Bird in Hand Gold Project
Mining Lease Application
MC 4473

CHAPTER 11
SURFACE WATER

BIRD IN HAND GOLD PROJECT

MINING LEASE PROPOSAL

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CONTENTS

FIGURES

TABLES

All maps presented in this chapter are in GDA94 / MGA zone 54 (EPSG: 28354) unless otherwise stated.

11 SURFACE WATER

This chapter provides an overview of the existing environmental values relevant to surface water both covered by the proposed Mining Lease (ML), and any potential impacts which could be experienced downstream of the operational area. The Woodside region experiences higher rainfall than most of South Australia Surface water and stormwater management is an integral element of the site design process. The chapter discusses the design measures and management strategies proposed that would minimise impacts and risks identified. Construction is considered to have the highest potential to impact surface water quality Management strategies for the construction period have been built into the impact mitigation framework, while the longer term surface water management strategies are establishing.

11.1 APPLICABLE LEGISLATION AND STANDARDS

Specific applicable legislation relating to surface water for the Project includes both the *Environment Protection Act 199*3 (SA) (EP Act) and the *Natural Resources Management Act 2004* (SA) (NRM Act).

The *Mining Act 1971* (SA) (Mining Act) also provides a legislative framework which seeks to ensure that mining operations manage environmental impacts and risks, as far as reasonably practicable, through the establishment of outcomes and measurement criteria, developed through both the Mining Lease Application (MLA) and the subsequent Program for Environment Protection and Rehabilitation (PEPR). This methodology has been discussed in detail in Chapter 6.

11.1.1 ENVIRONMENT PROTECTION ACT 1993 (SA)

The EP Act requires that 'all reasonable and practicable measures are taken to protect, restore and enhance the quality of the environment and to prevent, reduce, minimise or where possible, eliminate harm to the environment'. The EP Act establishes specific Environment Protection Policies (EPP) which outline enforceable requirements or standards. The Environment Protection (Water Quality) Policy (Water Quality EPP) together with the EP Act forms the legislative framework which regulates activities likely to affect surface water.

Specifically, the Water Quality EPP specifies the following environmental values to be protected:

- Fresh water aquatic ecosystems;
- Human water use, including:
    - Recreational use;
    - Aesthetic value;
    - Drinking water;
    - Agricultural water use (including irrigation and livestock); and
    - Industrial water use.

11.1.2 Natural Resources Management Act 2004 (SA)

Infrastructure development near or within riparian zones may require a Water Affecting Activity (WAA) permit. WAAs are administered under Section 127 of the NRM Act. To undertake most types of WAA, a permit is required from the relevant authority which, in most cases, is the Minister for Sustainability, Environment and Conservation through the South Australian Government Department of Environment and Water (DEW) or the relevant Regional Natural Resources Management Board (NRM Board).

The Mount Lofty Ranges (MLR) NRM Board will be consulted with and a WAA permit will be required through the PEPR stage for the culvert planned to cross the Goldwyn drainage line (Goldwyn Creek).

11.2 ASSESSMENT METHOD

11.2.1 Desktop

Initially, publically available existing information was obtained regarding the Inverbrackie Creek surface water sub-catchment, as well as the broader Onkaparinga Valley surface water catchment. The desktop investigation included a review of the following documentation:

- WaterConnect data portal (DEWNR, 2017) Surface water stream flow measurement data for the Inverbrackie Creek (DWLBC, 2002/29))
- Climate records for the Woodside weather station 023829 (BoM 2017)
- Where's the water going to come from? Environmental flows for the Onkaparinga river and Estuary, S. Gatti, P. Hill, H. Griffith and S. Smith (2003) Western Mount Lofty Ranges Water Allocation Plan
- 1 : 50 000 WaterCourses data (DEWNR, dataset 903)

11.2.2 Field Study

Field studies within the Inverbrackie Creek sub-catchment have been undertaken between 2014 and 2017. Water samples and macroinvertebrate samples have been taken by Terramin, and all data analysed by AC Environmental.

The *Before-After, Control-Impact* (BACI) approach was utilised (ANZECC, 2000). Surface water sampling sites were selected based upon their connectivity and proximity to the Bird in Hand Project ('the Project' or 'BIHGP') area, proposed ML area and the local sub-catchment areas. Two types of site are identified: those that have the potential to be impacted by the Project and those that will not (control sites). The same parameters are monitored at both types of site, before and after any disturbance, to determine whether or not a pattern of impact over time at the potentially disturbed site(s) changes relative to the control sites. After the disturbance starts, if the parameter's pattern of change in the affected area(s) differs from its pattern of change in the control areas, the differences are relatively unlikely to be due to chance.

11.2.2.1 SAMPLING METHODOLOGY

Chapter 3.4.1 of the Australian Guidelines for Water Quality Monitoring and Reporting (NWQMS, 2000) describes the general measurement parameters for the study of surface waters in Australia. Physical measurement parameters include flow, temperature, conductivity, suspended solids and turbidity. These indicators determine if there are any impacts of chemical stressors. Chemical measurement parameters include pH, alkalinity, hardness, salinity, dissolved oxygen and total organic carbon. Other parameters of interest include major anions and cations, sodium adsorption ratio, heavy metals and specific nutrients including phosphate, nitrite and nitrate, ammonia and silica. These analytes together with the physical measurement parameters determine the stability, chemical forms and bioavailability of a range of minor and trace contaminants such as metals, metalloids and specific organic compounds (NWQMS, 2000).

Following advice from the South Australia Environment Protection Agency (EPA) regarding surface water sampling for the Angas Zinc Mine (AZM) PEPR monitoring program, triplicate samples for the BIHGP were taken regularly from the sites “Inverbrackie Creek Upstream”, “Inverbrackie Creek Downstream” and “Airstrip South” when water was present. This is a method that uses the BACI paradigm (ANZECC, 2000) and is undertaken to reduce the likelihood of obtaining unrepresentative surface water samples and to provide for statistical power when comparing parameters between sites.

The Terramin standard analyte suite included:

- pH;
- Electrical Conductivity;
- Total Dissolved Solids;
- Turbidity;
- Major Anions and Cations;
- Anion and Cation Ratios;
- Total metals (As, Cd, Cu, Mn, Pb, Zn, Fe, Ni and Se); and
- Nutrients (Total phosphorous, Total Nitrate, Total Nitrite, Total Kjeldahl Nitrogen and Nitrogen oxides (NOx)).

Additional sites were sampled both as part of a Terramin regional ground and surface water census program, or opportunistically, if upon observation it was deemed to be potentially beneficial to gain a deeper understanding of conditions at a particular site or the current water quality in a particular part of the catchment, or to gain insight into historic land uses in a particular area. Additional analytes sampled and tested for baseline data collection have included:

- Cn, Hg – historic mining;
- Biochemical oxygen demand;
- Sodium Absorption Ratio;
- Organophosphates/Organochlorides;
- Herbicides;
- Poly Aromatic Hydrocarbons/Total Petroleum Hydrocarbons; and
- Benzene, Toluene, Ethylbenzene and Xylene compounds.

11.2.3 Stormwater Assessment Methodology

Tonkin Consulting Pty Ltd (Tonkin) were engaged in 2016 by Terramin to develop a Stormwater Management Plan for the proposed Project (see Appendix I3). The Tonkin (2016) report outlines the strategy for surface water and stormwater management for the Project and involves a number of measures to provide drainage service and flooding protection for the proposed infrastructure and operational activities on the site, while also providing a high level of water quality treatment.

The two key aspects related to stormwater and flood management are:

- Ensure that all development is kept out of the 100-yr ARI flood extents; and
- Ensure that peak flows leaving the site are no higher than pre-development rates.

The 100-yr ARI flood extents for the main creek that passes through the site have been determined through the development of a 'backwater curve model' known as a HEC-RAS model (Appendix I3), a widely used tool to calculate flood extent near river systems. The model is based on representative sections of the watercourse that passes through Goldwyn.

11.3 EXISTING ENVIRONMENT

The Inverbrackie creek is an upper sub-catchment of the Onkaparinga catchment. The health of the Onkaparinga River and estuary has decreased markedly since colonisation as a result of whole of landscape changes in land use, nutrient and sedimentation enrichment, the impoundment of water in farm dams and reservoirs, and flow diversion for irrigation and urban supply. The 2003 flow regime for the Onkaparinga catchment was modelled by the Department of Land, Water and Biodiversity Conservation (DWLBC – now DEW) to have approximately 4000 ML in reduced surface water flows due to water consumption via dams and reservoirs, as compared to unrestricted surface water catchment and this is thought to contribute to the poor health of surface waters. In spite of this, the river still contains ecological values that are key to river health recovery. The main driver in this recovery is the restoration of a flow regime that supports vital ecological and riverine processes. This view is supported by information provided by the former Inverbrackie creek catchment group chairperson, David Kerber.

During the 1930s the Inverbrackie creek could be travelled upon by canoe. Soon after, the catchment was developed to have a total of 32 dairies and 34 potato farms using the surface and groundwater resource for these activities. Over time the creek progressively became less healthy and increasingly infested with willow trees until by the 1960s and 1970s there were no, or limited fish and yabbies in the creek (pers comm D.Kerber 2016). When the landcare program was undertaken during the early 1990s, almost all of the willows within the riparian zones were removed and native trees and woodlots were extensively planted within the catchment. Since then the yabbies have returned and the ecological health of the creek has improved. Even so, the creek health has still ranked as poor or very poor since 2008 by the EPA.

The reports completed by the EPA for the Inverbrackie Creek are included in Appendix I2.

The proposed ML contains two drainage lines which form part of the Inverbrackie Creek surface water sub catchment, both of which ultimately join Inverbrackie Creek to the west of the proposed ML. One of these drainage lines occurs within the proposed Project footprint, as demonstrated in Figure 11-1. These drainage lines are ephemeral, and flow with water generally less than one month in every year during winter, and only once dams located upstream have been filled and overflow. Inverbrackie Creek is part of the wider Onkaparinga River catchment and Mount Bold Reservoir, which drains to the Gulf of Saint Vincent via an estuary at Port Noarlunga. The far south west corner of the proposed ML forms part of the Dawesley Creek sub-catchment which flows into Lake Alexandrina. No identified landholders rely upon the creeklines for irrigation or stock water.

All catchment zones within the Project area are shown in Figure 11-2, while catchment zones occurring within the proposed ML are located in Figure 11-1.

The Project is located predominantly within the Western Mount Lofty Ranges Prescribed Water Resource Area. The south western corner of the ML is covered by the Eastern Mounty Lofty Ranges Prescribed Water Resource Area (prescribed by the NRM Act as shown in Figure 11-1.

The project is not located within any area protected by the *River Murray Act 2003* (SA) or located within the Murray Darling Basin.

FIGURE 11-1 | SURFACE DRAINAGE LINES, SURFACE WATER SUB-CATCHMENTS AND PRESCRIBED WATER RESOURCE AREAS

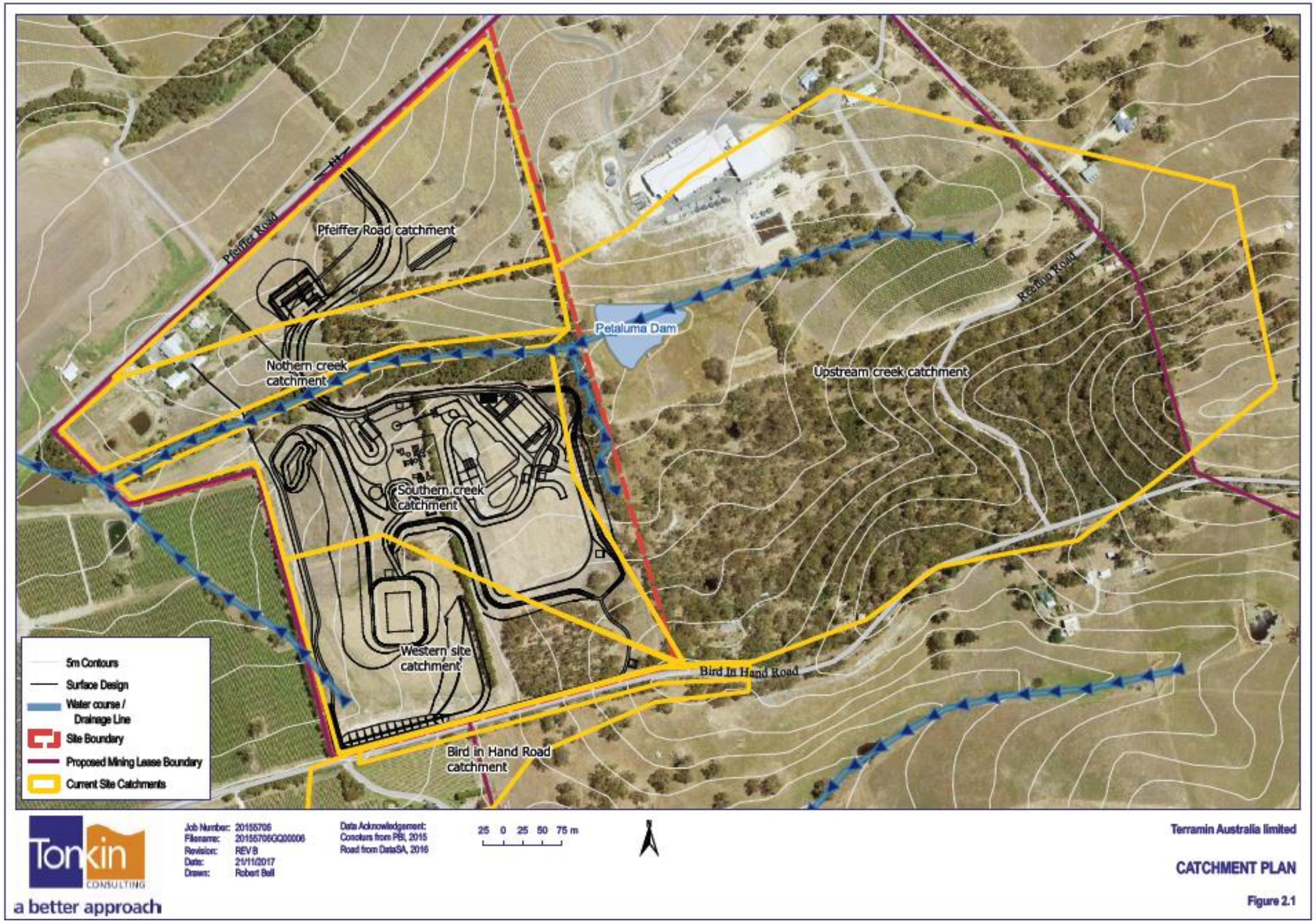


FIGURE 11-2 | SURFACE WATER SITE CATCHMENT AREAS (PRIOR TO DEVELOPMENT OF THE GOLDWYN SITE)

11.3.1 Rainfall and Evaporation

Woodside has an average annual rainfall of 814 mm. Most of the rain falls in the winter months, at around 42% of the total average annual precipitation.

Monthly annual rainfall data were analysed for the period 1884 to 2016.

Figure 11-3 presents average monthly rainfall data for Woodside and monthly evaporation data for Lenswood. The Lenswood BOM station recorded evaporation data from 1973 to 1999 and is located 6.6 km from Woodside, thus it is considered to be appropriate for use in this overview. Points to note about rainfall and evaporation are as follows:

- Average monthly evaporation is greater than the average monthly rainfall for January, February, March, April, October, November and December;
- Average monthly rainfall is greater than the average monthly evaporation in May, June, July, August and September;
- The greatest deficit (rainfall minus evaporation) occurs in summer (December, January and February), with a deficit between 137.5, 163.5 and 136.3mm;
- The greatest surplus (rainfall minus evaporation) occurs from May through to September, with a surplus of up to 84mm/month in July; and
- The highest rainfall on record was 110.7mm, which occurred in 18th April 1938.

The lowest monthly rainfall on record is 0mm, and commonly occurs in the months of January, February, March, November and December.

