Soil, surface and groundwater assessment report

Hillsborough Road

Transport for NSW

14 October 2022

→ **The Power of Commitment**

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Executive summary

Transport for NSW (TfNSW) proposes to duplicate a 1.8 kilometre section of Hillsborough Road between the Newcastle Inner City Bypass in the east and the duplicated section of Hillsborough Road about 300 metres west of the intersection with Crockett Street in Warners Bay (the proposal). The report presents the results of the soils, surface and groundwater assessment to inform the Review of Environmental Factors (REF) for the proposal.

The majority of the proposal area is within the catchment of Winding Creek with the western portion of the proposal within the catchment of North Creek. Winding Creek is a mixture of natural and semi-natural channels, as well as concrete-lined channel. These catchments include extensive areas of residential development.

The proposal is underlain by Quaternary aged alluvium in the vicinity of Winding Creek with the remainder of the alignment is underlain by the Permian aged Newcastle Coal Measures. Similarly, aquifers in the proposal area include the alluvium associated with Winding Creek and the underlying fractured rock aquifer associated with the Permian Newcastle Coal Measures. In the vicinity of Winding Creek, groundwater has been observed in test pits and boreholes in the alluvium within a range of 1.2 metres and 3 metres below ground level. Observed groundwater levels in the fractured rock based on observations in test pits and boreholes associated with the proposal are greater than 10 metres below ground level.

Registered groundwater use in the vicinity of the proposal is low. There are no stock, domestic, farming or irrigation bores within one kilometre of the proposal. There are no high priority groundwater dependant ecosystems listed in the relevant Water Sharing Plans within four kilometres of the proposal.

The proposed drainage network for the proposal includes modification of the Winding Creek culvert. The proposal will include the extension of the culvert both upstream and downstream of Winding Creek. There is an extensive history of flooding in the Winding Creek catchment. The design of the Winding Creek culvert will be optimised during detailed design to minimise flooding impacts.

Construction activities associated with the proposal has the potential to generate surface water pollutants including Sediments, entrained in runoff from open excavations, stockpiles and stripped areas, gross pollutants including litter and debris; nutrients including nitrogen and phosphorous; and oils and hydrocarbons from spills or inappropriate waste disposal.

Mitigation measures will be implemented during construction to minimse the potential of pollution of receiving drainage networks and watercourses. Erosion and sediment control measures will be implemented and maintained throughout construction. To mitigate the risk from spills during construction, storage of chemicals and hydrocarbons and refuelling activities will take place in bunded areas.

The updated drainage network will address water quality impacts within the Winding Creek and Lake Macquarie catchment during the operational phase. Preliminary drainage design and modelling during the concept design phase will be refined at the detailed design phase, addressing specific limits for velocity and flow rate.

Construction of the proposal would include excavation for a number of cuttings. Comparison of proposed cutting depths and observed groundwater levels indicates that these cuttings will not intercept groundwater. There is potential that excavations associated with foundations of the Winding Creek culvert extension may intercept alluvial groundwater.

Analytical equations were developed to estimate the potential rate of groundwater inflow into this excavation. As groundwater levels in the alluvium may vary over time due to rainfall trends, the analytical equations were also developed to estimate the potential rate of groundwater inflow into the cuttings within the alluvium. The analytical equations indicated that the rate of groundwater inflow would be low, less than 0.1 cubic metres per day and the associated radius of drawdown would be small, less than 10 metres. Therefore, the proposal will not result in significant drawdown of the regional groundwater table.

Impacts on groundwater level due to dewatering would be managed by minimising the number and size of excavations below groundwater table.

This report should be read in conjunction with the scope and limitations outlined in Section 1.3.

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Abbreviations

AEP	Annual exceedance probability
AHD	Australian Height Datum
AIP	Aquifer Interference Policy
AASS	Actual acid sulfate soils
ASS	Acid sulfate soils
bgl	Below ground level
CEMP	Construction Environmental Management Plan
CNCC	Combined Northern Canine Committee
DTIRIS	Department of Trade and Investment, Regional Infrastructure and Services
GDE	Groundwater dependent ecosystem
GHD	GHD Pty Ltd
HUA WSP	Water Sharing Plan for the Hunter Unregulated and Alluvial Water Sources 2009
km/hr	Kilometres per hour
L/s	Litres per second
LGA	Local government area
LMCC	Lake Macquarie City Council
m	Metres
mm	MIllimetres
m/day	Metres per day
m^3/day	Metres cubed per day
m/year	Metres per year
NICB	Newcastle Inner City Bypass
NSW	New South Wales
NTU	Nephelometric Turbidity Unit
NWQMS	National Water Quality Management Strategy
PASS	Potential acid sulfate soils
ppm	Parts per million
SWMP	Soil and Water Management Plan
WAL	Water Access Licence
WM Act	*Water Management Act 2000*
WSP	Water Sharing Plan
WSUD	Water sensitive urban design
WQO	Water quality objectives
µg/L	Micrograms per litre
µS/cm	Microsiemens per centimeter

1. Introduction

1.1 Background and proposal overview

Transport for NSW (TfNSW) proposes to duplicate a 1.8 kilometre section of Hillsborough Road between the Newcastle Inner City Bypass in the east and the duplicated section of Hillsborough Road about 300 metres west of the intersection with Crockett Street in Warners Bay (the proposal) (see Figure 1.1). The proposal is located within the Lake Macquarie City Council (LMCC) local government area (LGA).

The proposal is located within the 'B57 road corridor', which is a sub-arterial road that extends from Speers Point in the south-west to Charlestown and services west-east journeys for freight and general traffic.

This section of Hillsborough Road also currently serves as the main connection for the residential and commercial areas travelling between Warners Bay and Charlestown. The proposal is required to improve safety, congestion, and reduce delays that are currently experienced along this section of Hillsborough Road and associated connecting roads.

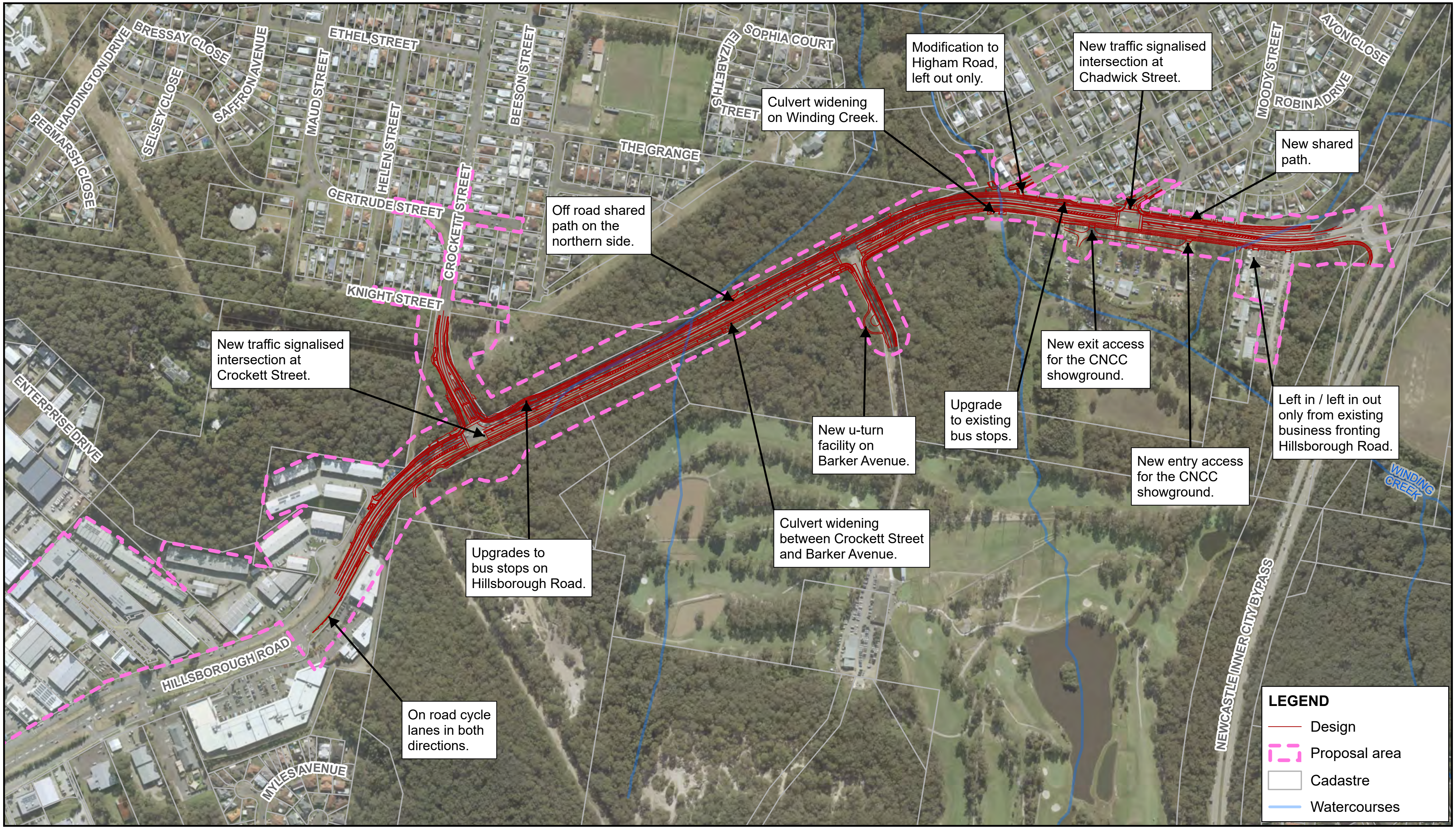
The main land uses surrounding the proposal include the residential area of Hillsborough, Combined Northern Canine Committee Showgrounds (CNCC), Charlestown Golf Club, and Charlestown Recreation Reserve.

Key features of the proposal include:

- Duplication of about 1.8 kilometres of Hillsborough Road from the NICB roundabout west to a tie in point about 300 metres west of Crockett Street.
- Two lanes each a minimum 3.3 metre wide each way with a solid central median barrier.
- Posted speed of 60 kilometres per hour.
- New traffic lights at the Chadwick Street intersection including pedestrian crossings.
- Modification of Higham Road intersection.
- New traffic lights at the Baker Avenue intersection including pedestrian crossing.
- U-turn bay on Barker Avenue.
- Access gates to be relocated beyond u turn facility.
- New traffic lights at the Crockett Street intersection including pedestrian crossings.
- Provision for on road cyclists within shoulder in both directions.
- Off road concrete shared path on the northern side tying into existing path.
- Upgraded bus stop facilities on Hillsborough Road at Crockett Street intersection, Chadwick Street intersection and on Crockett Street. All bus stops are to have shelters with the exception of the southbound bus lay over on Crockett Street.
- Culvert widening on Winding Creek both up stream and down stream of existing culvert structure.
- Culvert widening and full replacement of existing culvert between Crockett Street and Baker Avenue.
- New separated left in only entry and left out only exit for the CNCC Showgrounds located east (entry) and west (exit) of Chadwick Street intersection.
- Maintained access to the Hillsborough Road fire trail opposite Crockett Street.
- Left in / left out only access from existing business fronting Hillsborough Road, east of the CNCC Showgrounds.
- Left in / left out only access to residences on Hillsborough Road, east of CNCC Showgrounds.
- Relocation of utilities including, telecommunications, water, power, street lighting and minor adjustments to sewer infrastructure.
- New as well as upgraded street lighting on Hillsborough Road.
- Reinforced concrete retaining walls including facing panels.
- Site investigations, including but not limited to geotechnical investigations.
- Installation of fauna connectivity structures, such as rope crossings.

– Minor property acquisition and adjustments including fencing, access and driveway adjustments.
– Site preparation works, including establishing ancillary facilities, vegetation clearing, site fencing, temporary drainage measures, and implementation of environmental management measures.

Construction of the proposal is planned to be delivered in stages. The NSW Government has announced $35 million to deliver the first stage of the Hillsborough Road upgrade. Stage 1 involves upgrading Crockett Street intersection, including installation of traffic lights. Stage 1 is expected to commence construction in 2025 and take about 18 months to complete depending on final staging arrangements. Timing for construction of the remaining stages is subject to project approvals and funding.



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Map Projection: Transverse Mercator
Horizontal Datum: GDA2020
Grid: GDA2020 MGA Zone 56

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Project No. **12544418**
Revision No. **0**
Date **13 Oct 2022**

Project location

FIGURE 1.1

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1.2 Purpose of this report

This report was prepared as a working paper as part of, and to inform the Review of Environmental Factors for the proposal. The purpose of this report is to assess the soil, surface and groundwater conditions within the study area of the proposal, identify potential construction and operational impacts of the proposal on the surface water and groundwater environment and recommend feasible and reasonable mitigation measures.

1.3 Scope and limitations

This report has been prepared by GHD for Transport for NSW and may only be used and relied on by Transport for NSW for the purpose agreed between GHD and Transport for NSW as set out in Section 1.2 of this report.

GHD otherwise disclaims responsibility to any person other than Transport for NSW arising in connection with this report. GHD also excludes implied warranties and conditions, to the extent legally permissible.

The services undertaken by GHD in connection with preparing this report were limited to those specifically detailed in the report and are subject to the scope limitations set out in the report. Numerous data were sourced to inform this report including investigation data and publicly available information. GHD has not verified this data and disclaims any liability arising from any of the source data being incorrect.

The opinions, conclusions and any recommendations in this report are based on conditions encountered and information reviewed at the date of preparation of the report. GHD has no responsibility or obligation to update this report to account for events or changes occurring subsequent to the date that the report was prepared.

The opinions, conclusions and any recommendations in this report are based on assumptions made by GHD described in this report. GHD disclaims liability arising from any of the assumptions being incorrect.

2. Relevant policy and guidelines

The following legislation and guidelines are relevant to soil, surface water and groundwater aspects of the proposal.

2.1 Water Management Act 2000

The *Water Management Act 2000* (WM Act) is intended to ensure that water resources are conserved and properly managed for sustainable use benefitting both present and future generations. It is also intended to provide formal means for the protection and enhancement of the environmental qualities of waterways and their in-stream uses as well as to provide for protection of catchment conditions.

From 1 July 2016, the groundwater sources in the vicinity of the proposal are now regulated by the Water Sharing Plan (WSP) for the North Coast Fractured and Porous Rock Groundwater Sources 2016. So, the proposal is located within the Sydney Basin North Coast groundwater source of this WSP. The alluvial and surface water sources in the study area are regulated by the WSP for the Hunter Unregulated and Alluvial Water Sources 2009 (HUA WSP). Under the HUA WSPs, the proposal is located within the North Lake Macquarie Water Source.

Relevant approvals under the Act include water use approvals (section 89), water management work approvals (section 90) and activity approvals (section 91).

Section 89 of the WM Act establishes access licenses for the taking of water within a water management area. Under Clause 18(1) of the *Water Management (General) Regulation 2018*, Transport, as a roads authority, is exempt from the need to obtain an access licence in relation to water required for road construction and road maintenance.

2.2 NSW Aquifer Interference Policy

The NSW Aquifer Interference Policy (AIP) (Department of Trade and Investment, Regional Infrastructure and Services (DTIRIS) 2012) was finalised in September 2012 and clarifies the water licencing and approval requirements for aquifer interference activities in NSW.

This policy outlines the water licensing requirements under the WM Act. These licensing requirements are discussed in Section 2.1.

The AIP requires that potential impacts on groundwater sources, including their users and groundwater dependant ecosystems, be assessed against the minimal impact considerations outlined in the policy. If the predicted impacts of the proposal are less than the minimal impact considerations, then the potential groundwater impacts of the proposal are acceptable.

