Appendix E

Water Resources Impact Assessment

EMM
creating opportunities

HVO Continuation Project

Water resources impact assessment

Prepared for HV Operations Pty Ltd

April 2026

HVO Continuation Project

Water resources impact assessment

HV Operations Pty Ltd

H190408 RP1

April 2026

Version	Date	Prepared by	Reviewed by	Comments
1	26 September 2025	Kate Holder Katharine Bond	Kate Holder	Draft
2	10 October 2025	Kate Holder Katharine Bond	Kate Holder	Updated following client review
3	16 October 2025	Kate Holder Katharine Bond	Kate Holder	Updated for issue
4	20 February 2026	Kate Holder Katharine Bond	Kate Holder	Updated following IESC advice
5	11 March 2026	Kate Holder Katharine Bond	Kate Holder	Updated following client review
6	2 April 2026	Kate Holder Katharine Bond	Kate Holder	Minor update

Approved by

Kate Holder
Associate Director (Hydrogeologist)
2 April 2026

Level 10 201 Pacific Highway
St Leonards NSW 2065
ABN: 28 141 736 558

Executive Summary

ES1 Project introduction and overview

Hunter Valley Operations (HVO) is a well-established multi-pit open cut mining complex in the Hunter Valley of New South Wales (NSW). HVO comprises two mine sites separated by the Hunter River, HVO North and HVO South. While the two mine sites are approved under separate development consents issued under the NSW *Environmental Planning and Assessment Act 1979* (EP&A Act), they are operated as one complex with fully integrated environmental management systems. HVO North operates under Development Consent DA 450-10-2003 (the HVO North Consent) and HVO South operates under Project Approval 06_0261 (the HVO South Approval).

There is one existing approval under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) relating to the HVO Complex, EPBC 2016/7640, which allows for the continuation of coal mining operations in areas within the HVO Complex that were previously approved under the EP&A Act after the commencement of the EPBC Act.

A second referral (EPBC 2016/7641) was also submitted in 2016 relating to the extension of open cut coal mining operations at HVO South and proposed deeper mining in the Bayswater Seam within the Riverview Pit area. This action was considered not likely to significantly impact on a water resource and was determined as not a controlled action by the Minister on 20 March 2018.

HVO is seeking approval for the HVO Continuation Project (the Project). The Project broadly comprises the continuation of the life of HVO North and HVO South, from the current approved mining completion dates of 31 December 2026 and 24 March 2030 respectively, to 31 December 2045 at HVO North and 31 December 2042 at HVO South. The continuation of mining across the HVO Complex will increase resource recovery from the existing operation, predominantly by mining through previously mined areas and to the extent of existing mining tenements and extracting coal from deeper seams at HVO North (excluding Carrington West Wing extension area where mining depth is proposed to occur as approved).

At HVO South an extension to the life of the mine is proposed to facilitate improved mine sequencing outcomes and reduction in mining rate. The Project proposes a reduced mining footprint at HVO South compared to what is currently approved for extraction by HVO South Approval, with the previously approved coal extraction in the Riverview South East Extension (RSEE) area and South Lemington Pit (SLP) 1 and 2 areas proposed to be removed from the mine plan (and future approvals) for the Project. However, some rehabilitation works will be required to be undertaken in the SLP 1 area, as part of the mine closure process. The approved construction and operation of the Lemington Coal Preparation Plant (LCPP) and associated rail facilities, which is currently approved (but not constructed) under the HVO South Approval, has also been removed from the Project.

A number of infrastructure upgrades and changes are also required to facilitate the Project (and are included as part of it), including realignment of part of Lemington Road and improvements to Lake James (Dam 15S) and Parnells Dam (Dam 9W).

The Project involves continued operations within portions of catchments either already mined and/or disturbed, including previously rehabilitated areas. The existing operation has a well-established water management system (WMS) in place to minimise surface water impacts and operates in accordance with existing water access licences (WALs) for surface water and groundwater take and Environment Protection Licence (EPL) 640, as well as the Hunter River Salinity Trading Schedule (HRSTS) to manage excess water.

The existing WMS will continue to be used to manage runoff with all water captured in active mining areas and mine surface runoff directed to the WMS. The existing approved clean water diversions will continue to divert runoff around the WMS. There are no new creek diversions proposed or required as part of the Project, and there are no proposed changes to WALs or EPL limits.

The Project proposes the following key changes at HVO North which are relevant to potential impacts on water resources:

- realignment of Lemington Road and construction of a new Hunter River bridge crossing, which will significantly improve the flood immunity of this road adjacent to the Hunter River, reducing road closures in flooding events
- improved flood protection levee for North Void tailing storage facility (TSF) (up to 0.1% Annual Exceedance Probability (AEP)) as per HVO's operating standard
- improved flood protection for the Carrington West Wing Levee (up to 0.1% AEP)
- an increase in the capacity of Parnells Dam (Dam 9W) from approximately 1 gigalitre (GL) to approximately 4 GL
- construction of the Carrington West Wing low permeability barrier wall (LPBW) prior to mining within 100 metres (m) of the remnant western arm of the paleochannel in connection with the Hunter River, as per the HVO North Consent
- construction of the Mitchell East Levee as part of closure to provide flood protection for the main HVO North Void
- reducing the number of final voids that will remain post closure from three to two final voids.

At HVO South, there are limited changes proposed that will affect water resources, given that while changes to the approved mine sequencing are proposed, mining within the two primary open cut pits, Riverview and Cheshunt, will remain generally within the same footprint and will mine the same seams as approved. Changes proposed that are relevant to water resources are:

- construction of the Cheshunt and Riverview Pit flood protection levees
- enlargement of Lake James (Dam 15S) from approximately 0.7 GL to approximately 2 GL
- removal of coal extraction from the mine plan in the RSEE, SLP 1 and SLP 2 mining areas
- extended mine life.

Notably, the final void will remain largely the same as that currently approved at HVO South.

This water resources impact assessment provides an assessment of the potential impacts of the Project on water resources and water-dependent assets. The water resources impact assessment is an overarching report documenting and summarising the findings of the different water-related technical assessments conducted for the Project, including:

- the Groundwater Modelling Report (GMR) prepared by EMM (EMM 2026c)
- the Surface Water Impact Assessment (SWIA) prepared by Engeny Australia Pty Ltd (Engeny 2026)
- the Aquatic Ecology and Groundwater Dependent Ecosystems (GDEs) Assessment prepared by Eco Logical Australia (ELA 2025)
- the Geochemical Assessment prepared by Environmental Geochemistry International Pty Ltd (Egi 2022a).

ES2 Water resources

Surface water resources in the vicinity of the HVO Complex include the Hunter River, Wollombi Brook and other ephemeral watercourses such as Farrells Creek and Parnells Creek. The Hunter River, and highly connected alluvial groundwater within 40 m of the river bank, is managed under the NSW *Water Sharing Plan for the Hunter Regulated River Water Source 2016*. The tributaries to the Hunter River are managed under the *Water Sharing Plan for the Hunter Unregulated and Alluvial Water Sources 2022*.

The *Water Sharing Plan for the North Coast Fractured and Porous Rock Groundwater Sources 2016* applies to the Permian groundwater resources in the area.

The main groundwater resources that could be impacted by the Project include:

- alluvial aquifers, occurring mainly along the Hunter River and Wollombi Brook
- Permian groundwater systems:
  - thin and variably permeable regolith, with limited saturated thickness
  - interburden aquitards
  - low to moderately permeable coal seams.

Water receptors include:

- downstream water users accessing surface water via WALs and basic landholder rights
- third-party landholder bores located upstream and downstream of the HVO Complex, typically installed in the alluvium
- ecosystems that potentially rely on surface water and/or groundwater:
  - river red gum stands (including in the Carrington Billabong area) that opportunistically access shallow groundwater recharged by leakage from the Hunter River and Wollombi Brook, and rely on flooding for germination
  - stygofauna occurring principally in alluvial sediments along the Hunter River and its tributaries
  - aquatic ecosystems
  - Warkworth Sand Woodland communities which rely principally on rainfall infiltration and a seasonal perched watertable observed to occur after large rainfall events.

Vegetation associated with the Central Hunter Valley Eucalypt Forest and Woodland critically endangered ecological community (CEEC) occur in areas where the watertable is greater than 20 m below ground level and are therefore unlikely to access groundwater.

The ecological surveys conducted for the Project observed that all vegetation stands were in low to moderate condition. In addition, the aquatic ecosystems surveyed as part of the aquatic ecology and GDE assessment (Annexure C) are considered to be in poor ecological condition, based on the macroinvertebrate community and water quality (the ecological condition of the Hunter River is classed as poor to moderate). Macroinvertebrate communities were dominated by taxa that are robust and tolerant of pollution and poor environmental conditions.

ES3 Assessment approach

Assessment of the Project considers the *Significant Impact Guidelines 1.3: Coal seam gas and large coal mining developments – impacts on water resources* (DCCEEW 2022), the Independent Expert Scientific Committee (IESC) *Information guidelines for proponents preparing coal seam gas and large coal mining development proposals* (2024), and relevant explanatory notes.

The water related assessments have been prepared in accordance with requirements of the Public Environment Report (PER) guidelines and NSW requirements.

The water technical assessments have been informed by extensive groundwater, surface water, ecological and geochemical monitoring and historical assessments for the existing operations. Impact pathway diagrams are presented in Section 6 to illustrate causal pathway for potential impacts from mining on water resources (including water-dependent assets).

The SWIA (Engeny 2026) included the following:

- Assessment of the Project WMS performance using a GoldSim water balance model, consistent with the water balance model used for the existing operations. The water balance modelling was based on 121 years of local rainfall data. All 121 years of data have been used for forecasting the potential range of responses of the site WMS using a Monte Carlo approach. This allows for a range of climate scenarios and season variability to be modelled to estimate the resilience of the proposed WMS to extreme conditions (i.e. historical flood and drought sequences).

- Streamflow impact assessment based on flow sequencing analysis (for the Hunter River and Wollombi Brook) and an Australian Water Balance Model for the ephemeral watercourses. The streamflow impact assessment was based on estimated changes in catchment areas and changes in surface water-groundwater interaction (i.e. changes in baseflow (groundwater discharge) and/or river leakage to groundwater).

- Assessment of potential cumulative surface water quality impacts based on outcomes of the water balance model and streamflow analysis (including assessment of potential impacts of approved HRSTS discharges).

- Flooding impact assessment using detailed flood modelling of the Hunter River in accordance with the methods recommended in *Australian Rainfall and Runoff 2019* (Ball et al 2019).

Evaluation of potential groundwater impacts has been informed by updated groundwater modelling (EMM 2026c), which was conducted using the existing HVO groundwater model (AGE 2022) which was updated to predict changes to groundwater levels and fluxes due to the Project, and predict potential changes to groundwater levels and flows in the area due to other mining in the area (i.e. cumulative effects).

The assessment of potential impacts on groundwater quality has been informed by the geochemical assessment (EGi 2022a) and the groundwater modelling.

An assessment of potential impacts of the final void and post closure impacts of the Project has been informed by:

- final void hydrology and salt balance modelling developed by Engeny (2026) to predict the pit lake recovery for the HVO North and South voids (with inputs from groundwater modelling)

- groundwater modelling conducted for the Project

- hydrogeochemical modelling to predict pit lake water quality characteristics.

The aquatic ecology and GDE assessment conducted by ELA for the Project (Annexure C) is based on the outcomes of groundwater modelling (EMM 2025c), streamflow impact assessment and surface water quality assessment (Engeny 2025), completed to support the HVO Amendment Report (EMM 2025a). ELA (2025) conducted a risk assessment based on the ecological value, potential impact and risk magnitude of the Project on aquatic ecology, aquifer ecosystems and GDEs. The risk assessment was also used to identify management and mitigation measures.

ES4 Assessment findings

ES4.1 Overview

The assessments show the Project can operate within and meet the requirements of the water regulatory framework.

ES4.2 Surface water impacts

Key outcomes of the SWIA and aquatic ecology assessment are as follows:

- The streamflow assessment included consideration of predicted changes to baseflow and river leakage to groundwater and found:
  - impacts on Hunter River and Wollombi Brook streamflow will be negligible
  - in addition, a decrease in the duration of dry periods is predicted at Wollombi Brook due to the removal of previously approved mining in the RSEE, SLP 1 and SLP 2 areas from the Project (specifically HVO South)
  - minor changes in streamflow is predicted for three ephemeral watercourses during operations. The minor changes to streamflow mainly relates to small reductions in catchment areas associated with mining extending between the existing West and Mitchell pits to Carrington Pit, and changes in surface water-groundwater interaction (i.e. watertable drawdown). The predicted change in streamflow will have a minor impact on the number of dry days, as many of these ephemeral watercourses are dry (on average) for more than half of the year under current conditions. Post mining, potential streamflow impacts are expected to be negligible.
- Potential impacts on surface water downstream users will be negligible as no changes in streamflow regimes are predicted in the Hunter River, given it is a regulated system and HVO holds sufficient entitlement for the predicted reduction in streamflow due to the Project (i.e. to offset streamflow losses).
- No impacts are predicted on the aquatic ecology of the Hunter River, particularly as flow will be mitigated through regulated releases from Glenbawn Dam, and only minor impacts to the aquatic ecology in the tributaries to the Hunter River are expected.
- The proposed WMS for the Project is predicted to maintain a sufficient water supply for the operation and discharge capacity to preventing flooding of operational areas of the mine or unplanned discharges.
- Potential cumulative impacts on surface water quality are expected to be minimal and will continue to be mitigated through an appropriately sized, designed and operated WMS, including release from sediment dams in accordance with their design and discharge of mine water in accordance with approved environment protection licence limits and HRSTS credits. Modelling indicates that the impact of approved HRSTS discharges will have a negligible impact on water quality. Concentrations of key analytes are predicted to remain within the existing ranges observed in the Hunter River.

- The WMS has been designed to control overflows from all water storages and runoff generated by the 1% AEP 24-hour design event (or smaller) will be contained on site. Therefore, the main mechanism for discharges from the HVO Complex to change surface water quality is through the use of the HRSTS for which HVO has sufficient credits.
- Water balance modelling indicates that overflows from sediment dams (not mine water dams) may occur at the HVO Complex when rainfall events exceed the design rainfall depths of the sediment dams. However, based on the conservative WMS design standards implemented and their proposed adaption with climate change, it is considered that the risk of sediment dam overflows will continue to be the same as the existing operations with the likelihood of overflows driven by the NSW design standards (the Blue Book (Landcom 2004)).
- The potential for increased erosion and sedimentation to the Hunter River during construction of new Hunter River bridge as part of Lemington Road realignment will be managed by the implementation of erosion and sediment control measures in accordance with *Managing Urban Stormwater: Soils and Construction, Volume 1 and 2* (Landcom 2004, DECC 2006) and HVO's Erosion and Sediment Control Protocol. Prior to commencement of the construction of the Lemington Road realignment and bridge on the Hunter River, an erosion and sediment control plan (ESCP) will be developed to establish and maintain erosion and sediment control measures for the duration of works.
- The flood modelling for the Project indicates minor flooding impacts to properties not owned by the HVO JV partners. The Project is predicted to result in minor additional flood level changes ranging between 20 to 50 millimetres (mm), but generally less than 30 mm, at 15 properties (being contiguous landholdings) not owned by the HVO JV. The impact is predicted to be minor, as the properties are already subject to flooding, and the maximum modelled change in flood affected area is estimated to be 0.15% of the total property for any individual property. In addition, the predicted change in flooding will not have an impact on the use of the land (agricultural (grazing and cropping) or Crown land).
- The main public infrastructure in the vicinity of HVO prone to flooding impacts is Lemington Road. Currently, Lemington Road at Moses Crossing becomes inundated during events smaller than 10% AEP, and has been closed for an average of 60 days per year since 2010. The proposed realignment and new Hunter River bridge crossing of Lemington Road will significantly improve the flood immunity of this road adjacent to the Hunter River. The new Hunter River crossing will exceed 10% AEP flood immunity during the Project and post closure.
- Velocity impacts are generally predicted to be localised around Project infrastructure (levees, Lemington Road, SLP 1). The magnitude of velocities in these areas generally remain within the existing ranges experienced and remain a low likelihood of causing scour (<2 metres per second).
- There are no broad scale changes to flood hazard categories forecast as a result of the Project. Small changes in road inundation durations were forecast; however, the small changes are not expected to have an impact on use of the land or public safety or emergency management. Overall, there is a significant benefit to the local community through improved immunity and access of the realigned Lemington Road.
- HVO holds more than sufficient entitlement to account for the predicted direct and indirect surface water take during operations.

- During the closure period:
  - take associated with runoff captured from storages on non-minor streams within the Jerry Water Source (Jerrys management zone) during the transition period that exceeds HVO's existing entitlement will be sourced from the open market (including trade, in accordance with the WSP rules). There is adequate share entitlement within the Jerrys Water Source for the predicted take. In addition, the Hunter Unregulated and Alluvial WSP allows for trade (permanently and temporarily) into the Jerrys Water Source from several (17) other upstream water sources. This demonstrates there is sufficient entitlement within the water source and upstream water sources for HVO to obtain additional entitlement via the open market
  - HVO will apply to convert sufficient aquifer entitlements to unregulated river entitlements for the predicted peak take associated with dams on non-minor streams in the Lower Wollombi Brook Water Source during closure.

The potential impact of the Project on surface water resources and aquatic ecology is insignificant.

ES4.3 Groundwater impacts and groundwater dependent ecosystems

Key outcomes of the groundwater impact assessment and GDE assessment are:

- Potential groundwater level drawdown impacts at third-party groundwater bores is very unlikely to negligible.
- The proposed HVO North Action and HVO South Action are predicted to result in negligible to minor increased drawdown in the alluvial aquifer(s), as mining will largely occur in areas previously mined or approved for mining under the existing development consent (e.g. Carrington West Wing area). In addition, construction of the approved (but not yet constructed) Carrington West Wing LPBW will be an effective mitigation measure to limit drawdown in the Hunter River alluvium and the potential for seepage from the backfilled mine areas to the alluvium. The potential impact on water quality is minor. In addition, a LPBW monitoring and management plan will be developed, including development of early warning trigger levels and response plan, identifying mitigation measures to manage potential unexpected effects.
- Minimal incremental drawdown (less than 0.2 metre (m)) is predicted in the Hunter River alluvium near mapped river red gum stands in the Carrington Billabong and dewatering will not occur. This predicted drawdown will be buffered by leakage through the riverbed. Therefore, no significant impact is predicted.
- No additional drawdown in the Wollombi Brook alluvium is predicted during operations. In contrast, the avoidance measure of removing mining in the RSEE, SLP 1 and 2 areas from the mine plan is predicted to result in a reduction in potential drawdown in the Wollombi Brook alluvium (in comparison to the mine plan currently approved at HVO South under the existing HVO South Approval).
- The predicted minor cumulative maximum drawdown in the Hunter River alluvium between HVO North and HVO South (during operations) is due to depressurisation of the Permian hydrostratigraphy and an associated downward vertical gradient between the alluvial watertable and the Permian potentiometric surface. The depressurisation is related to mining at HVO North and HVO South, and dewatering of the alluvium is not predicted to occur.

- In the Wollombi Brook alluvium, a maximum cumulative drawdown of up to 1 m is predicted in the area above the historical Lemington underground mine. Drawdown is predicted due to the simulated continued extraction of groundwater from the Lemington underground bore for operational water use, continuing the downward vertical gradient between the Permian groundwater systems and the Wollombi Brook alluvium. The coal seams intersected by Lemington underground mine subcrop under parts of the Wollombi Brook, creating minor cumulative drawdown slightly further downstream towards the confluence with the Hunter River. The drawdown is a cumulative impact and not due to the Project.

- HVO holds sufficient entitlement to account for the predicted groundwater take over the Project life and beyond in most water sources. Where the indirect take is predicted to exceed HVO's existing entitlement, HVO will either apply to convert sufficient existing unregulated river entitlements to aquifer entitlements or purchase additional entitlement required via the open market to account for the small predicted indirect take, prior to the take occurring.

- The potential for acid rock drainage or metal leachate is low as the majority of rejects generated by mining at the HVO Complex are likely to be non-acid forming. Thorough intermingling of rejects and overburden, and the excess acid neutralising capacity in the overburden, suggests that emplacement areas are unlikely to result in any significant acid rock drainage issues or effects on rehabilitation.

- The potential for seepage from backfilled mining areas to the alluvial watertable and Hunter River is very unlikely because:

    - there is no proposed change to waste management and pit backfill at HVO South or HVO North from the existing approved operation

    - during mining, the floor of the pit will be deep and intercepted groundwater will be actively managed as part of the mine WMS, resulting in depressurisation of the Permian strata and development of a steep hydraulic gradient towards the pit area. Therefore, the active mining areas will be groundwater sinks.

- Seepage losses from out of pit storages and open cut pits are expected to be minor. In addition, potential seepage from the upgraded dams (Parnells Dam and Lake James) will be managed by an embankment filter, cut-off design and treatment of batters within the storages. Based on historical monitoring (including at dams in the mine WMS and bores in alluvium downgradient from existing dams), water management measures and proposed design, potential impacts to alluvial groundwater quality are expected to be minor.

- Potential for seepage from tailings areas to alluvial (or other shallow) groundwater systems is unlikely, as the main pit voids will act as groundwater sinks and tailings will be managed to avoid placement above the base of weathering.

- No changes to the environmental, community and cultural values are predicted.

- The risk to the stygofauna community associated with the Project is low. The cumulative impact (including that associated with the mine plan currently approved under the HVO North Consent) to the stygofauna community in the paleochannel is high and is categorised in the GDE Risk Matrix as C (High Ecological Value, High Risk). However, the aquatic ecology and GDE assessment demonstrates that the predicted watertable drawdown will not prevent the long-term viability of the ecosystem in the Hunter River alluvium outside of the HVO North and HVO South Action areas. Therefore, it is predicted that the Project will not have a significant impact on stygofauna communities in the study area.

The potential impact of the Project on groundwater resources and receptors, including ecological receptors, is not significant.

ES4.4 Final void

Key outcomes of the final void assessment are as follows:

- The predicted long-term watertable and pit lake levels will be depressed, with groundwater flow directions towards the HVO North Void and HVO South Void.
- The runoff area contributing to the voids is sufficiently small so that evaporation dominates, and the voids remain as strong long-term groundwater sinks thereby attracting seepage from the surrounding strata (at a very low rate).
- Infiltration of rainfall in the backfilled mine areas will gradually flow towards the pit lakes, as evidenced by the groundwater particle tracking completed as part of the updated groundwater modelling (Annexure A), and the risk of seepage from the backfilled mine areas migrating through the existing and proposed barrier walls to the Hunter River alluvium is negligible.
- The long-term pit lake level is considerably deeper than the base of the alluvium and the base of weathering, therefore the risk of seepage from the pit lakes to shallow groundwater is negligible.
- Salinity is expected to continue to increase over time in the pit lakes until solubility limits are reached (i.e. when precipitation of salts occurs) and an “equilibrium” of salt species with inflows and interactions between salt species is achieved.
- The risk of spill from the pit lakes to the environment is negligible.
- The Project is predicted to have a negligible impact on Hunter River flow and flooding regime post mining.
- The Hunter River alluvium is predicted to remain saturated due to the strong hydraulic connection with the Hunter River.

Post mining incremental alluvial drawdown is not predicted to have a significant impact on GDEs or surface water resources.

River red gums and riparian vegetation that opportunistically use shallow groundwater will continue to have access to shallow alluvial groundwater. In addition, the Project is predicted to have a negligible impact on Hunter River flow and flooding regime post mining. Therefore, river red gum stands will continue to rely on flooding for germination.

ES5 Monitoring, management and mitigations

Following Project approval, if granted, the approved water management plan (WMP) will be reviewed and updated, including review of the existing surface water, groundwater and ecological monitoring, so that water management plan performance criteria and verification of assessment findings can be assessed. Most of the proposed management and mitigation measures listed in the water-related assessments are consistent with the existing mitigation measures in place at HVO. This is appropriate and to be expected given the generally small predicted incremental impact associated with the Project.

In addition to review and extension of the existing WMP and associated monitoring, HVO will expand the existing groundwater monitoring network to include additional monitoring bores in the Carrington West Wing alluvium area (south of the proposed LPBW). A network of approximately eight nested monitoring bores will be installed in this area, with separate bores screened within the alluvium and Permian strata. The bores will be installed approximately one year prior to mining commencing in the remnant paleochannel to allow collection of background groundwater level trends prior to the effects of mining.

In addition, piezometers will be installed downstream of the Carrington West Wing LPBW, consistent with the approach used for the existing Carrington Pit LPBW. The purpose of the piezometers would be to monitor for changes in salinity and pressure.

The locations and designs of the additional groundwater monitoring locations will be determined in consultation with the NSW Government relevant agencies during updates to the WMP and development of a low permeability barrier monitoring and management plan.

Design of the WMS components will, during the detailed design stages, consider future increases in rainfall intensities associated with climate change. Any changes to government guidance will be incorporated, as required, into detail designs for construction of new WMS components as well as augmentation/management changes for existing WMS components.

HVO has successfully constructed two LPBWs at the HVO Complex (Alluvial Lands in 1996 and Carrington Pit in 2010) in accordance with design requirements by the NSW Government, with design and construction by appropriately qualified and experienced engineers and contractors.

Condition 23 of the HVO North Consent lists specific design requirements for the Carrington West Wing LPBW, including:

- detailed design by a suitably qualified and experienced expert(s)
- the design endorsed by the NSW Government prior to construction
- the design achieves the relevant performance measures including:
  - applicable permeability of 10^{-8} metres per second or less
  - applicable Australian Standard 3798-2007
  - hydraulic, geomorphologic and seismic stability which will withstand any blasting-related vibrations, mining operations, fluvial and weather events, decay corrosive and biological attack.

Consistent with the approaches for the Carrington and Alluvial Lands LPBWs, the Carrington West Wing LPBW will be conservatively designed, through consultation with relevant NSW Government agencies, and constructed to meet the consent requirements.

As part of closure planning HVO will also undertake further detailed analysis and hydrogeochemical modelling to further evaluate the final void water quality and any actions that could improve final void water quality (e.g. post mining beneficial uses).

Abbreviations

Abbreviation	Definition
AEP	Annual Exceedance Probability
AGE	Australasian Groundwater and Environmental Consultants Pty Ltd
AIP	Aquifer Interference Policy
Al	Aluminium
ANZG	Australian and New Zealand Guidelines for Fresh and Marine Water Quality
As	Arsenic
AWBM	Australian Water Balance Model
BAM	Biodiversity Assessment Method
BC Act	NSW *Biodiversity Conservation Act 2016*
BoM	Bureau of Meteorology
Cd	Cadmium
CEEC	Critically endangered ecological community
Cl	Chloride
Co	Cobalt
Cr	Chromium
Cu	Copper
DCCEEW	Commonwealth Department of Climate Change, Energy, the Environment and Water
DPE Water	Department of Planning and Environment – Water
DPHI	Department of Planning, Housing and Infrastructure
EC	Electrical conductivity
EGi	Environmental Geochemistry International Pty Ltd
EIS	Environmental impact statement
ELA	Eco Logical Australia
Engeny	Engeny Australia Pty Ltd
EP&A Act	NSW *Environmental Planning and Assessment Act 1979*
EPA	NSW Environment Protection Authority
EPBC Act	*Environment Protection and Biodiversity Conservation Act 1999*
EPL	environment protection licence
Fe	Iron
GDEs	Groundwater Dependent Ecosystems
GHG	Greenhouse gas
GL	Gigalitre

Abbreviation	Definition
GMR	Groundwater Modelling Report
HCPP	Howick Coal Preparation Plant
HRSTS	Hunter River Salinity Trading Scheme
HVCPP	Hunter Valley Coal Preparation Plant
HVLP	Hunter Valley Load Point
HVO	Hunter Valley Operations
IEAPM	NSW Independent Expert Advisory Panel for Mining
IESC	Independent Expert Scientific Committee
JV	Joint venture
K	Potassium
Kh	Horizontal hydraulic conductivity
LCO	Liddell Coal Operations
LCPP	Lemington Coal Preparation Plant
LPB MMP	Low permeability barrier monitoring and management plan
LPBW	Low Permeability Barrier Wall
LTC	Level temperature conductivity
LUG bore	Lemington underground bore
m	Metres
m/s	Metres per second
mAHD	metres Australian Height Datum
Mg	Magnesium
mg/L	Milligrams per litres
MIA	Mine infrastructure areas
ML/day	Megalitres per day
ML/year	Megalitres per year
mm	Millimetres
Mn	Manganese
MNES	Matters of national environmental significance
Mtpa	Million tonnes per annum
MTW	Mount Thorley-Warkworth
Na	Sodium
NAF	Non-acid forming
NAG	Net acid generation

Abbreviation	Definition
Ni	Nickel
NLP	Newdell Load Point
NRAR	Natural Resources Access Regulator
NSW	New South Wales
NSW DCCEEW	NSW Department of Climate Change, Energy, the Environment and Water
NZF Act	NSW *Climate Change (Net Zero Future) Act 2023*
PAF	Potential acid forming
PER	Public Environment Report
PMF	Probable Maximum Flood
PMP	Probable Maximum Precipitation
POEO Act	NSW *Protection of the Environment Operations Act 1997*
RCP	Representative Concentration Pathway
RFI	Request for information
ROM	Run of-mine
RSEE	Riverview South East Extension
SEARs	Secretary's Environmental Assessment Requirements
SILO	Scientific Information for Land Owners
SLP	South Lemington Pits
SO_4	Sulphate
Sr	Strontium
Ss	Specific storage
SSD	State significant development
SWIA	Surface Water Impact Assessment
Sy	Specific yield
TARP	Trigger action response plans
TDS	Total dissolved solids
TSF	Tailings storage facility
TSS	Total suspended solids
µS/cm	Microsiemens per centimetre
WAF	Water Accounting Framework
Water Act	*Water Act 1912*
WM Act	NSW *Water Management Act 2000*
WMP	Water management plan

Abbreviation	Definition
WMS	Water management system
WRIA	Water resources impact assessment
WVP	Vibrating wire piezometer
Zn	Zinc

TABLE OF CONTENTS

Annexures

Tables

Figures

1 Introduction

1.1 Background

Hunter Valley Operations (HVO) is a well-established multi-pit open cut coal mining complex in the Hunter Valley of New South Wales (NSW). HVO comprises two mine sites separated by the Hunter River; HVO North and HVO South (Figure 1.1 and Figure 1.2). While the two mine sites are separated by the Hunter River, they are operated as one complex with fully integrated environmental management systems. The HVO Complex is illustrated at a local scale in Figure 1.2.

Operations first commenced at HVO over 70 years ago, in 1949. Since its inception HVO has been, and continues to be, an important contributor to the Hunter Valley and NSW economy, producing high quality thermal and semi-soft coking coal suitable for use in international and domestic markets.

1.1.1 State approvals

HVO operates under separate approvals granted under the NSW *Environmental Planning and Assessment Act 1979* (EP&A Act). HVO North operates under Development Consent DA 450-10-2003 (as modified) issued by the then NSW Minister for Infrastructure and Planning in 2004, which allows extraction of up to 22 million tonnes per annum (Mtpa) of run of-mine (ROM) coal until 31 December 2026. Development Consent DA 450-10-2003 is herein referred to as the HVO North Consent. HVO North comprises the approved mining areas of West Pit, Mitchell Pit, Carrington Pit and North Pit as shown in Figure 1.2, as well as the Hunter Valley Coal Preparation Plant (HVCPP), the Howick Coal Preparation Plant (HCPP), and the Howick and HVO North mine infrastructure areas (MIA). The train loading facilities at the Newdell Load Point (NLP) and Hunter Valley Load Point (HVLP) are also at HVO North, as shown in Figure 1.2.

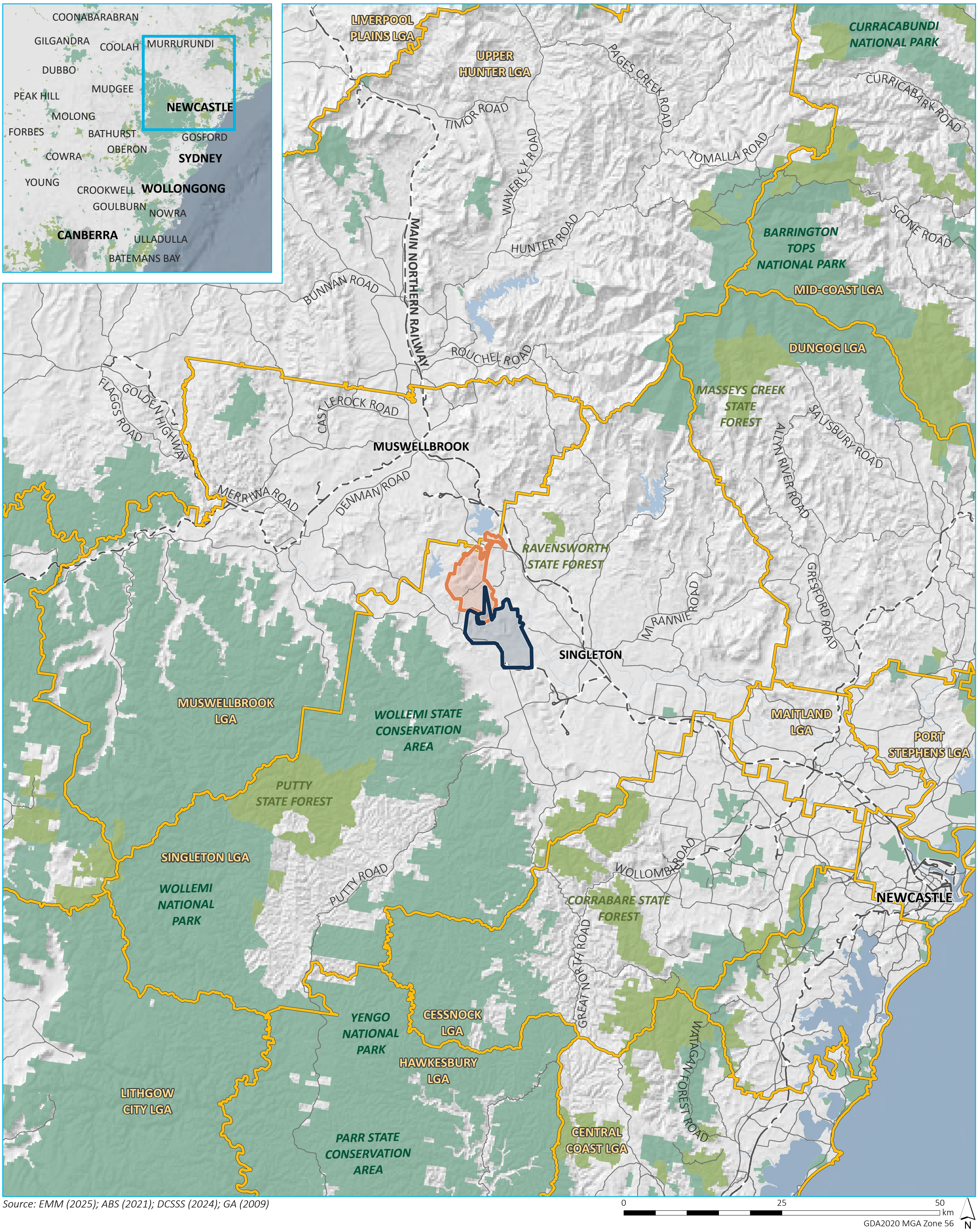
HVO South operates under Project Approval 06_0261 (as modified) issued by the then NSW Minister for Planning in 2009 and comprises the approved mining areas of Riverview Pit, Cheshunt Pit, Riverview South East Extension (RSEE) and South Lemington Pits (SLP) 1 and 2, as well as the MIA, and the Lemington CPP (LCPP) and rail loop (both approved but not constructed) as shown in Figure 1.2. Project Approval 06_0261 allows extraction of up to 20 Mtpa of ROM coal at HVO South until 24 March 2030. Project Approval 06_0261 is herein referred to as the HVO South Approval.

Significant coal resources remain across the HVO Complex beyond what is currently approved for extraction under the EP&A Act. HVO has undertaken extensive investigations into a long-term plan for the complex beyond the approved mine life to increase recovery of the remaining coal resources using existing infrastructure, while balancing social, environmental and economic outcomes. Based on the outcomes of these investigations, HVO is seeking the relevant approvals under the EP&A Act for the HVO Continuation Project (herein referred to as the Project).

In December 2022, HVO lodged two State significant development (SSD) applications with the NSW Department of Planning, Housing and Infrastructure (DPHI) under the EP&A Act, as follows:

- SSD-11826681 - HVO North Open Cut Coal Continuation Project.
- SSD-11826621 - HVO South Open Cut Coal Continuation Project.

The SSD applications were supported by one environmental impact statement (EIS) titled *Hunter Valley Operations Continuation Project, Environmental Impact Statement* (EMM 2022).



Source: EMM (2025); ABS (2021); DCSSS (2024); GA (2009)

\\emm.local\xdrive\Secured\Divisions\H190408\GIS\02_Maps_2025StandardReport\SR001_RegionalContext\SR001_RegionalContext_20250612_02.aprx 18/09/2025

KEY

- Existing HVO North development consent boundary (DA 450-10-2003)
- Existing HVO South project approval boundary (PA 06_0261)

Existing environment

- Rail line
- Major road
- Named watercourse
- Named waterbody
- NPWS reserve
- State forest
- Local government area

INSET KEY

- NPWS reserve
- State forest

Regional locality

HVO Continuation Project
Water Resources Impact Assessment
Figure 1.1

EMM creating opportunities

Source: EMM (2025); Glencore (2025); DCSSS (2024); GA (2009)

0 2.5 5 km
GDA2020 MGA Zone 56
N

KEY

- Existing HVO North development consent boundary (DA 450-10-2003)
- Existing HVO South project approval boundary (PA 06_0261)
- South Lemington Rail Loop and haul route (approved, not yet constructed)

Existing environment

- Rail line
- Major road
- Named watercourse
- Named waterbody
- NPWS reserve

Local context

HVO Continuation Project
Water Resources Impact Assessment
Figure 1.2

EMM
creating opportunities

The EIS was prepared in accordance with the Secretary's Environmental Assessment Requirements (SEARs) issued for HVO North and South on 11 March 2021, and the *State Significant Development Guidelines* (DPIE 2021). The EIS was placed on public exhibition for a period of four weeks from Monday, 30 January 2023 through to Monday, 27 February 2023.

During the public exhibition of the EIS, a total of 1,060 submissions were received by DPHI from individuals, organisations, public authorities, councils, and government agencies for the two SSD applications. Most community submissions supported the Project. NSW Government submissions provided advice to DPHI on the applications.

To respond to matters raised in submissions on the Project, a Submissions Report (EMM 2023a) was prepared, along with an amendment report (EMM 2023b) outlining proposed amendments to the HVO North Project (the HVO North Amendment Report).

