59.5	3.81
D-PZ-136	Sep-16	9.9	0.18	6	59	0.1	<1	2	4.7	<1	50,000	280	<0.05	25	78	-	120	0.13	120	9.3	<5	510	-	<5000	8.4	0.007	1.3	1.6	380	59	1200	<20	6.73	2148	19	101.5	1.95
D-PZ-222A	Sep-16	90	0.01	<1	820	<0.1	<1	<1	0.022	<1	770,000	440	<0.05	8	7	-	720	0.17	720	770	<5	3400	-	<5000	19	0.008	1.5	1.3	3800	3600	12,000	70	7.13	11950	16.8	133.4	1.88
D-PZ-222B	Sep-16	27	0.02	5	48	<0.1	<1	<1	7.1	<1	390,000	690	<0.05	5	7	-	410	0.86	410	300	<5	3800	-	<5000	17	<0.005	1.8	0.2	3000	440	7500	<20	7.08	10540	18.6	13.1	1.54
D-PZ-223A	Sep-16	95	0.05	3	1500	<0.1	<1	<1	1.6	<1	1,100,000	3000	<0.05	4	3	-	550	0.84	550	1200	<5	7000	-	<5000	20	<0.005	1.3	0.1	5700	2700	14,000	<10	7.00	17550	17.3	40.2	0.78
D-PZ-223B	Sep-16	33	0.05	3	20	<0.1	<1	<1	46	<1	490,000	5200	<0.05	180	46	-	180	0.008	180	540	<5	4700	-	<5000	17	<0.005	1.2	0.07	3200	530	11,000	>10000 NBO	7.84	10660	18.1	-290	0.66
D-PZ-438	Sep-16	4.2	0.14	<1	90	<0.1	2	1	0.099	<1	6300	29	<0.05	7	75	-	27	0.05	27	8.4	<5	210	-	<5000	11	0.35	1.5	<0.05	230	110	650	<10 NBO	6.85	1033	17.6	217.2	5.89
D-PZ-221A	Nov-16	84	-	18	-	<0.1	<1	<1	20	<1	450,000	980	<0.05	3	<1	-	580	0.49	580	420	<5	2300	-	<5000	-	<0.05	0.9	0.4	2600	3400	11,000	<20 MPN/100mL	6.98	5076.2	18.16	20.4	1.74
D-PZ-221B	Nov-16	15	-	1	-	<0.1	<1	<1	0.38	<1	99,000	280	<0.05	2	4	-	490	0.89	490	58	<5	1500	-	<5000	-	<0.005	1.1	0.1	1400	260	3300	<10 CFU/100mL	7.03	10553.7	17.59	20.1	7.5
D-PZ-439A	Nov-16	62	-	5	-	<0.1	<1	<1	40	<1	370,000	800	<0.05	30	26	-	360	0.37	360	380	<5	2300	-	<5000	-	<0.05	3.5	0.9	2200	2600	8100	<20 MPN/100ml	6.53	8457	13.35	41.1	4
D-PZ-439B	Nov-16	85	-	3	-	<0.1	<1	<1	22	<1	450,000	2000	<0.05	3	4	-	720	0.74	720	410	<5	2500	-	<5000	-	<0.05	2.3	1	2600	2800	11,000	<20 MPN/100mL	6.84	10357	18.08	13.8	5.89
D-PZ-440A	Nov-16	2.4	-	3	-	<0.1	<1	<1	8	<1	6700	49	<0.05	2	9	-	54	0.088	54	4.5	<5	43	-	<5000	-	<0.005	0.8	0.2	51	15	270	20 MPN/100mL	6.74	252.5	16.8	13.5	4.17
D-PZ-440B	Nov-16	1.8	-	<1	-	<0.1	1	<1	1.7	<1	8300	12	<0.05	<1	8	-	18	0.33	18	2	<5	44	-	<5000	-	<0.005	0.7	<0.05	34	27	150	<20 MPN/100mL	6.24	217.9	17.56	29.7	2.04
D-PZ-614	Nov-16	8.8	-	3	-	<0.1	36	2	7.8	2	2100	170	<0.05	8	12	-	220	4.2	220	12	<5	28	-	<5000	-	<0.05	14	0.5	170	1	910	<20 MPN/100mL	6.45	545.9	18.87	-47.6	1.26
D-PZ-615A	Nov-16	1.6	-	<1	-	<0.1	3	<1	0.99	<1	2000	6	<0.05	<1	4	-	<5	0.017	<5	2.3	<5	10	-	<5000	-	<0.005	0.4	<0.05	6.3	17	87	<10 CFU/100mL	6.38	61.8	19.05	14.3	1.94
D-PZ-615B	Nov-16	2.8	-	4	-	<0.1	2	<1	0.81	<1	1400	60	<0.05	<1	19	-	15	0.034	15	2.4	<5	11	-	<5000	-	<0.005	0.5	<0.05	10	8	98	<1000 NBO CFU/100mL					
D-PZ-616	Nov-16	3.3	-	1	-	<0.1	5	<1	4.2	<1	9400	250	<0.05	<1	4	-	55	0.35	55	15	<5	23	-	<5000	-	<0.005	1.2	<0.05	26	34	200	<10 CFU/100mL	5.96	250.9	19.31	-38.9	2.19
D-PZ-134	Mar-17	19	0.18	6	40	0.2	<1	<1	0.21	<1	130,000	200	<0.05	41	120	-	68	0.86	68	30	<5	2400	0.3	<5000	-	0.03	1.5	<0.05	1500	41	4600	200	4.96	7043	19.8	-9	2.69
D-PZ-135	Mar-17	1.8	1.1	1	70	<0.1	1	4	0.4	<1	2000	28	<0.05	4	25	-	10	0.15	10	0.8	<5	77	<0.1	<5000	-	0.23	1.2	<0.05	80	33	310	<200	5.66	473	20.4	-21	5.86
D-PZ-136	Mar-17	7.9	0.02	4	50	<0.1	<1	<1	2.6	<1	47,000	230	<0.05	15	37	-	44	0.16	44	6.5	<5	630	0.2	<5000	-	0.007	0.4	<0.05	450	60	1400	<200	5.65	2404	20.6	-33	2.31
D-PZ-221A	Mar-17	72	<0.01	14	790	<0.1	<1	<1	11	<1	350,000	1400	<0.05	7	7	-	610	0.44	610	480	<5	1700	0.3	<5000	-	<0.005	8	2.2	1900	3700	8000	3300	5.50	10172	20.1	-122	0.27
D-PZ-221B	Mar-17	15	0.01	1	60	<0.1	<1	<1	0.55	<1	110,000	310	<0.05	2	5	-	550	0.84	550	75	<5	1600	0.6	<5000	-	<0.005	1.3	0.1	1300	320	3700	<200	5.35	5940	18.1	-98	2.11
D-PZ-222A	Mar-17	94	0.01	<1	490	<0.1	<1	<1	0.016	<1	580,000	400	<0.05	9	9	-	610	0.11	610	790	<5	6100	0.3	<5000	-	0.008	5.5	1.7	2900	4600	13,000	<200	6.27	16444	21	-143	3.51
D-PZ-222B	Mar-17	29	<0.01	5	50	<0.1	<1	<1	6	<1	420,000	680	<0.05	6	9	-	410	0.96	410	320	<5	4700	0.7	<5000	-	0.01	1.3	0.2	2800	940	10,000	<200	5.05	14092	18.6	-145	2.19
D-PZ-223A	Mar-17	100	0.02	5	640	0.1	<1	1	0.67	<1	880,000	2800	<0.05	7	26	-	690	0.83	690	990	<5	7900	0.4	<5000	-	<0.005	9.7	2.6	4500	3200	19,000	3300	6.61	22989	20.2	-156	2.26
D-PZ-223B	Mar-17	40	0.01	<1	<20	<0.1	<1	<1	41	<1	600,000	7000	<0.05	5	4	-	310	0.51	310	640	<5	9000	0.4	<5000	-	<0.02	1	0.1	3300	960	14,000	<200	5.67	18283	18.2	-157	2.18
D-PZ-324A	Mar-17	27	0.02	9	410	0.1	1	<1	65	<1	80,000	560	<0.05	11	52	-	170	5.4	170	28	<5	1900	0.1	<5000	-	0.009	6.8	0.1	1400	400	4000	<200	5.38	7128	22.1	-0.7	2.55
D-PZ-324B	Mar-17	94	31	20	100	9.5	<1	2	160	21	970,000	2400	<0.05	94	820	-	<5	0.48	<5	220	<5	9100	<0.1	<5000	-	0.007	1.1	<0.05	5400	2400	19,000	<200	5.38	7128	22.1	-0.7	2.55
D-PZ-438	Mar-17	2.2	0.04	<1	90	<0.1	<1	<1	0.26	<1	5900	12	<0.05	3	14	-	17	0.11	17	3	<5	240	<0.1	<5000	-	0.36	0.7	<0.05	260	150	820	<200	5.52	1160	22	-5	4.58
D-PZ-439A	Mar-17	79	<0.01	3	1100	<0.1	<1	<1	24	<1	340,000	1100	<0.05	2	7	-	810	0.75	810	560	<5	2200	0.5	<5000	-	0.01	7.5	3.5	1900	2800	9100	<200	5.82	10627	20.2	-98	2.44
D-PZ-439B	Mar-17	60	<0.01	5	540	<0.1	<1	<1	5.7	<1	140,000	1200	<0.05	7	3	-	670	1.3	670	210	<5	1700	0.2	<5000	-	<0.005	1.6	0.3	1700	1400	5800	200	5.98	8077	22.2	-74	5.41
D-PZ-440A	Mar-17	7.2	0.27	<1	40	<0.1	<1	<1	2.2	<1	7500	57	<0.05	3	8	-	90	0.29	90	5.2	<5	46	0.1	<5000	-	0.01	4	0.8	79	51	880	<200	4.32	413	19.7	-91	3.26
D-PZ-440B	Mar-17	1.9	0.17	<1	30	<0.1	<1	<1	1.7	<1	9800	17	<0.05	<1	12	-	16	0.38	16	2.7	<5	52	<0.1	<5000	-	0.005	1.4	0.1	34	31	210	<200	4.17	281	17.8	-80	1.98
D-PZ-614	Mar-17	7.9	5.6	3	250	<0.1	36	2	6.4	2	2800	180	<0.05	6	15	-	230	7.4	230	9.3	<5	19	<0.1	<5000	-	<0.1	18	0.8	130	5	830	500	5.90	517	20.9	-142	0.82
D-PZ-615A	Mar-17	1.5	0.54	<1	20	<0.1	2	<1	0.87	<1	1900	10	<0.05	<1	5	-	11	0.05	11	2.4	<5	9	<0.1	<5000	-	0.01	1	0.2	6.3	6	140	<200	5.38	72	22.3	-50	1.41
D-PZ-615B	Mar-17	2.5	0.26	3	30	<0.1	2	<1	2.1	<1	1700	75	<0.05	<1	3	-	43	0.1	43	4.7	<5	13	<0.1	<5000	-	<0.005	0.8	0.06	16	4	110	<200	5.58	139	20.8	-141	0.92
D-PZ-134	Jul-17	-	0.18	7	40	0.4	<1	<1	0.045	<1	150,000	250	-	43	130	18	66	0.8	66	35	<5	2100	0.4	<5000	-	<0.005	1.1	<0.05	1600	50	4100	<20	5.24	6036	17.2	130.2	2.73
D-PZ-135	Jul-17	-	0.1	<1	60	<0.1	<1	4	0.09	<1	3300	37	-	3	18	2.2	42	0.17	42	1.7	<5	73	<0.1	<5000	-	0.02	5	0.1	91	18	310	20	5.66	405.5	17.6	87.4	2.88
D-PZ-136	Jul-17	-	0.01	4	60	<0.1	<1	<1	1.3	<1	51,000	280	-	22	40	8.1	81	0.18	81	8.7	<5	620	0.2	<5000	-	<0.005	0.5	0.1	480	52	1300	<20	5.36	2125	17.6	93.2	1.9
D-PZ-221A	Jul-17	-	<0.01	15	910	<0.1	<1	<1	14	<1	330,000	2100	-	13	7	55	620	0.43	620	530	<5	1100	0.3	<5000	-	<0.005	6.9	1.9	1700	2500	7200	<20	6.67	8450	14.8	-65.4	1.38
D-PZ-221B	Jul-17	-	<0.01	2	60	<0.1	<1	<1	0.62	<1	110,000	300	-	2	4	13	560	0.87	560	74	<5	1200	0.6	<5000	-	<0.005	1.4	0.2	1300	250	3400	<20	6.64	5459	15.8	-14.7	2.33
D-PZ-222A	Jul-17	-	<0.01	1	390	<0.1	<1	<1	0.058	<1	540,000	400	-	8	7	72	470	0.18	470	880	<5	3200	0.3	<5000	-	<0.005	1.5	1.2	2600	2400	12,000	<20	6.54	12400	14.5	-8.2	3.08
D-PZ-222B	Jul-17	-	<0.01	6	50	<0.1	<1	<1	8.1	<1	410,000	790	-	5	4	26	420	0.93	420	310	<5	4100	0.8	<5000	-	<0.005	1.2	0.2	2900	570	10,000	<20	6.27	12603	16.5	-21.7	1.62
D-PZ-223A	Jul-17	-	<0.01	9	640	<0.1	<1	<1	9.6	<1	870,000	4700	-	9	7	83	560	0.95	560	1000	<5	6400	0.4	<5000	-	<0.005	2.8	1	4600	2100	18,000	<20	6.36	18199	15.3	-38.8	6.6
D-PZ-223B	Jul-17	-	<0.01	<1	20	<0.1	<1	<1	58	<1	690,000	9300	-	46	3	37	230	0.44	230	750	<5	5900	0.4	<5000	-	<0.005	1	0.1	3800	690	15,000	<20	5.70	17946	15.8	-41.3	3.44
D-PZ-324A	Jul-17	-	0.05	8	490	0.1	2	<1	71	<1	76,000	840	-	8	47	19	97	6.6	97	32	<5	1200	<0.1	<5000	-	<0.005	8.7	<0.05	1300	640	3700	<20	5.16	6045	13.3	43.5	4.17
D-PZ-324B	Jul-17	-	40	24	100	7.4	<1	<1	160	7	990,000	2500	-	86	690	110	<5	0.51	<5	220	<5	7700	0.8	<5000	-	<0.005	1.2	<0.05	6400	2100	23,000	<20	4.00	22510	15.4	126	2.36
D-PZ-438	Jul-17	-	0.04	<1	90	<0.1	<1	4	0.27	<1	5000	33	-	2	16	2.3	24	0.12	24	3.9	<5	170	<0.1	<5000	-	0.25	0.8	<0.05	230	120	660	<20	5.31	960	16.6	99.3	6.26
D-PZ-439A	Jul-17	-	0.01	1	620	0.1	<1	<1	4.6	<1	240,000	710	-	29	51	41	100	0.064	100	230	<5	1400	0.1	<5000	-	<0.005	1.3	0.5	1600	1400	5700	<20	5.81	7412	13.4	65.5	2.94
D-PZ-439B	Jul-17	-	<0.01	3	770	<0.1	<1	<1	23	<1	170,000	1300	-	3	3	58	640	0.8	640	450	<5	1400	0.3	<5000	-	<0.05	1.4	0.8	1800	1600	6600	<20	6.36	8059	15.3	-62.7	4.62
D-PZ-440A	Jul-17	-	0.03	3	40	<0.1	<1	<1	6	<1	7500	45	-	2	3	3.1	67	0.06	67	4.5	<5	53	<0.1	<5000	-	0.02	0.5	0.3	69	23	220	<20	7.54	452.8	14	-97	5.43
D-PZ-440B	Jul-17	-	0.04	<1	30	<0.1	1	<1	2	<1	11,000	17	-	<1	3	2.1	15	0.38	15	2.7	<5	44	<0.1	<5000	-	<0.005	0.9	0.07	37	28	180	<20	5.50	295.7	15.8	60.9	1.67
D-PZ-614	Jul-17	-	4.7	6	300	<0.1	20	5	5.2	4	3100	170	-	4	110	6.3	69	1.1	69	9.1	<5	21	<0.1	<5000	-	3	12	0.5	110	70	530	<20	5.26	465.3	14.9	3.6	2.54
D-PZ-615A	Jul-17	-	0.91	<1	30	<0.1	3	<1	0.73	<1	2300	<5	-	<1	4	1.5	12	0.011	12	2.6	<5	6	<0.1	<5000	-	0.35	1.3	0.1	6.5	7	110	<20	5.11	75.5	15.2	65.3	2.61
D-PZ-615B	Jul-17	-	0.27	4	30	<0.1	2	<1	1.4	<1	1200	23	-	<1	2	2.4	12	0.089	12	2.1	<5	8	<0.1	<5000	-	<0.005	0.4	<0.05	7.8	7	76	<20	5.16	75.8	16.7	5.7	1.22

