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Kidston Pumped Storage Hydro Project

Impact Assessment Report

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Impact Assessment Report

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Executive Summary

AECOM Australia Pty Ltd (AECOM) has prepared this Impact Assessment Report (IAR) on behalf of Genex Power Limited (Genex) for the purpose of assessing the impacts of water releases from the Kidston Pumped Storage Hydro Project (the Project) in support of an approval application.

The Project

The Project is proposed as a beneficial reuse of the closed Kidston Gold Mine in Kidston, Queensland. The Project has a planned capacity of 250 megawatts (MW) and is proposed to be supported by an associated solar farm, and through a direct connection into the National Electricity Market. The Project effectively acts as natural battery storage, allowing solar energy to be stored and harnessed as baseload power on demand. This innovative use of the old Kidston mine infrastructure for the purpose of developing a regional renewable energy industry makes the Project unique.

The Coordinator-General declared the Project a Coordinated Project under the Queensland *State Development and Public Works Organisation Act 1971* (SDPWO Act) on 28 September 2018 for which an IAR is required. The primary activity for which an approval is being sought under the Coordinated Project process is for the water discharges as a result of excess water following significant rainfall events during operation, and to allow the lowering of water levels to facilitate construction of the Project.

Approvals

Release of mine-affected water is a common practice across Queensland. This activity is typically managed through a range of management and monitoring requirements in line with industry standards prescribed under the *Environmental Protection Act 1994* and regulated by the Department of Environment and Science (DES).

The Project presents a unique situation, in which a new non-resource project is proposed over an existing resource tenure. The Queensland legislative framework currently does not make provision for the land use transition of decommissioned mine sites to hydroelectric renewable energy projects, and as such no existing legislative mechanism allows for the approval and regulation of water releases required for the Project.

Through extensive consultation with government regulators in relation to approval mechanisms and best practice assessment for the Project, an approval pathway has been agreed between Genex and the relevant State government regulators. The following is a high level summary of the approval elements for the Project.

- Coordinated Project, IAR process under the SDPWO Act – to assess the proposed water discharges from the Project.
- Development Permit under *Planning Act 2016*:
    - to assess the change in land use under the Etheridge Shire Council Planning Scheme and clearing of native vegetation managed under *Vegetation Management Act 1994.*
    - to assess the dam design, risks and operation managed under the *Water Supply (Safety and Reliability) Act 2008*.

As highlighted above, the three key elements of the approval process for the Kidston Project, includes:

1. water discharge
2. change in the land use of the Project area
3. design, construction and operation of the dam structure requiring failure impact assessment under the relevant legislation.

Items 2 and 3 above have been obtained and will not form part of the IAR process, as there is a clear delineation and process in the Queensland legislation for assessment of these elements.

Other Project aspects discussed in the IAS, which do not form part of this IAR include land use, native title, cultural heritage, contaminated land, waste management, failure impact assessment, traffic, noise and vibration, air quality and fisheries waterways. A summary of these aspects are included in Appendix N for context.

An Initial Advice Statement (IAS) was submitted to the Coordinator General in September 2018. The Project was subsequently declared a Coordinated Project on 28 September 2018. It was declared that the Project would be assessed by an IAR, pursuant to Section 26(1)(b) of SDPWO Act.

Assessment Approach

The approach adopted for this IAR has been developed in accordance with the requirements of the DES Technical Guideline - Wastewater release to Queensland waters (ESR/2015/1654, Version 2) (herein referred to as "the Guideline"). The Guideline supports a risk-based assessment approach to managing release of waste water to surface water and applies the philosophy of the Australian and New Zealand Environment and Conservation Council (ANZECC) & Agricultural and Resource Management Council of Australia and New Zealand (ARMCANZ) (2000) Water Quality Guidelines and the intent of the Environmental Protection (Water) Policy 2009. The assessment approach in the IAR follows four key steps, as identified within the Guideline and illustrated in Figure E1.

Figure E1 Impact Assessment Approach

Receiving Environment

The main outcomes of the investigation of the baseline receiving environment are summarised as follows.

<u>Surface Water Quality</u>

- Environmental Values (EV) for the Gilbert River basin have not been defined under the EPP Water. In this instance, the EPP Water prescribes the application of all default EVs. EVs have been described for the Copperfield River over a 44km stretch downstream from the former Kidston mine site to the confluence of the Einasleigh River.
- Macroinvertebrate data supports the distinction of a 'Slightly Disturbed' aquatic ecosystem condition under the EPP Water. The management intent for this water type is to gradually improve water quality and to aim to achieve a Highest Ecological Value (HEV) waterway classification, however HEV Water Quality Objectives (WQOs) may not be achievable in the Copperfield River as there are a number of regionally based negative influences on water quality.
- The Queensland Water Quality Guidelines (QWQG) and EPP Water do not specify WQOs for the Gulf Rivers region or the Gilbert Basin. Instead they recommend the use of the ANZECC (2000) guidelines, cautioning that these values may not be appropriate for intermittent and ephemeral inland streams. In cases where more than one WQO is available for a particular parameter, the most stringent value from all EVs is applicable. Where applicable, site-specific trigger values were derived based on the upstream dataset for monitoring location WB. Hardness Modified Trigger Values (HMTVs) were developed for the area in the immediate vicinity of the release point, using the median baseline hardness values at monitoring location W2.
- Some anomalies in the receiving environment water quality datasets were noted and led to the exclusion of samples collected prior to 2012 (providing an adequate dataset size for analysis of 40 to 60 samples). Ongoing monitoring is recommended for parameters with limited dataset sizes.
- The baseline assessment indicated that a number of parameters are elevated above WQOs in the receiving environment. Monitoring site W2 has indicated potential impacts from seepage.

Hydrology

- In the absence of stream gauging, hydrological modelling was used to undertake a flow spells analysis which showed a definite seasonal distribution with a distinct high flow season occurring from December through April.
- Cease to flow conditions (less than 1 ML/d) are present on approximately 55% of all days for any day and reduce to approximately 32% during the wet season (November through April).

Aquatic Ecology

- The macroinvertebrate assessment determined that communities inhabiting the Copperfield River both upstream and within the receiving environment are in good condition. AusRivAS modelling determined that assemblages at some locations were considered to be significantly impacted. However these scores may be typical of the region and PET scores and taxa richness determined sensitive taxa were well represented.

Hydrogeology

- The groundwater flow regime of the Project has been modified by the construction of the tailings dam, interception drains, and by dewatering of the two pits. In their current state, Wises Pit and Eldridge Pit are both understood to function as groundwater 'sinks', as groundwater levels in the surrounds of both pits are higher than the surface water level in the pits.
- One confirmed wetland spring, Middle Spring, lies within the vicinity of the mine area. This spring is located west-northwest of the former mine; although it is not considered to be hydraulically connected to the groundwater regime of the proposed release area, it is recommended that this is further assessed/monitored as part of water modelling refinement and design phase work.

Sediment Quality

- The braided nature of the Copperfield River results in sediment transport that is limited to a few months per year during the wet season when discharge is high enough. Very little fine sediment is stored in the channel bed in the upper to mid catchments.
- Sediment samples have been collected annually between 2009 and 2013. No whole-sediment samples exceeded the SQG, indicating that sediment within the Copperfield River is considered to be unaffected by the historical mining processes. Although the <0.063 mm samples reported a number of SQG exceedances, this fraction is considered less useful for comparison to guideline values.
- For toxicants in the <0.063 mm fractions, exceedances reported around the potential release sites (e.g., W1 and W2) are also reported in the upstream and downstream monitoring sites (e.g., WB and W3, respectively) suggesting that there are no widespread impacts from historical mining activities evident within the Copperfield River and that the concentrations of metals found are a result of the overall catchment drainage. Additional sampling and monitoring is recommended in accordance with the REMP.

Dry Season Survey

- Six semi-permanent waterholes were identified within the floodplain of the Copperfield River through a drone flyover in September 2018. These waterholes were sampled in late September 2018, along with monitoring locations W1 and W3.
- Previous significant rainfall in the catchment occurred in March 2018, therefore the water in the pools is assumed to have been standing for a long duration and were likely subjected to evapo-concentration.
- Total manganese, total iron, total nitrogen and total phosphorus recorded results above their respective WQOs both upstream and downstream of the proposed release point.
- A comparison against the long-term (post 2011) dataset for W1 and W3 did not indicate any clear trends with regards to water quality.

Operational Releases

The operational releases will continue to be required throughout the life of the Project. The development of appropriate discharge limits has been used as a primary mitigation measure to ensure that environmental impacts are appropriately minimised. For operational releases, it is proposed that a maximum of 69% of the assimilative capacity of the receiving environment be utilised (this equates to an effective dilution ratio of 200 parts receiving environment to one part release water). By limiting the use of assimilative capacity to 69%, this allows for preservation of a portion of the capacity for future development. The assumptions behind calculating effective dilution ratios are highly conservative (based on maximum pit water qualities). In reality the actual assimilative capacity usage will be lower than 69% in most cases.

A comprehensive assessment has been undertaken to develop an understanding of the potential impacts of operational releases on the Environmental Values (EVs) of the receiving environment including potential impacts on water quality, hydrology, geomorphology, hydrogeology and ecology of the receiving environment. Key findings are summarised below.

Water Quality Impacts for Operational Releases

An assessment of near-field and far-field water quality modelling and Direct Toxicity Assessment (DTA) results indicates no significant adverse impacts to EVs relevant to the Project area resulting from operational releases. This is evidenced by the following.

- Parameters relevant to the aquatic ecosystem EV are below the Water Quality Objectives (WQO) at all locations, with the exception of total nitrogen and dissolved zinc.
- Proposed releases are subject to initial mixing within the near field and predicted water quality within the mixing zone reaches the HMTV for dissolved zinc (the constituent of most concern), within a maximum (worst-case) distance of 625 m. Other modelled scenarios indicate a much smaller mixing zone of between 50 and 70 m downstream.
- The concentration of total nitrogen is modelled to drop below the WQO by Einasleigh. Nitrogen does not have many toxicological impacts on aquatic organisms; rather it is a nuisance nutrient that promotes algal growth. It is noted however that there is no evidence of algal growth currently and phosphorus concentrations (required to trigger algal growth) in the Copperfield River are low.
- Under a worst case scenario, there may be rare exceedances of the default 95% species protection WQO for dissolved zinc from Charles Creek to Chinaman Creek. Given that these exceedances represent a 'maximum' modelled value, the likelihood of these concentrations being released is very low. In addition, the exceedances are within the likely margin of error of the various methods used in the assessment. For the scenarios assessed, the 90% species protection WQO will not be exceeded at any location in the receiving environment.
- The mass balance assessment indicates that the HMTV will not be exceeded in either of the two semi-permanent pools (Pond 4 and Pond 5) located downstream of the release location; therefore impacts to these pools are therefore anticipated to be negligible.
- During the operations phase, the simulated releases are well in excess (200:1) of the minimum dilution ratio for toxicity-related impacts in the receiving environment (9:1).
- Concentrations of parameters relevant to other EVs (including drinking water, irrigation, farm supply, stock watering, human consumption, industrial use and recreation) are all modelled to be below the specified WQO.

Hydrology Impacts for Operational Releases

Over the operational phase of the Project, median annual release volume is estimated to be 294 ML and the median release event volume of 68ML (refer to Table E1). The median number of release events is estimated to be 4.0 per year and with a median duration of 7.0 days per event.

Table E1 Annual Controlled Release Statistics Operational Phase

Statistic	Annual Volume Releases	Mean Volume Released per Event	Annual Number of Release Days	Annual Number of Release Events[1]	Mean Release Event Duration
	ML	ML	days	1/ 1yr	d
Mean	530	152	33.6	4.2	8.9
P5	10	6	3.0	1.0	2.1
P10	33	14	8.0	1.8	3.0
P20	70	22	12.0	2.0	4.1
P50	294	68	32.0	4.0	7.0
P80	920	207	51.8	6.0	11.9
P90	1,483	359	64.0	7.0	15.0
P95	1,737	537	74.4	8.0	19.5

As a result of the proposed release of water from the Project, some minor changes are expected to the magnitude of flows that are a direct result of the additional water added during releases. The magnitude of the increases is however small and is not expected to be of material impact to the existing flow regime.

Due to the event-based nature of the proposed releases, no changes to key temporal indicators (timing, frequency and duration of flow events) were noted as a result of the proposed releases. Some minor increases to the rates of rise and fall were noted; however, they are not considered to be of sufficient magnitude to result in any adverse impacts.

Confirming that sufficient streamflow continues in the Copperfield River after cessation of any potential releases is required to ensure that potential releases continue to move downstream, are subject to ongoing dilutionary inflows and do not become stranded due to natural streamflow recession. The median duration of each post release flush at the proposed release point is 32 days with a volume of 1,758 ML.

Aquatic Ecology Impacts for Operational Releases

It is suggested that the adoption and application of appropriate release management strategies for operational releases will sufficiently reduce the level of residual risk posed to the downstream aquatic ecology values for the following reasons.

- The proposed controlled releases will only be undertaken during flow events within the receiving environment with a minimum flow trigger stipulated and the cessation of the release occurring prior to natural flows subsiding to allow for an additional flushing effect.
- The proposed release ratio during the operational phase is 200:1, well above that required to achieve 95% species protection determined through DTA.

[1] A release event is the continuous controlled release of water occurring for one or more consecutive days

- Mixing zone modelling has indicated that the use of a diffused discharge outlet structure will facilitate rapid near field mixing at the outlet such that the WQO for the contaminant of most concern (dissolved zinc) will be met within 625m for the range of scenarios and outlet configurations assessed (most modelled scenarios suggest a mixing zone of between 50 and 70 m downstream). There are no known permanent or semi-permanent pools within 625 m downstream of the release location which could provide refuge for aquatic ecology. There are no other known sensitive receptors within this mixing zone.
- All fish species found to be occurring within the Copperfield River display relatively broad tolerances to a wide range of water quality characteristics, however, the macroinvertebrate communities were comprised of families sensitive to environmental change.
- As the releases are to be managed to occur as event-based, no changes to key temporal indicators (timing, frequency and duration of flow events) are expected. While some minor increases to the rates of rise and fall are expected, they are not considered to be of sufficient magnitude to result in any adverse impacts to the aquatic ecology values of the system. Fish passage will not be reduced by the minor increases in flow.
- The potential impacts to the downstream environment from increased erosion and sedimentation during the operation are anticipated to be restricted to the immediate area surrounding and downstream of the release point. Appropriate design and management of the diffuser will sufficiently reduce the level of residual risk posed to the downstream aquatic ecology values.

Hydraulics and Fluvial Geomorphology Impacts for Operational Releases

The base-case hydraulic model confirmed that the release into the channel at a ratio of 200:1 does not have a significant impact on the hydraulic characteristics of the Copperfield River. Minor increases to main channel depth of up to 0.01m were predicted, however this did not alter the overall water surface elevation for the river reach. The velocity for the high flow events did not change, and minor increases of 2% were noted in the medium flow scenario. With shear stress values increasing by only minor values (less than 2%) for the 'with releases' scenario, there is unlikely to be any increase in sediment transport as a result of Project releases.

Hydrogeology Impacts for Operational Releases

During the operational phase of the Project, the predictive groundwater modelling indicates that the Eldridge Pit will continue to act as a groundwater sink, reducing seepage migration risks to the north of the Project (and downstream in the Copperfield River). During operations the water discharged from the Project will contribute a maximum of 0.5% additional flow volume to the Copperfield River and only occur during medium and high flow events. The scale and timing of these discharges is therefore not expected to materially influence the groundwater regime.

Construction Releases

Temporary construction releases are anticipated to be required for a duration of approximately 2.15 years. For temporary construction releases, it is proposed that a maximum of 76.3% of the assimilative capacity of the receiving environment be utilised (this equates to an effective dilution ratio of 200 parts receiving environment to one part release water from the Eldridge Pit). By limiting the use of assimilative capacity to 76.3%, this allows for preservation of a portion of the capacity for future development. The assumptions behind calculating effective dilution ratios are highly conservative (based on the maximum pit water quality for Eldridge Pit). In reality the actual assimilative capacity usage will be lower than 76.3% in most cases.

A comprehensive assessment has been undertaken to develop an understanding of the potential impacts of temporary construction releases on the EVs of the receiving environment including potential impacts on water quality, hydrology, geomorphology, hydrogeology and ecology of the receiving environment. Key findings are summarised below.

<u>Water Quality Impacts for Temporary Construction Releases</u>

An assessment of far-field water quality modelling and DTA results indicates that any impacts occurring as a result of construction releases are temporary and reversible. This is evidenced by the following.

- Construction phase releases will occur over a short, finite period (approximately 2.15 years).
- Parameters relevant to the aquatic ecosystem EV are below the WQO at all locations, with the exception of total nitrogen and dissolved zinc.
- Proposed releases are subject to initial mixing within the near field and predicted water quality within the mixing zone reaches the HMTV for dissolved zinc (the constituent of most concern), within a maximum (worst-case) distance of 625 m. Other modelled scenarios indicate a much smaller mixing zone of between 50 and 70 m downstream.
- The concentration of total nitrogen is modelled to drop below the WQO by Einasleigh. Nitrogen does not have many toxicological impacts on aquatic organisms; rather it is a nuisance nutrient that promotes algal growth. It is noted however that there is no evidence of algal growth currently and phosphorus concentrations (required to trigger algal growth) in the Copperfield River are low.
- Under a worst case scenario, there may be rare exceedances of the default 95% species protection WQO for dissolved zinc from Charles Creek to Chinaman Creek. Given that these exceedances represent a 'maximum' modelled value, the likelihood of these concentrations being released is very low. In addition, the exceedances are within the likely margin of error of the various methods used in the assessment. For the scenarios assessed, the 90% species protection WQO will not be exceeded at any location in the receiving environment.
- The mass balance assessment indicates that the HMTV will not be exceeded in either of the two semi-permanent pools (Pond 4 and Pond 5) located downstream of the release location, therefore impacts to these pools are therefore anticipated to be negligible.
- During the construction phase, the simulated releases are well in excess (200:1) of the minimum dilution ratio for toxicity-related impacts in the receiving environment (9:1).
- Concentrations of parameters relevant to other EVs (including drinking water, irrigation, farm supply, stock watering, human consumption, industrial use and recreation) are all modelled to be below the specified WQO.

<u>Hydrology Impacts for Temporary Construction Releases</u>

Over the construction phase of the Project, median annual release volume is estimated to be 409 ML and the median release event volume of 101ML (refer to Table E2). The median number of release events is estimated to be 4.4 per year and with a median duration of 7.7 days per event. Releases may be made throughout the duration of the construction phase.

Table E2 Annual Controlled Release Statistics Construction Phase

Statistic	Mean Annual Release Volume	Mean Volume Released per Event	Mean Annual Number of Release Days	Mean Annual Number of Release Events[2]	Mean Release Event Duration
	ML	ML	days	1/ 1yr	d
Mean	612	157	38.1	4.5	9.1
P5	74	19	13.0	2.3	3.6
P10	124	25	17.4	2.8	4.1
P20	194	41	23.0	3.2	5.3
P50	409	101	33.1	4.2	7.7
P80	954	248	50.9	5.6	12.5
P90	1,420	332	67.0	6.9	14.9
P95	1,636	550	81.2	7.7	19.4

Construction phase releases are proposed to utilise the same release conditions (including a release trigger of 400 ML/d) as operational phase releases. This is unlikely to materially impact on the existing flow regime in terms of the timing, frequency, duration and magnitude of flows. Releases will coincide with naturally occurring streamflow events in the Copperfield River at the proposed release point and cease as streamflow recesses below the proposed 400 ML/d trigger. The use of the same dilution ratio (200 to 1) during the construction phase as the operational phase dilution ratio will result in a similar contaminant mass loading per release event. Possible stranding of releases in downstream pools and waterholes is, however, considered unlikely due to the significant post release flush volumes following each release event.

Ongoing tributary inflows downstream of the proposed release point provide significant additional flushing such that the median mean flush ratio of 5.6 % at the release point is reduced to 0.9 % by Einasleigh.

Aquatic Ecology Impacts for Temporary Construction Releases

It is suggested that the adoption and application of appropriate release management strategies for temporary construction releases will sufficiently reduce the level of residual risk posed to the downstream aquatic ecology values for the following reasons:

- The proposed controlled releases will only be undertaken during flow events within the receiving environment with a minimum flow trigger stipulated and the cessation of the release occurring prior to natural flows subsiding to allow for an additional flushing effect.
- The proposed release ratio during the operational phase is 200:1, well above that required to achieve 95% species protection determined through DTA.
- Mixing zone modelling has indicated that the use of a diffused discharge outlet structure will facilitate near field mixing at the outlet such that the WQO for the contaminant of most concern (dissolved zinc) will be met within 625m for the range of scenarios and outlet configurations assessed (most modelled scenarios suggest a mixing zone of between 50 and 70 m downstream).

[2] A release event is the occurrence of controlled releases occurring for one or more consecutive days

- All fish species found to be occurring within the Copperfield River display relatively broad tolerances to a wide range of water quality characteristics, however, the macroinvertebrate communities were comprised of families sensitive to environmental change.
- As the releases are to be managed to occur as event-based, no changes to key temporal indicators (timing, frequency and duration of flow events) are expected. While some minor increases to the rates of rise and fall are expected, they are not considered to be of sufficient magnitude to result in any adverse impacts to the aquatic ecology values of the system. Fish passage will not be reduced by the minor increases in flow.
- The potential impacts to the downstream environment from increased erosion and sedimentation during the construction phase are anticipated to be restricted to the immediate area surrounding and downstream of the release point. This is particularly relevant to the first wet season discharges when a temporary outfall structure may be utilised for a short period of time. Stabilisation of banks where discharge is proposed may be necessary to minimise these impacts. This will be further considered during detailed design.

Hydraulics and Fluvial Geomorphology Impacts for Temporary Construction Releases

The base-case hydraulic model confirmed that the release into the channel at a ratio of 200:1 does not have a significant impact on the hydraulic characteristics of the Copperfield River. Minor increases to main channel depth of up to 0.01m were predicted; however this did not alter the overall water surface elevation for the river reach. The velocity for the high flow events did not change, and minor increases of 2% were noted in the medium flow scenario. With shear stress values increasing by only minor values (less than 2%) for the 'with releases' scenario, there is unlikely to be any increase in sediment transport as a result of Project releases.

The discharge release infrastructure design will consider the potential risk of scouring as a result of the construction discharges which may cause localised erosion resulting in increased sedimentation. This may increase the sediment coarse fraction, which may impact the downstream environment by affecting turbidity. In order to ensure that erosion and scouring impacts are not occurring as a result of temporary construction releases, it is proposed that visual inspections of the outlet structure and surrounds are undertaken at appropriate times during the construction of the Project.

Inspections will look for signs of:

- Localised changes to channel bed and stream bank morphology such as undercutting, slumping or rotation,
- localised changes, loss or damage to riparian vegetation;
- Localised downstream sedimentation visible through the development of new lateral depositional features;
- Notable changes to instream water clarity (turbidity) immediately downstream of the release point; and,
- Notable damage to any hydraulic structures.

In the instance that signs of erosion or sedimentation are noted the following would be undertaken:

- Record, report and assess for severity and determine any requirement for mitigation.
- If required, suitable measures including (but not limited to) placement of appropriately dimensioned hard rock material, gabions, etc. could be employed to prevent further worsening.
- Issues not requiring immediate action will be subject to additional monitoring to determine the rate of, or potential for, ongoing propagation and any requirement for future mitigation (noting that the dynamic nature of bed material transport is to some extent, a natural part of fluvial process at the proposed release point).

Hydrogeology Impacts for Temporary Construction Releases

During the construction phase of the Project, the predictive groundwater modelling indicates that the Eldridge Pit will continue to act as a groundwater sink, reducing seepage migration risks to the north of the Project (and downstream in the Copperfield River). During construction, the water discharged from the Project will contribute a maximum of 0.5% additional flow volume to the Copperfield River and only occur during medium and high flow events. The scale and timing of these discharges is therefore not expected to materially influence the groundwater regime.

Project Controls

The proposed controlled release of water from the Project is governed by the availability of a release opportunity in the Copperfield River at the proposed release point; the amount of water released is dependent on the release ratio and discharge capacity. Table E3 summarises the key proposed release criteria that is required.

Table E3 Proposed Project Release Criteria

Aspect	Construction	Operations	Comment
Controlled Release Triggers	400 ML/d	400 ML/d	No releases into receiving environment when flows are equalled or less than 400 ML/d.
Dilution Ratio	200 parts receiving water to 1 part release water	200 to 1	
Release Ratio	0.5%	0.5%	Operational release ratio is based on a 69% utilisation of the available assimilative capacity for the contaminant of most concern, dissolved zinc which results in an effective total dilution ratio of 200:1. During construction, the utilisation of available assimilative capacity may increase to 76% due to the higher concentration of dissolved zone in the Eldridge Pit.
Maximum controlled release capacity	86.4 ML/d (1.0 m^3/s)	86.4 ML/d (1.0 m^3/s)	

It is important to note that the proposed release ratio (i.e. the ratio of the release flow to the receiving flow) is dependent on assumptions regarding:

- Concentration of the contaminant of most concern (dissolved zinc) in the potential release water
- Concentration of the contaminant of most concern (dissolved zinc) in the receiving environment; and
- Adopted utilisation of the available assimilative capacity for the contaminant of most concern.

However, real time monitoring in the receiving environment and the Eldridge and Wises Pits for metals such as dissolved zinc is not practical. Potential changes to the concentration of contaminants in either the release water or the receiving environment can influence the effective assimilative capacity utilisation. The proposed release ratio of 0.5% for the operational phase of the Project has been based on:

- A conservatively high release concentration of 1.5874 mg/L for dissolved zinc (based on the maximum values observed in the Wises and Eldridge Pits)
- A median (monitoring point W2) receiving environment concentration of 0.0025 mg/L for dissolved zinc;
- A conservative adoption of a 69% utilisation of the dissolved zinc available assimilative capacity; and,
- Maintenance of the same release ratio (0.5%) during the construction phase may result in a slightly greater use of the available assimilative capacity (76%) when water is released solely from the Eldridge pit where the observed maximum concentration of dissolved zine is 1.75 mg/L.

Consequently, at the proposed release ratio of 0.5%, these assumptions provide additional contingency to allow for possible increases to either the receiving environment or release concentrations releases to continue to meet the dissolved zinc HMTV.

Approach to releases

Definition of the proposed release operation is subject to ongoing refinement through detailed design however an indicative approach of the proposed release strategy would likely include the following key steps:

1. Continuous real-time monitoring of flow and other physical parameters such as temperature, electrical conductivity, pH, etc. in the receiving environment upstream and downstream of the proposed release location.
2. Continuous monitoring of flow in Copperfield River upstream of the proposed release location will provide an indication of when the proposed flow release trigger of 400 ML/d has been exceeded and a potential release opportunity is available.
3. The maximum release rate can be determined by multiplying the upstream monitored flow rate by the release ratio and could be adjusted based on real time data from the upstream stream gauge.
4. Verification that the releases are supporting downstream WQOs can be undertaken by collection of water quality samples at the downstream monitoring location(s) downstream of the proposed release point during the release event to demonstrate that the sustainable load objective is being met and environmental outcomes achieved.
5. Releases can be gradually reduced as data from the streamflow gauge indicates that flow recession is approaching the proposed release trigger of 400 ML/d. Releases will cease once the receiving flow equals or falls below the proposed release trigger of 400 ML/d.
6. On the basis of ongoing monitoring of the receiving environment, water in the pits and collection of samples during release events, adjustments would be made to the release ratio as required.

Monitoring and mitigation opportunities

A draft REMP for the Project has been prepared and will be finalised following the approvals process. The following types of monitoring are proposed:

1. Surface water quality;
2. Sediment;
3. Biological;
4. Flow; and
5. Groundwater quality and level.

A number of strategies have been identified to provide further mitigation strategies. These strategies are adaptive in their nature and can be applied if found to be necessary based on feedback from the downstream monitoring programme outlined in the REMP. Strategies include:

- Extending the Flushing Period through Asymmetrical Release Triggers
- Extended Flushing using Releases from the Copperfield Dam
- Cessation of Releases during the Dry Season

Conclusions

This impact assessment has investigated the implications of the Project on the identified receiving environment receptors. The assessment has been largely desktop-based, with some supplementary testing and analysis completed, and as such is subject to limitations of the largely historical database. In addition, model outcomes are determined by the assumptions made, which are based on the information available.

The assessment first determined a set of WQOs, supported by the DTA, with which to design the modelled operational and temporary construction releases. These models were used to simulate the likely Project regimes. Available information was used to assess the impacts of the Project regimes on the receptors.

Outcomes of the assessment indicate that both operational and temporary construction releases are likely to result in relatively low impacts on the receptors in the receiving environment.

The Project REMP will be developed and implemented as part of the Project (refer to draft REMP contained in Appendix I). The Project REMP includes monitoring of surface water quality, sediment, biology, stream flow and groundwater quality/level. The main objectives of the Project REMP are to verify assumptions presented in this assessment and report against relevant WQOs in order to monitor whether impacts to the receiving environment and associated EVs are potentially occurring and if further refinement of the release program is required to achieve acceptable environmental outcomes.

Acronyms

AusRivAS	Australian River Assessment System
ANZECC	Australian and New Zealand Environment and Conservation Council
ARMCANZ	Agricultural and Resource Management Council of Australia and New Zealand
CEMP	Construction Environmental Management Plan
COPC	Constituent of Potential Concern
DES	Department of Environment and Science
DTA	Direct Toxicity Assessment
DNRM	Department of Natural Resources and Mines
DNRME	Department of Natural Resources, Mines and Energy
DO	Dissolved oxygen
EA	Environmental Authority
EC	Electrical Conductivity
EHP	Department of Environment & Heritage Protection
EMP	Environmental Management Plan
ESA	Ecotox Services Australia
EV	Environmental value
FSL	Full Supply Level
GDE	Groundwater-dependant ecosystem
GL	Gigalitre
HEV	Highest Ecological Value
IAR	Impact assessment report
IQQM	Integrated Quantity and Quality Model
LOR	Limits of Reporting
MOL	Minimum Operating Level
NEM	National Electricity Market
OCG	Office of the Coordinator-General
RAP	River Analysis Package
RE	Regional Ecosystem
REMP	Receiving Environment Monitoring Program
REZ	Renewable Energy Zone
RO	Reverse Osmosis
ROPs	Resource Operation Plans
TEP	Transitional Environment Program
TSF	Tailings Storage Facility
WAD	Weak Acid Dissociable
WBM	Water Balance Model

WPs	Water Plans
WQOs	Water Quality Objectives

1.0 Introduction

AECOM Australia Pty Ltd (AECOM) has prepared this Impact Assessment Report (IAR) on behalf of Genex Power Limited (Genex) for the purpose of assessing the impacts of water releases from the Kidston Pumped Storage Hydro Project (the Project) in support of an approval application.

The Coordinator-General declared the Project a Coordinated Project under the Queensland *State Development and Public Works Organisation Act 1971* (SDPWO Act) on 28 September 2018 for which an IAR is required. The primary activity for which an approval is being sought under the Coordinated Project process is for the water discharges as a result of excess water following significant rainfall events during operation, and to allow the lowering of water levels to facilitate construction of the Project.

Release of mine-affected water is a common practice across Queensland for a range of activities. This activity is typically managed through a range of management and monitoring requirements in line with industry standards prescribed under the *Environmental Protection Act 1994* and regulated by the Department of Environment and Science (DES). Industry standards include model mining conditions (ESR/2016/1936) and the Technical Guideline for water release to Queensland waters (ESR/2015/1654).

Coupled with the reasons driving the need for a Coordinated Project declaration (the strategic significance of the Project and the lack of a defined approval process), the relevant existing practices and industry standards, the 'fit for purpose' IAR process was considered to be the most appropriate for the Project, and is the subject of this report.

2.0 Background

2.1 Overview of the Project

The Project is proposed as a beneficial reuse of the closed Kidston Gold Mine in Kidston, Queensland. The Project has a planned capacity of 250 megawatts (MW) and is proposed to be supported by an associated solar farm, and through a direct connection into the National Electricity Market (NEM).

The Project effectively acts as natural battery storage, allowing solar energy to be stored and harnessed as baseload power on demand. This innovative use of the old Kidston mine infrastructure for the purpose of developing a regional renewable energy industry makes the Project unique.

The significance of the Project has been recognised by the State of Queensland by being declared as both a Prescribed Project and a Project of Critical Infrastructure under the SDPWO Act on 3 March 2016 and 27 June 2017 respectively. Under section 76(E) of the SDPWO Act the Minister may declare a Project to be Critical Infrastructure if the Minister considers the Project is critical or essential to the State for economic, environmental or social reasons. The Project is also supported by the Australian Renewable Energy Agency through a funding agreement.

The key component of the Project, which is seeking approval and conditioning from the Coordinated Project process, is the construction and operational water releases associated with the Project. These are further defined and assessed in the body of this IAR.

2.2 Initial Advice Statement

An Initial Advice Statement (IAS) was submitted to the Coordinator General in September 2018. The Project was subsequently declared a Coordinated Project on 28 September 2018. It was declared that the Project would be assessed by an IAR, pursuant to Section 26(1)(b) of SDPWO Act.

The IAS provided information regarding the potential environmental, social and economic impact of the Project, as well as project need, justifications and alternatives considered. The IAS concluded that potential impacts associated with water quality and aquatic ecology would be subject to detailed assessment through the IAR process as relevant to the water releases.

The IAS detailed other Project aspects, and their potential impacts on environmental values that are subject to environmental management plans and / or approvals under Commonwealth or State legislation, separate to the Coordinated Project process. These items are discussed further in Section 2.3 below.

2.3 Approvals Context

The Project presents a unique situation, in which a new non-resource project is proposed over existing resource tenure. The Queensland legislative framework currently does not make provision for the land use transition of decommissioned mine sites to hydroelectric renewable energy projects, and as such no existing legislative mechanism allows for the approval and regulation of water releases required for the Project.

Through extensive consultation with government regulators in relation to approval mechanisms and best practice assessment for the Project, an approval pathway has been agreed between Genex and the relevant State government regulators. The following is a high level summary of the approval elements for the Project.

- Coordinated Project, IAR process under the *State Development and Public Works Organisation Act 1971* – to assess the proposed water discharges from the Project.
- Development Permit under *Planning Act 2016*:
  - to assess the change in land use under the Etheridge Shire Council Planning Scheme and clearing of native vegetation managed under *Vegetation Management Act 1994*
  - to assess the dam design, risks and operation managed under the *Water Supply (Safety and Reliability) Act 2008*.

As highlighted above, the three key elements of the approval process for the Kidston Project, includes:

1. water discharge
2. change in the land use of the Project area
3. design, construction and operation of the dam structure requiring failure impact assessment under the relevant legislation.

Items 2 and 3 above will not form part of the IAR process, as there is a clear delineation and process in the Queensland legislation for assessment of these elements. These approvals have been obtained and a copy of the Decision Notice is included in Appendix M. The conditions are not anticipated to conflict with any conditions that may be issued by the Coordinator-General.

Construction phase approvals may also be required dependant on the final detailed design. These may include the following.

- A development permit for waterway barrier works under the *Planning Act 2016*, pending the detailed design of the outfall structure and how it interacts with the waterway.
- A development permit for clearing of native vegetation under the *Planning Act 2016*, if vegetation clearing is required outside of the current approved footprint.
- A development permit for quarrying in a watercourse under the *Planning Act 2016* and environmental authority under the *Environmental Protection Act 1994*, if sand is required for a watercourse for concrete batching.

These approval requirements are typical of a large infrastructure project, and are expected to be obtained within the construction timeframes.

2.4 Other Project Aspects

Other Project aspects discussed in the IAS, which do not form part of this IAR are detailed in Table 1 below. A summary of these aspects are included in Appendix N for context. Table 1 identifies the mitigation and management strategies associated with each aspect. These aspects are not considered further in this IAR, but are provided for overall Project context and will be managed through a Construction Environmental Management Plan (CEMP) to be developed by the construction contractor.

Table 1 Other Project aspects, applicable legislation and proposed management and mitigation measures

Aspect	Applicable legislation	Management and Mitigation
Land Use	• *Planning Act 2016*	• Development in line with Development Permit issued by Etheridge Shire Council.
Land Management	• *Environmental Protection Act 1994*	• CEMP, including: - Contaminated land management and procedures - Erosion and sediment control.
Air Quality	• *Environmental Protection Act 1994* • Environmental Protection (Air) Policy	• CEMP, including: - Standard air quality management procedures in line with legislative requirements and site specific triggers.
Noise and Vibration	• *Environmental Protection Act 1994* • Environmental Protection (Noise) Policy	• CEMP, including: - Standard noise management procedures in line with legislative requirements and site specific triggers.

Aspect	Applicable legislation	Management and Mitigation
Terrestrial Ecology	• *Planning Act 2016* • *Vegetation Management Act 1994* • *Nature Conservation Act 1992*	• Development in line with Development Permit issued by State Government. • CEMP, including: - Pre-clearing surveys - Spotter catcher - Delineation of clearing areas. - Supplementary planting and revegetation where required.
Cultural Heritage	• *Aboriginal Cultural Heritage Act 2003*	• Development in line with Cultural Heritage Management Agreement. • Direct negotiations with traditional owners and the State. • CEMP, including: - cultural heritage inductions - unexpected finds protocol.
Traffic and Transport	• *Planning Act 2016* • *Transport Infrastructure Act 1994*	• Development in line with Development Permit issued by Etheridge Shire Council, including: - Road User Agreement with Etheridge Shire Council. • Traffic Management Plan

2.5 Community and Stakeholder Consultation

A number of consultation activities have been undertaken by Genex to date. Consultation has largely included the following stakeholders:

- directly affected land owners
- local, State and Commonwealth government regulators
- relevant infrastructure providers.

Consultation activities have been undertaken with the Etheridge Shire Council and State Government stakeholders. Genex met with Etheridge Shire Council formally to discuss the Project in a pre-lodgement forum and as part of the Material Change of Use development approval which was granted on 19 September 2018.

State Government regulators have also been consulted through the application stage of the Project. State Government regulators include:

- Coordinator-General
- Department of State Development, Manufacturing, Infrastructure and Planning
- Department of Natural Resources, Mines and Energy
- Department of Environment and Science
- Department of Agriculture and Fisheries
- Ergon Energy
- Powerlink Queensland.

A number of consultation activities have been undertaken with the indigenous party for the area, being the Ewamian People. A Cultural Heritage Management Agreement has been executed between Genex and the Ewamian People which makes provision for the discharge infrastructure proposed outside of the mine lease area.

3.0 Assessment Approach

3.1 Methodology

The activity of discharging mine affected waters is typically managed through a range of management and monitoring requirements in line with industry standards prescribed under the *Environmental Protection Act 1994* and regulated by the DES. Given the unique nature of the Project, extensive consultation has been undertaken with a range of key regulatory stakeholders to determine an appropriate assessment approach.

The approach adopted for this IAR has been developed in accordance with the requirements of the DES Technical Guideline - Wastewater release to Queensland waters (ESR/2015/1654, Version 2) (herein referred to as "the Guideline"). The Guideline supports a risk-based assessment approach to managing release of waste water to surface water and applies the philosophy of the Australian and New Zealand Environment and Conservation Council (ANZECC) & Agricultural and Resource Management Council of Australia and New Zealand (ARMCANZ) (2000) Water Quality Guidelines and the intent of the Environmental Protection (Water) Policy 2009.

The assessment approach in this IAR follows four key steps, as identified within the Guideline and illustrated in Figure 1.

Figure 1 Impact Assessment Approach

3.2 IAR Structure

This IAR has been structured as follows.

- Section 4 – This section aligns to Step 1 in the Guideline, and describes the:
  - Project construction, operation and decommissioning characteristics as relevant to this process
  - Project need, justification and alternatives considered for the Project
  - current, and historic pit water quality
  - proposed water releases.
- Section 5 – This section aligns to Step 2 in the Guideline, and describes the baseline receiving environment.
- Section 6 and 7 – This section aligns to Step 3 in the Guideline and presents the assessment of impacts from the Project on the baseline receiving environment.
- Section 9 – This section aligns to Step 4 in the Guideline and defines the proposed release and monitoring criteria for the Project.

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Step 1 – Activity Description

“Describe the Proposed Activity”

4.0 Activity Description

4.1 Project Description

Pumped storage hydro is a form of hydroelectric energy storage (Figure 2). The method stores energy in the form of the gravitational potential energy of water, which is gained when the water is pumped from a lower elevation reservoir to a higher elevation reservoir. During periods of high energy demand, this stored potential energy is converted to kinetic energy by releasing the stored water from the upper reservoir, through electricity-generating turbines into a lower reservoir. In periods of low energy demand, the water is pumped from the lower reservoir back into the upper reservoir to begin the electricity generation cycle again. Low-cost surplus off-peak power is typically used to run the pumps. Pumped storage allows energy from intermittent renewable energy sources to be saved for periods of higher demand. Pumped storage hydro is recognised as the largest-capacity form of grid energy storage available in the current market. The technique is currently the most cost-effective means of storing large amounts of energy. Capital costs and the presence of appropriate landforms and geography are critical decision factors in site selection of such projects.

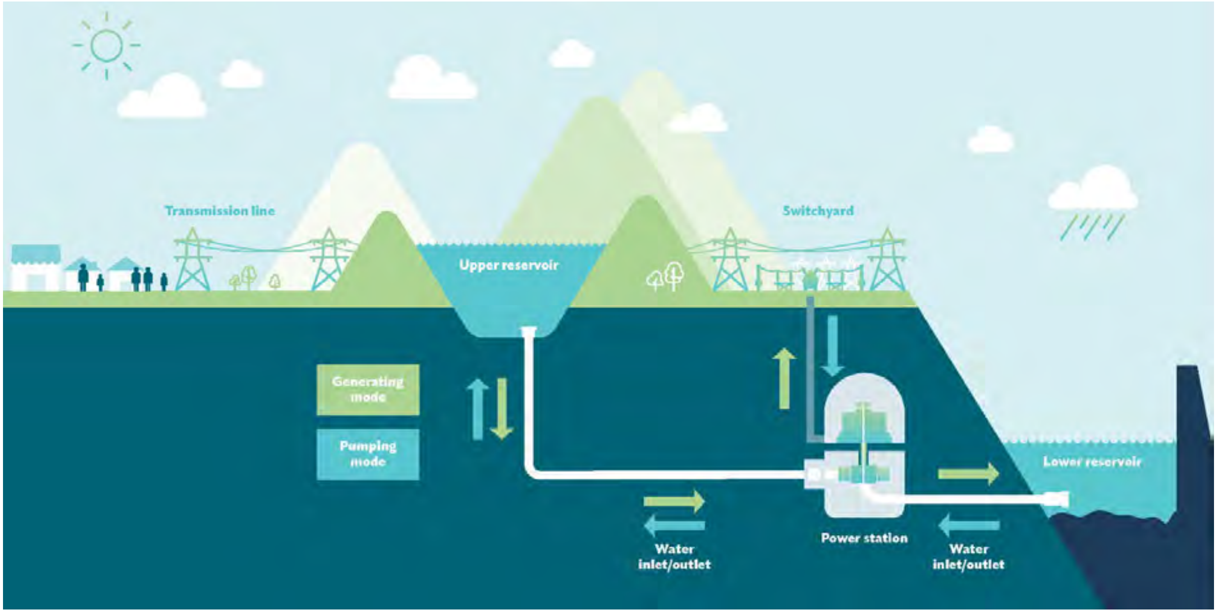

Figure 2 Schematic of pumped hydro storage (Hydro-Electric Corporation, 2018)

The Project utilises two pit voids from the decommissioned Kidston Gold Mine; Wises and Eldridge as the upper and lower reservoirs respectively. A concrete lined pressure tunnel and powerhouse will connect the upper and lower reservoir allowing water to be conveyed between the two pits, in pumping or generation mode. During daytime/off peak periods, water will be pumped from the lower Eldridge Pit to the upper Wises Pit reservoir. During peak power demand periods, the stored water will release from the upper reservoir to generate electricity. Figure 3 illustrates the general Project arrangement showing the final Wises Pit Dam at full water capacity and the Eldridge Pit at a reduced water level.

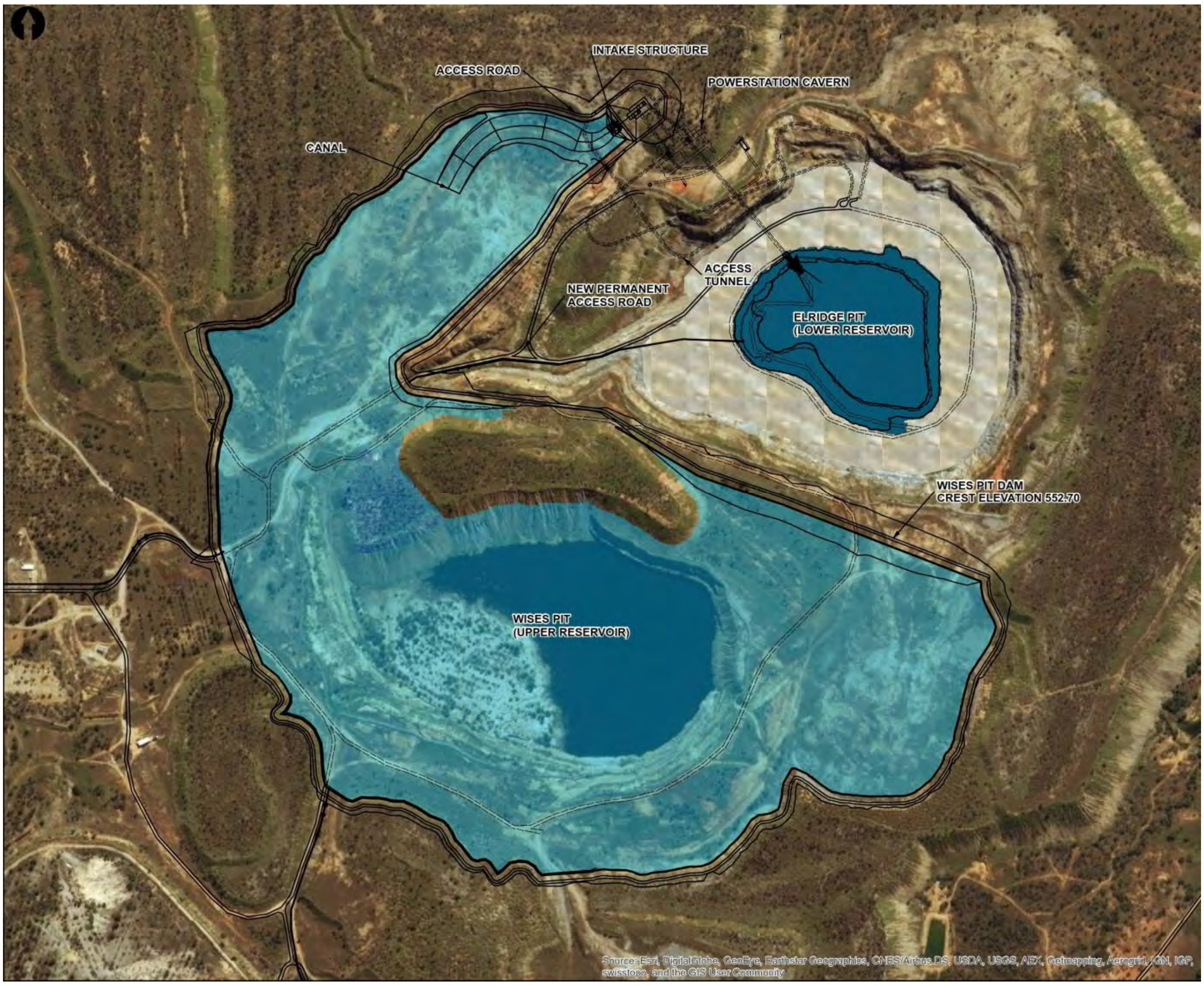

Figure 3 Kidston Project General Overview

Since 2015, the Project has undergone a technical feasibility study and a number of design optimisations resulting in the two-pit solution, utilising the existing mining voids. The Project has been sized to 250MW (approximately 1,870 megawatt hours (MWh)). Release of water from the pits will be required during both construction and operation to facilitate the Project. Water release requirements are discussed in detail in Section 4.6 - 4.7.

The Project consists of the following arrangement and civil components:

- Upper reservoir formed by excavating waste rock from the existing Wises Pit, and utilising a portion of this to build a dam of up to 20m high around the existing Wises Pit, with the balance to be relocated within the Project site.
- Lower reservoir utilising the existing Eldridge Pit.
- Upper gated intake to control the release of water.
- Lower reservoir intake/outlet with stoplog gates to cut off or stop the flow of water.
- Water conveyance shafts, short power tunnels and tailrace tunnel. Once passed through the power station, the tailrace tunnel is where the water passes through to the reservoir.
- Powerhouse cavern to accommodate two fixed speed reversible Francis pump-turbines, main transformers and auxiliaries; and Main Inlet Valve (MIV), which is the valve between the headrace water conveyance shaft and the pump-generator turbines.
- Transformer access tunnel parallel to the powerhouse cavern.

- Single construction and access tunnel from the Eldridge Pit to the powerhouse.
- Cable, vent and emergency access shaft(s).
- Switchyard and control building including offices, store rooms and workshop.
- Pipework and spillway from Wises Pit Dam to Copperfield River for flood management and water balancing.
- Onsite access roads.

Figure 4 shows the below ground hydropower infrastructure proposed between the completed Wises and Eldridge Reservoirs.

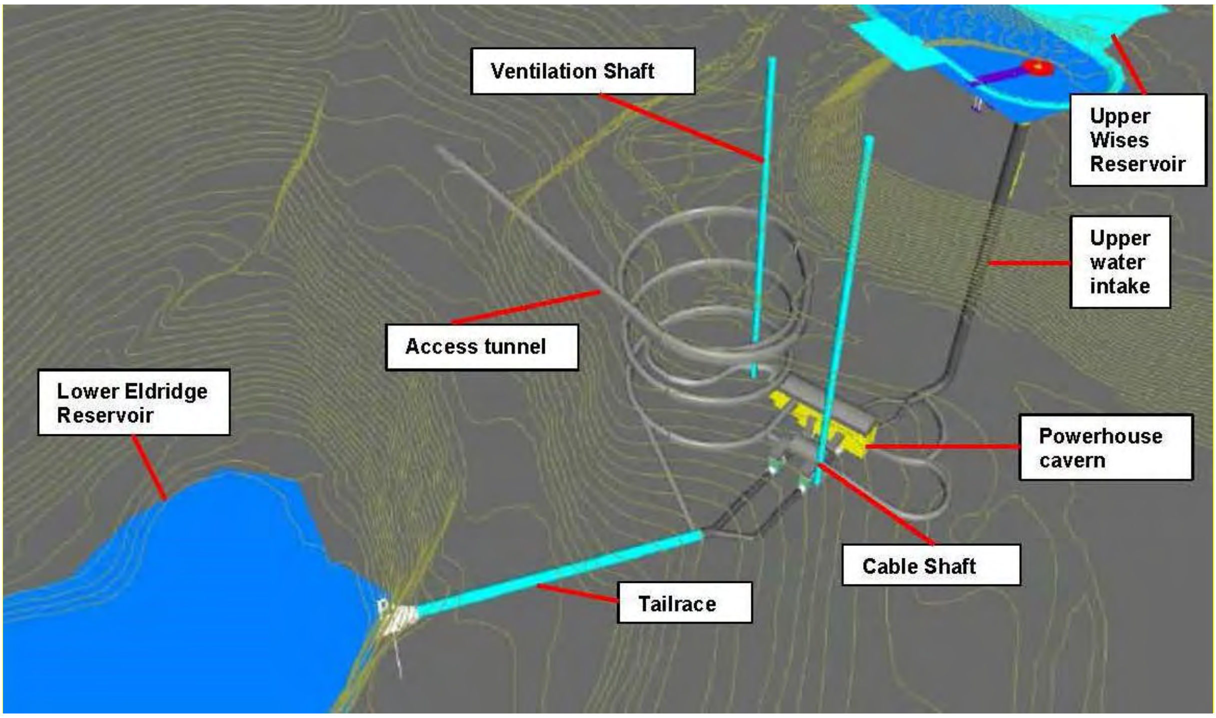

Figure 4 Kidston Project Below-Ground Hydropower Infrastructure

4.1.1 Construction Phase

The existing pits are to be upgraded to make them suitable for operational storage and water discharge requirements. This will include increasing the storage volume of the Wises Pit by excavating existing waste rock (refer to Section 4.2.2.5 for further detail), building a dam (utilising a portion of this waste rock), construction of tunnel infrastructure and dewatering the Eldridge Pit to gain access to allow completion of tailrace outlet construction. The conceptual design and construction methodology will continue to be revised as the Project detailed design progresses and as additional information becomes available (e.g., revising slope stability). The proposed construction works will be carried out in accordance with relevant requirements to protect the integrity of liners. Further details of the construction elements of both the Wises and Eldridge Pits are described below:

Wises Pit (Upper Reservoir)

- An area of the existing waste rock stored within the Wises Pit will be excavated to create additional storage within the Wises Pit, totalling approximately 1.6 million m^3 (of which 200,000 m^3 is virgin rock).
- The dam will be constructed by utilising 130,000 m^3 of this waste rock and a further 900,000 m^3 of waste rock material surrounding the Wises Pit. This will include the re-grading of existing waste rock dump slopes (approximately 5km of the total 5.5km levee) and the construction of a new embankment section (approximately 0.5km of the total 5.5km levee).

- The balance of the excavated waste and virgin rock material (totalling approximately 1.5 million m^3 will be stored at a site adjacent to the dam wall and managed to ensure compliance with the existing Environmental Authority (EA) which was granted over the site following mine closure.
- A high-density polyethylene (HDPE) liner will be installed on the water side of the dam to reduce seepage loss from the dam.
- The water side of the rockfill dam will be overlain by both a transition layer and a fine material layer; the HDPE liner will be installed on these.
- The HDPE liner will be connected to the rock foundation through a reinforced concrete plinth anchored to the rock and from which consolidation grouting can be executed.
- A spillway structure will be constructed to direct excess water from the dam to the adjacent Copperfield River. The detailed design of this structure will incorporate an appropriate dispersion device to facilitate mixing.

