Appendix 9 – Myara North Power/Water/Boundary Alignments, Black Cockatoo Breeding Habitat Survey (Kirkby, 2024)

MYARA NORTH POWER/WATER ALIGNMENTS, BLACK COCKATOO BREEDING HABITAT SURVEY.

The purpose of the survey was to locate black cockatoo nests, possible nests and habitat trees at the Myara North Power/Water Alignments. A polygon of approximately 11 hectares located at the western end of the power alignment.

Methods and timing

The areas were surveyed using Alcoas 'Procedure for surveying haul road alignments and mine pits for black cockatoo habitat (MIN).

Trees are described as:

- Nest trees - that show signs of use by black cockatoos, including worn and chewed entrance of a suitable sized hollow (NB: it is possible some of these trees no longer provide suitable nest habitat but have either been used as nests in the past or been well prospected by cockatoos);
- Possible nest trees – that have a suitable size and shape hollow entrance but show no signs of use. During assessment of these trees, the position, entrance size and orientation of the hollow should be considered because these will influence the likelihood of a suitable depth of hollow for cockatoos; These will indicate a suitable entrance type but not the depth?
- Habitat trees – mature marri trees (>500mm diameter) that have the potential to provide nest habitat in the future either based on:
  i) Already starting to develop a hollow; or

ii) Tree form conducive to hollow formation/development such as elbows or major V branching of primary trunk (that may hollow out); tall, straight trunked trees, particularly showing signs of decay (that may form a top entrance hollow in the event of the top of the trunk being blown off); trees with major branches coming off the main trunk (that may hollow out if branch drops); photos or drawings?

- Roost sites – groups of trees with evidence of roosting, e.g. bird faeces and feathers found beneath the roost trees.

Note. The above mentions Marri trees but the current surveys also include Blackbutt *Eucalyptus patens* and Bullich *E. megacarpa.* These species provide nest hollows but are restricted in distribution to wet areas and creeklines and are rarely encountered other than where a haul road crosses a stream zone.
Alcoas current surveys also allow for significant stands of suitable trees (>500mm diameter) which may provide a future hollow but are not necessarily forming a hollow at present.,

Haul road alignments are normally surveyed to a width of 50m either side of the centre alignment, but the water and power alignment footprints are narrower and were surveyed to a total of 20m either side of the alignment.

All trees of interest were picked up using handheld GPS. AGD84.

The survey was undertaken between September and November 2022.

Results

A total of 155 trees (two from pre-mine surveys) and two black cockatoo roosting sites were picked up during the survey.

Trees

- Marri – 43
- Bullich – 20
- Blackbutt – 91
- Jarrah – 1

Of these 155 trees, three of the Marri – identification numbers 618,1475,1477 were considered nest trees and numbers 851 and 680 were considered possible nest trees. One each of the Blackbutt and Jarrah were significant trees being over 1500mm and 2000mm diameter respectively. All other trees were classed as ‘habitat trees’.

Roost sites

Two black cockatoo roost sites were located. The first (number 597) was located in Bullich/Blackbutt in the 11 ha power polygon and the second (number 625) on the power alignment near the old POW camp at Balmoral Rd. Judging by the broken twigs, leaves and droppings they appeared to of significant size and may have been being used by up to 50 birds at he time of the survey.

Tony Kirkby

2nd November 2022

Point number	Tree species	Coordinates AGD84		App. Dia. Mm	Comments
589	Blackbutt	417257	6419388	1100	Dead
593	Blackbutt	417316	6419373	1200	Dead
542	Blackbutt	417138	6419429	2000	Forks early into two smaller trunks
540	Blackbutt	417147	6419378	800	Habitat tree
541	Blackbutt	417144	6419392	700	Habitat tree
549	Blackbutt	417083	6419509	700	Habitat tree
553	Blackbutt	417028	6419601	1000	Habitat tree
565	Blackbutt	417168	6419466	600	Habitat tree
568	Blackbutt	417189	6419442	1000	Habitat tree
570	Blackbutt	417191	6419419	1000	Habitat tree
571	Blackbutt	417178	6419411	900	Habitat tree
572	Blackbutt	417172	6419411	900	Habitat tree
574	Blackbutt	417166	6419399	600	Habitat tree
575	Blackbutt	417178	6419392	1000	Habitat tree
576	Blackbutt	417197	6419353	700	Habitat tree
577	Blackbutt	417202	6419343	700	Habitat tree
578	Blackbutt	417207	6419339	700	Habitat tree
579	Blackbutt	417207	6419333	800	Habitat tree
580	Blackbutt	417207	6419334	700	Habitat tree
581	Blackbutt	417212	6419323	1000	Habitat tree
582	Blackbutt	417227	6419302	1000	Habitat tree
583	Blackbutt	417233	6419300	600	Habitat tree
584	Blackbutt	417235	6419285	1200	Habitat tree
585	Blackbutt	417213	6419368	600	Habitat tree
586	Blackbutt	417223	6419381	600	Habitat tree
587	Blackbutt	417230	6419383	500	Habitat tree
588	Blackbutt	417248	6419387	600	Habitat tree
590	Blackbutt	417274	6419382	1000	Habitat tree
591	Blackbutt	417277	6419381	1000	Habitat tree
592	Blackbutt	417285	6419383	900	Habitat tree
595	Blackbutt	417314	6419391	500	Habitat tree
596	Blackbutt	417246	6419418	1000	Habitat tree
603	Blackbutt	417367	6419390	1300	Habitat tree
604	Blackbutt	417365	6419393	800	Habitat tree
606	Blackbutt	417269	6419268	1000	Habitat tree
608	Blackbutt	417287	6419334	600	Habitat tree
619	Blackbutt	421169	6418684	600	Habitat tree
620	Blackbutt	421171	6418685	600	Habitat tree
621	Blackbutt	421175	6418685	600	Habitat tree
622	Blackbutt	421176	6418685	600	Habitat tree
623	Blackbutt	421183	6418685	500	Habitat tree
624	Blackbutt	421204	6418689	900	Habitat tree
627	Blackbutt	421214	6418673	1000	Habitat tree
628	Blackbutt	421232	6418669	900	Habitat tree
629	Blackbutt	421260	6418664	600	Habitat tree
630	Blackbutt	421264	6418667	600	Habitat tree
631	Blackbutt	421280	6418677	1400	Habitat tree
632	Blackbutt	421270	6418694	800	Habitat tree
633	Blackbutt	421247	6418697	700	Habitat tree
634	Blackbutt	421234	6418703	1100	Habitat tree
635	Blackbutt	421213	6418697	500	Habitat tree
636	Blackbutt	421206	6418699	900	Habitat tree
637	Blackbutt	421192	6418690	500	Habitat tree
638	Blackbutt	421364	6418669	1100	Habitat tree
639	Blackbutt	421388	6418673	800	Habitat tree
640	Blackbutt	421390	6418674	500	Habitat tree
641	Blackbutt	421388	6418680	700	Habitat tree
642	Blackbutt	421388	6418683	1000	Habitat tree
643	Blackbutt	421399	6418679	800	Habitat tree
644	Blackbutt	421418	6418678	1000	Habitat tree
645	Blackbutt	421419	6418681	1100	Habitat tree
646	Blackbutt	421459	6418673	1000	Habitat tree
647	Blackbutt	421458	6418677	1200	Habitat tree
648	Blackbutt	421454	6418654	1000	Habitat tree
649	Blackbutt	421452	6418651	1000	Habitat tree
650	Blackbutt	421452	6418624	900	Habitat tree

651	Blackbutt	421431	6418611	1000	Habitat tree
652	Blackbutt	421422	6418610	1000	Habitat tree
653	Blackbutt	421427	6418605	900	Habitat tree
654	Blackbutt	421407	6418532	800	Habitat tree
655	Blackbutt	421411	6418493	1000	Habitat tree
656	Blackbutt	421411	6418488	500	Habitat tree
657	Blackbutt	421406	6418469	1100	Habitat tree
658	Blackbutt	421406	6418467	1000	Habitat tree
659	Blackbutt	421411	6418449	700	Habitat tree
660	Blackbutt	421420	6418412	1000	Habitat tree
661	Blackbutt	421440	6418404	1000	Habitat tree
662	Blackbutt	421439	6418403	1200	Habitat tree
663	Blackbutt	421450	6418379	600	Habitat tree
664	Blackbutt	421438	6418383	1000	Habitat tree
665	Blackbutt	421439	6418382	1000	Habitat tree
666	Blackbutt	421473	6418318	600	Habitat tree
667	Blackbutt	421474	6418310	600	Habitat tree
668	Blackbutt	421475	6418294	600	Habitat tree
669	Blackbutt	421460	6418280	1200	Habitat tree
670	Blackbutt	421464	6418247	800	Habitat tree
671	Blackbutt	421459	6418247	1000	Habitat tree
673	Blackbutt	421473	6418195	1200	Habitat tree
674	Blackbutt	421475	6418182	1000	Habitat tree
678	Blackbutt	421494	6418104	900	Habitat tree
607	Blackbutt	417290	6419324	1500	Significant tree/habitat tree
536	Bullich	417169	6419356	800	Habitat tree
537	Bullich	417172	6419353	800	Habitat tree
538	Bullich	417169	6419356	500	Habitat tree
543	Bullich	417106	6419463	1000	Habitat tree
548	Bullich	417102	6419495	1000	Habitat tree
550	Bullich	417081	6419526	800	Habitat tree
551	Bullich	417068	6419536	800	Habitat tree
552	Bullich	417064	6419544	1000	Habitat tree
554	Bullich	417034	6419597	800	Habitat tree
555	Bullich	417039	6419598	700	Habitat tree
556	Bullich	417045	6419586	600	Habitat tree
557	Bullich	417049	6419581	800	Habitat tree
558	Bullich	417061	6419581	1000	Habitat tree
559	Bullich	417063	6419580	1000	Habitat tree
560	Bullich	417068	6419570	1000	Habitat tree
561	Bullich	417079	6419563	1000	Habitat tree
562	Bullich	417127	6419520	800	Habitat tree
563	Bullich	417130	6419506	800	Habitat tree
564	Bullich	417155	6419485	1200	Habitat tree
567	Bullich	417187	6419445	1000	Habitat tree
850	Jarrah	419259	6417197	2000	Significant tree. 2 m dia
545	Marri	417113	6419436	1000	Forks early into two smaller trunks
838	Marri	418715	6416512	700	Forming hollows. Habitat tree
839	Marri	418718	6416492	1000	Forming hollows. Habitat tree
840	Marri	418748	6416493	1000	Forming hollows. Habitat tree
845	Marri	419008	6416733	900	Forming hollows. Habitat tree
842	Marri	418934	6416660	1100	Habitat tree
843	Marri	418977	6416697	800	Habitat tree
844	Marri	418972	6416702	600	Habitat tree
846	Marri	419016	6416744	600	Habitat tree
847	Marri	419018	6416743	500	Habitat tree
848	Marri	419061	6416744	600	Habitat tree
849	Marri	419150	6416825	800	Habitat tree
539	Marri	417145	6419367	600	Habitat tree
546	Marri	417107	6419431	1000	Habitat tree
547	Marri	417136	6419387	1100	Habitat tree
573	Marri	417171	6419404	700	Habitat tree
594	Marri	417319	6419385	500	Habitat tree
599	Marri	417586	6419304	1000	Habitat tree
600	Marri	417614	6419306	1100	Habitat tree
601	Marri	417761	6419260	1200	Habitat tree
602	Marri	417723	6419307	1100	Habitat tree

605	Marri	417265	6419265	800	Habitat tree
609	Marri	417297	6419298	700	Habitat tree
610	Marri	417296	6419295	600	Habitat tree
611	Marri	417300	6419295	1000	Habitat tree
612	Marri	417316	6419271	1000	Habitat tree
613	Marri	417326	6419256	700	Habitat tree
614	Marri	417298	6419260	1100	Habitat tree
615	Marri	417276	6419240	1100	Habitat tree
616	Marri	417496	6419204	1100	Habitat tree
617	Marri	417523	6419217	800	Habitat tree
672	Marri	421469	6418224	1000	Habitat tree
675	Marri	421492	6418154	1000	Habitat tree
676	Marri	421487	6418163	600	Habitat tree
677	Marri	421492	6418108	800	Habitat tree
679	Marri	421487	6418099	700	Habitat tree
685	Marri	421487	6418304	1000	Habitat tree
686	Marri	421473	6418333	700	Habitat tree
618	Marri	419113	6418957	2202	Nest tree and significant tree. Tagged 1887. Cockatoo egg on ground
1475	Marri	417398	6419195		Nest tree located in Alcoa premine surveys
1477	Marri	417346	6419278	1100	Nest tree located in Alcoa premine surveys
851	Marri	419250	6417604	1200	Possible nest hollow
680	Marri	421526	6418013	1200	Possible nest tree
597	Roost site	417122	6419518		
625	Roost site	421202	6418681		

Hydrology and Water Quality Assessment for Huntly Mine

Pinjarra Alumina Refinery Revised Proposal

Alcoa of Australia Limited

14 January 2022

→ The Power of Commitment

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The Power of Commitment

Executive summary

Alcoa of Australia Limited (Alcoa) is proposing to increase production at the Pinjarra Alumina Refinery (Refinery) by 5 per cent from 5.0 million tonnes per annum (Mtpa) to 5.25 Mtpa and transition the Huntly Bauxite mine to the proposed Myara North and Holyoake mine regions (the Proposal). The Proposal is located in the Peel region of Western Australia (WA), approximately 100 km south-east of Perth.

The Proposal will be subject to environmental impact assessment under Part IV of the WA *Environmental Protection Act 1986* (EP Act), and the *Environment Protection Biodiversity Conservation Act 1999* (EPBC Act). The environmental impact assessment will be via a Public Environmental Review (PER).

The Myara North mine region lies adjacent and north of the existing Myara mining operations. The Holyoake mine region lies north-east of Dwellingup, approximately 20 km south of Myara North.

This Hydrology and Water Quality Assessment has been prepared to support the EPA assessment and addresses the Myara North and Holyoake Development Envelopes (DE) of the Proposal.

The aim of this Hydrology and Water Quality Assessment technical report is to present an understanding of the setting and impacts to the receptors, as a consequence of bauxite mining and related activities.

The proposed Myara North DE and Holyoake DE (Mine DE) are located in State Forest, which is managed for multiple uses including drinking water production, timber harvesting, pine plantation and recreation.

The scope of works to support this Hydrology and Water Quality Assessment technical report comprised the following:

– Complete a comprehensive desktop assessment comprising review of databases, existing studies and geospatial information for the Huntly Mine, and proposed Mine DE to inform the baseline monitoring program and development of conceptual and numerical models
– Undertake a baseline monitoring program, including development of a surface water and groundwater Sampling and Analysis Quality Plan, installation of surface water monitoring equipment and groundwater monitoring bores, and completion of baseline surface and groundwater monitoring
– Complete catchment scale groundwater and surface water modelling, using updated Mine DE conceptualisation from field investigations including the outcomes from the baseline monitoring program
– Carry out a public drinking water risk assessment for the Serpentine, Pipehead and South Dandalup reservoirs and upper Wungong Brook catchment, considering potential contaminants arising from mining and non-mining activities, and including a detailed assessment of potential impacts to human health.
– Provide technical reports for the various supporting studies including:
    - Baseline Surface and Ground Water Monitoring Report – Myara North and Holyoake
    - Sampling Analysis and Quality Plan
    - Surface and Groundwater Monitoring Installation Report
    - Hydrological Setting and Understanding – Myara North and Holyoake
    - Groundwater Modelling Report for Huntly Mine – Myara North
    - Groundwater Modelling Report for Huntly Mine - Holyoake
    - Drinking Water Risk Assessment - Serpentine, Serpentine Pipehead, South Dandalup and Wungong Brook Catchments.

This report is subject to, and must be read in conjunction with the limitations, assumptions and qualifications contained throughout the report.

A literature review of previously analogous cleared and mined areas indicates increased stream flows of 7% to 30% of rainfall. In addition, an assessment of a former mining area adjacent to the Myara North DE indicates increased groundwater levels of on average 5.5 metres (but as much as 14 metres) as a response to mining and land clearing. This supports that a local rise in groundwater levels (mounding), which will progressively dissipate towards the groundwater discharge boundaries, will accompany mining.

The potential rise in groundwater levels and associated increase in groundwater discharge may temporarily alter the water regime that supports identified environmental values in the Mine DE, which include riparian and swamp vegetation, aquatic ecosystems, reservoir/drinking water and recreational beneficial uses, associated with the drainage lines and streams.

Within the Myara North DE the Serpentine reservoir is fed by the Serpentine River, with other major tributaries including Big Brook and 39 Mile Brook. The South Dandalup reservoir in the Holyoake DE is fed primarily by the South Dandalup River. In the western part of the Darling Plateau, in the area identified as the high rainfall zone (HRZ), these rivers are characterised by sharply incised drainage lines.

The drying climate across the south-west of Western Australia has resulted in a decline in groundwater storage and consequently in groundwater levels, reducing groundwater connectivity with stream beds, reducing streamflow, and leading to a shift from perennial to ephemeral streamflow conditions.

A review of long-term trends in groundwater levels and streamflow for the Mine DE support these general trends in diminished groundwater streamflow connectivity, and reduced streamflow.

Long-term groundwater level data in the Myara North DE exhibits a decline of between 1 to 10 m since the 1990s, with an average decline of close to 4.5 m. While historic groundwater level data in the Holyoake DE is sparse the long-term trends from six bores with timeseries information suggests a similar average groundwater level decline of close to 9 m since the 1990s.

The change in groundwater levels is reflected in annual and seasonal streamflow data. Within the Myara North, flow gauging stations with long-term records observe a step change reduction in annual average streamflow in the period after 2000. A marked decline in streamflow is observed with a minor reduction in rainfall. Review of historical streamflow data also identifies a delay in flow commencement and typically earlier cease to flow for streamflows records post 2000 when compared to the preceding period.

As with groundwater level data, long-term surface water flow data in the Holyoake DE is even more sparse. For surface water gauging stations with long-term records (data pre and post 2000), there is an observed step change reduction in annual average streamflow as observed for Myara North DE gauging station locations. Flow seasonality in Holyoake DE also has a similar trend to Myara North DE with delay in flow commencement and earlier cease to flow.

The Serpentine, Pipehead, Wungong and South Dandalup reservoirs are key reservoirs that form part of the Water Corporation Integrated Water Supply System (IWSS) supplying drinking water to the Perth metropolitan region. The dams are protected by a Reservoir Protection Zone (RPZ), which forms a 2 km buffer area around the top water level of the reservoir, including the reservoir itself, but not extending outside the catchment area.

Changes in groundwater recharge and quickflow dynamics due to vegetation removal and subsequent bauxite mining have the potential to increase the groundwater level by several metres, with variations reflecting local hydrogeological conditions and properties. Historical data from an area south of Myara North indicates that in some cases groundwater levels can rise by up to 14 m in locations next to cleared and mined areas.

Mining also has the potential to temporarily increase stream flows during mining followed by their return to their natural status reflective of climatic conditions. Catchment-scale numerical modelling was completed to estimate groundwater level changes due to the Proposal for indicative mining periods comprising clearing/mining and rehabilitation periods.

The numerical modelling results suggest that proposed mining within Myara North results in an average increase in stream flows to the Serpentine Reservoir from the modelled catchments of 1.3 GL/year over the active clearing, mining, and rehabilitation period from about 2023 to 2033 (indicative clearing/mining to rehabilitation timeframe).

These effects slowly recede over the post-mining rehabilitation period, with:

– Groundwater level mounding, typically of 1 to 5 m scale by the end of the model simulation in 2060 during drier periods, and 1 to 10 m during wetter (recharge event) periods. The latter observation arises from enhanced recharge in previously mined areas. This estimate is consistent with the history-matching to observed groundwater level responses to rehabilitation, noting that there is only a limited historical period and limited areas where rehabilitation has been historically conducted within the model domain. In the simulated drying climate case (simulated as decrease in recharge and quickflow), relative groundwater level changes between the cases with and without Myara North mining are of a similar order but are generally smaller in magnitude and in area.

– The extent of mounding is predicted to be generally localised to cleared and mined areas, with the magnitude of mounding decreasing towards low-lying areas and groundwater receptors (potential Groundwater Dependent Ecosystems, GDEs).
– An average decrease of 0.3 GL/year in surface water inflows to the Serpentine Reservoir from the modelled catchments over the simulated post-mining period in the base climate case, relative to the unmined case at Myara North. For the simulated drying climate case, the modelling estimates an average decrease of 0.2 GL/year inflow.

Within the proposed Holyoake mine region, similar to Myara North the modelling indicates increase in groundwater levels and streamflows. The modelling estimates average increases in streamflows to the South Dandalup Reservoir from the modelled catchments of 0.1 GL/year during the modelled active clearing and mining period from 2029 to 2033 and 0.2 to 0.3 GL/year in the post-mining period. These effects recede over the post-mining period, with:

– Groundwater level mounding, typically 1 to 10 m, in some case more than 10 m directly beneath previously cleared and mined areas. The latter observation arises from enhanced recharge in previously mined areas (in Myara), even after rehabilitation. This estimate is based on the history-matching to observed groundwater level responses to rehabilitation, noting that there is only a limited historical period and limited areas where rehabilitation has been historically conducted within the (Myara) model domain which in this case is used as proxy to the Holyoake model. Mounding near and away from previously cleared areas will be progressively smaller.
– In the simulated drying climate case, relative groundwater level changes between the cases with and without Holyoake mining are of a similar order but are generally slightly smaller in magnitude and in area.
– An average increase of 0.2 GL/year in surface water inflows to the South Dandalup Reservoir from the modelled catchments over the post-mining period in the base climate case, relative to the unmined case at Holyoake. For the simulated drying climate case, the modelling estimates an average increase of 0.1 GL/year inflow. During the modelled active clearing and mining phase, the modelling forecasts similarly increased inflows to the reservoir (0.1 GL/year in both climate cases). Uncertainty in these estimates of inflow reduction to the South Dandalup Reservoir are narrow, ranging from increases of 0.2 to 0.3 GL/year in the post-mining period.

These predictions are of similar magnitude to historical observations of groundwater level effects from clearing and mining, and to the outcomes of similar studies in the Darling Range (e.g., Dixon et al., 2019).

Model scenarios under “current” climatic conditions (last 20 years), and a drying climate under climate change (30% step reduction in recharge, runoff, and near surface flow from the last 20 years’ conditions) indicate the following for the Myara North mine region:

– Variable years of salinity increases and decreases during the land clearing and mining period, with an average reduction in TDS of between 1 mg/L and 10 mg/L for the current climate case and between 1 mg/L and 7 mg/L under the climate change case.
– In the modelled post-mining period the modelling estimates an increase in average TDS of between 3 mg/L and 20 mg/L for the current climate case, and between 3 mg/L and 24 mg/L for the drying climate case. This indicates relatively small differences in relative impact from Myara North mining activities between the climate scenarios modelled.

In the Holyoake mining region:

– Variable salinity increases during the land clearing and mining period on an inter-annual basis, with elevated TDS during low streamflow years as groundwater comprises a larger than usual proportion of streamflow. Averages over this period for the current climate case are 5 mg/L to 11 mg/L. Corresponding average increases under the drying climate case are 3 mg/L and 6 mg/L.
– In the post-mining period, the modelling estimates less inter-annual variability. The increase in average annual TDS due to mining is between 11 mg/L and 24 mg/L for the current climate case, and between 6 mg/L and 13 mg/L for the drying climate case. Differences in relative impact from Holyoake mining activities between the climate scenarios modelled are considered minor.

A Drinking Water Risk Assessment and Source Vulnerability Assessment was undertaken in accordance with the Australian Drinking Water Quality Guidelines and relevant contemporary guidance. Qualitative and quantitative methods were used to estimate the risk of microbial pathogens, turbidity, hydrocarbons and other hazardous agents. The major conclusions reached from the risk assessment included the following:

- The highest risk event, of direct faecal deposition in the Pipehead Dam catchment, was elevated above the threshold of acceptable risk for pathogen exposure. As an elevated risk, this hazard requires attention during detailed design, to define how to reduce the risk to an acceptable level.
- Extreme combinations of turbidity input variables have minimal impact to the Serpentine Pipehead and South Dandalup offtake turbidity levels, but will exceed the guideline value for significantly longer than the baseline pre-mining condition in the Serpentine reservoir. After assessing the range of results for likelihood and consequence, the overall turbidity risk is considered moderate.
- Concentrations of hazardous hydrocarbons associated with a diesel spill did not exceed guideline values.

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Terminology

Terminology	Definition
Alcoa of Australia Limited (Alcoa)	The proponent of the Proposal.
GHD Pty Ltd (GHD)	Consultant engaged by Alcoa to prepare environmental approvals documentation and supporting technical studies for the Proposal.
Myara North Development Envelope	Myara North mine region and associated infrastructure corridor within the Huntly mine region. 22,703 ha total
Myara North Infrastructure Corridor	Corridor adjacent to Myara North mine region in which a conveyor, haul road and other infrastructure may be developed. May also be referred to as a transport study area or conveyor/haul road corridor. 5,254 ha
Holyoake Development Envelope	Holyoake mine region and associated infrastructure corridor within the Huntly mine region. 18,700 ha total
Holyoake Infrastructure Corridor	Corridor adjacent to Holyoake mine region in which a conveyor, haul road, access road and other infrastructure may be developed. May also be referred to as a transport study area or conveyor/haul road corridor. 9,542 ha
Mine Development Envelope	Total Mine Development Envelope for the Proposal, this being Myara North and Holyoake mine regions and associated infrastructure corridors. 41,403 ha
Mining region	Sub-regions that comprise the Huntly Mine, including current (Myara), past (O'Neil, McCoy) and future (Myara North, Holyoake), etc.
Haul Road	Truck and mine infrastructure access road linking into existing corridors.
Huntly Mine	Huntly Bauxite Mine within ML1SA. This includes the previous and current mine regions of Del Park, Huntly, White Road, McCoy, O'Neil, and Myara, and the transition to the future mine regions of Myara North and Holyoake.

Abbreviations

Abbreviations	Definition
ANZG	Australia New Zealand Guidelines
BoM	Bureau of Meteorology
BTEX	Benzene, Toluene, Ethylbenzene and Xylene
CAR	Comprehensive Adequate Representative
CRD	Cumulative Rainfall Departure
DE	Development Envelope
DWER	Department of Water and Environmental Regulation
EC	Electrical Conductivity
EPA	Environmental Protection Authority Western Australia
EP Act	Environmental Protection Act 1986
EPBC Act	Environmental Protection and Biodiversity Conservation Act
ERD	Environmental Review Document
ESD	Environmental Scoping Document
GDE	Groundwater Dependent Ecosystem
ha	Hectares
HRZ	High Rainfall Zone
IRZ	Intermediate Rainfall Zone
km	Kilometres
MBAS	Methylene Blue Active Substances
mBGL	Metres Below Ground Level
µS/cm	Microsiemens Per Centimetre
mg/L	Milligrams Per Litre
ML	Megalitre
NTU	Nephelometric Turbidity Units
PAH	Polycyclic Aromatic Hydrocarbons
PER	Public Environmental Review
PDWSA	Public drinking water source area
PFAS	Per- and Polyfluoroalkyl Substances
RPZ	Reservoir Protection Zone
SWL	Standing Water Level
TDS	Total Dissolved Solids
TMP	Trial Mining Project
TRH	Total Recoverable Hydrocarbons

1. Introduction

1.1 Project background

Alcoa of Australia Limited (Alcoa) is proposing to increase production at the Pinjarra Alumina Refinery (Refinery) by 5 per cent from 5.0 million tonnes per annum (Mtpa) to 5.25 Mtpa and transition the Huntly Bauxite mine to the proposed Myara North and Holyoake mine regions (the Proposal). The Proposal is located in the Peel region of Western Australia (WA), approximately 100 km south-east of Perth.

The Proposal will be subject to environmental impact assessment under Part IV of the WA *Environmental Protection Act 1986* (EP Act), and the *Environment Protection Biodiversity Conservation Act 1999* (EPBC Act). The environmental impact assessment will be via a Public Environmental Review (PER).

This Hydrology and Water Quality Assessment has been prepared to support the EPA assessment and addresses the Myara North and Holyoake mine regions of the Proposal. The Hydrology and Water Quality Assessment is supported by several technical documents including the Baseline Hydrology Monitoring Report, Groundwater-Surface Water Conceptual Model report, Groundwater Modelling Reports, Drinking Water Risk Assessment, and Reservoir Modelling Report and associated environmental technical studies.

1.2 Purpose of this report

This Hydrology and Water Quality Assessment has been prepared to support the EPA assessment of the Proposal with respect to surface water and groundwater systems (Inland Waters) in the Myara North and Holyoake mine regions of the Proposal. The Hydrology and Water Quality Assessment will guide mine and infrastructure planning, and environmental mitigation for the Proposal.

The assessment has been prepared in accordance with the Environmental Scoping Document (ESD) prepared for the Proposal under Part IV of the EP Act. The Surface and Groundwater Assessment report has been undertaken in accordance with EPA (2018) *Environmental Factor Guideline – Inland Waters*.

The purpose of this report is to assess the hydrological and water quality impacts of the proposal on the existing environment as part of the assessment of Inland Waters for the Proposal. Table 1-1 outlines the EPA scoping requirements as outlined in the ESD.

Table 1-1 EPA scoping requirements

EPA scoping requirements	Where addressed in this assessment
47. Characterise the surface water and groundwater systems in a local and regional context and describe recharge and discharge mechanisms, aquifer connectivity, surface water/groundwater interaction and water chemistry. This should include identifying and mapping groundwater and surface water dependent ecosystems, including the catchment interactions with the Peel-Yalgorup System Ramsar Site.	Sections 4, 5, and 6
48. Undertake surveys to establish baseline water quality and the environmental values identified.	Sections 5 and 6
49. Characterise the hydrology of the Serpentine and South Dandalup Rivers and upper Wungong Brook, and the beneficial use of the Serpentine, Pipehead and South Dandalup reservoirs, including reservoir protection zone. Characterise the current water quality and hydrodynamics of the Serpentine, Pipehead and South Dandalup reservoirs. Describe the impacts from this Proposal on the water yield and water and sediment quality of the Serpentine, Pipehead and South Dandalup reservoirs, upstream rivers, tributaries, upper Wungong Brook, and Peel-Yalgorup System Ramsar Site. This is to include a detailed description of the development of river crossings for access/haul roads and conveyors.	Section 7 Section 8
50. Undertake a public drinking water risk assessment for the Serpentine, Pipehead and South Dandalup reservoirs and upper Wungong Brook catchment, including source vulnerability assessment, in accordance with the Australian Drinking Water Quality	Section 8.5

EPA scoping requirements	Where addressed in this assessment
Standards and relevant contemporary guidance. The risk assessment should consider potential contaminants arising from mining activities and infrastructure, as well as mobilisation of existing contaminants from past catchment activities. For identified high risks to public drinking water beneficial uses, undertake a detailed assessment of potential impacts to human health in accordance with contemporary guidance.	
51. Analyse, describe and assess surface water and groundwater impacts, including direct and indirect impacts, from the Proposal. This should include, but not limited to: a. changes to groundwater levels and surface water flows associated with the Proposal; b. changes to water quality; c. the nature, extent and duration of impacts; and d. impacts on environmental values of ground and surface water dependent ecosystems; e. impacts to aquatic fauna species or communities; f. impacts to Peel-Yalgorup System – Ramsar Site; g. cumulative impacts with existing operations, and other development and activities in the region including mining, timber harvesting, rehabilitation activities, fire, and interactions under projected climate change.	Section 8

1.3 Scope of works

The scope of works is to:

- Complete a comprehensive desktop assessment comprising review of databases, existing studies and geospatial information for the Huntly Mine, and Mine DE to inform the baseline monitoring program and development of conceptual and numerical models
- Develop and install a baseline monitoring program, including development of a surface water and groundwater Sampling and Analysis Quality Plan, installation of surface water monitoring equipment and groundwater monitoring bores, and completion of baseline surface and groundwater monitoring
- Carry out catchment scale modelling groundwater surface water interaction, using updated Mine DE conceptualisation from field investigations including the baseline monitoring program
- Undertake public drinking water risk assessment for the Serpentine, Pipehead, Wungong and South Dandalup reservoirs, considering potential contaminants arising from mining and non-mining activities, and including a detailed assessment of potential impacts to human health.
- Complete technical reports for the various supporting studies including the Baseline Surface and Ground Water Monitoring Report and the associated Sampling Analysis and Quality Plan and Surface and Groundwater Monitoring Installation Report (Appendix B), Hydrological setting and Understanding – Myara North and Holyoake (Appendix C), Groundwater Modelling Report for Huntly Mine – Myara North (Appendix D), Groundwater Modelling Report for Huntly Mine – Holyoake (Appendix E), and Drinking Water Risk Assessment (Appendix F)with associated Reservoir Modelling Report.).
- Provide a Hydrology and Water Quality Assessment technical report that consolidates the results and findings of the various supporting studies (this report).

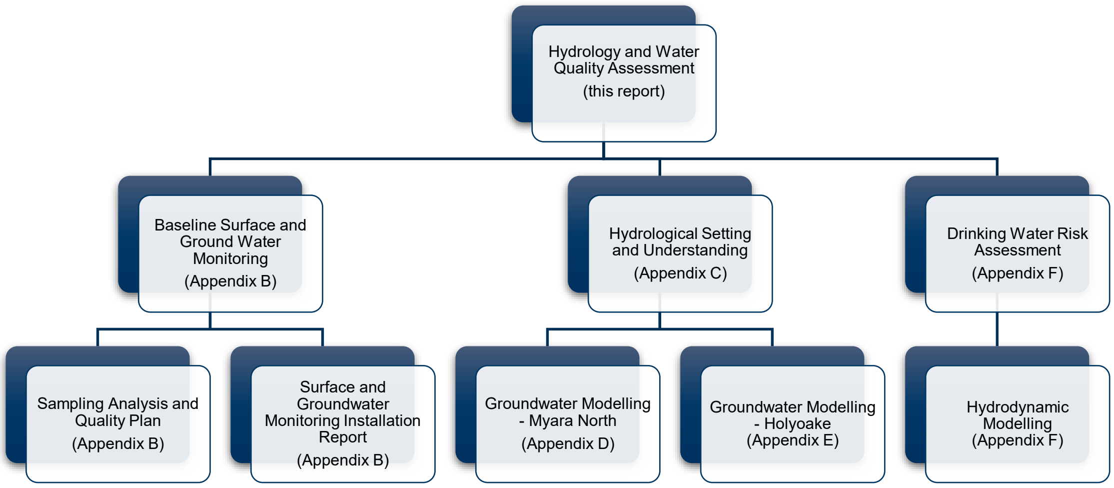

Figure 1-1 Reporting structure

1.4 Limitations and assumptions

This report has been prepared by GHD for Alcoa of Australia Limited and may only be used and relied on by Alcoa of Australia Limited for the purpose agreed between GHD and Alcoa of Australia Limited as set out in section 1.3 of this report.

GHD otherwise disclaims responsibility to any person other than Alcoa of Australia Limited arising in connection with this report. GHD also excludes implied warranties and conditions, to the extent legally permissible.

The services undertaken by GHD in connection with preparing this report were limited to those specifically detailed in the report and are subject to the scope limitations set out in the report.

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

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

GHD has prepared this report on the basis of information provided by Alcoa of Australia Limited and others who provided information to GHD (including Government authorities), which GHD has not independently verified or checked beyond the agreed scope of work. GHD does not accept liability in connection with such unverified information, including errors and omissions in the report which were caused by errors or omissions in that information.

The opinions, conclusions and any recommendations in this report are based on information obtained from, and testing undertaken at or in connection with, specific sample points. Site conditions at other parts of the site may be different from the site conditions found at the specific sample points.

Investigations undertaken in respect of this report are constrained by the particular site conditions. Site conditions (including the presence of hazardous substances and/or site contamination) may change after the date of this Report. GHD does not accept responsibility arising from, or in connection with, any change to the site conditions. GHD is also not responsible for updating this report if the site conditions change.

2. Assessment methodology

2.1 Desktop assessment

A hydrological desktop assessment was completed to inform the various technical studies that were completed as part of the Hydrology and Water Quality Assessment.

The hydrological desktop assessment comprised a review of various literature and data sources related to the surface water and groundwater hydrology and water quality of the proposed Myara North Development Envelope (DE) and Holyoake DE.. The hydrological desktop assessment also incorporated a review of the existing Huntly Mine operations and management relevant to hydrology and water quality, including mine water use and water supply.

2.1.1 Data sources and previous studies

Alcoa has supported studies to assess the potential impacts of its mining activities on the environment since the 1970s, previously in association with the former Water and Rivers Commission as part of the *Joint Intermediate Rainfall Zone Research Program*. This research was overseen by the Bauxite Hydrology Committee, formerly a subcommittee of the MMPLG, which was suspended in 2014.

The following generalised information sources were reviewed, the reference and details of which are presented in section 9:

– Alcoa Environmental Research Bulletins No 16 and No 22, relating to salinity research within mining exploration boreholes across the Darling Range
– Reports prepared by and for the Bauxite Hydrology Committee, a subcommittee of the Mine Management Program Liaison Group (Section 3.4)
– Published technical journal and research papers
– Geotechnical and hydrogeological reports and data including for soils and groundwater
– Flora and fauna surveys of the Proposal area, conducted as part of this study or previously conducted.

Groundwater and surface water related reports for historical, current, and future mining operations were also reviewed, including:

– Triennial Environmental Review 2015-2017; Alcoa WA Mining Operations, September 2018 (Alcoa of Australia Limited 2018)
– Annual Environmental Review 2018; Alcoa WA Mining Operations, July 2019 (Alcoa of Australia Limited 2019)
– Alcoa/DEC Working Arrangements; Bauxite Mining Operations, 2011-2015 (2011)
– Water Working Arrangements, Version 5 Effective Years of Operation 2018-2023(2019)
– Alcoa Mining and Management Program, 2019-2023 Inclusive, Huntly and Willowdale Mines, Western Australia Mining Operations, January 2019 (Alcoa of Australia Limited 2019)
– Draft Alcoa Mining and Management Program 2020-2024 Inclusive, Huntly and Willowdale Mines, Western Australia Mining Operations, December 2019 (2019)
– Huntly Mine Operations 10 Year Mine Plan 2019-2028 (1st edition May 2019)
– The following data have also been reviewed within the Mine DE and wider region:
– Data relating to sensitive environmental receptors, such as wetlands, threatened flora and fauna from published reports and Government of Western Australia databases
– Water monitoring data, including quality, levels, flows, and abstraction rates from Alcoa database and DWER Water Information Reporting and Water Register databases.
– Spatial and temporal data, including topography, drainage, vegetation, land use from Government of Western Australia databases.

A summary of the findings of key studies is chronicled in section 3.5, along with their gaps and limitations with respect to the proposed mining areas.

2.2 Baseline surface and groundwater monitoring program

A baseline monitoring program commenced in August 2020 to characterise current baseline surface water and groundwater conditions of the Myara North and Holyoake mine regions. The monitoring program was built on previous Alcoa and DWER monitoring data and designed to be commensurate with the key risks associated with existing and proposed activity.

The Alcoa Huntly Mine – Myara North and Holyoake Regions Baseline Hydrology Monitoring Program and Sampling Analysis and Quality Plan (SAQP) (GHD 2020a) documents the development of the baseline monitoring program, the sampling program and analytical work for the collection and validation of field data.

The scope of the baseline surface water and groundwater monitoring program included:

- Monitoring short-term, baseline surface water and groundwater conditions from August 2020 to February 2021
  - Surface water levels and quality
  - Groundwater levels and quality
- Installation of surface water monitoring instruments at six (6) locations within the Myara North DE and three (3) locations within the Holyoake DE.
- Installation of 18 groundwater monitoring wells at Myara North and 17 at Holyoake.

The monitoring locations were selected to establish baseline conditions, regarding historical and existing monitoring locations, and with selected reference locations using existing groundwater monitoring bores.

A summary of the 2020 baseline monitoring results (August 2020 to February 2021) is presented in section 5 for Myara North and section 6 for Holyoake.

Detail of the baseline monitoring program is provided in the following supporting technical reports:

- GHD (2020b) Pinjarra Alumina Refinery Revised Proposal –Surface Water and Groundwater Monitoring: Installation Report (Appendix B)
- GHD (2021a) Pinjarra Alumina Refinery Revised Proposal – Baseline Surface Water and Groundwater Monitoring Report (Appendix B)

2.3 Model development

Numerical modelling was completed to:

- Estimate changes to the watertable due to mining and rehabilitation, to inform the potential Groundwater Dependent Ecosystem (GDE) impact assessment.
- Estimate changes in surface flows due to mining and rehabilitation.
- Evaluate those changes in a model uncertainty framework for risk analysis.