2.3 Protection of the Environment Operations Act 1997

The *Protection of the Environment Operations Act 1997* (POEO Act) is administered by the NSW Environment Protection Authority (EPA), which is an independent statutory authority and the primary environmental regulator for NSW. The objectives of the POEO Act are to protect, restore and enhance the quality of the environment. Some of the mechanisms that can be applied under the POEO Act to achieve these objectives include programs to reduce pollution at the source and monitoring and reporting on environmental quality. The POEO Act regulates and requires licensing for environmental protection, including for waste generation and disposal and for water, air, land and noise pollution.

Road construction is a scheduled activity under Schedule 1 of the POEO Act if it results in four or more traffic lanes (not including bicycle lanes or lanes used for entry or exit), where the road is classified or proposed to be classified as a main road for at and least three kilometres of its length in the metropolitan area. Extractive industries is also a scheduled activity under Schedule 1 of the POEO Act.

While the proposal involves four or more traffic lanes and Hillsborough Road is classified as a main road, the proposal is about 1.8 km in length. The proposal would not result in the extraction of more than 30,000 tonnes of material per year. Therefore, an Environment Protection Licence (EPL) would not be required for the proposal.

2.4 NSW State Groundwater Policy Framework Document

The objective of the NSW State Groundwater Policy Framework Document (NSW Department of Land and Water Conservation (DLWC) 1997) is to manage the State's groundwater resources so that they can sustain environmental, social and economic uses for the people of NSW. The policy has three component parts:

– NSW Groundwater Quantity Protection Policy
– NSW Groundwater Quality Protection Policy
– NSW Groundwater Dependent Ecosystem Policy

The *Draft Guide to Groundwater Management in NSW* (NSW Department of Planning and Environment, 2022) is intended to 1997 NSW State Groundwater Policy Framework Document.

2.5 Transport for NSW Groundwater Assessment Guideline

The Transport for NSW Groundwater Assessment Guidelinee has been developed as a companion to the templates and guidance notes developed as part of the Transport for NSW Environmental Impact Assessment Procedures and Guidelines. The purpose of the Groundwater Assessment Guideline is to guide the assessment, mitigation and management of groundwater impacts required for Transport for NSW development projects.

The requirements of this guideline have been incorporated into the groundwater modelling investigation and impact assessment discussed in Section 3.2, Section 5.2 and Section 6.3.

2.6 Managing Urban Stormwater – Soils and Construction Volume 1 and Volume 2D – Main road construction

The principles for the management of stormwater during construction are documented in Managing Urban Stormwater – Soils and Construction Volume 1 (Landcom 2004) and Volume 2D – Main road construction (DECC 2008). These guidelines are commonly referred to in the construction industry as "the Blue Book". The Blue Book provides guidelines to help mitigate the impacts of land disturbance activities on soils, landforms and receiving waters by focussing on erosion and sediment control.

The proposal has the potential to impact on stormwater during the construction period. These guidelines have been used to develop mitigation measures to manage potential construction phase risks, presented in Section 5.1.

2.7 Water Sensitive Urban Design Guideline

The Water Sensitive Urban Design Guideline (RMS 2017) provides guidance on how to best apply water sensitive urban design (WSUD) to NSW transport projects. The guideline also provides a process to ensure that broader infrastructure design aspects are considered in the adoption of WSUD.

The guidelines have been used to develop the operational water quality measures discussed in Section 2.7.

2.8 Technical Guideline: Temporary stormwater drainage for road construction

The Technical Guideline: Temporary stormwater drainage for road construction (RMS 2011) provides design considerations and example drawings to assist Transport for NSW and contractor project management teams to plan and design for temporary stormwater drainage on Transport for NSW construction sites. The use of the Guideline is intended to support improved environmental performance and efficient construction delivery.

The proposal has the potential to impact on stormwater drainage during the construction period. This technical guideline has been used to develop mitigation measures to manage potential construction phase drainage, discussed in Section 5.1.

2.9 Procedure for selecting treatment strategies to control road runoff (RMS 2003)

The Procedure for selecting treatment strategies to control road runoff (RMS 2003) applies to stormwater treatment during the operation of roads following construction.

This procedure has been used to develop the operational water quality measures discussed in Section 7.

2.10 NSW Water Quality and River Flow Objectives

The NSW Water Quality Objectives are the agreed environmental values and long-term goals for NSW's surface waters. They set out the community's values and uses for our rivers, creeks, estuaries and lakes (i.e. healthy aquatic life, water suitable for recreational activities like swimming and boating, and drinking water). The guidelines develop a range of water quality indicators to assess the current condition of waterways supports those values and uses.

Water Quality Objectives have been agreed for Fresh and Estuarine surface waters*.* The Objectives are consistent with the agreed national framework for assessing water quality set out in the ANZECC (2000) Guidelines. These guidelines provide an agreed framework to assess water quality in terms of whether the water is suitable for a range of environmental values (including human uses). The Water Quality Objectives provide environmental values for NSW waters and the ANZECC (2000) Guidelines provide the technical guidance to assess the water quality needed to protect those values.

The Water Quality Objectives for Lake Macquarie, the catchment that the proposal is located within, are discussed in Section 3.2.3.

The River Flow Objectives are the agreed high-level goals for surface water flow management. They identify the key elements of the flow regime that protect river health and water quality for ecosystems and human uses.

2.11 National Water Quality Management Strategy

Since 1992, the National Water Quality Management Strategy (NWQMS) has been developed by the Australian and New Zealand Governments in cooperation with state and territory governments. The NWQMS aims to protect the nation's water resources, by improving water quality while supporting the businesses, industry, environment and communities that depend on water for their continued development. The NWQMS consists of three major elements: policy, process and guidelines. The main policy objective of the NWQMS is to achieve sustainable use of water resources, by protecting and enhancing their quality, while maintaining economic and social development. The process strives to form a nationally consistent approach to water quality management through the development of high-status national guidelines. The guidelines provide the point of reference when issues are being determined on a case-by-case basis. These include guidance on regulatory and market-based approaches to managing water quality as well as regional water quality criteria.

3. Assessment methodology

3.1 Overview

The aim of this study is to assess the potential surface water quality and groundwater impacts from the operation and construction of the Hillsborough Rd upgrade, where required, identify feasible and reasonable management measures.

The assessment incorporated high-level consideration of a wider area than the proposed boundaries. This included the consideration of surface water and groundwater receptors within a radius of approximately three kilometres of the proposed boundaries, referred to herein as the study area. The extent of the study area is shown in Figure 3.1.

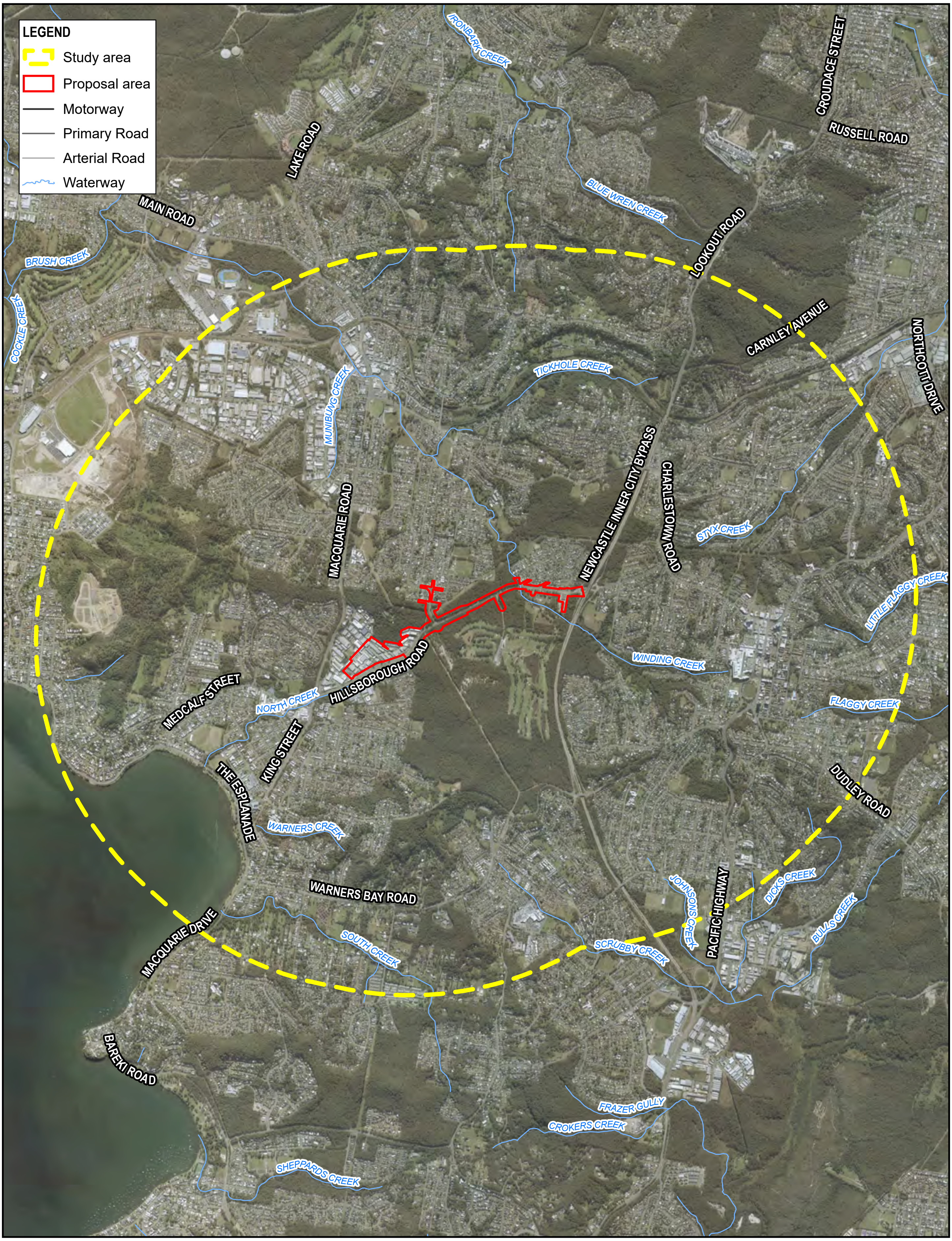
This groundwater assessment includes characterisation of the existing groundwater conditions, including groundwater level, and identification of potential groundwater receptors. The assessment included the identification of locations where groundwater may be intercepted by the proposal. There are no major cuts cuts proposed for the Hillsborough Road upgrade, however this methodiology is valid in estimating groundwater ingress where groundwaters may be intercepted. This method, utilising analytical equations from Marinelli and Niccoli (2000) to estimate the groundwater take and groundwater drawdown. Further information on the modelling methodology is provided in Section 3.2.1. Groundwater impacts have been assessed against the criteria specified in the NSW AIP. Groundwater management measures have been identified as part of this groundwater assessment.

The surface water assessment included a review of soils, topographic information, climate and rainfall, along with potential sensitive receiving environments downstream of the proposal. The assessment included a discussion of construction methodologies and operational impacts in terms of the relevant legislation and guidelines.

3.2 Impact assessment methodology

The following tasks were undertaken:

– Consideration of the location of the proposal area in the context of surrounding and upstream catchment areas and potential influence of downstream waterways (in particular Winding Creek).
– Identification of construction activities likely to impact on surface water quality and groundwater.
– Review of the reference design and activities likely to cause an impact on water quality and groundwater.
– Assessment of water quality. The water quality assessment has included:
  - A desktop review of available information (e.g. soils, rainfall, existing drainage lines and watercourses, downstream sensitive receiving environments, historic data, previous assessments.
  - Identify the relevant water quality objectives, based on the relevant guidelines.
  - An assessment of the potential impacts of the proposal on the surrounding water quality during construction and operational phases, against the water quality objectives.
  - Identification of mitigation measures, including erosion and sediment controls (including consideration of the requirement for sediment basins: as per the Blue Book) that would be required during construction and operational phases.
  - Conclusion identifying residual impacts and any further required studies.
– Estimation of groundwater inflows for construction elements that may intercept groundwater using the analytical equations and approach outlined in Marinelli and Niccoli (2000).
– Assessment of potential groundwater impacts against the criteria specified in the NSW AIP.
– Assessment of the expected residual impacts on surface water following the implementation of measures and controls.



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Map Projection: Transverse Mercator
Horizontal Datum: GDA2020
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Study area

FIGURE 3.1

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3.2.1 Groundwater inflow estimate

Preliminary groundwater inflow estimates have been carried out using the analytical equations and approach outlined in Marinelli and Niccoli (2000). The equations presented by Marinelli and Niccoli (2000) provide a simple means of estimating steady state or long-term average inflows to an excavation or cutting. This method is often used in larger projects such as mining operations with cuts and fills of mine pits.

The solutions presented consider:

– The effect of decreased saturated thickness near the cutting walls.
– Distributed recharge to the water table.
– Upward flow through the bottom of the cutting.

Separate flow calculations are carried out for inflow into the cutting walls (Q1, Zone 1) and excavation base (Q2, Zone 2) (Figure 3.2). Assumptions inherent in the flow calculation for Zone 1 include:

– Cutting walls are approximated as a circular cylinder.
– Groundwater flow is horizontal (Dupuit - Forchheimer approximation is valid).
– The static (pre-mining (cutting)) water table is horizontal.
– Groundwater flow toward the cutting is axially symmetric.
– Uniform distributed recharge occurs across the site as a result of surface infiltration.
– All recharge in the radius of influence is captured by the cutting.
– The perched aquifer extends below the base of the cutting.

Assumptions relevant to Zone 2 include:

– Hydraulic head is initially uniform throughout the zone. Initial head is equal to the elevation of the initial water table in Zone 1.
– The disk sink has constant hydraulic head equal to the elevation of the pit late water surface. If the excavation is completely dewatered the disk sink is equal to the elevation of the bottom of excavation.
– Flow to the disk sink is three dimensional and axially symmetric.
– Materials in Zone 2 are anisotropic and the principal co-ordinate directions for hydraulic conductivity are horizontal and vertical.

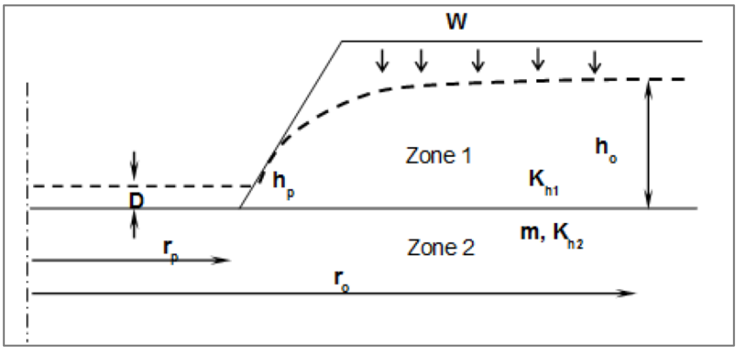


Figure 3.2 Pit inflow hydraulic model (Marinelli and Niccoli 2000)

Relevant equations presented in Marinelli and Niccoli (2000) are:

$$h_o = \sqrt{h_p^2 + \frac{W}{K_{h1}}\left(r_o^2 \ln\left(\frac{r_o}{r_p}\right) - \left(\frac{r_o^2 - r_p^2}{2}\right)\right)}$$

$$Q_1 = W\pi\left(r_o^2 - r_p^2\right)$$

$$Q_2 = 4r_p\left(\frac{K_{h2}}{m_2}\right)(h_o - d)$$

$$m_2 = \sqrt{\frac{K_{h2}}{K_{v2}}}$$

Where:

- – h_o = Initial (pre-mining (cutting)) saturated thickness (metres above base of pit (cut))
- – h_p = Saturated thickness at pit wall (metres above base of pit (cut))
- – W = Distributed recharge flux (metres per day)
- – K_{h1} = Horizontal hydraulic conductivity Zone 1 (metres per day)
- – K_{h2} = Horizontal hydraulic conductivity Zone 2 (metres per day)
- – K_{v2} = Vertical hydraulic conductivity Zone 2 (metres per day)
- – r_p = Effective pit (cut) radius (metres)
- – r_o = Radius of influence (metres)
- – d = Depth of the pit (cut) lake (metres)

3.2.2 Modelling input data

Data sources and assumptions used to derive input values for each of the parameters required for the equations developed by Marinelli and Niccoli (2000) are outlined in the following sections.