Table G-1 Median field parameter results for project monitoring bores

Hydrogeological unit	Location	Average results				
		pH	EC (µS/cm)	Temperature (°C)	Redox (mV)	Dissolved oxygen (ppm)
Tomago Coal Measures	D-PZ-134	5.43	5847	18.4	84.3	2.86
	D-PZ-135	6.03	812	18.8	42.0	4.18
	D-PZ-136	5.91	2226	19.1	53.9	2.05
	D-PZ-221B	6.34	7318	17.2	-30.9	3.98
	D-PZ-222B	6.13	12412	17.9	-51.2	1.78
	D-PZ-223B	6.40	15630	17.4	-162.8	2.09
	D-PZ-324B	4.69	14819	18.8	62.7	2.46
	D-PZ-438	5.89	1051	18.7	103.8	5.58
	Average	***5.85***	***7514***	***18.3***	***12.7***	***3.12***
Hunter Alluvium	D-PZ-221A	6.38	7899	17.7	-55.7	1.13
	D-PZ-222A	6.65	13598	17.4	-5.9	2.82
	D-PZ-223A	6.66	19579	17.6	-51.5	3.21
	D-PZ-324A	5.27	6587	17.7	21.4	3.36
	D-PZ-439A	6.05	8832	15.7	2.9	3.13
	D-PZ-439B	6.39	8831	18.5	-41.0	5.31
	D-PZ-440A	6.20	373	16.8	-58.2	4.29
	D-PZ-440B	5.30	265	17.1	3.5	1.90
	Average	***6.11***	***8246***	***17***	***-23.1***	***3.14***
Tomago Sandbeds	D-PZ-614	5.87	509	18.2	-62.0	1.54
	D-PZ-615A	5.62	70	18.9	9.9	1.99
	D-PZ-615B	5.37	107	18.8	-67.7	1.07
	D-PZ-616 [1]	5.96	251	19.3	-38.9	2.19
	Average	***5.71***	***234***	***18.8***	***-39.7***	***1.70***

Notes: [1] Only one data point.