Conceptual model development informed model build, simulation, and calibration, and is detailed in Appendix C.

The catchment-scale hydrological system responds to natural variability in climate, with spatial differences in response controlled by the topography, recharge and discharge mechanisms, and the variability in the subsurface material properties. The hydrological response in the study area is to be further affected by the effects of progressive clearing, mining, and rehabilitation. The combined effects of these spatially and temporally varying stressors result in hydrological responses that can be complex and highly variable.

While replicating such complex behaviour with a high degree of accuracy is often not feasible, the modelling provides an important mechanism for closely examining the cause-effect relationship observed in the field data. For example, the incremental effects of mining can be easily discerned from the natural variability simulated by the model. Where this is supported by data, the numerical modelling can provide a sensible basis for projecting potential impacts of future mining activities. The goal of numerical modelling is to simulate the overall system behaviour and incremental effects of mining, using the data collected over a period of several decades and knowledge gained from relevant prior studies.

The broad approach to the modelling is centred around assimilation of as much data of relevance to the required predictions of interest as is possible. This is implemented in a framework that recognises model input and process representation uncertainties, in such a way that they are carried through to their effects on model predictions.

Detail of the numerical modelling is provided in the following supporting technical reports:

– GHD (2021b) Pinjarra Alumina Refinery Revised Proposal; Hydrological Setting and Understanding Report – Myara North and Holyoake (Appendix C)
– GHD (2021c) Pinjarra Alumina Refinery Revised Proposal; Groundwater Modelling Report for Huntly Mine Myara North (Appendix D)
– GHD (2021d) Pinjarra Alumina Refinery Revised Proposal; Groundwater Modelling Report for Huntly Mine Myara North – Holyoake (Appendix E)

2.4 Drinking water risk assessment

A Drinking Water Risk Assessment (DWRA) has been prepared in accordance with the Australian Drinking Water Guidelines (ADWG), the Health Based Targets Manual (WSAA, 2020), and other contemporary guidance. The DWRA:

– Identifies biological, chemical, and physical agents that have the potential to cause harm;
– Identifies hazardous events that can lead to the presence of a hazard;
– Estimates the likelihood and consequence of the hazardous event occurring and causing harm; and
– Estimates the level of risk after consideration of typical preventive measures.

The risk assessment identified the following unmitigated risks:

– Very High
  - Nil.
– High
  - Staff member with asymptomatic cryptosporidiosis in Pipehead Dam catchment area defecates in gully or riparian zone, followed by heavy rainfall.
  - Staff member with asymptomatic cryptosporidiosis in Serpentine or South Dandalup Dam catchment area defecates in gully or riparian zone, followed by heavy rainfall.
  - Mining-related inputs in reservoir results in 5 NTU or greater turbidity of source waters

With barriers and preventative measures, all residual risks are classified as Medium risk or lower. Details of the drinking water risk assessment is provided in the following supporting technical report:

– GHD (2021e) Drinking Water Risk Assessment; Serpentine, Serpentine Pipehead, South Dandalup and Wungong Brook Catchments (Appendix F).

2.5 Associated technical studies

This report draws upon a number of associated technical studies completed to establish the baseline environmental values of the Myara North and Holyoake mine regions. These technical studies are listed below and referred to where relevant within the current report:

– GHD (2021f) Terrestrial Fauna Survey and Black Cockatoo Habitat Assessment for Huntly Mine – Myara North.
– GHD (2021g) Terrestrial Fauna Survey and Black Cockatoo Habitat Assessment for Huntly Mine – Holyoake.
– Mattiske (2021a) Detailed Flora and Vegetation Survey for Huntly Mine – Myara North.
– Mattiske (2021b) Detailed Flora and Vegetation Survey for Huntly Mine – Holyoake.
– WRM (2021) Aquatic Fauna Desktop Assessment – Myara North and Holyoake Regions.

3. Project site setting

3.1 Project locations and overview

This surface water and groundwater study relates to the transition of mining and associated infrastructure to Alcoa's proposed Myara North DE and Holyoake DE, within the overall Huntly mining region. (Appendix A, Figure A 1). The location of the Myara North DE and Holyoake DE are presented in Appendix A, Figure A 2 and Figure A 3.

The proposed Myara North DE comprises approximately 17,449 ha and lies north of the existing Myara mine region. The Myara North DE is bounded by Serpentine National Park to the west, Serpentine Dam to the south, Monadnocks Conservation Park to the east, and the former Jarrahdale Mine to the north.

The Myara North DE is predominantly zoned as State Forest, which is managed for multiple uses including drinking water production, timber harvesting, pine plantation and recreation. The Myara North DE also features a small number of private properties used for residential and small-scale agriculture. Alcoa mined in this vicinity, near Jarrahdale, from 1963 to 1998.

The Holyoake DE comprises approximately 9,158 ha and lies south of the former McCoy mine region, which retains operating mine facilities. The Holyoake DE is bound by Lake Banksiadale (South Dandalup Dam) to the north-west and Pinjarra-Williams Road immediately to the south (Appendix A, Figure A 3).

The Holyoake DE is predominantly zoned as State Forest, which is managed for multiple uses including drinking water production, timber harvesting and recreation. Construction in Myara North DE is scheduled to occur from approximately 2023, with operations taking place from 2025 to 2030. The transition to Holyoake DE is scheduled to commence around 2030, post construction activities.

Conveyors and/or haul roads will be extended from existing infrastructure into each Mine DE to new mine facilities.

3.2 Overview of the bauxite mining process

Alcoa's bauxite mining process involves:

– Pre-mining environmental and heritage surveys.
– Exploration drilling (120 m or 60 m grid, subsequently refined to 30 m and 15 m grids) to identify ore bodies suitable for mining.
– Salvage of timber by the Forest Products Commission.
– Vegetation clearing.
– Topsoil and overburden are removed and stockpiled separately for re-use later or immediate re-use on an area undergoing rehabilitation.
– Caprock is broken by drilling and blasting, and in some areas by bulldozers.
– Drainage protection shots are established at the toe of each pit to capture runoff and sediment from the mine pit, where required.
– Mining of bauxite, haul road transport and associated crushing and conveying to the refineries.
– Rehabilitation to jarrah forest by regrading and contouring of pits to be compatible with the surrounding terrain, and ripping is undertaken up to 1.5 m depth to remove compaction.
– After replacing the topsoil and overburden in sequence, the area is ripped again up to 0.8 m to prepare for seeding and to facilitate infiltration and reduce erosion.
– Seeding and planting of nursery raised seedlings and fertilising

Bauxite is found in the form of tabular ore bodies averaging 4 to 5 m thick and in aerial extent varying from approximately 0.5 to 150 hectares (ha). Mining of bauxite is characterised by a mosaic of shallow and widespread mine voids linked to a centrally-located crusher by a network of haul roads.

The top soil and overburden vary in depth from 0 to 1.5 m, with the underlying bauxite ore consisting of 1 to 4 m of friable material and, in some cases, a cemented layer or duricrust.

Mine clearing is integrated with forest harvesting through Alcoa's working arrangements with the Forest Products Commission (FPC), along with other third parties, to maximise wood residue re-use practices. Alcoa completes removal of forest residue through burning, scraping and excavation.

After mining, the area is rehabilitated with the intention of restoring a functioning jarrah forest ecosystem that can support pre-mining land uses. Approximately up to 10 years are considered for the process of vegetation re-establishment and return to pre-mining hydrological trends. Around 40 to 50 different plant species are planted as seeds sourced from the surrounding forest within defined provenance zones or from nursery-raised recalcitrant plants.

3.3 Potential effects of bauxite mining on hydrological systems

Bauxite mining activities have the potential to cause increased rainfall recharge to groundwater given the reduced or removed evapotranspiration (vegetation removal) and increased soil disturbance (relative increase in soil surface area and possible increase in permeability).

During this process, bauxite mining typically causes a rise in groundwater levels and changes surface water quantity and potentially quality. This may affect environmental receptors including potential GDEs comprising swamps, wetlands, springs and rivers and creeks, the ecology of which may be sensitive to changes in groundwater levels, changes in water flows volumes / flow regime and salinity.

The groundwater level rise may also mobilise salts present in the unsaturated zone into the groundwater flow systems which could discharge into creeks or other surface water features in the area.

Given reduced evapotranspiration and increased infiltration, bauxite mining has been recognised as potentially causing a site based or off-site based rise in groundwater levels that may have the following effects:

– Waterlogging of surface soils causing salt build-up in soils through increased evaporation
– Waterlogging or saturation of dispersive soils – causing increase erosion and sediment load to rivers and creeks
– Waterlogging or saturation of dieback risk areas and vegetation/root systems – causing an increased risk of dieback transmission and stress to vegetation
– Mobilisations of salts, where stored within the soil profile
– Changes in volumes of groundwater discharge into rivers and creeks – causing alteration to flow regime
– Changes in streamflow salinity due to changing proportion of groundwater discharge
– Changes in quality of groundwater – change in groundwater salinity may cause stress to groundwater dependent vegetation

These above changes to the groundwater flow regime and quality have potential to impact the following receptors where confirmed as present within the areas potentially effected by mining,

– Riparian vegetation
– Potential GDEs
– Streams to which groundwater is discharging
– Aquatic fauna and flora
– Drinking water quality and irrigation/stock water use.

Following successful rehabilitation and establishment of pre-mining conditions, rainfall recharge and groundwater levels previously raised during mining should reduce and return to pre-mining conditions, which is anticipated to occur over decadal timeframes.

3.4 Mining Management Program Liaison Group

All Alcoa mining operations are currently conducted under the supervision of the Mining Management Planning Liaison Group (MMPLG), which oversees aspects of mining and rehabilitation that occur within ML1SA. The MMPLG was established in 1979.

Prior to the MMPLG, the Steering Committee on Research into the Effects of Bauxite Mining on the Water Resources of the Darling Range was established in 1973 to research effects on water resources and provide advice to a Bauxite Policy Committee (Croton et al. 2011).

The MMPLG comprises representatives from appropriate State Government departments and agencies whose areas of responsibility are associated with Alcoa's operations, including the Department of Jobs, Tourism, Science and Innovation (JTSI), Department of Biodiversity, Conservation and Attractions (DBCA), Department of Mines, Industry Regulation and Safety (DMIRS), Department of Water and Environmental Regulation (DWER) and the Water Corporation.

The MMPLG has two subcommittees:

– Mining Operations Group (MOG), which oversees and reports to the MMPLG regarding environmental and community issues of its operations; and
– CAR Informal Reserves Evaluation Committee (CARIREC), which evaluates planned incursions into Comprehensive, Adequate, and Representative (CAR) Informal Reserves.

The MMPLG receives rolling 5 Year Mining and Management Plans (MMPs) from Alcoa on an annual basis for review.

3.5 Previous studies

Alcoa has undertaken and supported research to assess the potential impacts of its mining activities on water resources and the environment since the 1970s. A number of studies were completed in association with the former Water and Rivers Commission as part of the Joint Intermediate Rainfall Zone Research Program, and overseen by the Bauxite Hydrology Committee, a former subcommittee of the MMPLG.

A summary of the findings of this research and other key studies is chronicled in Table 3-1 along with gaps and limitations with respect to the proposed mining areas.

The research has had a significant focus in understanding the relationship between rainfall, runoff, groundwater levels, and salinity in the region with respect to mining and other land uses.

Table 3-1 Technical documents reviewed

Title	Key features	Findings	Gaps/limitations/comments
Hydrology			
(Ruprecht & Stoneman, 1993 (Bari & Ruprecht, Water yield response to land use change in south-west Western Australia, 2003 (Croton & Reed, 2007	Mining in public drinking water catchments	Mining initially caused increases in stream flow, followed by a return to pre-mining levels or below after rehabilitation.	
Hydrological Response of the O'Neil to McCoy Mining Area (Water & Environmental Consultants, 2013	Six year GW/SW/salinity monitoring Mining in public drinking water catchment and control catchment Some mining areas within IRZ	Mining-related stream-salinity response observed, albeit much less than had previously been modelled.	Given mining-related stream-salinity response observed, there may be cumulative impacts from other areas in Myara yet to be mined or rehabilitated within Serpentine catchment.
Review of the Trial Mining Project (Water & Environmental Consultants, 2011 (Water & Environmental Consultants, 2013	10 year GW/SW/salinity monitoring in IRZ Mined catchments compared to control catchments	Experimental catchments in IRZ dominated by below-average rainfall conditions since 1974, with groundwater recharge processes essentially at zero or reducing. Streamflow and stream-salinity records not attributed to mining. Little to no potential for significant streamflow or stream-salinity response in experimental catchments to mining as long as below-average rainfalls continue.	
Hydrological response to bauxite mining and rehabilitation in the jarrah forest in south west Australia (Grigg, Hydrological response to bauxite mining and rehabilitation in the, 2017	36-year monitoring period Mined, thinned, control catchments compared	Mining caused peak streamflow response of 225 mm or 18% rainfall, returned to pre-disturbance levels 11 years after mining commenced. Changes in groundwater level related to rainfall and LAI, indistinguishable between rehabilitated and unmined areas. Mining could not be distinguished from thinning, clearing or clear-felling. No shallow-subsurface flow processes beyond valley floor and immediately adjacent slopes. Catchment disconnection observed such that paired catchment approach may be ineffective for future forecasts.	Localised impacts of short-term events (significant storm events) immediately after clearing.
A standardised Landsat time series (1973–2016) of forest leaf area index using pseudoinvariant features and	Remotely sensed imagery from Landsat dating back to 1972	Standardised time series of LAI was developed that could inform future hydrological modelling in the area, as previous modelling has typically	Potential for application of LAI time series in new models in the area.

Title	Key features	Findings	Gaps/limitations/comments
spectral vegetation index isolines and a catchment hydrology application (McFarlane, Grigg, & Daws, 2017		been based on rainfall only. For long-term annual average rainfall of 1,200 mm their model predicts zero streamflow when catchment average LAI reaches 2.	
On the contribution of groundwater to streamflow in laterite catchments of the Darling Range, south-western Australia (Grigg and Kinal 2020)	Estimation of baseflow proportion to streamflows. Groundwater contributions to streamflows	Groundwater contributions to streamflows have a large variability. Contributions from quickflow components vary primarily linearly with annual rainfall.	Applied to catchments outside of MDEs, however the approach is applicable to MN and HO MDEs.
Nonstationarity driven by multidecadal change in catchment groundwater storage: A test of modifications to a common rainfall–run-off model (Grigg & Hughes, Nonstationarity driven by multidecadal change in catchment groundwater storage: A test of modifications to a common rainfall-run-off model, 2018	GR8J Model 21,000 individual groundwater records 40 year dataset Model incorporates “catchment memory”	Improved rainfall-runoff model	Not applied to proposed mining areas
Salinity			
Environmental Research Bulletin No. 16. Salt Storage in the Bauxitic Laterite Region of the Darling Range, Western Australia (Slessar, Murray, & Passchier, 1983	327 bores drilled in Darling Range	Darling Range exhibits low soil salt storage west of 1,100 mm isohyet (0.16±0.15 kg/m^3) Near-exponential increase in soil salt content with distance inland (0.79 ± 0.84 kg/m^3)	Limited resolution within proposed mining areas, and in close proximity east of 1,100 mm isohyet
Environmental Research Bulletin No. 22. Estimation of Soil Salinities East of the Huntly Mine, Darling Range, WA (Tsykin, 1989	70 bores drilled east of Huntly mine (south-east of Myara North), predominantly in IRZ Soil salt content estimated in grid-cells based on rainfall, terrain type, vegetation “greenness” and position in landscape.	High rainfall areas had low soil salt contents (<0.4 kg/m^3), lower rainfall areas had high salt contents.	Limited resolution within proposed mining areas
Hydrology and Bauxite Mining on the Darling Plateau (Croton & Reed, 2007	Literature review	Under current rainfall regimes, it is unlikely that there will be a significant salinity response due to Alcoa’s mining, but it is inadvisable to discount the salinity issue in the lower rainfall zone, and research will need to consider the possibility of further climate change.	Water quality issues only discuss salinity. Myara North has specific setting in a drinking water catchment and would require assessment beyond salinity.

Title	Key features	Findings	Gaps/limitations/comments
Salinity Risk Assessment for the O'Neil to McCoy Mining Area (Water & Environmental Consultants, 2010	Mining in public drinking water catchment Application of a simple (unknown) groundwater flow model (data from 1970 to 2007) Application of salinity risk methodology	Stream salinities below average for the period of low rainfall post 1999, likely driven by falling groundwater levels. Modelling concluded that there will be streamflow, stream salt-load and stream salinity increases due to the mining of O'Neil to McCoy.	Unspecified groundwater model. Limited information on the model and its spatial domain.
Modelling long-term flow and salinity response to bauxite mining in the upper Serpentine catchment (DWER, 2019	Mining/rehab in dam catchment LUCICAT SW/salinity modelling	Regardless of mining case or future climate, change in inflows due to mining was <~2 GL/year, or five per cent of flow on an annual average basis. Effects on reservoir salinity of mining within Upper Serpentine were within acceptable limits (within 3% of no-mining case).	Dynamics of simulated groundwater levels in context of strong drought years not well understood in model (flows in these instances are overestimated). Model is suited to large catchment areas, however, the proposal area includes one large catchment (Upper Serpentine), and two smaller separate catchment areas (Lower Serpentine, and Wungong Brook). Model data is 10 years old. Landsat LAI data from 1963 to 1972 is linearly extrapolated. Short term impacts are either not captured by the model, or not described in the report.

4. Regional setting

This section provides a summary of the desktop assessment of the regional and groundwater and surface water systems of the Mine DE. It includes a summary of the Aquatic Fauna Desktop Assessment completed for the Mine DE.

4.1 Climate

Western Australia's south west region has a 'Mediterranean' type climate characterised by typically high winter rainfalls and an intense summer drought. A summary of the nearest Bureau of Meteorology (BoM) to the Mine DE is provided in Table 4-1.

Table 4-1 Summary of nearest BoM climate stations

BoM Station	Station number	Distance from Mine DE	Data range
Serpentine Main Dam Station	009115	Within Myara North DE	1963 to 2016 Rainfall
Karnet Station	009111	4 km south of Myara North DE, 47 km north of Holyoake DE	1963 to 2021 Rainfall, evaporation and solar radiation data
Dwellingup Station	009538	7 km from Holyoake DE	1935 to 2021 Rainfall, evaporation and solar radiation data

Given the proximity of the three stations, this review presents data from Karnet Station as representative of both the Myara North DE and Holyoake DE. Monthly statistics for the site since its inception are shown in Figure 4-1, and SILO[1] point data was extracted annual rainfall plotted in Figure 4-2. Dwellingup rainfall data has been used for site-specific comparison for Holyoake DE surface water and groundwater datasets.

The mean monthly maximum temperature ranges from 15.8°C in July to 30.9°C in January. Average annual evaporation (1,520 mm) typically exceeds average annual rainfall (1153 mm), albeit rainfall exceeds evaporation during winter and shouldering months.

Western Australia's south west region has undergone a 15 to 20% reduction in rainfall since the 1970s, as illustrated in Figure 4-2. This trend has been forecast to continue with a further 2% to 14% reduction predicted by 2030. Temperature increase and potential evapotranspiration are also forecast to increase by 0.7°C and 2 to 3%, respectively (CSIRO, 2009; DoW, 2015.

Rainfall is also known to decline with distance inland. Historical rainfall isohyets including the 1,100 mm annual rainfall isohyet (referred to as the High Rainfall Zone or HRZ) and the historical 900 to 1,100 mm annual rainfall isohyet (referred to as the Intermediate Rainfall Zone or IRZ) have been identified in research as defining features for differing hydrological effects across the Huntly Mine.

[1] Rainfall, temperature, and evaporation data sourced from the SILO data downloaded from https://legacy.longpaddock.qld.gov.au/silo/ppd/ on 5 June 2020. Point data from the SILO climate database (Queensland Department of Science, 2015) provides a continuous daily climatic record for a given point with gaps infilled based on interpolation of records from nearby weather stations.

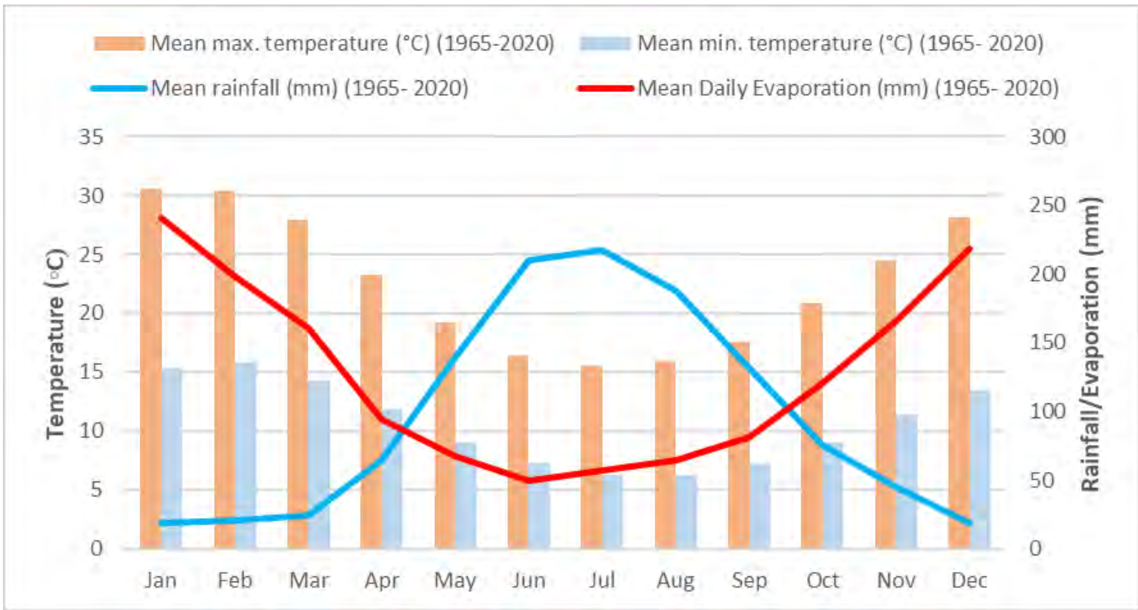

Figure 4-1 ***Monthly climate statistics at Karnet Station (1965 to 2020)***

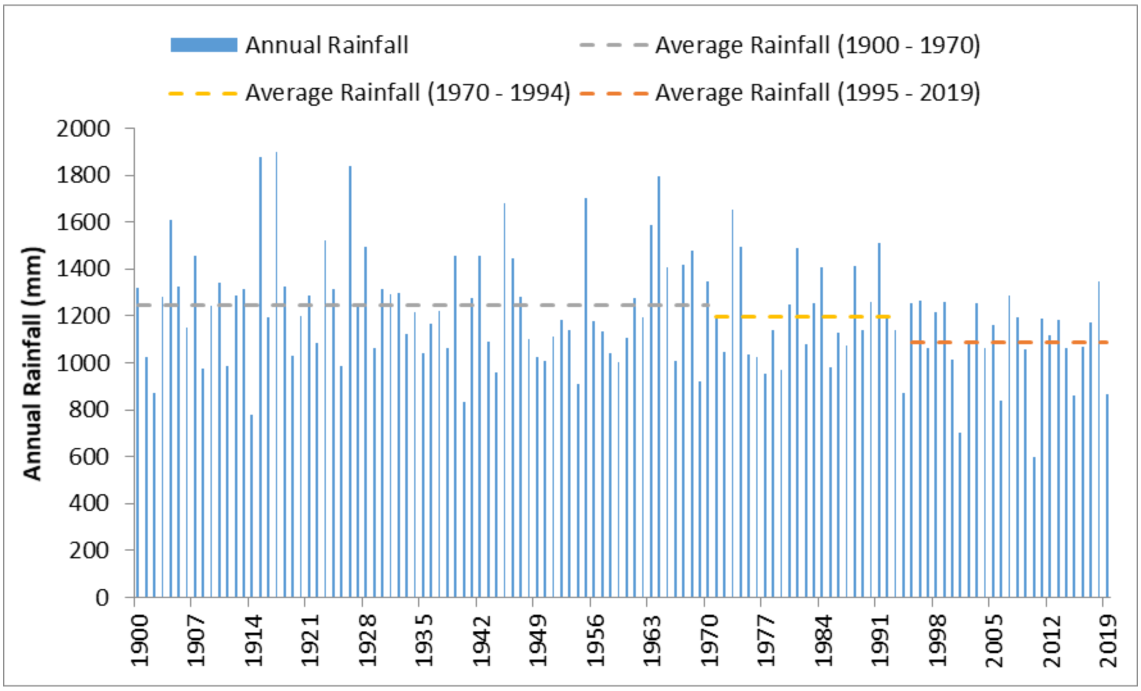

Figure 4-2 ***Annual rainfall at Karnet Station***

4.2 Landforms and topography

The Huntly Mine is situated within the Darling Plateau, at 240 m AHD to 370 m AHD. The area is characterised by lateritic profiles (>30 m depth), formed from the in-situ weathering of basement rock. The laterite surface is undulating, dissected by streams and extending through a zone of variable thickness to weathered bedrock.

Landforms have been described by Churchward and McArthur (1980) and mapped as part of vegetation complexes of the South West forest region (Mattiske and Havel 1998). Table 4-2 presents the landform descriptions and mapped extent over the Myara North and Holyoake DEs.

Table 4-2 Soil landscape mapping in the Mine Development Envelope

Landform name	Landform Description	Myara North DE (ha)	Holyoake DE (ha)	Proportion of current extent in Mine DE (%)
Cooke	Hills rising above general plateau level; mainly mantled by laterite but with some rock outcrop	435	69	1.9
Dwellingup	Gently undulating landscape with duricrust on ridges; sands and gravels in shallow depressions	7,711	5,449	49.5
Goonaping	Shallow upland valleys with grey sands and some swamps	212	0	0.8
Murray	Deeply incised valleys with red and yellow earths on slopes; narrow alluvial terraces.	1,732	28	6.6
Pindalup	Valleys of the central part of the plateau; gravelly duplex soils on slopes; some rock outcrop; grey sands, duplex yellow soils and orange earths in broad floors.	33	0	0.1
Swamp	Depressions and swamps on uplands		68	0.3
Yarragil	Valleys of the western part of the plateau; sandy gravels on the slopes; orange earths in swampy floors.	7,322	3,544	40.8
Total		**17,446**	**9,157**	

As presented in Table 4-2, the landforms over the Myara North DE are predominantly Dwellingup lateritic uplands interspersed by Yarragil minor valleys with swampy floors. Murray landform major valleys occur along the Serpentine River on the southern boundary of the region. Goonaping sandy upland valley occurs in a shallow depression in the headwaters of Honour Brook north of Jack Rocks. Cooke upland hills and rock outcrops occur as pockets along the eastern portion of the region.

The landforms over the Holyoake DE are less diverse than in the Myara North DE and comprise almost totally (99%) Dwellingup lateritic upland and Yarragil minor valley landforms. A small area of Cooke upland hills occurs at Inglehope and a small area of Murray major valley in the headwaters of the Murray River on the southern boundary.

4.3 Regional geology

The Myara North and Holyoake DEs are located in the Yilgarn Craton, a predominantly granitic geological terrain. The regional geology of the area has been mapped by the Geological Survey of Western Australia (GSWA) and is presented in Appendix A, Figure A 4.

The bedrock outcrops over less than 10% of the region, as there is an extensive layer of Cainozoic laterite developed. A typical lateritic profile in the Darling Range is distinctly zoned. The laterite has been derived from the weathering of parent rock and consists of a ferruginous or aluminous hard cap layer which overlies a pallid, and often mottled kaolinitic zone of varied thickness (saprolite). The transition zone between the fresh rock and saprolite is referred to as saprock.

The laterite layer includes the bauxite resources which are proposed to be mined. Bauxitisation has been especially pronounced along the flanks and tops of ridges. The lateritic (bauxite) horizon is on average 2 to 3 m thick for granite-derived bauxite.

The younger-age tholeiitic quartz dolerite dykes intrude the Precambrian basement. The dykes are generally 10 m thick although the width can vary widely. These dykes generally follow east-west to northwest to southeast directions.

Observations of outcrops along the railway cutting near Jarrahdale suggest significant differences between the profile developed over metagranites and dolerites. These are related to the dominance or preservation of quartz in the profile developed over the metagranite whereas it is almost totally absent from the profile developed over the dolerite.

4.4 Hydrogeology

The groundwater host rocks of the Myara North DE and the Holyoake DE predominantly comprise the weathered and fresh Archaean basement crystalline rocks. In addition, more recent sediments are incised into the basement rocks, coincident with existing drainage or palaeodrainage lines.

The understanding of the generalised hydrogeology of the Myara North DE and Holyoake DE comprises the following main aquifer units:

– Shallow weathered zone aquifer: comprising lateritic caprock and shallow gravely to sandy sediments with represents a seasonal aquifer with significant storage, infiltration and flow capability
– Deep weathered zone aquifer (lower saprolite), an aquifer of some storage potential, but limited bulk permeability (comprising clays). The clayey nature of this zone can be interspersed by macropore features developed along deep root systems which were subsequently filled with more clastic material
– Transition zone between the fresh basement and saprolite, referred to as saprock, which typically has enhanced permeability
– Fractured bedrock aquifer, permeability and yields are dependent on facture development and connectivity of the fractures.

Groundwater has been an active part of lateritisation process, particularly in development of cemented ferruginous hardcap (duricrust) often seen on the surface. Formation of duricrust has been driven by groundwater flow and capillary action which lead to precipitation of iron minerals leached from the weathered bedrock. Duricrust can also form in valley floors due to accumulation of iron brought by groundwater flow and its precipitation due to evapotranspiration or exposure to the surface.

In addition to the above, where drainage lines are sufficiently developed, and have eroded the basement material, sediments, typically alluvial, have accumulated in the lower lying areas. The permeability of the sediments is variably distributed and related to lithology, depth and degree of weathering.

Broadly, groundwater levels within all aquifers appear to follow the topography, such that groundwater level is highest in areas of highest topography and lowest in areas of lowest topography. Where groundwater levels intersect the base of the creek groundwater discharges provide baseflow following the winter rains (topped up aquifer storage and groundwater levels).

Given that topographical slopes reflect the groundwater gradient, the groundwater of the Myara North DE and the Holyoake DE is inferred as discharging into low lying creek lines when groundwater is in connection to the stream zone. These creek lines feed into, and discharge into the Serpentine Dam in the Myara North DE. The Myara North DE also includes several smaller catchments in the far north where the discharge is to the north towards the Wungong Dam, Gooralong Brook and some minor tributaries that drain towards the Pipehead Dam.

In the Holyoake DE, groundwater predominantly discharges towards the South Dandalup Dam. In the far south of the Holyoake DE, the catchments drain to the south of the South Dandalup Dam and towards the Murray River.

Previous work from the Darling Range catchments suggested that groundwater was a minor contributor to streamflows (e.g., Bari and Ruprecht, 2003, and others). This has been recently disputed (e.g., Grigg and Kinal, 2020). It was shown that groundwater contribution, as baseflow component of streamflows, varies within a wide range, and it includes years in which groundwater is the dominant proportion of streamflows (shown in tested Lemon, Wights and Yarragil 4X catchments).

4.5 Soils

The Huntly Mine (including proposed Myara North and Holyoake DEs) lies within the Darling Plateau, an undulating lateritic plateau. Soils have developed over the granitic terrain in a typical laterite profile with sand and gravelly topsoils which transition into a saprolite zone of weathering.

Soils typically comprise gravels, sands and loams including a discontinuous cemented layer or duricrust mostly in mid- to upper-slopes, merging with underlying mottled and pallid clays of the saprolite zone. Coarse gravels can be found on the upper slopes, trending to finer gravels downslope and sands near the valley floor, dominated by loams and clay loams (Churchwood and Dimmock, 1989), (Figure 4-3).

Of hydrological significance, root channels penetrating vertically via fissures and discontinuities in the cemented layer and deep into the clay zones are a consistent feature in the lateritic profiles. These channels form preferential flow paths and are understood to form significant vertical fluxes into groundwater systems (Grigg, 2017; McFarlane and Williamson, 2002; Turner et el. 1987).

The ‘dry flats’ and ‘wet flats’ are broadly consistent with alluvial deposits, developed along major drainage lines and creeks which may contain finer fraction especially in their downstream sections. The ‘dry flat’ term includes both the edge of the valley floor and permanently dry’ slightly elevated part of the flat. The ‘wet flat’ is the part of the valley floor which is waterlogged during winter. The soil profile is sometimes missing along the deeply incised drainage lines or at elevated highs which are often the granite outcrops.

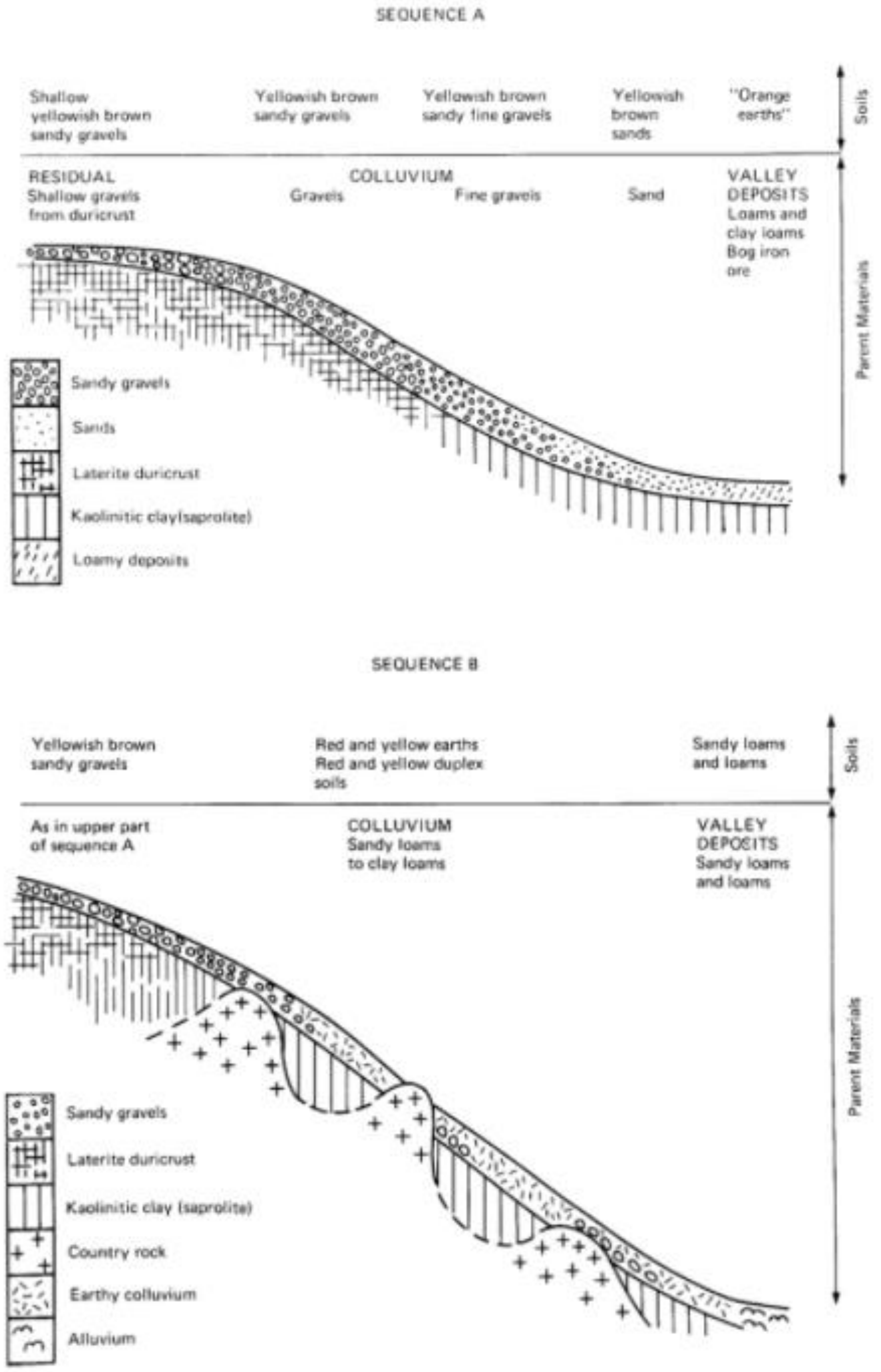

Fig. 2. **Schematic presentation of common soil/slope sequences for the northern jarrah forest ecosystem, south-western Australia. Sequence A associated with the shallow valleys of the plateau; sequence B associated with deep valleys.**

Figure 4-3 Typical textural changes in soils along the slopes (after Churchward and Dimmock, 1989)

4.6 Surface water hydrology

The Darling Plateau is characterised by sharply incised drainage lines forming dense drainage networks in the western, higher rainfall zone (HRZ), with these transitioning to open, flat-floored valleys in the eastern, intermediate rainfall zone (IRZ).

Some of the larger streams in the HRZ have previously exhibited perennial baseflows (Reed et al. 2012). However, the drying climate discussed in section 4.1 has caused a significant reduction in streamflow, leading to a shift from perennial to ephemeral streams and a decline in the runoff coefficient in recent decades. These declines have been observed as a step-change response to below-average rainfall years (Petrone, Hughes, Van Niel, & Silberstein, 2010; Hughes, Petrone, & Silberstein, 2012. For the Upper Serpentine catchment, a further decline in streamflow of 24% has been forecast by 2030, compared to the historical (1997-2007) average streamflow (Silberstein, et al., .

Groundwater storage is a key factor influencing the step-change response in streamflow, as it acts as the catchment "memory". Where permanent groundwater levels fall below the stream bed and become 'disconnected' after low rainfall years, this step-change in streamflow is observed as a result of reduction in soil-water storage (Reed, et al. 2012). Unless above-average annual rainfalls persist, these streams will thereafter only flow after saturation has occurred causing runoff and infiltration to occur (Petrone, Hughes, Van Niel, & Silberstein, 2010; Hughes, Petrone, & Silberstein, 2012.

4.6.1 Myara North mine region surface watercourses

The Myara North DE lies predominantly within the Serpentine River catchment and lies adjacent to the Serpentine River and Serpentine Dam and Pipehead Dam Reservoirs (Appendix A, Figure A 5). The Serpentine River, originates to the east of the Myara North mine region, flowing north-west along the southern boundary towards the Serpentine Dam. Drainage floors occur in areas of alluvial deposits along the Serpentine River and tributaries and form ephemeral waterlogged damplands during the winter and spring.

The Myara North mine region comprises three dominant catchment areas:

– The majority of the Myara North mine region (129 km^2 or 74%) lies within the Serpentine Dam catchment area, including the main tributaries 39 Mile Brook, Banksia Gully and Goldmine Gully. The Serpentine River runs adjacent the southern boundary of the Myara North mine region. Linear hydrographic mapping of the Myara North mine region identifies a further eight tributaries that are second order streams and above, and a further twelve first order tributaries that discharge directly into the Serpentine River and Serpentine Dam.
– The north western portion of the Myara North mine region (25 km^2, 14%) is drained by Gooralong Brook flows west through Jarrahdale townsite then south-west through Serpentine National Park and discharges into the Serpentine River approximately 5.5 km downstream of the Serpentine Pipehead Dam.
– The northern portion of the Myara North mine region (21 km^2, 12%) includes the Chandler Road sub-catchment and Cobiac sub-catchments which flows in a north and north-westerly direction, converging as the Wungong Brook. Wungong Brook flows north-west through State Forest, including the former Jarrahdale Mine (operating 1963 to 1998), and discharges into the Wungong Reservoir.

4.6.2 Holyoake mine region surface watercourses

The Holyoake mine region lies predominantly within the South Dandalup River catchment (Appendix A, Figure A 6). The South Dandalup River has multiple tributaries that contribute flows that originate from within and outside the Holyoake mine region.

The Holyoake mine region comprises two dominant catchment areas:

– The majority of the Holyoake mine region (67 km^2 or 66%) lies within the South Dandalup Dam catchment. This part of the Holyoake mine region drains either into the main tributary of South Dandalup River or one of four of its tributaries. The South Dandalup Dam catchment extends well beyond the Holyoake boundary.
– The south-western portion of the Holyoake mine region (34 km^2, or 34%) drains south to the Murray River catchment, in one of two tributaries, Davis Brook and Swamp Oak Brook.

4.7 Public drinking water supply reservoirs

The Myara North and Holyoake mine regions intersect the catchment areas of public drinking water supply reservoirs, including:

– Serpentine Dam and Serpentine Pipehead Dam (Myara North mine region);
– Wungong Brook Dam (Myara North mine region); and
– South Dandalup Dam (Holyoake mine region).