During the subsequent assessment of the Project by DPHI, the Department issued a number of requests for information (RFI) to HVO, who provided responses as required. In March 2024, DPHI requested the NSW Independent Expert Advisory Panel for Mining (IEAPM) conduct an assessment of the Project in respect to water resources and greenhouse gas (GHG) emissions. The IEAPM advice concluded that:

- in relation to water-related impacts, there is no reason why the Project should not be conditionally approved
- in relation to GHG emissions, the IEAPM acknowledged that the only fugitive emissions avoidance measure available is changes to the mine plan that restricts the areal extent of mining and that a significant fugitive emissions avoidance measure at HVO would be not to mine Zones 2, 3 and 4 in gas Domain 1.

On 5 July 2024, a further RFI from DPHI was received by HVO, which included supporting information made up of correspondence to the Planning Secretary from the Hon Paul Scully (Minister for Planning and Public Spaces) and the Hon Penny Sharpe (Minister for Climate Change, Minister for Energy, Minister for the Environment and Minister for Heritage) regarding consideration of the NSW *Climate Change (Net Zero Future) Act 2023* (the NZF Act) which was enacted after the SSD applications were lodged. In his correspondence to the Planning Secretary, the Minister for Planning and Public Spaces acknowledged that NSW is not on track to meet its 2030 and 2035 targets of the NZF Act without action by the NSW Government and private sector. Further, it was reiterated that agencies involved in the decision-making process within the planning system have regard to the NSW Government's emission reduction targets, the guiding principles for the NZF Act, and the then draft *NSW Guide for Large Emitters* (now finalised, EPA 2025) and the new climate change assessment requirements for large emitters.

The RFI from DPHI stated that, in light of the correspondence from the Minister and the conclusions of the IEAPM, the Department requested that HVO provide a response that further considered the implications for the Project if all coal extraction from gas Domain 1 at HVO North was avoided and for HVO to have further consideration of the guiding principles of the NZF Act.

In response to the RFI, HVO completed a detailed review of the Project and has amended the SSD applications for the Project, which includes, amongst other things, the removal of coal extraction in gas Domain 1. To document and assess the amendments to the Project, a second amendment report (EMM 2025a) was prepared and submitted to DPHI (the HVO Amendment Report).

At the time of publication of this report, DPHI were undertaking its assessment of the Project.

1.1.2 Commonwealth approval

There is one existing approval under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) relating to the HVO Complex: EPBC 2016/7640, which allows for the continuation of coal mining operations in areas within the HVO Complex that were previously approved under the EP&A Act after the commencement of the EPBC Act. EPBC 2016/7640 is herein referred to as the HVO EPBC Act Approval.

A second referral (EPBC 2016/7641) was also submitted in 2016 relating to the extension of open cut coal mining operations at HVO South and proposed deeper mining in the Bayswater Seam within the Riverview Pit area. This action was considered not likely to significantly impact on a water resource and was determined as not a controlled action by the Minister on 20 March 2018.

On 16 April 2025, two EPBC referrals for the Project were submitted to the Commonwealth Department of Climate Change, Energy, the Environment and Water (DCCEEW), being:

- EPBC 2025/10177 – HVO North Project (the HVO North Action)
- EPBC 2025/10176 – HVO South Project (the HVO South Action).

On 27 and 28 October 2025, a delegate of the Minister for the Environment determined that approval is required before the proposed the HVO North Action and HVO South Action can commence as they are likely to have a significant impact on the following matters protected by the EPBC Act:

- listed threatened species and communities (sections 18 and 18A)
- a water resource, in relation to unconventional gas development and large coal mining development (sections 24D and 24E).

The delegate also determined that the proposed actions will be assessed by public environment reports (PERs); one for HVO North and one for HVO South. DCCEEW subsequently issued guidelines for the content of the PERs (the PER guidelines) on 30 January 2026.

Further details on the Commonwealth approvals for the Project, both existing and proposed, are contained in chapters 1 and 2 of the draft PERs for the HVO North Action (EMM 2026a) and HVO South Action (EMM 2026b).

1.2 Project overview

The Project broadly comprises the continuation of the life of HVO North and HVO South, from the current approved mining completion dates of 31 December 2026 and 24 March 2030 respectively, to the end of 2045 at HVO North and the end of 2042 at HVO South. The continuation of mining across the HVO Complex will increase resource recovery from the existing operation, predominantly by mining through previously mined areas and to the extent of existing mining tenements and extracting coal from deeper seams at HVO North (excluding Carrington West Wing extension area where mining depth is proposed to occur as approved).

At HVO South an extension to the life of the mine is proposed to facilitate improved mine sequencing outcomes and reduction in mining rate. The Project proposes a reduced mining footprint at HVO South compared to what is currently approved for extraction by the existing HVO South Approval, with the previously approved coal extraction in the RSEE area and SLP 1 and 2 areas proposed to be removed from mine plan (and future approvals) for the Project. However, some rehabilitation works will be required to be undertaken in the SLP 1 area, as part of the mine closure process. The approved construction and operation of the LCPP and associated rail facilities, which is currently approved (but not constructed) under the HVO South Approval, has also been removed from the Project.

A number of infrastructure upgrades and changes are also required to facilitate the Project (and are included as part of it), including realignment of part of Lemington Road to enable the continuation of mining at HVO North, relocation of transmission and telecommunication lines, an upgrade of the Newdell LP including construction of a new product stockpile and train loading bin, an upgrade of the HVLP product stockpile including an extension to the existing coal stockpile, expansion of the HVO North ROM coal stockpile and improvements to Lake James (Dam 15S) and Parnells Dam (Dam 9W).

A detailed description of the HVO North Action is provided in Section 3 of the HVO North Public Environment Report (PER) (EMM 2026a). A detailed description of the HVO South Action is provided in Section 3 of the HVO South PER (EMM 2026b). The proposed conceptual layout of the Project inclusive of both HVO North and HVO South Action areas is provided in Figure 1.3.

1.3 Project terminology

Key terms used throughout this report are defined below:

- HVO Complex: The combined operations of HVO North and HVO South.
- HVO North: Existing operations authorised by the HVO North Consent and the HVO EPBC Act Approval.
- HVO North Action Area: Area defined on Figure 1.3. The HVO North Action Area is consistent with the proposed State Development Consent boundary sought under the SSD application under the EP&A Act (SSD-11826681).
- HVO South: Existing operations authorised by the HVO South Approval and the HVO EPBC Act Approval.
- HVO South Action Area: Area defined on Figure 1.3. The HVO South Action Area is consistent with the proposed State Development Consent boundary sought under the SSD application under the EP&A Act (SSD-11826621).
- The Project: The HVO Continuation Project in its entirety, as described in Section 3.1 of the PERs, encompassing the continuation of the life of the complex, i.e. both HVO North and HVO South, within their respective proposed action areas, as illustrated in Figure 1.3. Approval for the Project is sought by:
  - HVO North:
    - SSD-11826681 (under the NSW EP&A Act)
    - EPBC 2025/10177 (under the EPBC Act)
  - HVO South:
    - SSD-11826621 (under the NSW EP&A Act)
    - EPBC 2025/10176 (under the EPBC Act).
- Study area: Area defined on Figure 1.5.
- Approved operation: Existing operations authorised by the HVO North Consent, the HVO South Approval and the HVO EPBC Act Approval.

1.4 Purpose of this report

This water resources impact assessment (WRIA) forms part of the PER and provides an assessment of the potential impacts of the Project on water resources including water-dependent assets (incremental and cumulative, where possible). This WRIA is an overarching report documenting and summarising the findings of the different water-related technical assessments conducted for the Project, including:

- the Groundwater Modelling Report (GMR) prepared by EMM (EMM 2026c), attached in Annexure A
- the Surface Water Impact Assessment (SWIA) prepared by Engeny Australia Pty Ltd (Engeny 2026), attached in Annexure B
- the Aquatic Ecology and Groundwater Dependent Ecosystems (GDEs) Assessment prepared by Eco Logical Australia (ELA 2025), attached in Annexure C
- the Geochemical Assessment prepared by Environmental Geochemistry International Pty Ltd (EGi 2022a), attached in Annexure D.

The WRIA documents the methods and results of the studies listed above, initiatives to avoid and minimise impacts and additional mitigation and management measures proposed to address residual impacts not able to be avoided.

As noted above, an EIS was submitted in 2022 to support the SSD applications under the EP&A Act. The EIS was supported by various technical assessments that commenced in 2020 and included:

- groundwater modelling and impact assessment prepared by AGE (2022)
- a SWIA prepared by Engeny (2022)
- an Aquatic Ecology and GDE Assessment prepared by ELA (2022)
- the Geochemical Assessment prepared by EGi (2022a).

The groundwater and surface water studies were peer reviewed and found to be fit for the intended purpose. Those studies were used to support the HVO Amendment Report (EMM 2025a) submitted to DPHI, and reported in a Water Assessment Report (EMM 2025b) that supported the HVO Amendment Report. The approach to methodologies and model designs for the assessments completed to support the PERs are consistent with and based on the methods and designs used for the NSW State approval applications. The outcomes of the PER related studies are consistent with those presented in the Water Assessment Report (EMM 2025b):

- water management system (WMS) performance including water surplus and deficits informing supply and discharge requirements
- streamflow and surface water quality impact assessment
- changes in flooding characteristics
- groundwater incremental and cumulative drawdown effects
- pit lake recovery modelling
- potential impacts on water resources and water dependent assets (including GDEs).

Figure 1.4 illustrates the inter-relationships and overarching approach between the water-related studies from 2020 to 2025, including the studies used to inform the EIS, HVO Amendment Report and this WRIA. Further discussion on the approaches to the studies and assessments is provided in Section 6 and the attachments to this report.

1.5 Assessment requirements

The water related assessments have been prepared in accordance with requirements of the PER guidelines for HVO North and HVO South. Appendix A of the PERs (EMM 2026a and 2026b) lists the PER guidelines and where they are addressed in the technical reports.

The WRIA and supporting technical studies have been undertaken in accordance with the Independent Expert Scientific Committee (IESC) *Information guidelines for proponents preparing coal seam gas and large coal mining development proposals* (2024) and with consideration of relevant explanatory notes (discussed further in Section 3). Annexure E of this report also includes a checklist of the IESC requirements relevant to the water technical studies and where they are addressed.

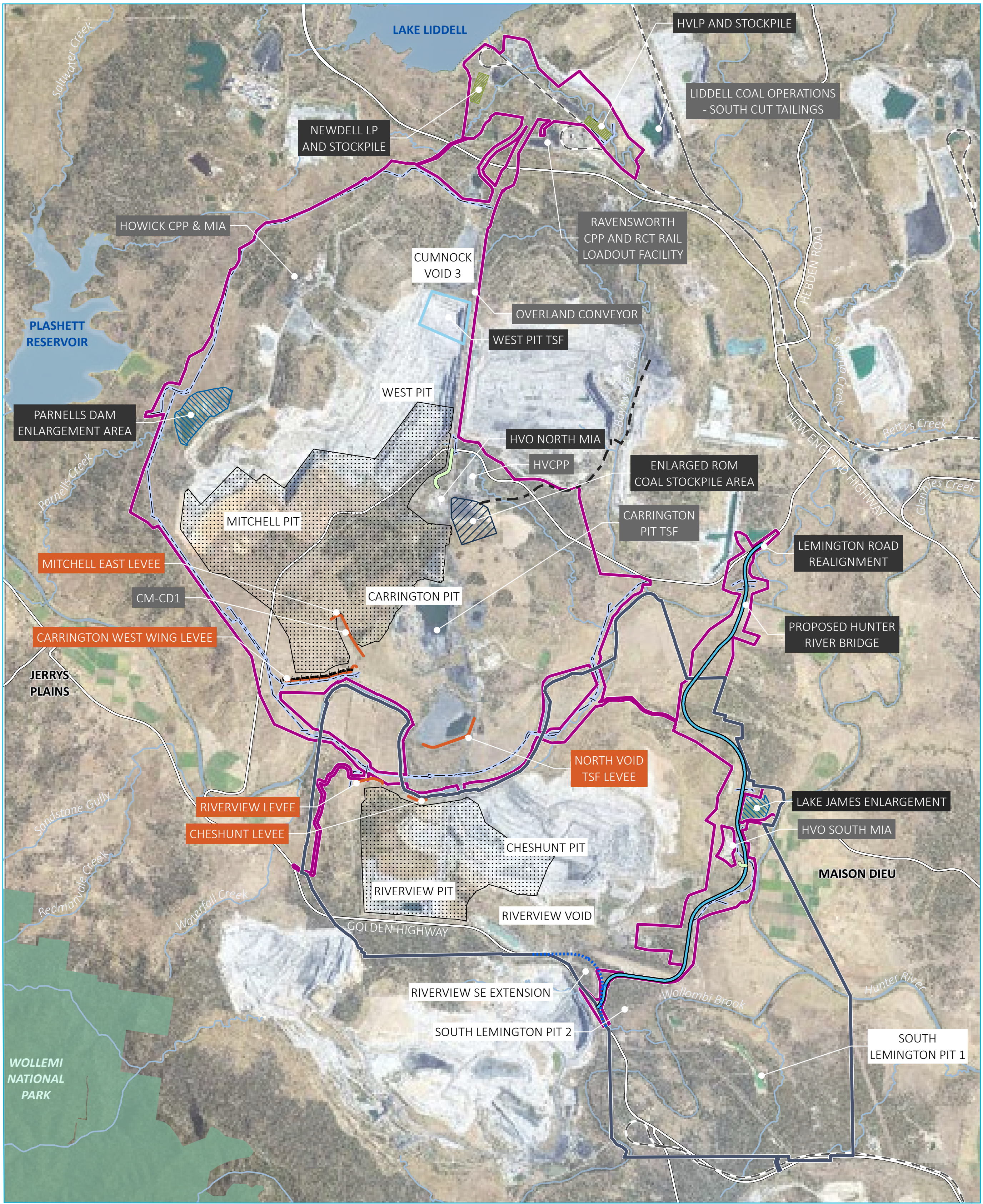
1.6 IESC review and advice

In response to specific questions from the Commonwealth DCCEEW, the IESC completed a review of the WRIA (version 3, dated 16 October 2025) and provided advice (dated 10 December 2025) titled *IESC 2025-161: Hunter Valley Operations (HVO) North Open Cut Coal Continuation Project (EPBC 2025/10177) and Hunter Valley Operations (HVO) South Open Cut Coal Continuation Project (EPBC 2025/10176) – Expansion* (IESC Advice).

The IESC Advice water-related questions included:

- Question 1 – Does the IESC consider the decision maker can have confidence in the impact assessment, modelling and impact predictions provided? In particular, are the water balance and groundwater models adequate to understand the risks to water resources? If not, what additional data and information should be provided?
- Question 2: Do the water assessment reports identify effective strategies to avoid, mitigate or reduce the likelihood, and extent of impacts, including cumulative impacts to water-related resources? In particular:
  - a) Are the design plans for the Carrington West Wing barrier wall sufficient to mitigate groundwater flows from the Hunter aquifer into Carrington Pit?
  - b) Are the flood levees appropriate to mitigate the modelled flood risks to the mine?
  - c) What, if any, additional surface water monitoring parameters should be included in the surface water monitoring program?
  - d) Does the final landform design appropriately mitigate the risk of offsite seepage migration?
- Question 3: Are there any additional mitigation, monitoring, management or offsetting measures that should be considered?

The WRIA and supporting technical reports have been updated to address the advice from the IESC. A summary of responses to the IESC Advice is provided at Annexure G.



\\emm.local\xdrive\Secured\Divisions\H190408\GIS\02_Maps_2025AmendmentReport\AR006_HVONorthSouthComplexConceptualLayout\AR006_HVONorthSouthComplexConceptualLayout_20250930_05.aprx 2/10/2025

Source: EMM (2025); Glencore (2025); DCSSS (2024); GA (2009)

KEY

- HVO North Action Area
- HVO South Action Area

Proposed HVO continuation project element

- Approved barrier wall (not yet constructed)
- Alternative Golden Highway alignment
- Lemington Road realignment
- Levee
- Mine access road
- Proposed haul route to Ravensworth Operations
- Proposed transmission line relocation
- Dam enlargement
- Mining area
- Product stockpile
- ROM coal stockpile area
- West Pit TSF

Existing environment

- Rail line
- Major road
- Named watercourse
- Named waterbody
- NPWS reserve

Label format

- Existing item
- Levee
- Project related item

HVO Complex conceptual layout

HVO Continuation Project
Water Resources Impact Assessment
Figure 1.3

EMM
creating opportunities

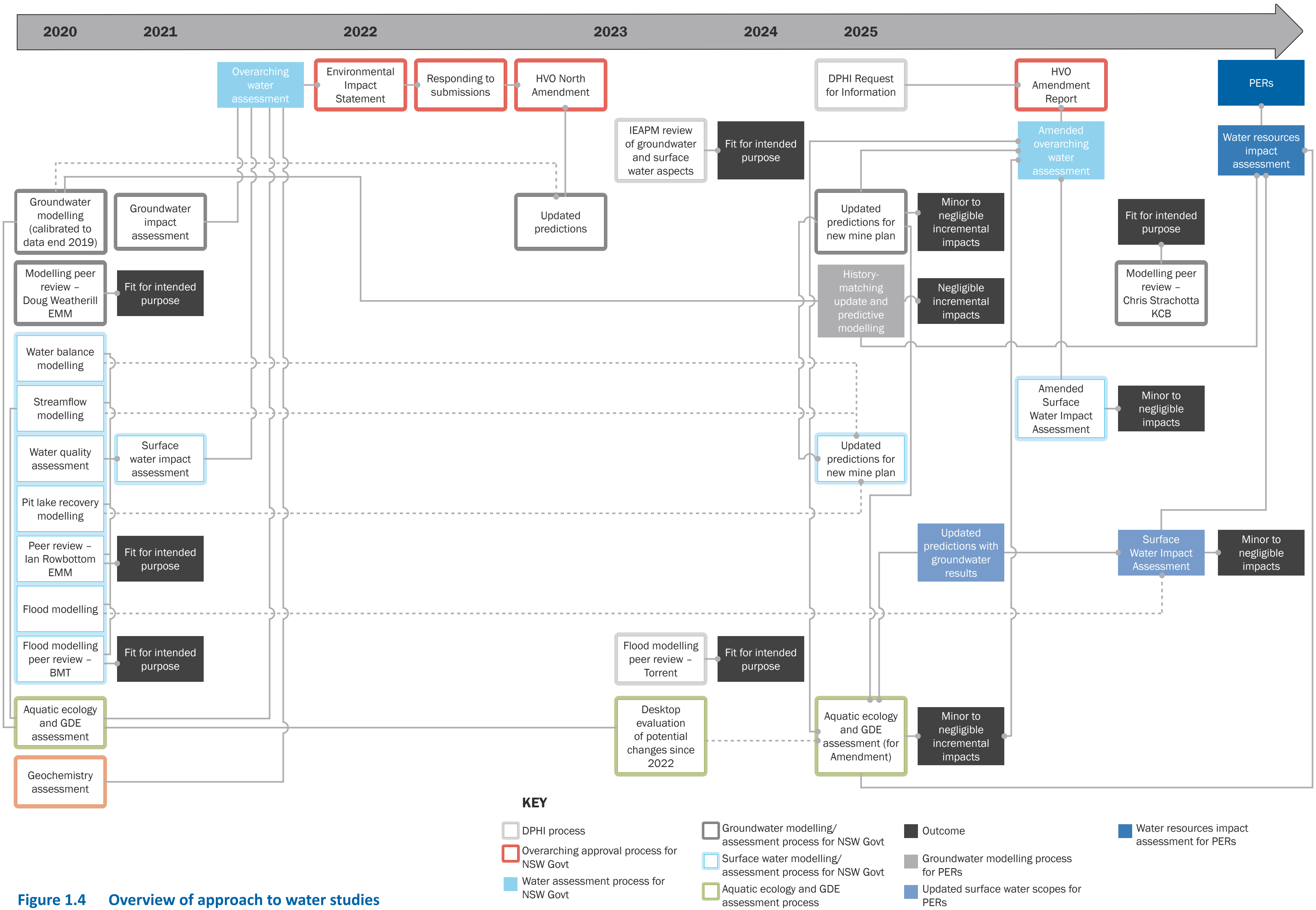


Figure 1.4 Overview of approach to water studies

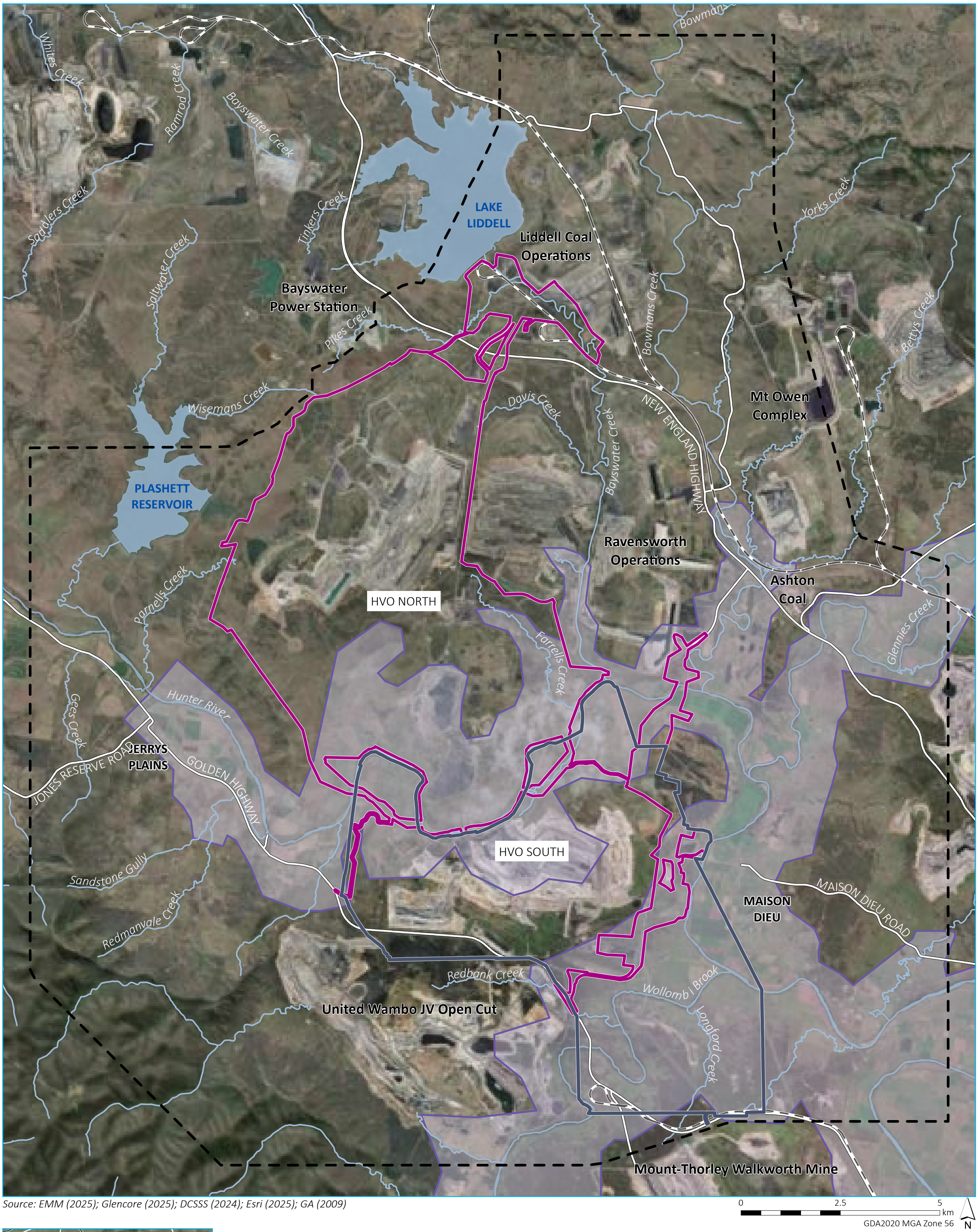
1.7 Water study areas

Each technical assessment (as discussed in Section 1.4) focused on a particular area that was relevant to the subject matter. For example, the study area for the GMR is larger than that considered in the water balance. The study area for each technical assessment is listed in Table 1.1. The combination of these study areas is the overall study area for this WRIA report.

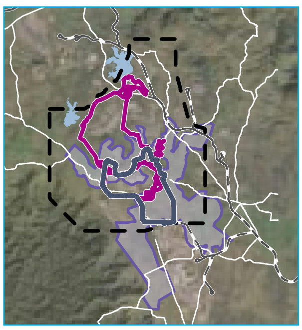
The study areas are illustrated in Figure 1.5.

Table 1.1 Study areas for each technical assessment

Technical assessment	Study area
WMS and water balance model	HVO North Action and HVO South Action Areas (Figure 1.5).
Streamflow impact assessment and water quality assessment	The Hunter River in the study area and associated tributaries: • Parnells Creek • Farrells Creek • Pikes Creek • Bayswater Creek • Wollombi Brook • unnamed tributaries draining into Hunter River and Wollombi Brook in the study area. Refer to Figure 1.5.
Flooding	Floodplain of the Hunter River and Wollombi Brook (Figure 1.5). Model downstream boundary: • approximately 3 kilometres (km) downstream of Singleton. Upstream boundaries: • Hunter River – approximately 2 km upstream of the Liddell gauge • Bowmans Creek – at the confluence of Bowmans Creek and the Hunter River • Glennies Creek – approximately 5 km upstream of the confluence with the Hunter River • Wollombi Brook – in the vicinity of the Warkworth Gauge, approximately 6.5 km upstream of the confluence with the Hunter River.
Groundwater model	The 2025 model domain remains unchanged from the 2022 groundwater modelling to support the EIS (EMM 2022). The model domain was designed by AGE (2022), to be adequately large enough to: • encompass all the identified potential receptors • include the main hydrogeological boundary conditions influencing groundwater flow • encompass anticipated changes to the groundwater system in relation to mining and tailings seepage • simulate potential cumulative changes to the groundwater system associated with other, nearby mines.
Geochemistry characterisation	HVO North Action and HVO South Action Areas (Figure 1.5).
Aquatic ecology and GDE assessment	Hunter River in the study area including survey locations from approximately 6 km upstream of Parnells Creek confluence and downstream of the Wollombi Brook confluence (Figure 1.5). Surveys were also conducted at locations within the study area: • Bayswater Creek upstream • Farrells Creek • Bowmans Creek, just upstream of the confluence with the Hunter River • Wollombi Brook near HVO South and Warkworth Bridge.



Source: EMM (2025); Glencore (2025); DCSSS (2024); Esri (2025); GA (2009)



KEY

- HVO North Action Area
- HVO South Action Area
- Groundwater model extent
- Flood model boundary

Existing environment

- Rail line
- Major road
- Named watercourse
- Named waterbody

Water study area

HVO Continuation Project
Water Resources Impact Assessment
Figure 1.5

EMM
creating opportunities

\\emm.local\xdrive\Secured\Divisions\H190408\GIS\02_Maps_2025AmendmentWA\AWA001_WaterStudyArea\AWA001_WaterStudyArea_20250616_02.aprx 8/10/2025

2 Project context

2.1 Existing water management

2.1.1 Water management system

The HVO Complex currently operates under an integrated WMS across HVO North and South, in accordance with the approved water management plan (WMP). The integrated mine WMS also facilitates approved water transfers with other mining operations (Mount Thorley Warkworth (MTW) via the Lemington Underground which is used for water storage and water access), Wambo, Liddell Coal Operations (LCO; via LPs), and Ravensworth Operations (via the Cumnock Void 3 tailings decant return). Water to support operations is also sourced from the Hunter River under relevant water access licences (WALs) held by HVO.

Key water management components at the HVO Complex include water storages, licensed discharge points, Hunter River pumping stations, approved flood protection levees, and low permeability barrier walls (LPBWs) at HVO North, which have been constructed in the eastern arm of the paleochannel in the Carrington Pit area and in the Alluvial Lands. The purpose of these LPBWs is to limit the groundwater drainage from the mined areas and potential for seepage from the backfilled areas towards the Hunter River. Construction of another LPBW is also approved (by NSW Government) in the Carrington West Wing area in the western arm of the paleochannel; however, this LPBW has not been constructed due to the Carrington West Wing area not being mined to date. The diversion of an Unnamed Tributary (Unnamed Tributary 1) to the west of Carrington West Wing is also approved; however, similarly to the Carrington West Wing LPBW, this has not yet been diverted due to mining operations not commencing in the Carrington West Wing.

The existing WMS for the HVO Complex consists of a network of infrastructure (dams, pipelines, contour banks) to control the movement of water around the HVO Complex. Water is shared between HVO South and HVO North via pipelines across the Hunter River bridge. HVO uses sufficient water storage capacity to minimise against drought and flood interruptions and prevent off site discharge except in accordance with the Environment Protection Licence (EPL) 640 which was issued under the NSW *Protection of the Environment Operations Act 1997* (POEO Act).

HVO holds a water licence to access water from the decommissioned Lemington underground mine workings via the Lemington underground bore ('LUG bore'). The bore can supply water to both HVO and the neighbouring MTW mining operation.

Water is managed according to type whether it be mine water, sediment water or clean water (Table 2.1).

Table 2.1 HVO WMS water classification

Water category	Description
Clean	Runoff from undisturbed or rehabilitated areas.
Sediment	Runoff from disturbed areas (does not include water captured in mining pit areas or runoff from mine infrastructure areas where the water has been in contact with coal). Runoff draining away from pits where overburden stockpile areas have been shaped but without established ground cover.
Mine	Runoff from areas exposed to coal or water used in coal processing or from coal stockpile areas. Runoff draining into pits from the active/unshaped overburden that forms the low wall.

The WMS is designed to:

- minimise water abstraction from the Hunter River to meet water supply deficits (through existing entitlement)
- minimise impacts to the environment and neighbours
- provide adequate water to facilitate the processing of coal and dust suppression to minimise interference with mining production, with preferential use of mine water for coal preparation and dust suppression
- recycle on-site water
- control discharge of water to the environment in accordance with statutes and regulations.

Where possible, surface water is diverted away from disturbed areas at the HVO Complex via clean water diversions to minimise impact to the receiving environment.

The surface water monitoring program, under the WMP, includes monitoring surface water quality at several locations both upstream and downstream of the HVO Complex. The WMP monitors compliance with State approval conditions and contains mechanisms to minimise impacts to surface water resources.

Key existing water management components are identified in Figure 2.1. Further discussion on the existing and proposed water management infrastructure for the Project is provided in Annexure B.

2.1.2 Tailings

Fine rejects (tailings) have been emplaced in various approved tailings storage facilities (TSFs) across the HVO Complex. Currently, tailings are emplaced within approved TSFs in Carrington Pit as well as Cumnock Void 3 (Dam 22W) under agreement with Ravensworth Operations to utilise the void capacity. Tailings from the HCPP are currently pumped via a pipeline to Cumnock Void 3, while tailings from the HVCPP are pumped via a pipeline to the Carrington Pit TSF.

Intermittent deposition of tailings occurs in the North Void TSF, Dam 6W TSF and Central TSF (Dam 28N) as part of ongoing management towards decommissioning. The South East TSF (Dam 27N) has recently been capped, with the sump to be backfilled for closure. Prior to TSFs reaching capacity a detailed closure plan is developed for the individual facility to determine effective closure requirements including capping depth.

Existing TSF areas are shown on Figure 2.1.

2.1.3 Discharge of excess water

HVO holds approval to release water from the complex via licensed discharge points into the Hunter River under EPL 640 and the Hunter River Salinity Trading Scheme (HRSTS). Discharges are only allowed during high and flood flow periods in the Hunter River (refer to Annexure B for further detail).

EPL 640 also includes licensed discharge from the Alluvial Lands. This discharge point has specific discharge parameters, in accordance with EPL 640 and is not regulated under the HRSTS.

The HRSTS operates to minimise the impact of saline water discharges from industry on the Hunter River. This is done by allowing saline water to be discharged only at times of high flow or flood, when it is diluted by the Hunter River. When the river is in low flow, no discharges are allowed. The objective of the scheme is to manage saline water discharges to minimise impacts on irrigation, other water uses, and on the aquatic ecosystems of the Hunter River catchment.

Source: EMM (2025); Glencore (2025); DCSSS (2024); GA (2009)

KEY

- Existing HVO North development consent boundary (DA 450-10-2003)
- Existing HVO South project approval boundary (PA 06_0261)
- Hunter River pump station
- Licensed discharge facility
- Approved barrier wall (not yet constructed)
- Low permeability barrier wall
- Existing levee
- Levee

Dam water type

- Freshwater
- Saline
- Sediment
- Tailings

Existing environment

- Rail line
- Major road
- Named watercourse
- Named waterbody
- NPWS reserve

Key existing water management aspects

HVO Continuation Project
Water Resources Impact Assessment
Figure 2.1

EMM
creating opportunities

2.2 Key water affecting activities of the Project

Key aspects of the HVO North and HVO South water management activities and infrastructure is shown on Figure 2.2 and described below.

2.2.1 HVO North Project key elements

Key project elements (that differ to the approved operations) with the potential to affect water resources and water-dependent assets at HVO North comprise the following:

- Extending the mine life from the current approved cessation date of 31 December 2026 until 31 December 2045, including increasing the mining extent (to the base of the Barrett Seam) in the area between the existing West and Mitchell Pits to Carrington Pit. Noting that mining will occur as per the existing HVO North Consent in the Carrington West Wing extension area (to the base of the Bayswater Seam).

- The proposed realignment and new Hunter River bridge crossing of Lemington Road. This will significantly improve the flood immunity of this road adjacent to the Hunter River, reducing road closures in flooding events. This is discussed further in Section 1 and Annexure B.

- Tailings management will mostly remain as approved with emplacement within approved TSFs, including Carrington In-Pit TSF at HVO North and the Cumnock Void 3 TSF at Ravensworth Operations. Proposed operations also include additional tailings infrastructure, relocation and/or reprocessing of tailings from existing TSFs, and emplacement of tailings within the northern extent of West Pit and at LCO (discussed further in the HVO North PER (EMM 2026a).

- Water management will mostly continue as approved, including continuation of the ability to transfer water to and from other mining operations where permitted. The proposed changes/upgrades are summarised as:

  - improved flood protection levee for North Void TSF (up to 0.1% Annual Exceedance Probability (AEP)) as per HVO's operating standard

  - additional mine/sediment water containment dams as required, as mining progresses

  - clean water diversions as required, as mining progresses, including an extension of the Mitchell clean water diversion, noting this drain diverts upslope runoff away from mining or disturbed areas and is not a creek diversion

  - Parnells Dam (Dam 9W) enlargement from approximately 0.7 gigalitre (GL) to 4 GL, new spillway, refurbishment of existing HRSTS discharge facility (no change to EPL)

  - improved flood protection for the Carrington West Wing Levee (up to 0.1% AEP)

  - construction of the Carrington West Wing LPBW prior to mining within 100 metres (m) of the remnant western arm of the paleochannel in connection with the Hunter River, as per the HVO North Consent (currently assumed to occur in around Mining Year 8).

- The proposed rehabilitation will be progressive, with the post mining land use to comprise a mixture of grazing and native habitat areas (as approved). The proposed changes to the approved rehabilitation comprise:

  i) Carrington West Wing Levee will be removed and incorporated into the final landform

ii) establishment of Mitchell East Levee to provide flood protection for the HVO North Void

iii) North Void TSF Levee 1 (north-west levee) and Levee 2 (south-east levee) (both at HVO North) will be incorporated into the final landform.

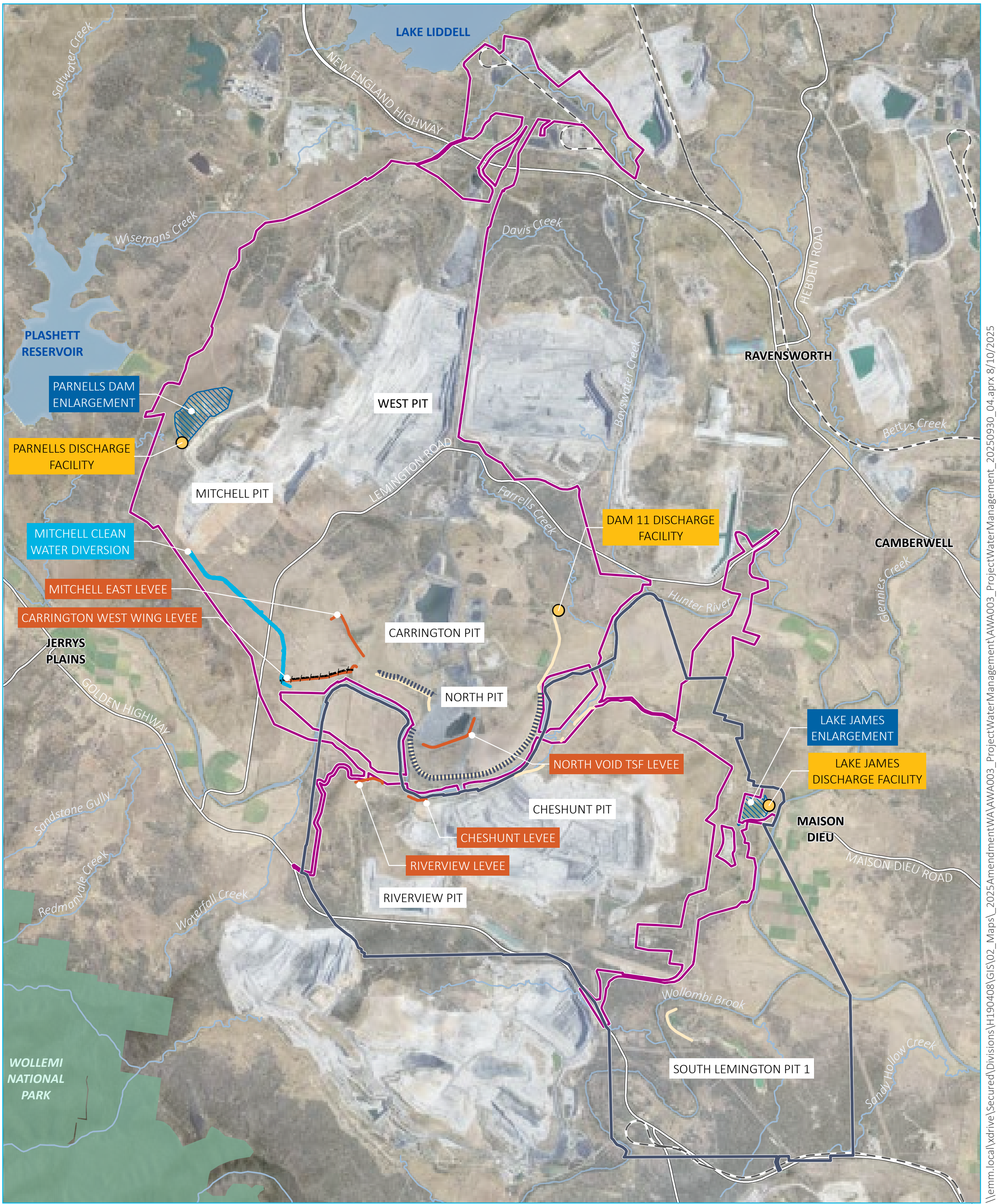
- Two final voids (HVO North Void and the approved Carrington Pit Void) will remain at HVO North representing a reduction in the number of voids that will remain post mining compared to existing HVO North Consent (i.e. from three to two).