Appendix H. Water quality calculations for groundwater affected basins

Water quality – Construction

Basin code	Basin name	Basin type	Excavation invert (mAHD)	Basin water level (mAHD)	Modelled groundwater level (mAHD)	Depth of groundwater above invert (m)	Approx. volume groundwater (m^3)	Approx. volume surface water (m^3)	Indicative monitoring bore	Indicative groundwater quality (uS/cm)	Indicative runoff water quality (uS/cm)	Indicative blend water quality (uS/cm)
B00950L	TB01	Construction Only	9.25	10.75	10.88	1.63	372	0	D-PZ-134	5,847	150	5,847
B01000L	TPB04	Construction and Operation	9.25	10.75	11.08	1.83	1794	0	D-PZ-134	5,847	150	5,847
B01120L	TPB05	Construction and Operation	9.10	10.10	9.73	0.63	118	70	D-PZ-134	5,847	150	3,726
B02460L	TPB06	Construction and Operation	3.25	4.75	4.00	0.75	1949	2923	D-PZ-221A	7,899	150	3,250
B03340M	TPB09	Construction and Operation	-1.05	0.45	0.75	1.80	875	570	D-PZ-221A	7,899	150	4,842
B03350L	TB05	Construction only	0.50	2.00	1.72	1.22	350	120	D-PZ-221A	7,899	150	5,921
B03480R	TB04	Construction only	-1.60	-0.10	0.16	1.76	880	38	D-PZ-222A	13,598	150	13,041
B03750L	TPB10	Construction and Operation	-1.25	0.25	0.70	1.95	288	49	D-PZ-222A	13,598	150	11,643
B03800M	TPB11	Construction and Operation	-0.45	1.05	-0.13	0.32	533	2902	D-PZ-222A	13,598	150	2,237
B04300L	TB06	Construction only	-1.35	0.15	-0.07	1.28	492	129	D-PZ-223A	19,579	150	15,543
B07150L	TPB12	Construction and Operation	0.25	1.75	1.53	1.28	53	146	D-PZ-324A	6,587	150	1,864

Basin code	Basin name	Basin type	Excavation invert (mAHD)	Basin water level (mAHD)	Modelled groundwater level (mAHD)	Depth of groundwater above invert (m)	Approx. volume groundwater (m^3)	Approx. volume surface water (m^3)	Indicative monitoring bore	Indicative groundwater quality (uS/cm)	Indicative runoff water quality (uS/cm)	Indicative blend water quality (uS/cm)
B07300R	TPB13	Construction and Operation	3.15	4.65	3.38	0.23	23	191	D-PZ-438	1,051	50	158
B07450R b	TB08	Construction only	9.25	10.75	9.57	0.32	110	608	D-PZ-438	1,051	50	203
B07500L	TPB14	Construction and Operation	-0.25	1.25	0.33	0.58	180	428	D-PZ-438	1,051	50	346
B07800R	TPB15	Construction and Operation	3.75	5.35	4.29	0.54	196	615	D-PZ-438	1,051	50	292
B08000L	TPB16	Construction and Operation	-0.45	1.05	0.55	1.00	767	574	D-PZ-438	1,051	50	623
B08150L	TPB17	Construction and Operation	-0.43	1.07	0.61	1.04	506	336	D-PZ-438	1,051	50	652
B08360R	TB10	Construction only	0.25	1.75	1.48	1.23	221	73	D-PZ-438	1,051	50	802
B08980M	TPB19	Construction and Operation	-0.80	0.70	0.47	1.27	1907	529	D-PZ-439A	8,832	50	6,925
B09120M	TPB18	Construction and Operation	-0.25	1.25	1.35	1.60	1700	0	D-PZ-439A	8,832	50	8,832
B09360L	TPB21	Construction and Operation	-0.80	0.70	0.52	1.32	654	137	D-PZ-440A	373	50	317
B09440L	TPB22	Construction and Operation	0.15	1.65	1.53	1.38	1380	180	D-PZ-440A	373	50	336
B11550L	TB13	Construction only	1.20	2.70	1.94	0.74	163	252	D-PZ-614	509	50	230
B11950R	TB14	Construction only	1.65	3.15	1.99	0.34	88	449	D-PZ-614	509	50	125
B12460R	TPB26	Construction and Operation	0.90	2.40	1.91	1.01	630	1052	D-PZ-614	509	50	222

Basin code	Basin name	Basin type	Excavation invert (mAHD)	Basin water level (mAHD)	Modelled groundwater level (mAHD)	Depth of groundwater above invert (m)	Approx. volume groundwater (m^3)	Approx. volume surface water (m^3)	Indicative monitoring bore	Indicative groundwater quality (uS/cm)	Indicative runoff water quality (uS/cm)	Indicative blend water quality (uS/cm)
B12650R	TPB27	Construction and Operation	0.60	2.10	1.78	1.18	289	306	D-PZ-614	509	50	273
B13450L	TPB28	Construction and Operation	2.25	3.25	2.59	0.34	143	278	D-PZ-614	509	50	206
B13850L	TPB30	Construction and Operation	1.34	2.84	1.40	0.06	14	475	D-PZ-615A	70	50	51
B13900L	TPB29	Construction and Operation	0.98	2.49	1.41	0.43	66	252	D-PZ-615A	70	50	54
B14160M	TPB31	Construction and Operation	1.10	2.60	1.43	0.33	161	851	D-PZ-615A	70	50	53
B14400M	TPB32	Construction and Operation	0.05	1.55	1.48	1.43	515	253	D-PZ-616	251	50	185

Water quality – Operation

Basin code	Basin name	Basin type	Excavation invert (mAHD)	Basin water level (mAHD)	Modelled groundwater level (mAHD)	Depth of groundwater above invert (m)	Approx volume groundwater (m^3)	Approx volume surface water (m^3)	Indicative monitoring bore	Indicative groundwater quality (uS/cm)	Indicative runoff water quality (uS/cm)	Indicative blend water quality (uS/cm)
B01000L	PB05	Construction and Operation	9.25	10.75	11.08	1.83	1794	0	D-PZ-134	5,847	150	5,847
B01120L	PB06	Construction and Operation	9.10	10.10	9.73	0.63	118	70	D-PZ-134	5,847	150	3,726
B02460L	PB07	Construction and Operation	3.25	4.75	4.00	0.75	1949	2923	D-PZ-221A	7,899	150	3,250
B03340M	PB10	Construction and Operation	-1.05	0.45	0.75	1.80	875	570	D-PZ-221A	7,899	150	4,842
B03750L	PB12	Construction and Operation	-1.25	0.25	0.70	1.95	288	49	D-PZ-222A	13,598	150	11,643
B03800M	PB13	Construction and Operation	-0.45	1.05	-0.13	0.32	533	2902	D-PZ-222A	13,598	150	2,237
B05700L	PB14	Operation only	-1.31	0.19	0.04	1.35	1324	213	D-PZ-223A	19,579	150	16,886
B06100L	PB15	Operation only	-0.70	0.55	0.12	0.82	42	27	D-PZ-223A	19,579	150	11,976
B07150L	PB17	Construction and Operation	0.25	1.75	1.53	1.28	53	146	D-PZ-324A	6,587	150	1,864
B07300R	PB19	Construction and Operation	3.15	4.65	3.38	0.23	23	191	D-PZ-438	1,051	50	158

Basin code	Basin name	Basin type	Excavation invert (mAHD)	Basin water level (mAHD)	Modelled groundwater level (mAHD)	Depth of groundwater above invert (m)	Approx volume groundwater (m^3)	Approx volume surface water (m^3)	Indicative monitoring bore	Indicative groundwater quality (uS/cm)	Indicative runoff water quality (uS/cm)	Indicative blend water quality (uS/cm)
B07500L	PB20	Construction and Operation	-0.25	1.25	0.33	0.58	180	428	D-PZ-438	1,051	50	346
B07800R	PB21	Construction and Operation	3.75	5.35	4.29	0.54	196	615	D-PZ-438	1,051	50	292
B08000L	PB22	Construction and Operation	-0.45	1.05	0.55	1.00	767	574	D-PZ-438	1,051	50	623
B08150L	PB23	Construction and Operation	-0.43	1.07	0.61	1.04	506	336	D-PZ-438	1,051	50	652
B08980M	PB25	Construction and Operation	-0.80	0.70	0.47	1.27	1907	529	D-PZ-439A	8,832	50	6,925
B09120M	PB24	Construction and Operation	-0.25	1.25	1.35	1.60	1700	0	D-PZ-439A	8,832	50	8,832
B09360L	PB27	Construction and Operation	-0.80	0.70	0.52	1.32	654	137	D-PZ-440A	373	50	317
B09440L	PB28	Construction and Operation	0.15	1.65	1.53	1.38	1380	180	D-PZ-440A	373	50	336
B12460R	PB32	Construction and Operation	0.90	2.40	1.91	1.01	630	1052	D-PZ-614	509	50	222
B12650R	PB33	Construction and Operation	0.60	2.10	1.78	1.18	289	306	D-PZ-614	509	50	273

Basin code	Basin name	Basin type	Excavation invert (mAHD)	Basin water level (mAHD)	Modelled groundwater level (mAHD)	Depth of groundwater above invert (m)	Approx volume groundwater (m^3)	Approx volume surface water (m^3)	Indicative monitoring bore	Indicative groundwater quality (uS/cm)	Indicative runoff water quality (uS/cm)	Indicative blend water quality (uS/cm)
B13450L	PB34	Construction and Operation	2.25	3.25	2.59	0.34	143	278	D-PZ-614	509	50	206
B13850L	PB36	Construction and Operation	1.34	2.84	1.40	0.06	14	475	D-PZ-615A	70	50	51
B13900L	PB35	Construction and Operation	0.98	2.49	1.41	0.43	66	252	D-PZ-615A	70	50	54
B14160M	PB37	Construction and Operation	1.10	2.60	1.43	0.33	161	851	D-PZ-615A	70	50	53
B14400M	PB38	Construction and Operation	0.05	1.55	1.48	1.43	515	253	D-PZ-616	251	50	185