The south-west extent of the Myara North mine region lies within the Reservoir Protection Zone of the Serpentine Dam and Pipehead Dam reservoirs. Holyoake mine region intersects a smaller portion of the South Dandalup Reservoir Protection Zone in proximity to its central western boundary.

The reservoirs form part of the Water Corporation's Integrated Water Supply System (IWSS) supplying drinking water to the Perth metropolitan region. The reservoirs are managed in accordance with their respective Drinking Water Source Protection Plan.

Figure 4-4 summarises the extent of current approved mine clearing and Proposal mine clearing within major river and reservoir catchment areas. The figure identifies that the current approved mine clearing (Myara) occurs within the Serpentine Dam (Big Brook, Reservoir Tributary and Serpentine River) and Pipehead Dam (Reservoir Tributary) catchment areas.

Within the Myara North mine region, proposed mine clearing will occur within less than 10% of the Gooralong Brook and Wungong Brook catchment areas. Within the Serpentine Dam catchment, proposed mine clearing areas will occur within less than 10% of the Serpentine River and Reservoir Tributaries, and comprise under 20% of the 39 Mile Brook catchment area.

No current mining occurs within the South Dandalup Reservoir catchments (Figure 4-4). Proposal mine clearing areas will comprise less than 10% of the South Dandalup River catchment.

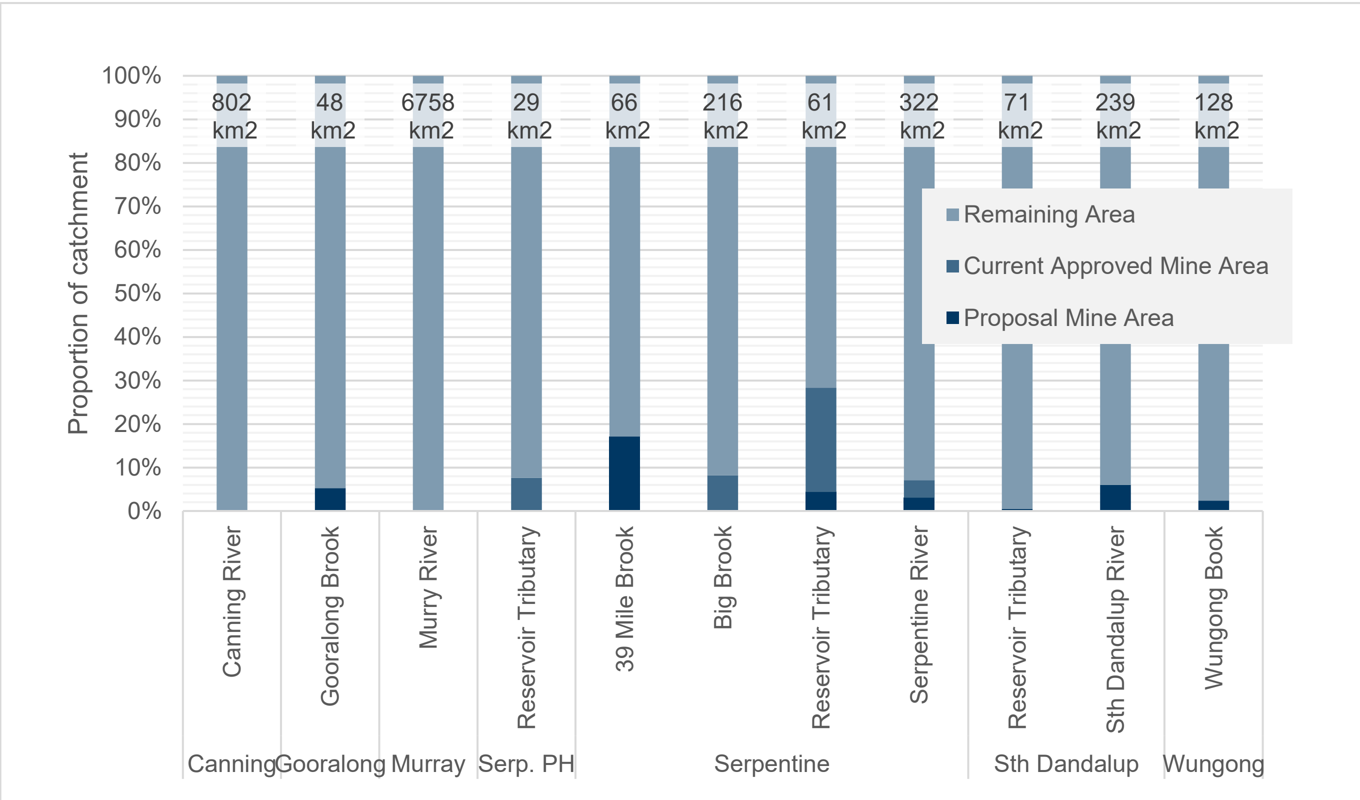

Figure 4-4 Extent of Myara North and Holyoake DE clearing areas within major river and reservoir catchment areas

4.8 Surface water bodies

The Landgate Medium Scale Topo Water Polygon dataset identifies several water bodies within and in proximity to the Myara North mine region (Appendix A, Figure A 5). The largest of these are the Serpentine Dam and Serpentine Pipehead Dam, both perennial reservoirs, which form part of the Water Corporations Integrated Water Supply System (IWSS) supplying drinking water to the Perth metropolitan region.

Non-perennial marshes are mapped as occurring within the mid and upper 39 Mile Brook valley floors, in the mid catchment valley floor of Goldmine Gully and in the unnamed eastern tributaries. A non-perennial swamp is also mapped in the unnamed eastern tributaries.

Within the Holyoake mine region, the largest mapped water body is the South Dandalup Dam (Appendix A, Figure A 6), a perennial reservoir, and part of the Water Corporations IWSS. Other water bodies distributed primarily through the central part of the Holyoake DE are described as non-perennial swamps.

4.9 Mapped wetlands

The Holyoake mine region is located approximately 30 km to the east of the Peel-Yalgorup System which is the closest Ramsar Wetland of International Importance and is also mapped under the Directory of Nationally Important Wetlands.

The Myara North mine region is located approximately 35 km north-east of the Peel Yalgorup System.

The Myara North mine region is located at the eastern extent of the Department of Biodiversity Conservations and Attractions *Geomorphic Wetlands Swan Coastal plain dataset*. The mapping classifies wetlands present within valley floors as palusplain or floodplain flats, and headwater swamps as sump or dampland basins. The geomorphic wetland mapping classifies wetlands as conservation category where they are relatively intact, and resource enhancement where they partially cleared for development.

The north-western portion of the Myara North mine region includes some mapped geomorphic wetlands which are summarised in Table 4-3 and presented in Appendix A, Figure A 5. The wetlands mapped as conservation category reflect the absence of clearing and relatively intact nature.

Unmapped valley floors and swamps that occur within the Myara North mien region and the Holyoake mine region are similarly expected to be of similar environmental values as those classified as conservation category, reflecting the absence of clearing of the wetlands except for occasional roads or access tracks.

Table 4-3 Myara North geomorphic wetland mapping

Management category	Wetland type	UFI number	Myara North DE sub-catchment
Conservation	Palusplain	12,396	Gooralong Brook
Multiple use	Dampland	12,398	Gooralong Brook
Resource enhancement	Palusplain	13,483	Gooralong Brook
Resource enhancement	Palusplain	12,525	Gooralong Brook
Multiple use	Dampland	12,300	Gooralong Brook
Multiple use	Palusplain	12,315	Gooralong Brook
Conservation	Dampland	12,330	Serpentine Pipehead Dam
Conservation	Dampland	12,325	Serpentine Pipehead Dam
Conservation	Dampland	12,312	Serpentine Pipehead Dam
Conservation	Dampland	12,316	Serpentine River
Resource enhancement	Sumpland	12,314	Serpentine River

4.10 Comprehensive Adequate Representative (CAR) Reserves

The Comprehensive Adequate Representative (CAR) Reserves system were a series of reserves delineated as part of the Regional Forest Agreement in 1999. The CAR reserves include a series of formal and informal reserves, the majority of which are identified along streamzones within the Myara North and Holyoake mine regions.

Ephemeral damplands occur within the valley floors of some tributaries (section 4.8), which contain vegetation communities that are distinct from the upland Jarrah forest and providing important habitats for terrestrial fauna. The CAR reserves are also considered to support vegetation communities important to terrestrial fauna.

4.11 Water use and environmental values

The water use and environmental values in the vicinity of the Myara North mine region and the Holyoake mine region were identified through review of existing mapping and published information, site survey of vegetation types and desktop assessment of aquatic fauna ecological values.

The surface water resources in the vicinity of the Myara North mine region and the Holyoake mine region support a wide range of social and environmental values including:

- Drinking water supply – Both existing and proposed Huntly Mine Operations occur within the catchment areas of public drinking water supply reservoirs (section 4.7, Figure 4-4).
- GDE which include terrestrial ecosystems that rely on the subsurface presence of groundwater – This is considered to include riparian and phreatophytic terrestrial vegetation (where depth to groundwater less than 10 m), where vegetation has a seasonal or occasional dependence on groundwater.
- Aquatic ecosystems that rely on surface expression of groundwater which include the surface watercourses that receive groundwater flow, groundwater fed springs and swamps within the study area and their respective biological and environmental values.
- Recreational use including aesthetic values.
- Cultural heritage values – Within the Myara North mine region the Serpentine River is a registered mythological/ethnographic Aboriginal heritage site.

This report includes a brief summary of the environmental values of the Myara North mine region and the Holyoake mine region, with detail of the ecology, drinking water and recreational values provided in the relevant Proposal Environmental Review Document chapter; chapter 5 (flora and vegetation), chapter 6 (terrestrial fauna), chapter 8 (inland waters) and chapter 11 (social surroundings).

5. Myara North hydrological setting

This section summarises the results of the historical surface and groundwater data review, baseline surface and groundwater monitoring program and supporting environmental technical investigations that were completed across the Myara North mine region.

5.1 Hydrogeological characterisation

Alcoa has collected groundwater level and groundwater quality data within the Myara North mine region since the 1970s, with available groundwater data typically concentrated within the eastern areas of the mine region. As part of the baseline monitoring program 18 new groundwater bores were installed at 16 locations within the Myara North mine region, to supplement 25 existing Alcoa groundwater bores (Appendix A, Figure A 7). Two sites included installation of a shallow and deep paired bores, providing data on groundwater for the upper ‘perched’ unit and the underlying more regional groundwater.

The baseline groundwater monitoring program comprised monthly water level dips and physico-chemical parameter measurements from October 2020, with groundwater samples collected for laboratory analysis of a broader suite of parameters in October 2020 and February 2021.

5.1.1 Aquifer units

Hydrogeological information on the aquifer system units was confirmed from installation and hydraulic testing of groundwater monitoring bores by GHD at Myara North. Data on bore depths and screen interval were reviewed to interpret the lithology profile (i.e. to infer depth to basement rock). A summary of the geological logs is provided below and monitoring bore locations are presented in Appendix A, Figure A 7. Detailed geological logs of GHD bores are presented in GHD (2020b) (Appendix B).

A review of the GHD geological logs indicates a broadly consistent lithology profile was identified across Myara North mine region with a typical weathering profile as follows:

– **Lateritic/ duricrust caprock:** 1 to 4.5 m thick, comprising of minor soils with pea-gravel and cemented duricrust or laterites. Caprock is hard to very hard and often strongly cemented with pisolitic nodules. In valley floors this can be overlain or replaced by relatively thin alluvial sediments.
– **Saprolite**: Highly variable depths from 1 to 29 m thickness, comprising clays derived from weathered basement. Clays are mottled or pallid towards the top becoming less pallid with depth reflecting the weathered bedrock lithology.
– **Weathered basement:** Weathered basement zone is characterised by decreasing clay content, an increasing rock texture/relict features which grades sharply into basement rocks, with a thickness of less than 2 to 4 m. Most active groundwater flow occurs in this zone and was often pressurised.
– **Fractured (fresh) basement**: Depth to fractured basement varies from 6 to 28.5 m below ground level (m BGL) and extended to end of bore hole. Basement rocks were dominantly granite interspersed with a few occurrences of dolerite.

The results of slug testing GHD (2021a) are summarised and presented in Figure 5-1. The monitoring bore slotted intervals were set along water strikes, which were generally identified within the transition zone from weathered bedrock to basement materials.

Figure 5-1 indicates an average hydraulic conductivity (K) of approximately to 0.6 m/day for the transition zone, and the range of hydraulic conductivity is relatively high (<0.05 to 1.2 m/day). The saprolite clays which overlie the transition zone are inferred to be less permeable at less than 0.001 m/day (saprolite clays were not hydraulically tested).

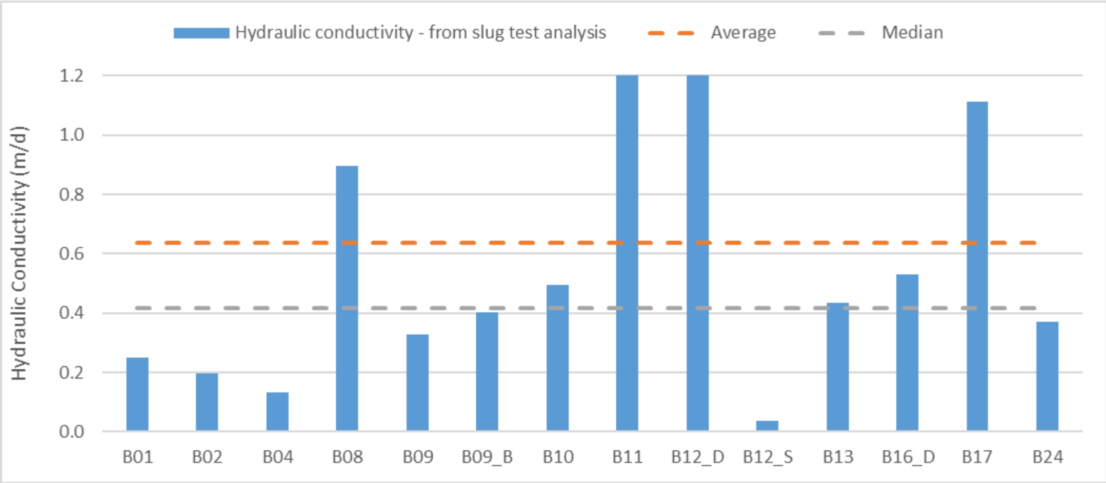

Figure 5-1 ***Myara North slug test results (hydraulic conductivity)***

Alcoa's internal report (Raper and Croton, 1996) provides a regional summary of hydraulic conductivity data which provides information on various horizons of the weathering profile with wider range of K values (0.001 to 16 m/d) dependent on lithological textures and the geomorphological position. The average storativity was stated to be 0.013, with a range of values between 0.0037 to 0.1.

5.1.2 Groundwater levels and flow

Groundwater levels and flow

The groundwater level surface for the Myara North mine region is a subtle replica of the topography. There is an understandably strong correlation between the topographic elevation and measured water levels of all monitoring bores (see for comparison between maximum water levels and terrain elevation in Figure 5-2).

Groundwater flows from topographical highs towards the groundwater discharge boundaries of the region which, based on the regional groundwater flow direction, is generally to the west and southwest, but can be locally modified in response to topographic and drainage trends.

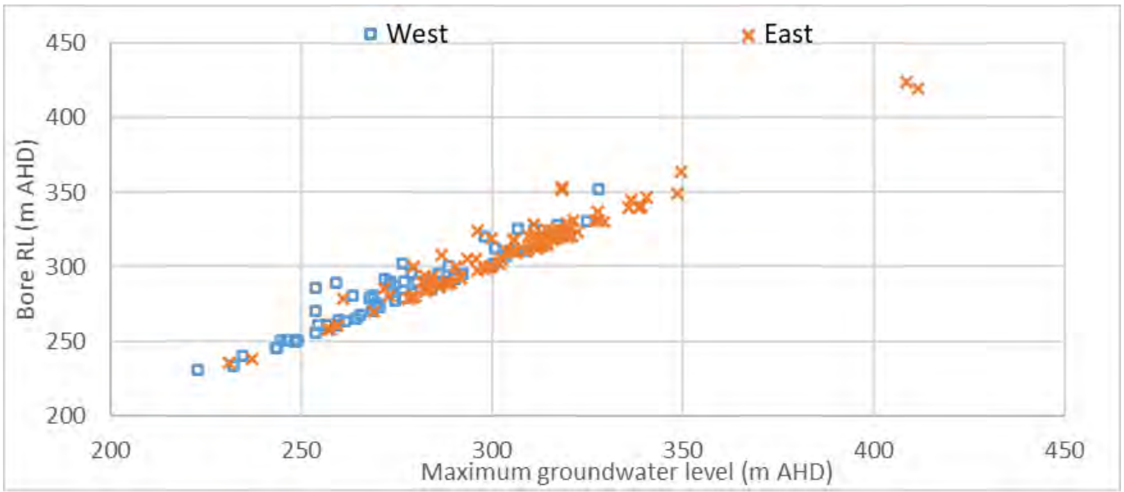

Figure 5-2 ***Comparison of measured maximum groundwater levels and ground elevation***

Groundwater level trends and observations

A review to determine trends of the historical monitoring data collated for monitoring bores within the Myara North mine region was undertaken with results presented in the Hydrological Setting and Understanding Report (GHD 2021b) and summarised in Table 5-1. The table identifies the following key features and long-term trends in groundwater levels (groundwater salinity discussed in the section 5.1.3):

– A typical strong seasonal variation in groundwater levels, typically varying over an annual cycle by between 1 to 5 m.
– Most monitoring bores show declining groundwater levels since the 1990s which is considered to reflect the reducing rainfall pattern. This can be seen when groundwater levels are compared to cumulative rainfall departure (CRD) plots (GHD 2021b, Appendix C and Appendix F). These plots shown a declining trend in rainfall over the same period as the reduction in groundwater levels. Bore hydrographs are included in the Baseline Hydrology Monitoring Report (Appendix B).
– The summary data presented in Table 5-1 indicates that all but two monitoring bores show declining groundwater levels of between 1 to 10 m since the 1990s, with an average decline of close to 4.5 m (since the 1990s).

Installation of the new groundwater bores within the Myara North mine region provided further spatial representation and enabled refinement of groundwater level understanding across the proposed mine region. Key observations from the new groundwater bores include:

– Groundwater is generally shallow (<10 m BGL), with groundwater at depths of more than 10 m only observed in the far south (B02, B03 and B04), and B10 in the far east of the mine region.
– Average seasonal groundwater level decline over the winter to summer 2020-2021 season for all new bores is 1.9 m, with over 3.5 m range recorded in four bores (B12D, B13, B18 and B24). The least seasonal variation is seen in the bore with the greatest depth to groundwater (B02, B03 and B04).
– Seasonal reduction in groundwater levels resulted in the drying out of five of the monitoring bores. Of these, two (B12S and B16S) are shallow screened bores, with the paired deep bore also observing a decline in groundwater level though not drying out.
– Bores B01, B09, B18 also dry out during the summer monitoring, however these bores are installed just above the granite basement rock, indicating the absence of a saturated profile in these areas during summer periods.

Table 5-1 Myara North mine region - summary of groundwater level trends and salinity from selected Alcoa long term monitoring bores

Monitoring well ID	Groundwater levels			Groundwater Salinity		
	1990 SWL[1] (mBGL)	2020 SWL[1] (mBGL)	Change SWL (m)	1990 TDS[1] (mg/l)	2020 TDS[1] (mg/L)	Change TDS (mg/L)
MJ38033A	3	4	-1	500	800	300
MJ38034A	6	10	-4	400	200	-200
MJ39222A	4	10	-6	200	400	200
MJ40121A	2	6	-4	2000	500	-1500
MJ41081A	7	5.5	1.5	NA	NA	NA
MK382511A	3	3	0	1500	500	-1000
MK39171A	1	2	-1	200	200	0
MK39181A	4	8	-4	400	400	0
MK39191A	2	10	-8	400	500	100
MK40102A	5	15	-10	NA	NA	NA
MK40111A	4	8	-4	300	300	0
MK40181A	2	10	-8	250	300	50
MK40182A	5	15	-10	100	250	150
MK40191A	2	8	-6	400	500	100
MK40251A	10	14	-4	NA	NA	NA
MK40252A	15	25	-10	NA	NA	NA
MK40261A	3	5	-2	150	100	-50

Monitoring well ID	Groundwater levels			Groundwater Salinity		
	1990 SWL[1] (mBGL)	2020 SWL[1] (mBGL)	Change SWL (m)	1990 TDS[1] (mg/l)	2020 TDS[1] (mg/L)	Change TDS (mg/L)
MK41041A	2	5	-3	200	200	0
MK41061A	10	15	-5	1550	1590	0
ML40092A	3	4	-1	400	300	-100
ML40093A	2	4	-2	300	300	0
ML40131A	4	6	-2	250	300	50
ML40271A	20	25	-5	NA	NA	NA
ML41011A	10	20	-10	NA	NA	NA
Notes	SWL - Standing Water Level					
	TDS – Total Dissolved Solids					
	1 - average values estimated from graphs observations (semi-quantitative)					
	NA - Not applicable, no data or unreliable data					

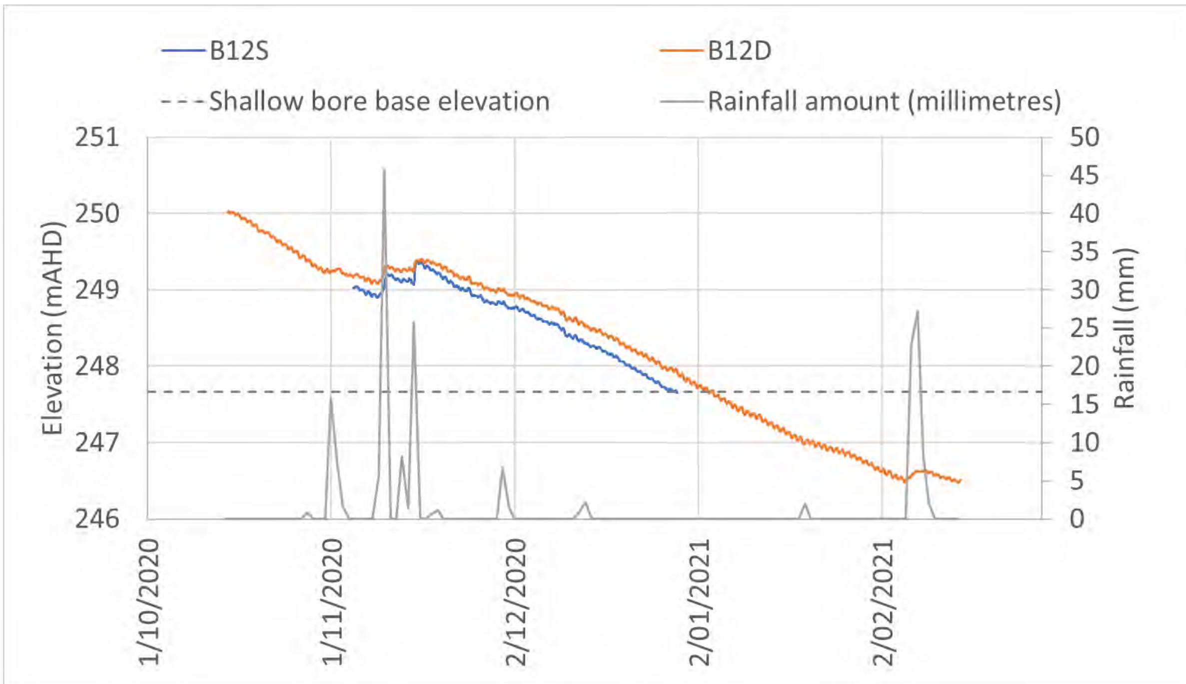

Figure 5-3 ***Groundwater levels (logger data) in B12 and rainfall during 2020/2021 summer period***

5.1.3 Groundwater quality

Groundwater salinity

Groundwater quality within the Myara North mine region is typically fresh. The majority of the monitoring data for the study area, available for some sites since the 1970s, indicates generally fresh conditions with an average salinity of around 450 mg/L. However, as shown by the salinity trend data shown in Table 5-1 there is some variability within the salinity dataset with isolated bore locations having salinities around 2,000 mg/L. Unlike the long-term groundwater level data, the long-term salinity dataset does not show any site-wide trends in groundwater salinity (i.e., generally stable or variable up or down).

Within the limited spatial extent of the data, there does not appear to be a relationship between bore salinity and location with salinity ranges within each catchment being as variable as those between catchments. Whereas there has been a definite reduction in-site wide groundwater levels, the groundwater quality data, albeit less comprehensive, does not show any widespread long-term trends. This may be partly explained by fewer salinity observations available for the last decade.

Other groundwater quality parameters

The groundwater quality sampling rounds for this study included the laboratory assessment for a wide range of water quality parameters. Sampling was carried out in later winter 2020 (October) and summer 2021 (February). The data indicated no discernible seasonal change in groundwater quality, however some effects of sampling soon after drilling of the bores was noted.

The results showed low nutrient levels, typical for the land-use, suggesting lack of applied nutrients. Dissolved metal concentrations were typical of ‘natural’ conditions and representative of the geological setting. Low concentrations of per- and polyfluoroalkyl substances (PFAS) were detected in four of the sampled bores, however all detections were significantly below the drinking water assessment criteria. Minor detection of total recoverable hydrocarbons (TRH) and polycyclic aromatic hydrocarbons (PAH) was noted, with concentrations reducing in the second sampling round, possibly indicating that the drilling was the source, or alternatively the low levels are associated with bush fire effects.

5.2 Surface water characterisation

5.2.1 Surface water flow

Myara North gauging stations

There are several stream gauging stations (GS) relevant to the Myara North mine region and study area (Appendix A, Figure A 5), details of which are summarised in Table 5-2. The River Road (Serpentine River) upstream of the Myara North mine region and Jack Rocks (39 Mile Brook) gauging stations provide a robust annual flow dataset from the early 1980s to 1998, and again from the mid to late 2000s through to late 2010s (Figure 5-4). Vardi Road (Wungong Brook) has a near continuous flow dataset from 1981 to present (Figure 5-5).

It is noted that there are large areas of the proposed mining catchment in which no stream gauging data exists.

Table 5-2 Gauging stations relevant to Myara North mine region

Site ID	Site name	Flow record	GS catchment area (km^2)	Annual average rainfall (mm) [2]	Annual average streamflow (ML) [3]	Runoff (mm)
Serpentine Catchment - regulated						
614035	River Road	1982 to 1998 2008 to 2019	243	840.7	5,572	22.9
614031	Jack Rocks	1981 to 1998 2006 to 2016	55	1,025.7	3,660	66.5
Serpentine Catchment - unregulated						
614073 [1]	Gooralong Brook - Mundlimup	1951 to 1998	51	*1,144.4*	10,594	207.7
Wungong Brook Catchment						
616041 [1]	Wungong Brook – Vardi Rd	1981 to current	81	*1,144.4*	7,368	90.9
616124	Wungong Brook – Chandler Rd	2005 to 2013	18	*1,144.4*	1,208	67.1
616058	Wungong Brook – Cobiac Rd	1992 to 2016	4	*1,144.4*	202	50.5
Note: [1] Gauging stations 614073 and 616041 are located > 5km downstream of the DE boundary						

Site ID	Site name	Flow record	GS catchment area (km^2)	Annual average rainfall (mm) [2]	Annual average streamflow (ML) [3]	Runoff (mm)

[2] Annual average rainfall for 614035 and 614031 derived from SILO 5 km daily grid data (1970-2020), remaining sites derived from SILO extraction for Karnet station (1970-2019)

[3] Average of available streamflow record

Long-term trends in annual flow

The step change in rainfall discussed in section 4.1 is reflected in observed step changes in streamflow, whereby annual average streamflows after year 2000 were considerably lower than the preceding period (Figure 5-4,Figure 5-5). Average annual streamflow in the Serpentine River has declined by more than 50% at River Road (614035), from 6,810 ML (1982-1998) to 3,232 ML (2008-2018), with an 80% decline in the streamflow record at Jack Rocks (614031), from 5,432 ML (1981-1998) to 1,093 ML (2006-2016)

A similar decline in average annual streamflow (70%) is observed in the upper Wungong River catchment with flows at Vardi Road (616041) reducing from 11,172 ML (1981-2000) to 3,416 ML (2000-2020).

The impact of decline in groundwater levels on streamflows (discussed in section 4.6) is also apparent at Jack Rocks with average annual streamflows from 2012 to 2016 approximately 75% lower than the six years prior to 2012, despite average rainfall decreasing by only 8% over the same period.

Long-term trends in flow seasonality

The long-term flow data for the River Road and Jacks Rocks gauging sites was used to generate box and whisker plots of monthly flow data (Figure 5-6 and Figure 5-7). The plots group the monthly flow data by the observed step changes in annual streamflow (pre-2000, post-2000), with the post 2000 flow data demonstrating a delay in flow commencement and typically earlier cease to flow, in comparison to the pre-2000 flow data.

Short-term trends in surface water levels and flow conditions

During the 2020 baseline monitoring period flow conditions at surface water sampling locations were recorded during monthly surface water sampling events (GHD 2021a, Appendix B). Surface water level loggers were installed late September at six Myara North surface water monitoring locations, five at the downstream extent of representative catchments prior to discharge to the Serpentine River or Serpentine Dam, and one in the Serpentine River downstream of the proposed conveyor crossing.

The observed periods of flow during the baseline monitoring program align with historical seasonality of flow observed across the Myara North mine region.

One site (SW05, Pipehead Dam catchment) sustained flows throughout the monitoring period, with upwelling water observed in the January 2021 monitoring round which may indicate a local groundwater source. Sustained flows were also observed at site SW06 (cease to flow in November 2020) within the upper Gooralong Brook catchment.

This site was located in the catchment of a prescribed burn completed in late September 2020. Talau (2015) report increased stream flow responses within areas subject to prescribed burns, however these are generally of a smaller magnitude compared to wildfire responses.

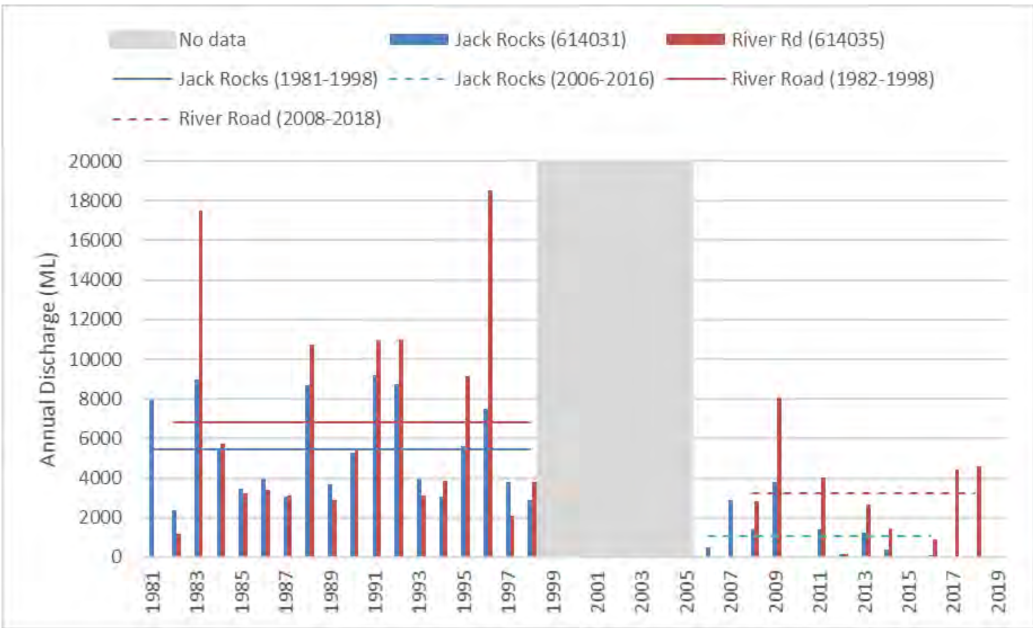

Figure 5-4 ***Annual flows at key Serpentine catchment gauging stations***

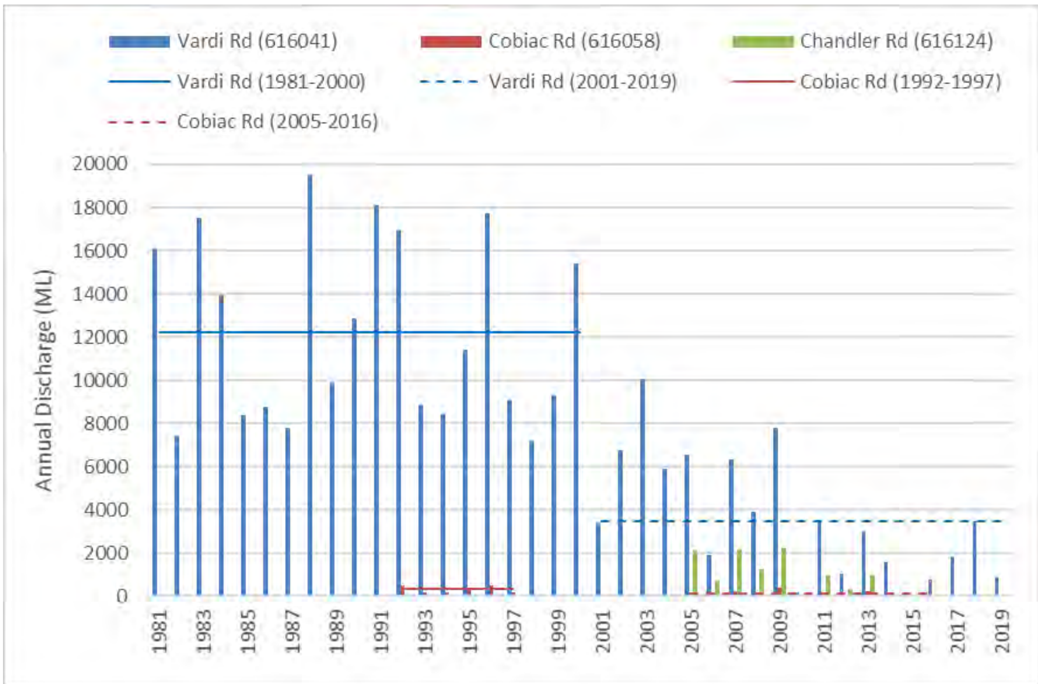

Figure 5-5 ***Annual flows at relevant Wungong catchment gauging stations***

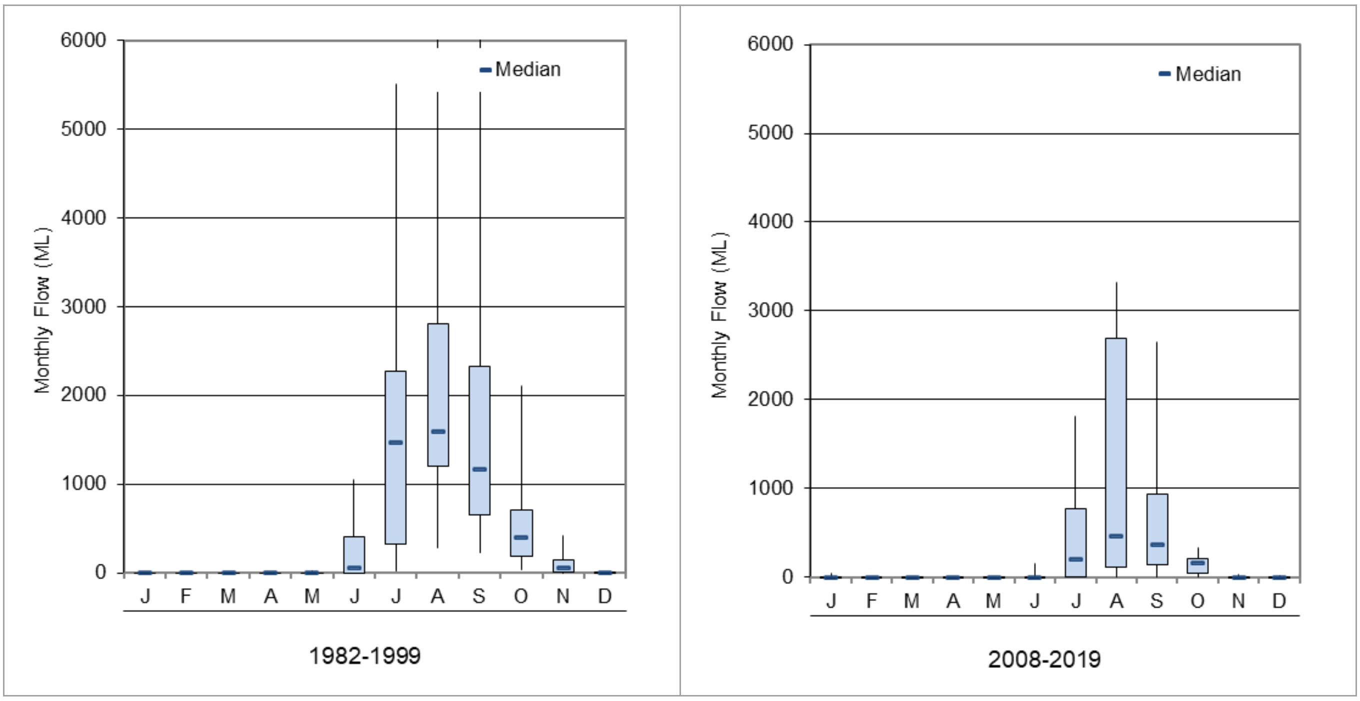

Figure 5-6 ***Flow seasonality – River Road (Serpentine River) for periods 1982-1999 and 2008-2019***

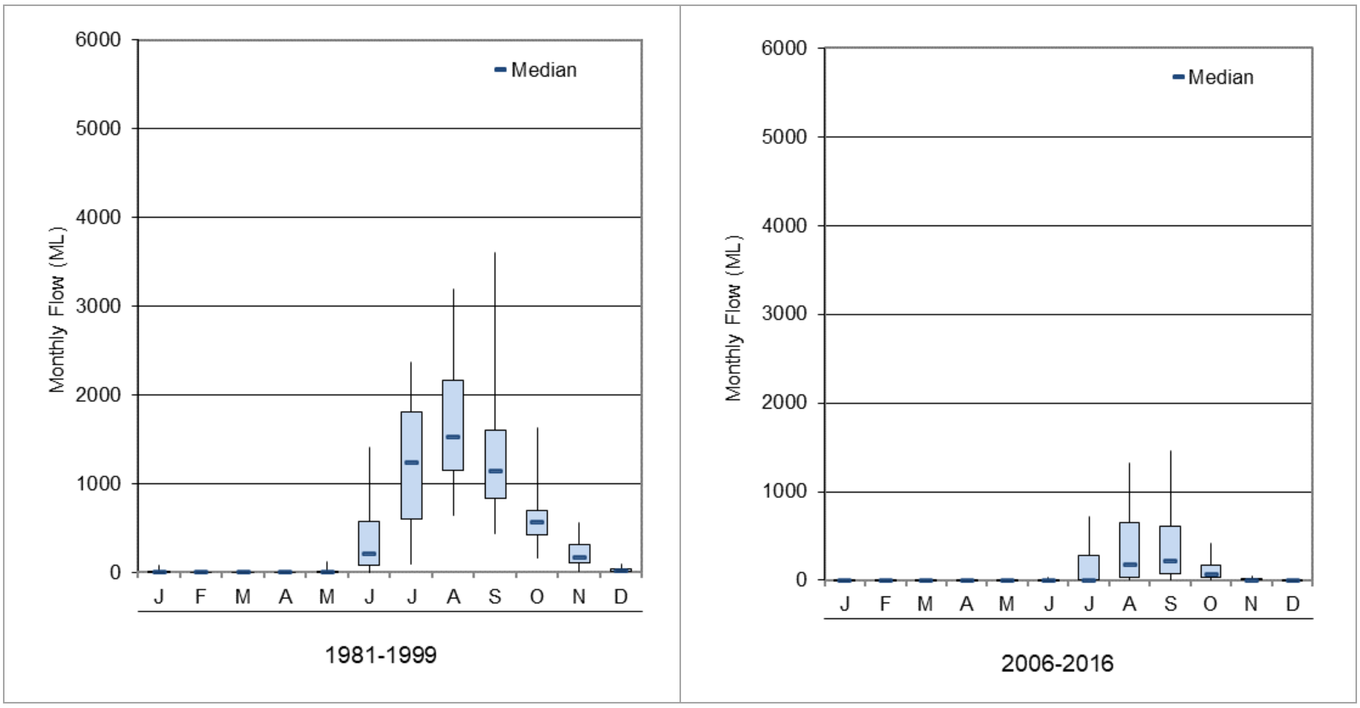

Figure 5-7 ***Flow seasonality – Jack Rocks (39 Mile Brook) for periods 1981-1999 and 2006-2016***

Baseflow and interflow

Baseflow is the portion of streamflow that is sustained between precipitation events but also forms part of the flow during rainfall events. Interflow represents lateral movement of water in the unsaturated zone. It is usually considered a component of baseflow, depending on the response time – and in this case in position with respect to the stream.