Eldridge Pit (Lower Reservoir)

- The lower reservoir will make use of the existing Eldridge Pit. As part of the original pit construction, cable bolting was undertaken to maintain the stability of the excavated slopes. To limit the need for slope stabilisation around the pit, the permanent access tunnel has been elevated with a portal at an elevation in the pit which will minimise the requirement to dewater before tunnelling can start.
- Underground excavation between the Wises Pit and the Eldridge Pit will commence to construct access tunnels, the powerhouse cavern as well as shafts using a variety of construction methods such as drill and blast, rock bolting and shotcreting.
- Construction work will include the installation of temporary services such as ventilation, power, water supply, and installation of gantry cranes.
- Dewatering will be staged to suit the construction program of the Wises Pit Dam (which will need to store this water). The outfall portal entry has been designed to remove the requirement for full Eldridge Pit dewatering before the tunnelling can start.
- Underground construction of key infrastructure will include the powerhouse cavern, the tailrace (channel that carries water away from the dam) and pressure piping.
- Once the tunnelling has been competed, installation of the turbines can then proceed, including supply and installation of electrical, transformer, instrumentation and controls.

HDPE liners may leak if damaged during or after installation. Suitable mitigation measures to minimise the likelihood of any damage and also limit potential environmental impacts are as follows:

- regular inspections as part of the operations and maintenance phase works
- all water leaked will report to Eldridge Pit as part of the existing drainage system
- site will continue to be monitored and managed under the existing Environmental Authority.

4.1.2 Release Infrastructure

The same release point on the Copperfield River will be used during both the construction phase and operational phase however the source of water potentially released, conveyance of water to the proposed release point and actual release infrastructure will differ from the construction to operational phase as summarised below in Table 2. All releases during the construction phase will be Type 1 controlled releases; during the operational phase releases would predominately be Type 1. During extreme rainfall conditions a Type 2 discharge may be employed (Section 4.7).

Table 2 Project Release Infrastructure

Aspect	Construction Phase	Operational Phase
Release location	Subject to detailed site constraint analysis but indicative location shown on Figure 14 and Figure 49.	As per construction phase
Source of release water	Water will initially be sourced from the Eldridge Pit only. This will continue until the final stage of dewatering of the Eldridge Pit has completed and construction of the tailrace works has commenced. For the remainder of the construction phase releases will be from the Wises upper reservoir at the operational phase mixture of 9 parts Eldridge water to 1 part Wises.	Releases will be from the Wises upper reservoir at the operational phase mixture of 9 parts Eldridge water to 1 part Wises.
Conveyance of release water to proposed release point	Until completion of dewatering of Eldridge Pit (and prior to commencement of construction of the tailrace outlet works) the temporary pit dewatering infrastructure (pontoon mounted submersible pumps and HDPE pipes) will be utilised. When a release opportunity arises water will be pumped directly to the proposed release point via a temporary network of pipes laid out to the proposed release point. Upon completion of dewatering of Eldridge Pit and during construction of the tailrace outlet works the completed Wises Pit spillway chute and conveyance channel (gravity flow) will be used to direct water to the proposed release point. Water will enter the spillway chute via a gated structure inset into the spillway.	Water released from Wises upper reservoir will be conveyed to the potential release point via the spillway chute and conveyance channel (gravity flow). Water will enter the spillway chute via a gated structure inset into the spillway.
Release infrastructure into the Copperfield River	Design and construction of the operational phase outlet works has been identified for early works and is proposed to be completed as close to commencement of construction phase dewatering operations as possible. In the event that the works are not complete prior to this, initial releases during the construction phase may be via a simple outfall structure (incorporating relevant erosion and sedimentation control measures). This is necessary for the Project to take advantage of potential release opportunities as soon as the construction phase commences. It is anticipated that this would only be required for a short period during the first wet season of the construction phase. Ongoing releases during the remainder of the construction phase are anticipated to be via the completed operational phase release infrastructure (instream diffused, outlet structure). Use of any temporary outfall structure would cease following the commissioning of the operational phase outlet works. Decommissioning and removal of any temporary outfall structure would be completed as soon as practical following commissioning of the operational phase outlet works.	Releases will be via an instream diffused, outlet structure.

4.1.3 Operational Phase

The Project will seek to sell electricity during peak demand periods when prices are high (typically in the morning and evening). This will be achieved by releasing water from the upper reservoir, through a reversible turbine-generator system, into the lower reservoir (known as a generation cycle).

Once the generation cycle is completed, the reversible turbine-generator system will pump the water back into the upper reservoir when prices are lowest, typically overnight by using grid power (known as a pumping cycle) or during the day by utilising the electricity produced from Genex's proposed co-located solar project (K2S).

4.1.4 Rehabilitation

The Project is located predominantly on a freehold site which was a former open cut gold mine. During the final stages of the mining operation and following the closure in 2001, a number of key rehabilitation works occurred. The major rehabilitation works included:

- grading and revegetation of the tailing's facility and waste rock dumps
- implementing a water management plan for surface and groundwater flows within the existing site, including flooding of the pits
- removing all mining related buildings and revegetation of associated footprints during these activities.

An EA was granted over the site in October 2013 to govern the management of the site following closure and rehabilitation of the mine. This was inherited by Genex following its acquisition of the site in 2015 and included providing an environmental bond to the Queensland State Government of $3.8 million.

While managing the site under the terms of the EA, Genex is seeking to beneficially reuse the site through a new productive industrial use, being a renewable energy generation and storage facility. Genex completed the development of its 50MW Kidston – Stage 1 Solar Farm (KS1) on the old tailings site, which was energised in December 2017. Stage 2 of the development involves further reuse of the site through repurposing the existing mine pits into a new pumped storage hydro facility (the Project) and developing the associated K2S solar farm.

Based on current design specifications, the Project will have a minimum lifespan of 50 years, with various components having a lifespan extending beyond this. With operation anticipated to commence in 2021, the Project lifespan would run until 2071 at a minimum.

On this basis, Genex considers that it would be extremely difficult to foresee the available rehabilitation methods at this future date, given it is highly likely that there will be significant advances and modifications to rehabilitation methods, available technologies to assist with rehabilitation, and changes to government policies on adequate rehabilitation procedures.

Notwithstanding this, Genex considers that it or the asset owner would have several available options once the Project nears the end of its design life, which would include:

- spending capital to upgrade the facility to extend the economic life of the Project
- repurposing the facility for an alternative solution (e.g. tourism)
- closing the facility and proceeding with rehabilitation works.

Genex considers that the most likely option would be to upgrade the facility to extend the economic life of the Project. If Genex or the asset owner took the decision to repurpose or close the facility at the end of its design life, Genex considers that to achieve a successful rehabilitation program, Genex or the asset owner at the time would need to take into account current rehabilitation methods (including technology advances), current government policies on rehabilitation and best-industry practices for safety and environmental protection.

4.1.5 Timeframe for the Project

For the purpose of the IAR, the following timeframes in Table 3 are anticipated.

Table 3 Project Development Timeframes

Milestone	Timeframe
• Feasibility Study	Completed November 2016
• Optimisation Study	Completed October 2017
• Selection of preferred EPC Contractors	Completed October 2017
• Selection/procurement of hydroelectric turbine equipment package	Completed April 2018
• Financial Close	Q2 2019
• Construction Phase (including construction phase releases)	2019 - 2022
• Commissioning & operation (including operations phase releases)	2022

4.2 Project Need, Justification and Alternatives Considered

4.2.1 Project Objectives

The Project, along with the proposed co-development of K2S, has several objectives which benefit Genex, the State of Queensland and the NEM. These can be summarised as follows.

- To underpin a new Renewable Energy Zone (REZ) in Far North Queensland, where an abundance of wind and solar resources exist, through the provision of energy storage and ancillary services to support further renewable generation projects, including localised load, inertia, voltage control and other ancillary services.
- To facilitate the development of new transmission infrastructure as a cornerstone of the new REZ, which will be required to support further renewable generation projects.
- Improving the reliability and system strength of the Queensland transmission network through the addition of new dispatchable, synchronous generation.
- Helping to maintain the affordability of electricity for consumers in Queensland, through supporting development of additional low cost renewable generation.
- To contribute to the overall lowering of carbon emissions, through supporting the development of renewable projects, including Genex's co-located solar projects.
- To re-purpose an abandoned mine site into a new industrial use for the next 50+ years.
- To benefit the local and regional community through providing local employment opportunities for over 500 people, future growth of tourism and support of the local indigenous community through sponsorship of tourism projects.
- To deliver commercial returns to Genex's shareholders.

4.2.1.1 Project Need, Justification and Strategic Benefits

The Project offers a large-scale, low-cost and flexible solution to Queensland's growing peaking power requirements. The Project is well positioned to take advantage of the combined effects of an oversupply of baseload generation capacity and escalating peak power prices being driven by increasing gas turbine fuel costs. As renewable power gains momentum in Queensland, especially the prevalence of rooftop solar but increasingly supplemented by the deployment of large-scale solar projects, the need for energy storage and energy management will play a far more important role in the electricity network.

Large-scale storage projects such as the Project will provide stability in supply to the grid which will become even more important because of intermittent generation issues associated with renewable energy. The Project will significantly contribute towards alleviating the growing pressure on peaking power demand and peak power prices in Northern Queensland and in Queensland more generally.

Besides delivering rapid response, flexible and renewable peaking power into the network in Northern Queensland, the Project also is expected to create more than 370 jobs in the construction phase as well as numerous indirect jobs and demand generally for services in the greater Etheridge Shire. The Project is also expected to create approximately 9 jobs during the operation phase.

Queensland Peaking Power Deficit and Rising Prices

The Northern Queensland region is currently a net importer of electricity from the Central Queensland region, with a forecast growing peaking power deficit. Once operational, the Project will significantly alleviate this emerging issue.

The Queensland electricity market is currently experiencing high peak prices during hot summer days and cold winter days, and frequent power price spikes compared with other Australian States. Furthermore, the Mount Stuart Power Station (a peaking power generation station) is scheduled for decommissioning in 2023. This issue is further compounded by the increase of liquefied natural gas (LNG) export which is making existing gas generators (for peaking and shoulder generation) costly to run.

At 250MW, the Project will add significantly to the State's peaking and shoulder power generation capacity. Aside from the capacity issues, the Project will also mitigate price increases forecast as a direct consequence of open cycle gas turbine peaking generators operating in an environment of escalating gas prices.

Blackstart Capability and Ancillary Services

Approximately 90% of Queensland's power needs are met through the operation of coal fired power stations (59%) and gas turbines (31%). These generators have a restricted ability to self-start in the event of a power grid failure. Hydroelectric power plants are renowned for their ability to offer rapid response grid "blackstart" capabilities, that is, the ability to restart other generators and the electricity grid within seconds in the event of network shutdown. With potential cyclone events and bushfire threats, the Project will provide Queensland with a more reliable solution during these events.

The Project will also provide a full range of ancillary services to the grid, including frequency and voltage control, load levelling, synchronous generation capacity and capacity deferral. In addition, it has the potential to support grid stability through inertial spinning reserve and fast ramp rates, which is particularly important in the context of growing deployment on the network of intermittent renewable energy.

Economic Stimulus and Employment – Etheridge Shire

The Project will significantly contribute to the economic wellbeing of the Etheridge Shire. It will require extensive use of local building materials, construction services and human resources during construction and operation, in a region that could considerably benefit from economic and social uplift.

KS1 is already providing economic activity and employment opportunities to Kidston and the Etheridge Shire, and more than 160 jobs were created during the construction period.

As noted in Section 4.2.1.1, it is anticipated that the Project and K2S will generate a total of more than 500 jobs during construction, which Genex anticipates will be filled primarily by personnel from within the immediate Local Government Area (Etheridge Shire) and other nearby locations (Townsville, Cairns etc.). The Project alone will generate over 250 of those jobs.

In addition to these economic benefits, Genex currently supplies water on a voluntary basis, at no cost, to the local township of Kidston and to surrounding cattle stations.

The Copperfield Dam, which is the source of the water for Kidston, also plays an important role in regulating the river flow down to Einasleigh. The dam is currently maintained by the State with Kidston Gold Mines Limited (KGML, 100% owned by Genex) providing 100% of private sector funding via its water services agreement with the State. The success of the Project will ensure the continuation of the various social benefits to residents in and around the Kidston area as a result of being able to use the Copperfield Dam.

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Once completed, the Project will be the first in the world to utilise two disused mine pits for hydroelectric power generation, and the first hybrid large-scale solar photovoltaic and pumped hydro storage plant. The Project has already found interest internationally, and Queensland, as the host State, will receive recognition as an enabling partner in this innovative and ground-breaking use of a redundant mining asset for a clean energy power solution.

Queensland currently has over 11,000 abandoned/closed mines of various scales, most of which are in locations with excellent solar resources. The maintenance of abandoned mines and their environmental footprint currently poses a significant financial drain on the State. If the Project is successful, it is possible for the scheme to be duplicated across a number of sites within Queensland. This would not only substantially alleviate environmental costs and liability to the State, but also demonstrate an innovative approach for repurposing mining projects for new industrial uses beyond the end of mine life.

4.2.2 Design Refinement and Assessment of Alternatives[3]

The Project design has progressed through a number of design iterations that have considered key selection criteria including environmental impact, constructability, operations and maintenance, and relative costs (capital and operational). A summary of the development of the proposed design is outlined below.

Approximately 27.5 GL of water is required to be removed from Eldridge Pit to gain access for construction of the tailrace outlet works. In the following discussion, ‘excess construction water’ refers to the residual volume of water from the Eldridge Pit not able to be accommodated in onsite storage for each design option.

4.2.2.1 Design Option 1 – Original Design (Prefeasibility)

The initial prefeasibility design called for a 330MW installed capacity based on a market study of the optimum installed capacity.

Limited availability of survey information (due to the pits being full of water) resulted in uncertainty regarding the available driving head (i.e. the difference in water level between the upper and lower reservoir - a key driver of generating capacity) and the storage volumes of these reservoirs.

Whilst a higher capacity was considered preferable, the prefeasibility study concluded that current pit capacity without modification would only allow for 220MW installed capacity by using the pits in their current configuration.

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[3] Note that the following section summarises in part, high level preliminary documentation that utilised contemporary information and data that, in some instances has been subsequently revised and/or updated. For example the current estimated volume of water required to be dewatered from Eldridge Pit is around 28 GL due to additional inflows over the 2017/18 wet season. Similarly, initial estimates of the current capacity of the existing Wises pit have also been refined and are now in the order of 8.5 GL.

Key concerns arising from prefeasibility design included:

- Significantly large volume of excess construction water (approximately 27.5 GL) that would need to be removed from the Eldridge Pit ahead of construction to allow installation of the tailrace. As the existing Wises Pit can only hold approximately 10 GL, and the balance of 17.5 GL would need to be released.
- Potential stability issues associated with construction of key infrastructure such as the access road into Eldridge Pit
- The high dollar per MW cost resulting from a smaller installed capacity; especially in light of the high cost of required enabling infrastructure such as the transmission line.

4.2.2.2 Design Option 2 – Turkeys Nest Design (Feasibility)

The feasibility-level Design Option 2 sought to overcome the geometric deficiencies (head difference and volume able to be transferred between pits) in the original design. Genex initially advised that an installed capacity of 330MW was not optimised and that alternatives should be considered. An alternative design was proposed to Genex which involved the construction of a turkey's nest reservoir (a ring dam with no external catchment) on top of the northern waste rock dump area in order to overcome the deficiencies inherent in the original design.

This option presented additional benefits including having Wises Pit as a balancing reservoir instead of as the upper reservoir, increased head and therefore potential for higher installed capacities, and a potential reduction in the volume of water required to be released from Eldridge Pit if the turkeys nest dam was used to hold water removed from Eldridge Pit. However, the turkey's nest only provided for an additional 4.4 GL of storage; meaning that, in combination with the additional 10 GL provided by Wises Pit in its current configuration, this still left a water surplus of approximately 13 GL - which would need to be removed during construction.

Genex engaged a number of specialist sub-consultants such as Water Treatment Services (for in pit treatment) and AGE (for groundwater modelling[4]) as well as consulting several suppliers to assess a range of potential options to address the surplus water volume to avoid the need for discharging the water to the Copperfield River. Several options were compared for the management of surplus water as follows, and summarised in Table 4.

- It was found that Options A, B and C provided optimum solutions for the storage of a portion of the water from the Eldridge Pit and it was recommended that these options were carried forward along with Option D (raising of Wises Pit full supply level (FSL) to 543 m AHD).
- Options E (in pit treatment) and F (reverse osmosis) were able to provide technically viable solutions but at considerable additional cost, complexity, generation of additional waste streams and energy consumption, and significant risk to the construction schedule due to the need to treat additional interim inflows from weather events during construction. For these reasons these options were not considered to be feasible.
- Option G (evaporative blowers) and H (dilution using water from the Copperfield Dam) were only able to provide potential additional contingency measures for the removal of up to 2 GL each and were not considered viable alternatives for treatment of the large volume of excess construction water.

[4] AGE assumed an FSL of 551m AHD as a 'worst case' throughout modelling of Option D, which was nevertheless considered to present a low risk of impact to groundwater.

Table 4 Summary of Options from the 2016 Workshop

Options		Volume addressed (GL)	Treatment cost ($M)	Pumping cost ($M)	Option ranking	Notes
Probable options						
A	Store in Wises Pit, current capacity up to 530m AHD	10	N/A	5.6	1	No constraints except ensuring adequate freeboard maintained in case of heavy rain during construction.
B	Store in Turkey's Nest (up to 581.5m AHD)	Up to 4.1GL	N/A	N/A	1	Not available until 1.5 years after the commencement of construction
C	Water use during construction	~0.3	N/A	0.1	1	Could be used for the construction of turkey's nest, Wises Dam, etc.
	Subtotal	14.4	N/A	5.7	N/A	Currently 10GL storage available straight away but the rest only during construction
Potential options						
D	Storage in Wises Pit between 530m and raising to FSL of 543m AHD	11	2.7	2.4	2	Potential risk of impact to groundwater. This risk was assessed and considered to be low based modelling work undertaken by AGE. AGE assumed an FSL of 551m AHD as a 'worst case' throughout modelling of Option D, which was nevertheless considered to present a low risk of impact to groundwater.
E	In pit treatment and release	17.5	>9.5		4	Costs of in pit treatment higher than anticipated and not viable.
F	Reverse osmosis and release	12	14.5	3.4	3	Approximately 400 days required to treat 14 GL of water. This treated water would still need to be released to the Copperfield River. Significant volumes of brine concentrate would need to be stored.
G	Evaporative blowers	2	6.5	N/A	N/A	2 GL over 2 year construction window assuming normal years (not heavy rain)
H	Dilution	2	1.2	0.8	N/A	Requires regulatory approval for release.

Key factors which made this design unfeasible included:

- Large scale earthworks associated with construction of the turkey's nest dam.
- Unacceptable geotechnical risks associated with construction of the turkey's nest dam on modified ground conditions.
- The construction of the turkey's nest was necessary for dewatering of Eldridge Pit and therefore added significant time to the construction program.
- None of the options assessed were able to completely address the construction water surplus.
- The high cost per MW due to the cost of the proposed turkeys nest dam was only considered viable for a 450MW project, but not for a 250MW project.

The following option was therefore recommended to be taken forward:

- Upgrading the Wises Pit by creating a dam to an FSL of 551m AHD (crest of 552.7m AHD) and excavating its northern dump area down to 546.90m AHD.
- Raising the entrance of the access tunnel to disconnect the underground works from the Eldridge Pit dewatering and pumping of 11 GL from Eldridge Pit to the Wises Pit.
- Once the dam has been built and infrastructure to transfer water between the pits was constructed, to pump the remaining 16.5 GL of water from the Eldridge Pit to the upgraded Wises Dam thereby allowing for storage of this water without discharge.

4.2.2.3 Design Option 3 – Optimised Reference Design

At the feasibility level it was concluded that the concept of utilising the two existing mine pits as the upper and lower reservoirs was optimum for a 250MW installed capacity. While the turkey's nest concept was well accepted, it was only deemed necessary for higher installed capacities. In addition, a number of geotechnical and operational risks were identified with its proposed location on the northern waste rock dump.

Groundwater modelling undertaken for the feasibility stage was updated to include this 250MW concept and concluded that the Eldridge Pit would continue to act as a sink and intercept potential groundwater seepage from the Wises Pit for this revised design option.

Dewatering of the Eldridge Pit to enable the construction of the underground infrastructure was considered further. Of the approximately 27.5 GL of water required to be removed from the Eldridge Pit to enable access to the tailrace outlet, the majority (95%, 26 GL) could be temporarily stored in the upgraded Wises Pit reservoir up to the FSL of 551m AHD.

Water sampling and chemical analysis from the Eldridge Pit showed that any water released (including potential additional inflows from rainfall) would require significant time-consuming and expensive treatment to enable the water to be released from site (e.g. to the Copperfield River) without dilution by receiving environment waters.

The design team concluded that the most effective solution to this dewatering issue would be an engineering solution involving the modification of the Wises Pit to store the excess water if possible.

This design phase also established that treatment of surplus water from significant rainfall inflows during the operational phase of the Project would be impractical to treat given that the volumes of water requiring treatment are highly variable. A number of key aspects of this design required further consideration including:

- Management of excess water during the dewatering of Eldridge Pit along with any additional rainfall inflows during the construction period.
- Minimising discharge of surplus water during the significant rainfall events during the operational phase of the Project.

4.2.2.4 Design Option 4 – Proposed Design

This design phase confirmed that the Optimised Reference Design (Design Option 3) concept of utilising the two existing mine pits as the upper and lower reservoirs was optimum for a 250 MW installed capacity. A number of engineered solutions were explored in order to enlarge the constructed Wises Pit upper reservoir to provide sufficient capacity to contain the entirety of the water required to be dewatered from Eldridge Pit during construction of the tailrace outlet. These included removal of the backfilled waste rock material in Wises Pit and an additional raising of the proposed Wises Pit embankment.

Similar to the costs associated with treatment options explored during the Optimised Reference Design, the costs of including additional capacity to Wises Pit were found to be unacceptably high. In addition, the provision of a fixed capacity solution (in terms of either storage or treatment capacity) could still present a risk to the Project construction resulting from additional ingress of water during storm events occurring during the dewatering of Eldridge Pit and the subsequent tailrace construction period.

The Proposed Design has also included an engineered mitigation for the management of excess water during operations. The design proposed for the Wises Pit upper reservoir incorporates an additional 0.5 GL buffer volume between 550.56 m AHD and 551 m AHD. The purpose of the buffer is to limit the likelihood of uncontrolled discharge by:

- Allowing the Project to store some additional water without unacceptable impacts to power generation and general operations.
- Allowing for the temporary storage of water until an opportunity to release is presented by naturally occurring stream flow in the Copperfield River.
- Act as a balancing storage during storm events when the rate of inflow is higher than the rate of water able to be released.

Key advantages of the Proposed Design include:

- Minimal volume of excess water during construction (reduced from 17.5 GL to potentially less than 1.5 GL).
- Significant operational flexibility provided by the buffer storage volume to absorb stormwater inflow or control the timing of potential releases.
- No generation of additional waste streams or handing of large quantities of chemicals resulting from water treatment processes.
- Low technology risk solution.

4.2.2.5 Design Option 5 – Optimised Proposed Design

Following discussion and consultation with DES during 2018, Genex reconsidered the Proposed Design in light of the requirement to discharge over 1.5 GL of water during the construction phase to facilitate construction of the tailrace outlet structure within Eldridge Pit.

This resulted in the development of the Optimised Proposed Design, which was based on the Proposed Design but incorporated the following additional attributes:

- Excavation of additional waste rock (1.3 million m^3 from Site A in Figure 5) and virgin rock (200,000m^3 from Site B in Figure 5) material from within Wises Pit to create an additional 1.5GL of water storage below the proposed MOL of 546m AHD
- Temporarily raising the spillway level in Wises Dam to 552.0m AHD (from 551.5m AHD during operation) to temporarily store a further 1.0 GL of water during construction of the tailrace within Eldridge Pit.

Further detail on these two attributes is provided below.

On the basis that the Optimised Proposed Design was able to further minimise the construction phase water discharges, it was selected as the final design to be adopted for the Project.

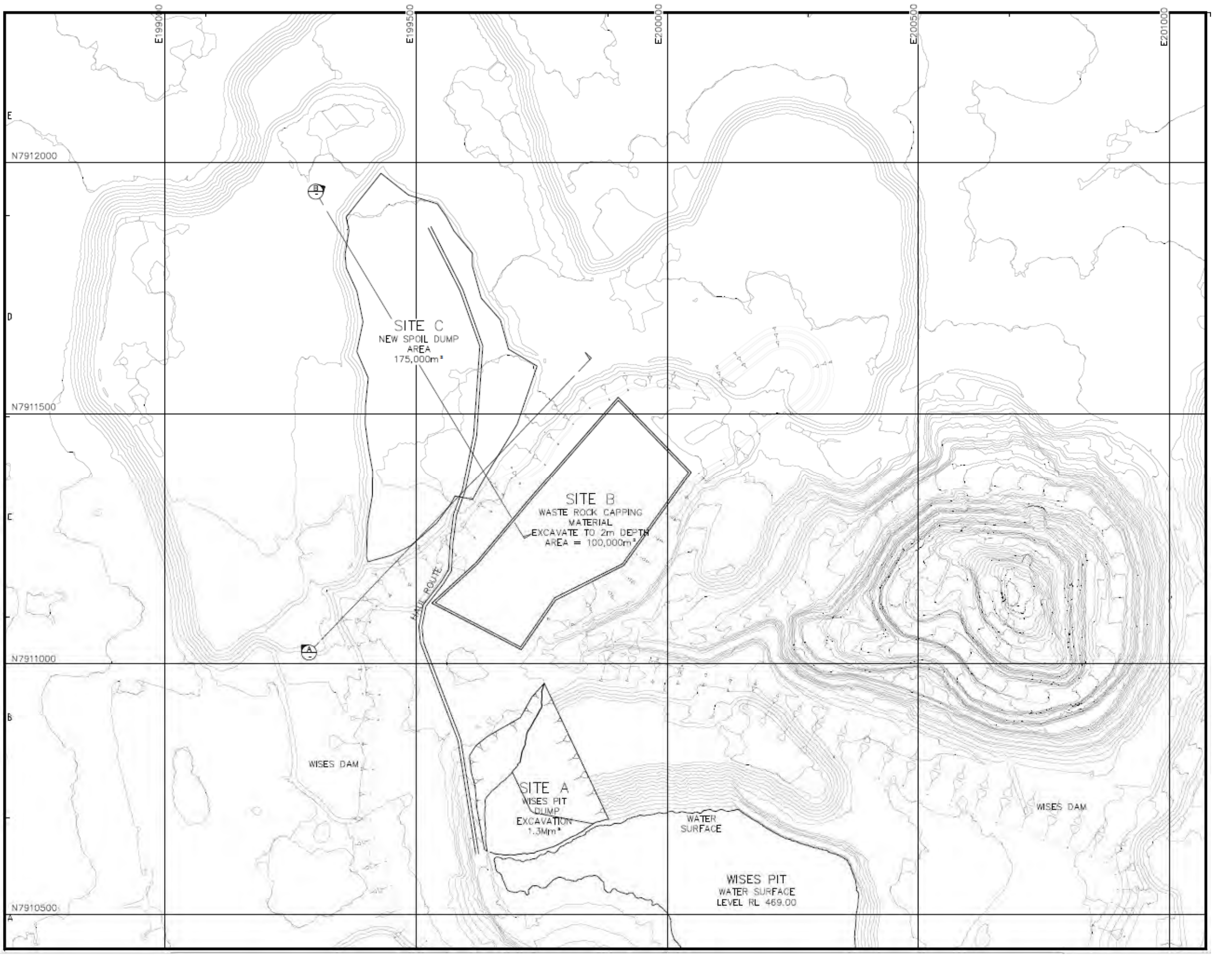


Figure 5 Design Option 5 Excavation Areas

Excavation of additional rock

Site C was selected as it is an area that was previously cleared by the mine site but is not a rehabilitated waste rock dump (the site was prepared but never utilised as a waste rock dump). The material from Site A will be placed, capped with material from Site B and vegetated in compliance with the existing EA. The design of this new rock dump will incorporate appropriate drainage arrangements to allow potential seepage from the dump to be contained on site and directed to the Wises and/or Eldridge pits or to one of the existing collection points and pump stations around the site. Cross sections of the preliminary design are shown in Figure 6.

It is noted that the Wises Dam design incorporates drainage arrangements around the full perimeter of the dam levee to firstly ensure water pressure does not build up against the outside of the dam levee and secondly to capture and direct seepage from the existing waste rock dumps (including the new rock dump at Site C) to the Eldridge pit and/or the existing seepage capture points and pump stations on site.

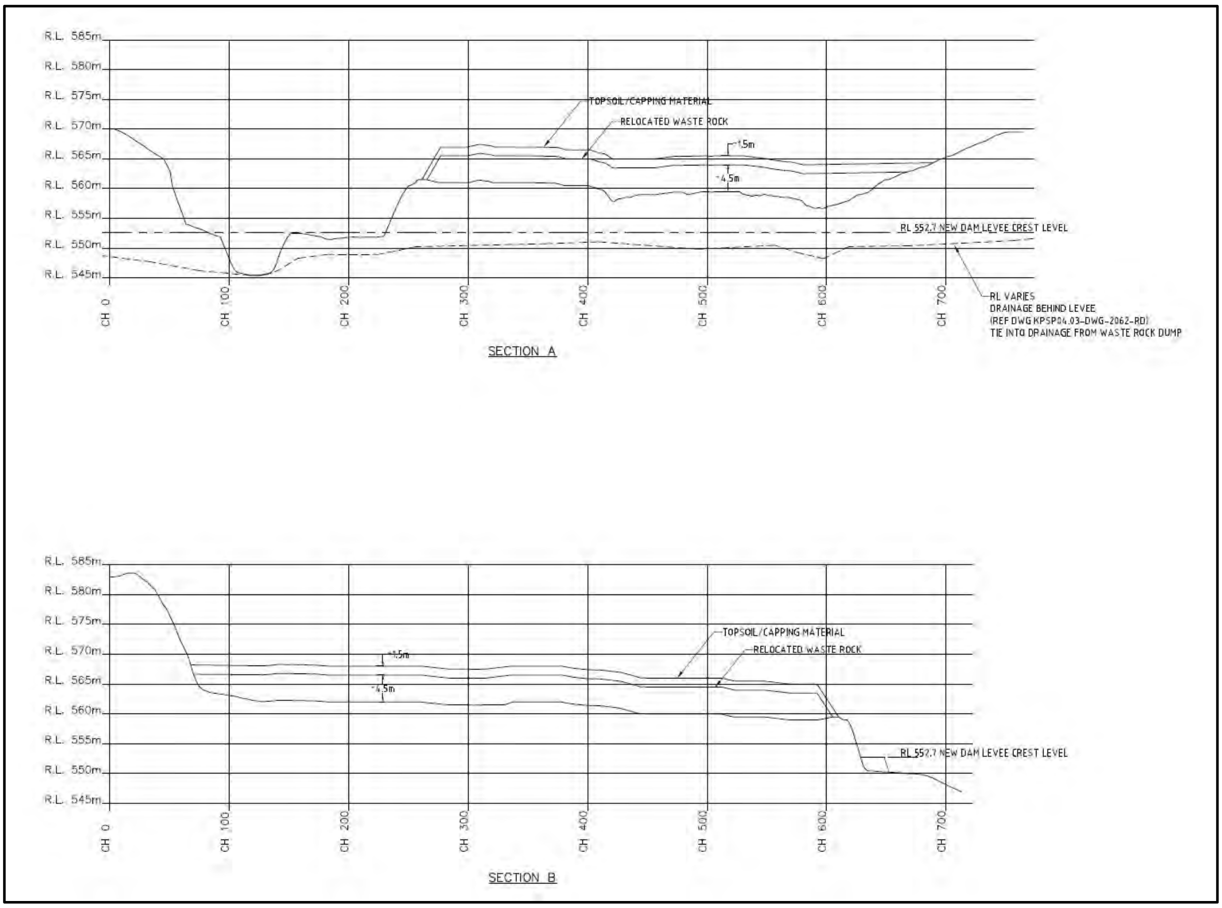


Figure 6 Additional Storage Sections for Design Option 5 (refer to Figure 5 for Cross Section Locations)

Temporary raising of spillway

DNRME has confirmed to Genex that it is comfortable with the proposal of temporarily holding excess water in Wises Dam above the FSL of 551.0m AHD (with the final design incorporating a spillway at 551.5m AHD and the dam crest of 552.7m AHD). The dam design incorporates a hydraulic gate arrangement that can be raised and lowered to adjust the effective spillway level to allow this temporary additional storage capacity in the dam and this functionality would be used temporarily to raise the spillway level. It is intended that this will only to be undertaken for the period during which the tailrace portal is being constructed, comprising approximately 6 months.

4.2.3 Design consistency with Management Hierarchy for Surface or Groundwater (EPP Water)

The Optimised Proposed Design has been reviewed against the management hierarchy for surface and ground water outlined in the EPP (Water). Table 5 provides a summary of the review of the Optimised Proposed Design against each step of the management hierarchy.

Table 5 Review of the Proposed Design against Management Hierarchy for Surface or Groundwater (EPP (Water), Part 5, Sec, 13)

Step 1 – Water Conservation	Step 2 – Waste Prevention	Step 3 – Treatment or Recycling	Step 4 – Release Options
Development of the Optimised Proposed Design has progressively reduced the excess construction water by approximately 18.0 GL. During operations, water conservation measures are not applicable as the generation of pumped storage hydro power does not consume water as a process input. The existing body of water contained in the pit is effectively continually recycled around a semi-closed loop consisting of power generation and pump back. In the absence of evaporative losses and wet season inflows, the volume would remain constant. Water is still required to replace evaporative losses as evaporation typically exceeds rainfall during an annual cycle. While this may be considered a process water input there is little operational flexibility to minimise this demand as the successful operation of the Project requires that the total volume of water in both pits is maintained at an optimum level.	Development of the Optimised Proposed Design from the Proposed Design considered mitigating the requirement to discharge excess construction water, such that this volume has now been reduced to zero and water can be managed in line with the operational phase. During operations, the generation of additional volumes of potentially contaminated water has been minimised to the greatest extent possible through the passive diversion of stormwater runoff around the Eldridge Pit (Wises Pit has only a very small external catchment). Rainwater falling directly on each dam's water surface will however continue to contribute additional inflows. The lining of the embankment of Wises Pit has been designed to mitigate any potential for ongoing deterioration in water quality	Onsite reuse of water for bulk earthworks including construction of the Wises Pit dam is estimated to use approximately 0.3 GL of water from the pits. Due to the quality of the water within the pits, no practical offsite reuse of the excess water is possible. Water stored in the pits does not currently meet water quality objectives (WQOs) for stock watering or irrigation without extensive treatment. There are no identified industrial demands for the untreated water within a reasonable distance. The presence of the Copperfield Dam also provides a significant alternative source of uncontaminated water that does not require treatment. A number of treatment options have been explored, most extensively as part of Design Option 2. Options investigated considered reverse osmosis, forced evaporation (mechanical blowers) and in-pit treatment. A key reason for why treatment options were found to be unviable for the Project was that the volumes of water requiring treatment are highly variable. The operational water balance model shows that releases caused by heavy rainfall could exceed 1GL per year. The periodic nature of the generation of excess water volumes and the requirement for intermittent operation is not suited to membrane filtration water treatment which must remain	There are no practical options for disposal of excess water at a waste treatment facility due to the remote nature of the Project location. The ability of irrigation to land to remove surplus water during the wet season is very limited as soils are typically at or near saturation point and unable to absorb irrigation water. Whilst irrigation to land was considered during the development of the Proposed Design, especially during construction, it was considered unsuitable given the volumes able to be removed and given the land area available. The subsequent Optimised Proposed Design was developed to store excess construction water such that releases of excess water are only required to cater for seasonal inflows during both the construction and operational phases under a controlled, event-based release of water from the Project under conditions that will not cause unacceptable environmental harm to downstream EVs is deemed to present the best option for the periodic release of excess water from the Project.

Step 1 – Water Conservation	Step 2 – Waste Prevention	Step 3 – Treatment or Recycling	Step 4 – Release Options
	through mobilisation of potential sources of contamination originating from waste rock dump material used in the embankment construction.	continuously operational for optimum use. The use of enhanced evaporation does not provide a suitable disposal solution as treatment rates are slow, largely unavailable during wet weather (low evaporative potential) and are subject to high running costs and low reliability. The subsequent Optimised Proposed Design was developed to store excess construction water such that treatment or recycling of excess construction water is not required.	

4.3 Kidston Site Overview

4.3.1 Existing Kidston Site Water Management

The seepage interception system (SIS) consists of a number of interception dams, evaporation ponds and or sumps that also have pump-back systems directing poor quality seepage originating from the waste rock dump (WRDs) and Tailings Storage Facility (TSF) to one or other of the existing pit voids (refer to Figure 7). During the initial period of closure planning it was assumed that capping of the WRD's and TSF would in the long term eliminate expression of poor quality seepage to the existing collection points including:

- North Dump Dam
- East Dump Dam
- South-East Dump Dam; and
- TSF Reclaim Pond.

Medium term planning identified the use of a series of sulfate reducing bacteria (SRB) wetlands for passive treatment of poor quality seepage. However, seepage flow rates have not significantly decreased and the SRB strategy has not proven to be effective in reducing sulfate concentrations. Consequently, active pump-back systems are still being utilised. Following the extreme 2011/2012 wet season, the following additional pump-back locations were installed at the request of DES (formerly DEHP):

- Sedimentation dams HD2, HD3 and HD5
- Managers Creek; and
- South-East Dump seepage point.

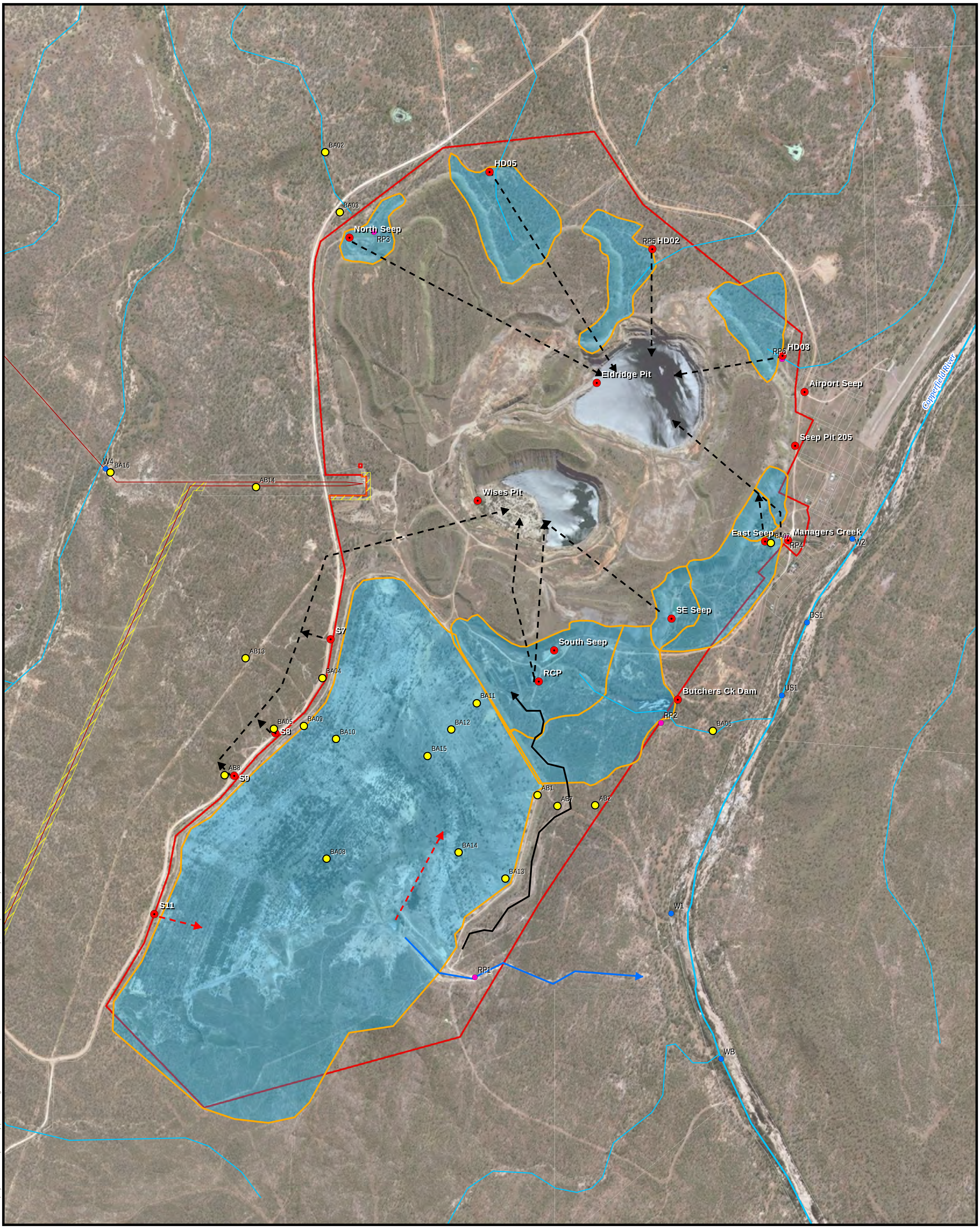
(Barrick Australia, 2013)

Discharge of seepage from the SIS to the receiving environment can occur during periods of intense or prolonged rainfall. SIS pump back locations around the WRDs (refer to Figure 7) are subject to ingress of surface runoff as well as seepage. In addition, surface runoff from the TSF can exceed the capacity of the TSF sediment dam during the wet season. Quantification of the temporality, volume and concentration of discharges from key locations such as the TSF sediment dam has not been undertaken due to a lack of available data. However, examination of baseline receiving environment data (Sections 4.9.3. and 5.6) for monitoring point W2 indicates a localised elevation of key contaminant concentrations which are likely to be as a result of release of seepage water from point sources in the SIS as well and more diffuse subsurface sources entering the Copperfield River at or near to W2.

While the discharge of water from the SIS concurrent with the proposed controlled release of water from the Project is possible during periods of intense or prolonged rainfall, it is noted that:

- Estimation of available assimilative capacity in the receiving environment at the proposed release location (Section 7.1.1) has been informed with water quality data taken from monitoring site W2.
- A review of data for W2 indicates a strong likelihood that water quality at W2 is already impacted by possible discharges (point or diffuse) of poor quality runoff or seepage from the Project site.
- The resultant estimation of available assimilative capacity in the receiving environment therefore includes partial inclusion of the existing contaminant load leaving the Project site.
- Ongoing and proposed additional monitoring (refer to Section 9.2 and Appendix I (Receiving Environment Monitoring Program (REMP)) will allow for the refinement and understanding of the existing potential for export of contaminant loadings from the Project to the receiving environment. This information will be used to revise and update estimations of the available assimilative capacity in the receiving environment and inform refinement of the proposed release conditions as required and outlined in Section 9.1.

Potential changes to the SIS as a result of the Project are not able to be reliably assessed due to a lack of relevant data. However, no significant changes to the SIS are expected as a result of either the construction or operation of the Project. Key activities with the potential to alter fluxes to and from the SIS are related to the excavation and placement of waste rock material from within the existing Wises Pit (refer to Section 4.2.2.5). It is noted however that the contemporary design of the new rock dump will incorporate appropriate drainage arrangements to allow potential seepage from the dump to be contained on site and directed to the Wises and/or Eldridge pits or to one of the existing collection points and pump stations around the site. Detailed design of the new rock dump will determine any requirements for enhanced capture and/or conveyance (i.e. pump transfer capacity) that may be required. It is noted however that the new rock dump will minimise any potential additional contribution of seepage to the existing SIS through contemporary capping design criteria which are designed to minimise infiltration of surface water into the dump.



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DATUM GDA 1994, PROJECTION MGA ZONE 56

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LEGEND

- Groundwater Monitoring Bores
- SIS Pump Back Locations
- Existing Monitoring Point
- Reference Site
- Release Point
- Kidston Substation
- Electrical Network - TR CABLE
- Electrical Network - TR LINE
- Watercourse - Major
- Watercourse - Minor
- Easements
- Cathments
- Site Boundary
- Property Boundaries Queensland
- Pumped To Surface Discharge
- Pumped Seepage Flow
- TSF Seepage Toe Drain
- TS1 Overflow

Data sources:

KIDSTON PUMPED STORAGE HYDRO PROJECT
IMPACT ASSESSMENT REPORT

Existing Surface Water Management and Groundwater Locations

PROJECT ID	60544566
CREATED BY	RF
LAST MODIFIED	RF - 11 Jan 2019
VERSION:	1

Figure
7

A3 size

Filename: P:\605X\60544566\4. Tech Work Area\4.99 GIS\02_MXDs\Hydro\G60544566_002_ExistingWaterManagementt_v4_A4_2018011.mxd

4.4 Pit Water Quality

This section summarises the water quality of the Eldridge and Wises Pits and describes water quality processes operating within the pits. This is undertaken to define the likely range in quality of the water that may be released by the Project. Wises Pit currently has a relatively shallow water column to a depth of ~ 10 m and is expected to be unstratified with homogeneous water quality. In contrast, Eldridge Pit has been filled with water to a depth of ~ 240 m, which has the potential for stratification and varying water quality.

To provide an indication of the possible variation in water quality at depth and to assess the potential impact of this water following transfer to the Wises Pit, two water quality profiling exercises have been undertaken. The first profiling was undertaken by Entura in November 2015 (Entura, 2016). This exercise undertook profiling of the top 200m of the water column in the Eldridge Pit but did not reach the base of the pit. The exercise found that the Eldridge Pit was largely un-stratified in terms of physio-chemical parameters (pH, EC, temperature etc). The second profiling campaign was undertaken by AECOM in March 2018 to confirm the findings of the earlier study and to attempt to analyse the physio-chemical parameters to the base of the pit. Furthermore, additional profiling samples were collected in August 2018 by Genex in order to assess whether similar trends were observed. A summary of all profiling investigations is provided in Appendix C.

Overall, the August 2018 results are comparable to the 2016 Entura profiles. In general, dissolved metal/metalloid concentrations reported from the August 2018 profile sampling are slightly lower than those recorded in 2016. The August 2018 results also indicate an apparent homogeneity along the pit profile. The differences may be due to the different sampling methods (a Niskin bottle was used in the 2016 study, whereas HydraSleeves were employed in the 2018 work) and/or may reflect seasonal variations (the 2016 study was completed in the wet season, whereas the 2018 study was conducted in the dry season).

The 2016 study reported variations in water quality both at the top and the base of the pit profile, which are not observed (or not observed in the same magnitude) in the 2018 investigation. Differences in surface water quality may reflect seasonal variations. The 2016 study may have perturbed the base of the pit leading to marked variations in water quality in the lowest section of the profile; these were not observed in the 2018 study. August 2018 dissolved nickel concentrations are reportedly higher than total nickel concentrations; however, total suspended solids are recorded at or below limits of detection for most of the 2018 profile. In addition, repeat analysis of profile samples indicates that the total and dissolved concentrations are within analytical precision. It is suggested, therefore, that there were very little suspended solids entrained in the water column during sampling and that the total and dissolved concentrations are equivalent.

The water quality statistics for both pits are outlined in Section 4.4.2. As part of this baseline investigation, variations in the water quality since pit rehabilitation have been assessed and are included as time-series trends of key parameters in Appendix D. The conclusions of this section are drawn upon in the assessment of water quality against relevant guideline values.

4.4.1 History of Pit Development

Mining in the Wises Pit ceased in August 1997 and commenced in the Eldridge Pit to 2001 (Metago Environmental Engineers, 2008). The Wises Pit had been installed to 292m AHD, approximately 252m below ground level. The Wises Pit was then backfilled with co-disposed tailings (27 million tonnes) and waste rock (35 million tonnes) from the Eldridge Pit (Metago Environmental Engineers, 2008).

The Eldridge Pit was mined to a depth of approximately 270m below ground level (260m AHD). It was closed and rehabilitated in 2001. A pit lake began to form from groundwater ingress once dewatering had ceased. Rehabilitation of the pit involved accelerated flooding over a five year period to the estimated equilibrium groundwater level (i.e. the level estimated following groundwater rebound and inflow). This was undertaken to cover any exposed potentially acid forming rock and reduce the generation of metalliferous drainage from oxygen ingress. Water was sourced from the Copperfield River Dam as well as Wises Pit and the Tailings Storage Facility to accelerate flooding of the pit to this level. Water was pumped into the pit until a water level of 450m AHD, approximately 80m below the pit's full supply level, was achieved.

Since closure of the mine, seepage from the waste rock dumps into a series of seepage collection dams has been pumped back into the Eldridge and Wises Pits. This seepage pumpback system operates autonomously and is also designed to prevent the uncontrolled discharge of low quality water into the Copperfield River and Charles Creek receiving environments. Data for the pumpback system was only available for 2012 to 2015, but suggests that seepage pumpback water has an average electrical conductivity of between 3,500µS/cm and 4,000µS/cm.

The water quality in the pit since 2001 would therefore be determined by the composition of rocks comprising the Eldridge Pit walls, seepage pumpback water, rainfall and runoff, as well as the composition of water in Eldridge Pit once accelerated flooding activities ceased.

A comprehensive wall wash analysis was undertaken by Australian Laboratory Services (ALS) to determine contaminant generation rates for all rock types found in the pit (Metago Environmental Engineers, 2008). The rock exposure of the Eldridge Pit final wall and floor was mapped as (Metago Environmental Engineers, 2008):

- Einasleigh Metamorphics (51%)
- Quartz feldspar porphyry (1%)
- Metamorphic breccia (36%)
- Sheeted veins and mineralisation (12%).

The above geologies were tested in a comprehensive wall wash analysis (Australasian Groundwater & Enviornmental Consultants, Gilbert & Associates, Dobos & Associates, 2001). Tests indicated that the highest cadmium and zinc concentrations originate from sheeted vein areas and copper, arsenic and sulfate are generated from the breccia zones (Table 6).

Table 6 Contaminant generation rates (mg/m[2] per day) sourced from (Australasian Groundwater & Enviornmental Consultants, Gilbert & Associates, Dobos & Associates, 2001)

	Sheeted Veins		Metamorphic Breccia		Metamorphics		Porphyry	
	Low Generation	High Generation	Low Generation	High Generation	Low Generation	High Generation	Low Generation	High Generation
Ca	2.33	94.3	1.53	116.5	0.238	10.75	0.377	20.7
Mg	0.323	19.9	0.28	21.8	0.015	0.72	0.069	4.3
Na	0.265	16.01	0.53	130.2	0.046	2.12	0.073	5.9
K	0.035	1.9	0.068	6.2	0.015	0.45	0.019	1.02
SO4	8.04	2.96	5.78	484.1	0.417	10.26	1.19	62.2
As	0.115	0.001	0.00015	0.019	0.000068	0.00233	0.0011	0.049
Cd	0.00048	0.061	0.000015	0.009	0.000027	0.00092	0	0
Cu	0.00004	0.015	0.000027	0.0047	0.000014	0.00047	0	0.002
Zn	0.067	3.3	0.00013	0.049	0.000027	0.00092	0.000014	0.003

Heavy metals and sulfide that may be made soluble from the rocks in question largely reside in sulfide minerals. The potential release rate of these metals and sulfate is governed almost wholly by the rate at which oxygen can access sulphide minerals. Generally acidification is also associated with oxygenation of sulfide minerals. However acidification has not been experienced historically in pit waters of the site as a result of high acid neutralising capacity of the host rocks.

4.4.2 Pit Water Quality Assessment

Each pit has been sampled eighteen times over a period of approximately 15 years, which is approximately one sample per year since 2003. Generally, samples were collected towards the end of the dry season in October to November, when the effects of evapo-concentration are the greatest. As a result, the water quality is likely to represent the worst-case in any given year.

All water samples have been collected from the surface of each pit lake close to each access ramp. The sampling regime provides an indication of long-term water quality changes but does not provide an indication of the potential seasonal water quality variability. As outlined above, two depth profile investigations have been conducted (Appendix C). Water quality data for the Eldridge Pit, collected in August 2018 is presented in Appendix J.

Table 7 presents statistics of water quality sampled from each pit. The water quality statistics are compared to the default WQOs applicable to relevant EVs, as set out in Section 5.5. Where applicable, site-specific WQOs (including HMTVs) are used in preference to default WQOs, as justified by an assessment of the baseline water quality in the Copperfield River (refer to Section 5.6).

Cells which exceed the lowest WQO are highlighted in Table 7. Parameters which are elevated above the default WQOs are listed in Table 8.