Appendix I. Proposed temporary sediment basins and permanent water quality basins

Construction footprint
The project
Bridges/ viaduct
Earthworks cut
Earthworks fill

Water quality basins
Temporary basin
Temporary to permanent basin
Waterways
Creek diversion

0 150 300 m

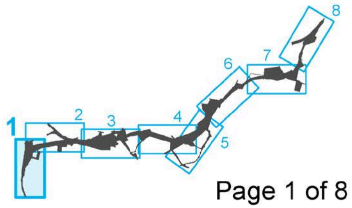
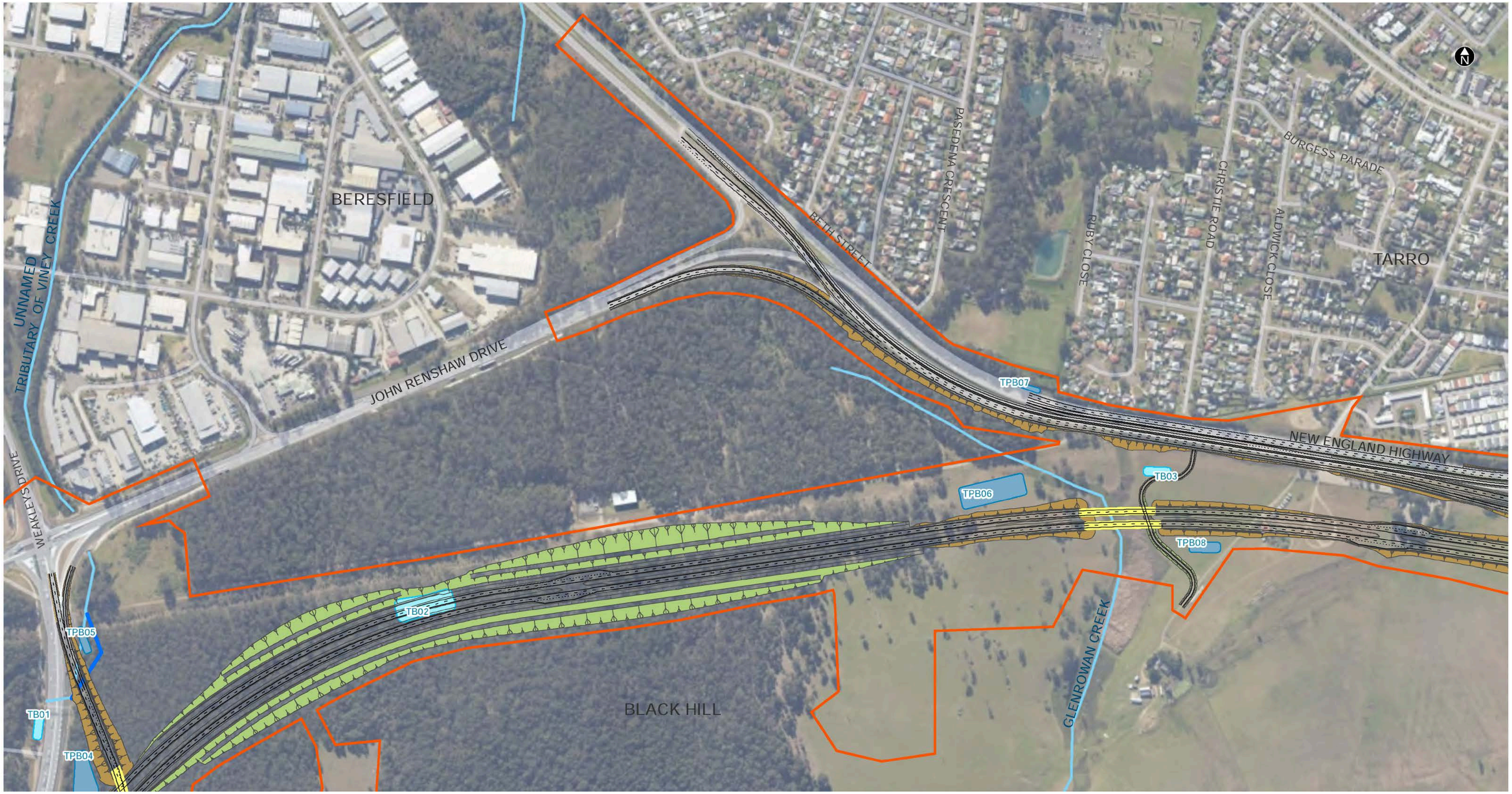


Figure I-1 Proposed temporary construction sediment basins (map 1 of 8)

Date: 11/03/2021 Path: \\Jacobs.com\ANZ\IE\Projects\04_Eastern\IA230000\22_Spatial\GIS\Directory\Templates\Figures\EIS\3_TechnicalReports\Surface_Water\IA230000_CD_SW_023_ConstructionDrainageBasins_JAC_A4L_8250_V04.mxd



	Construction footprint		Water quality basins
	The project		Temporary basin
	Bridges/ viaduct		Temporary to permanent basin
	Earthworks cut		Waterways
	Earthworks fill		Creek diversion

0 150 300 m

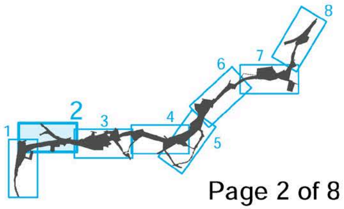


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Figure I-1 Proposed temporary construction sediment basins (map 2 of 8)

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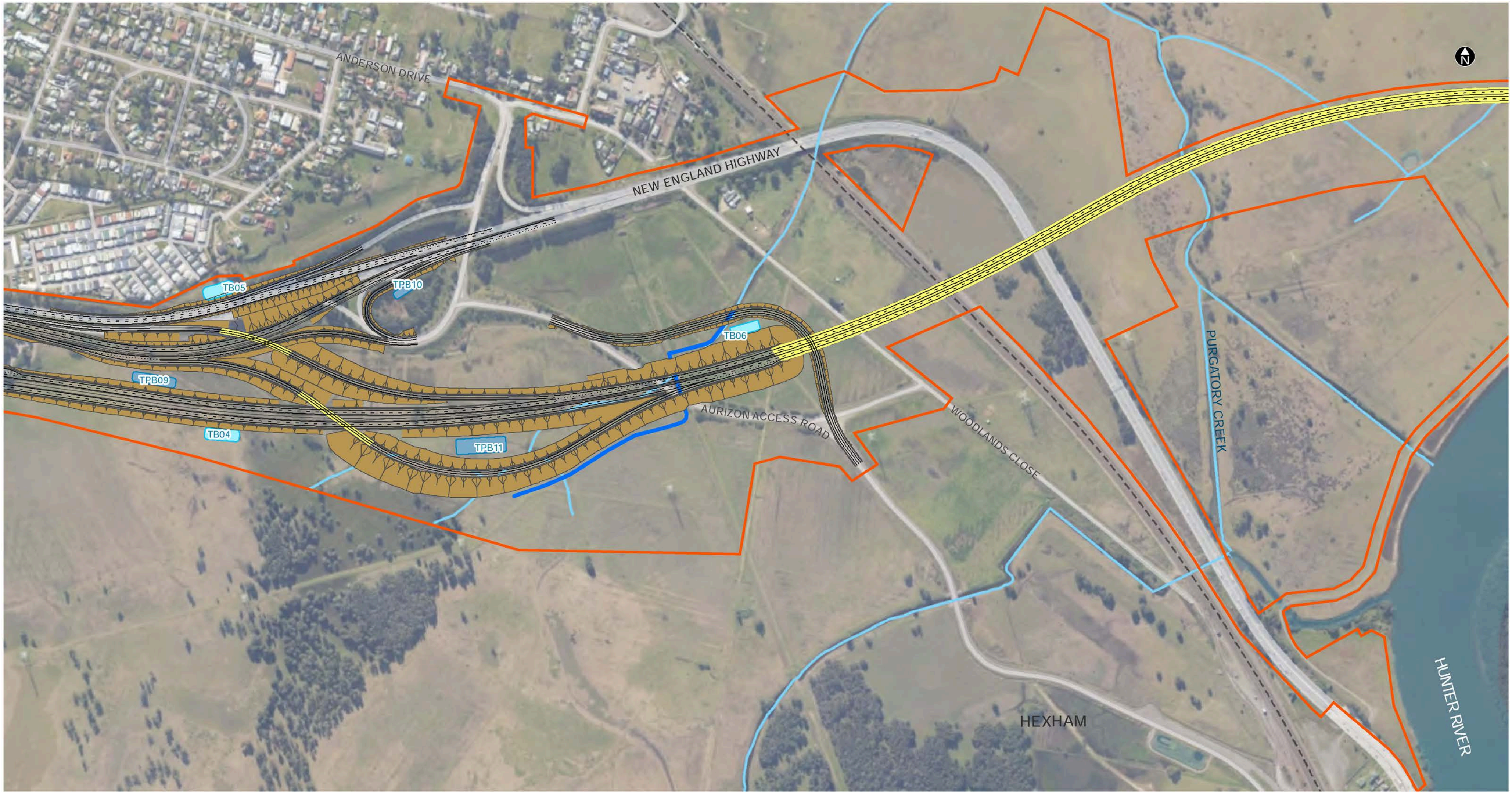

Construction footprint
The project
Bridges/ viaduct
Earthworks fill

Water quality basins
Temporary basin
Temporary to permanent basin
Waterways
Creek diversion