For the Serpentine catchment, Bari et al. (2010) used a model to estimate that interflow is the largest contributor to streamflow followed by groundwater connected baseflow and surface runoff.

Data analysis by GHD using methods described by Barlow, et. al., (2014) for the gauging stations located in the Myara North DE and study area indicates that baseflow represents between 45% and 67% of streamflow, depending on location and baseflow separation methodology.

For the O'Neil Road station (Big Brook, located to south of Myara North mine region), representing the largest catchment of the Serpentine River and longest record, the baseflow proportion of runoff has a weak downward trend.

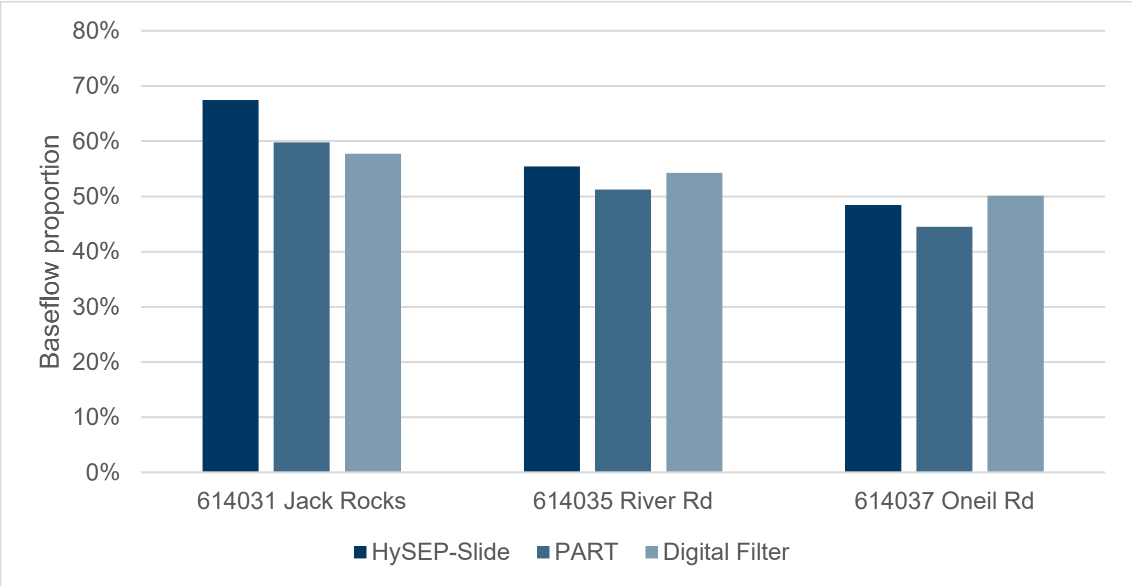

Figure 5-8 ***Baseflow contribution to runoff***

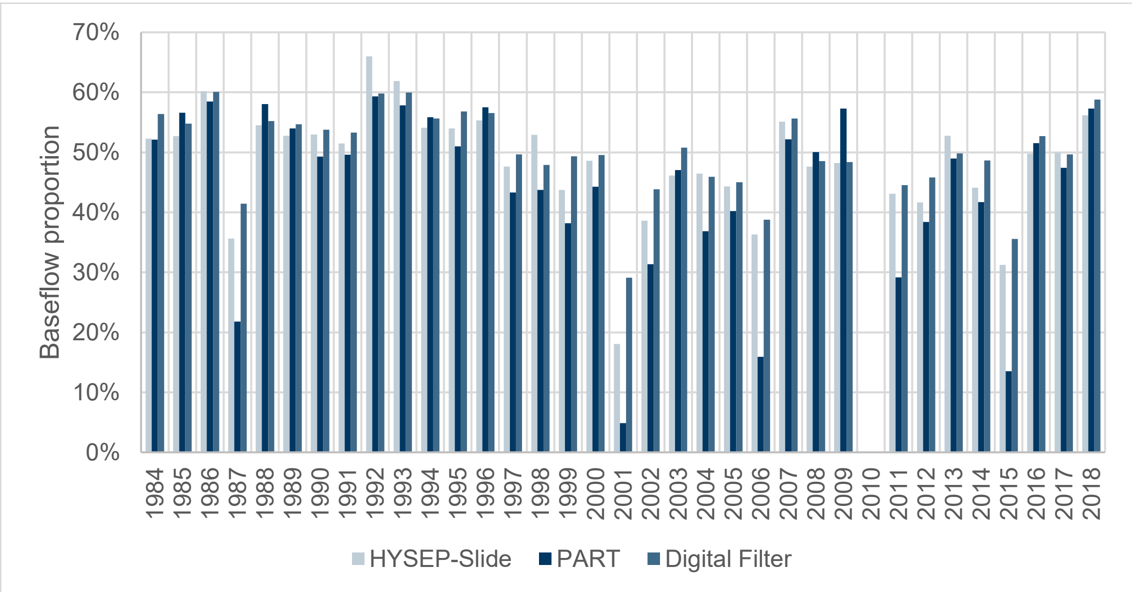

Figure 5-9 ***Baseflow trends***

5.2.2 Surface water quality

Historical water quality data

Surface water quality monitoring data across the Myara North region has historically been completed by Alcoa and DWER, and is limited to salinity, pH and some turbidity data.

The spatial distribution and frequency of Alcoa monitoring data varies widely across the Myara North mine region, with historical focus on research catchments and proposed mining catchments. Data for many sampling locations is not continuous. Data records range from short periods in the 1970s, with more extensive data from the mid 1970s through mid 1980s and mid 1990s.

The historical data identifies that surface water salinity is classified as fresh (0 to 500 mg/L TDS) in the surface water tributaries west of the 1,100 mm isohyet. Median salinity is comparable across all sampling locations, however maximum salinity values (as TDS and electrical conductivity (EC)) typically increase for tributaries east of the 1,100 mm isohyet.

Available pH data indicates that median pH of all tributaries is neutral, with some tributaries reporting minimum pH values in the acidic range.

Historical turbidity data for surface water tributaries in the Myara North study area identify median turbidity values below 1.5 nephelometric turbidity units (NTU). DWER monitoring of Serpentine River locations identifies marginally higher median turbidity values ranging from 1.6 to 2.6 NTU.

Baseline surface water laboratory results

Baseline surface water sampling events were completed monthly at selected Myara North monitoring locations between August 2020 and January 2021.

The results of the baseline monitoring program identify that surface water quality is generally similar across the Myara North mine region, reflecting the similar hydrological and hydrogeological conditions. As with groundwater quality the surface water quality is typically fresh, unimpacted by anthropogenic activities and consistent with the site setting within state forest.

The salinity, pH and turbidity data observed during the baseline monitoring period is consistent with the historical data record for the various subcatchments of the Myara North region.

Surface water is non-saline and moderately acidic, with marginally elevated surface water salinity observed in some samples during late season monitoring or when sampling occurred from pools. A short continuous EC logger record at two tributaries east of the 1,100 mm isohyet identified EC at the lower end of historically observed ranges. There is a trend observed between streamflow rates and salinity, the latter increases as the streamflow decreases (Figure 5-11).

Surface water samples typically had low turbidity and low total suspended solids. The low background turbidity was also observed in a short continuous turbidity logger record at four representative sites, with short pulses of elevated turbidity rapidly returning to background levels. The short duration of these pulses are indicative of passing debris rather than elevated turbidity. The salinity, pH and turbidity data observed during the baseline monitoring period is consistent with the historical data record for the various sub-catchments of the Myara North region.

An extended suite of surface water quality parameters were also sampled during the first three months of sampling in August, September and October 2020. As with groundwater within the Myara North mine region the surface water results had low nutrient levels, and metal concentrations representative of the geological setting. Microbiological parameters were detected at all sampling sites, with widespread detection consistent with the presence of fauna species within the national park setting.

Low concentrations of PFAS were detected at four sites, however all detections were significantly below the drinking water assessment criteria.

Detection of PAHs elevated above the drinking water guideline was recorded at site SW06 in October 2020, with PAH concentration dominated by naphthalene. Site SW06 is located in the catchment of a prescribed burn that occurred in late September 2020, and it is assumed that the elevated PAH concentration occurred due to natural introduction of PAHs from the prescribed burn. Dieldrin was detected in a single sample at a concentration significantly lower than the drinking water assessment criteria.

For other contaminants of potential concern, including methylene blue active substances (MBAS) surfactants, Benzene, Toluene, Ethylbenzene and Xylene (BTEX) compounds, TRH and explosives, all samples analysed returned results less than laboratory limits of reporting.

5.3 Conceptual understanding of surface water and groundwater connectivity

5.3.1 Introduction

Surface water and groundwater are hydraulically connected through drainage lines (and potentially springs), valley floors (wetlands, damplands) and the water reservoir (the Serpentine Dam). Surface water is at least intermittently connected to both the regional (or in some instances perched) watertable and the interflow vadose zone.

This is supported by observations from the surface water flow monitoring data. An example of recorded observations is shown for the Jack Rocks gauge and the nearby bore MJ40122A which documents the correlation between elevated groundwater levels and surface flows (Figure 5-10). Surface flows occur at the same time when groundwater levels are elevated by several metres in response to winter rainfall.

5.3.2 Surface and near surface flow

Stream gauges within and in proximity to the Myara North mine region (Appendix C), confirm that surface water flows are relatively short-lived following winter rains, ceasing to flow within two to three weeks following peak surface water flows.

The short duration of surface water flow following rainfall supports that the contribution to surface water flow from catchment runoff and other short-term storage such as shallow subsurface flow top up the baseflow contribution from groundwater in short term, following the winter rains.

The near-surface flow occurs in the variably saturated shallow subsurface where sufficient rainfall inputs can temporarily resaturate permeable materials where these are present on top of less permeable substrate (for example clayey saprolite or basement subcrop) and cause short-term flows from these perched conditions downgradient. Due to the large heterogeneity of the weathering zone materials this component of flow can often exfiltrate to the surface when encountering a barrier such as a basement outcrop or where the shallow subsurface zone otherwise pinches out.

These flows are thought of as a patchwork of locally occurring flows, largely non-contiguous, but able to support – in short term – streamflows activated by winter rainfalls. This flow component is likely to merge with baseflow in the slopes surrounding the drainage lines where these sufficiently cut into the regional watertable.

Given the short duration, the streamflow flows carry the surface and near-surface flow contribution until it is exhausted, and the streamflow becomes dependent on contribution from groundwater (i.e., baseflow only). An examination of TDS values in Figure 5-11 between May 1990 and May 1991 suggests that winter rains at Jack Rocks gauge lead to low TDS values (around 150 mg/L) at the start of winter streamflows consistent with the initial larger proportion of surface runoff and near surface flow (and rain) contribution. As flow subsequently diminishes, TDS values rise to just below 350 mg/L, more typical of groundwater, i.e., dominated by baseflow.

5.3.3 Baseflow

Discharge in the form of baseflow or seepage, at smaller rates, is then present for the subsequent period typically extending some weeks or months following the winter rains and peak storage (when groundwater levels are highest).

Given the shallow depth to groundwater in areas beneath the potential GDEs and wetlands, the regional groundwater continues to support the potential GDEs and wetlands, particularly during the summer months in absence of surface water flows. As long as groundwater within the topographical slopes surrounding the drainage lines or creeks does not considerably fall below the creek level (which would lead to hydraulic disconnection), or the flow gradient reduces such that the incoming flow is completely removed by riparian evpotranspiration, groundwater continues to exfiltrate to the creek, or supporting sufficiently shallow watertable in the riparian zone accessible for support of vegetation communities .

5.3.4 Salinity changes during streamflow

Major rainfall events that produce streamflows lead to changes in streamflow salinity. These are interpreted to reflect changing proportions of more saline groundwater and less saline runoff and near surface flow. A relationship between streamflow rates and TDS (Figure 5-11) clearly demonstrates increase in TDS with falling streamflows and the importance of surface and near surface flows.

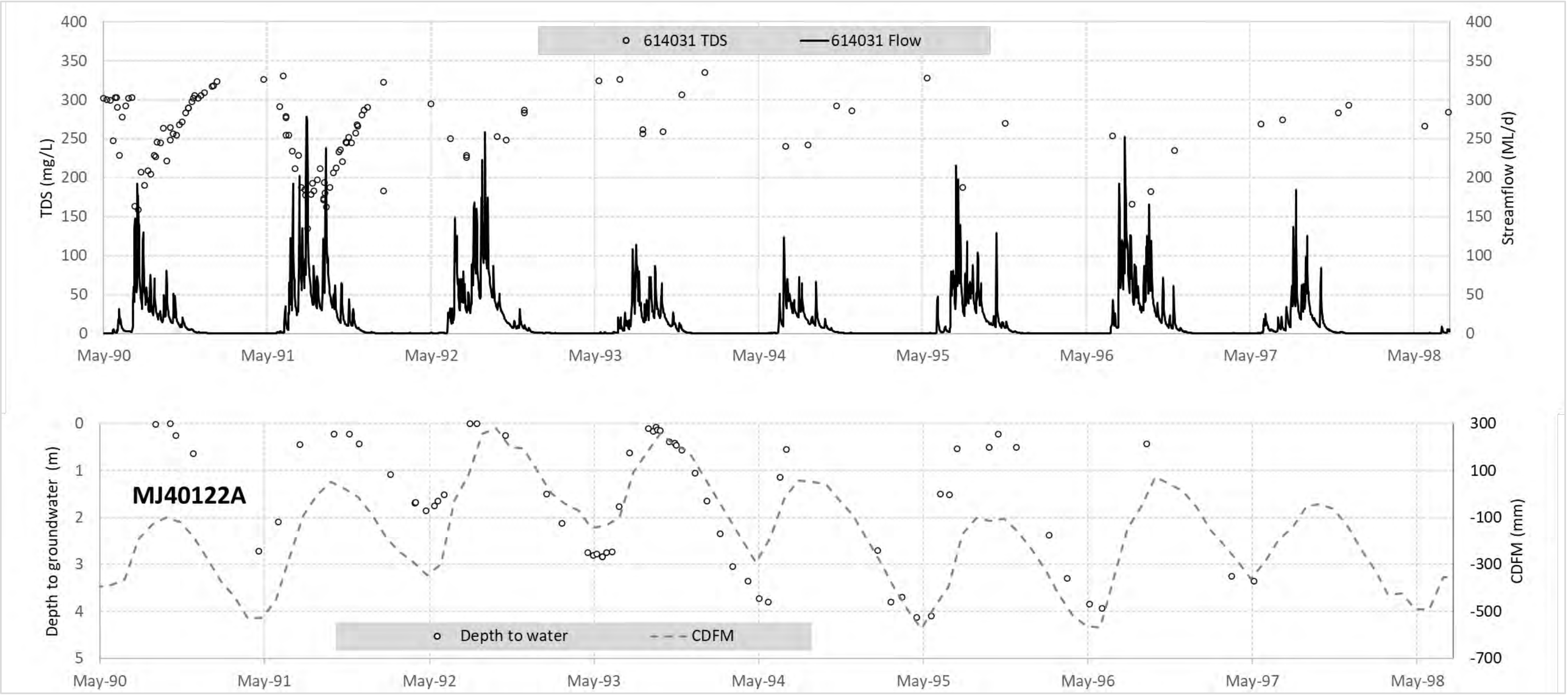

Figure 5-10 Example of streamflow and groundwater level response to seasonal rainfall (Jack Rocks gauge and bore MJ40122A)

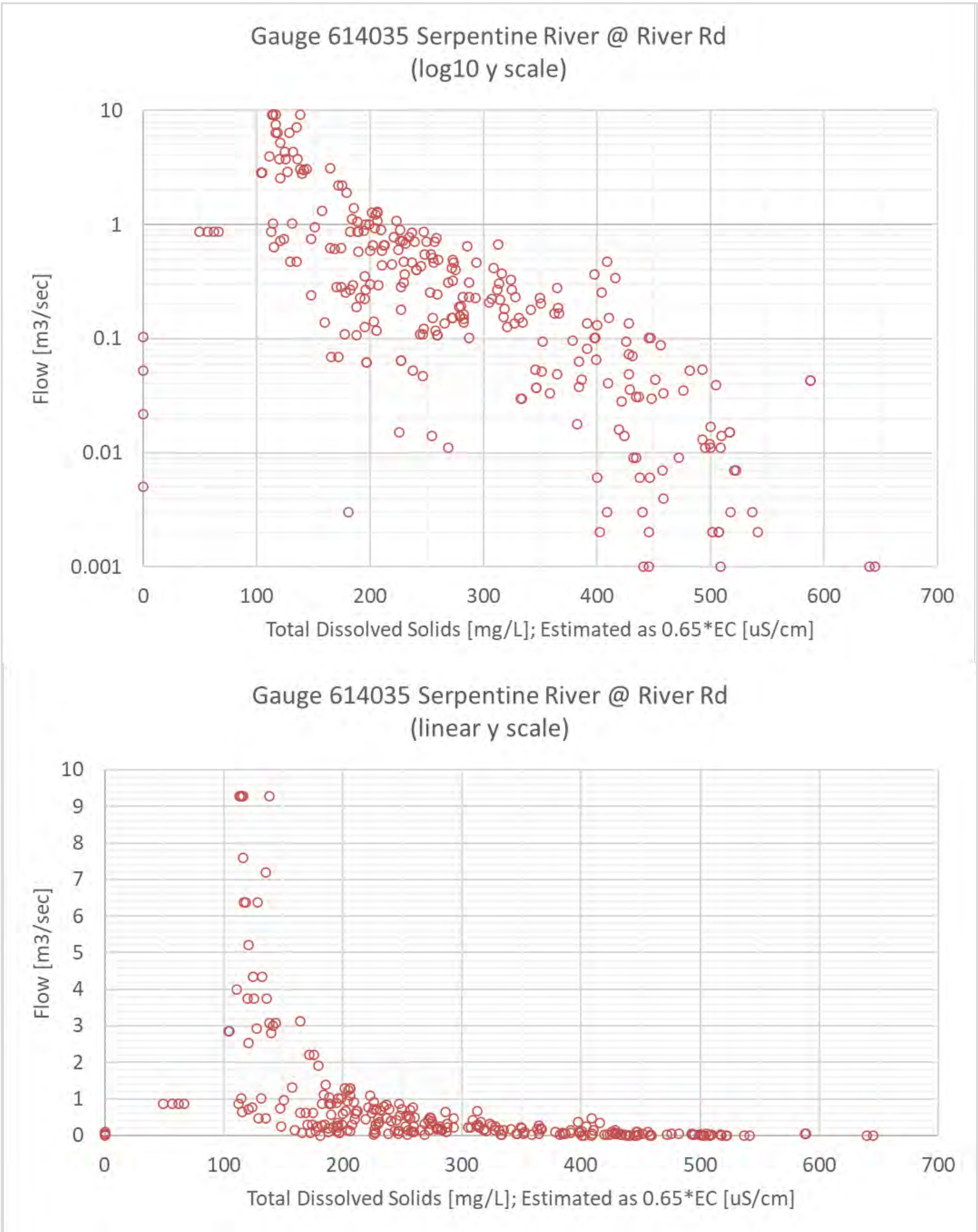

Figure 5-11 ***Example of relationship between streamflow rate and salinity (TDS)***

5.3.5 Key components of stream aquifer interaction

The key water components active during the stream aquifer interaction (occasionally including the top profile that is unsaturated for most times) and the conceptual model of this interaction are sketched in Figure 5-12.

In summary there are three potential sources of water which support streamflows and the riparian zones, including wetlands, areas where the potential GDEs are also mapped:

– **Surface runoff** – the proportion of rainfall flowing down-slope on the surface. It is short-term and proportionally small due to thick forestation.
– **Occasional near-surface flow in variably-saturated shallow subsurface** – a patchwork of shallow subsurface flow within lateritic material/sands/gravels, which eventually discharges into the creek or riparian zone or merges with baseflow. This component of flow represents occurrences of lateral flow through otherwise mostly unsaturated zone, perched above the less permeable saprolite clays or basement material of low permeability. The proportion of flow may occasionally exfiltrate (for example on encountering outcrop, or less permeable soil) and then infiltrate again, or removed by e.g., evaporation or evapotranspiration.

– **Baseflow - groundwater discharge** where the topographic low points (e.g., creeks, wetlands) intersect the regional ground watertable. For shorter periods after rainfalls the flow overcomes evapotranspiration in the riparian zone and discharges as baseflow into the stream.

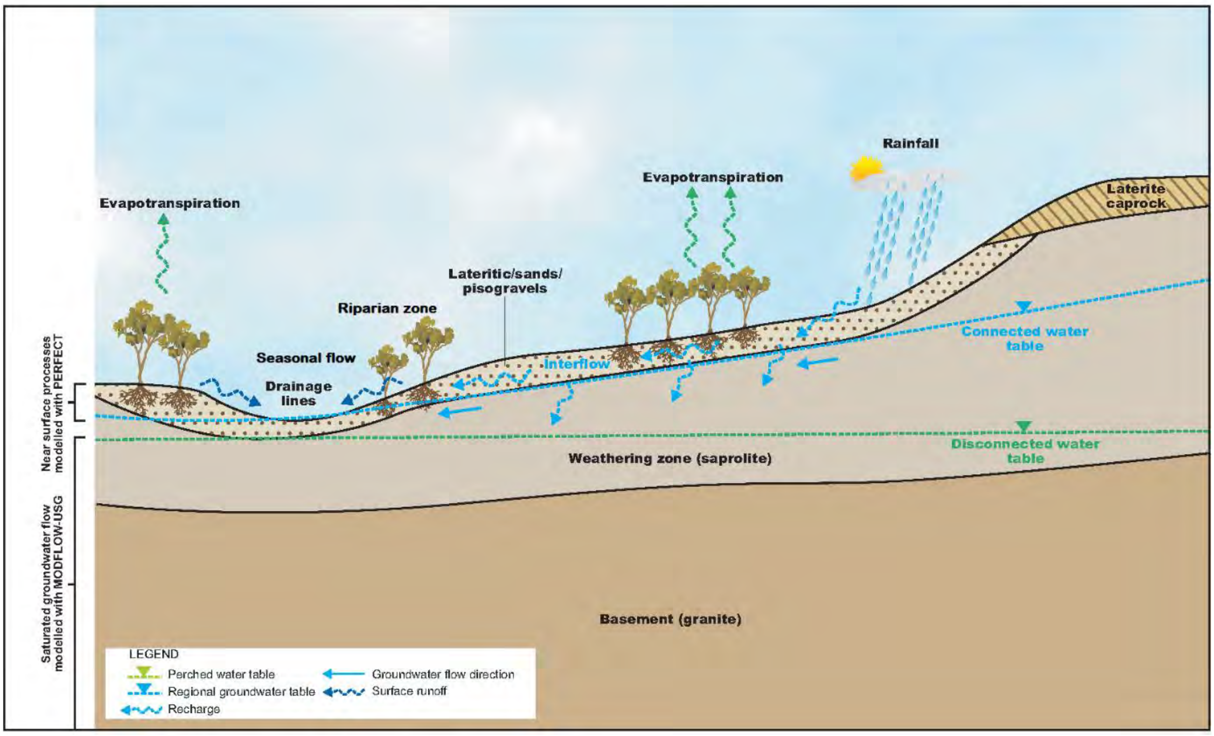

Figure 5-12 Conceptual representation of surface water groundwater interaction

5.3.6 Proportional representation of flow components

Attribution of flow components to streamflows has been examined on Jack Rocks gauge data which has a reasonable density of flow and EC data during 1981 and 1999 observation period. Grigg et al. (2020) provided a case that principal contribution to the Darling Range streams comes from groundwater (i.e., baseflow), which is also supported by baseflow estimates in section 5.2.1 (45% to 67% interpreted as baseflow).

In the following, we present a simple case calculation, based on Jack Rocks data, using TDS and streamflow data to estimate flow components.

The calculation is based on an example of several similar approaches, in this case on Gonçalvès et. al. (2020) who presented a methodology that uses hydrochemical data to constrain various flow components (they refer to baseflow and surface/hypodermic flow) with a monthly time step. Their methodology uses major ions to characterise hydrochemical end-members and also assumes fast responding reservoir to runoff and the near-surface flows; and slower responding reservoir to baseflow.

In absence of detailed hydrochemical data for Jack Rocks gauge, only TDS is applied as the hydrochemical constraint. Assuming the average TDS values for the two end-members, runoff/near-surface flow and baseflow, at 100 and 350 mg/L, respectively, it is possible to estimate attribution of these two flow components during 1981 and 1999 winters. The results of a several possible realisations obtained using the approach by Gonçalvès et. al. (2020) are presented in Figure 5-13.

In this case we present the following possible realisations which yield similar streamflow timeseries results:

– "Low baseflow", and low recharge rate realisation (in this case using 46 mm/yr recharge rate)
– "High baseflow" – and higher recharge realisation (in this case using 113 mm/yr recharge rate)
– Baseflow aligned with the chloride mass balance (CMB) recharge estimate (in this case using 56 mm recharge rate)
– Baseflow aligned with the CMB recharge estimate and peak flows

A reasonable match (Figure 5-13) between measured and calculated data (both flows and TDS) using a simple parsimonius analytical model indicates a clear interaction between flow components and the ability of this simple model to reasonably represent streamflows. All presented realisations have similar correlation between observed and simulated results, with correlation coefficient (R^2) varying between 0.71 and 0.77.

The results also indicate that using a range of recharge rate values it is possible to obtain similar streamflow results, even when constrained by TDS. The recharge rate in this case varied between 46 and 113 mm/yr, with the balance of streamflow supplied from quickflow (mainly interflow) components. In these evaluated realisations baseflow contributes between 18% to 50% of streamflow.

This range could be potentially even larger given that the analytical solution can accommodate it and produce plausible streamflow estimates. Baseflow proportion is likely to vary more during shorter timesteps, e.g., quickflow would be dominant during the initial phases of the streamflow event, while baseflow will be dominant in the receding part of the event. This is also reflected in the simulated realisations in which the streamflow peak precedes the baseflow peak. More detail on these realisations is provided in GHD (2021b).

Streamflow salinity data can also provide indications of the prevailing flow regimes. The relationship (Figure 5-14) between the recorded streamflows and TDS for the same period indicates a relatively stable range of TDS at low flows and then linear decrease in TDS with rising flow rates.

Below average flow rates of 0.05 m^3/s the recorded TDS ranges between 280 and 345 mg/L. It is reasonable to assume that at these flow rates practically all contribution is coming from groundwater as baseflow. In this particular case the surface flow becomes active when the flow rate exceeds 0.05 m^3/s.

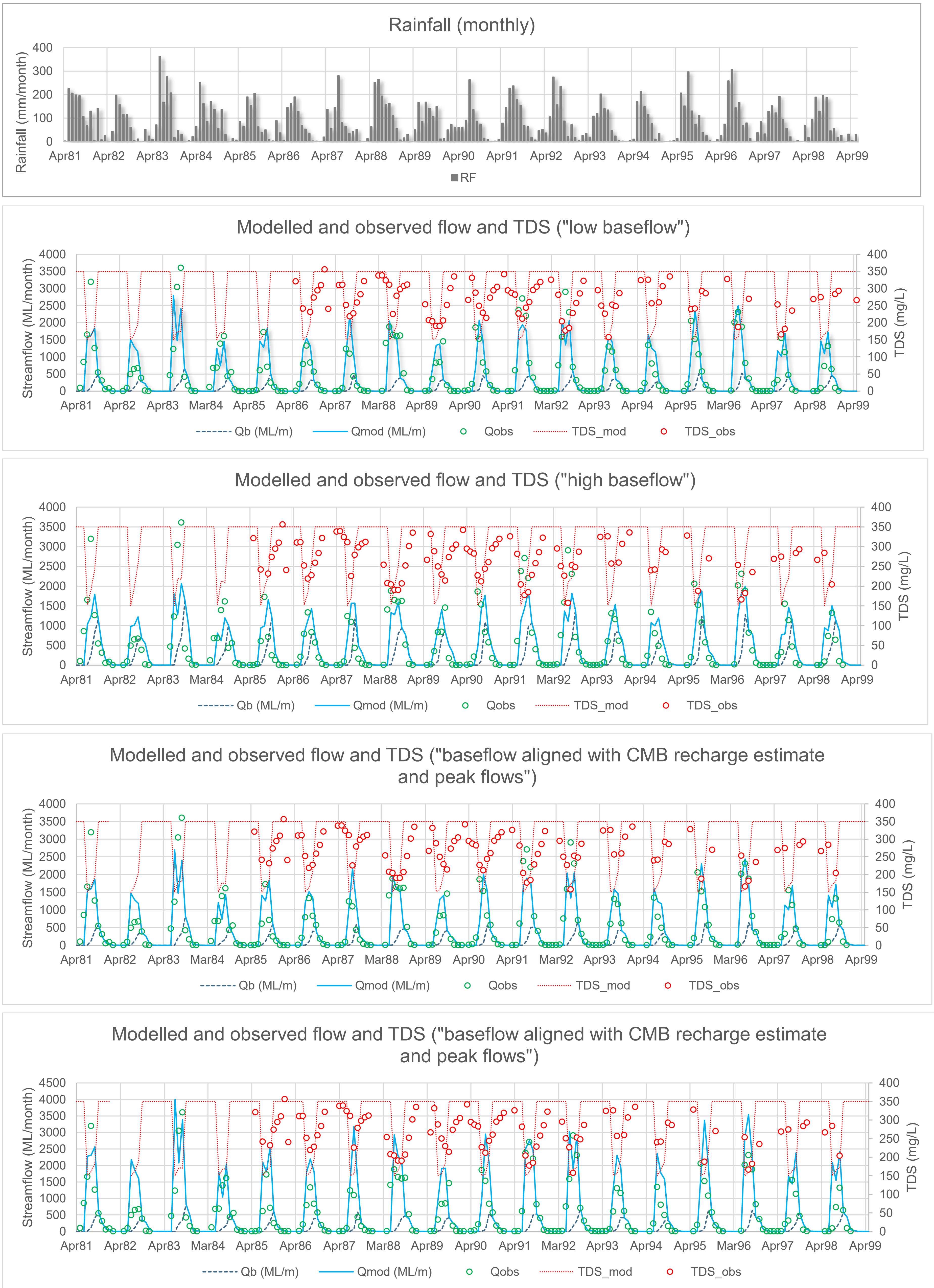

Figure 5-13 ***Application of simple analytical TDS-constrained baseflow-quickflow models to represent measured streamflows at Jack Rocks gauge (Qb – baseflow; Qmod – modelled streamflow; Qobs – observed streamflow; TDS_mod – modelled TDS; TDS_obs observed TDS)***

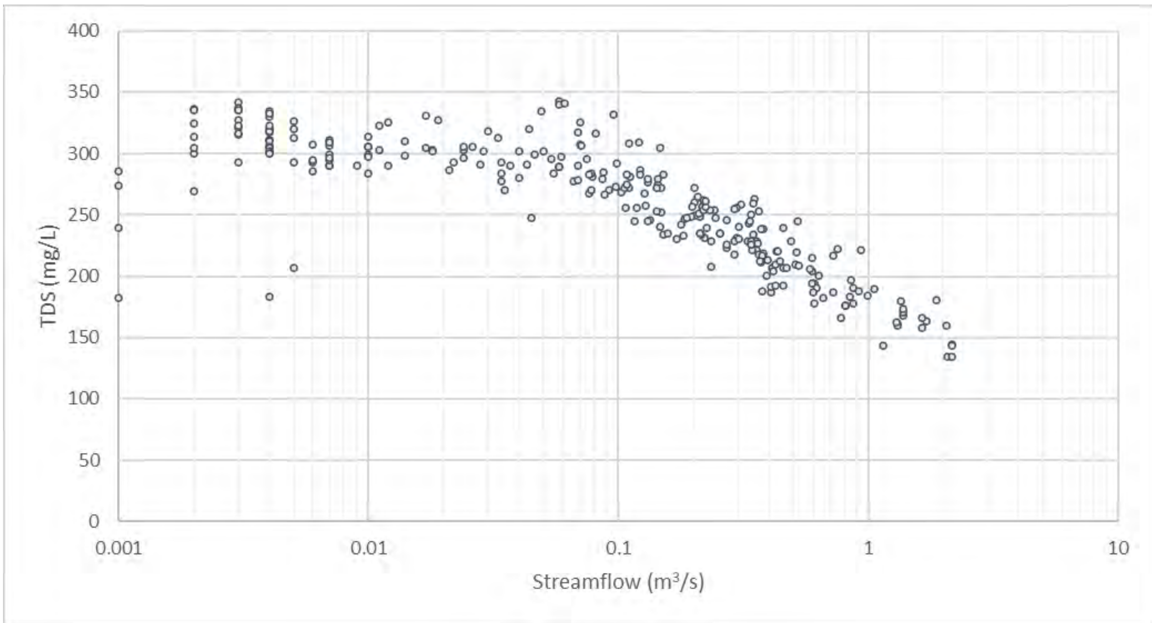

Figure 5-14 ***Relationship between average daily flow rates and TDS***

5.4 Environmental values

5.4.1 Potential groundwater dependent ecosystems

Potential GDEs were derived from detailed flora and vegetation assessment completed to assess site-vegetation types of the Myara North mine region by Mattiske (2021a).

The site-vegetation type mapping was compared to extensive flora and vegetation studies completed in the northern jarrah forest region to identify vegetation complexes that support species and site-vegetation types that prefer and occur on seasonally moister and wetter soils of the swamps and lower slopes of the valley systems (Mattiske 2021a), with this approach considered a precautionary approach in the absence of detailed groundwater level data.

Mapping of potential GDEs in the Myara North mine region is presented in Figure 5-15, with detail provided in chapter 5 (flora and vegetation) of the Proposal Environmental Review Document. Potential GDEs cover 28% of the Myara North mine region.

5.4.2 Aquatic ecosystems

Fauna habitat

The detailed fauna survey of the Myara North mine region identified that the drainage lines supporting relatively low dense vegetation have a linkage value as preferred habitat for medium sized mammals such as Quenda and Quokka (GHD 2021f).

Aquatic fauna

Limited historical aquatic fauna surveys were completed for parts of the Myara North mine region as part of the Wungong Catchment Trial (WRM 2013). Aquatic fauna values from these surveys as well as surveys of other catchments across wider Northern Jarrah Forests region were used to inform a desktop assessment of the aquatic fauna values of the Myara North and Holyoake mine regions as summarised in the report Aquatic Fauna Desktop Assessment - Myara North and Holyoake Regions (WRM 2021).

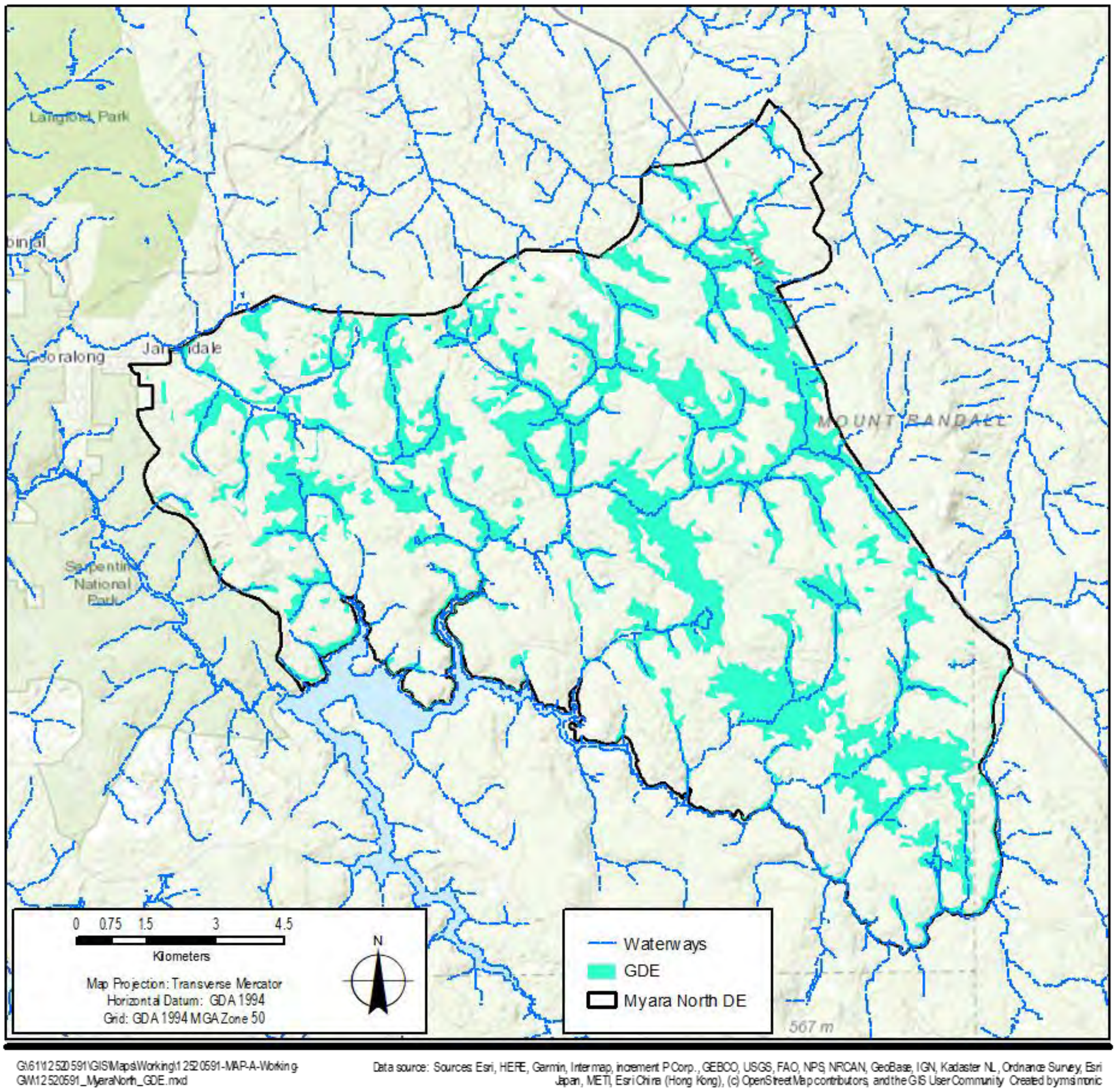

Figure 5-15 Spatial distribution of potential GDEs in Myara North mine region

WRM (2021) identified that the aquatic fauna habitats are likely to be dominated by first-order seasonal creeklines and ephemeral headwater swamps/damplands. In higher rainfall years, baseflow in higher-order streams may maintain isolated pool refuges over summer. Aquatic fauna communities are expected to be characterised by a high degree of seasonality and high level of species endemism.

A targeted Carter's Freshwater Mussel (EPBC and BC Act Vulnerable) survey completed as part of the Phase 2 detailed and targeted fauna survey of the Myara North mine region (GHD 2021f) did not identify any signs of mussels.

Carter's Freshwater Mussel population has previously been located (Klunzinger et al. 2012) at Serpentine River Pipehead Dam. The species is known to reside in the Serpentine Dam on the southern boundary of Myara North mine region.

The fauna survey identified that while mussels may disperse upstream from the Dam during winter/spring flows, all streams are seasonal, and any dispersing mussels are unlikely to survive the extended dry summer period. Therefore, significant populations are unlikely in the Myara North mine region.

6. Holyoake hydrological setting

This section summarises the results of the baseline groundwater, surface water and environmental technical investigations that were completed across the Holyoake area. The aim of investigations was to establish baseline hydrological conditions, including water quality (surface water and groundwater).

6.1 Hydrogeological characterisation

6.1.1 Information base

Alcoa and DWER have collected limited groundwater level and groundwater quality data within the Holyoake mine region, however regions neighbouring Holyoake were investigated in more detail.

GHD, as part of the current investigation installed 17 new groundwater monitoring bores in 2020, to supplement 8 existing Alcoa groundwater bores. The subsequent baseline monitoring program comprised monthly water level dips and physico-chemical parameter measurements from October 2020. Groundwater samples collected for laboratory analysis of a broader suite of parameters in October 2020 and February 2021.

6.1.2 Aquifer units

Aquifer system information for the proposed Holyoake mine region was investigated using hydrogeological drilling and installation of groundwater monitoring bores by GHD. Details of geological logs are presented in GHD (2020b).