Table 7 Pit water quality statistics (results are in mg/L unless otherwise stated)

Variable	Site	Num Obs	# Missing	Minimum	10%ile	20%ile	25%ile (Q1)	50%ile (Q2)	75%ile (Q3)	80%ile	90%ile	95%ile	99%ile	Maximum	Mean	SD	Default WQO
pH	E	21	0	7.4	7.5	7.6	7.6	7.85	7.9	7.9	7.93	8	8	8	7.774	0.189	6-8
	W	19	0	7.4	7.7	7.836	7.865	7.92	8.175	8.2	8.24	8.42	8.564	8.6	7.996	0.272	
Electrical Conductivity (EC) (μS/cm)	E	21	0	2000	2200	2300	2310	3020	3340	3360	4100	4150	4662	4790	3017	750.2	500
	W	19	0	3800	4192	4590	4760	5300	6614	7060	8040	8380	9676	10000	5858	1637	
Cations / Anions																	
Calcium	E	9	12	302	313.2	317.2	318	342	400	404	427	461	488.2	495	362.1	62.13	
	W	8	11	452	460.4	484.8	503	585	604	608.2	625	639	650.2	653	558.6	72.94	
Magnesium	E	9	12	77.8	87.56	90.6	91	98	100	102	109.2	117.6	124.3	126	98.42	13.04	
	W	8	11	130	134.9	137.4	137.8	139	144.5	146.6	161.3	175.7	187.1	190	145.6	18.72	
Sodium	E	3	18	41.9	90.92	139.9	164.5	287	296.5	298.4	302.2	304.1	305.6	306	211.6	147.3	
	W	3	16	135.5	226.6	317.7	363.3	591	596	597	599	600	600.8	601	442.5	265.9	
Potassium	E	3	18	44	44	44	44	44	150.7	172	214.7	236.1	253.1	257.4	115.1	123.2	
	W	3	16	116	116.2	116.4	116.5	117	374.8	426.3	529.4	581	622.2	632.5	288.5	297.9	
Chloride	E	3	18	62	66.92	71.84	74.3	86.6	88.8	89.24	90.12	90.56	90.91	91	79.87	15.63	
	W	3	16	181	181	181	181	181	209	214.6	225.8	231.4	235.9	237	199.7	32.33	
Sulfate as SO4	E	21	0	240	1000	1200	1200	1625	1870	2110	2200	2400	2480	2500	1591	546.3	250
	W	19	0	2300	2404	2660	2755	3210	3900	4000	4134	4283	4377	4400	3302	670.2	
Fluoride	E	2	19	2.8	2.85	2.9	2.925	3.05	3.175	3.2	3.25	3.275	3.295	3.3	3.05	0.354	1
	W	2	17	4.3	4.38	4.46	4.5	4.7	4.9	4.94	5.02	5.06	5.092	5.1	4.7	0.566	
Alkalinity	E	3	18	45	46	47	47.5	50	110	122	146	158	167.6	170	88.33	70.77	
	W	3	16	28	40.2	52.4	58.5	89	90	90.2	90.6	90.8	90.96	91	69.33	35.81	
Hardness	E	2	19	1130	1139	1148	1153	1175	1198	1202	1211	1216	1219	1220	1175	63.64	

Variable	Site	Num Obs	# Missing	Minimum	10%ile	20%ile	25%ile (Q1)	50%ile (Q2)	75%ile (Q3)	80%ile	90%ile	95%ile	99%ile	Maximum	Mean	SD	Default WQO
	W	2	17	1700	1702	1704	1705	1710	1715	1716	1718	1719	1720	1720	1710	14.14	
Metals																	
Aluminium (Filtered)	E	9	12	0.005	0.005	0.005	0.005	0.005	0.005	0.011	0.02	0.02	0.02	0.02	0.008	0.006	0.57*
	W	8	11	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0	
Aluminium (Total)	E	20	1	0.005	0.0095	0.01	0.0175	0.025	0.0354	0.05	0.136	0.191	0.206	0.21	0.0477	0.0599	1.52*
	W	18	1	0.0038	0.005	0.005	0.005	0.025	0.025	0.07	0.32	0.399	0.44	0.45	0.081	0.141	
Arsenic (Filtered)	E	8	13	0.01	0.01	0.0108	0.0115	0.0183	0.0335	0.044	0.056	0.056	0.056	0.056	0.0258	0.0196	0.013
	W	7	12	0.0226	0.0258	0.0288	0.03	0.044	0.19	0.223	0.623	0.906	1.133	1.19	0.242	0.426	
Arsenic (Total)	E	20	1	0.012	0.0177	0.0206	0.0218	0.0255	0.0415	0.0526	0.083	0.118	0.232	0.26	0.0466	0.0563	0.01
	W	18	1	0.007	0.0234	0.05	0.05	0.072	0.184	0.206	0.243	0.432	1.158	1.34	0.17	0.302	
Barium (Filtered)	E	1	20	0.036	0.036	0.036	0.036	0.036	0.036	0.036	0.036	0.036	0.036	0.036	0.036	N/A	
	W	1	18	0.038	0.038	0.038	0.038	0.038	0.038	0.038	0.038	0.038	0.038	0.038	0.038	N/A	
Barium (Total)	E	1	20	0.042	0.042	0.042	0.042	0.042	0.042	0.042	0.042	0.042	0.042	0.042	0.042	N/A	1
	W	1	18	0.044	0.044	0.044	0.044	0.044	0.044	0.044	0.044	0.044	0.044	0.044	0.044	N/A	
Beryllium (Filtered)	E	1	20	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	N/A	0.00013
	W	1	18	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	N/A	
Beryllium (Total)	E	1	20	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	N/A	
	W	1	18	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	N/A	
Boron (Filtered)	E	2	19	0.025	0.0288	0.0326	0.0345	0.044	0.0535	0.0554	0.0592	0.0611	0.0626	0.063	0.044	0.0269	0.37
	W	1	18	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	N/A	
Boron (Total)	E	2	19	0.0025	0.00855	0.0146	0.0176	0.0328	0.0479	0.0509	0.057	0.06	0.0624	0.063	0.0328	0.0428	0.5
	W	1	18	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	N/A	
Cadmium	E	8	13	0.0011	0.0093	0.0134	0.0139	0.0217	0.0245	0.0258	0.0287	0.0304	0.0318	0.0321	0.0193	0.0097	0.0003*

Variable	Site	Num Obs	# Missing	Minimum	10%ile	20%ile	25%ile (Q1)	50%ile (Q2)	75%ile (Q3)	80%ile	90%ile	95%ile	99%ile	Maximum	Mean	SD	Default WQO
(Filtered)	W	7	12	0.0002	0.0004	0.0005	0.0005	0.0006	0.0007	0.0008	0.0010	0.0011	0.0012	0.0012	0.0006	0.0003	
Cadmium (Total)	E	20	1	0.0001	0.0005	0.0074	0.0127	0.0210	0.0256	0.0276	0.0366	0.0406	0.0449	0.0460	0.0195	0.0132	
	W	18	1	0.0004	0.0005	0.0005	0.0007	0.0010	0.0016	0.0026	0.0038	0.0041	0.0045	0.0046	0.0016	0.0013	0.002
Cobalt (Filtered)	E	8	13	0.003	0.0037	0.004	0.004	0.005	0.0068	0.0092	0.0171	0.0231	0.0278	0.029	0.0083	0.0087	
	W	7	12	0.0005	0.0005	0.0006	0.0008	0.0020	0.0020	0.0020	0.0100	0.0160	0.0208	0.022	0.0042	0.0078	0.0028
Cobalt (Total)	E	19	2	0.005	0.005	0.005	0.0055	0.025	0.025	0.0282	0.0504	0.456	3.163	3.84	0.223	0.876	
	W	17	2	0.001	0.002	0.002	0.002	0.005	0.025	0.025	0.175	0.438	0.56	0.591	0.0673	0.165	0.05
Chromium (Filtered)	E	8	13	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0000	
	W	7	12	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0000	0.0017*
Chromium (Total)	E	2	19	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0000	
	W	2	17	0.0005	0.0006	0.0006	0.0006	0.0008	0.0009	0.0009	0.0010	0.0010	0.0010	0.0010	0.0008	0.0004	0.05
Copper (Filtered)	E	8	13	0.0005	0.0009	0.0010	0.0010	0.0020	0.0020	0.0020	0.0029	0.0040	0.0048	0.0050	0.0019	0.0014	
	W	7	12	0.0005	0.0008	0.0010	0.0010	0.0010	0.0015	0.0018	0.0032	0.0041	0.0048	0.0050	0.0016	0.0016	0.003*
Copper (Total)	E	19	2	0.0010	0.0020	0.0020	0.0020	0.0050	0.0100	0.0112	0.0232	0.0420	0.0564	0.0600	0.0102	0.0151	
	W	18	1	0.0020	0.0020	0.0024	0.0033	0.0050	0.0058	0.0060	0.0121	0.0249	0.0610	0.0700	0.0088	0.0157	0.2
Iron (Filtered)	E	1	20	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	N/A	
	W	1	18	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	N/A	0.3
Iron (Total)	E	4	17	0.025	0.0325	0.04	0.0438	0.105	0.193	0.212	0.251	0.271	0.286	0.29	0.131	0.121	
	W	4	15	0.025	0.025	0.025	0.025	0.128	0.433	0.554	0.797	0.919	1.016	1.04	0.33	0.483	0.43*
Mercury (Filtered)	E	1	20	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	N/A	
	W	1	18	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	N/A	0.00005
Mercury (Total)	E	1	20	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	N/A	
	W	1	18	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005	N/A	0.001

Variable	Site	Num Obs	# Missing	Minimum	10%ile	20%ile	25%ile (Q1)	50%ile (Q2)	75%ile (Q3)	80%ile	90%ile	95%ile	99%ile	Maximum	Mean	SD	Default WQO
Manganese (Filtered)	E	8	13	0.091	0.273	0.405	0.452	1.235	1.773	2.280	2.860	2.860	2.860	2.860	1.316	1.063	1.9
	W	7	12	0.001	0.001	0.002	0.002	0.003	0.095	0.115	1.005	1.662	2.188	2.320	0.360	0.866	
Manganese (Total)	E	16	5	0.001	0.228	0.484	0.516	1.320	1.925	2.600	3.050	3.373	3.691	3.770	1.473	1.130	0.1
	W	14	5	0.001	0.008	0.025	0.025	0.055	0.087	0.098	0.194	0.950	2.022	2.290	0.220	0.599	
Molybdenum (Filtered)	E	8	13	0.05	0.05	0.05	0.05	0.0565	0.06	0.06	0.0607	0.0615	0.0621	0.0623	0.0557	0.0054	0.034
	W	7	12	0.045	0.0456	0.0472	0.049	0.054	0.0673	0.0728	0.0791	0.0811	0.0826	0.083	0.0592	0.0148	
Molybdenum (Total)	E	19	2	0.012	0.025	0.0382	0.0485	0.053	0.0632	0.0648	0.0678	0.0739	0.0948	0.1	0.0524	0.0202	0.01
	W	17	2	0.025	0.043	0.052	0.056	0.0765	0.23	0.278	0.3	0.304	0.317	0.32	0.134	0.109	
Nickel (Filtered)	E	8	13	0.0020	0.0153	0.0218	0.0225	0.0255	0.0283	0.0286	0.0317	0.0349	0.0374	0.0380	0.0240	0.0103	0.019
	W	7	12	0.0005	0.0005	0.0006	0.0008	0.0020	0.0025	0.0028	0.0058	0.0079	0.0096	0.0100	0.0027	0.0033	
Nickel (Total)	E	19	2	0.0020	0.0164	0.0202	0.0225	0.0250	0.0325	0.0380	0.0424	0.0441	0.0448	0.0450	0.0268	0.0112	0.02
	W	17	2	0.0010	0.0020	0.0020	0.0020	0.0025	0.0150	0.0230	0.0250	0.0400	0.0880	0.1000	0.0134	0.0241	
Lead (Filtered)	E	8	13	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0000	0.0075*
	W	7	12	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0000	
Lead (Total)	E	19	2	0.0005	0.0005	0.0005	0.0005	0.0005	0.0010	0.0010	0.0034	0.0307	0.1580	0.1900	0.0112	0.0434	0.01
	W	17	2	0.0005	0.0005	0.0005	0.0005	0.0020	0.0025	0.0025	0.0082	0.0106	0.0125	0.0130	0.0029	0.0037	
Selenium (Filtered)	E	2	19	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0	0.011
	W	2	17	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0	
Selenium (Total)	E	2	19	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0	0.01
	W	2	17	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0	
Vanadium (Filtered)	E	1	20	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	N/A	0.006
	W	1	18	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	N/A	
Vanadium	E	1	20	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	N/A	0.1

Variable	Site	Num Obs	# Missing	Minimum	10%ile	20%ile	25%ile (Q1)	50%ile (Q2)	75%ile (Q3)	80%ile	90%ile	95%ile	99%ile	Maximum	Mean	SD	Default WQO
(Total)	W	1	18	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	N/A	
Zinc (Filtered)	E	8	13	0.097	0.114	0.124	0.126	0.745	1.2	1.27	1.47	1.61	1.722	1.75	0.761	0.625	0.014*
	W	7	12	0.023	0.0404	0.0538	0.0565	0.106	0.12	0.122	0.205	0.266	0.315	0.327	0.115	0.1	
Zinc (Total)	E	20	1	0.006	0.0145	0.029	0.0353	0.22	0.989	1.238	1.918	2.09	2.242	2.28	0.632	0.76	2
	W	18	1	0.011	0.0345	0.0464	0.0473	0.092	0.149	0.169	0.301	0.727	2.545	3	0.27	0.687	
Nutrients																	
Ammonia	E	2	19	0.2	0.318	0.436	0.495	0.79	1.085	1.144	1.262	1.321	1.368	1.38	0.79	0.834	0.5
	W	2	17	0.1	0.121	0.142	0.153	0.205	0.258	0.268	0.289	0.3	0.308	0.31	0.205	0.148	
Nitrate	E	2	19	5.13	5.162	5.194	5.21	5.29	5.37	5.386	5.418	5.434	5.447	5.45	5.29	0.226	0.7
	W	2	17	0.01	0.039	0.068	0.0825	0.155	0.228	0.242	0.271	0.286	0.297	0.3	0.155	0.205	
Nitrite	E	2	19	0.005	0.0135	0.022	0.0263	0.0475	0.0688	0.073	0.0815	0.0858	0.0892	0.09	0.0475	0.0601	1
	W	2	17	0.005	0.0055	0.006	0.00625	0.0075	0.00875	0.009	0.0095	0.00975	0.00995	0.01	0.0075	0.00354	
TKN	E	1	20	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	N/A	
	W	0	19	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
Total Nitrogen	E	2	19	7	7.02	7.04	7.05	7.1	7.15	7.16	7.18	7.19	7.198	7.2	7.1	0.141	0.15
	W	2	17	0.9	0.91	0.92	0.925	0.95	0.975	0.98	0.99	0.995	0.999	1	0.95	0.0707	
Reactive Phosphorous	E	2	19	0.0050	0.0070	0.0090	0.0100	0.0150	0.0200	0.0210	0.0230	0.0240	0.0248	0.0250	0.0150	0.0141	
	W	2	17	0.0200	0.0220	0.0240	0.0250	0.0300	0.0350	0.0360	0.0380	0.0390	0.0398	0.0400	0.0300	0.0141	
Total Phosphorous	E	2	19	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0	0.01
	W	2	17	0.02	0.027	0.034	0.0375	0.055	0.0725	0.076	0.083	0.0865	0.0893	0.09	0.055	0.0495	
Other																	
Cyanide (Total)	E	3	18	0.002	0.002	0.002	0.002	0.002	1.111	1.333	1.776	1.998	2.176	2.22	0.741	1.281	0.08
	W	3	16	0.002	0.002	0.002	0.002	0.002	0.188	0.225	0.3	0.337	0.367	0.374	0.126	0.215	

Variable	Site	Num Obs	# Missing	Minimum	10%ile	20%ile	25%ile (Q1)	50%ile (Q2)	75%ile (Q3)	80%ile	90%ile	95%ile	99%ile	Maximum	Mean	SD	Default WQO
Cyanide (WAD).	E	13	8	0.002	0.002	0.002	0.002	0.0025	0.0025	0.0025	0.0189	0.0258	0.0292	0.03	0.006	0.00921	
	W	12	7	0.002	0.002	0.002	0.002	0.0025	0.0025	0.0025	0.0111	0.0341	0.0556	0.061	0.008	0.0169	

Notes:

Red values denote a concentration above the default WQO. An exceedance in the release water is not necessarily indicative of an exceedance in the receiving environment.

Analysis included an initial screen of key contaminants; not every constituent with a WQO was analysed.

*Site-specific WQO (refer to Section 5.6.12 for further detail).

Table 8 Parameters exceeding default WQOs in each Pit

Eldridge Pit	Wises Pit
Electrical conductivity	Electrical conductivity
Sulfate	Sulfate
Fluoride	Fluoride
Aluminium (total)	Aluminium (total)
Arsenic (filtered)	Arsenic (filtered)
Arsenic (total)	Arsenic (total)
Cadmium (filtered)	Cadmium (filtered)
Cadmium (total)	Cadmium (total)
Cobalt (filtered)	Cobalt (filtered)
Cobalt (total)	Cobalt (total)
Copper (filtered)	Copper (filtered)
Iron (total)	Iron (total)

Eldridge Pit	Wises Pit
Manganese (filtered)	Manganese (filtered)
Manganese (total)	Manganese (total)
Molybdenum (filtered)	Molybdenum (filtered)
Molybdenum (total)	Molybdenum (total)
Nickel (filtered)	Nickel (total)
Nickel (total)	Lead (total)
Lead (total)	Zinc (filtered)
Zinc (filtered)	Zinc (total)
Zinc (total)	Total Nitrogen
Ammonia as N	Total Phosphorus
Nitrate as N	Cyanide (total)
Total Nitrogen	
Total Phosphorus	
Cyanide (total)	

4.5 Project Water Balance

4.5.1 Overview

The Project site water balance model (WBM) has been developed to assess the site water budget (balance of inputs and outputs to identify water excess or deficit) at a variety of temporal scales and under a range of assumed operating scenarios. A full description of the model, its development and key input data and assumptions is provided in Appendix L. While it is expected that on an annualised basis, the site water balance will typically be negative, there is significant potential for a high degree of inter-annual variability as a result of rainfall variability. The distinct wet season experienced at the Project site results in the majority (88%, 620mm) of the mean annual rainfall total (705mm) occurring during the wet season months of November through March. These short term, rapid influxes of water to the Project (through direct rainfall and runoff) drive a strongly positive, short to medium term water balance that is often compounded by consecutive large, above average wet seasons.

In the absence of a controlled release option, the rapid accumulation of water within the Project during the wet season has the potential to impact both the ability of the Project to meet its power generation obligations whilst also presenting a significant risk to the receiving environment via the uncontrolled discharge of water from the Project.

In order to better understand the overall Project water balance and how the Project may be impacted by the aggregation of excess water within the system, two model scenarios are presented below.

- **A base case** that considers the estimated excess water ingress to the Project assuming the maintenance of the Wises upper reservoir no higher than FSL (RL 551 m AHD). Any excess water in the system above the Wises FSL is considered as excess. Water deficit is any water topup from the Copperfield Dam which is required to maintain Wises upper reservoir at the minimum operating level (MOL) required for power generation.
- **An unmitigated case** that assumes no excess water is removed from the system (i.e. no Type 1 releases). Excess water in the system therefore continues to aggregate above FSL and eventually spillway level when an uncontrolled discharge occurs.

This model simulation is a simple representation of the Project operational phase in the absence of any mitigated measures such as the controlled release of excess water.

4.5.2 Water Balance Metrics

Key metrics for assessing the Project water balance are:

- Project excess water – the volume of water above the Wises upper reservoir FSL. This volume is assumed as excess and removed from the system without reference to any controlled release conditions or opportunity to release. It is a measure of the excess volume of water in the system over and above the FSL.
- Project water deficit – the additional topup water required from the Copperfield Dam to replace evaporative losses. The topup maintains water level in Wises upper reservoir at the MOL.
- The number of days that the water level in the Wises upper reservoir is above the FSL of RL 551 m AHD. Continual or prolonged storage of water above this level progressively reduces the available freeboard allowance and increases the likelihood of uncontrolled discharges either though spillway overflows or wave-induced run-up.
- Uncontrolled releases:
  - Number of days uncontrolled spillway discharges occurred
  - Number of uncontrolled spillway discharge events occurred; and
  - Total uncontrolled spillway discharge volume.

4.5.3 Base Case – Estimated Water Excess and Deficit

Table 9 provides results from the base case water balance based on an annual simulation:

- The overall water balance is negative on an annual basis for all results indicating that replenishment of evaporative losses with additional top-up water will be a normal operating requirement.
- The mean annual excess is 335 ML and the median 94 ML.
- It is noted that excess water volumes have been estimated assuming maintenance of water levels in Wises upper reservoir at or below FSL. Operational phase water management objectives will need to consider potential seasonal requirements for provision of the buffer storage volume below the FSL (refer to Section 4.7.1) in order to provide additional containment capacity for wet season inflows.

Table 9 Base Case Annual Project Water Balance – Estimated Excess and Deficit

Statistic	Annual Water Excess	Annual Water Deficit
	ML/yr.	ML/yr.
Mean	335	1,046
P5	-	608
P10	-	677
P20	-	760
P50	94	950
P80	633	1,349
P90	1,029	1,577
P95	1,290	1,712

4.5.4 Unmitigated Case – Estimated Uncontrolled Releases

In the absence of any controlled releases the continued aggregation of water can eventually result in an uncontrolled spillway discharge. Table 10 shows the estimated number of days the water level in the Wises upper reservoir is in excess of the FSL and the number and volume of uncontrolled discharges:

- The mean number of days Wises upper reservoir is estimated to be above FSL is 85 days per year increasing to 219 days for the P95 result.
- The mean number of uncontrolled releases per year consists of approximately:
  - 4 days
  - 1 event; and
  - A volume of 100 ML.
- The high degree of rainfall variability experienced at the site results in a significant increase in uncontrolled releases for lower probability results such that the P95 result indicates an estimated uncontrolled release of 674 ML.
- Figure 8 shows the estimated probability distribution for uncontrolled releases from the Wises upper reservoir. It can be seen that uncontrolled releases are concentrated in the wet season months of January through March. The estimated frequency and rate of uncontrolled releases becomes increasingly unlikely through April and May.
- Figure 9 shows the estimated probability distribution for water levels in Wises upper reservoir. A distinct seasonal variation can be seen with water levels at their peak through the wet season

months of January through March and, in the absence of any controlled releases, only gradually subside through the following dry season.

- Median water levels can be seen to remain relatively consistent during the months of September to November. This indicates that water levels are being maintained at the MOL through the addition of top-up water from the Copperfield Dam.

Table 10 Unmitigated Case – Uncontrolled Releases

Statistic	Days Wises Above FSL	Uncontrolled Release Days	Uncontrolled Release Events	Uncontrolled Release Volume
	d/yr	d/yr	d/yr	ML/yr
Mean	85	4	1	101
P5	0	0	0	0
P10	0	0	0	0
P20	0	0	0	0
P50	39	0	0	0
P80	202	1	1	20
P90	219	17	3	414
P95	240	24	4	674

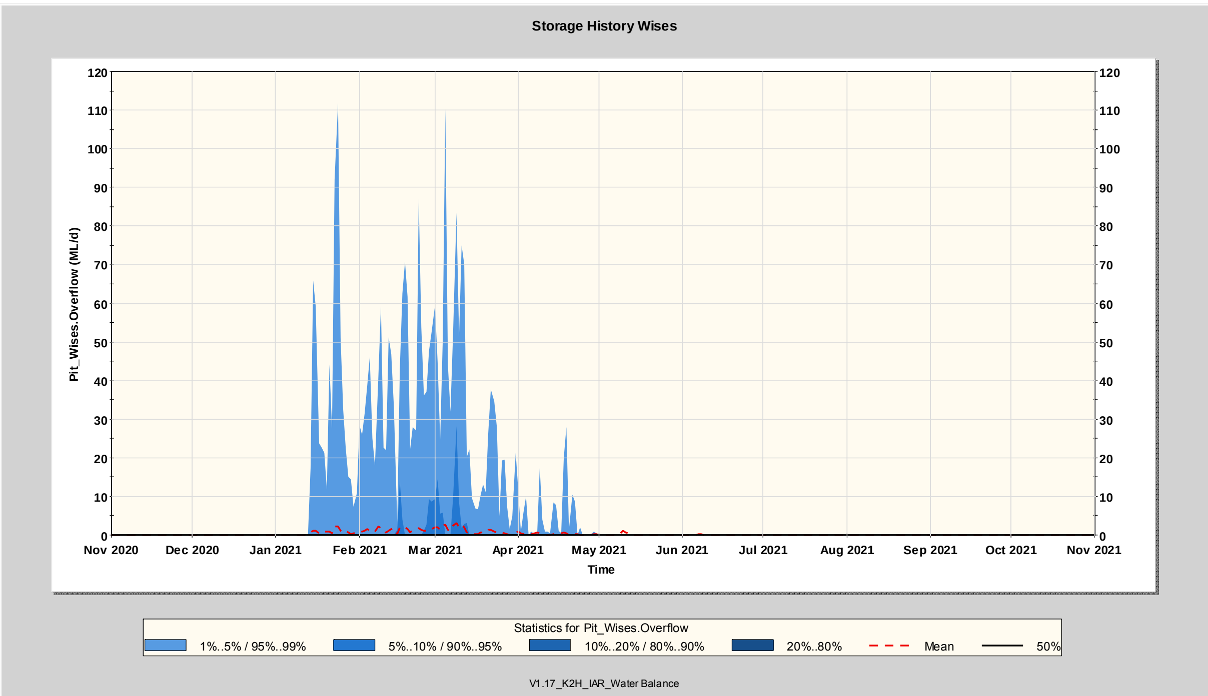


Figure 8 Probability Distribution - Unmitigated Case Wises Upper Reservoir Uncontrolled Releases

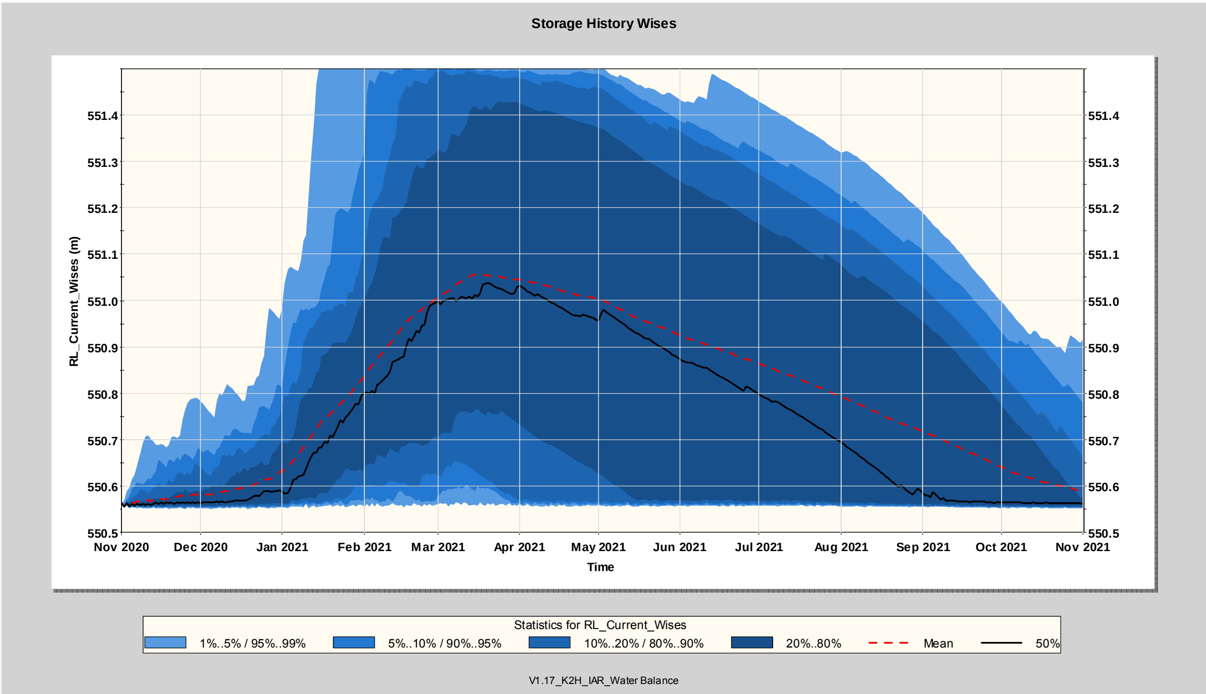


Figure 9 Probability Distribution - Unmitigated Case Wises Upper Reservoir Water Level (Spillway is at 551.5 and FSL at 551.5 m)

4.5.5 Project Water Balance Summary

The results of the base case water balance assessment indicate that on an annualised basis, the Project has a negative water balance and will typically require additional top-up water to replenish evaporative losses. However, due to the pronounced wet season experienced at the Project site the intra-annual water balance is considered to be of much greater significance and the driver of the need to release water from the system.

A positive water balance during the wet season months of January through March is likely to result in the uncontrolled discharge of water from the system and/or loss of power generating opportunity. In the absence of the ability to release excess water, predominately during the wet season, inflows will gradually aggregate in the system until uncontrolled releases of water will occur and/or the duration of a power generation cycle becomes uneconomic (refer to Section 4.2). In addition, the continued aggregation of wet season inflows results in prolonged periods where the estimated water level in the Wises upper reservoir remains above FSL, significantly reduces the ability of the system to contain subsequent inflows without triggering a controlled release.

4.6 Requirement for Water Releases

As discussed above, the Project is subject to a variable water balance which, while largely negative annually, is subject to significant and rapid inflows during the wet season. It is proposed therefore for the Project to periodically release water to the Copperfield River during the operational phase, as well as temporarily during the construction phase as outlined below:

4.6.1 Operational Phase Water Release Objectives

Operational phase water releases may be required in order to:

- Ensure the safe operation of the Wises upper reservoir by, as far as practical, minimising the prolonged storage of water above the FSL.
- Maintain sufficient water storage capacity to temporally contain, without uncontrolled release, inflows from significant wet season inflows.
- Ensure that Project power generation potential is not adversely impacted by the excessive aggregation of excess water within the system.

4.6.2 Construction Phase Water Release Objectives

Construction phase water releases will be required in order to:

- Facilitate the construction of the access and tailrace tunnel works in Eldridge Pit which require the dewatering of Eldridge Pit.
- To maintain the ongoing safety and integrity of key construction activities such as the construction of the tailrace tunnel works by ensuring that water levels in both the Wises upper reservoir and the Eldridge Pit are kept at optimum levels.

4.7 Proposed Water Release Approach

In order to facilitate the release of water from the Project in accordance with the required need to release outlined above, a number of different approaches to water releases are proposed. Each approach is differentiated by the need to respond to different causal events and results in two distinct approaches to the release of water from the Project. However the release location on the Copperfield River will be the same (refer to Section 4.1.2)

4.7.1 Release Event Type 1 - Controlled Discharges to Maintain Water Levels

Operational Phase

The Project has been designed with additional contingency water storage that affords the Project the ability to temporally store up to 500ML of additional water without exceeding the FSL. This buffer compartment therefore gives the Project ability to temporally buffer the rate of water inflow against the opportunity to release excess water (e.g. when the Project is subject to a significantly localised rainfall event that does not generate a requisite opportunity to release).

It is noted that effective use of the buffer compartment will necessitate the use of seasonal operating rules. While these are subject to ongoing definition as the Project design progresses it is noted that:

- During the wet season the effectiveness of the buffer allowance to provide contingency storage and reduce the likelihood of an uncontrolled discharge will be progressively limited as water accumulates in the reservoirs.
- Maintenance of additional water in the buffer allowance in the lead up to, and during the dry season (when the likelihood of significant inflow events is low) provides an opportunity for reduced reliance on an external water source (Copperfield Dam).

Therefore water management objectives for the buffer allowance are likely to be subject to seasonally varying operating rules.

Release of excess water is primarily planned to consist of the controlled release of water during naturally-occurring streamflow events in the Copperfield River. This type of release (Type 1 - Controlled Discharges) will be made to ensure that Project water equilibrium is maintained. Releases will only be made in accordance with the proposed release criteria outlined in Section 9.0. These criteria outline when a release may commence and must stop as well defining the potential rate at which water may be released. The release criteria have been developed to ensure that relevant downstream EVs are protected and that the WQOs are not exceeded. Additional description of release infrastructure is given in Section 4.1.2.

Construction Phase

Potential releases during the construction phase would also utilise a Type 1 controlled release with discharges to the Copperfield River being made at the same location as that utilised by operational phase releases. Proposed release trigger conditions (i.e. minimum streamflow in the Copperfield River at the proposed release point) for construction phase releases (Section 9.0) would also remain the same as per operations. However, due to the additional sensitivity of the Project to further inflows during this critical period releases are proposed to be made at a lower dilution ratio than operational phase releases and with a higher maximum discharge capacity (refer to Section 7.2.1.4). Additional description of release infrastructure is given in Section 4.1.2.

4.7.2 Release Event Type 2 – Pass-Through Discharge

In the event of an extreme rainfall event being forecast (e.g. cyclonic or major regional monsoonal trough, during the operational phase of the Project), a pass-through discharge (Type 2 release event of rainfall may be required. A Type 2 release is considered an option of last resort (i.e. an emergency response) to maintain the integrity of key Project infrastructure, minimise the ingress of excessive volumes of water to the system and to ensure resumption of normal Project operation within as minimal a timeframe as reasonably possible.

A Type 2 release would be achieved by using the pump-turbines in pump back mode to maintain the upper reservoir at spillway level so that any additional rainwater entering the Wises Dam would pass-through the reservoir during the event and discharge via the spillway. Depending on the duration and timing of the event, the power generation cycle would likely be required to stop. It is also likely that some additional Type 1 water releases would need to be made following the rainfall event to remove any surplus water collected in the lower reservoir.

By their definition, Type 2 discharges are considered rare in their occurrence and as such, limited controls are available for the Project to regulate the rate and quality of water being discharged. While a Type 2 pass through discharge is effectively uncontrolled (the rate of release being proportional to the rate of ingress as compared to a Type 1 release where the rate of release is dictated by the availability of a release opportunity and assimilative capacity) cessation of the release could be facilitated at any time by allowing water to pass back into the lower reservoir.

4.7.2.1 Type 2 Releases – Event-Based Hydrologic Assessment

Type 2 discharge events have not been dynamically assessed for causality, frequency or discharge volume and quality. Dynamic operational phase water balance modelling indicates no requirement to make such a release. However, inclusion of this type of release recognises the fact that any open system remains vulnerable to extreme events that may not be present in the recorded climate data. In addition, potential causal events are a function of short to medium term antecedent conditions and contemporary operating conditions. As described in Section 4.2.2.4, potential differences between the rate of water accumulated during storm events and the ability of the Project to compliantly release water have been mitigated through the provision of up to 530 ML of temporary buffer storage. In addition to the buffer volume, an additional 625 ML of storage is possible through utilisation of the freeboard volume between RL 551 and 551.5 m AHD.

In order to assess the potential airspace afforded by both the buffer and freeboard compartments, a volumetric hydrologic assessment has been completed using intensity-frequency-duration date (IFD) sourced from the Bureau of Meteorology (BOM) 2016 IFD service. Key criteria for the assessment have been adopted from Section 2.2.2.1 of the Manual for assessing consequence categories and hydraulic performance of structures[5] (DEHP, 2016):

- Use of the 72-hour duration storm for estimation of the storm event inflow as per estimation of the extreme storm surge (ESS); and
- 100% runoff of all rainfall.

A total of 3 scenarios were assessed as per Table 11. It is reiterated however, that the buffer compartment is only intended to be utilised for short term balancing of stormwater inflows and the ability to release water to the Copperfield River and its availability will be dependent on the final defined seasonal operating rules. Similarly, the freeboard volume is not intended as a water storage compartment. This assessment has been completed to demonstrate, *in the absence of any releases of water*, the estimated stormwater ingress that could be accommodated before an overflow would occur and henceforth, the relatively unlikely need to conduct a Type 2 pass though discharge.

[5] The use of 'The Manual' is not intended to imply regulation of the Project water storage structures, criteria were adopted for comparative purposes only.

Table 11 Event-Based Hydrologic Assessment Scenarios

Scenario	Description	Capacity (ML)	Comments
1	Buffer capacity	530	• Buffer empty at start of event – initial water level of RL 550.56 m AHD • Buffer capacity of 530 ML from RL 550.56 to 551 m AHD • Normal operational conditions – Eldridge lower reservoir maintained at MOL • Instantaneous transfer of direct rainfall and catchment runoff from Eldridge to Wises during 72 hour storm event • 100% runoff of the rainfall from catchment (i.e. runoff coefficient assumed is1.0) • No evaporation was assumed
2	Freeboard capacity	625	• Buffer is full at start of storm event – initial water level of RL 551 m AHD • Freeboard capacity of 625 ML from RL 551 to 551.5 m AHD • No transfer of water from Eldridge to Wises during the storm event – only potential ingress to Wises (direct rainfall) considered • 72-hour storm event, direct rainfall over Wises upper reservoir only considered • No evaporation was assumed
3	Combined buffer and freeboard capacity	1,155	• Buffer and freeboard empty at start of event – initial water level of RL 550.56 m AHD • Buffer and freeboard capacity of 1,155 ML from RL 550.56 to 551.5 m AHD • Normal operational conditions – Eldridge lower reservoir maintained at MOL • Instantaneous transfer of direct rainfall and catchment runoff from Eldridge to Wises during 72 hour storm event • 100% runoff of the rainfall from catchment (i.e. runoff coefficient assumed is1.0) • No evaporation was assumed

Results

Scenario results are presented in Table 12 below:

- Referring to Scenario 1:
  - The buffer compartment, under normal operating conditions is capable of containing at least the 1 in 2 AEP 72-hour storm event;
  - This is indicative of its intended purpose of providing short- to medium-term storage to balance potential stormwater inflows against the ability to release water to the Copperfield River.
- Referring to Scenario 2:
  - Assuming that the buffer compartment was full prior to the storm event and that only the additional contribution of direct rainfall to Wises upper reservoir is included, the freeboard compartment has sufficient capacity to contain the 1 in 2,000 AEP 72-hour storm event without overflow.

- Referring to Scenario 3:
  - Under normal operating conditions, the combined buffer and freeboard compartments are capable of containing up to the 1 in 200 AEP 72-hour event.

Table 12 **Event-Based Hydrologic Assessment of Buffer and Freeboard Compartment Capacity - Results**

AEP	63.2%	50%	20%	10%	5%	2%	1%	1 in 200	1 in 500	1 in 1,000	1 in 2,000
AEP (1 in xx)	1.58	2	5	10	20	50	100	200	500	1,000	2,000
Event Frequency Description	Frequent				Infrequent			Rare			
72-Hour Rainfall Depth (mm)[1]	113	129	180	214	247	291	324	354	396	429	461
Scenario 1 - Buffer compartment (525 ML)											
Estimated 72-hour rainfall event (ML)[2,3]	369	421	***588***	***699***	***806***	***950***	***1,058***	***1,156***	***1,293***	***1,400***	***1,505***
Scenario 2 - Freeboard compartment (625 ML)											
Estimated 72-hour rainfall event (ML)[2]	141	161	225	268	309	364	405	443	495	536	576
Scenario 3 - Combined buffer and freeboard compartments (1,155 ML)											
Estimated 72-hour rainfall event (ML)[2,3]	369	421	588	699	806	950	1,058	***1,156***	***1,293***	***1,400***	***1,505***

Notes:

Bold italics **indicate storm event inflow exceeds nominated scenario capacity**

1 – Bureau of Meteorology (BOM) IFD (2016) for -18.8878 144.1625 (decimal degrees)

2 – As per *Manual for assessing consequence categories and hydraulic performance of structures* (DEHP, 2016),*structures* , sect. 2.2.2.1, use of the 72-hour duration storm for estimation of the extreme storm surge (ESS)

3 – Runoff contribution at 100% of rainfall as per (DEHP, 2016),

4.7.2.2 Summary

In summary, the following points are made in relation to Type 2 pass through discharges:

- Type 2 pass through discharges have been identified as a practical way for the Project to manage rare and extreme storm events. Due to the potential for interruption to the power generation cycle, the semi-uncontrolled nature of the release and the relative rarity of the casual storm events, regular releases of water from the Project via Type 2 pass-through discharges are not expected, not planned and are not the preferred method of water release.
- Continuous, dynamic, life of Project water balance modelling (Section 6.3.1.2) indicates that the proposed operational phase release criteria for Type 1 releases (Section 9.0) are sufficient to negate the requirement for a Type 2 release under the modelled climatic conditions and assumed operational rules. As a result, the causality, frequency, discharge volume or quality of potential Type 2 pass-through discharges has not been identified and cannot be quantified.
- In order to demonstrate the degree of conservatism adopted in the Project design, a volumetric based hydrologic assessment of the potential storage capacity afforded by the buffer and freeboard compartments indicates that *in the unlikely absence of any releases of water to the Copperfield River,* the Project could contain up to the 1 in 200 AEP 72-hour storm event. This is intended to demonstrate the relatively unlikely requirement for a Type 2 discharge. Under normal operations, the ability to discharge excess water afforded by Type 1, controlled releases of water is considered sufficient to maintain Project operations and safeguard the integrity of key infrastructure.
- However, it must be reiterated that any open system remains vulnerable to extreme rainfall events beyond measured climatic data and the identification of potential for a Type 2 discharge is cognisant of this. A Type 2 release provides a practical and safe way to minimise disruptions to Project operations and to safeguard key infrastructure as a result of rare and extreme storm events. Regulation of discharges made via a Type 2 discharge is not considered any more practical than regulation of overflow discharges from any other water containment structure. The Project has demonstrably provided a number of contingency measures (buffer storage compartment, freeboard) as well as the proposed use of Type 1 releases as a way to ensure that the likelihood of a Type 2 discharge is a low a practical. However, the requirement to make a Type 2 discharge, despite its expected rarity, remains the most practical way for the Project to manage extreme and rare events.
- It is noted that if a Type 2 discharge were to be made, a number of potentially mitigating circumstances could limit any potential for harm to downstream environmental values:
  - The magnitude of any causal event leading up to a Type 2 pass through discharge is highly likely to induce a similarly sized streamflow event in the Copperfield River. Water discharged during the Type 2 release is therefore expected to be subject to significant dilution upon entering the Copperfield River.
  - Differences in water density between the incident rainfall and water already within the Project are likely to result in some initial separation. While the rapidity of any potential mixing has not been estimated (and is not proposed), it is possible that the incident rainfall will remain at least partially separated from the higher density pit water during a pass through discharge event. This may potentially afford some additional dilution prior to discharge into the Copperfield River at the proposed discharge point.

Initiation of a Type 2 discharge during the construction phase by raising the water level in the Wises upper reservoir to the spillway elevation preceding the event would not be possible as the pump-turbines would not be available.

4.8 Representative Release Water Quality

Sources of release water for the two Project phases are listed following:

1. Operations phase releases:
   - All releases during the operations phase will consist of a mixture of water from both the Eldridge and Wises Pits.
2. Temporary construction phase releases:
   - During the initial stages of construction, releases will most likely originate from the Eldridge Pit only
   - During the latter stages of construction, it is possible that a mixture of water from both the Eldridge and Wises Pits will be released.

The likely composition of water for mixed releases (i.e. the relative proportion of water from each pit presented as a ratio) is presented in Section 4.8.1 below.

4.8.1 Pit Water Mixture Calculation

The volumes of water within both the Wises Pit and the Eldridge Pit were estimated to calculate the mixing volumes of two waters representing the operational water mixture for the Project, and potentially the latter stages of the construction phase. The following assumptions were incorporated to determine this mixture:

- The water level in the Eldridge Pit at 482.31m AHD represents 28.5GL at ~ 238m depth.
- Wises Pit currently stores 0.8GL as 'free water' at a water surface elevation of 493.7m AHD at ~ 10m depth.
- Water pumped into Wises from Eldridge may also mix with pore water stored in the tailings used to backfill the pit. An estimate of the volume of water that could likely interact with the main body of water in the Wises Pit was assessed based on the following assumptions:
  - A porosity of space of 30% within the tailings.
  - Any water addition or extraction from the Wises Pit may cause water to interact with pore water within 27m of the surface (Genex, *pers. comm*), ~ 14m below the floor of the pit. This is ~ 2.2GL.
  - Therefore the mixture of water in the Wises Pit that would affect the representative sample is ~ 3.0GL.

The representative water mixture for the operation is taken to be 28.5GL of Eldridge Pit water to 3.0GL of Wises Pit water, assuming that pore water up to 14m below the base of the Wises Pit may interact with water stored in the pit as 'free water'. This is a conservative estimate of the potential contribution from the Wises Pit (which generally has poorer water quality). The mixing volumes correspond to 90.5% per volume of Eldridge Pit water to 9.5% per volume of Wises Pit water. This was rounded to 90% Eldridge Pit water and 10% Wises Pit water (i.e. a nine to one ratio of water from the Eldridge Pit versus the Wises Pit).

4.8.2 Sensitivity Analysis for Mixed Releases from Both Pits

In order to determine the potential range of release water quality for mixed releases, various combinations of water qualities were assessed, including:

- 50th percentile of Wises Pit plus 50th percentile of Eldridge Pit mixed together at 1 to 9 ratio
- 80th percentile of Wises Pit plus 80th percentile of Eldridge Pit mixed together at 1 to 9 ratio
- 90th percentile of Wises Pit plus 90th percentile of Eldridge Pit mixed together at 1 to 9 ratio
- 95th percentile of Wises Pit plus 95th percentile of Eldridge Pit mixed together at 1 to 9 ratio
- Maximum of Wises Pit plus maximum of Eldridge Pit mixed together at 1 to 9 ratio

- 50% Eldridge Pit and 50% Wises Pit
  - 50th percentile
  - 80th percentile
  - Maximum
- 20% Eldridge Pit and 80% Wises Pit
  - 50th percentile
  - 80th percentile
  - Maximum
- Depth-averaged values from Entura, 2016 (the maximum from either the Wises or Eldridge Pits)
- Composite 1 sample submitted for Direct Toxicity Assessment (DTA) analysis (refer to Section 4.9 for further detail)
- Composite 2 sample submitted for DTA analysis (refer to Section 4.9 for further detail), with the W2 50th percentile adjusted to equal the Limits of Reporting (LOR) (instead of half of the LOR applied otherwise).

As a result of the sensitivity analysis, it was determined that the 'worst case scenario' (i.e. highest overall parameter concentrations) for a mixed pit water release was achieved by using the maximum concentrations observed over the full dataset, mixed at a ratio of nine parts Eldridge Pit to one part Wises Pit.

4.8.3 Release Water Quality

In summary, the following release water qualities were assessed for the Project:

- Construction Phase:
  - 50th percentile value for Eldridge Pit
  - Historical maximum value for Eldridge Pit
  - 50th percentile value for each pit, mixed at a ratio of nine parts Eldridge to one part Wises
  - Maximum value for each pit, mixed at a ratio of nine parts Eldridge to one part Wises
- Operations Phase:
  - 50th percentile value for each pit, mixed at a ratio of nine parts Eldridge to one part Wises
  - Maximum value for each pit, mixed at a ratio of nine parts Eldridge to one part Wises.

Assumed values for key parameters for releases (prior to mixing in the receiving environment) are presented in Table 13.

Table 13 Release Water Quality Assumptions

Parameter	Units	WQO	Median Value Eldridge Pit	Maximum Value Eldridge Pit	Median Value Mixed at 9 Parts E to 1 part W	Maximum Value Mixed at 9 Parts E to 1 part W
Electrical Conductivity @ 25°C	µS/cm	500	**2950**	**4790**	**3179**	**5311**
Total Hardness as CaCO3	mg/L		1274	1754	1374	1810
Total Alkalinity as CaCO3	mg/L		107.5	170.0	105.7	162.1

Parameter	Units	WQO	Median Value Eldridge Pit	Maximum Value Eldridge Pit	Median Value Mixed at 9 Parts E to 1 part W	Maximum Value Mixed at 9 Parts E to 1 part W
Sulfate as SO4 - Turbidimetric	mg/L	250	**1500**	**2500**	**1671**	**2690**
Chloride	mg/L	175	91	91	100	100
Calcium	mg/L		349	495	372.1	506.8
Magnesium	mg/L		98	126	102	132.4
Sodium	mg/L	115	**287**	**287**	**317.9**	**318.4**
Potassium	mg/L		44	44	51.25	51.3
Aluminium (F)	mg/L	0.57*	0.005	0.02	0.005	0.0185
Arsenic (F)	mg/L	0.013	0.013	**0.056**	**0.0155**	**0.1694**
Beryllium (F)**	mg/L	0.00013	0.0005	0.0005	0.0005	0.0005
Barium (F)	mg/L		0.036	0.036	0.0362	0.0362
Cadmium (F)	mg/L	0.0003*	**0.0203**	**0.0321**	**0.0183**	**0.0290**
Chromium (F)	mg/L	0.0017*	0.0005	0.0005	0.0005	0.0005
Cobalt (F)	mg/L	0.0028	**0.005**	**0.029**	**0.0047**	**0.0283**
Copper (F)	mg/L	0.003*	0.002	**0.005**	0.0019	**0.0047**
Lead (F)	mg/L	0.0075*	0.0005	0.0005	0.0005	0.0005
Manganese (F)	mg/L	1.9	1.21	**2.86**	1.0893	**2.59**
Molybdenum (F)	mg/L	0.034	**0.0565**	**0.06**	**0.05625**	**0.0623**
Nickel (F)	mg/L	0.019*	**0.025**	**0.038**	**0.0227**	**0.0352**
Selenium (F)	mg/L	0.011	0.005	0.005	0.005	0.005
Uranium (F)	mg/L	0.01	NM	NM	NM	NM
Vanadium (F)	mg/L	0.006	0.005	0.005	0.005	0.005
Zinc (F)	mg/L	0.014*	**0.688**	**1.75**	**0.6298**	**1.5874**
Boron (F)	mg/L	0.37	0.025	0.025	0.0285	0.0285
Iron (F)	mg/L	0.3	0.025	0.025	0.025	0.025
Mercury (F)	mg/L	0.00006	0.00005	0.00005	0.00005	0.00005
Aluminium (T)	mg/L	1.52*	0.025	0.21	0.025	0.234
Arsenic (T)	mg/L	0.01	0.026	**0.26**	0.0306	**0.368**
Beryllium (T)	mg/L	0.06	0.0005	0.0005	0.0005	0.0005
Barium (T)	mg/L	1	0.042	0.042	0.0422	0.0422
Cadmium (T)	mg/L	0.002	**0.0221**	**0.046**	**0.01999**	**0.04186**
Chromium (T)	mg/L	0.05	0.0005	0.0005	0.00055	0.00055
Cobalt (T)	mg/L	0.05	0.025	**3.84**	0.02305	**3.52**
Copper (T)	mg/L	0.2	0.005	0.06	0.005	0.061
Lead (T)	mg/L	0.01	0.0005	**0.19**	0.00065	**0.1723**

Parameter	Units	WQO	Median Value Eldridge Pit	Maximum Value Eldridge Pit	Median Value Mixed at 9 Parts E to 1 part W	Maximum Value Mixed at 9 Parts E to 1 part W
Manganese (T)	mg/L	0.1	**1.34**	**3.77**	**1.21**	**3.62**
Molybdenum (T)	mg/L	0.01	**0.052**	**0.1**	**0.054**	**0.122**
Nickel (T)	mg/L	0.02	**0.025**	**0.045**	**0.023**	**0.0505**
Selenium (T)	mg/L	0.01	0.005	NM	0.005	NM
Uranium (T)	mg/L	0.01	NM	NM	NM	NM
Vanadium (T)	mg/L	0.1	NM	NM	NM	NM
Zinc (T)	mg/L	2	0.152	**2.28**	0.1496	**2.35**
Boron (T)	mg/L	0.5	NM	NM	NM	NM
Iron (T)	mg/L	0.43*	0.16	0.225	0.2075	0.3065
Mercury (T)	mg/L	0.001	0.00005	0.00005	0.00005	0.00005
Free Cyanide	mg/L	0.08	NM	NM	NM	NM
Total Cyanide	mg/L		0.002	2.22	0.002	
Weak Acid Dissociable Cyanide	mg/L		0.0025	0.03	0.0025	
Fluoride	mg/L	1	**2.8**	**2.8**	**2.99**	**3.03**
Ammonia as N	mg/L	0.5	0.2	0.2	0.211	0.211
Nitrite as N	mg/L	1	0.005	0.005	0.005	0.005
Nitrate as N	mg/L	0.7	**5.45**	**5.45**	**4.935**	**4.935**
Nitrite + Nitrate as N	mg/L		NM	NM	NM	NM
Total Kjeldahl Nitrogen as N	mg/L		NM	NM	NM	NM
Total Nitrogen as N	mg/L	0.15	**7**	**7**	**6.39**	**6.39**
Total Phosphorus as P	mg/L	0.01	**0.025**	**0.025**	**0.0315**	**0.0315**
Reactive Phosphorus as P	mg/L		NM	NM	NM	NM

NM = Not measured. Analysis included an initial screen of key contaminants; not every constituent with a WQO was analysed.
F = Filtered
T = Total
Values highlighted in grey indicate an exceedance of the WQO pre-release. Note that an exceedance in the release water is not necessarily indicative of an exceedance in the receiving environment.
*Site-specific WQO (refer to Section 5.6.12 for further detail).
**LOR above WQO

4.9 Release Water Toxicity Assessment

4.9.1 Overview

DTA allows for the assessment of the absolute toxicity of discharge waters and the development of a dilution ratio based on laboratory observed impacts to suitable test species. DTA tests are limited to off-the-shelf toxicity tests that utilise standard species (Water Quality and Investigation, Department of Environment and Science, 2018).

Whole of effluent toxicity testing was used in a Species Sensitivity Distribution (SSD) to derive a safe dilution of effluent. The concentration that causes an effect to 10% of the test population (i.e., the EC_{10} value) is used as the input into the SSD. Safe dilution is then extrapolated from the data according to the method of ANZECC & ARMCANZ (2000) to ensure protection of 95% of species in the aquatic ecosystem of the receiving environment. The nature of the test ensures that the dilution ratio between pit water and receiving waters takes into consideration all contaminants, no matter which is the most toxic.

Ecotoxicology testing was undertaken for the Project by Ecotox Services Australia (ESA). Hydrobiology Pty Ltd were commissioned to interpret the ecotoxicology results and to create a SSD for each sample to advise of a dilution ratio between each composite sample and waters from W2 that would achieve a 95% species protection level. The ecotoxicology testing results as well as the assessments by Hydrobiology are provided in Appendix F and Appendix G Release Water (Composite Samples)

Water samples collected from the Eldridge and Wises Pits were mixed at the ratio that is expected to represent the release water quality, to provide an indicator mixed water composition for analysis and ecotoxicology studies.

Eldridge Pit and Wises Pit were sampled on 24 April 2018. These samples were dispatched to ESA for DTA. Instead of the 90% Eldridge – 10% Wises volume mixes, mixtures of 10% Eldridge to 90% Wises were erroneously made up; this mistake was not identified until the results were available from ALS Laboratories and the DTA had been completed. This composite sample is dated 11 May 2018 and is hereafter referred to as “Composite 1”.

The pits were re-sampled on 13 June 2018 and a composite sample was created by AECOM with a mixture of 90% Eldridge and 10% Wises; a composite with the same volume mixes was created independently by ALS Laboratories. This composite was then re-submitted to ESA for DTA analysis. The sample name of this mixture is “Composite Sample 20/06” and is hereafter referred to as “Composite 2”.