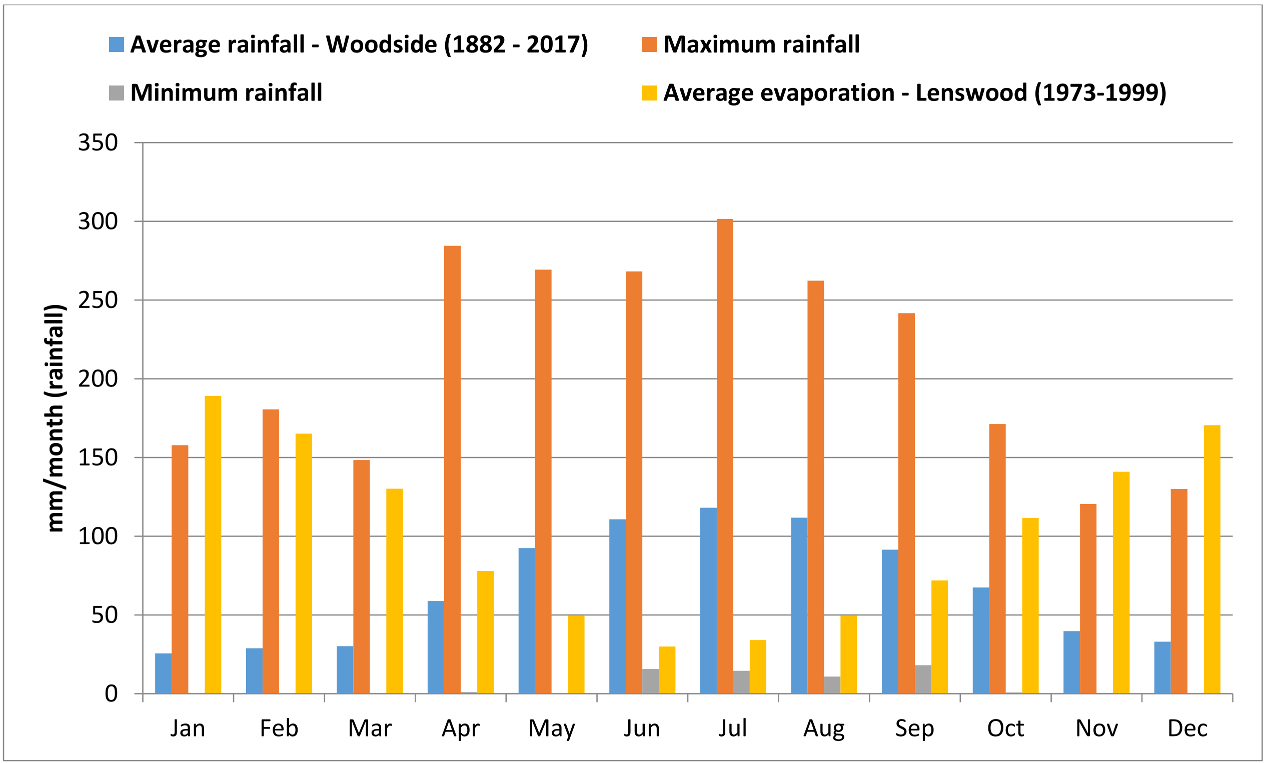


Figure 11-3 | Average Monthly Rainfall and Evaporation

Figure 11-4 presents basic rainfall characteristics for Woodside, including the cumulative deviation from the annual rainfall mean.

The plot indicates positive cumulative deviation or wetter than average periods from 1905 to 1925, 1945 to 1955 and 1970 to 1975 and negative cumulative deviation or dryer than average periods from 1895 to 1905, 1930 to 1945 and 1975 to 2007.

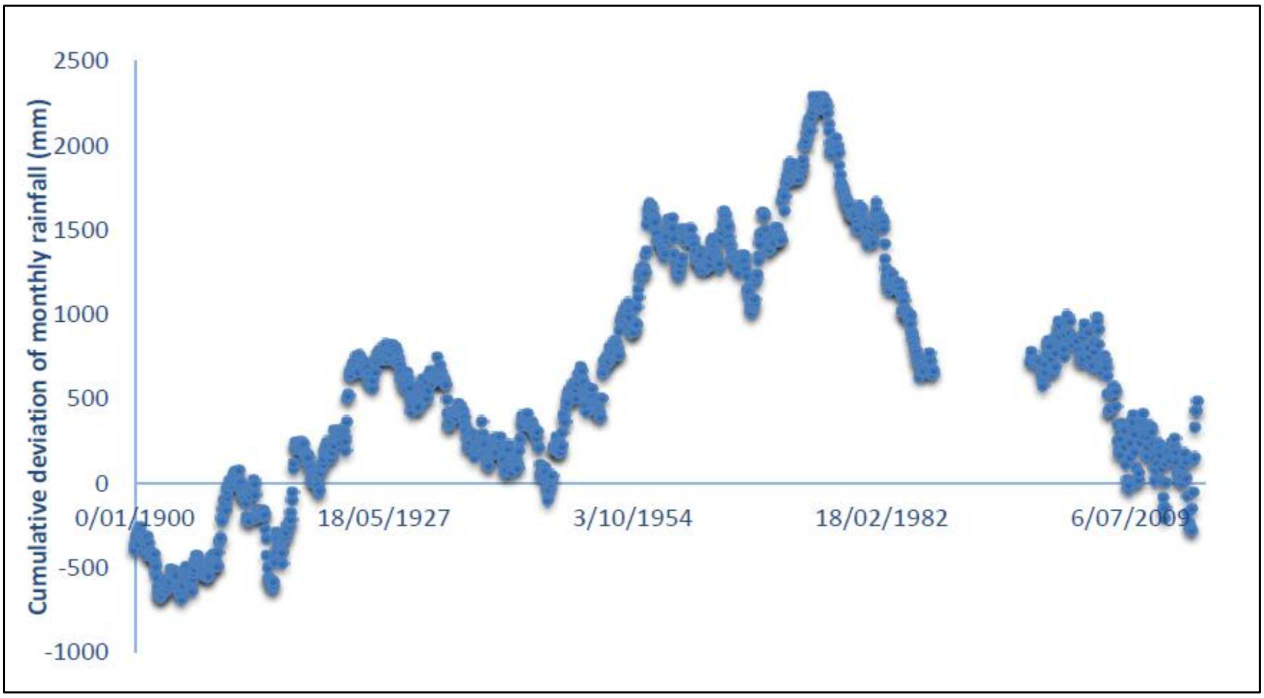


FIGURE 11-4 | CUMULATIVE DEVIATION FROM THE MEAN RAINFALL (BOM DATA, 2017).

11.3.2 EPA AQUATIC ECOSYSTEM CONDITION REPORTS 2008-2016

Inverbrackie Creek is a moderately sized stream that rises to the north and east of Woodside in the southern Mount Lofty Ranges, and flows west into the Onkaparinga River, to the south of Woodside. Grazing modified pastures (53%) was the main land use in the 2,589 hectare catchment upstream from the site sampled, with smaller areas used for irrigated pastures and horticulture, cropping, roads, residential housing, plantation forestry, dams, irrigated cropping and native vegetation. The EPA have selected a site for monitoring located in the lower reaches of the stream, off the Woodside–Nairne Road, 1.7 kilometres downstream of the proposed ML, undertaking water assessments in line with the AUSRIVAS protocol in 2008, 2011 and 2013. The most recent report in 2016 shows a slight improvement from 2008, with the creek rating increased to “poor” from “very poor”.

Key points obtained from the 2016 EPA report state that the Inverbrackie Creek has:

- Permanent flowing stream in autumn and spring 2016;
- Sparse macroinvertebrate community lacking any rare or sensitive species;
- Water was moderately fresh, turbid and slightly coloured, and enriched with nutrients; and
- Riparian vegetation consisted of weedy shrubs over introduced grasses.

The water was moderately fresh (salinity ranged from 510-1,460 mg/L), well oxygenated (66-116% saturation), turbid and slightly coloured, with moderately high concentrations of nutrients such as phosphorus (0.04-0.08 mg/L) and nitrogen (0.63-0.76 mg/L). Froth was also present at the site in autumn 2016.

In summary, the creek was given a Poor rating because the site sampled showed evidence of major changes in ecosystem structure and moderate changes to the way the ecosystem functions. There was clear evidence of both long term and recent anthropogenic disturbance at the site due to nutrient enrichment, the mobilisation of fine sediment and the extent of weeds in the riparian zone.

The EPA aquatic ecosystem reports from 2008 to 2016 have been included in Appendix I3.

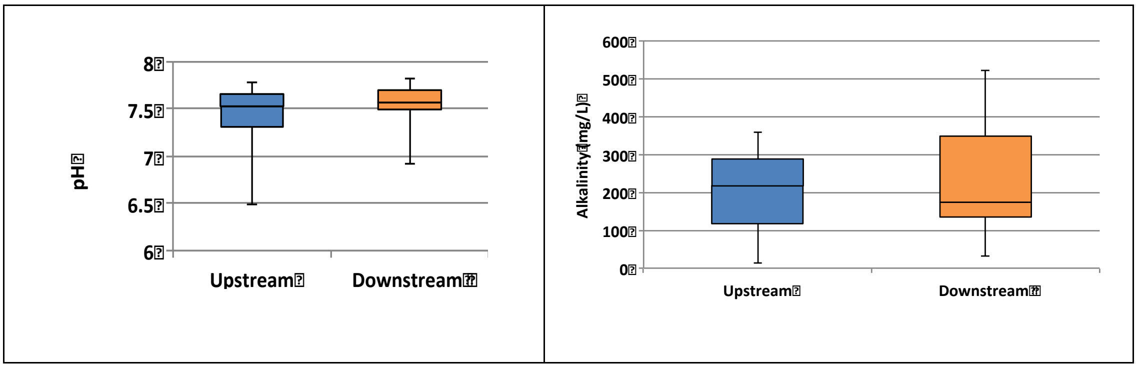
11.3.3 Surface Water Quality Data and Analysis

Terramin have undertaken 18 continuous months (from May 2014) of baseline creek sampling from 4 locations along Inverbrackie Creek, as well as 25 paired sampling events both up and downstream between May 2014 and October 2017. When possible, the drainage tributaries emanating from the proposed mining lease have also been sampled during this period.

Macroinvertebrate sampling was undertaken upstream and downstream in 2014, 2016 and 2017. Macroinvertebrate diversity is an indicator of ecosystem health and the sampling has been analysed and reported for 2014 and 2016 at the time of writing. The results concur with the EPA assessments that the creek contains no rare or sensitive species and that the ecosystem is in generally poor condition. Unpublished results from the 2017 sampling confirm no change in ecosystem health.

This data has been analysed by AC Environmental in the Inverbrackie Creek Macroinvertebrate and Water Quality Investigation located in Appendix I1.

The long term monitoring of Inverbrackie Creek at the upstream and downstream monitoring sites indicates that pH is similar between locations but with a wider variance at the upstream sites (Figure 11-5). Alkalinity was high at the downstream site, which helps explain the smaller variance in the pH at the downstream site due to the buffering capacity. The average electrical conductivity was higher at the downstream site and the site exhibited a wider variance. Turbidity was also higher at the downstream and exhibited a higher variance over time. TDS was also higher at the downstream site with greater variability.



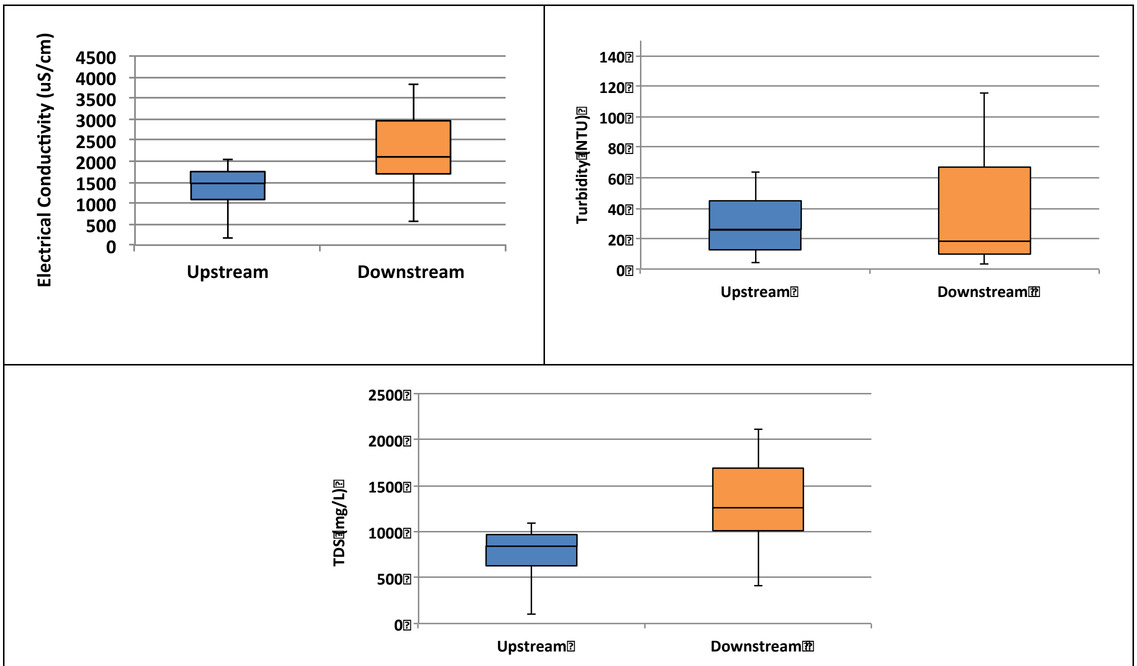


FIGURE 11-5 | INVERBRACKIE CREEK WATER QUALITY VARIATION

The plot of turbidity measurements over the monitoring period further support the inference that the downstream Inverbrackie Creek site regularly has higher readings (Figure 11-6). A peak in the readings occurred in the later part of 2015 before settling to similar readings from the upstream site. Turbidity readings were regularly above the ANZECC (2000) guideline for upland rivers of 25 NTU and highly impacted by stock access. The plot of electrical conductivity (Figure 11-7) indicates that the downstream site is consistently higher than the upstream site and rises and falls in a similar pattern to that observed upstream, the electrical conductivity was consistently above the upland river ANZECC (2000) level of 350 uS/cm. No consistent pattern in the pH readings between the upstream and downstream sites was evident (Figure 11-8). No ANZECC (2000) trigger values exist for dissolved oxygen, pH or electrical conductivity for upland rivers in South Central region.