2.2.2 HVO South Project key elements

Key Project elements (that differ to the approved operations) with the potential to affect water resources and associated water-dependent assets at HVO South comprise:

- extending the mine life from the current approval of March 2030 until 31 December 2042; however, the rate of mining will decrease from that currently approved
- the mining associated disturbance area is proposed to be reduced compared to the HVO South Approval due to the removal of the approved mining at SLP 1 and 2, and the RSEE area and removal of the approval for the construction and operation of the LCPP and associated rail facilities, which is currently approved, but not constructed
- water management integrated with HVO North will continue as approved. The proposed changes/upgrades are summarised as:
    - construction of Cheshunt and Riverview flood protection levees
    - Lake James (Dam 15S) enlargement (from approximately 0.7 GL to 2 GL)
- the proposed rehabilitation will be progressive, with the natural landform designs supporting final land use objectives including agriculture and native habitat (as approved). Minor changes to the final landform design are proposed due to rescheduling and or infrastructure relocations, including:
    - Cheshunt Levee will be incorporated into the final landform
    - Riverview Levee will be left in place to provide flood immunity to the final void
- one final void will remain at HVO South, consistent with the existing HVO South Approval. Some changes to the final void catchment and dimensions due to rescheduling are proposed.

HVO South will maintain an integrated tailings management strategy with HVO North.



Source: EMM (2025); Glencore (2025); DCSSS (2024); GA (2009)

KEY

- HVO North Action Area
- HVO South Action Area
- HRSTS discharge facility
- Existing levee
- Existing low permeability barrier wall

Water management infrastructure upgrade

- Approved barrier wall (not yet constructed)
- Clean water diversion
- Levee
- Dam enlargement

Existing environment

- Rail line
- Major road
- Named watercourse
- Named waterbody
- NPWS reserve

Project water management components

HVO Continuation Project
Water Resources Impact Assessment
Figure 2.2

EMM
creating opportunities

2.2.3 Proposed water management

The WMS for the Project is described in detail in the SWIA in Annexure B and a summary is provided here. The WMS for the Project will mostly remain similar to the existing WMS (described above in Section 2.1.1) with some additional considerations, infrastructure and upgrades.

The proposed water management strategy is consistent with existing HVO Complex strategies:

- diversions of clean catchment around mine infrastructure and disturbed land through catchment drains
- containment of mine affected runoff in dedicated storages for reuse in the WMS
- capture and treatment of sediment water runoff from disturbed areas in sediment dams
- minimise external catchment runoff reporting to the mining pits
- preferential re-use of mine water and sediment water captured by the WMS to supply operational water demands (dust suppression and CPP demands)
- progressive rehabilitation/stabilisation of overburden emplacement areas and MIAs to reduce the generation of sediment laden runoff
- protection of mining infrastructure and open cut pits by the construction of flood protection levees.

Key aspects of the Project WMS are presented on Figure 2.2. Conceptual WMS stage plans and design criteria are presented in the SWIA (Annexure B). Water management schematics for the Project are also presented and discussed in the SWIA (Annexure B).

2.2.4 Final voids

The Project has been designed to optimise resource recovery and operational efficiencies at the HVO Complex whilst avoiding and minimising environmental and social impacts; ultimately resulting in final voids. Under the existing HVO North Consent and HVO South Approval, four voids are approved (three at HVO North and one at HVO South). The final landform for the Project includes three residual voids: two at HVO North (HVO North Void and the approved Carrington Pit Void); and one at HVO South (HVO South Void). The conceptual final landform and voids are shown on Figure 2.3.

The final voids are predicted to be long-term sinks in which no water is expected to be released from the voids to the receiving environment. A discussion on the predicted pit lake recovery is provided in Section 10 and Annexure B. The proposed final voids at HVO North and HVO South are briefly described below:

- **HVO North:** The reduction from three voids to two, results in a reduction in catchment area reporting to the voids at HVO North when compared to the current HVO North Consent.
- **HVO South:** Consistent with the current Project Approval, one final void will remain at HVO South, in the south-western corner of Riverview Pit. The proposed final void dimensions will be smaller than currently approved due to mine sequencing refinement and infrastructure relocation.

In terms of use, the conceptual rehabilitation and closure strategy for the Project identifies the final voids as pit lakes; however, the voids have been designed so that other potential beneficial uses have not been precluded.

Rehabilitation and closure activities related to the surface WMS will involve:

- decommissioning and removal of pumps and associated infrastructure
- desilting and where relevant dewatering of sediment dams and mine water dams identified to remain for future use
- dewatering and rehabilitation of any sediment dams or mine water dams not required for future farm water supply or ecological functions
- rehabilitation of any clean and dirty water drainage structures not required post rehabilitation and closure.

The closure drainage lines shown in Figure 2.3 is conceptual and provides for management of the remaining sediment water during the establishment period in accordance with the Basis of Design outlined in Annexure B (Engeny 2026). Ultimately all rehabilitated areas will be suitably established and vegetated to be considered clean runoff and suitable for direct release without sediment dams. At that stage, all dams would be decommissioned with the exception of storages that remain to support the final land use, to maximise return of runoff to the receiving environment and minimise licensing requirements.

Post mining, both Parnells Dam and Lake James may be dewatered to one or both of the final void pit lakes and will be decommissioned and rehabilitated. These dams may be reconfigured as smaller storages to provide water for ongoing land uses, e.g. as farm water supply for livestock.

2.3 Consultation

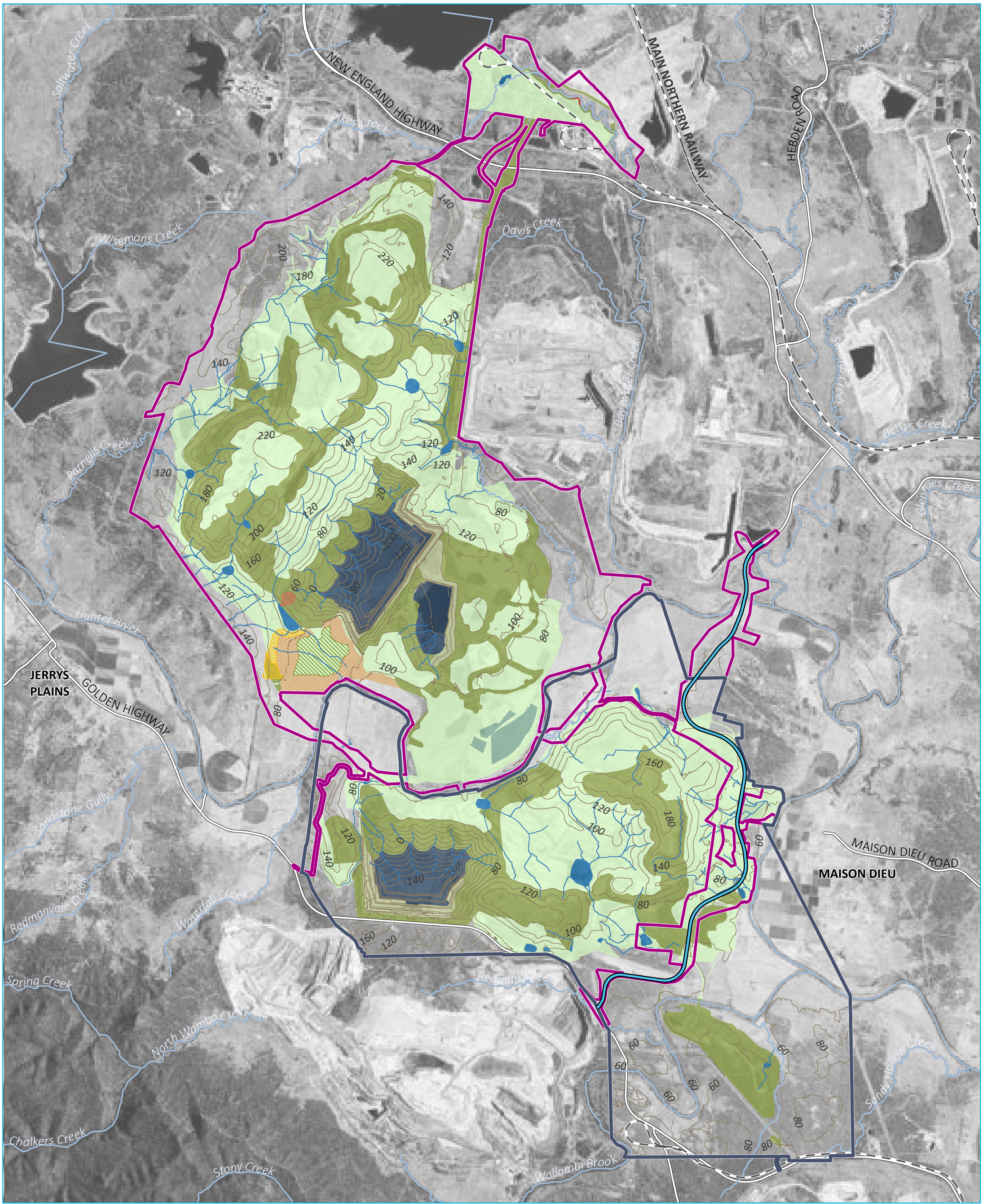
HVO has been part of the local community since operations commenced in 1949. A range of engagement mechanisms have been used to consult with neighbouring property owners, the local community, Federal, State and local government, regulators, service providers, local community groups, Aboriginal stakeholders and groups and HVO Community Consultive Committee members.

Community and stakeholder engagement activities have been carried out during the assessment and determination process for the Project, including during the preparation of the EIS (EMM 2022), Submissions Report (EMM 2023a), HVO North Amendment Report (EMM 2023b) and the HVO Amendment Report (EMM 2025a) to support the assessment process under the EP&A Act and the preparation of the referrals and the PER for the assessment process under the EPBC Act.

Between 2020 and 2025, HVO and the technical water specialists regularly engaged with the NSW Government, including NSW DCCEEW-Water and the IEAPM, presenting on the approach to the studies (including baseline, modelling approaches and assessment findings).

The HVO team also presented the assessment approach and findings of the various water and ecological studies to Commonwealth DCCEEW at various stages between 2021 and 2026.

Section 9 of the HVO North PER (EMM 2026a) and HVO South PER (EMM 2026b) discusses consultation in more detail.



\\emm.local\xdrive\Secured\Divisions\H190408\GIS\02_Maps_2025AmendmentReport\AR013_HVONorthSouthFinalLandform\AR013_HVONorthSouthFinalLandform20250729_04.aprx 25/09/2025

Source: EMM (2025); Glencore (2025); DCSSS (2024); GA (2009)

0 2.5 5 km

GDA2020 MGA Zone 56

N

KEY

HVO North Action Area
HVO South Action Area
Predicted drainage
Predicted 20 m contour
Lemington Road realignment

Existing environment

Rail line
Major road
Named watercourse
Named waterbody

Final landform land use domain

Domain A | Native ecosystem
Domain A- Sub domain Ka | Other- Native ecosystem- partial vegetation on highwall benches
Domain B | Agriculture- grazing
Domain B- Sub domain Kb | Other- Agriculture- alluvial land
Domain G | Water storage
Domain J | Pit Lake

Existing commitments maintained by the Project (indicative location)

Rural land capability

Class 2- DA 450-10-2003 MOD3
Class 3- DA 450-10-2003 MOD3
Class 4- DA 450-10-2003 MOD3

Native ecosystem

Central Hunter Box-Ironbark Woodland - DA 450-10-2003 MOD3
Swamp Oak Floodplain Forest - DA 450-10-2003 MOD5

Conceptual final landform

HVO Continuation Project
Water Resources Impact Assessment
Figure 2.3

EMM
creating opportunities

3 Regulatory and policy context

3.1 Relevant Commonwealth legislation

The EPBC Act provides a legal framework to protect and manage nationally and internationally important flora, fauna, ecological communities and heritage places which are defined as 'matters of national environmental significance' (MNES). The EPBC Act was amended in June 2013 to include water resources as a MNES in relation to coal seam gas and large coal mining developments (known as the 'water trigger'). Any action that 'has, will have or is likely to have a significant impact on a matter of national environmental significance' is deemed a 'controlled action' under the EPBC Act and may not be undertaken without prior approval from the Commonwealth Environment Minister.

DCCEEW has determined that the HVO North Continuation Project and HVO South Continuation Project are controlled actions under the EPBC Act as the Project has the potential to have a significant impact on MNES including water resources and that each action will be assessed by a PER. DCCEEW subsequently issued PER guidelines for HVO North and HVO South. This WRIA report has been prepared to address these PER guidelines.

3.1.1 Relevant guidelines

The IESC is a statutory body under the EPBC Act and provides scientific advice to Australian government regulators on proposed coal seam gas and large coal mining developments that are likely to have a significant impact on water resources. The information guidelines (IESC 2024) outline the information requirements of the IESC to adequately assess a proposal and provide scientific advice on potential water-related impacts.

This WRIA has considered the information guidelines specified by the IESC. The information guidelines checklist is provided in Annexure E and includes where each requirement has been addressed in this report (or supporting reports).

The IESC has also released explanatory notes to supplement the information guidelines and includes the following topics that are of relevance to the Project:

- *Uncertainty analysis for groundwater modelling* (Peeters and Middlemis 2023; updated from Middlemis and Peeters 2018)
- *Characterisation and modelling of geological faults* (Murray and Power 2021)
- *Using impact pathway diagrams based on ecohydrological conceptualisation in environmental impact assessment* (Commonwealth of Australia 2024)
- *Assessing groundwater dependent ecosystems* (Doody et al 2019).

The information guidelines note that proponents are encouraged to refer to the explanatory notes of relevance to their project, recognising that the explanatory notes provide detailed guidance rather than mandatory requirements.

Other relevant guidelines include:

- *Significant Impact Guidelines 1.3: Coal seam gas and large coal mining developments – impacts on water resources* (DCCEEW 2022)
- *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (ANZG 2018)
- *Australian Rainfall and Runoff* (ARR 2019)– a Guide to Estimation
- *Australian Groundwater Modelling Guidelines* (Barnett et al 2012).

3.2 Relevant NSW regulation, policies and guidelines

The primary NSW water related statutes that apply to the Project are the NSW *Water Act 1912* (Water Act), NSW *Water Management Act 2000* (WM Act) and POEO Act. The provisions of each act are applied in accordance with their attendant regulation.

Table 3.1 lists the legislation relevant to the Project to assess potential impacts on water resources and water-dependent assets.

Table 3.1 Relevant NSW legislation and regulations

Legislation	Authority	Relevant statutes, plans, policies, licensing requirements
EP&A Act	DPHI	HVO North Consent HVO South Approval
WM Act	NSW DCCEEW Natural Resources Access Regulator (NRAR)	Water sharing plans (WSPs) WALs for water take *NSW Aquifer Interference Policy* (AIP, DPI 2012)
NSW *Water Management (General) Regulation 2025*	NSW DCCEEW	Water approval and licensing exemptions
POEO Act	NSW Environment Protection Authority (NSW EPA)	EPL 640 HRSTS
NSW *Protection of the Environment Operations (Hunter River Salinity Trading Scheme) Regulation 2002*	NSW EPA	
NSW *Biodiversity Conservation Act 2016* (BC Act)	NSW DCCEEW - Conservation Programs, Heritage and Regulation	
NSW *Fisheries Management Act 1994* (FM Act)	Department of Primary Industries (DPI)	

The Hunter River, and highly connected alluvial groundwater within 40 m of the river bank, is managed under the NSW *Water Sharing Plan for the Hunter Regulated River Water Source 2016*. The tributaries to the Hunter River are managed under the *Water Sharing Plan for the Hunter Unregulated and Alluvial Water Sources 2022*.

The *Water Sharing Plan for the North Coast Fractured and Porous Rock Groundwater Sources 2016* applies to the Permian groundwater resources in the area.

HVO holds considerable water entitlement (WALs) in the relevant surface water and groundwater sources in the study area, including the regulated river and unregulated river and aquifer licences.

Regulated rivers, like the Hunter River, are water resources that have large public dams that capture natural flows for managed supply downstream. WaterNSW operates these storages for the benefit of the downstream environment and entitlement and other rights holders, consistent with the rules in the applicable WSP. The main categories of WALs of relevance to HVO and the Project are:

- Regulated river (high security and general security): for take of water from regulated rivers (rivers below large dams) and allow the licence holder to order water for release from the dam. High security licences are given a higher priority to access water than general security licences.

- Supplementary: for take of water on regulated rivers and allow the licence holder to access a share of an uncontrolled high flow event. Access to supplementary water depends on the timing, amount and location of rainfall and resulting streamflow, and the catchment conditions at the time.
- Unregulated river: for take of surface water from watercourses without dams or above dams on regulated rivers. Allows licence holders to access water based on river flow and WSP rules.
- Aquifer: for take of groundwater from alluvial, coastal sands, porous and/or fractured rock aquifers.

4 Description of the environment

4.1 Introduction

The conceptualisation of the existing environment is presented in the following sections. It is based upon many years of monitoring, testing and assessments in the area, forming a robust conceptual understanding of the study area.

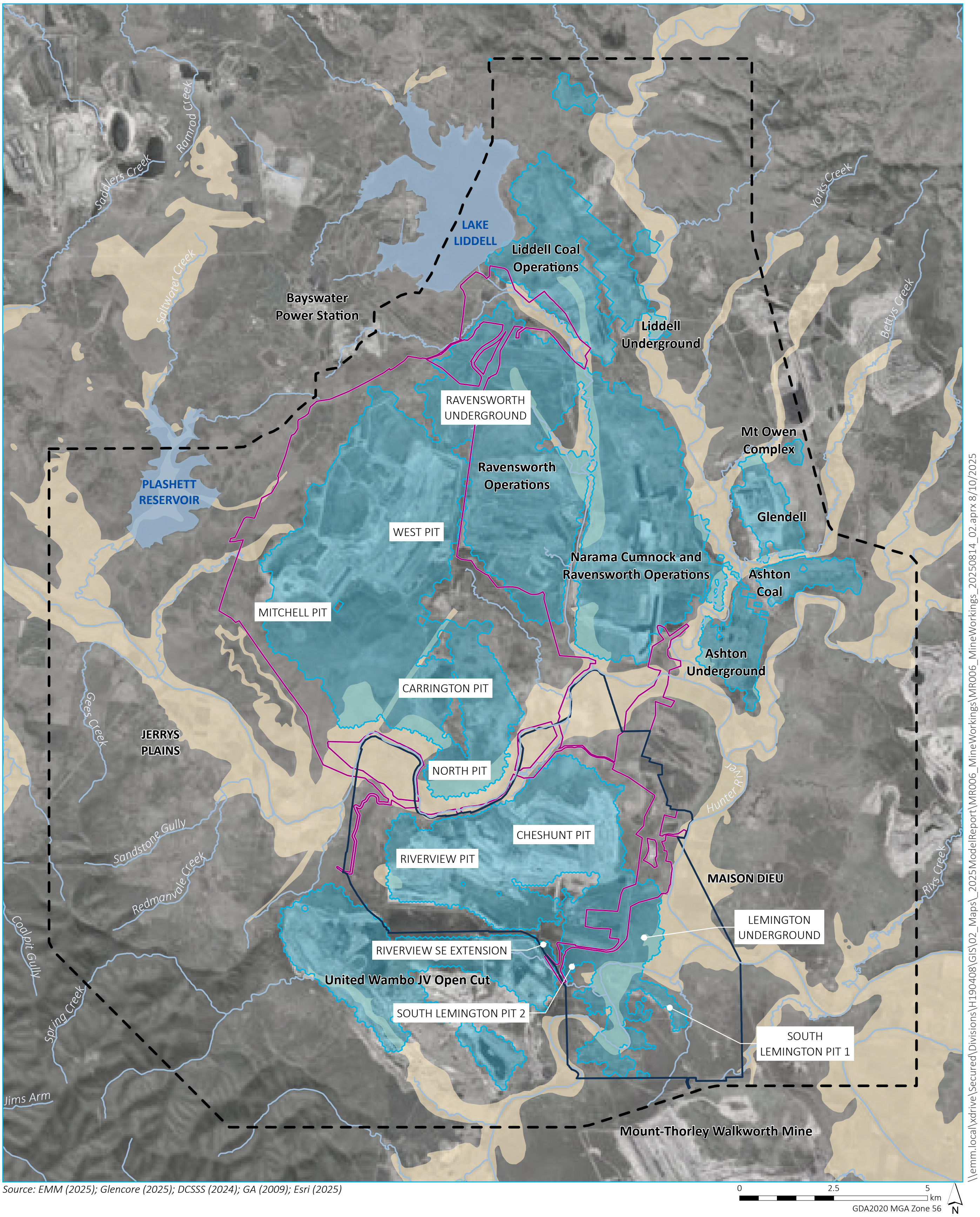
4.2 Regional historical and existing mining

The HVO Complex is located within the mid Hunter Valley coalfields. The mid Hunter Valley has a long history of mining the Permian Coal Measures dating back to the 1800s. Mining commenced at the HVO Complex in 1949 (at HVO North's West Pit).

Figure 4.1 shows the locations of the approved mines in the immediate area surrounding HVO and include:

- United Wambo Joint Venture (JV) (south of the HVO South)
- Mt Thorley Warkworth (MTW) mine complex (south of the HVO South)
- Ravensworth Operations (east of the HVO North)
- Ashton Coal Operations (east of the HVO Complex)
- Liddell Coal Operations (north-east of the HVO Complex)
- Glendell (north-east of the HVO Complex).

The above includes open cut developments and underground operations. The closest underground mines to the HVO Complex are the historical Lemington Underground mine at HVO South and the Ravensworth Underground Mine to the north. Mining at Lemington Underground commenced in 1971 and ceased in 1992.



Source: EMM (2025); Glencore (2025); DCSSS (2024); GA (2009); Esri (2025)

KEY

HVO North Action Area
HVO South Action Area
Groundwater model domain
Alluvial extent (state mapping)
Mining areas

Existing environment

Named watercourse
Named waterbody

Historic and approved mining

HVO Continuation Project
Water Resources Impact Assessment
Figure 4.1

EMM creating opportunities

4.3 Climate

The regional climate of the study area is characterised by hot summers and mild dry winters.

The SWIA report (Annexure B) provides a comparison of the different station data and demonstrates the SILO dataset is an adequate representation of the long-term climate in the study area.

Figure 4.2 compares the mean monthly evaporation and rainfall from the SILO dataset. Rainfall is relatively consistent throughout the year, although slightly lower in winter than in summer. Evaporation exceeds rainfall throughout the year, and a soil moisture deficit is likely (especially in the summer months). Annual average evaporation is 1,538 millimetres (mm).

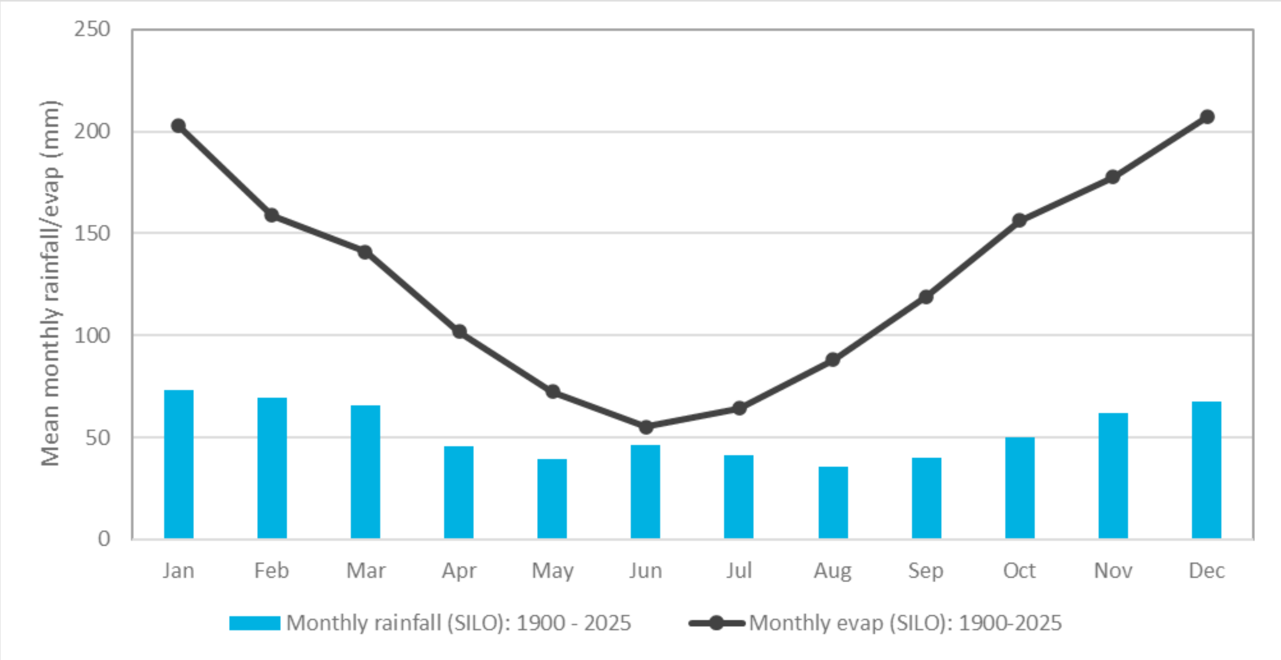


Figure 4.2 Mean monthly rainfall and evaporation (SILO data)

A review of rainfall trends shows:

- rainfall was below average between 2000 and 2006
- a wetter period followed between 2007 and 2016
- a significant drought was recorded between 2016 and 2019
- rainfall has been above the long-term average since 2020.

4.4 Hydrological setting

4.4.1 Watercourses and catchments

The HVO Complex is within the Hunter River Basin catchment and is drained by the Hunter River, Wollombi Brook and tributary drainage channels, including Parnells Creek, Farrells Creek, Bayswater Creek and Hobden Gully (Figure 4.3). The Hunter River is a regulated river, regulated by releases from Glenbawn Dam and Glennies Creek Dam. The Hunter River flows in an eastward direction between the HVO North and HVO South, then flows in a south direction towards Singleton.

Other minor watercourses in the vicinity of the Project are ephemeral, flowing after rainfall events. There are also several unnamed tributaries within the HVO North Action and HVO South Action areas. Streamflow analysis indicates many of the ephemeral watercourses are dry (on average) more than half the year.

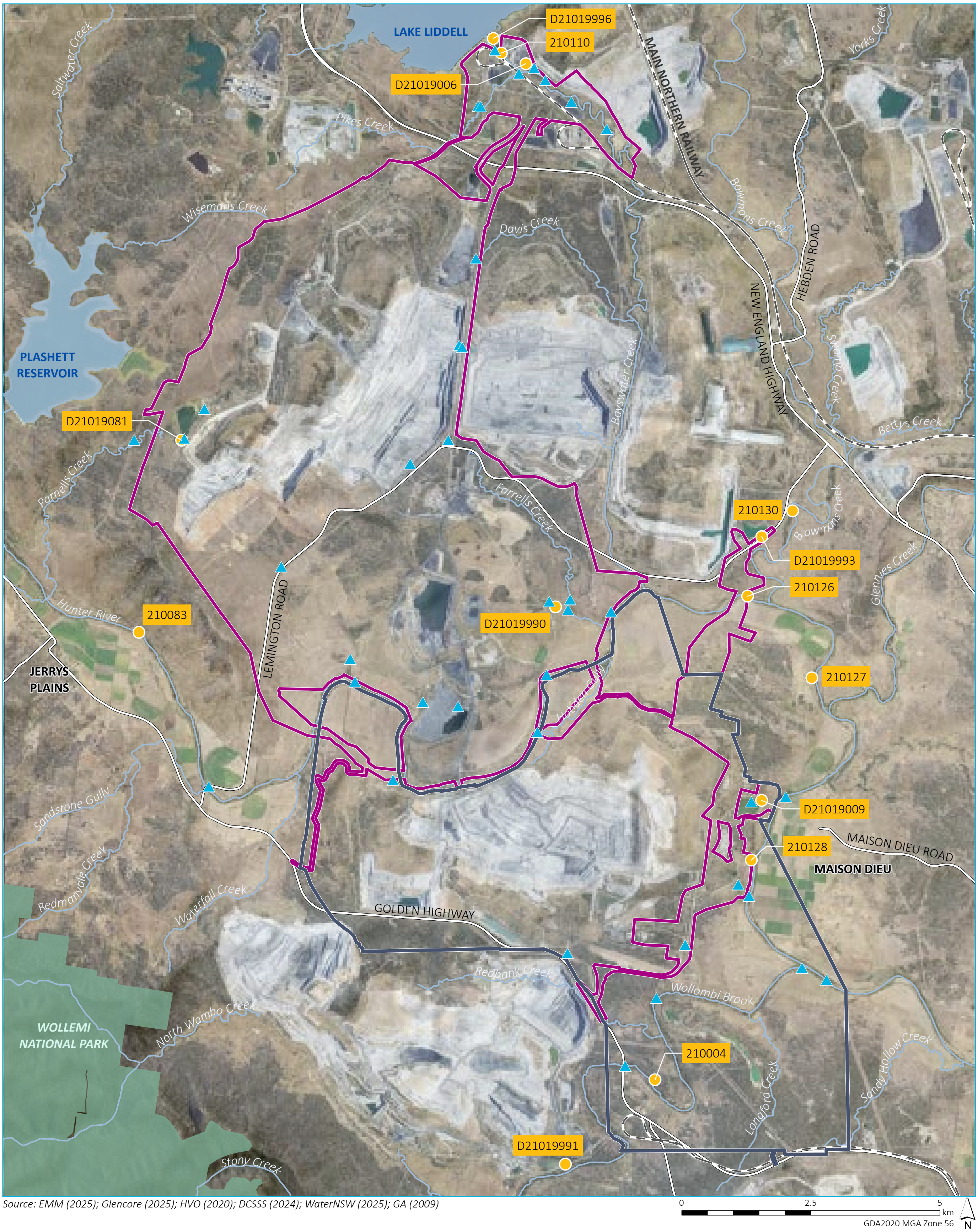
The flow duration curve analysis for the Mason Dieu gauge (gauge 210128; see Figure 4.3 for location) shows the Hunter River is perennial with daily flows typically exceeding 100 megalitres per day (ML/d) 90% of the time. The flow duration curve analysis at the Warkworth gauge (210004; see Annexure B) shows that Wollombi Brook stops flowing (i.e. is dry) 13% of the time and daily flows typically exceed 100 ML/d only 30% of the time at Warkworth.

Further descriptions of individual watercourses and catchments are provided in the SWIA in Annexure B.

4.4.2 Surface water monitoring

Extensive monitoring at watercourses and within the HVO Complex has been occurring in the study area since 2011, in accordance with the WMP.

The surface water monitoring program is described in the WMP and SWIA (Annexure B). Monitoring locations are presented in Figure 4.3.



Source: EMM (2025); Glencore (2025); HVO (2020); DCSSS (2024); WaterNSW (2025); GA (2009)

\\emm.local\xdrive\Secured\Divisions\H190408\GIS\02_Maps_2025AmendmentWA\AWA006_SurfaceWaterContext\AWA006_SurfaceWaterContext_20250930_02.aprx 10/10/2025

KEY

- HVO North Action Area
- HVO South Action Area
- HVO surface water monitoring location
- Stream flow gauge

Existing environment

- Rail line
- Major road
- Named watercourse
- Named waterbody
- NPWS reserve

Surface water context

HVO Continuation Project
Water Resources Impact Assessment
Figure 4.3

EMM
creating opportunities

4.4.3 Surface water quality

i Hunter River basin

Water quality is generally poor due to typically high salt concentrations in the Hunter River basin. This is largely due to the geology of the area and groundwater discharge contributing to the high salinity in the Hunter River catchment (McVickar et al 2015).

The HRSTS was introduced in 1995 to minimise the impact of saline water discharges from industry. There are three key salinity monitoring stations located on the Hunter Regulated River: Denman, Glennies Creek and Singleton (McVickar et al 2015).

Salinity levels are typically low in the north-east of the Hunter River basin. Along the Hunter Regulated River, the mean salinity (as electrical conductivity, EC) between the 1995 and 2013 varied from around 600 microsiemens per centimetre (µS/cm) at Denman to 750 µS/cm at Glennies Creek, to 640 µS/cm at Singleton. A high variability was observed, particularly at low flows when baseflow discharges dominate the streamflow response (McVickar et al 2015).

ii Local setting

The HVO surface water monitoring program was extended for the Project in 2018 following a review of the available historical monitoring data conducted by Engeny (2018). Sufficient water quality monitoring data (greater than two years of monthly sampling, i.e. 24 samples) have been collected to adequately analyse data and trends for pH, EC, total suspended solids (TSS) and total dissolved solids (TDS), as well as nutrients and a range of metals/metalloids.

Detailed statistical analyses as set out in *the Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (ANZG 2018) has been conducted as part of the SWIA (Annexure B). Recorded ranges in pH, EC and TSS have been compared to ANZG (2018) default guideline values and *Managing Urban Stormwater: Soils and Construction, Volume 1* (Landcom 2004, herein referred to as the Blue Book). Further statistical analysis conducted by Engeny (2026) is provided in Annexure B. Review of water quality trends to site-specific trigger values is conducted as part of HVO's Annual Review reporting as required by the HVO North Consent and HVO South Approval.

Historical water quality data (2011 to 2024) for the Hunter River, Wollombi Brook and the ephemeral creeks, generally remain within historical trends and trigger levels for pH, EC and TSS for the 80th percentile, with the following observations:

- pH is generally neutral to alkaline. pH values for the Hunter River are consistently higher than the Wollombi Brook and ephemeral creek systems, with a typical range of 8.0 to 8.4.
- EC is below the ANZG (2018) default guideline value, except for the ephemeral creeks.
- The 80th percentile TSS is somewhat higher than the Blue Book value for the ephemeral creeks.

In addition to routine parameters, surface water quality monitoring has been undertaken regarding nutrients and metals/metalloids in all clean water systems, the sediment water system and mine water system for the complex. The statistical analysis for metals and nutrients at each monitoring location is detailed in Attachment B of the SWIA (Engeny 2026).

4.4.4 Environmental and community values

An environmental and community value is defined in the national water quality guidelines (ANZG 2018) as a particular value or use of the environment that is important for a healthy ecosystem or for public benefit, health, safety or welfare, and requires protection from the effects of stressors. Environmental and community values recognised by the national water quality guidelines (ANZG 2018) are listed in Figure 4.4.

Source: Adapted from ANZG (2018)

Figure 4.4 Environmental and community values

The NSW Government has river flow and water quality objectives for different catchments in the NSW for use in developing plans and actions affecting river health. In the Hunter River catchment, the river flow and water quality objectives relevant to the study area relate to "uncontrolled streams" (i.e. unregulated watercourses) and "major regulated rivers"[1].

The water quality objectives for uncontrolled streams and major regulated rivers relate to the protection of:

- aquatic ecosystems
- visual amenity
- primary and secondary contact recreation
- livestock water supply
- irrigation water supply
- homestead water supply
- aquatic foods (cooked).

The NSW river flow objectives are:

- protect natural water levels in pools of creeks and rivers and wetlands during periods of no flow
- protect natural low flows

[1] https://www.environment.nsw.gov.au/ieo/Hunter/report-02.htm#P178_22807

- protect or restore a proportion of moderate flows, 'freshes' and high flows
- maintain or restore the natural inundation patterns and distribution of floodwaters supporting natural wetland and floodplain ecosystems
- mimic the natural frequency, duration and seasonal nature of drying periods in naturally temporary waterways
- maintain or mimic natural flow variability in all rivers
- maintain rates of rise and fall of river heights within natural bounds
- maintain groundwaters within natural levels, and variability, critical to surface flows or ecosystems
- minimise the impact of in-stream structures
- minimise downstream water quality impacts of storage releases
- ensure river flow management provides for contingencies
- maintain or rehabilitate estuarine processes and habitats.

The Hunter River catchment has undergone extensive modification in the study area. It is generally considered as having low to medium instream value. There are some medium and high value areas, particularly in the upper regions of the regulated river. The regulated river has generally low diversity and no vital habitat value. The sub-catchments of the Hunter River are generally considered as under medium or high environmental stress. They have relatively poor bank condition, bed condition and riparian vegetation (DPI Water 2017). Within the study area, the Hunter River and its tributaries are considered as having Poor Ecological Value (Annexure C, ELA 2025).

The Hunter River supports a variety of uses including irrigation, town water supply, mining and power generation. Downstream of the HVO Complex, the town of Singleton relies on the river for its industries and water supply.

Landholders also access water through basic landholder rights and/or through WALs.

In addition to environmental, social and economic value, the Hunter River also has cultural value for Aboriginal people. Aboriginal names for the Hunter River include *Coquun*, *Myan*, *Coonanbarra*, *Terrybong* or *Gingamboon*, depending on the point of its course (Wafer 2014); *Terrybong* appears to be the *Wonnarua* name for the Hunter River within the study area (Gardner 1854). Derived from the *Awabakal* language, Wollombi means 'meeting of the waters' (NSW Geographical Names Board n.d.).

4.5 Geological setting

The coal seams at the HVO Complex are contained within the Late Permian Wittingham Coal Measures which are further sub-divided into the Vane subgroup and the Jerrys Plains subgroup. The coal measures are stratified sequences dipping in a general west to south-east direction and outcrop over most of the mapped extent.