3.2.2.1 Initial (pre-construction) saturated thickness (h_o)

As discussed in Section 5.2, observed groundwater levels are below the base of the cuttings. It should be noted that monitored groundwater levels are indicative of conditions at the time at which monitoring occurred and that groundwater levels may increase or decrease over time. Therefore, as part of this assessment, it was assumed that alluvial groundwater is present 0.7 metres below ground level (0.5 metres higher than observed alluvial groundwater levels).

3.2.2.2 Saturated thickness at pit wall (h_p)

The cuttings are assumed to be fully dewatered during construction and fully drained during operation. Therefore, the saturated thickness at cut wall (h_p) was assumed to be equal to zero.

3.2.2.3 Distributed recharge flux (W)

Based on climate and rainfall investigations explained in Section 4.14.1, a net recharge rate of 5% (Douglas Partners, 2013) of long-term average rainfall recorded at the grid point –32.95, 151.65 from the Queensland Governments' daily meteorological database SILO (SILO 2022) was adopted for the assessment. This station was adopted for the assessment based on the length and the quality of the data record and the proximity to the site. The long-term average annual rainfall over the period from January 1957 to April 2022 was 1134.6 millimetres per year. A net recharge rate of 5% gives an estimated long-term average recharge rate of 1.55×10^{-4} metres per day.

3.2.3 Water quality objectives

The proposal is located within the catchment area of Lake Macquarie, in the section of the catchment identified as "Waterways affected by urban development" by the NSW Water Quality and River Flow Objectives.

The Water Quality Objectives (WQOs) of the Lake Macquarie catchment are based on trigger values for aquatic ecosystems for lowland rivers draining to the coast as drawn from the ANZECC guidelines. These trigger values are:

- – Total phosphorus – 25 µg/L
- – Total nitrogen – 350 µg/L
- – Chlorophyll-a – 5 µg/L
- – Turbidity – 6–50 NTU
- – Salinity (electrical conductivity) – 125–2200 µS/cm
- – Dissolved oxygen – 85–110%
- – pH – 6.5–8.5

Trigger values are the numeric criteria that if exceeded indicate potential for harmful environmental effects to occur. If they are not exceeded, a very low risk of environmental damage can be assumed. If they are exceeded, further investigation is "triggered" for the pollutant concerned.

4. Existing environment

4.1 Rainfall

A historical record of climate data was obtained in the form of a point data set from the Scientific Information for Land Owners (SILO) database operated by the Queensland Department of Environment and Science (DES). SILO point data is based on spatially interpolating observed historical data from surrounding Bureau of Meteorology (BoM) stations (DSITI, 2021).

Data have been obtained from SILO grid point -32.95 (latitude) and 151.65 (longitude). This point is located approximately 1.5 kilometres north west of the proposal. The period of rainfall data used for this assessment extended from January 1957 to March 2022.

The historical SILO annual rainfall data between 1901 and 2022 are shown in Figure 4.1. Average monthly rainfall is shown in Figure 4.2.

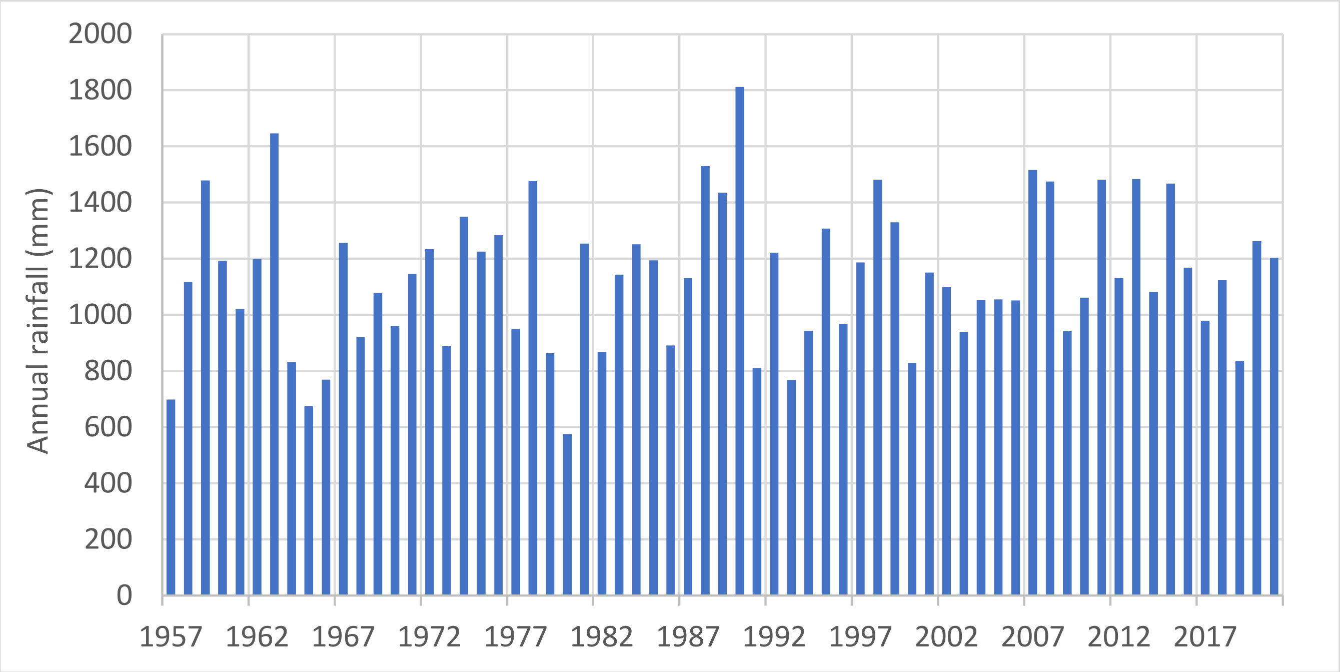


Figure 4.1 Historical annual rainfall

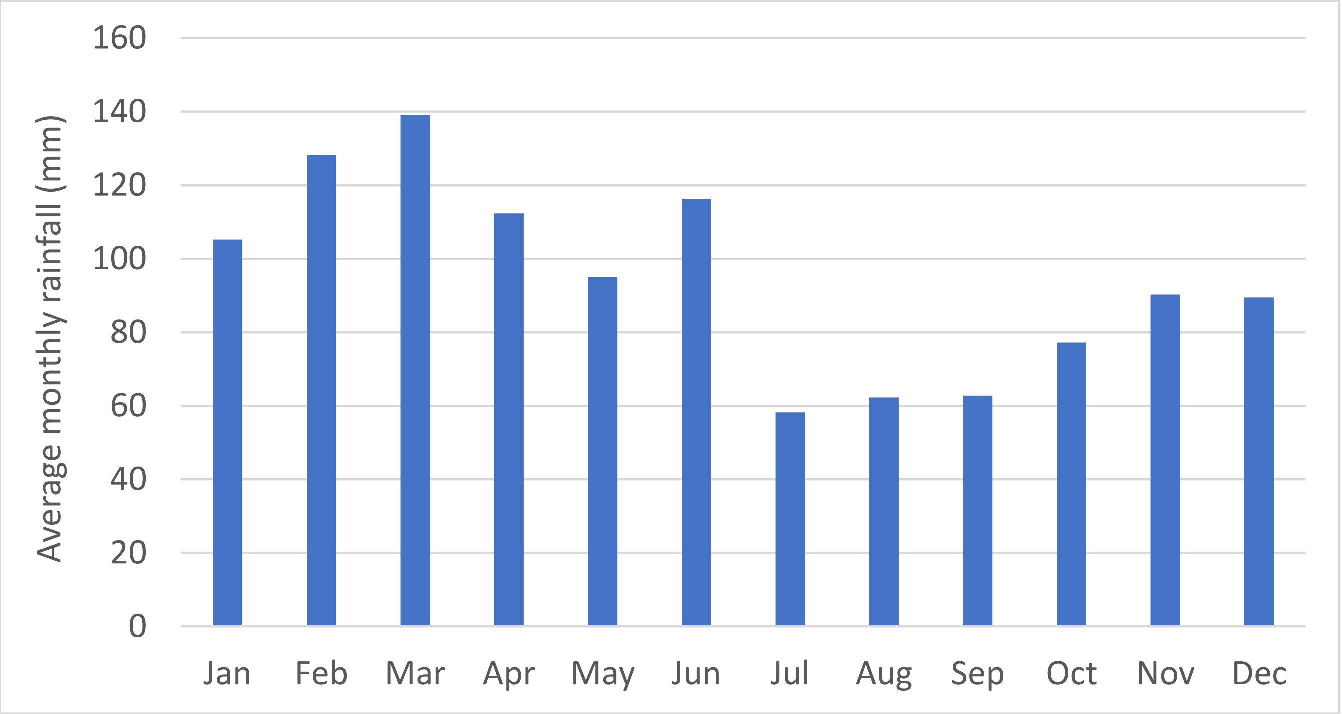
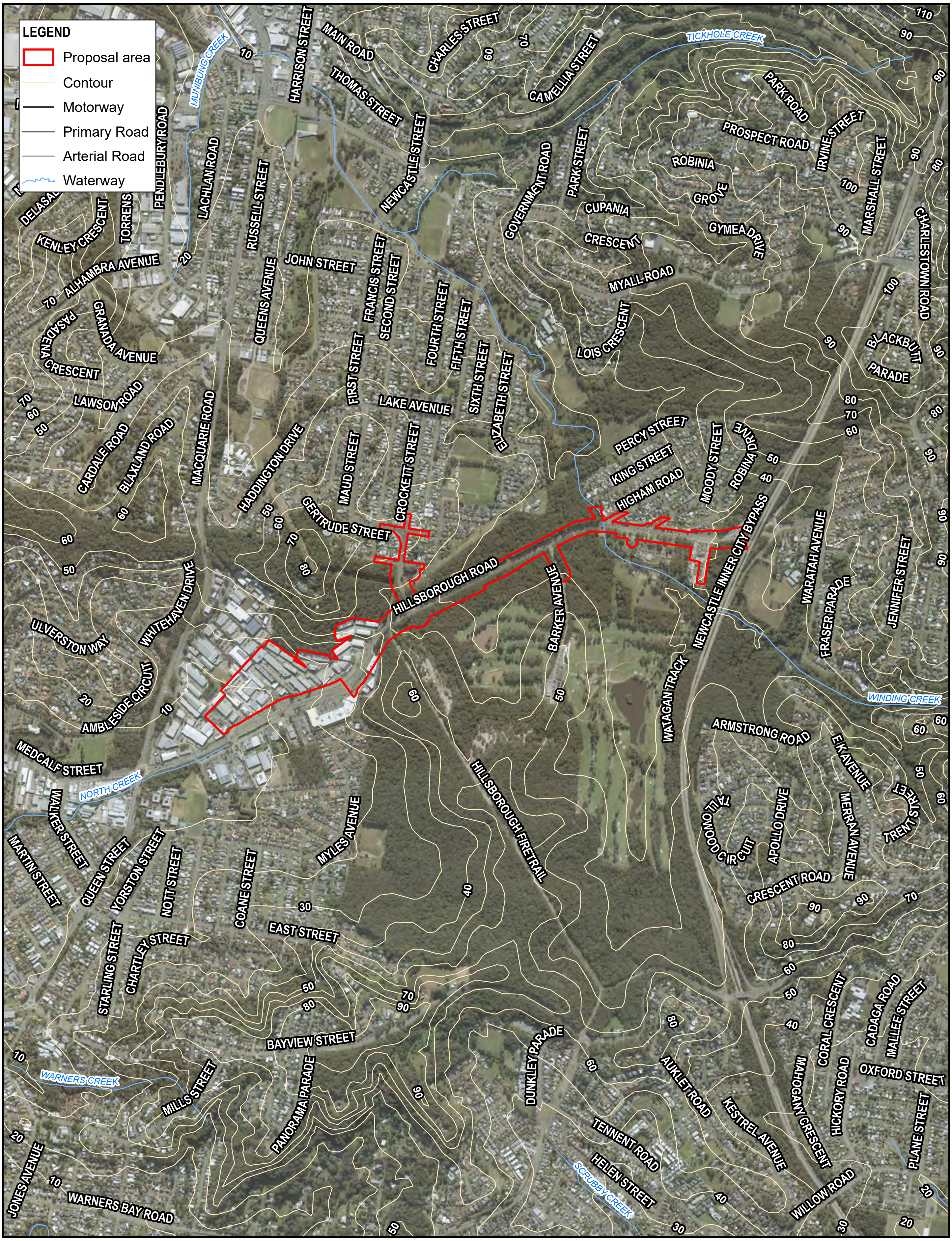


Figure 4.2 Average monthly rainfall

As shown in Figure 4.2 average monthly rainfall varies from a high of 139 millimetres (mm) in March to a low of 58 mm in July.

4.2 Topography

Ground surface levels near Crockett Street (close to the western end of the alignment) are approximately 40 metres Australian Height Datum (AHD), falling gently eastwards towards Winding Creek. To the east of Winding Creek, ground surface levels gradually increase to approximately 40 metres AHD at the eastern end of the proposal. To the west of the intersection of Crockett Street and Hillsbrough Road, ground surface levels fall towards North Creek. Topographic contours are shown in Figure 4.3.



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Date **13 Oct 2022**

Topography contours

FIGURE 4.3

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Data source: Metromap Tile Service: . Created by: tmorton

4.3 Geology

4.3.1 Surface geology

As shown in Figure 4.4, the 1:100,000 scale Newcastle Coalfield Regional Geology Map (Department of Mineral Resources, 1994), indicates that the eastern 200 metres of the alignment is underlain by the Permian aged Newcastle Coal Measures which typically comprises conglomerate, sandstone, siltstone, coal and tuff. Heading west, the alignment transitions into a 300 metres long section of Quaternary aged alluvium associated with Winding Creek. The remainder of the alignment is underlain by the Permian aged Newcastle Coal Measures.

MinView and DIGS database records (Ref. R00026064) indicate that kaolin clay was quarried from the Mount Hutton Formation to the south of Hillsborough Road for brick making purposes.

Historical mining records held by Subsidence Advisory NSW indicate shallow abandoned coal mine workings exist west of Crockett Street and beneath Hillsborough Road in the Australasian Seam (Cardiff Borehole Colliery, Record Tracing 339, discontinued 1932). Abandoned workings in the Hartley Hill Seam to the north of Hillsborough Road are also recorded (Camden Colliery, Record Tracing 642, abandoned 1923). Reference should be made to the *Hillsborough Road Concept Design Mine Subsidence Report – Phase 1* (GHD, 2022a) as part of this investigation for more details relating to previous working in the area.