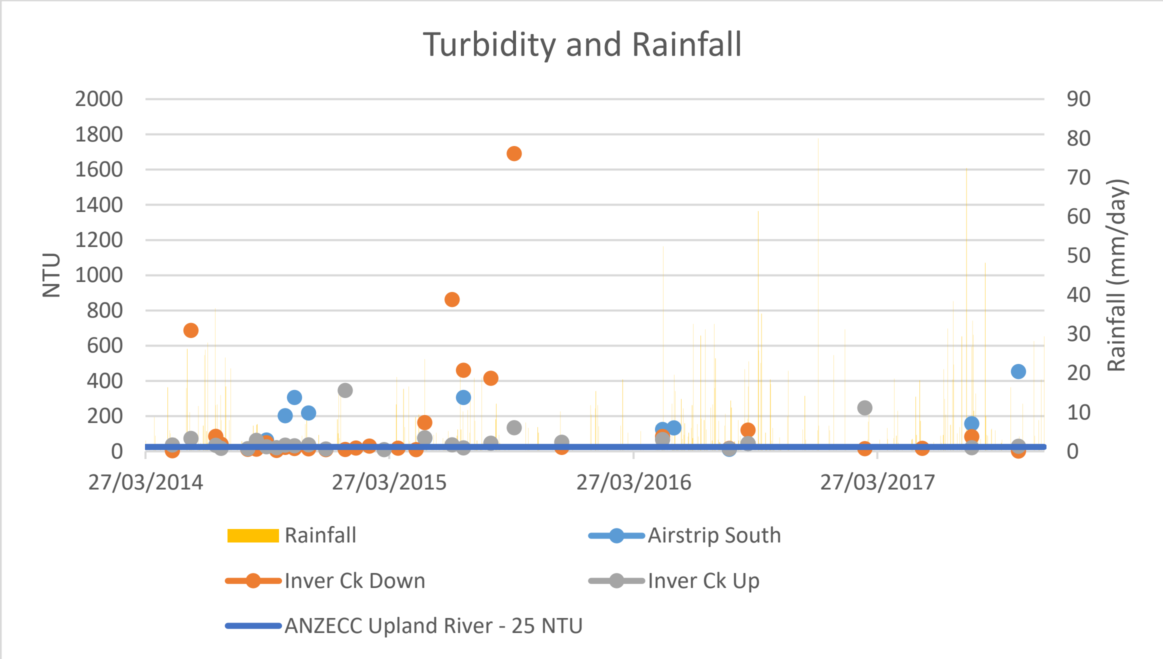


FIGURE 11-6 | INVERBRACKIE CREEK LONG TERM WATER QUALITY MONITORING - TURBIDITY

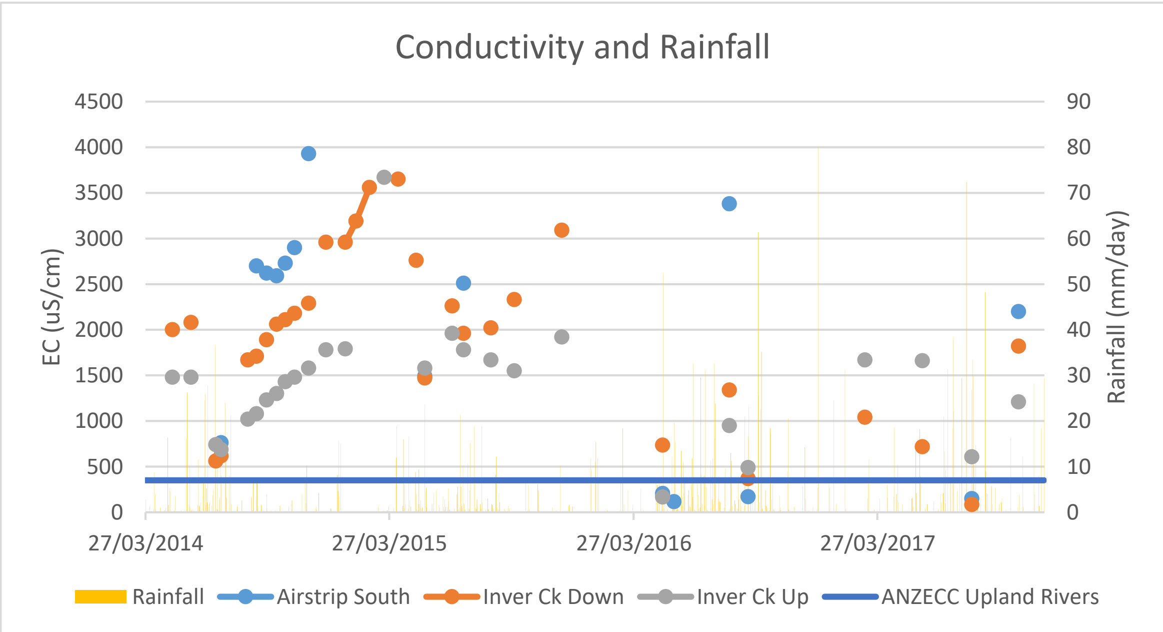


FIGURE 11-7 | INVERBRACKIE CREEK LONG TERM WATER QUALITY MONITORING - ELECTRICAL CONDUCTIVITY

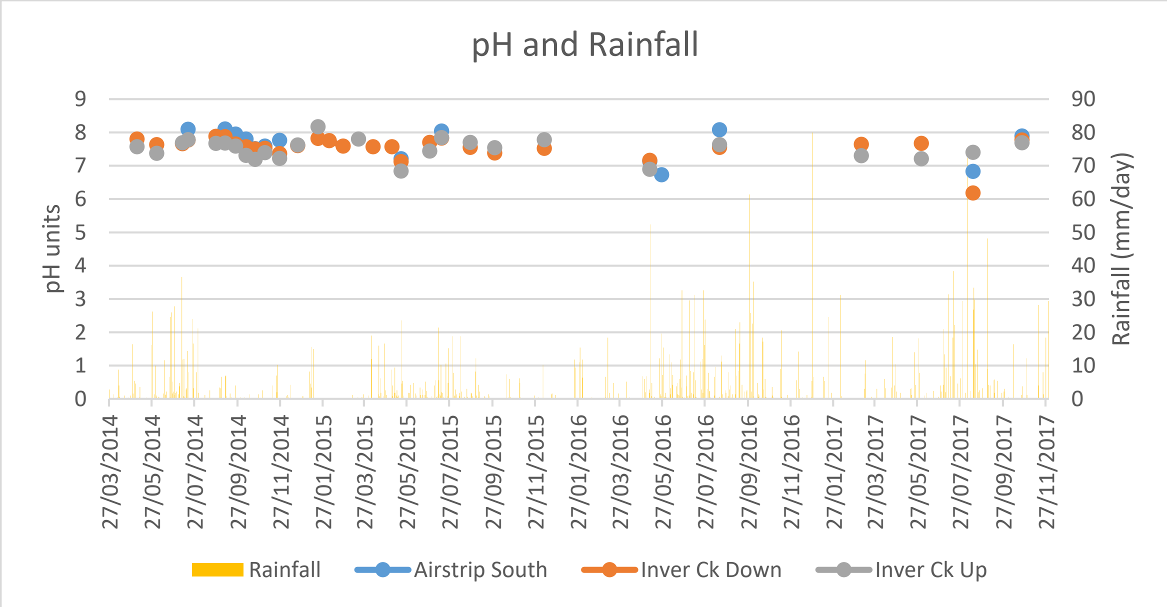


FIGURE 11-8 | INVERBRACKIE CREEK LONG TERM WATER QUALITY MONITORING - PH

Upstream Inverbrackie Creek was characterised as having lower concentration of Manganese but higher average concentrations of Iron, Arsenic, Chromium, Copper, Lead and Zinc over the monitoring period (Figure 11-9). While Cadmium and Selenium were also measured the data is not presented as results were consistently below or just above the detection limit. Unusual readings were obtained for Selenium at both sites on the 9 October 2014. The readings were similar between the locations and show as a clear outlier to all other results.

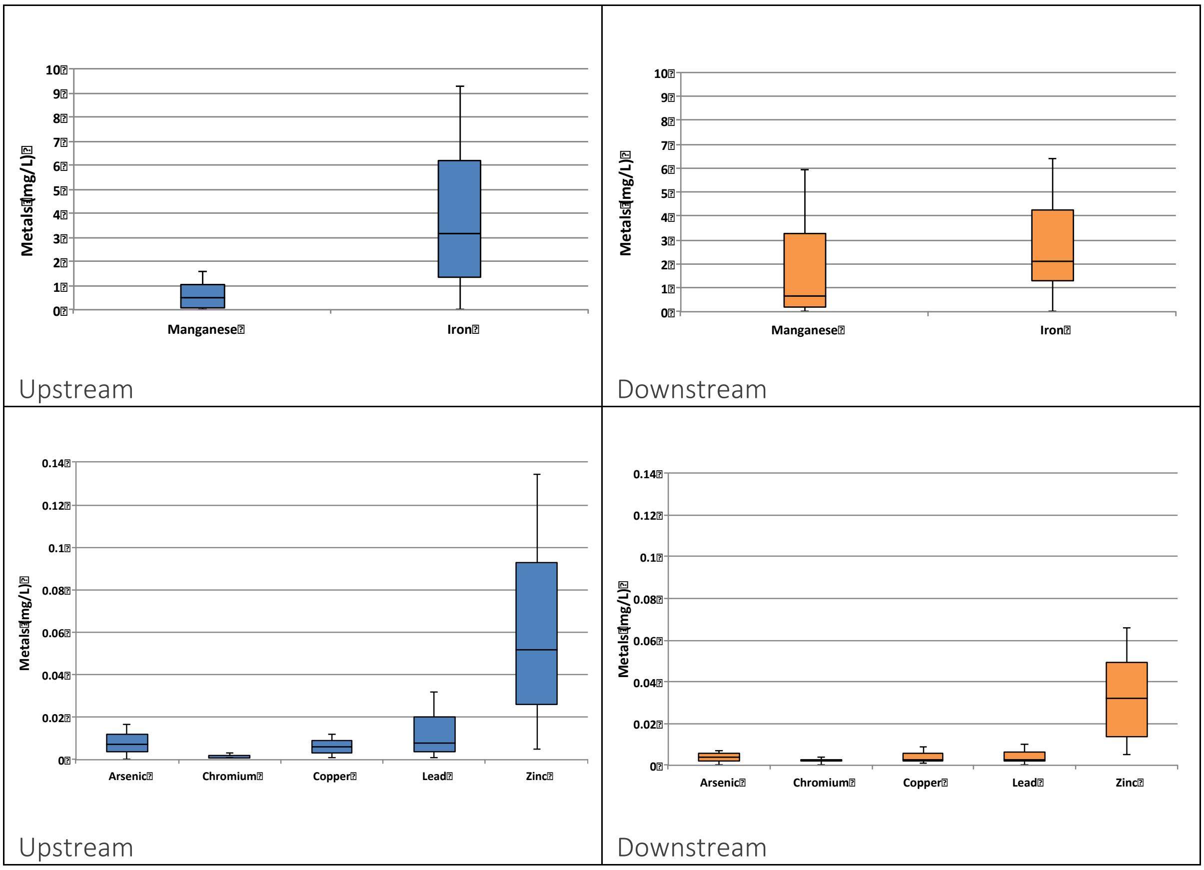


FIGURE 11-9 | FILTERED METAL CONCENTRATIONS IN INVERBRACKIE CREEK

The highest arsenic concentration was observed at the upstream site in January 2015 (Figure 11-10). However, there was no clear pattern in the data set with the downstream site having higher concentrations in mid-2015. Arsenic values were above the ANZECC (2000) trigger value of 0.024 mg/L for 95 % species protection in freshwaters at both locations but with no consistent pattern evident. Although cadmium and total copper concentrations were determined as highest at the upstream site in October 2014 there was no consistent pattern with regards to location and maximum concentrations (Figure 11-11 and Figure 11-12). Dissolved copper concentrations were also regularly above the ANZECC trigger at both sites (Appendix 6). Manganese concentrations were generally higher downstream but with no consistent pattern (Figure 11-13). Manganese concentrations were often recorded at both locations above the ANZECC (2000) trigger of 1.9 mg/L. Total lead concentrations were measured at their highest at the upstream site in October 2014 and were considerably higher than the remaining study period (Figure 11-14). Total Lead levels were above the ANZECC (2000) trigger of

0.0034 mg/L at the upstream site and were highest in 2014. Dissolved lead concentrations were higher at the upstream site and were above the ANZECC trigger in late 2014 but were also slightly above the trigger value in July 2016. The highest zinc concentrations were recorded in October 2015 where concentrations were higher at the upstream location (Figure 11-15). Total zinc concentrations were regularly above the ANZECC (2000) trigger of 0.008 mg/L on all occasions. Dissolved zinc concentrations were also regularly above the ANZECC trigger at both locations.

