MALABAR COAL

MAXWELL PROJECT

APPENDIX F

Aquatic Ecology and Stygofauna Assessment

Maxwell Project

Aquatic Ecology and Stygofauna Assessment

Prepared for
Malabar Coal Limited

12 July 2019

DOCUMENT TRACKING

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Abbreviations

Abbreviation	Description
ANZECC	Australian and New Zealand Environment Conservation Council
AUSRIVAS	Australian River Assessment System
BC Act	NSW *Biodiversity Conservation Act, 2016*
BoM	Bureau of Meteorology
CL	Coal Lease
DO	dissolved oxygen
DPI	Department of Primary Industries
EC	electrical conductivity
EIS	Environmental Impact Statement
EL	Exploration Licence
ELA	Eco Logical Australia Pty Ltd
EPBC Act	Commonwealth *Environment Protection and Biodiversity Conservation Act, 1999*
FM Act	NSW *Fisheries Management Act, 1994*
IBRA	Interim Biogeographic Regionalisation for Australia
km	kilometres
mAHD	metres above Australian Height Datum
Malabar	Malabar Coal Limited
mg/L	milligrams per litre
ML	Mining Lease
ML/day	megalitres per day
mm	millimetre
m^3/s	cubic metres per second
NSW	New South Wales
ppm	parts per million

Abbreviation	Description
RCE	Riparian, Channel and Environmental
ROM	run-of-mine
SEARs	Secretary's Environmental Assessment Requirements
SIGNAL	Stream Invertebrate Grade Number-Average Level
µm	micrometre
µS/cm	microSiemens per centimetre
ºC	degrees Celsius

Glossary

Term	Description
Depression	A landform element that stands below all, or almost all, points in the adjacent terrain.
Invertebrate	Animal species that do not possess a vertebral column (spine).
Knickpoint	A local steep fall in channel bed elevation.
Periphyton	A biofilm that comprises of algae, fungi, bacteria and detritus (Department of Infrastructure, Planning and Natural Resources 2003).
Macroinvertebrate	Invertebrates that can be seen with the naked eye (Department of Primary Industries [DPI] 2012).
Macrophyte	Generic term for aquatic plant.
Riparian	Of, on or relating to the banks of a natural waterway.
Riparian vegetation	Plants located on the banks of a river or other water body.
SIGNAL	A biotic index for river macroinvertebrates, developed initially for application to eastern Australia, it was adapted from the Average Score Per Taxon version of the Biological Monitoring Working Party System used in Great Britain. The SIGNAL score for a macroinvertebrate sample is calculated by averaging the pollution sensitivity grade numbers of the families present, which may range from 10 (most sensitive) to 1 (most tolerant) (Chessman 2003).
Snags	Large woody debris from trees and shrubs, including whole fallen trees, broken branches and exposed roots that have fallen or washed into a waterway and are now wholly or partially submerged by water (DPI 2013).
Stygofauna	Animals that occur in subsurface waters (DPI 2012).
Taxa	A group of organisms of any taxonomic rank, e.g. family, genus, or species.
Taxa richness	The number of different families (or taxa) in a sample.

Executive Summary

The Maxwell Project (the Project) is a proposed underground mining operation located in the Upper Hunter Valley of New South Wales (NSW), east-southeast of Denman and south-southwest of Muswellbrook. Eco Logical Australia Pty Ltd (ELA) was commissioned by Maxwell Ventures (Management) Pty Ltd, a wholly owned subsidiary of Malabar Coal Limited (Malabar), to prepare this aquatic ecology and stygofauna assessment for the Project.

The Project is within the broader Hunter River catchment, and its tributaries, including, Saddlers Creek, Saltwater Creek and Ramrod Creek. The Hunter River is a large, regulated river with extensive alluvial aquifers. Flow in the Hunter River is regulated by releases (primarily for agricultural use) from Glenbawn Dam, approximately 90 kilometres upstream of the Project area. The underground mining area is adjacent to Saddlers Creek, an intermittent stream and a tributary of the Hunter River, which has experienced significant erosion and disturbance by historical agriculture.

This assessment consists of desktop assessments and field surveys for aquatic ecology and stygofauna. Seven surface sites were sampled for fish, macroinvertebrates, water quality, and aquatic habitat in May and October 2018. Macroinvertebrate samples were collected following the NSW Australian River Assessment System (AUSRIVAS) protocol, using a standard 250 micrometre (µm) mesh net, and fish samples were collected with box traps placed in different aquatic habitats. Stygofauna samples were collected from 13 bores in May 2018, using six hauls of a stygofauna sampling net.

One aquatic ecology site, in an unnamed tributary of Saltwater Creek, was dry during the surveys and had little potential for aquatic habitat during periods of flow. For three sites on Saddlers Creek, and one on Ramrod Creek, aquatic habitat was restricted to isolated pools of varying depths, with fringing vegetation providing the main habitat feature. These sites had between 8 and 15 invertebrate taxa and Stream Invertebrate Grade Number-Average Level (SIGNAL) scores of between 2 and 3.1. The low diversity and low SIGNAL scores indicate severe disturbance, caused by historical agricultural impacts and the current drought conditions.

The Hunter River had more water, and a better-developed range of habitats available for invertebrate and vertebrate fauna. Invertebrate diversity at these sites was higher than the other sites (6 to 21 taxa) and higher SIGNAL scores (3.1 to 4.3). Large woody debris, consisting of fallen trees, was common at Hunter River sites, as was the topographic variation in bed and bank structure that leads to diverse habitat features such as deep pools, gradually-sloping gravel bars, riffles, pools, and steep banks.

No threatened fish species were recorded during the survey. Two threatened fish species listed under the NSW *Fisheries Management Act, 1994* (FM Act) are mapped as having potential habitat in or near the study area. While there is potential habitat for both species in the Hunter River, neither the Purple-spotted Gudgeon, nor the Darling River Hardyhead have been collected from the study area. It is unlikely that any threatened aquatic species will be affected by the Project. No threatened ecological communities listed under the FM Act potentially occur in the study area.

Five invertebrate taxa were collected from six bores during stygofauna sampling in May 2018. Of these, *Notobathynella* sp. is certainly a stygofaunal taxon; Cyclopoida and Ostractoda are likely to be stygofauna; and Oligochaete and Acarina may be stygofauna but are more likely to be members of the soil invertebrate fauna. Stygofauna were collected from the Saddlers Creek and Hunter River alluvial aquifers, indicating that the aquifers are functioning as ecosystems capable of supporting invertebrates. All of the taxa collected are known from previous surveys of the Hunter River alluvium or its tributaries.

Assessment of the potential impacts indicates that the proposed underground mine, associated surface infrastructure, and subsequent subsidence are unlikely to affect aquatic or groundwater ecology to a significant extent. Surface infrastructure is located away from waterways, so there will be little risk of eroded sediments increasing turbidity. Groundwater modelling indicates that there is unlikely to be large changes in groundwater quality, and that the impact of these on surface waterways will be minor.

Subsidence may result in the formation of new depressions, or the expansion/deepening of existing depressions in channels. The depressions formed as a result of subsidence would be conducive to coarse sediment deposition, and would trap sediment released from upstream degraded hillslopes and gullies. Ultimately, the depressions would fill with sediment, reforming an even stream grade. The risk of knickpoint formation and stream channel alignment change due to subsidence related depressions would be managed through regular monitoring, assessment of potential consequences of the observed threat and the development of appropriate control works.

Malabar would develop a water management plan for the Project that would include a monitoring strategy, acceptable water quality trigger values, and trigger response actions for surface water and groundwater. The plan would be designed to safeguard aquatic ecosystems on-site and downstream against significant impacts.

With the implementation of proposed mitigation measures, the Project is not likely to have a significant impact on aquatic ecology in the surrounding waterways or stygofauna.

1 Introduction

1.1 Project Background

Maxwell Ventures (Management) Pty Ltd, a wholly owned subsidiary of Malabar Coal Limited (Malabar), is seeking consent to develop an underground coal mining operation, referred to as the Maxwell Project (the Project). The Project is in the Upper Hunter Valley of New South Wales (NSW), east-southeast of Denman and south-southwest of Muswellbrook (**Figure 1**).

Underground mining is proposed within Exploration Licence (EL) 5460, which was acquired by Malabar in February 2018. Malabar also acquired existing infrastructure within Coal Lease (CL) 229, Mining Lease (ML) 1531 and CL 395, known as the "Maxwell Infrastructure". The Project would include the use of the substantial existing Maxwell Infrastructure, along with the development of some new infrastructure.

This aquatic ecology and stygofauna assessment forms part of an Environmental Impact Statement (EIS) which has been prepared to accompany a Development Application for the Project in accordance with Part 4 of the NSW *Environmental Planning and Assessment Act, 1979*.

The Project would involve an underground mining operation that would produce high quality coals over a period of approximately 26 years.

At least 75% of coal produced by the Project would be capable of being used in the making of steel (coking coals). The balance would be export thermal coals suitable for the new generation High Efficiency, Low Emissions power generators.

The Project would involve extraction of run-of-mine (ROM) coal, from four seams within the Wittingham Coal Measures using the following underground mining methods:

- underground bord and pillar mining with partial pillar extraction in the Whynot Seam; and
- underground longwall extraction in the Woodlands Hill Seam, Arrowfield Seam and Bowfield Seam.

The substantial existing Maxwell Infrastructure would be used for handling, processing and transportation of coal for the life of the Project. The Maxwell Infrastructure includes an existing coal handling and preparation plant (CHPP), train load-out facilities and other infrastructure and services (including water management infrastructure, administration buildings, workshops and services).

A mine entry area would be developed for the Project in a natural valley in the north of EL 5460 to support underground mining and coal handling activities and provide for personnel and materials access (Figure 1, Figure 2).

ROM coal brought to the surface at the mine entry area would be transported to the Maxwell Infrastructure area. Early ROM coal would be transported via internal roads during the construction and commissioning of a covered overland conveyor system. Subsequently, ROM coal would be transported to the Maxwell Infrastructure area via the covered overland conveyor system.

The Project would support continued rehabilitation of previously mined areas and overburden emplacements areas within CL 229, ML 1531 and CL 395. The volume of the East Void would be reduced through the emplacement of reject material generated by Project coal processing activities and would be capped and rehabilitated at the completion of mining.

The Project area comprises the following main domains:

- the Maxwell Underground (the proposed area of underground mining operations and the mine entry area within EL 5460);
- the Maxwell Infrastructure (the area within existing mining and coal lease boundaries, consisting of the substantial existing infrastructure [including the CHPP] and previous mining areas);
- the transport and services corridor between the Maxwell Underground and Maxwell Infrastructure; and
- the potential realignment of Edderton Road (**Figure 2**).

A detailed description of the Project is provided in the main document of the EIS.

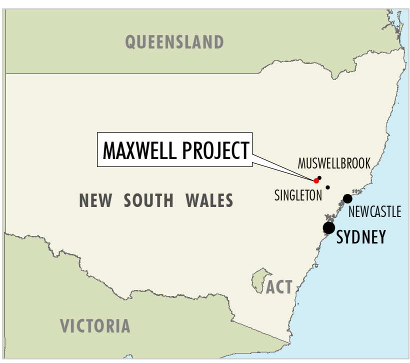
The proposed Maxwell Underground is in the Saddlers and (to a lesser extent) Saltwater Creek catchments which flow to the Hunter River. The proposed underground operations are not expected to cause subsidence beneath either of these waterways (Mine Subsidence Engineering Consultants [MSEC] 2019). Nevertheless, aquatic ecology and stygofauna assessments have been conducted to determine any potential impact on riverine and groundwater ecological communities.

The Maxwell Infrastructure is within the Ramrod Creek catchment to the north, with a small portion within the Bayswater Creek catchment, to the east.

1.2 Scope of Work

This document was prepared in accordance with the Secretary's Environmental Assessment Requirements (SEARs) for the EIS. This Aquatic Ecology and Stygofauna Assessment includes the following:

- a description of the survey methods, including timing, duration and survey effort;
- a description of waterbodies present (including maps showing survey locations), and their value and importance;
- a description of native and introduced aquatic flora and fauna (including mammals, fish, reptiles and aquatic invertebrates) present;
- a description of any conservation significant aquatic species listed under the NSW *Fisheries Management Act, 1994* (FM Act) or the Commonwealth *Environment Protection and Biodiversity Conservation Act, 1999* (EPBC Act) that are present in the study area;
- a review of stygofauna survey methods and results from previous assessments and surveys conducted within the study area, and from contemporary sampling for the Project;
- potential impacts on the aquatic ecological values and groundwater dependant ecosystems;
- proposed impact avoidance, mitigation measures and ongoing monitoring; and
- assessments of significance in accordance to Division 12, Part 7A of the FM Act and the *Threatened Species Assessment Guidelines – The Assessment of Significance* (Department of Primary Industries [DPI] 2008).