The composite samples are discussed below in the context of the historical water quality concentrations in the pits. In addition, sensitivity analysis was conducted on the composite samples to provide an indication of the potential variability in the mixed water concentrations.

4.9.2 Comparison to Historical Water Quality Ranges in the Pits

Composite 2 water sample concentrations were compared to the historical water quality in the Wises and Eldridge Pits (represented as percentile values on box and whisker plots) in and to provide an indication of how the mixture compared to the temporal variations in the pits. Although the Wises Pit shows higher concentrations for a number of parameters (including electrical conductivity, sulfate, lead and molybdenum), the volume of water contributing from the Wises Pit is relatively small (10%), and most concentrations are expected to be reduced when mixed with the greater-volume Eldridge water.

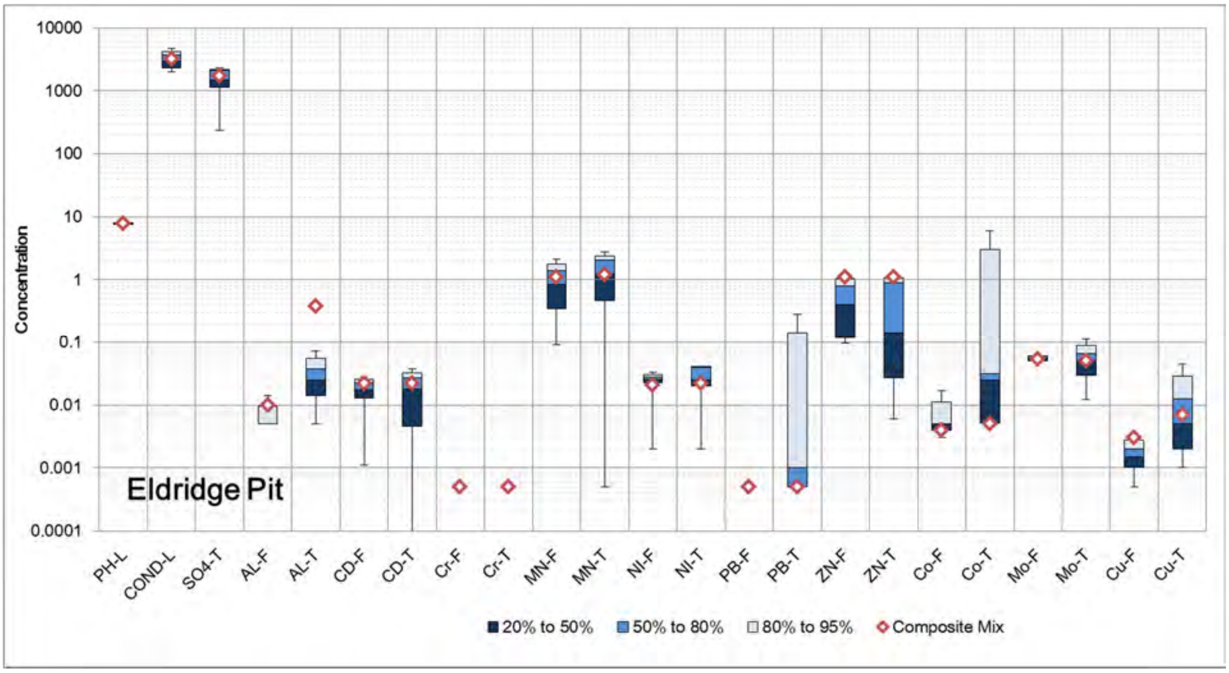


Figure 10 Comparison of composite sample to ranges in the Eldridge Pit

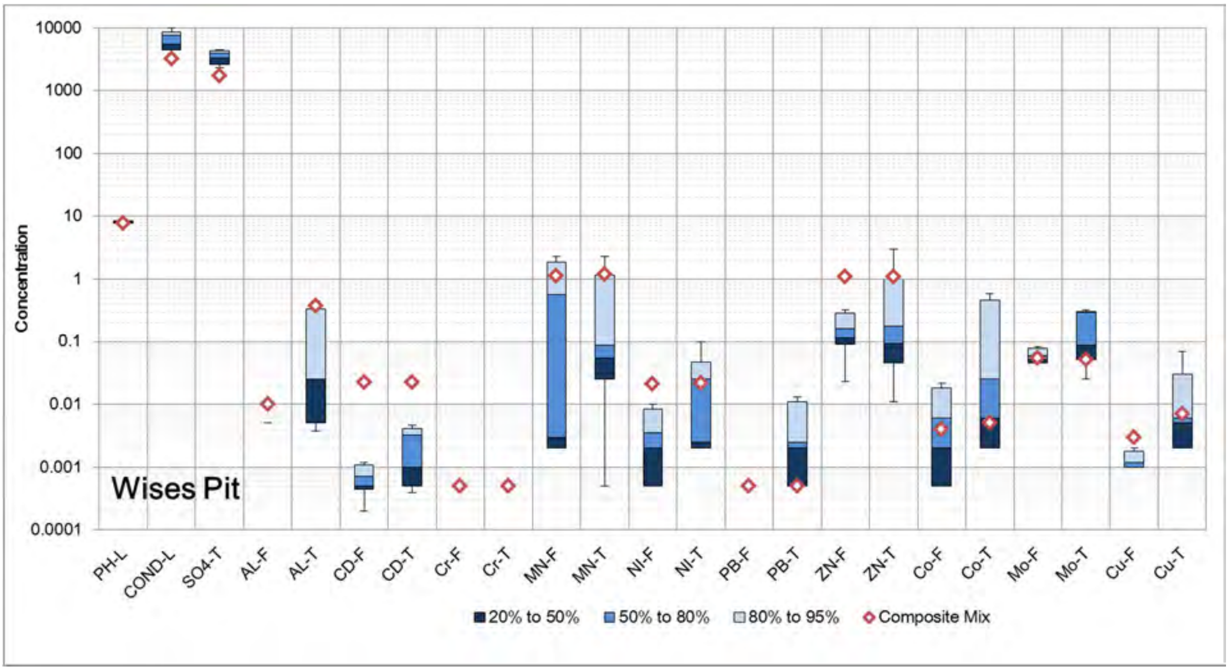


Figure 11 Comparison of the composite sample to ranges in the Wises Pit

Comparison of the Composite 2 concentrations with the historical ranges of the two pits shows the following parameters may be considered ‘low’ in the composite sample compared to the historical data, and may be reported at or below the limits of reporting (LOR):

- Total and dissolved lead
- Total and dissolved cobalt
- Total and dissolved molybdenum.

However, the historical samples themselves generally report these parameters at lower concentrations than parameters such as zinc, which reports among the highest trace-element concentrations and therefore governs the ultimate dilution ratio required to meet the WQOs.

The water quality of each of the samples collected for the DTA is provided in Table 14 and is referred to in the following sections.

Table 14 Water quality of samples submitted for DTA analysis

Parameter	Units	LOR	Composite 1 (10% Eldridge, 90% Wises)		Composite 2 (90% Eldridge, 10% Wises)		Default WQO [SSTV/HMTV]
			Composite	Receiving Environment (W2 May 2018)	Composite	Receiving Environment (W2 June 2018)	
pH Value	pH Unit	0.01	**7.82**	**7.74**	**7.78**	**8.1**	6 – 7.5 [6.0 – 8.4]
Sodium Adsorption Ratio		0.01	6.04	0	4.02	0.62	
Electrical Conductivity @ 25°C	µS/cm	1	**4600**	98	**3210**	153	500
Total Dissolved Solids (Calc.)	mg/L	1	2990	0	2090	99	
Total Hardness as CaCO3	mg/L	1	1530	27	1230	50	
Hydroxide Alkalinity as CaCO3	mg/L	1	0.5		0.5	0.5	
Carbonate Alkalinity as CaCO3	mg/L	1	0.5		0.5	0.5	
Bicarbonate Alkalinity as CaCO3	mg/L	1	84	0	48	60	
Total Alkalinity as CaCO3	mg/L	1	84	43	48	60	
Sulfate as SO4 - Turbidimetric	mg/L	1	**2630**	2	**1720**	7	250
Chloride	mg/L	1	161	6	107	8	175
Calcium	mg/L	1	410	6	338	10	
Magnesium	mg/L	1	124	3	94	6	
Sodium	mg/L	1	544	10	324	10	
Potassium	mg/L	1	110	2	52	2	

Parameter	Units	LOR	Composite 1 (10% Eldridge, 90% Wises)		Composite 2 (90% Eldridge, 10% Wises)		Default WQO [SSTV/HMTV]
			Composite	Receiving Environment (W2 May 2018)	Composite	Receiving Environment (W2 June 2018)	
Aluminium (F)	mg/L	0.01	0.005#	**0.47**	0.01	0.005#	0.055 [0.57]
Arsenic (F)	mg/L	0.001	**0.247**	0.0005	**0.047**	0.0005#	0.013
Beryllium (F)	mg/L	0.001	**0.0005***	NM	**0.0005***	0.0005*#	0.00013
Barium (F)	mg/L	0.001	0.042	NM	0.037	0.023	1
Cadmium (F)	mg/L	0.0001	***0.0012***	0.00005#	**0.0221**	0.00005#	0.0002 [0.0003]
Chromium (F)	mg/L	0.001	0.0005#	0.0005#	0.0005#	0.0005#	0.001 [0.0017]
Cobalt (F)	mg/L	0.001	0.002	0.0005#	**0.004**	0.0005#	0.0028
Copper (F)	mg/L	0.001	**0.002**	0.0005#	**0.003**	0.0005#	0.0014 [0.003]
Lead (F)	mg/L	0.001	0.0005#	0.0005#	0.0005	0.0005#	0.0034 [0.0075]
Manganese (F)	mg/L	0.001	0.236	0.02	1.11	0.004	1.9
Molybdenum (F)	mg/L	0.001	0.042	0.0005#	0.054	0.0005#	
Nickel (F)	mg/L	0.001	0.003	0.0005#	**0.021**	0.0005#	0.011 [0.019]
Selenium (F)	mg/L	0.01	0.005#	NM	0.005#	0.005#	0.011
Uranium (F)	mg/L	0.001	**0.006**	NM	**0.006**	NM	0.0005
Vanadium (F)	mg/L	0.01	0.005	NM	0.005	0.005	0.006
Zinc (F)	mg/L	0.005	***0.08***	0.0025#	**1.09**	0.0025#	0.008 [0.014]
Boron (F)	mg/L	0.05	0.08	NM	0.05	0.025	0.37
Iron (F)	mg/L	0.05	0.025	NM	0.025	0.025	0.3

Parameter	Units	LOR	Composite 1 (10% Eldridge, 90% Wises)		Composite 2 (90% Eldridge, 10% Wises)		Default WQO [SSTV/HMTV]
			Composite	Receiving Environment (W2 May 2018)	Composite	Receiving Environment (W2 June 2018)	
Mercury (F)	mg/L	0.0001	0.00005[#]	NM	0.00005[#]	0.00005[#]	0.00005
Aluminium (T)	mg/L	0.01	0.14	**0.69**	**0.38**	0.06	0.2 [1.52]
Arsenic (T)	mg/L	0.001	**0.25**	0.0005	**0.05**	0.0005	0.01
Beryllium (T)	mg/L	0.001	0.0005	NM	0.0005	0.0005	0.06
Barium (T)	mg/L	0.001	0.043	NM	0.05	0.027	1
Cadmium (T)	mg/L	0.0001	0.0015	0.00005[#]	**0.0222**	0.00005[#]	0.002
Chromium (T)	mg/L	0.001	0.0005[#]	0.0005	0.0005[#]	0.0005[#]	0.05
Cobalt (T)	mg/L	0.001	0.003	0.025	0.005	0.0005[#]	0.05
Copper (T)	mg/L	0.001	0.002	0.0005	**0.007**	0.0005[#]	0.0014
Lead (T)	mg/L	0.001	0.0005[#]	0.0005[#]	0.0005[#]	0.0005[#]	0.01
Manganese (T)	mg/L	0.001	**0.256**	0.028	**1.21**	0.053	0.1
Molybdenum (T)	mg/L	0.001	**0.056**	0.0005[#]	**0.051**	0.0005[#]	0.01
Nickel (T)	mg/L	0.001	0.003	0.0005[#]	**0.022**	0.0005[#]	0.02
Selenium (T)	mg/L	0.01	0.005	NM	0.005	0.005	0.01
Uranium (T)	mg/L	0.001	0.007	NM	0.006	NM	0.01
Vanadium (T)	mg/L	0.01	0.005[#]	NM	0.005[#]	0.005[#]	0.1
Zinc (T)	mg/L	0.005	0.081	0.0025	1.1	0.0025[#]	2
Boron (T)	mg/L	0.05	0.09	NM	0.05	0.0025[#]	0.5
Iron (T)	mg/L	0.05	0.08	***0.71***	***0.6***	0.16	0.2 [0.43]
Mercury (T)	mg/L	0.0001	0.00005[#]	NM	0.0005[#]	0.00005[#]	0.001

Parameter	Units	LOR	Composite 1 (10% Eldridge, 90% Wises)		Composite 2 (90% Eldridge, 10% Wises)		Default WQO [SSTV/HMTV]
			Composite	Receiving Environment (W2 May 2018)	Composite	Receiving Environment (W2 June 2018)	
Free Cyanide	mg/L	0.004	0.002#	NM	NM	NM	
Total Cyanide	mg/L	0.004	0.002#	NM	NM	NM	0.08
Weak Acid Dissociable Cyanide	mg/L	0.004	0.002#	NM	NM	NM	#N/A
Fluoride	mg/L	0.1	**4.9**	NM	**2.8**	0.2	1
Ammonia as N	mg/L	0.01	0.35	NM	0.16	0.02	0.5
Nitrite as N	mg/L	0.01	0.01	NM	0.005	0.005	1
Nitrate as N	mg/L	0.01	0.31	NM	**5.19**	0.005	0.7
Nitrite + Nitrate as N	mg/L	0.01	0.32	NM	5.19	0.005	
Total Kjeldahl Nitrogen as N	mg/L	0.1	0.4	NM	0.6	0.2	
Total Nitrogen as N	mg/L	0.1	**0.7**	NM	**5.8**	**0.2**	0.15
Total Phosphorus as P	mg/L	0.01	**0.09**	NM	**0.03**	0.005	0.01
Reactive Phosphorus as P	mg/L	0.01	0.04	NM	0.01	0.005	

Values in red exceed the default WQO

Italicised values exceed the SSTV/HMTV

Values below the LOR are reported as 50% of the LOR

*LOR above default WQO

NM = Not measured

4.9.3 Dilution Water

W2 is considered to be the most representative location for water quality at the proposed release location within the Copperfield River. Site W2 is in close proximity to the proposed release location and also receives releases from the TSF and overflows from Butchers Creek Dam and Manager's Creek Dam. Historically it has the poorest water quality of all monitored sites in the Copperfield River. Analysis of water quality parameters indicates that the site may be impacted by waters from the historical Kidston mine as a majority of W2 samples show a relationship between EC and SO_4 that is similar to those shown in the pit water (refer Section 5.8). This relationship is not found at the other receiving environment sites.

Concentrations of the W2 samples from are overlaid on the historical distribution of all water quality at the site, and also compared to default WQOs for all EVs in Figure 12. Generally the sample collected in May 2018 and used for the dilution with the incorrect composite sample (Composite 1) shows higher concentrations of aluminium and manganese than the follow up sample taken in June 2018. The sample collected for dilution water for the DTA testing with the correct composite sample (Composite 2) in June shows relatively low concentrations for most metals as well as EC and SO_4 compared to the historical percentiles of each parameter at W2.

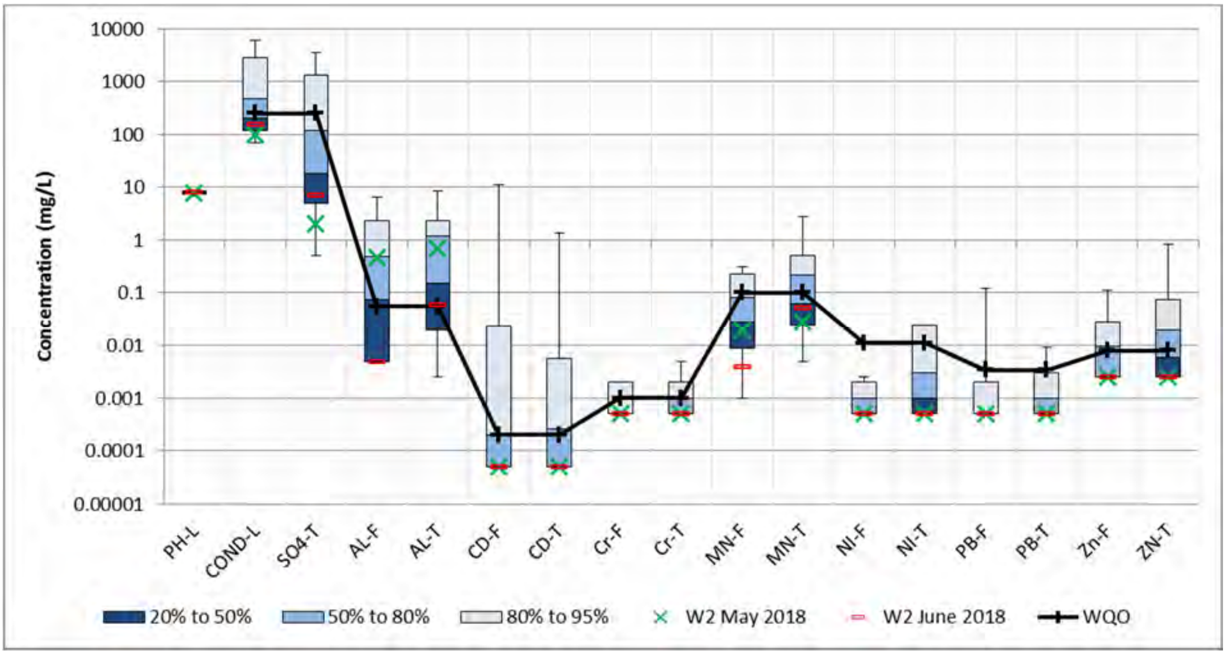


Figure 12 Comparison of W2 dilution water sample with historical distribution and default WQOs

The sample collected from W2 in May 2018 exceeds the default WQO for Aquatic Ecosystems (pH and dissolved aluminium), Long Term Irrigation (total iron) and Recreation (total aluminium). The sample collected from W2 in June 2018 exceeds the default WQO for Aquatic Ecosystems (pH and total nitrogen) (not shown in Figure 12).

4.9.4 Ecotoxicology Tests

A minimum of five tests from four taxonomic groups are required to enable the derivation of safe dilutions of discharges using a species sensitivity distribution (SSD) approach (ANZECC & ARMCANZ, 2000). The following established laboratory tests were undertaken on both DTA samples:

- 96hr growth inhabitation of the freshwater duckweed *Lemna aequinoctialis* (based on OECD method 221, 2006)
- 72hr microalgal growth inhibition (cell yield) test using the freshwater alga *Chlorella vulgaris* (based on USEPA method 1003.0)
- 96hr population growth toxicity test using *Hydra viridissima* (based on Riethmullet et al 2003)

- Fish embryonic development and post-hatch survival toxicity test using the rainbowfish *Melanotaenia splendida splendida* (based on USEPA 2002)
- 7 day reproductive impairment toxicity test using the freshwater cladoceran *Ceriodaphnia dubia* (based on USEPA 2002 and Bailey et al 2000).

The above tests are sub-chronic to chronic tests that are preferred and satisfy the minimum data requirement of ANZECC & ARMCANZ (2000). The majority of these tests have been used to undertake toxicity assessments for mine water releases in the Northern Territory and Queensland (Harford, Trenfield, Cheng, & van Dam, 2014). The occurrence of the species tested is outlined below in Table 15.

Table 15 Occurrence and habitat of species subject to DTA

Common Name	Scientific Name	Occurrence
Freshwater duckweed	*Lemna aequinoctialis*	Widespread in freshwater habitats of tropical areas. Found at Einasleigh
Freshwater algae	*Chlorella vulgaris*	Generic algae species commonly found in waterways
Green hydra	*Hydra viridissima*	Generic hydra found commonly in waterways
Rainbow fish	*Melanotaenia splendida splendida*	Rainbow fish are generally found in streams east of the Great Dividing Range between Gladstone to Cape York Peninsula. They are abundant in almost every kind of freshwater habitat
Water Flea	*Ceriodaphnia dubia*	Generic water flea species found in waterways

The rainbow fish is the only species that is not found at the subject site. Known distributions do not place any of this species in the Gulf Rivers region. Instead the Checkered Rainbowfish (*Melanotaenia splendid inornata*) was found during the Aquatic Ecology survey (Appendix E). The Checkered Rainbowfish is considered an acceptable species to use for DTA assessment at Kidston (refer Section 5.13.6 and Appendix E).

4.9.5 Results

A summary of the release rates calculated by Hydrobiology for the two samples submitted for DTA are presented in Table 16. As is expected, the results indicate that the dilution ratio is required to be much higher for the Composite 1 (with a high percentage of Wises Pit water) than for the more representative discharge ratio Composite 2 (with 90% Eldridge Pit water), which is considered to be more representative of the release water.

Table 16 Dilution ratios from DTA toxicity testing for different species protection levels

Level of Protection	Dilution Ratios for Composite 1 (10% Eldridge, 90% Wises) (May 2018) (Appendix F)	Dilution Ratios for Composite 2 (90% Eldridge, 10% Wises) (June 2018) (Appendix G)
99% species	19.4	1.6
95% species	9.0	1.0
90% species	5.7	0.8
80% species	3.8	0.6

For both samples it appears that EC is the main factor contributing towards toxicity. The most sensitive species to Composite 1 was the *Chlorella vulgaris* where the EC_{10} was estimated to be 11.8% (Appendix F). In Composite 2 the most sensitive species was the freshwater cladoceran, *Ceriodaphnia cf. dubia* where the EC_{10} was estimated to be 54.3% (Appendix G). The EC_{10} for *Ceriodaphnia cf.dubia* in Composite 1 was 30.9%.

The DTA results indicated a minimum dilution ratio required to meet 95% species protection. Both during the construction phase and during the operational phase of the Project, the simulated releases are expected to significantly exceed this minimum dilution ratio, thereby indicating that the proposed releases will not result in toxicity-related impacts to aquatic ecosystems during mixing.

4.10 Unexpected Water Quality Changes

As a contingency management strategy, and in the unlikely event that water quality in the pits should begin to change beyond an acceptable limit for infrastructure (eg. chloride ≤ 100 mg/L), it may be necessary to release additional water from the Project over and above that gained through inflow of rainfall. It is envisaged that this would be managed through the use of a Type 1 release as described above. Based on work undertaken as part of this assessment it is unlikely that such an event would be required. As such this potential scenario is not proposed to be included in this approval application.

4.11 Replenishment of Freshwater

The Project has an annual water allocation of 4,650 ML per annum from the Copperfield Dam under an existing water services agreement between Genex and DNRME. Genex plans to use the water allocation during the construction and operation phases to mitigate the risk of water deficiency caused by extended drought or unforeseen weather events, and to avoid having to supplement water from other sources such as the Copperfield River. It is understood that additional water allocations may be available if required.

Step 2 – Baseline Receiving Environment

“Describe the receiving environment”

5.0 Baseline Receiving Environment

5.1 Overview

The baseline assessment and field investigations included the following elements:

- Comprehensive review of existing information including information provided by Genex and review of site records held by the DES.
- Review of Copperfield River catchment, including climate, geology, soils, land use, water users and an overview of historic releases from the Kidston site.
- Review and assessment of EVs.
- Review of relevant WQOs.
- Review and additional sampling of current water quality characteristics and trends, including an assessment of the relationship between water quality and stream flow and comparison against default WQOs.
- Modelling of Stream hydrology (spells analysis).
- Modelling and assessment of stream hydraulics (HEC-RAS modelling).
- Review of stream geomorphology.
- Review of hydrogeology and surface water interaction.
- Assessment of sediment quality.
- Desktop assessment and field investigation of aquatic ecology values.
- Additional field survey of Copperfield River during the dry season to identify the location of ponded water, and collection of dry season water quality samples.

The findings of the baseline assessment are presented below.

5.2 Copperfield River Catchment Overview

The Copperfield River lies in the Gilbert River basin, draining towards the Gulf of Carpentaria. The nearest townships include Einasleigh to the north and Georgetown to the north-west.

5.2.1 Climate

The climate for the Project site is located within the grassland zone (hot, winter drought), according to the Köppen Classification system. No open Bureau of Meteorology (BoM) weather stations are located within close proximity to the Project site however data is available for the closed Kidston Gold Mine recording station (30027, open 1915 to 2002). Monthly and annual rainfall statistics were obtained for the station from the BoM online climate data service and are presented in Figure 13 and Table 17.

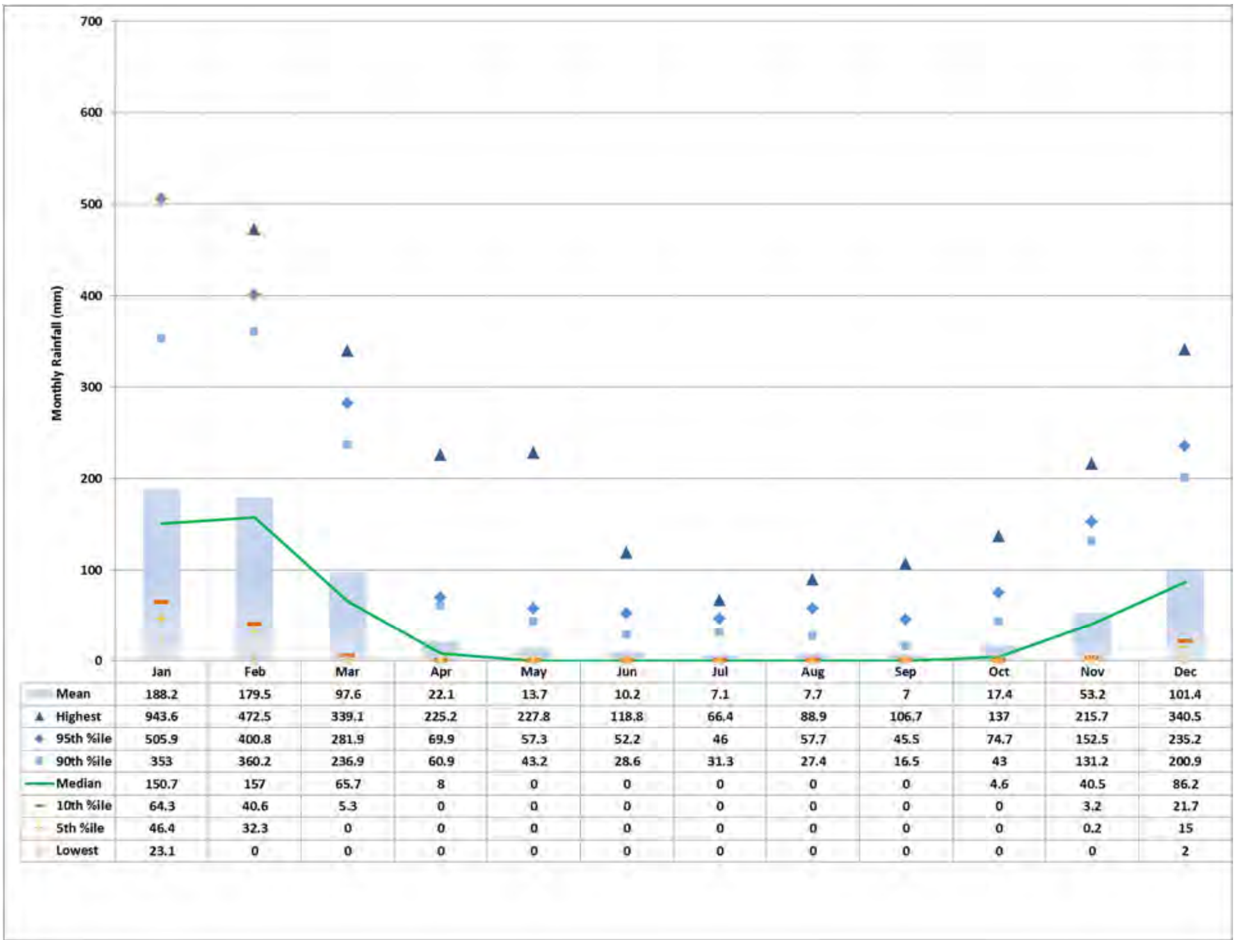
From Table 17 it can be seen that rainfall is seasonally distributed with a distinct wet season typically commencing in November and extending through March. The winter dry season extends from April through October.

The total annual (calendar year) rainfall is highly variable. The 90th and 95th percentile totals represent approximately 145% and 186% of the mean respectively i.e. there is a 10% and 5% probability that annual rainfall may exceed the mean by 145% and 186% respectively.

The majority (88%, 620mm) of the mean annual rainfall total (705mm) occurs during the wet season months of November through March. Mean monthly rainfall during the dry season months of April through October ranges from a minimum of around 7mm per month in July through September to approximately 22mm in April; median rainfall for May through September is zero.

Monthly rainfall variability during the wet season is high with significant potential for both flood and drought. Variability is greatest during January where total rainfall ranges from approximately 47mm (5th percentile) to 506mm (95th percentile).

The closest open temperature recording station for the Project site is located in Georgetown (BoM station 30018, approximately 90 km north west) which indicates that mean daily maximum summer temperatures are around 35-36°C and approximately 12-28°C during winter.



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mean	188.2	179.5	97.6	22.1	13.7	10.2	7.1	7.7	7	17.4	53.2	101.4
Highest	943.6	472.5	339.1	225.2	227.8	118.8	66.4	88.9	106.7	137	215.7	340.5
95th %ile	505.9	400.8	281.9	69.9	57.3	52.2	46	57.7	45.5	74.7	152.5	235.2
90th %ile	353	360.2	236.9	60.9	43.2	28.6	31.3	27.4	16.5	43	131.2	200.9
Median	150.7	157	65.7	8	0	0	0	0	0	4.6	40.5	86.2
10th %ile	64.3	40.6	5.3	0	0	0	0	0	0	0	3.2	21.7
5th %ile	46.4	32.3	0	0	0	0	0	0	0	0	0.2	15
Lowest	23.1	0	0	0	0	0	0	0	0	0	0	2

Figure 13 Monthly Rainfall - Kidston Gold Mine (30027), 1915 – 2002 (BoM)

Table 17 Annual Rainfall Statistics - Kidston Gold Mine (30027), 1915 – 2002 (BoM)

Statistic	Annual Total (mm)
Mean	704.7
Lowest	101.9
5th %ile	346.9
10th %ile	383.7
Median	631.4
90th %ile	998.4
95th %ile	1,276.3
Highest	1,535.2

5.2.2 Geology & Soils

The Project Site is located on the Einasleigh - Copperfield Plain within the geological Pre-Cambrian Georgetown Inlier of the North Australian Craton. The Georgetown Inlier is a member of the Etheridge Province, which represents one of four inliers where Precambrian Paleoproterozoic rocks outcrop in northern Queensland (Jell, 2013).

Regional geology, as described in the 1: 100,000 Einasleigh Sheet (7760) geological map (Department of Natural Resources and Mines (DNRM), 2003a), comprises complex geology inclusive of the Precambrian Einasleigh Metamorphics, Siluro-Devonian Oak River Granodiorite, Carboniferous to Early Permian elements (rhyolite, microgranite, microdiorite, dolerite, gabbro, and andesite), and Quaternary Chudleigh Basalt and alluvial sediments. Further details on geology are found in Section 5.11.1.

Soils were mapped of “rolling metamorphics”, CH (Chromosol) in the Copperfield upstream of the study area and downstream of the dam. The upper catchment around East Creek consists of Calcarosols. Upstream of the Copperfield Dam consists of significant areas of tenosols and rudosols. Downstream, around the confluence with the Oak River, soils change to Sodosols.

5.2.3 Land Use

The dominant land use within the region is agriculture. Up to 95% of the entire Gilbert, Norman and Mitchell basins comprise grazing land uses (Tait, Rizvi, & Waller, 2015). Cattle grazing occupies almost all land uses between the mine site and the Copperfield Dam to the south and extends to Einasleigh in the north. The land use surrounding the Project is consistent with the broader Basin. The surrounds consist predominantly of agricultural land which is primarily used for grazing.

The Project site is a historically disturbed mine site. Directly adjoining the mine is the Kidston Township to the east, and the proposed K2S Project, to the west. Other land uses within immediate proximity to the site, includes transmission lines and road infrastructure.

The Gilbert River Basin has been the focus of specific proposals for ‘green field’ irrigation. More than 6,000 ha of soils moderately suited to irrigated crop production are located downstream of the Copperfield Dam and around the township of Einasleigh (Petheram, Watson, & Stone, 2013). It was determined that while it is physically possible for the Copperfield Dam to support a small irrigation development near the town of Einasleigh, there is limited economic capacity to support a forage-based development under the default price of hay (Petheram, Watson, & Stone, 2013).

There are historical ‘dead’ mining leases in the upstream areas of East Creek. There is minimal data on these historical mining leases but available data from Queensland Spatial shows the following:

- Three mining leases covered 275ha.
- Mining leases consisted of ML3316, ML3322, ML3315.
- All mining leases were approved in 1978 and expired in 1991.
- Authorised entity was Allstate Explorations NL.
- Minerals identified are Copper, Lead, Iron, Molybdenum, Zinc, Uranium and Silver.
- Inspection of aerial photographs does not show any visible signs of historic mining infrastructure or rehabilitated landforms.

The presence of these mining leases implies that there could be historical legacy contamination issues in East Creek which drains into the proposed study area.

5.2.4 Water Users

There are a number of identified water uses within the Project area and surrounds. Identification of water users has been undertaken based on desktop information, and includes the following.

- Copperfield Gorge Dam used for stock and domestic water supply as well as recreation.

- Copperfield Dam is located upstream of the Project and was constructed in 1984 to provide water supply to the Kidston Gold Mine. Lease to the company ended when mining ceased in 2005. Dam is now owned by Queensland and managed by DNRME. In October 3,000ML of water is released from the dam to top up the Einasleigh River downstream for use by local farmers and the Etheridge Shire Council (Petheram, Watson, & Stone, 2013).
    - Releases made from the Copperfield Dam for the supplementation of downstream usage (e.g. the Gorge at Einasleigh) are not anticipated to effect potential discharges of water from the Project. Supplementary releases from the Copperfield Dam occur during the dry season when there are limited drivers for or opportunity to release from the Project.
    - In the event that releases are made from the Copperfield Dam for augmentation of supply to downstream users, no releases would be made from the Project into the streamflow. In addition, the streamflow resulting from such releases is unlikely to exceed the release flow trigger of 400 ML/d.
- A search of the water entitlements database shows that there are no water licences, water permits, seasonal water allocations or interim water allocations from the Copperfield River between the Copperfield Dam and the Einasleigh township.
- A water licence (44967K) held by Department of Environment and Heritage Protection (EHP) for any purpose – Max rate of take = 200L/s, for 4,650ML per year, daily max limit is 16ML/day.

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LEGEND

- Boundary Points
- Water Intake Pipeline
- Key Project Infrastructure Footprint
- Spillway Options Corridor
- Mining Lease Boundary
- K2S Boundary
- Watercourses
- Major Roads
- Minor Roads
- Cadastral Parcel

KIDSTON PUMPED STORAGE HYDRO PROJECT
IMPACT ASSESSMENT REPORT

Indicative Release Location

PROJECT ID	60544566
CREATED BY	RF
LAST MODIFIED	RF - 11 Jan 2019
VERSION:	1

Figure 14

Data sources:

Filename: P:\605X\60544566\4. Tech Work Area\4.99 GIS\02_MXDs\Hydro\60544566_002_Indicative_Project_Area_20190111_A3L_v3.mxd

A3 size

5.2.5 Historical Releases

The Kidston site has historically released water to the receiving environment via a number of mechanisms. An understanding of historical releases is required in order to properly assess the baseline condition of the receiving environment at the time of this application.

Table 18 represents a timeline of known releases from the historical Kidston mine site. This data was assembled from records made available for the site from DES as well as records provided by Genex. The majority of releases have occurred into the Charles Creek catchment, which collects runoff from the western portions of the mining lease and transmits flows towards the Copperfield River downstream from the proposed release area.

Table 18 Timeline of releases

Date	Description of Release
23 February 2014 – 26 March 2014	Discharge of water from the TSF. pH, aluminium and copper exceeded at upstream and downstream sites. However when using 95th percentile of upstream sites compared to impact sites, no exceedance occurs.
February 2013	Transitional Environmental Program (TEP) Approved (MAN17662) to allow mixing zone for discharges to the Copperfield River.
11 September 2009	Water from Butchers Creek lower dam spillway into the Copperfield River. Department of Environment and Heritage Protection (EHP) notified. Water overflow was because of a pump failure. Higher EC was input into the Copperfield River as a result of the TSF. Cadmium had significant number of exceedances. However there are instances which show excess cadmium coming from upstream of WB. Cadmium in the river was higher (0.266mg/L) compared to Butchers Creek (0.04mg/L).
2009	An Environmental Investigation Notice (EIN) was issued in 2009 as a result of discharges to the Charles Creek catchment. A subsequent Environmental Investigation was undertaken and found: • Short term exceedance of trigger limits of sulfate, EC and manganese at W2 occurred but did not produce any likely environmental harm
2008	TEP (MAN4413) granted on 2 December 2008 to collect additional information for the Voluntary Environmental Management Plan (EMP).
5-6 February 2008	Release from the “North Reclaim Dam” following monsoonal storms to the Charles Creek catchment. There was no discharge to the Copperfield River.

Date	Description of Release
2005	Placer Dome submitted a Voluntary EMP with the purposes of improving water quality on site, as well as improving water quality monitoring and reporting frameworks within the EA. There were 6 Action Plans including: • Review trigger levels for sulfate in receiving waters • On site contaminant redirection of discharges • Risk assessment • Fencing of existing dams and drains • Fencing of proposed dams • Research study on the effects of sulfate uptake by cattle
1995	Release of poor quality water from Kidston North Dump Dam. Release from 10^{th} to 16^{th} September into Charles Creek.

Water quality analysis presented in the sections below indicates that the W2 site is potentially impacted by seepage. Review of graphs in Appendix A shows that the site is consistently elevated for a majority of parameters. A potential relationship exists between sulfate and EC in samples from W2 (Section 5.8). However a thorough review of the data of the W2 sampling site shows that it is not possible to definitively separate samples which are impacted by mining activities from samples which are not impacted by mining activities. It is theorised that seepage from waste rock dumps has affected the sampling results at this site. The mechanism for this impact is not known, whether that is seepage from the toes of waste rock dumps which accumulates in pools in the receiving environment, or seepage into shallow groundwater which expresses at the W2 monitoring point.

The available information suggests that there were no long-lasting impacts to the Copperfield River (aside from at W2) as a result of releases to the environment. The majority of releases have been to the Charles Creek catchment.

5.3 Surface Water Quality

5.3.1 Sample Sites and Frequency

Water quality data has been assessed from the monitoring points outlined in Table 19 and Figure 16. Site WB is upstream of all influences of the mine and is used to determine contaminants that enter the Copperfield River upstream from the site. Site W3 is the most downstream site on the Copperfield River and is located at the Gilberton Road crossing used to gain access to the site. E1 and E2 are additional sites on the Copperfield River used to monitor the influence of East Creek. These two monitoring locations were added for the studies supporting this IAR and as such have only been sampled once.

Table 19 Monitoring Locations used to Assess Baseline Quality of Copperfield River in Vicinity of Proposed Release Location

Monitoring Location	Proximity to Proposed Release Location	Easting	Northing	Period of Record	Description
WB	2km upstream	201087	7907273	13/09/2004 – 05/06/2017	Upstream of all historic mining impacts
W1	1.2km upstream	200799	7908133		Copperfield River below the TSF Dam Spillway
W2	1.1km downstream	201851	7910299		Copperfield River below Butchers' Creek Dam and Manager's Creek Dam
W3	7.4km downstream	202667	7915973		Downstream monitoring site at the Causeway
E1#	Additional upstream / control site	203774	7912124	24/03/2018	East Creek 900m upstream of confluence with the Copperfield River
E2#	4.3km downstream	202887	7912971		Copperfield River immediately downstream of the confluence with the East Creek

Additional site added as part of this IAR assessment.

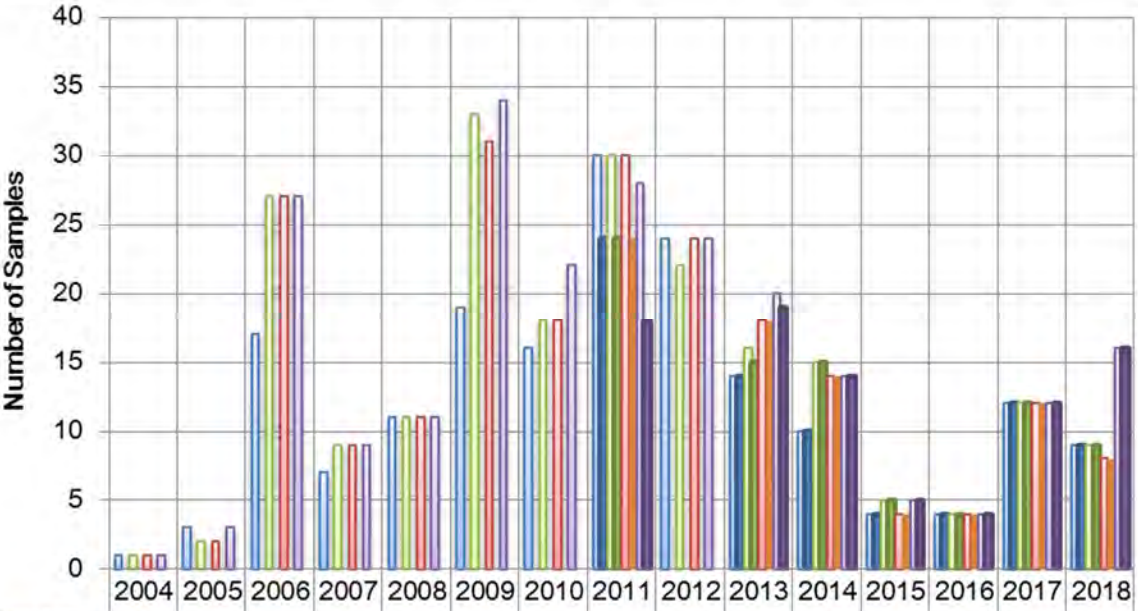
The majority of water quality samples from the monitoring sites were collected from 2009 to 2012, with a lower number of samples collected in 2015 and 2016 (Figure 15). During 2017 there were 12 samples collected from each site (Figure 15).

Not all grab samples were analysed for total as well as dissolved metals. Collection of dissolved metal concentrations following filtration through a 0.45µm filter commenced in 2011. These dissolved fraction samples are required to assess against ANZECC (2000) default WQOs for toxicants while total concentrations are required to assess against WQOs of most other EVs. The number of samples with total metals analysis (T) and filtered metals analysis (F) is shown for each site in Figure 15. There are adequate background water quality samples for calculation of the required statistics as outlined in Section 5.5.3 and no additional reference sites are required.

Metals which have been analysed as part of the historical mining activities at the Kidston site include:

- Aluminium
- Arsenic
- Cadmium
- Chromium (partially)
- Cobalt

- Copper
- Iron (partially)
- Manganese
- Molybdenum
- Nickel
- Lead
- Zinc.



	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
WB-T	1	3	17	7	11	19	16	30	24	14	10	4	4	12	9
WB-F								24	0	14	10	4	4	12	9
W1-T	1	2	27	9	11	33	18	30	22	16	15	5	4	12	9
W1-F								24	0	15	15	5	4	12	9
W2-T	1	2	27	9	11	31	18	30	24	18	14	4	4	12	8
W2-F								24	0	18	14	4	4	12	8
W3-T	1	3	27	9	11	34	22	28	24	20	14	5	4	12	16
W3-F								18	0	19	14	5	4	12	16

Figure 15 Number of Samples per Year since 2003 for Relevant Surface Water Monitoring Sites

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LEGEND

- Monitoring Point
- Existing Release Points
- Key Project Infrastructure Footprint
- Spillway Options Corridor
- Major Watercourse
- Minor Watercourse

Data sources:

KIDSTON PUMPED STORAGE HYDRO PROJECT
IMPACT ASSESSMENT REPORT

Surface Water Sampling Locations

PROJECT ID	60544566
CREATED BY	RF
LAST MODIFIED	RF - 11 Jan 2019
VERSION:	1

Figure
16

5.3.1.1 Water Quality Data Controls and Checks

The water quality database supplied by Genex was screened for water quality data inconsistencies, using the following methods:

- Comparison of the level of dissolved contaminant compared to total contaminant (i.e. whether dissolved zinc was greater than total zinc for that sample). Where these were found, the analyses were removed.
- Values that were below the LOR were transformed to 50% of the LOR (i.e. <0.001 mg/L becomes 0.0005 mg/L) for statistical interrogation.
- All values were graphed and checked visually for obvious outliers.

A number of anomalies were found in the time-histories for receiving environment data, which included:

- Total cadmium concentrations in early 2011 were elevated by several orders of magnitude at all receiving environment sites.
- One total cobalt reading was elevated by several orders of magnitude at W1 in 2006. One reading at W3 in 2006 was an order of magnitude too-low and was potentially a typo.
- An elevated total chromium concentration in March 2011 at WB and W3.
- Total copper concentrations were elevated by several orders of magnitude at WB in one sample from 2007 and 2010, in one sample from 2006 at W1, and in one sample in 2011 at W3.
- Erroneously low values of total manganese in 2007 for W1, March 2009 and September 2011 for WB and January 2012 for W3. These values were excluded from the dataset.
- Elevated values of total nickel at WB and W3 in March 2011, which were several orders of magnitude above surrounding values. It is unknown whether or not these were due to error.
- Elevated value of total lead at W3 in March 2011. It is unknown whether this is a real value, but it is an order of magnitude above all values prior to and following this sampling event. This value corresponds to the elevated total nickel at the time at W3.
- W1 records a total zinc concentration several orders of magnitude above all other values in 2006.

The majority of anomalies in the datasets occur prior to 2012. Therefore the water quality dataset was only analysed for samples which have been collected during or after 2012 for the receiving environment sites. This nevertheless provides a dataset of 40-60 samples with dissolved metal analyses and provides an adequate dataset.

5.3.2 Summary of Water Quality Statistics

Key statistics for receiving environment monitoring locations WB, W1, W2 and W3 are presented in Table 20 to Table 23 respectively. Statistics for both the full dataset and the post 2011 dataset are presented.