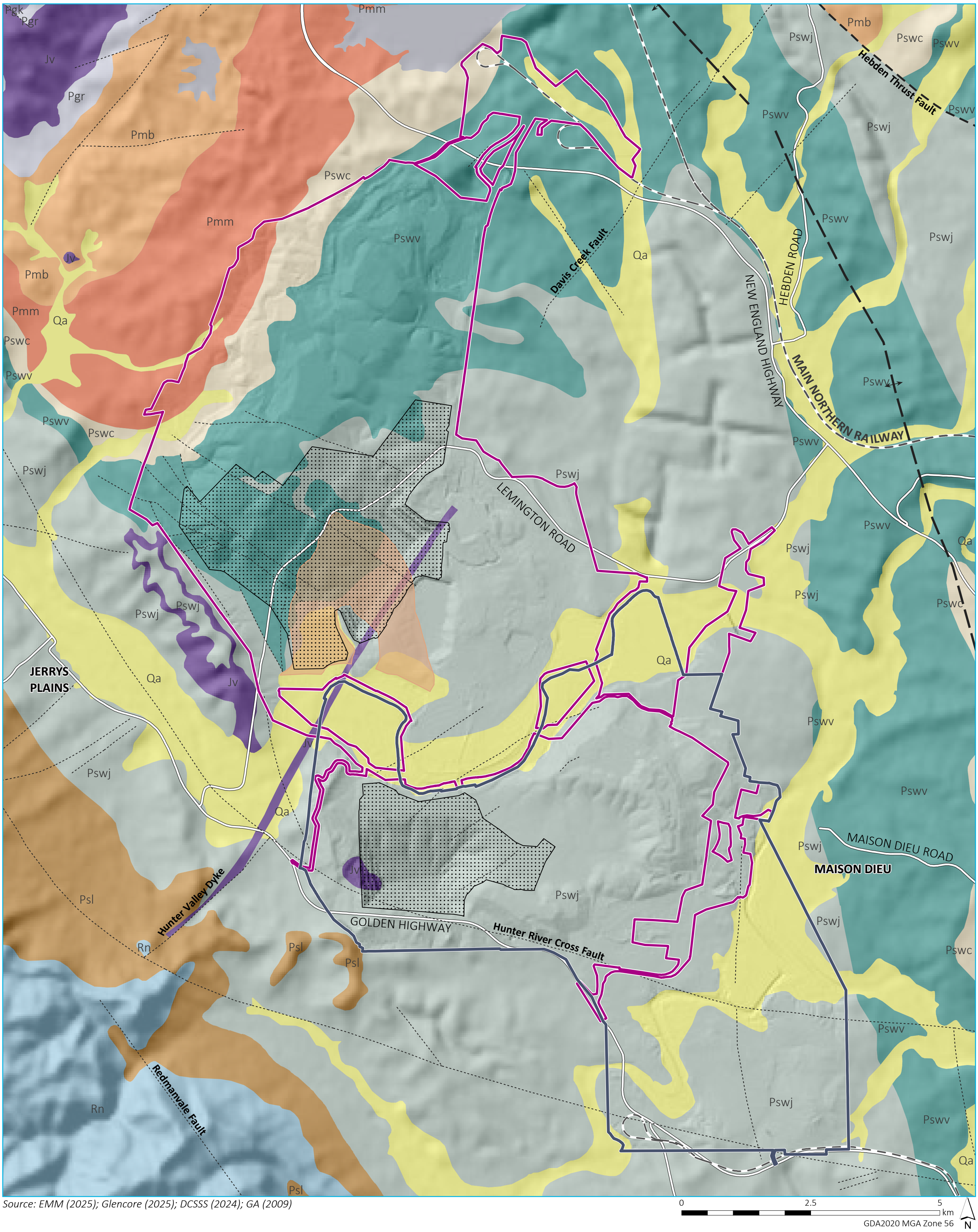
In the HVO Complex area, most of the younger Permian and Triassic units overlying the Wittingham Coal Measures have been eroded. Consequently, the Permian Wittingham Coal Measures, forming the bedrock, is now unconformably overlain by thin meandering areas of Quaternary alluvial sediments deposited along the Hunter River floodplain and its tributaries.

A weathering profile is typically present as a thin heterogeneous layer of unconsolidated weathered material (regolith) grading through weathered rock to fresh bedrock. The depth of weathering varies in the area and can extend to 50 m below surface (AGE 2022).

The main geological units present within the study area are summarised in Table 4.1. The surface geology in the study area is presented in Figure 4.5.

Table 4.1 Summary of main geological units in the study area

Geological unit	Description
Quaternary/Tertiary alluvium	The Quaternary alluvium occurring along the Hunter River and Wollombi Brook floodplains contains two main depositional units, a surficial fine-grained sediment (clay, silt and sand) overlying a coarser basal material (sand and gravel). The alluvial sediments are generally confined to the current course of the Hunter River and some tributaries near the confluence with the Hunter River.
Paleochannel alluvium	An ancient river meander carved into the Permian sediments at HVO and infilled with alluvial sediments forming a paleochannel to the north of the Hunter River near Carrington Pit (refer Figure 4.5). The paleochannel was formed during the Tertiary period and consists of silt, sand and gravel. MER (2010) discusses the investigations conducted in the paleochannel area to define the geometry, lithology and hydrogeological properties of the paleochannel. Exploration drilling and groundwater monitoring installations, and associated monitoring, resulted in a robust conceptual understanding of the paleochannel. The depositional environment for the unconsolidated paleochannel alluvium was characterised by frequent flooding and resulting deposition of gravelly sandy material with silts and clays. Colluvial deposits are also present from hill slope runoff and sheet wash from surrounding hard rock (MER 2010). The alluvium thickness varies and ranges from 11 to 18 m, pinching out at the channel perimeter. The bottom 3 to 6 m generally comprises fine to coarse gravel contained within a silty-clayey matrix that is overlain by clay 2 to 8 m in thickness. This clay is overlain by relatively thin surficial sands, silts, clays and loams (MER 2010).
Aeolian deposits	Cenozoic dune sands and associated high level sand deposits mapped in the state geology dataset is locally referred to as 'Warkworth Sands' in the area. The feldspathic quartz aeolian sands are approximately 3 m (1 to 6 m) thick and form a thin capping on the underlying Permian bedrock. The fine-grained sands overlie a low permeability base of residual clay associated with the underlying strata (AGE 2022).
Permian Wittingham Coal Measures • Jerrys Plains subgroup • Vane subgroup	The Permian strata comprise sequences of coal seams separated by layers of sandstone, siltstone, tuffs and conglomerate and are generally referred to as overburden and interburden in the context of mining. In the HVO Complex area, the regular layered sedimentary sequence dips gently to the south-east. The Jerrys Plains subgroup outcrops in HVO North, gradually thickens from its outcrop towards the south and is up to 300 m thick at HVO South. It is underlain by the Archerfield Sandstone consisting of a massive light brown or honey coloured well-sorted quartz lithic sandstone which marks the change into the underlying Vane subgroup. Mining at both HVO North and HVO South has intersected the Jerrys Plains subgroup. The Vane subgroup comprises six coal seams with the Lemington seam at the top and the Hebden seam at the base. The interburden consists of sandstone and siltstone. Mining at the Mitchell/West Pit at HVO North is currently approved to mine to the base of the Barrett seam. The Project proposes to extend mining to the base of the Bayswater seam in the Carrington West Wing extension area as per the existing HVO North Consent.



Source: EMM (2025); Glencore (2025); DCSSS (2024); GA (2009)

KEY

- HVO North Action Area
- HVO South Action Area
- Pre-mining paleochannel extent
- Mining area

Geological feature

- Anticline
- Thrust fault
- Fault

Geology - Hunter coalfield 100K

- Qa - Quaternary Alluvium
- Jv - Jurassic Volcanics
- Rn - Narrabeen Group
- Psl - Wollombi Coal Measures
- Pswj - Wittingham Coal Measures, Jerrys Plains Subgroup
- Pswv - Archerfield sandstone, Vane Subgroup
- Pswc - Wittingham Coal Measures, Saltwater Creek Formation
- Pmm - Maitland Group, Mulbring Siltstone
- Pmb - Maitland Group, Branxton Formation
- Pgr - Greta Coal Measures, Rowan Formation
- Pgk - Greta Coal Measures, Skeletar Formation
- Water

Existing environment

- Rail line
- Major road

Geological setting

HVO Continuation Project
Water Resources Impact Assessment
Figure 4.5

EMM
creating opportunities

\\emm.local\xdrive\Secured\Divisions\H190408\GIS\02_Maps_2025AmendmentWA\AWA007_GeologicalSetting\AWA007_GeologicalSetting_20250930_02.aprx 2/10/2025

4.5.1 Structural geology

In the Hunter Coalfield, a group of small thrust faults running parallel to subparallel to the Hunter-Mooki thrust fault and a series of northerly trending folds displaces the Permian sequences. The study area is incised by a series of faults that trend in a north-west to south-east direction.

The main mapped structures in the study area are:

- The Hunter River Cross Fault: little is documented on the fault, but historical information suggests it is narrow with a maximum displacement of approximately 10 m.
- The Hunter Valley Dyke: a north-east trending volcanic intrusion adjacent to the Carrington Pit. The dyke is likely to exhibit lower permeability due to its thickness and localised alteration of geology but also localised fracturing which can enhance groundwater storage.
- The Block Fault Zone: a zone of faults north-east of the HVO Complex area up to 250 m to 300 m wide with typical fault displacements of less than 12 m.
- The Davis Creek Fault that strikes in a north-east orientation adjacent to the Ravensworth Operations east of HVO North and continues through to LCO. At LCO there were observations of distinct groundwater pressure differences on either side of the fault structure. Based on this, the fault is inferred to act as a barrier to groundwater flow (AGE 2022).
- The Muswellbrook Anticline (west of the HVO Complex).
- The Bayswater Syncline north-west of Singleton (north and east of the HVO Complex).

As documented by AGE (2022), the hydrogeological properties of most faults have not been estimated through testing and so represent an uncertainty in the conceptual understanding of the area. This uncertainty has been addressed through history-matching (discussed in Annexure A).

The main mapped structures are shown on Figure 4.5.

4.6 Hydrogeological setting

4.6.1 Hydrogeological units

The main hydrostratigraphic units (HSUs) within the study area are summarised below based on the geological units and their ability to store and transmit water:

- Alluvial aquifers, occurring along the major creeks and rivers, mainly the Hunter River; and the paleochannel, forming shallow unconfined aquifers.
- Permian groundwater systems:
  - thin and variably permeable weathered rock at the surface (regolith) that generally do not form aquifers due to limited saturated thickness
  - non coal interburden aquitards
  - low to moderately permeable coal seam aquifers, generally confined.

4.6.2 Groundwater monitoring

There is an extensive groundwater monitoring network in the study area that spans the various mining areas, targeting various lithologies including the alluvium and deeper Permian units. Groundwater monitoring at the HVO Complex commenced in 1995. Monitoring locations and frequency have been revised and updated over the operating years and in accordance with the WMP. Groundwater monitoring is also undertaken at surrounding mines including Ravensworth Operations, LCO, Mt Owen Complex, Integra Underground, MTW, and United Wambo. In addition, there is groundwater monitoring data available from Government-owned/monitored bores in the area.

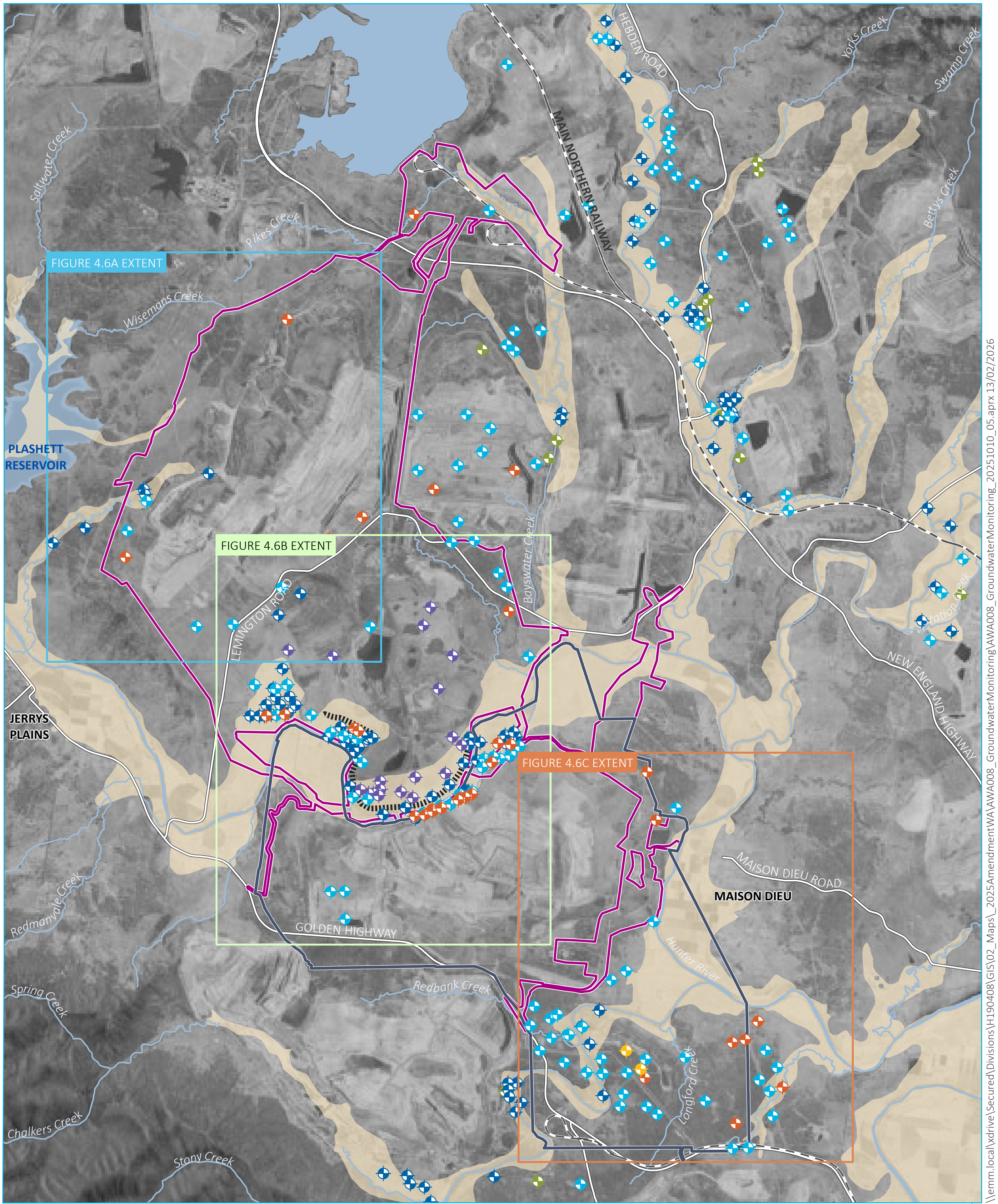
Groundwater monitoring locations in the HVO Complex area are shown in Figure 4.6.

There are numerous groundwater monitoring sites within and near the HVO Complex and good spatial coverage in the alluvium. Annual groundwater monitoring reports prepared by HVO also provide details of groundwater level and quality monitoring data (temporal and spatial) that has been used to support the conceptual hydrogeological model and groundwater model.

Groundwater monitoring locations are a combination of bores/standpipes and vibrating wire piezometers (VWPs), which can include multiple sensors monitoring pressures at multiple depths in the same hole. VWPs are typically used for deeper holes where installation of bore casing is challenging.

4.6.3 Hydraulic properties

As reported in AGE (2022), extensive hydraulic testing has been undertaken across the Hunter Valley using field packer testing, laboratory core permeability testing and falling/rising head tests (studies back to 2009 by MER and more recently in 2020/22 by AGE). Further discussion is provided in Annexure A.



Source: EMM (2025); Glencore (2025); BoM (2025); DCSSS (2024); GA (2009)

0 2.5 5 km
GDA2020 MGA Zone 56
N

KEY

- HVO North Action Area
- HVO South Action Area
- Alluvial extent (state mapping)
- Existing low permeability barrier wall

Existing environment

- Rail line
- Major road
- Named watercourse
- Named waterbody

Groundwater monitoring location (HVO)

Lithology

- Alluvium
- Aeolian sands
- Spoil
- Regolith

Permian

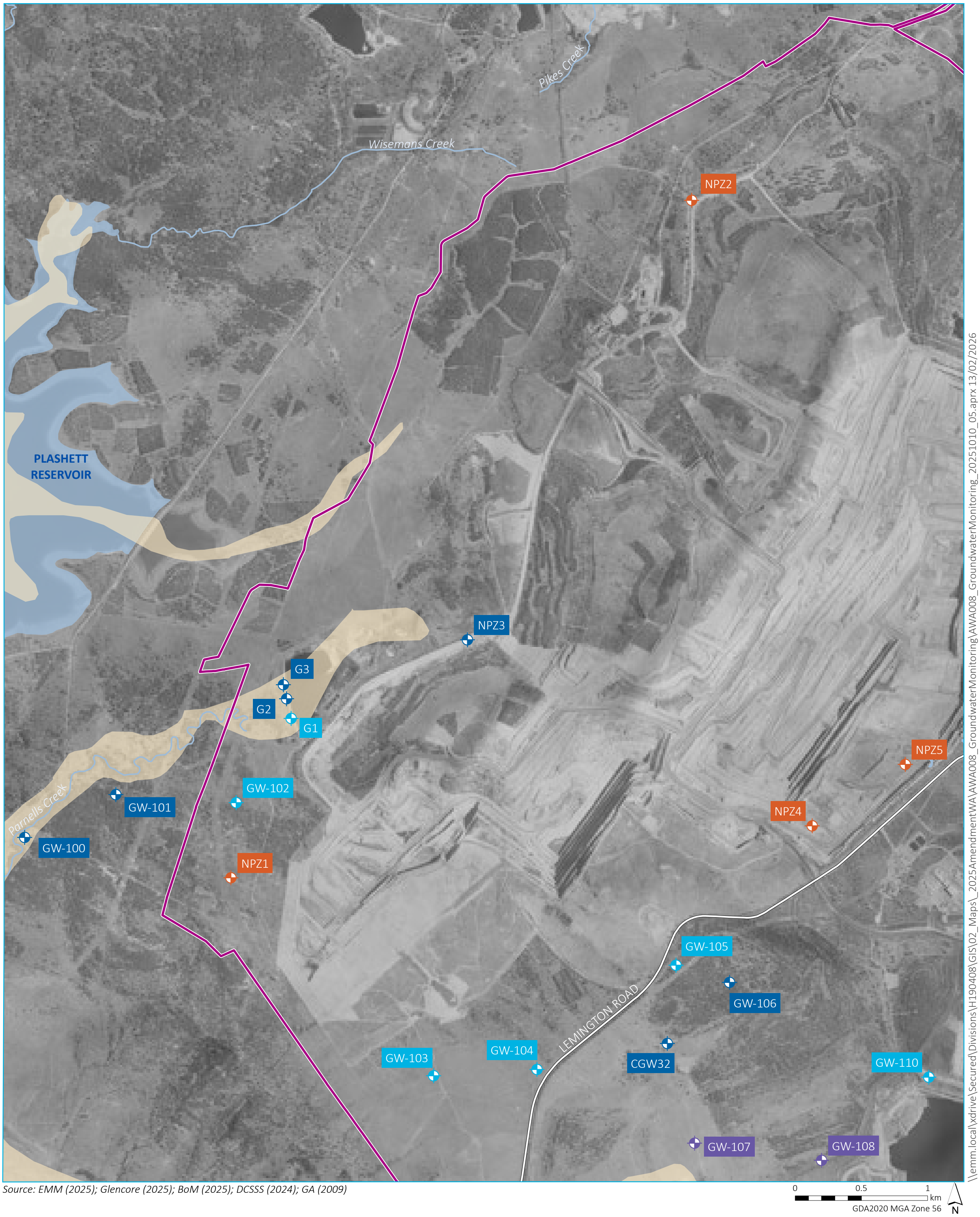
- Coal seam
- Interburden

- Figure 4.6a extent
- Figure 4.6b extent
- Figure 4.6c extent

Groundwater monitoring network

HVO Continuation Project
Water Resources Impact Assessment
Figure 4.6

EMM creating opportunities



Source: EMM (2025); Glencore (2025); BoM (2025); DCSSS (2024); GA (2009)

KEY

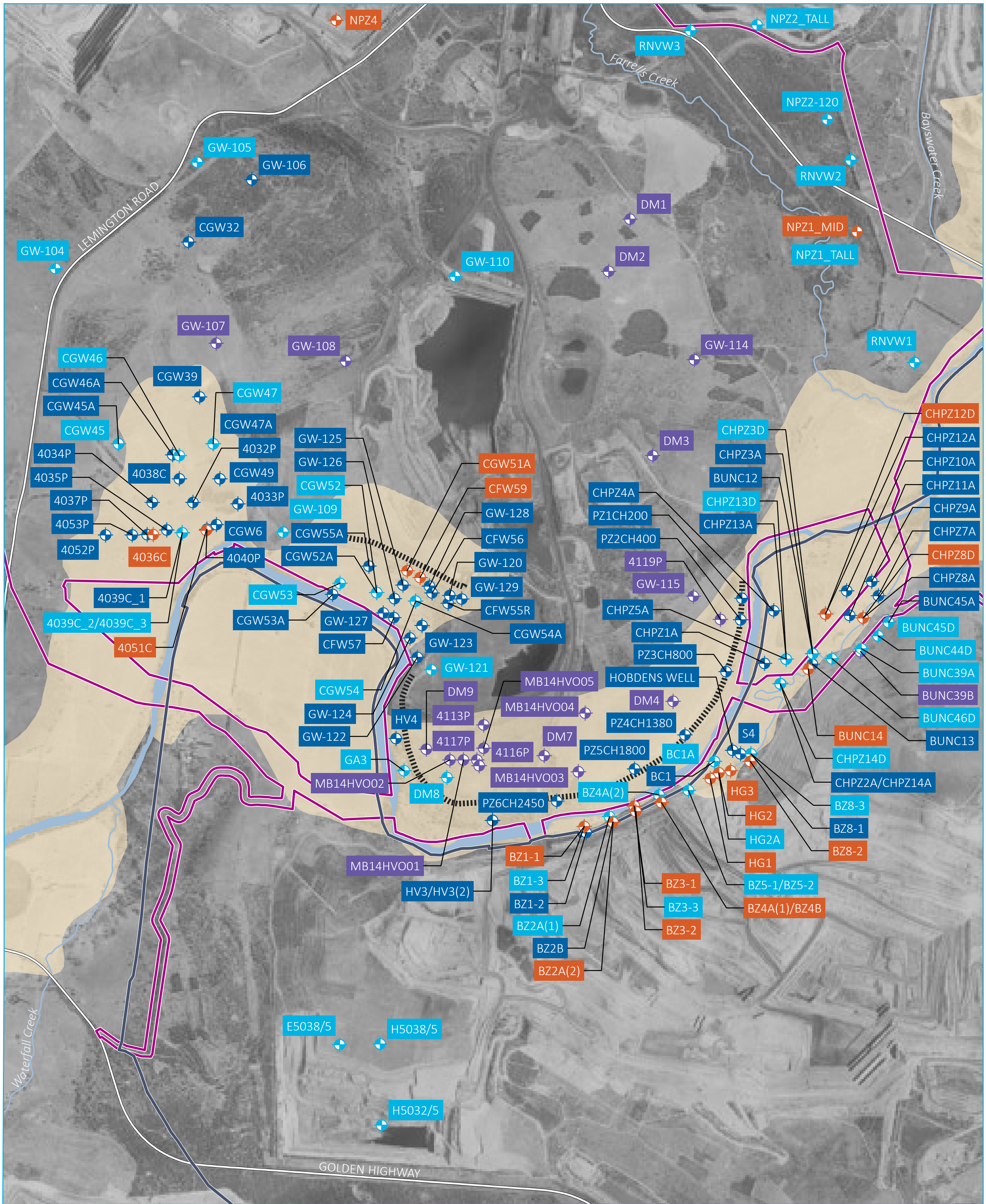
HVO North Action Area
HVO South Action Area
Alluvial extent (state mapping)
Existing low permeability barrier wall

Existing environment
Rail line
Major road
Named watercourse
Named waterbody

Groundwater monitoring location (HVO)
Lithology
Alluvium
Aeolian sands
Spoil
Regolith
Permian
Coal seam
Interburden

Groundwater monitoring network

HVO Continuation Project
Water Resources Impact Assessment
Figure 4.6a



Source: EMM (2025); Glencore (2025); BoM (2025); DCSSS (2024); GA (2009)

0 0.5 1 km
GDA2020 MGA Zone 56
N

KEY

- HVO North Action Area
- HVO South Action Area
- Alluvial extent (state mapping)
- Existing low permeability barrier wall

Existing environment

- Rail line
- Major road
- Named watercourse
- Named waterbody

Groundwater monitoring location (HVO)

Lithology

- Alluvium
- Aeolian sands
- Spoil
- Regolith

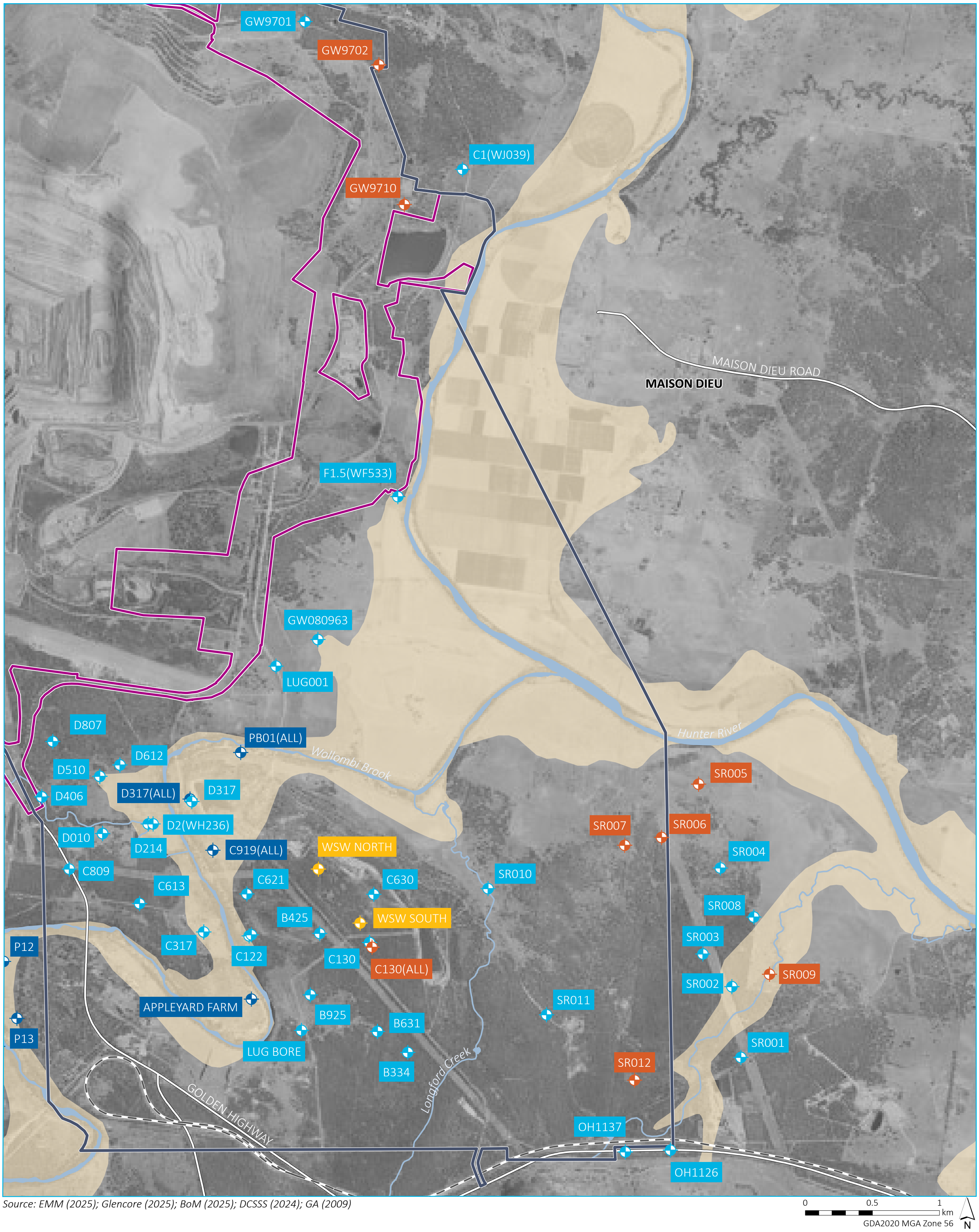
Permian

- Coal seam
- Interburden

Groundwater monitoring network

HVO Continuation Project
Water Resources Impact Assessment
Figure 4.6b

EMM
creating opportunities



Source: EMM (2025); Glencore (2025); BoM (2025); DCSSS (2024); GA (2009)

KEY

- HVO North Action Area
- HVO South Action Area
- Alluvial extent (state mapping)
- Existing low permeability barrier wall

Existing environment

- Rail line
- Major road
- Named watercourse
- Named waterbody

Groundwater monitoring location (HVO)

Lithology

- Alluvium
- Aeolian sands
- Spoil
- Regolith

Permian

- Coal seam
- Interburden

Groundwater monitoring network

HVO Continuation Project
Water Resources Impact Assessment
Figure 4.6c

\\emm.local\xdrive\Secured\Divisions\H190408\GIS\02_Maps_2025AmendmentWA\AWA008_GroundwaterMonitoring\AWA008_GroundwaterMonitoring_20251010_05.aprx 13/02/2026

4.6.4 Groundwater levels and flow direction

Detailed groundwater level and spatial analysis for bores at HVO was conducted by AGE (2022) for the EIS submitted to the NSW Government. Since this time, monitoring has continued and an evaluation of groundwater level trends confirms the findings of AGE (2022) remain appropriate.

i Alluvium

Groundwater levels and flow direction in the alluvium are largely controlled by surface topography and surface water flows.

The analysis completed by AGE (2022) shows a strong connection between alluvial groundwater level trends, climate and streamflow. This observation is supported by observations provided in HVO's Annual Reviews and by groundwater level monitoring at a NSW Government monitoring bore upstream of HVO (GW271031). Figure 4.7 presents a hydrograph of publicly available groundwater level data and stream height data from the WaterNSW Liddell gauge (station 210083), which demonstrates the strong connection between the regulated Hunter River and the alluvium.

GW271031 is located upstream of the HVO Complex and therefore not influenced by mining activities at HVO. Figure 4.7 shows the climatic variation in the alluvial watertable from January 2010 to mid-2025, where the watertable varied by approximately 1.5 m (within the 10th and 90th percentile range of the measurements).

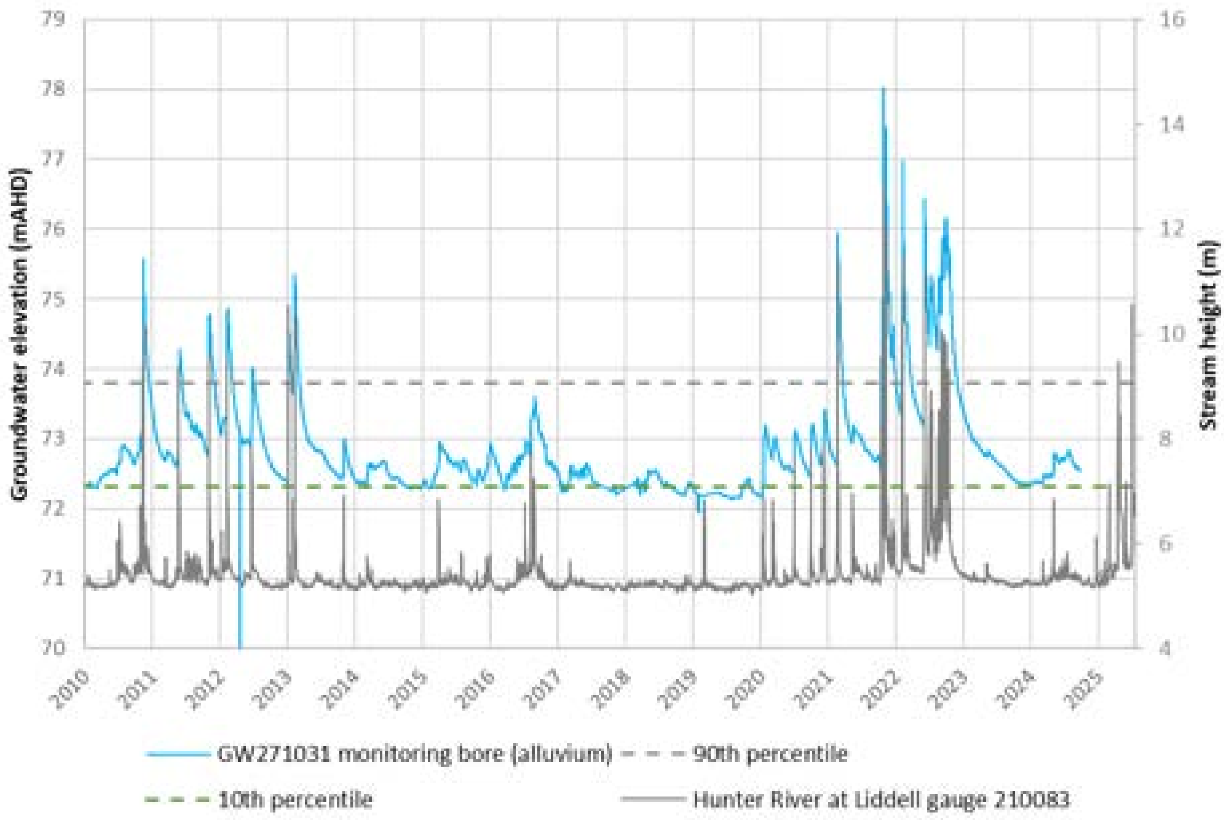


Figure 4.7 GW271031 hydrograph

Alluvial groundwater level monitoring data collected since 2011 for the Hunter River alluvium between HVO North and HVO South is presented on Figure 4.8 to Figure 4.10, along with a comparison to the cumulative deviation from mean monthly rainfall (CDFM). The charts show:

- groundwater levels in the alluvial sediments associated with the remnant paleochannel (GW-106 and CGW-32) are relatively stable, showing minimal response to climate and demonstrating the hydraulic separation between the remnant paleochannel and the Hunter River alluvium (due to historical approved mining activity) (Figure 4.8)
- the alluvial sediments at the edge of the western arm of the paleochannel have historically gone dry, based on monitoring at CGW47A (Figure 4.8)
- closer to the Hunter River in the both the west and the eastern Carrington areas, the alluvial watertable fluctuates with seasonal variations in rainfall and streamflow (e.g. 4037P, 4040P, GW-127, GW-128, CGW52A; Figure 4.8 and Figure 4.9)
- alluvial monitoring in the Alluvial Lands LPBW area also shows groundwater response to climate (Figure 4.10)
- groundwater level monitoring shows no mining induced drawdown in the alluvial aquifer.

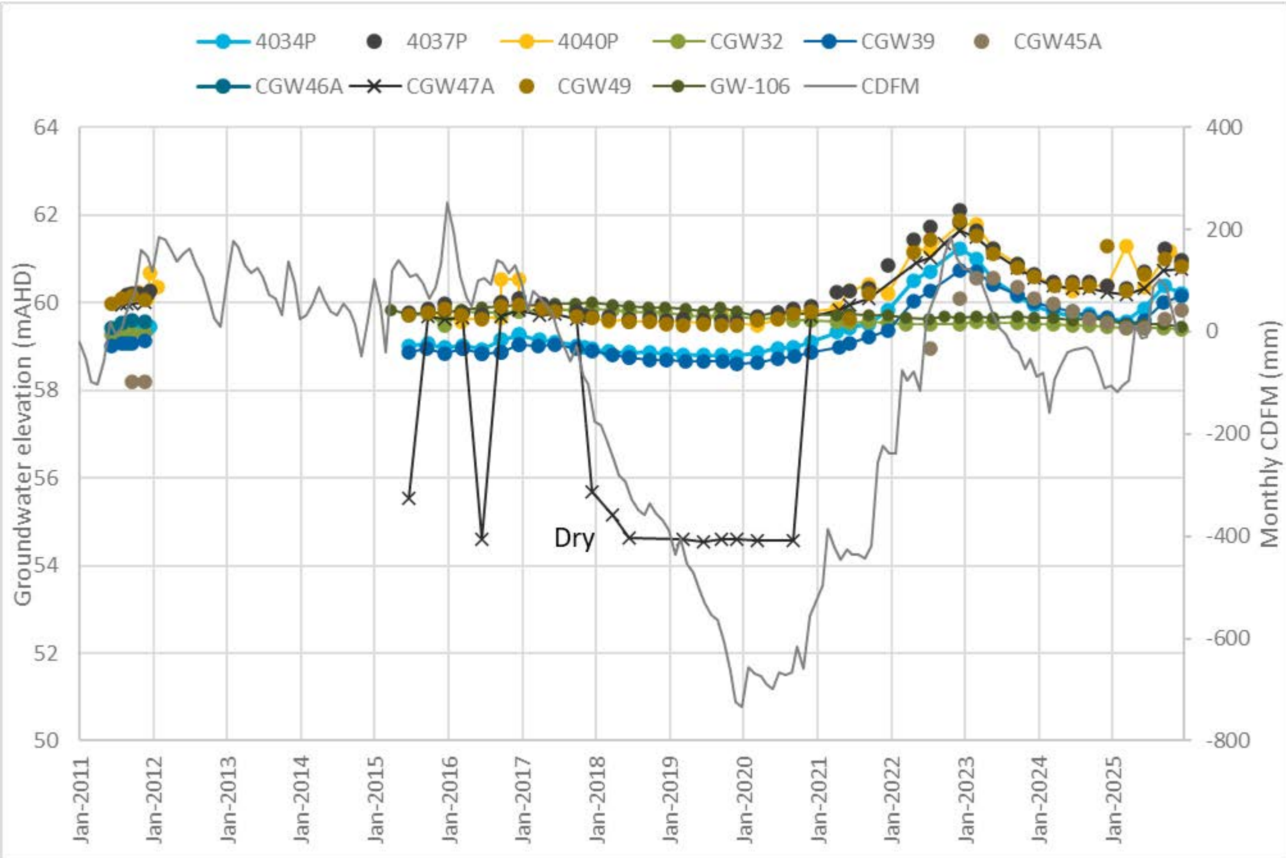


Figure 4.8 Hunter River alluvium Carrington west area - hydrographs

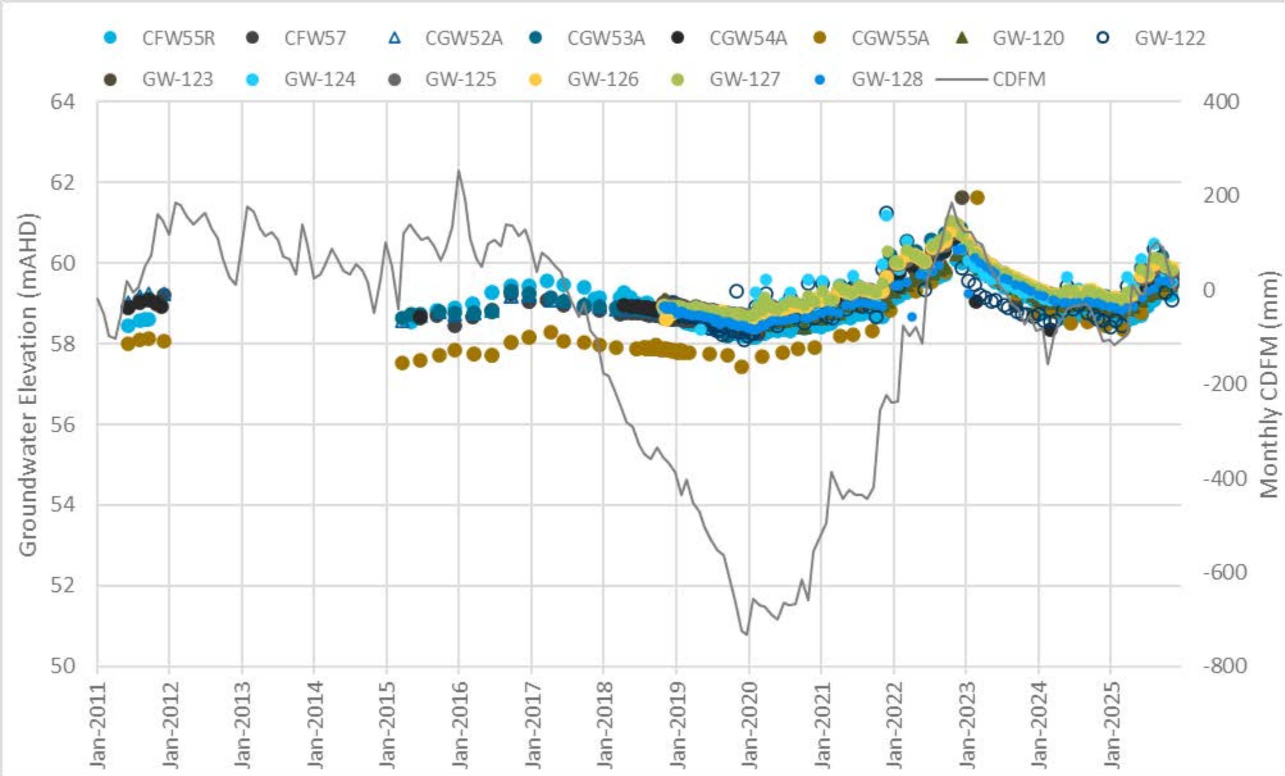


Figure 4.9 Hunter River alluvium Carrington east area - hydrographs

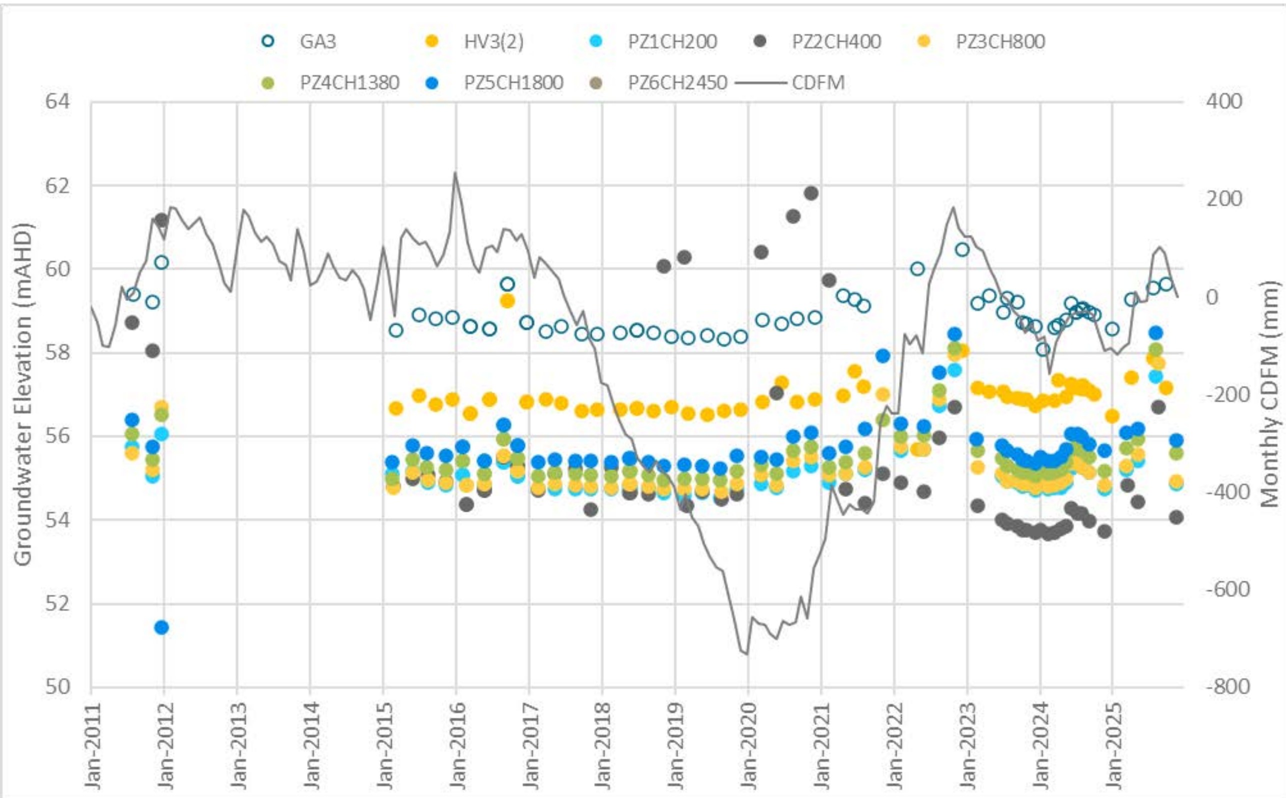


Figure 4.10 Hunter River alluvium Alluvial Lands LPBW area - hydrographs

a Alluvial saturated thickness

Available data indicate the alluvial saturated thickness:

- in the Hunter River alluvium south of Carrington Pit ranges between 1 and 8 m
- ranges from 1 to 6 m in the western arm of the paleochannel
- ranges from 2 to 10 m in the area between Alluvial Lands and HVO South
- increases up to 14 to 24 m in the Hunter River alluvium east of HVO South
- ranges from <1 to 6 m in the Wollombi Brook alluvium in the SLP 1 area, increasing with distance downstream towards the confluence with the Hunter River.

ii Permian coal measures

The potentiometric surface in the Permian HSUs is generally lower than the alluvial watertable (downward gradient from the alluvium to the Permian units) due to historical mining in the area (Figure 4.11 and Figure 4.12). Therefore, there is expected to be downward leakage from the alluvium to the Permian units that will be limited by hydraulic properties of the regolith and interburden.