A summary of the geological logs is provided below and monitoring bore locations are presented in Appendix A, Figure A 8. A review of the GHD geological logs indicates a thicker lateritic profile than that of the Myara North mine region and depth to fractured bedrock was deeper, with a generalised profile as described below:

– **Lateritic/ duricrust caprock**: 1 to 7.5 m deep with an average of 1 to 2 m. The caprock comprises minor soils with pea-gravel and cemented duricrust or laterites and is less developed than in Myara North. One bore returned a well sorted sand from surface with an absence of caprock.
– **Saprolite**: Highly variable depths from 1 to 32 m, comprising completely weathered clay. Generally, clay is mottled or pallid towards the top becoming greener with depth indicating transition to weathered bedrock. Several bores also returned a uniform silty clay lens up to 20 m thick within this succession.
– **Weathered zone**: Weathered basement zone (which includes saprock) is characterised by a gravelly texture and decreasing clay content but with a higher clay content that in Myara north. Groundwater flow was minor with measured flows during drilling of only 4 L/minute, significantly less than in Myara North.
– **Fractured basement**: Depth to fractured granite varies from 6 to 36 mbgl. Two notably shallower bores intercepted a quartzite and dolerite intrusions whereas one deep bore recorded a schist at 33.5 m.

Slug tests (GHD 2021a) were conducted on GHD monitoring bores, and the results are summarised and presented in Figure 6-1. The monitoring bore slotted intervals reflect the horizons with water strikes, which were generally identified within the transition zone from weathered bedrock to fractured granite.

Highest hydraulic conductivity values were returned from bores screened in the basement saprock to highly weathered granite and likely related to discrete high permeable zones within this unit. Hydraulic conductivity ranges from <0.1 to just over 1.0 m/day with an average of 0.3 m/day as shown in Figure 6-1. The average hydraulic conductivity for Holyoake mine region is lower in comparison to Myara North mine region. This is consistent with the described lithology and drilling, where higher groundwater flows, associated with the basement/saprock profile, were more common.

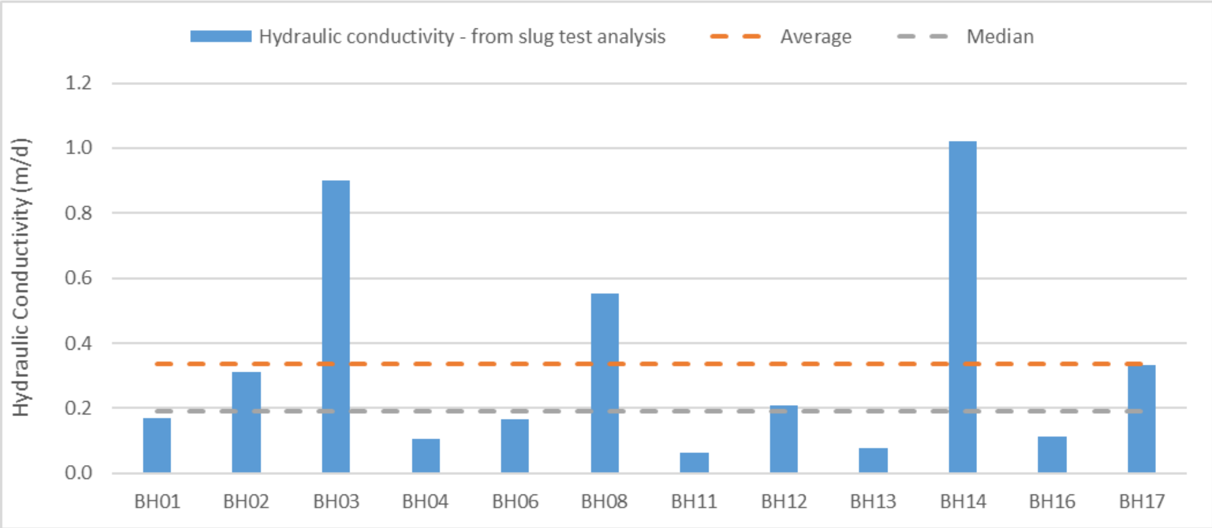

Figure 6-1 Holyoake slug testing results (hydraulic conductivity)

6.1.3 Groundwater levels and flow

Groundwater levels, flow and discharge

The newly instated monitoring bores, which are located close to, or within the valley floors and creek lines, indicate that the depth to groundwater is generally greater than 10 meters below ground level (valley floor level), with one of the 17 locations exhibiting depth to groundwater less than 5 m (BH12). The average depth to groundwater is 14.5 meters below ground level.

At a regional scale, an inferred relationship between topography and depth to groundwater indicate that groundwater flows towards the north-west, where it would discharge in or along the major drainage lines, including the lower lying areas of the South Dandalup Dam and associated lower lying tributaries (e.g., South Dandalup River).

Groundwater level trends and observations

There is lack of historical monitoring data within the Holyoake mine region to assess long-term groundwater level changes. A total of six bores were identified that have longer-term monitoring data, combined with more recent data (2020/21), and extrapolation from knowledge about the neighbouring regions, provide a basis for estimation of long-term groundwater trends.

Summary of historical groundwater level trends and salinity is presented in Table 6-1. The groundwater levels of the six monitoring bores show declining groundwater levels since 1990s, of close to 9 meters, which is considered to reflect the reducing rainfall patterns, which also appears to be declining since 1990s.

The installation of 17 new groundwater monitoring bores within and in proximity to the Holyoake mine region facilitated a better understanding of groundwater levels across the mine region, with the data providing a more spatially representative dataset for groundwater within the whole of Mine DE. Key observations from the new monitoring bores include:

- Data from the new bores, which are predominately located close to, or within the valley floors/ creek lines, highlighted that groundwater levels are more variable and generally deeper than in the Myara North mine region.
- The groundwater is more than 10 meters below ground level (valley floor level), with one of the 17 locations exhibiting depth to groundwater levels less than 5 m (BH12). The average depth to water is 14.5 meters below ground level.
- The average seasonal groundwater level decline for all new bores is 0.7 m, significantly less than Myara North mine region (1.9 m for Myara North mine region bores), which may reflect based on the observations in Myara North mine region and Holyoake mine region, the bores with shallower depth to water, tend to have a greater seasonal range in groundwater levels.

Table 6-1 *Holyoake mine region- summary of historical groundwater level trends and salinity*

Monitoring well ID	Groundwater levels			Groundwater salinity		
	1990 SWL (mBGL)[1]	2020 SWL (mBGL)[1]	Change SWL (m)	1990 TDS (mg/l)[1]	2020 TDS (mg/L)[1]	Change TDS (mg/L)
MJ46071A	10	17	-7	250	300	50
MJ46071B	10	17	-7	NA	NA	NA
MK46051A	17	22	-5	NA	NA	NA
MK46101A	10	25	-15	150	200	50
MK49162A	9	20	-11	2000	2000	0
ML49131A	10	20	-10	1000	1400	400
Notes	SWL - Standing Water Level					
	TDS – Total Dissolved Solids					
	1 - average values estimated from graphs observations (semi-quantitative)					
	NA - Not applicable, no data or unreliable data					

6.1.4 Groundwater quality

Groundwater salinity

Groundwater quality within the Holyoake mine region is typically fresh, consistent with the current site setting within the state forest. The limited historical data (Table 6-1) suggests a slight rise in TDS consistent with the noted general decline in groundwater levels.

Historical and current monitoring data indicates an average salinity of around 400 mg/L, however the dataset is quite variable, for example of the 16 new monitoring bores, three bores have an elevated TDS of between 1,000 to 1,500 mg/L (BH03, BH05 and BH12).

Two of these sites (BH03 and BH05) are located relatively close together (1.8 km) along the same drainage line in the far north-east of the project area and may reflect local hydrological and hydrogeochemical conditions.

Other groundwater quality parameters

The groundwater quality sampling for this assessment included the analysis for a wide range of water quality parameters. The data from the two comprehensive monitoring rounds indicated no discernible seasonal change in groundwater quality, although some effects of sampling following the drilling of the new groundwater monitoring bores was noted.

The results showed low nutrient levels, albeit marginally higher than in Myara North mine region. Metal concentrations were also marginally higher than Myara North mien region but still typical of ‘natural’ conditions and representative of the geological setting.

Low concentrations of PFAS were detected in five of the sampled bores, however all detections were below the drinking water assessment criteria. Low-level detection of PAH (pyrene) was noted in most bores during the first minoring round. PAH concentrations reduced in the second sampling round, possibly indicating that the drilling was the original source, or that the PAHS source was related to short-term impacts from bush fires.

6.2 Surface water characterisation

6.2.1 Surface water flow

Holyoake gauging stations

There are several flow-gauging sites relevant to the broad region of the Holyoake mine region (Appendix A, Figure A 6), details of which are summarised in Table 6-2 Gauging stations relevant to Holyoake. It is noted that all gauged sites are situated outside of the Holyoake mine region, and there are large areas of the proposed mining catchment for which no flow-gauging data is available.

Table 6-2 Gauging stations relevant to Holyoake

Site ID	Site name	Flow record	GS catchment area (km)	Average annual rainfall (mm)	Annual average streamflow (ML) [3]	Runoff (mm)
South Dandalup tributary						
614043	Pindalup	1984 to 1998	7 km^2	1130.5	59	8.4
614059 [1]	Skeleton Road	1988 to 1998	19 km^2	1,112.2	2519	133
614060 [1]	Gordon Catchment	1988 to 2018	2 km^2	948.8	17	8.5
Murray River and tributaries						
614045	Chadoora (Swamp Oak Tributary)	1984 to 1997	5 km^2	1130.5	20	4.0
614047	Davis Brook – Murray Valley Plntn (Murray River Tributary)	1954 to 2002	66 km^2	1130.5	6407	97.1

Note:
1 Annual average rainfall for 614059 and 614060 derived from SILO 5 km daily grid data (1970-2020), remaining sites derived from SILO extraction for Karnet station (1970-2019)

Long-term trends in annual flow

Long-term annual flow data for the area neighbouring the Holyoake region is restricted to the Gordon catchment for the South Dandalup River (Figure 6-2). The Baden Powell gauging station is the only other site in proximity to the Holyoake area, with data from other stations predating 2000.

As with Myara North there is an observed step change in streamflow in the Gordon catchment after 2000 (Figure 6-2), with similar step changes observed in Baden Powell annual flow data (data not shown).

Long-term trends in flow seasonality

Similar to the long trends in flow seasonality in Myara North the box plots of monthly flow data (grouped by pre 2000 and post 2000) for Gordon (South Dandalup River) show a delay in flow commencement and typically earlier cease to flow for periods after 2000 (Figure 6-3).

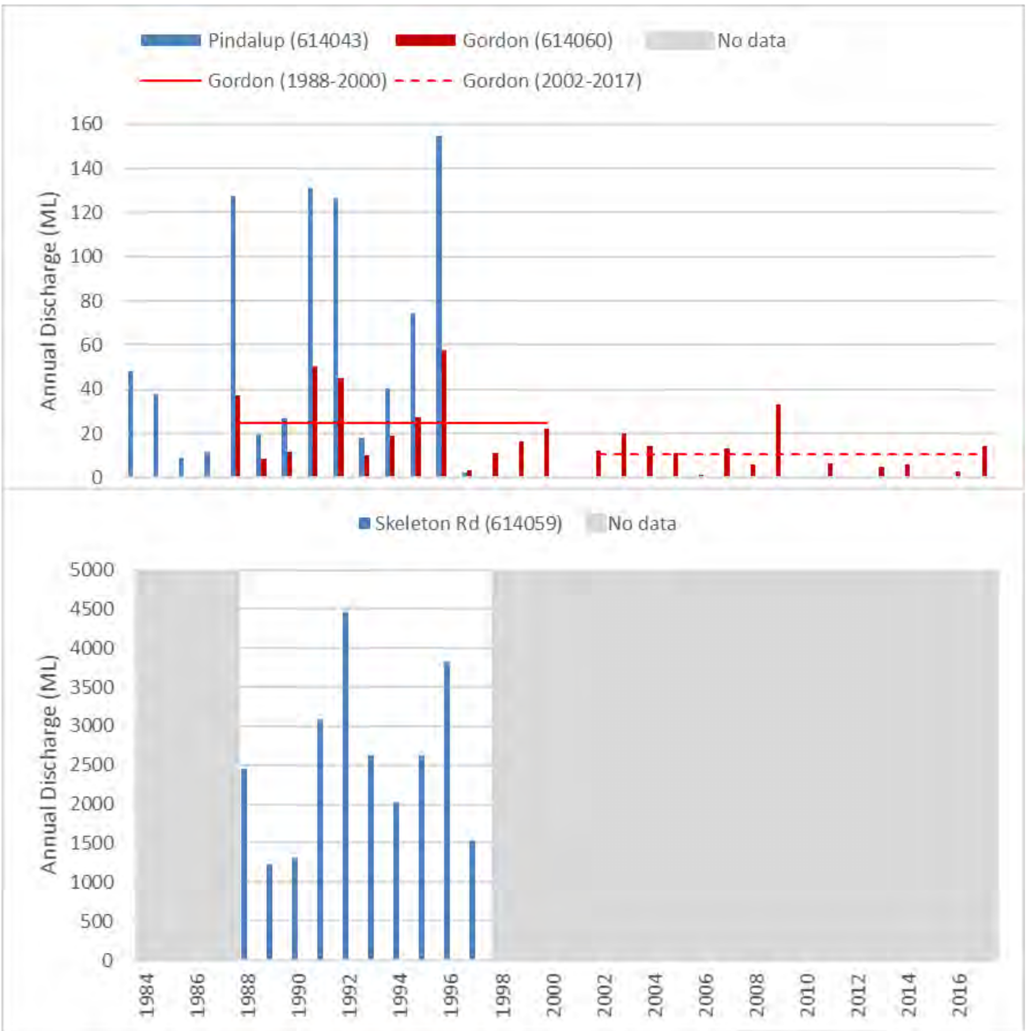

Figure 6-2 Annual flows at relevant South Dandalup catchment gauging stations

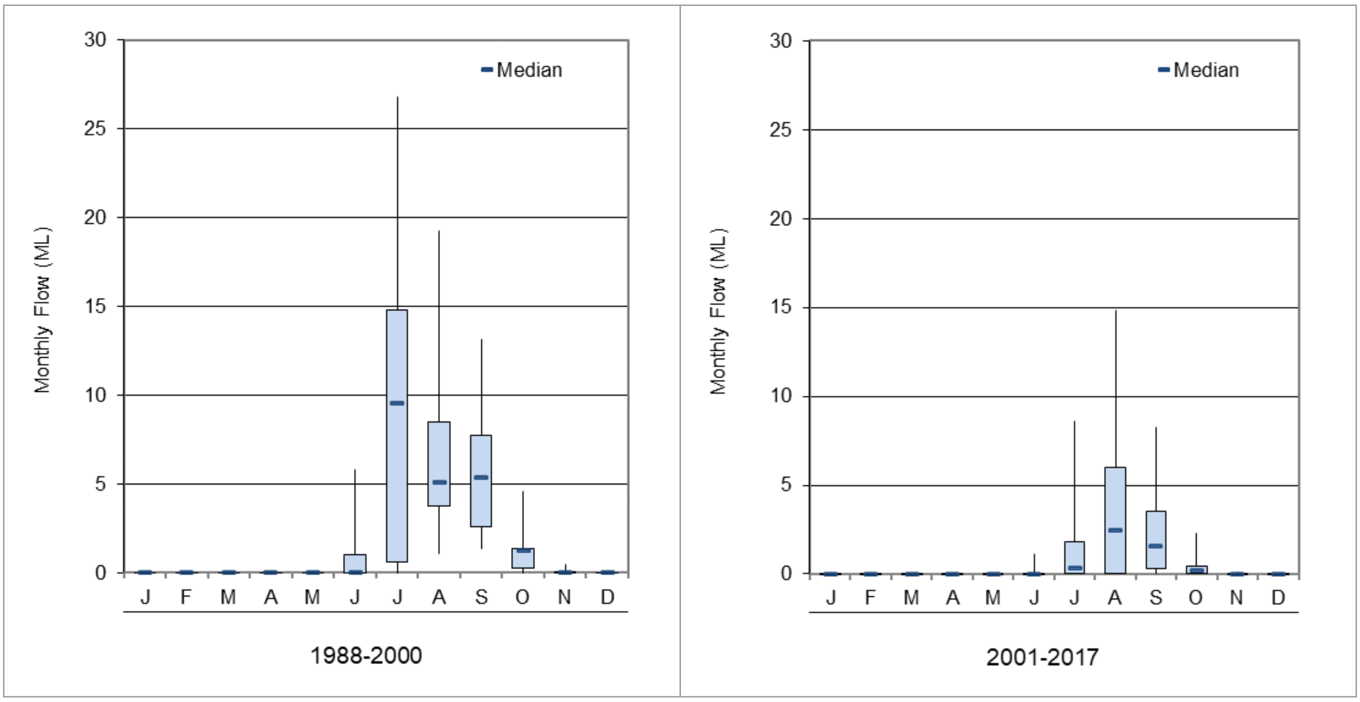

Figure 6-3 Flow seasonality, Gordon (South Dandalup) for periods 1988-2000 and 2001-2017

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Short-term trends in surface water level and flow conditions

During the 2020 baseline monitoring period flow conditions at surface water sampling locations were recorded during monthly surface water sampling events (GHD 2021a, Appendix C). Surface water level loggers were installed late September at three Holyoake surface water monitoring locations, two at the downstream extent of representative catchments prior to discharge to the South Dandalup Dam, and one in Swamp Oak Brook downstream of the Holyoake DE in the Murray River catchment.

Key observations from the surface water flow observations include dry conditions observed across multiple sites for all sampling events, including the central South Dandalup tributary through the Holyoake DE, with its upstream location observed to flow during one sampling event. No water level data was recorded at the Swamp Oak Brook monitoring location, while water levels at the other logger locations observed variable response to seasonal rainfall events.

Baseflow and interflow

Data analysis by GHD for the gauging stations located in the study area indicates that baseflow and interflow represents between 37% and 80% of streamflow, depending on location and baseflow separation methodology. The analysis was undertaken for the full streamflow record, varying between sites, between 1980 and 2018. These gauging stations are for much smaller catchments than those used for Serpentine Catchment (section 5.2.1) and represent a wider range or results.

6.2.2 Surface water quality

Historical water quality data

Historical surface water quality monitoring within the proposed Holyoake mine region has primarily been undertaken by DWER, with Alcoa monitoring limited to one site on Davis Brook (DV04) with sufficient data for review. Data is limited to salinity, pH and some turbidity data. As with Myara North mine region, data for many sampling locations is not continuous, and records range from short periods in the 1970s, to periods from the mid 1970s through mid-1980s, or mid-1980s to mid-1990s.

The historical data identifies that surface water is typically fresh, with median EC typically below 350 µS/cm. Limited pH data is available for gauging locations which indicates that median pH of tributaries is neutral.

Baseline turbidity for monitoring locations in the South Dandalup catchment (Holyoake mine region) are marginally higher than Myara North mine region, with median values ranging between 0.9 and 7.3 NTU.

Baseline surface water laboratory results

Baseline surface water sampling events were completed monthly at selected Holyoake mine region surface water monitoring locations between August 2020 and January 2021.

The results of the baseline monitoring program identify that surface water quality is generally similar across the Holyoake region, reflecting the similar hydrological and hydrogeological conditions. As with groundwater quality the surface water quality is typically fresh and consistent with the site setting within state forest.

The surface water physico-chemical samples collected and tested in-situ as well as those tested in the laboratory are similar to historical observations across the Holyoake mine region. Surface water is non-saline with neutral pH. Surface water samples typically had low to moderate turbidity and low total suspended solids. A short continuous turbidity logger record at two sites identified pulses of elevated turbidity that were sustained for up to several hours before returning to background levels. Unlike the fleeting pulses measured at Myara North mine region, these longer pulses are representative of an actual turbidity event. The pulses correspond to storm events, with higher peaks earlier in the season and lower peaks later in the season. The source of the turbidity is unknown. Prescribed burns covering a significant proportion of the catchment were conducted in late 2018.

An extended suite of surface water quality parameters were sampled during the first three months of sampling in August, September and October 2020. Total nutrient levels in surface water of the Holyoake mine region were higher compared to Myara North mine region. Metals concentrations were representative of the similar geological setting, with ANZECC guideline exceedances reported for zinc and copper in limited samples. Microbiological parameters were detected at all sampling sites, with comparatively higher maximum detections reported at Holyoake mine region than in Myara North mine region.

Low concentrations of PFAS were detected at five sites, however all detections were below the drinking water assessment criteria.

For other contaminants of potential concern, including MBAS surfactants, BTEX compounds, TRH, PAH, OC pesticides and explosives, all samples analysed returned results less than the laboratory limit of reporting.

6.3 Conceptual understanding of surface water and groundwater connectivity

Long-term observations of streamflows and groundwater level observations from the downgradient part of the Holyoake mine region are not available. In their absence, section 6.2.1 presents data from outside of the Holyoake mine region for illustration of likely streamflows expected within the Holyoake mine region.

Despite the lack of observational data within the Holyoake mine region, the nature of and the processes involved in surface water and groundwater connectivity are considered identical to Myara North mine region (described in section 5.3). The notable potential differences are related to:

- Groundwater in Holyoake mine region is deeper than in Myara North mien region. This means that access to watertable for phreatophytic communities is potentially more limited which would also limit their lateral extent. This is also illustrated by the proportion of potential GDEs of the Holyoake mine region which constitutes 17% compared to 28% in Myara North mine region.
- Due to the deeper groundwater levels, surface flows are also likely to be smaller and flow events shorter than in Myara North mine region, since less baseflow would be available to support streamflows. This is supported by baseline surface water monitoring completed in 2020. It is however possible that during the historical period before the last two decades the groundwater levels in Holyoake mine region were shallower and surface flows greater than observed in 2020.

6.4 Environmental values

6.4.1 Potential groundwater dependent ecosystems

Potential GDEs were delineated from detailed flora and vegetation assessment of the Holyoake mine region by Mattiske (2021b), and are presented in Figure 6-4 and detailed in chapter 5 (flora and vegetation) of the Proposal Environmental Review Document.

6.4.2 Aquatic fauna

Fauna habitat

The detailed fauna survey of the Holyoake mien region identified that the drainage lines supporting relatively low dense vegetation have a linkage value as preferred habitat for medium sized mammals such as Quenda and Quokka (GHD 2021g).

Aquatic fauna values

Desktop assessment of the aquatic fauna values of the Holyoake mine region were summarised in WRM (2021). The desktop assessment identified that the Holyoake mine region is expected to support similar diversity of aquatic habitats to the Myara North mine region. Aquatic fauna communities are also expected to be characterised by a high degree of seasonality and high level of species endemism.

A targeted Carter's Freshwater Mussel (EPBC and BC Act Vulnerable) survey completed as part of the detailed and targeted fauna survey of the Holyoake mine region (GHD 2021g) did not identify any presence of mussels. Carter's Freshwater Mussel shells were recorded at two locations during Phase 1 of the Holyoake mien region fauna survey (GHD 2021g), with shells located outside of the Holyoake mine region in the original infrastructure corridor survey area.

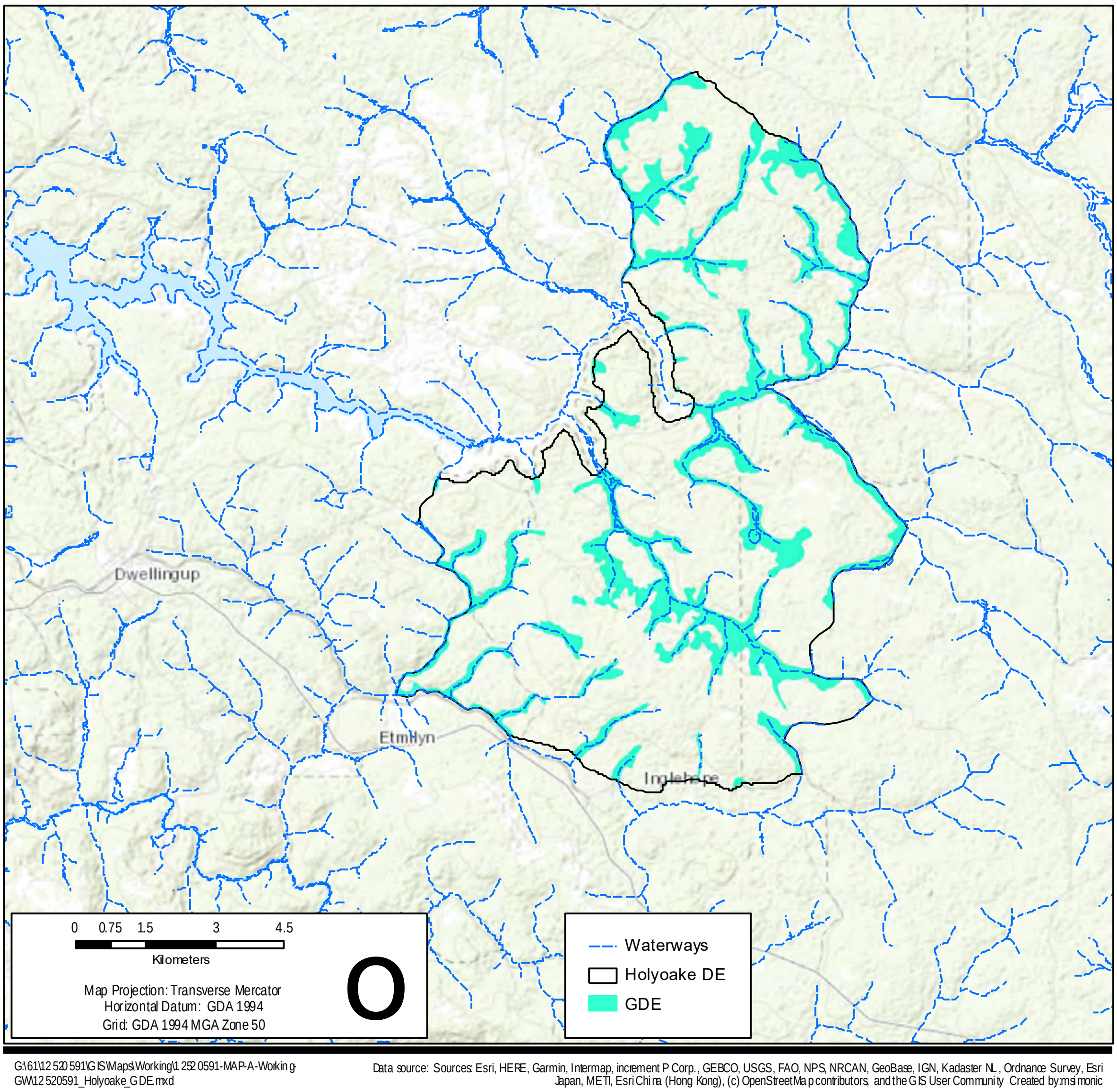

Figure 6-4 *Spatial distribution of potential GDEs in Holyoake mine region*

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7. Catchment and reservoir hydrology and hydrodynamics

7.1 Hydrology and beneficial use

7.1.1 Serpentine

The Serpentine River and its tributaries, including 39 Mile Brook and Gooralong Brook, are seasonal watercourses that are intermittently connected to both the regional (or in some instances perched) groundwater and the interflow vadose zone.

Surface water flows in these watercourses comprise predominantly baseflow, with short-term contribution from surface flow (surface runoff and near-surface flow) in response to rainfall events. Discharge in the form of baseflow or seepage, at smaller rates, is then present for the subsequent period typically extending some weeks or months following the winter rains and peak storage (highest groundwater levels).

Review of groundwater levels in long term groundwater monitoring bores identifies an average groundwater level decline of approximately 4.5 m since the 1990s (section 5.1.2), with all but two monitoring bores showing declining groundwater levels of between 1 to 10 m.

Streamflows in the Serpentine River and its tributaries have also declined significantly since 2000 (section 5.2.1), with long term streamflow records showing a 50% reduction in streamflow at River Road (Serpentine River) and 80% reduction at Jack Rocks (39 Mile Brook).

Flow from the Serpentine River and tributaries, excluding Gooralong Brook, contribute flow to the Serpentine Dam reservoir. Flow from Gooralong Brook flows through the Jarrahdale townsite, joining the Serpentine River downstream of the Pipehead Dam.

The Serpentine Dam has a full supply capacity of 137.7 GL and collects water from a 664 km^2 catchment. Directly downstream of Serpentine Dam, the 2.6 GL full supply capacity Pipehead Dam is fed by a 28 km^2 catchment consisting entirely of State Forest and Serpentine National Park. Water from Serpentine Dam is released into the Pipehead catchment, and after chlorine disinfection and fluoridation, is piped into the Integrated Water Supply System (IWSS).

Both catchments are proclaimed under the *Metropolitan Water Supply, Sewerage and Drainage (MWSSD) Act (1909)*. Both dams are primarily classified as Priority 1 Public Drinking Water Source Areas (PDWSA's), with some private land in the Serpentine Dam catchment area classified as Priority 2. Priority 1 source protection areas have the fundamental water quality objective of risk avoidance. Priority 2 source protection areas have the fundamental water quality objective of risk minimisation.

The dams are also protected by a Reservoir Protection Zone (RPZ), which is delineated by a two kilometre buffer area around the top water level of the reservoir, including the reservoir itself, and not extending outside the catchment area.

Water Corporation's current allocation licence for Serpentine Dam and Serpentine Pipehead Dam (licence 56737) totals 53.89 GL/annum and is issued for the purpose of providing water for public potable water supply and irrigation.

7.1.2 South Dandalup

The South Dandalup River and its tributaries, are seasonal watercourses.

Long-term groundwater levels in a limited set of groundwater monitoring bores in the Holyoake DE have showed declining groundwater levels of close to 9 meters since 1990s (section 6.1.3). Annual streamflow in the adjacent Gordon sub-catchment (gauging station 614060) have also been observed to decline in the period since 2000 (section 6.2.1), with the decline in streamflow considered to be representative of streamflow in watercourses in the Holyoake DE.

The South Dandalup Dam (SDD) has a full supply capacity of 208.2 GL, making it the largest reservoir supplying the IWSS. The South Dandalup Pipehead Dam (SDPD) acts as a pumpback for SDD, adding to the available water for supply to the IWSS. Water from the SDPD is chlorinated before pump back to the SDD. The water abstracted from SDD is further disinfected by chlorination and fluoridated before supplying the IWSS.

The SDD catchment area covers 311 km^2 and is proclaimed under the *MWSSD Act 1909*. Like Serpentine Dam, the catchment is predominantly classified as a priority 1 PDWSA, with a small area of private land managed as a priority 2 source protection area.

Water Corporation's current allocation licence for SDD (licence 56734) is 26.9 GL/annum. This licence is issued for the purpose of providing potable water for public water supply to the IWSS. Alcoa currently have two licences (No. 83356 and 153635) to abstract a total of 100 ML/a from SDD, which is used to supply water (primarily for dust suppression) to the Huntly Mine.

7.1.3 Upper Wungong Brook

Part of the upper Wungong Brook catchment lies within the north-eastern extent of the Myara North DE. As with other surface watercourses in the Myara North study area the upper Wungong Brook and its tributaries are seasonal watercourses that are intermittently connected to both the regional (or in some instances perched) groundwater and the vadose zone.

Longer term groundwater monitoring of two groundwater bores in the upper Wungong Brook catchment, identified strong seasonal variation in groundwater level (section 5.1.2) and indicates a groundwater level decline which is well pronounced in the upper slopes (7 m over the last three decades) and less so along the valley floors (1 m decline over the last three decades).

Similar to surface watercourses within the Myara North DE, streamflow in the upper Wungong River and its tributaries has declined significantly since 2000 (section 5.2.1).

7.2 Reservoir water quality and hydrodynamics

7.2.1 Serpentine and Serpentine Pipehead

Historical turbidity data for the Serpentine and Serpentine Pipehead reservoirs was estimated from the turbidity data collected for the period 2000-2020 at the offtake (GHD 2021f). The historical turbidity data indicates that offtake turbidity was generally less than 1 NTU throughout the 20 year period, including during mining disturbance within the PDWSAs and RPZ.

The data does not display any increasing trend with turbidity associated with cumulative mining disturbance or the effects of large bushfires within the PDWSAs or RPZ. While it is noted that dispersion and mixing across the reservoir may flatten turbidity spikes, any significant turbidity events would be noticeable at the outlet.

7.2.2 South Dandalup

Historical turbidity data for the South Dandalup reservoir was estimated from the turbidity data collected for the period 2000-2020 at the offtake (GHD 2021f). As with the Serpentine and Serpentine Pipehead reservoirs (section 7.2.1) the offtake turbidity data was generally less than 1 NTU, with no significant turbidity events from catchment disturbance observed within the data.

7.3 Proposed river crossings

Transition of the Huntly Mine into the Myara North DE and the Holyoake DE will require construction of new waterway crossings over Big Brook, Serpentine River, and South Dandalup River and tributaries. The waterway crossings will comprise haul road crossings or conveyor crossings.

The Myara North conveyor crossings at Big Brook and Serpentine River are located on former reservoir inundation areas, lying at an elevation of approximately 203.3 mAHD and 207.7 mAHD which correspond to Serpentine Reservoir levels at 45% and 68% capacity, respectively. The former inundation areas are now covered by native vegetation regrowth, as reservoir water levels have been less than 70% capacity since 1999 and less than 60% capacity since 2010.

The conveyor crossings will be provided with drainage controls to capture potential water contaminants, as follows:

– A series of three sumps located on each side of the waterway, each with a holding capacity of 1% Annual Exceedance Probability (AEP) storm event of seven-day duration.
– The first of the three sumps lined with high-density polyethylene (HDPE) to capture hydrocarbons in the event of a diesel spill and prevent infiltration.
– A three-stage sump configuration with a controlled outlet that is only opened after sampling confirms water quality to ensure no release of hydrocarbon-contaminated or turbid water into the stream channel.
– Emergency overflows constructed above the maximum reservoir level (RL 212.39 m) in the third stage of the sumps which are rock pitched to slow water velocity preventing scour and associated turbidity.

Each conveyor will be constructed on an earth causeway across the waterways, with the following design:

– Multiple culverts or arch to accommodate 0.2% AEP storm event of 72 hour duration.
– Wing walls installed on culverts or arch to protect causeway embankment.
– Access road bitumen sealed to reduce generation of sediment and turbidity.
– Minimum cross fall on the causeway of 3% to allow free draining of the sealed surface.
– Fully enclosed conveyor and road to reduce windblown dust generated from the conveyor or travelling light vehicles and to reduce the size of the catchment requiring treatment by the sumps.

The haul road crossing over the Serpentine River would be as for the conveyor crossing with the following changes to cater for 190 tonne haul trucks rather than light vehicles and a conveyor:

– Dual lane road that meets DMIRS safety specifications.
– Wider and higher earth causeway.
– Higher load capacity and longer culverts.

8. Assessment of potential mining impacts

8.1 Impacts to water dependent ecosystems and upstream tributaries

8.1.1 Groundwater level changes

Numerical modelling was completed to assess groundwater level changes due to the Proposal on groundwater flow processes and interaction of those processes with intermittent streamflows in the Myara North mine region (GHD 2021c) and Holyoake mine region (GHD 2021d). The numerical modelling used a combination of numerical groundwater with streamflow routing and soil water balance models (MODFLOW-USG and PERFECT).

Within both mine regionss, the modelling indicates that changes in recharge and surface flow dynamics due to bauxite mining have the potential to raise the groundwater levels in mined areas by several metres. Predicted change in groundwater levels is noted to follow seasonal variation.

Within the Myara North mine region, groundwater level mounding during the clearing and mining period has the potential to increase groundwater levels by several metres, with more than 10 m rises immediately below cleared and mined areas in some instances compared to unmined conditions. Areas of greatest rise lie directly beneath the most densely mined areas. This agrees well with historical observations of groundwater level change around other mined areas, for example at MK42132A location, near cleared area south of the Myara North mining region, a rise of 12 m was observed, with MK43041A, MK43071A, and MK43072A also showing similar increases. If bores situated some distance away from the cleared areas show water level increases of this magnitude, the groundwater rise directly underneath the cleared areas would be even more pronounced.

Within the Holyoake mine region, groundwater level mounding during the clearing and mining period has the potential to temporarily raise groundwater levels by several metres, again with more than 10 m rises below cleared and mined areas compared to unmined conditions. Groundwater levels in and around mined and cleared areas rise over the first 15 years. The climate change model, that considers a step decrease in recharge and runoff by 30% shows groundwater levels to be projected deeper but with similar mounding effects. In locations close to mining, mining essentially offsets and delays climate related groundwater level declines.

Within both the Myara North mine region and the Holyoake mine region the extent of mounding is predicted to be generally localised to cleared and mined areas.

The magnitude of mounding decreases towards low-lying areas and groundwater receptors (potential GDEs). Mounding within most of the potential GDEs is predicted to be less than 1 m, however in some localised areas, groundwater rise during mining is predicted also in 1 m to 2 m and 2 m to 5 m bands. The predicted mounding bands in potential GDE areas for dry, typical, and wet climate during mining and post mining are presented in Figure 8-1 and Figure 8-2.

The groundwater level mounding effects in the Myara North mine region and the Holyoake mine region recede over the post-mining rehabilitation period with the following key observations made:

– In the Myara North mine region, residual groundwater level mounding of between 1 to 5 m is predicted by the end of the simulation in 2060 for drier periods, and up to 10 m during wetter periods.
– In the Holyoake mine region, residual groundwater level mounding is predicted to be typically 1 to 10 m, but up to 20 m beneath the most densely mined areas.
– The magnitude of mounding diminishes to approximately 1 m in valley floor areas away from mining.

The predicted change in groundwater levels are within the historical groundwater level range of potential GDEs located in the valley floor systems, and therefore the temporary change in groundwater levels is not anticipated to have an adverse impact on potential GDEs.

The predicted change in groundwater levels are a snapshot in time relative to the baseline scenario. Due to the trend decline in groundwater levels, the rise is less when compared to current or historic groundwater levels.