LEGEND

- Mining Operation
- Proposed Mining Operation
- Railway
- Local Government Boundary
- State Forest
- National Parks and Wildlife Service Estate
- Maxwell Project Exploration Licence Boundary
- Maxwell Project Mining and Coal Lease Boundary
- Indicative Extent of Underground Development

Source: © NSW Department of Planning and Environment (2019); NSW Department of Finance, Services and Innovation (2019); Office of Environment and Heritage NSW (2019)

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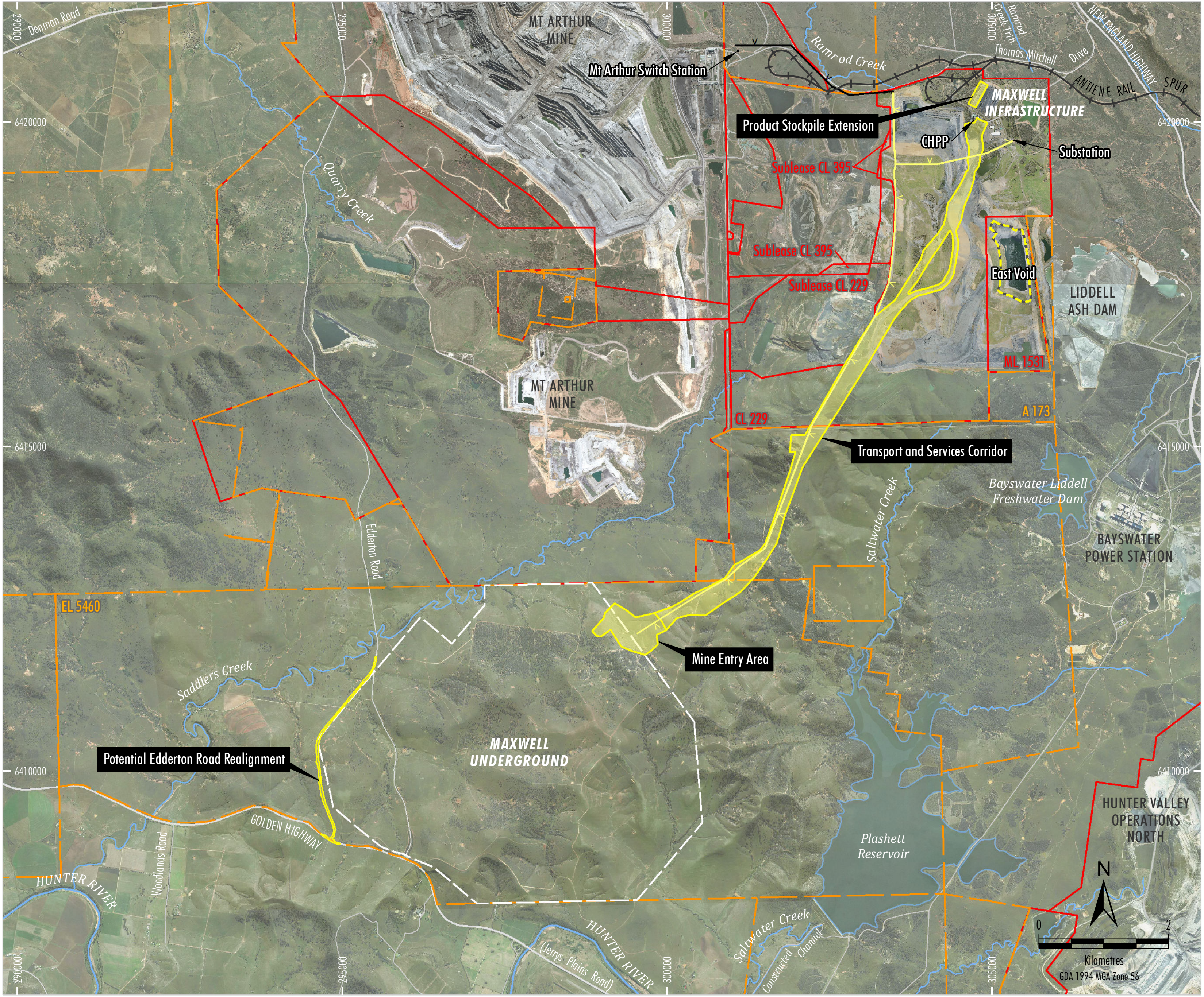
Location of the Project

Figure 1



LEGEND

- Railway
- Exploration Licence Boundary
- Mining and Coal Lease Boundary
- Indicative Extent of Underground Development
- Indicative Surface Development Area
- CHPP Reject Emplacement Area
- Proposed 66 kV Power Supply
- Proposed Ausgrid 66 kV Power Supply Extension#

Subject to separate assessment and approval.

Source: © NSW Department of Planning and Environment (2019); NSW Department of Finance, Services & Innovation (2019) Orthophoto Mosaic: 2018, 2016, 2011

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General Layout of the Project

Figure 2

SHM-18-03 Maxwell_EIS_App_Aquatic_202B

2 Existing Environment

2.1 Regional Setting

The Project is located in the Hunter Interim Biogeographic Regionalisation for Australia (IBRA) sub-region of the Sydney Basin IBRA Bioregion.

The study area for this assessment includes:

- the section of the Hunter River from the Saddlers Creek confluence to the Saltwater Creek confluence;
- Saddlers Creek;
- Ramrod Creek;
- Saltwater Creek; and
- unnamed minor streams within the extent of predicted subsidence from the proposed underground mining operations.

2.2 Climate

Long-term climatic data collected at the closest Bureau of Meteorology (BoM) weather station at Jerrys Plains Post Office (Station Number 061086) was used to characterise local climate. The Jerrys Plains Post Office is approximately 7 kilometres (km) south-southeast of the Project.

January is the hottest month, with a mean maximum temperature of 31.8 degrees Celsius (ºC), and July is the coldest month with a mean minimum temperature of 3.8ºC (Bureau of Meteorology [BoM] 2019).

Rainfall peaks during the summer months, with January having average rainfall of 77.1 millimetres (mm) over 6.4 days. August is the driest month, with an average rainfall of 36.1 mm over 5.2 days (BoM 2019).

Relative humidity levels fluctuate throughout the day and exhibit seasonal fluctuations. Mean 9.00 am relative humidity levels range from 59% in October to 80% in June. Mean 3.00 pm relative humidity levels vary from 42% in October, November and December, to 54% in June (BoM 2019).

2.3 Landform and Hydrology

Landform

The landform above the Maxwell Underground consists of undulating foothills to moderately-sloping hills over open paddock grazing land. Surface elevations vary from a low point of approximately 110 metres above Australian Height Datum (mAHD) to a high point of approximately 240 mAHD along a north-east to south-west trending ridgeline. The Maxwell Infrastructure consists of areas of previous open cut mining and rehabilitated overburden emplacement, with existing infrastructure located in the north of the area.

Hydrology

The Maxwell Underground is located in the Saddlers and (to a lesser extent) Saltwater Creek catchments, which flow to the Hunter River. The thalweg of the Hunter River is approximately 525 metres (m) south of the underground mining area, at its closest point. The Hunter River is the most significant water body in the Hunter Valley, and in the area south of the Project generally flows from west to east through a channel approximately 30 m wide and 3 m to 6 m deep. The Hunter River cuts across a well-developed floodplain, which can be up to several kilometres wide at its widest point.

Saddlers Creek, an intermittent watercourse, is located north of the Maxwell Underground (**Figure 2**). Saddlers Creek is a 4th order stream to the north of the Maxwell Underground, and a 5th order stream downstream of Edderton Road. Saddlers Creek is fed by several small ephemeral creeks and drainage lines that traverse the central and northern portions of the Maxwell Underground area. These creeks and drainage lines form complex drainage networks that comprise the central reaches of the Saddlers Creek catchment area. Dry for much of the year, these watercourses commonly only flow after large rain events. The watercourses vary in width from less than 1 m at their headwaters to instances of greater than 20 m where they meet Saddlers Creek. Many of the watercourses, including Saddlers Creek, show evidence of heavy erosion associated with historic native vegetation clearance activities, particularly along their mid and lower reaches.

In the eastern portion of the Maxwell Underground area, another series of ephemeral creeks and drainage lines drain moderate to steeply sloping hills before feeding into Saltwater Creek, a 5th order stream immediately upstream of the Hunter River. As with the watercourses feeding Saddlers Creek, these feeder creeks are mostly dry, running only during rain and flood events. Heavy erosion is likewise a feature, particularly along the middle to lower reaches, with transported soils draining to the Saltwater Creek floodplain. Plashett Reservoir, constructed to supply water to the nearby Bayswater Power Station and Jerrys Plains township, occupies much of the original alignment of Saltwater Creek. Both Plashett Reservoir and Bayswater Power Station are to the east of the Project.

The Maxwell Infrastructure is within the Ramrod Creek catchment to the north, with a small portion within the Bayswater Creek catchment, to the east. Ramrod Creek drains to the Hunter River approximately 10 km to the north-west of the Maxwell Infrastructure, immediately downstream of Muswellbrook.

2.4 Hydrogeology

The hydrogeological regime of the locality comprises three key groundwater systems consistent with the relevant water sharing plans for the region (HydroSimulations 2019):

- an alluvial groundwater system associated with the Hunter River;
- an alluvial groundwater system associated with Saddlers Creek; and
- the Permian porous and fractured rock groundwater sources within the Sydney Basin – North Coast Groundwater Source.

Hunter River Alluvium

The Hunter River alluvium is up to 20 m thick with sand and gravel deposits that fill palaeochannels. The material overlying the basal gravel is less permeable and consists predominantly of silt and minor clay.

Groundwater levels within the alluvium have remained relatively stable over time, despite periods of below average rainfall. This indicates a degree of recharge to the alluvium from regulated flows in the Hunter River (HydroSimulations 2019).

The Hunter River alluvium varies from fresh to moderately saline, with total dissolved solid concentrations ranging between 354 milligrams per litre (mg/L) to 5070 mg/L (HydroSimulations 2019). The pH ranges from 6.9 (slightly acidic) to 8.4 (slightly alkaline).

Saddlers Creek Alluvium

Quaternary alluvium is present along Saddlers Creek, with the extent of alluvium greatest near the confluence with the Hunter River. The alluvium comprises permeable sands and gravels in the lower reaches of the creek, while low permeability silts and clays are present within the upper reaches (HydroSimulations 2019).

The alluvium is unconfined and is likely recharged from rainfall and potentially stream flow following peak rainfall events. There is also potential for upward leakage from the Permian coal measures at the lower reaches of Saddlers Creek (HydroSimulations 2019).

Permian Hard Rock

The Permian hard rock can be categorised into the following hydrogeological units:

- very low yielding to dry sandstone and lesser siltstone that comprise the majority of the Permian interburden; and
- low to moderately permeable coal seams, ranging in thickness from 1 m to 5 m, which are the predominant water bearing strata within the Permian porous rock aquifers.

Groundwater occurrence is largely associated with the coal seams due to secondary porosity through the fractures and cleats. The interburden material (sandstone and siltstone) generally has a low permeability, and due to the stratified nature of the stratigraphy has a very low vertical hydraulic conductivity. There is a relatively low hydraulic connection between the Permian coal measures and overlying alluvium (HydroSimulations 2019).

The Permian hard rock aquifers are considered “less productive” in accordance with the NSW Aquifer Interference Policy (NSW Government 2012), because they have a low yield (less than 5 litres per second [L/s]) and an average total dissolved solids concentration in excess of 1,500 mg/L (HydroSimulations 2019).

2.5 Land Use

Agricultural industries in the surrounding area include cattle grazing, cropping, horse breeding and viticulture. Freehold land in the Project area is owned by Malabar, except for a small area in the northern part of the transport and services corridor and a portion of the Maxwell Infrastructure, which are owned by AGL Energy Limited (AGL).

Land within the Project area is primarily cleared, open paddock grazing land, with some areas of remnant forest and open woodland and mainly used for cattle grazing along with minor cropping.

These agricultural activities are supported by farm dams, unsealed tracks, land contouring, cattle yards and fencing. Land to the north of the Maxwell Underground area is associated with active or previous open cut coal mining activities (i.e. the Mt Arthur Mine).

AGL-owned land associated with the Bayswater and Liddell Power Stations is located to the east of the Project. The Plashett Reservoir serves as an off-river water storage for the Bayswater Power Station along with water supply to the Jerrys Plains township.

2.6 Previous Aquatic Ecology and Stygofauna Surveys

An aquatic vertebrate survey was completed by The Ecology Lab Pty Ltd in 2000, which included visual habitat assessments at two locations on Saddlers Creek (at a site upstream of the Edderton property and at the Edderton Road causeway) (The Ecology Lab Pty Ltd 2000). This survey concluded that minimal fish habitat exists in Saddlers Creek due to its small size and degraded, intermittent nature. The creek has been damaged by cattle trampling and bank erosion.

Cumberland Ecology (2015) conducted an assessment of the flora and fauna within the study area. As part of the report, previous surveys within the study area were reviewed, and new surveys undertaken to quantify the condition of the existing aquatic habitat (**Figure 3**). The main findings of these surveys were:

- The site condition and ecological integrity of aquatic survey locations were severely impaired (NSW Australian River Assessment System [AUSRIVAS] band C).
- No threatened aquatic species were recorded during vertebrate surveys of the Hunter River and Saddlers Creek.