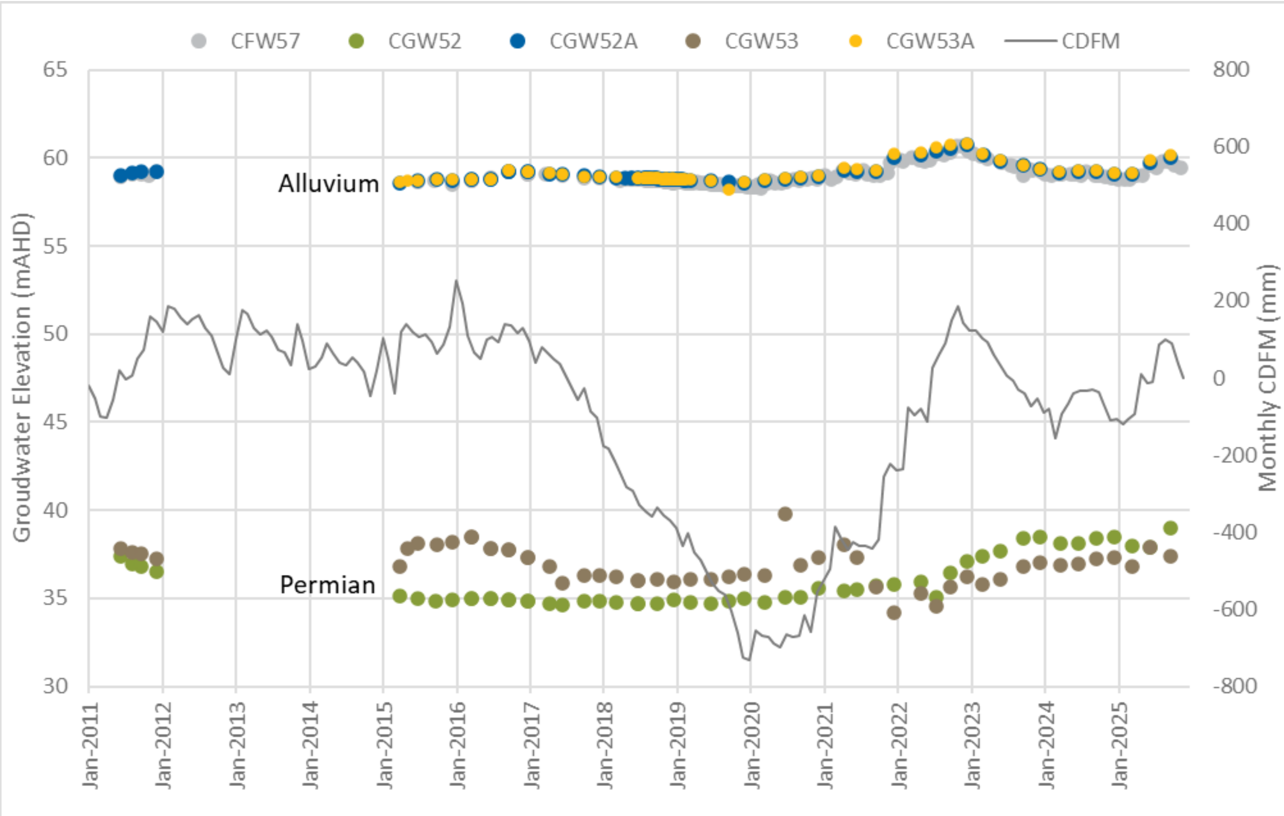


Figure 4.11 Carrington area Permian and alluvium hydrographs

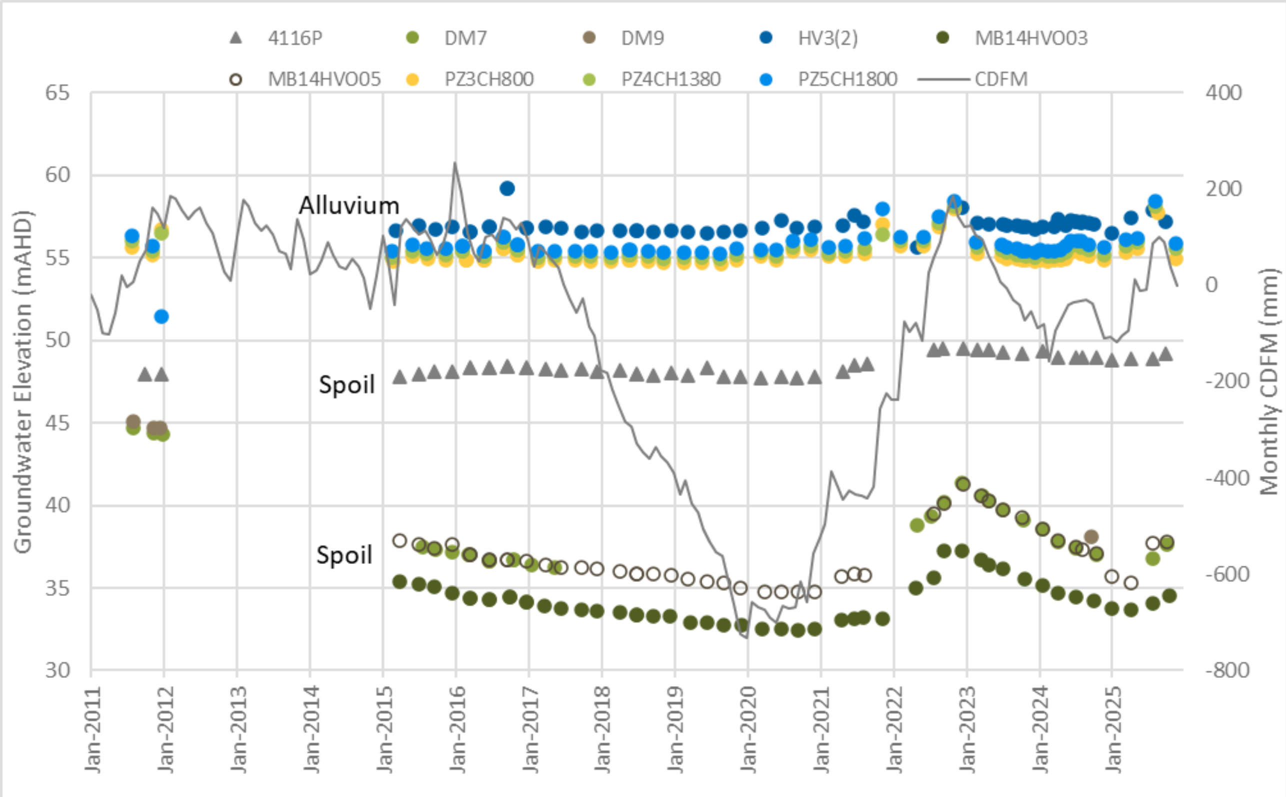


Figure 4.12 Alluvial Lands spoil and alluvium hydrographs

4.6.5 Groundwater quality

Groundwater sampling for water quality analysis has been undertaken extensively within the HVO Complex area and surroundings (Section 4.6.2).

Monitoring shows the Hunter River alluvium has relatively low salinity (brackish) and variability. The Permian groundwater is characterised by higher salinity (moderately saline). Figure 4.8 presents EC measurements in monitoring bores from various geological formations near HVO North and HVO South, the neighbouring Ravensworth Operations, United Wambo Joint Venture and Liddell Coal Operations mines. The EC measurements are presented as a box and whisker plot which shows the spread of the data and a range of statistics (including 5th and 95th percentiles, median, interquartile range (25th percentile to 75th percentile) excluding any outliers) (AGE 2022).

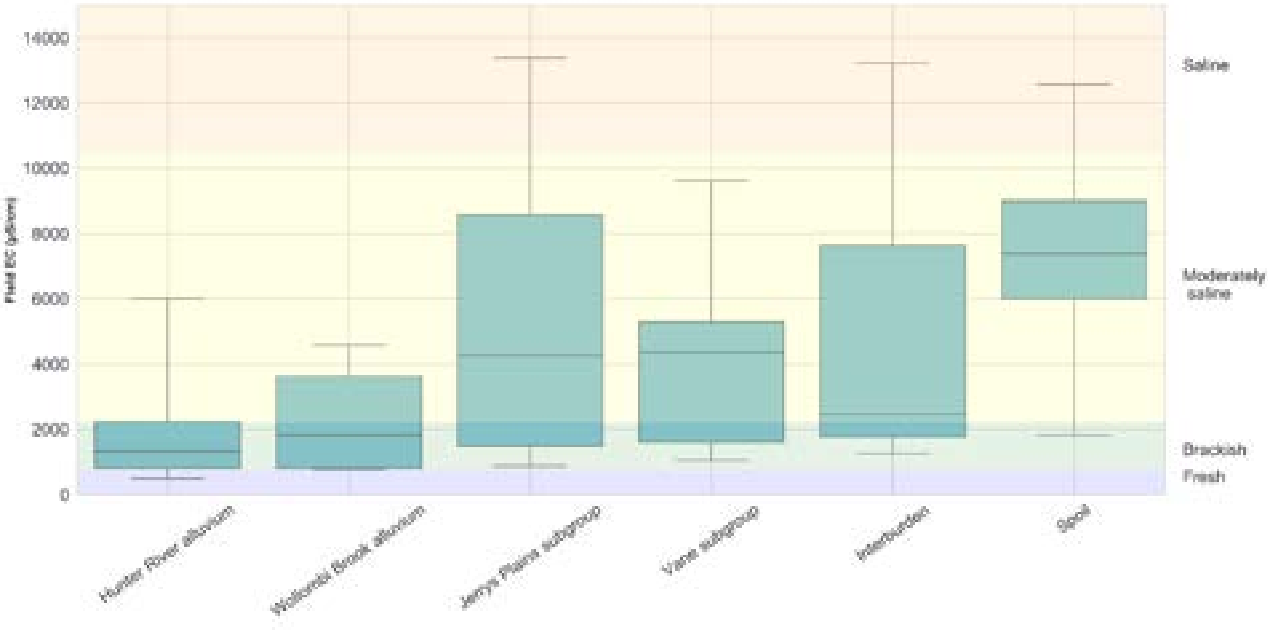


Figure 4.13 Distribution of groundwater field EC by formation in the study area (AGE 2022)

Historically, the salinity of the paleochannel alluvium has been elevated, freshening in areas close to the river where the effects of recharge and mixing are more evident (MER 2010). Figure 4.14 presents salinity (as field measured EC) for alluvial sediments in the Carrington West Wing area, including the remnant area of the paleochannel which is also disconnected from the Hunter River (GW-106 and CGW32). It shows the alluvial groundwater salinity is higher in the remnant paleochannel than in alluvial sediments closer the river. Figure 4.14 also shows the freshening of alluvial groundwater over time in the northern area of the Carrington West Wing alluvium (CGW39 and CGW47A).

In the Carrington area, south of the existing LPBW, alluvial groundwater salinity (e.g. CGW52A, CGW53A) has been relatively stable and is fresher than groundwater sampled from the Permian and interburden monitoring bores (e.g. CGW51A, CGW52, CGW53A; Figure 4.15).

Similarly, alluvial groundwater salinity (e.g. PZ4CH1380, PZ5CH1800) has been relatively stable and is fresher than groundwater sampled from the backfilled spoil material in the Alluvial Lands area (e.g. 4116P, DM7, MB14HVO03; Figure 4.16).

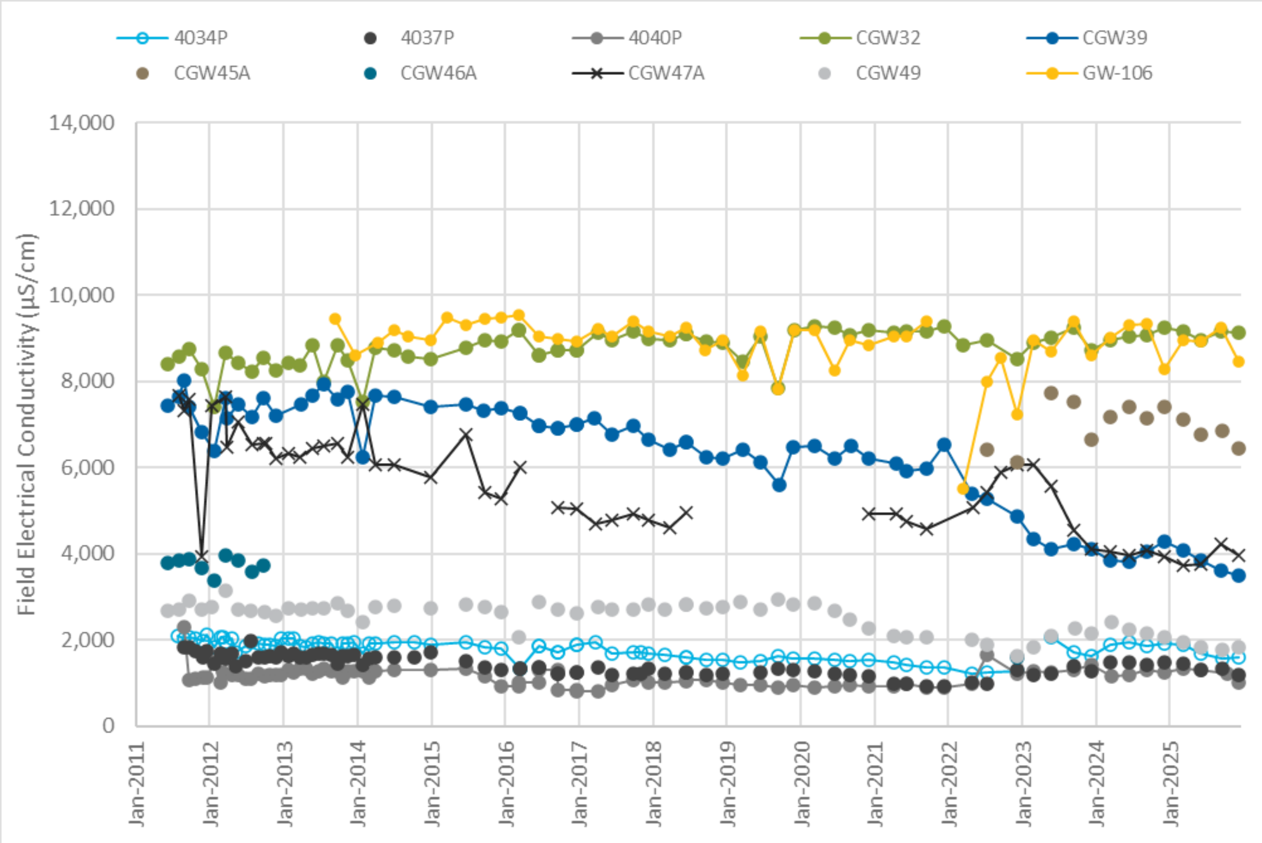


Figure 4.14 Carrington West Wing area (alluvium) – salinity time series chart

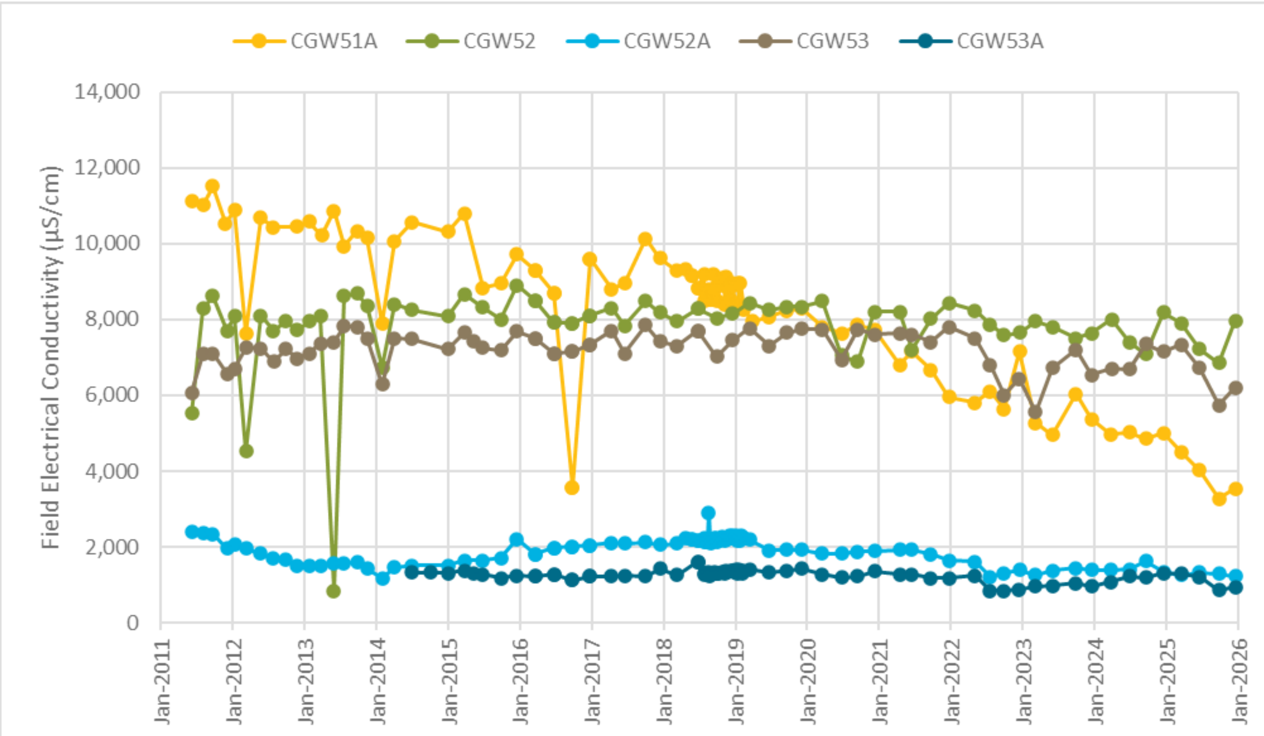


Figure 4.15 Carrington LPBW area – salinity time-series charts

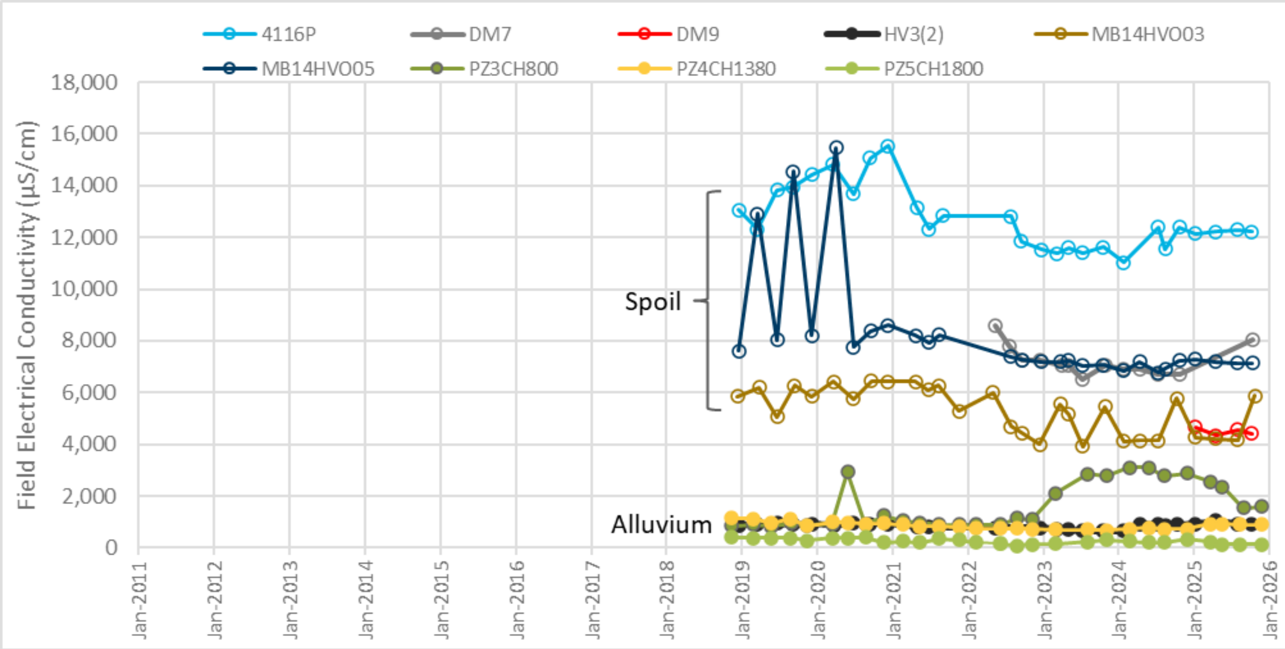


Figure 4.16 Alluvial Lands LPBW area – salinity time-series chart

4.6.6 Environmental and community values

Beneficial uses of groundwater are limited to the alluvium. Groundwater extracted from the Hunter River alluvium supports irrigation, livestock drinking water and domestic and stock purposes. However, the alluvium groundwater is generally not suitable for long-term irrigation purposes.

Shallow groundwater also supports ecosystems that rely on (e.g. stygofauna) or opportunistically access water (e.g. river red gums) and therefore is likely to have cultural and spiritual value to Aboriginal people.

Permian groundwater has limited beneficial use due to the salinity. It is intercepted through mining activities and used where possible (as a priority over other water sources) within the WMS.

Groundwater users, including ecosystems that are potentially dependent on water (i.e. GDEs) are discussed further in Section 4.8.2.

4.7 Geochemistry

This section provides a summary of the geochemical assessment completed for the Project (Annexure D; Egi 2022a). The objectives of the geochemistry work were to assess the potential for acid rock drainage, salinity and metal/metalloid leaching (including neutral mine drainage) of the proposed mine materials; identify any geochemical issues; and provide recommendations for materials management and any follow up test work if required.

Results of geochemical testing indicate most overburden/interburden materials represented by the samples tested is:

- non-acid forming (NAF)
- of low sulphur content
- has an excess of acid neutralising capacity
- low leachable salinity.

Potential acid forming (PAF) materials are estimated to comprise only 3% of overburden/interburden. Thin pyritic zones of elevated sulphur were identified generally close to coal seams, but dilution and mixing during mining should be sufficient to mitigate any acid rock drainage generation.

Overburden/interburden samples tested indicate the material is a potential source of buffering to help mitigate any acid rock drainage from PAF materials. Sandstone and siltstone tended to have higher acid neutralising capacity than other lithologies and are also the most common lithologies.

Given the expected high proportions of NAF (approximately 97% of overburden/interburden intervals tested were classified NAF) relative to PAF (approximately 3%), operational blending of NAF and PAF overburden/interburden together with the excess alkaline leachate from NAF materials is expected to be a robust approach to controlling acid rock drainage from PAF materials.

Most coal samples tested were PAF. Approximately half of immediate seam roof, floor and partings materials is also likely to be PAF, with NAF materials estimated to be 52%. These materials are generally thin (less than 0.3 m) and are expected to report to the raw coal process stream, however if they were to report to overburden/interburden then dilution and mixing during mining would be sufficient to negate acid rock drainage risk from these materials.

Kinetic net acid generation (NAG) testing indicated that the PAF samples tested were relatively fast reacting and, despite varying acid neutralising capacity, lag times of one month or less were indicated.

Sulphur speciation testing suggests that the total sulphur in non-coal overburden/interburden samples and in rejects samples is likely to be mainly pyritic, and that coal samples and tailings samples are likely to include a higher proportion of non-pyritic sulphur forms.

The results of water and peroxide extraction tests indicate that significant metal/metalloid release from materials represented by the samples tested would only be associated with generation of acid rock drainage. The solubility of metals/metalloids will largely be determined by pH and therefore prevention of acid generation will effectively control metal/metalloid leaching.

Extracts from low sulphur NAF materials indicated that drainage from these materials is likely to be slightly saline to moderately saline and is unlikely to contain significant metal/metalloid concentrations, but elevated sulphate may occur from NAF materials with significant pyrite.

As observed in the surface water quality monitoring data, water quality within the mine water system is generally neutral to alkaline, with salinity up to 5,170 milligrams per litre (mg/L) TDS.

Extracts show that metal/metalloid release associated with any acid rock drainage generated from pyritic overburden materials would include aluminium (Al), cadmium (Cd), cobalt (Co), chromium (Cr), copper (Cu), iron (Fe), manganese (Mn), nickel (Ni), strontium (Sr) and zinc (Zn), and possibly arsenic (As) at low pH (less than 3).

4.8 Water receptors

At commencement of the various water studies conducted for the Project, the technical specialists (ELA, Engeny, AGE, Umwelt and EMM) held a risk assessment workshop and water receptor identification workshop, with consideration of available historical data, knowledge and the proposed project activities.

The location of identified water receptors is presented in Figure 4.17 and are described in the subsequent sections.

4.8.1 Surface water users

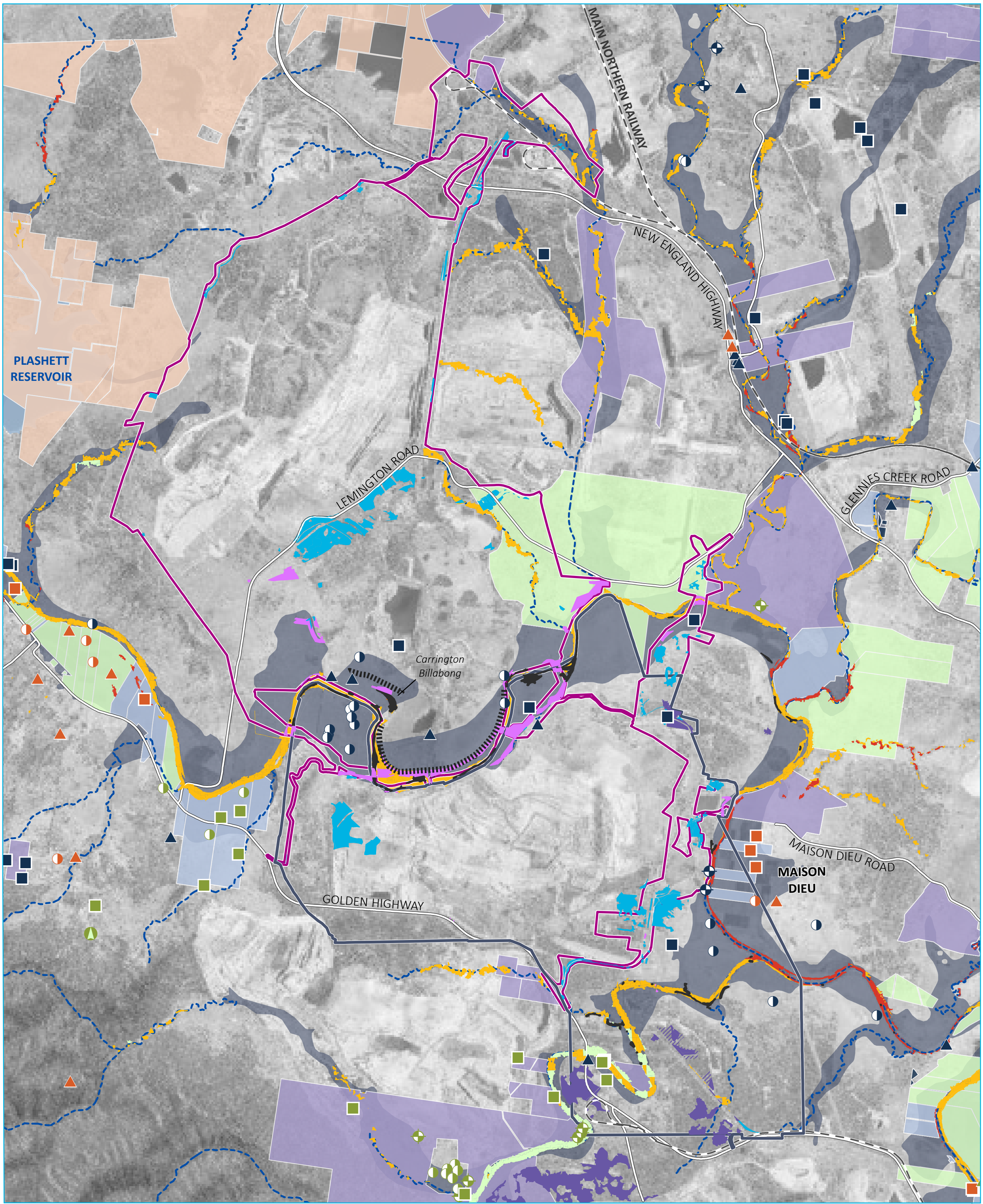
Extraction from the Hunter River and tributaries in the study area is mainly for town water supply, power generation, mining, industrial, agriculture and irrigation purposes.

In NSW, landholders can take water under basic landholder rights without a WAL or approval in certain circumstances. There are three types of basic landholder rights under the WM Act[2]:

- **Domestic and stock rights**: owners or occupiers of land overlaying an aquifer or with river, estuary or lake frontage can take water without a licence for domestic purposes or for stock watering.
- **Harvestable rights:** landholders can capture and store a proportion of the rainfall runoff from their landholding in one or more harvestable rights dams without requiring a WAL, water supply work approval, or water use approval.
- **Native title**: anyone who holds native title with respect to water, as determined under the Commonwealth *Native Title Act 1993*, can take and use water for a range of personal, domestic and non-commercial purposes.

It is assumed that water is captured for domestic and stock rights and harvestable rights in the study area. The specific location of these activities is not known; however, most of the land adjacent to the HVO Complex is owned by the HVO JV parties or other mining operations.

2 https://www.dpie.nsw.gov.au/water/licensing-and-trade/basic-landholder-rights



Source: EMM (2025); Glencore (2025); BoM (2025); DCSSS (2024); GA (2009); Umwelt (2025)

KEY

- HVO North Action Area
- HVO South Action Area
- Alluvial extent (state mapping)
- Existing low permeability barrier wall

Groundwater Dependent Ecosystem (GDE) probability (BOM GDE Atlas)

- High
- Medium
- Low

Owner

- Glencore
- Private
- Other mine

Bore type

- Commercial and industrial
- Irrigation
- Stock and domestic
- Unknown
- Water supply

Plant community type (PCT) (Umwelt, 2025)

- PCT 4089 | Namoi-Upper Hunter River Red Gum Forest
- River Red Gum (HVO, 2025)

EPBC Act vegetation (Umwelt, 2025)

- Central Hunter Valley Eucalypt Forest and Woodland CEEC
- Warkworth Sands Woodland of the Hunter Valley CEEC
- Possible Warkworth Sands Woodland of the Hunter Valley CEEC

Other water access user

- Domestic and stock
- Local water utility
- Major utility
- Regulated river
- Supplementary water
- Unregulated river

Existing environment

- Rail line
- Major road
- Named watercourse
- Named waterbody

Water receptors

HVO Continuation Project
Water Resources Impact Assessment
Figure 4.17

EMM creating opportunities

4.8.2 Groundwater users

Most third-party (non HVO JV) landholder bores are primarily located upstream and downstream of the HVO Complex along the Hunter River and most are screened within the Quaternary alluvium.

Figure 4.17 shows the locations of the third-party bores.

4.8.3 Water-dependent ecosystems

i Overview

Ecosystems that are potentially reliant on surface water include in-stream ecosystems that depend on streamflow (including in-stream ecosystems reliant on groundwater baseflow), and riparian ecosystems that depend on surface water and overbank flows.

GDEs are ecosystems that potentially rely on either the surface or subsurface expression of groundwater. A review of the relevant WSPs, GDE Atlas and other literature has been conducted in relation to the Project. The GDE Atlas was developed as a national dataset of Australian GDEs to inform groundwater planning and management. However, ground-based surveys and hydrogeological information is necessary to evaluate the presence of mapped GDEs and/or identify the presence of other potential GDEs.

An aquatic ecology and GDE assessment of the study area was conducted by ELA (2025) and comprised a desktop assessment to identify potential GDEs in the study area and follow-up field surveys to identify aquatic habitat and assess ecological condition of identified potential GDEs and aquatic ecology. The full report is attached as Annexure C.

The desktop phase of the aquatic ecology and GDE assessment identified the following potential water dependent ecosystems in the study area (ELA 2025):

- baseflow discharge to the Hunter River
- aquifer ecosystems of the Hunter River alluvium and associated tributary aquifers
- river red gum populations at Carrington Billabong, and along the Hunter River and Wollombi Brook
- Central Hunter Ironbark Grassy Woodland (in the Hunter River riparian zone), which conforms (or partially conforms) to the Central Hunter Valley Eucalypt Forest and Woodland critically endangered ecological communities (CEEC)
- Warkworth Sands Woodland of the Hunter Valley CEEC associated with the unconsolidated aeolian sediments in the area.

ELA conducted field surveys in April 2020, September 2020 and January 2022, that included:

- macroinvertebrate and water quality sampling to assess baseline conditions (pre-Project) along the Hunter River, and at sites on Bayswater Creek, Wollombi Brook, Bowmans Creek, Farrells Creek and Parnells Creek (including locations upstream and downstream of HRSTS discharge locations)
- stygofauna surveys at 30 monitoring bores across the HVO Complex, of which 11 were dry and could not be sampled
- field surveys to assess the ecological values and conditions of the identified potential GDEs using the protocol outlined in the *Risk Assessments Guidelines for Groundwater Dependent Ecosystems* (Serov et al 2012)

- condition assessment of four vegetation sites selected from the desktop and remote sensing analyses using the Biodiversity Assessment Method (BAM).

Figure 4.18 shows the survey locations.

ii Aquatic ecology

The following was observed during the aquatic ecology surveys:

- large flow events result in erosion and movement of sand and gravel beds along the Hunter River
- Wollombi Brook (in the study area) had moderate flow and high turbidity
- Bowmans Creek had shallow isolated pools in April and September 2020, and was flowing in January 2022
- Bayswater Creek was dry in April and September 2020, and the channel was full of terrestrial weeds, and was assessed to be poor aquatic habitat
- Farrells Creek was dry, with no macrophytes or other habitat features present.