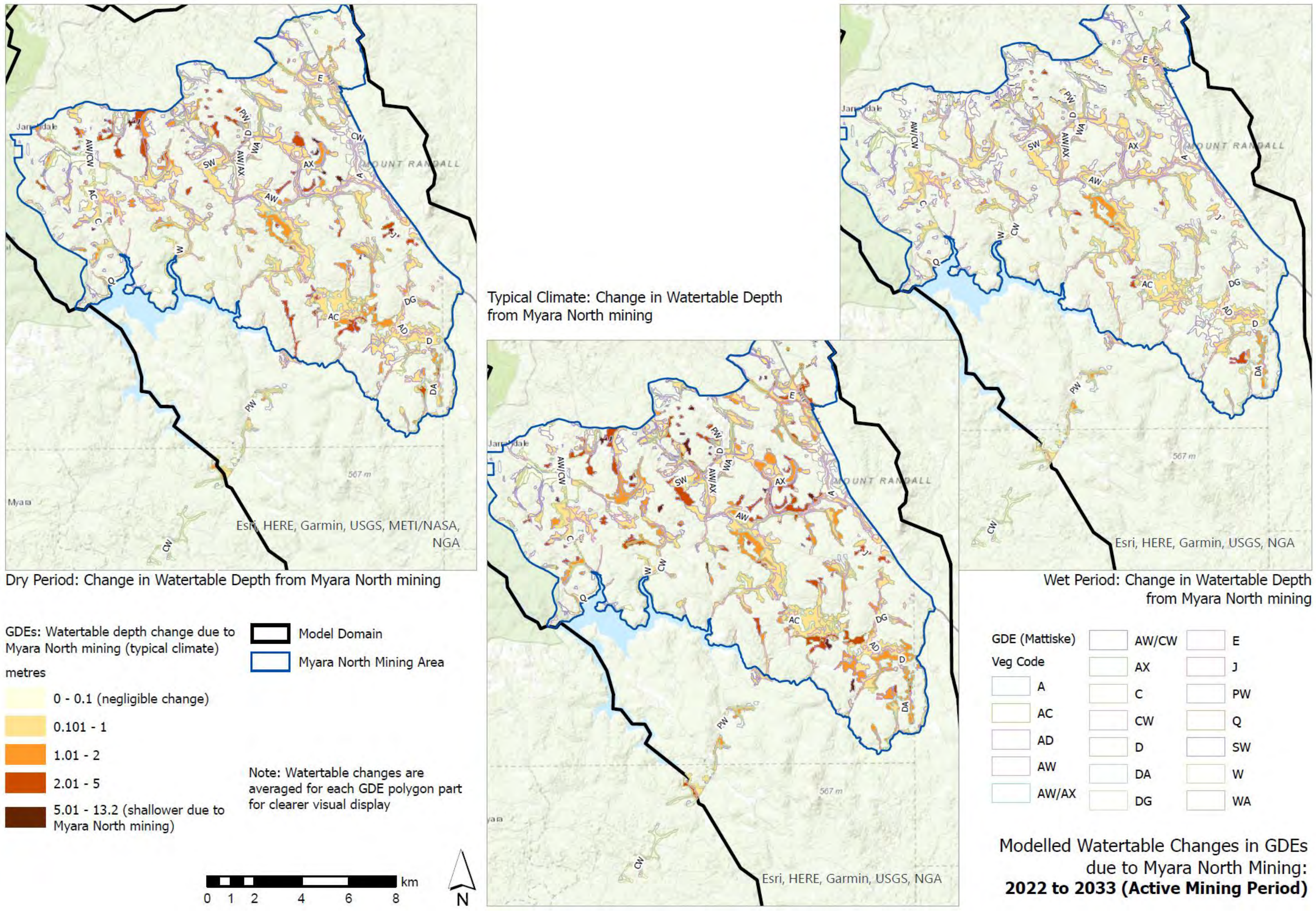

Figure 8-1 ***Modelled change in depth to groundwater within mapped GDEs, Myara North, 2022 to 2033 (during mining)***

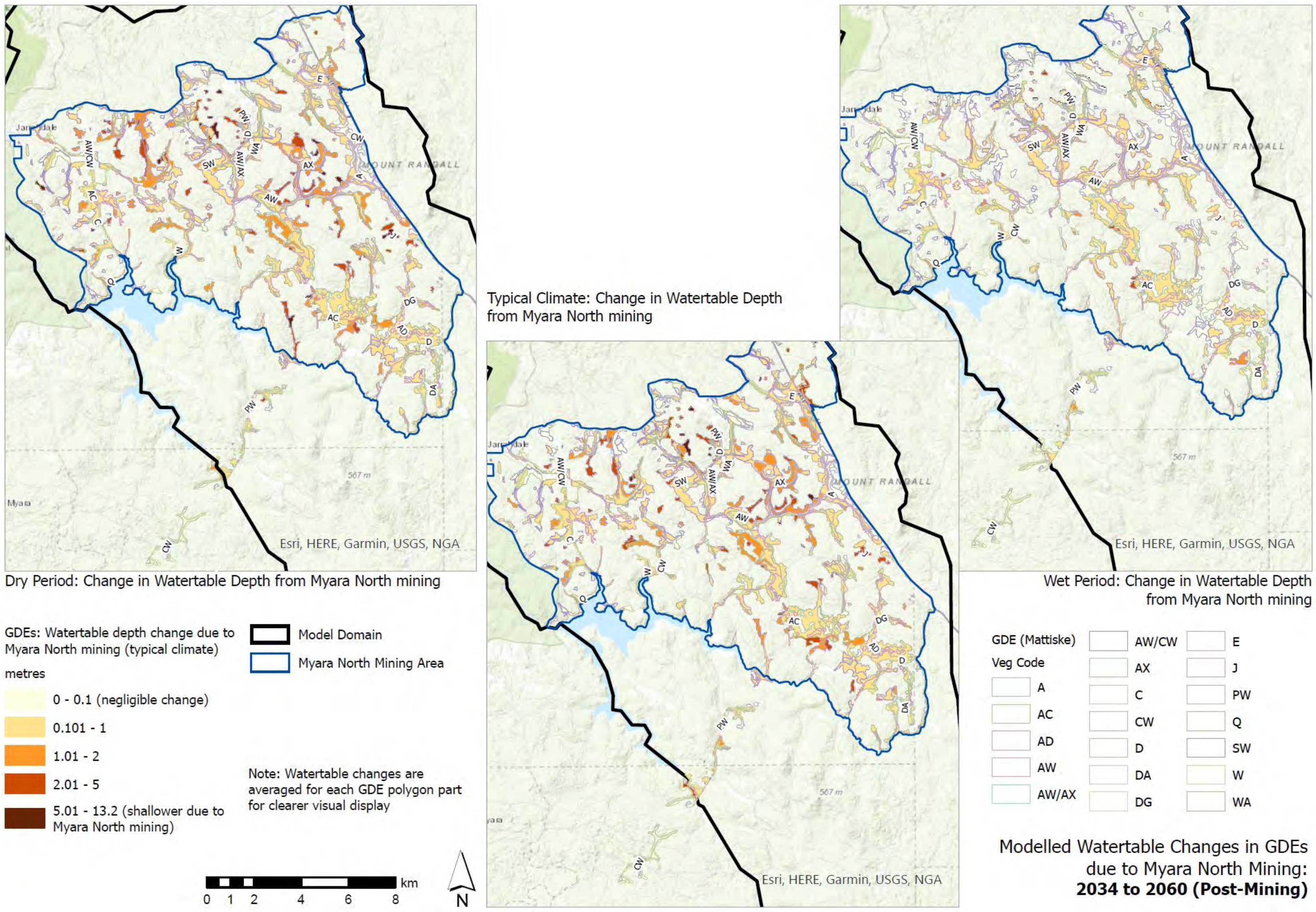

Figure 8-2 ***Modelled change in depth to groundwater within mapped GDEs, Myara North, up to 2060 (post mining)***

8.1.2 Streamflow changes

Historical impacts

Historical mining impacts on streamflow provide an indication of future mining impacts. Historical mining in the McCoy and O'Neil regions represented approximately 15% of the Big Brook stream gauge catchment area. The clearing associated with this mining commenced in 2002 and ceased in 2014.

Rehabilitation commenced in 2006 and is ongoing. Referring to Figure 8-3 and Figure 8-4, there is a slight change in gradient of the double-mass runoff curve since the commencement of mining, indicating an increase in runoff from the mined area relative to nearby unmined catchments. Mining in the Serpentine River catchment commenced in 2010 but represents less than 2% of the stream gauge catchment area and is therefore considered "largely unmined" for comparison purposes.

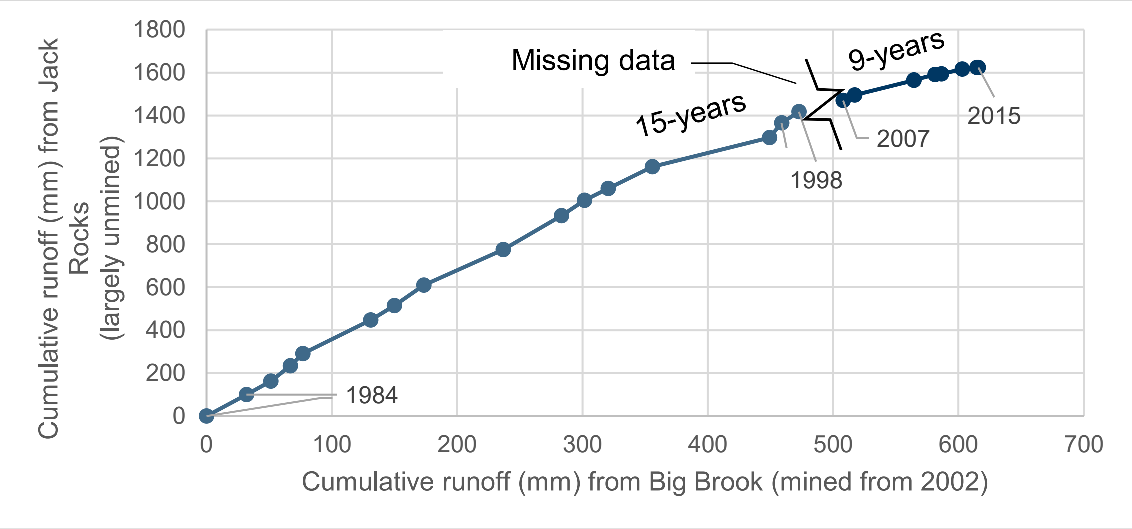

Figure 8-3 Mining impacts to Big Brook runoff compared to Jack Rocks

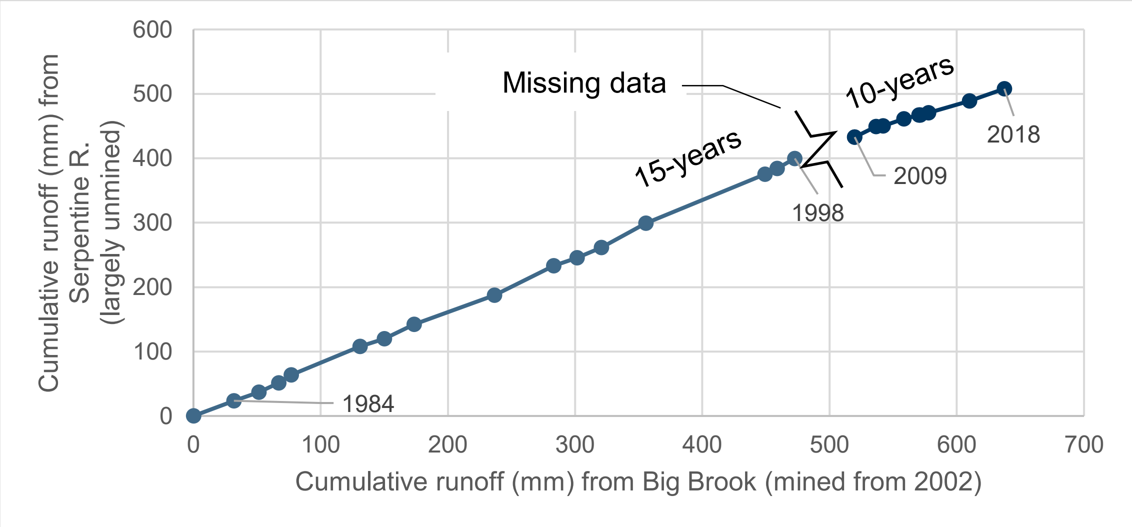

Figure 8-4 Mining impacts to Big Brook runoff compared to Serpentine River

Future impacts

The changes in recharge and flow dynamics due to bauxite mining and the increase in groundwater levels predicted from the numerical modelling, has the potential to increase streamflows during clearing, mining and rehabilitation periods.

Serpentine Reservoir (Myara North)

Within the Myara North DE, mining will result in an estimated average increase in streamflows of the Serpentine Reservoir from the modelled catchments of 1.3 GL/year over the active clearing and mining period. The following patterns of streamflow change are predicted as a comparison for mined and unmined cases (Figure 8-5):

– Higher annual flows are predicted to occur in the first decade of mining, typically 1 GL/yr but ranging as high as 2 to 3 GL/yr in some years (Figure 8-5).
– From 2030 onwards, during the post-rehabilitation period, annual flow decreases occur, ranging from nil in dry years, to 1 GL/yr in wetter years
– In some dry years marginally higher annual flows to the reservoir are simulated to occur due to higher residual groundwater level from the mining and clearing period.
– The modelled climate change (not shown in Figure 8-5), simulated as 30% decrease in recharge and surface flows, indicates reduced inflows into the reservoir but also reduced impact from mining (Figure 8-6).

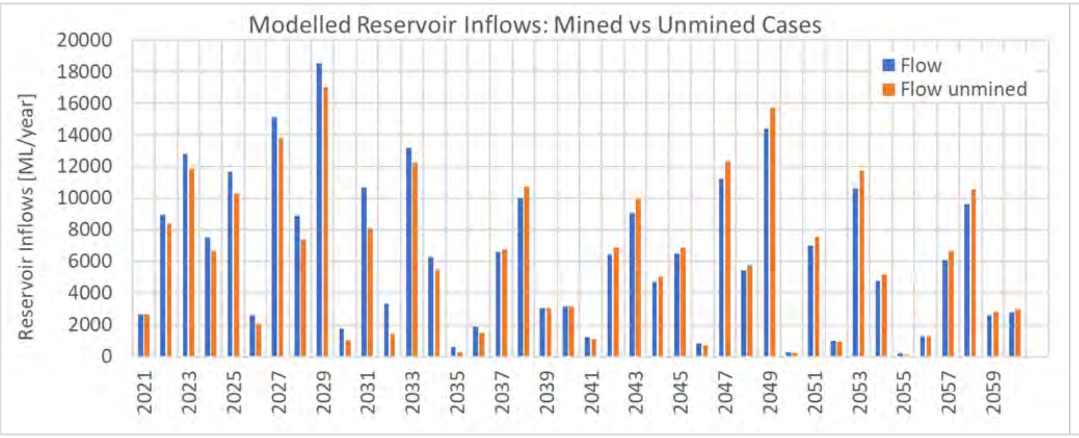

Figure 8-5 ***Modelled streamflow to Serpentine Reservoir (mined vs unmined)***

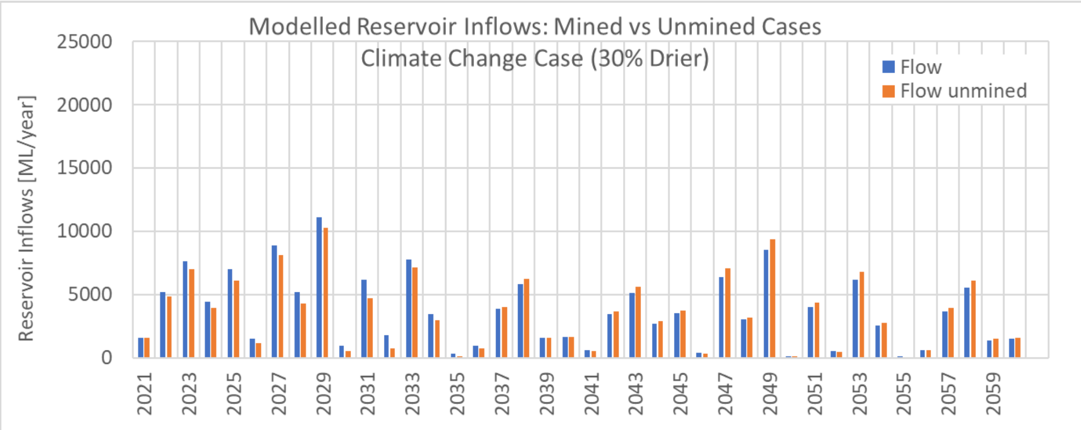

Figure 8-6 ***Modelled streamflow to Serpentine Reservoir (mined vs unmined), climate change case***

Wungong Brook (Myara North DE)

Within the Wungong Brook Catchment the streamflows are predicted to slightly increase during mining (on average between 0.05 to 0.1 GL/yr, followed by minor flow reduction (on average 0.02 GL/yr) during post-mining period (Figure 8-7), similar to catchments feeding the Serpentine Reservoir.

During mining the predicted flows are on average 0.6 GL/yr, while post-mining they will be approximately 0.35 GL/yr. These represent only minor change when compared to non-mining scenario (0.09 and -0.005 GL, respectively).

Climate change, modelled as 30% decrease in recharge and surface flows will result in reduced flows in the Wungong Brook, typically by over 50% (Figure 8-8).

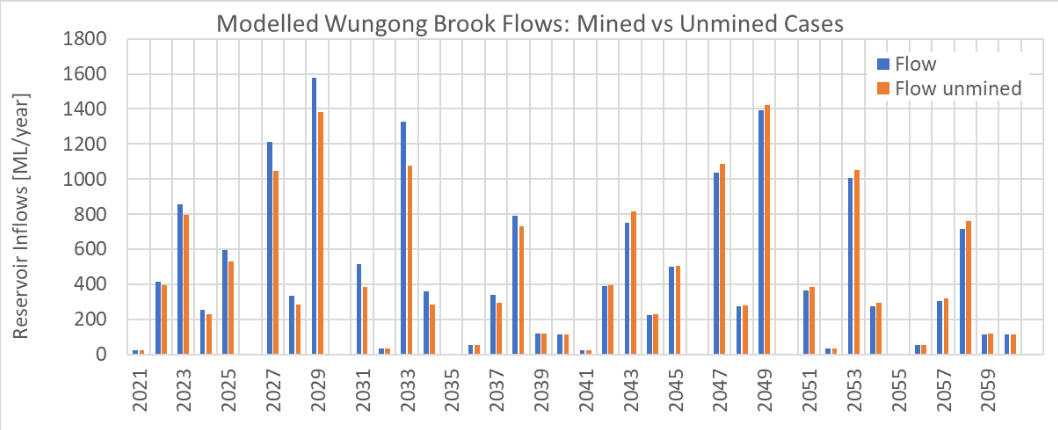

Figure 8-7 Modelled streamflow to Wungong Reservoir (mine vs unmined)

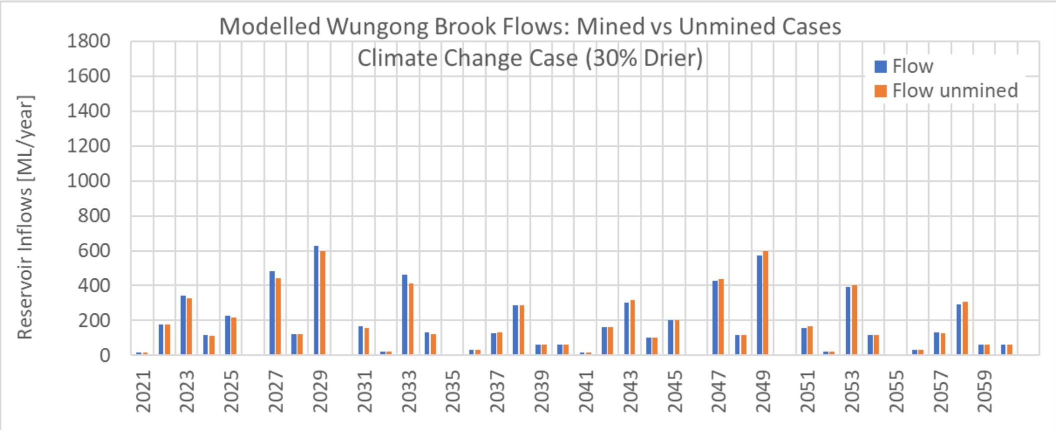

Figure 8-8 Modelled streamflow to Wungong Reservoir (mined vs unmined), climate change case

Gooralong Brook (Myara North DE)

The streamflow change in Gooralong Brook is predicted to follow the same pattern as Wungong Brook and streamflows to the Serpentine Reservoir. Slight increase in streamflows is predicted during mining and clearing, followed minor reductions in the rehabilitation and post-mining (Figure 8-9).

During mining the predicted flows are on average 2.3 GL/yr, while post-mining they will be approximately 1.7 GL/yr. These would constitute only a minor change when compared to non-mining scenario (2.25 and 1.74 GL, respectively).

The climate change effect, represented as 30% reduction in groundwater recharge and surface flow, however this is attributable to climate change rather than the effect of mining. The climate change scenario suggests average flows of 1.42 and 1.0 GL/yr for mining and post-mining periods, respectively. The differences between mining and non-mining scenarios are minor, flows under non-mining scenario would be 1.40 and 1.06 GL/yr.

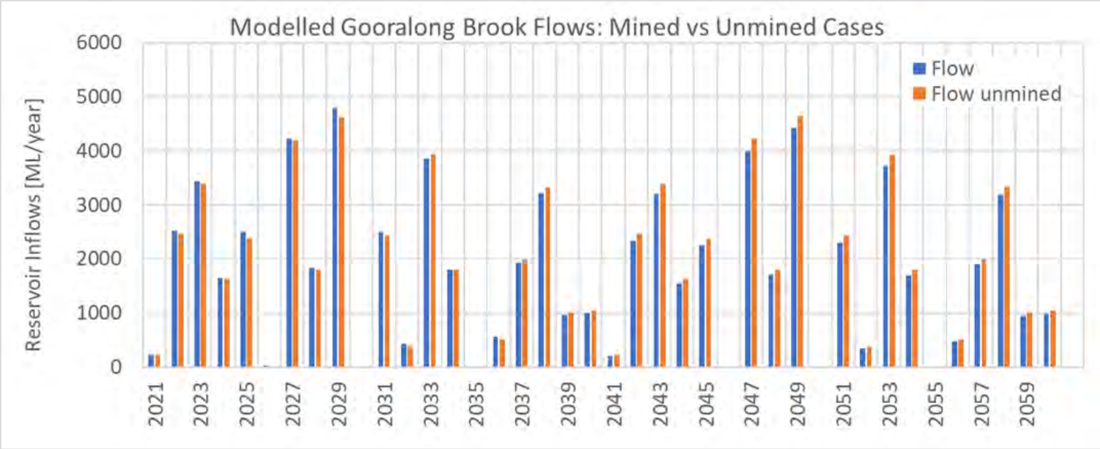

Figure 8-9 ***Modelled streamflow, Gooralong Brook (mined vs unmined)***

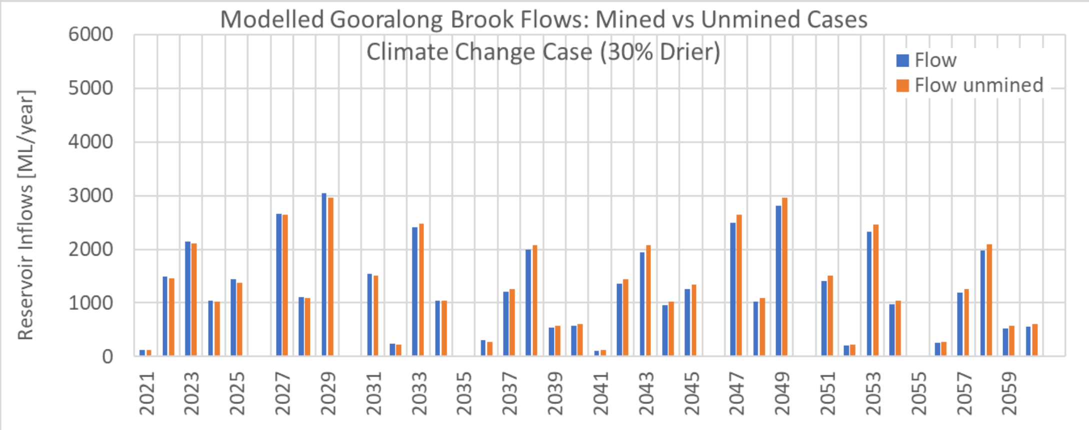

Figure 8-10 ***Modelled streamflow, Gooralong Brook (mined vs unmined), climate change case***

South Dandalup Reservoir (Holyoake DE)

Within the Holyoake DE, numerical groundwater modelling identified average increases in streamflows to the South Dandalup Reservoir from the modelled catchments of 0.1 GL/year during the active clearing and mining period from 2029 to 2033, and 0.2 to 0.3 GL/year in the post-mining period (GHD 2021d). The annual variability is shown in Figure 8-11.

Streamflows in the Holyoake DE are predicted to be marginally higher during and after mining compared to the base case without mining.

The potential impact of the climate change – drying conditions – will result in further reduction of streamflows, which are predicted to reduce by approximately 30% (Figure 8-12), i.e., equivalent to reduction of recharge. Mining will still provide minor increase of streamflows.

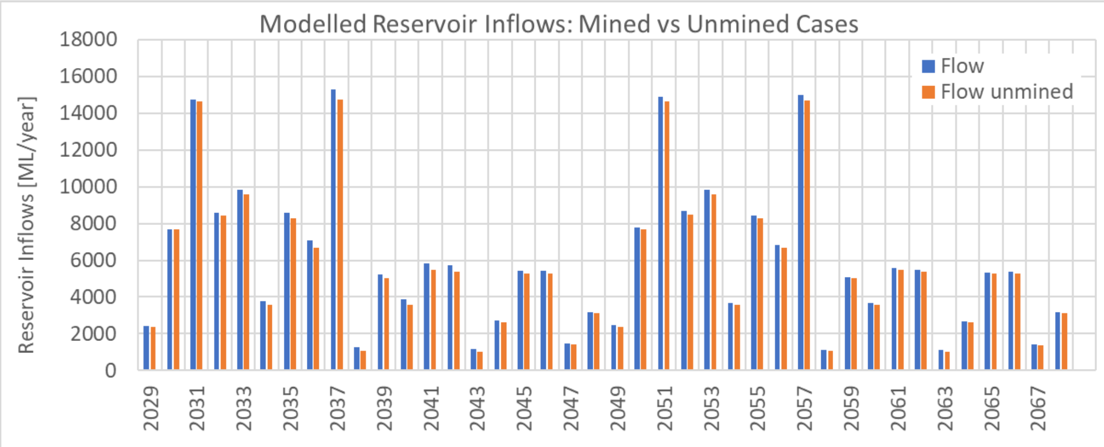

Figure 8-11 ***Modelled streamflow to South Dandalup Reservoir (mined vs unmined)***

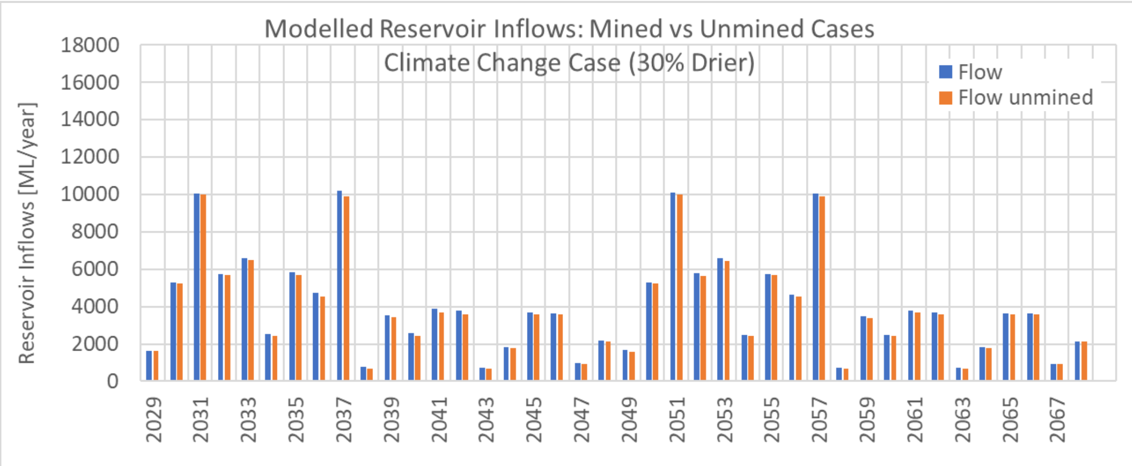

Figure 8-12 ***Modelled streamflow to South Dandalup Reservoir (mined vs unmined), climate change case***

Davis Brook (Holyoake DE)

Mining in the Holyoake DE is predicted to increase flows in the Swamp Oak Brook during mining and partly post mining. In absolute values the increases will be small, on average 0.06 GL/yr and 0.17 GL/yr during and post mining (Figure 8-13). During some years of mining the increases will be more notable, for example between 2034 and 2042 the increases may represent a multiple of flows that would have occurred for the unmined case. During dry years of the post-mining period the flows are predicted to be very similar to unmined cases, but in wetter years flows may increase 25% to 50%.

The potential climate change effect on Davis Brook flows is reduction of overall flows when compared to the current case. M, mining effects will remain the same (i.e., higher flows in wetter years, similar flows in dry years (Figure 8-14). The flow increases for the climate change case would still occur, but will be reduced, i.e., 0.01 GL/yr and 0.06 GL/yr during and post-mining.

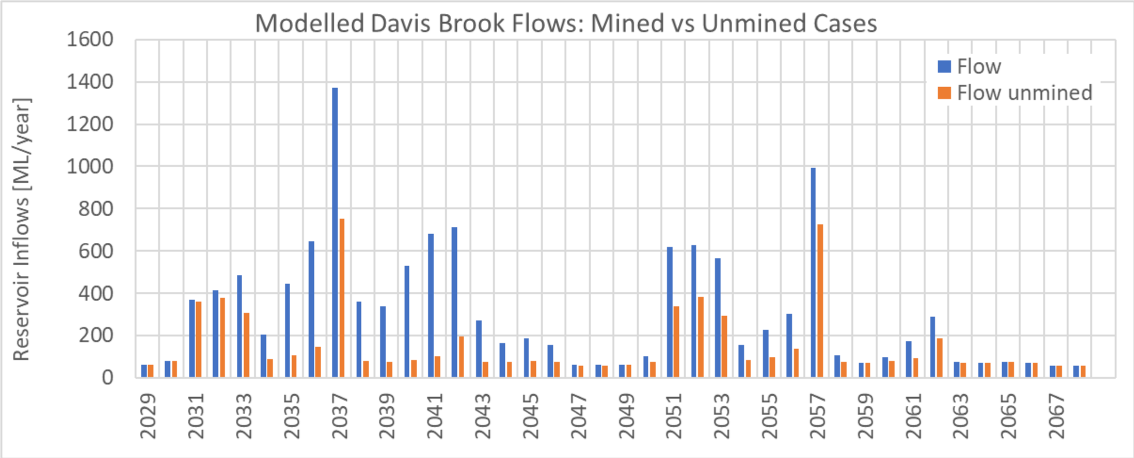

Figure 8-13 ***Modelled flows, Davis Brook (mined vs unmined)***

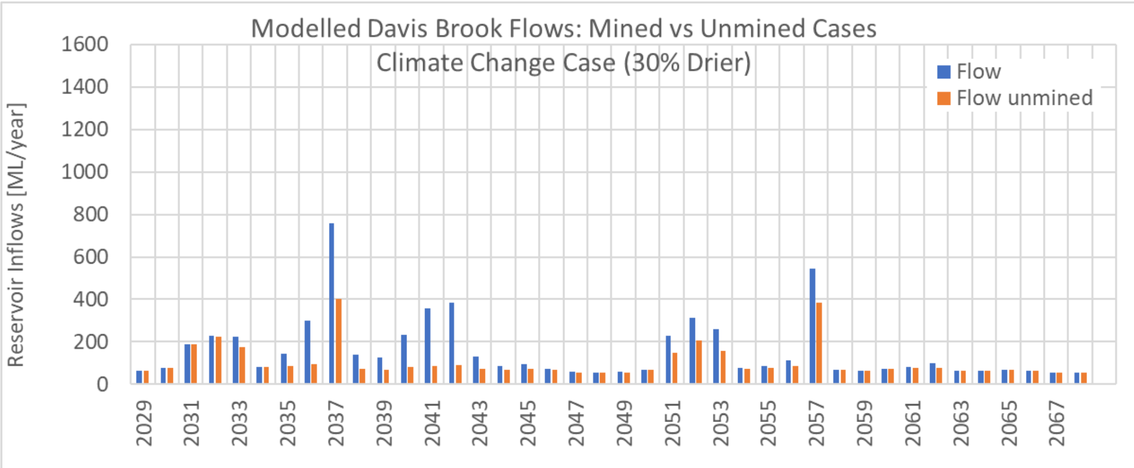

Figure 8-14 ***Modelled flows, Davis Brook (mined vs unmined), climate change case***

Swamp Brook (Holyoake DE)

Mining in the Holyoke DE is predicted to introduce minor flow increases in Swamp Brook, 0.01 GL/yr and 0.02 GL, during mining and during the post-mining period (Figure 8-15). Slightly increased flows will occur during both, the wet and dry years.

The drying climate is predicted to reduce the flows by almost 50% (Figure 8-16), while preserving the overall effect of mining on streamflows (slight increase of flows during and post-mining).

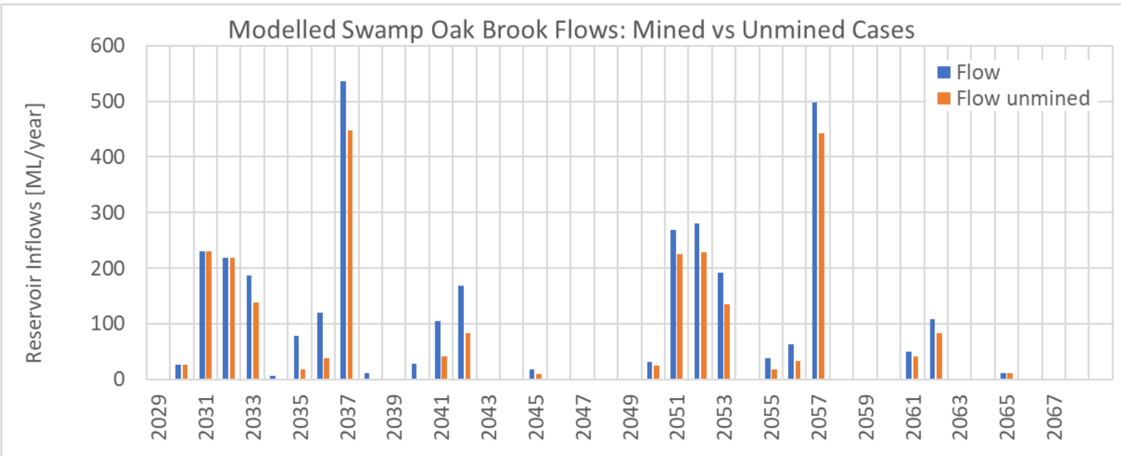

Figure 8-15 ***Modelled flows, Swamp Oak Brook (mined vs unmined)***

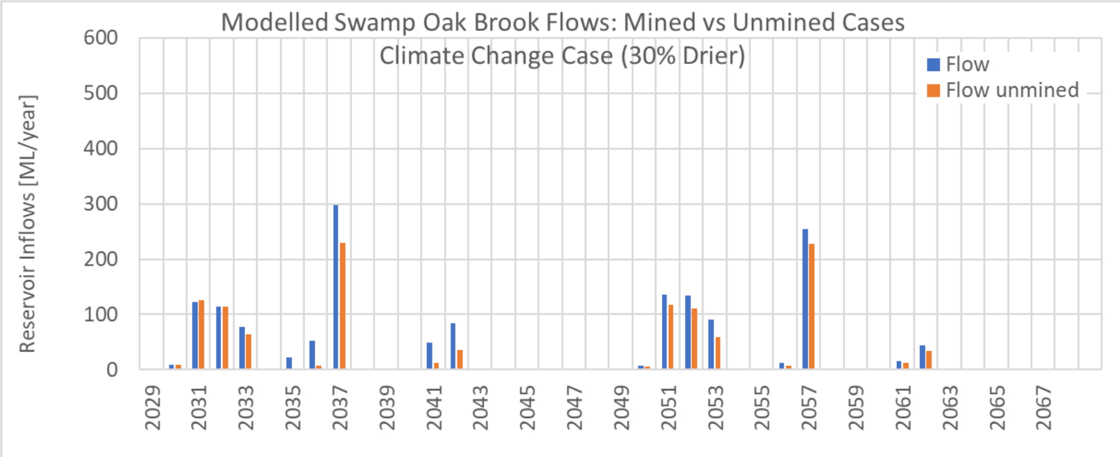

Figure 8-16 Modelled flows, Swamp Oak Brook (mined vs unmined), climate change case

8.2 Water quality changes

8.2.1 Salinity

Estimates of potential changes to the TDS of streamflows entering the reservoir(s) are made using the modelled changes in streamflows along with observed groundwater salinity (measured as TDS). This is achieved by comparing modelled streamflow volumes and their proportional groundwater discharge component between mined and unmined cases. Modelled streamflows are converted to salt loads using observed TDS ranges.

Observed groundwater TDS (for example average 417 mg/L for the Myara North DE, with lower and higher estimates of 180 and 650 mg/L, respectively, is assumed to be reflective of the potential near-stream groundwater that discharges into the stream. For the Holyoake DE, the lower and higher estimates of groundwater TDS are 430 and 850 mg/L, respectively.

Equally the surface component of streamflows (surface runoff and nears surface intermittent flow) is assumed to be consistently low (adopted 100 mg/L in this case) compared to that of groundwater. It is also assumed the salinity contribution from surface flows between mining and non-mining cases is negligible.

The numerical model was used to forecast changes in salinity (salt load as TDS) of surface watercourses within the Myara North DE (GHD 2021c) and the Holyoake DE (GHD 2021d). The model predictions indicate some variability in salinity increases.

For the Myara North mining region, the predicted TDS change is -1 mg/L to -10 mg/L for mining and 3 to 20 mg/L post-mining periods compared to the non-mining case, with annual variations shown in Figure 8-17 Modelled reservoir inflow TDS change, Serpentine Reservoir (that uses the upper groundwater TDS estimate). When considering the drying climate case, the predicted average change is -1 to -7 mg/L and 3 to 24 mg/L for mining and post-mining cases, respectively.

For the Holyoake mining region, the predicted TDS increase is 3 to 7 mg/L and 11 to 17 mg/L for mining and post-mining periods compared to the non-mining case. The annual variations are presented in Figure 8-18.

When considering the effect of drying climate, the predicted average change is 3 to 7 mg/L and 6 to 13 mg/L for mining and post-mining cases, respectively. The lower TDS increase under the climate change scenario is attributed to the deeper groundwater level in response to reduced recharge, and hence reduced groundwater contribution to streamflows.

The robustness in estimating the predicted salinities is demonstrated in Figure 8-19, which indicates that the use of the upper groundwater TDS values is appropriate for salinity estimates.