Eco Logical Australia (2015) conducted stygofauna surveys within the Project area and surrounds, and assessed potential impacts to stygofauna and groundwater dependent ecosystems **(**Figure 4). The main findings of this assessment were:

- stygofauna are known to occur in the alluvial sediments associated with the Hunter River, and Saddlers Creek;
- no stygofauna were found in the Hunter River alluvial aquifer during field surveys, however the surveys did confirm the presence of two taxa of stygofauna in the Saddlers Creek alluvial aquifer, including *Diacyclops* copepods and an ostracod;
- due to the depth of the water table, the low hydraulic conductivity and the isolation of the deeper Permian aquifers, these areas were considered unsuitable as stygofauna habitat; and
- further field surveys in September 2011 found no stygofauna in Permian bores.

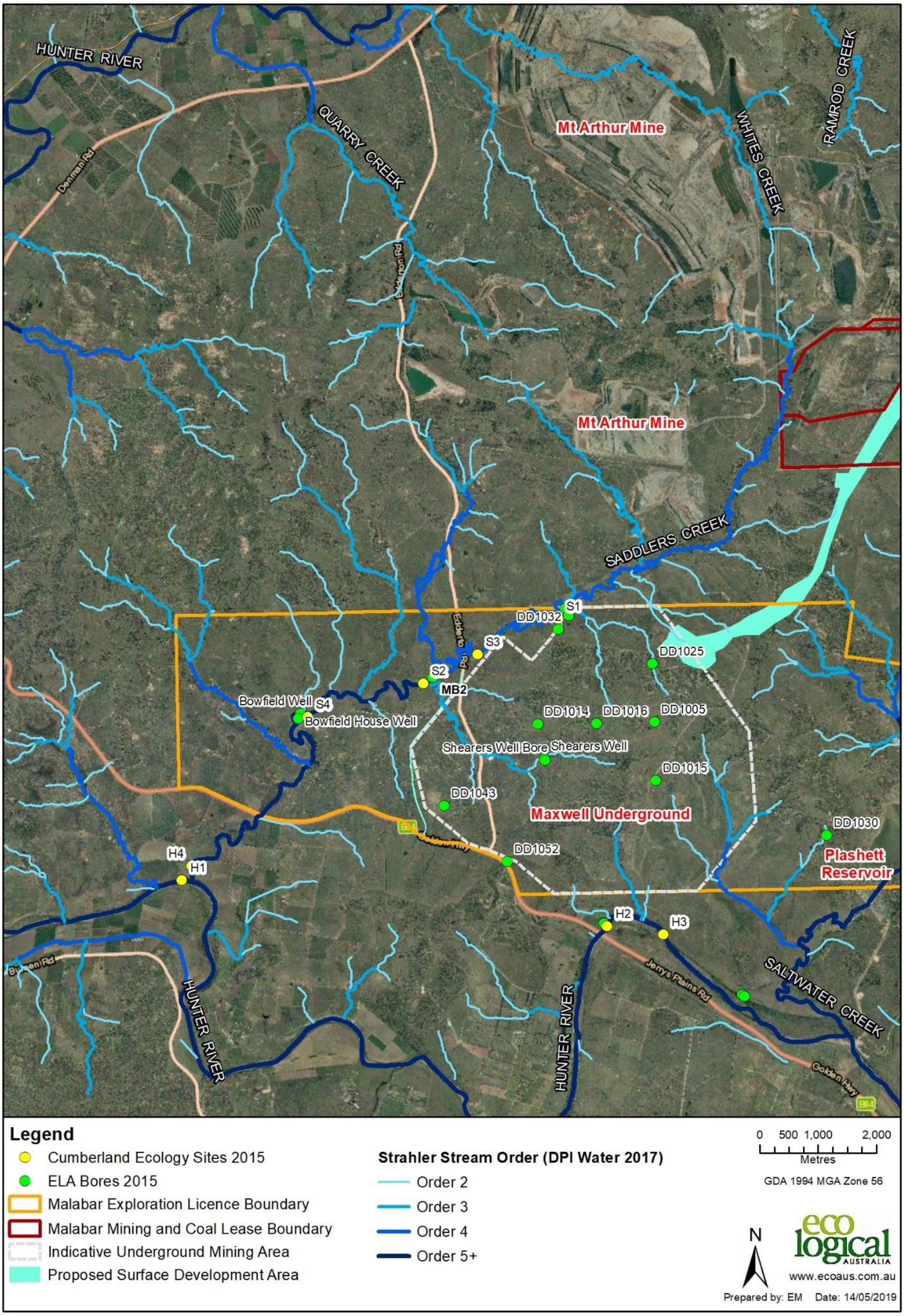

Figure 3. Location of previous aquatic ecology (yellow dots) and stygofauna (green dots) survey sites

3 Methods

3.1 Desktop Assessment

Prior to the field survey, online database searches were used to confirm the presence of threatened aquatic species in the region. This was then used to infer what was likely to be present at the survey sites. Databases accessed included:

- EPBC Act – *Protected Matters Search Tool* (Department of the Environment and Energy 2018);
- FM Act – listed protected and threatened species and populations species profiles;
- NSW Department of Primary Industries, Fisheries NSW Spatial Data Portal (DPI 2013);
- "Primefact" publications for Purple-spotted Gudgeon (NSW DPI 2017) and Darling River Hardyhead (DPI 2014);
- expected distribution maps (DPI 2016);
- *Online Zoological Collections of Australian Museum* (Council of Heads of Australian Faunal Collections 2018); and
- NSW *Biodiversity Conservation Act, 2016* (BC Act) – Threatened Species Search Tool (BioNet) (Office of Environment and Heritage 2018).

Relevant aquatic ecology reports were also reviewed prior to the field survey, these included the ELA (2015) and the Cumberland Ecology (2015) reports (Section 2.6).

3.2 Licences and Permits

All fish surveys were conducted under ELA's Scientific Collection Permit Number P09/0038-2.1, issued by the DPI under section 37 of the FM Act.

3.3 Survey Conditions

Peter Hancock, Tim Henderson and Emily Messer sampled seven surface sites for aquatic ecology, and 13 bores for stygofauna between 28 and 30 May 2018 (autumn) (**Figure 4**). Spring surveys were conducted by Emily Messer and Byron Heffernan from 16 to 18 October 2018.

During the autumn survey, daytime temperatures ranged from 6.9 °C to 23.1 °C (**Table 1**). The month prior to the autumn survey was relatively dry, with a total rainfall of 6.3 mm in April 2018, and there was no rain in May 2018 until the 5.4 mm that fell on the third day of survey. Temperatures were warmer in the spring 2018 survey, with minimums of around 15.7 °C and maximums of 23.6 to 27.7 °C.

Table 1: Temperature and rainfall data during survey dates from Maxwell Underground MET03

Date	Season	Rainfall (mm)	Minimum Temp (ºC)	Maximum Temp (ºC)
28 May 2018	Autumn	0	7.9	19.9
29 May 2018	Autumn	0	6.9	23.1
30 May 2018	Autumn	5.4	8.8	17.1
16 October 2018	Spring	0	15.7	25.3
17 October 2018	Spring	6.8	15.7	23.6
18 October 2018	Spring	15.2	15.8	27.7

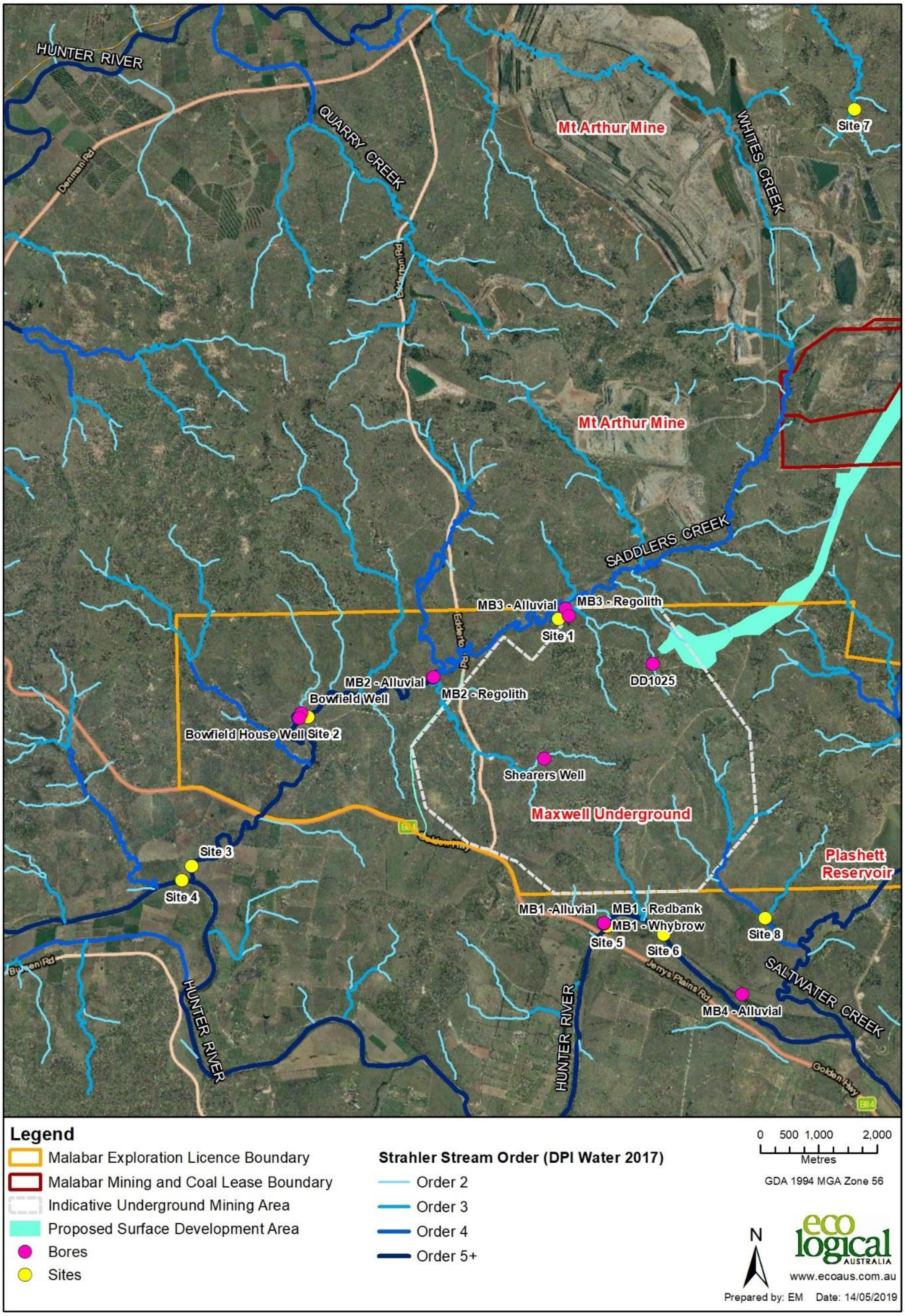

Figure 4. Location of sites and bores sampled in 2018

Average daily flow in the Hunter River at Denman, upstream of the sites, was 7.7 to 8.2 cubic metres per second (m^3/s) during the autumn surveys, and stayed above 7.8 m^3/s for most of the period until 10 July 2018 (**Figure 5**). From then on, flow declined relatively steeply, until reaching a low of 0.95 m^3/s on 29 July 2018. There was an increase in river levels in late August 2018, which remained until early September before falling again. By mid-October 2018, for the spring survey, flow was 1.1 to 1.4 m^3/s (**Figure 5**).

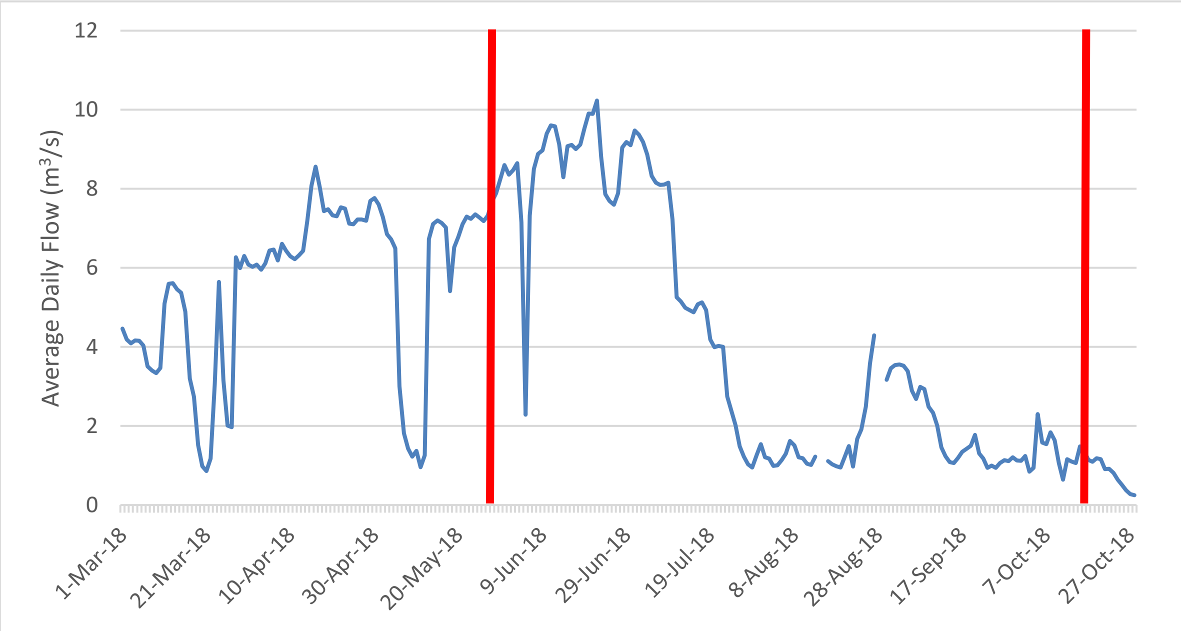

Figure 5. Average daily flow (m^3/s) in the Hunter River at Denman (station 210055) between 1 March and 28 October 2018

3.4 Sampling Protocol

3.4.1 Aquatic Vegetation and Riparian, Channel and Environmental Inventory

Aquatic ecology surveys were completed at a total of seven sites along the Hunter River, Saddlers Creek and Ramrod Creek (**Figure 4**). An eighth site on a tributary of Saltwater Creek was dry during both spring and autumn surveys.