Table 20 Summary of Water Quality Data for Monitoring Site WB

Parameter	Unit	LOR	Full dataset							Post 2011 Dataset						
			Count	Min.	P20	P50	P80	P95	Max.	Count	Min.	P20	P50	P80	P95	Max.
pH	pH Unit	0.01	179	6.47	7.378	7.65	7.96	8.16	8.73	77	6.47	7.47	7.73	7.99	8.29	8.73
Electrical Conductivity @ 25°C	µS/cm	1	179	55	88.6	110	190.4	274.2	1200	77	55	88.2	111	218	266	313
Sulfate as SO4 - Turbidimetric	mg/L	1	179	0.5	1	2	4	10.1	24	77	0.5	1	2	4.8	8.6	20
Aluminium (T)	mg/L	0.01	174	0.005	0.025	0.41	1.522	3.948	7.6	77	0.005	0.02	0.54	2.066	3.802	5.57
Arsenic (T)	mg/L	0.001	179	0.0005	0.0005	0.0005	0.002	0.0025	0.005	77	0.0005	0.0005	0.0005	0.001	0.002	0.005
Cadmium (T)	mg/L	0.0001	179	0.00005	0.00005	0.00005	0.0001	0.00205	1.17	77	0.00005	0.00005	0.00005	0.00005	6E-05	0.0009
Cobalt (T)	mg/L	0.001	179	0.0005	0.0005	0.0005	0.0025	0.025	0.05	77	0.0005	0.0005	0.0005	0.0005	0.002	0.003
Chromium (T)	mg/L	0.001	123	0.0005	0.0005	0.0005	0.001	0.003	0.068	77	0.0005	0.0005	0.0005	0.002	0.003	0.005
Copper (T)	mg/L	0.001	179	0.0005	0.0005	0.002	0.005	0.009	0.534	77	0.0005	0.0005	0.002	0.004	0.0082	0.01
Manganese (T)	mg/L	0.001	150	0.0025	0.0238	0.0365	0.0822	0.28535	0.988	77	0.009	0.024	0.047	0.1114	0.443	0.988
Molybdenum (T)	mg/L	0.001	179	0.0005	0.0005	0.0005	0.0025	0.025	0.025	77	0.0005	0.0005	0.0005	0.0005	0.0005	0.007
Nickel (T)	mg/L	0.001	179	0.0005	0.0005	0.001	0.003	0.025	0.055	77	0.0005	0.0005	0.0005	0.002	0.003	0.004
Lead (T)	mg/L	0.001	179	0.0005	0.0005	0.0005	0.001	0.005	0.007	77	0.0005	0.0005	0.0005	0.002	0.006	0.007
Zinc (T)	mg/L	0.005	179	0.0025	0.0025	0.0025	0.0124	0.0271	0.5	77	0.0025	0.0025	0.0025	0.0108	0.028	0.074
Free Cyanide	mg/L	0.004	52	0.002	0.002	0.002	0.002	0.002	0.002	52	0.002	0.002	0.002	0.002	0.002	0.002
WAD Cyanide	mg/L	0.004	123	0.002	0.002	0.002	0.0025	0.0025	0.014	24	0.002	0.002	0.002	0.002	0.002	0.002
Total Alkalinity as CaCO3	mg/L	1	3	30	36	45	53.4	57.6	59	1	45	45	45	45	45	45

Parameter	Unit	LOR	Full dataset							Post 2011 Dataset						
			Count	Min.	P20	P50	P80	P95	Max.	Count	Min.	P20	P50	P80	P95	Max.
Iron (T)	mg/L	0.05	17	0.01	0.062	0.16	0.432	0.728	0.96	1	0.67	0.67	0.67	0.67	0.67	0.67
Calcium	mg/L	1	53	0.5	3.8	7	14	18.8	24	52	0.5	3.4	7	14	18.9	24
Magnesium	mg/L	1	54	0.5	2	4	9	12	17	53	0.5	2	4	9	12	17
Sodium	mg/L	1	3	0.001	3.9206	9.8	9.92	9.98	10	1	10	10	10	10	10	10
Potassium	mg/L	1	2	2	2	2	2	2	2	1	2	2	2	2	2	2
Chloride	mg/L	1	3	0.82	2.892	6	6	6	6	1	6	6	6	6	6	6
Aluminium (F)	mg/L	0.01	123	0.005	0.005	0.22	0.568	2.867	5.14	77	0.005	0.005	0.28	0.818	3.09	5.14
Arsenic (F)	mg/L	0.001	77	0.0005	0.0005	0.0005	0.0005	0.0012	0.004	53	0.0005	0.0005	0.0005	0.0005	0.002	0.004
Cadmium (F)	mg/L	0.0001	77	0.00005	0.00005	0.00005	0.00005	0.0002	0.519	53	0.00005	0.00005	0.00005	0.00005	0.00005	0.00005
Cobalt (F)	mg/L	0.001	77	0.0005	0.0005	0.0005	0.0005	0.001	0.002	53	0.0005	0.0005	0.0005	0.0005	0.001	0.002
Chromium (F)	mg/L	0.001	77	0.0005	0.0005	0.0005	0.0005	0.001	0.002	53	0.0005	0.0005	0.0005	0.0005	0.001	0.002
Copper (F)	mg/L	0.001	77	0.0005	0.0005	0.002	0.003	0.005	0.015	53	0.0005	0.0005	0.002	0.003	0.005	0.015
Manganese (F)	mg/L	0.001	77	0.0005	0.003	0.016	0.0478	0.2892	0.877	53	0.0005	0.01	0.029	0.0888	0.3612	0.877
Molybdenum (F)	mg/L	0.001	77	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	53	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005
Nickel (F)	mg/L	0.001	77	0.0005	0.0005	0.0005	0.0005	0.0012	0.0025	53	0.0005	0.0005	0.0005	0.001	0.002	0.0025
Lead (F)	mg/L	0.001	77	0.0005	0.0005	0.0005	0.0005	0.002	0.582	53	0.0005	0.0005	0.0005	0.001	0.002	0.582
Zinc (F)	mg/L	0.005	77	0.0005	0.0025	0.0025	0.006	0.0114	0.019	53	0.0005	0.0025	0.0025	0.005	0.0112	0.019
Bicarbonate	mg/L	1	2	54.9	58.316	63.44	68.564	71.126	71.98	1	54.9	54.9	54.9	54.9	54.9	54.9
Total Dissolved Solids	mg/L	1	1	62	62	62	62	62	62	1	62	62	62	62	62	62
Hardness	mg/L	1	53	3.3	17.7	33.9	71.9	91.74	124.7	52	3.3	16.7	33.9	71.9	91.945	124.7

Parameter	Unit	LOR	Full dataset							Post 2011 Dataset						
			Count	Min.	P20	P50	P80	P95	Max.	Count	Min.	P20	P50	P80	P95	Max.
Selenium (F)	mg/L	0.01	1	0.005	0.005	0.005	0.005	0.005	0.005	1	0.005	0.005	0.005	0.005	0.005	0.005
Iron (F)	mg/L	0.05	1	0.21	0.21	0.21	0.21	0.21	0.21	1	0.21	0.21	0.21	0.21	0.21	0.21
Selenium (T)	mg/L	0.01	1	0.005	0.005	0.005	0.005	0.005	0.005	1	0.005	0.005	0.005	0.005	0.005	0.005

Table 21 Summary of Water Quality Data for Monitoring Site W1

Parameter	Unit	LOR	Full dataset						Post 2011 Dataset					
			Count	Min.	P20	P50	P80	P95	Max.	Count	Min.	P20	P50	P80	P95	Max.
pH	pH Unit	0.01	207	5.66	7.40	7.69	8.00	8.33	9.10	83	6.7	7.46	7.75	8.00	8.38	9.05
Electrical Conductivity @ 25°C	µS/cm	1	207	63	96.2	139	244	352.4	3420	83	70	95.8	135	235	312.8	3420
Sulfate as SO4 - Turbidimetric	mg/L	1	207	0.5	1.2	4	12	80.7	634	83	0.5	2	4	11.6	36.7	634
Aluminium (T)	mg/L	0.01	209	0.005	0.025	0.24	1.418	2.96	7.15	83	0.005	0.054	0.55	1.512	2.817	5.11
Arsenic (T)	mg/L	0.001	214	0.00025	0.0005	0.0005	0.0015	0.003	0.007	83	0.0005	0.0005	0.0005	0.002	0.003	0.007
Cadmium (T)	mg/L	0.0001	214	0.00005	0.00005	0.00005	0.0002	0.01185	0.708	83	0.00005	0.00005	0.00005	0.00005	0.00058	0.0024
Cobalt (T)	mg/L	0.001	214	0.00025	0.0005	0.0005	0.005	0.025	0.47	83	0.0005	0.0005	0.0005	0.0005	0.002	0.005
Chromium (T)	mg/L	0.001	147	0.0005	0.0005	0.0005	0.001	0.004	0.009	83	0.0005	0.0005	0.0005	0.001	0.0029	0.006
Copper (T)	mg/L	0.001	214	0.0005	0.001	0.002	0.005	0.0187	3.2	83	0.0005	0.001	0.002	0.004	0.0107	0.114
Manganese (T)	mg/L	0.001	176	0.00025	0.025	0.0405	0.094	0.211	0.459	83	0.016	0.0284	0.046	0.102	0.1906	0.459
Molybdenum (T)	mg/L	0.001	214	0.00025	0.0005	0.0005	0.0074	0.025	0.025	83	0.0005	0.0005	0.0005	0.0005	0.0019	0.002
Nickel (T)	mg/L	0.001	214	0.0005	0.0005	0.001	0.003	0.025	0.54	83	0.0005	0.0005	0.0005	0.001	0.003	0.005
Lead (T)	mg/L	0.001	214	0.0005	0.0005	0.0005	0.001	0.003	0.012	83	0.0005	0.0005	0.0005	0.001	0.0086	0.012
Zinc (T)	mg/L	0.005	214	0.00025	0.0025	0.0055	0.016	0.06275	53	83	0.0025	0.0025	0.0025	0.009	0.0893	0.177
Free Cyanide	mg/L	0.004	59	0.002	0.002	0.002	0.002	0.002	0.005	59	0.002	0.002	0.002	0.002	0.002	0.005
WAD Cyanide	mg/L	0.004	153	0.00025	0.00025	0.002	0.002	0.0025	0.012	23	0.002	0.002	0.002	0.002	0.002	0.012

Parameter	Unit	LOR	Full dataset							Post 2011 Dataset						
			Count	Min.	P20	P50	P80	P95	Max.	Count	Min.	P20	P50	P80	P95	Max.
Total Alkalinity as CaCO3	mg/L	1	3	42	42.4	43	53.2	58.3	60	1	43	43	43	43	43	43
Iron (T)	mg/L	0.05	22	0.025	0.09	0.205	0.432	0.8905	0.95	1	0.71	0.71	0.71	0.71	0.71	0.71
Calcium	mg/L	1	60	2	5	8	13	18.05	20	59	2	5	8	13	18.1	20
Magnesium	mg/L	1	61	1	2	5	10	14	16	60	1	2	5	10	14	16
Sodium	mg/L	1	2	9	9.4	10	10.6	10.9	11	1	11	11	11	11	11	11
Potassium	mg/L	1	2	1.8	1.84	1.9	1.96	1.99	2	1	2	2	2	2	2	2
Chloride	mg/L	1	2	5	5.2	5.5	5.8	5.95	6	1	5	5	5	5	5	5
Aluminium (F)	mg/L	0.01	138	0.005	0.005	0.13	0.552	2.1195	5.71	83	0.005	0.005	0.19	0.776	2.727	5.71
Arsenic (F)	mg/L	0.001	84	0.0005	0.0005	0.0005	0.001	0.00285	0.005	60	0.0005	0.0005	0.0005	0.001	0.003	0.005
Cadmium (F)	mg/L	0.0001	84	0.00005	0.00005	0.00005	0.00005	0.00131	0.591	60	0.00005	0.00005	0.00005	0.00005	0.00005	0.0014
Cobalt (F)	mg/L	0.001	84	0.0005	0.0005	0.0005	0.0005	0.001	0.002	60	0.0005	0.0005	0.0005	0.0005	0.000525	0.001
Chromium (F)	mg/L	0.001	84	0.0005	0.0005	0.0005	0.0005	0.001	0.002	60	0.0005	0.0005	0.0005	0.0005	0.002	0.002
Copper (F)	mg/L	0.001	84	0.0005	0.0005	0.002	0.0034	0.005	0.024	60	0.0005	0.0005	0.002	0.004	0.005	0.006
Manganese (F)	mg/L	0.001	84	0.0005	0.0036	0.012	0.0254	0.0557	0.162	60	0.0005	0.007	0.017	0.0282	0.0567	0.1
Molybdenum (F)	mg/L	0.001	84	0.0005	0.0005	0.0005	0.0005	0.001	0.003	60	0.0005	0.0005	0.0005	0.0005	0.001	0.002
Nickel (F)	mg/L	0.001	84	0.0005	0.0005	0.0005	0.0005	0.002	0.003	60	0.0005	0.0005	0.0005	0.0006	0.002	0.0025
Lead (F)	mg/L	0.001	84	0.0005	0.0005	0.0005	0.0005	0.002	0.033	60	0.0005	0.0005	0.0005	0.0006	0.002	0.033
Zinc (F)	mg/L	0.005	84	0.0025	0.0025	0.0025	0.007	0.01455	0.237	60	0.0025	0.0025	0.0025	0.008	0.012	0.077
Bicarbonate	mg/L	1	1	52.46	52.46	52.46	52.46	52.46	52.46	1	52.46	52.46	52.46	52.46	52.46	52.46

Parameter	Unit	LOR	Full dataset							Post 2011 Dataset						
			Count	Min.	P20	P50	P80	P95	Max.	Count	Min.	P20	P50	P80	P95	Max.
Total Dissolved Solids	mg/L	1	1	61	61	61	61	61	61	1	61	61	61	61	61	61
Hardness	mg/L	1	60	9.1	20.7	40.5	76.32	98.315	104.9	59	9.1	20.7	40.5	76.64	98.53	104.9
Selenium (F)	mg/L	0.01	1	0.005	0.005	0.005	0.005	0.005	0.005	1	0.005	0.005	0.005	0.005	0.005	0.005
Iron (F)	mg/L	0.05	1	0.23	0.23	0.23	0.23	0.23	0.23	1	0.23	0.23	0.23	0.23	0.23	0.23
Selenium (T)	mg/L	0.01	1	0.005	0.005	0.005	0.005	0.005	0.005	1	0.005	0.005	0.005	0.005	0.005	0.005

Table 22 Summary of Water Quality Data for Monitoring Site W2

Parameter	Unit	LOR	Full dataset							Post 2011 Dataset						
			Count	Min.	P20	P50	P80	P95	Max.	Count	Min.	P20	P50	P80	P95	Max.
pH	pH Unit	0.01	206	6.82	7.40	7.72	8.00	8.39	8.81	84	6.89	7.52	7.77	8.00	8.55	8.81
Electrical Conductivity @ 25°C	µS/cm	1	206	68	120	203	479	2825	6100	84	68	106	170	294.8	556.1	910
Sulfate as SO4 - Turbidimetric	mg/L	1	206	0.5	5	18	118	1300	3600	84	0.5	4	10.5	31.4	121.5	260
Aluminium (T)	mg/L	0.01	208	0.0025	0.02	0.15	1.17	2.2965	8.61	84	0.005	0.02	0.455	1.396	2.02	3.92
Arsenic (T)	mg/L	0.001	213	0.0005	0.0005	0.002	0.005	0.0194	0.039	84	0.0005	0.0005	0.001	0.003	0.01085	0.032
Cadmium (T)	mg/L	0.0001	213	0.00005	0.00005	0.00005	0.00026	0.00552	1.38	84	0.00005	0.00005	0.00005	0.00005	0.000185	0.0013
Cobalt (T)	mg/L	0.001	213	0.0005	0.0005	0.0005	0.004	0.025	0.025	84	0.0005	0.0005	0.0005	0.0005	0.002	0.003
Chromium (T)	mg/L	0.001	139	0.0005	0.0005	0.0005	0.001	0.002	0.005	84	0.0005	0.0005	0.0005	0.001	0.002	0.005
Copper (T)	mg/L	0.001	213	0.0005	0.0005	0.002	0.005	0.0094	0.024	84	0.0005	0.0005	0.002	0.003	0.00585	0.018
Manganese (T)	mg/L	0.001	174	0.005	0.025	0.0625	0.217	0.545	2.81	84	0.008	0.0332	0.075	0.226	0.3893	1.72
Molybdenum (T)	mg/L	0.001	213	0.0005	0.0005	0.001	0.025	0.0258	0.12	84	0.0005	0.0005	0.0005	0.001	0.003	0.006
Nickel (T)	mg/L	0.001	213	0.0005	0.0005	0.001	0.003	0.025	0.025	84	0.0005	0.0005	0.0005	0.001	0.002	0.004
Lead (T)	mg/L	0.001	213	0.0005	0.0005	0.0005	0.001	0.003	0.009	84	0.0005	0.0005	0.0005	0.001	0.003	0.009
Zinc (T)	mg/L	0.005	213	0.0025	0.0025	0.006	0.02	0.0762	0.84	84	0.0025	0.0025	0.0025	0.0108	0.0294	0.115
Free Cyanide	mg/L	0.004	59	0.002	0.002	0.002	0.002	0.002	0.008	59	0.002	0.002	0.002	0.002	0.002	0.008
WAD Cyanide	mg/L	0.004	153	0.002	0.002	0.002	0.0025	0.0025	0.067	24	0.002	0.002	0.002	0.002	0.002	0.031
Total Alkalinity as CaCO3	mg/L	1	3	30	35.2	43	53.2	58.3	60	1	43	43	43	43	43	43

Parameter	Unit	LOR	Full dataset							Post 2011 Dataset						
			Count	Min.	P20	P50	P80	P95	Max.	Count	Min.	P20	P50	P80	P95	Max.
Iron (T)	mg/L	0.05	21	0.025	0.07	0.22	0.59	0.71	1.2	1	0.71	0.71	0.71	0.71	0.71	0.71
Calcium	mg/L	1	60	3	6	12	19.2	34	41	59	3	6	12	19.4	34	41
Magnesium	mg/L	1	61	1	3	7	12	20	30	60	1	3	7	12.4	20.15	30
Sodium	mg/L	1	10	0.0005	0.0005	0.004	1.8888	9.73	10	1	10	10	10	10	10	10
Potassium	mg/L	1	2	1.8	1.84	1.9	1.96	1.99	2	1	2	2	2	2	2	2
Chloride	mg/L	1	10	0.005	0.044	0.07	1.352	6	6	1	6	6	6	6	6	6
Aluminium (F)	mg/L	0.01	130	0.005	0.005	0.075	0.482	2.36	6.48	84	0.005	0.005	0.16	0.808	3.016	6.48
Arsenic (F)	mg/L	0.001	84	0.0005	0.0005	0.0005	0.002	0.005	0.022	60	0.0005	0.0005	0.0005	0.002	0.00905	0.022
Cadmium (F)	mg/L	0.0001	84	0.00005	0.00005	0.00005	0.0002	0.023875	10.9	60	0.00005	0.00005	0.00005	0.00005	0.000105	0.0253
Cobalt (F)	mg/L	0.001	84	0.0005	0.0005	0.0005	0.0005	0.0005	0.002	60	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005
Chromium (F)	mg/L	0.001	84	0.0005	0.0005	0.0005	0.0005	0.002	0.002	60	0.0005	0.0005	0.0005	0.0005	0.002	0.002
Copper (F)	mg/L	0.001	84	0.0005	0.0005	0.002	0.003	0.00585	0.017	60	0.0005	0.0005	0.002	0.003	0.006	0.007
Manganese (F)	mg/L	0.001	84	0.001	0.0086	0.0275	0.082	0.22595	0.309	60	0.001	0.0168	0.038	0.113	0.2443	0.309
Molybdenum (F)	mg/L	0.001	84	0.0005	0.0005	0.0005	0.002	0.004	0.008	60	0.0005	0.0005	0.0005	0.001	0.002	0.006
Nickel (F)	mg/L	0.001	84	0.0005	0.0005	0.0005	0.001	0.002	0.0025	60	0.0005	0.0005	0.0005	0.001	0.002	0.0025
Lead (F)	mg/L	0.001	84	0.0005	0.0005	0.0005	0.0005	0.002	0.125	60	0.0005	0.0005	0.0005	0.0006	0.002	0.125
Zinc (F)	mg/L	0.005	84	0.0025	0.0025	0.0025	0.0094	0.02755	0.114	60	0.0025	0.0025	0.0025	0.007	0.0121	0.028
Bicarbonate	mg/L	1	1	52.46	52.46	52.46	52.46	52.46	52.46	1	52.46	52.46	52.46	52.46	52.46	52.46
Total Dissolved	mg/L	1	1	64	64	64	64	64	64	1	64	64	64	64	64	64

Parameter	Unit	LOR	Full dataset							Post 2011 Dataset						
			Count	Min.	P20	P50	P80	P95	Max.	Count	Min.	P20	P50	P80	P95	Max.
Solids																
Hardness	mg/L	1	61	0	27.3	56.2	101.7	162.9	208	60	0	27.24	57.45	101.7	163.97	208
Selenium (F)	mg/L	0.01	1	0.005	0.005	0.005	0.005	0.005	0.005	1	0.005	0.005	0.005	0.005	0.005	0.005
Iron (F)	mg/L	0.05	1	0.2	0.2	0.2	0.2	0.2	0.2	1	0.2	0.2	0.2	0.2	0.2	0.2
Selenium (T)	mg/L	0.01	1	0.005	0.005	0.005	0.005	0.005	0.005	1	0.005	0.005	0.005	0.005	0.005	0.005
Ammonia as N	mg/L	0.01	1	0.02	0.02	0.02	0.02	0.02	0.02	1	0.02	0.02	0.02	0.02	0.02	0.02
Nitrite as N	mg/L	0.01	1	0.005	0.005	0.005	0.005	0.005	0.005	1	0.005	0.005	0.005	0.005	0.005	0.005
Nitrate as N	mg/L	0.01	1	0.06	0.06	0.06	0.06	0.06	0.06	1	0.06	0.06	0.06	0.06	0.06	0.06
Nitrite + Nitrate as N	mg/L	0.01	1	0.06	0.06	0.06	0.06	0.06	0.06	1	0.06	0.06	0.06	0.06	0.06	0.06
Total Kjeldahl Nitrogen as N	mg/L	0.1	1	0.2	0.2	0.2	0.2	0.2	0.2	1	0.2	0.2	0.2	0.2	0.2	0.2
Total Nitrogen as N	mg/L	0.1	2	0.2	0.22	0.25	0.28	0.295	0.3	2	0.2	0.22	0.25	0.28	0.295	0.3
Total Phosphorus as P	mg/L	0.01	1	0.005	0.005	0.005	0.005	0.005	0.005	1	0.005	0.005	0.005	0.005	0.005	0.005

Table 23 Summary of Water Quality Data for Monitoring Site W3

Parameter	Unit	LOR	Full dataset							Post 2011 Dataset						
			Count	Min.	P20	P50	P80	P95	Max.	Count	Min.	P20	P50	P80	P95	Max.
pH	pH Unit	0.01	223	6.70	7.32	7.60	7.98	8.18	8.51	95	6.81	7.48	7.80	8.05	8.23	8.51
Electrical Conductivity @ 25°C	µS/cm	1	223	21	96.4	131	258.4	309.7	404	95	60	98.8	150	285.4	338.5	404
Sulfate as SO4 - Turbidimetric	mg/L	1	223	0.5	2.2	5	10	17.9	56	95	0.5	2	4	10	18.9	56
Aluminium (T)	mg/L	0.01	225	0.005	0.025	0.32	1.482	4.57	16	95	0.005	0.01	0.52	1.642	5.849	16
Arsenic (T)	mg/L	0.001	229	0.00025	0.0005	0.0015	0.0025	0.003	0.116	95	0.0005	0.0005	0.001	0.0022	0.004	0.016
Cadmium (T)	mg/L	0.0001	230	0.00005	0.00005	0.00005	0.0002	0.016135	72.4	95	0.00005	0.00005	0.00005	0.00005	0.0005	0.0005
Cobalt (T)	mg/L	0.001	223	0.00005	0.0005	0.0005	0.003	0.025	0.125	88	0.0005	0.0005	0.0005	0.0005	0.001	0.004
Chromium (T)	mg/L	0.001	153	0.0005	0.0005	0.0005	0.001	0.004	0.123	95	0.0005	0.0005	0.0005	0.001	0.0053	0.022
Copper (T)	mg/L	0.001	230	0.0005	0.0005	0.002	0.005	0.00855	0.116	95	0.0005	0.0005	0.002	0.004	0.0096	0.024
Manganese (T)	mg/L	0.001	184	0.0005	0.025	0.046	0.0894	0.2007	0.34	88	0.0005	0.0328	0.064	0.0958	0.2003	0.333
Molybdenum (T)	mg/L	0.001	223	0.0005	0.0005	0.0005	0.0025	0.025	0.025	88	0.0005	0.0005	0.0005	0.0005	0.001	0.002
Nickel (T)	mg/L	0.001	230	0.0005	0.0005	0.001	0.003	0.025	0.12	95	0.0005	0.0005	0.0005	0.002	0.004	0.013
Lead (T)	mg/L	0.001	230	0.0005	0.0005	0.0005	0.001	0.004	0.114	95	0.0005	0.0005	0.0005	0.002	0.006	0.018
Zinc (T)	mg/L	0.005	230	0.0025	0.0025	0.005	0.014	0.0412	0.17	95	0.0025	0.0025	0.0025	0.012	0.0414	0.09
Free Cyanide	mg/L	0.004	69	0.002	0.002	0.002	0.002	0.002	0.002	69	0.002	0.002	0.002	0.002	0.002	0.002
WAD Cyanide	mg/L	0.004	162	0.002	0.002	0.002	0.0025	0.0025	0.056	32	0.002	0.002	0.002	0.002	0.002	0.028

Parameter	Unit	LOR	Full dataset							Post 2011 Dataset						
			Count	Min.	P20	P50	P80	P95	Max.	Count	Min.	P20	P50	P80	P95	Max.
Total Alkalinity as CaCO3	mg/L	1	11	24	29	32	50	70.5	80	8	24	27.2	30	32	43.7	50
Iron (T)	mg/L	0.05	31	0.025	0.15	0.4	2.04	6.275	15.6	8	0.65	2.064	3.32	6.652	12.996	15.6
Calcium	mg/L	1	70	2	4	9	18	20.55	24	69	2	4	8	18	20.6	24
Magnesium	mg/L	1	71	1	2	5	10	12	15	70	1	2	5	10	12	15
Sodium	mg/L	1	17	0.0005	0.0016	4	4	11.2	12	8	4	4	4	4.6	8.9	11
Potassium	mg/L	1	9	1	2	2	2	2	2	8	1	2	2	2	2	2
Chloride	mg/L	1	17	0.05	0.062	3	4	6.2	7	8	3	3.4	4	4.6	5.65	6
Fluoride	mg/L	0.1	7	0.05	0.05	0.05	0.05	0.05	0.05	7	0.05	0.05	0.05	0.05	0.05	0.05
Aluminium (F)	mg/L	0.01	152	0.005	0.005	0.12	0.568	2.1485	6.25	95	0.005	0.005	0.22	0.958	3.561	6.25
Arsenic (F)	mg/L	0.001	88	0.0005	0.0005	0.0005	0.0016	0.002	0.006	70	0.0005	0.0005	0.0005	0.002	0.00255	0.006
Cadmium (F)	mg/L	0.0001	88	0.00005	0.00005	0.00005	0.0001	0.07886	1.08	70	0.00005	0.00005	0.00005	0.00005	0.0005	0.0005
Cobalt (F)	mg/L	0.001	81	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	63	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005
Chromium (F)	mg/L	0.001	88	0.0005	0.0005	0.0005	0.0005	0.00165	0.003	70	0.0005	0.0005	0.0005	0.0005	0.002	0.003
Copper (F)	mg/L	0.001	88	0.0005	0.0005	0.002	0.0026	0.004	0.027	70	0.0005	0.0005	0.002	0.0022	0.00455	0.027
Manganese (F)	mg/L	0.001	81	0.0005	0.005	0.019	0.039	0.106	0.221	63	0.0005	0.013	0.023	0.0476	0.1069	0.221
Molybdenum (F)	mg/L	0.001	81	0.0005	0.0005	0.0005	0.0005	0.001	0.001	63	0.0005	0.0005	0.0005	0.0005	0.00095	0.001
Nickel (F)	mg/L	0.001	88	0.0005	0.0005	0.0005	0.0005	0.002	0.004	70	0.0005	0.0005	0.0005	0.0006	0.002	0.004
Lead (F)	mg/L	0.001	88	0.0005	0.0005	0.0005	0.0005	0.00165	0.116	70	0.0005	0.0005	0.0005	0.0005	0.002	0.116

Parameter	Unit	LOR	Full dataset							Post 2011 Dataset						
			Count	Min.	P20	P50	P80	P95	Max.	Count	Min.	P20	P50	P80	P95	Max.
Zinc (F)	mg/L	0.005	88	0.001	0.0025	0.0025	0.0025	0.00965	0.054	70	0.001	0.0025	0.0025	0.0025	0.00855	0.038
Bicarbonate	mg/L	1	8	29.28	33.184	36.6	39.04	53.314	61	8	29.28	33.184	36.6	39.04	53.314	61
Total Dissolved Solids	mg/L	1	1	68	68	68	68	68	68	1	68	68	68	68	68	68
Hardness	mg/L	1	70	9.1	18.2	42.18	87.14	99.2	121.5	69	9.1	18.2	40.5	88.28	99.2	121.5
Beryllium (F)	mg/L	0.001	1	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	1	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005
Barium (F)	mg/L	0.001	1	0.03	0.03	0.03	0.03	0.03	0.03	1	0.03	0.03	0.03	0.03	0.03	0.03
Selenium (F)	mg/L	0.01	1	0.005	0.005	0.005	0.005	0.005	0.005	1	0.005	0.005	0.005	0.005	0.005	0.005
Vanadium (F)	mg/L	0.01	1	0.005	0.005	0.005	0.005	0.005	0.005	1	0.005	0.005	0.005	0.005	0.005	0.005
Boron (F)	mg/L	0.05	1	0.025	0.025	0.025	0.025	0.025	0.025	1	0.025	0.025	0.025	0.025	0.025	0.025
Iron (F)	mg/L	0.05	1	0.19	0.19	0.19	0.19	0.19	0.19	1	0.19	0.19	0.19	0.19	0.19	0.19
Beryllium (T)	mg/L	0.001	1	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	1	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005
Barium (T)	mg/L	0.001	1	0.032	0.032	0.032	0.032	0.032	0.032	1	0.032	0.032	0.032	0.032	0.032	0.032
Selenium (T)	mg/L	0.01	1	0.005	0.005	0.005	0.005	0.005	0.005	1	0.005	0.005	0.005	0.005	0.005	0.005
Vanadium (T)	mg/L	0.01	1	0.005	0.005	0.005	0.005	0.005	0.005	1	0.005	0.005	0.005	0.005	0.005	0.005
Boron (T)	mg/L	0.05	1	0.025	0.025	0.025	0.025	0.025	0.025	1	0.025	0.025	0.025	0.025	0.025	0.025

5.4 Environmental Values

EVs are qualities designed to provide requirements to make water suitable for supporting aquatic ecosystems and human uses. They require protection from the effects of habitat alteration, waste releases, contaminated runoff and changed flows to ensure healthy aquatic ecosystems and waterways that are safe for community use. The EVs of waters are protected under EPP Water. The policy sets WQOs, which are physical and chemical measures of the water (i.e. pH, nutrients, salinity etc.) to achieve the EVs set for a particular waterway or water body. EVs define the suitable uses of the water (i.e. aquatic ecosystems, human consumption, industrial use etc.).

Table 24 lists the EVs that can be chosen for protection and provides definitions of each. EVs for the Gilbert River basin have not been defined under the EPP Water. Therefore EVs relevant to the Project have been identified following a review of all available information and site specific knowledge.

Table 24 Suite of Environmental Values that can be Chosen for Protection

Environmental Value	Definition
Aquatic ecosystem	A community of organisms living within or adjacent to water, including riparian or foreshore area (EPP Water, Schedule 2). The intrinsic value of aquatic ecosystems, habitat and wildlife in waterways and riparian areas, for example, biodiversity, ecological interactions, plants, animals, key species (such as turtles, platypus, seagrass and dugongs) and their habitat, food and drinking water. Waterways include perennial and intermittent surface waters, groundwaters, tidal and non-tidal waters, lakes, storages, reservoirs, dams, wetlands, swamps, marshes, lagoons, canals, natural and artificial channels and the bed and banks of waterways.
Irrigation	Suitability of water supply for irrigation, for example, irrigation of crops, pastures, parks, gardens and recreational areas.
Farm water supply	Suitability of domestic water supply, other than drinking water. For example, water used for laundry and produce preparation.
Stock watering	Suitability of water supply for production of healthy livestock.
Aquaculture	Health of aquaculture species and humans consuming aquatic foods (such as fish, molluscs and crustaceans) from commercial ventures.
Human consumption of aquatic foods	Health of humans consuming aquatic foods, such as fish, crustaceans and shellfish from natural waterways.

Environmental Value	Definition
Primary Recreation	Health of humans during recreation which involves direct contact and a high probability of water being swallowed, for example, swimming, surfing, windsurfing, diving and water-skiing. Primary recreational use, of water, means full body contact with the water, including, for example, diving, swimming, surfing, water-skiing and windsurfing. (EPP Water, s. 6).
Secondary recreation	Health of humans during recreation which involves indirect contact and a low probability of water being swallowed, for example, wading, boating, rowing and fishing. Secondary recreational use, of water, means contact other than full body contact with the water, including, for example, boating and fishing. (EPP Water, s. 6).
Visual recreation	Amenity of waterways for recreation which does not involve any contact with water - for example, walking and picnicking adjacent to a waterway. Visual recreational use, of water, means viewing the water without contact with it. (EPP Water, s. 6).
Drinking water supply	Suitability of raw drinking water supply. This assumes minimal treatment of water is required, for example, coarse screening and/or disinfection.
Industrial use	Suitability of water supply for industrial use, for example, food, beverage, paper, petroleum and power industries. Industries usually treat water supplies to meet their needs.
Cultural and spiritual values	Indigenous and non-indigenous cultural heritage, for example: • Custodial, spiritual, cultural and traditional heritage, hunting, gathering and ritual responsibilities • Symbols, landmarks and icons (such as waterways, turtles and frogs) • Lifestyles (such as agriculture and fishing). • Cultural and spiritual values, of water, means its aesthetic, historical, scientific, social or other significance, to the present generation or past or future generations. (EPP Water, s. 6).

Source: Adapted from EHP 2009

A review of the available literature was undertaken to define the catchment characteristics upstream and downstream of the proposed release zone (refer Section 5.1). EVs were assessed for the Copperfield River over a 44km stretch downstream from the former Kidston mine site to the confluence of the Einasleigh River. This is considered to be a sufficient distance downstream from the Project site in that the additional streamflow generated by the increased catchment area is likely to result in an insignificant risk to EVs further downstream. This may also be demonstrated through the catchment areas presented in Table 25.

Table 25 Catchment Areas

Catchment Description	Area (km^2)
Approximate Copperfield River catchment area reporting to the proposed release site	1,566
Approximate Copperfield River catchment area downstream of the proposed release site	1,455
Approximate Einasleigh River catchment area reporting to the confluence with the Copperfield River at Einasleigh	5,180
Approximate total reporting catchment area downstream of the potential release site and the downstream extent of area considered for nomination of site-specific EVs	6,635

The receiving environment for the EVs assessment includes the following details:

- Approximately 95% of the Gilbert Catchment is comprised of cattle grazing land uses. Cattle have access to the river directly for various stretches.
- The Copperfield River associated with the Project site is mapped as a High value under the Aquatic Conservation Assessment, with the Einasleigh River mapped as Very High value.
- There are no mapped Groundwater Dependent Ecosystems (GDEs) or springs within the Copperfield River catchment area, with the closest occurring west of the Project site within the neighbouring Oak River upper catchment. Oak River enters Copperfield River immediately prior to the confluence with the Einasleigh River.
- No wetlands of national or international importance are known to occur within the Copperfield River catchment or within a 50km radius of the Project site. The closest nationally important wetlands occur far afield downstream (>200km) within the coastal plain associated with the Gilbert River (Tait, 2015). Approximately 6.5% of the Gilbert Basin area is comprised of wetlands however, the majority of these are located within the downstream coast alluvial plains (Tait, 2015). Note, the Kidston Dam is currently mapped as a lacustrine wetland.
- The diverse array of aquatic flora and fauna (including migratory wetland birds) known to occur within the region based the detailed over presented in Tait (2015).
- A sub-dominant, of-concern Regional Ecosystem (RE) occurs in the riparian vegetation of the Copperfield River (RE 9.3.3a).
- Cultural heritage studies through the catchment have identified numerous artefacts and have identified that major watercourses such as the Einasleigh and Copperfield Rivers were a focus of indigenous occupation.
- Recreational use of waters from the Copperfield River occurs at Einasleigh in the Copperfield Gorge, 50km downstream from the Project.
- There are occasional releases from the Copperfield Dam to 'top up' the water level at the Copperfield Gorge.
- There is the potential for domestic supply to be sourced from the Copperfield River at Einasleigh, approximately 50km downstream from the proposal.
- There are no registered water licences, water permits, seasonal water allocations or interim water allocations in the Copperfield River between the Copperfield Dam and Einasleigh.

5.4.1 Site Specific Environmental Values

Schedule 1 of the EPP Water lists rivers and catchments where EVs have been determined and issued by the regulatory authority. The Copperfield River, as part of the Gilbert River Basin, does not fall within Schedule 1 of the EPP water and therefore no EVs have been designated. In this instance the EPP Water prescribes the use of default EVs. Section 2.1.3 of the (ANZECC, 2000) guidelines also suggests that where a clear and agreed set of EVs has not been designated that *appropriate* EVs apply to the resource as default. A site-specific assessment of the Copperfield River has been undertaken from the Kidston site to the confluence of the Copperfield River with the Einasleigh River, 44km downstream in order to determine which EVs are specifically relevant for the study area.

Three exercises were undertaken for this site specific assessment:

- Literature and internet review
- Search of the Queensland Entitlements Database
- Aerial imagery mapping.

5.4.1.1 Literature and Internet Review

The literature and internet review was undertaken to provide data from a wide range of sources that may indicate environmental values or users of the water between the Project and Einasleigh. This search included the following:

- Queensland Wetland Mapping (Version 4.0)
- Wetland Protection Areas
- Matters of State Environmental Significance (MSES)
- Aquatic Conservation Assessments
- Vegetation Management Wetlands Mapping
- Groundwater Dependent Ecosystems (GDE) mapping version 1.5 including potential GDE aquifers
- Fish Habitat Areas
- Water Feature Mapping (dams, rockpools, waterholes, waterfalls, flats or swamps, pondage areas)
- River Improvement Trust Areas
- Bureau of Meteorology Geofabric
- Aquatic Ecosystem Monitoring Programs
- World Heritage Areas
- RAMSAR wetlands
- Agricultural Land Audit
- Search engine queries.

The literature review identified that the Newcastle Range – The Oaks Nature Refuge is a MSES and occurs on the Western bank of the Copperfield River approximately 635m downstream from its confluence with East Creek and extends for a further 8km. The beginning of this nature refuge is approximately 3.3km downstream from the proposed release zone.

A number of potential GDEs were identified in the region, most outside of the range of the Project influence (see Section 5.11.12).

No other layers consulted above showed any features in the Copperfield River and the township of Einasleigh.

The literature and internet review showed that there is a high level of recreational use of the Copperfield River at the Copperfield Gorge (approximately 46km downstream of the proposed release location), with publically accessible areas for swimming and recreational fishing tournaments held associated with the Einasleigh Races around Easter of each year (Einasleigh Progress Association, 2018). However, there were no specifically identified uses of the Copperfield River outside the immediate vicinity of Einasleigh.

5.4.1.2 Search of the Queensland Entitlements Database

A search of the Queensland water entitlements database showed no results for the following entitlements within the Copperfield River catchment between the Copperfield Dam and Einasleigh:

- Active water licences
- Active water permits
- Interim water allocations
- Seasonal water allocations
- Riverine protection permits
- Works acknowledgement notices
- Quarry Material Allocation Notices.

Subsequently, there are no licenced users of water from the Copperfield River catchment between the Copperfield Dam and Einasleigh.

5.4.1.3 Aerial Imagery Mapping

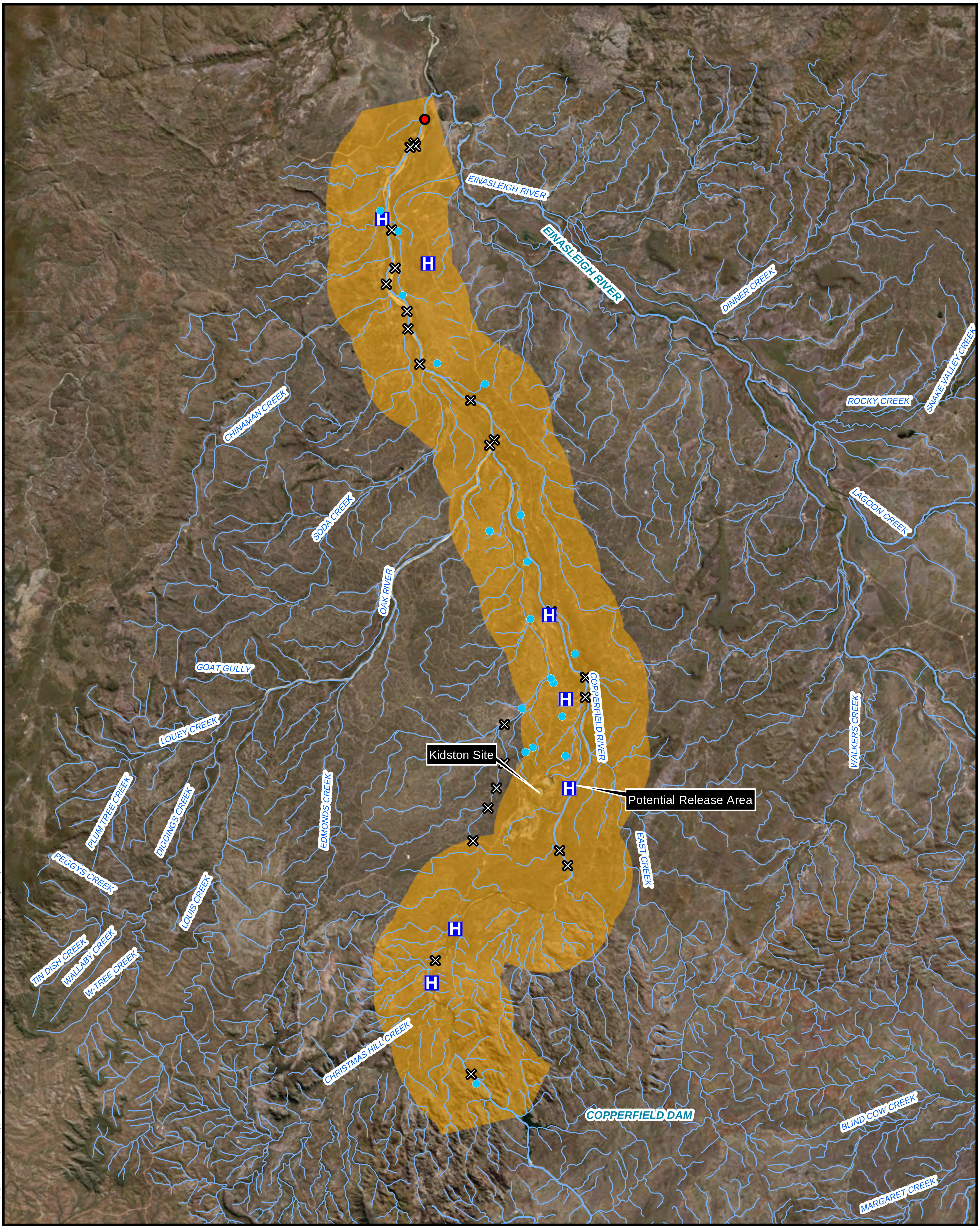
Aerial photographs of the Copperfield River catchment were obtained from ESRI ArcGIS Online streaming services as well as Queensland Government online streaming services. The available aerial images were taken in 2014. Potential water users, in the context of all EVs, were mapped at a scale of 1:20,000 which covered approximately 3.5km of use either side of the Copperfield River. This was considered a reasonable mapping extent as the cost of extracting water using pipeline and pumping infrastructure for agricultural requirements increases significantly at distances >3.5km from the river, the probability of infrastructure beyond a 3.5km corridor either side of the Copperfield River to extract from the Copperfield River itself (rather than a tributary that may be closer) is considered to be low.

Mapping rules as outlined in Table 26 were used to constrain potential water users of the Copperfield River within the 3.5km buffer. A map showing all potential users is provided in Figure 17. The results of this exercise were also correlated with distance downstream from the proposed release area (Table 27).

This assessment assumes that Aquatic Ecosystems, Stock (Cattle) Watering and Cultural and Spiritual Uses are applicable to all waters in the study area. The assessment seeks to identify locations where recreational use (via access points to the river), unlicensed drinking water use (provided by the location of farm dams or homesteads within the 3.5km corridor), or other additional uses of the water are possible.

Table 26 Mapping Rules Used to Identify Potential Users of the Copperfield River

Surface Water Environmental Value	Mapping Rules	Justification	Mapping Category (Legend)
Recreation (all including human consumption of aquatic foods)	Any track within 200m of the main channel of the Copperfield River Any cleared vegetation associated with linear infrastructure (transmission line, fence, track) within 200m of the Copperfield River banks	Represents areas where the public *could* potentially access the Copperfield River for recreational uses such as swimming, fishing etc.	Potential Access
Drinking Water and Primary Industries	Any farm dams visible within the mapping extent	Any dams that are within 3.5km of the Copperfield River could reasonably extract water from the river via pipelines that are not visible in the aerial photographs. Water could be conveyed to nearby potable users via similar pipelines with limited treatment (chlorination etc.).	Farm Dams
Drinking Water Only	Any homesteads or buildings visible	Homesteads *could* extract water from the Copperfield River and use for drinking within the mapping extent (3.5km)	Homesteads
Aquatic Ecosystems	Not mapped	Assumed to apply to all waterways	
Stock Watering (Cattle Drinking)	Not mapped	Assumed to apply to all waterways	
Cultural and Spiritual values	Not mapped	Assumed to apply to all waterways	
Industrial use	Only adjacent to the Einasleigh township.	Only visible potential industrial use of water apart from Kidston itself	Included in “Einasleigh Township” legend category.



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DATUM GDA 1994, PROJECTION MGA ZONE 56

0 2,500 5,000 10,000

metres

1:200,000 (when printed at A3)

LEGEND

- Copperfield Assessment Area
- Sub-Catchments
- Einasleigh Township
- Farm Dam
- Homestead
- Potential Access
- Major Watercourse
- Minor Watercourse

Data sources:

KIDSTON PUMPED STORAGE HYDRO PROJECT
IMPACT ASSESSMENT REPORT

Copperfield Potential Users

PROJECT ID	60544566
CREATED BY	RF
LAST MODIFIED	RF - 11 Jan 2019
VERSION:	1

Figure
17

A3 size

Filename: P:\605X\60544566\4. Tech Work Area\4.99 GIS\07_Working\RF_WORKING\Water\COPPERFIELD_POTENTIAL_USERS.mxd

The assessment identified a number of potential locations where access of the Copperfield River may be possible within the downstream environment (Table 27). The first location where access to the Copperfield River can be granted is approximately 6.2km downstream of the release location (Table 27). This is the causeway crossing of the Copperfield River used to access the Kidston site. This location could potentially be used for public recreation (fishing, swimming etc.); however it is not a location where potable drinking water would be sourced.

The closest location that may potentially source water from the Copperfield River for potable – albeit unlicensed – supplies is at the Oaks homestead, approximately 11.3km downstream of the proposed release point (Table 27). The homestead consists of several buildings within 50m of the high bank of the Copperfield River as well as several small farm dams situated nearby. Farm dams located closer to the release point are not likely to be used to source potable supply given the close proximity of the homestead to the river. Therefore, conservatively this is considered the most sensitive human water user in the immediate receiving environment.

Significant dilution of any water released from the Project will occur at the confluence of East Creek, approximately 2.6km downstream of the proposed release point. East Creek drains 242km^2 compared to the 412km^2 catchment area of the Copperfield River below the Copperfield Dam. Mixing/dilution of release water will also occur within the Copperfield River prior to the confluence with East Creek.

Several other drainage lines enter the Copperfield River further downstream. The most significant is Charles Creek which enters the Copperfield River approximately 17km downstream of the proposed release point and has a catchment area of 141km^2 compared to the 800km^2 catchment of the Copperfield River below the Copperfield Dam. This would provide further dilution to any releases from the Project.

The Oak River joins the Copperfield River 22km downstream. The Oak River drains a 526km^2 catchment while the catchment area of the Copperfield River downstream of the Copperfield Dam is 944km^2 to its confluence with the Oak River. If the Copperfield Dam was not overflowing and runoff was generated evenly in both catchments from local rainfall, any flows along the Copperfield River would be diluted by approximately 35% by flows entering from the Oak River.

Although there are several points nominated in (Table 27) where access to the Copperfield River could occur via visible tracks, fences or other cleared linear features, the use of these areas for recreation (fishing, swimming etc.) is considered to be very unlikely compared to the Copperfield Gorge, situated 44km downstream of the potential release zone, which has easy, signed access and is advertised as a local tourist attraction. Recreational use of the Copperfield River upstream of the Einasleigh township is expected to be limited to a few local individuals and tourists seeking unique, out of the way, fishing and swimming spots.

Table 27 Mapped Potential Water Users for the Copperfield River between the Proposed Release Zone and the Confluence with The Einasleigh River

Distance Downstream	Cumulative Distance Downstream	Rural Property Name	Mapped Feature	Description	Relevant User Category
2.6km	2.6km	Oak (Western Bank) Carpentaria Downs (Eastern Bank)	None	Confluence with East Creek, a 242km^2 clean water catchment that combines with the Copperfield River.	N/A
+3.6km	6.2km	Oak (Western Bank) Carpentaria Downs (Eastern Bank)	Access to the Copperfield River	Causeway across the Copperfield River used to access the Kidston site. Also corresponds to monitoring point W3.	• Recreation
+0km	6.2km	Oak (Western Bank) Carpentaria Downs (Eastern Bank)	"Homestead"	Oaks Rush Resort, 1km away from the Copperfield River. NOTE: Oaks Rush Resort sources drinking water from the Copperfield Dam pipeline which also supplies the Project. Therefore this is not considered a potential user of drinking water.	• Recreation
+0.8km	7km	Oak (Western Bank) Carpentaria Downs (Eastern Bank)	2x Farm Dam	2x Small farm dams 1.7km west from the Copperfield River.	• Drinking Water • Stock Watering • Farm Water Supply/Use
+0.2km	7.2km	Oak (Western Bank) Carpentaria Downs (Eastern Bank)	Potential Access	Gilberton Road comes within 200m of the high bank of the Copperfield River. Potential access for recreation.	• Recreation
+1.8km	9km	Oak (Western Bank) Carpentaria Downs (Eastern Bank)	1x Farm Dam	1x farm dam 450m east of the Copperfield River.	• Drinking Water • Stock Watering • Farm Water Supply/Use
+2.25km	11.25km	Oak (Western Bank) Carpentaria Downs (Eastern Bank)	Homestead	"The Oaks" homestead 50m from the high bank of the Copperfield River. Chances of water withdrawal use, although unlicensed, is high.	• Drinking Water • Stock Watering • Farm Water Supply/Use

Distance Downstream	Cumulative Distance Downstream	Rural Property Name	Mapped Feature	Description	Relevant User Category
+0.35km	11.6km	Narrawa (Western Bank) Carpentaria Downs (Eastern Bank)	Farm Dam	Farm Dam 1km west of the Copperfield River. Near The Oaks homestead. Closer to Charles Creek.	• Drinking Water • Stock Watering • Farm Water Supply/Use
+0.9km	12.5km	Narrawa (Western Bank) Carpentaria Downs (Eastern Bank)	Farm Dam	Farm Dam 280m west of the Copperfield River.	• Drinking Water • Stock Watering • Farm Water Supply/Use
+2.1km	14.6km	Narrawa (Western Bank) Carpentaria Downs (Eastern Bank)	Farm Dam	Farm Dam 1.5km west of the Copperfield River.	• Stock Watering • Farm Water Supply/Use
+0.6km	15.2km	Narrawa (Western Bank) Carpentaria Downs (Eastern Bank)	Farm Dam	Farm Dam 700m east of the Copperfield River.	• Drinking Water • Stock Watering • Farm Water Supply/Use
+4.36km	19.56km	Narrawa (Western Bank) Carpentaria Downs (Eastern Bank)	Potential Access	Cleared easement or fence within 200m of the Copperfield River western high bank. Access to this location would be difficult. Just downstream of the confluence of the Copperfield and Oak Rivers.	• Recreation
+0.3km	19.86km	Narrawa (Western Bank) Carpentaria Downs (Eastern Bank)	Potential Access	Small cleared track from Glenlyon Road to the high eastern high bank of the Copperfield River.	• Recreation
+1.0km	20.86km	Narrawa (Western Bank) Carpentaria Downs (Eastern Bank)	Potential Access	Small cleared 1.3km track from the Gregory Development Road to the eastern bank of the Copperfield River.	• Recreation

Distance Downstream	Cumulative Distance Downstream	Rural Property Name	Mapped Feature	Description	Relevant User Category
+1.7km	22.56km	Narrawa (Western Bank) Carpentaria Downs (Eastern Bank)	Farm Dam	Small farm dam or borrow pit adjacent to the Gregory Development Road, 1km east of the Copperfield River.	• Drinking Water • Stock Watering • Farm Water Supply/Use
+3.0km	25.56km	Narrawa (Western Bank) Carpentaria Downs (Eastern Bank)	Farm Dam and Access Track	Small farm dam 500m east of the Copperfield River. Access track to the dam provided from the Gregory Development Road.	• Drinking Water • Stock Watering • Farm Water Supply/Use • Recreation
+0.7km	26.26km	Narrawa (Western Bank) Baroota (Eastern Bank)	Potential Access	Powerline easement or fence extending from Beverley Hills Road approximately 1km to the western bank of the Copperfield River around the confluence with Soda Creek.	• Recreation
+2.20km	28.46km	Narrawa (Western Bank) Baroota (Eastern Bank)	Potential Access	Fence extending 3.3km from the Gregory Development Road to the eastern bank of the Copperfield River.	• Recreation
+1.00km	29.46km	Narrawa (Western Bank) Baroota (Eastern Bank)	Potential Access	Fence or other clearing extending from Beverley Hills Road for 1.1km to the western bank of the Copperfield River.	• Recreation
+0.86km	30.32km	Narrawa (Western Bank) Baroota (Eastern Bank)	Farm Dam	Farm Dam 100m from the eastern bank of the Copperfield River with a track leading to it. Access to the Copperfield could be granted for recreational activities.	• Drinking Water • Stock Watering • Farm Water Supply/Use • Recreation

Distance Downstream	Cumulative Distance Downstream	Rural Property Name	Mapped Feature	Description	Relevant User Category
+0.30km	33.32km	Narrawa (Western Bank) Baroota (Eastern Bank)	Potential Access	Beverley Hills Road crosses Chinaman Creek 500m upstream from its confluence with the Copperfield River. Access to the Copperfield River could be granted on foot from this location.	• Recreation
+0.64km	33.96km	Narrawa (Western Bank) Baroota (Eastern Bank)	Potential Access	500m cleared track or road extending from Beverley Hills Road to the western bank of the Copperfield River.	• Recreation
+0.98km	34.94km	Narrawa (Western Bank) Baroota (Eastern Bank)	Potential Access “Homestead”	2.25km cleared track or fence extending from the Gregory Development Road to the eastern bank of the Copperfield River. Also near a quarry/borrow pit adjacent to the Gregory Development Road which could theoretically source water for potable supply from the Copperfield River.	• Drinking Water • Recreation
+2.05km	36.99km	Narrawa (Western Bank) Baroota (Eastern Bank)	Farm Dam Potential Access	Farm dam 360m from the eastern high bank of the Copperfield River Potential to the eastern bank from a fence line	• Drinking Water • Stock Watering • Farm Water Supply/Use • Recreation
+0.76km	37.75km	Narrawa (Western Bank) Stockman’s Creek (Eastern Bank)	Homestead Potential Access Farm Dam	Narrawa homestead located 150m from the western bank of the Copperfield River. Includes a farm dam.	• Drinking Water • Stock Watering • Farm Water Supply/Use • Recreation

Distance Downstream	Cumulative Distance Downstream	Rural Property Name	Mapped Feature	Description	Relevant User Category
+4.3km	42.05km	Narrawa (Western Bank) Stockman's Creek (Eastern Bank)	3x Potential Access	3x potential access along fence lines. 2x extending approximately 800m from the "Etheridge Railway" and 1.5km from the Etheridge Forsayth Road providing access to the western bank. The other provides access to the eastern bank approximately 2km west of the Gregory Development Road.	• Recreation
+0.76km	42.81km	Freehold Land	Primary Industries	"Einasleigh Dump" located approximately 400m from the western bank of the Copperfield River. Theoretically could withdraw unlicensed water from the river for use.	• Industrial Use • Stock Watering • Farm Water Supply/Use
+0.70km to +1.4km	43.51km to 44.21km	Freehold Land	"Einasleigh Township"	First identified feature of the Einasleigh Township – rural residential properties. Theoretically could withdraw unlicensed water from the Copperfield River for any use.	• Drinking Water • Stock Watering • Farm Water Supply/Use • Recreation • Industrial Use
+0km	44.21km	Freehold Land	Gregory Development Road Crossing of Copperfield River	Bridge crossing of the Copperfield River at the Einasleigh Township. Provides easy access to the Copperfield River. Potentially any use.	• Drinking Water • Stock Watering • Farm Water Supply/Use • Recreation • Industrial Use
+0.07km	44.28km	Freehold Land	Copperfield Gorge	Significant tourist feature. Primary use would be recreation.	• Recreation
+0.7km	44.98km	Freehold Land	Confluence with the Einasleigh River	Confluence with the Einasleigh River. End of assessment area.	

5.4.2 Site Specific Environmental Values Applicable to the Release Regime

An evaluation of site specific EVs that are relevant to the proposed release regime and the local receiving environment is provided in Table 28 and is based on the mapping exercise undertaken in Table 27.

Table 28 Surface Water Environmental Values Potentially Relevant to the Project Site

Environmental Value	Copperfield River	Justification
Aquatic ecosystems (incorporating Habitat value)	✓	The macroinvertebrate field survey and desktop assessment supports the definition of a 'Slightly Disturbed' aquatic ecosystem condition (waters that have the biological integrity of high ecological value waters with slightly modified physical or chemical indicators but effectively unmodified biological indicators) as discussed in Section 3.3.3.
Irrigation (Short Term < 20 years)	✓	There are no known irrigation operations within the receiving environment. There are no current water allocations. However there is the potential for irrigation subject to economic feasibility (Petheram, Watson, & Stone, 2013). Therefore this EV is considered relevant.
Irrigation (Long Term ~100 years)	✓	There are no known established irrigation operations within the receiving environment. There are no current water allocations. However there has been an assessment of the ability for irrigation to occur in the catchment. Economic factors were found to be the main limiting factor. Economic factors within the next 100 years could change and ensure irrigation projects within the receiving environment, sourcing water from the Copperfield Dam, are feasible. Subsequently this environmental value has been applied.
Farm supply (e.g. fruit washing, milking sheds, intensive livestock yards)	✓	There are no intensive farm uses within the downstream receiving environment. There are no water allocations within the receiving environment. There are a number of farm dams that *could* obtain water via unlicensed extraction from the Copperfield River. Therefore this EV is considered applicable.
Stock watering (e.g. grazing cattle)	✓	The majority of the land use of the downstream receiving environment comprises cattle grazing. Cattle are able to directly access the river upstream and downstream of the proposed release location.
Aquaculture	✗	Whilst this EV has been assessed and is potentially relevant to the larger catchment, it is not considered to be relevant to the receiving environment immediately downstream. The ephemeral nature of the Copperfield River catchment means that future use for aquaculture is highly unlikely.
Human consumption (e.g. of wild or stocked fish)	✓	As outlined in the site specific assessment there are a number of locations where the Copperfield River could be accessed (Table 27).

Environmental Value	Copperfield River	Justification
Primary recreation (fully immersed in water e.g. swimming)	✓	As outlined in the site specific assessment, there are a number of locations where the Copperfield River *could* be accessed (Table 27). The most likely location for primary recreation and secondary recreation is at the Copperfield Gorge 44km downstream. Although outside the expected area of impact, this EV has been nominated as applicable to the receiving environment.
Secondary recreation (possibly splashed with water, e.g. sailing)	✓	
Visual appreciation (no contact with water, e.g. picnics)	✓	Visual appreciation is applicable downstream at Einasleigh in the Copperfield Gorge. It could be applicable at possible access points as outlined in Table 27.
Drinking water (raw water supplies taken for drinking)	✓	The closest location that could *potentially* extract water from the Copperfield River for potable supply is at the Oaks Homestead, 11.2km downstream from the proposed release point; however it has not been confirmed. There is no municipal water supply to Einasleigh township. Personal communications with Etheridge Shire Council on 16 May 2018 indicated that there are a number of unlicensed spears into the river in the vicinity of Einasleigh township; it is assumed that these could be used for domestic supply.
Industrial use (e.g. power generation, manufacturing, road maintenance)	✓	The only industrial user of water in the receiving environment is the Project and its co-located solar projects. There is a potential for industrial use in the Einasleigh township.
Cultural and spiritual values	✓	There are a large number of indigenous artefacts identified in the Copperfield River catchment. The Copperfield and Einasleigh Rivers were focuses of indigenous occupation of the area.