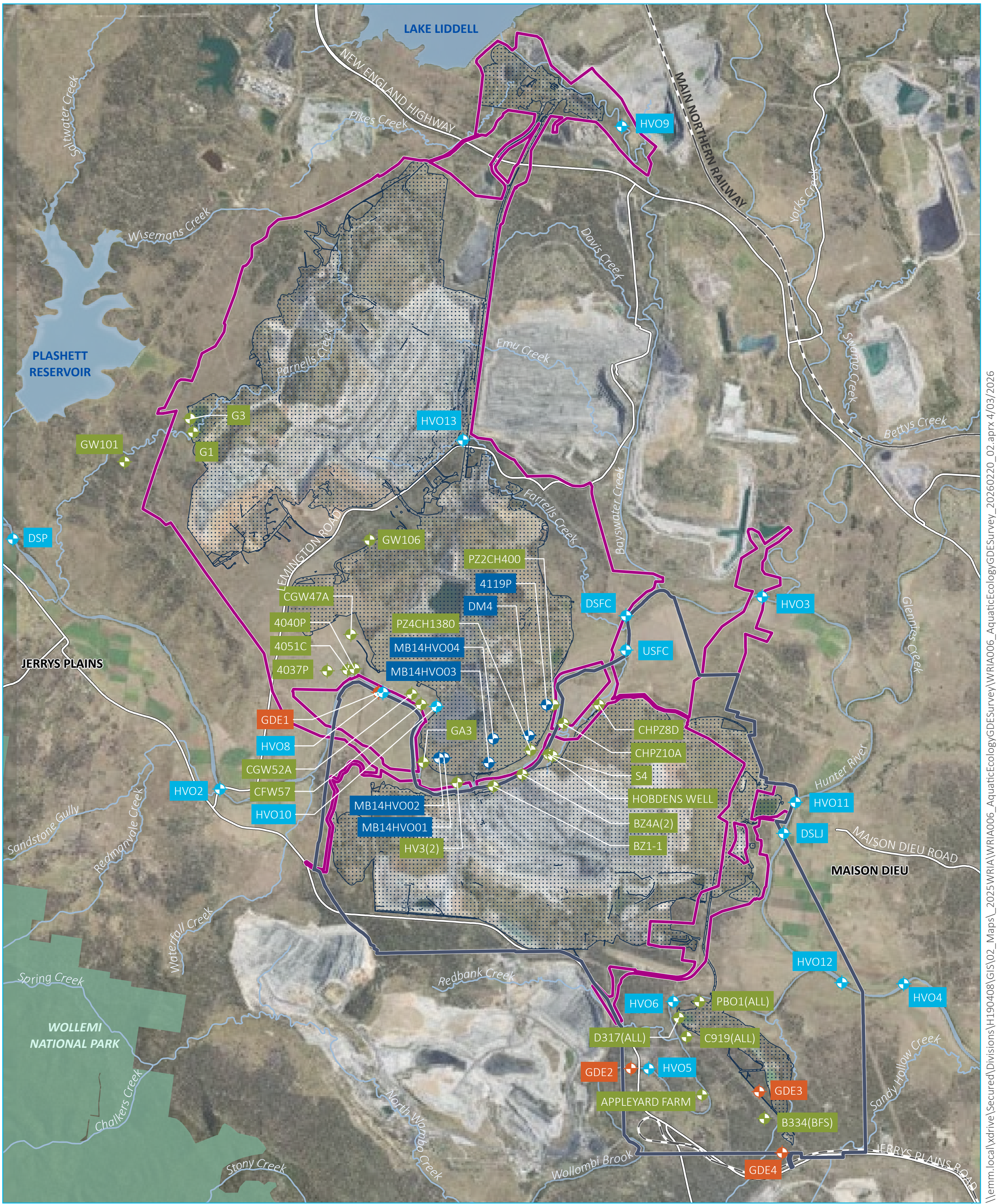
iii Potential groundwater dependent ecosystems

a Carrington Billabong and river red gum stands

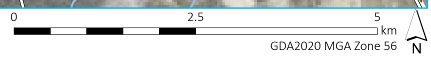
The Carrington Billabong is an ephemeral freshwater billabong south of the previously mined Carrington Pit at HVO North. Ecological health monitoring of the vegetation in the billabong is conducted by HVO. The main vegetation at the billabong are stands of river red gum that opportunistically access groundwater stored within the alluvium and rely on river flooding for germination. As discussed above, the alluvium is predominantly recharged by leakage from the Hunter River. Historical monitoring has shown relatively stable groundwater levels despite the presence of historical and ongoing mining.

The ecological surveys conducted for the Project observed that all vegetation stands were in low to moderate condition. Minimal cover of native shrub and ground layer vegetation contributed to lowering the condition rating.

Figure 4.19 presents a conceptual diagram of the river red gums and their reliance on water.



Source: EMM (2025); Glencore (2025); DCSSS (2024); GA (2009)



KEY

- HVO North Action Area
- HVO South Action Area
- Previous mining disturbance

Survey location

- Monitoring bore
- GDE vegetation site
- Rehabilitated alluvial lands rehabilitation bore
- Aquatic ecology site

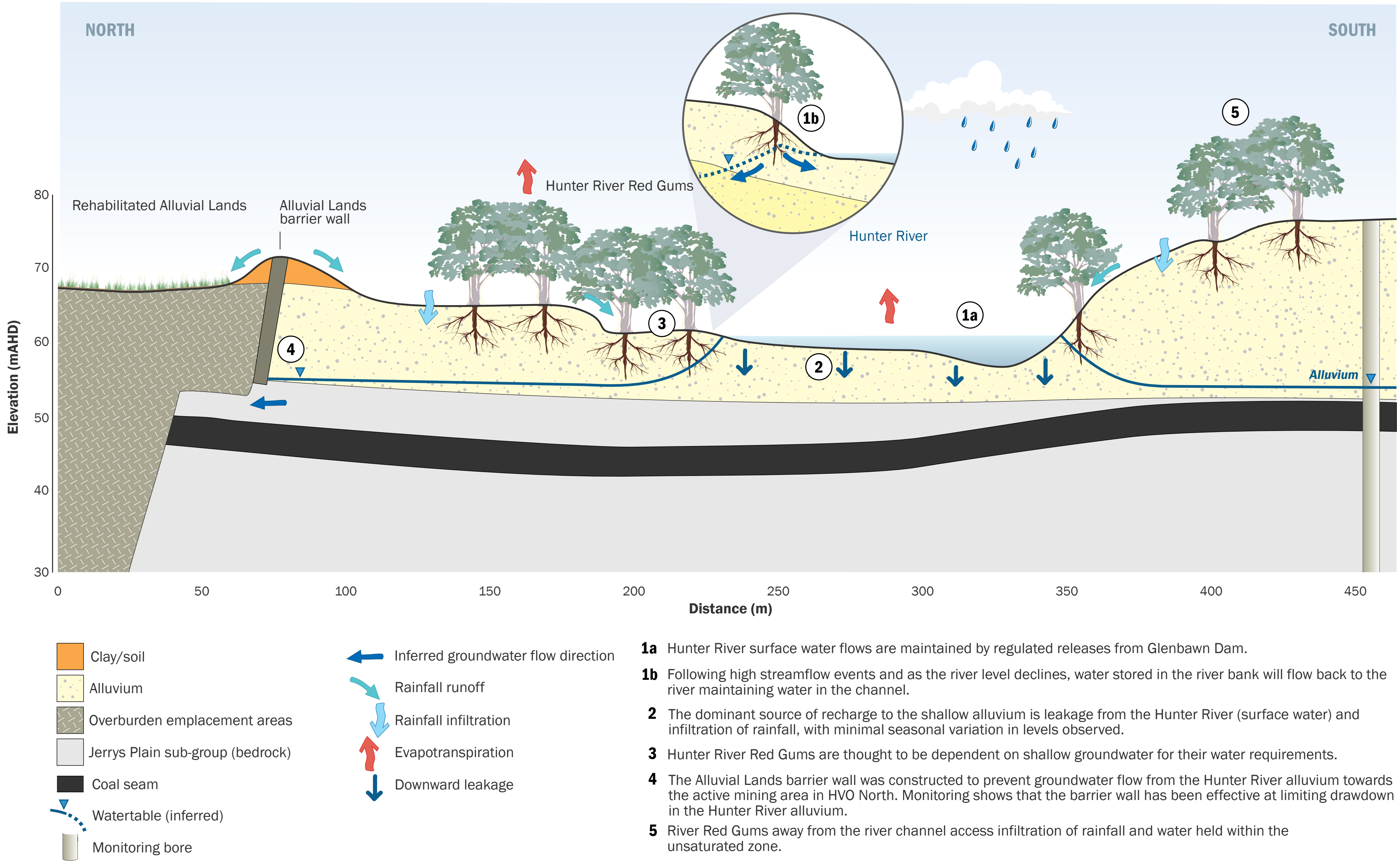
Existing environment

- Rail line
- Major road
- Named watercourse
- Named waterbody
- NPWS reserve

Aquatic ecology and GDE survey locations

HVO Continuation Project
Water Resources Impact Assessment
Figure 4.18

EMM
creating opportunities



1a Hunter River surface water flows are maintained by regulated releases from Glenbawn Dam.

1b Following high streamflow events and as the river level declines, water stored in the river bank will flow back to the river maintaining water in the channel.

2 The dominant source of recharge to the shallow alluvium is leakage from the Hunter River (surface water) and infiltration of rainfall, with minimal seasonal variation in levels observed.

3 Hunter River Red Gums are thought to be dependent on shallow groundwater for their water requirements.

4 The Alluvial Lands barrier wall was constructed to prevent groundwater flow from the Hunter River alluvium towards the active mining area in HVO North. Monitoring shows that the barrier wall has been effective at limiting drawdown in the Hunter River alluvium.

5 River Red Gums away from the river channel access infiltration of rainfall and water held within the unsaturated zone.

This diagram is a conceptual representation only

Figure 4.19 Receptor conceptual diagram – Hunter River and River Red Gums

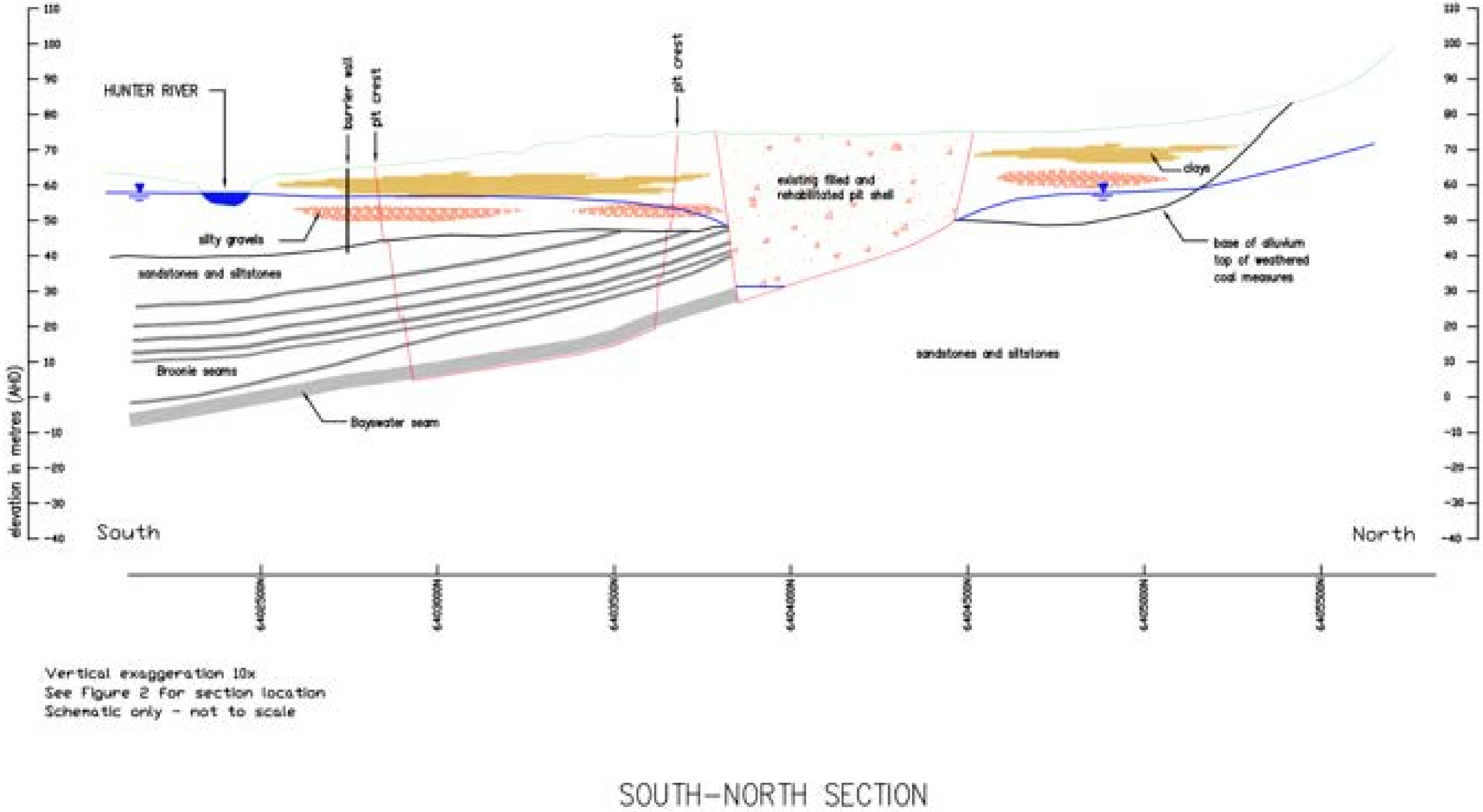
b Stygofauna

Stygofauna are known to occur in alluvial sediments within the study area along the Hunter River, Bowmans Creek, Glennies Creek and Wollombi Brook (ELA 2025). They may also occur in the shallow fractured rock up to 60 m depth where they colonise fracture networks of secondary porosity. The presence of stygofauna becomes increasingly uncommon in the deeper, unweathered rock where high groundwater salinity, and low dissolved oxygen levels limit their occurrence (ELA 2025).

Of the sampled bores around the HVO Complex, EC (at the time of sampling) ranged from 311 to 9,158 µS/cm, with all but two bores having EC less than 5,000 µS/cm (ELA 2025). A total of five stygofauna taxa were collected over two survey periods. No stygofauna were collected in September 2020. Most stygofauna collected came from the Hunter River alluvium. Stygofauna from the Parabathynellidae family were the most abundant stygofauna collected, with 189 individuals collected from GW-106 (in the remnant paleochannel) in 2020, 23 collected from CHPZ8D (in the shallow Mt Arthur coal seam[3], north-east of the Cheshunt Pit at HVO South (and north of the rehabilitated Barry's Pit))) and one individual collected at CGW47 and CGW52A (in the Carrington West Wing alluvium area). Further discussion is provided in Annexure C.

For context, Figure 4.20 shows a generalised north-south cross section, reproduced from MER (2010), through the Hunter River alluvium, north through the Carrington West Wing area, previously mined area near Carrington Pit to the remnant paleochannel (where GW-106 and CGW-32 are located).

[3] Note that at the time of reporting, ELA (2025) understood CHPZ8D was screened in the alluvium; however, records confirm this shallow bore (~8 m deep) is screened in the shallow Mt Arthur coal seam. This change does not have a material impact on the findings of the ELA (2025) study



Source: MER (2010)

Figure 4.20 Conceptual cross section through remnant paleochannel

c Central Hunter Valley Eucalypt Forest and Woodland CEEC

The Central Hunter Valley Eucalypt Forest and Woodland CEEC occurs in the Hunter Valley region on soils derived from Permian sedimentary bedrock. It does not occur on alluvial flats, river terraces, windblown sands, Triassic sediments, or escarpments (TSSC 2015). As described in the *Biodiversity MNES Assessment* reports (Umwelt 2026a and 2026b), the Project will directly impact of the Central Hunter Valley Eucalypt Forest and Woodland CEEC.

HVO has sought to avoid and minimise potential impacts on ecological values throughout the Project planning process. This included targeted avoidance and minimisation measures to reduce the Project's impact on areas of higher value vegetation and habitat, including (but not limited to):

- locating impacts predominantly in previously mined and/or disturbed areas, and areas approved to be disturbed
- refinement and location selection of the Lemington Road realignment to remove all direct impacts to Warkworth Sands Woodland of the Hunter Valley CEEC
- reduction to the area of Central Hunter Eucalypt Forest and Woodland CEEC disturbed
- careful consideration of proposed transmission line easement alignments to avoid areas of higher quality vegetation and habitats, and to provide for maximum vegetation and habitat retention in easement corridors
- habitat retention following decommissioning of existing transmission lines.

HVO has committed to the design and implementation of a comprehensive biodiversity mitigation strategy to mitigate the unavoidable impacts of the Project.

Central Hunter Valley Eucalypt Forest and Woodland CEEC is mapped in the Lemington Road area between West Pit and Carrington Pit at HVO North, where there are Permian sediments and alluvial sediments associated with the remnant paleochannel (disconnected from the Hunter River due to historical approved mining). Groundwater monitoring bores GW-106 and CGW32 are located in the area (Figure 4.6) and record depths to the watertable ranging from 19 to 23 m below ground level (mbgl); salinity is also high at approximately 9,000 µS/cm. Given the depth to the watertable, the vegetation is thought to rely on infiltration of rainfall and water held in the unsaturated zone, rather than the deeper watertable. A hydrograph of groundwater level monitoring data from GW-106 and CGW32 is shown on Figure 4.21.

Central Hunter Valley Eucalypt Forest and Woodland CEEC is also mapped in the HVO South MIA area and Lemington Road realignment area east of the HVO South mine. The mapped surface geology is the Permian Jerrys Plains Subgroup. Monitoring data in this area (NSW Government bore GW080963) and HVO bores (GW9701, GW9702, GW9710) also indicates the depth to the watertable (in the Permian lithology) is deep:

- GW080963 notes depth to groundwater at 60 mbgl at construction (2005), increasing to approximately 80 mbgl in 2020
- Monitoring data for GW9701, GW9702 and GW9710 (Figure 4.6) notes depths of 20 mbgl to 37 mbgl in 2011 to 2015.

Given the reported depth to groundwater in these areas, the vegetation within the Central Hunter Valley Eucalypt Forest and Woodland CEEC are unlikely to access groundwater associated with the regional watertable.

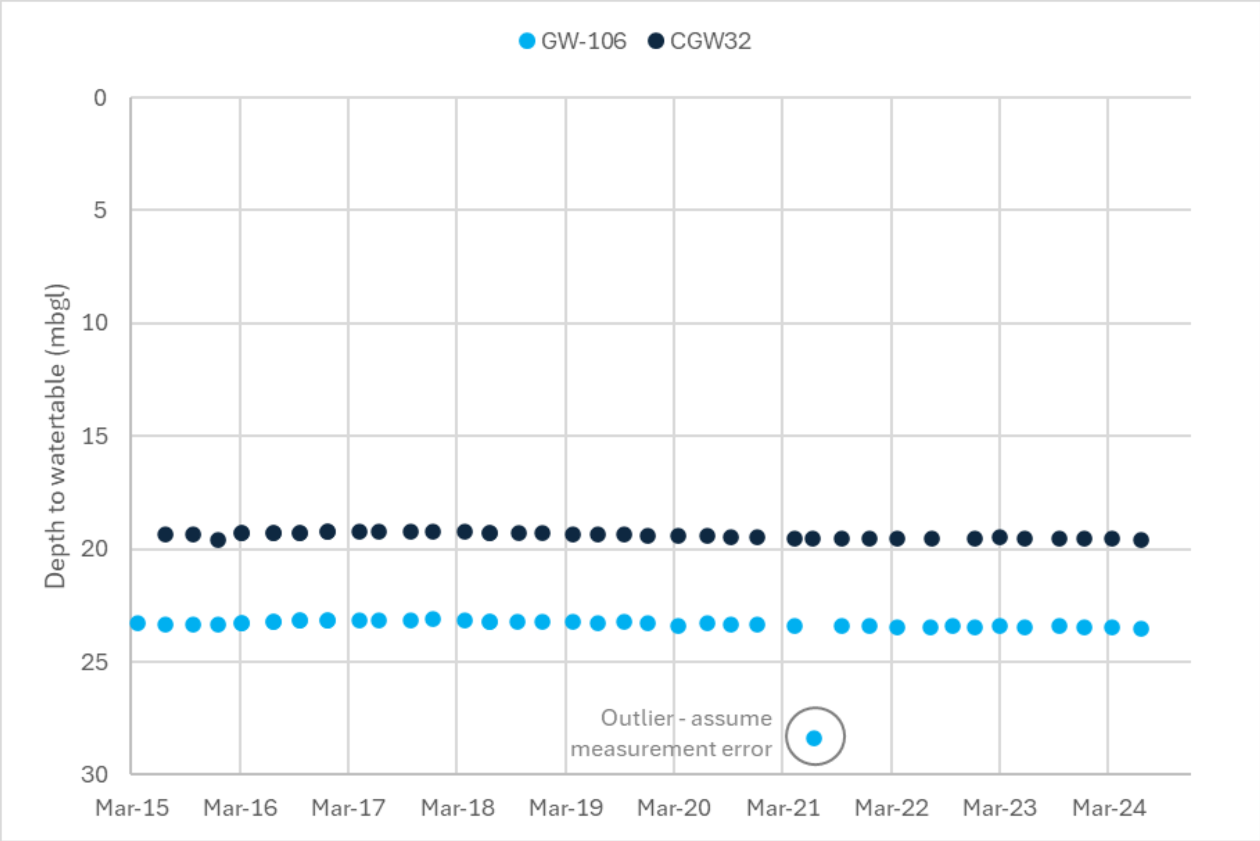


Figure 4.21 GW-106 and CGW32 hydrograph

d Warkworth Sands Woodland of the Hunter Valley CEEC

The Warkworth Sands Woodland of the Hunter Valley CEEC is largely associated with the unconsolidated aeolian sediments in the area. The saturation in the sands is variable. In October 2020, two dedicated monitoring bores were installed within the sand in the SLP 1 area (WSW North and WSW South; Figure 4.6), with the screened interval installed at the base of the sand. At the time of the installation, the sand was dry. Pressure transducer data loggers were installed in the bores and data shows infiltration of rainfall following large (or continuous) rainfall events results in temporary saturation. Figure 4.22 presents a hydrograph of groundwater level monitoring at these bores and shows temporary saturation occurring following large rainfall events in March 2021 (at the south bore only), November 2021, March 2022 and July 2022, which are separated by dry periods. The aeolian sand in this location is not in hydraulic connection with the Hunter River alluvium and is disconnected from the underlying potentiometric surface in the Permian. This is supported by groundwater level monitoring data at nearby nested location C130, which monitors groundwater elevations in the Woodlands Hill seam, Bowfield seam and Arrowfield seam (Figure 4.23).

The vegetation associated with the Warkworth Sands Woodland of the Hunter Valley CEEC are thought to rely on infiltration of rainfall and a seasonal perched watertable that is not in hydraulic connection with the underlying Permian hydrostratigraphy. Therefore, there is no impact pathway for the mining associated depressurisation to affect the seasonal watertable in the aeolian sands and the Warkworth Sands Woodland of the Hunter Valley CEEC is not discussed further in the WRIA.

A diagram showing the conceptual understanding of the Warkworth Sands Woodland of the Hunter Valley CEEC in the HVO South area and the interaction between terrestrial vegetation with water is presented in Figure 4.24.

More information on the potential water dependent ecosystems present in the study area is provided in the aquatic ecology and GDE assessment report (ELA 2025; Annexure C).

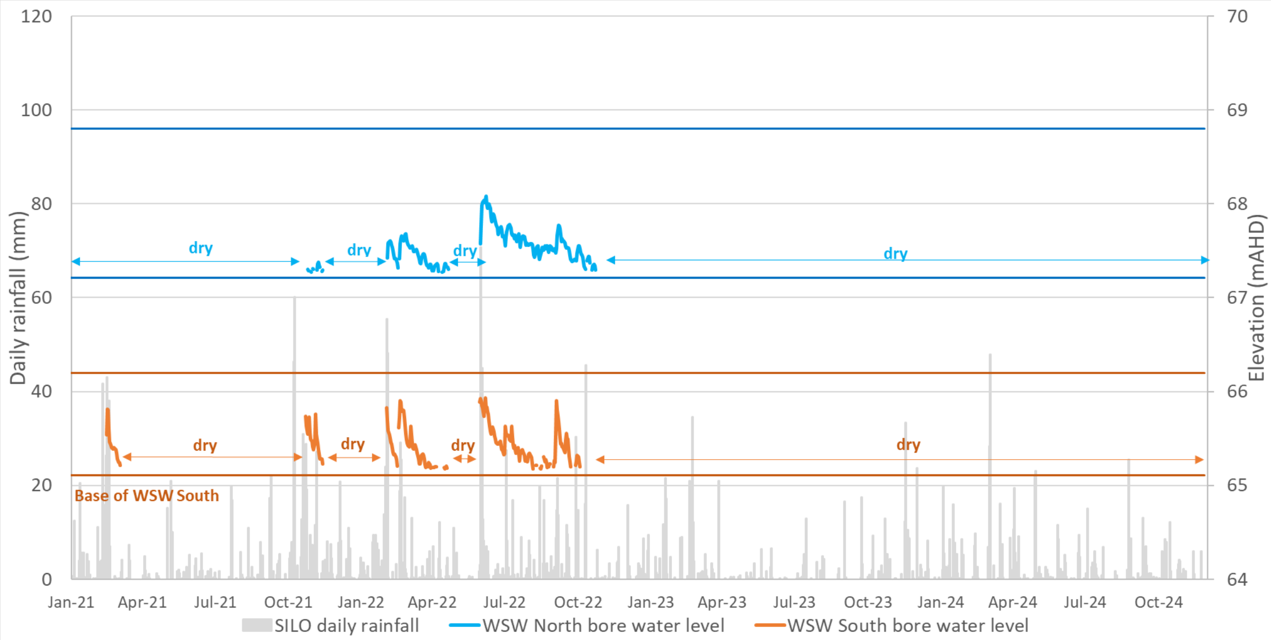


Figure 4.22 Warkworth Sands monitoring bore hydrograph

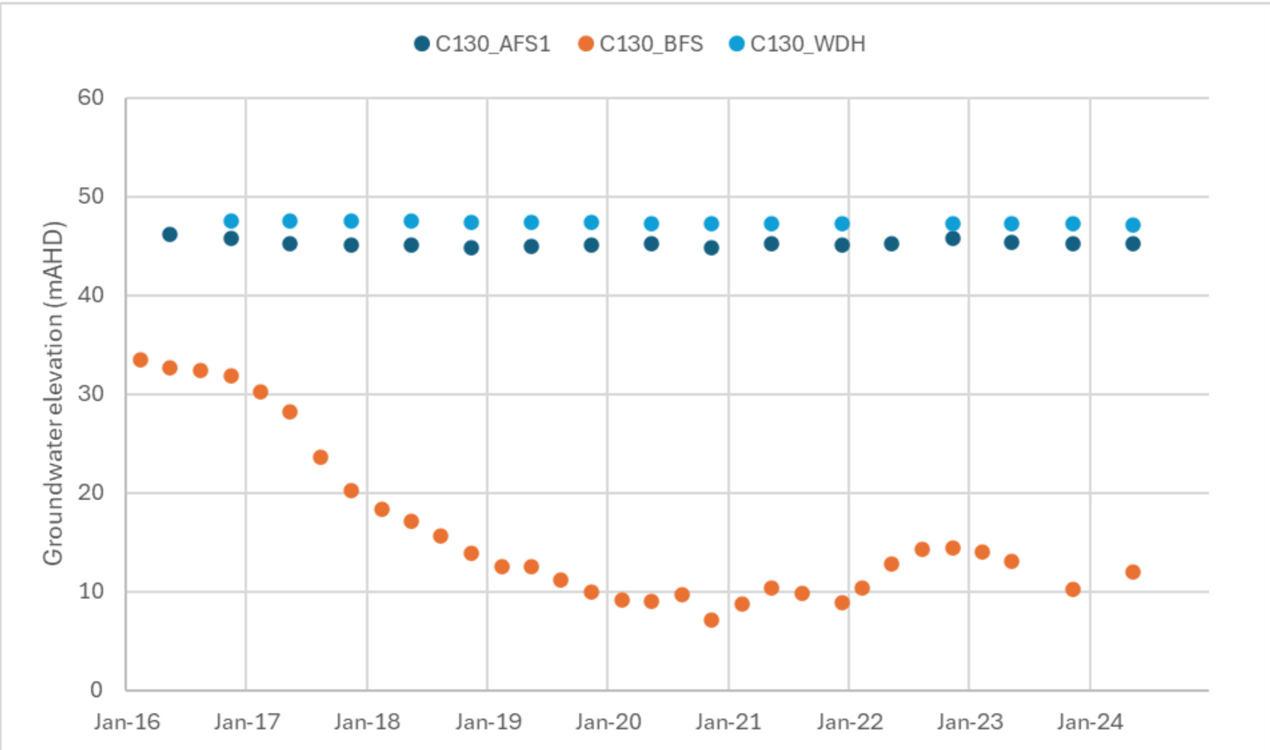
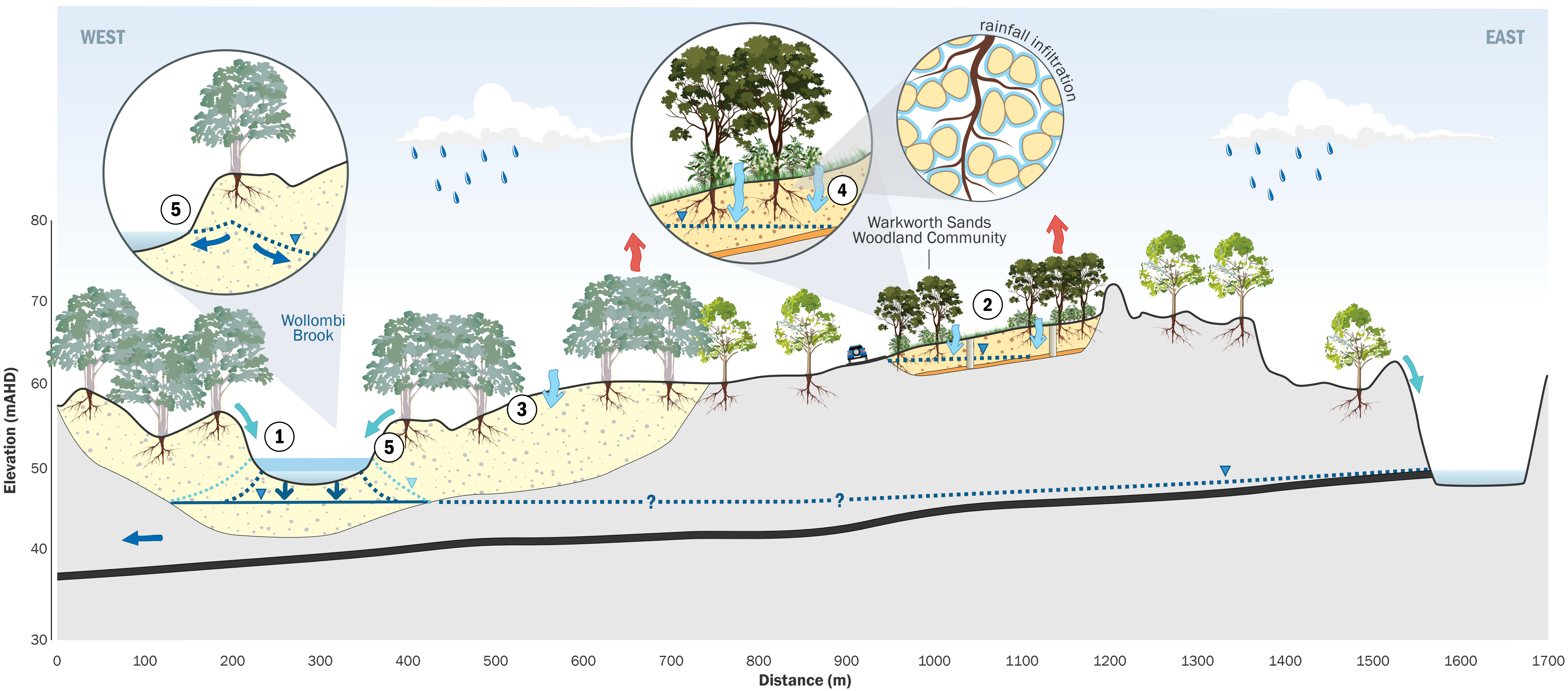


Figure 4.23 C130 nested monitoring location hydrograph (Lemington South)



- Alluvium
- Aeolian sands
- Clay (weathered Permian bedrock)
- Jerrys Plain sub-group (bedrock)
- Coal seam
- Watertable (inferred)
- High watertable following large streamflow event
- Inferred groundwater flow direction
- Rainfall runoff
- Rainfall infiltration
- Evapotranspiration
- Monitoring bore
- Downward leakage

1 Flows in Wollombi Brook are variable, with no streamflow observed between 2017 and 2019. The main contribution to watercourse flows is rainfall runoff.

2 The Warkworth Sands Woodland Community occurs on aeolian sand deposits and comprises a small tree layer, shrubs and groundcover species.

3 Vegetation access water from infiltration of rainfall.

4 Vegetation in the Warkworth Sands Woodland Community access rainfall infiltration that creates a perched watertable following rainfall events (e.g. March and November 2021). This ephemeral perched watertable is not in hydraulic connection with the deeper Permian coal measures.

5 Wollombi Brook is predominantly a losing watercourse. Surface water is the main source of recharge to the shallow alluvium. Following high streamflow events (occuring only 20% of the time according to WaterNSW stream gauge 210004), as the water level declines, water stored in the river bank will flow back to the river maintaining water in the channel until depleted.

This diagram is a conceptual representation only

Figure 4.24 Receptor conceptual diagram – Warkworth Sands and Wollombi Brook

iv Conditions between 2022 and 2024

The aquatic ecology and GDE surveys occurred through to late 2022 when the EIS (EMM 2022) was submitted to the NSW Government. ELA has provided commentary on whether the ecological condition of the aquifers and waterways assessed are likely to have changed in the intervening time of the surveys and the preparation of this report, or whether the samples collected and observations made during these surveys remain representative of the aquatic and aquifer ecological environment. This commentary is included as an addendum to ELA's aquatic ecology and GDE assessment, provided in Annexure C, and is summarised below.

- Flow in the Hunter River between January 2020 and January 2022 experienced eight large flow events where river height upstream of Singleton exceeded 4 m. Large flow events during this period were relatively frequent, with the biggest interval between events being five months. The frequency and magnitude of these large events would have shaped the aquatic invertebrate communities collected during the monitoring period, with the brief period between events not allowing sufficient time for invertebrate communities to recover.

- Large floods generally cause an initial decline in macroinvertebrate diversity and abundance at a site. Following a flood, sites are recolonised by macroinvertebrates that were able to take refuge in slow pockets of water during flooding, or by fauna colonising from upstream or elsewhere. Depending on the magnitude of the flood, it can take a long time for communities to recover. If another flood occurs before the community recovers, then the impact on the aquatic community becomes compounded, and the ability to recover declines. The repeated flooding in the Hunter River during the survey period is likely why macroinvertebrate communities had low diversity and consisted mainly of disturbance-tolerant taxa. Similar patterns would likely have occurred across the aquatic ecosystems in the river, with fish and aquatic plant communities impacted to differing degrees.

- Since January 2023, flow in the Hunter River has generally been declining, returning to a more controlled flow with releases from Glenbawn Dam and Glennies Creek Dam. It is expected that the stable period may have allowed aquatic communities to recover, though it is not clear to what level, as it can take a number of years for this to occur.

- Additional sampling in the period between 2022 and the time of preparation of the aquatic ecology and GDE assessment report (2025) would be unlikely to result in any changes to findings of the aquatic ecology and GDE impact assessment prepared in 2022, as the aquatic ecological community in the Hunter River (including fish) is robust and not sensitive to the minimal changes to flow regime that is predicted by modelling (ELA 2025). The long history of monitoring data in the alluvium at HVO and within the Hunter Valley provides confidence in the conceptual hydrogeological model and provides insight into aquifer ecological condition.

- Groundwater levels in the Hunter River alluvium have remained relatively consistent with historical trends (monitoring spanning more than a decade), responding to changes in streamflow (including flooding) and large rainfall events (refer Figure 4.8 to Figure 4.10). Groundwater salinity (as EC) in the Hunter River alluvium near Carrington (including the remnant paleochannel sediments) ranges from approximately 850 to 9,400 µS/cm (refer Figure 4.14 to Figure 4.16). GDE surveys recorded stygofauna present in these areas. Although outside of the optimal range for stygofauna (<5,000 µS/cm; Hancock and Boulton 2008), the alluvial groundwater salinity appears still tolerable for stygofauna. Given aquifer conditions have remained relatively stable and consistent with historical trends, and the diversity of locations where stygofauna were found at HVO, it is unlikely that stygofauna communities would have changed since the surveys were conducted.

- Additional sampling of stygofauna would provide little additional useful information, apart from potentially finding more taxa in the Project area (most likely taxa already collected from the broader alluvial aquifers of the Hunter River and its tributaries). In addition, the impact assessment (presented in Section 9) is already based on the premise that the Hunter River alluvial aquifer is a high priority GDE, and mitigation recommendations already aim to minimise impact.
- Given the minimal change to groundwater levels and quality since 2022, groundwater dependent vegetation is expected to be in a similar condition as it was when surveyed. It is likely that short-rooted components of the vegetation community, such as grasses, herbs, and shrubs will have changed, but these are primarily dependent on surface water or soil moisture. The river red gum community at HVO is subject to a rehabilitation and restoration strategy that assesses ecological health. Additional surveying of this community would not alter the findings of the aquatic ecology and GDE assessment.

5 Ecohydrological conceptual model

A conceptual model describes the key processes in the hydrological and hydrogeological environment. It is based on hypotheses and assumptions, some of which are derived from data sourced from the water environment under investigation, and others based on general hydrogeological or hydrological principles. As the IESC (2024) describe, ecohydrological conceptual models are a type of conceptual model used to understand and describe relationships between hydrological (surface water and groundwater) components and ecological ones (e.g. specific taxa, communities and ecosystems). The conceptual model(s) form the basis of assumptions adopted in the numerical models and is the basis for the water-related impact assessments.

Figure 5.1 provides a generalised illustration of the conceptual model under the existing conditions, which is discussed in Section 4. Figure 4.19 and Figure 4.24 also illustrate the conceptual hydrological understanding focused on two ecological communities that access water (Hunter River, river red gums, Wollombi Brook and Warkworth Sands Woodland CEEC). The following points summarise the processes/activities shown with the corresponding numbers on Figure 5.1.

1. The Hunter River is a regulated river controlled by releases from Glenbawn Dam and Glennies Creek Dam, maintaining streamflow and supply to downstream entitlement holders and basic landholder rights.

2. The tributaries to the Hunter River are unregulated and as such are ephemeral. Some of the smaller watercourses (such as Farrells Creek and Parnells Creek) are mostly dry and only flow following high rainfall events. Figure 5.2 illustrates the conceptual understanding of the surface water and groundwater interaction for these minor watercourses.