Riparian condition assessment was undertaken using a version of the Riparian, Channel and Environmental (RCE) inventory (Peterson 1992) that was modified for Australian conditions (Chessman *et al*. 1997). The modified RCE has 13 descriptors, each with a score from 1 to 4. Descriptors include width and condition of the riparian zone, surrounding land use, the extent of bank erosion, stream width, water depth, the occurrence of pools, riffles and runs, sub-stratum type, the presence of snags and woody debris, in-stream and emergent macrophytes, algae, and barriers to fish passage. The total score for each site was then derived by summing the score for each descriptor and calculating the result as a percentage of the highest possible score.

Sites with a high RCE score (up to 52, or 100%) indicate that the riparian zone is unmodified by human activity, while those with a low score have been substantially modified. Based on the original classification established by Peterson (1992), site condition was rated as:

- Poor for RCE scores of 0-24%.
- Fair for RCE scores of 25-43%.
- Good for RCE scores of 44-62%.

- Very good for RCE scores of 63-81%.
- Excellent for RCE scores of 82-100%.

Other habitat features were assessed in accordance with the AUSRIVAS proforma and *Policy and Guidelines for Fish Habitat Conservation and Management (2013 update)* (DPI 2013). Each site was photographed, and the GPS location recorded (**Appendix A**).

3.4.2 Physico-chemistry

To complement biological data, physico-chemical parameters were measured at each site that had water. Temperature, dissolved oxygen (DO) concentration, electrical conductivity (EC), turbidity and pH measurements were taken with a Horiba U-52/10m multi-parameter water quality meter. EC and pH were calibrated in the laboratory prior to the field survey and DO was calibrated at the start of each field day. Alkalinity was measured with a Hanna HI755 Freshwater Alkalinity Checker.

Physico-chemical measurements were compared to the Australian and New Zealand Environmental Conservation Council (ANZECC) trigger value range for aquatic ecosystems in south-eastern Australia (ANZECC and Agriculture and Resource Management Council of Australia and New Zealand [ARMCANZ] 2000).

3.4.3 Macroinvertebrate Sampling and Analysis

Macroinvertebrate samples were collected with a standard 250 micrometre (µm) sweep net. The net was moved in one-metre sweeps with the lower edge of the mouth bounced across the stream bed, then twice through the water column above the disturbed area of the bed. This process was repeated until a cumulative length of 10 m was sampled. The purpose was to collect representative samples from each edge habitat feature present (i.e. woody debris, macrophytes, riffles) in the 100 m length of river, therefore, there was no need for each sweep to be adjacent to the next. A combined sample was taken when riffles were present.

Net contents were emptied into a white sorting tray and scanned for 40 minutes so that each invertebrate taxon could be removed and preserved in a jar of 100% ethanol. If additional taxa were still being collected after 40 minutes, the sample was scanned for an additional 20 minutes. The methods follow the NSW AUSRIVAS protocol (Turak and Waddell 2002).

Invertebrates were identified to family in the laboratory using a Leica M80 dissecting microscope. Each family was assigned a Stream Invertebrate Grade Number-Average Level (SIGNAL) score based on Chessman (2003). The SIGNAL score indicates how sensitive an invertebrate family is to disturbance and is used as an indication of habitat health. Families that are sensitive to pollution have scores between six and ten and are likely to only occur in healthy habitats, while those with scores below six can tolerate pollution and will occur in impacted stream habitats (Gooderham and Tsyrlin 2002).

3.4.4 Fish Sampling

Fish samples were collected using bait traps. Five unbaited bait traps were deployed at each site where there was adequate water. The traps were placed in different habitats (i.e. deep pools, overhung edges or logs) at each site and left in place for an hour before being retrieved. At Sites 4, 5, and 6, where there were deeper pools, snorkel surveys were conducted.

3.4.5 Stygofauna Sampling

During autumn 2018, stygofauna samples were collected from thirteen bores (**Figure 4**) using a stygofauna net. The 63 µm-mesh net was lowered to the bottom of each bore, then raised and dropped approximately 50 centimetres (cm) three to five times to dislodge resting invertebrate fauna. It was then slowly retrieved to the surface. Slow retrieval was used to avoid a bow-wave pushing invertebrate fauna from the entrance of the net. Once at the surface the contents were emptied into a 63 µm-mesh sieve. The cumulative contents of six hauls were washed with 100% ethanol into a pre-labelled sample jar.

Samples were transported to the laboratory and sorted under a Leica MZ8 dissecting microscope. They were identified as far as possible using taxonomic keys.

4 Results

4.1 Site Descriptions

Eight sites were visited along creeks and rivers in and adjacent to the Project area. Photographs of the sites are included in **Appendix A**.

Site 1 – Upstream of Edderton Road on Saddlers Creek

Site 1 was located on a relatively narrow stretch of Saddlers Creek, north of the Maxwell Underground. The channel bed and banks consisted of sand and silt, with scattered woody debris throughout. Although the bottom was heavily silted, it was stable. There was evidence of erosion by livestock throughout the channel bed. Both banks were steep, 1 to 1.5 m high, and covered in pasture grasses, or were bare where cattle access the creek. Banks were undercut and eroded at narrow points in the channel. Water at the site was restricted to two long (15 and 10 m), shallow (20 cm deep) pools. *Typha orientalis* (Broadleaf Cumbungi) was present in these pools, and *Juncus acutus* lined the banks. *Chelodina longicollis* (Eastern Long-necked Turtle) were observed at this site.

Riparian vegetation was patchy, with areas of little to no tree or shrub coverage. Where there was vegetation, *Casuarina* sp., *Eucalpytus* sp., and *Angophora floribunda* (Rough-barked Apple) were the dominant native species. *Lycium ferocissimum* (African Boxthorn), an exotic shrub, occurred in areas devoid of native trees. Groundcover was dominated by pasture grasses, with moderate densities of *Cirsium vulgare* (Black Thistle). This site did not change significantly between survey periods, although there was slightly more water present in the spring survey.

Site 2 – *Upstream of Bowfield House Well on Saddlers Creek*

At Site 2, the channel bed was comprised of gravel and cobble embedded in sand. In autumn, there were three pools of turbid water separated by gravel bars. Each pool was approximately 20 m long and 4 m wide, heavily shaded, and less than 1 m deep. The water had a shiny, organic film on the surface. Woody debris, covered in periphyton, was present in all three pools. Scattered patches of *Phragmites australis* (Common Reed) were present in the pools and along the channel edge. These have been damaged by livestock. The banks were steep and undercut where the channel narrowed. *Juncus* spp. and *Juncus acutus* lined the banks.

In spring, the water level had increased enough for the three pools to become connected. There was no organic film on the surface.

The riparian vegetation was dense and dominated by *Casuarina* sp. Of varying age classes. *Casuarina* litter covered exposed sections of gravel bar, smothering the groundcover. No shrubs were observed at the site. Beyond the riparian zone, on both sides, were grazed paddocks.

Site 3 – Saddlers Creek upstream of the confluence with the Hunter River

At Site 3, the creek bed was dominated by pebbles and gravel embedded in silt. Upstream, the channel was only 1 to 2 m wide, before widening to approximately 5 m at the downstream end of the reach. The upstream end of the reach was dry and filled with *Amaranthus albus* (Tumbleweed). A long run started mid-way through the site, with clear water that was less than 1 m deep, and patches of *P. australis* around the margins. *J. acutus* was scattered along the edges and within the channel. This run had scattered woody debris throughout, which was covered in periphyton. The banks were steep, undercut and held together by Casuarina roots and grasses. This site changed little between survey periods.

Riparian vegetation on the right bank consisted of a single row of mature Casuarinas with large gaps between trees. Beneath the trees, a dense littering of Casuarina needles covered the ground. The left bank lacked trees and shrubs and had dry pasture grass as a patchy ground cover. *Opuntia stricta* (Prickly Pear) and Black Thistle were present in low densities. A small cluster of *Willow* sp. grew in the downstream section of the reach. Beyond the immediate riparian zone, the landscape opened up into a grazed agricultural area with no trees or shrubs.

Site 4 – Hunter River upstream of Saddlers Creek confluence

The Hunter River at Site 4 was 20 m wide, with a moderate flow level at the time of the survey. The channel bed comprised of pebble and cobbles embedded in sand. The water was clear, 0.5 to 1 m deep, and flowing relatively quickly during autumn, although water level was slightly lower in spring. *Potamogeton crispus* (Curly Pondweed) was the only submerged aquatic vegetation. *P. australis* and *T. orientalis* were present in patches along the left bank. Instream retention devices consisted of boulders and logs. The banks were steep and heavily vegetated, shading the outer edges of the river.

The right bank was lined with Willows, and groundcover consisted predominantly of grasses. The left bank was lined with native juvenile Casuarina trees, and extremely dense exotic species that included *Cardiospermum grandiflorum* (Balloon Vine), *Ricinus communis* (Castor Oil Plant), *Urtica* sp. (Stinging Nettle), and Willows. At the furthest point upstream, on the edge of the riparian zone were mature native trees including Casuarina and *Eucalyptus* sp. The broader riparian zone was grazed farmland.

Site 5 – Hunter River at Bowmans Bridge

Site 5 was downstream of Site 4. The river was 15 to 20 m wide when sampled in autumn, and water was between 0.4 and 1.5 m deep. Water level was lower in spring, with depths of approximately 0.2 to 1.3 m. Bed sediments consisted of pebbles and cobbles in the riffle area, and fine to coarse sand in the pools and edges. As with Site 4, the water was clear and moving relatively quickly over a large riffle mid-way through the site. Curly Pondweed, filamentous algae and *Azolla filiculoides* were growing in areas sheltered from the main flow. Native macrophytes, including *Persicaria decipiens* (Slender Knotweed), *P. australis* and *Eleocharis* sp.(Spikerush), grew in patches along the edge of the river. This stretch of the Hunter River had scattered woody snags throughout. Both banks sloped gradually into the water, with no undercutting or erosion evident. An extensive gravel bar ran for approximately 500 m along the right bank. The bar was vegetated with Casuarina, Willows, and herbaceous vegetation.

The riparian vegetation on the left bank was dense, with a mix of Casuarina, Willows and Balloon Vine. The right bank was predominately bare gravel substrate, with Casuarina trees, Castor Oil Plants, *Xanthium spinosum* (Bathurst Burr), and other exotic shrubs scattered sporadically throughout. As there were very few mature trees lining the banks, the river was relatively unshaded, with minimal overhanging vegetation.

Site 6 – Hunter River upstream of Saltwater Creek confluence

Site 6 was on the Hunter River, downstream of Site 5. The river was 25 m wide, deeper than 1.5 m and flowed slowly through a long run that extended through the whole site. The bed consisted of pebbles and cobbles embedded in coarse to medium-sized sand or silt. There were no pools or riffles present. *A. filiculoides* and filamentous algae grew in areas of slow flow that were created by fallen logs. These logs were covered in dense periphyton. A small patch of *P. australis* was present on the right bank.

The left bank was undercut at the water's edge and rose steeply to 10 m above current water level. The right bank sloped more gradually into the water. Riparian vegetation on both banks was extremely dense and trailed into the water. Trees consisted of mature Casuarinas, Willows and Castor Oil Plants. Balloon Vine and *Urtica urens* (Stinging Nettle), and exotic vines, were extremely dense and covered the ground, and most of the trees throughout the riparian zone. Below these vines the ground was bare. As the river runs north to south through this site, the mature trees and steep banks cast shade on the river in the morning and afternoon. Dominant land use beyond the immediate riparian zone consisted of farmland that was grazed by cattle.

The site was similar between survey events, although the water level was lower in spring 2018.