5.4.3 Management Intent

Generally the condition of aquatic ecosystems in the vicinity of the proposed release falls within the category of “Slightly to Moderately Disturbed” as outlined in the ANZECC (2000) and QWQG (2009). However the EPP water (2009) allows for the separation of slightly disturbed waters from moderately disturbed waters. The definitions of both of these levels of aquatic ecosystem protection are outlined below:

- **Slightly disturbed waters** (waters that have the biological integrity of high ecological value waters with slightly modified physical or chemical indicators but effectively unmodified biological indicators) – the measures for the slightly modified physical or chemical indicators are progressively improved to achieve the water quality objectives for high ecological value water.
- **Moderately disturbed waters** (waters in which the biological integrity of the water is adversely affected by human activity to a relatively small but measurable degree):
  - If the measures for indicators of the environmental values achieve the water quality objectives for the waters – the measures for the indicators are maintained at levels that achieve the water quality objectives for the waters;

    or

- If the measures for the indicators of the environmental values do not achieve the water quality objectives for the waters – the measures for indicators of the environmental values are improved to achieve the water quality objectives for the water.

Macroinvertebrate monitoring from 2009 – 2013 shows that the aquatic health of Copperfield River sites falls into the Australian River Assessment System (AusRivAS) “Band A” category, which infers that the receiving environment sites are relatively undisturbed. There is more of a change in macroinvertebrate composition from year to year than between sites, indicating that any impact (if present) is regional in nature and felt across upstream and downstream sites. The 2018 Aquatic Ecology study (Appendix E) compares the AusRivAS macroinvertebrate data to Central Queensland Guidelines and finds that upstream and downstream sites (WB, W3) fall into “Band B” but interim sites (such as W1, W2) fall into “Band A” for edge habitat.

The macroinvertebrate data supports the distinction of a ‘Slightly Disturbed’ aquatic ecosystem condition. The management intent is to gradually improve water quality and to aim to achieve a Highest Ecological Value (HEV) waterway classification. HEV WQOs may not be achievable in the Copperfield River as there are a number of regionally based negative influences on water quality, including:

- Large-scale historical clearing
- Cattle grazing and direct access to the river by cattle
- Flow regulation by the Copperfield Dam.

5.5 Default Water Quality Objectives

5.5.1 Copperfield River Classification

The ANZECC (2000) guidelines separate upland and lowland freshwaters at an elevation of 150m AHD. The guidelines also define upland freshwaters as small (first or second order) streams that are moderate to fast flowing as a result of steep gradients and have cobble, gravel or sand beds. Lowland streams are defined as larger streams (greater than 3rd order) that meander with generally slower flows and beds comprised of sand, silt and mud. The Copperfield River falls into both of these classifications as it is above an elevation of 150m AHD but is a large 5th order stream with a bed of sand, silt, rock and mud. For the purposes of this assessment the Copperfield River in the vicinity of the Project has been classified as upland freshwater.

5.5.2 Default Water Quality Objectives

The QWQG and EPP Water do not specify WQOs for the Gulf Rivers region or the Gilbert Basin. Instead they recommend the use of the ANZECC (2000) guidelines, cautioning that these values may not be appropriate for intermittent and ephemeral inland streams. In cases where more than one WQO is available for a particular parameter, the most stringent value from all EVs is applicable. As outlined above, the WQOs for Aquaculture (specifically referring to commercial aquaculture operations) have not been incorporated into the assessment of the lowest WQO from all EVs.

The simplified decision tree for assessing toxicants in ambient waters was applied from the ANZECC (2000) guidelines to select and refine WQO's for the Project. Figure 18 provides a description of how the decision tree was applied and provides an 'index' for the following sections.

The default WQOs as outlined in Table 29 were evaluated against the local background water quality data collected for the site. The evaluation was undertaken in accordance with the decision tree framework outlined in ANZECC (2000) as shown in Figure 18.

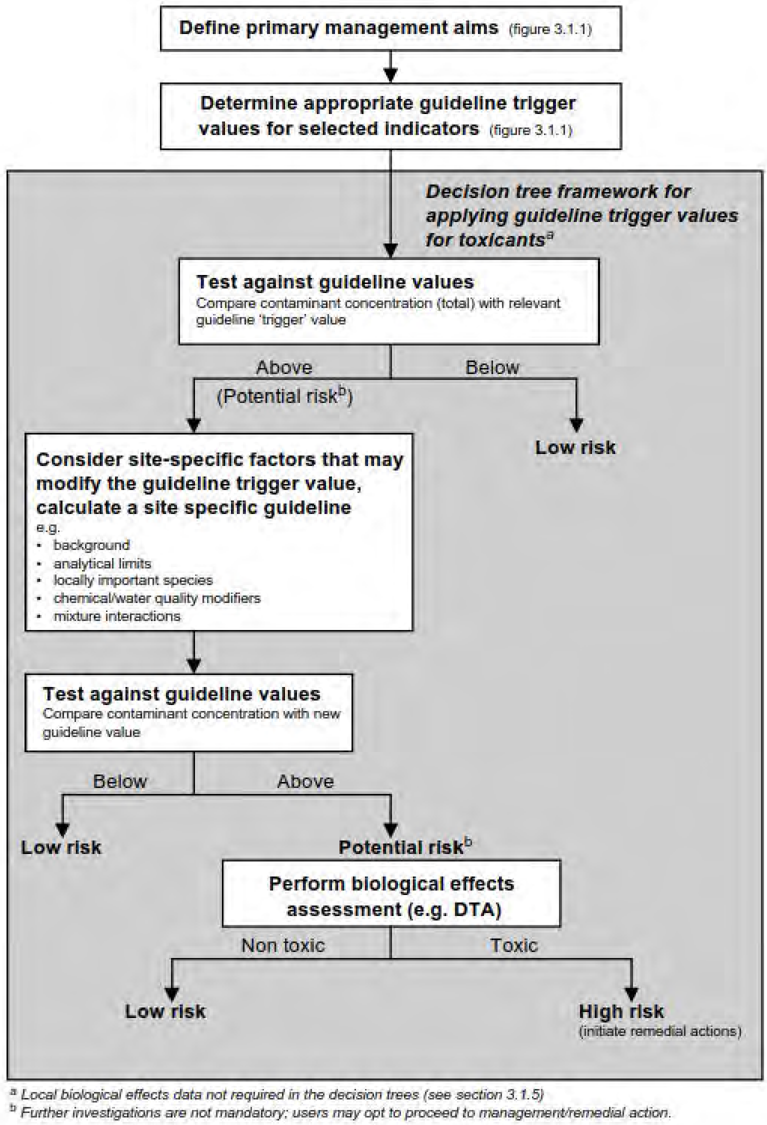
	Appropriate guidelines and trigger values (WQOs) were assembled for the applicable EVs that are outlined in Table 28. Default WQOs were assembled (Table 29). Section 3.5 tests the assembled WQOs against data held by the site for the Copperfield River. DTA was then undertaken to identify locally relevant guidelines based on toxicity. This is outlined in Section 4.9.

Figure 18 Simplified decision tree for assessing toxicants in ambient waters (ANZECC (2000))

The default WQOs for the Project are provided below in Table 29.

Table 29 Comparison of WQOs

Parameter (all units mg/L unless otherwise specified)	Default WQOs For Each EV									
	Aquatic Ecosystems (95% species protection)	Cattle Drinking Water	Long Term Irrigation	Short Term Irrigation	Human Consumption	Recreation	Drinking Water – Health	Drinking Water – Aesthetic	Lowest Applicable WQO[3]	Source[3]
pH value	6.0-7.5[1]		6-9	6-9		6.5-8.5			6.0 – 7.5	ANZECC (2000) Tropical Australia upland freshwaters
Electrical Conductivity (µS/cm)	500[2]	6150*							500	QWQG Gulf Rivers Region
Sulfate as SO_4^{2-}		1000				400	500	250	250	Drinking Water - Aesthetic
Aluminium (total)		5	5	20		0.2			0.2	Recreation
Aluminium (dissolved)	0.055							0.2	0.055	ANZECC (2000) trigger value for 95% species protection
Arsenic (total)		0.5	0.1	2		0.05	0.01		0.01	Drinking Water – Health
Arsenic (dissolved)	0.013								0.013	ANZECC (2000) trigger value for 95% species protection
Cadmium (total)		0.01	0.01	0.05		0.005	0.002		0.002	Drinking Water – Health
Cadmium (dissolved)	0.0002								0.0002	ANZECC (2000) trigger value for 95% species protection
Cobalt (total)			0.05	0.1		1			0.05	Long Term Irrigation
Cobalt (dissolved)	0.0028#								0.0028	ANZECC (2000) trigger value for 95% species protection – low reliability trigger
Chromium (total)		1	0.1	1		0.05	0.05		0.05	Drinking Water - Aesthetic/Recreation

Parameter (all units mg/L unless otherwise specified)	Default WQOs For Each EV									
	Aquatic Ecosystems (95% species protection)	Cattle Drinking Water	Long Term Irrigation	Short Term Irrigation	Human Consumption	Recreation	Drinking Water – Health	Drinking Water – Aesthetic	Lowest Applicable WQO[3]	Source[3]
Chromium (dissolved)	0.001								0.001	ANZECC (2000) trigger value for 95% species protection
Copper (total)		1	0.2	5.0	1.0		1	1	0.2	Long Term Irrigation
Copper (dissolved)	0.0014								0.0014	ANZECC (2000) trigger value for 95% species protection
Manganese (total)			0.2	10		0.1	0.5	0.1	0.1	Recreation
Manganese (dissolved)	1.9								1.9	ANZECC (2000) trigger value for 95% species protection
Molybdenum (total)		0.15	0.01	0.05			0.05		0.01	Long Term Irrigation
Nickel (total)		1	0.2	2		0.1	0.02		0.02	Drinking Water – Health
Nickel (dissolved)	0.011								0.011	ANZECC (2000) trigger value for 95% species protection
Lead (total)		0.1	2	5		0.05	0.01		0.01	Drinking Water – Health
Lead (dissolved)	0.0034								0.0034	ANZECC (2000) trigger value for 95% species protection
Zinc (total)		20	2	5	5	5		3	2	Long Term Irrigation
Zinc (dissolved)	0.008								0.008	ANZECC (2000) trigger value for 95% species protection
Total Cyanide	0.1[3]					0.1	0.08		0.08	Drinking Water – Health
Iron (total)			0.2	10		0.3		0.3	0.2	Long Term Irrigation

Parameter (all units mg/L unless otherwise specified)	Default WQOs For Each EV									
	Aquatic Ecosystems (95% species protection)	Cattle Drinking Water	Long Term Irrigation	Short Term Irrigation	Human Consumption	Recreation	Drinking Water – Health	Drinking Water – Aesthetic	Lowest Applicable WQO[3]	Source[3]
Iron (dissolved)	0.3[#]								0.3	ANZECC (2000) trigger value for 95% species protection
Chloride			175			400		250	175	Long Term Irrigation
Sodium			115			300		180	115	Long Term Irrigation
Boron (total)		5	0.5				4		0.5	Long Term Irrigation
Boron (dissolved)	0.37								0.37	ANZECC (2000) trigger value for 95% species protection
Barium (total)						1.0			1.0	Recreation
Beryllium (total)			0.1	0.5			0.06		0.06	Drinking Water - Health
Beryllium (dissolved)	0.00013[#4]								0.00013	ANZECC (2000) trigger value for 95% species protection – low reliability trigger
Mercury (total)		0.002	0.002	0.002		0.001	0.001		0.001	Drinking Water – Health/Recreation
Mercury (dissolved)	0.00005								0.00005	ANZECC (2000) trigger value for 95% species protection
Selenium (total)		0.02	0.02	0.05		0.01	0.01		0.01	Drinking Water – Health/Recreation
Selenium (dissolved)	0.011								0.011	ANZECC (2000) trigger value for 95% species protection
Uranium (total)		0.2	0.01	0.1			0.017		0.01	Long Term Irrigation

Parameter (all units mg/L unless otherwise specified)	Default WQOs For Each EV									
	Aquatic Ecosystems (95% species protection)	Cattle Drinking Water	Long Term Irrigation	Short Term Irrigation	Human Consumption	Recreation	Drinking Water – Health	Drinking Water – Aesthetic	Lowest Applicable WQO[3]	Source[3]
Uranium (dissolved)	0.0005[#]								0.0005	ANZECC (2000) trigger value for 95% species protection – low reliability trigger
Vanadium (total)			0.1	0.5					0.1	Long Term Irrigation
Vanadium (dissolved)	0.006[#]								0.006	ANZECC (2000) trigger value for 95% species protection – low reliability trigger
Fluoride		2	1	2			1.5		1	Long-Term Irrigation
Ammonia as N	0.9							0.5	0.5	Drinking Water - Aesthetic
Nitrate as N	0.7[5]	400				10	50		0.7	ANZECC (2000) trigger value for 95% species protection
Nitrite as N		30				1	3		1	Recreation
Total N	0.15[1]		5	125					0.15	ANZECC (2000) default trigger value for physical and chemical stressors for tropical Australia for slightly disturbed systems
Total P	0.01[1]		0.05	12					0.01	ANZECC (2000) default trigger value for physical and chemical stressors for tropical Australia for slightly disturbed systems

[#] Low reliability trigger for 95% species protection as outlined in Volume 2 of ANZECC (2000)
* derived from a TDS concentration for cattle drinking water by using a conversion of EC to TDS = EC x 0.64
[1] Sourced from ANZECC (2000) Aquatic Ecosystem Guidelines for Upland & Lowland Rivers for Tropical Australia – Table 3.3.4
[2] Sourced from Table G.1 of the Queensland Water Quality Guidelines for the Gulf Rivers region (75th percentile value)

[3] A cyanide value of 0.007mg/L (as un-ionised hydrogen-cyanide) is recommended by the ANZECC (2000) guidelines. However the Leading Practice Sustainable Development Program for the Mining Industry publication on Cyanide Management (2008) states:

"Measurement of total cyanide values below 0.1 mg/L and Weak Acid Dissociable (WAD) cyanide below 0.05 mg/L present in mining related discharges may be unreliable and should be reported as 'less than' and not used for compliance purposes… The possible reasons for reporting measured levels of cyanide in surface waters or treated effluent needs to be taken into account when interpreting results of a monitoring program. The first is analytical error; the second is naturally produced cyanide excreted by plants, micro-organisms and insects; and the third is manufactured cyanide. Incorrect conclusions can easily be drawn, with potentially serious consequences if valid measurements are not used" pp 14

Following from these conclusions it is recommended that a total cyanide WQO of 0.1mg/L is set for the Project. If this value is exceeded further investigation may be warranted.

[4] The default WQO for beryllium (0.00013 mg/L) is below the standard LOR of 0.001 mg/L, therefore it is not possible to accurately assess concentrations against the WQO.

[5] There is no scheduled default physico-chemical stressor guideline value for nitrate in the Gulf Rivers region. There is currently insufficient data available to establish a site-specific value for nitrate and there is a lack of published data available for an adjacent similar catchment, therefore the ANZECC (2000) trigger value for the protection of 95% species is applied. Nitrate monitoring in the receiving environment will form part of the REMP in order to gather sufficient information to establish a site-specific WQO for nitrate.

5.5.3 Water Quality Data Protocols

5.5.3.1 Data Requirements for Background Data

The QWQG 2009 provides a framework for developing locally relevant Water Quality Objectives (WQOs). Background data can be used if samples are collected from a suitable location and there are enough samples collected over a relevant time period. It is preferable to have 18 samples over 24 months. (Claus, Dunlop, & Ramsay, 2017). Until minimum data requirements have been established, comparison of test site median should be made with reference to the default guidelines. A discussion of the water quality monitoring sites and data suitability is outlined below.

5.5.3.2 Water Quality Data Controls and Checks

The water quality database supplied by Genex was screened for water quality data inconsistencies, using the following methods:

- Comparison of the level of dissolved contaminant compared to total contaminant (i.e. whether dissolved zinc was greater than total zinc for that sample). Where these were found, the analyses were removed.
- Values that were below the LOR were transformed to 50% of the LOR (i.e. <0.001 mg/L becomes 0.0005 mg/L) for statistical interrogation.
- All values were graphed and checked visually for obvious outliers.

A number of anomalies were found in the time-histories for pit water samples, which included:

- Total manganese appears to be erroneously low at Eldridge Pit in samples dated 14/11/2006, and in the Eldridge and Wises Pits in 16/10/2012. Considering that the concentrations in samples prior to and following these anomalous readings are of the order of 1 mg/L for the Eldridge Pit, it is concluded that these low values are outliers and they have been excluded from the dataset.
- Total nickel concentration in the 21/02/2013 sample from Eldridge Pit appears to be erroneously low compared to results prior to and following this sample date. This value was removed.
- Total lead concentrations from samples in the Eldridge Pit on 14/11/2006 appear to be artificially elevated at a concentration of 0.19 mg/L. A pit sample taken one month prior had a concentration of 0.001 mg/L.
- Total cobalt concentrations in the Eldridge (3.84 mg/L) and Wises Pit (0.591 mg/L) samples on 16/10/2012 are elevated by an order of magnitude compared to the sample results before and after. It is unknown whether this is an anomaly or real data so the sample results were included.
- Total cadmium concentrations in the Eldridge Pit are erroneously low in three samples (August 2006, October 2006 and October 2012). These values were removed from the dataset.
- A total aluminium concentration from November 2006 in the Eldridge Pit potentially represents an outlier and is erroneously low. This value was removed from the dataset.

There are only 20 representative samples from each pit, with 10 samples collected since 2012, and the entire (i.e., including pre-2012) pit dataset has been included, with obvious outliers removed.

5.5.3.3 Requirements for comparison with WQOs for Aquatic Ecosystems

The recommended method to assess whether a WQO has been exceeded depends on the parameter type (ANZECC, 2000). For Slightly to Moderately Disturbed water, the assessment is:

- **Physical and chemical stressors**[6]

  Trigger values are exceeded when the median of at least 8 samples (preferably 24 collected over a 2 year period) at a test site exceed the WQO. Alternatively, if suitable background data exists,

[6] Includes nutrients, biodegradable organic matter, dissolved oxygen, turbidity, suspended particulate matter, temperature, salinity, pH.

when the median of the 8 to 24 samples exceeds the 80th percentile of the reference site (from the same number of samples), the TIL is exceeded (ANZECC (2000) Guidelines).

- **Toxicants**[7]

  A trigger value is exceeded when the 95th percentile of the test distribution exceeds the default value; no action is triggered if 95% of all values fall within the default WQO.

  If background data exists, compare the 80th percentile of background data (calculated over at least 10 to 24 samples gathered over the previous 24 months) to the default WQO. If the 80th percentile exceeds the WQO, then the 80th percentile becomes the new WQO and exceedance occurs if the running median (from the same period of samples) of the test site exceeds the running 80th percentile of background data (EHP, 2013).

Statistical measures (medians, 80th percentiles, 95th percentiles) for this assessment are calculated from the entire dataset, rather than the most recent 10 to 24 samples. Where an exceedance of the default WQO applies, time series data is then investigated.

With reference to comparison of site data to ANZECC (2000) WQOs for Aquatic Ecosystems it is important to note that Section 3.4.3.2 of the ANZECC (2000) guidelines states:

"… Comparison of total concentrations will, at best, overestimate the fraction that is bio-available. The major toxic effect of metals comes from the dissolved fraction so it is valid to filter samples (e.g. to 0.45µm) and compare the filtered concentration against the trigger value" (pp 3.4-15)

There are numerous references that cite that complex metals are less harmful to fish and aquatic organisms than their free (i.e. Zn^{2+}) forms (Baker & Walden, 1984). Throughout the rest of this assessment, site data from 'filtered' samples is compared to default WQOs for Aquatic Ecosystems. However if the WQO is sourced from an alternate EV (such as recreation or cattle drinking etc.) the 'total' concentration from site data is compared.

[7] Includes ammonia, heavy metals and other toxic compounds

5.6 Comparison of Baseline Water Quality and Default Water Quality Objectives

Project water quality data was assessed against the default WQOs identified in Table 29 to determine whether there are any site-specific exceedances that need to be considered (as outlined in Figure 18).

Water quality showing the 20^{th} percentile, 50^{th} percentile (median), 80^{th} percentile and 95^{th} percentile values for each parameter at WB, W1, W2 and W3 is provided in Section 3.3.2.

Parameters Compliant with WQOs

The following parameters do not exceed the default WQOs at site WB, W1, W2 or W3 and are not considered further in this assessment:

- Dissolved arsenic
- Dissolved cobalt
- Dissolved molybdenum
- Dissolved nickel
- Dissolved lead
- Cyanide (Weak Acid Dissociable (WAD) or Total).

Following the decision tree framework outlined in Figure 18, the above criteria are considered 'low risk'.

Parameters Not Analysed

The following parameters have not been analysed at all receiving environment sites:

- Chloride
- Sodium
- Boron
- Beryllium
- Mercury
- Selenium
- Uranium
- Vanadium
- Ammonia
- Nitrate
- Nitrite
- Total N
- Total P
- Fluoride.

These parameters are represented by only one or two samples collected from W2 in 2018 as a result of sampling for DTA analysis. The risk of these parameters is not known.

The above parameters are not listed on the current EA applicable to the historic mining activity, but are listed in the Model Mining Conditions. Therefore it is recommended that future sampling, and the REMP to be developed for this Project, incorporate these parameters.

Parameters above WQOs

The following parameters exceed[8] the default WQOs (Table 29) at site WB, W1, W2 or W3:

- Dissolved aluminium (95th percentile exceeds the default WQO for Aquatic Ecosystems for all sites).
- Total arsenic (95th percentile exceeds the default WQO for Drinking Water - Health at W2).
- Dissolved chromium (95th percentile exceeds the default WQO for Aquatic Ecosystems at W1, W2 and W3).
- Dissolved copper (95th percentile exceeds the default WQO for Aquatic Ecosystems at WB, W1, W2 and W3).
- Total manganese exceeds the default WQO for Drinking Water Recreation at all sites.
- Total iron exceeds the default WQO for long-term irrigation at all sites.
- Dissolved zinc (95th percentile exceeds the default WQO for Aquatic Ecosystems at WB and W1; the 80th percentile is in exceedance at W2).

pH and Electrical Conductivity (EC) are considered physical and chemical stressors, rather than toxicants like the parameters outlined above and median values are compared to the WQO (250µS/cm for EC, pH 6.0-7.5 for pH). As physical and chemical stressors, EC is compliant with the default WQO while the median for pH lies outside the default WQO range for ANZECC (2000) Tropical Australia upland freshwaters.

Following the decision tree framework provided in Figure 18 the above parameters are considered ‘high risk’. Further evaluation is undertaken for each parameter in the sections below.

5.6.1 Hardness Modification

Calcium and magnesium ions may inhibit uptake of trace metals in aquatic organisms (Riethmuller, 2000). Calcium is known to stabilise gill membranes of fish, reducing ionic permeability (Riethmuller, 2000). Increasing calcium concentrations may compete with free ions (i.e. Zn^{2+}, Cu^{2+} etc) for binding sites on the gill surface (Riethmuller, 2000). Increases in water hardness, which is primarily composed of calcium and magnesium in solution, may decrease the bioavailability of many dissolved metal species.

Hardness Modified Trigger Values (HMTV) are derived for cadmium, chromium, copper, nickel, lead and zinc for WQOs for Aquatic Ecosystems. The HMTVs account for the potential toxicity impact of these dissolved metals considering site-specific pH and alkalinity.

Hardness or calcium and magnesium values have not been analysed for all samples. Instead, approximately 25-30% of the available dataset possesses hardness or calcium and magnesium values (from which hardness can be calculated) for each receiving environment monitoring site.

Hardness statistics for the receiving water sites are provided in Table 30. The median hardness (50th percentile) for each site is between 33.9 – 56.2 mg/L with the highest values at site W2. ANZECC/ARMCANZ 2000 default WQOs have been calculated using a hardness of 30 mg/L CaCO3. As stated in footnote H of Table 3.4.1 of the guidelines, these should be adjusted to the site-specific hardness.

The median hardness in the receiving environment at W2 is 56 mg/L, therefore the procedure outlined in Section 3.4.4 of the ANZECC/ARMCANZ 2000 (‘Applying guideline trigger values to sites’), was applied, using a hardness value of 56 mg/L. This is considered to be a conservative estimate of the trigger value, as once mixed with the release water (median hardness of 1374 mg/L) the hardness will be higher than 56 mg/L, thereby resulting in a higher HMTV.

[8] An exceedance in this instance means that the 95th percentile is above the WQO

Table 30 Hardness statistics for receiving water sites (all values mg/L)

Parameter	WB	W1	W2	W3
Minimum	3.3	9.1	11.6	9.1
20th Percentile	17.7	20.7	27.3	18.2
50th Percentile	33.9	40.5	56.2	42.2
80th Percentile	71.9	76.3	101.7	87.1
Maximum	124.7	104.9	208	121.5

Table 31 Hardness Modified Trigger Values

Parameter	Default TV (mg/L)*	HMTV** (mg/L)
Cadmium	0.0002	0.0003
Chromium(III)	0.001	0.002
Copper	0.0014	0.0024
Lead	0.0034	0.0075
Nickel	0.011	0.019
Zinc	0.008	0.014

*ANZECC/ARMCANZ 2000, Table 3.4.1.
**Calculated using algorithms presented in Table 3.4.4 of ANZECC/ARMCANZ 2000, applying a hardness value of 56 mg/L (median hardness at Copperfield River monitoring location W2).

5.6.2 pH

The pH of the water indicates the activity of hydrogen ions and is used to indicate whether water is acidic (low pH), neutral (pH ~ 6.5) or alkaline (high pH). The ANZECC 2000 Tropical Australia upland freshwaters WQO recommends a range of 6.0 to 7.5. This small pH range is at odds with the water quality at the Copperfield River (Section 5.3.2), which reports the median pH of the upstream site (WB) at 7.73. Statistics from the dataset collected between 2012 and present show a 20th percentile of 7.47 and an 80th percentile of 7.99.

Approximately 20 pH readings that have been recorded from the DNRME gauge “Copperfield River at Spanner Waterhole” (gauge ID 917115A), which was sampled between 1984 and 1991, report an 80th percentile pH of 8.4. The “Spanner Waterhole” gauge is a known reference site in Queensland (QWQG, 2009); a further 40 samples were field analysed for pH between 1997 and 2017 and reported a median pH of 8.6. A similar dataset exists for the Kidston Dam Tailwater gauge (gauge ID 917118A) which shows an 80th percentile of 8.6 and 8.66 for laboratory and field pH, respectively.

Given that the sampling campaigns report pH outside the ANZECC range, it is recommended that a site specific WQO for the upper pH limit is adopted for the site, whilst retaining the ANZECC Tropical Australia upland freshwaters WQO as the lower value. The recommended WQO is therefore a pH range of 6 - 8.4.

5.6.3 Sulfate

The ANZECC (2000) guidelines for Aquatic Ecosystems do not provide a default WQO for sulfate. More recent studies in the Fitzroy Basin in Australia have undertaken toxicity testing that has determined a 95% species protection level of 770 mg/L based on a representative water type of the entire basin (Dunlop, Hobbs, Mann, Nanjappa, Smith, & Vink, 2011). The report also found that macroinvertebrates from the Fitzroy Catchment and those from South-East Queensland have similar tolerances to sulfate. A separate study found a 95% species protection level for the Fitzroy Basin of 545 mg/L for the salt Na_2SO_4, where the Na^+ ion does not contribute significantly to toxicity (Dunlop, et al., 2016). The study reinforced that water hardness plays a pivotal role in sulfate toxicity (Dunlop, et al., 2016). (Hydrobiology, 2012) similarly identified that water hardness (Ca and Mg) as well as chloride concentrations play the highest role in contributing to sulfate toxicity. Other studies have found that sulfate is not attributable to toxic effects in *Corella sp.* (alga) but that the overall electrical conductivity (as an indicator of the overall ion concentration of the water) was a better indicator of toxicity (van Dam, Harford, Lunn, & Gagnon, 2014). This suggests that the guideline values cannot be extrapolated to other areas and that a site specific assessment is recommended.

In lieu of a WQO for sulfate for Aquatic Ecosystem EVs, site specific data are evaluated against the WQO for Drinking Water Quality - Aesthetic guideline, which provides a relatively conservative (i.e., stringent) value of 250 mg/L.

Analysis of a long-term running 80th percentile (based on the previous 24 values) in accordance with the ANZECC (2000) methodology shows that sulfate exceedances are limited to W2 between 2006 and 2011 (Figure 19). Sulfate values within the Copperfield River at all sites have gradually diminished since this date and are well below the default WQO for Recreation. Since the sulfate values within the Copperfield River have decreased it is evident that the source of elevated values is no longer present and is not affecting contemporary processes.

Following the decision tree framework provided in Figure 18 sulfate is considered ‘high risk’ given its historical exceedances of the default WQO for recreation. Despite this, the more recent observations of reduced sulfate concentrations demonstrates that this risk is expected to reduce. Notwithstanding this, sulfate levels will be monitored as part of the REMP (refer to Section 9.2).

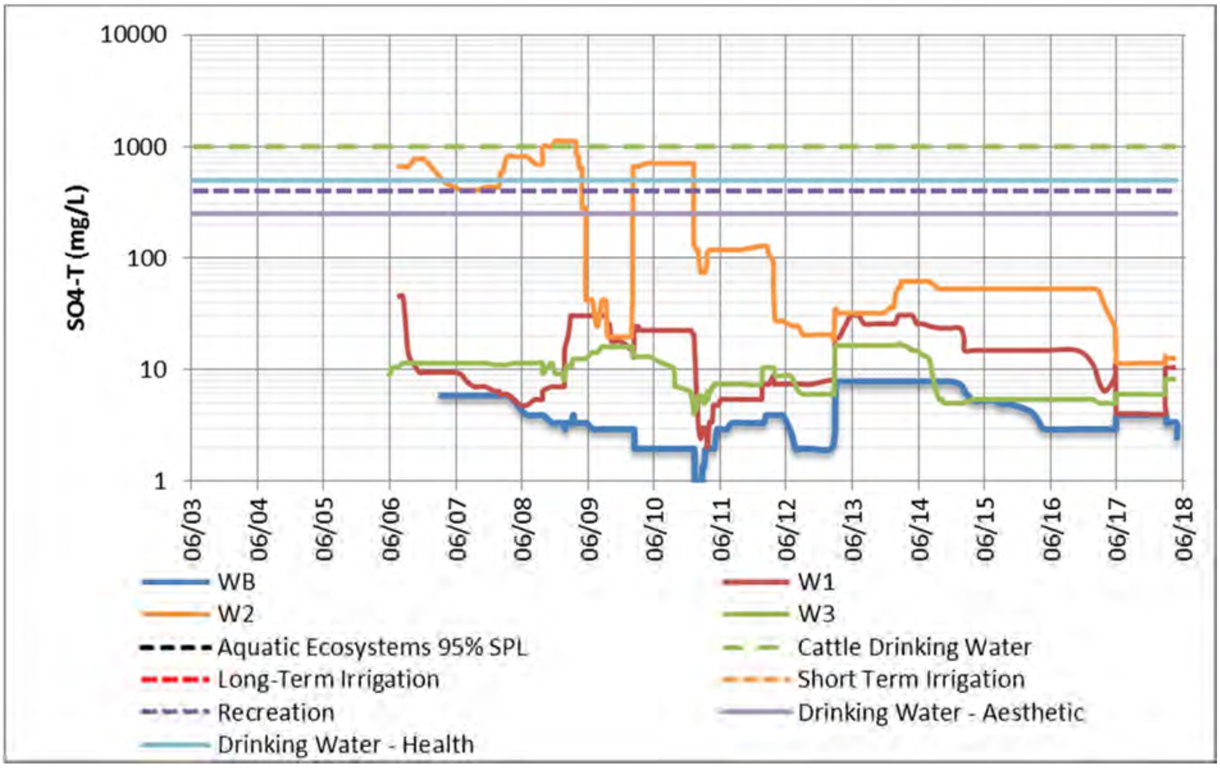


Figure 19 Running 80th percentile of sulfate values for the Copperfield River based on 24 previous samples

5.6.4 Total and Dissolved Aluminium

Aluminium typically bonds to colloids less than 0.45µm that pass through a filter. When aluminium is bonded to these colloids it is typically not bio-available and subsequently of minimum risk to aquatic ecosystems, but it is reported as 'dissolved' aluminium in laboratory results. Lead & Wilkinson (2006) show that 10-15% of aluminium is bound in fine colloids in waters from Northern Britain, 75-85% from Nova Scotia, 99% in Sacremento (USA), 55-85% in New Jersey (USA) and 35-91% in the Amazon basin.

Dissolved and total aluminium concentrations in all Copperfield River sites (WB, W1, W2 and W3) are high and are well above relevant WQOs (0.055 mg/L dissolved and 0.2 mg/L total). The upstream site (WB) also shows high concentrations of dissolved and total aluminium compared to WQOs, indicating that aluminium is sourced from areas upstream of the Kidston site.

There have been two water quality analyses for dissolved aluminium from the Copperfield River at Spanner Waterhole DNRM gauge (DNRM ID 917115A). The gauge is an official 'reference site' according to the Queensland Water Quality guidelines and is suitable to set WQOs if there is sufficient data. This gauge is located above the Copperfield Dam, upstream of the Project. The average of these samples is a dissolved aluminium concentration of 0.245 mg/L. This shows that dissolved aluminium concentrations throughout the catchment are expected to be high and are unlikely to be a result of mining activities at Kidston. The source of aluminium entering the river system before site WB is attributed to natural denudation and weathering of the parent geology. A common occurrence in Queensland is the mobilisation of soils that have a high aluminium concentration into waterways from erosion. This increases the naturally occurring aluminium concentrations in these waterways, which can often be above the ANZECC 95% species protection level of 0.055 mg/L.

The running 80th percentile (from the previous 24 values) dissolved aluminium concentrations shows that aluminium is consistently elevated above WQOs (Figure 20), including at the reference site WB. Aluminium concentrations in the receiving environment also appear to be increasing.

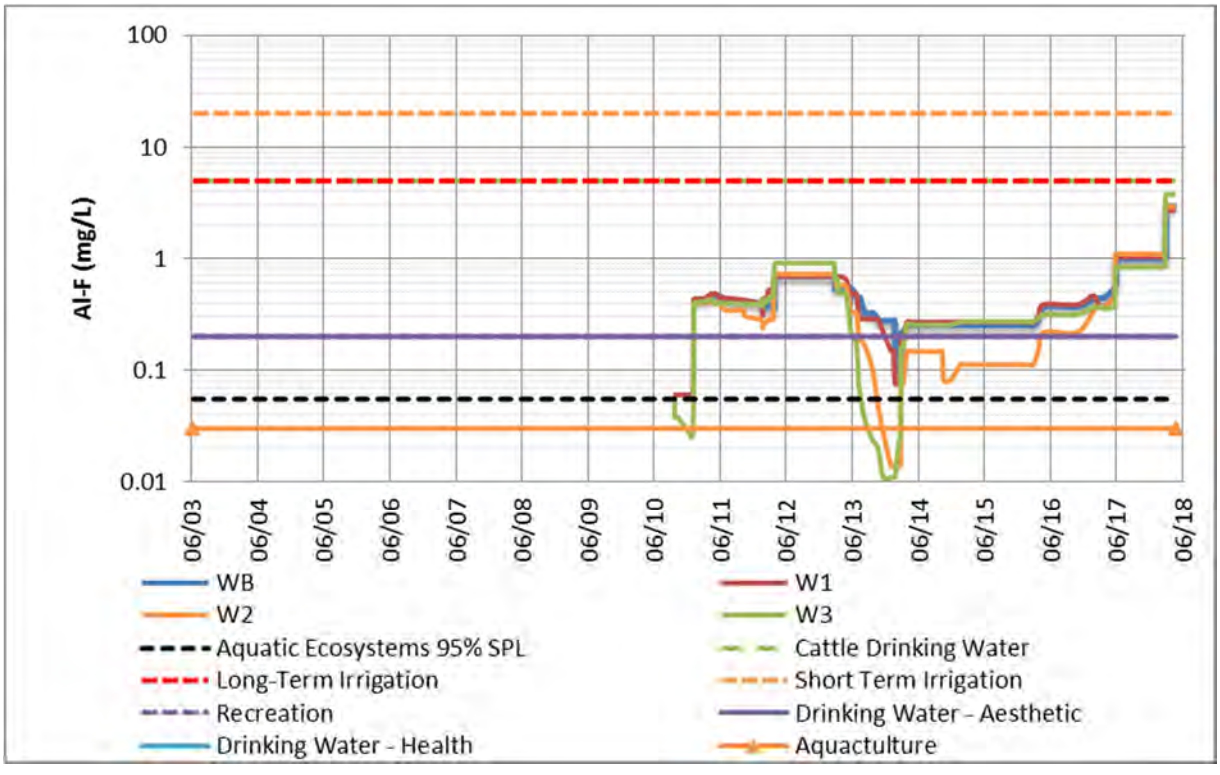


Figure 20 Long-Term Running 80th Percentile of Dissolved Aluminium (Using the previous 24 Values)

The 80th percentile values of dissolved aluminium in the receiving environment are shown below in Table 32. It is recommended that the long-term 80th percentile value for aluminium at WB (0.57 mg/L dissolved and 1.52 total) is adopted as the site specific trigger values for the Project.

Table 32 80th percentile of dissolved and total aluminium at each site in the Copperfield River

Site	Aluminium 80th percentile for full dataset (mg/L)		Aluminium 80th percentile post 2011 (mg/L)	
	Dissolved	Total	Dissolved	Total
WB	0.568	1.522	0.818	2.066
W1	0.552	1.418	0.776	1.512
W2	0.482	1.170	0.808	1.396
W3	0.568	1.482	0.050	1.642

5.6.5 Dissolved Cadmium

Time-series values for dissolved cadmium show a periodic spike in the data in 2011 (Figure 21). The majority of samples at WB, W1, W2 and W3 since this date have shown concentrations at or below the LOR (<0.0001 mg/L). Following the decision tree framework provided in Figure 18 cadmium is not considered 'high risk' but will be evaluated further with DTA because of the historically high concentrations.

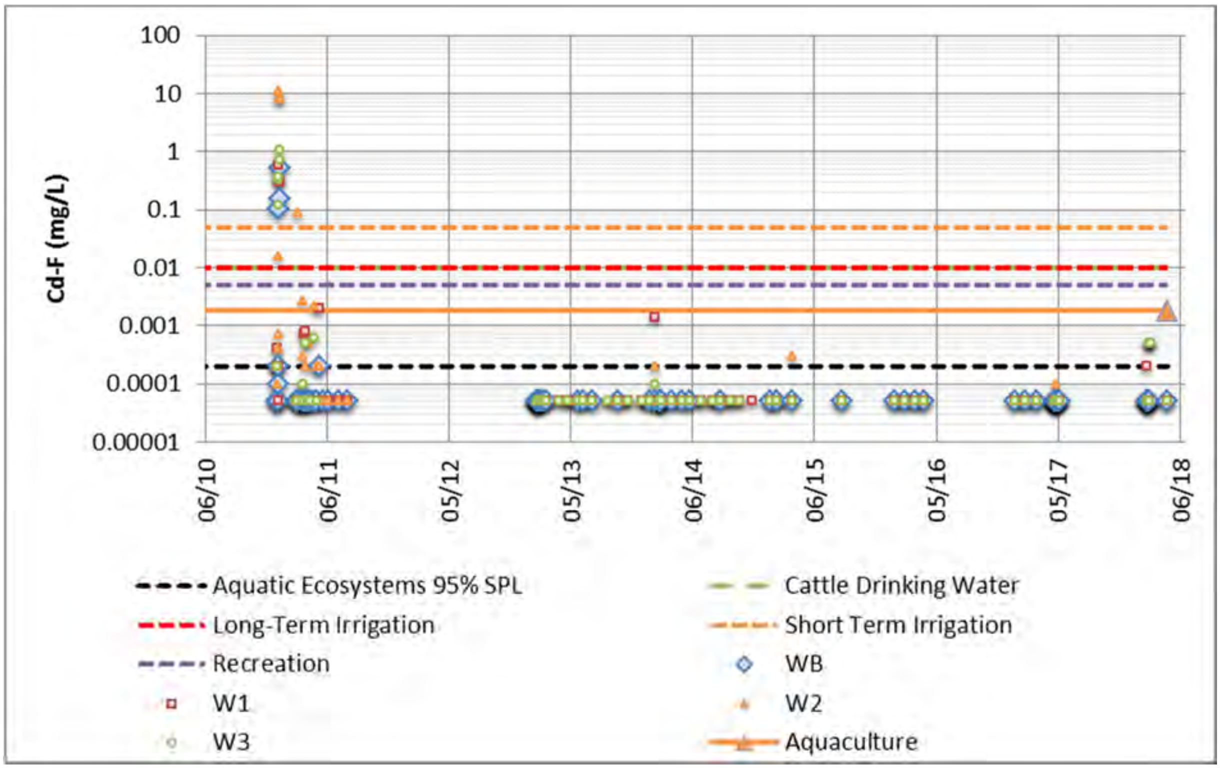


Figure 21 Time Series of Dissolved Cadmium Values

5.6.6 Dissolved Chromium

There have been no long-term exceedances of dissolved chromium. A time-series plot shows that the majority of dissolved chromium is below the ANZECC 95% species protection level for Aquatic Ecosystems (Figure 22). Chromium concentrations generally increase at all sites in unison, indicating that chromium in the system is likely to be sourced from areas upstream of the site. However, the long-term 80th percentile for dissolved chromium is below the LOR (<0.001 mg/L) for all sites. Following the decision tree framework provided in Figure 18 chromium is not considered 'high risk' but will be evaluated further with DTA because of the high concentrations that have been found upstream of the mine at WB.

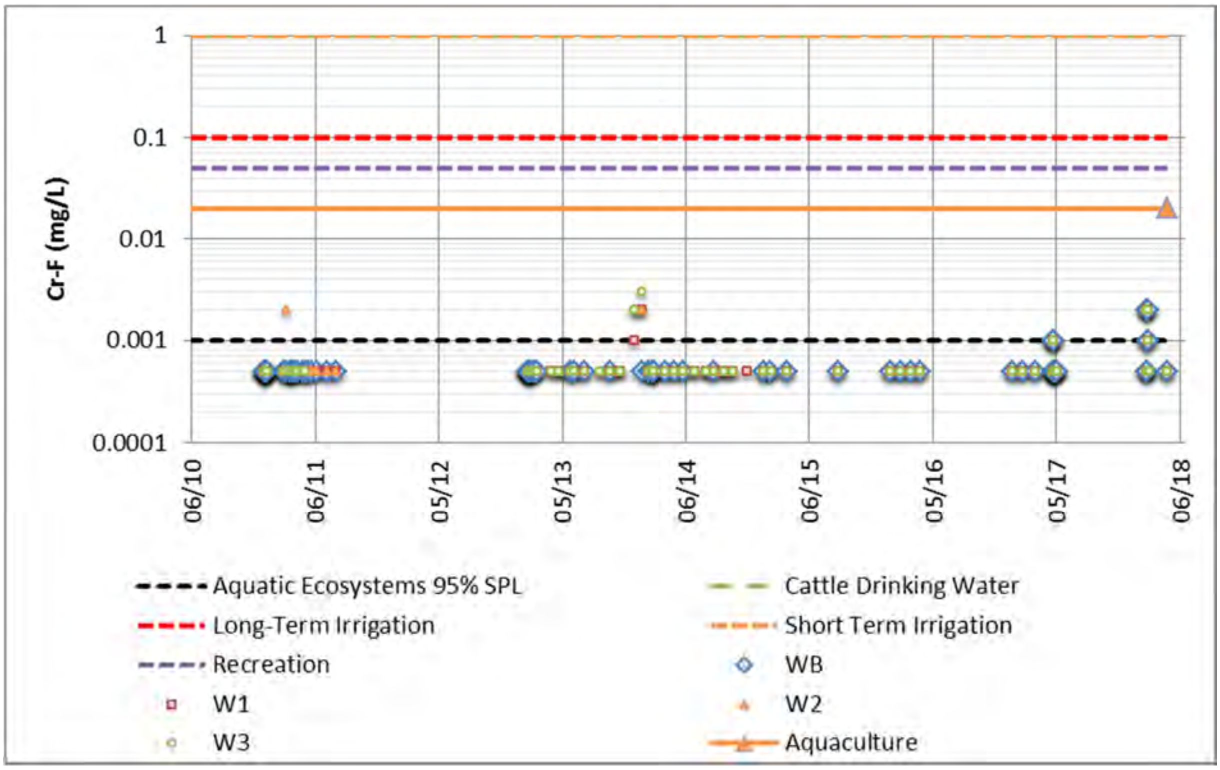


Figure 22 Time Series of Dissolved Chromium Values

5.6.7 issolved Copper

The concentration difference between optimal growth conditions (for algae) and copper toxicity to freshwater organisms is relatively low (ANZECC, 2000). The most toxic inorganic species of copper are free copper (Cu^{2+}) and copper hydroxyl species. As for aluminium, copper is readily adsorbed onto colloidal material.

The long-term running 80th percentile of dissolved copper (from the previous 24 samples) shows that concentrations were generally elevated above the 95% Aquatic Ecosystem species protection level at WB, W1 and W2 for a period of several years (Figure 23). Concentrations at W3 have only increased in the most recent sampling. This suggests that dissolved copper entering the Copperfield River was potentially sourced from historic mining activities between WB and W2, but that there are other sources of copper entering the waterway above the Kidston site as well.

There has been one sample from the Copperfield River at Spanner Waterhole DNRM Gauge (DNRM ID 917115A). This sample shows a dissolved copper concentration of 0.05 mg/L, much higher than is experienced at the site (80th percentile of 0.003 mg/L at monitoring location WB). The gauge on the Copperfield Dam Tailwater (917118A) contains two samples of dissolved copper (0.04 mg/L and 0.02 mg/L). This confirms the data from site WB indicating that there are sources of copper entering the Copperfield River above the Kidston site.

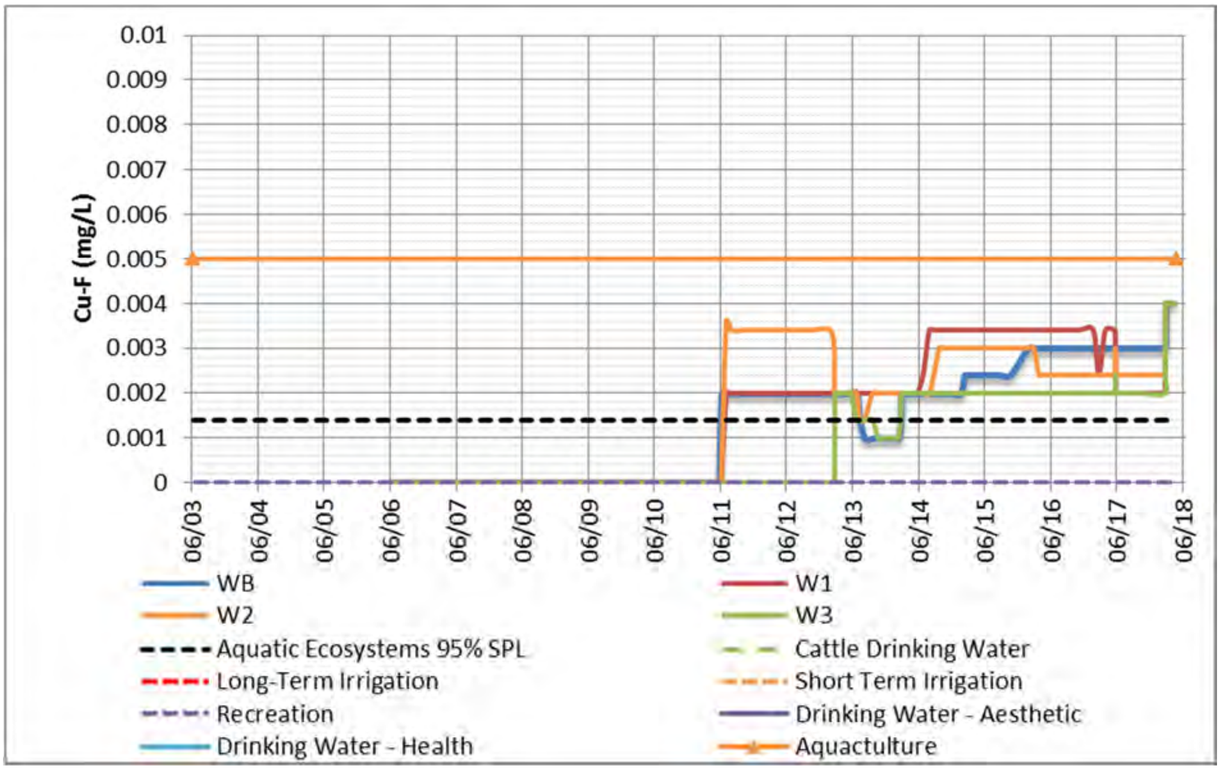


Figure 23 Long Term 80th Percentile (from the Previous 24 values) for Dissolved Copper in the Copperfield River

The long-term 80th percentile for copper at each site is outlined below in Table 33, calculated from the entire dataset. All of these values are higher than the default WQO (0.0014mg/L). It is recommended that the long-term 80th percentile value for dissolved copper at WB (0.003 mg/L) is adopted as the site specific trigger values for the Project.

Table 33 80th percentile of dissolved copper at each site in the Copperfield River

Site	Dissolved Copper 80th percentile for full dataset (mg/L)	Dissolved Copper 80th percentile post 2011 (mg/L)
WB	0.0030	0.0030
W1	0.0034	0.0040
W2	0.0030	0.0030
W3	0.0026	0.0022

5.6.8 Total Manganese

Total manganese is provided with a Recreation WQO of 0.1 mg/L from Table 29 for total manganese. The recreation WQO is sourced from the 'aesthetic' trigger value of the Drinking Water Guidelines, which states that a value of 0.1 mg/L should be found at the tap. The long-term running 80th percentile shows that even site WB has values that are above this WQO (Figure 24), although generally manganese concentrations are highest at W2.

Iron and manganese in their divalent forms (i.e. Fe^{2+} and Mn^{2+}) can precipitate based on various water quality parameters such as pH, redox potential, dissolved CO_2, sulfur, organic matter and the presence of microorganisms (NHMRC, 2011). The 'aesthetic' guideline from the Drinking Water Guidelines is to protect against the potential formation of dark scales on pipe and tap fittings as a result of manganese precipitation.

The site-specific EV assessment in Section 5.4.2 reveals that recreational use of the Copperfield River will not occur until Site W3, approximately 6.2km downstream from W2 and the proposed release point for the Project. The historic mining activity was assigned a WQO of 1.9 mg/L attributable to the WQO for Aquatic Ecosystems (refer EA EMPL00817013 dated 4 October 2013) for dissolved manganese.

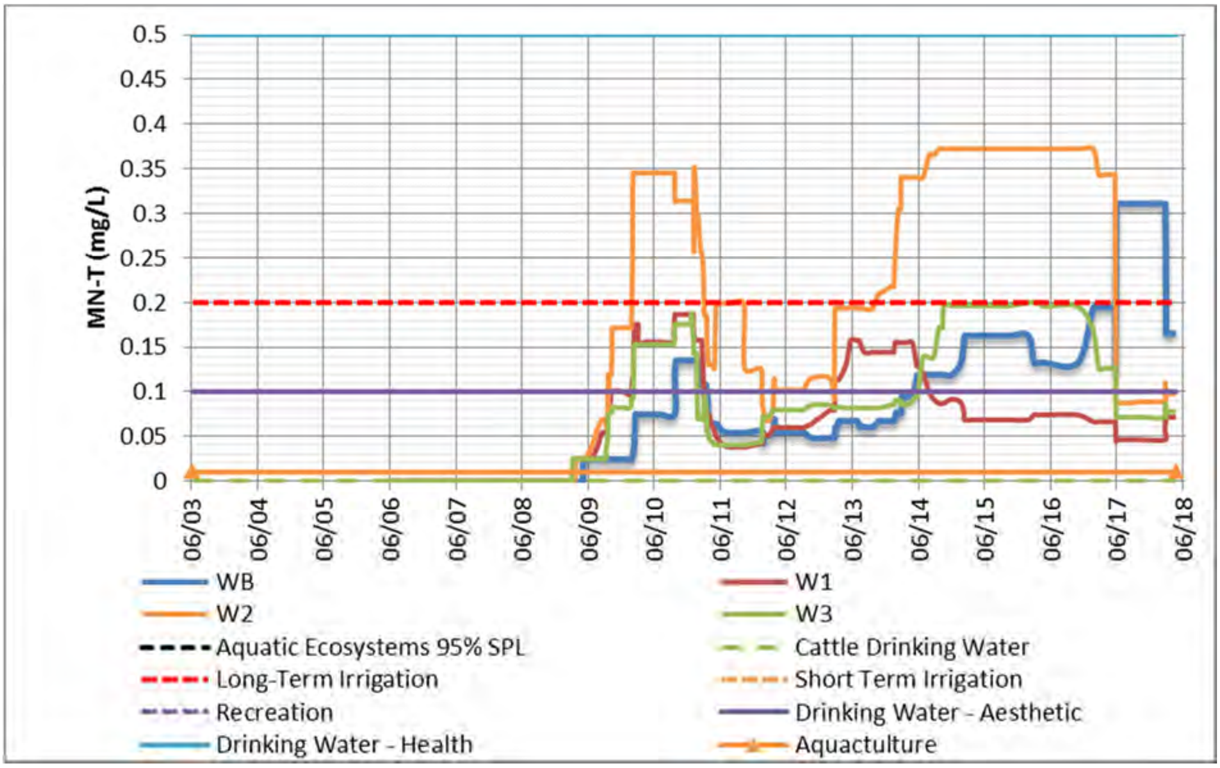


Figure 24 Long-Term Running 80th Percentile (from the Previous 24 samples) for Total Manganese

The long-term 80th percentile for each site is shown below in Table 34 for dissolved and total manganese. The total manganese 80th percentile at WB (0.111 mg/L) exceeds the Recreation WQO of 0.1 mg/L post 2011.