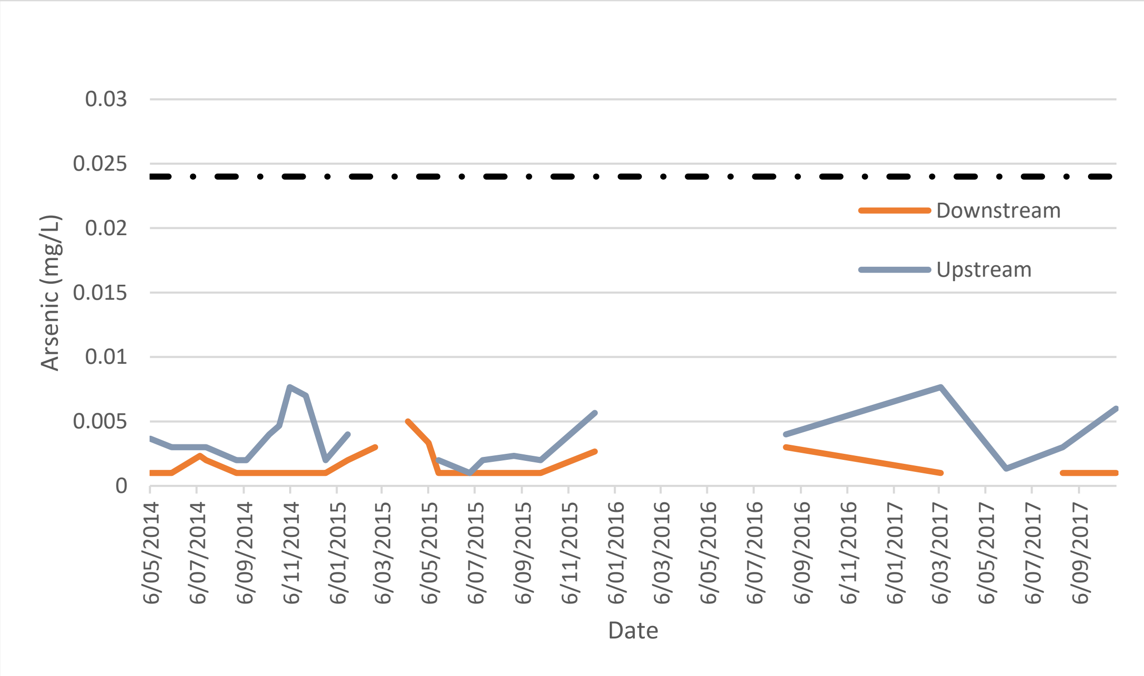


FIGURE 11-10 I INVERBRACKIE CREEK LONG TERM WATER QUALITY MONITORING - ARSENIC

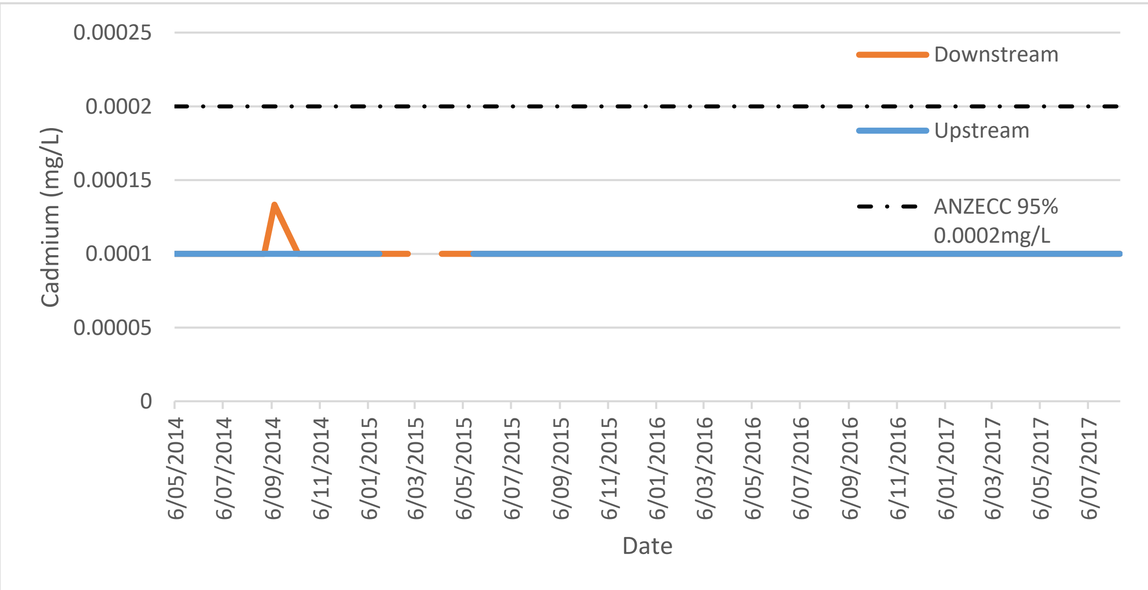


FIGURE 11-11 | INVERBRACKIE CREEK LONG TERM WATER QUALITY MONITORING - CADMIUM

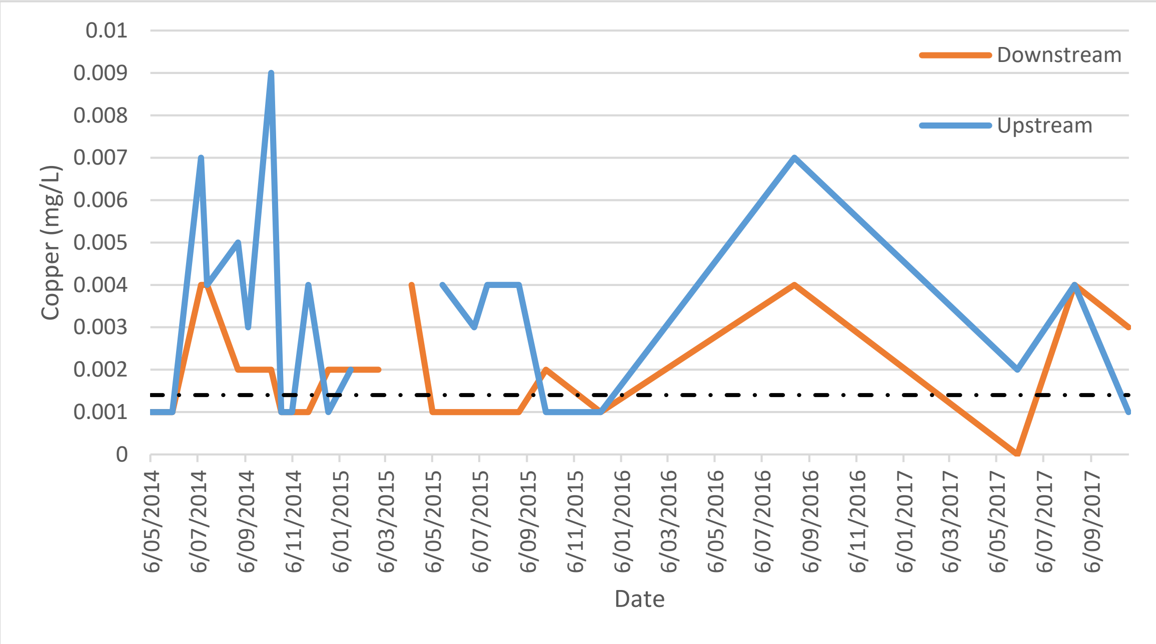


FIGURE 11-12 | INVERBRACKIE CREEK LONG TERM WATER QUALITY MONITORING - COPPER

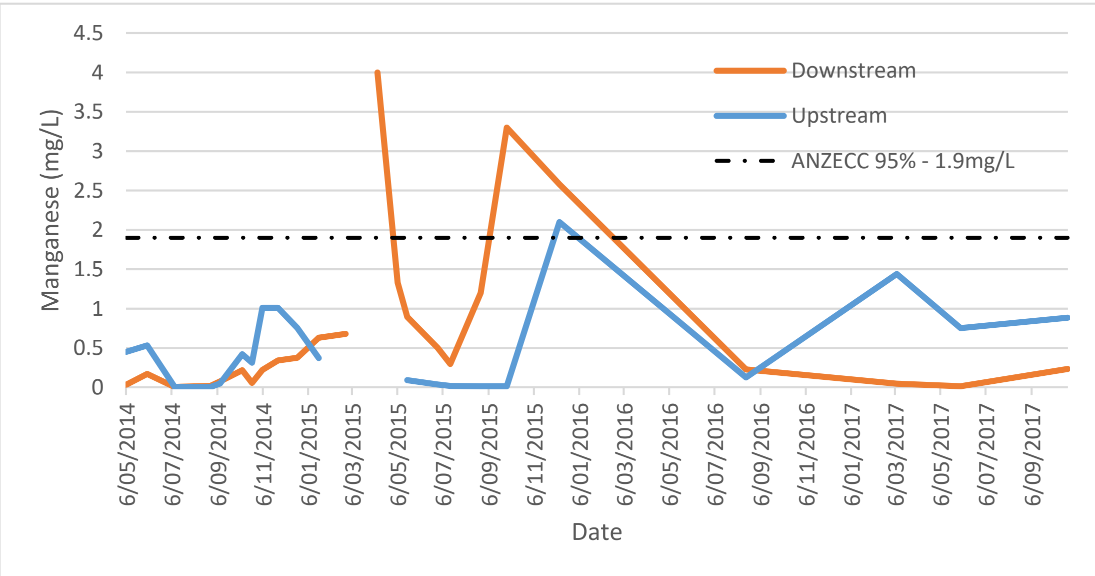


FIGURE 11-13 | INVERBRACKIE CREEK LONG TERM WATER QUALITY MONITORING - MANGANESE

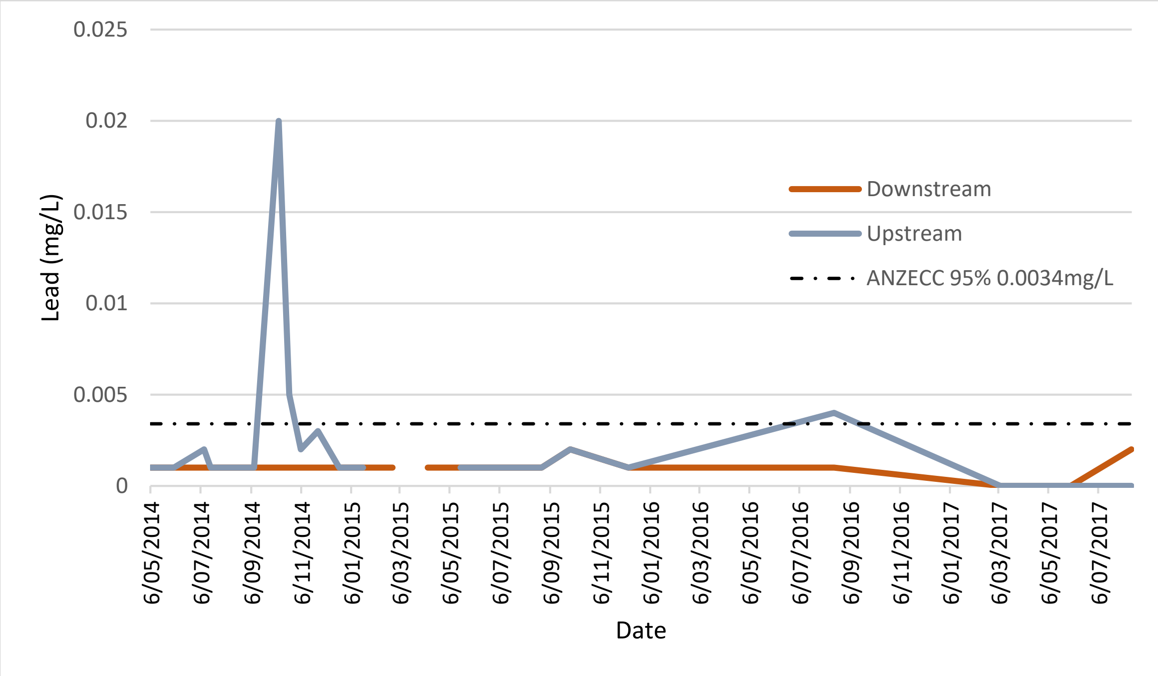


FIGURE 11-14 | INVERBRACKIE CREEK LONG TERM WATER QUALITY MONITORING – LEAD

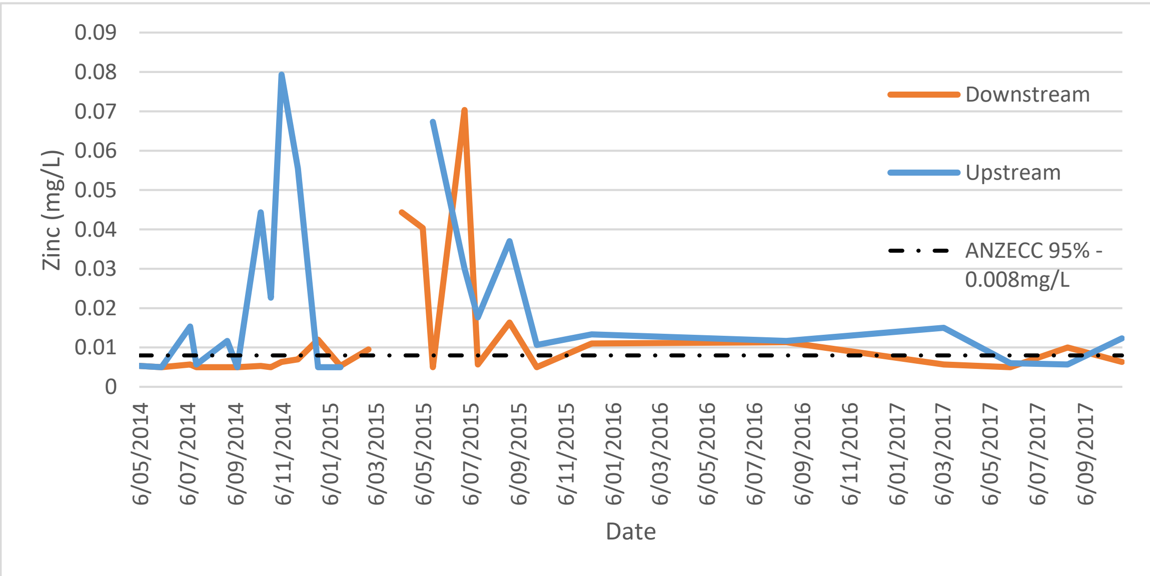


FIGURE 11-15 | INVERBRACKIE CREEK LONG TERM WATER QUALITY MONITORING - ZINC

The average total nitrogen concentration was similar at the downstream and upstream locations (Figure 11-16). Total Kjehldahl Nitrogen (TKN) dominated the form, TKN is the total concentration of organic nitrogen and ammonia. The average concentration of ammonia and nitrate was slightly higher downstream. The average total phosphorus and filterable phosphorus was also slightly higher at the downstream site. At both locations the average Total Nitrogen and Total Phosphorus concentrations are well above the ANZECC (2000) south-east Australia trigger values for the protection of 95 % of freshwater species. The ANZECC (2000) south-eastern trigger values for Total Nitrogen are 0.25 mg/L and for Total Phosphorus are 0.02 mg/L. No trigger ANZECC (2000) trigger values exist for total N and total P in the South Central region. The concentration of NOx and ammonia were below the toxicity concentration triggers for the protection of 95% of taxa.

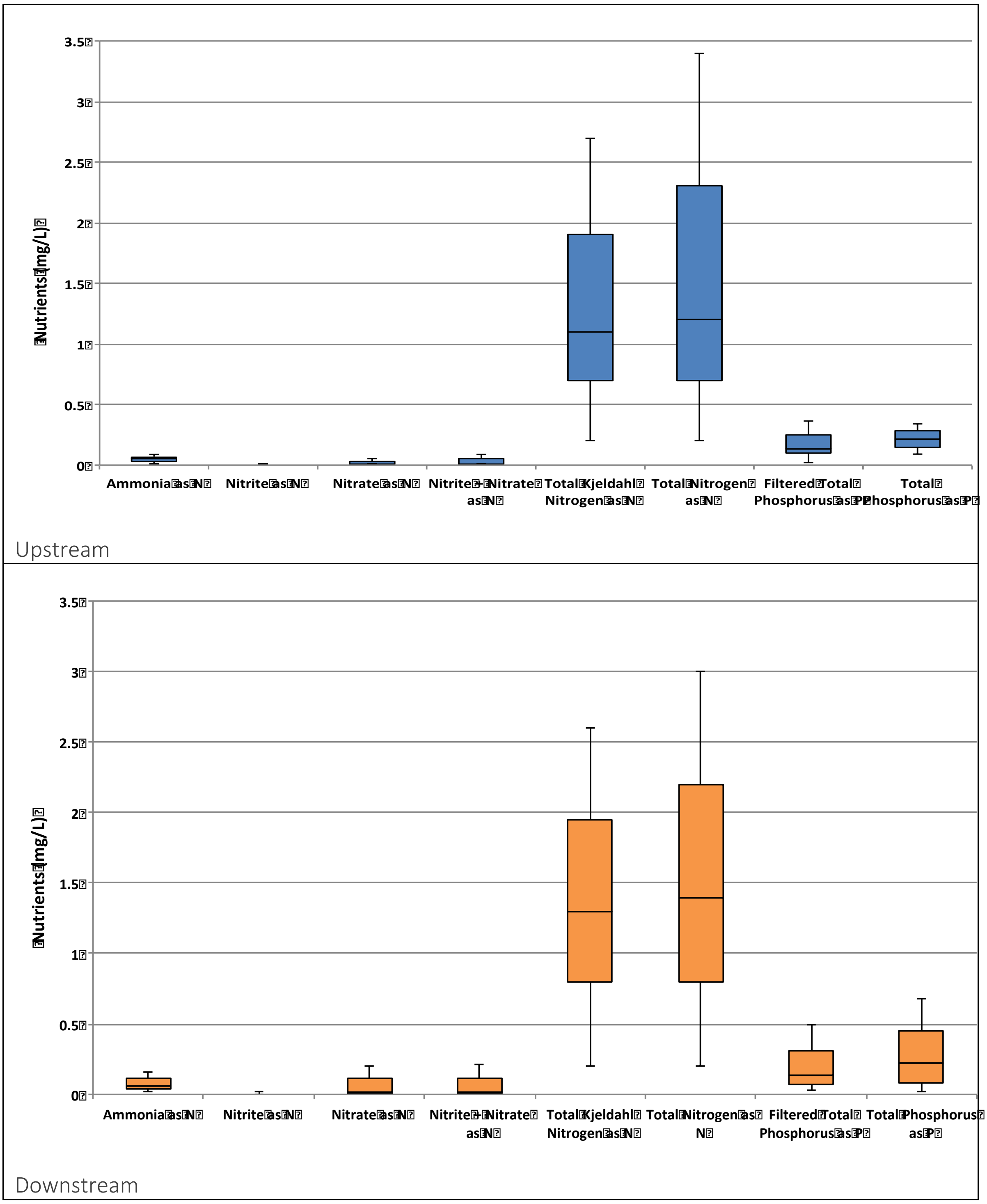


FIGURE 11-16 | NUTRIENT CONCENTRATIONS IN INVERBRACKIE CREEK

The highest concentration of total nitrogen was recorded at the downstream site in October 2015 (Figure 11-17). Similarly the highest total phosphorus was also recorded in October 2015 (Figure 11-18). Similar patterns are observed between total phosphorus and total nitrogen with regards to the higher concentrations being recorded upstream or downstream. Total P and Total N measurements are consistently above the above the ANZECC (2000) south-east Australia trigger values for the protection of 95 % of freshwater species.

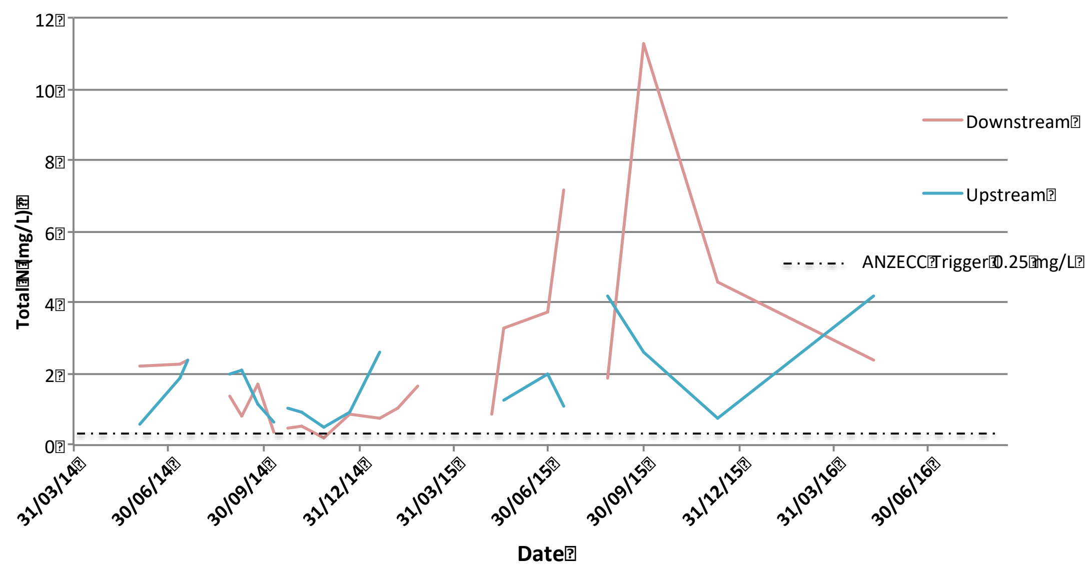


FIGURE 11-17 | INVERBRACKIE CREEK LONG TERM WATER QUALITY MONITORING - TOTAL N

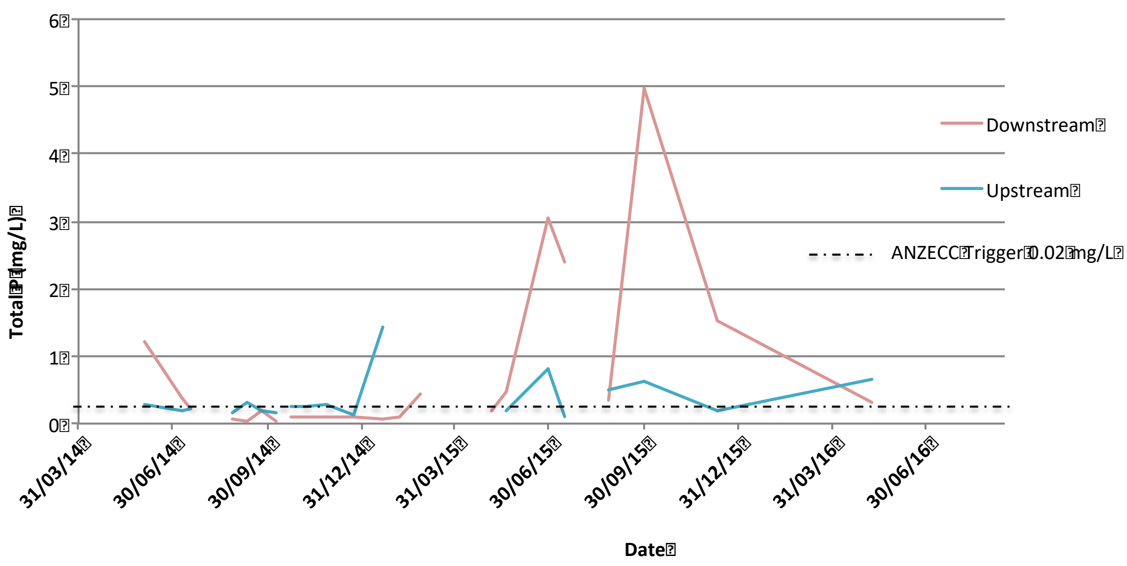


FIGURE 11-18 | INVERBRACKIE CREEK LONG TERM WATER QUALITY MONITORING - TOTAL P

Additionally, surface water samples have been obtained from various run off points emanating from the proposed ML between 2014 and now. This includes significant rain events in May 2016, which caused most ephemeral drainage lines to flow. Significantly, this includes the drainage line located in the southern side of the proposed ML, south of Bird in Hand Road. Locations of surface water samples taken between 2014 and 2018 are shown below in Figure 11-19.