0 150 300 m

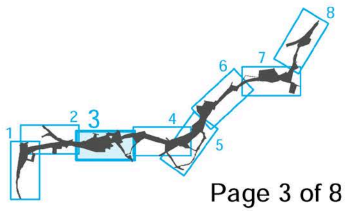

Figure I-1 Proposed temporary construction sediment basins (map 3 of 8)

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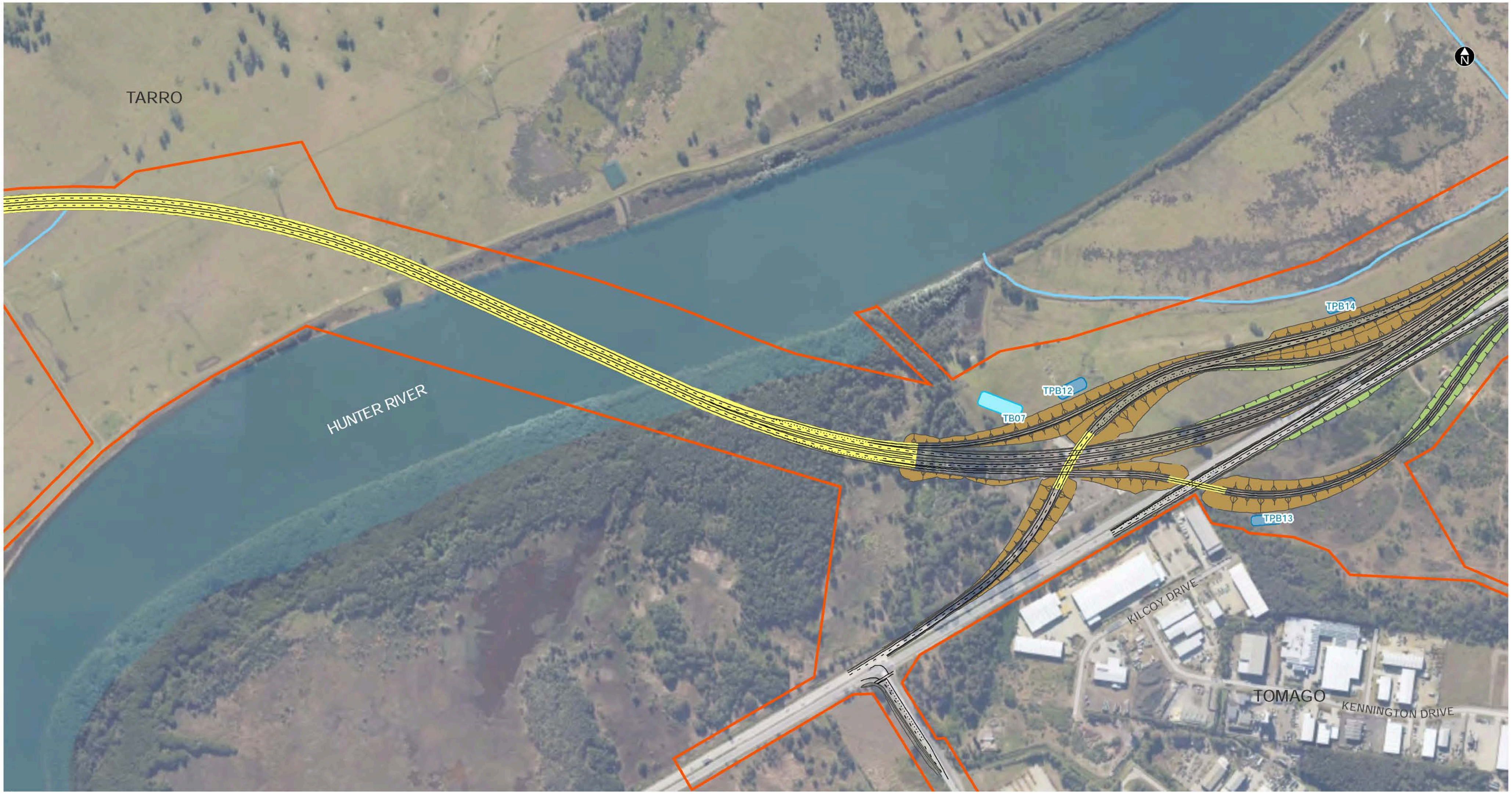
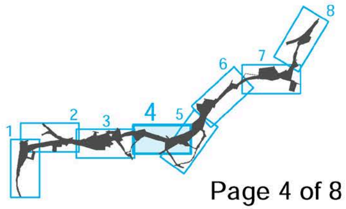


Construction footprint
The project
Bridges/ viaduct
Earthworks cut
Earthworks fill

Water quality basins
Temporary basin
Temporary to permanent basin
Waterways

0 150 300 m



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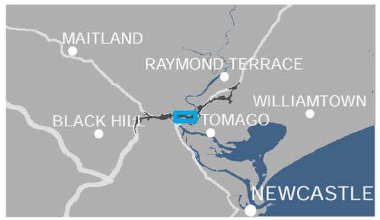

Figure I-1 Proposed temporary construction sediment basins (map 4 of 8)

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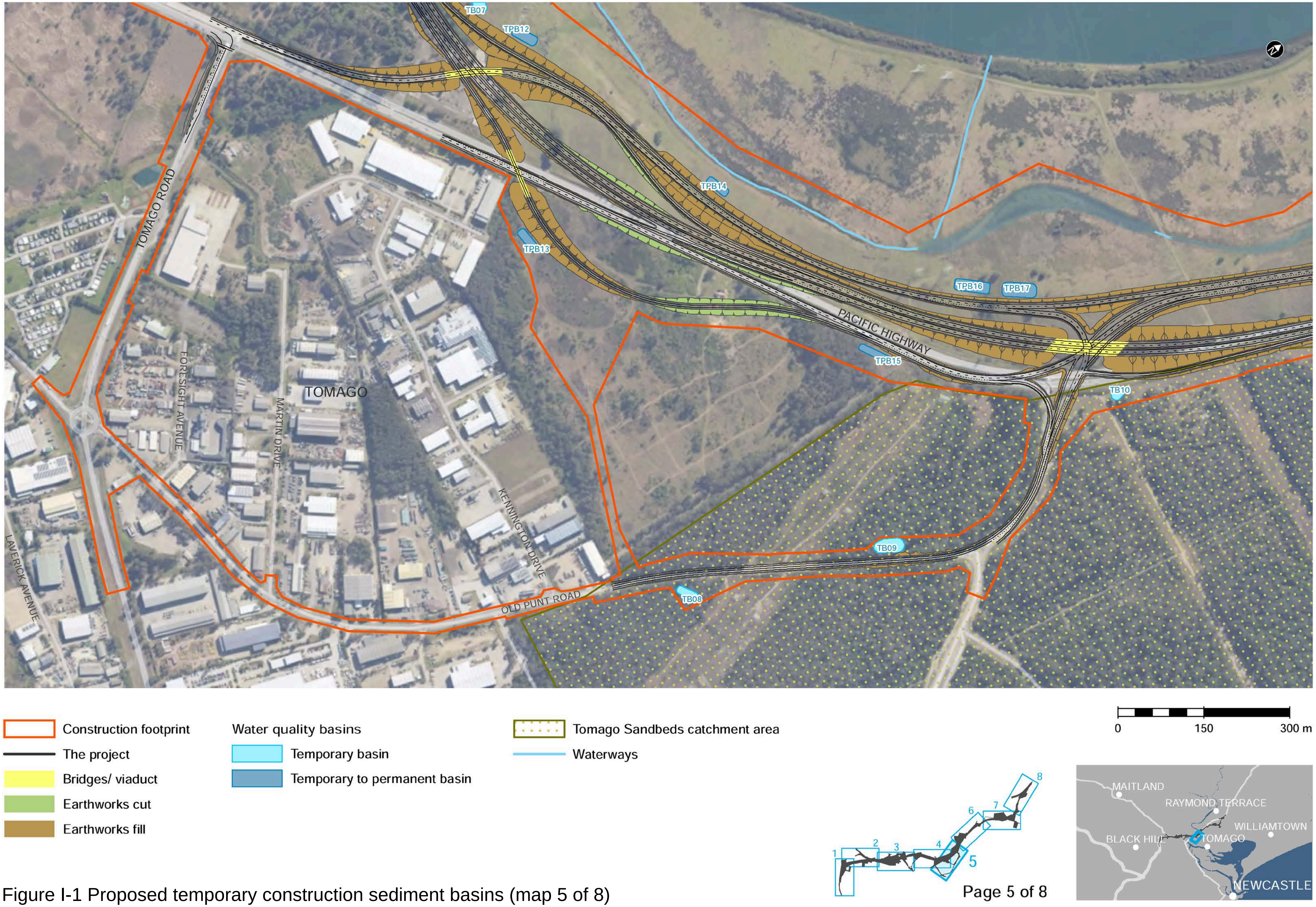

Figure I-1 Proposed temporary construction sediment basins (map 5 of 8)