Table 34 80th percentile of total and dissolved manganese at each site in the Copperfield River

Site	Manganese 80th percentile for full dataset (mg/L)		Manganese 80th percentile post 2011 (mg/L)	
	Dissolved	Total	Dissolved	Total
WB	0.048	0.082	0.089	0.111
W1	0.025	0.094	0.028	0.102
W2	0.082	0.217	0.113	0.226
W3	0.039	0.089	0.048	0.096

5.6.9 Dissolved Zinc

The running 80th percentile (from the previous 24 values) shows that dissolved zinc concentrations in the Copperfield River historically (Figure 25) exceed the Aquatic Ecosystems 95% species protection level (0.008 mg/L). The results also show that zinc concentrations are increasing at all sites (WB, W1, W2, W3) over recent times (since 2017). Since 2017 there has only been one sample at WB, two samples at W1 and three samples at W2 that have exceeded the trigger value of 0.008 mg/L. No samples from W3 have exceeded this value in this time.

A HMTV of 0.014 mg/L has been adopted for dissolved zinc.

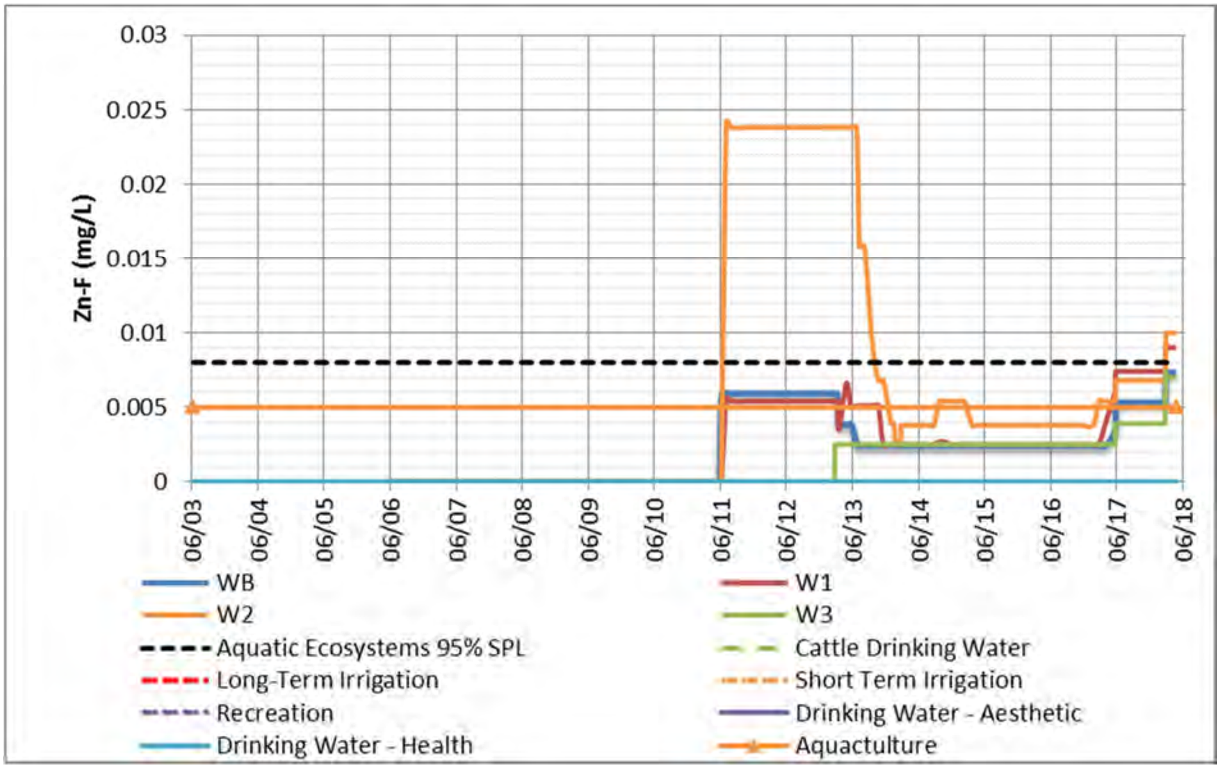


Figure 25 Long-Term Running 80th Percentile Data for Zinc (from the Previous 24 Values)

The 80th percentile values for dissolved zinc are presented in Table 35 below.

Table 35 80th percentile of dissolved zinc at each site in the Copperfield River

Site	80th percentile full dataset (mg/L)	80th percentile post 2011 (mg/L)
WB	0.006	0.005
W1	0.007	0.008
W2	0.009	0.007
W3	0.0025	0.0025

5.6.10 Total Iron

The default WQO for total iron (0.2 mg/L) is based on the long term irrigation EV (ANZECC 2000). There have been numerous exceedances of iron in the receiving environment. The 80th percentile for all sites exceeds the WQO for Long Term Irrigation, Drinking Water – Aesthetic and Recreation (Appendix A). Receiving water sites generally have higher iron concentrations than the Pit waters (Appendix A).

Table 36 80th percentile of Total Iron at each site in the Copperfield River

Site	80th percentile*
WB	0.43
W1	0.43
W2	0.59
W3	2.04

*Given that only one sample has been analysed for total iron post 2011 at sites WB, W1 and W2, statstics for the full data set are presented above (based on a minimum of 17 samples).

Iron concentrations are also elevated at DNRM gauges situated upstream. There are 14 samples that have been collected and analysed for soluble iron concentrations between 1984 and 1991 at the "Spanner Waterhole" gauge (gauge ID 917115A) situated upstream of the Kidston Dam. The 80th percentile of soluble iron concentrations at this gauge is 0.64 mg/L. This aligns with the values found at the WB monitoring site. However the concentrations at the DNRM gauge (80th percentile of 0.64 mg/L) applies to 'dissolved' iron rather than total iron as analysed from the site specific data and provided in Table 36.

Elevated iron concentrations are a naturally occurring phenomenon and not a result of mining activities. Since there is considerable evidence of elevated iron concentrations it is recommended that the 80th percentile of WB is adopted as the site-specific WQO for the Project. The default WQO of 0.43 mg/L is to protect against possible scaling in the catchment. Data from the site as well as upstream gauges indicate that this is likely to be a problem throughout the catchment regardless of the Project. Furthermore, the iron concentration in Pit water is generally lower than that found in the receiving environment, posing little risk to downstream users.

5.6.11 Nitrogen

There have only been two samples for nutrients collected within the receiving environment. Both of these samples were taken in 2018 as part of the DTA analysis from site W2. Total nitrogen was found to be 0.3 mg/L on 24 March 2018 and 0.2 mg/L on 13 June 2018. Both of these values are above the WQO of 0.15 mg/L.

Ammonia (0.02 mg/L for both samples), nitrite (0.005 mg/L for both samples), and nitrate (0.06 mg/L and 0.005 mg/L) were all below the WQOs.

There are no samples from any other receiving water sites. Subsequently it is recommended that nutrients are monitored at all receiving environment sites as a priority to establish whether these values are elevated in areas upstream of the site (site WB) or if they are sourced from the historical mining activities.

It is noted that there is no scheduled default physico-chemical stressor guideline value for nitrate in the Gulf Rivers region. There is currently insufficient data available to establish a site-specific value for nitrate and there is a lack of published data available for an adjacent similar catchment, therefore the ANZECC (2000) trigger value for the protection of 95% species is applied. Nitrate monitoring in the receiving environment will form part of the REMP in order to gather sufficient information to establish a site-specific WQO for nitrate.

5.6.12 Summary of Site Specific Water Quality Objectives

Based on the assessment of baseline water quality in the Copperfield River presented above, several site-specific WQOs (including HMTVs) are proposed. These are outlined in Table 37 below.

Table 37 Site-Specific Water Quality Guidelines

Parameter	Concentration	Source
Total iron	0.43 mg/L	Long-term 80th percentile for WB
pH – lower limit	6.0 pH units	ANZECC 2000 Tropical Australia upland freshwaters WQO lower limit
pH – upper limit	8.4 pH units	80th percentile for DNRME gauge “Copperfield River at Spanner Waterhole” (gauge ID 917115A)
Dissolved aluminium	0.57 mg/L	Long-term 80th percentile for WB
Total aluminium	1.52 mg/L	Long-term 80th percentile for WB
Dissolved copper	0.003 mg/L	Long-term 80th percentile for WB
Dissolved cadmium	0.0003 mg/L	HMTV
Dissolved chromium	0.0017 mg/L	HMTV
Dissolved lead	0.0075	HMTV
Dissolved nickel	0.019	HMTV
Dissolved zinc	0.014	HMTV

5.7 Comparison of Water Quality and Stream Flow

Stream flow data were extracted from the Integrated Quantity and Quality Model (IQQM) on a daily basis and compared to site water quality data. There is an apparent relationship between pH and flow as well as EC and flow, although the latter is difficult to quantify.

5.7.1 pH

There is a distinct relationship between pH and flow (Figure 26). Higher flow values (>10,000 ML/d) generally correlate with neutral pH; very low flows correspond to higher pH. This may represent occasions when there is standing water as waterholes in the Copperfield River.

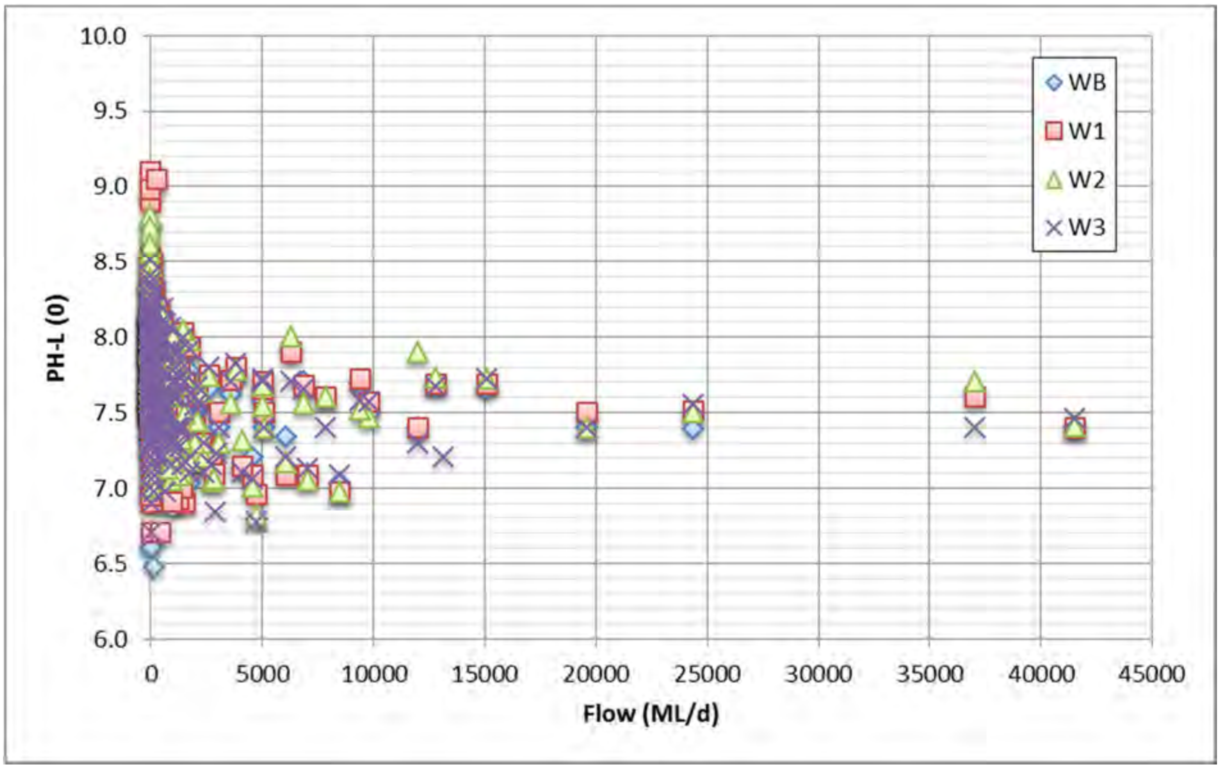


Figure 26 Relationship between pH and flow

5.7.2 Electrical Conductivity

There is an apparent 'loose' relationship between EC and stream flow at the majority of sites. However curve fitting algorithms will not fit a curve[9] to the data for any of the sites. W2 has been chosen to represent the receiving environment in the calculations outlined below. EC values are generally lower at higher flow events. It is obvious from Figure 27 that W2 has the highest EC values out of all sites and that these higher EC values mostly correspond to low flow periods. High flow events generally have a lower EC with two notable exceptions sampled at W2 (Figure 27).

[9] In this instance, a R^2 value above 0.2 cannot be obtained with curve-fitting software for any site

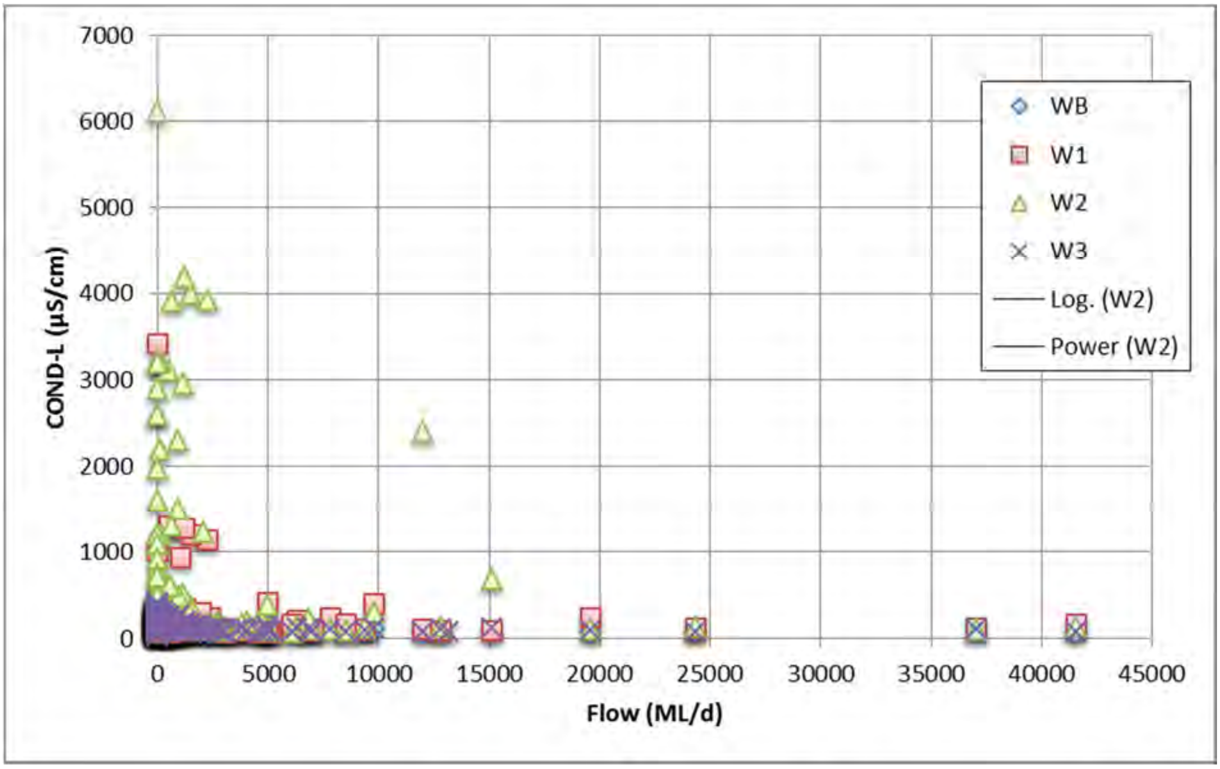


Figure 27 Relationship between EC and flow in the Copperfield River

5.7.3 Zinc

There is no correlation between zinc concentrations and flow values in the Copperfield River. Whereas EC values decline with increasing flow, high total zinc values remain at higher flow rates in the Copperfield.

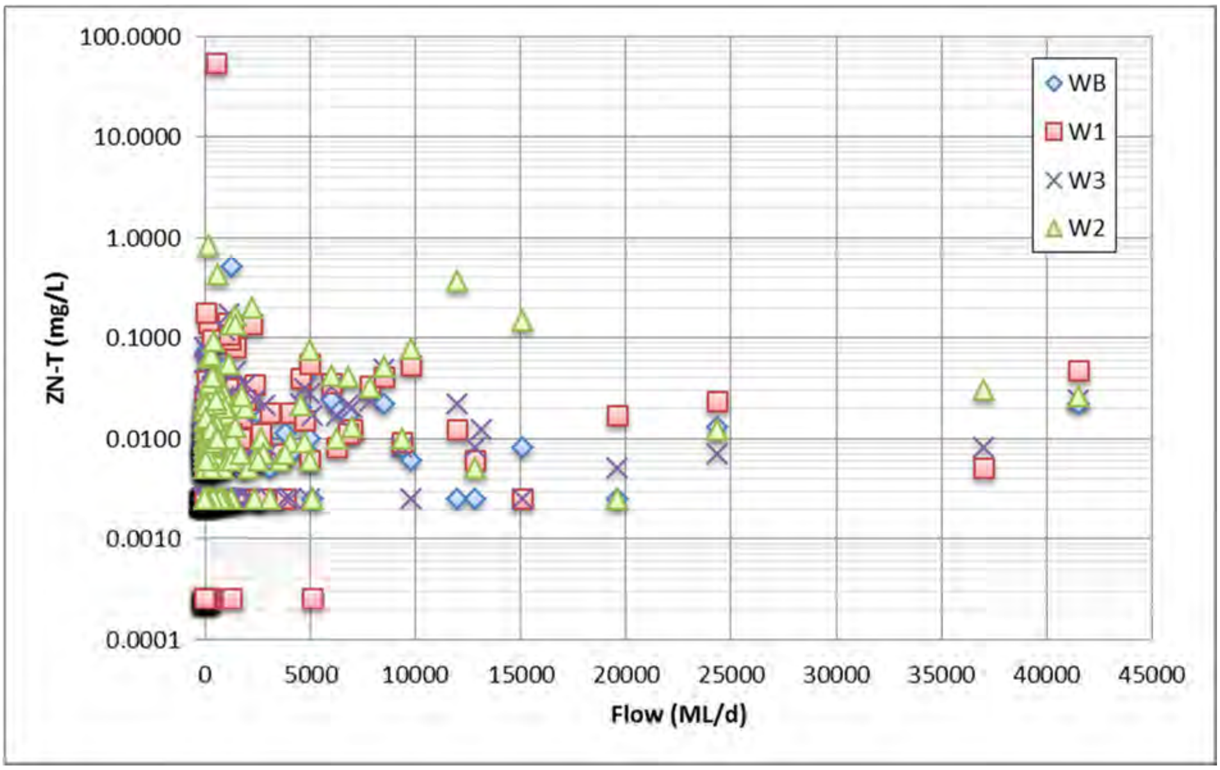


Figure 28 Plot of total zinc against flow

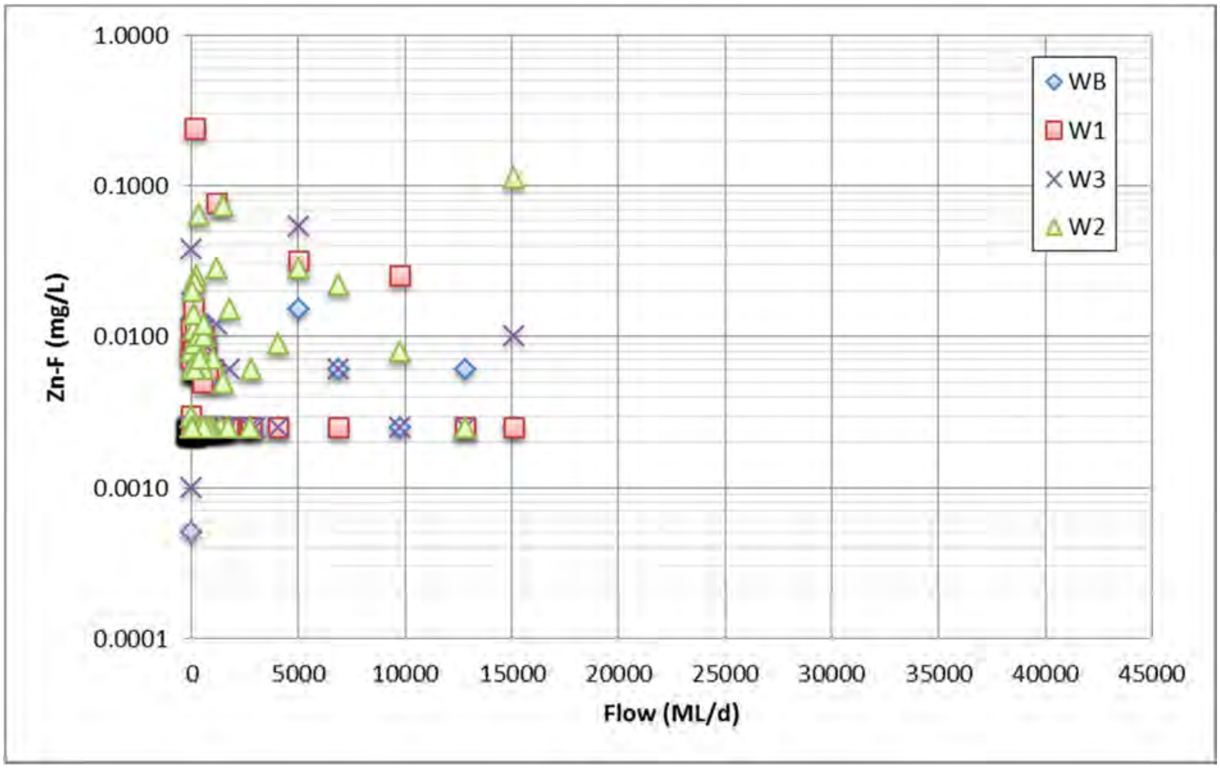


Figure 29 Plot for dissolved zinc against flow

5.7.4 Other Parameters

There are no relationships between any other parameters that are routinely monitored and flow found in the receiving environment sites.

5.8 Representative Water Quality Baseline Site (WB)

The furthest upstream monitoring location is site WB, situated 2km upstream from the proposed release location. The site shows elevated concentrations of parameters such as aluminium, copper and manganese. Although the site is situated upstream, the AGE (2001) study suggested potential limited transport of seepage to the Copperfield River in the vicinity of the WB monitoring site or further upstream, although it is noted that this is based primarily on model results, rather than observations.

There is a distinct 'signature' to mine affected water on the Kidston site. A relationship between EC and sulfate exists in samples taken from the Eldridge and Wises Pits (refer Appendix F and G). This relationship is also partially evident at site W2 (Figure 30). This indicates that W2 has received mine-affected water in the past via either seepage, releases or another mechanism.

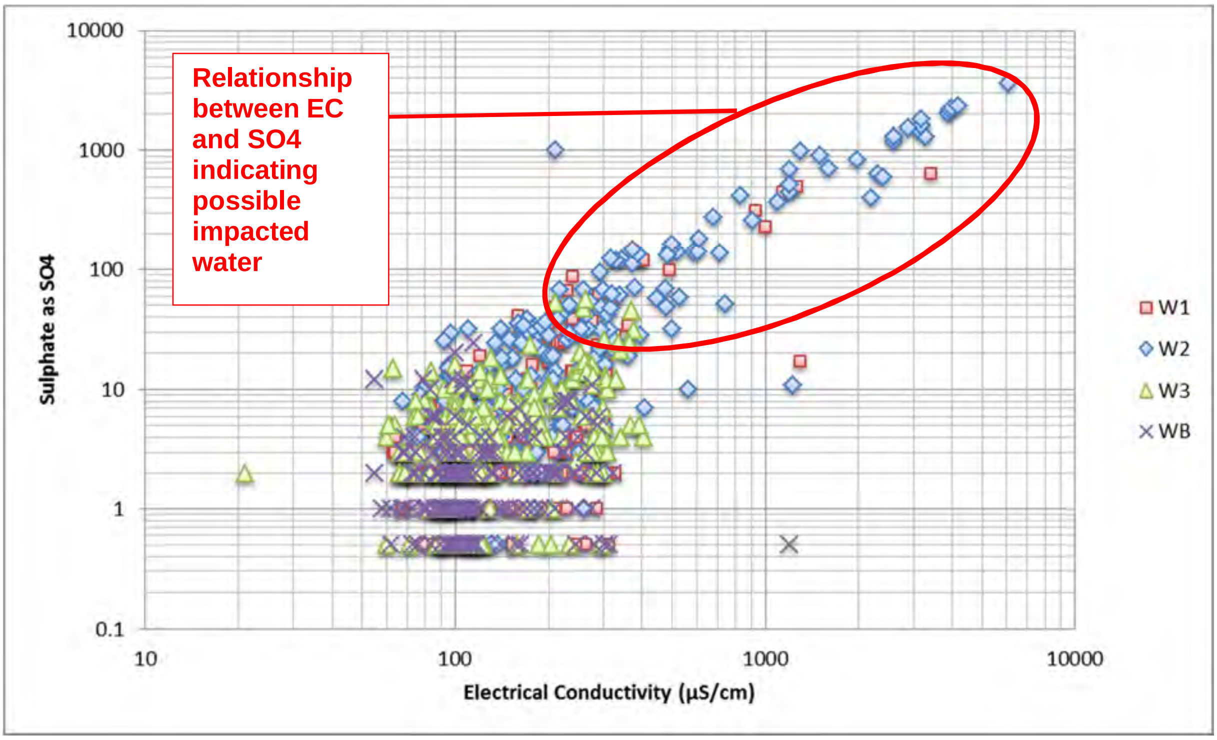


Figure 30 Relationship between EC and sulfate as SO4 in receiving water samples

Samples at WB do not show a relationship between EC and sulfate. In addition, waters from the mine generally have lower aluminium concentrations (80th percentile of 0.0376 mg/L for the Eldridge and 0.025 mg/L for the Wises Pit) than water in all receiving water locations (80th percentile of 0.568 mg/L). Only one sample has been collected from the East Creek monitoring location (dated 24/04/2018) and this sample has a concentration (0.08 mg/L) that is above the 80th percentile of the pit waters. This shows that aluminium is naturally elevated in the receiving environment. Therefore, if mine-affected water was impacting on the WB monitoring location it would be expected to result in low concentrations of aluminium in the sample results.

A piper diagram of available cation and anion data was produced for the receiving environment sites as well as available DNRM stream gauges in Copperfield catchment and nearby areas. The position of WB, W1 and W3 sites plot very closely to the historical gauged data from the tailwater of the Kidston Dam (DNRM gauge ID 917118A) (Figure 31). Sites W1, W3, WB and the Kidston tailwater gauge fall within the Na-HCO_3 water facies, whereas those from the the Wises and Eldridge Pits plot in the top-right corner of the piper diagram indicating Na-SO_4 facies water. The W2 site is a Ca-HCO_3 dominated facies water. Its position on the piper diagram (Figure 31) indicates a marginal impact from waters with a similar composition of the Eldridge and Wises Pits. If the WB site was impacted by water from mining activities, its position in the Piper Diagram would be expected to be similar to that of the W2 site.

The lack of a relationship between EC and sulfate, the comparison between low aluminium bearing pit waters and high aluminium concentrations in receiving waters, and water composition data indicates that there are likely to be minimal impacts from the mine at site WB.

The site does not meet the criteria required for a ‘reference site’ as outlined in the QWQG (2009) as the Copperfield Dam regulates upstream from the monitoring point. As the site is in reasonable condition and represents the only long-term monitoring dataset on the Copperfield River downstream of the Copperfield Dam and upstream of the historical Kidston mine, the site is used to identify which parameters naturally occur above WQOs in the receiving environment.

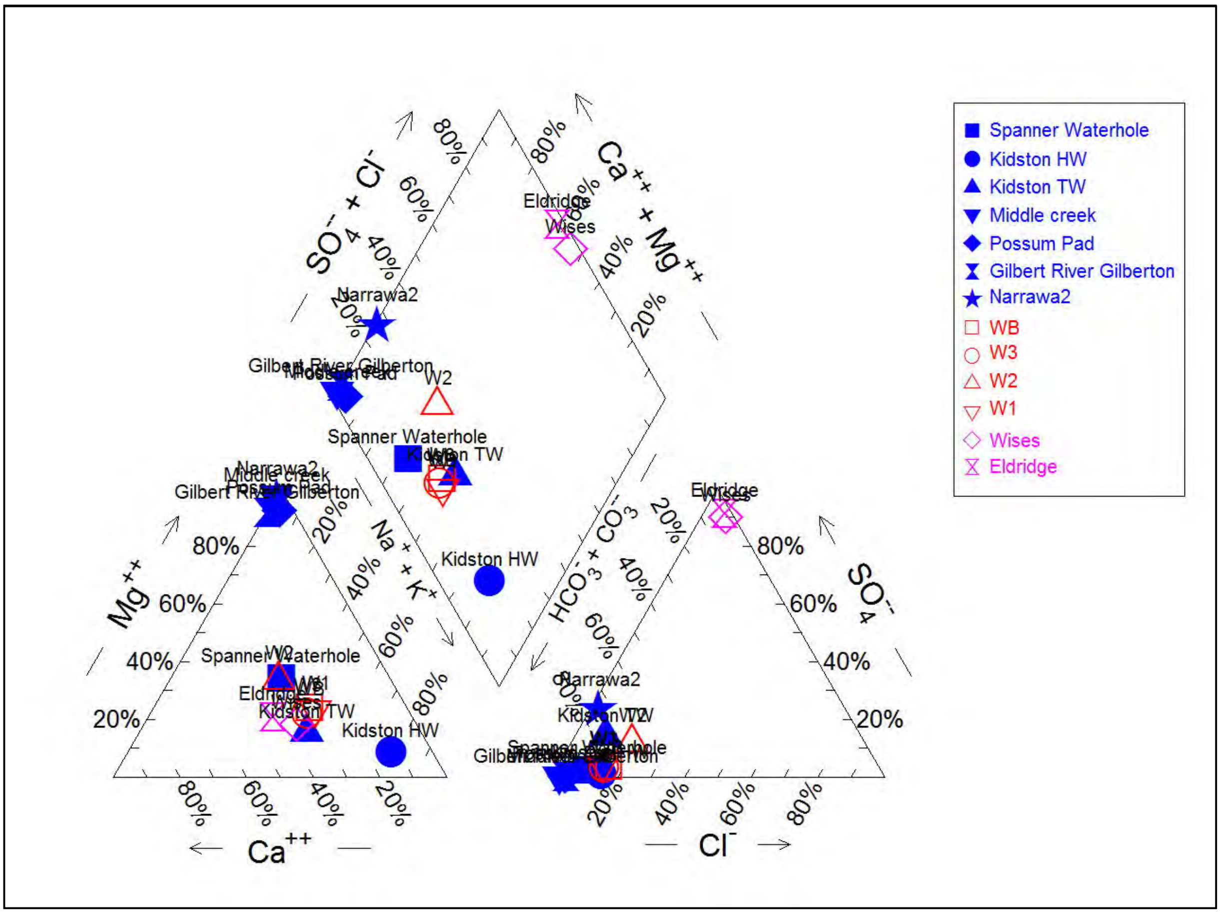


Figure 31 Piper diagram of local waters compared to pit water samples

5.9 Hydrology

Streamflow in the Copperfield River at the Project site is currently ungauged. The closest open, readily available stream gauge located on the Copperfield River is approximately 23 km upstream from the Project (Copperfield River at Spanner Waterhole, 917115A). Although the gauge is located reasonably close to the Project site it is located upstream of the Copperfield River Dam and catchment area scaling of the gauge data would therefore be unable to account for the impact of the dam on streamflow regulation.

Quantification of streamflow at the Project site is required in order to complete a flow spells analysis which is used to assess the magnitude, frequency and duration of streamflow events (a flow spell). The analysis enables quantification of the following key characteristics of the receiving environment flow regime:

- Flow seasonality
- Flow variability (both seasonally (intra-annual) and in response to climatic conditions (inter-annual))
- Flow predictability (expressed as the flow rate likely to be exceeded for a given probability)
- Flow volume (expressed as a daily volume); and
- Flow event duration (expressed as length of time/number of times flow of a certain likelihood is continuously exceeded).

5.9.1 Development of Water Resource Model

A water resource model was developed using the IQQM software for the purpose of simulating a long term streamflow record for the Copperfield River at the Project site. The model was developed to provide additional capability for conducting both near and far field water quantity and quality assessment of proposed releases of water from the Project.

IQQM is a well-known software package that is used in Australia for water resource modelling and planning including the DNRME. DNRME has used IQQM for water resource planning during development and assessment of WPs (water plans) and ROPs (resource operation plans).

A fully-developed model of the Gilbert Basin which was used as recently as 2016[10] for water planning assessment of the Water Plan (Gulf) 2007 was obtained from DES (herein referred to as the WRP Model) through the DES hydrology request facility. The supplied WRP Model was revised and updated (to allow increase of the model simulation length from 1890 to 2003 to 1890 to 2017) for use in the IAR assessment as summarised in Table 38 and shown in Figure 32.

A number of additional nodes were added to the IAR model downstream of the Project site in to assist in completion of the impact assessment. These are also shown on Figure 32 and are discussed in more detail in Section 5.9.2.

[10] Pers. Com. Paul Roe, Senior Hydrologist, Queensland Hydrology, 10/04/2018

Table 38 Summary of Development of IQQM Model

Aspect	WRP Model (Provided by DES)	IAR Model
IQQM Version	6.42	Updated to 7.53.6 to leverage graphical user interface and statistical analysis tools
Model Spatial Representativeness	Gilbert Basin including all major tributaries	All nodes and links representation of WRP Model for all watercourses upstream and directly downstream of the Project site: • Copperfield River; and • Einasleigh River between confluence with Copperfield River and confluence with Gilbert River. All other tributary inflows were reduced to single nodal inflow points using input flows at key locations extracted from the WRP Model outputs (refer to Figure 32)
Input Data	1890 to 2003	All input data informing the model catchments reporting to Einasleigh were extended to allow the model to run to 31/12/2017. Due to the spatially distributed nature of the input climate data[11] it was not practical to extend the remaining model inputs within the available timeframe. Consequently, model results for any nodes below Einasleigh are only valid until the end date of the WRP Model – i.e. 2003. This has no impact on the model's ability to estimate streamflow for the Copperfield River and Einasleigh River above Einasleigh to the the end of 2017.
Demands, Transmission Losses, Dam Operations, etc.	As per received model	All nodes and links taken from the WRP Model were replicated identically in the IAR Model (refer to Figure 32) including any associated data or assumptions (e.g. routing parameters). Input data and assumptions for the Copperfield Dam were adopted as per the WRP Model and consisted of: • Storage curve data; • Spillway capacity; • Outlet works; • Demand (Kidston Gold Mine) – 4,650 ML/yr; and • Environmental release – 1,143 ML/d pass though.
Model simulation capability	1890 to 2003	• 1890 to 2017 for catchment reporting to Einasleigh (Copperfield River and Einasleigh River upstream of Einasleigh) • 1890 to 2003 for Einasleigh River downstream of Einasleigh to Gilbert River.

[11] Averaged SILO Data Drill for every grid point within every calibration catchment

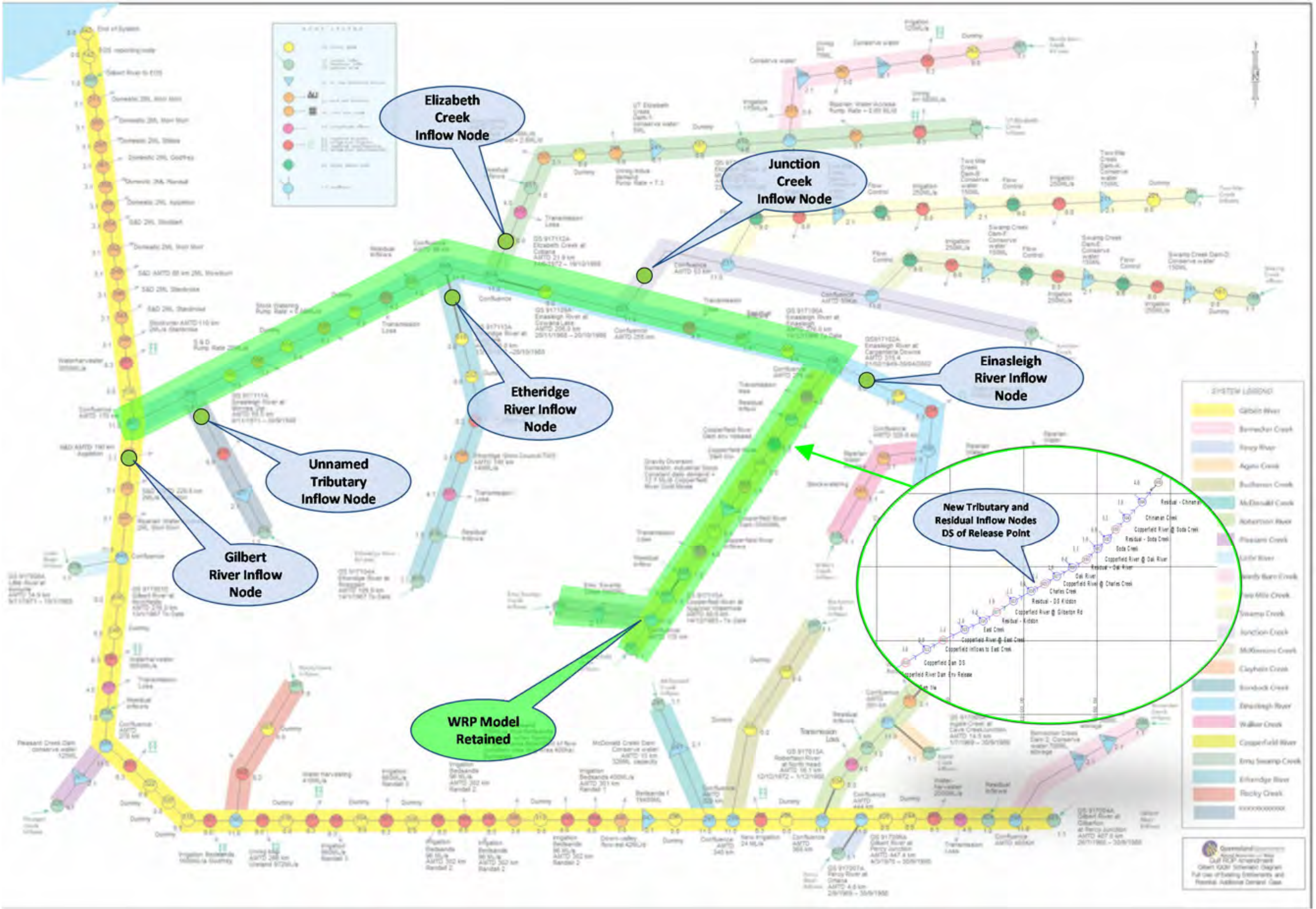


Figure 32 Development of IAR IQQM Model

5.9.2 Model Validation

Once the model was developed, the IAR Model was compared to the WRP Model to ensure consistency in results over the concurrent simulation period (1890 to 2003). Figure 33 shows the modelled daily flow duration curve for the Gilbert River immediately downstream of the confluence with the Einasleigh River (the effective end of the IAR Model). It can be seen that the IAR model replicated the WRP Model. In addition, when compared to the WRP Model, the IAR Model exhibited a volume ratio of 100.0% and a coefficient of determination (R^2) of 1.0 when comparing daily flows from both models over the same period.

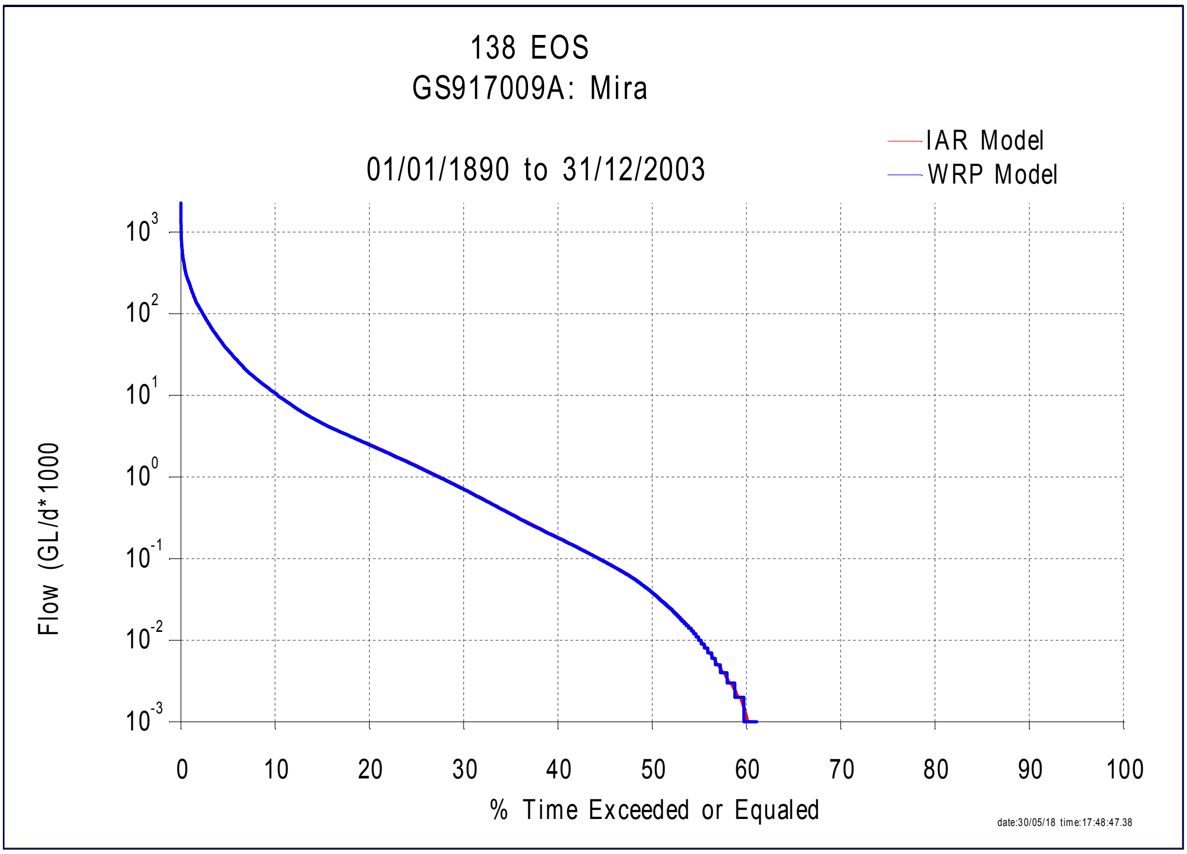


Figure 33 Flow Duration Comparison – WRP Model and IAR Model (Downstream of Gilbert and Einasleigh Rivers Confluence)

5.9.3 Streamflow Assessment

The IAR model was used to generate a long term streamflow record for the Copperfield River at the Project site. The simulation was conducted over 127 years for the period 1/1/1890 to 31/12/2017. The output streamflow record was subsequently subjected to statistical analysis using the River Analysis Package (RAP (v3.08), available from the eWater Toolkit).

Table 39 shows key environmental flow performance indicators that are used by the Water Plan (Gulf) 2007 to assess medium to high modelled streamflow at a node within the WRP Model. Mean annual discharge in the Copperfield River is estimated to be 162 GL/yr. and the 10% daily flow is approximately 391 ML/d. Annual (water year, November through October) discharge and annual flow duration (representing the likelihood that annual discharge of a specific volume will be exceeded for any given year) are shown in Figure 35 and Figure 34 respectively. From the figures it can be seen that total annual discharge is highly variable ranging from approximately 1,300 GL/yr. to less than 1 GL/yr.

Table 39 Water Plan (Gulf) 2007 Performance Indicators for Assessing Periods of Medium to High Flow at a Node (Copperfield River at Project Site)

Indicator*	Units	Discharge
Mean Annual Flow	GL/yr	162
Median Annual Flow	GL/yr	69
10% Daily Flow	ML/d	391
1.5 Year Daily Flow Volume	ML/d	4,674
5 year Daily Flow Volume	ML/d	30,325
20 year Daily Flow Volume	ML/d	97,694

* As per Section 17 (b)

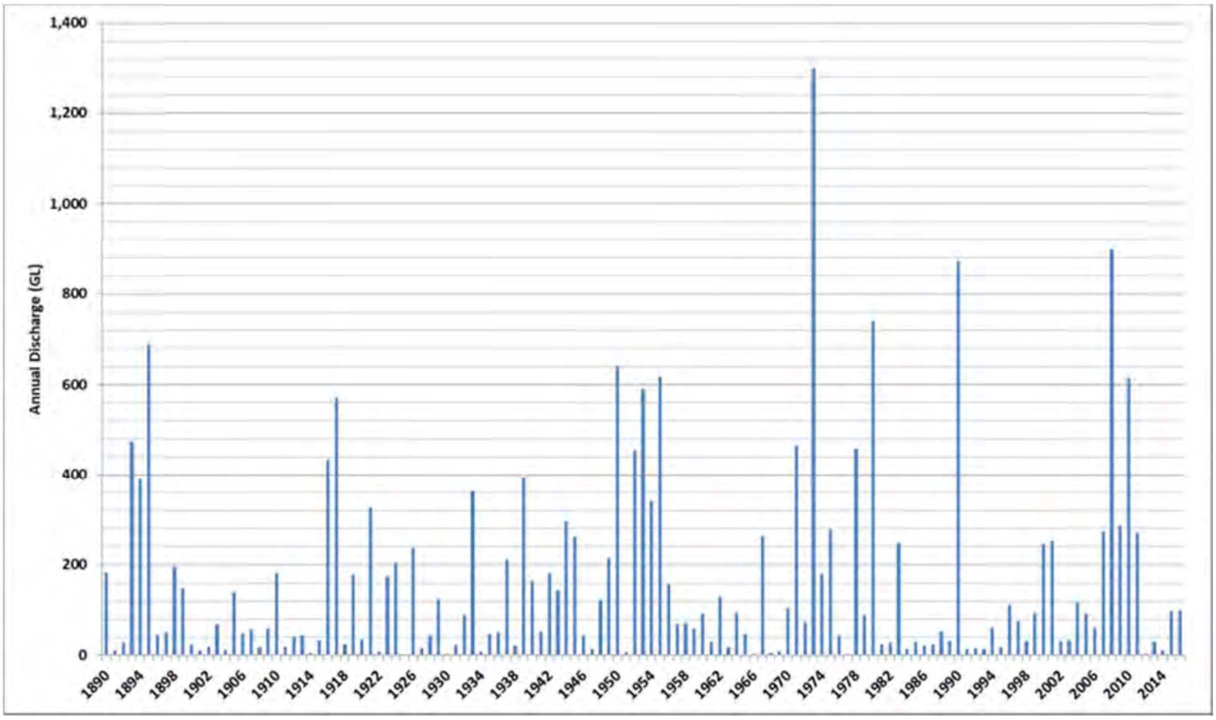


Figure 34 Estimated Annual Discharge for Copperfield River at Project Site (Water Years Nov – Oct)

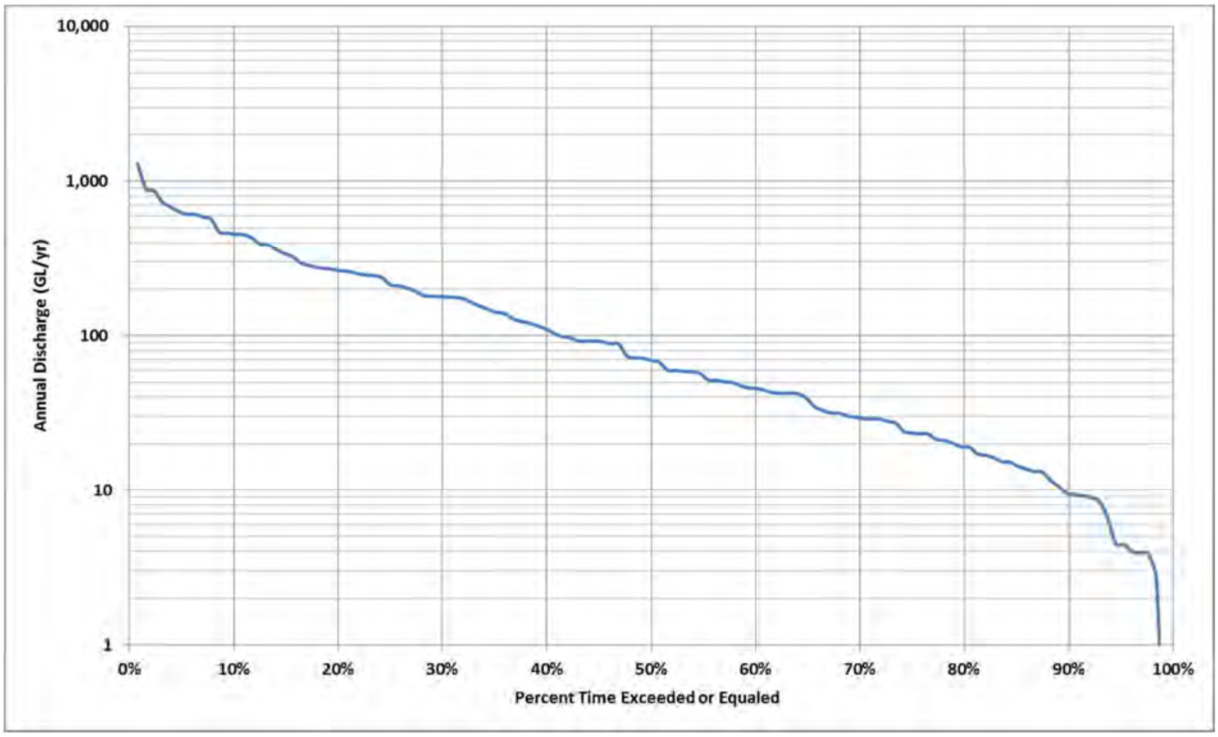
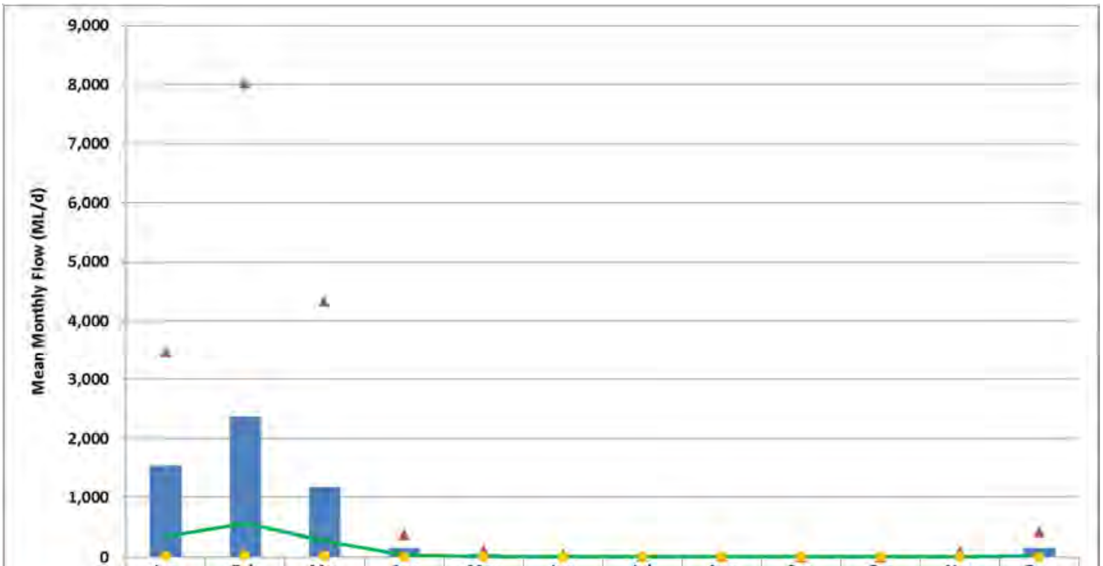


Figure 35 Annual Flow Duration Plot for Copperfield River at Project Site (Water Years Nov – Oct)

Mean daily discharge is shown in Figure 36 and the daily flow duration curve (representing the likelihood that flow of a specific rate will be exceeded on any given day) for all daily flows is shown in Figure 37:

- Streamflow shows a distinct seasonal distribution with a distinct high flow season occurring from December through April; however the majority of mean daily flow is restricted to the months of January through March (Figure 36).
- Significant variability in streamflow can be seen during the high flow period of January through March which is reflective of the wet season rainfall variability discussed in Section 5.2.1 , for example, mean daily flow for February ranges from approximately 2,400 ML/d (P90 result) to 22 ML/d (P10 result).
- Cease to flow conditions (less than 1 ML/d) are present on approximately 55% of all days for any day and reduce to approximately 32% during the wet season (November through April).