4.3.2 Subsurface investigations

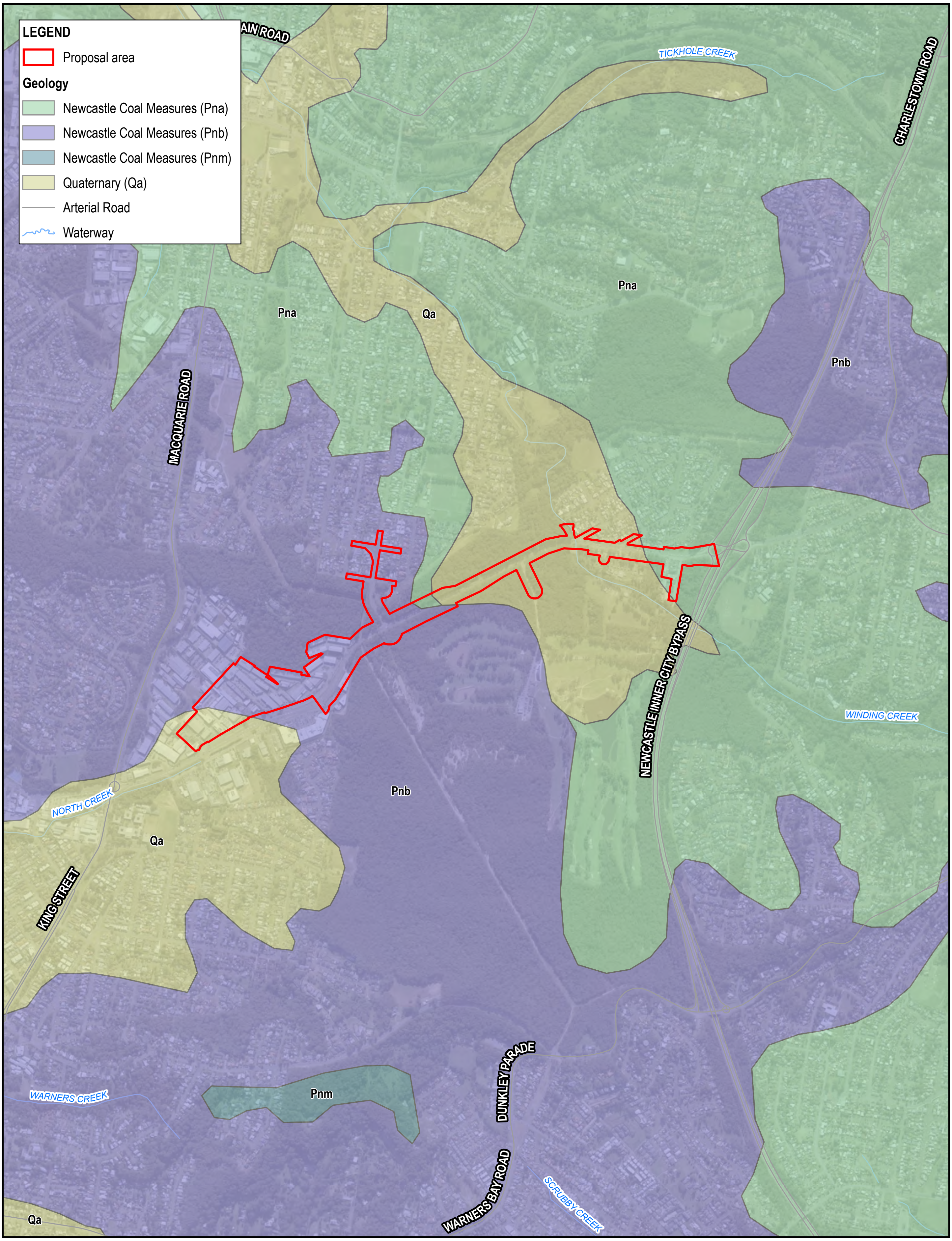
As part of the *Hillsborough Road Concept Design Geotechnical Interpretive Report* (GHD, 2022b) existing geotechnical reports/data were reviewed to identify the subsurface stratigraphic unit near the proposal area.

Referring to the borehole, test pit and pavement core test pit logs, the subsurface stratigraphic units were identified by GHD (2022b) and have been summarised in Table 4.1. The stratigraphic units have been separated into sub-units based on rock type (lithology), summarised in Table 4.1.

Table 4.1 Summary of stratigraphic unit descriptors

Unit	Descriptor	Sub-unit	General description
1	Pavement, topsoil and general fill	1A	Asphalt
		1B	Bound pavement
		1C	Unbound pavement
		1D	Topsoil
		1E	General fill
2	Alluvial soils	2A	Soft cohesive material
		2B	Firm cohesive material
		2C	Stiff to very stiff or hard cohesive material
		2D	Loose non-cohesive material
		2E	Medium dense or dense non-cohesive material
3	Residual soils	3A	Firm cohesive material
		3B	Stiff to very stiff or hard cohesive material
4	Rock	4A	Extremely low strength sandstone
		4B	Medium to high strength tuffaceous sandstone
		4C	Coal/predominantly carbonaceous material
		4D	Extremely low strength tuffaceous siltstone or claystone
		4E	Medium strength siltstone

An overview of the inferred geological model for the alignment suggests that the alignment is dominated by Unit 1 fill or topsoil strata overlying Unit 3 residual soils. Alluvial strata (Unit 2) was only present in the vicinity of Winding Creek with relatively thin alluvial strata noted between Unit 1 and Unit 3 at about CH 2090 to CH 2250, CH 2740 to CH 2930 and CH 2990 to CH 3050. Deeper alluvium was noted below Unit 1 east of and leading up to Winding Creek (approx. CH 2290 to CH 2540). Adjacent to Winding Creek, bedrock was encountered below depths ranging from 4.0 metres to 5.5 metres (GHD, 2022b).



Paper Size ISO A4

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Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA2020
Grid: GDA2020 MGA Zone 56

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Surface geology

FIGURE 4.4

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4.4 Soil landscapes

Reference to the Newcastle 1:100,000 scale Soil Landscape Series Sheet 9232 (Matthei, 1995), shows that three soil landscape units are mapped across the site, with the 'Warners Bay' ('wa') residual unit mapped west of the Winding Creek alluvium; the 'Cockle Creek' ('cc') alluvial unit mapped in the vicinity of Winding Creek alluvium and the 'Gateshead' ('ga') erosional unit mapped east of Winding Creek alluvium. An extract from the NSW Office of Environment and Heritage eSPADE V2.1 website mapping is provided as Figure 4.5 below.

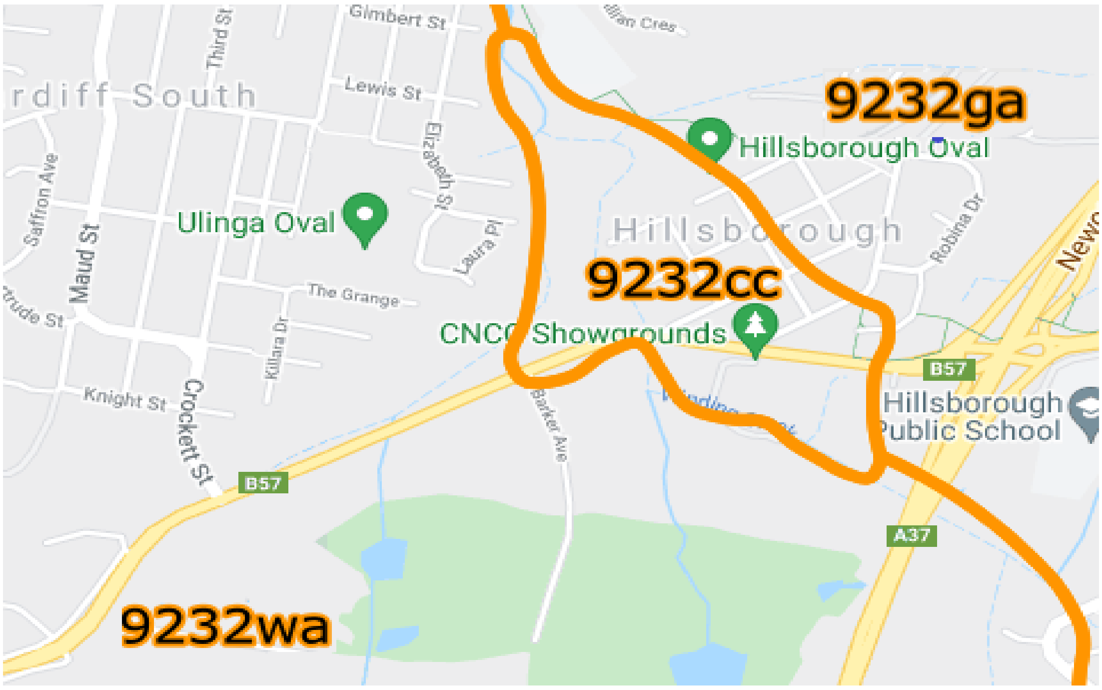


Figure 4.5 Annotated extract from NSW Soil Landscape mapping (eSPADE V2.1)

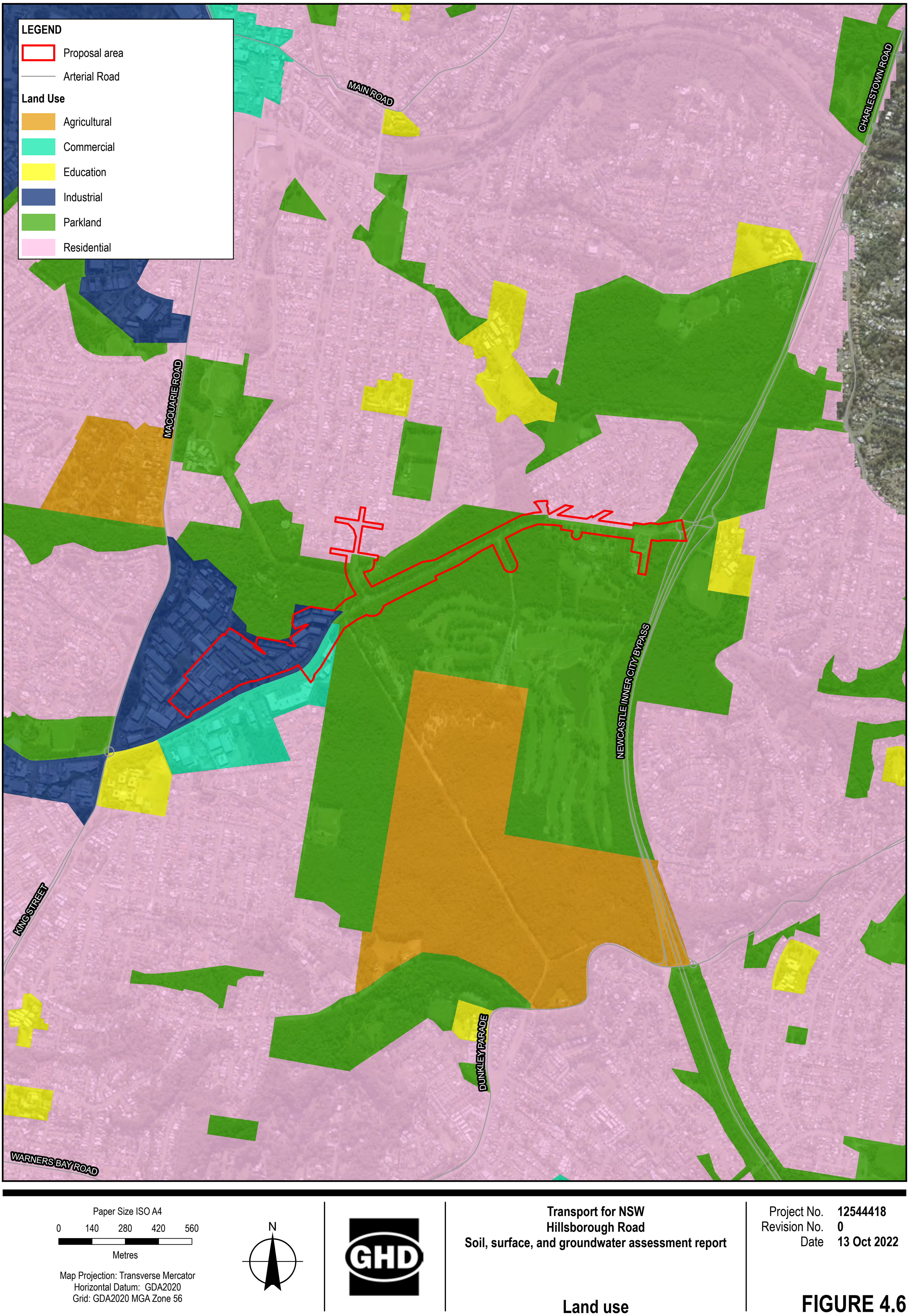
The Warners Bay soil landscape unit is characterised by undulating to rolling low hills and rises on fine-grained sediments of the Newcastle Coal Measures. Slope gradients are typically 3% to 20%. The dominant soils include silt and sandy clay topsoils underlain by silts and clays. Landscape limitations include foundation hazard, localised steep slopes, mass movement hazard on steep slopes, high water erosion hazard, seasonal waterlogging, high run-on and mine subsidence.

The Cockle Creek soil landscape unit is characterised by poorly drained narrow floodplains, alluvial fan and broad delta depositional environments. Slope gradients are typically less than 2%. The typical soil profile consists of a brownish black sandy loam to brown sandy clay loam topsoil overlying a clay or sandy clay subsoil. Limitations within this unit are reported to include flood hazard, waterlogging, permanently high watertables, acid sulfate potential, high run-on, foundation hazard and mine subsidence.

The Gateshead soil landscape is characterised by undulating to rolling rises on Permian aged conglomerate, shale and sandstone, with slopes ranging from 5% to 15%. Dominant soil materials are typically moderately well to imperfectly drained and include sandy to clayey loams underlain by clays and sandy clays. Noted landscape limitations include localised steep slopes, localised seasonal waterlogging on lower slopes and a potential water erosion and high run-on hazards. Possible limitations within the loam include low wet bearing strength and high localised organic matter, while limitations in the clay soils include high plasticity, low permeability, high potential for aluminium toxicity and localised shrink-swell.

4.5 Land use

General land use in the vicinity of the proposal includes urban development, commercial, light industrial development, parkland and natural forests (Figure 4.6). In the vicinity of the proposal, the urban developments are mostly residential dwellings and associated areas of open space.



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Land use

FIGURE 4.6

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4.6 Acid sulfate soils

Reference to the Wallsend 1:25,000 scale Acid Sulfate Soil Risk Map (Edition 2) (DLWC, 1998) shows that no acid sulfate soil (ASS) risk zones are mapped at the site. The closest mapped occurrences include areas about one kilometre to the southwest where alluvium associated with North Creek approaches Hillsborough Road at Warners Bay and also about four kilometres downstream (north west) along Winding Creek (which is a tributary of Cockle Creek) at Cardiff.

A total of 16 acid sulfate soil (ASS) field indicator tests and chromium reducible sulfur tests were conducted as part of the TfNSW 2020 investigations, with results included in Appendix I of GHD (2022c).

None of the 16 tested samples recorded field pH values indicative of actual acid sulfate soils (AASS), but most samples did show a significant reduction in oxidised pH, which may be indicative of potential acid sulfate soils (PASS). It is also noted that only three of the 16 samples recorded pH_{ox} values of less than 3 (generally considered confirmatory of PASS).

4.7 Hydrology and surface water catchments

As shown in Figure 4.7, the majority of the proposal area is within the catchment of Winding Creek with the western portion of the proposal within the catchment of North Creek.

Winding Creek is a mixture of natural and semi-natural channels, as well as concrete-lined channel. Winding Creek is within the Cockle Creek catchment. Winding Creek drains towards the north west of the proposal to the confluence with Brush Creek, approximately 4.5 kilometres downstream of the proposal area. Brush Creek is a tributary of Cockle Creek. Cockle Creek drains into Lake Macquarie at Boolaroo.

North Creek flows into Lake Macquarie in Warners Bay, approximately 1.8 kilometres south west of the proposal area.