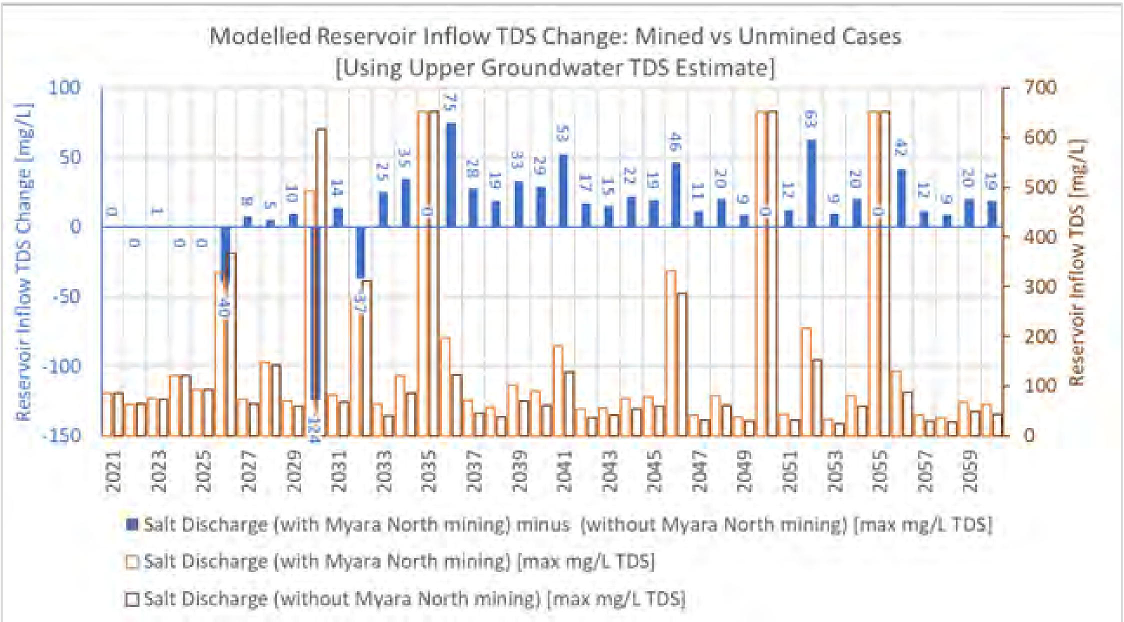

Figure 8-17 Modelled reservoir inflow TDS change, Serpentine Reservoir

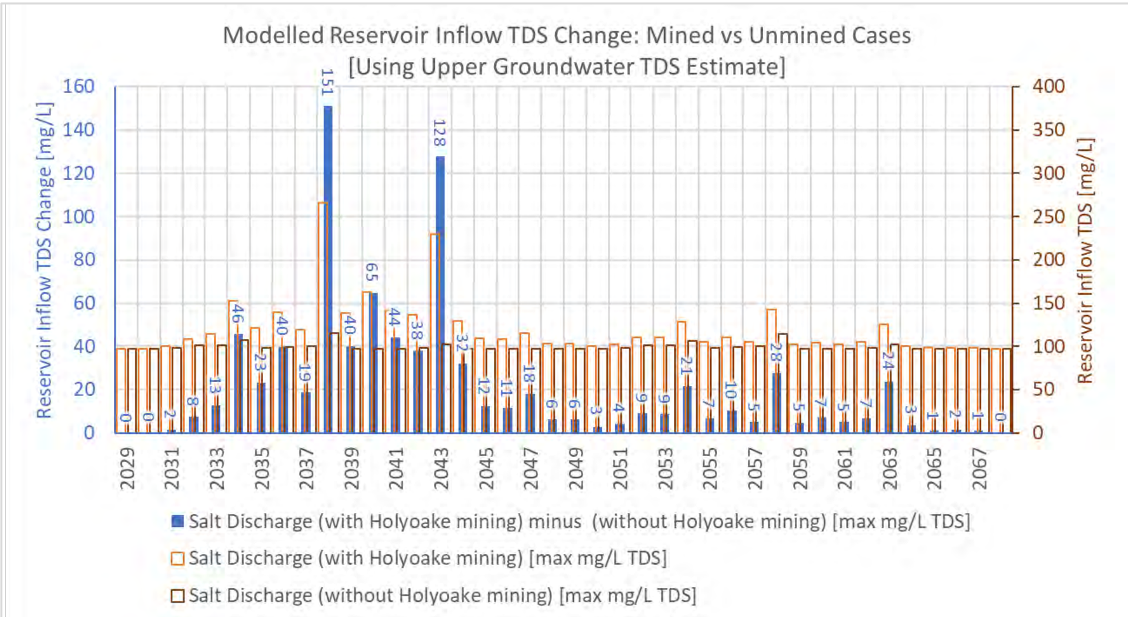

Figure 8-18 Modelled reservoir inflow TDS change, South Dandalup Reservoir

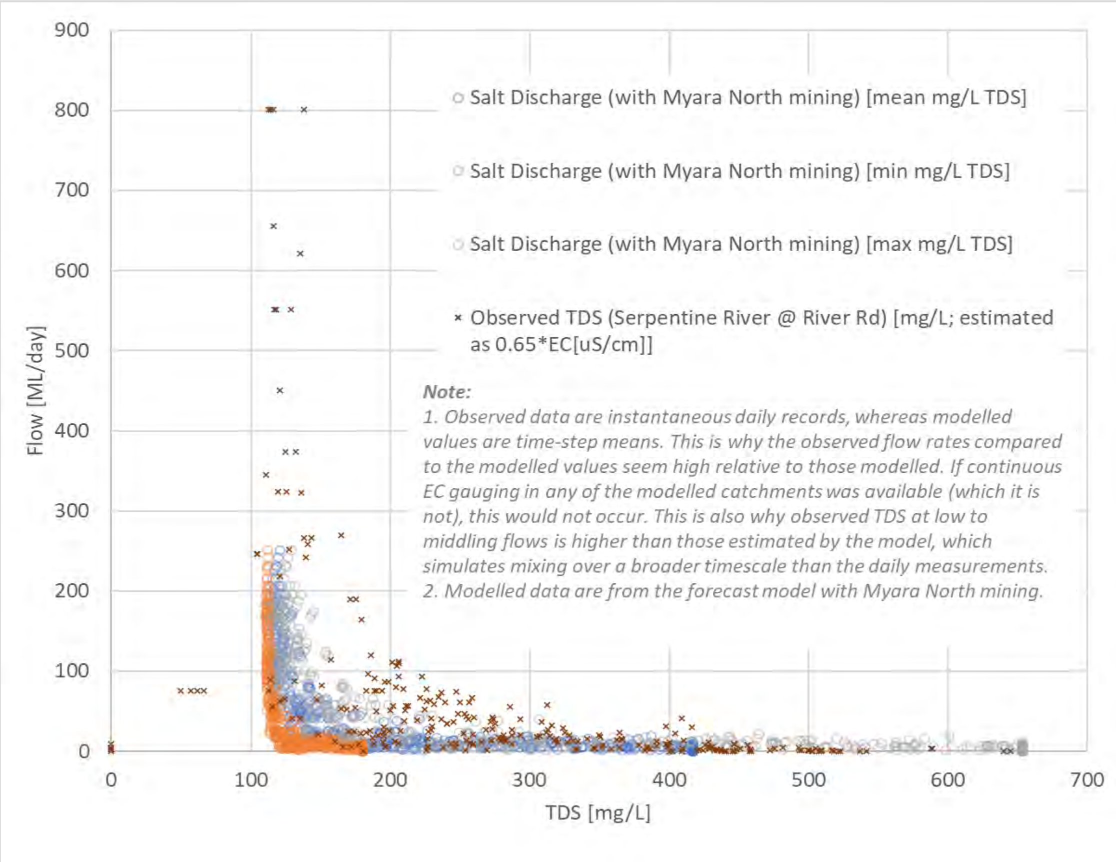

Figure 8-19 Relationship between streamflows and TDS

Uncertainty analysis of the base climate case indicates relatively narrow uncertainty in projected TDS loads to the reservoir, except in the driest of years, when groundwater discharge becomes a significant component of remaining streamflow. The analysis estimates are from 2 to 23 mg/L increased average annual TDS of surface streams entering the reservoir during active mining, and from 10 to 55 mg/L in the post-mining period (Myara North).

Average annual TDS over these two periods is estimated to range from 100 to 130 mg/L and from 105 to 163 mg/L, respectively, when mining occurs in Holyoake.

8.2.2 Sediment and turbidity

Erosion, sedimentation, and turbidity occur naturally and because of clearing activities. Naturally occurring sedimentation and turbidity spikes are associated with large storm events. Where clearing and mining has occurred, exposed soils are subject to erosive action, mobilising sediment and suspended solids. The amount of erosion is a factor of soil properties (erodibility), catchment slope and length, rainfall intensity (erosivity), and vegetative cover. Historical mining activities have used drainage infrastructure to control sedimentation and turbid discharge, however failure or exceedance of some structures has resulted in sedimentation and turbid discharge occurring.

In the absence or failure of drainage controls, sediment laden discharge has the potential to impact the flora and fauna of downstream tributaries through the process of sedimentation, accumulating in areas of low velocity and smothering bottom-dwelling organisms and their habitats. Further downstream in the reservoir, turbidity reduces the penetration of light and therefore the ability of algae and other aquatic plants to photosynthesize and clogs the gills of fish (DWER, 2017. Fine sediment and the nutrients it transports are also associated with seasonal blue-green algal blooms in other waterbodies. As a consequence of excess sediment, the abundance and distribution of aquatic plants and animals change, natural food webs are disrupted and aquatic diversity declines (DWER, 2017.

With drainage controls that prevent the discharge of sediment and turbid runoff, no turbidity or sedimentation impacts to streams and reservoirs will occur.

8.3 Impacts to reservoirs

8.3.1 Serpentine

Streamflow

The changes in recharge and flow dynamics due to bauxite mining and increase in groundwater levels predicted from the numerical groundwater modelling, has the potential to increase streamflows during clearing, mining and rehabilitation periods.

Within the Myara North DE mining will result in an estimated average increase in streamflows of the Serpentine Reservoir from the modelled catchments of 1.3 GL/year over the active clearing and mining period from 2023 to 2033. This additional streamflow produced by mining will partially counterbalance the water use from mining, described in section 8.5.3, and to a lesser extent decreases due to climate change.

The following patterns of streamflow change are predicted as a comparison for mined and unmined cases (Figure 8-5):

– Higher annual flows are predicted to occur in the first decade of mining, typically 1 GL/yr but ranging as high as 2 to 3 GL/yr in some years (Figure 8-5).
– From 2030 onwards, during the post-rehabilitation period, annual flows decreases occur, ranging from nil in dry years, to 1 GL/yr in wetter years
– In some dry years marginally higher annual flows to the reservoir are simulated to occur due to higher residual groundwater level from the mining and clearing period.
– The modelled climate change (not shown in Figure 8-5), simulated as 30% decrease in recharge and surface flows, indicates reduced inflows into the reservoir but also reduced impact from mining (Figure 8-6).

Salinity

The Myara North DE numerical groundwater model was also used to forecast changes in salt load (TDS) of surface waters inflowing to the Serpentine reservoir from the catchments modelled, arising from the Myara North DE mining. Model scenarios under “current” climatic conditions (last 20 years), and a drying climate under climate change (30% step reduction in recharge, runoff, and interflow from the last 20 years’ conditions) indicate the following:

– Variable years of salinity increases and decreases during the land clearing and mining (including clearing for roads and infrastructure a year before clearing for mining pits) period (2022 to 2033), with an average reduction of between -1 mg/L and -10 mg/L for the current climate case and between -1 mg/L and -7 mg/L under the climate change case.
– In the post-mining period (2034 to 2060), the modelling estimates an increase in average TDS load of between 3 mg/L and 20 mg/L for the current climate case, and between 3 mg/L and 24 mg/L for the climate change case. This indicates relatively small differences in salinity load impact from Myara North mining activities between the climate scenarios modelled.

Sediment and turbidity

Sediment and turbidity impacts to the reservoir are described in section 8.5.

Hydrocarbons

Hydrocarbon impacts to the reservoir are described in section 8.5.

PFAS, PFOA and PFOS

PFAS, PFOA and PFOS impacts to the reservoir are described in section 8.5.

Other water quality impacts

- Explosives residue
- Carbide residue
- Contamination from spills and/or leaks from storage and handling of hazardous materials and waste

8.3.2 Serpentine Pipehead

8.3.3 Sediment and turbidity impacts to the reservoir are described in section 8.5.South Dandalup

Streamflows

Numerical groundwater modelling completed to assess impacts of mining on near surface groundwater flow processes and interaction of those processes with intermittent streams flows in the Holyoake DE identified average increases in streamflows to the South Dandalup Reservoir from the modelled catchments of 0.1 GL/year during the active clearing and mining period, and 0.2 to 0.3 GL/year in the post-mining period (GHD 2021e, Figure 8-11).

The potential impact of the climate change – drying conditions – will result in further reduction of streamflows, which are predicted to reduce by approximately 30% (Figure 8-12), i.e., equivalent to reduction of recharge. Mining will still provide minor increase of streamflows.

Salinity

The outcomes of the Holyoake DE numerical groundwater model (GHD 2021e) were also used to forecast changes in salt load (TDS) of surface waters inflowing to the South Dandalup reservoir from the catchments modelled, arising from Holyoake DE mining. During the clearing and mining period the salinity increases averaged between 5 mg/L and 11 mg/L for the current climate case (last 20 years climate looped) and between 3 mg/L and 7 mg/L for the climate change scenario (30% reduction in recharge, runoff and interflow from the current conditions). For the post-mining period the salinity increases averaged between 11 mg/L and 24 mg/L under current climate conditions, and between 6 mg/L and 13 mg/L for the climate change scenario.

Sediment and turbidity

Sediment and turbidity impacts to the reservoir are described in section 8.5.

Hydrocarbons

Hydrocarbon impacts to the reservoir are described in section 8.5.

PFAS, PFOA and PFOS

PFAS, PFOA and PFOS impacts to the reservoir are described in section 8.5.

Other water quality impacts

Water quality impacts from the following potential contaminants of concern are described in section 8.5:

- Explosives residue
- Carbide residue
- Contamination from spills and/or leaks from storage and handling of hazardous materials and waste
- Fertilisers during rehabilitation

8.3.4 Upper Wungong Brook

Streamflows

Numerical groundwater modelling completed to assess impacts of mining on near surface groundwater and streams flows in the Myara North DE identified slight increases in streamflows within the Wungong Brook catchment during mining (on average between 0.05 to 0.1 GL/yr, followed by minor flow reduction (on average 0.02 GL/yr) during post-mining period (Figure 8-7), similar to catchments feeding the Serpentine Reservoir.

During mining in the Myara North DE the predicted flows are on average 0.6 GL/yr, while post-mining they will be approximately 0.35 GL/yr. These represent only minor change when compared to non-mining scenario (0.09 and -0.005 GL, respectively). Climate change, modelled as 30% decrease in recharge and surface flows will result in reduced flows in the Wungong Brook, typically by over 50% (Figure 8-8).

Salinity

Salinity changes were not calculated for the Upper Wungong Brook catchment, however given that clearing associated with mining activity represents just 2.4% of this catchment, compared to 3.5% for the Serpentine catchment, Wungong Brook salinity changes are expected to be similar to or less than those predicted for Serpentine.

Sediment and turbidity

Sediment and turbidity impacts to the reservoir are described in Section 8.5.

Hydrocarbons

Hydrocarbon impacts to the reservoir are described in Section 8.5.

PFAS, PFOA and PFOS

PFAS, PFOA and PFOS impacts to the reservoir are described in Section 8.5.

Other water quality impacts

Water quality impacts from the following potential contaminants of concern are described in section 8.5:

- Explosives residue
- Carbide residue
- Contamination from spills and/or leaks from storage and handling of hazardous materials and waste

8.4 Impacts to Peel-Yalgorup System Ramsar Site

8.4.1 Myara North

The north-west portion of the Myara North DE (24.72 km^2) is located within the Gooralong Brook sub-catchment. Downstream of the Myara North DE the Gooralong Brook flows through the Jarrahdale townsite before discharging into the lower Serpentine River approximately 5.5 km downstream of the Serpentine Pipehead Dam.

The Gooralong Brook - Mundlimup gauging station (site 614073), located downstream of the Jarrahdale townsite, reports average annual flow for the period 1951 to 1998 of 10,594 ML (Table 5-2). It is noted that this flow record precedes the observed step change in streamflow reported after 2000 (Section 5.2.1), with streamflow declines of between 30% and 80% reported for other Myara North study area gauging stations in the period post 2000.

Average annual flow in the lower Serpentine River at Lowlands gauging station (gauging station 614114) for the period 1998 to 2020 is 13,535 ML.

Further, DWER (2017) report that average annual summer flow release volume from the Serpentine and Pipehead Dam reservoirs to the lower Serpentine River is between 800 and 860 ML/year (for low inflow and standard inflow years respectively).

While the north-west portion of the Myara North DE comprises a significant proportion of the Gooralong Brook catchment at the Gooralong Brook - Mundlimup (~48%), it comprises just 2.4% of the unregulated lower Serpentine River catchment area.

8.4.2 Holyoake

As noted in Section 4.6.2, the majority of the Holyoake DE (11,808 ha or 63% of total) is located within the South Dandalup Dam catchment. There is no release to the South Dandalup River downstream of the South Dandalup Dam.

The southern 2,461 ha of the Holyoake DE (13% of total) lies within the catchments of Davis Brook (1,792 ha) and Swamp Oak Brook (669 ha), which are un-regulated tributaries to the Murray River, comprising approximately 26% of the Davis Brook catchment and 9% of the Swamp Oak Brook catchment respectively.

Davis Brook has a catchment of approximately 6,900 ha and has a gauging station the Murray Valley Plantation (614047) approximately 1.5 km upstream of the confluence with Murray River. Swamp Oak Brook has a catchment of approximately 7,100 ha, with a gauging station on its upper reach at Chadoora (614045) recording limited historical flow.

During the baseline monitoring period (GHD 2021a) a single sample was collected from site DV04 on Davis Brook in August, with the site dry during all other monthly monitoring events. Samples were collected in August and September at site HSW02 downstream of Chadoora, two downstream monitoring sites (6141470 or HSW03) were dry for all monthly monitoring events, and a water level logger at HSW03 recorded no surface water flows.

The Murray River is gauged at the Baden Powell station (614006) which has a catchment of 6,760 km^2 (approximately 676,000 ha). The station lies immediately downstream of Lane Poole Reserve, approximately 1.7 km downstream of the confluence with Davis Brook and approximately 5.6 km downstream of the confluence with Swamp Oak Brook.

The southern section of the Holyoake DE comprises <1% of the Murray River at Baden Powell station.

8.5 Impacts to drinking water

8.5.1 Public health

Sediment and turbidity

Turbidity is a key water quality concern for drinking water sources. Whilst not hazardous in itself, turbidity is able to reduce the efficacy of the chlorine treatment processes to inactivate or remove pathogens. Historically, mining has generated turbid runoff from the failure of drainage controls. As described in section 7.2, offtake monitoring data does not display any increasing trend with turbidity associated with mining disturbance.

Turbidity of water at customer taps should be less than 5 NTU, and it is desirable that turbidity be <1 NTU at the time of disinfection (NHMRC, 2011. As part of the DWRA, GHD (2021 undertook hydrodynamic modelling of suspended solids (SS) inputs to the reservoirs, in the form of 1 μm diameter inorganic particles (clay) and 5 μm diameter inorganic particles (silt). The proportion of these particles in the modelled inputs was allocated to simulate natural waterways for un-mined catchment areas, and to simulate mining sumps for inputs from mined catchment areas. The model was simulated for a range of existing and future mining conditions, drainage failure scenarios (5%, 30%, 75%), climatic seasons (winter, summer), and storm intensities (1 Exceedance per Year, 10% Annual Exceedance Probability, 1% Annual Exceedance Probability), for the Serpentine, Serpentine Pipehead, and South Dandalup reservoirs.

Results indicate that for the Serpentine Main Dam, baseline turbidity exceeds 1 NTU at the offtake but never 5 NTU, adopting a 1:1 TSS:NTU relationship. Turbidity concentrations are sensitive to changes in sump failure suspended solids concentrations, as mining comprises a sufficient proportion of the catchment landscape to do so. In contrast, South Dandalup Dam is not sensitive to sump failure suspended solids concentrations, as the future clearing area is a small proportion (4.8%) of the overall catchment area. This relationship is assumed to exist for the upper Wungong Brook, where the future clearing area is 2.4% of the reservoir catchment.

It is important to note that the 30% and 75% drainage failure rates are an order of magnitude higher than what has been observed in the Huntley and Willowdale mine to date for a single rainfall event. Failures are also assumed to be complete and total failures directly connected to the reservoir without any capture or settlement in overland flow paths or streams.

Due to the hydrodynamic barrier effect induced by the Serpentine Pipehead primary inflow and outflow in proximity to the dam wall, there was little change in turbidity predicted for this reservoir.

The following figures illustrate the cumulative frequency of SS (turbidity) concentrations for existing and future mine scenarios compared to the baseline.

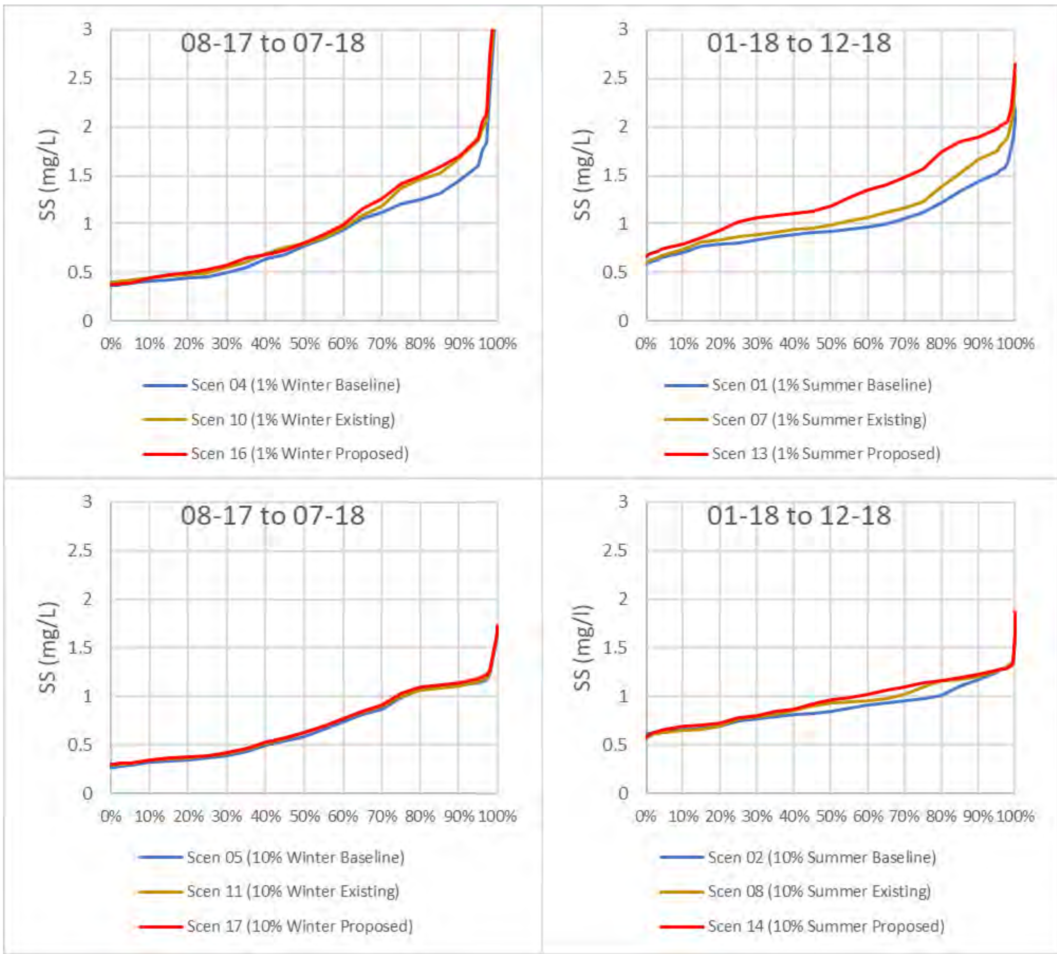

Figure 8-20 ***Percentile plots of simulated Serpentine withdrawal SS (silt + clay) of winter[2] and summer[3] 1% and 10% AEP inflow event scenarios with 30% sump failure SS levels***

[2] Percentiles over 1 year from 1 August 2017 to 31 July 2018.
[3] Percentiles over 1 yar from 1 January to 31 December 2018.

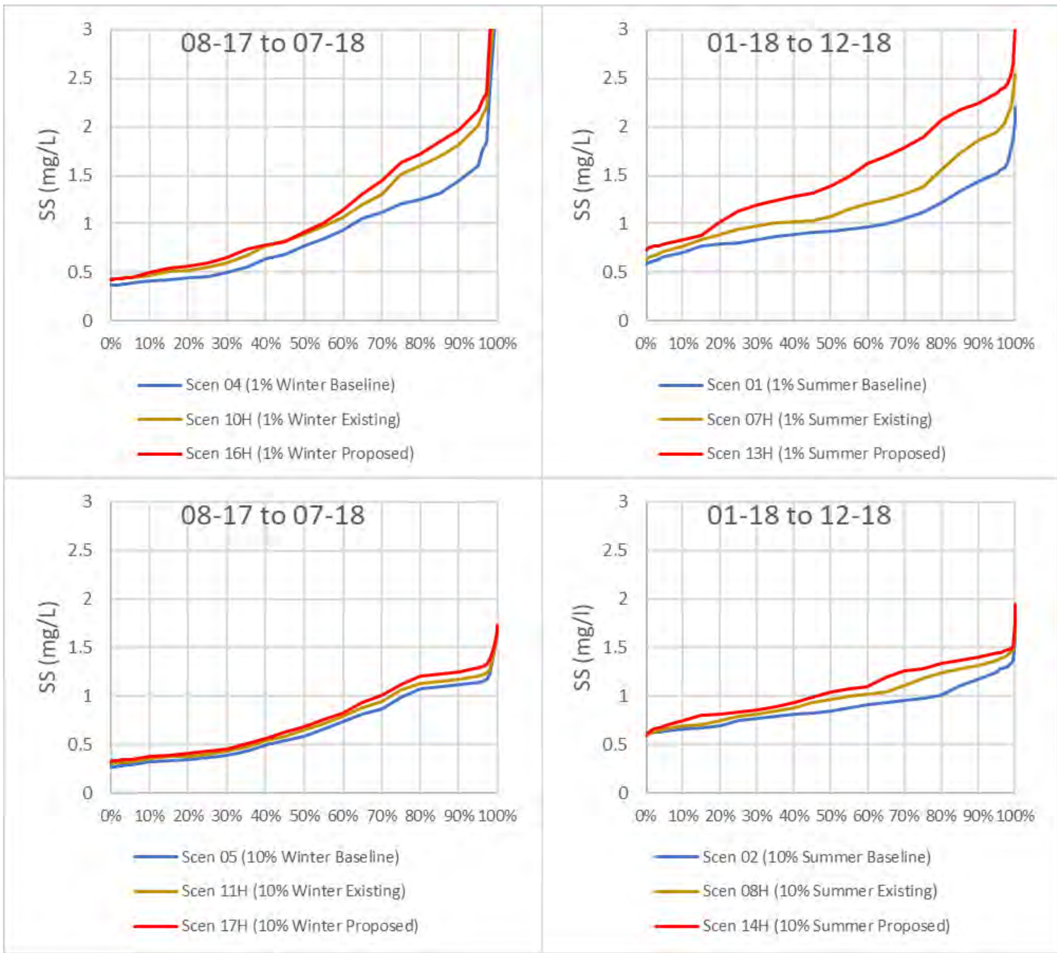

Figure 8-21 ***Percentile plots of simulated Serpentine withdrawal SS (silt + clay) of winter and summer 1% and 10% AEP inflow event scenarios with 75% sump failure SS levels***

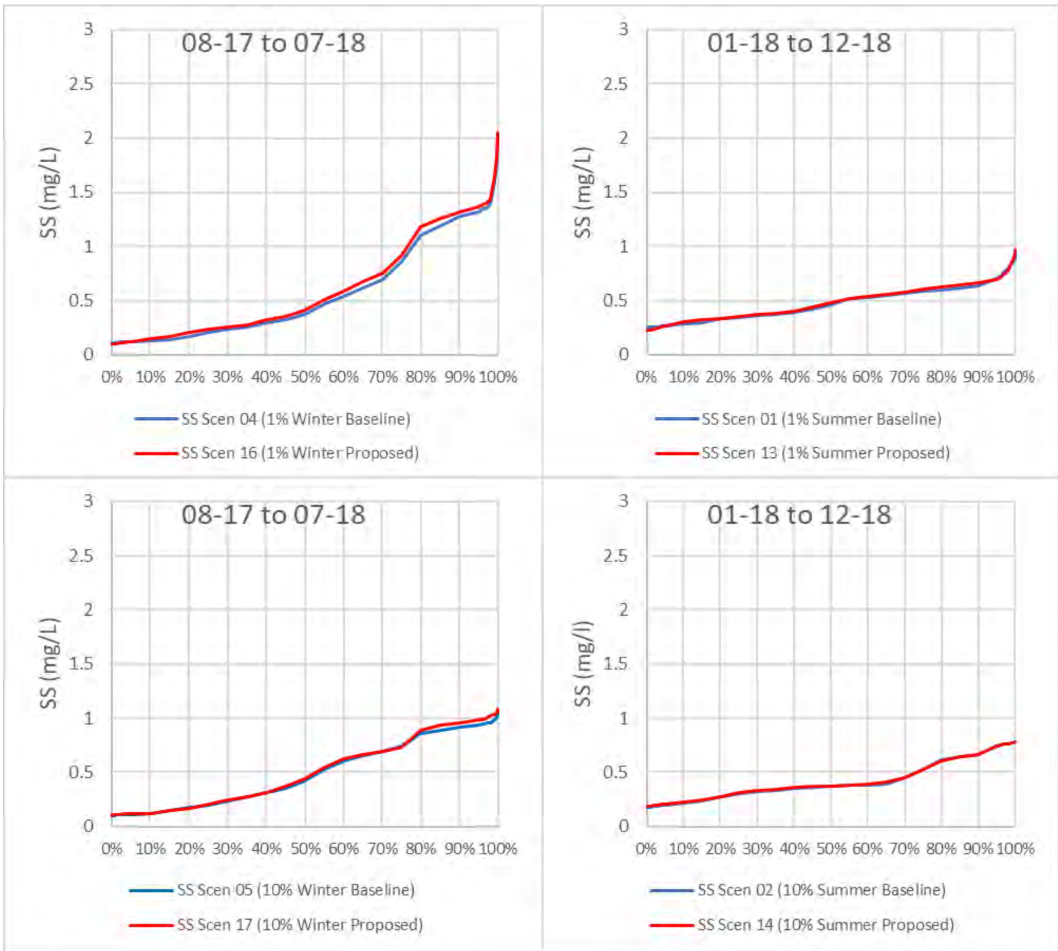

Figure 8-22 ***Percentile plots of simulated South Dandalup withdrawal SS (silt + clay) of winter and summer 1% and 10% AEP inflow events with 30% sump failure SS levels.***

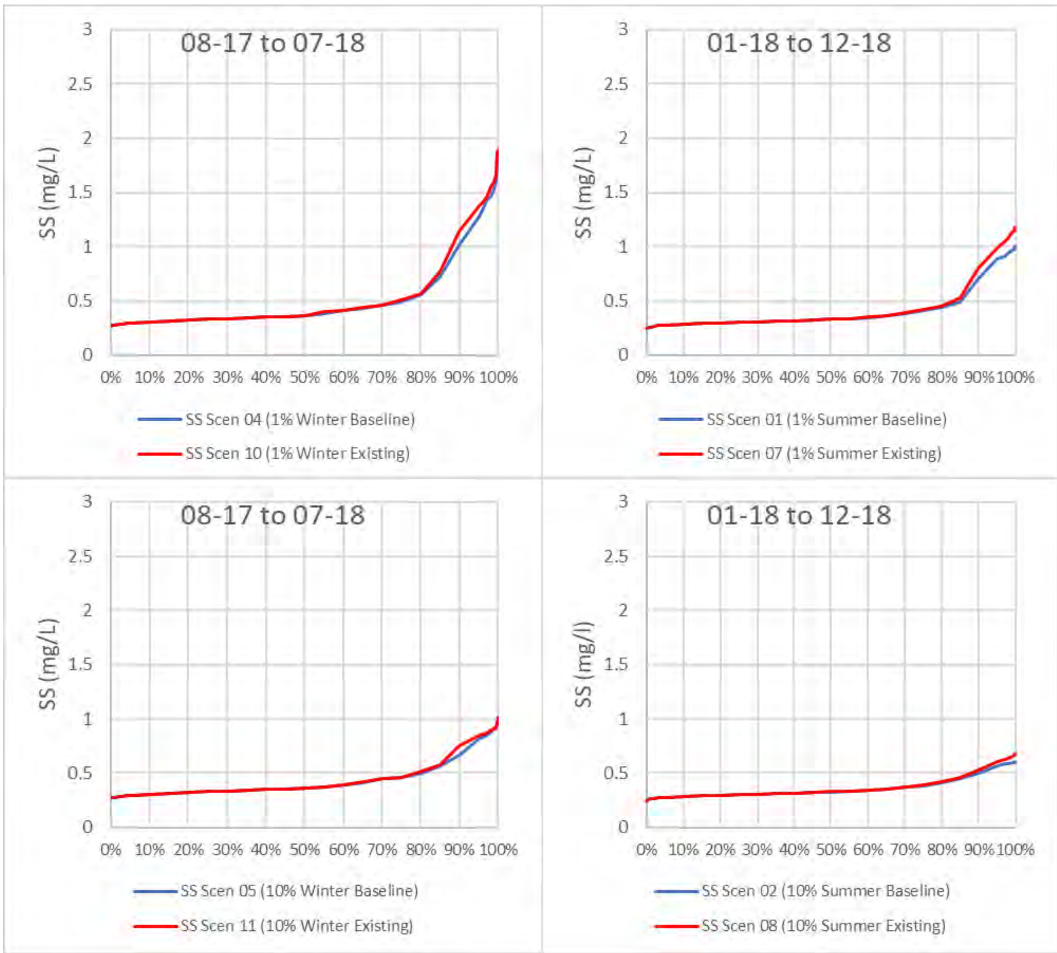

Figure 8-23 ***Percentile plots of simulated South Dandalup withdrawal SS (silt + clay) of winter and summer 1% and 10% AEP inflow events with 75% sump failure SS levels.***

Hydrocarbons

The ADWG (NHMRC, 2011 recommends:

- A health based guideline limit for benzene of 1 µg/L, consistent with WHO guidance for this parameter;
- A health based guideline limit for xylenes of 600 µg/L and an aesthetic based limit of 20 µg/L; and
- An aesthetic taste and odour threshold for diesel of 5 µg/L.

Carting of diesel fuel to machinery using small (15 kL) tankers has been identified as the highest risk hydrocarbon discharge event. GHD (2021 simulated a full tanker spill discharging directly to a stream at each reservoir. The modelled processes leading to decreased diesel concentrations were river dilution, reservoir mixing and dispersion, and withdrawals from the dams.

Noting that benzene constitutes 0.5% of the mass of fuel diesel, and xylene 0.03%, the simulation results at the offtake indicate that:

- For the Serpentine and South Dandalup reservoirs, the peak diesel concentration is predicted to be less than 1 µg/L, well below ADWG guidelines.
- For the Serpentine Pipehead reservoir, the peak diesel concentration is predicted to be less than 5 µg/L, well below ADWG heath based guidelines and at the threshold for the aesthetic guideline.

Microbes

Human activity in a drinking water catchment can result in release of microbial pathogens into the drinking water. In addition to the presence of workers throughout the DE's, Alcoa are proposing to construct Sewage Treatment Plants (STP) in the Myara North and Holyoake DE's. The risk of illness for exposed populations is estimated and expressed as Disability Adjusted Life Years (DALYs). The health based target for drinking water favoured by WSAA is a risk of 10^{-6} DALYs per person per annum.

Four potential hazardous events were identified:

1. A raw sewage overflow event located within the STP within the Serpentine or South Dandalup catchment areas during heavy rainfall.
2. Treated effluent accumulates at the surface of the designated treated wastewater irrigation area and is subsequently washed out by heavy rainfall.
3. Treated effluent leaches into a subsurface perched aquifer during a period when rainfall exceeds evapotranspiration, flows to a steep creek or a downstream seepage face over tens of metres, and then in the reservoir or a creek.
4. An asymptomatic staff member with cryptosporidiosis defecates in bushland in any of the three catchment areas, shortly before a heavy rainfall event.

After allowing for dilution and overland transport losses, only scenario 4 for the Serpentine Pipehead catchment exceeds the health based target. This hazard requires attention during detailed design, to define how to reduce the risk to an acceptable level.

A highly conservative scenario when all four hazardous events are combined will also exceed the health based targets threshold at South Dandalup and Serpentine Pipehead dams.

PFAS, PFOA and PFOS

Impacts associated with PFAS, PFOA and PFOS are discussed in the DWRA.

8.5.2 Service interruptions

Should the risks identified in the DWRA eventuate, there may be a disruption to the withdrawal of water from the affected reservoir. The impact of such a disruption depends on the nature of the hazard, duration of the disruption, which reservoirs are affected, and how the IWSS is operated. It is beyond the scope of this report to assess the likelihood and consequence of such a disruption.

8.5.3 Mine water demands

Mining and construction activities require access to clean water. Water supply for Myara North is to be sourced from South Dandalup, Bandsiadale and/or Serpentine Dams. There may be a short period during initial clearing and construction activities where pipelines and pumping infrastructure will not be in place. Alcoa are investigating different options and sources for this interim water supply.

For the Myara North mine region, mining is expected to consume up to approximately 3 GL/year of water for the first 6-24 months (interim long haul trucking), primarily for dust suppression on haul roads and minor water demand for mine facilities (e.g., ablutions, vehicle washing). Alcoa are investigating alternatives to using water for dust suppression. For the interim long haul trucking scenario, once the conveyor is constructed (if the preferred option post detail design) then the frequency of haul truck movements will reduce and the water demand would reduce to approximately 1 GL/year. For the life of mine long haul trucking scenario, water demand would remain at approximately 3 GL/year for the duration of mining (2023-2030). Investigations are underway for the capture and reuse of runoff water from the Myara North facilities area. Increases in streamflow due to mining described in section 8.3.1 will partially counterbalance the water demands from mining.

Water supply for the Holyoake DE is expected to be supplied from the South Dandalup and Banksiadale Dams. Water demands are yet to be estimated.

8.6 Cumulative impacts

8.6.1 Timber harvesting and other forest industries

8.6.1.1 Impacts on water yields and salinity

Timber harvesting has historically caused a larger disturbance to LAI within the Northern Jarrah Forest, with annual clearing about an order of magnitude greater than that of mining, however harvesting will be relatively distributed across the forest and surface water catchments. In light of the decision to end logging of native forests in then the upcoming Forest Management Plan 2024-33 and in the absence of long-term harvesting plans it was not possible to incorporate timber harvesting into groundwater modelling for the Myara North or Holyoake mine regions to predict the effect on stream salinity. However, given the distribution of timber harvesting between catchments and the demonstrated regrowth that occurs in a comparable timeframe (or less) to that of mining is it likely that there would be limited changes to stream salinity in any single drinking water catchment, and that freshwater quality will be maintained.

8.6.1.2 Impacts on water quality

Timber harvesting has potential for spills or leaks of diesel and oils during harvesting operations, which would involve refuelling and potentially maintenance of harvesting equipment and heavy vehicles. There is also potential for ongoing, low level oil leaks from vehicles and equipment, and rare collisions that result in fuel or oil spills. As with mining, most spills and leaks, particularly those from major incidents and involving large volumes, are expected to be identified quickly and the contaminated soils excavated and disposed off-site at a licensed waste facility.

Smaller spills and leaks may potentially be missed and the contaminants leach through the unsaturated zone. As with mining, small volumes of diesel and oil that escape detection and remediation are unlikely to result in substantial migration of hydrocarbons that reach streams and can be transported into reservoirs. Accordingly, the storage and handling of hazardous materials during timber harvesting is expected to pose a low risk to water quality.

Further impacts associated with mining, timber harvesting and other forest industries are discussed in the DWRA and ERD.

8.6.2 Rehabilitation

8.6.2.1 Impacts on water yields and salinity

Rehabilitation of approved mining regions will overlap temporally with clearing, mining, and rehabilitation of the proposed mine development envelope. Spatially this is closest for the Myara and Myara North mining regions. Rehabilitation restores groundwater levels, streamflow, and salinity from the peaks that occur prior to rehabilitation. Therefore, cumulative impacts of rehabilitation of water yields and salinity are expected to be minor.

There is potential for past mine rehabilitation that has a higher leaf area index (LAI) to decrease recharge relative to un-mined forest. Contemporary rehabilitation from 2016 onwards has achieved about 1000 stems/ha in tree establishment, whereas from 1998-2015 it achieved about 1400 stems/ha and from 1988-1997 about 3000 stems/ha. This indicates that the Jarrahdale Mine (mined 1963-1998) north of Myara North may contain areas of higher LAI that may reduce recharge relative to un-mined forest and potentially reduce streamflows in Upper Wungong Brook. Similarly, older regions of the Huntly Mine (e.g. White region mined in 1989-2006, Huntly 1&2 region mined in 1986-1997) may have areas of higher LAI that may reduce recharge relative to un-mined forest and potentially reduce streamflow in South Dandalup River, North Dandalup River and Conjurunup Creek.

8.6.2.2 Impacts on water quality

Certain rehabilitation techniques can introduce more erodible (and potential dispersive) clayey material into the shallow subsurface surface. Analysis of gully erosion at the Huntly, Willowdale and Boddington bauxite mines suggested a minimum catchment of 0.3 ha for gully development, with gully volumes typically remaining small (20-100 m^3) but potentially increasing for higher slopes (> 10°) and shallower topsoil/overburden placement

(< 200 mm). Erosion was highest in the first two to three years following rehabilitation completion until rehabilitation establishes, though there was a lack of long term data with which to compare the erodibility of rehabilitation to that of un-mined Jarrah forest (Mengler et al 2006). For the period at higher risk of erosion, the major triggers for gully erosion were identified as:

– directing excessive off-site runoff into the rehabilitation
– poor surface completion (e.g. ripping that does not adhere to contours) that concentrates flow or impairs infiltration
– insufficient depth of returned topsoil and overburden (< 200 mm combined)

Given that rehabilitation occurs progressively, erosion risk from rehabilitation of approved mining regions is not expected to accumulate with rehabilitation of the Myara North and Holyoake DE’s. Further impacts associated with rehabilitation are discussed in the DWRA.

8.6.3 Climate change and fire

8.6.3.1 Climate change effects on water yields and salinity

Cumulative impacts to water yield and salinity from mining and climate change are assessed in section 8.1 to 8.5.

As presented, climate change is expected to have the greatest effect on groundwater and streamflow, exceeding the effects of mining and rehabilitation. Temporary removal of vegetation during mining and the associated increase in recharge is predicted to result in a localised and temporary counterbalance to the historic groundwater and streamflow decline observed across the catchments and wider Northern Jarrah Forest. However, as rehabilitation establishes the recharge is expected to return to the non-mining baseline and groundwater and streamflow to be subject to further decline in line with climate change forecasts for the South-West region.

8.6.3.2 Climate change effects on fire and associated water yields and salinity

The climate change projections described in section 4.1 are expected to extend the period at which vegetation is flammable, increasing the frequency and scale of forest fires, though drying may also reduce the rate of fuel accumulation (Burrows and Wardell-Johnson 2003). Detailed investigation has not been undertaken for the South-West region, however analysis for south-east Australia indicated an increase in cumulative forest fire danger index (FDI) by 0-8% for low severity climate change scenarios and 10-30% for high severity scenarios by 2050 (Maher *et al* 2010). In addition to cumulative fire danger, there is a predicted increase in number of days of high fire risk in south-east Australia, with ‘very high’ fire danger days predicted to increase by 5-23% for low severity scenarios and 20-100% for high severity scenarios by 2050 (Maher *et al* 2010). The analysis for south-east Australia, which also has a projected drying and warming climate, suggests that the South-West region is likely to be subject to increasing fire risk.