Site 7 – Downstream of Maxwell Infrastructure on Ramrod Creek

Most of this site was dry. There was a pool in the middle of the reach which was 10 m long by 3 m wide, and approximately 1.1 m deep. This site was similar in autumn and spring. The channel bed was predominately silt. Upstream of the pool the channel was 3 m wide, relatively straight and filled with remnant Broadleaf Cumbungi. Downstream, the pool was lined with Cumbungi, with patches of *Brachiaria* sp. (Signalgrass), *Triglochin* sp. (Water Ribbon) and *J. acutus*. Filamentous algae was the only submerged macrophyte in the pool. Dense iron flocs were also present. Downstream of the pool, the bed rose approximately 1.3 m and the channel narrowed and was dry. There were two fences crossing the creek, these may catch debris and dam the water in times of higher flow. Throughout the creek, there were few instream features such as logs or boulders. There were no gravel bars that would create riffles.

The banks were between 0.5 to 1.5 m high, increasing in height around and downstream of the pool. Both banks were lined with dense *J. acutus*. Upstream, there was a patch of Casuarinas (30 x 30 m), but most of the reach lacked trees and shrubs. Exotic grasses and sedges dominated the riparian vegetation, with a few juvenile Casuarina trees scattered downstream near the two fences. Prickly Pear was present in low numbers downstream of the pool. There was evidence of cattle in and around the creek bed, but no livestock was observed during the site visit.

Site 8 –Fourth order tributary of Saltwater Creek

Site 8 was dry in autumn and spring and had no aquatic vegetation. The channel bed was sand and highly incised. Banks were 10 m high, steep and eroded. Severe undercutting and bank collapses were common throughout the reach. Riparian vegetation was sparse. Scattered *Acacia* sp. (Wattle) trees lined the banks and extended into the channel bed. Sparse pasture grasses were also present on the banks and in the channel. The broader riparian zone was dry pasture being grazed by cattle.

4.2 Physico-chemistry

Average surface water temperatures ranged from 10.1 ºC to 19.7 ºC in the autumn survey and 15.4 ºC to 21.1 ºC in spring (**Table 2**). EC (electrical conductivity) was above the ANZECC and ARMCANZ (2000) trigger value at all sites in both autumn and spring, with measurements between 433 and 13,500 microSiemens per centimetre (µS/cm) (**Table 2**). EC was highest at Site 2, mid-way along Saddlers Creek, and lowest in Site 4 in the Hunter River, upstream of the confluence with Saddlers Creek. Water in Saddlers Creek was restricted to isolated pools during the survey periods, and EC for the two sites upstream (Sites 1 and 2) appear to be influenced by saline groundwater. EC at Site 3 may also be affected by groundwater, although the dominant aquifer near this site may be the Hunter River alluvium, which appears to have a lower EC. EC in the Hunter River (Sites 4-6) was generally lower than that in Saddlers Creek (**Table 2**).

During autumn, DO (dissolved oxygen) concentration (% saturation) was the highest at the Hunter River sites, but below the ANZECC and ARMCANZ (2000) guideline range at all sites (**Table 2**). In spring, DO concentrations were within ANZECC and ARMCANZ (2000) range for the three Hunter River sites, but below it for the other sites. Site 5 had the highest DO concentration in both surveys (**Table 2**). Concentrations were lower in autumn than spring, measuring between 23.1% and 75% saturation compared to 51.7 to 98% saturation respectively.

At sites 2, 4, and 5, pH was above the ANZECC and ARMCANZ (2000) guideline range for both survey periods, and within guideline range for both periods only for Sites 1 and 7. The pH in autumn was between 7.23 and 9.03, and for spring was between 7.42 and 8.48 (**Table 2**).

Alkalinity ranged between 120 and 240 parts per million (ppm) in autumn, with lower measurements taken from the Hunter River than at other sites (**Table 2**). In spring, the Hunter River alkalinity was between 181 and 194 ppm, and was lower than the other tributary sites, except Site 1 (**Table 2**).

Turbidity was between 14.6 and 84.5 NTU in autumn, and 4.8 and 29 in spring. At all sites, turbidity was lower in spring than autumn (**Table 2**). ANZECC and ARMCANZ (2000) guidelines were exceeded at four sites in autumn, but only one site in spring (**Table 2**).

Table 2: Physico-chemical properties of creek and river sites sampled during aquatic ecology surveys

	Temp. (°C)		EC (µS/cm)		DO (% saturation)		DO (mg/L)		pH		Alkalinity (ppm)		Turbidity (NTU)	
ANZECC and ARMCANZ (2000) Range			**30-350**		**90-110**				**6.5-8.0**				**2-25**	
Season	aut	spr	aut	spr	aut	spr	aut	spr	aut	spr	aut	spr	aut	spr
Site 1 (Saddlers Creek)	12.2	21.1	3090	1105	23.1	86.8	2.4	7.5	8.0	7.4	240	134	46.5	29.0
Site 2 (Saddlers Creek)	10.1	15.4	13500	12900	23.7	51.7	2.5	4.8	9.0	8.5	240	500	33.7	14.7
Site 3 (Saddlers Creek)	15.2	15.0	608	1740	59.9	52.0	5.8	5.1	8.2	7.8	240	498	41.7	4.8
Site 4 (Hunter River)	14.2	17.6	433	581	73.4	95.7	7.3	8.8	8.3	8.1	120	181	14.6	11.7
Site 5 (Hunter River)	14.3	18.1	444	658	75.0	98.0	7.4	9.0	8.3	8.2	120	194	17.8	12.8
Site 6 * (Hunter River)	19.7	18.4	1090	661	-	95.7	-	8.7	7.2	8.3	120	191	84.5	21.2
Site 7 (Ramrod Creek)	13.7	20.8	5760	8250	37.5	78.6	3.7	6.7	7.5	7.6	240	368	15.8	9.8
Site 8** (Saltwater Creek)	-	-	-	-	-	-	-	-	-	-	-	-	-	-

*Dissolved oxygen probe malfunctioned in autumn at Site 6.

**Site 8 was dry in autumn and spring.

Note: There are no ANZECC guidelines for temperature or dissolved oxygen (mg/L).

Cells shaded green fall within the ANZECC and ARMACNZ (2000) criteria range, while those in pink fall outside the range.

At the sites sampled for stygofauna, groundwater temperature was between 17.1 ºC and 21.7 ºC, and pH ranged from 6.9 to 8.4 (**Table 3**). EC was lowest in MB4 Alluvial and also low in MB4 Regolith and Bowfield Well. EC was highest at Shearers Well, MB3 Alluvial, and DD1025 (**Table 3**). DO was low in all bores, with concentrations between 12% and 56% saturation (**Table 3**).

Table 3: Physico-chemical parameters for bores sampled for stygofauna

	Temperature (°C)	EC (µS/cm)	DO (% saturation)	DO (mg/L)	pH
Bowfield Well	20.8	2043	55.9	4.96	8.0
Bowfield House Well	17.1	7230	29.9	2.83	7.8
Shearers Well	21.3	8792	12.0	1.02	7.4
DD1025	20.6	13 260	23.6	2.02	6.9
MB1 Alluvial (Hunter River)	18.9	4789	14.6	1.31	7.2
MB1 Redbank	19.9	5332	21.4	1.89	7.2
MB1 Whybrow	20.1	5877	18.4	1.59	7.2
MB2 Alluvial (Saddlers Creek)	19.9	8320	14.3	1.32	7.8
MB2 Regolith	19.6	6201	26.6	2.35	8.4
MB3 Alluvial (Saddlers Creek)	21.7	9017	18.9	1.61	7.5
MB3 Regolith	20.5	5273	28	2.47	7.7
MB4 Alluvial (Hunter River)	19.6	1360	16.1	1.58	7.6
MB4 Coal	18.9	3392	24.8	2.24	7.9

4.3 Riparian, Channel and Environmental Inventory

RCE scores ranged between 61.5% and 78.8% in autumn and 57.7% and 80.8% in spring. Based on the classification described in Section 3.4.1, Site 3 (Saddlers Creek) had an RCE classification of 'good' for both survey periods, with scores of 61.5% and 57.7% respectively, for autumn and spring (**Table 4**). Site 7 (Ramrod Creek) was also in 'good' condition in spring, although was 'very good' in autumn. The remaining sites were all classified as 'very good' during both surveys. Site 3 showed poor stream characteristics including less than 5 m of woody riparian zone that consisted of native and exotic trees, with no shrubs. There were large gaps between strips of vegetation, with few macrophytes in the stream and no alternation of pools and riffles.

In contrast, Site 2 (Saddlers Creek), one of the highest scoring sites, had a well-connected, predominately native riparian zone with banks stabilised by vegetation. The bed was shaded by the surrounding vegetation and there were retention features including large logs in the channel. The bed consisted of pebbles and cobbles stabilised in silt. Site 6 (Hunter River), which had the same RCE score (79%) as Site 2, had a wide, dense riparian zone comprised of native and exotic trees, shrubs and vines, with vegetation over-hanging into the water. There were retention features including large logs and boulders in the channel, creating variation in flow and habitat. These were covered in periphyton.

Table 4: RCE scores for sites visited in autumn and spring

	Site 1 (Saddlers Creek)		Site 2 (Saddlers Creek)		Site 3 (Saddlers Creek)		Site 4 (Hunter River)		Site 5 (Hunter River)		Site 6 (Hunter River)		Site 7 (Ramrod Creek)		Site 8 (Saltwater Creek Tributary)	
Survey period:	aut	spr	aut	spr	aut	spr	aut	spr	aut	spr	aut	spr	aut	spr	aut	spr
Land-use pattern beyond immediate riparian zone	2	2	2	2	2	2	2	2	3	2	2	2	2	2	2	2
Width of riparian strip of woody vegetation	3	3	3	3	2	2	3	3	3	3	3	3	3	3	3	3
Completeness of riparian woody strip of vegetation	3	3	4	4	2	2	2	4	3	3	4	4	3	2	3	3
Vegetation of riparian zone within 10 m of channel	3	3	4	4	3	3	3	3	3	3	3	3	4	4	2	2
Stream bank	3	2	4	3	2	2	4	4	2	2	4	4	3	3	1	1
Bank undercutting	3	3	3	3	2	2	4	4	4	4	2	2	3	3	4	4
Channel form	4	4	4	4	4	4	4	2	4	4	4	4	3	3	4	4
Riffle/pool sequence	2	2	3	3	2	2	2	3	3	3	2	2	2	2	2	2
Retention devices in stream	4	4	2	3	4	3	3	2	2	2	3	3	1	1	3	3
Channel sediment accumulations	4	4	3	3	2	2	4	3	3	3	4	4	4	4	4	4
Stream bottom	2	2	2	2	2	2	2	3	2	2	2	3	1	1	4	3
Stream detritus	3	3	3	3	3	3	3	3	2	3	4	4	3	3	1	1
Aquatic vegetation	4	4	4	4	2	1	2	2	3	4	4	4	1	1	4	4
RCE Score	**40**	**39**	**41**	**41**	**32**	**30**	**38**	**38**	**37**	**38**	**41**	**42**	**33**	**32**	**37**	**36**
RCE Score %	**76.9**	**75**	**78.8**	**78.8**	**61.5**	**57.7**	**73.1**	**73.1**	**71.2**	**73.1**	**78.8**	**80.8**	**63.5**	**61.5**	**71.2**	**69.2**

4.4 Aquatic Macroinvertebrates

Aquatic macroinvertebrate diversity was relatively poor across the study area, with 6 to 21 taxa per site over the two survey periods (**Table 5**). 42 taxa were collected over the two survey periods. Richness ranged from 6 to 15 taxa per site during autumn, and 7 to 21 taxa during spring. Chironominae and Corixidae were the most widespread taxa, occurring at most sites in spring and autumn. Across the two survey periods, 28 macroinvertebrate taxa were collected from Saddlers Creek and 36 macroinvertebrate taxa were collected from the Hunter River (**Table 6**).

SIGNAL scores were between 2.7 and 3.7 in autumn, and 2.0 and 4.3 in spring (**Table 5**). The lowest-scoring site was Site 7 (Ramrod Creek) in autumn and Site 3 (Saddlers Creek) in spring, while Sites 5 and 6 (Hunter River) scored highest in spring and autumn, respectively.

Sensitive taxa made up low proportions of taxa at most sites, although they made up more than 15% of families present at Sites 4 and 6 for both seasons, and at Site 5 for the spring survey (**Table 5**). The highest scoring taxa were the trichopteran families Calocidae and Glossosomatidae, present at Sites 4, 5, and 6 in spring.

The three sites on the Hunter River had higher proportions of sensitive taxa than other sites, ranging from 10% to 23% (**Table 5**). The Hunter River sites all had lower taxonomic richness than the non-Hunter River sites during autumn, except for Site 2 (Saddlers Creek) (**Table 5**). However, taxonomic richness increased during the spring surveys, so that the Hunter River sites were richest (**Table 5**).

Table 5: Macroinvertebrate community indices

	Site 1 (Saddlers Creek)		Site 2 (Saddlers Creek)		Site 3 (Saddlers Creek)		Site 4 (Hunter River)		Site 5 (Hunter River)		Site 6 (Hunter River)		Site 7 (Ramrod Creek)	
	aut	spr	aut	spr	aut	spr	aut	spr	aut	spr	aut	spr	aut	spr
Taxa richness	15	12	8	7	11	10	6	21	10	17	9	12	13	7
Average SIGNAL	2.8	2.1	3.0	3.1	3.1	2.0	3.6	3.9	3.1	4.3	3.7	3.5	2.7	3.1
Proportion of sensitive taxa (%)	7	0	0	0	10	0	17	23	10	22	20	15	0	0

Note: SIGNAL scores are used as an indication of habitat health, as invertebrate families that score between six and ten are sensitive to pollution and are likely to occur in healthy habitats, while scores below six indicate the family can tolerate pollution and will occur in impacted stream habitats (Gooderham and Tsyrlin 2002). SIGNAL scores of less than 4 are categorised as being severely impacted.