3. Groundwater systems include:

    a) alluvial aquifers (including the paleochannel) form unconfined aquifers, and quality is fresh to brackish. The alluvium is generally more permeable than other lithologies, with recorded hydraulic conductivities ranging from 10^{-2} metres per day (m/d) to 10^{2} m/d (AGE 2022)

    b) the regolith does not form aquifers due to limited saturated thickness

    c) Permian interburden layers form aquitards

    d) Permian coal seams generally form low to moderately permeable confined aquifers, with poor groundwater quality. Hydraulic conductivity generally decreases with depth (AGE 2022).

4. Recharge to the alluvium occurs via infiltration of rainfall and leakage from surface water to the watertable. In the Hunter River alluvium, groundwater levels and aquifer saturation are strongly correlated to flow in the Hunter River, which is mostly a losing watercourse in the study area. River leakage into the alluvium in the region is up to four times greater than direct rainfall recharge (McVicar et al. 2015). The saturated thickness of the paleochannel ranges from 1 m to 6 m.

5. Recharge to the Permian groundwater system(s) occurs via downward leakage from the overlying saturated alluvium (with seepage rates limited by the vertical hydraulic conductivity of the regolith, overburden and interburden) and/or gradual infiltration of rainfall where the Permian outcrops.

6. Groundwater discharge occurs via:

    a) evapotranspiration from vegetation, such as the river red gums, where the watertable is sufficiently shallow

    b) seepage to active or disused mining areas (where in hydraulic connection)

c) as baseflow to watercourses in areas where the watertable is in hydraulic connection with the watercourse and at higher elevation than the height of water in the watercourse (this may occur seasonally)

d) management of groundwater inflows to mining areas (i.e. mine dewatering) or evaporation from pit walls in mining areas

e) active pumping from bores.

7. The vertical hydraulic gradient between the alluvium and the Permian is generally downward, due to historical mining depressurising the Permian.

8. Surface water users in the study area include water extracted from the Hunter River for industrial, mining, domestic and stock or agricultural purposes. Landholders with waterfront land who have basic landholder rights also extract water.

9. The existing HVO WMS includes levees for flood protection and drains to divert clean water from undisturbed or rehabilitated areas.

10. Ecosystems that potentially rely on surface water and/or groundwater:

a) river red gum stands (including in the Carrington Billabong area) that opportunistically access shallow groundwater recharged by leakage from the Hunter River and Wollombi Brook, and rely on flooding for germination

b) stygofauna occurring principally in alluvial sediments along the Hunter River and its tributaries

c) aquatic ecosystems

d) Warkworth Sand Woodland communities which rely principally on rainfall infiltration and a seasonal perched watertable observed to occur after large rainfall events (see Figure 4.24).

11. Water discharges from the HVO Complex is licensed to occur under the HRSTS and EPL 640 during periods of sufficiently high flow (or flooding).

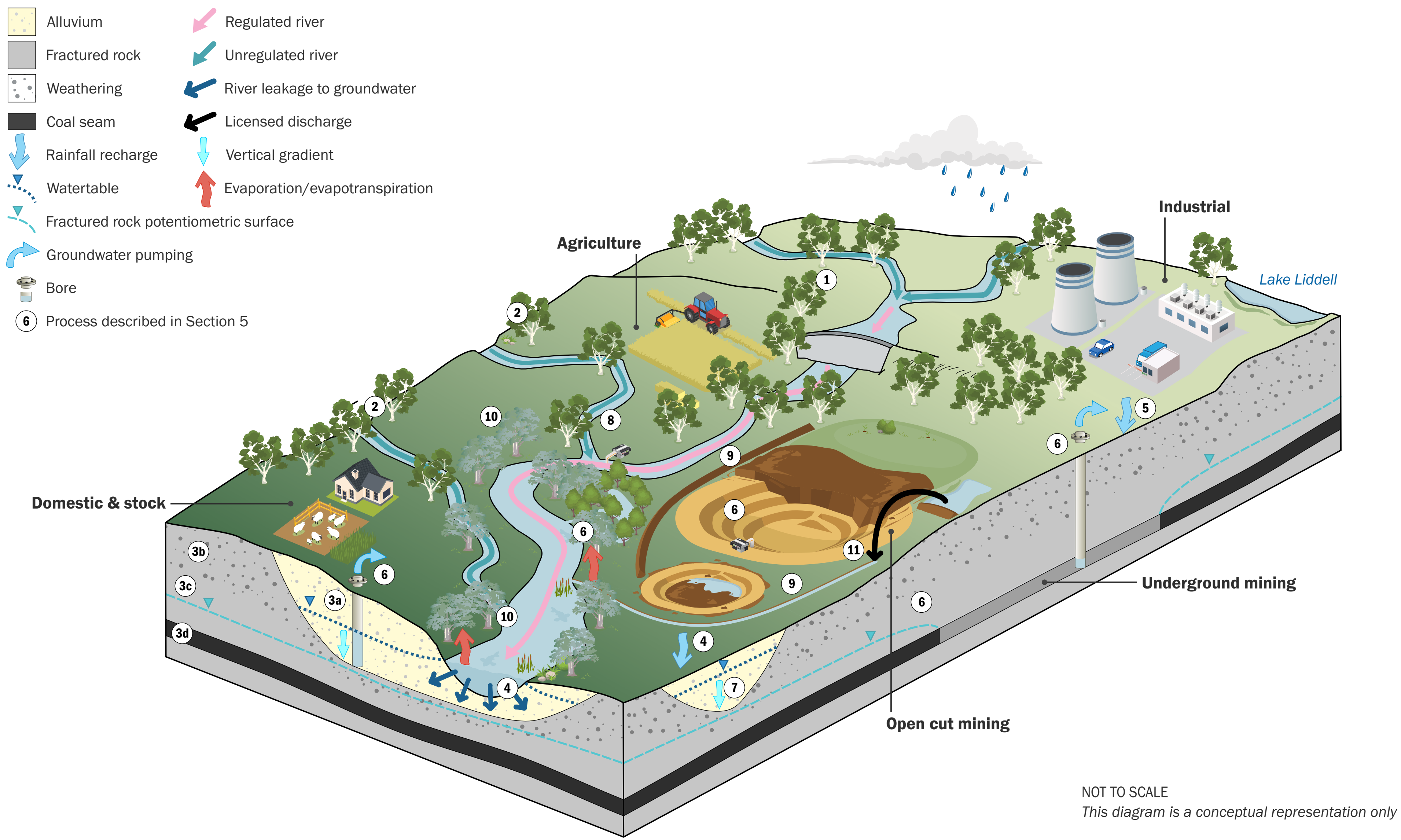


Figure 5.1 Generalised ecohydrological conceptual model (existing conditions)

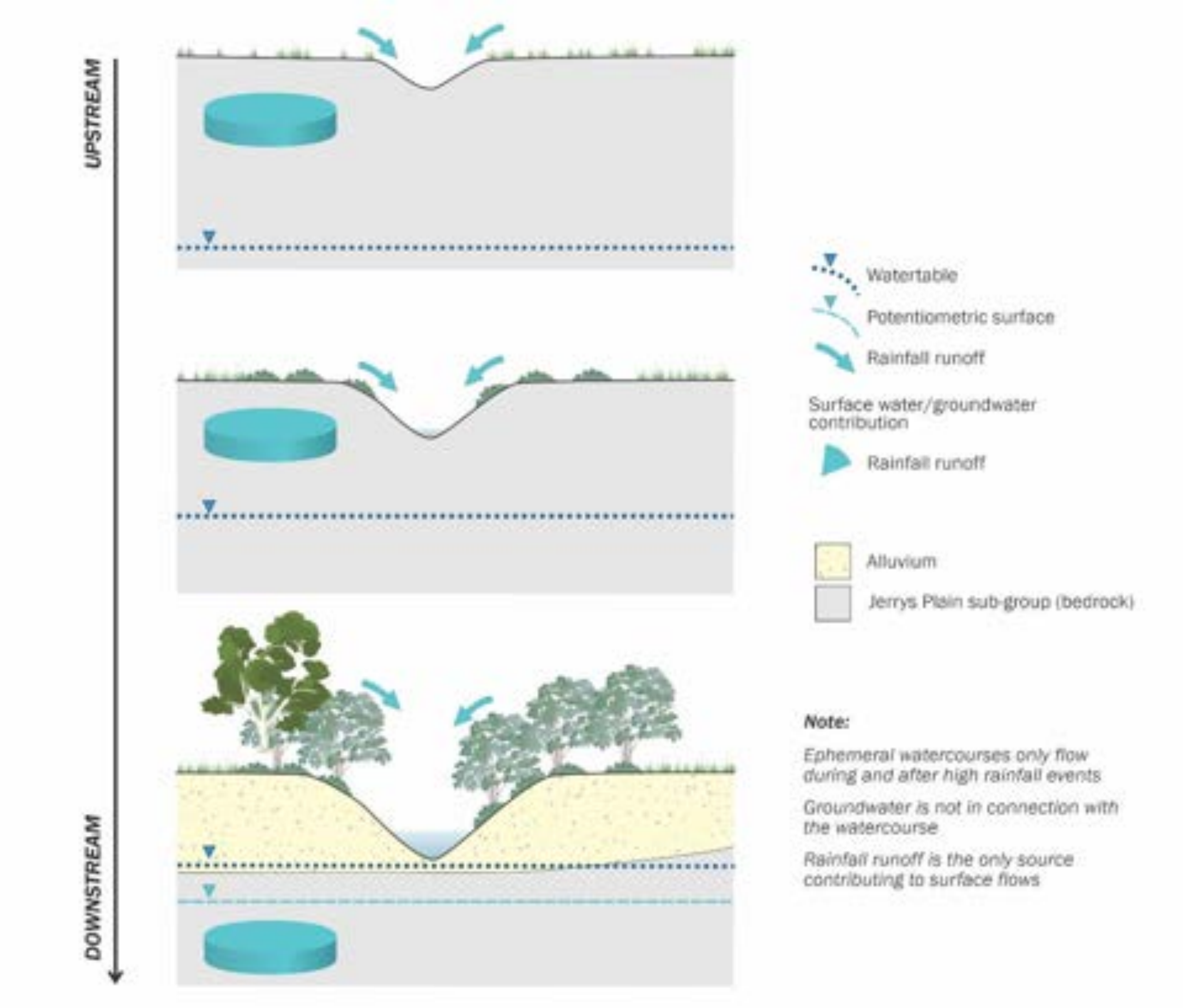


Figure 5.2 Ephemeral creek generic conceptual diagram

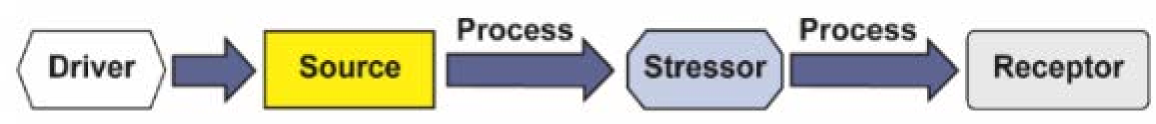
6 Assessment approach

6.1 Introduction

The Project will include minor additional mining disturbance areas between West Pit and Carrington Pit at HVO North and will continue to operate the HVO integrated WMS.

The Project will intercept groundwater and has the potential to result in changes to the existing groundwater and surface water regime. The Project will result in additional depressurisation of the Permian strata directly intersected by mining. However, because the HVO Complex already comprises active and approved mining, the potential for the Project to result in a significant incremental impact on water resources is reduced due to existing and approved impacts and existing depressurisation.

The impact assessment completed for the Project has been conducted in a method consistent with the suggested approach described in the IESC (2024) explanatory note regarding ecohydrological models and impact pathway diagrams to support environmental impact assessments. The pathways in impact pathway diagrams (as described in IESC (2024)) are represented as linking consecutive categories of components, starting with drivers and ending in receptors (Figure 6.1).



Source: IESC (2024)

Figure 6.1 Consecutive categories of components along an impact pathway in a typical impact pathway diagram

Where:

- A *driver* is a major external force that has large-scale influences. It can be natural, such as climate, geology and latitude of a given area; or anthropogenic (human-induced), such as climate change, urbanisation and resource development. In the case of the Project, the driver is the proposed continued operation of the existing HVO Complex.
- A *source* is an entity or action that generates or increases stressors in the environment. For the Project, example sources are the continued open cut mine, water storages, Lemington Road realignment and the new Hunter River crossing.
- *Stressors* are physical, chemical or biological entities (or a change in a stressor) that can induce an adverse response. Examples include altered flow regimes, temperature, and salinity.
- *Process* describes the way(s) in which a stressor is conveyed from one or more sources to one or more receptor. It is often called 'pathway' and can be physical (e.g. via surface water runoff, groundwater flux) biological or chemical.
- A *receptor* includes all water-dependent species, communities and ecosystems as well as the physical, chemical and biological components of surface waters and groundwaters.

Activities (or *sources*) specific to the Project that have the potential to have an incremental impact on water resources and water users include:

- new or upgrades to WMS infrastructure (including upgrades to approved flood levees and existing water storages (Parnells Dam and Lake James)) and continued use of the integrated WMS
- realignment of Lemington Road and construction of the associated Hunter River crossing (bridge)
- direct interception of groundwater by mining (including mining deeper in previously disturbed areas)
- capture and storage of different water qualities within the WMS
- waste management, including tailings and overburden/interburden material
- physical disruption of hydrogeological units (mainly mining deeper in previously disturbed areas)
- continued water discharge in accordance with existing HRSTS requirements and EPL 640.

6.2 Avoidance and mitigation measures

The Project considers a design that avoids and minimises impacts to water resources and water dependent assets, including:

- removing the currently approved by the HVO South Approval coal extraction in RSEE, SLP 1 and SLP 2 from the Project mine plan
- realignment of Lemington Road and improving flood immunity at the new proposed Hunter River crossing
- establishment of the Mitchell East Levee to provide flood protection for the main HVO North final void
- mainly limiting disturbance to previously disturbed or approved areas, thereby avoiding disturbing new catchments
- construction of the Carrington West Wing LPBW prior to mining within 100 m of the remnant western arm of the paleochannel (as approved under the HVO North Consent)
- continued operation of the existing WMS, including preferential use of sediment-laden and mine water over extraction from the Hunter River
- operating in accordance with the requirements of EPL 640 and WALs.

6.3 Assessment criteria

The adopted assessment criteria are based on the assessment requirements (PER guidelines) and policies and guidelines listed in Section 3. In addition, the licensing requirements of the Project have also been assessed against the WM Act, relevant WSPs and the AIP. Further detailed discussion is available in the Water Assessment report (EMM 2025b) prepared for the NSW Government.

Table 6.1 presents the water affecting activities (*sources*) and potential effects typically associated with, the potential duration of the effect and associated impact on a receptor and a summary of the assessment method(s) used for the impact assessment.

Table 6.1 Water affecting activities, potential effects, impacts on receptors, and assessment methods

Direct effect	Water affecting activity (source)	Potential effect (stressor)	Potential duration	Potential impact at a receptor	Assessment method
Construction					
Quantity	Built infrastructure (Lemington Road realignment and new Hunter River bridge)	Increased potential for erosion and sedimentation in the Hunter River, scouring (changes to geomorphology)	During construction	Changes to aquatic habitat	Surface water impact assessment (Section 7 and Annexure B) Flood modelling (Annexure B)
Quality		Increased potential for erosion and sedimentation in the Hunter River, changes to chemical characteristics of flow		Changes to chemistry available oxygen, turbidity; potential changes to aquatic habitat	Surface water impact assessment (Section 7 and Annexure B)
During operations					
Quantity	Groundwater inflows to open cut pits, including mining deeper in previously mined areas	Additional aquifer depressurisation or drawdown, changed groundwater flow paths, local induced flows, indirect take from overlying or adjacent water sources	Duration of the development, may take years to observe	Reduced access to water, reduced or loss of habitat	Groundwater modelling (Annexure A) Streamflow modelling (Annexure B) Aquatic ecology and GDE assessment (Annexure C)
	Built infrastructure (new or re-alignment of roads, WMS)	Minor change in watercourse catchment reducing or changing streamflow/flood regime, diversion of/changes to watercourses geomorphology		Changes to aquatic habitat, change to access during flooding events	Water balance modelling (Annexure B) Streamflow modelling (Annexure B) Flood modelling (Annexure B) Aquatic ecology and GDE assessment (Annexure C)
	Upgraded water storages, operation of the mine WMS	Altered aquifer recharge, perched watertable, watertable mounding, changes to baseflow Overflow/spills from water storages during high rainfall events	Duration of the development	Waterlogging, changes to habitat, changes to streamflow characteristics	Surface water impact assessment (Section 7 and Annexure B) Groundwater impact assessment (Section 8 and Annexure A)

Direct effect	Water affecting activity (source)	Potential effect (stressor)	Potential duration	Potential impact at a receptor	Assessment method
	Tailings storage	Perched watertable, seepage, watertable mounding	Continuous (depends on management)	Waterlogging, detrimental changes to habitat	Not applicable – tailings will either be stored below the base of weathering and alluvium, if present, or a seepage assessment will be undertaken to prevent seepage and overtopping prior to depositing above the base of weathering
	Spoil emplacement	Altered recharge	Duration of the development, may take years to observe	Changes to habitat, reduced access to water	Groundwater modelling (Annexure A)
Quality	Groundwater inflows to open cut pits	Mobilisation of salt (water quality changes), development of acid sulphate soils or acid mine drainage from pit walls	Duration of the development	Change in beneficial use/environmental or cultural value, detrimental change to ecosystem, reduction in or removal of biodiversity or species	Soil and Land Impact Assessment Report (Minesoils 2022) Geochemistry Assessment (Annexure D)
	Water storage	Leaching of solutes, overflow to watercourses altering surface water quality			Water balance modelling (Annexure B) Water quality assessment (Annexure B)
	Licensed water discharge	Mixing of water quality			Water quality assessment (Annexure B) Aquatic ecology and GDE assessment (Annexure C)
	Spoil emplacement/tailings storage	Acid mine drainage, leaching of solutes, seepage from backfilled areas to the alluvium			Geochemistry assessment (Annexure D) Groundwater modelling (Annexure A)

Direct effect	Water affecting activity (source)	Potential effect (stressor)	Potential duration	Potential impact at a receptor	Assessment method
Surface water-groundwater interactions	Groundwater inflows to open cut pits	Altered baseflow to watercourse, increased leakage from watercourse to groundwater, induced inflows of different water quality	Duration of the development, may take years to observe	Increase in number of no flow days, reduced fish migration passage	Groundwater modelling (Annexure A) Streamflow modelling (Annexure B) Aquatic ecology and GDE assessment (Annexure C)
Aquifer disruption	Excavation	Removal of part of whole of an aquifer and/or aquitard, change in groundwater flow paths (noting that the disturbance area for the Project will largely not change, so this included only for cumulative impact assessment purposes)	Permanent, unless backfilled	Reduction in ecosystem habitat, change in groundwater levels in adjacent water source(s)	Groundwater modelling (Annexure A) Aquatic ecology and GDE assessment (Annexure C)
	Backfilling	Altered hydraulic properties, change in groundwater flow paths	May be permanent		Groundwater modelling (Annexure A)
Closure					
Quantity	Groundwater inflows to final voids	Evaporative losses of water from final voids, continued groundwater drawdown, slow groundwater level recovery	Often hundreds of years	Reduced access to water, reduced or loss of habitat (possibly permanent)	Groundwater modelling (Annexure A)
	Final landform / final void	Capture of catchment runoff, pit lake recovery, risk of spill	Potentially hundreds of years	Permanent /long-term reduction in streamflow and/or changes to flooding regime	Final void recovery water balance modelling (Annexure B), noting the final landform has been designed to limit the catchment reporting to the voids
	Tailings storage	Perched watertable, seepage, watertable mounding	Potentially hundreds of years	Waterlogging, detrimental changes to habitat	Not applicable – tailings will either be stored below the base of weathering and alluvium, if present, or a seepage assessment will be undertaken prior to deposition to prevent seepage and overtopping

Direct effect	Water affecting activity (source)	Potential effect (stressor)	Potential duration	Potential impact at a receptor	Assessment method
Quality	Final pit lakes	Evapoconcentration of salts within the pit lake, potential acid mine drainage (acidification of pit lake)	Continuous	Change in beneficial use/environmental or cultural value, detrimental change to ecosystem, reduction in or removal of biodiversity or species	Groundwater model (Annexure A) Final void recovery water balance modelling (Annexure B) Geochemistry assessment (Annexure D)
	Spoil emplacement	Seepage from backfilled areas to the alluvium	Potentially many years		Groundwater model (Annexure A) Geochemical assessment (Annexure D)
	Tailings storage	Acid mine drainage, leaching of solutes, seepage to the alluvium / surface water	Potentially many years		Not applicable – tailings will be stored in pit below the base of weathering and alluvium, if present, and will be capped as part of rehabilitation and closure, or a seepage assessment will be undertaken prior to deposition to prevent seepage and overtopping
Surface water-groundwater interactions	Groundwater inflows to final voids	Altered baseflow to watercourse, increased leakage from watercourse to groundwater	Often hundreds of years	Increase in number of no flow days, reduced fish migration passage (possible permanent)	Groundwater model (Annexure A) Streamflow modelling (Annexure B) Aquatic ecology and GDE assessment (Annexure C)
	Rehabilitation	Altered flow regimes	Potentially hundreds of years, dependent on rehabilitation		Streamflow modelling (Annexure B)

6.4 Impact pathway diagrams

IESC (2024) describes impact pathway diagrams as:

> diagrams that illustrate how impacts of a proposed project are predicted to adversely affect environmental assets (receptors), the potential pathways of the impacts from sources to receptors, and how these pathways might interact with each other.

Impact pathway diagrams have been prepared for the HVO North Action and HVO South Action (during mining and post mining) and are presented and discussed below.

6.4.1 Conditions during mining

The ecohydrological conceptual model will mostly remain the same during mining. Impact pathway diagrams for HVO North and HVO South, during mining, are provided on Figure 6.2 and Figure 6.3 respectively. The key changes associated with the Project that have the potential to affect water resources and water-dependent assets include the following:

- Permian depressurisation would increase as mining progresses to the Barrett seam at HVO North in the area between West Pit and Carrington Pit. The extension of the mining life may also contribute to increased extent of depressurisation in the Permian. However, the potentiometric surface in the shallow Permian strata is already lower than the alluvial watertable due to approved existing and historical mining.
- In the Carrington West Wing area in HVO North, where mining is currently approved to the base of the Bayswater seam, mining would occur as per the current HVO North Consent:
  - Prior to mining in the Carrington area advancing within 100 m of the remnant paleochannel that is hydraulic connection with the Hunter River, a LPBW (with engineered specifications with a design permeability of 1 x 10^{-8} m/s) would be constructed across the width and thickness of the paleochannel, outside the planned pit area.
  - The LPBW would limit groundwater inflow into the active mining area and associated alluvial watertable drawdown. In the long-term drawdown in the alluvial watertable in the Carrington West Wing area may be observed due to downward leakage from the alluvium to the Permian potentiometric surface due to depressurisation from mining. LPBWs have been constructed at HVO North (Carrington Pit in 2010 and Alluvial Lands in 1995) and monitoring has demonstrated they are an effective mitigation measure (refer Section 4.6.4 and 4.6.5).
- The main causal pathway for potential impacts from mining on the water dependent ecosystems is depressurisation of the Permian strata resulting in drawdown within the Hunter River alluvium. However, the Permian is already depressurised in this area due to historical and approved mining and there is a downward hydraulic gradient from the shallow alluvial watertable to the Permian. The additional mining extent at HVO North is unlikely to significantly affect the shallow groundwater table within the alluvium based on existing observations and the conceptual understanding. As a result, potential impacts on the Hunter River and associated alluvial aquifers are expected to be minor beyond already approved operations:
  - The extent of the drawdown in the alluvium would be buffered by continued leakage from the Hunter River, and the alluvium would remain saturated. The drawdown induced leakage from the Hunter Regulated River currently is and would continue to be accounted for within HVO's existing entitlements (high security entitlements) and therefore streamflow in the Hunter River will not be affected.

- Ecosystems that rely on groundwater, such as stygofauna and vegetation opportunistically accessing shallow groundwater in the alluvium, would continue to have access to groundwater due to continued recharge from the Hunter River regulated flows and potential changes to the watertable would not prevent the long-term viability of the water-dependent assets.

- Upgrades to Lake James and Parnells Dam would be conducted to increase the capacity to store water intercepted during mining:

  - As these upgrades are being undertaken on existing dams with no change in the location of the dam, the upgrades would not result in a change to the contributing catchments. The upgraded dams will include diversions around the structures so that upstream clean water catchments can flow unimpeded to the downstream natural watercourse.

  - Potential seepage from Parnells Dam (Dam 9W and 18W) and Lake James (Dam 15S) will be minimised by embankment filter and cut-off design and treatment of batters within the excavated storages.

- Operation of the WMS includes measures to control overflows from all water storages. Sediment dams are designed in accordance with Blue Book (Landcom 2004 and NSW DECC 2008), where overflow will occur during rainfall events above the design criteria specified in the Blue Book, which has been established by the NSW Government specifically for sediment control at mining operations. For mine water storages, these overflows would typically be either into another storage/pond, or into a mining pit. In addition, mine water storages are designed and operated to safely manage the stormwater runoff generated by the 1% AEP 24-hour design storm event. Therefore, runoff generated from mining areas during "excess" rainfall events are expected to be contained on site, thereby minimising the risk of impacts to the environment. Any discharges from the HVO Complex will occur within the conditions of the HRSTS and existing EPL limits.

- HVO is not seeking to change existing State approvals or licences for the discharge of mine water under the HRSTS and EPL. Therefore, the potential impact of the Project on water quality is expected to be negligible.

- As the Project will not intercept new surface water catchments, the potential impact on streamflow is expected to be negligible. Conversely, the Project has a reduced impact on surface water catchments through changes to the mining areas as approved under existing consents and approvals.

- The potential for seepage to the alluvial aquifers from TSFs is low as tailings stored at West Pit will be stored below the base of weathering and alluvium, if present, or a seepage assessment will be undertaken prior to deposition to prevent seepage and overtopping. The active mining areas will act as groundwater sinks during mining.

- Given the expected high proportions of NAF (approximately 97%) relative to PAF (approximately 3%), operational blending of NAF and PAF material is expected to be a robust approach to controlling acid rock drainage from PAF materials.

- Potential for erosion and sedimentation associated with the construction of the Lemington Road realignment and new Hunter River crossing will be managed by the implementation of erosion and sediment control measures in accordance with Blue Book and HVO's Erosion and Sediment Control Protocol.

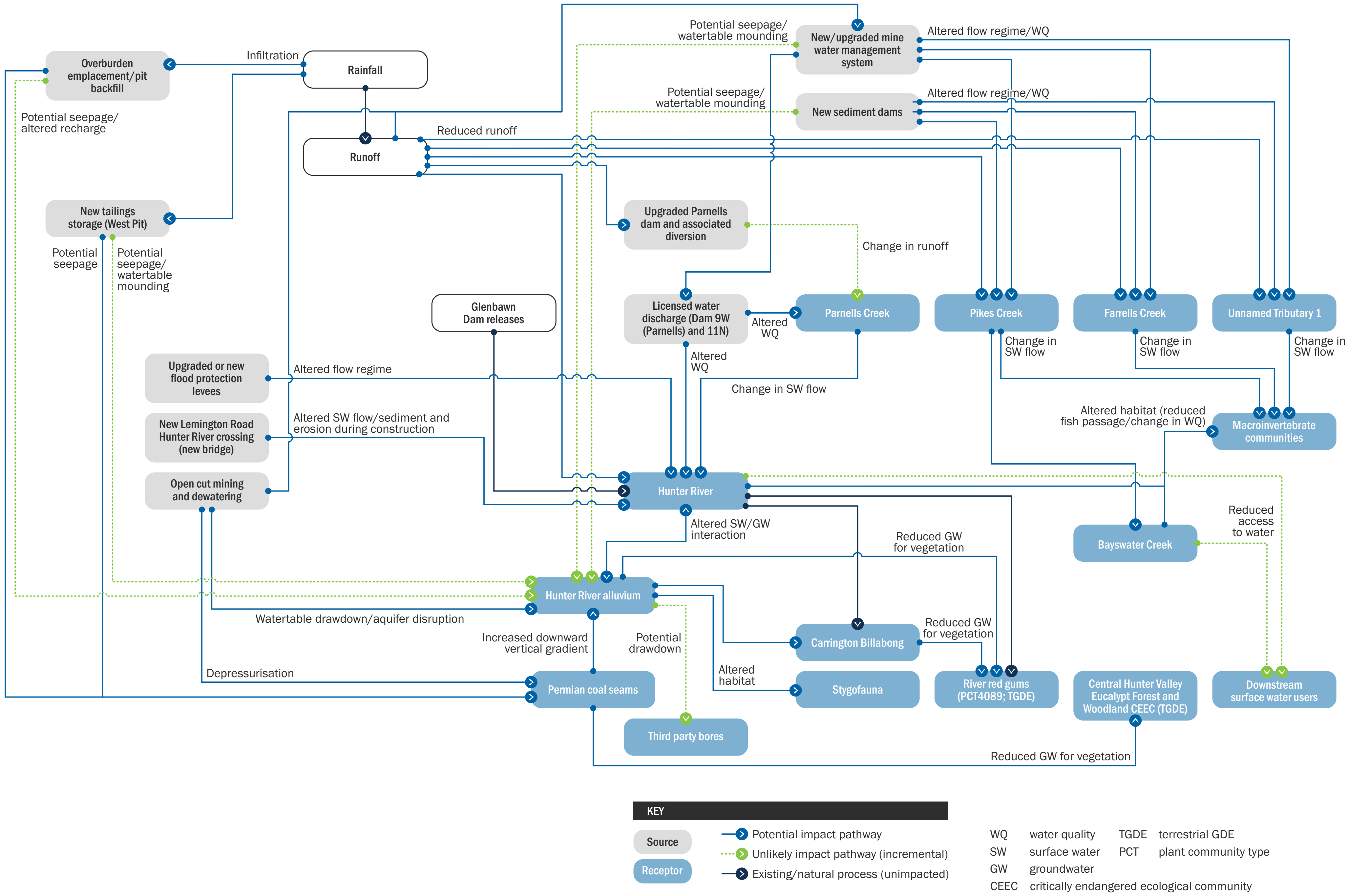


Figure 6.2 HVO North impact pathway diagram (during mining)

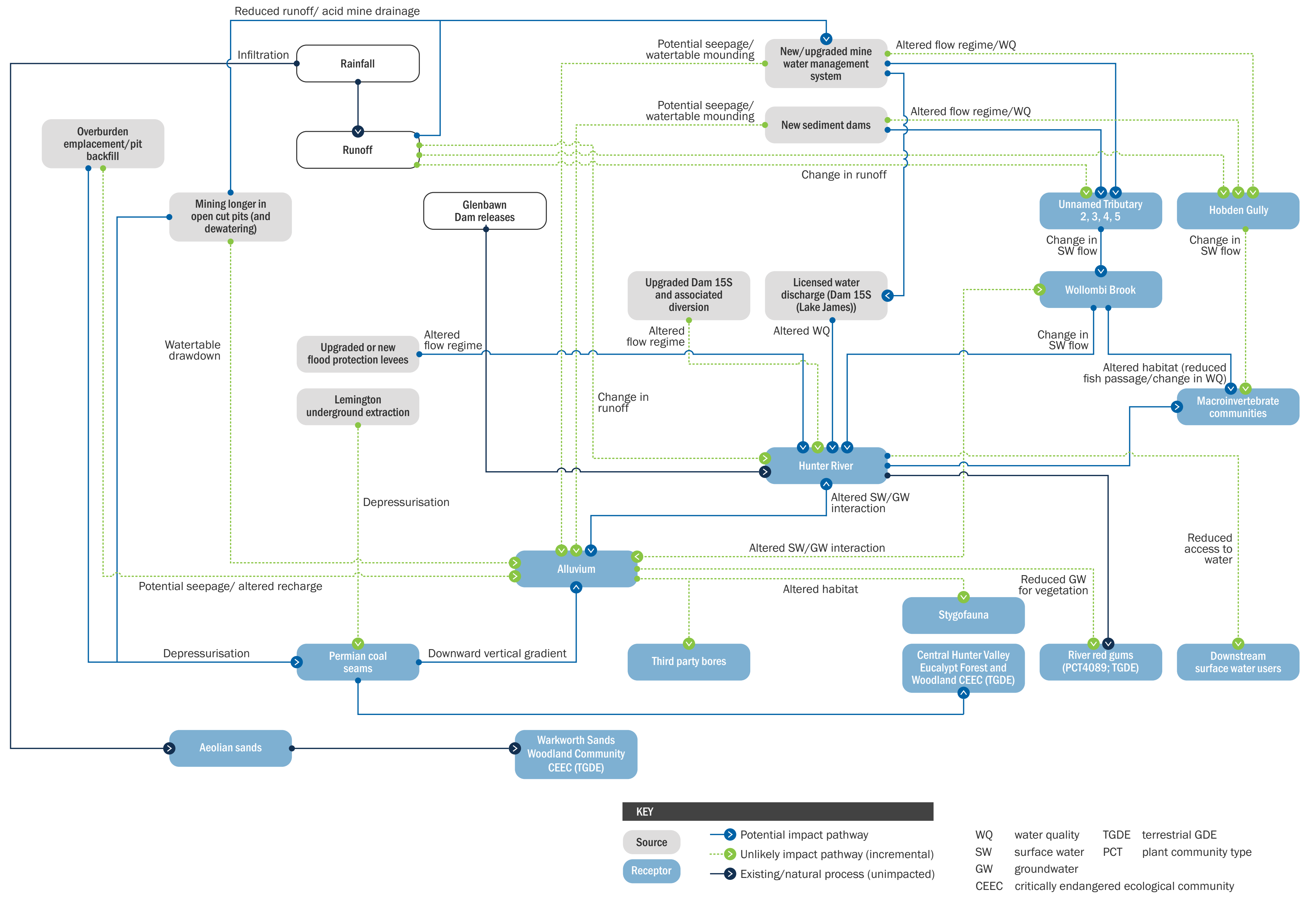


Figure 6.3 HVO South impact pathway diagram (during mining)

6.4.2 Post mining conditions

Impact pathway diagrams for HVO North and HVO South, after mining, are provided on Figure 6.4 and Figure 6.5 respectively. The key conceptual considerations post mining for the Project (that differ from the current HVO North Consent and HVO South Approval) are:

- The Project will result in two final voids at HVO North, rather than three voids as per the current approved operations.
- Permian potentiometric surface would slowly rise after cessation of mining activities. However, the HVO North voids and HVO South void will remain groundwater sinks due to the depth and size of the voids.
- The LPBWs will remain in place post mining. Therefore, groundwater inflows from the alluvium to the final voids and associated watertable drawdown are expected to be minor, due to the continued recharge from the Hunter River.
- The LPBWs, along with the inward gradient to the final void, would also prevent potential seepage from the overburden emplacement areas to the alluvium, thereby avoiding contamination of the Hunter River alluvium. The potential for density-driven flow (due to salinisation of the voids) is also considered unlikely to cause a reversal in groundwater flow directions, due to the depth and height of the water column in the voids.
- Drawdown in the alluvium as a result of the final voids would be limited with the main mechanism associated with the downward vertical gradient from the alluvium to the Permian. Ecosystems that rely on alluvial groundwater would not to be significantly impacted due to the strong hydraulic connection with the Hunter River, the presence of the LPBWs and HVO's existing water access entitlements (which relates to controlled releases from Glenbawn Dam).
- Following closure, the drainage systems at the HVO Complex will be established to divert upstream catchment runoff away from the final voids (as much as practical) and to downstream watercourses.
- The Carrington West Wing Levee will be decommissioned and incorporated into the final landform, returning floodplain storage capacity for the Hunter River in this area.