Water quality results for each individual water sampling event have been included in the Inverbrackie Creek Macroinvertebrate and Water Quality Investigation located in Appendix I1.

FIGURE 11-19 | SURFACE WATER SAMPLE LOCATIONS

11.3.4 INVERBRACKIE CREEK FLOW VOLUMES

Visual estimation of stream flows of the Inverbrackie Creek from March 2014 to October 2016 have demonstrated a creek which often has little to no flow, with small periods of flow observed through the winter months or periods of high rainfall. Analysis of the data often indicates a higher flow rate at locations further downstream than the site selected upstream of the BIHGP site ("Inverbrackie Creek Up"), indicating that the Inverbrackie Creek is a gaining stream through spring-fed pools located along a section, as shown in Figure 11-20 (discussed in more detail below).

Visual estimation flow rate data is located in Appendix I1.

The Mount Lofty Ranges Groundwater Assessment: Upper Onkaparinga Catchment report, DWLBC (now DEW) modelled median stream flows for the ungauged Inverbrackie Creek of 874ML baseflow, with 2175ML run off into the creek-line from 1990 to 1998. These estimations were carried out by the Surface Water Assessment Branch of DWLBC, using methodology derived from Method 1, Chapman and Maxwell (Chapman and Maxwell, 1996) to model flow outputs (DWLBC, 2002). These estimations fit well with the calibrated groundwater model which, from date collected in 2014 – 2017, calculated Inverbrackie creek base flows as 716 ML per year. The Groundwater Assessment is located in Appendix H1 (see Appendix F).

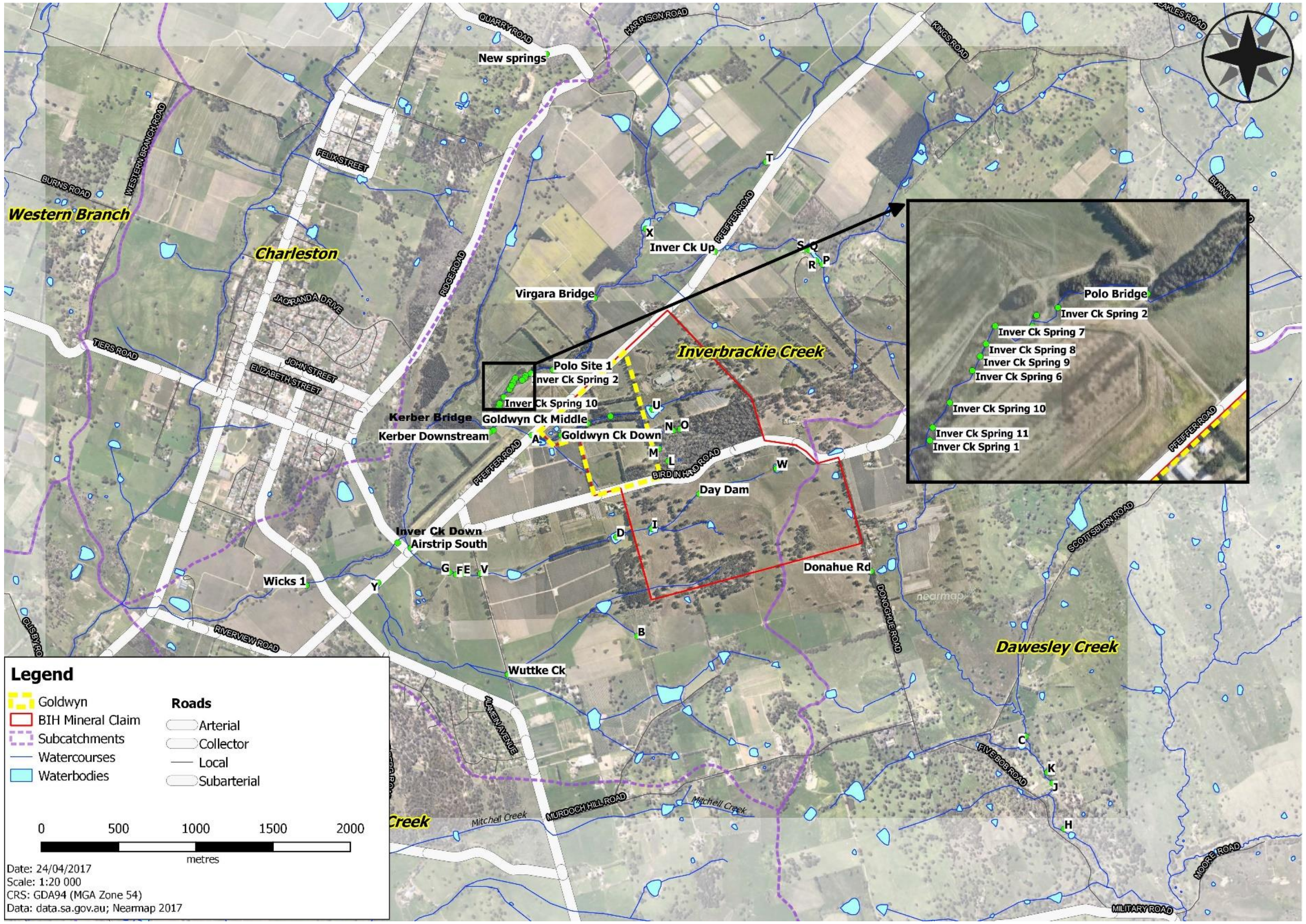


FIGURE 11-20 | WATER QUALITY SAMPLING SITES (FULL LIST OF COORDINATES LOCATED IN APPENDIX I1)

11.3.5 Ground and Surface water interactions

At its closest point, Inverbrackie Creek is located 535 m to the north-northwest of the proposed underground workings (Figure 11-1).

Monitored stream level and salinity together with groundwater level data captured over the winter and summer seasons has been assessed to understand the interaction between surface water and groundwater within the catchment area surrounding the BIHGP site.

Topographic and creek bed level data along Inverbrackie Creek suggest the creek is a losing system in the north eastern (higher relief) portion of the catchment, where winter groundwater elevations are more than 5 m below the creek level (Figure 11-2). This is supported by the historic creek level data recorded at Craigbank (Station A5030508) (Figure 11-22) which indicates that Inverbrackie Creek is ephemeral, flowing during winter months and following major rainfall events only.

Downstream, there is some evidence to suggest that Inverbrackie Creek acts like a drain for the Fractured Rock Aquifer (FRA) in a number of locations. Figure 11-21 shows that groundwater levels are higher than the base of the creek in a number of locations and this has been confirmed by the presence of a number of small discontinuous pools that were noted to exist towards the end of summer 2014/15. For example, next to one pool, the groundwater elevation measured in nearby monitoring well ONK017 (located 28 m from the creek line) was 370 mAHD, which is some 4 m higher than the creek bed at this point (366 m AHD).

The historic data from the gauging station positioned downstream indicates that the baseflow contribution to the creek is small and variable (i.e., impacted by seasonal pumping for irrigation) (Figure 11-21). In summer for example, groundwater abstraction from the Tapley Hill Formation has resulted in the lowering of groundwater levels around most of the Inverbrackie Creek area, eliminating much of the baseflow contribution throughout the summer months (Figure 11-21).

The surface salinity of the creek upstream averages approximately 800 mg/L and downstream averages approximately 1,900 mg/l between May 2014 and October 2017. During higher flows the salinity at both sites generally reduces to 400 mg/L. However during some high rainfall events salinity and copper increase in the creek, presumably due to being washed off soils within the catchment. The higher salinity downstream could be attributed to some groundwater baseflow and possible evapo-concentration of pools (which are flushed during high flows). When compared to local groundwaters, the major ion chemistry of the pools suggested the waters were derived from groundwater baseflow.

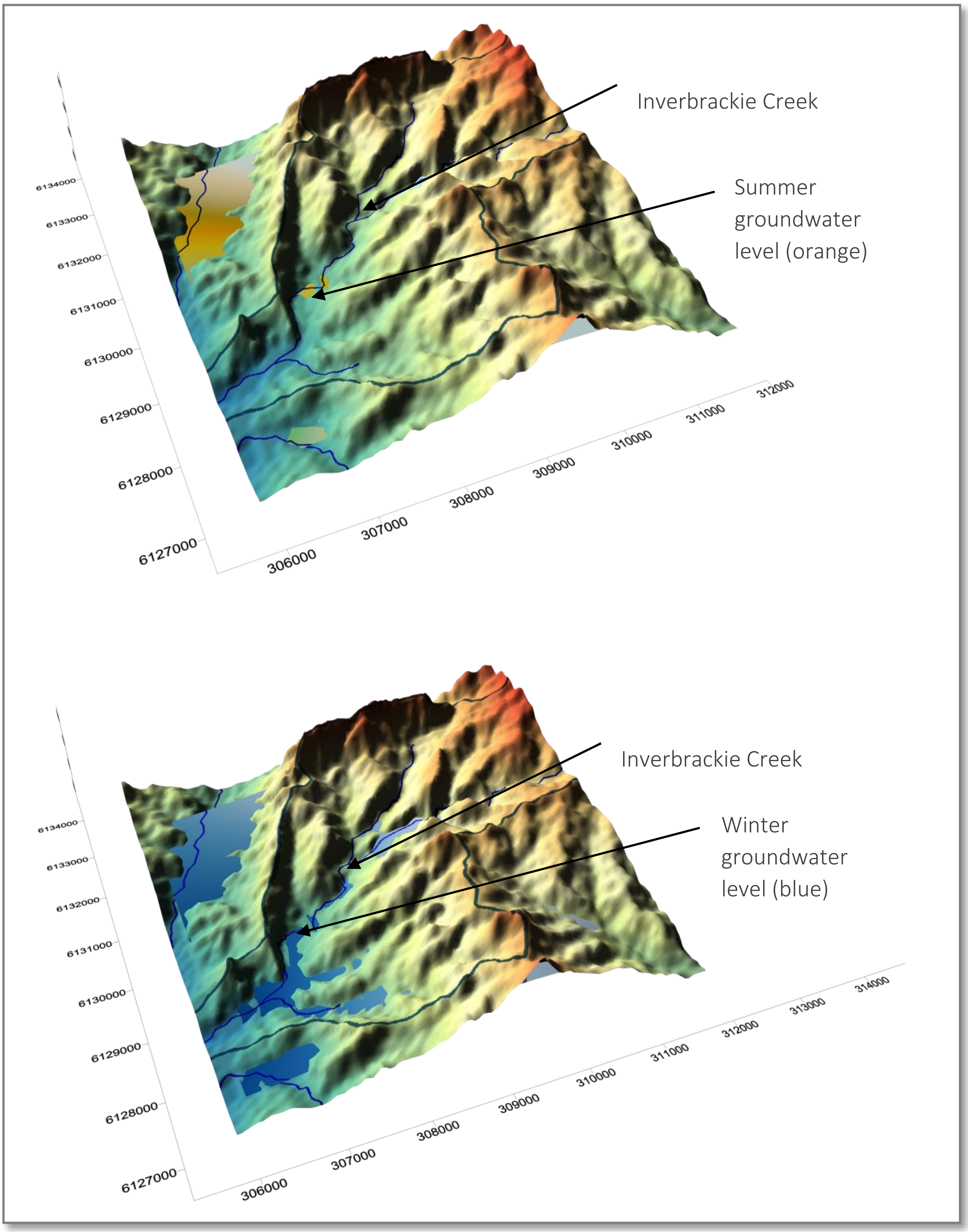
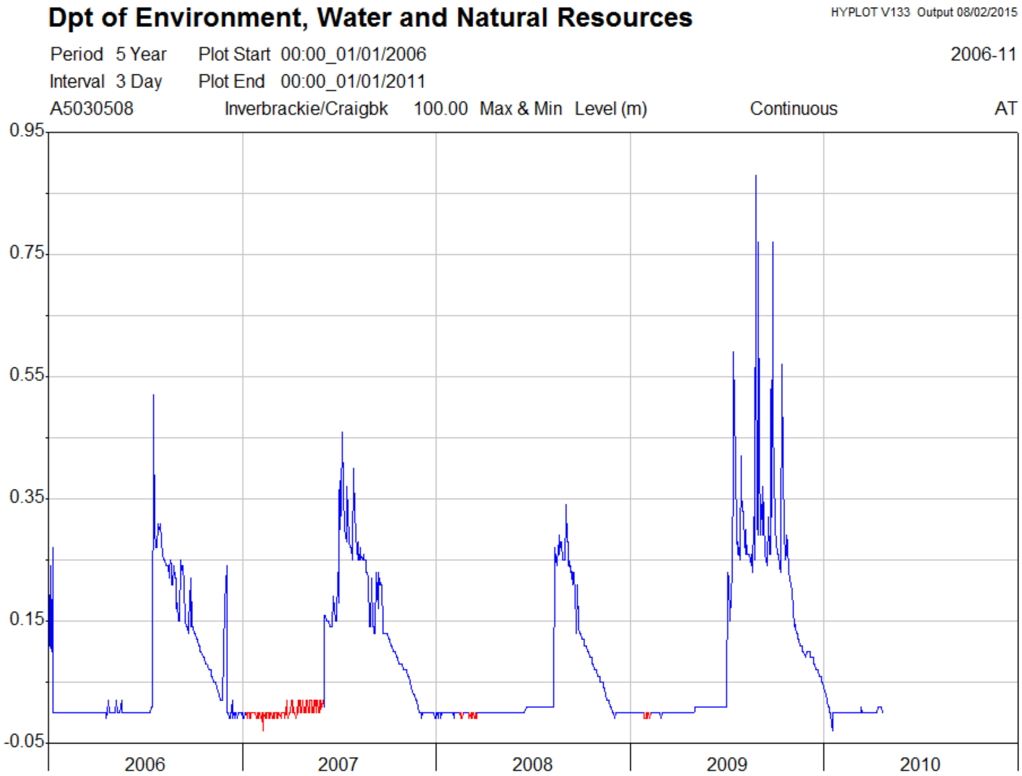


FIGURE 11-21 | TOPOGRAPHIC ELEVATION AND GROUNDWATER ELEVATION FOR SUMMER (TOP) AND WINTER (BOTTOM)

Areas where water is visible (winter) as compared to the topmost image in Figure 11-21 (summer), the interpolated groundwater pressure head is greater than land surface elevation, representing surface expression of groundwater (springs/discharge to creek). Springs are identified in orange in summer in Figure 11-21.



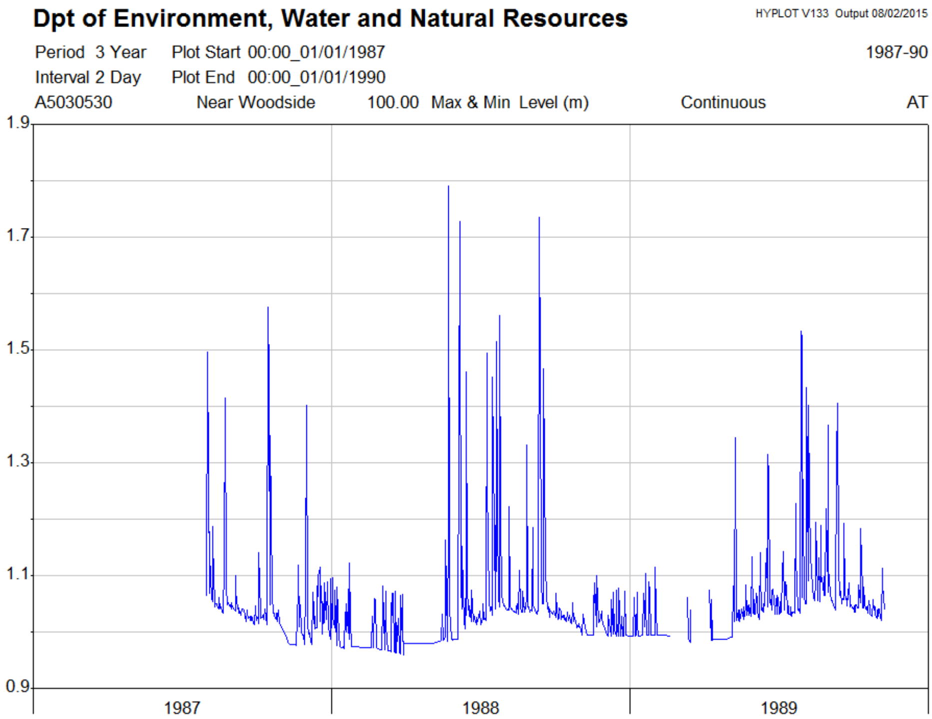


FIGURE 11-22 | SURFACE WATER GAUGING STATION FOR UPSTREAM (TOP) AND DOWN-STREAM (BOTTOM)

11.4 SENSITIVE RECEPTORS

Identified potential sensitive receptors are presented in Table 11-1 and illustrated in Figure 11-23.