Table 6: Macroinvertebrate taxa collected at each site

Class/Order	Family	Subfamily	SIGNAL	Site 1 (Saddlers Creek)		Site 2 (Saddlers Creek)		Site 3 (Saddlers Creek)		Site 4 (Hunter River)		Site 5 (Hunter River)		Site 6 (Hunter River)		Site 7 (Ramrod Creek)	
				aut	spr	aut	spr	aut	spr	aut	spr	aut	spr	aut	spr	aut	spr
Acarina			6								1			1			
Coleoptera	Dytiscidae		2	37	21	6	1	1	3		1					21	13
Coleoptera	Elmidae		2		13				1								
Coleoptera	Gyrinidae		4								1	2	4				
Coleoptera	Hydraenidae		3												2	1	
Coleoptera	Hydrochidae		4						1						2		
Coleoptera	Hydrophilidae		2	4								1					
Crustacea/ Decapoda	Atyidae		3	3								2	4	2			
Crustacea/ Decapoda	Palamonidae		4								3		2				
Crustacea/Copepoda	Calanoida			250	6	7		4		4		5				5	
Crustacea/Copepoda	Cyclopoida			200	20	4		2		2						4	
Crustacea/Ostracoda	Ostrocoda				50												
Diptera	Chironomidae	Chironominae	3	37	4	18	50	4	48	2	3	3	6		2	27	50
Diptera	Chironomidae	Tanypodinae	3	3		12	5	6			7		1			3	
Diptera	Chironomidae	Orthocladinae	3								32		5				
Diptera	Culicidae		1	13	34				4		3						
Diptera	Ceratopogonidae		4				1	7						1		2	8
Diptera	Empididae		5								2		1				
Diptera	Sciomyzidae		2				1					2					
Diptera	Simuliidae		5								19						
Diptera	Stratiomyidae		2		11									2			
Diptera	Tabanidae		3	1													
Diptera	Tipulidae		5		1												

Class/Order	Family	Subfamily	SIGNAL	Site 1 (Saddlers Creek)		Site 2 (Saddlers Creek)		Site 3 (Saddlers Creek)		Site 4 (Hunter River)		Site 5 (Hunter River)		Site 6 (Hunter River)		Site 7 (Ramrod Creek)	
				aut	spr	aut	spr	aut	spr	aut	spr	aut	spr	aut	spr	aut	spr
Ephermeroptera	Baetidae		5	2				2			21	2	17				
Ephemeroptera	Caenidae		4								1		14		3		
Ephemeroptera	Leptophlebiidae		8								4		15				
Gastropoda	Lymnaediae		1		1										1		
Gastropoda	Physidae		1	1					2		2	1				2	
Gastropoda	Planorbidae		2						4				2				1
Hemiptera	Corixidae		2	4	9			14	1	22	13	12	15	13	16	3	
Hemiptera	Notonectidae		1	2	2			3	3							2	
Hemiptera	Veliidae		3			1	1							3	2		
Odonata	Aeshnidae		4	1												14	2
Odonata	Corduliidae		5			1	2							1		23	2
Odonata	Coenagrionidae		2			9			1		2		2	2	6	9	11
Odonata	Lestidae		1												1		
Oligochaeta			2					7		3	3						
Trichoptera	Calocidae		9										1		2		
Trichoptera	Glossosomatidae		9								2						
Trichoptera	Hydroptillidae		4								2		2		1		
Trichotera	Hydropsychidae		6								101		12				
Trichoptera	Leptoceridae		6	1				1		3	12	7	5	11	11		

4.5 Stygofauna Communities

Invertebrates were collected from six of the 13 bores sampled (**Table 7**). The samples contained:

- one known stygofauna taxon, *Notobathynella* sp. (Syncarida) crustacean, from the Hunter River alluvium collected at a single bore (i.e. Bore MB4 Alluvial);
- two likely stygofauna crustacean taxa (*Diacyclops* sp. [Cyclopoida] and Ostractoda) in the Hunter River alluvium and Saddlers Creek alluvium (collected from Bores MB1 Alluvial, MB3 Alluvial and MB4 Alluvial); and
- two possible, but unlikely, stygofauna taxa in the Hunter River alluvium (Acarina mite, collected at Bore MB1 Alluvial) and Saddlers Creek alluvium (Oligochaete worm, collected at Bore MB2 Alluvial) which are more likely to be members of the soil invertebrate fauna.

Cyclopoida (*Diacyclops* sp.) copepods were the most abundant and widespread taxon, with 16 individuals collected from three locations (MB1 Alluvial, MB3 Alluvial, and MB4 Alluvial). Ostracoda were also collected from three locations (Bowfield Well, MB1 Alluvial, Shearer's Well). MB1 Alluvial had three taxa (Acarina, Ostracoda, and Cyclopoida) and had the most invertebrates, with a total of 24. Apart from MB4 Alluvial, which had Cyclopoida and *Notobathynella* sp., all other bores had only one taxon.

Table 7: Invertebrates collected from bores during sampling

Order	Lower taxa	Bowfield Well	MB1 Alluvial (Hunter River Alluvium)	MB2 Alluvial (Saddlers Creek Alluvium)	MB3 Alluvial (Saddlers Creek Alluvium)	MB4 Alluvial (Hunter River Alluvium)	Shearers Well	Likelihood of stygofauna
Oligochaeta				8				Unlikely
Acarina			10					Unlikely
Ostracoda		6*	2				1*	Likely
Cyclopoida	*Diacyclops*		12		2	2		Likely
Syncarida	*Notobathynella*					4		Known
	Total number of taxa	**1**	**3**	**1**	**1**	**2**	**1**	
	Total number of individuals	**6**	**24**	**8**	**2**	**6**	**1**	

* The invertebrate taxa (Ostracoda) collected from wells (Bowfield Well, Shearers Well) are potentially surface aquatic invertebrates, introduced to the wells either through wind-blown eggs, or overflow from Saddlers Creek.

4.6 Fish Communities

Gambusia holbrooki (a pest fish) was collected at Sites 2, 3, 6, and 7 and observed during both seasons at all sites that had water. In autumn, they were more abundant at Site 7, with five fish being caught in unbaited bait traps. Three fish were caught at Site 2, two fish at Site 6 and one fish at Site 3. Many *G. holbrooki* were observed during the field survey at all sites.

A school of approximately 30 *Mugil cephalus* (Sea Mullet) were observed swimming in the riffles of Site 5 (Hunter River) in autumn. A school of *Cyprinus carpio* (Carp) (another pest fish) were seen at Site 6 (Hunter River) during spring. These were the only other species sighted during the field survey.

4.7 Threatened Species, Populations and Communities

Prior to the field surveys, three threatened species (one fish and two frogs) and one threatened population were identified during the desktop review as potentially occurring in the survey area (**Table 8**). None of these species were seen during the field survey. No threatened ecological communities listed under the FM Act potentially occur in the study area.

Table 8: Threatened species and populations listed under the FM Act and EPBC Act

Scientific Name	Common Name	FM Act	BC Act	EPBC Act
Mogurnda adspersa	Purple-spotted Gudgeon	Endangered	-	-
Craterocephalus amniculus	Darling River Hardyhead in the Hunter River Catchment	Endangered Population	-	-
Litoria aurea	Green and Golden Bell Frog	-	Endangered	Vulnerable
Litoria booroolongensis	Booroolong Frog	-	Endangered	Endangered

No Purple-spotted Gudgeons (*Mogurnda adspersa*) have been recorded in the Hunter River or Saddlers Creek (Atlas of Living Australia 2018). The Hunter River is modelled as part of *M. adspersa*s distribution range (DPI 2018), although the only Purple-spotted Gudgeons to have been reported from the Hunter River catchment, have been from Goorangoola Creek, a tributary of Glennies Creek that flows into the Hunter River downstream of Camberwell (DPI 2017). No *M. adspersa* were collected or observed during the field survey, although there was suitable habitat at Sites 4, 5 and 7. Snorkel surveys were undertaken at all three Hunter River sites, which were the only locations deep enough and with suitable Purple-spotted Gudgeon habitat (i.e. low turbidity or slow-moving water with cover from aquatic vegetation, overhanging vegetation or snags).

No Darling River Hardyheads (*Craterocephalus amniculus*) were observed during the field survey. Although mapped as having habitat in the Goulburn River and the Hunter River catchment upstream of the Goulburn confluence, they have not been mapped in the Hunter River adjacent to the Project (DPI 2018). Juveniles of this species may be confused with *G. holbrooki* but differ in having a forked tail and dark mid-lateral stripe. No fish with these characteristics were collected or observed during surveys for the Project.

No frogs were observed or heard during the survey. Future Ecology (2019) surveyed for frogs in the study area and also did not find *Litoria aurea* (Green and Golden Bell Frog) or *Litoria booroolongensis* (Booroolong Frog). These frogs are not considered further in this report, assessment of these species under the BC Act and EPBC Act has been undertaken as part of the Appendix E of the EIS (Hunter Eco 2019).

5 Discussion

5.1 Aquatic Habitat and Water Quality

The Hunter River had the broadest range of habitats and was in better condition than the other creeks assessed. The smaller tributaries, including Saddlers Creek, were mostly dry or contained isolated pools at the time of the survey. The overall condition of the tributary (non-Hunter River) surface water sites was relatively poor. This was largely due to erosion and the historical impacts of long-term livestock access and agricultural land use.

During the field surveys, Saddlers Creek and Ramrod Creek contained only isolated pools of remnant water. River levels were moderately high at the three Hunter River sites, supplemented by water released from Glenbawn Dam (located approximately 90 km upstream, or 43 km north). The tributary of Saltwater Creek at Site 8 was dry when visited.

As would be expected, the Hunter River has more extensive aquatic habitat than Saddlers Creek, Ramrod Creek, and the unnamed tributary of Saltwater Creek because it is larger, and flow is regulated and continuous. There is a better-developed range of habitats available to invertebrate and vertebrate fauna as well as plants. Large woody debris, consisting of fallen trees, is common in the Hunter River, as was the topographic variation in bed and bank structure that leads to diverse habitat features such as gradually-sloping gravel bars, riffles, pools, and steep banks.

The riparian channel environment changed little between visits, and at all three sites on the Hunter River (4, 5, and 6) was classified as ‘very good’, with RCE scores of between 71% and 81%. These sites all scored highly in their channel form, the completeness of riparian vegetation, and their channel sediment accumulation.

While there were features with potential to create aquatic habitat at the other sites, the extent of these in comparison to the Hunter River was minor, and their ability to support riverine taxa is restricted only to periods when there was flow present. Even though the habitats are present, their ability to support aquatic fauna, especially longer-lived taxa, is limited because of the time lag between the creek filling and being colonised.

Sites on the smaller tributaries (i.e. Ramrod Creek) had a high density of emergent macrophytes around remnant pools (predominantly *Phragmites australis* and *Typha orientalis*), which, at Site 7 extended across the entire channel.

Water quality was poor during May 2018, with most variables outside of the recommended ANZECC and ARMCANZ (2000) guidelines. Water quality generally remained poor for spring, though improved at the Hunter River sites for DO and turbidity. Water quality in these surveys was similar to what was recorded in the 2015 survey completed by Cumberland Ecology (2015) for most variables except EC, which was slightly higher at most sites in 2018. Similarly, in 2011, the EC and alkalinity measurements were very high across all sites (Cumberland Ecology 2015). The pH levels were relatively similar, with all sites being slightly alkaline except for Site 2, which had very high pH readings in both surveys.

At all sites, DO concentration was well below the recommended ANZECC and ARMCANZ (2000) range in autumn, but concentrations had increased at all sites by spring, to a point where it was within ANZECC and ARMCANZ (2000) range at the Hunter River sites.

EC was well above ANZECC and ARMCANZ (2000) trigger levels for both survey periods.

5.2 Macroinvertebrate Communities

The number of macroinvertebrate taxa collected in autumn 2018 across all sites was 24, which is similar to the 29 collected in autumn 2011 (Cumberland Ecology 2015). Site-specific diversity in the Hunter River was also similar between the two sampling periods, with 6 or 7 taxa each (Cumberland Ecology 2015). However, Hunter River SIGNAL scores have fallen from an average of 5.3 ± 3.0 in 2011, to 3.7 ± 5.3 in 2018.

Overall diversity was higher in spring 2018, than it was in autumn 2018. This reflects the better water quality in spring, and the higher water temperature. Aquatic invertebrates are more active in warmer water, especially in the few months following winter (Boulton *et al*. 2014). In the autumn, although there was plenty of water, the invertebrate fauna was low and communities were dominated by taxa with low-scoring SIGNAL scores. Cool water temperatures probably contributed to the low diversity, as well as the comparative width of the river compared to the sampled area.