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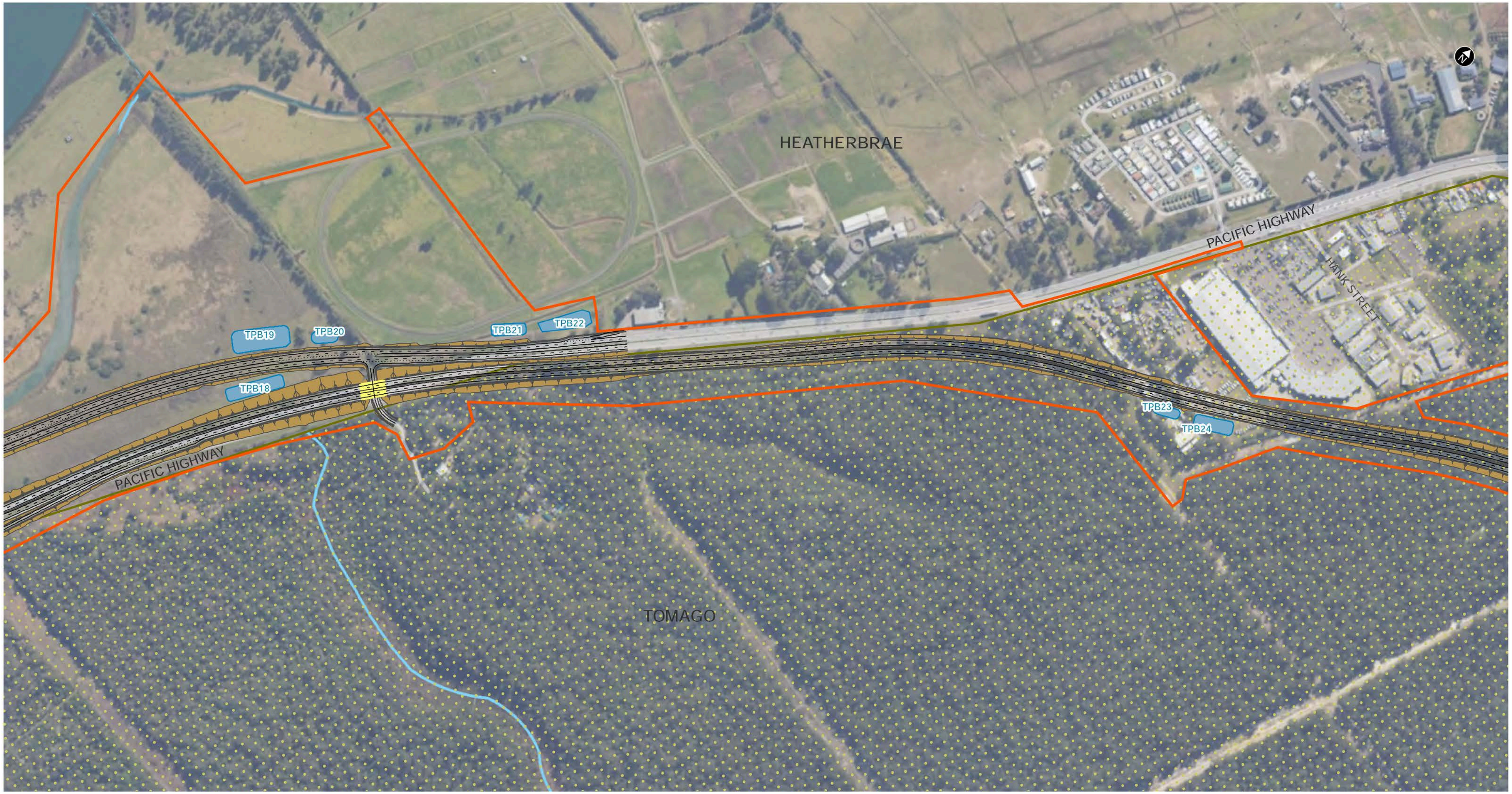

Construction footprint
The project
Bridges/ viaduct
Earthworks fill

Water quality basins
Temporary to permanent basin

Tomago Sandbeds catchment area
Waterways

0 150 300 m

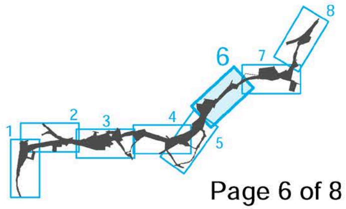

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Figure I-1 Proposed temporary construction sediment basins (map 6 of 8)

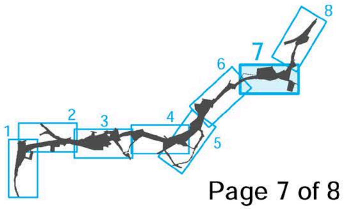
Date: 11/03/2021 Path: \\Jacobs.com\ANZ\IE\Projects\04_Eastern\IA230000\22_Spatial\GIS\Directory\Templates\Figures\EIS\3_TechnicalReports\Surface_Water\IA230000_CD_SW_023_ConstructionDrainageBasins_JAC_A4L_8250_V04.mxd

Construction footprint
The project
Bridges/ viaduct
Earthworks cut
Earthworks fill

Water quality basins
Temporary basin
Temporary to permanent basin

Tomago Sandbeds catchment area
Waterways

0 150 300 m



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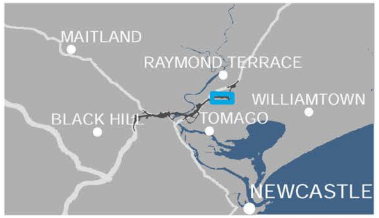

Figure I-1 Proposed temporary construction sediment basins (map 7 of 8)

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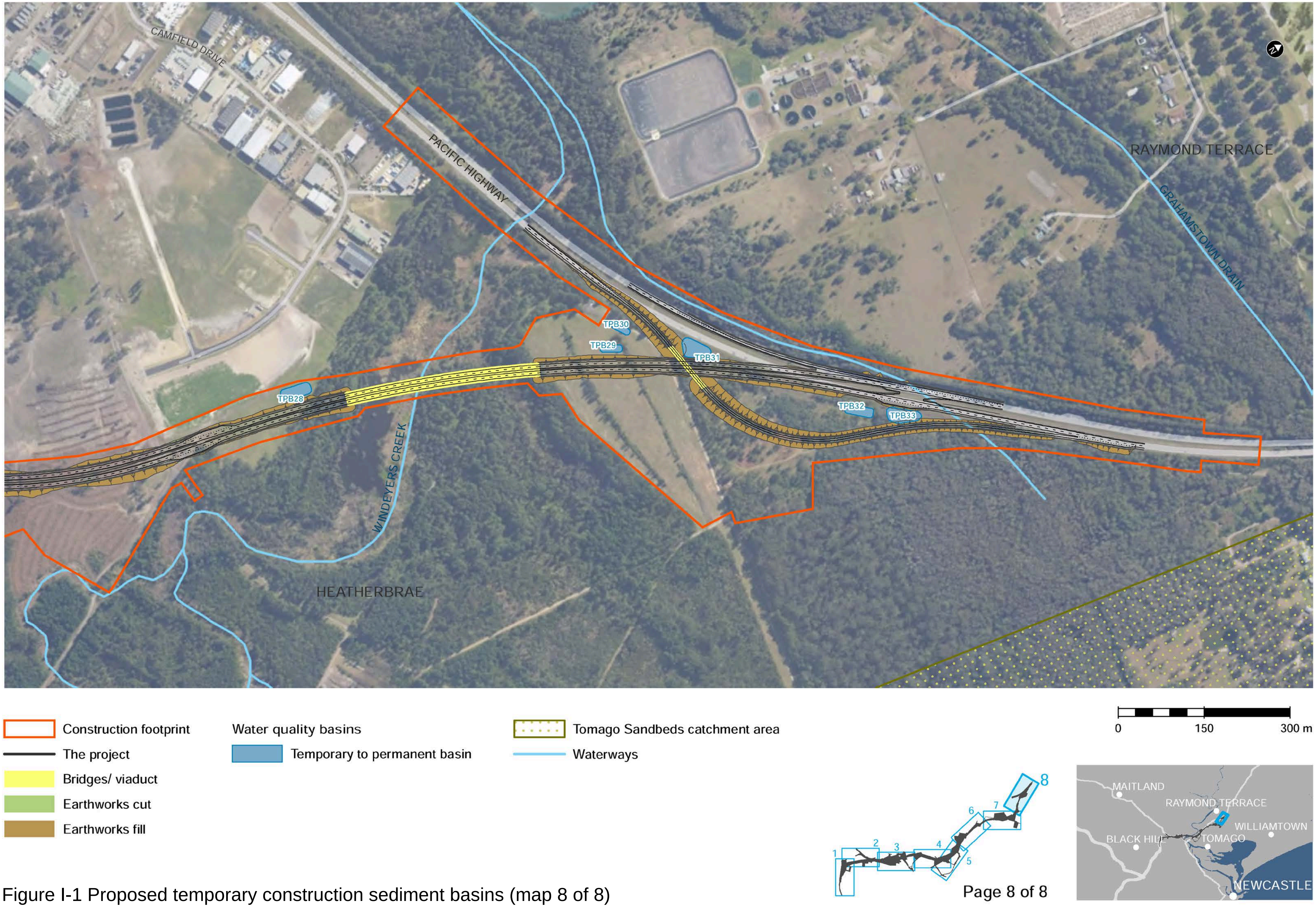

Figure I-1 Proposed temporary construction sediment basins (map 8 of 8)

Date: 11/03/2021 Path: \\Jacobs.com\ANZ\IE\Projects\04_Eastern\IA230000\22_Spatial\GIS\Directory\Templates\Figures\EIS\3_TechnicalReports\Surface_Water\IA230000_CD_SW_023_ConstructionDrainageBasins_JAC_A4L_8250_V04.mxd

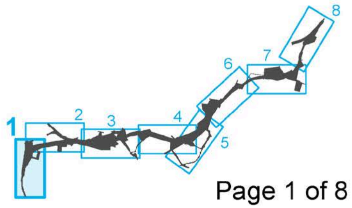

Figure I-2 Proposed permanent operational water quality basins (map 1 of 8)

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Operational footprint

The project

Bridges/ viaduct

Earthworks cut

Earthworks fill

Water quality basins

Proposed location of operational water quality basins

Waterways

Creek diversion

0 150 300 m

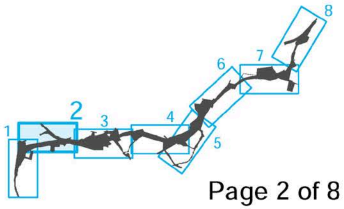

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Figure I-2 Proposed permanent operational water quality basins (map 2 of 8)