The sensitive receptor which appears most frequently within the impact assessment is the ecological values of Inverbrackie Creek (surface water ecosystem).

No users of Inverbrackie Creek were identified as reliant upon the flow volumes, however stock (cattle) access the creek incidentally to drink water at times but stock have trough access as well. The surface water systems are degraded and have minimal environmental value in their current state (as identified by both the EPA and AC Environmental), with many contaminates often being above guideline limits and no sensitive or listed fauna readily identified (e.g. sensitive macroinvertebrates, fish, frogs or platypus).

TABLE 11-1 | SENSITIVE RECEPTORS

Sensitive Receptor	Summary	Impact ID
Surface water ecosystem (Inverbrackie Creek and tributaries)	Part of Inverbrackie Creek is located downstream of the Goldwyn, MAR bores and exploration sites. Springs are located along Inverbrackie Creek – see Figure 11-20	PIE_11_04 PIE_11_05 PIE_11_07 PIE_11_08 PIE_11_13 PIE_11_14 PIE_11_15 PIE_11_16 PIE_11_18 PIE_11_20
Agricultural land (BIH Winery vineyard)	Part of the BIH Winery vineyard is located within the riparian zone, which is downstream of a drainage line which begins in the western paddock of Goldwyn	PIE_11_03
Riparian zones	Riparian zones have been defined as 30m either side of a drainage line	PIE_11_17
Groundwater dependent ecosystems	As defined by the National Groundwater Dependent Ecosystem Atlas – includes Inverbrackie Creek	PIE_11_10
Fauna (listed species)	No listed species have been discovered or are likely to be found within the Inverbrackie Creek system	PIE_11_01 PIE_11_02 PIE_11_19
Surrounding agricultural land	Surrounding agricultural land along riparian areas identified in Chapter 22 and shown in Figure 11-24 (replicated from Chapter 22).	PIE_11_06 PIE_11_09 PIE_11_11 PIE_11_12

FIGURE 11-23 | IDENTIFIED POTENTIAL SENSITIVE RECEPTORS

FIGURE 11-24 | IDENTIFIED AGRICULTURAL SENSITIVE RECEPTORS

11.5 POTENTIALLY IMPACTING EVENTS

Potentially impacting events are generally linked to contamination of surface water from either acid or metalliferous drainage from the mullock, chemicals and/or hydrocarbons used onsite, and the risk of water erosion from construction works and various landforms increasing the sedimentation of Inverbrackie Creek or adjacent agricultural properties.

As the Native Vegetation Heritage Agreement (NVHA) area is located upslope of the proposed Project site, there are no credible potentially impacting events linked to surface water (Table 11-2).

Groundwater dependent ecosystems are not considered to be a viable receptor for mobilisation of salt, as water used on the site surface for either irrigation or dust suppression is not highly saline and of the same quality as adjacent irrigators.

Listed fauna species are not considered to be a viable receptor as none have been discovered or are likely to be found within the Inverbrackie Creek system.

Other potentially impacting events not considered credible include contamination of agricultural land via surface flows, as all surface water that comes into contact with the operational area will be diverted to the water treatment system. The only surface water that would not drain into the water treatment system and could possibly reach agricultural land would have to come from the water storage dam, either from overflowing or geotechnical failure.

The most credible potentially impacting events which require the most design measures and management strategies to ensure successful mitigation includes water erosion from construction works and newly constructed landforms increasing sedimentation downstream into Inverbrackie Creek.

TABLE 11-2 | IDENTIFIED POTENTIALLY IMPACTING EVENTS

Potentially Impacting Events	Mine Life Phase	Source	Potential Pathway	Sensitive Receptors	Confirmation of S-P-R	Impact IDs
Water storage dam overflows resulting in flooding event downstream impacting listed fauna in Inverbrackie Creek	Construction, Operation, Closure	Water storage dam	Surface water flows	Fauna (listed species) within Inverbrackie Creek	No	PIE_11_01
Water storage dam geotechnical failure resulting in flooding event downstream impacting listed fauna in Inverbrackie Creek	Construction, Operation, Closure	Water storage dam	Surface water flows	Fauna (listed species) within Inverbrackie Creek	No	PIE_11_02
Water storage dam overflows/geotechnical failure resulting in flooding event downstream impacting agricultural land (BIH Winery Vineyard)	Construction, Operation, Closure	Water storage dam	Surface water flows	Agricultural land (BIH Winery vineyard)	Yes	PIE_11_03

Potentially Impacting Events	Mine Life Phase	Source	Potential Pathway	Sensitive Receptors	Confirmation of S-P-R	Impact IDs
Water storage dam overflows/geotechnical failure resulting in flooding event downstream impacting surface water ecosystem (Inverbrackie Creek)	Construction, Operation, Closure	Water storage dam	Surface water flows	Surface water ecosystem (Inverbrackie Creek)	Yes	PIE_11_04
AMD or NMD material has the potential to contaminate surface water runoff and impact on surface water ecosystem (Inverbrackie Creek)	Operation, Closure	AMD or NMD in mined materials or other materials at surface	Surface water flows	Surface water ecosystem (Inverbrackie Creek)	Uncertain	PIE_11_05
Changes to surface water flows impacts on surface water availability for agricultural land	Construction, Operation, Closure, Post-closure	Altered drainage and surface topography	Surface water flows	Surrounding agricultural land	No	PIE_11_06
Sedimentation of surface water via erosion of IML results in reduction in water quality impacting surface water ecosystem (Inverbrackie Creek)	Operation, Closure	Overland flow erosion of IML	Surface water flows	Surface water ecosystem (Inverbrackie Creek)	Yes	PIE_11_07
Hazardous materials stored onsite have the potential to be washed into surface water drainage system and impact on surface water ecosystem (Inverbrackie Creek)	Operation, Closure	Hazardous materials stored on site	Surface water flows	Surface water ecosystem (Inverbrackie Creek)	No	PIE_11_08
Hazardous materials stored onsite have the potential to be washed into surface water drainage system and impact on agricultural land	Operation	Hazardous materials stored on site	Surface water flows	Surrounding agricultural land	No	PIE_11_09
Irrigation or dust suppression on IML or other earthworks has the potential to mobilise salt and impact on groundwater by increasing electrical conductivity	Operation	Irrigation or dust suppression	Infiltration of mobilised salt	Groundwater Dependent Ecosystems	No	PIE_11_10
AMD or NMD material in post-closure landforms has the potential to contaminate surface water runoff and impact on agricultural land	Post-closure	AMD or NMD material in post-closure surface landforms	Surface water flows	Surrounding agricultural land	No	PIE_11_11
Changes to surface water flows result in increased erosion and impacts on agricultural land	Construction, Operation, Closure, Post-closure	Overland flow erosion of exposed surfaces	Surface water flows	Surrounding agricultural land	Yes	PIE_11_12

Potentially Impacting Events	Mine Life Phase	Source	Potential Pathway	Sensitive Receptors	Confirmation of S-P-R	Impact IDs
Hydrocarbon pollution (oils and greases) of surface water due to runoff from car parking area impacts on surface water ecosystem (Inverbrackie Creek)	Operation, Closure	Oils and greases in car park	Surface water flows	Surface water ecosystem (Inverbrackie Creek)	Yes	PIE_11_13
Unintentional discharge of untreated water from underground (pipe leak) impacts on surface water ecosystem (Inverbrackie Creek)	Construction, Operation, Closure	Groundwater contaminants	Pipe leak	Surface water ecosystem (Inverbrackie Creek)	No	PIE_11_14
High impact rainfall event on mine site facilities has the potential to overwhelm the stormwater site design (WSUD) and release highly turbid water impacting on surface water ecosystem (Inverbrackie Creek)	Construction, Operation, Closure	High impact rainfall event	Overflow of WSUD features	Surface water ecosystem (Inverbrackie Creek)	Uncertain	PIE_11_15
Sedimentation of surface water from construction works results in reduction in water quality impacting surface water ecosystem (Inverbrackie Creek)	Construction	Overland flow erosion of exposed surfaces	Surface water flows	Surface water ecosystem (Inverbrackie Creek)	Yes	PIE_11_16
Irrigation or dust suppression on IML or other earthworks has the potential to mobilise salt and impact on surface riparian zones	Construction, Operation	Irrigation or dust suppression	Surface water salt mobilisation	Riparian zones	Uncertain	PIE_11_17
Changes to groundwater levels has the potential to alter the hydrological / hydrogeological regime of springs (Inverbrackie Creek baseflow) and impact on surface water ecosystem (Inverbrackie Creek)	Operation, Closure, Post-closure	Changes to groundwater level due to mine water management	Inverbrackie Creek springs (baseflow)	Surface water ecosystem (Inverbrackie Creek)	Yes	PIE_11_18
Sedimentation or contamination of surface water results in reduction in water quality impacting listed fauna in Inverbrackie Creek	Construction, Operation, Closure, Post-closure	Overland flow erosion of exposed surfaces	Surface water flows	Fauna (listed species) within Inverbrackie Creek	No	PIE_11_19

Potentially Impacting Events	Mine Life Phase	Source	Potential Pathway	Sensitive Receptors	Confirmation of S-P-R	Impact IDs
Sedimentation of surface water via erosion of bunds results in reduction in water quality impacting surface water ecosystem (Inverbrackie Creek)	Operation, Closure, Post-closure	Overland flow erosion of bunds	Surface water flows	Surface water ecosystem (Inverbrackie Creek)	Uncertain	PIE_11_20
Exploration works result in remobilisation of potential contaminants in the drainage line within the ML (south of Bird in Hand Road)	Exploration	Overland flow	Surface water flows	Surface water ecosystem (Inverbrackie Creek)	No	PIE_11_21
Heavy rain event causes sedimentation of surface water from exploration works resulting in reduction in water quality impacting surface water ecosystem (Inverbrackie Creek)	Exploration	Overland flow erosion of exposed surfaces	Surface water flows	Surface water ecosystem (Inverbrackie Creek)	Yes	PIE_11_22

11.6 CONTROL MEASURES TO PROTECT ENVIRONMENT

11.6.1 Design Measures

Design measures are integral in preventing water erosion, acidification and sedimentation of surface waters.

A very distinct zone of potentially acid forming material (PAF) has been identified in the supergene zone.). As a result there is a small amount of mullock that is expected to contain PAF material (the estimate is ~200-300t from the ventilation shaft). The PAF material identified is hosted within limestone/marble (carbonates) and other material that are classified as acid consuming (ACM) which has the effect of neutralising any potential acid formation resulting in an overall non-acid forming environment.

To minimise the likelihood of intersecting the identified PAF zone, the decline has been designed to pass below the supergene zone. In order to ensure that any unexpectedly encountered PAF material is managed, additional capacity has been allowed for PAF storage on the Integrated Mullock Landform (IML). All PAF material will be placed upon clay lining, and will be prioritised for storage underground and incorporated into the cemented backfill process as soon as possible.

An acid and metalliferous drainage (AMD) assessment was undertaken by Tonkin (2017) by examining the geochemical characteristics of 58 representative samples of selected country rock drill-core that represent the proposed mine geology (Appendix M2) and is discussed further in Chapter 13.

The Goldwyn site is divided up into specific catchments, with specific areas which have run off directed to the water treatment plant via a network of sumps and pumps. Areas which report to the water treatment plan include run off from the IML, workshop and cement batching plant. This manages the risk of runoff from the identified potential PAF mullock and/or hydrocarbons and/or cement from the workshop and cement batching plant entering into the surface water drainage and ultimately Inverbrackie Creek.

The IML has been designed to be encapsulated within landscape amenity bunding (retaining walls on the inside), and a drainage system which reports to the mine water storage dam via a silt and hydrocarbon trap, prior to undergoing water treatment through the sites water treatment facility. This ensures all sedimentation from the IML is captured within the water treatment system, preventing it from entering stormwater runoff and into the riparian areas. This is outlined in the Stormwater Management Plan in Appendix I3. Water quality of water discharged into the mine water storage dam is tested to ensure it meets water quality targets prior to being used for other purposes on site (i.e. dust suppression). If a water sample failed to meet its water quality target it would be re-processed through the water treatment system and re-tested when discharged into the mine water storage dam. For more information relating to the water treatment system please refer to Chapter 3 (Section 3.7.9.5).

Additionally, the shape of the IML has been configured with broad radius curves (50m) to minimise the impact of erosion caused by water runoff. This manages the risk of runoff from identified PAF mullock and/or hydrocarbons from the workshop entering into the surface water drainage and Inverbrackie Creek, as can be seen in Figure 11-25.

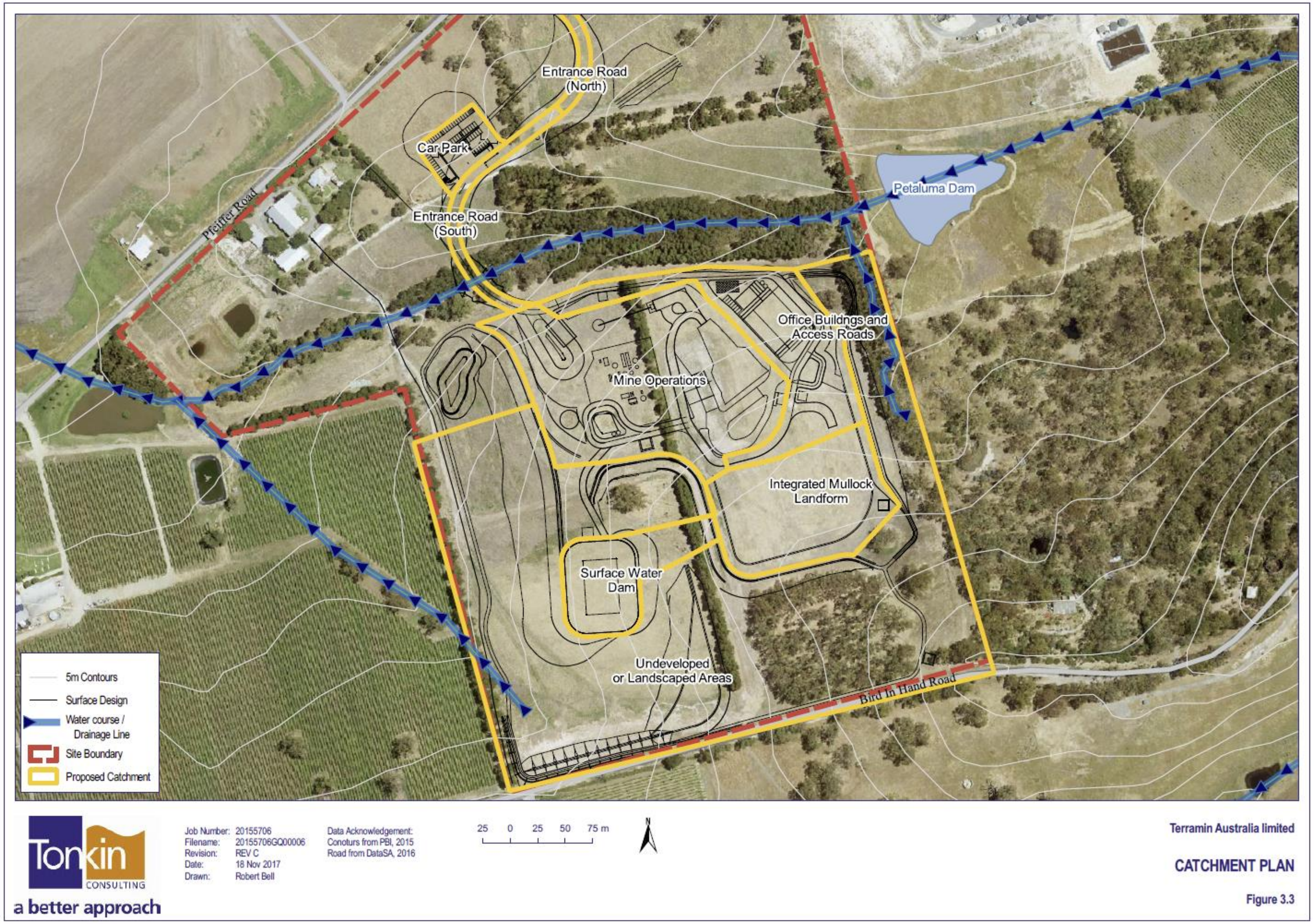


FIGURE 11-25 | STORMWATER SITE DESIGN – SITE CATCHMENTS

Collection sumps and gross pollutant traps have been integrated into the stormwater management site design to reduce the risk of hydrocarbons and sedimentation exiting site, as well as the construction of a surface water retention dam (detention basin) to allow sediments to drop out naturally before entering the surface drainage system which reports to Inverbrackie Creek.