Flooding along Winding Creek and to a lesser extent along Cockle Creek has been recorded since the 1930’s. Flooding will have also occurred in many other events but no records are available of these. Two retarding basins were constructed by Hunter Water in 1993 on Winding Creek to reduce peak flowrates downstream. One of these basins is located immediately upstream of the proposal while another basin is located approximately 500 metres downstream of the proposal area.

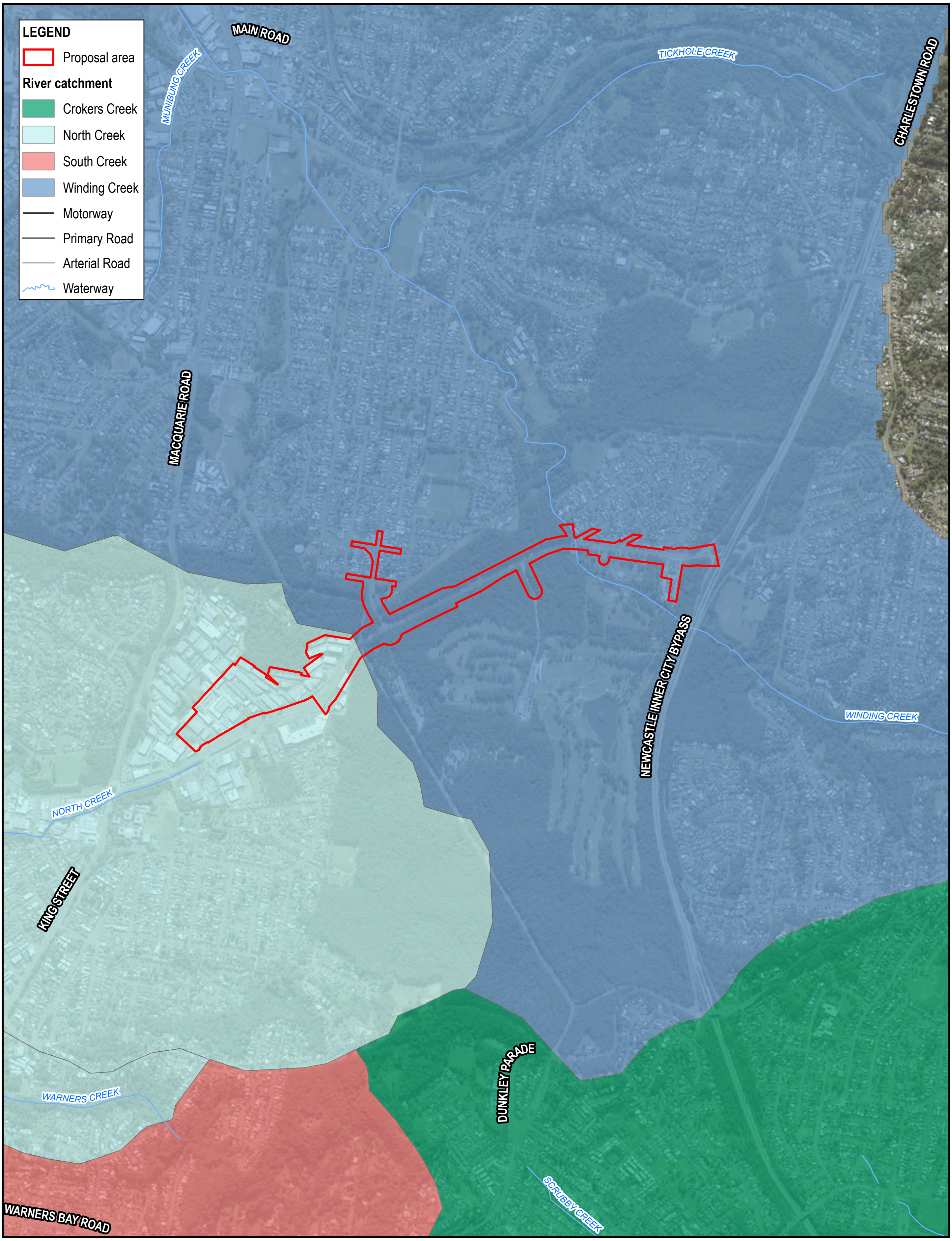
4.7.1 Waterway health and water quality monitoring data

Lake Macquarie - Freshwater Catchment Ecosystem Health data (LMCC, 2022) reports on the freshwater waterway health of Lake Macquarie’s main catchments including Winding Creek and North Creek. As part of the assessment three components of waterway health (water quality, stream pollution and riparian evaluation) are assessed and graded. Water quality is graded on an ‘A to F’ scale; while stream quality and riparian evaluation are graded on a Poor to Excellent (or ‘A to D’) scale. Water quality data compiled by Lake Macquarie City Council (LMCC) is presented in Appendix A.

Over the period 2011 to 2021 water quality at Winding Creek has been graded A to B and overall site grade has been graded as C to D (LMCC, 2022).

Over the period 2011 to 2021 water quality at North Creek has been generally graded at D to F with the exception of 2016 where water quality was graded as C and 2021 where water quality was graded as B. Between 2011 and 2021 overall site grade of North Creek has generally been graded between D and E.

Comparison of water quality data presented in Appendix A against the WQOs in Section 3.2.3 indicates that electrical conductivity and pH of Winding Creek and North Creek is consistently within the WQOs with the exception two exceedances of the electrical conductivity trigger value in North Creek and two exceedances of the lower level pH trigger value in Winding Creek. Additionally, there is some variability in dissolved oxygen concentrations, particularly in North Creek. There are a number of recorded dissolved oxgen concentrations in Winding Creek and North Creek below the WQOs.



Paper Size ISO A4

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Metres

Map Projection: Transverse Mercator
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Catchments areas

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FIGURE 4.7

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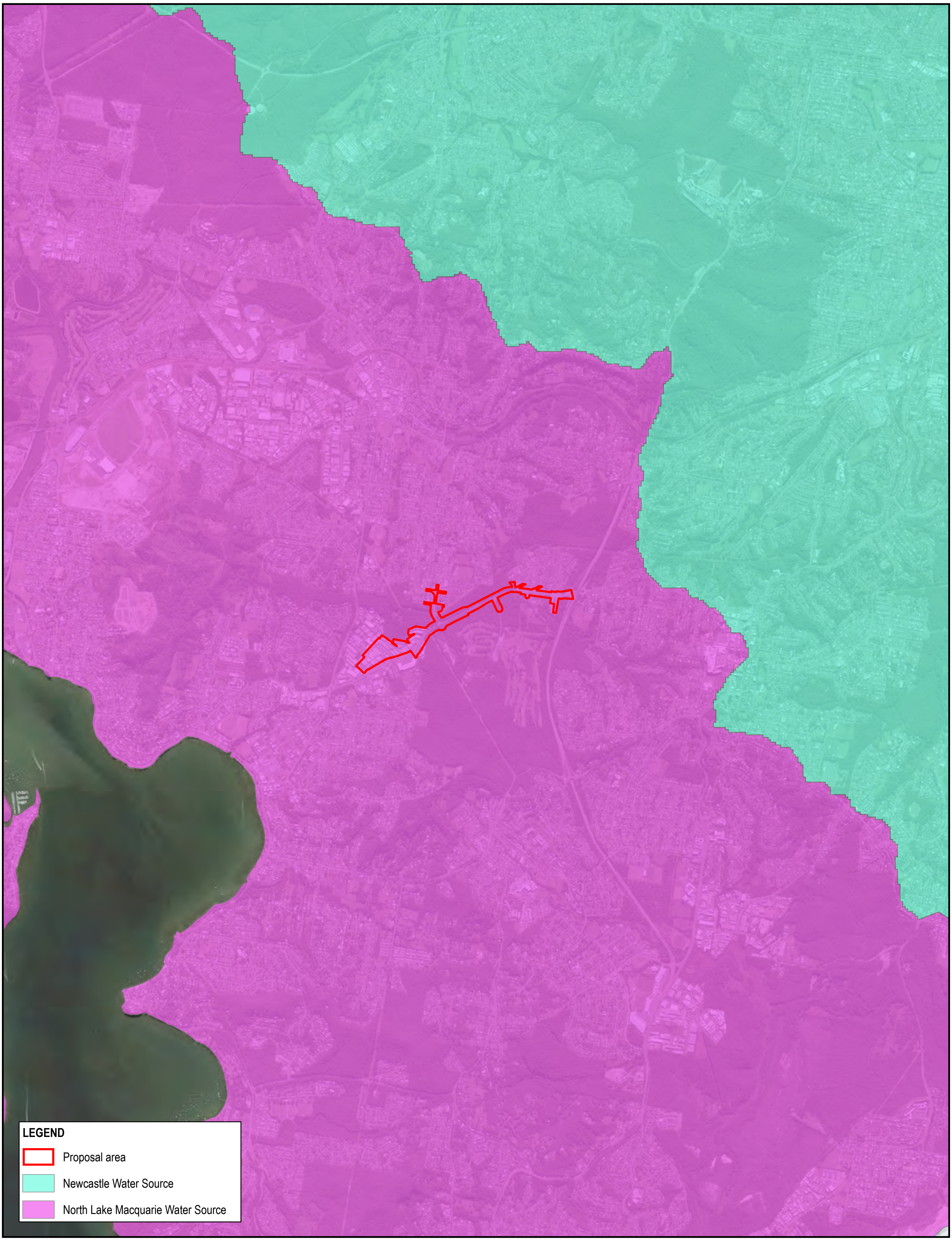
4.8 Hydrogeology

The site is located within the Sydney Basin North Coast groundwater source within the WSP for the North Coast Fractured and Porous Rock Groundwater Sources and within the HUA WSP. The WSP for the North Coast Fractured and Porous Rock Groundwater Sources applies to groundwater within fractured and porous rock within the plan area. The HUA WSP applies to all surface water and alluvial groundwater within the plan area. Under the HUA WSPs, the proposal is located within the North Lake Macquarie Water Source, shown in Figure 4.8.

The main groundwater sources throughout the study area include Quaternary alluvium, Fractured sandstone of the Narrabeen Group, and coal seams within the Permian Newcastle Coal Measures, separated by Permian interburden sediments (functioning as aquitards). The properties of each of the aquifer systems are summarised in Table 4.2.

Table 4.2 Aquifer systems properties

Aquifer system	Properties
Quaternary alluvium	Unconfined shallow aquifers. Saturated zones are laterally discontinuous and occur in isolated pockets. Perched groundwater present in unconsolidated sands, silts and peat. Generally isolated, of minimal thickness and low groundwater yield.
Fractured rock	Includes overburden/interburden sandstones, siltstones, mudstones and coal seams. Variable hydraulic conductivity, generally in the order of 0.03 m/year to 30 m/year. Recharge of coal seams occurs in areas of seam subcrop.



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Kilometers

Map Projection: Transverse Mercator
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Grid: GDA2020 MGA Zone 56

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Hunter Unregulated and Alluvial Water Sources boundaries

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FIGURE 4.8

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4.8.1 Groundwater receptors (NSW bore database search)

Search of the NSW Groundwater Bore Database were (BoM, 2022a) was carried out on 4 May 2022 to identify registered bores within a three-kilometre radius of the proposal area. The search identified 81 bores within three kilometres of the proposal area. Bore locations are shown in Figure 4.9 and bore details are provided in Appendix B.

The majority of identified bores (63 bores) were registered as monitoring bores. The remaining bores were registered as stock, domestic, farming or irrigation purposes (12 bores), environmental rehabilitation (three bores), industrial (one bore), drainage (one bore) or recreation purposes (one bore).

Review of bore details in Appendix B indicates all of the stock, domestic, farming or irrigation bores are installed within the fractured rock strata. This indicates that in the vicinity of the proposal, there is limited reliance on the fractured rock aquifer and no reliance on the alluvial aquifer for stock, domestic, farming or irrigation purposes. Reported yields are very low, less than one litre per second.

As shown in Figure 4.9, the closest bores to the proposal include:

- GW047633 registered for dewatering and located within 100 metres of the proposal
- GW078258 registered for irrigation and located 1.1 kilometres north of the proposal
- GW058977 registered for water supply and located 1.3 kilometres north of the proposal

All other registered bores are located over 1.5 kilometres from the site.

4.8.2 Observed groundwater levels and groundwater flows

Groundwater has been observed in a number of test pits in the Winding Creek alluvium. Coffey (2014) recorded groundwater inflows at depths of 1.2 metres and 1.7 metres in test pits COF-TP28 and COF-TP27. The locations of these test pits are shown in Figure 4.10.

As part of previous geotechnical investigations undertaken by Douglas Partners (2014) and TfNSW (2020) free groundwater was found within ranges of 1.2 metres and 3 metres depths in four of six boreholes (including boreholes DP-BH01, DP-BH02 and TfNSW BH01 to TfNSW BH04) in the vicinity of the proposed Winding Creek culvert southern extension. The locations of these boreholes are shown in Figure 4.10.

Groundwater was encountered in TfNSW-BH01 within the alluvium (Unit 2E stratum) at the invert level of the existing culvert (at about 19.9 metres AHD).

Outside the extent of the alluvium, groundwater has typically not been intercepted in the boreholes and test pits. The exception to this is at DP-BH04 where the groundwater was observed at a depth of 4 metres within clay strata. The only long-term monitoring of groundwater levels has been undertaken with a GHD standpipe piezometer (GHD BH301) that was dry when installed, however, a groundwater level depth of 10.61 metres (25.345 metres AHD) was recorded on the 25th of February 2022 after a period of heavy rainfall. The groundwater encountered at BH301 is likely associated with the fractured rock aquifer.

Groundwater levels at the site are likely to vary over time due to rainfall conditions and the inflow rate from the detention basin upstream from the Winding creek culvert. The shallow alluvial groundwater in the vicinity of Winding Creek likely discharges to the lower reaches of Winding Creek as baseflow.

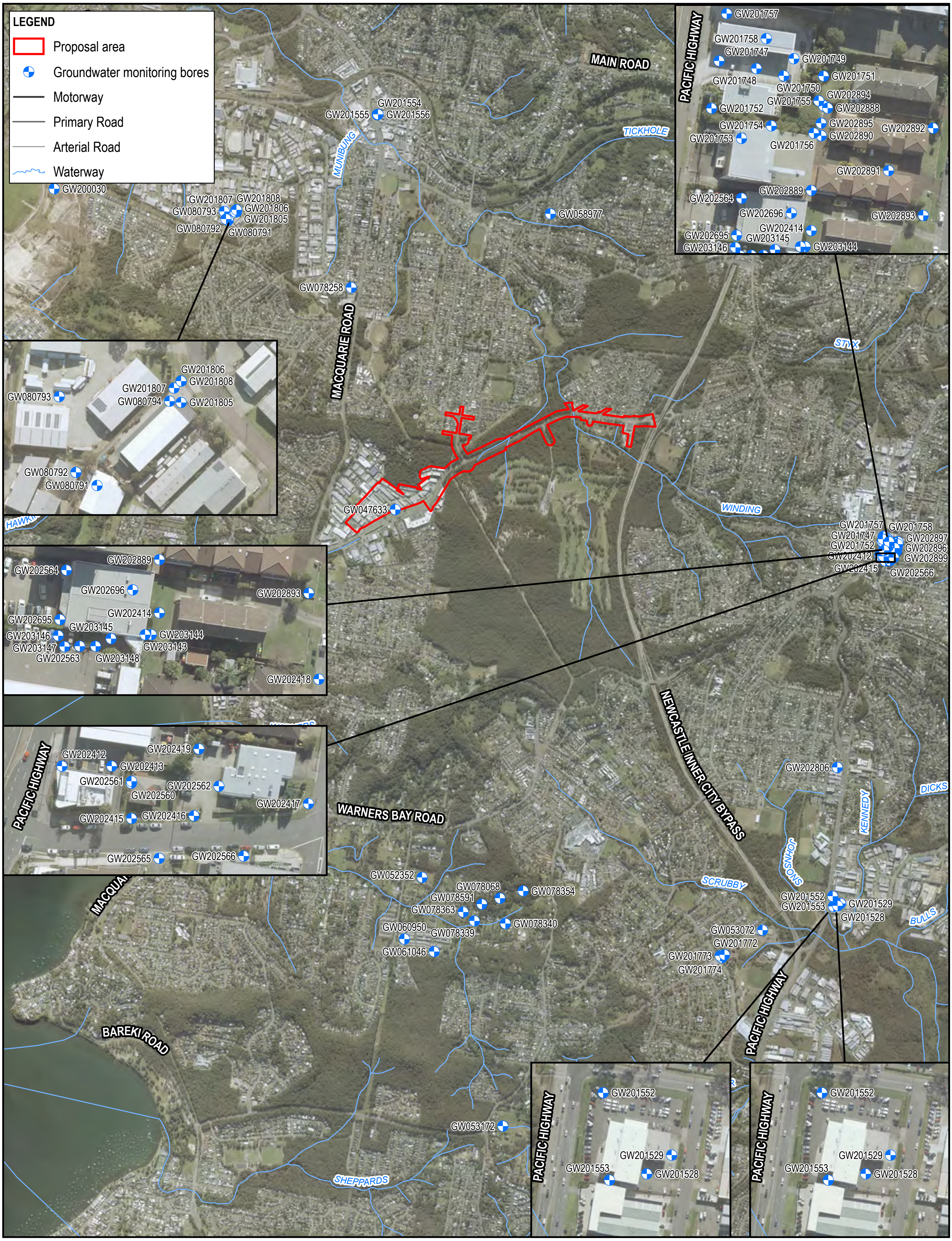
A summary of the observed groundwater levels is provided in Table 4.3. The locations of these boreholes are shown in Figure 4.10.