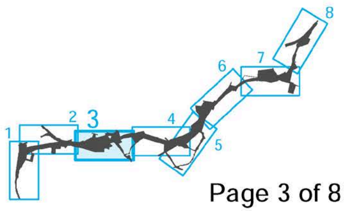
Date: 11/03/2021 Path: \\Jacobs.com\ANZ\IE\Projects\04_Eastern\IA230000\22_Spatial\GIS\Directory\Templates\Figures\EIS\3_TechnicalReports\Surface_Water\IA230000_CD_SW_015_OperationalDrainageBasins_JAC_A4L_8250_V04.mxd

0 150 300 m

- Operational footprint
- The project
- Bridges/ viaduct
- Earthworks fill

Water quality basins

- Proposed location of operational water quality basins
- Waterways
- Creek diversion



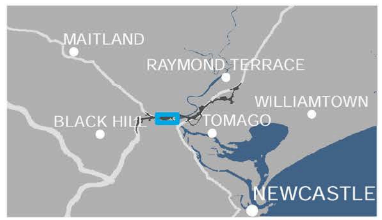


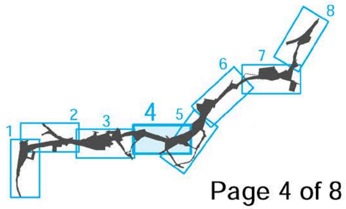
Figure I-2 Proposed permanent operational water quality basins (map 3 of 8)

Date: 11/03/2021 Path: \\Jacobs.com\ANZ\IE\Projects\04_Eastern\IA230000\22_Spatial\GIS\Directory\Templates\Figures\EIS\3_TechnicalReports\Surface_Water\IA230000_CD_SW_015_OperationalDrainageBasins_JAC_A4L_8250_V04.mxd

Operational footprint
The project
Bridges/ viaduct
Earthworks cut
Earthworks fill

Water quality basins
Proposed location of operational water quality basins
Operational biofiltration
Waterways

0 150 300 m



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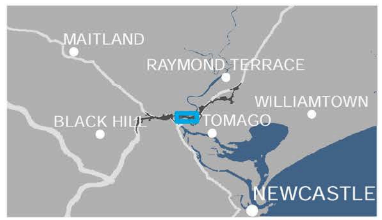

Figure I-2 Proposed permanent operational water quality basins (map 4 of 8)

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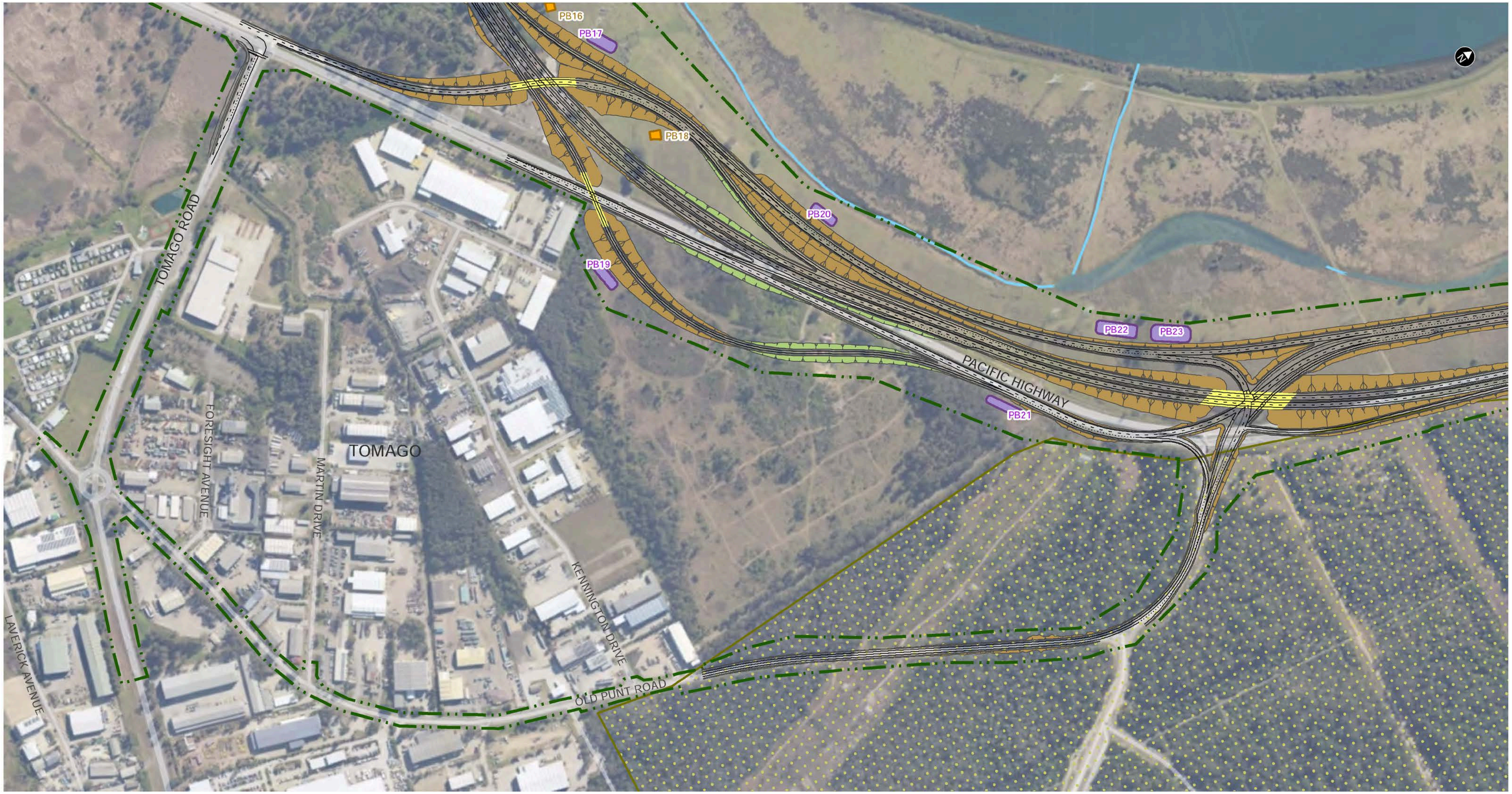

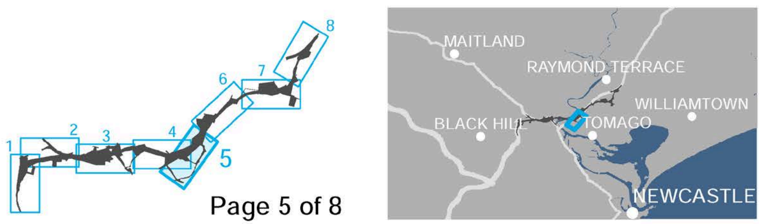

Figure I-2 Proposed permanent operational water quality basins (map 5 of 8)

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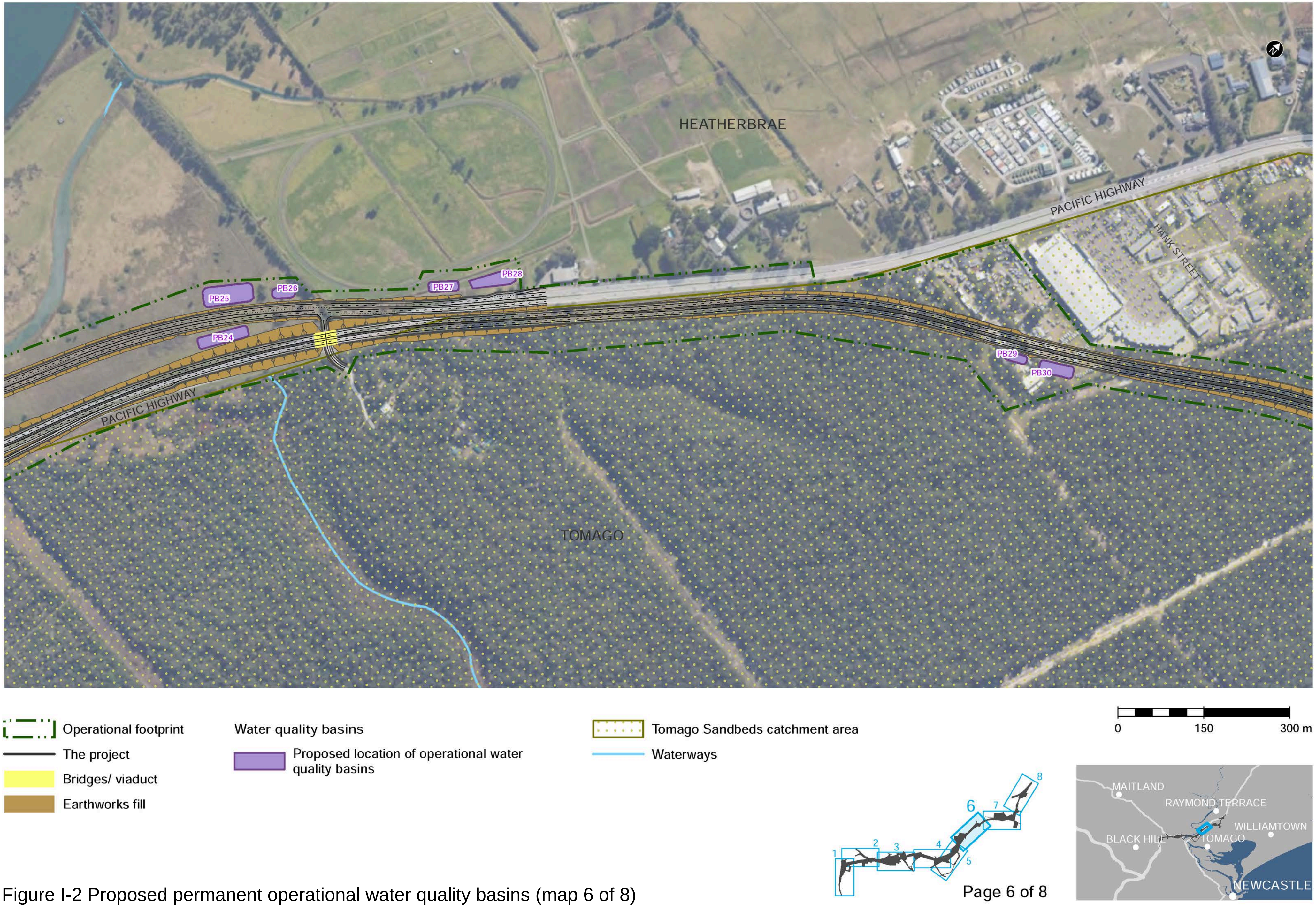