Swales utilising water sensitive urban design principles will be installed with endemic vegetation along drainage lines which traverse the Goldwyn property to aid the reduction of sedimentation from overland runoff from both the "clean" operational area, the drainage line along the eastern boundary of Goldwyn and the drainage line located along the south-western boundary of Goldwyn.

The Stormwater site design (Appendix I3), completed by Tonkin Consulting, includes a detention/retention basin, which receives run off from the site as outlined in Figure 11-27 . Based on the output of the DRAINS model of the site, the detention component of the basin will require a volume of 300m3 to limit peak runoff flow rates to pre-development levels. The 100-yr ARI predevelopment runoff from the 6.3 hectares of the mine site is estimated to be 0.39m3/s based on the Rational Method with a 0.28 runoff coefficient and a 25-minute time of concentration. The post development catchment has been modelled based on the parameters contained within Table 3.1. Contribution from pervious (undeveloped/landscaped) areas has been based on an initial loss of 30mm and a continuing loss of 3mm/hour.

The retention portion of the pond has been designed to mimic the seasonal pre-development flow regime by retaining the additional volumes that are generated from the developed portions of the site and to provide additional water quality improvement. Initial assessment suggests a volume of approximately 1000m^3 is required with an additional allowance for sedimentation accumulation.

A high flow spillway is also incorporated to allow the basin to safely discharge into the main creek that passes through the site during larger, extreme rainfall events. For more information on the detention/retention basin please refer to Chapter 3 (Section 3.7.8.6.4).

Access to the site will require crossing the creek. To ensure uninterrupted access to the site the culvert has been sized for the predicted 100-yr ARI flow of 2.5m3/s (this ARI relates to a 71 m/hour event over 30 minutes with a runoff coefficient of 0.28). This will require a minimum 1.5m wide by 0.75m high box culvert, based on inlet control conditions. The final design maybe larger than this to accommodate final construction design requirements of the access road. A water affecting activity permit will be required for the construction of the creek crossing.

DESIGN MEASURES INCLUDING COLLECTION SUMPS, SWALES, PRIMARY AND SECONDARY GROSS POLLUTANT TRAPS, THE CREEK CROSSING AND THE SURFACE WATER RETENTION DAM HAVE BEEN SHOWN IN FIGURE 11-27.SWALES

Swales are designed drainage lines that are placed to intercept surface water flows and control water velocity (Figure 11-26). Swales constructed using Water Sensitive Urban Design principles will enhance the settling characteristic of the flow channels through the use of surface treatments (rock lining) and beneficial vegetation planting. Swales provide the following benefits:

- Remove course to medium sized sediments by the vegetated surface;
- Improves infiltration into the soils and hence reduces surface run-off;
- Delaying run-off peaks by reducing flow velocities; and
- Reduces sediment from high velocity erosion.

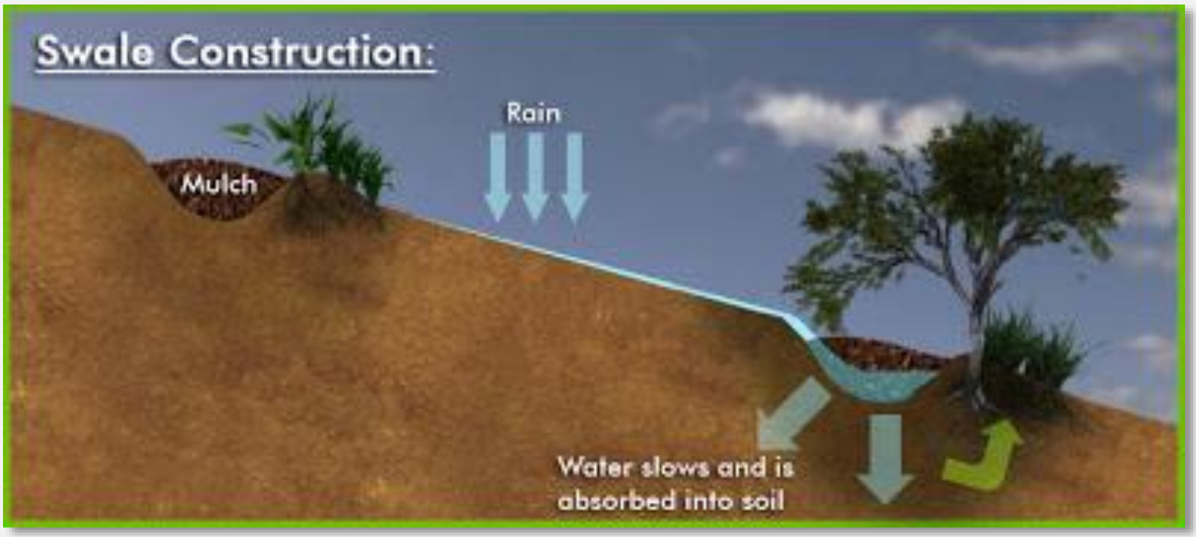


FIGURE 11-26 | EXAMPLE OF TYPICAL SWALE CONSTRUCTION ON A SLOPE FOR STORM WATER MANAGEMENT

The swales will require occasional maintenance to ensure that they are operating effectively. This includes:

- Removal of sediment build up;
- Repairing localised areas of erosion, scour of damage;
- Removal or management of invasive weeds; and
- Mowing or slashing of vegetation.

When mowing occurs in the swales, cut grass will be removed from the swale to prevent flows transporting the material to the creek during a rain event.

FIGURE 11-27 | STORMWATER SITE DESIGN – SURFACE WATER DESIGN MEASURES

Primary design methods incorporated into the landscape design include testing soil characteristics and utilising erosion modelling during the design process of the landscape amenity bunds to determine appropriate slope characteristics, as well as cover management strategies. Design options include reducing slope angles, hyperbolic bund slopes and contour lines on bund slopes.

All disturbed areas which are not to be sealed for roads or hardstand areas will be sprayed as soon as is practical with hydro-mulching to stabilise the soil surface to reduce potential for wind and water erosion until vegetation germinates. Native grass varieties will be used in the hydro-mulching as they carry a lower risk of bushfire and are ideal for the climatic and soil conditions, however, a sterile annual grass will be used in the first year to increase soil stability in the short term.

The landscape amenity bunds will then be planted with tubestock vegetation which is endemic to the region.

Between the hydro-mulching and seeding of native grasses and tubestock planting, Terramin expect a self-sustaining system to establish which stabilises the soil and prevents surface water sedimentation from occurring from the landscape amenity bunds.

<u>Hydro-mulching</u>

Hydro-mulching is a one-step process that uses water as a carrier to spray seed, fertiliser, tracking dye onto the seedbed, but has the benefits of Australian-tested cellulosic Growth Medium mulches and a binder added to the slurry. Hydro-mulching provides a temporary layer of erosion control from wind and water until vegetation germinates and is perfect for batter stabilisation. It is important to note that hydro-mulching is not hydro-seeding; hydro-seeding is simply a method of applying seed and does not provide extra protection against erosion.

Slopes of the landscape amenity bunds located on the inside of the operational area are designed to be of a steeper gradient, to allow maximum use of the available area and reduce the overall footprint of the site. As a result, they carry a higher likelihood of water erosion. A synthetic erosion control blanket that has a flexible membrane that works to protect the soil surface from erosion and can be altered to support the growth of vegetation or prevent it through the use of a hydrophobic polymer will be used to prevent erosion in these cases.

All chemical and hydrocarbon storage will be in accordance with:

- AS 1940-2004: The storage and handling of flammable and combustible liquids;
- AS 1692-2006: Steel tanks for flammable and combustible liquids;
- Relevant South Australian legislation;
- Best practice guidelines.

The wheelwash and washdown area will bunded, with wash-water recycled within the washdown area.

Parts of Goldwyn not utilised for the project will allow rainfall to flow to the natural low points through existing drainage and low points where it will be allowed to evaporate/infiltrate as it has historically.

Overall, the objective of the design of the surface water management design is to prevent contamination from known sources and minimise sedimentation from within Goldwyn. Design measures are outlined in Table 11-3

11.6.1.1 DESIGN MEASURES FOR MAR PIPELINES

The proposed managed aquifer recharge system (MAR) will require a network of 50mm-110mm diameter pipelines to carry water from the water treatment plant to the MAR bores, as well as from the extraction/depressurisation bores to the reinjection bores for the water that will not require treatment. Where possible, the pipelines will follow fence lines and will be located within easements on properties within the lease. There will be a need to pass the pipelines under the Bird in Hand Road – directional drilling is proposed for this to occur to prevent damage and excavation of the existing road surface.

Any pipe burst will be able to be identified immediately, as the MAR bores are designed to have flow meters and alarms installed, which would trigger an alarm and action to be taken.

Proposed pipeline locations are shown in Figure 11-28.

FIGURE 11-28 | PROPOSED MAR AND DEPRESSURISATION BORE LOCATIONS AND ASSOCIATED PIPELINES

11.6.1.2 EXPLORATION WORKS

All exploration works are subject to the exploration management plan, outlined in Appendix B7. This includes waste and drill cutting management, erosion control, topsoil management, earthworks and sump requirements, and the requirements which prevent surface drainage lines. All sites and new access tracks must have sediment traps installed down slope to eliminate the risk of sediment travel in heavy rainfall events. These control measures have been used through all approved drilling programs through 2014, 2016 and 2018.

Importantly, the soil management plan, including the unexpected finds protocol prepared by Golder Associates (appendix L4), will apply for all exploration works. Although there is currently no soil test results indicating contamination sources, the soil management zone has been expanded to include all historic workings located on the southern side of Bird in Hand Road – shown in Figure 11-29. Terramin do not expect to access the dam area for exploration.

FIGURE 11-29 | EXPLORATION SUBJECT TO SOIL MANAGEMENT ZONE SOUTH OF BIRD IN HAND ROAD

TABLE 11-3 | DESIGN MEASURES

Design Measures	Impact ID
Landscape amenity bund slope design and cover management informed by erosion modelling	PIE_11_16 PIE_11_19 PIE_11_20
Drainage system designed around wheelwash and washdown area	PIE_11
Chemical and hydrocarbon storage in accordance with Australian standards and applicable legislation and best practice methods	PIE_11_13 PIE_11_08 PIE_11_09
Bunding around storage areas of chemicals and hydrocarbons (AS standards)	PIE_11_13
Hydro-mulching of exposed soils as soon as practical	PIE_11_07 PIE_11_16 PIE_11_19 PIE_11_20
Retaining walls utilised where required on steeper slopes	PIE_11_13
Contour lines to be included during construction on the sides of bunds	PIE_11_13
Synthetic erosion control blanket on steeper landscape amenity bunding where required	PIE_11_13
Sealing of internal access roads for external vehicles (excluding fire access roads and road between underground and IML)	PIE_11_13
If any PAF material encountered, directed to designated storage within IML structure (PAF management plan)	PIE_11_05
Runoff from IML directed to sump and pumped to water treatment plant (surface water management plan)	PIE_11_05 PIE_11_10 PIE_11_17
Runoff from workshop areas directed to sump and pumped to water treatment plant (surface water management plan)	PIE_11_13
Primary and secondary Gross Pollutant Traps (GPT) within stormwater management design	PIE_11_13
Water Sensitive Urban Design (WSUD) swales incorporated near existing drainage lines to further reduce potential for sedimentation leaving site	PIE_11_15
Stormwater dam to allow analytes to be removed before entering the surface drainage system	PIE_11_15
Stormwater dam overflow to be directed to WSUD swale system	PIE_11_15
Mine water storage dam to be designed to accepted AS standards	PIE_11_01 PIE_11_02 PIE_11_03 PIE_11_04
Sewerage system to be designed to AS standards	PIE_11_19
Covered/shedded areas to capture rainfall and overflow to be direct WSUD swale areas	PIE_11_06
MAR pipework to be pressure tested and valved, to allow system maintenance and repair	PIE_11_14
MAR bore pipework flow can be reversed through system maintenance	PIE_11_14

11.6.2 MANAGEMENT STRATEGIES AND COMMITMENTS

In order to minimise and mitigate impacts to surface water during construction, operation, and closure activities, control and management strategies will be incorporated into the PEPR and implemented for relevant project phases. Key control and management strategies are outlined below in Table 11-4.

11.6.2.1 EROSIONAL POTENTIAL (REPLICATED FROM CHAPTER 12: LAND AND SOIL QUALITY)

Water erosion potential of the topsoil through the proposed ML has been classified by DEW as moderately high, with the majority of the proposed operational area classified as Moderate. The entirety of the proposed ML is classified as a low potential for wind erosion.

More recent erosional testwork undertaken of soils within the proposed operational area (Locations shown in Chapter 12: Land and Soil Quality and Appendix L5) demonstrate that erosion of the proposed operational area can be maintained at the accepted background rates of less than 5 tonnes per hectare, both during operations and post closure.

The management and control strategies proposed demonstrate that long term erosion control is achievable.

Utilising the Universal Soil Loss Equation has demonstrated that erosion control and management strategies are required. This is due to the soil types, the various slope lengths and angles of the proposed landscape amenity bunds within the operational area. Different strategies were tested, but the erosion assessment report recommends that all the proposed landscape amenity bunds initially be treated by Hydromulching in conjunction with planting and seeding dense shrub and native grass cover. For the Southern Bund Extension, Hillside Screening Bund and for Central Bunds 2 and 4, the cover from dense shrub and native grasses is sufficient erosion control, but for the remainder of the landscape amenity bunds, there is a need for additional mulch placement for the life of the mine. Further control actions, will be required through retaining walls and contour intervals along the slope lengths. For Central Bunds two and four, there is proposed retaining walls on both sides of the slopes preventing potential erosion. Furthermore, for all the landscape amenity bunds, excluding the Northern Topsoil Bund, the Car Park and Central Bund one, there is a need for contour intervals at approximately every 3m with a slope of 2-5° to be added along the slope lengths. These management and control strategies have resulted in less than the 5 ton/hectare/year natural erosional potential for the BIH location for each of the proposed landscape amenity bunds.

Finally, the erosion assessment report has recommended a number of management and control strategies to allow the proposed landscape amenity bunds to achieve sustainable natural erosional levels post closure of the mine. For the Northern Topsoil Bund, the Southern Bund Extension and the Hillside Screening bund, the proposed management strategies are sufficient to remain as native vegetation cover. For the Eastern Screening Bund, the bund should be cut down to a height of 1.5 metre, with interval contours and to be covered in dense shrub vegetation. The remainder of the landscape amenity bunds are proposed to remain under the post mining land uses. As part of the management strategy, it is proposed that a soil erosion Trigger Action Response plan (TARP) be in place and that after the proposed landscape amenity bunds have been constructed, erosion monitoring and regularly review be undertaken. It is envisaged a topsoil management plan will be developed and submitted with the PEPR to ensure the integrity of stockpiled topsoils for use during rehabilitation, as well as the development of both erosion and air quality (dust) management plans.

The Erosion Assessment for the BIHGP is located in Appendix L5.

TABLE 11-4 | MANAGEMENT STRATEGIES

Management Strategies	Impact ID
Dust from internal unsealed roads (fire access tracks) will be suppressed using either dust suppressing products or water trucks.	
Dust Management Plan to manage impacts to surface water quality	
PAF Management Plan to be implemented which outlines storage requirements for identified PAF material from mining operations and includes no PAF material to be left on surface at close of operations.	PIE_11_05 PIE_11_11
Identified PAF material documented and prioritised for backfill	PIE_11_05 PIE_11_11
Surface Water Monitoring Plan to be developed with reference to baseline surface water quality data, the EPA Water Quality Policy 2015 (SA) and ANZECC water quality guidelines (as referred to in the EPA Water Quality Policy 2015 (SA)).	PIE_11
For appropriate storage and handling of hydrocarbons and chemicals, the following measures will be implemented: • Develop and implement chemical and fuel storage, handling and emergency response procedures in accordance with AS 1940-2004. • Develop and implement a regular inspection programme to audit and monitor fuel and chemical storage areas to ensure integrity, housekeeping and correct use. • Maintain appropriate spill kit/clean up material, as required by the developed procedures.	PIE_11_08 PIE_11_09 PIE_11_13
Construction activities will incorporate sediment and erosion management practices outlined in an Erosion and Sediment Control Plan, which align with standard industry practice to manage sediment from construction sites, such as WSUD swales, contour lines, hay baling, temporary sediment traps, dust generation management and bunding of stockpiles.	PIE_11_16
The IML will be covered using hydro-mulching or a biodegradable binding product to manage water and wind erosion.	PIE_11_07 PIE_11_10 PIE_11_17
Water Storage Dam Management Plan which includes monitoring of water storage dam embankments through survey prisms and water level trigger levels	PIE_11_01 PIE_11_02 PIE_11_03 PIE_11_04
Routine maintenance and inspection of pipework and associated infrastructure on surface to reduce likelihood of blockage and leaks	PIE_11_14
Maintain site water balance to demonstrate no unauthorised discharge of water from mining operations	PIE_11_18 PIE_11_14
Erosion Trigger, Action and Response Plan (TARP) to be developed	PIE_11_20
Topsoil Management Plan	PIE_11_20

11.7 IMPACT ASSESSMENT

This section identifies and assesses the impact and risk associated with the existing surface water values (receptors) as a result of construction, operation, and closure of the proposed mine.