In contrast to the Hunter River, Saddlers Creek diversity was higher at most sites in 2018, than in 2011 and SIGNAL scores indicated severe disturbance at all of the sites included in both surveys (Cumberland Ecology 2015). The main disturbances at these sites are the contracting waterholes, increased sediment load, and declining water quality.

Sites 5 and 6 on the Hunter River, had the highest SIGNAL scores, while Site 4 (also on the Hunter River) had the lowest. Apart from Site 5 in spring, all sites surveyed in 2018 had SIGNAL scores of less than 4, so were categorised as being severely impacted. The main over-riding impacts on the non-Hunter River sites would be the low water levels experienced at the time of survey. As these sites become smaller and dry up, they are less buffered against physical and chemical changes at the site.

Although there was an increase in macroinvertebrate taxa compared to the 2011 survey (Cumberland Ecology 2015), the average SIGNAL score declined. Most of the taxa sampled had a high tolerance to pollution and poor water quality.

5.3 Stygofauna Communities

Previous surveys by ELA (2015) collected *Diacyclops* sp. (Cyclopoida) along with a damaged ostracod from the Saddlers Creek alluvium (Bore MB2 Alluvial) (**Figure 3**).

As described in Section 4.5, one known and two likely stygofauna taxa were collected from the Hunter River alluvium during the surveys (Syncarida: *Notobathynella* sp., Cyclopoida: *Diacyclops* sp. and Ostractoda crustaceans). One likely stygofauna taxon (*Diacyclops* sp.) was collected from the Saddlers Creek alluvium during the surveys.

All the above taxa have previously been collected from the Hunter River alluvium from Singleton upstream to Aberdeen (Hancock and Boulton 2008, 2009; ELA 2015). None of the stygofauna taxa collected in 2018 are endemic to the Project area, as all are widespread along aquifers of the Hunter River or associated tributaries, so populations are not likely to be threatened by the Project.

The presence of stygofauna in the aquifers, regardless of whether any species are endemic or not, indicates that the aquifer ecosystems are in relatively good condition. Stygofauna and the microbial community associated with aquifers are important moderators of water quality (Hakencamp and Palmer 2000; Hancock *et al.* 2005).

5.4 Fish Communities

Twenty-two native, and five exotic species of freshwater fish have previously been listed for the Hunter River, although for five species, no records have been collected since 2001 (Howell and Creese 2010). During our surveys, samples were collected using bait traps, and observations were made from the bank and during snorkelling surveys. Only three species were observed: (i) *Gambusia holbrooki* (a pest species) at all sites except Site 1 and 8 (dry); (ii) a small school of *Mugil cephalus* (Sea Mullet) were observed in the riffles of the Hunter River in autumn; and (iii) a school of *Cyprinus carpio* (Carp) (another pest species) were observed in the Hunter River in spring.

DPI Fisheries (DPI 2018) have mapped part of the Hunter River as having potential habitat suitable for *Morgunda adspersa* (Purple-spotted Gudgeon) (**Figure 4**). Purple-spotted Gudgeon prefer slow-moving or still water with low turbidity and aquatic vegetation, trailing vegetation, rocks and snags. They are correlated with sites that have high macroinvertebrate diversity, with specific species including mites, crustaceans, damsel flies and dragonfly larvae. Suitable habitat was observed at all three of the Hunter River sites, and at Site 7 in Ramrod Creek. However, the only Purple-spotted Gudgeons to have been reported from the Hunter River catchment, have been from Goorangoola Creek, a tributary of Glennies Creek that flows into the Hunter River downstream of Camberwell (DPI 2017). There have been no other records of this species in the Hunter River catchment (Howell and Creese 2010), and it is uncertain whether the Goorangoola Creek population is endemic or has recently been introduced (NSW DPI 2017).

The other threatened fish species that showed up in the threatened species search was the Darling River Hardyhead (*Craterocephalus amniculus*), which is a threatened population in the Hunter River Catchment. This species is mapped by DPI Fisheries (DPI 2018) as potentially occurring in the Hunter River upstream of the Goulburn River confluence, so may be affected by potential impacts in the northern-flowing creeks in the study area (e.g. Ramrod Creek). Darling River Hardyheads prefer slow-flowing, clear water with aquatic vegetation along the edges, but are also found in the edges of fast-flowing habitats (DPI 2014). The species has previously been collected from headwater tributaries of the Hunter River but has not been reported since 2003 (DPI 2014) and is unlikely to occur in the reach of the Hunter River adjacent to the Project.

6 Impact Assessment

6.1 Aquatic Habitat Clearance

Degradation of native riparian vegetation along NSW water courses is a key threatening process listed under the FM Act. The removal of trees from river banks decreases bank stability and results in bank slump and erosion. Tree removal can also reduce contributions of large woody debris to river channels, which not only provide structure and habitat for fish, but also act as scour points that help created deep sections in rivers. Most of the waterways in the study area have already had their riparian zones extensively modified, either through previous clearing for agricultural purposes or encroachment of exotic species such as willows.

The Hunter River, Saddlers Creek and Ramrod Creek are downstream of the Project area, and there would be no clearing near the banks of these watercourses associated with the Project, so no subsequent impact on riparian vegetation. Vegetation disturbance along smaller, unnamed watercourses within the Project area would be minimal.

6.2 Subsidence

Underground mining activities would result in surface subsidence. Subsidence movements may result in surface deformations, with cracking in flatter areas expected to be between 25 and 50 mm, with widths greater than 150 mm in some places (MSEC 2019).

MSEC (2019) concludes there would be no adverse subsidence impacts to the surface channels of any named streams, including the Hunter River and Saddlers Creek, given the separation distance between these streams and the Maxwell Underground.

The geomorphology assessment by Dr Christopher Gippel (Fluvial Systems Pty Ltd 2019) concluded that subsidence may result in the formation of new depressions, or the expansion/deepening of existing depressions along the channels of smaller, unnamed watercourses above the Maxwell Underground. The depressions formed from subsidence would be conducive to coarse sediment deposition, and would trap sediment from upstream hillslopes and gullies. Ultimately, the depressions would fill with sediment, reforming an even stream grade.

Near-surface cracking may occur due to horizontal tension at the edges of a subsidence trough, however, it would only be shallow and transitory, and any loss of water would cease once cracks become saturated (HydroSimulations 2019).

Potential subsidence impacts on these unnamed ephemeral and intermittent watercourses would be monitored and managed through a process of adaptive management. Under this process: (i) regular monitoring would detect if and where the threat occurs, (ii) an assessment would be made to determine the potential consequences of the observed threat, and then, (iii) appropriate control works would be put in place.

None of these potential subsidence impacts are likely to significantly affect aquatic ecosystems, given the limited habitat available along watercourses above the Maxwell Underground and the proposed adaptive management approach.

6.3 Surface Water Flow and Aquatic Biota

WRM Water & Environment (2019) has considered the potential impacts of the Project on surface water flow in Saddlers Creek and the Hunter River, including:

- a reduction in catchment due to Project-related surface disturbance;
- potential baseflow impacts; and
- potential reduction in flows due to Project-related subsidence.

As an underground mine, the Project would result in limited catchment excision. New infrastructure development for the Project has been minimised through the planned use of already-existing structures where possible. This would result in a relatively small excision of catchment (approximately 38 ha) that would otherwise drain to Saddlers Creek. The infrastructure would be rehabilitated post-mining so there would be no additional long-term impact on Saddlers Creek flows post-mining (WRM Water & Environment 2019).

The cumulative impact of the Project (including the existing Maxwell Infrastructure) and the Mt Arthur Mine on the Saddlers Creek catchment area would be 12% during the operational phases of both mining operations (0.3% incremental change due to the Project). The cumulative impact would fall to 8% post-mining (WRM Water & Environment 2019).

HydroSimulations (2019) has modelled the potential impacts of the Project on baseflow in the Hunter River and Saddlers Creek. The Project would result in negligible increased leakage from surface flows to the underlying alluvium in the Hunter River or Saddlers Creek (HydroSimulations 2019).

The potential reduction in flows due to Project-related subsidence (including increased ponding and surface cracking) are also considered negligible (WRM Water & Environment 2019).

The effect of the Project (incorporating the existing Maxwell Infrastructure) on aquatic ecology in Saddlers Creek is unlikely to be significant due to high natural climatic variability.

6.4 Surface Water Quality and Aquatic Biota

Alteration of the surface water quality in aquatic ecosystems can impact aquatic habitats and species. Changes to surface water quality can generally occur due to soil disturbance (sedimentation and mobilisation of nutrients), nutrient leachates and pollution leaks.

Clearing of vegetation and earthworks away from river channels for access roads and infrastructure areas are potential sources of sediment that could increase turbidity and siltation in watercourses, especially during periods of heavy rainfall, or during dry, windy periods.

The transport and services corridor for the Project runs approximately mid-way between Saddlers Creek and Saltwater Creek and is at least 1 km from either waterway. The site access road would be sealed along its full length after Year 1 of operations.

Any water runoff areas of exposed sediment would be directed through sediment traps or other measures effective in reducing silt load. During dry times, appropriate dust suppression measures such as water carts, would be employed.

The Project water management system would maintain separation between runoff from areas undisturbed by mining and water generated within surface disturbance areas or from underground. An objective of the on-site water management for the Project is to operate such that there is no discharge to the environment. The site water balance model results indicate that there would be no need for releases of mine water from the Project water management system (WRM Water & Environment 2019).

Final voids would remain at the Maxwell Infrastructure site following cessation of mining at the Project. A water balance of the final voids indicates that none of the voids would spill to the receiving environment (WRM Water & Environment 2019).

Overflows from sediment dams are possible during wet periods, however, WRM Water & Environment (2019) concludes that any overflows are unlikely to have a measurable impact on the receiving water quality.

Based on the above, there would be nil or negligible change to the aquatic ecology in Saddlers Creek, Ramrod Creek or the Hunter River due to surface water quality given the range of controls incorporated into the Project.

6.5 Groundwater Drawdown and Stygofauna

Stygofauna were recorded in the Hunter River and Saddlers Creek alluvial aquifer, although none of the taxa collected are endemic to the study area. Negligible drawdown has been predicted for the Hunter River alluvium, as a result of the Project (HydroSimulations 2019), so impacts to the stygofauna community will be negligible.

A small long-term increase in leakage from the Hunter River to the Hunter River alluvium to a maximum of 0.1 ML/day by the end of mining may result in a slight decrease in salinity of alluvial groundwater (HydroSimulations 2019). Currently, EC of the aquifer is higher than that of the Hunter River. This is unlikely to have a significant impact on stygofauna communities.

Some drawdown of alluvial groundwater along Saddlers Creek is expected (HydroSimulations 2019). This would be caused by a reduction in upward leakage from coal seams to the alluvium and would reach a maximum of up to 8 m, hundreds of years post-mining. The connectivity between the lower reaches of Saddlers Creek and Hunter River alluvial aquifers would be maintained.

6.6 Threatened Species and Populations

One threatened species (Purple-spotted Gudgeon) and one endangered population (Darling River Hardyhead), have modelled distributions along the Hunter River, adjacent to the Project. However, neither of these species have been recorded near the study area. There is not expected to be a significant impact on either species or their habitat, as the Project would have negligible impact on flow frequency in the Hunter River.

Habitat features including aquatic vegetation, snags and overhanging vegetation would not be impacted, as the Project is an underground mining operation that would not directly impact the Hunter River.

Potential impacts to these species are assessed in accordance with Division 12, Part 7A of the FM Act and the *Threatened Species Assessment Guidelines: the Assessment of Significance* (DPI 2008) (**Appendix B**). Overall, it is unlikely the Project would directly or indirectly harm the species, nor the habitat that supports them. Therefore, a Species Impact Statement would not be required for the Project.

There are no relevant species listed under the EPBC Act.

6.7 Key Fish Habitat and Fish Passage

Saddlers Creek, Ramrod Creek and the Hunter River have all been mapped as key fish habitat by NSW DPI Fisheries.

The Hunter River fits the definition of Type 1 (highly sensitive) key fish habitat, as it contains permanent flow, and has in-stream gravel beds, rocks greater than 500 mm in two dimensions, snags greater than 300 mm in diameter or 3 metres in length, and native aquatic plants (DPI 2013). The Hunter River is also a Class 1 (major) key fish habitat as it is mapped as having a threatened species (Purple-spotted Gudgeon).

Saddlers and Ramrod Creeks are intermittent and highly impacted by previous agricultural activities, but they have some areas where native aquatic vegetation occurs. They are predominantly Class 2 (moderate) waterways with Type 3 (minimally sensitive), although some pools would qualify as Type 2 (moderately sensitive) key fish habitat.

The Project (including the proposed underground mine, post-mining subsidence, and associated surface infrastructure) would not restrict fish passage, and is unlikely to affect the habitat quality of the Hunter River, Ramrod Creek or Saddlers Creek.

6.8 Cumulative Impacts

Potential cumulative impacts of groundwater drawdown and catchment excision have been considered as part of the Groundwater Assessment (HydroSimulations 2019) and Surface Water Assessment (WRM Water & Environment 2019). The assessments considered impacts from nearby water users and surrounding mines, including the Mt Arthur Mine, and previous mining at the Maxwell Infrastructure.