Table 4.3 Observed groundwater levels

Bore with observed GW level	Groundwater level (m bgl)	Surface elevation	Groundwater elevation (metres AHD)	Groundwater system intercepted	Geological strata
COF-TP28	1.2	26.5	25.3	Alluvium	General fill and clay
COF-TP27	1.7	25.17	23.47	Alluvium	Topsoil and clay
COF-TP26	1.7	24.34	22.64	Alluvium	Topsoil, sandy clay and clay
DP-BH01*	1.9	23.78		Alluvium	General fill, sandy clay, gravely clay and sand
DP-BH02*	3		22.58-20.78	Alluvium	General fill, sandy clay, gravely clay and sand
DP-BH03	4			Perched	General fill, clay, clayey sand
TfNSW-BH01			19.9	Alluvium	Clay, Gravely clay, sand
TfNSW-BH02	1.3			Alluvium	Clay, Gravely clay, sand
TfNSW-BH03	4			Alluvium	Clay, Gravely clay, sand
GHD BH301	10.61	35.95	25.34	Fractured and porous rock	General fill, clay, coal

*Boreholes BH01 and BH02 are closest to the proposed culvert works near Winding Creek. These boreholes are closest to the excavation works and the depths are not anticipated to reach groundwater level.

Note: blank cells denote unknown data



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Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

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Registered groundwater bores

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FIGURE 4.9

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Geotechnical borehole locations

FIGURE 4.10

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4.8.3 Groundwater dependent ecosystems (GDEs)

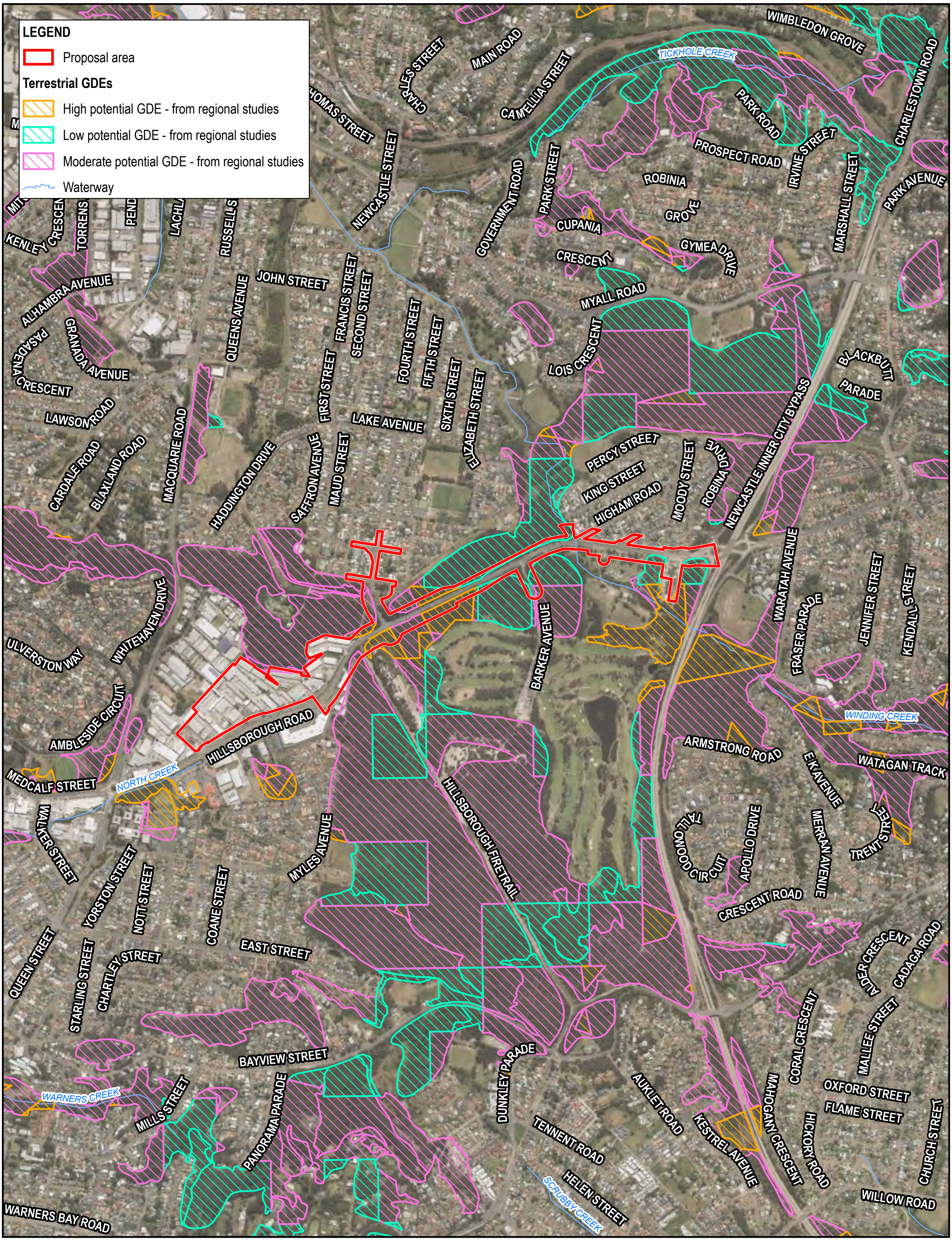
Review of WSPs indicates that there are no high priority GDEs listed within four kilometres of the proposal. Note that high priority GDEs are listed in the WSPs that regulate groundwater sources within the proposal area.

Potential dependence (or interaction) of the vegetation communities within the study area on groundwater was determined by searching the GDE Atlas (BoM, 2022b). These potential GDEs differ from the high priority GDEs that are listed in the relevant WSPs. As shown in Figure 4.11, mapped vegetation communities within and surrounding the proposal were mapped as either low, moderate or high potential for dependency on groundwater. Details of these potential groundwater dependent ecosystems are summarised in Table 4.4.

These communities are likely to rely on surface water runoff and accessing groundwater when groundwater levels are high and were therefore potentially classified as being intermittently dependent on groundwater.

Table 4.4 Potential groundwater dependent ecosystems

Plant community type	Ecosystem type	Habitat	Dependency on groundwater
Smooth-barked Apple/ Red Bloodwood/ Brown Stringybark/ Hairpin Banksia heathy open forest	Terrestrial Ecosystem - Sydney Coastal Dry Sclerophyll Forests	Terrestrial - Macquarie -Tuggerah Lakes	High potential GDE - from regional studies
Smooth-barked Apple/ Red Mahogany/ Swamp Mahogany/ Melaleuca sieberi heathy swamp woodland	Coastal Swamp Forests	Terrestrial	High potential GDE - from regional studies
Spotted Gum/ Broad-leaved Mahogany/ Grey Gum grass/ shrub open forest on Coastal Lowlands	Hunter-Macleay Dry Sclerophyll Forests	Terrestrial	Moderate potential GDE - from regional studies
Lake Macquarie	Coastal lagoons and lakes	Aquatic	Moderate potential GDE - from national assessment
Smooth-barked Apple/ Red Bloodwood/ Brown Stringybark/ Hairpin Banksia heathy open forest	Terrestrial Ecosystem - Sydney Coastal Dry Sclerophyll Forests	Terrestrial - Macquarie -Tuggerah Lakes	Moderate potential GDE - from regional studies
Smooth-barked Apple/ Red Bloodwood/ Brown Stringybark/ Hairpin Banksia heathy open forest	Terrestrial Ecosystem - Sydney Coastal Dry Sclerophyll Forests	Terrestrial - Macquarie -Tuggerah Lakes	Low potential GDE - from regional studies



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Map Projection: Transverse Mercator
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Potential groundwater dependent ecosystems

FIGURE 4.11

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Data source: BOM: GDEs, 2022. LPI: DTDB, 2017. public_NSW_Imagery: © Department of Customer Service 2020. Created by: tmorton

5. Potential construction impacts

This section discusses the potential impact of the construction phase activities on surface water,groundwater quality and hydrology. This assessment is based upon construction activities for the proposal outlined in Section 3.3 of the Hillborough Road Upgrade Review of Environmental Factors. Relevant construction activities include:

– Demolition and construction work
– Civil earthworks i.e. excavation and trenching
– Concreting, asphalt, and surfacing (including chemicals and spill hazards)
– Temporary works i.e. construction of access roads, hardstand, access roads, compounds, laydown areas and pads
– Culvert extensions and installation of a new piped culvert drainage
– Temporary diversion of drainage infrastructure
– Clearing and grubbing
– Stockpiling of materials

5.1 Surface water quality

Typical surface water pollutants that may result from the construction phase of the proposal could include:

– Sediments, entrained in runoff from open excavations, stockpiles and stripped areas
– Gross pollutants including litter and debris, carried by runoff from general construction and un-controlled domestic waste
– Nutrients including nitrogen and phosphorous, in particular from vegetation and nutrients absorbed to sediment particles
– Oils and hydrocarbons from spills or inappropriate waste disposal, or from refuelling construction equipment and plant on site

Typical impacts on watercourses would be through the transport of these pollutants by surface water runoff, degrading water quality in the receiving environment.

Potential impacts on local surface water features during the construction phase of the proposal include:

– Impacts of typical surface water pollutants on North Creek and Winding Creek and increased nutrient loads associated with sedimentation on Lake Macquarie, in excess of the water quality guidelines outlined in Section 3.2.3.
– Increased nutrient loads within North Creek, Winding Creek and Lake Macquarie.
– Increased pollutant loads within stormwater treatment devices within the catchment, resulting in decreased treatment effectiveness.

5.1.1 Pre-construction works

Preparatory works carried out prior to the early stages of construction involve site establishment works and provision of construction access. Pre-construction works for both stages would typically also include:

– Installation of environmental controls, including sediment and erosion controls following best practice guidelines such as Managing Urban Stormwater, the “Blue Book” Volume 2D (DECC, 2008)
– Stormwater drainage channel protection and diversion works where necessary to maintain the function of the system during the construction period
– Any necessary flood mitigation measures to manage overland flows and minimise adverse impacts on surrounding environment where possible

Impacts associated with pre-construction works generally relate to poorly designed, inappropriately installed and inadequately maintained mitigation measures failing. Failure of mitigation measures can result in impacts varying from pollutants not being prevented from entering waterways from the start of the construction period, to large loads of accumulated materials such as sediment washing into receiving waters if failure occurs later in the construction period. Poorly maintained erosion and sedimentation controls such as sediment fencing can also become a gross pollutant if it is entrained in runoff.

5.1.2 Construction works

Construction and drainage activities increase risks associated with sediment-laden water, with increased turbidity and nutrient loading, draining from unprotected areas during periods of heavy rainfall and major surface runoff events. During construction, there is potential for a range of pollutants to enter waterways, particularly during high rain events. These include sediment laden water and soil nutrients resulting from the following earthworks related activities:

– Removal of vegetation currently stabilising soils and increasing the risk of erosion and sedimentation through the exposure of soils to weathering processes
– Cut/fill excavation works for road construction
– Reinstatement of work areas following completion of construction
– Mobilisation of fine sediment within Winding Creek during movement of plant and equipment associated with culvert widening works at this waterway
– Deposition of dust during construction activities
– Construction waste
– Fuels, hydraulic and lubricating oil spilled or leaked from plant and equipment, particularly when operating within proximity to waterways
– Fuels leaking during refuelling of plant and equipment
– Water from washing down of plant and equipment
– Water containing biological contaminants such are nutrients and bacteria from site toilets and taps associated with the site compound
– Disturbance of contaminated soils and/or ASS, which may adversely affect water chemistry including pH and dissolved solids
– If flood waters were to affect any areas where chemicals and fuels have been stored, this could lead to chemical pollution of the local stormwater network and downstream receiving environment
– Introduction of new drainage network elements into the water ways in addition to the risk of working on an 'online' drainage network has the potential to impact water quality, by disrupting existing flow paths and runoff velocities, which can cause an additional disturbance to soils

Construction would include excavation for a number of cuttings. Within the extent of the mapped alluvium based on regional geological mapping (Department of Mineral Resources, 1994), (CH2220 to CH3120) the maximum proposed cutting depth is approximately 0.9 metres. Outside the mapped extent of the alluvium, the maximum cutting depth is approximately two metres.

Culvert works may impact upon surface water during the construction phase of the proposal. These culvert works include:

– new culvert crossing at Crockett
– two new culvert crossings Hillsborough Road near Barker Avenue
– two culvert extensions across Hillsborough Road near Barker Avenue
– the Winding Creek culvert Extension

The existing culverts discussed above are observed to be flowing in rain events or holding water during wetter periods. These culvert works will be undertaken in accordance with specific Environmental Works Methods Statements (EWMS) to be prepared prior to construction.

At the southern extension of the Winding Creek culvert, Localised over excavation of unsuitable founding material (Unit 2A – non cohesive alluvial material) and replacement with compacted gravel or cobbles will be required to provide a suitable foundation for culvert slab footings (GHD, 2022b). The non cohesive material extend to approximately four metres below ground level.

5.2 Groundwater impact assessment

As discussed in Section 5.1.2, based on observed groundwater levels and proposed cutting depths, the majority of construction activities are not expected to intercept groundwater, as the groundwater table is lower than the proposed excavations. While observed groundwater levels are below cutting depths, groundwater levels are likely to vary over time, particularly within the alluvium associated with Winding Creek. Therefore, while unlikely, there is potential that groundwater may be intercepted by construction of cuttings in the alluvium.

As discussed in Section 4.8.2, within the extent of the alluvium, groundwater has been observed at depths between 1.2 metres and four metres while outside the extent of the alluvium groundwater has been observed between four metres and 10.61 metres. Therefore, based on observed groundwater levels and proposed cutting depths, the construction activities are not expected to intercept groundwater, as the groundwater table is lower than the proposed excavations.

Additionally in the vicinity of Winding Creek, localised dewatering may be required where over-excavation and replacement of foundation soils are proposed as part of construction of culvert footings.