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mean	1,545.0	2,377.1	1,179.8	149.9	44.4	22.2	6.4	6.1	3.5	7.3	36.3	146.0
P90	3,481.5	8,032.6	4,335.7	383.6	109.1	56.2	12.9	9.6	3.8	6.2	100.8	424.0
P50	344.8	564.6	273.0	28.6	3.4	0.4	0.1	-	-	0.1	0.7	26.6
P10	9.3	21.3	13.2	0.1	-	-	-	-	-	-	-	0.2

Figure 36 Mean Daily Discharge for Copperfield River at Project Site

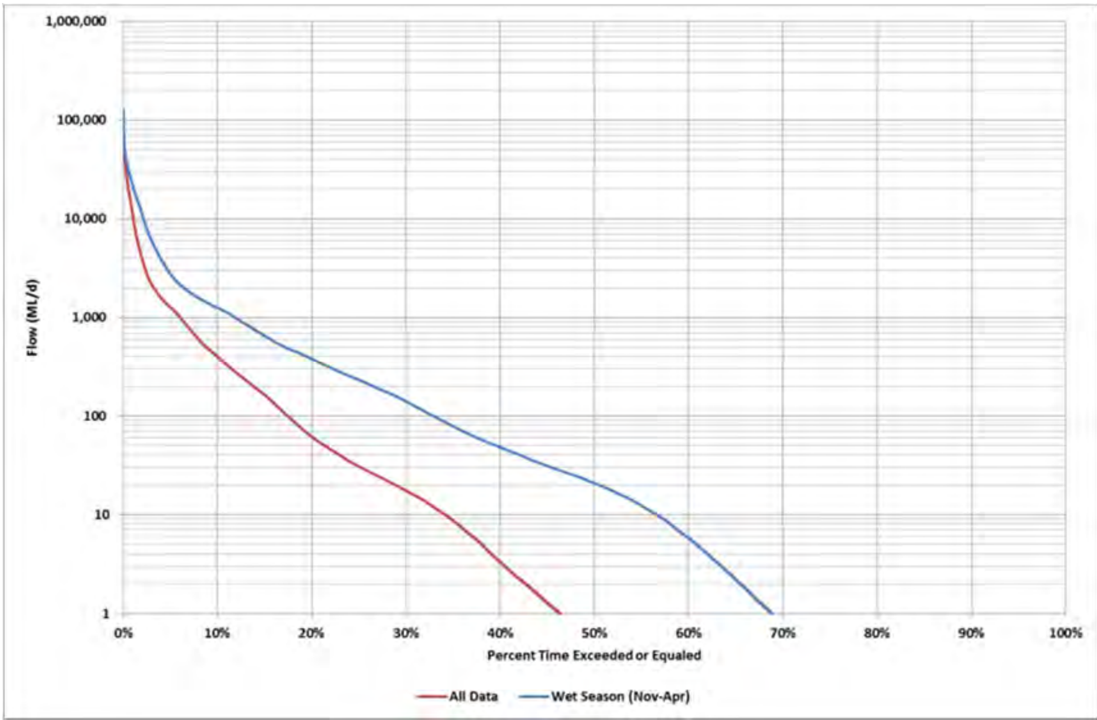


Figure 37 Daily Flow Duration Plot for Copperfield River at Project Site

The simulated streamflow record for the Project site was subjected to a flow spells analysis as per the definitions shown in Table 40. Summary results are presented below in Table 41 and Table 42 for the flow spells statistics relevant to the proposed release of water i.e. high flow spell and during the wet season. Results for cease to flow conditions are also included for context:

- When assessed continually for the 127 years of streamflow data, the 10% flow (391 ML/d) has a mean duration of approximately 9 days during the wet season (Table 41) with a mean duration between spells of around 82 days. The estimated mean duration of cease to flow conditions is approximately 20 days.

- Wet season inter-annual results (Table 42):
  - Show that the 10% flow (391 ML/d) occurs approximately 3 times during the wet season, has a duration of approximately 8 days and with approximately 14 days between spells (median results).
  - Cease to flow conditions may occur approximately 8 times with a duration of around 19 days (median results).

Table 40 Flow Spells Assessment – Adopted Definitions

Aspect	Adopted Definition
Seasons	Wet – November through April
	Dry – May through October
Flow Spells	High flow spell - 10%, 5% and 2% daily flow exceedance probability
	Low flow spell – cease to flow condition

Table 41 Flow Spells Summary - All Years (Wet Season, Nov-Apr)

Statistic	Units	High Spell Daily Exceedance Probability			Cease to Flow Conditions
		10%	5%	2%	
Spell Threshold	ML/d	391	1,254	3,790	-
Number of Spell	Count	509	387	188	1,032
Longest Spell	Days	123	77	42	272
Mean of Spell Peaks	ML/d	6,961	10,356	21,398	-
Mean Duration of Spell	Days	9.1	6.0	4.9	19.6
Mean period Between Spells	Days	82	114	241	25.4

Table 42 Flow Spells Summary - Inter-Annual Summary (Wet Season, Nov-Apr)

Statistic	Units	High Spell Daily Exceedance Probability			Cease to Flow Conditions
		10%	5%	2%	
Spell Threshold	ML/d	391	1,254	3,790	-
Mean of Wet Season Number of High Spell	Count	3.7	2.9	1.5	8.8
Mean of Wet Season Longest High Spell	Days	22.4	11.3	6.8	88.3
Mean of Wet Season Mean Duration of High Spell	Days	11.6	6.5	4.5	21.5
Mean of Wet Season Mean period Between High Spells	Days	16.6	16.9	18.1	35.7
Median of Wet Season Number of High Spell	Count	3.0	3.0	1.0	8.0
Median of Wet Season Longest High Spell	Days	16.0	9.0	5.0	81.5
Median of Wet Season Mean Duration of High Spell	Days	7.7	5.0	4.0	18.7

Statistic	Units	High Spell Daily Exceedance Probability			Cease to Flow Conditions
		10%	5%	2%	
Median of Wet Season Mean period Between High Spells	Days	14.0	13.0	13.9	25.1

The IQQM streamflow record for the Project site indicates that streamflow is highly seasonal and variable. Medium to high flow conditions of 391 ML/d (defined as the flow likely to be exceeded on 10% of all days) typically occur multiple times during the wet season and persist over a number of days. However cease to flow conditions are also likely during the wet season as a result of the highly variable rainfall described in Section 3.2.1.

5.10 Hydraulics and Fluvial Geomorphology

5.10.1 Stream Hydraulics

5.10.1.1 Model Development

A one-dimensional hydraulic model was developed using software HEC-RAS to assess impacts to the Copperfield River. Model data, inputs and parameters are listed below.

Available Data

Freely available LiDAR from Geoscience Australia's online portal *ELVIS* was used for the development of the hydraulic model. The Digital Elevation Model (DEM) used has a resolution of 5m.

Aerial Imagery available through ArcGIS's World Imagery Layer has been utilised for this study. Inspection of the aerial imagery was undertaken for purposes of understanding vegetation cover for catchment roughness.

Inputs & Parameters

Hydraulic inputs and parameters used in the development of the HEC-RAS model are listed below in Table 43.

Table 43 Hydraulic Model Parameters

Parameter	Information
Scenarios Modelled	Base-case (without releases); Design-case (with releases)
Flow inputs	Three flow cases were modelled for each scenario: • Medium flow of 400 ML/d (10th percentile daily flow) • High flow of 1,270 ML/d (5th percentile daily flow) • 2% High flow of 3,790 ML/d (2nd percentile daily flow)
Hydraulic Modelling Approach	HEC-RAS 5.05
Model Extent	4,100m upstream and 7,500m downstream of release point
Manning's Roughness	Main Channel n=0.035, Overbanks n=0.05
Downstream Boundary Condition	Average Hydraulic Slope=0.2%

Model Scenarios

As described in Table 43 two scenarios being the base-case (without releases) and design-case (with releases) were modelled for the three flow cases.

5.10.1.2 Baseline Results

HEC-RAS was setup to assess hydraulic base-case characteristics such as velocity, water level, shear stress, stream power and active flow width. The base-case model is defined as the 'without releases' scenario. Channel flow rates considered for the 'without releases' scenario cover the expected ranges that may provide release opportunities. Medium, High and 2% High flow rates were developed and applied to the model.

The flow depths, velocities, shear stresses, stream power and active flow widths from the 'without releases' HEC-RAS model are reported in Figure 38 to Figure 42.

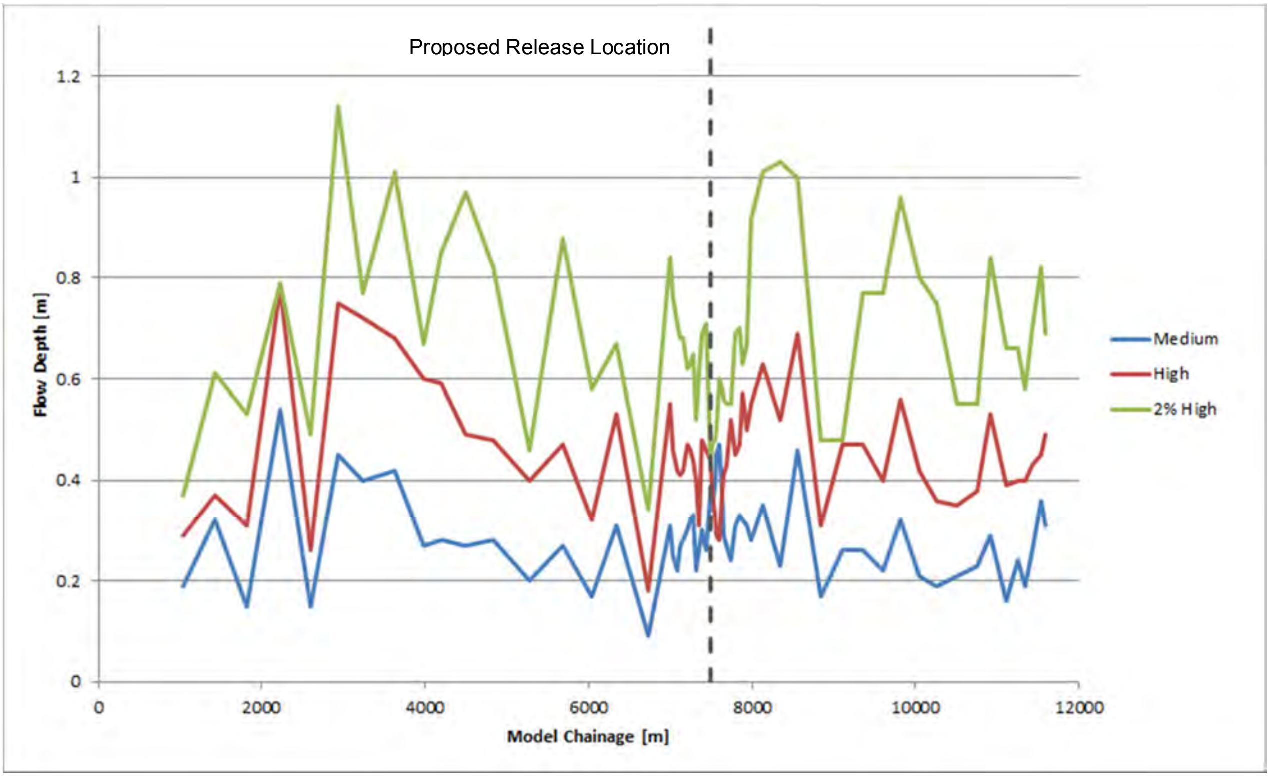


Figure 38 Flow depth along channel in HEC-RAS model for three investigated flows (downstream to upstream, left to right)

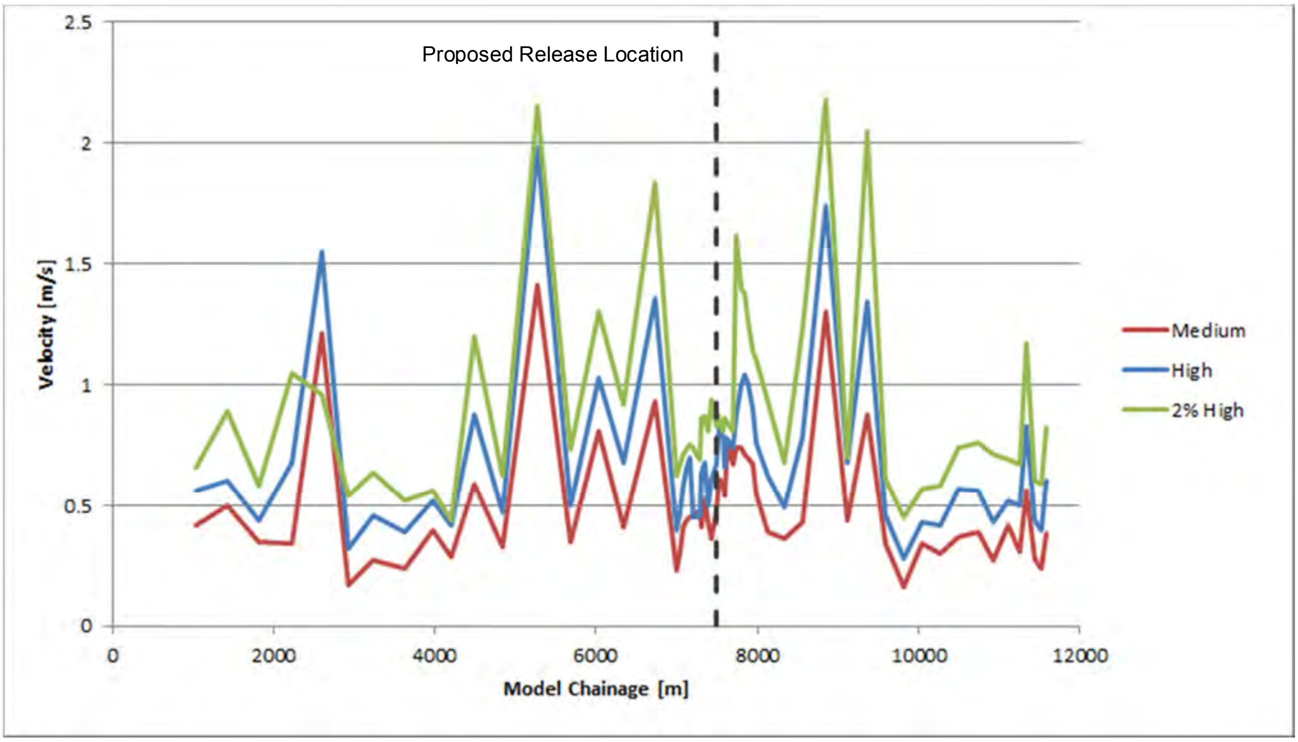


Figure 39 Velocity along channel in HEC-RAS model for three investigated flows (downstream to upstream, left to right)

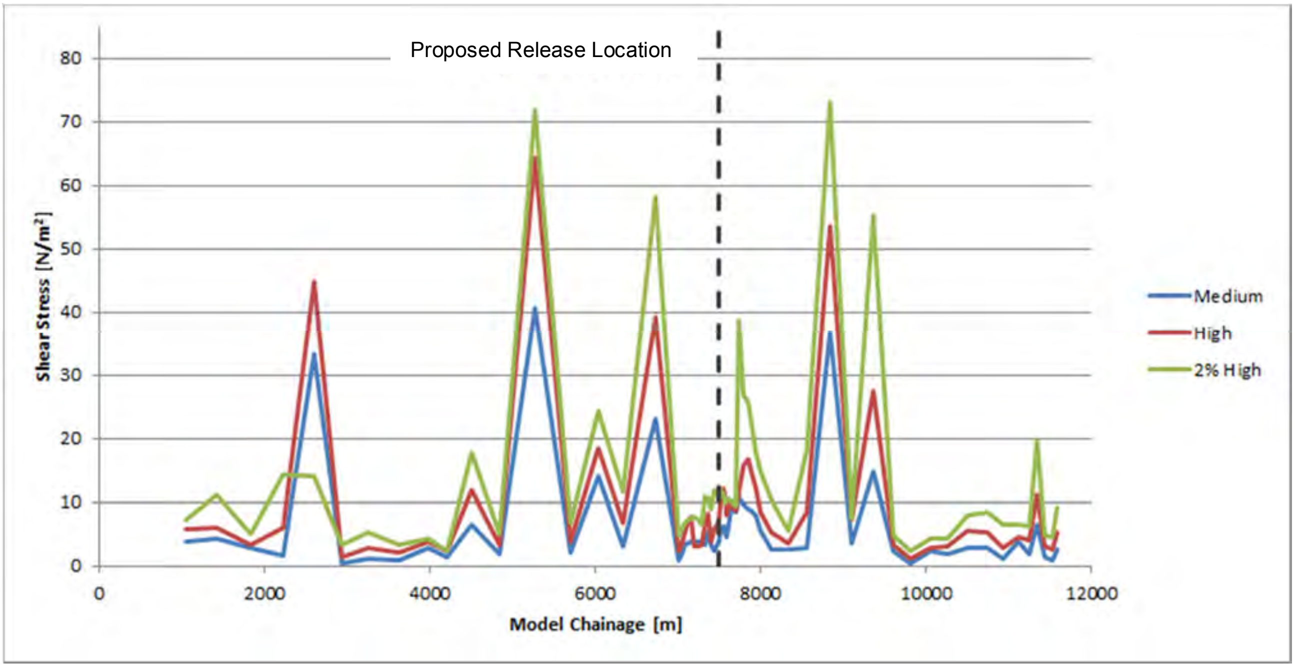


Figure 40 Shear stress along channel in HEC-RAS model for three investigated flows (downstream to upstream, left to right)

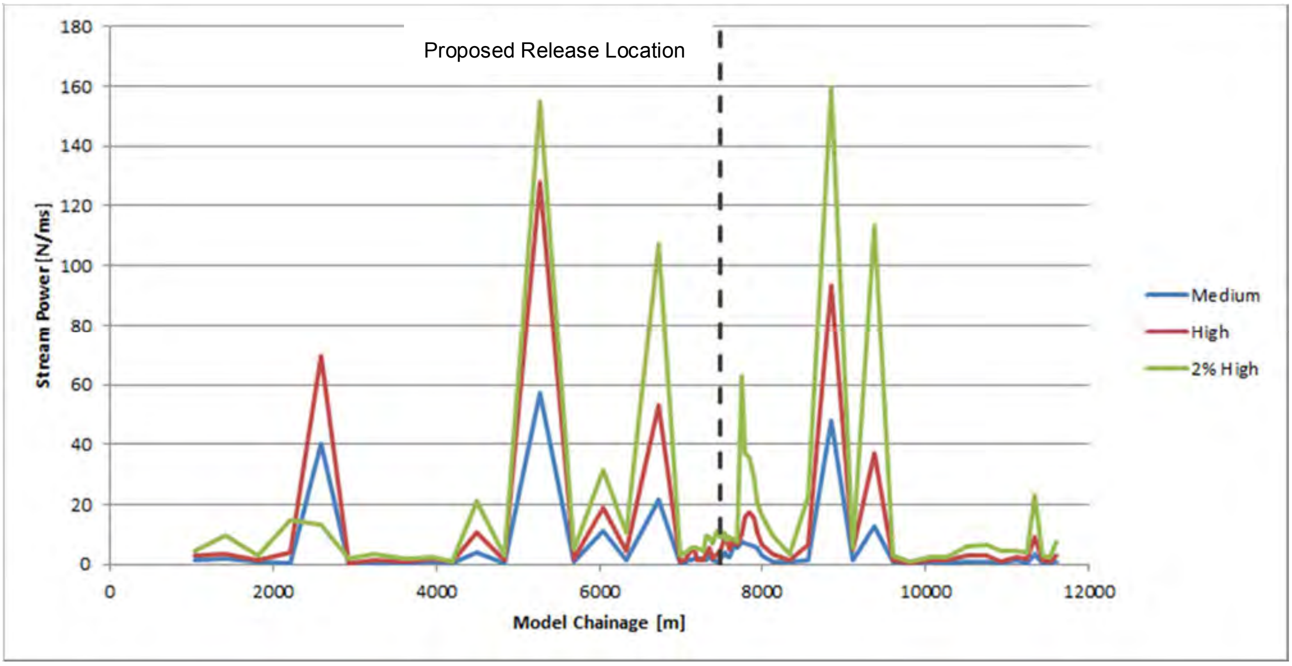


Figure 41 Stream Power along channel in HEC-RAS model for three investigated flows (downstream to upstream, left to right)

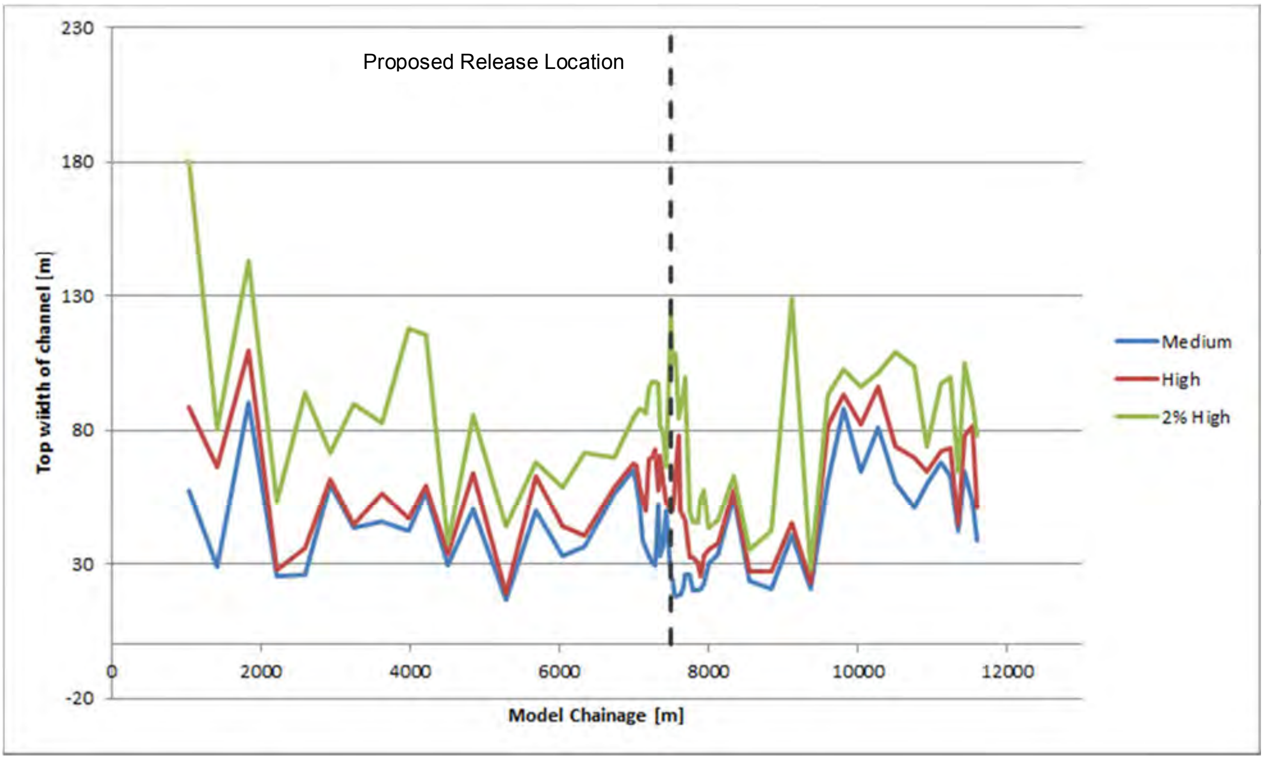


Figure 42 Active Flow width along channel in HEC-RAS model for three investigated flows (downstream to upstream, left to right)

5.10.2 Fluvial Geomorphology

The Project site is located adjacent to the Copperfield River, a major tributary of the Einasleigh River which is in turn, a major tributary of the Gilbert River which gives its name to the Basin. Key watercourses generally flow in a north-west to south-east alignment as a result of the underlying structural controls relating to uplift, warping, doming, faulting and subsidence that that provide a strong influence on both relief and drainage (Tomkiins, 2013). Major rivers such as the Gilbert and Einasleigh can be seen to follow this alignment which is consistent with regional lineaments (a large scale linear feature expresses in terms of surface topography and an expression of the underlying structural features) and many of the ranges and plateaux like the Gregory and Newcastle Ranges are up-warped features (Tomkiins, 2013).

The Gilbert Basin consists of a number of distinct physiographic regions (morphological unit with an internal coherence in its landform characteristics). At the division level, the Basin is split between the Eastern Uplands Division to the south east and the Interior Lowlands Division to the north east (Pain, Gregory, Wilson, & McKenzie, 2011). Located in the far south east of the Gilbert basin, the Copperfield River catchment is located within the Peninsular Uplands Province which includes the upland and coastal areas of the western part of the Cape York Peninsula and the great Escarpment.

Upper headwater tributaries and the main channel of the Copperfield River to approximately 10km below the Copperfield River Dam are located within the Newcastle Ranges (Pain, Gregory, Wilson, & McKenzie, 2011) region which is comprised of rugged hills on acid volcanic, granitic and metamorphic rocks. The dissected ranges show maximum elevation to around 1,000 m and comprise notable outcrops of resistant porphyry forming a high erosion plain with bare, rounded slopes.

The remaining lower half of the Copperfield River catchment (including the Project site) is part of the Einasleigh Plains physiographic region and characterised by undulating to irregular plains and low hills on granite and metamorphic rocks with ridges and mesas formed of basalts, sandstones, siltstones and porphyry dykes (Tomkiins, 2013). Drainage density is low and contained within shallow until the basalt flows at Einasleigh where valleys become more gorge-like.

Adjacent to the Project site and downstream to the confluence with East Creek, the Copperfield River comprises a wide and relatively shallow bedload-dominated channel. Relatively frequent structural controls result in features such rock outcrops, ledges and pools that are interspersed by extensive deposits of medium to coarse grained sands, gravels and some occasionally larger material up to cobble and occasionally boulder sizes. A well-defined low flow channel traverses the broad sand deposits which are, at times partially vegetated with stands of trees and bushes. While showing signs of a high degree of lateral mobility in some reaches, the low flow channel also has a well-developed but narrow and discontinuous band of riparian vegetation comprised of an open forest structure dominated by Melaleuca and Acacia *spp.*

It is possible that the characteristically high bedload in the Copperfield River and common to the region is the remnant from a past period of more active transport when flow conditions were higher. These periods are linked to the more hydrologically effective climates associated with the glacial/inter-glacial cycles when stream power and potential sediment transport were much greater than present (Nanson, Jones, Price, & Pietsch, 2005). This bedload is typically only reworked downstream during the high energy wet season flow events however it is probable that even during these events that only some of the surface sediment is actively reworked and transported a distance downstream at present, with the remainder stored in the channel bed (Tomkiins, 2013).

5.11 Hydrogeology

5.11.1 Previous Studies

There have been a number of previous investigations of the hydrogeology of the Kidston Gold Mine area. Most of these studies have concentrated on the local regime around Wises and Eldridge Pits and the tailings dam (see Section 8.3 in AGE [2001] for a description of these studies). The studies have tested rock properties and drilled holes to collect geological and hydrogeological information. There has been limited regional scale studies, with AGE (2001) providing some regional context to the hydrogeology, including the development of a groundwater flow model of the Kidston area to investigate groundwater behaviour around the tailings dam.

More recent studies looking at the Project by AGE (including the most recent January 2019 memorandum presented in Appendix H) rely on their original work, and modelling, reported in AGE (2001). The 2019 memorandum (refer to Appendix H) presents predicted changes to the groundwater flow regime from the Project. The modelling has been done through a steady state approach and thus assumes the Project is in place for infinite time. The Project is represented by its extreme pit levels during operation, and this combined with the steady state representation maximises the predicted extent of changes to the groundwater system from the Project. Further to this the model adopts reasonably high hydraulic conductivities to what has been measured in the field for fresh rock. This means that the predicted impacts extend further than would be the case applying the actual measurements for the fresh rock.

The modelling (Appendix H) also indicates potential changes to baseflow to and seepage from Copperfield River, though as the pathline analysis indicates those changes may not occur during the life of the Project.

5.11.2 Regional Geology

The Project Site is located on the Einasleigh - Copperfield Plain within the geological Pre-Cambrian Georgetown Inlier of the North Australian Craton. The Georgetown Inlier is a member of the Etheridge Province, which represents one of four inliers where Precambrian Paleoproterozoic rocks outcrop in northern Queensland (Jell, 2013).

Regional geology, as described in the 1: 100,000 Einasleigh Sheet (7760) geological map (DNRM, 2003a), comprises complex geology inclusive of the Precambrian Einasleigh Metamorphics, Siluro-Devonian Oak River Granodiorite, Carboniferous to Early Permian elements (rhyolite, microgranite, microdiorite, dolerite, gabbro, and andesite), and Quaternary Chudleigh Basalt and alluvial sediments.

The stratigraphy in the region is presented in Table 44.

Table 44 Regional Stratigraphy

Period	Unit	Lithology	Thickness (m)
Quaternary	Alluvium	Sand, gravel, clay, silt	5-6 m in proximity to surface water features
	Chudleigh Basalt	Basalt	
Early Permian			
Carboniferous			
Silurian	Oak River Granodiorite	Granodiorite	
Precambrian	Einasleigh Metamorphics	Gneiss, migmatite, textural granulite, minor schist, quartzite, amphibolite	unknown

5.11.3 Local Geology

The Copperfield River, at the proposed release area, drains through Quaternary alluvial sediments which directly overlie the Einasleigh Metamorphics.

The alluvial sediments (comprising clay, silt, sand, and gravel) extend laterally from the river bed as flood-plain alluvium. Drilling indicates limited thickness of alluvial sediments within the Copperfield River, some 5 to 6 m.

The Einasleigh Metamorphics, predominantly biotite gneisses, outcrop adjacent and (in some sections) within the Copperfield River.

5.11.4 Structural Geology

Regionally, a series of northeast trending faults related (sympathetic) to the Gilberton Fault (described as the Gilberton Corridor) and northwest trending structures parallel to Paddy's Knob dyke swarm and regional foliation are the dominant structures of the area (Genex, 2015).

Near the proposed release area of the Copperfield River, vertical foliation and a platy alignment (dipping east 68 degrees) is mapped in the river bed upstream from the proposed release area; a vertical platy alignment with a dip of 80 degrees westwards is located downstream.

5.11.5 Hydrogeological Setting

The alluvial aquifer is constrained to the terrace containing the Copperfield River.

5.11.6 Hydraulic Properties

Recent investigations by Entura (2015) included in situ permeability testing (packer tests) of seven boreholes measured from less than 8.6×10^{-4} m/day to more than 8.6×10^{-1} m/day with average of 4×10^{-2} m/day. Testing was performed on both 'fresh' and 'weathered' intervals and their results are skewed upwards by testing of the weathered zone.

5.11.7 Groundwater Levels

Two registered bores (BA06 and BA07) are known to be screened in the alluvium. One bore, RN126212, is reported to be constructed in granite as a water supply bore, considered to be the Einasleigh Metamorphics within the mine area. As a result, the impact assessment focused on results from these three locations only. All other bores are designed to monitor the site operations and are not relevant to the assessment of impacts associated with the proposed releases.

The locations of existing groundwater bores are shown in Figure 43.The bore report cards, report that water levels for these alluvial bores range from 1.57 metres below ground level (mbgl) for monitoring well BA07 to 2.8 mbgl for bore BA06.

Water level data for the alluvial bores provided by Genex (2015), in the form of a time-series graph, indicates water levels for bore BA06 varied over time but generally reflects an unconfined aquifer with low water levels during the dry season and elevated levels just after commencement of the wet season. It is noted that from December 2014 through June 2015 (no data was available after June 2015) bore BA06 has been dry.

5.11.8 Groundwater Flow

Regional groundwater flow within the alluvium is considered to mimic the topography of the Copperfield River and subsequent flow direction, generally north.

AGE described the groundwater regime in 2001 as follows:

> *"In the Kidston Mine area the regional watertable is between RL 515-525m and groundwater flow is to the north consistent with the regional drainage pattern. In the area of Eldridge Pit pre-mining water levels ranged from about RL 500m to RL 525m as measured in July 1994. The groundwater flow system around the mine however has been grossly modified by dewatering of the two mine pits and by construction of the tailings dam and interception drains. Dewatering of the pits has created a very steep cone of depression in the water table with a gradient of about 1:1, around the pits."*

The cone of depression around the pits continues to this day and is indicative of the tight host rock that exists around the mine, although the gradient in the cone of depression has become less as the pits received water to aid in their recovery after mining.

The hydrological regime of the Copperfield River is ephemeral; flows are highly episodic and likely sustained only during and immediately after significant rainfall events and the wet season. As such, no permanent pools have been identified through a desktop review of aerial photographs in proximity to the proposed release location. However, the locations of semi-permanent waterholes within the floodplain of the Copperfield River were identified through flyover with a drone by Genex in September 2018.. Section 5.14 provides information regarding the location of these semi-permanent pools, along with the results of dry season water quality sampling undertaken in September 2018.

The presence of semi-permanent pools suggests the river is, at least for some parts of the year, fed by groundwater discharge. The fact that the pools do not persist throughout the year indicates that the groundwater source aquifer (likely the alluvium in the surrounds of the river) has limited storage. Groundwater inflows to the river are potentially sourced from surface water that has infiltrated the alluvium when the river is in flood.

In 2001, AGE further identified that the Gilberton Corridor may be tenuously connected to the Copperfield River (AGE, 2001). No further conceptualisation was performed by AGE; however, it is considered that in the instance a hydraulic connection between the fault system and the river is present, there is potential for migration between the former mine area and the Copperfield River.

5.11.9 Recharge and Discharge

The unconfined alluvial sediments are directly responsive to rainfall and surface water recharge, which occurs during periods of high flows and during the extensive wet season. The alluvial aquifer is considered to have limited groundwater resource potential due to limited (and discontinuous) lateral extent from the Copperfield River, limited saturated thickness, and is expected to have limited effective storage (bores are dry during dry season).

During the operation of the Project, surrounding groundwater will flow into Eldridge pit based on hydraulic gradients. AGE (2019) have estimated this inflow could conservatively be 770 kL/day, but this dependent on an established cone of depression within a more permeable simulated environment than exists at the site. Mounding of groundwater around Wises pit is also predicted to occur as there will be seepage through its base and the elevated groundwater here will interrupt the natural flow of groundwater north, causing water to deviate around the operation, with some of the water moving north being intercepted by the cone of depression around Eldridge Pit.

5.11.10 Groundwater Quality

Alluvial aquifer

Limited hydrochemistry data for the alluvium associated with the Copperfield River is available. Groundwater quality monitoring data provided by Genex was assessed and bore reports from the DNRME registered GWBD were interrogated for groundwater quality data in proximity to the proposed release area.

Two registered bores are reported to be constructed to intersect the floodplain alluvial sediments of the Copperfield River, RN139937 (KGM monitoring bore BA06) and RN139938 (KGM monitoring bore BA07) located adjacent to the mine pits and north and south of the proposed release area.

The available groundwater quality data for these bores, provided by Genex, comprises monitoring from October 2008 through October 2017, which includes some seasonal variability (wet and dry season monitoring) and spatial variability.

Figure 43 Groundwater Bore Locations

- The available data from monitoring bore BA06 indicates magnesium/calcium-sulfate-rich water quality. Sulfate concentrations have varied throughout the monitoring period but generally ranged between ~ 2,500 and 3,000 mg/L, although a marked increase was observed in January 2017, to ~ 5,000 mg/L.
- The available quality data for monitoring bore BA07 indicates a greater proportion of dissolved sodium and chloride, and lower dissolved sulfate concentrations (< 1,000 mg/L) than bore BA06. The January 2017 sulfate 'spike' observed in BA06 was also observed in water quality from BA07 sampled on the same date; however, sulfate concentrations reported subsequently decreased in both bores (to < ~ 1,000 mg/L). Electrical conductivity trends mirror sulphate concentrations.

Samples from both bores record relatively high alkalinity (~ 200-500 mg/L) and pH has remained consistently between 7 and 8 for both bores throughout the monitoring period. Recorded dissolved metals concentrations are generally at or below laboratory LOR in samples from both monitoring bores.

The location of BA07 (just east and down topographic gradient from the former mine pits) and the marked variation in water quality from bore BA06, suggests that seepage from the former mine area may be acting as artificial recharge to the alluvial sediments in proximity to the proposed release area. Figure 44 illustrates the potential impact of former site operations on the water quality at BA06 and BA07. Of the surface water quality samples, monitoring location W2 potentially records some impact, although it is unclear as to whether this is directly from BA07, or from other former mine site sources. The other monitoring points record relatively unimpacted water quality. The assessment of assimilative capacity usage and surface water quality impacts associated with releases are based on historical data from the Copperfield River at monitoring location W2 and therefore take into account the potential seepage impacts as a 'worse case' scenario.

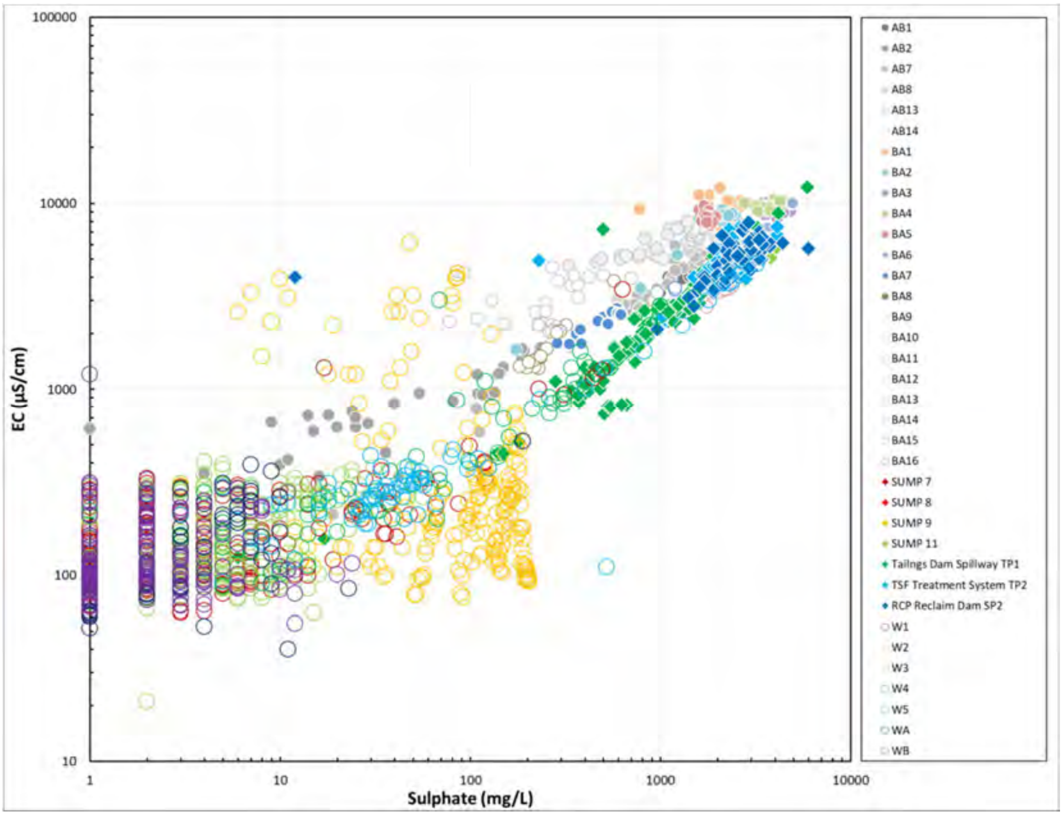


Figure 44 Variation in sulfate concentrations (in mg/L) and EC (in µS/cm) in groundwater sampled from the Project site monitoring bores ('ABxx', 'BAxx'), surface water sampled from sumps and TSF spillways (e.g., 'SUMP xx', 'TP1', etc.), and surface water quality monitoring points W1 to WB

Einasleigh Metamorphics

One bore, RN126212, is reported to be constructed in granite as a water supply bore, considered to be the Einasleigh Metamorphics. Groundwater collected from RN126212 is brackish, with 2,850 mg/L total dissolved solids (TDS).

Regionally, other bores are understood to be installed in the Einasleigh Metamorphics, however these are located northwest of the former mine area considered to be a different hydrogeological system and no corresponding water quality data is available.

5.11.11 Registered Groundwater Bores

The registered groundwater bore database (GWBD), maintained by the DNRME, was interrogated in June 2018 to identify registered groundwater bores within and adjacent to the Project area. The search identified nine bores within a 10 km radius of the proposed Project area. Of the nine bores, eight are identified as monitoring bores (assumed to be for the former mine) and one is reported as a water supply bore. All bores are reported to be existing and sub-artesian groundwater conditions.

Table 45 below presents the registered bore details as recorded in the DNRME GWBD.

Table 45 Registered groundwater bores within 10km of the proposed release area

Registered Number (RN)	Site Name	Easting	Northing	Depth (m)	Geology	Water Level (mbgl)	Yield (L/s)	Type / Name
RN126212	N/A	201242	7908347	25.0	Fractured Granite	9.95	0.26	-
RN139932	BA01	198611	7913081	22.0	Decomposed granite, sandy granite, granite	5.90	-	Monitoring Bore 1
RN139933	BA02	198831	7912522	17.0	Sandy loam, decomposed granite, granite	5.80	-	Monitoring Bore 2
RN139934	BA03	198912	7912195	13.0	Decomposed granite, granite	0.37	-	Monitoring Bore 3
RN139935	BA04	198780	7909475	17.0	Decomposed granite, sandy granite, granite	3.0	-	Monitoring Bore 4
RN139936	BA05	198500	7909198	23.0	Decomposed granite, sandy granite, granite	2.0	-	Monitoring Bore 5
RN139937	BA06	201067	7909160	6.0	River loam, sand	2.80	-	Monitoring Bore 6
RN139938	BA07	201595	7910262	5.0	River loam, sand	1.57	-	Monitoring Bore 7
RN139946	BA16	197557	7910673	17.0	Decomposed granite, granite	1.90	-	Monitoring Bore 16

5.11.12 Groundwater Dependant Ecosystems

A search of the State of Queensland (2018) Queensland Globe was undertaken for known GDEs from south of Kidston to Einasleigh. A total of four (4) known GDEs were identified in the search area where the reported information for each spring is included in Table 46. No registered springs are located within the proposed release area.

A review of the Queensland Wetlands (2013) map for the Einasleigh area (sheet 7760) indicates one confirmed wetland spring, Middle Spring, within the vicinity of the former mine area. As included in Table 45 above, this spring is located west-northwest of the former mine and not considered to be hydraulically connected to the groundwater regime of the proposed release area, however it is recommended that this spring is further assessed as part of water modelling refinement and design phase work.

Table 46 Summary of GDEs

GDE Name	GDE Type	Spring vent ID	Status	Source Rock Type	Source Aquifer	Direction from Project	Distance from Project
Middle Spring	Surface expression (Spring)	482_1	Permanent / near permanent	Fractured rock (predominantly secondary porosity)	Einasleigh Metamorphics	West-northwest	~4.8 km
Topwater Spring	Surface expression (Spring)	438_1	Permanent	Fractured rock (predominantly secondary porosity)	Beverley Hills Granite	Northwest	~22 km
Pigeon	Surface expression (Spring)	437_1	Permanent	Fractured rock (predominantly secondary porosity)	Oak River Granodiorite	North	~34 km
Pigeon II	Surface expression (Spring)	439_1	Permanent	Alluvial sediments	Quaternary Alluvium	North	~34 km

A desktop assessment of riparian REs in the Copperfield River, downstream of the Project site has been undertaken. Additionally, the desktop assessment identified alluvial REs in Copperfield River from the Project site to its confluence with Oak River some 20 km downstream, to determine if GDEs were present. Four REs were identified and are presented in Table 47 below. None of these REs were identified as GDEs and as a result, there is no risk of impact to alluvial vegetation communities in Copperfield River as a result of stream flows.

Table 47 REs downstream Copperfield River

RE	Short Description
RE 9.3.3a	*Corymbia* spp. and *Eucalyptus* spp. dominated mixed woodland on alluvial flats, levees and plains.
RE 9.3.12a	Sandy river beds sometimes with patches of ephemeral grassland, herbland or sedgeland, which can include *Heteropogon contortus (*black speargrass), *Bothriochloa spp.*, and *Ammannia multiflora.*
RE 9.3.13	*Melaleuca* spp., *Eucalyptus camaldulensis* and *Casuarina cunninghamiana* fringing open forest on streams and channels.
RE 9.3.20	*Eucalyptus microneura* +/- *Corymbia* spp. +/- *E. leptophleba* woodland on alluvial plains.

Appendix H presents groundwater level changes predicted by AGE on a map containing the GDE mapping from the National Atlas of Groundwater Dependent Ecosystems (BOM, 2018). From a groundwater perspective, the mapping indicates:

> *"… that terrestrial GDEs may be present over large areas of land close to the K2-Hydro Project. Areas of highest potential are located along the drainage lines. It is possible that high potential GDEs along the Copperfield River could see a reduction in groundwater as a result of the Project. The majority of the area predicted to draw down by more than 1 m is unclassified over the historically disturbed mining areas, or at low potential for terrestrial GDEs.*
>
> *Potential aquatic GDEs are located along many of the nearby drainage lines, with the locations correlating strongly with the high potential terrestrial GDE mapping. The majority of aquatic GDEs are classified as moderate or low potential, with a small area of high potential along the Copperfield River to the northeast of the K2 Project. It is possible that GDEs along the Copperfield River could see a reduction in groundwater inputs as a result of the K2 Project.*
>
> *Although there are potential changes in groundwater levels predicted in the vicinity of several potential GDEs additional work will be required to determine if the changes could result in a negative impact to the vegetation communities.*
>
> *There is one permanent spring (SPR482 - Middle Spring), located approximately 4.8 km west-northwest of the Project. This is close to the edge of the model domain and is predicted to be impacted by less than 0.2 m from a very conservative steady state assessment."*

It is important to note that last comment, in that the steady state predictions AGE make in their memo (AGE, 2019) are reasonably conservative and assume there is sufficient time for the drawdowns and mounding to propagate to the presented extents.

5.12 Sediment Quality

The Copperfield River is a braided river system. Geomorphic models of this kind of river system place it as transport limited; that is, there is not enough stream power to transport the sediment that it is required to carry. Sediment transport throughout the region is limited to a few months per year during the wet season when discharge is high enough to enable sediment transport. The majority of sediment throughout the region is transported as bedload (Tomkins, 2013). Suspended sediment is transported further during flow events or deposited overbank with very little fine sediment stored in the channel bed in the upper to mid catchments (Tomkins, 2013).

Sediment infilling rates for the Copperfield River Dam are between 12% and 22% over a 30 year period (Tomkins, 2013). The predicted sediment yield of the Copperfield River to the Copperfield Dam is approximately 109,002 tonnes per year (Tomkins, 2013).

Sediment sampling to date has been guided by the EA for the historical mining activities as well as the REMP. Sediment samples have been collected annually between 2009 and 2013. An additional set of sediment samples was collected as part of this assessment in accordance with the methods outlined in the REMP (Genex Power, 2015). Sediment samples have been collected from monitoring locations WB, W1, W2 and W3. Additional sediment samples were also collected from sites E1 and E2 as part of this assessment.

Each sample has been analysed for particle size distribution as well as a limited number of metals as outlined in the site's current EA. Sediment samples have been collected in accordance with the Australian/New Zealand Standard "Water Quality Sampling Part 12: Guidance on Sampling of Bottom Sediments" (AS/NZS 5567.12). All sediment samples were collected by creating a composite sample while walking at a right angle to the stream bank and taking a 100g scoop of sediment approximately every 10 steps as outlined in the REMP (Genex Power, 2015). Sediment trigger values and contaminant limits are based on the Sediment Quality Guidelines (SQG) and SQG-High found in Simpson, Graeme, & Chariton (2013).

Generally the Copperfield River consists of 60% coarse sands (between 0.6 mm to 2 mm), 20% medium sands (between 0.15mm to 0.6mm), and 10% fine gravel (between 2.36 mm to 4.75 mm) (Figure 45). Approximately 5% of the sediment distribution in the river is greater than 4.75 mm in diameter (Figure 45). The percentage that comprises fine clay and silts (<0.063 mm) is generally around 1 to 3% of each sample (Figure 45). Particle size distribution of each sample is highly variable between sites as well as between years (Figure 45). This is a result of the inherent uncertainty with sediment sampling within an ephemeral river system over time.

A selection of samples have undergone metals analysis on the total composite sample as well as the <0.063 mm fraction only (Table 48). Total samples are analysed on the whole sediment fraction after undergoing a mineral acid dissolution after oven drying to establish dry weight (Genex Power, 2015). A similar process is undertaken after sieving the sample to <0.063 mm to determine metal concentrations. The <0.063 mm sediment fraction is the most readily ingested by organisms (Simpson, Graeme, & Chariton, 2013). Particles <0.063 mm are more common in the gut of sediment-ingesting biota (Simpson, Graeme, & Chariton, 2013). Assessment of the <0.063 mm fraction is considered warranted when more detailed investigations of bioavailable contaminants are required (Simpson, Graeme, & Chariton, 2013).

Metal analyses for the total sediment fraction indicate that there are no samples that exceed the SQG provided by Simpson, Graeme, & Chariton (2013) (Table 48). Sediment within the Copperfield River at the nominated monitoring sites is therefore considered to be unaffected by historical mining processes.

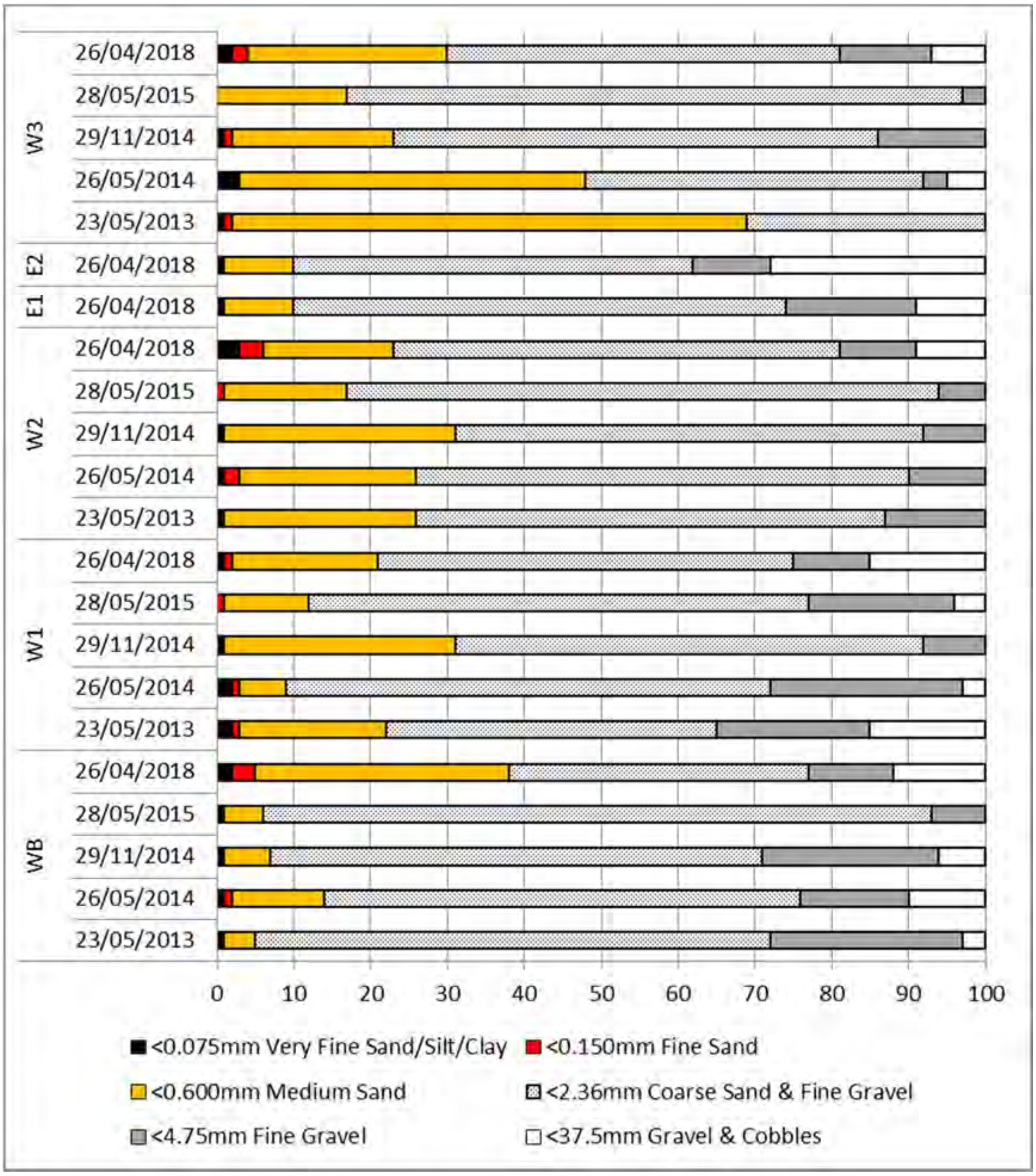


Figure 45 Particle Size Distributions for Sediment Samples

Metal concentrations for the <0.063 mm fraction are high compared to the total sample results (Table 48). Graphs produced of these in Figure 46 and Figure 47 show that all metals analysed have an exceedance of the trigger values in at least one receiving environment monitoring location. This is expected as the <0.063 mm fraction contains the largest surface area per mass and is therefore the most geochemically reactive. Contemporary guidelines (Simpson, Graeme, & Chariton, 2013) do not recommend comparison of the <0.063 mm fraction to sediment trigger values at the outset and this analysis is only considered worthwhile for metal speciation and bioaccumulation studies.

The ANZECC (2000) guidelines (Table 2.2.2) recommend that an exceedance occurs in toxicants in sediments when the 95th percentile exceeds the ISQG low (i.e. trigger level). The 20th, 50th, 80th and 95th percentiles for metal concentrations in the <0.063 mm fraction have been plotted on Figure 46 and Figure 47 as well as the trigger levels and contaminant limits outlined in (Simpson, Graeme, & Chariton, 2013). The 95th percentile exceeds the trigger value at almost all sites for almost all metals. Concentrations are highest at interim sites (W1 and W2) whereas the concentrations at the upstream and downstream site (WB and W3 respectively) are generally similar.

Where trigger levels are exceeded, they are also exceeded at the upstream site (WB). Arsenic and zinc are the only parameters that exceed guideline values in the <0.063 mm fraction at either site W1 or W2, or where the trigger value is not exceeded at the upstream site (WB). This indicates that there are no widespread impacts from historical mining activities evident within the Copperfield River and that the concentrations of metals found are a result of the overall catchment drainage.

Although the <0.063 mm fraction shows exceedances of most trigger values and some contaminant limits, the total sediment fraction does not. Although not specifically outlined in any documentation, including the DES's latest Monitoring and Sampling Manual (2018), contemporary stream sediment monitoring programs for mines involve:

- Targeted sampling at areas of finer sediments such as scour holes or waterholes.
- Fractionation of the sediment sample into <0.063 mm and <2 mm and subsequent metals analysis on both.
- Some degree of initial replication of samples to define variability and refine sampling methodology.

It is recommended that future monitoring occurs in accordance with the above guidance. The REMP developed for the Project will incorporate this sampling design into the sediment monitoring sections.