Climate change is also expected to increase the frequency of tropical cyclone incursion into the South West region, which can create un-seasonally high winds such as contributed to large wildfires in 1937 and 1978 (Maher *et al* 2020).

The drying climate may also affect the rate and pathways of recovery following fire, slowing down post-fire recovery including reproduction and recruitment (Burrows and Wardell-Johnson 2003).

Changes to vegetation due to a wildfire may therefore result in cumulative impacts to water yields and salinity beyond those from mining alone.

A large scale wildfire may affect thousands or tens of thousands of hectares of an individual river catchment in a short period, causing a substantial decrease in LAI and increase in recharge until vegetation re-establishes over a few years. Wildfire may also result in greater surface water runoff through removal of surface litter and the increased rainfall impaction and water repellence on soils. The net effects of a large scale wildfire are therefore expected to be an increase in streamflows and reservoir yields over a period of a few years, relative to an un-burnt catchment. Streamflows and reservoir yields are expected to return to un-burnt conditions as vegetation and soils recover from the wildfire effects. Large wildfires may therefore have a substantial effect on streamflow and reservoir yield, but the effects are expected to be highly variable and episodic rather than a long term trend such as the forecast decline from climate change. Accordingly, the potential effects of wildfires are not incorporated into the groundwater modelling for the Proposal.

8.6.3.3 Climate change effects on fire on associated water quality

GHD (2021e) conducted a literature review of the impacts of bushfire within Australia and Western Australia. The evidence reviewed by Australian authors and the impact of 2005 Perth Hills and 2016 Waroona-Yarloop fires suggest that the Serpentine Dam, Pipehead Dam, South Dandalup Dam and Wungong Dam reservoirs may be susceptible to water quality impacts from bushfires. Such an event may include a high intensity wildfire that covers a large proportion of a catchment, occurs over steep terrain and in the year prior to heavy rainfall events.

The 2005 Perth Hills bushfire covered approximately 19% of the catchment of Mundaring Weir, which had a water volume of approximately 27 GL at the time. Turbidity in the catchment streams increased with ranges from 5 NTU to more than 1000 NTU. A turbid plume was observed within the upper end of Mundaring reservoir (Batini and Barrett 2007), with turbidity peaks of up to 37 NTU, attenuating towards the dam wall (Battin and Barrett 2007, WSAA 2020).

The 2016 Waroona-Yarloop bushfire burnt more than 90% of the catchment of Samson Brook Dam and Samson Brook Pipehead Dam (DWER 2019). The Samson Brook Dam had a water level of less than 1 GL at the time. The fire resulted in elevated levels of turbidity, pathogens and other contaminants, resulting in the Water Corporation keeping the dams offline for over a year (DWER 2019b).

A major wildfire and heavy rainfall sequence may result in widespread ash deposition, runoff and erosion that generate substantial discharges of ash and sediment into the catchment’s reservoir (GHD 2021e). Depending on the severity and location of fire and rainfall, there is potential for the scale of discharges to exceed the attenuating capacity of the reservoir and cause elevated contaminant levels at the offtake that exceed drinking water quality criteria (GHD 2021e).

Climate change is expected to extend the period at which vegetation is flammable, increasing the frequency and scale of forest fires in the Jarrah forest, though drying may also reduce the rate of fuel accumulation. Analysis undertaken for south-east Australia, which is predicted to undergo similar drying and warming as is forecast for the South-West region, suggests a potential for increased cumulative forest fire danger index and increased number of high and very high fire risk days. Accordingly, there is potential for the frequency of wildfires to increase in the future.

Potential changes to the fire regime and fire management practices due to mining and rehabilitation are described in the ERD. The cumulative impacts of mining and fire, regardless of the cause, is described hereafter.

Whilst turbid runoff from cleared mining areas is managed through drainage control measures, turbid runoff leaving fire affected areas will flow freely into streams and the reservoir. The impacts of a large wildfire on water quality have been observed to be catastrophic to downstream water quality. Comparatively, water quality impacts from a widespread drainage failure scenario were assessed in the DWRA to be moderate.

The occurrence of wildfire events may result in cumulative impacts to water quality beyond those from mining alone. As with yield, large wildfires may have a substantial effect on stream and reservoir water quality, but the effects are expected to be highly variable and episodic. Further impacts associated with climate change and fire are discussed in the DWRA and ERD. As noted in the ERD, it is expected that the transition of mining into the Myara North and Holyoake regions will continue to enable DBCA’s prescribed burning program to be effectively planned, funded and implemented, as has been demonstrated within the Huntly Mine to date. Accordingly, the Proposal is expected to maintain and support the State Government’s program to limit fuel accumulation in the Northern Jarrah Forest, thereby reducing the likelihood of large wildfires occurring in the surface water catchments that lie within the mine regions.

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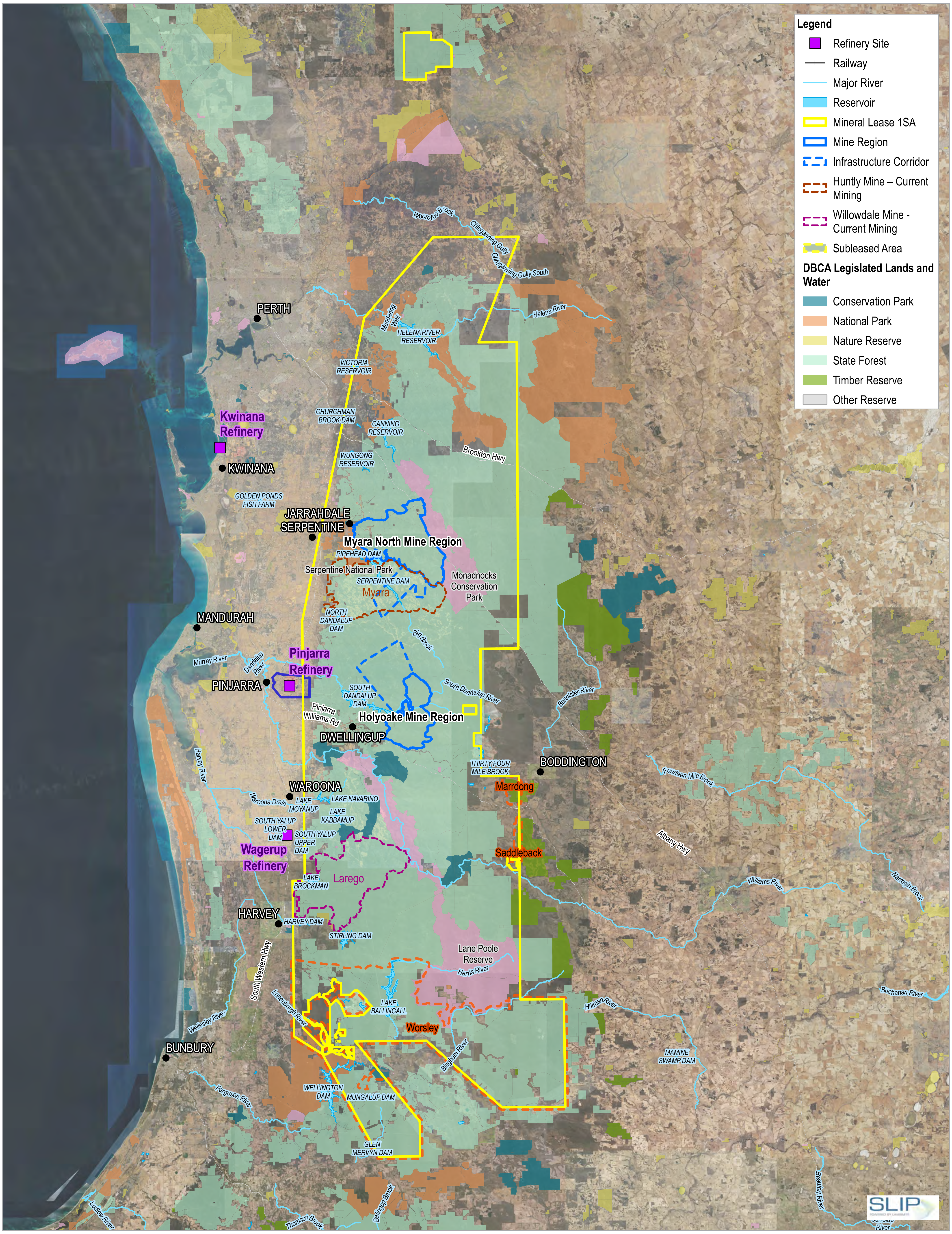
Appendices

Appendix A

Figures



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GHD

Alcoa of Australia Limited
Hydrology and Water Quality Assessment

Project No. 12520591
Revision No. 0
Date 11/01/2022

Locality Plan and Mining Regions

FIGURE A-1

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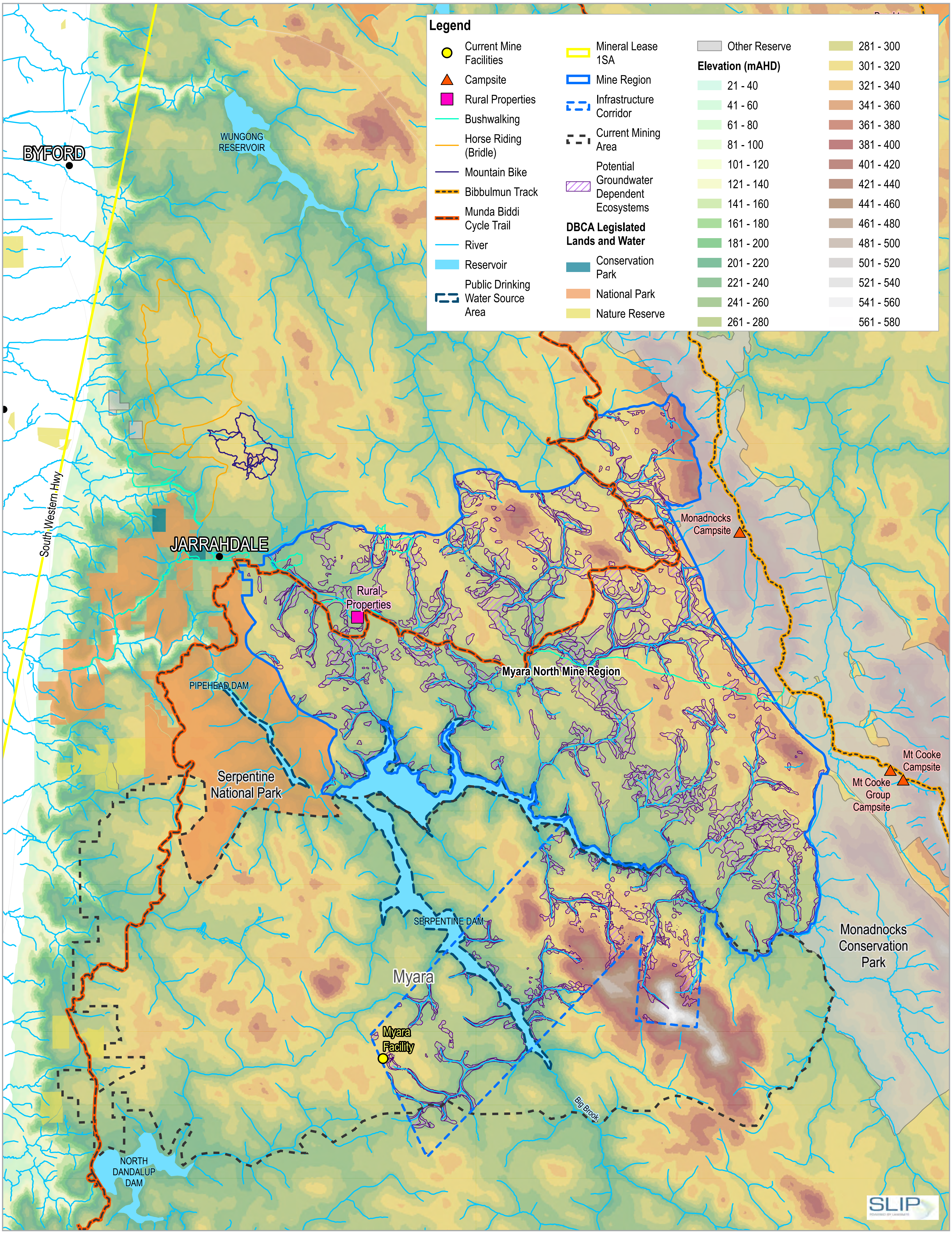

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Grid: GDA 1994 MGA Zone 50

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Alcoa of Australia Limited

Location and boundaries of Myara North proposed development area

Project No. 12520591
Revision No. 0
Date 03/06/2021

FIGURE A-2

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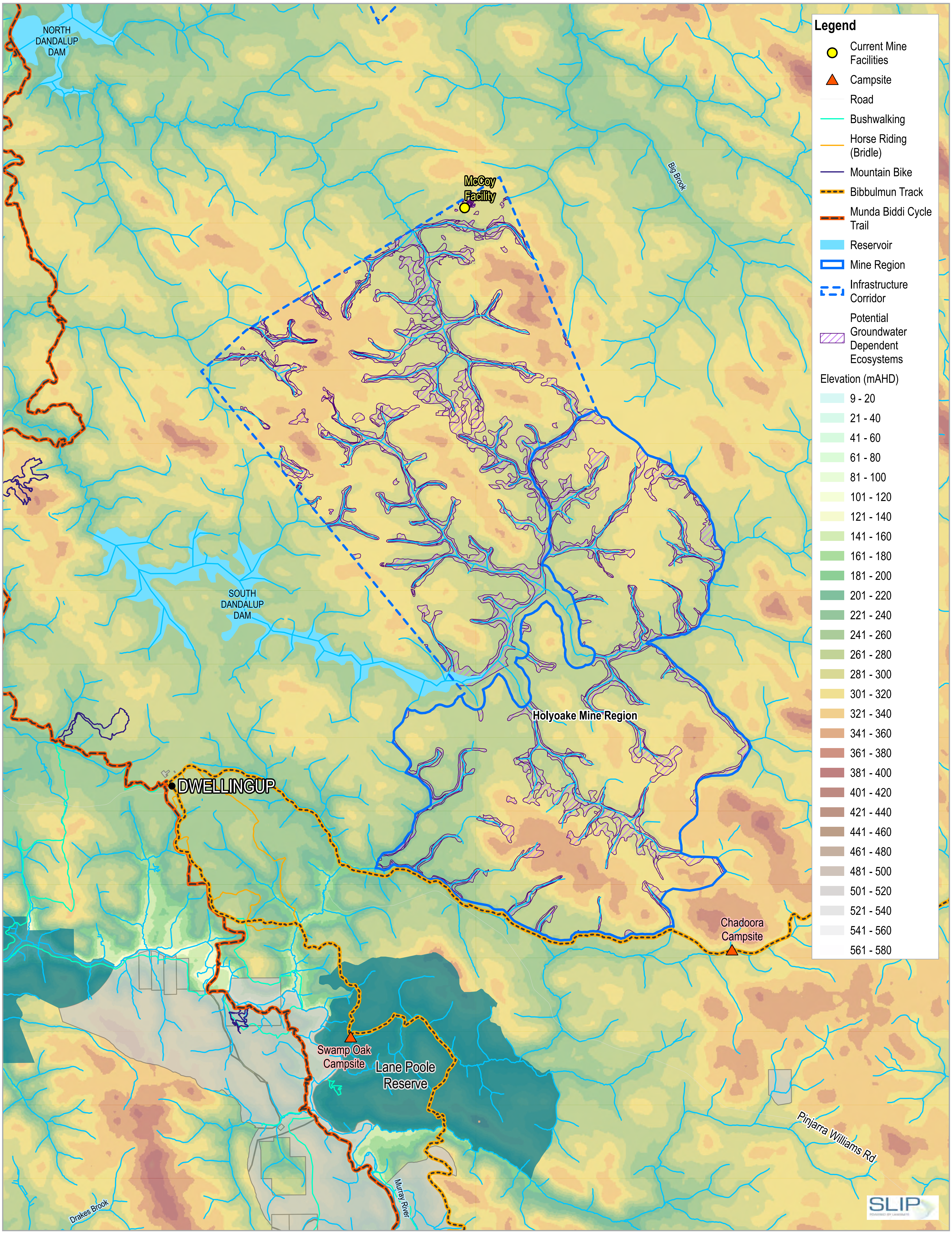

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Alcoa of Australia Limited

Holyoake Local Context

Project No. **12520591**
Revision No. **0**
Date **03/06/2021**

FIGURE A-3

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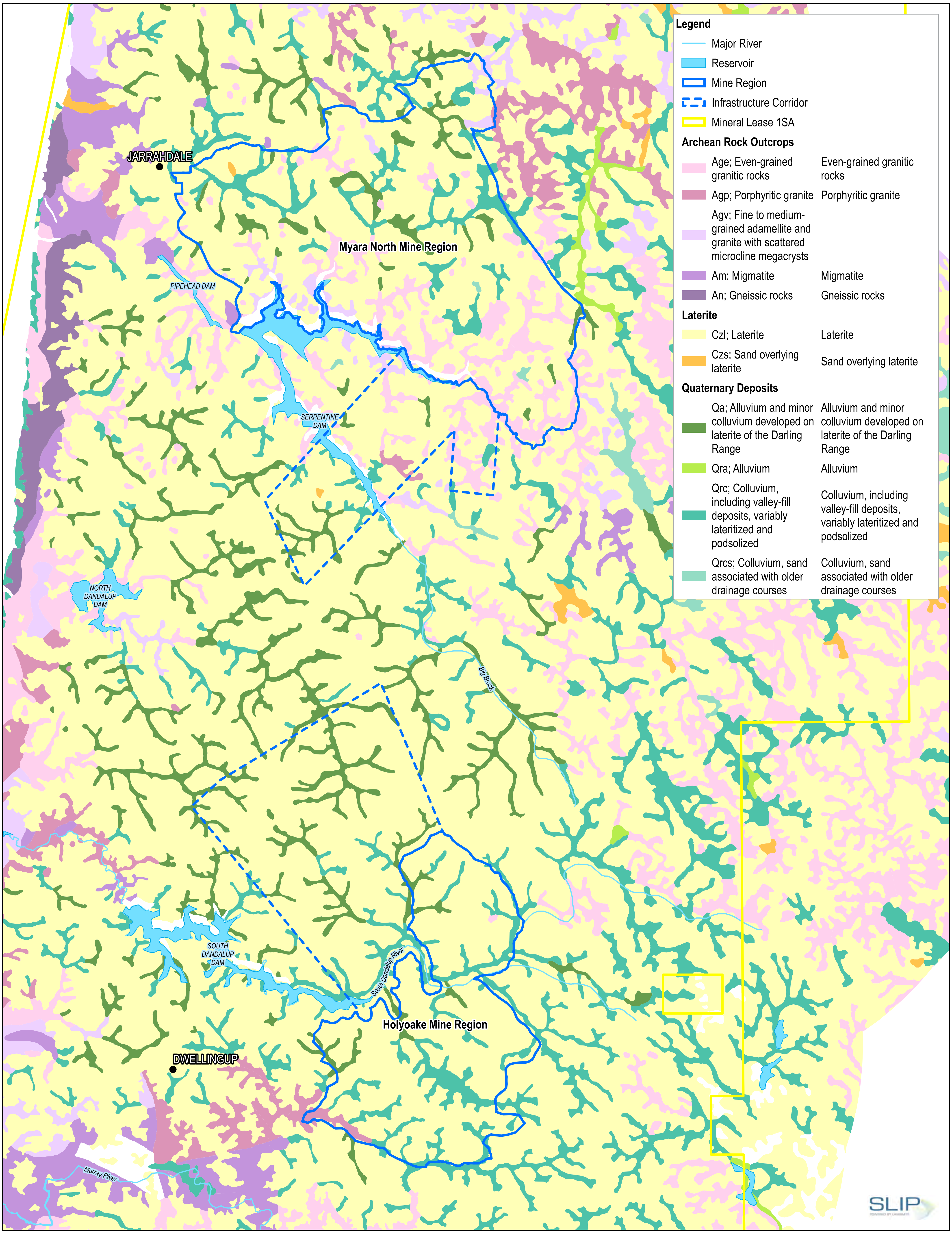

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Alcoa of Australia Limited

Hydrology and Water Quality Assessment

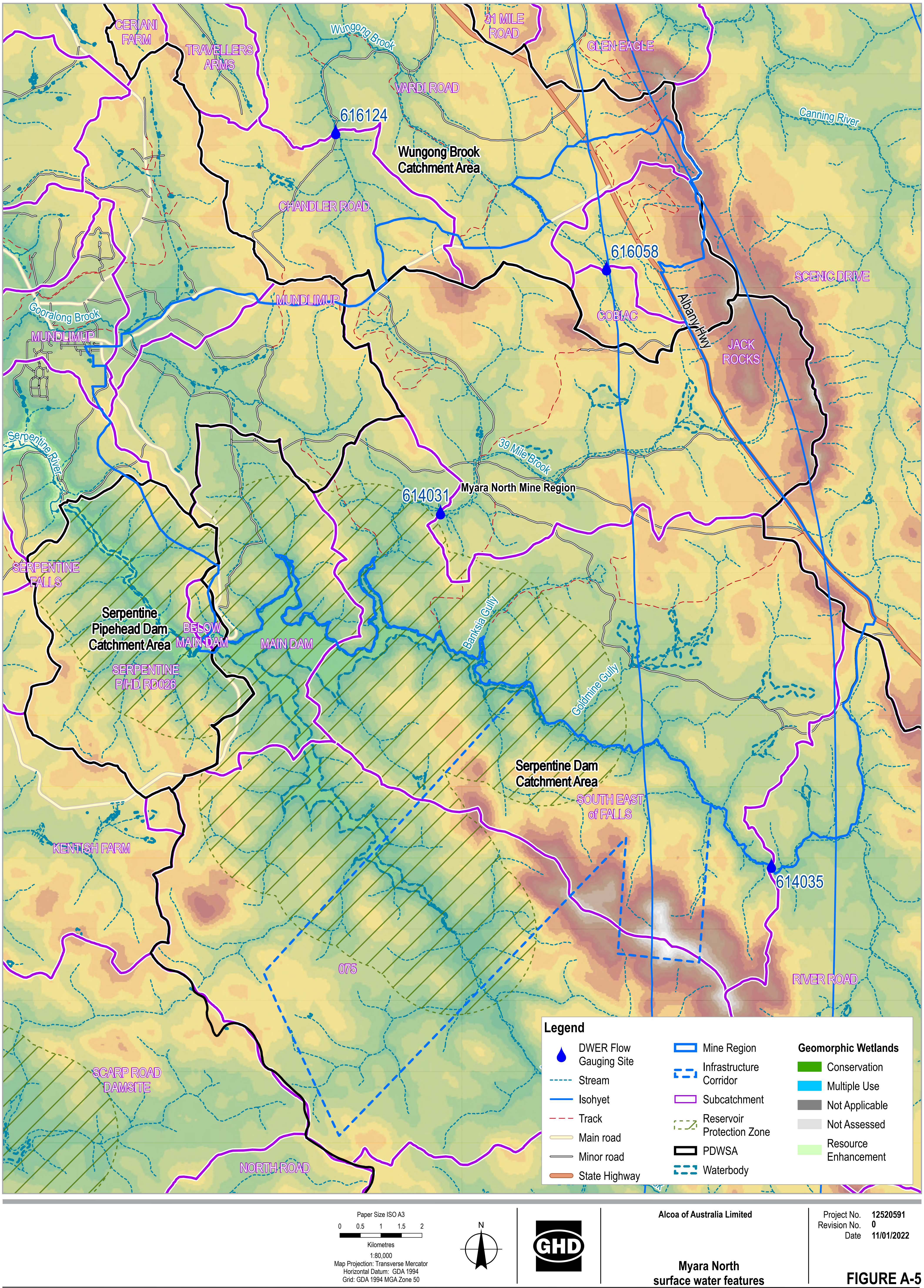
Hydrology and Water Quality Assessment GSWA 250K Geology Map

Project No. 12520591
Revision No. 0
Date 11/01/2022

FIGURE A-4

\\ghdnet\ghd\AU\Perth\Projects\61\12520591\GIS\Maps\Working\12520591_Hydrology\12520591_Hydrology\12520591_Hydrology.aprx\12520591_004_Geology_RevA
Print date: 11 Jan 2022 - 13:00

Data source: Alcoa/GHD: Pinjarra Refinery Development Envelope - 20200618; DoW: Watercourse - 20200221; DPLH: Zones and Reserves - 20200525; Landgate: Railway - 20190304, Roads - 20190114,accessed 20200204. Created by: rbrown3



Alcoa of Australia Limited

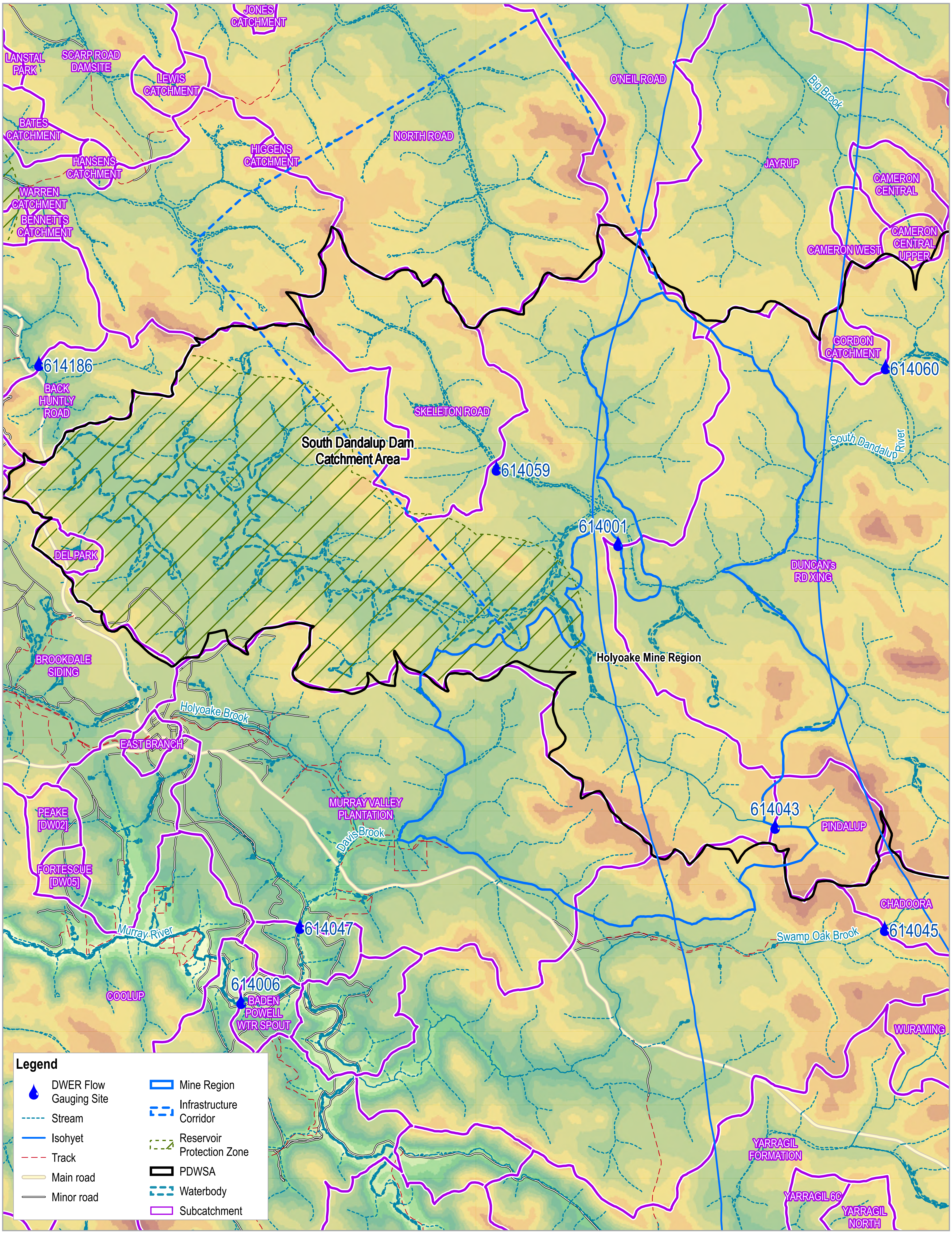
Project No. 12520591
Revision No. 0
Date 11/01/2022

Myara North
surface water features

FIGURE A-5

\\ghdnet\ghd\AU\Perth\Projects\61\12520591\GIS\Maps\Working\12520591_Hydrology\12520591_Hydrology\12520591_Hydrology.aprx\12520591_005_MyaraNorthCatchmentsAndDrainage_Rev0
Print date: 11 Jan 2022 - 10:42

Data source: GHD: Subcatchments - 20200624; Alcoa: Myara North Boundary - 20200618, LiDAR Elevation - 20200626, Reservoir Protection Zone, Isohyet - 20200225, Streams - 20200617; GA: SRTM - 20200526; DBCA: Geomorphic Wetlands 20200117 - DWER: SW Monitoring Sites - 20200629; DoW: PDWSA - 20160607; Landgate: Roads - 20190128, . Created by: rbrown3



Paper Size ISO A3

0 0.5 1 1.5 2

Kilometres

1:83,601

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 50

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Alcoa of Australia Limited

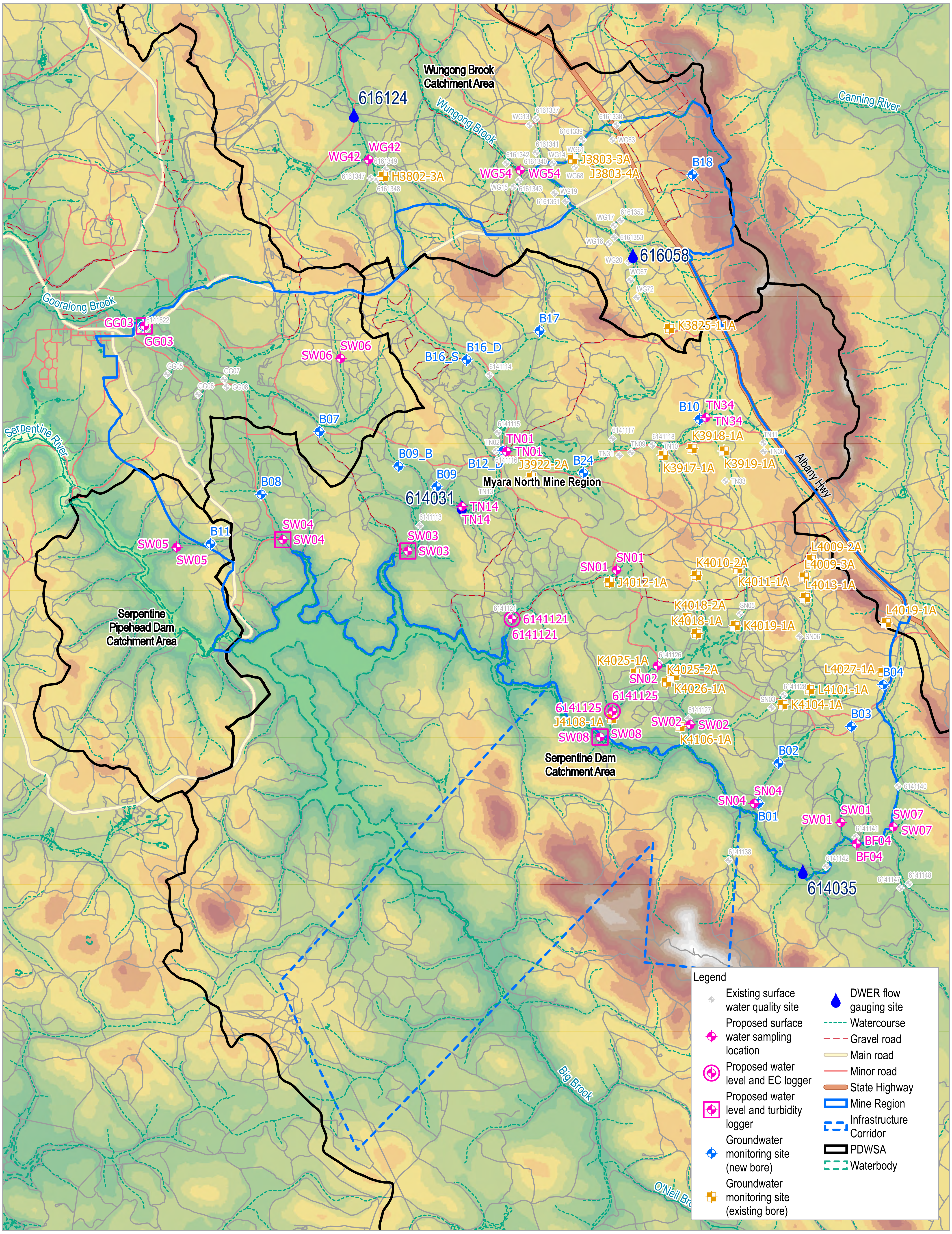
Holyoake
surface water features

Project No. **12520591**
Revision No. **0**
Date **11/01/2022**

FIGURE A-6

\\ghdnet\ghd\AU\Perth\Projects\61\12520591\GIS\Maps\Working\12520591_Hydrology\12520591_Hydrology\12520591_Hydrology.aprx\12520591_006_HolyoakeCatchmentsAndDrainage_Rev0
Print date: 11 Jan 2022 - 10:46

Data source: Alcoa: Myara North Boundary - 20200618, LiDAR Elevation - 20200626, Reservoir Protection Zone, Isohyet - 20200225, Streams - 20200617; GA: SRTM - 20200526; DWER: SW Monitoring Sites - 20200629; DoW: PDWSA - 20160607, Subcatchments - 20130902; Landgate: Roads - 20190128, . Created by: rbrown3



Paper Size ISO A3

0 0.5 1 1.5 2

Kilometres

1:80,000

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 50

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Alcoa of Australia Limited

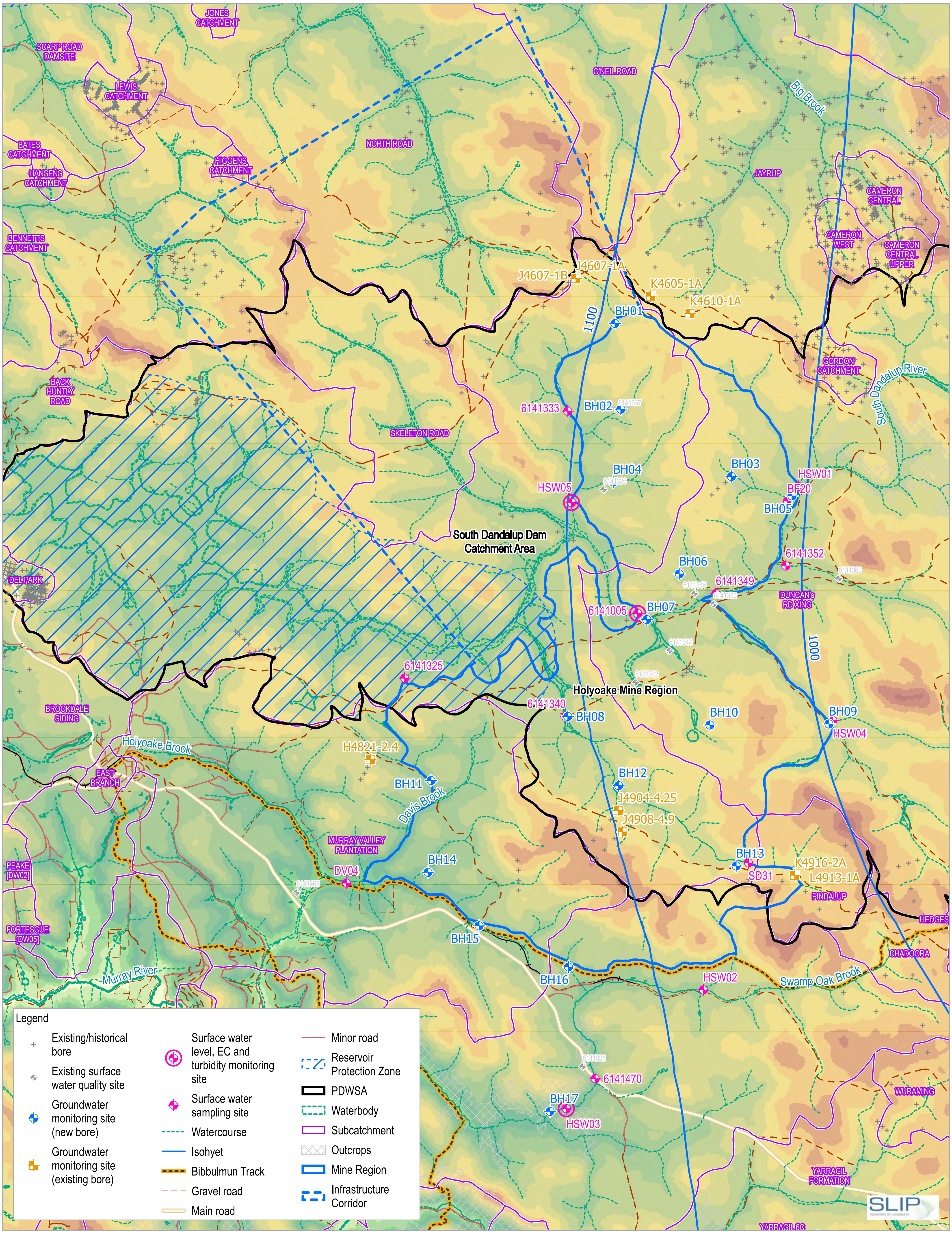
Myara North Water Monitoring Locations

Project No. 12520591
Revision No. 0
Date 11/01/2022

FIGURE A-7

\\ghdnet\ghd\AU\Perth\Projects\61\12520591\GIS\Maps\Working\12520591_Hydrology\12520591_Hydrology\12520591_Hydrology.aprx\12520591_007_SAQP_MyaraNorthWaterMonitoringLocations_RevA1
Print date: 11 Jan 2022 - 13:50

Data source: GHD: Proposed sites - 20200825, Subcatchments - 20200624; Alcoa: Myara North Boundary - 20200618, LiDAR Elevation - 20200626, Reservoir Protection Zone, Isohyet - 20200225, Streams - 20200617; GA: SRTM - 20200526; DWER: Existing Monitoring Sites - 20200629; DoW: PDWSA - 20160607; Landgate: Roads - 20190128, . Created by: rbrown3



Paper Size ISO A3

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Kilometres

1:80,000

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 50

GHD

Alcoa of Australia Limited

Holyoake Water Monitoring Locations

Project No.	12520591
Revision No.	0
Date	11/01/2022

FIGURE A-8

\\ghdnet\ghd\AU\Perth\Projects\61\12520591\GIS\Maps\Working\12520591_Hydrology\12520591_Hydrology\12520591_Hydrology.aprx\12520591_008_SAQP_HolyoakeWaterMonitoringLocations_RevA1
Print date: 11 Jan 2022 - 10:58

Data source: GHD: Proposed monitoring sites - 20200825, Subcatchments - 20200624; Alcoa: Holyoake Boundary - 20210125, LiDAR Elevation - 20200626, Reservoir Protection Zone, Isohyet - 20200225, Streams - 20200617; GA: SRTM - 20200526; DWER: SW Monitoring Sites - 20200629; DoW: PDWSA - 20160607; Landgate: Roads - 20190128, . Created by: rbrown3

Appendix B

Baseline Surface and Ground Water Monitoring Report – Myara North and Holyoake

GHD (2021a) Baseline Surface and Ground Water Monitoring Report – Myara North and Holyoake; Pinjarra Alumina Refinery Revised Proposal, unpublished report prepared for Alcoa of Australia Limited by GHD.

Appendix C

Hydrological Setting and Understanding - Myara North and Holyoake

GHD (2021b) Hydrological Setting and Understanding – Myara North and Holyoake; Pinjarra Alumina Refinery Revised Proposal, unpublished report prepared for Alcoa of Australia Limited by GHD.

Appendix D

Groundwater Modelling Report for Huntly Mine - Myara North

GHD (2021c) Groundwater Modelling Report for Huntly Mine - Myara North; Pinjarra Alumina Refinery Revised Proposal, unpublished report prepared for Alcoa of Australia Limited by GHD.

Appendix E

Groundwater Modelling Report for Huntly Mine - Holyoake

GHD (2021d) Groundwater Modelling Report for Huntly Mine – Holyoake; Pinjarra Alumina Refinery Revised Proposal, unpublished report prepared for Alcoa of Australia Limited by GHD.

Appendix F

Drinking Water Risk Assessment

GHD (2021d) Drinking Water Risk Assessment; Serpentine, Serpentine Pipehead, South Dandalup and Wungong Brook Catchments unpublished report prepared for Alcoa of Australia Limited by GHD.

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