Through the adoption of design modification or specific mitigation measures, all identified impacts and risks were categorised as low (or negligible) and considered ALARP. The key environmental risks would be monitored through the environmental management framework.

11.7.1.1 SEDIMENTATION/TURBIDITY

Water erosion provides the highest risk rating of potential impacts to surface water quality, specifically though construction.

Through the use of temporary strategies, including erosion management practices which align with standard industry practice to manage sediment from construction sites, such as hay baling, temporary sediment traps, dust generation management and bunding of stockpiles, as well as the design of the landscape amenity bunding and the use of contour banks, hydro-mulching, and synthetic erosion control blankets, the risks associated with sedimentation have been reduced to as low as reasonably practical. Still, the erosion management system relies upon successful implementation and checking of human controlled system. For this reason, a credible worst case scenario which results in increased sedimentation in the surface water exiting Goldwyn is **possible** through construction, however, due to the pre-existing understanding of Inverbrackie Creek and turbidity levels it frequently experiences pre-mining, the impact of such an event is considered **minor**, as the ecological value of the Creek is considered poor, and the impact would be a relatively short timeframe (that is, over hours), the overall impact is considered **low**. Once the site is constructed, control measures installed and vegetation established, no impact is expected.

Landscape amenity bunds will all have contour banking and hydro-mulching applied which will reduce potential for wind and water erosion until vegetation germinates, further stabilising the soil. The landscape amenity bunds will then be planted with native vegetation tubestock containing species which are endemic to the region. Between the surface treatments, spraying of grasses and tubestock planting, Terramin expect a self-sustaining system to establish which stabilises the soil and prevents surface water sedimentation from occurring from the landscape amenity bunds.

Surface drainage (overland flow paths and swales) will be protected by erosion control measures, where required (to be determined by assessing soil particle size distribution, slope and other variable parameters). Erosion control measures typically consist of providing a surface treatment to slow water velocity, or resist scouring velocities and structures within the channel to reduce flow velocities.

Given the relatively high rainfall in the area, site vegetation cover within the drainage channels will establish naturally once planted with sedges. However, other treatment measures will be required to minimise channel flow velocities, where high flows are experienced. In these areas rock rip rap utilising local materials won from the site during the construction phase will be installed at critical locations within the channels.

Rock rip rap will be placed:

- at pipe outlet points,
- at the culvert road crossing of the existing creek,
- at the upstream end of the surface water retention dam (detention basin), and
- within swales where flow velocities are estimated to be greater than 2 m/s.

11.7.1.1.1 EXPLORATION WORKS

All exploration works will be managed as per the exploration management plan, which includes erosion and sedimentation control measures, including silt fencing around earthworks. Additionally, all exploration works south of Bird in Hand road in the outline zone (discussed in chapter 3) will be subject to the soil contamination management plan prepared by Golder Associates (Appendix L4). For this reason, sedimentation of surface water or remobilisation of contaminants from historic activities from exploration sites is expected to be of **low** impact to the Inverbrackie Creek (surface water ecosystem).

11.7.1.2 MOBILISATION OF CONTAMINANTS

The site has been designed with specific catchment areas and contaminant traps (gross pollutant traps (GPT)) for solids and oil and sediment separation devices (Table 11-5), which report to either the surface water retention dam (detention basin) or the water storage dam and water treatment plant. Any contaminated surface water would be restricted within the boundary of the mine site. Water quality testing from the water treatment plant prior to water leaving site and a comprehensive monitoring plan further reduces the likelihood of this occurring.

More information on the water treatment plant is included in chapter 3, section 3.7.9.5.

TABLE 11-5 | CONTAMINANT CATCHMENT AREAS

Catchment name	Area (ha)	Impervious area (%)
Integrated Mullock Landform (IML)	1.4	70
Mine Operations	3.6	25
Office and access roads	1.3	60

The 100-yr ARI flood extents for the main creek that passes through the site have been determined through the creation of a HEC-RAS model. The flood extents are contained within the well-defined valley that the creek passes through. The width of the flood plain typically ranges between 10 and 15m wide. All development, other than the access road which crosses the creek, has been kept at least 40-50m away from the flood extents.

Chemicals and hydrocarbons will be kept within designated storage areas bunded to prevent the accidental mobilisation of contaminants affecting soil and surface water quality. Final design of the bunding of the hazardous materials storage area(s) will be designed to retain or redirect away from the area, surface water flows during a 1 in 100 year flood event. A storm event exceeding the capacity of the storage area could result in the contamination of surface water flows by contaminants, subsequently affecting soil and surface water quality.

A flood event exceeding the capacity of the storage area is considered **unlikely** (i.e. during the 8 year project lifespan) during construction and operation of the proposed mine, and as the storage area reports to contained water storage dams or the treatment plant located onsite, the consequence of the flood event can be contained and therefore is considered **minor**. As such, the overall risk of contamination of surface water is considered to be **low**.

Acid and metalliferous drainage and neutral and metalliferous drainage potential from mullock has been assessed and Potential Acid Forming (PAF), Non-acid Forming (NAF), NAF-Acid Consuming Material (ACM) or Uncertain (UC), and were used to identify an AMD field within the current geological block model. Resultantly, the underground mine plan and decline has been moved to avoid this area and reduce the potential volume of PAF material. Stormwater Management Plan considers location and potential contaminants from mined materials into treatment design. Any AMD/NMD material to be placed within inside of the IML and drainage directed to sump and then pumped to water treatment plant. No AMD/NMD material will be left on surface at close of underground operations.

If the credible worst case impact event of AMD/NMD contaminating surface water was to occur, due to the containments built into the site design, the impact is considered **moderate**, however, **unlikely** to occur, giving it an overall risk of **medium**.

A site contamination audit during the closure phase will be undertaken to reduce any chance of impacts to surface water post-closure, eliminating, as far as is possible, the risk of post closure impacts to both surface water and soil.

11.7.1.2.1 FORMER RIDGE TAILINGS DAM

There is a concern that metalliferous drainage may exist from former tails and mine waste areas from the historic Ridge Mine. This includes a private landholder stock dam located directly downstream from the historic ridge chimney and downstream from Terramin exploration sites - location shown in Figure 11-30 and Figure 11-31.

Water quality obtained from the dam from 2014-2016 indicates no traces of mercury, cyanide, and within average ranges of metals as all other dams and surface water in the region – as seen in Table 11-6. The dam was cleaned out during 2015 by the landholder and waste soil located to the south of the dam. The dam is currently used for stock. Stock access the dam and there are a number of shallow depressions within the floor of the dam, presumably from stock pugging whilst seeking water. Stock access has resulted in a low pH during 2018 due to low water levels and animal waste. The dam is located in the creekline and fills each year, overflows generally each winter and is equipped with a flow diversion for when the dam is full. This diversion flows each year and has been observed operating the last 4 years and presumably has done so since the property was used for agricultural uses. There is no additional credible risk to the surface water sources from Terramin's activities.

FIGURE 11-30 | RIDGES MINE'S TAILINGS DAM AND CHIMNEY. FACING SOUTH.

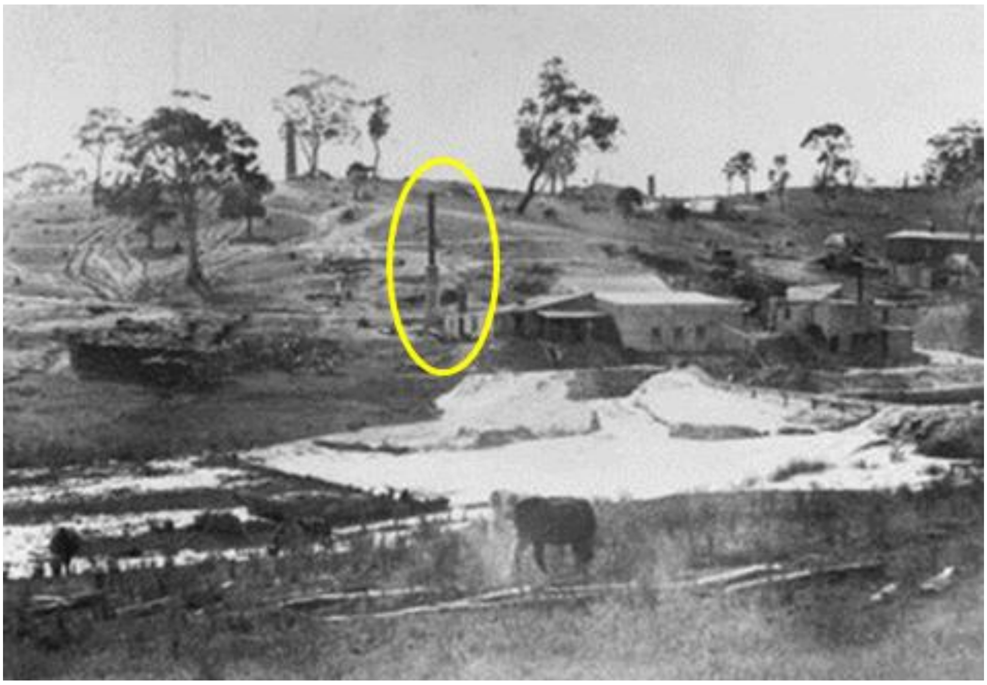


FIGURE 11-31 | VIEW OF CHIMNEY AND TAILINGS DAM FROM OTHER SIDE OF THE VALLEY, C1887

TABLE 11-6 | RESULTS OBTAINED FROM FORMER RIDGE DAM AND REGIONAL STATISTICS TO DATE (2018)

Date Sampled	pH	EC uS/cm	TDS mg/L	As Tot mg/L	Cd Tot mg/L	Cu Tot mg/L	Fe Tot mg/L	Mn Tot mg/L	Pb Tot mg/L	Zn Tot mg/L	Hg Diss mg/L	Hg Tot mg/L	Cn Tot mg/L
24-Mar-14	7.04	167	89	0.01	<0.0001	0.009	7.1	0.236	0.053	0.006	<0.0001	<0.0001	<0.004
30-Jun-14	7	156	291	0.004	0.0001	0.016	8.53	0.059	0.049	0.016	<0.0001	0.0002	<0.004
14-Jul-14				<0.001	<0.0001	0.007	1.36	0.021	0.005	0.015	<0.0001	<0.0001	
26-Nov-14	9.34	272	421	0.017	0.0003	0.021	13.2	0.276	0.093	0.05			
07-Sep-16	7.19	160	154	0.003	0.0001	0.006	1.91	0.043	0.011	0.005			
26-Apr-18	3.07	1310	769	0.033		0.027	18.4	0.805	0.153	0.041	<0.0001	<0.0001	
Regional surface water ranges (excl. former Ridge dam)	5.5-9.8	62-3930	99-3280	0.001-0.89	0.0001-0.0066	0.001-0.17	0.07-649	0.003-59.9	0.001-0.898	0.005-0.509	<0.0001	0.0012	<0.004
Sample count regionally (excl. former Ridge dam)	358	366	353	277	258	297	285	285	297	297	70	53	12

11.7.2 Disturbance to Existing Flow Regimes

The retention portion of the pond has been designed to mimic the seasonal pre-development flow regime by retaining the additional volumes that are generated from the developed portions of the site and to provide additional water quality improvement. A high flow spillway is also incorporated to allow the basin to safely discharge into the main creek that passes through the site during larger, extreme rainfall events.

11.8 DRAFT OUTCOME(S) AND MEASUREMENT CRITERIA

In accordance with the methodology presented in Chapter 6, draft outcomes have been developed for surface water impact events with a confirmed link between a source, pathway and receptor (S-P-R linkage), see Table 11-7.

All outcomes are supported by draft measurement criteria which will be used to assess compliance against the draft outcomes during the relevant phases (construction, operation and closure), and where relevant draft leading indicator criteria. These measurement criteria and leading indicators are indicative only and will be developed further through the PEPR.

No existing users of Inverbrackie Creek have been identified as reliant upon the flow volumes.

Outcomes for the entire project are presented in Appendix D1.

Table 11-7 | Draft Outcomes and Measurement Criteria

Draft Outcome	Draft Measurement Criteria	Draft Leading Indicator Criteria
No adverse impact to the quantity or quality of water caused by the mining activities to existing and future licenced users and water dependant ecosystems	During rainfall events which generate runoff, three samples will be taken to measure turbidity at the car park, south-western drainage line, central drainage line and at the overflow point of the surface water retention dam as per sampling method AS/NZS 5667.1:1998 standards. A paired t-test will demonstrate that turbidity at the car park, south-western drainage line and at the overflow point of the surface water retention dam is not significantly greater (p-value ≤ t-test value) from the mean of the samples taken at Inverbrackie Creek upstream of the ML at that point in time.	Monitoring will demonstrate turbidity is less than or equal to upstream monitoring sites of the Petaluma boundary and/or the Bird in Hand road boundary drain. After high rainfall events which generate runoff, records of visual inspections of silt traps, the surface water retention dam, and surface drainage systems demonstrates that silt volumes are no more than 50% of trap capacity and there is no breach in walls.
	Triplicate surface water samples will be undertaken monthly (when flowing) at Inverbrackie Creek Downstream and Upstream sampling locations as per AS/NZS 5667.1:1998 for pH, EC, TDS, turbidity, SO42-, sulphur, calcium, poly aromatic hydrocarbons/total petroleum hydrocarbons, benzene, toluene,	Live monitoring to be installed at Inverbrackie Creek downstream and upstream and

Draft Outcome	Draft Measurement Criteria	Draft Leading Indicator Criteria
	ethylbenzene and xylene compounds and lead[1]. A paired t-test will demonstrate that water quality downstream is not significantly greater as a result of mining activities (p-value ≤ t-test value) from the mean of the samples taken at Inverbrackie Creek upstream of the ML at that point in time.	significant elevations[2] in downstream Electrical Conductivity will be investigated to determine whether water has emanated from Goldwyn. If yes, sampling will be undertaken as per OMC undertaken as per OMC.
	All chemical and hydrocarbon spills are remediated to meet EPA standards within 48 hours of the spill, or a longer time agreed by the Director of Mines.	None proposed
No adverse impact to the quantity or quality of water caused by the mining activities to existing and future licenced users and water dependant ecosystems	Annual assessment until Lease surrender, or at a frequency as recommended by a suitably qualified and experienced independent party, of rehabilitation success and landscape function measured using standardised LFA monitoring techniques at proposed monitoring sites as agreed between the Director of Mines and the Tenement Holder demonstrates the self-sustainability (success) of rehabilitated areas, when compared to baseline monitoring	Evidence of establishment of native plant species on designated rehabilitation areas 12 months after progressive rehabilitation
No adverse impact to the quantity or quality of water caused by the mining activities to existing and future licenced users and water dependant ecosystems	Construct to Design Audit of water storage dam completed by a suitably qualified and experienced independent party within 3 months of completion of surface construction demonstrates water storage dam was constructed to design specifications.	None proposed
	Quarterly prism surveying in dam walls shows no differential movement in survey prisms demonstrating geotechnical stability of dam embankments	None proposed

[1] Sulphur, calcium and lead occur at levels within in the ore and mullock at levels above background water quality, making them effective indicators of AMD/NMD from the operating site.
[2] Trigger values be determined through the PEPR development

Draft Outcome	Draft Measurement Criteria	Draft Leading Indicator Criteria
	Monthly surveying of water level against survey monitoring points demonstrates water level is below designed freeboard levels ("trigger levels")[3].	None proposed

11.9 FINDINGS AND CONCLUSIONS

The key elements of the Stormwater Management Plan for the proposed BIHGP site are:

- The separation of catchments based on their potential for pollutant generation such that clean water does not intermix with areas that have higher pollutant levels;
- That the water quality treatment measures are appropriately matched to the pollution production potential for each area of the site;
- Ensuring all development is kept outside of the 100-yr ARI floodplain extents;
- That detention basins have been incorporated to limit peak flows to pre-development levels; and
- That infiltration systems (swales) and on-site retention have been incorporated into the design to mimic the pre-development flow regime such that the site is essentially water neutral from a stormwater runoff perspective.

Sedimentation will be controlled through construction by the Erosion and Sediment Control Plan, which will align with standard industry practice to manage sediment from construction sites, such as hay baling, temporary sediment traps, contour banking lines, dust generation management and bunding of stockpiles.

Hydrocarbon and chemical contamination will be prevented by complying with Australian standards regarding storage and bunding, and any spills to be reported and remediated in accordance with the NEPM.

In the longer term, sedimentation will be reduced, if not eliminated, by the establishment of self-sustaining vegetated areas on the landscape amenity bunding and dam walls, and monitored for emerging rills and gullies to allow active, adaptive management of the landscape.

11.10 REFERENCES

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