Figure I-2 Proposed permanent operational water quality basins (map 6 of 8)

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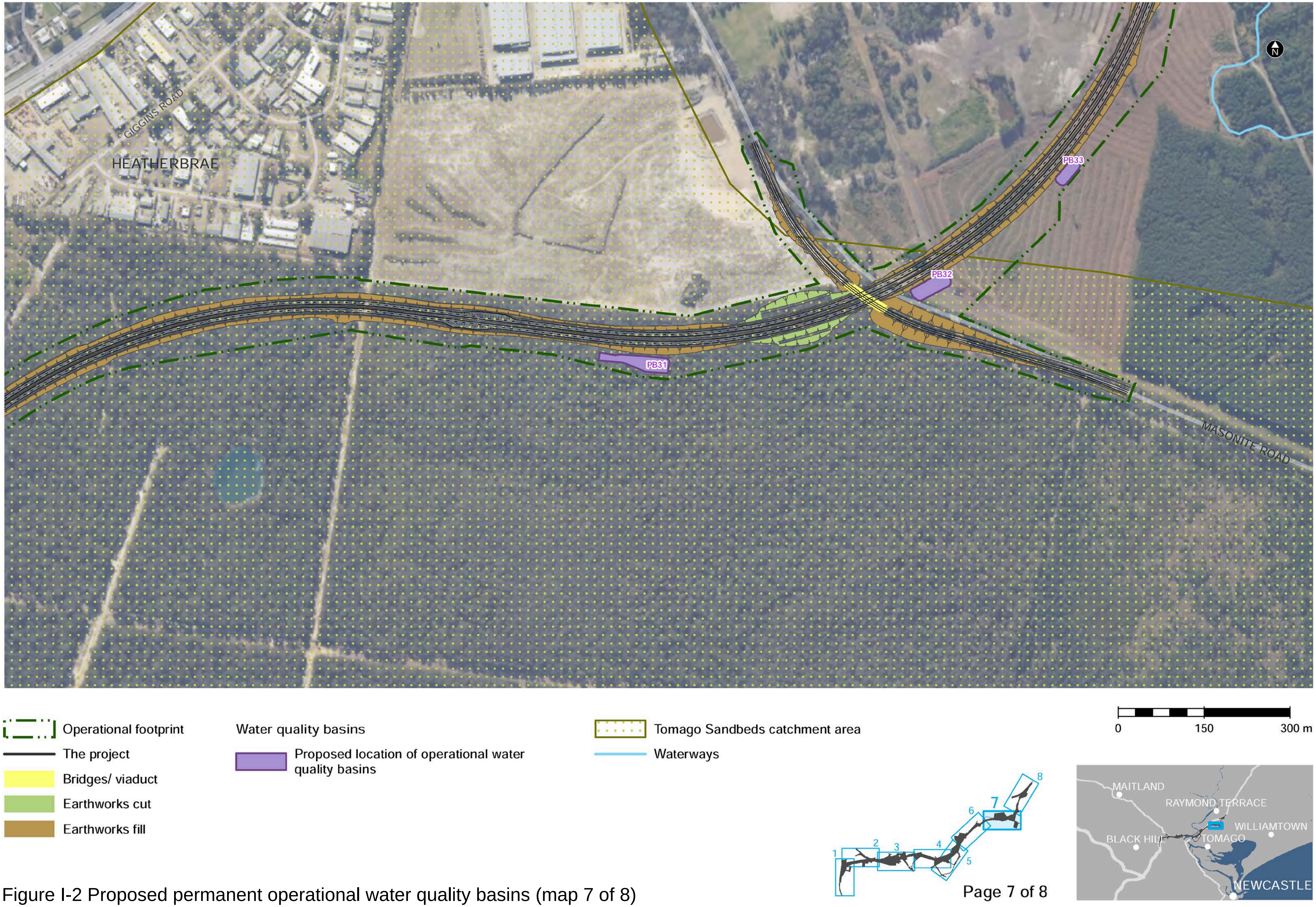

Figure I-2 Proposed permanent operational water quality basins (map 7 of 8)

Date: 11/03/2021 Path: \\Jacobs.com\ANZ\IE\Projects\04_Eastern\IA230000\22_Spatial\GIS\Directory\Templates\Figures\EIS\3_TechnicalReports\Surface_Water\IA230000_CD_SW_015_OperationalDrainageBasins_JAC_A4L_8250_V04.mxd

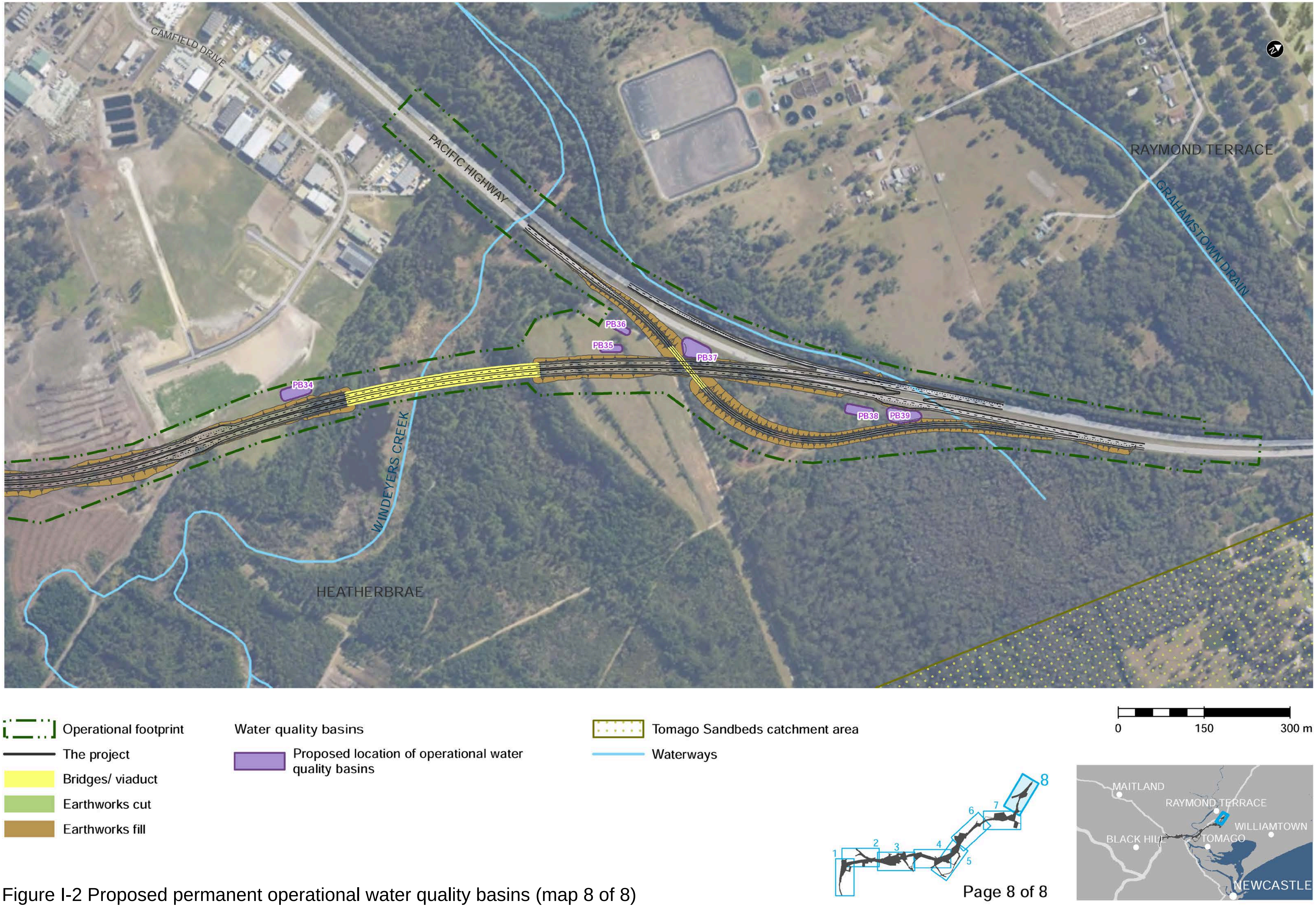

Figure I-2 Proposed permanent operational water quality basins (map 8 of 8)

Date: 11/03/2021 Path: \\Jacobs.com\ANZ\IE\Projects\04_Eastern\IA230000\22_Spatial\GIS\Directory\Templates\Figures\EIS\3_TechnicalReports\Surface_Water\IA230000_CD_SW_015_OperationalDrainageBasins_JAC_A4L_8250_V04.mxd