Preliminary groundwater inflow estimates have been carried out to estimate the potential rate of groundwater inflow into cuttings and excavations within the alluvium. The preliminary groundwater inflow estimates have utilised the methodology presented in Section 3.2.1.

5.2.1.1 Hydraulic conductivity Zones 1 and 2 (K_{h1}, K_{h2} and K_{v2})

Alluvial material in the vicinity of Winding Creek observed in test pits and boreholes is typically silty clay and clay. In the vicinity of Winding Creek clayey silt, clayey gravel, sandy gravel, sandy clay and gravelly sand were also observed (GHD, 2022b).

Hydraulic conductivity of 1×10^{-3} metres per day to 1×10^{-1} metres per day have been adopted for the assessment based on hydraulic conductivity for clay, sand and gravel mixes reported by Kruseman and de Riddler (1994). It was assumed that the horizontal hydraulic conductivity is 10 times greater than vertical hydraulic conductivity.

5.2.1.2 Effective radius (r_p)

Effective pit (cut) radius was estimated by calculating the area of the cutting based on the length and the width of the cutting. The area of inflow was estimated by comparing the adopted groundwater level for this assessment to proposed design levels and cutting widths along the length of each cutting.

Within the alluvium, proposed depth of cuttings excceds 0.7 metres along a length of approximately 20 metres, between CH2560 and CH2580 and along lengths of the road of less than 20 metres in the vicinity of CH2680 and CH2720. The Winding Creek southern culvert extension will have similar dimensions of 10 metres by 7 metres. For the purposes of this assessment, dimensions of the cutting and excavation for the culvert extension were conservatively adopted as 20 metres by 10 metres. The area of this pit (200 metres squared) was input into the formula for the area of a circle (ie $A = \pi r_p^2$), to give an effective pit radius of 8.0 metres.

5.2.1.3 Radius of influence (r_o)

The radius of influence (r_o) of any groundwater abstraction represents a balance between the hydraulic conductivity of the strata and the rate of recharge incident at the water table. The radius of influence has been estimated from the calculation.

5.2.2 Predictions of inflow and radius of influence

As discussed in Section 5.2, based on observed groundwater levels, cuttings associated with the proposal are not expected to intercept groundwater. However, groundwater inflows have been conservatively estimated for each of the proposed cuttings in the alluvium near Widing Creek and for the excavation for the Winding Creek culvert extension using the analytical equations developed by Marinelli and Niccoli (2000), as described in Section 3.2.1. Groundwater inflows have been estimated for a range of scenarios. Table 5.1 provides the predicted inflows for each of the cuttings for the following scenarios:

– Scenario 1 adopted depth to groundwater (initial saturated thickness) of 0.7 m, horizontal hydraulic conductivity of 0.1 metres per day and distributed recharge flux of 5%.

– Scenario 2 adopted the same parameters as Scenario 1 but decreased the horizontal hydraulic conductivity to 1×10^{-3} metres per day.

– Scenario 3 adopted the same parameters as Scenario 1 but decreased the distributed recharge flux to 2.5%.

Table 5.1 Predicted groundwater inflows

Scenario	Distributed recharge flux, W (m/d)	Horizontal hydraulic conductivity kh (m/day)	Calculated radius of influence ro (m)	Initial saturated thickness ho (m)	Horizontal groundwater inflow Q1 (m^3/day)	Vertical groundwater inflow Q2 (m^3/day)	Total groundwater inflow Qt (m^3/day)
1	1.55E-04	1.00E-01	10	0.7	0.02	0.07	0.09
2	1.55E-04	1.00E-03	8	0.7	0.00	0.00	0.00
3	7.77E-05	1.00E-01	10	0.7	0.01	0.7	0.08

m – metres, m/day – metres per day, m^3/day - cubic metres per day

As shown in Table 5.1, conservative estimate of the rate of groundwater inflow into the cuttings and excavations in the vicinity of Winding Creek is 0.09 cubic metres per day. However, as observed groundwater levels are likely below the base of the cuttings, no groundwater is expected to be intercepted by the cuttings.

It is important to note, however, that the actual rate of inflow is unlikely to be constant along the entire length of each cutting. The actual inflow rate would likely change along the length of each cutting as the base of each cutting changes in level and as groundwater levels vary along the length of each cutting.

The groundwater levels utilised in calculating groundwater inflows may vary over time. It is expected that groundwater inflows (if any) into the proposed cuttings and excavations would increase following rainfall events due to the recharge of the alluvial aquifer. Conversely, groundwater inflows (if any) would likely be low to potentially negligible following extended periods of little or no rainfall (once all groundwater, if any exists above the cutting depth, has been released from storage).

The potential radius of influence on groundwater of the cuttings has been estimated. The extent of the alluvial aquifer is bounded by the extent of the alluvium and by the presence of Winding Creek, where alluvial groundwater likely discharges. Estimates of the potential radius of influence range from eight metres to ten metres.

Therefore, while significant volumes of groundwater is not expected to be intercepted during construction, the results of the analysis indicate that if groundwater levels during construction are higher than observed, impacts to groundwater will be negligible.

Potential impacts have been assessed against the NSW AIP in Section 6.3.1.

6. Potential operational impacts

6.1 Hydrology and catchment flows

The proposed drainage network for the proposal includes modification of the Winding Creek culvert. The new minimum cross section widths including kerb side curve lane widening to be adopted have dictated a culvert extension is now required both upstream and downstream.

The proposed drainage network has been designed to address flooding across Hillsborough Road in the vicinity of the Barker Street intersection. The proposed drainage system has been designed to convey the 10% annual exceedance probability (AEP) storm in the longitudinal drainage system while providing 1% AEP flood immunity for any transverse drainage systems.

The proposed drainage systems will, as far as possible maintain existing flowpaths and catchments to minimise local drainage impacts on the receiving drainage.

6.1.1 Flooding

A flood impact assessment for the proposal has been undertaken by WMAwater (2022). The flood impact assessment indicated that the proposal will result in increases in flood water levels within the road corridor or undeveloped areas with reductions or approved increases in water levels within downstream residential properties (WMAwater, 2022).

6.2 Surface water quality

Discussions of the potential operational risk and impacts on water quality associated with the operation of the proposal are provided in the following sections.

6.2.1 Stormwater runoff

Stormwater runoff from the proposal area may contain pollutants such as oils and greases, petrochemicals and heavy metals as a result of vehicle use of the street. The contamination of waterways by these pollutants can result in habitat degradation and negatively impact on the health of aquatic flora and fauna species. However, the potential for the concentrations of these pollutants to increase substantially from that of the existing conditions is considered low.

The catchments of the receiving watercourses are currently largely pervious, due to undeveloped or residential development. The increase in road pavement area is approximately 1.5 hectares. Considering that the land use of much of the catchment is residential development, and that the total catchment area of Winding Creek and it’s tributaries is 2,900 hectares (WMAwater, 2017), the proposal represents a minor increase in road surface. The minor increase in impervious area due to the proposal does not have significant impact on the overall catchment water quality.

6.2.2 Drainage

The proposed upgrades to cross drainage structures would improve the hydraulic efficiency across Hillsborough Road, which would also increase peak velocities within culverts and open channels as flow moves faster through the proposal. As a result, peak velocities at the upstream end of the culverts passing under Hillsborough Road increase by up to 0.5 to 1.0 m/s. Peak velocities at the downstream end of the culverts only increase by up to 0.2 m/s.

To protect against these increased velocity flows entering and exiting the cross-drainage structure, scour protection has been included as per section 3.13 in Austroads Part 5B (Austroads, 2021). Minimum rock size and length of apron at the outlet has been checked and would be based upon the pipe diameter at the outlet and the outlet flow velocity as per the hydraulic model. Design of the scour protection required for each outlet would be undertaken in the detailed design stage within the proposal boundary. Scour protection is provided at the outlets to ensure that discharges would not scour or erode the earth downstream of the discharge point. Further discussion on flooding potential and impacts as a result of the construction and operation of the proposal are included in the REF and the Flooding Impact Assessment report.

6.2.3 Potential for spills/leaks

The potential impacts on water quality from the operation of the widened road would be related to the spill of vehicle oils, lubricants, and hydraulic fluids.

Any such spill has the potential to pollute receiving waterways and therefore cause adverse effects on the surface water and groundwater environments. However, the proposed road follows the existing road path and reduces the risk of accidents that may produce spills through the improvement of traffic flow. Therefore the proposal will not result in any increased impacts from spills and leaks.

6.2.4 Erosion and sedimentation

With the increase in impervious area as a result of the proposal, there would be a comparable increase in stormwater runoff volumetric flow rate which can potentially scour surface soils and increase sediment loading in downstream waterways.

As the change in impervious areas are in this case small relative to the receiving catchments as a whole, the potential impacts would be expected to be limited in nature and less than those associated with the construction phase.

6.3 Groundwater impacts

As discussed in Section 5.2, the construction of the proposal could potentially intercept minimal volumes of groundwater. Analytical equations have been developed to estimate the rate of groundwater inflow and associated radius of influence for conservatively high groundwater levels for the construction phase of the proposal.

Groundwater level measurements closest to the culvert were taken at 1.9m (DP-BH01) and 3m (DP-BH02). The anticipated excavation depth needed to construct the widened culvert would not intercept at these depths and is therefore unlikely to encounter groundwater. Groundwater impacts are less than the Level 1 minimal impact considerations.

Dewatering of excavations or basins would be carried out in accordance with dewatering plan prepared in accordance with the *Technical Guideline for Dewatering (Roads and Maritime, 2011)*. Any dewatered groundwater may be used on-site for dust suppression or irrigation, with excess water potentially discharged in accordance with the dewatering procedure. If water is to be discharged, then water quality testing will be undertaken

The increased impervious areas may result in some local changes to the rates of rainfall infiltration. The main groundwater receptor is considered to be baseflow to waterways. Runoff from hard stand areas will continue to drain towards North Creek or Winding Creek.

6.3.1 NSW Aquifer Interference Policy

The proposal has been assessed against the adopted Level 1 minimal impact considerations below.

Groundwater dependent ecosystems

As discussed in Section 4.8.3, the closest high priority groundwater receptor is located over four kilometres from the proposal. Therefore the proposal is unlikely to impact on any high priority GDEs.

Water supply works

While cuttings associated with the proposal are not expected to intercept groundwater, analytical calculations have been undertaken to estimate the potential radius of influence based on a conservatively high water table. Based on these analytical calculations, the radius of influence estimated in Section 5.2.2 extends up to eight metres to ten metres from cuttings and excavations in the vicinity of Winding Creek. There are no water supply works (water bores) within this range. Therefore, the proposal would not result in any impacts to a water supply work.

High priority culturally significant sites

There are no high priority culturally significant sites listed in the WSP for the Hunter Unregulated and Alluvium Water Sources and the WSP for the North Coast Fractured and Porous Rock Groundwater Sources. Therefore, the proposal would not result in any impacts on culturally significant sites.

Summary

Overall, it is predicted that the groundwater impacts from the proposal would be less than the Level 1 minimal impact considerations specified in the AIP and therefore are considered to be acceptable.

The proposal is not predicted to result in any decline in groundwater pressure or groundwater head at any water supply work and is not predicted to alter the beneficial use of the groundwater, culturally significant sites or high priority GDEs .

6.4 Cumulative impacts

Development of the Cockle Creek Precint on the land formerly occupied by the Cockle Creek lead and zinc smelter at Boolaroo is ongoing. The Cockle Creek Precinct includes retail, light industrial, business park, residential and open space development.

The footprint of the Cockle Creek Precinct is significantly larger than the footprint of the proposal. The proposal site is extremely small compared to the footprints of existing and proposed developments that may impact the Winding Creek and Cockle Creek catchment and local groundwater system. Attempts have been made to minimise any surface water and ground water impacts of the proposal and therefore are likely to be negligible over the long term compared to any impacts from other developments. Therefore the proposal is not considered to present a significant risk of cumulative impacts in the broader area.

7. Recommended mitigation measures

An assessment of the soils, surface water and groundwater risks associated with the construction of the proposal and measures for their avoidance, mitigation or minimisation is provided in Table 7.1.

Table 7.1 Potential construction risks and mitigation measures

Risk	Potential impacts	Measures to avoid, mitigate or minimise impacts	Timing
Construction activities	Pollution of receiving waterways	A Soil and Water Management Plan will be prepared in accordance with QA Specification G38 and implemented as part of the CEMP. The Plan will identify all reasonably foreseeable risks relating to soil erosion and water pollution associated with undertaking the activity, and describe how these risks will be managed and minimised during construction. That will include arrangments for managing pollution risks associated with spillage or contamination on the site and adjoining areas, and monitoring during and post-construction.	Pre-construction and construction
		A site-specific Progressive Erosion and Sediment Control Plan/s will be prepared and implemented as part of the Soil and Water Management Plan. Erosion and sediment control measures are to be designed, implemented and maintained in accordance with the Blue Book (DECC 2008). The Plan will include arrangements for managing wet weather events, including monitoring of potential high-risk events (such as storms) and specific controls and follow-up measures to be applied in the event of wet weather.	Pre-construction and construction
	Disturbance of creek beds and banks	A detailed Environmental Work Method Statement (EWMS) will be prepared and implemented as part of the SWMP for all works undertaken within waterways. The EWMS will detail measures to avoid or minimise risks from erosion and sedimentation to water quality and biodiversity. It will be prepared in accordance with relevant guidelines including, but not limited to: – RMS Biodiversity Guidelines – Protecting and managing biodiversity on RTA projects The EWMS will consider any temporary access points required to be installed for construction access to waterways for construction works.	Pre-construction and construction
		Batters will be designed and constructed to minimise risk or exposure, instability and erosion, and to support long-term, on-going best practice management, in accordance with the RMS Guideline for Batter Stabilisation Using Vegetation (April 2015).	Pre-construction and construction
Chemical or hydrocarbon spill	Pollution of receiving drainage networks and watercourses	Prepare a spill emergency management plan that would be included in the SWMP. Including: – Storage of hazardous goods and refuelling activities to take place in bunded areas. – Parking of vehicles and storage of plant/equipment is to occur on existing paved areas. Where this is not possible, vehicles and plant/equipment are to be kept away from environmentally sensitive areas and outside the dripline of trees. – Open drainage channels provided through construction areas will be protected by appropriate spill management measures such as bunding to prevent any spills and leaks to stormwater drainage networks. – Monitor spill management measures at specified intervals during the construction period. These include checks of the location of stored materials and of the condition of containers and bunding.	Construction