Cumulative groundwater depressurisation contours showing the magnitude and water table pattern caused by coincident mining at the Mt Arthur Coal Mine and the Project are presented in the Groundwater Assessment (HydroSimulations 2019). The results show:

- No predicted cumulative drawdown over 2 m in the Hunter River alluvium.
- Drawdown is predicted along Saddlers Creek, which is largely due to the Project, with no additional predicted impact from future approved operations at Mt Arthur Mine.
- No connection in groundwater depressurisation within the shallow Permian coal measures between the Project and mining at Mt Arthur Mine.
- Some interaction in groundwater depressurisation for the deeper coal seams that would be mined at the two mining operations. However, the extent of depressurization in the coal seams is limited to the north and east by the outcrop of the coal seams.

The cumulative impact of the Project (including the existing Maxwell Infrastructure) and the Mt Arthur Mine on the Saddlers Creek catchment area would be 12% during the operational phases of both mining operations (0.3% incremental change due to the Project). The cumulative impact would reduce to 8% post-mining (WRM Water & Environment 2019).

The cumulative impacts of the Project on aquatic ecology have been considered in the preceding sections.

7 Mitigation Measures

Malabar would develop a water management plan for the Project that would include a monitoring strategy, acceptable water quality trigger values, and trigger response actions for surface water and groundwater. The plan would be designed to mitigate potential impacts on aquatic ecosystems on-site and downstream.

Erosion and sediment control measures

Gullies and watercourses crossed by the transport and services corridor and other roads, would contain sediment fences or sediment traps to reduce the influx of sediments to waterways.

Surface water monitoring

Water quality would be monitored regularly in the Hunter River at points upstream and downstream of the Project and at locations along Saddlers Creek and Ramrod Creek. Water quality would also be monitored in the pre-existing mine voids that occur within the Maxwell Infrastructure. Any significant change in water quality at or immediately downstream of the Project should be investigated to determine the source of change.

Groundwater monitoring

Water quality and water levels would be monitored regularly in the existing bore network. Any significant, unexpected change in water quality or water level would be investigated to determine the source of change and the risk to groundwater or surface water ecosystems.

If the change is significant enough to threaten groundwater or surface water ecosystems, then attempts would be made to reduce the impact. This may be through sealing any fractures, if possible, or supplementing with better quality water.

Subsidence monitoring and surface remediation measures

The geomorphology assessment by Dr Christopher Gippel (Fluvial Systems Pty Ltd 2019) concluded that subsidence may result in the formation of new depressions or the expansion/deepening of existing depressions in channels. These depressions would fill with sediment, reforming an even stream grade.

The risk of knickpoint formation and stream channel alignment change due to subsidence related depressions would be managed through regular monitoring, assessment of potential consequences of the observed threat and the development of appropriate control works.

8 Offset Requirements

As detailed in Section 6, the Project:

- would not result in a significant impact to any aquatic threatened species, population or community listed under the FM Act, as assessed against the *Threatened Species Assessment Guidelines – the Assessment of Significance* (DPI 2008); and
- would not result in the net loss of any key fish habitat as identified by DPI Fisheries (2013); and
- would not result in a significant impact to any aquatic threatened species or community listed under the EPBC Act.

As such, the Project would not require any biodiversity offset or compensatory measures for potential impacts to aquatic ecology in accordance with DPI Fisheries (2013) *Policy and Guidelines for Fish Habitat Conservation and Management (Update 2013)* or the *EPBC Act Environmental Offsets Policy* (Department of Sustainability, Environment, Water, Population and Communities 2012).

9 Conclusion

Aquatic habitat along Saddlers Creek and Ramrod Creek is limited, and at the time of the surveys was restricted to shallow pools of remnant water. The main habitat at these sites consisted of the fringing vegetation at the waters' edge, although riffle-pools sequences are likely to form during periods of flow.

The Hunter River has a better-developed range of habitats available for invertebrate and vertebrate fauna. Large woody debris, consisting of fallen trees, is common at Hunter River sites, as is the topographic variation in bed and bank structure that leads to diverse habitat features such as deep pools, gradually-sloping gravel bars, riffles, pools, and steep banks.

No threatened species listed under the FM Act or EPBC Act have been collected from the study area and it is unlikely that any threatened species would be adversely affected by the Project.

Stygofauna are known from the Hunter River alluvium and Saddlers Creek alluvium. All taxa collected during this survey have previously been found in aquifers of the Hunter River, or its' tributaries (i.e. are not endemic species). The presence of stygofauna in the aquifers indicates that they are in relatively good condition. Stygofauna and the microbial community associated with aquifers, are important moderators of water quality.

With the implementation of proposed mitigation measures, the Project is not likely to have a significant impact on aquatic ecology in the surrounding waterways or stygofauna.

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Appendix A - Site Photos

Autumn Survey 2018

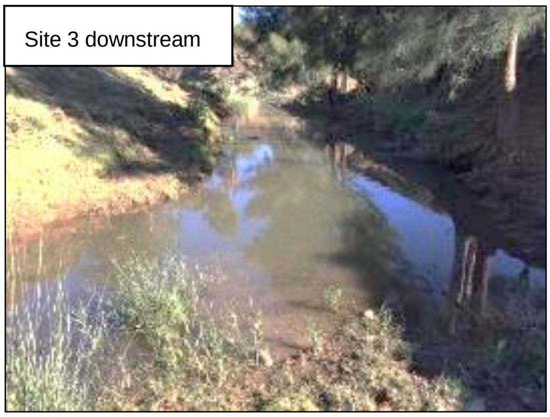
Site 1 upstream

Site 1 downstream

Site 2 upstream

Site 2 downstream

Site 3 upstream



Site 3 downstream


Site 4 upstream


Site 4 downstream


Site 5 upstream


Site 5 downstream


Site 6 upstream


Site 6 downstream

Site 7 upstream

Site 7 downstream

Site 8 upstream

Site 8 downstream

Spring Survey 2018


Site 1 upstream


Site 1 downstream


Site 2 upstream


Site 2 downstream


Site 3 upstream


Site 3 downstream


Site 4 upstream


Site 4 downstream


Site 5 upstream


Site 5 downstream


Site 6 upstream


Site 6 downstream


Site 7 upstream


Site 7 downstream


Site 8 upstream


Site 8 downstream

Appendix B - Assessments of Significance

Purple-spotted Gudgeon (*Mogurnda adspersa*)

Overview:

The Purple-spotted Gudgeon is listed as an endangered species under the FM Act and has a modelled distribution in the Hunter River catchment (DPI 2018a, b). The only Purple-spotted Gudgeons reported in the Hunter River catchment have been from Goorangoola Creek, a tributary of Glennies Creek that flows into the Hunter River downstream of Camberwell (DPI 2017). These records are well outside the anticipated range of this fish, and it is thought that this population was translocated. Suitable habitat was recorded along the Hunter River and Ramrod Creek, therefore, these are the only waterways relevant to this assessment of significance.

(a) in the case of a threatened species, whether the action proposed is likely to have an adverse effect on the life cycle of the species such that a viable local population of the species is likely to be placed at risk of extinction,

The Purple-spotted Gudgeon has not been recorded within the Project, or the surrounding waterways but suitable habitat does occur along the Hunter River and Ramrod Creek. The Project involves underground mining, with no expected subsidence impacts on these waterways (Mine Subsidence Engineering Consultants 2019). Habitat along the Hunter River will remain unaffected as environmental flow releases from Glenbawn Dam (approximately 90 km upstream) are expected to continue. The works are not likely to impact habitat features required for breeding including aquatic vegetation, snags and overhanging vegetation. There is not likely to be a cooling of the in the Hunter River, which is a stimulus for breeding.

(b) in the case of an endangered population, whether the action proposed is likely to have an adverse effect on the life cycle of the species that constitutes the endangered population such that a viable local population of the species is likely to be placed at risk of extinction,

This question is not applicable.

(c) in the case of an endangered ecological community or critically endangered ecological community, whether the action proposed:

> ***(i) is likely to have an adverse effect on the extent of the ecological community such that its local occurrence is likely to be placed at risk of extinction, or***
>
> This question is not applicable.
>
> ***(ii) is likely to substantially and adversely modify the composition of the ecological community such that its local occurrence is likely to be placed at risk of extinction,***
>
> This question is not applicable.

(d) in relation to the habitat of a threatened species, population or ecological community:

(i) the extent to which habitat is likely to be removed or modified as a result of the action proposed, and

The Hunter River is potential habitat for Purple-spotted Gudgeon. One site along Ramrod Creek also had potentially suitable habitat, but this was isolated as a result of limited rainfall and is likely to be cut off from the Hunter River most of the time. This makes it very unlikely to have Purple-spotted Gudgeon. It is not expected that these habitats would be removed, or directly modified because of the Project. No short or long-term impacts are expected.

(ii) whether an area of habitat is likely to become fragmented or isolated from other areas of habitat as a result of the proposed action, and

Potential habitat is not likely to become fragmented or isolated as a result of the Project. The Hunter River's flow is controlled by Glenbawn Dam. Environmental flows would continue to be released irrespective of the Project. Ramrod Creek is ephemeral and naturally contains isolated pools due to the lack of rain in the catchment.

(iii) the importance of the habitat to be removed, modified, fragmented or isolated to the long-term survival of the species, population or ecological community in the locality,

It is not anticipated that the Project would modify, remove, fragment or isolate potential habitat for the Purple-spotted Gudgeon. Habitat features including vegetation, rocks and snags are unlikely to be impacted. The works would not impact the long-term survival of this species.

(e) whether the action proposed is likely to have an adverse effect on critical habitat (either directly or indirectly),

No critical habitat for this species would be impacted by the Project.

(f) whether the action proposed is consistent with the objectives or actions of a recovery plan or threat abatement plan,

The Project is not inconsistent with the recovery actions listed in the *Priority Action Statement for the Southern Purple Spotted Gudgeon* (DPI 2018b)

(g) whether the action proposed constitutes or is part of a key threatening process or is likely to result in the operation of, or increase the impact of, a key threatening process.

The Project does not involve any key threatening processes.

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Darling River Hardyhead (*Craterocephalus amniculus*)

Overview:

The Darling River Hardyhead Population in the Hunter River Catchment is listed as an endangered population under the FM Act. This species is endemic to the headwaters of the Hunter River catchment, although it has not been recorded near the Project. There has been no detection of the species in the broader Hunter catchment since 2003 (DPI 2014a).

(a) in the case of a threatened species, whether the action proposed is likely to have an adverse effect on the life cycle of the species such that a viable local population of the species is likely to be placed at risk of extinction,

This question is not applicable.

(b) in the case of an endangered population, whether the action proposed is likely to have an adverse effect on the life cycle of the species that constitutes the endangered population such that a viable local population of the species is likely to be placed at risk of extinction,

The endangered population of Darling River Hardyheads have not been mapped near the Project. There is no data on the reproductive biology of this species, however, based on the closely related Murray Hardyhead, it is thought that the species breeds from spring through to autumn with eggs deposited in/on aquatic vegetation (DPI 2014a). The Project is not expected to impact aquatic vegetation that may be used for breeding. Nor is it expected to isolate habitat, increase turbidity or have long-term effects on water quality. Flow releases from Glenbawn Dam are thought to have an effect on potential populations, however, these releases are unrelated to the Project.

(c) in the case of an endangered ecological community or critically endangered ecological community, whether the action proposed:

> ***(i) is likely to have an adverse effect on the extent of the ecological community such that its local occurrence is likely to be placed at risk of extinction, or***
>
> This question is not applicable.
>
> ***(ii) is likely to substantially and adversely modify the composition of the ecological community such that its local occurrence is likely to be placed at risk of extinction,***
>
> This question is not applicable.

(d) in relation to the habitat of a threatened species, population or ecological community:

> ***(i) the extent to which habitat is likely to be removed or modified as a result of the action proposed, and***
>
> The Project is not expected to directly isolate, modify or remove potential habitat. No short or long-term impacts are expected.
>
> ***(ii) whether an area of habitat is likely to become fragmented or isolated from other areas of habitat as a result of the proposed action, and***
>
> Habitat is not likely to become fragmented or isolated as a result of the Project. The Hunter River's flow is controlled upstream by Glenbawn Dam. Environmental flows would continue to be released irrespective of the Project.

(iii) the importance of the habitat to be removed, modified, fragmented or isolated to the long-term survival of the species, population or ecological community in the locality,

It is not anticipated that the Project would modify, remove, fragment or isolate Darling River Hardyhead habitat. Habitat features including riffles / rapids, algae and vegetation are unlikely to be impacted.

(e) whether the action proposed is likely to have an adverse effect on critical habitat (either directly or indirectly),

No critical habitat for this species would be impacted by the Project.

(f) whether the action proposed is consistent with the objectives or actions of a recovery plan or threat abatement plan,

The Project is not inconsistent with the recovery actions listed in DPI (2014b and 2018).

(g) whether the action proposed constitutes or is part of a key threatening process or is likely to result in the operation of, or increase the impact of, a key threatening process.

The Project does not involve any key threatening processes.

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