Risk	Potential impacts	Measures to avoid, mitigate or minimise impacts	Timing
Impeding flows	Surface water flow	During construction, surface water flow within Winding Creek will be managed such that water will temporarily bypass the construction site, where required.	Construction
Dewatering impacts	Surface water quality impact	A detailed Environmental Work Method Statement (EWMS) will be prepared and implemented as part of the SWMP for all dewatering activities. The EWMS will detail measures to avoid or minimise risks from potential offsite water quality impacts. Any dewatering activities will be undertaken in accordance with the RTA Technical Guideline: Environmental management of construction site dewatering in a manner that prevents pollution of waters.	Pre-construction Construction
		If groundwater is encountered during excavations potential adverse impacts would be minimized through the implementation of the measures identified in the RTA Technical Guideline: Environmental management of construction site dewatering, where applicable.	Construction
Inappropriate rehabilitation	Soil stabilisation and restoration	The rehabilitation of disturbed areas will be undertaken progressively as construction stages are completed, and in accordance with: – Landcom's Managing Urban Stormwater: Soils and Construction series – RTA Landscape Guideline RMS Guideline for Batter Stabilisation Using Vegetation (draft June 2014).	Construction
Stockpiles	Surface water quality impact	Stockpiles will be designed, established, operated and decommissioned in accordance with the RTA Stockpile Site Management Guideline 2011.	Construction
Topsoil Management		Topsoil will be stockpiled in existing disturbed areas and managed in accordance with the RTA Stockpile Site Management Guideline until: – If not suitable or not required for use in future rehabilitation or revegetation works – it is removed from the construction site and disposed of an appropriately licensed facility, OR – If suitable and required for future use – it is re-used per Beneficial re-use under waste exemption or DA.	Construction
ASSMP		Acid Sulfate Materials Management Plan will be prepared and implemented as part of the CEMP, if greater than 1000 tonnes of potential acid sulphate soil material is to be disturbed. The Plan will be prepared in accordance with the RTA Guidelines for the Management of Acid Sulfate Materials.	Pre-construction, Construction
Rehabilitation	Erosion and sedimentation	A rehabilitation plan will be prepared covering all areas disturbed as part of the proposal and will include the following: – Progressive stabilisation and rehabilitation of construction areas back to the original condition or re-vegetated with appropriate native species, as soon as practicable. – Rehabilitation of riparian areas (i.e. within 40 m from the highest bank on relevant waterways) and meets the requirements of Guidelines for Controlled Activities on Waterfront Land; Guidelines for Riparian Corridors on Waterfront Land. This may include fencing of riparian areas being rehabilitated. – Monitoring to meet clear targets in relation to vegetation establishment and stabilisation of disturbed areas.	Pre-construction, Construction and Post-construction

<table>
<tr><th>Risk</th><th>Potential impacts</th><th>Measures to avoid, mitigate or minimise impacts</th><th>Timing</th></tr>
<tr><td>Pre / Post Construction Land Condition Assessment</td><td>Contamination liability assumed by Transport</td><td>Land condition assessments will be completed for each compound area intended to be leased.</td><td>Pre-construction, and post-construction</td></tr>
<tr><td rowspan="2">Waste Soil and Excavated Materials</td><td rowspan="2">Illegal waste disposal</td><td>Waste materials (such as soils and aggregates) obtained from the project and to be exported to a non road construction site or project will be sampled and managed in accordance with relevant Roads and Maritime Waste Fact Sheets.</td><td>Construction</td></tr>
<tr><td>Where excavated material cannot be classified as virgin excavated natural material or reused via a resource recovery exemption, it would be classified and disposed of to an appropriately licensed landfill in accordance with the Waste Classification Guidelines–Part 1: Classifying Waste and Part 2: Immobilisation of Waste.</td><td>Construction</td></tr>
</table>

8. Conclusion

This report involved a review of available surface water and ground water quality information related to the proposal, and has assessed and identified surface water and groundwater impacts that may occur as a result of the construction and operation of the Hillsborough Road Upgrade. The assessment indicates that the construction and operation of the proposal is unlikely to result in serious adverse impacts to local surface water quality and quantity, including receiving environments such as Winding Creek and North Creek. The assessment drew on sources of information including:

– A desktop review of available water quality and groundwater information
– A review of the results from the geotechnical investigations in the proposal area
– A review of the flood impact assessment (WMAwater, 2022)
– Concept design documentation

The proposal is located in a highly urbanised environment that has been substantially altered from its natural state.

Potential construction impacts include drainage and culvert works, contamination from chemical or hydrocarbon spills and increased sediment loads being discharged to downstream systems as a result of runoff from exposed areas. Construction impacts would be managed through implementation of a SWMP and Erosion and Sedimentation Control Plan in accordance with the Blue Book (DECC 2008).

Water quality impacts have been managed for the concept design phase through measures, during the construction phase. The updated drainage network will include additional scour protection as part of the design to minimise potential for water quality impacts within the Winding Creek and Lake Macquarie catchment during the operational phase. Preliminary drainage design and modelling during the concept design phase will be refined at the detailed design phase, addressing specific limits for velocity and flow rate.

Based on observed groundwater levels, proposed cuttings as part of the proposal will not intercept the water table. There is potential that excavation of foundations for the extension of the Winding Creek culvert may intercept groundwater. However, analytical calculations indicate that excavation depths will be above the predicted depth to groundwater. If groundwater is encountered, rate of inflows into this excavation will be very low (less than 0.1 cubic metres per day) and the associated radius of drawdown will be approximately 10 metres. Therefore, the proposal will not result in significant drawdown of the regional groundwater table.

Operational impacts on water quality are not expected. The proposal will result in a small increase in impervious areas of about 1.5 ha. This small change in the imperviousness over the proposal area is unlikely to result in any measurable changes in the hydrology or water quality of the downstream receiving environment of the Winding Creek Catchment.

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Appendices

Appendix A

Water quality data

Table A.1 Freshwater catchment ecosystem health scorecard data – North Creek

Year	Overall site grade	Stream quality grade (A to D)	Water Temperature (°C)	Conductivity (µS/cm)	Turbidity (NTU/FNU)	Dissolved Oxygen (mg/Litre)	Dissolved Oxygen (%)	pH	ORP (Oxidation Reduction Potential)	Available Phosphorous (PO_4 mg/L)	Water Quality Grade (A to F)	Riparian Assessment grade (A to D)
2011	C	B	17.1	1100	15	6.37	88	6.88		0.09	D	B
2012	D	C	16.2	1220	6	6.12	84	6.81		0.09	D	C
2013	E	D	18.8	2130	6	4.33	76	7.77		0.16	F	C
2014	E	D	19.2	2500	32	4.39	80	8.12		0.04	F	C
2015	D	D	18.4	1520	4	5.42	60	7.86		0.12	F	C
2016	D	D	17.6	990	7	5.64	60	7.37		0.09	C	C
2017	D	C	17.9	1040	2	0.3	4	7.07		0.18	F	C
2018	D	C	18.7	1040	9	4.56	48	6.93		0.14	D	C
2019	D	C	16.3	1880	3	5.85	60	7.58		0.06	F	C
2020	D	C	12.8	2260	3	7.2	69.2	6.87		0.03	F	C
2021	D	C	17.7	797	5.62	4	42.8	7.52	90.9	0.15	B	C

Table A.2 Freshwater catchment ecosystem health scorecard data – Winding Creek

Year	Overall site grade	Stream quality grade	Water Temperature (°C)	Conductivity (µS/cm)	Turbidity (NTU/FNU)	Dissolved Oxygen (mg/Litre)	Dissolved Oxygen (%)	pH	ORP (Oxidation Reduction Potential)	Available Phosphorous (PO_4 mg/L)	Water Quality Grade (A to F)	Riparian Assessment grade (A to D)
2011	C	C	14.5	353	20	6.09	80	6.27		0.08	A	C
2012	D	C	18.2	524	15	6.5	90-100	6.56		0.09	A	C
2013	D	D	17	466	7	3.4	64	6.96		0.03	A	C
2014	D	C	18	433	12	5.78	85	6.92		0.04	A	D
2015	D	D	19	360	17	5.5	60	7.4		0.12	A	D
2016	D	C	17.8	346	8	5.72	60	7.15		0.05	A	D
2017	D	C	19.7	285	9	2.1	22	7.08		0.09	B	C
2018	D	C	18.7	286	26	4.23	47	6.53		0.12	A	C
2019	C	B	14.6	447	6.49	4.9	50	6.49		0.08	A	D
2020	D	C	14.2	387	6	7.4	75	6.77		0.01	A	D
2021	C	C	17.5	352.4	2.99	5.69	60.1	7.5	165	0.04	A	D

Appendix B

Landholder bore search

Table B.1 Results of NSW bore database search – bores within three kilometres of the proposal

Bore ID	Easting	Northing	Authorised use	Depth (m)	SWL (m bgl)	Salinity (ppm)	Yield (L/s)	Geology description
GW047633	374666	6351909	Drainage	27.7	–	1001-3000 ppm	–	Overburden (3m thick) overlayed 20 m thickness shale and coal seam
GW052352	374855	6349324	Stock	18	5	–	–	Shale
GW053072	377247	6348953	Recreation (groundwater)	23	3.5	1001-3000 ppm	3.5	Sandstone
GW053172	375422	6347575	Horticulture	17.4	3.1	3001-7000 ppm	0.1	Conglomerate
GW058977	375756	6353986	Domestic	7	–	–	–	–
GW060950	374730	6348891	Stock, domestic	18.3	5.4	1001-3000 ppm	1.5	Coal
GW061046	374939	6348801	Stock, domestic	24.2	4.7	3001-7000 ppm	0.3, 0.7	Sandstone
GW078068	375402	6349177	Domestic	21.2	8	Good	0.4	Sandstone
GW078258	374357	6353470	Stock, domestic, farming, irrigation	46	6	Fresh	0.7	Sandstone
GW078339	375222	6349017	Domestic	16.6	6	Fair	0.3, 0.3	Shale, coal
GW078340	375440	6348999	Domestic	22.1	15	Fair	0.4	Sandstone
GW078354	375564	6349228	Domestic	35	–	300, 600	0.11	Sandstone
GW078363	375143	6349081	Domestic	36.5	13	–	0.2	Sandstone
GW078591	375275	6349135	Domestic	42.6	15.2	Good	0.05, 0.07	Shale
GW080791	373491	6353942	Monitoring	9	6	–	–	Clay
GW080792	373476	6353951	Monitoring	8.5	4.3	–	–	Clay
GW080793	373464	6354004	Monitoring	11	–	–	–	Clay, shale
GW080794	373542	6354001	Monitoring	–	–	–	–	N/A
GW200030	372268	6354162	Industrial	47	–	–	–	Coal
GW201528	377775	6349125	Monitoring	9	–	–	–	Clay
GW201529	377795	6349140	Monitoring	15	–	–	–	Clay
GW201552	377740	6349190	Monitoring	9	6.1	–	–	Clay
GW201553	377745	6349120	Monitoring	9	6	–	–	Clay
GW201554	374542	6354684	Monitoring	4.4	1.295	–	–	Silty sandy clay, silty clay
GW201555	374539	6354685	Monitoring	6	1.146	–	–	Silty clay, gravel
GW201556	374545	6354685	Monitoring	5.6	1.25	–	–	Silty clay, gravelley, clayey sand
GW201747	378093	6351700	Monitoring	7	5	–	–	Fill, silty clay, conglomerate

Bore ID	Easting	Northing	Authorised use	Depth (m)	SWL (m bgl)	Salinity (ppm)	Yield (L/s)	Geology description
GW201748	378108	6351697	Monitoring	5.9	4.7	–	–	Fill, silty clay
GW201749	378123	6351701	Monitoring	5.5	3.3	–	–	Silty clay, conglomerate
GW201750	378119	6351694	Monitoring	5.4	3.5	–	–	Fill, silty gravelly clay, conglomerate
GW201751	378135	6351694	Monitoring	6	3.3	–	–	Gravelly clayey silt, conglomerate
GW201752	378090	6351681	Monitoring	6.5	4.8	–	–	Silty gravelly clay, conglomerate
GW201753	378102	6351669	Monitoring	7.4	4.5	–	–	Silty clay, conglomerate
GW201754	378114	6351674	Monitoring	6.8	3.3	–	–	Silty clay, silty gravelly clay, conglomerate
GW201755	378133	6351684	Monitoring	7.4	3.3	–	–	Clay, conglomerate, silty clay
GW201756	378131	6351671	Monitoring	7.3	3.2	–	–	Silty clay, conglomerate
GW201757	378096	6351719	Monitoring	6.4	4.9	–	–	Silty clay, conglomerate
GW201758	378112	6351709	Monitoring	5.7	4.8	–	–	Fill, conglomerate
GW201772	376980	6348779	Monitoring	7	–	–	–	Shale
GW201773	376949	6348772	Monitoring	5	–	–	–	Sandy clay, sandstone, shale
GW201774	376961	6348759	Monitoring	6	–	–	–	Sandy clay, sandstone, shale
GW201805	373550	6354000	Monitoring	9	–	–	–	Clay
GW201806	373550	6354015	Monitoring	7.5	–	–	–	Clay
GW201807	373545	6354010	Monitoring	1.7	–	–	–	Clay
GW201808	373550	6354015	Monitoring	1.7	–	–	–	Sandy gravel, clay
GW202412	378070	6351585	Monitoring	7.5	5	–	–	Silty clay, clay/gravel
GW202413	378090	6351585	Monitoring	8.3	–	–	–	Silty clay, rock
GW202414	378130	6351632	Monitoring	5.5	3.3	–	–	Rock
GW202415	378098	6351564	Monitoring	6.5	2	–	–	Clay, gravelly clay, gravelly sand
GW202416	378123	6351565	Monitoring	6	3.5	–	–	Clay
GW202417	378169	6351570	Monitoring	7	4.7	–	–	Clay
GW202418	378178	6351612	Monitoring	6	0.3	–	–	Fill, clay, gravelly clay
GW202419	378125	6351592	Monitoring	5.8	0.7	–	–	Clay
GW202560	378098	6351578	Monitoring	7	–	–	–	Clay, silty clay, sandstone
GW202561	378098	6351579	Monitoring	5.9	–	–	–	Clayey silt, silty gravelly clay
GW202562	378133	6351577	Monitoring	6	3.2	–	–	Clay, gravelly clay, silty clay
GW202563	378106	6351622	Monitoring	6.5	3.1	–	–	Sandy clay

Bore ID	Easting	Northing	Authorised use	Depth (m)	SWL (m bgl)	Salinity (ppm)	Yield (L/s)	Geology description
GW202564	378102	6351645	Monitoring	5.3	1.9	–	–	Clay, sandy clay
GW202565	378109	6351548	Monitoring	6.2	4.3	–	–	Clay
GW202566	378143	6351549	Monitoring	6	4.15	–	–	Clay, gravelly sandy clay
GW202695	378100	6351630	Monitoring	5.4	2.6	–	–	Clay
GW202696	378122	6351639	Monitoring	6	3.2	–	–	Sandy clay
GW202806	377773	6350096	Monitoring	7	–	–	–	Silty clay, coal, claystone
GW202888	378137	6351681	Monitoring	6	1.588	–	–	Clay, silty clay, conglomerate
GW202889	378130	6351648	Monitoring	6	–	–	–	Silty clay, silty sandy clay
GW202890	378134	6351670	Monitoring	6	1.693	–	–	Silty clay, conglomerate
GW202891	378161	6351656	Monitoring	6	1.561	–	–	Silty clay, silty sandy clay, conglomerate
GW202892	378179	6351673	Monitoring	6	0.959	–	–	Silty clay, silty sandy clay, conglomerate
GW202893	378175	6351638	Monitoring	6	0.564	–	–	Silty clay, conglomerate
GW202894	378135	6351682	Monitoring	5	–	–	–	Sandy clay, sandstone
GW202895	378134	6351675	Monitoring	4.5	–	–	–	Clay, sandy clay
GW202896	378193	6351642	Monitoring	6	0.342	–	–	Silty clay
GW202897	378200	6351682	Monitoring	6	2.071	–	–	Silty clay
GW202898	378198	6351666	Monitoring	5.4	1.273	–	–	Silty clay
GW202899	378190	6351617	Monitoring	5.8	–	–	–	Silty clay
GW203143	378126	6351625	Monitoring	4.3	1.84	–	–	Sandy clay
GW203144	378128	6351626	Monitoring	6.1	1.69	–	–	Clay, sandstone
GW203145	378115	6351624	Monitoring	4.7	3.93	–	–	Sandstone
GW203146	378100	6351625	Environment rehabilitation	4.7	–	–	–	Clay, sandstone
GW203147	378101	6351622	Environment rehabilitation	5.9	3.75	–	–	Clay, sandstone
GW203148	378111	6351622	Environment rehabilitation	6	3.81	–	–	Clay, sandy clay

m bgl – metres below ground level, ppm – parts per million, L/s – litres per second, '–' denotes data not available ghd.com

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