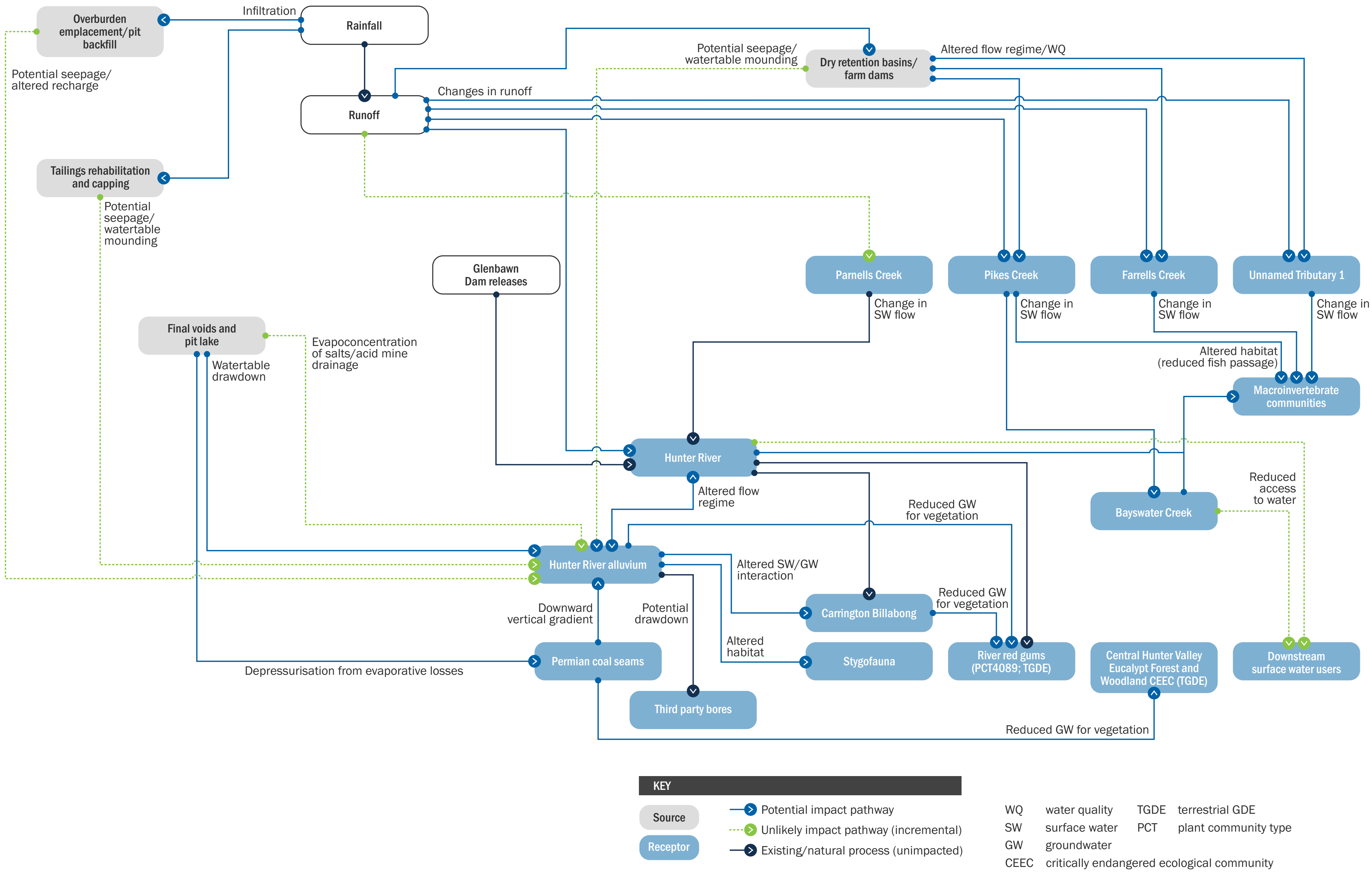


Figure 6.4 HVO North impact pathway diagram (closure)

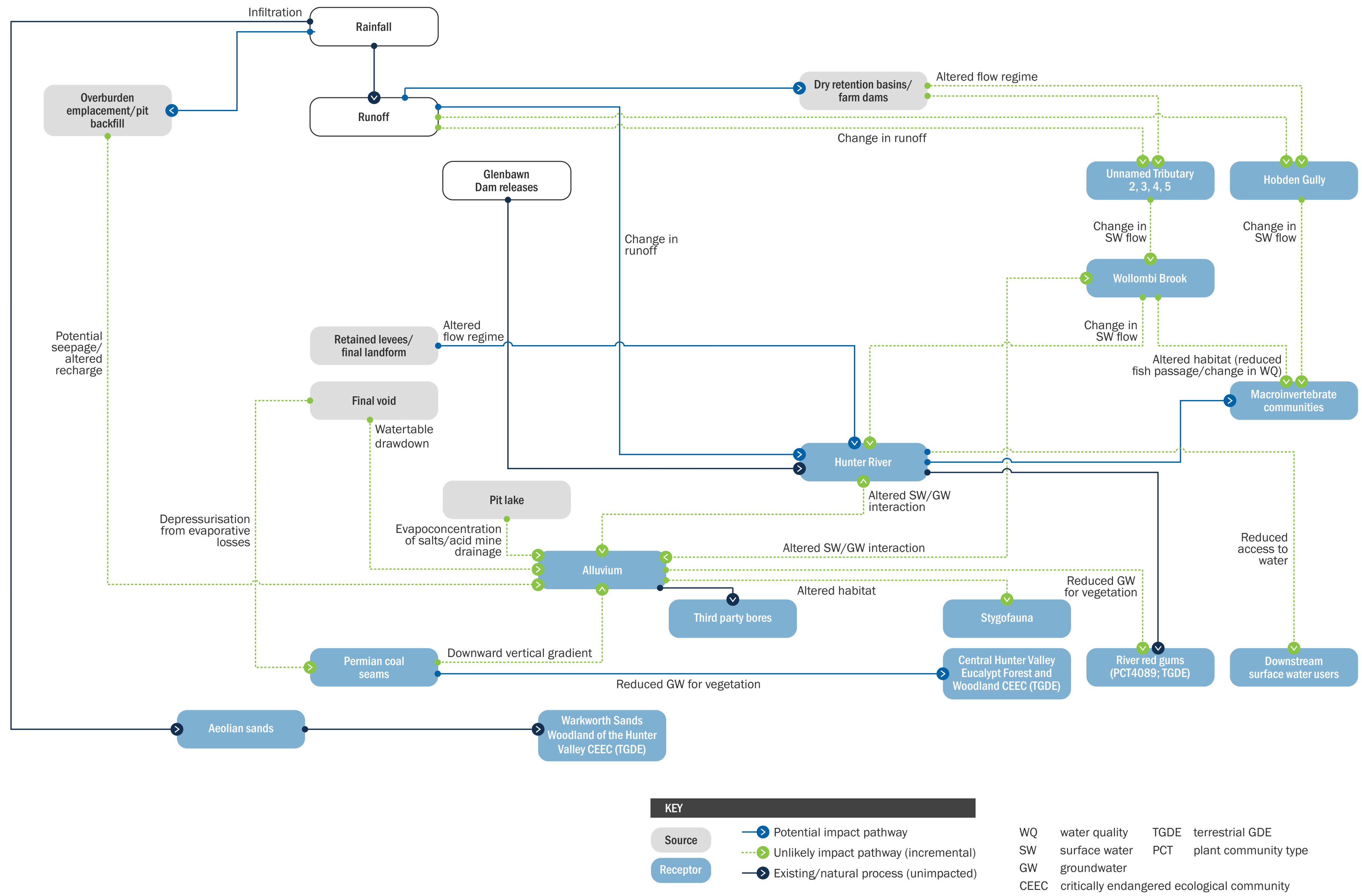


Figure 6.5 HVO South impact pathway diagram (closure)

6.5 Assessment methods

Details of the assessment approach and methods is discussed in the technical assessment reports in Annexure A, Annexure B, Annexure C and Annexure D.

6.5.1 Groundwater impact assessment

A regional numerical groundwater model was developed using MODFLOW-USG to predict the potential impact of the Project on the groundwater regime. Groundwater modelling for the Project builds upon many previous groundwater modelling efforts in the region, reflecting the extensive and ongoing mining in the region surrounding the HVO Complex.

The HVO regional groundwater model was originally designed and history-matched by AGE in 2022 and reported as part of the EIS (EMM 2022, AGE 2022). The general model design, including domain, geometry, and most boundary conditions are largely the same as reported by AGE (2022) as the conceptual understanding is unchanged. Modifications have been made to represent the revised HVO mine plan, as well as updates to approved mines in the model domain since 2022. The current model version (supporting the Project) is based on that developed by AGE (2022) and incorporates updates to the model parameterisation and simulated mining activities associated with the Project.

A peer review of the groundwater modelling that supports this WRIA was conducted by Chris Strachotta (Klohn Crippen Berger). The review was undertaken in accordance with the Australian Groundwater Modelling Guidelines (Barnett et al 2012) and found that the modelling is fit for the intended purpose (refer Section 6.8).

The objectives of the groundwater model were to:

- at an overarching level, use the model structure developed by AGE in 2022 to simulate groundwater-affecting activities associated with the Project
- predict groundwater inflows to mining areas to inform water management and licensing requirements
- predict changes in watertable elevation in the alluvium due to the Project (incremental and cumulative)
- predict changes in surface water-groundwater interaction between the Hunter River/Wollombi Brook and the alluvium/Permian due to the Project (to inform streamflow impact assessment)
- predict watertable drawdown at GDEs and third-party bores
- predict long-term post mining groundwater heads associated with residual void lakes
- predict fate of potential contaminants introduced to the groundwater system from backfilled mining areas at HVO (emplacement areas) near the Hunter River.

The modelling has been conducted in accordance with:

- the requirements of the PER guidelines (the HVO North and HVO South PERs (EMM 2026a and 2026b) list the PER guidelines and where they are addressed in the technical reports)
- IESC explanatory notes, including:
  - uncertainty analysis for groundwater modelling (Peeters and Middlemis 2023)
  - characterisation and modelling of geological faults (Murray and Power 2021)
- *Australian groundwater modelling guidelines* (Barnett et al. 2012).

The model was used to predict incremental and cumulative changes to the groundwater resources due to the Project by comparing outcomes from the approved operations and the Project. Current approved mining within the region (i.e. non-HVO) was included to account for cumulative effects.

The following model scenarios were developed and run to calculate incremental (Project-induced) and cumulative effects:

1. Baseline – approved operations within the region, with all mining deactivated at the end of 2009, providing a 'null' scenario for quantification of cumulative effects.

2. Approved – currently approved operations at HVO North and HVO South, and approved and foreseeable operations within the region.

3. Proposed – proposed mine plans associated with the Project and approved and foreseeable mining operations (non-HVO) within the region.

Climate stresses are consistent between the scenarios.

To meet the requirements of the AIP, the predicted cumulative drawdown was calculated by comparing the results of the "Proposed" scenario (i.e. the Project) to the "Baseline" scenario where simulated mining ceases at the end of 2009 (which is when the WSP for the Hunter Unregulated and Alluvial Water Sources commenced), which effectively allows the modelled groundwater system to recover post-2009. Comparison to this '2009' baseline scenario is therefore conservative. This represents a limitation in the requirements of the AIP to estimate cumulative drawdown effects "post-water sharing plan".

Predicted incremental drawdown was calculated by comparing the results of the Proposed scenario and the Approved scenario, with differences only associated with the proposed change in mine plan.

i Predictive uncertainty analysis

Predictive uncertainty analysis was undertaken in accordance with current best practice guidance (Peeters and Middlemis 2023). The three model scenarios were run with a 500-realisation parameter ensemble to provide probabilistic predictions. Of these, 414 realisations successfully converged through the prediction and recovery period. Non-converging runs were not consistently linked to extreme parameter values, and their exclusion is not expected to bias overall results (see Annexure A, Section 5.2).

Model outputs are reported as probabilistic outcomes, with predictions expressed in terms of likelihood to exceed certain values (e.g. inflows or drawdown). Table 6.2 describes the numeric approach to describing likelihood, with a focus of language centred on 'likelihood to exceed' a given value. Percentiles (e.g. P10, P50, P90) provide an indication of the range of possible outcomes: P10 values represent outcomes that are very likely to be exceeded, while P90 values represent outcomes that are very unlikely to be exceeded. For example, a prediction of interest might be inflows to mine workings between 2027 and 2045. This is exported from the ensemble of model realisations, and percentiles calculated. The 10th percentile, P10, represents a value where 90% of realisations return a larger inflow. The in-text description would say that it is **very likely** for inflows to be larger than this value. Conversely, the 90th percentile, P90, would be representative of a value that is **very unlikely** to be exceeded, within the assumptions and limitations of the predictive modelling.

Table 6.2 Combined numeric, narrative, and visual approach for assessing likelihood of effects

Percentile band	Colour code	Explanation of likelihood
<P10	(dark green)	It is **very likely** for effect to be larger than this value
P10-P33	(light green)	It is **likely** for effect to be larger than this value
P33-P67	(yellow)	It is **as likely as not** for effect to be larger than this value
P67-P90	(orange)	It is **unlikely** for effect to be larger than this value
>P90	(red)	It is **very unlikely** for effect to be larger than this value

A full description of the predictive uncertainty analysis is provided in Annexure A. Parameter sensitivity analysis was also conducted and is reported in Annexure A.

6.5.2 Surface water impact assessment

As outlined in Section 6.3, quantitative water balance modelling (conducted using GoldSim), streamflow modelling, flood modelling and water quality evaluation have been undertaken to support the SWIA for the Project (Annexure B).

i Water balance modelling

The water balance used for the assessment was based on the current calibrated operational water balance model maintained by the site. The operational water balance model is used to forecast site water inventories to assist in water infrastructure design as well as managing water deficits and surpluses.

The water balance model is calibrated to various observed data sets, has been reviewed and updated as part of the operational water management plans prepared for the site, and the approach and methodology used has been peer reviewed. This has reduced the requirement for some sources of uncertainty (especially hydrology model parameterisation) sensitivity testing.

The current calibrated operational water balance model is also used by HVO to report water statistics in accordance with the Minerals Council of Australia Water Accounting Framework (WAF). A site WAF was developed for the water balance model in 2020. Subsequently the WAF has been updated annually to reflect the changing mining catchments, groundwater inflows, land uses, etc. In addition, the water balance model has been re-calibrated and validated against recorded mine water inventories during this period, with the last review occurring in 2024. As part of the WAF, HVO reports on the accuracy of WAF in accordance with the guidelines.

As noted in the SWIA (Annexure B), the water balance modelling was based on 121 years of rainfall data, extracted from the SILO data set. All 121 years of data are used for forecasting the potential range of responses of the site WMS using a Monte Carlo approach, by starting each model realisation at every year of the 121 years of rainfall data, looping the data set as required. This allows for a range of climate scenarios and season variability to be modelled to estimate the resilience of the proposed WMS to extreme conditions (i.e. historical flood and drought sequences).

ii Streamflow modelling

Historical streamflow analysis was undertaken by Engeny (2026) using publicly available gauging data collected by WaterNSW. However, streamflow monitoring is only undertaken on the Hunter River and Wollombi Brook. Streamflow at ephemeral watercourses within the study area were assessed using an Australian Water Balance Model (AWBM). The assessment of impacts on the flow regimes was based on flow sequencing analysis for the Hunter River and relevant tributaries. The analysis identified periods of low and zero flow.

Lowering of the watertable due to the Project has the potential to result in changes in groundwater discharge (baseflow) and/or increased leakage from surface water to groundwater, thereby potentially changing streamflow. The streamflow assessment was informed by estimated changes in surface water-groundwater interaction, predicted by the numerical groundwater modelling presented in Annexure A and summarised in Section 8.

iii Surface water quality

The water balance model was used to conduct a mixing water quality assessment downstream of the HVO Complex to evaluate the potential impact of licensed discharges under the HRSTS.

iv Flood modelling

In 2022, Engeny developed and calibrated a flood model (TUFLOW hydraulic model) of the Hunter River to assess the potential impact of the Project on the flood regime to support the EIS. As the Project does not encroach onto the floodplain further than what was modelled in 2022 or further reduce floodplain storage it is considered that the impacts from the Project will be no greater than those modelled in Engeny (2022). The flood modelling has also undergone two separate independent peer reviews (Section 6.8). As such, the 2022 flood assessment is described in Annexure B and summarised here and has not been re-simulated for the Project.

Calibration of the flood model included calibration to the rating table for the Liddell gauge (210083). The June 2007 flood event was then simulated to assess the level of calibration along the Hunter River at the seven available streamflow gauging stations, including the Liddell gauge. A close match was achieved at not only the Liddell gauge but also the other downstream gauges for the June 2007 flood (i.e. US Foybrook, US Glennies, Mason Dieu, Long Point, US Singleton, Singleton).

Due to the size of the catchment and the availability of long-term streamflow records the adopted methodology used flood frequency analysis rather than a rainfall runoff model. This approach is consistent with the approach used by the Singleton Council. Given the adopted methodology, it was not possible to estimate the Probable Maximum Flood (PMF) using Probable Maximum Precipitation (PMP) methodology. An alternative approach was adopted to estimate an Extreme Flood deemed to be the maximum flood likely to occur by scaling the 1% AEP design flood. The Extreme Flood for the HVO flood model has been defined as ratio of 4 (i.e. multiplying the 1% AEP by a factor of 4). This approach is consistent with other studies in the area.

6.5.3 Aquatic ecology and groundwater dependent ecosystem assessment

The aquatic ecology and GDE assessment conducted by ELA for the Project (Annexure C) is based on the outcomes of groundwater modelling (EMM 2025c), streamflow impact assessment and surface water quality assessment (Engeny 2025), completed to support the HVO Amendment Report (EMM 2025a).

EMM (2025c) and Engeny (2025) provided the following outputs to ELA for the aquatic ecology and GDE impact assessment:

- predicted incremental and cumulative maximum drawdown of the alluvial watertable, and information about the duration of the drawdown extent and magnitude
- predicted alluvial aquifer saturated thickness at 2020 (for a baseline comparison), 2030, 2040 and 2050
- predicted long term average annual flow characteristics for watercourses assessed as part of the SWIA
- predicted change in long term annual flow characteristics for watercourses assessed as part of the SWIA.

ELA (2025) conducted a risk assessment based on the ecological value, potential impact and risk magnitude of the Project on aquatic ecology, aquifer ecosystems and GDEs. The risk assessment was also used to identify management and mitigation measures.

The results of the groundwater modelling presented in Annexure A are consistent with the predictions presented in the Water Assessment for the HVO Amendment Report (EMM 2025b) and therefore have not been revisited for the assessment completed by ELA (2025).

6.5.4 Final void

i Pit lake recovery and water quality

The final void hydrology and salinity assessment for each final void was undertaken by Engeny (2026) as part of the SWIA (Annexure B) using GoldSim software. A final void water and salt balance model simulates inflows to the final voids (i.e. rainfall runoff, direct rainfall, seepage from backfilled areas and groundwater inflow from host rock) and outflows (i.e. evaporation) (Figure 6.6).

The water and salt balance model used predictions of groundwater flux and pit lake level relationship from the groundwater model (EMM 2026c) and groundwater salinity observations from the geochemistry assessment (EGi 2022a). Based on the geochemical assessment (EGi 2022a), runoff and seepage from overburden is not expected to be acidic and should not contain significant metals concentrations. Therefore, long-term salinity is expected to be the main issue for final void lake water quality.

In simulating void lake salinity, the model assumes conservation of mass and fully mixed conditions.

EGi (2022b) developed a hydrogeochemical model in *PhreeqC* (using the results of the Engeny (2022) and AGE (2022) modelling) to predict potential pit lake water quality characteristics. The hydrogeochemical model calculates pH and chemical speciation reactions including solubility, redox, ion exchange and surface complexation, adsorption, and mixes of two or more solutions.

Further detail of the development of the final void water and salt balance model is detailed in Attachment J of the SWIA report (Engeny 2026).

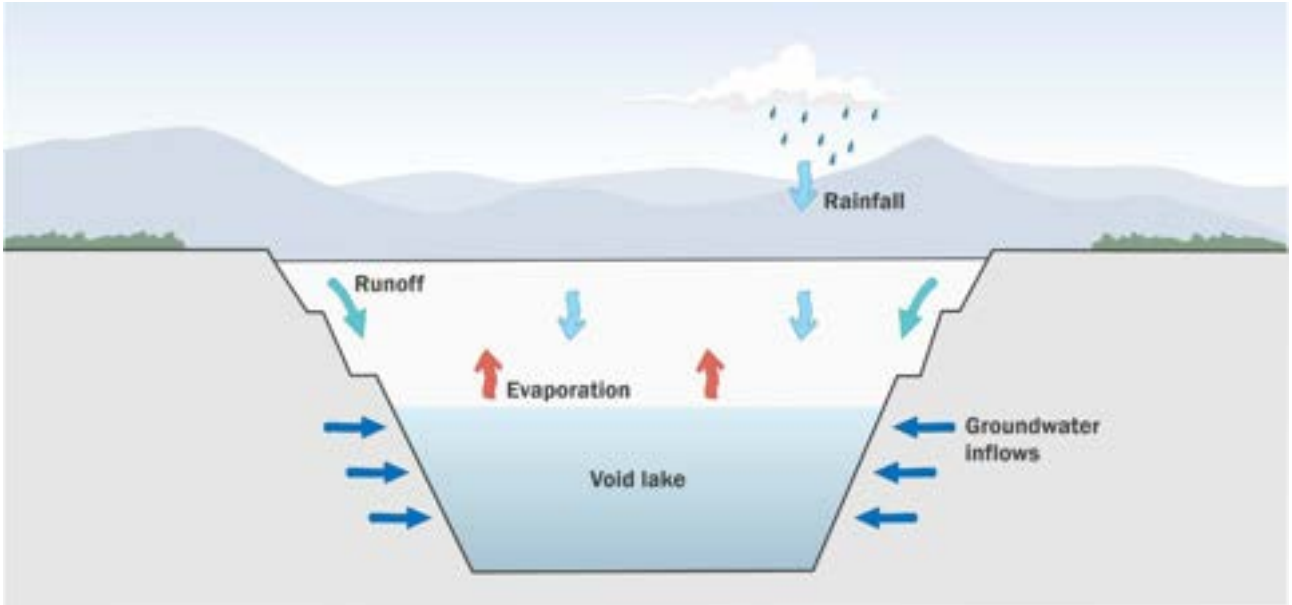


Figure 6.6 Final void water balance conceptual model

6.6 Climate change

The potential effects of climate change have been considered for:

- groundwater modelling of long-term effects (Annexure A)
- performance of the operational WMS (water balance modelling; Annexure B)
- flooding (Annexure B)
- pit lake recovery (Annexure B).

6.7 Cumulative impacts

As previously discussed, the HVO Complex is located in an area where the surface water and groundwater environment has been highly modified by historical mining, industrial and agricultural activities over the past 70 years or so. Due to the dynamic nature of the regional hydrogeology, ongoing impacts associated with approved and historic mining will continue to affect groundwater levels and pressures, and connected surface water resources, irrespective of whether the Project occurs.

Due to the minor change to the approved disturbance area, removal of coal extraction from RSEE, SLP 1 and SLP 2 from the mine plan and mainly restricting continued mining to deeper seams in previously mined areas at West Pit/Mitchell Pit at HVO North, the potential incremental impact of the Project on water resources and water-dependent assets is expected to be minor.

Potential cumulative impacts are assessed in Sections 8 and 9.

From a surface water perspective, as the Hunter River is a regulated system, the main potential cumulative impact pathway is related to changes in baseflow or river leakage through changes in groundwater levels. As such, the potential cumulative impact on streamflow has been informed by the groundwater modelling. The potential cumulative impact of licensed water discharge on the Hunter River water quality has been considered as part of the SWIA (Annexure B) and is managed by the EPA as part of the HRSTS.

6.8 Peer review

6.8.1 Surface water

i Flood modelling

Between March 2020 and October 2022, Barry Rodgers (Principal Scientist) at BMT undertook a peer review of the flood modelling completed for the SWIA (Engeny 2022). As BMT has undertaken an update of the Hunter River Flood Study for Singleton Council (draft published in December 2022), HVO engaged BMT as the peer reviewer of the HVO flood model to seek consistency in approach and outcomes between the two models.

Peer review of flood models and outputs was undertaken by BMT at key stages throughout the assessment, including review baseline flood model, Project simulations, and results. Meetings were held between the Project team and BMT as required to progressively discuss recommendations made and the proposed approach.

BMT's review focused on the modelling approach and the ability of the modelling to adequately define Project related flood impacts. The peer reviewer found the modelling adequately met the requirements of the assessment requirements, with additional clarification in reporting provided in the final SWIA.

Following the exhibition of the EIS (EMM 2022), in 2024 DPHI requested Torrent Consulting undertake an additional peer review of the flood modelling and assessment. The outcomes of the review found that the design and approach to the modelling is in accordance with industry practice and meets the requirements of the SEARs.

The flooding peer reviews are attached in Annexure F.

ii Water balance modelling, streamflow and pit lake recovery

A peer review of the remaining SWIA study aspects was conducted by Ian Rowbottom (EMM) between 2020-2022. Ian Rowbottom's review comprised input to and involvement over the following aspects of the SWIA:

- WMS and water balance modelling
- streamflow modelling
- water quality assessment and cumulative impact assessment
- final void hydrology modelling and climate change assessment.

The peer review is still considered valid as the approach and methodology detailed in the 2022 SWIA remains unaltered in the Engeny (2026) SWIA. The peer review is attached in Annexure F.

6.8.2 Groundwater modelling

A peer review of the groundwater model that supports this WRIA was conducted by Chris Strachotta (Klohn Crippen Berger). The review was undertaken in accordance with the *Australian Groundwater Modelling Guidelines* (Barnett et al 2012). A staged approach was adopted to undertake the independent review of the groundwater modelling, which included:

- model validation criteria development and validation process
- historic-matching update approach and results
- predictive simulation approach and results
- GMR review.

The peer reviewer deemed that the model objectives were satisfied and that the model is fit for purpose where the purpose is to assess potential groundwater impacts as a result of the Project development. The peer review report is attached in Annexure F.

7 Surface water impact assessment

7.1 Introduction

Due to the integrated nature of the WMS, most aspects of the SWIA have been considered together (for HVO North and HVO South). In general, impacts are presented for the HVO Complex with discussion provided on the two operations where appropriate.

The following sections are a summary of the SWIA; further discussion is available in Annexure B (Engeny 2026).

7.2 Water management system performance

Water balance model results indicate that average inflows are dominated by rainfall runoff (58% of the total inflow) while groundwater inflow is a small contributor (5% of the total inflow). Hunter River extraction via HVO's existing high security WALs represents the main water source (10% of the total inflow on average) while use of HVO's general security water access entitlements is minor (1% or less through the Project). Even in very dry years, where the Project will have greater demand from the Hunter Regulated River, the water demand can be met via HVO's existing WAL entitlements.

Most of the water used on site is for coal processing (44% on average) and dust suppression (22% on average). Discharge via the HRSTS represents approximately 15% of the average outflows over the life of the Project.

The proposed WMS for the Project is predicted to maintain a sufficient water supply for the operation and discharge capacity to preventing flooding of operational areas of the mine, operating in accordance with existing EPL conditions. During very wet years (95th percentile) the Project utilises more than the average allowable discharge potential but still well below the release limits.

The WMS includes measures to control overflows from all water storages. For mine water storages, these overflows would typically be either into another storage/dam, or into a mining pit. In addition, mine water storages are designed and operated to safely manage the stormwater runoff generated by the 1% AEP 24-hour design storm event. Therefore, runoff generated from mining areas during rainfall events are expected to be contained on site, thereby minimising the risk of overflows and potential impacts to the environment.

Water balance modelling indicates that overflows from sediment dams are predicted continue to occur at the HVO Complex when rainfall events exceed the design rainfall depths of the sediment dams (Engeny 2026). The design standards for the HVO Complex sediment dams include a settling zone and a sediment zone and they are conservatively designed with sediment zones equal to 50% of the settling zone. Given the WMS design standards implemented and their proposed adaption with climate change, it is considered that the risk of sediment dam overflows will continue to be the same as the existing operations with the likelihood of overflows driven by the NSW design standards (the Blue Book (Landcom 2004)).The water balance model is a tool to identify risks to operational water management. HVO has appropriate management measures (including triggers) to avoid, minimise and manage risk of spills from the WMS to the environment.

7.3 Streamflow impacts

As described above, the WMS for the Project will be consistent with the requirements of the existing approved operations, with the exception of mining through new areas (between Mitchell Pit and Carrington Pit at HVO North) and re-disturbance of some rehabilitated areas. As outlined in Section 6, lowering of the watertable due the Project has the potential to result in changes in surface water-groundwater interaction. Engeny (2026) has used the groundwater model (EMM 2026c) predicted changes in surface water-groundwater interaction (changes in groundwater discharge (baseflow) and changes in river leakage to the watertable; 50th percentile (P50) results) to inform the streamflow impact assessment.

Engeny (2026) combined the P50 predicted peak change in baseflow and river leakage values to calculate a net loss from the surface water system (Attachment A of Annexure B).

Section 5.3.3 of Annexure A (GMR) presents the maximum predicted cumulative and incremental change in baseflow and river leakage irrespective of time for 10th, 50th, and 90th percentiles for each river reach. This was calculated by comparing modelled baseflow and river leakage in the Proposed and Approved Project scenarios.

The 90th percentile predicted cumulative and incremental change in baseflow and river leakage are presented below for each river reach with comparison to the average annual streamflow reported in the SWIA (where reported in Annexure B) in Table 7.1. Generally, the predicted change (90th percentile) in baseflow and river leakage is minor to negligible.

Table 7.1 Comparison of predicted peak change in groundwater-surface water interaction and annual average flow conditions

River reach	Average annual flow volume (ML/yr)[1]	Predicted cumulative leakage increase (ML/yr) (P90)	Predicted cumulative baseflow decrease (ML/yr) (P90)	Predicted incremental leakage increase (ML/yr) (P90)	Predicted incremental baseflow decrease (ML/yr) (P90)	Baseflow change as % of total flow (cumulative)	River leakage change as % of total flow (cumulative)	Baseflow change as % of total flow (incremental)	River leakage change as % of total flow (incremental)
Hunter River to Mason Dieu	410,000	484	281	64	92	0.1%	0.12%	<0.1%	<0.1%
Hunter River – Mason Dieu to Wollombi Brook[3]	-	20	2	6	0	-	-	-	-
Wollombi Brook	172,400	13	85	2	15	<0.1%	<0.1%	0%	<<0.1%
Glennies Creek[3]	-	8	50	0	0	-	-	-	-
Bowmans Creek[3]	-	35	478	0	16	-	-	-	-
Bayswater Creek[2]	870		63	-	0	7%	-	0%	-
UN3[2]	380		0	-	0	0	-	0%	-
UN5[2]	150		0	-	0	0	-	0%	-
Farrells Creek[2]	370		3	-	0	<1%	-	0%	-
Hobden Gully[2]	80		0	-	0	0%	-	0%	-
Parnells Creek[2]	640		4	-	0	<1%	-	0%	-
Pikes Creek[2]	400		3	-	0	<1%	-	0%	-
Redmanvale Creek[2, 3]	-		5	-	0	-	-	-	-
Saltwater Creek[2,3]	-		0	-	0	0%	-	-	-

Notes: 1. Sourced from Engeny's SWIA (Annexure B)

2. Ephemeral watercourse, modelled as a discharge only boundary condition (no river leakage to groundwater)

3. Not assessed as part of the SWIA

The streamflow assessment indicates there will be minimal to no changes to the annual flow and average duration of dry periods for Hunter River and most of its tributaries. Only three ephemeral watercourses were found to have increases of 1% or more in the number of dry days or average duration of dry periods in the representative dry year (2006) due to the Project:

- Unnamed Tributary 1 at HVO North: the average duration of dry periods within the representative "dry" year increased from 155 days to 163 days (5% increase) during operations, due to extending mining between the Mitchell Pit and Carrington Pit.
- Farrells Creek: the average duration of dry periods within the representative "dry" year increased from 156 days to 159 days (2% increase) during operations.
- Bayswater Creek: the average duration of dry periods within the representative "dry" year increased from 144 days to 145 days (1% increase) during operations.

The predicted change in streamflow is negligible for the Hunter River and Wollombi Brook and minor for the ephemeral tributaries. Modelling indicates the Project will result in reduced operational impacts to Wollombi Brook streamflow compared to the approved operations due to no changes to catchment area and reduced baseflow losses.

Potential impacts on surface water downstream users, including basic landholder users will be negligible.

EMM developed a water licensing strategy for the Project based on the predicted indirect and direct groundwater and surface water take related to mining, extraction from the Hunter River and capture of catchment runoff.

HVO holds more than sufficient entitlement to account for the predicted direct and indirect surface water take during operations.

During the closure period:

- Take associated with runoff captured from storages on non-minor streams within the Jerry Water Source (Jerrys management zone) during the transition period that exceeds HVO's existing entitlement will be sourced from the open market (including trade, in accordance with the WSP rules). There is adequate share entitlement within the Jerrys Water Source for the predicted take. In addition, the Hunter Unregulated and Alluvial WSP allows for trade (permanently and temporarily) into the Jerrys Water Source from several (17) other upstream water sources. This demonstrates there is sufficient entitlement within the water source and upstream water sources for HVO to obtain additional entitlement via the open market.
- HVO will apply to convert sufficient aquifer entitlements to unregulated river entitlements for the predicted peak take associated with dams on non-minor streams in the Lower Wollombi Brook Water Source during closure.

The final detail of any post mining dam configuration, design of the drainage systems and associated licensing will be further investigated and resolved during preparation of the relevant stages of the Rehabilitation Management Plan and in the detailed closure planning process.

7.4 Surface water quality

7.4.1 Overview

This section considers the following potential mechanisms for changes to surface water quality due to the Project:

- Overflow from the WMS during large rainfall events: as discussed above, the WMS has been designed to control overflows from all water storages and runoff generated by the 1% AEP 24-hour design event (or smaller) will to be contained on site. Therefore, the main mechanism for discharges from the HVO Complex to change surface water quality is through the use of the HRSTS, which is discussed below.

- Construction of the new Lemington Road bridge at the Hunter River.

- Water discharge under HVO's existing HRSTS and EPL requirements.

7.4.2 Construction of new Lemington Road at Hunter River

As outlined in Section 6, there is the potential for increased erosion and sedimentation to the Hunter River during construction of new Hunter River bridge as part of Lemington Road realignment. This will be managed by the implementation of erosion and sediment control measures in accordance with the Blue Book, Volume 1 and 2 (Landcom 2004, DECC 2006), and HVO's Erosion and Sediment Control Protocol. Prior to commencement of the construction of the Lemington Road realignment and bridge on the Hunter River, an Erosion and Sediment Control Plan (ESCP) will be developed to establish and maintain erosion and sediment control measures for the duration of works. This would typically include:

- upslope diversion drains to keep clean water runoff from flowing into active construction areas

- downslope measures, including sediment filter fences, or catch drains and sediment basins (where practical and/or required) to manage sediment-laden runoff generated by the construction activities

- monitoring and inspection requirements of any and all erosion and sediment control devices

- staging plan for the installation (and removal) of any erosion and sediment controls tailored to the progression of construction

When designed and implemented correctly, the potential for increased erosion and sedimentation to the Hunter River as well as potential impacts to the downstream water quality due to construction activities are expected to be minimal.

7.4.3 Licensed water discharge

As discussed in Section 4.6 of the SWIA (Annexure B), all discharges from the HVO Complex are expected to occur under the HRSTS and existing EPL conditions. Under the HRSTS, releases can occur during periods of high streamflow. The water balance model predicts the Project will, on average, utilise 19% to 52% of the average total allowable discharge opportunities during operations (Annexure B). The Project does not fully utilise the average allowable discharge opportunity as the operating rules established in the water balance model prevent releases from occurring when there are low inventories on site (Engeny 2026).

The water balance modelling predicts that 78% of the time that release occur, flow in the Hunter River will be 100 times greater than the estimated median discharge volume. On 96% of release days, flow in the Hunter River is predicted to be 80 times greater than the calculated discharge volume.

Engeny (2026) calculated the potential change to water quality in the Hunter River due to licensed discharge via the HRSTS, using the conservative dilution ratio of 80:1 (Hunter River flow 80 times larger than discharge volume). This calculation included observed water quality concentrations in the Hunter River upstream of the HVO Complex, which includes water quality effects from upstream mining discharges and other activities.

Following mixing, water quality concentrations in the Hunter River are generally predicted to remain below the observed 80th percentile background concentrations. The exceptions are listed in Table 7.2.

All mixed concentrations were found to remain below the 95th percentile background concentrations indicating that the expected water quality is within the existing natural range of the Hunter River (detailed results are provided in Annexure B).

Therefore, discharge under the HRSTS is not expected to have an adverse effect on surface water quality or social and environmental values.

Every 10 years a statutory review of the HRSTS is conducted, with the last being conducted between 2013 and 2016. The next review of the scheme is to be completed by 2026. Although the focus of the HRSTS is on managing salinity within the river, the 2013 *Hunter Catchment Salinity Assessment* (EPA) also considered how different analytes might have an influence on the ecological health of the river.

Table 7.2 Estimated change in water quality concentrations due to HRSTS discharge following mixing (Engeny 2026)

Analyte	Mixed concentration[1] (mg/L)	Hunter River upstream 80th percentile concentration (mg/L)	Hunter River upstream 95th percentile concentration (mg/L)	Percent change relative to Hunter River upstream 80th percentile
TDS (mg/L)	544.8	531.2	725.5	2.6%
Potassium (K) (mg/L)	5.1	5.0	21.0	2.5%
Magnesium (Mg) (mg/L)	51.5	51.4	59.8	0.3%
Sodium (Na) (mg/L)	88.2	83.2	101.0	6.0%
Sulfate (SO_4) (mg/L)	46.3	42.4	59.9	9.2%
Total Alkalinity (mg/L)	261.1	259.2	300.0	0.7%
Bicarbonate Alkalinity (mg/L)	259.7	259.4	286.6	0.1%
Carbonate Alkalinity (mg/L)	1.8	1.0	17.6	81.5%

1. 50th percentile release water

7.5 Flooding assessment

Details of the flood model development and results are provided in the SWIA (Annexure B). The following sections provide a summary of the key outcomes.

The modelled scenarios included:

- Project Baseline: Baseline conditions utilising the available topographic data (2016 and 2020) with adjustments for operational changes planned for completion prior to the Project, including haul road approach to Cheshunt Pit at the Hunter River crossing, construction of the North Void TSF Levee 1 (north-west levee) and construction of the SLP 1 flood protection upgrade at the haul road ramp.

- Project Operation: Construction of Project infrastructure including Carrington West Wing Levee, North Void TSF Levee 2 (south-east levee), Riverview Levee, Cheshunt Levee and Lake James upgrades, as well as construction of the Lemington Road realignment. This scenario also included incorporation of the planned mine progression to select the worst case for potential impact on the floodplain during operations.

- Project Closure: Consistent with Project Operations with the incorporation of the final landform design and decommissioning of levees, except for the Riverview Levee and Alluvial Lands Levee.

7.5.1 Impacts to mine infrastructure

The flood modelling predicts the following flood immunity of key mine infrastructure:

- Active open cut pits are shown to meet the minimum 0.1% AEP flood immunity (plus freeboard) standard adopted by HVO during the operational phase of the Project. During the later years of operations, HVO North will be exposed to a risk of flood ingress during Extreme Events (defined as four times the 1% AEP) via overtopping of the Carrington West Wing Levee.

- The final voids will have flood immunity up to and including the Extreme Event.

7.5.2 Impacts to public infrastructure

The main public infrastructure in the vicinity of the HVO Complex prone to flooding impacts is Lemington Road. Currently, Lemington Road at Moses Crossing becomes inundated during events smaller than 10% AEP and has been closed for an average of 60 days per year since 2010. The proposed realignment and new Hunter River bridge crossing of Lemington Road will significantly improve the flood immunity of this road adjacent to the Hunter River. The new Hunter River crossing will exceed 10% AEP flood immunity during the Project and post closure.

7.5.3 Impacts to third-party properties

The flood modelling indicates minor flooding impacts to properties not owned by the HVO JV partners. The Project is predicted to result in minor additional flood level changes ranging between 20 to 50 mm, but generally less than 30 mm, at 15 properties (being contiguous landholdings) not owned by the HVO JV. The impact is predicted to be minor, as the properties are already subject to flooding, and the maximum modelled change in flood affected area is estimated to be 0.15% of the total property for any individual property. In addition, the predicted change in flooding will not have an impact on the use of the land (agricultural (grazing and cropping) or Crown land).

7.5.4 Flood hazard and emergency management

There are no broad scale changes to flood hazard categories forecast due to the Project. Small changes in road inundation durations are predicted; however, the small changes are not expected to have an impact on use of the land or public safety or emergency management. Overall, there is a significant benefit to the local community through improved immunity of and access to the realigned Lemington Road.

Detailed results are provided in the SWIA (Annexure B).

7.5.5 Channel stability

i Overview

Predicted velocity impacts are generally localised around Project infrastructure (e.g. levees, Lemington Road realignment/new bridge, SLP 1). The magnitude of velocities in areas of impact generally remain within the existing ranges experienced and remain a low likelihood of causing scour (<2 m/s). No significant change to flood velocities is predicted on properties not owned by the HVO JV partners.

Detailed results and maps of the change in maximum modelled flood velocity due to the Project are provided in the SWIA (Annexure B).

ii Carrington West Wing Levee

During consultation with the NSW Government on the Project, it queried the potential for geomorphic changes due to constriction caused by construction of the proposed Carrington West Wing Levee. This levee (previously called the Mitchell Levee) is already approved under the HVO North Consent (designed up to 1% AEP).

As the 5% AEP event is the most frequent event causing flood flows in the area, Engeny (2026) adopted this event to assess potential geomorphic impacts of the reduced flood storage associated with the Carrington West Wing Levee.

The peak velocity distribution in the vicinity of the Carrington West Wing Levee indicate that changes are concentrated between the river channel and the downstream (eastern) half of the levee and are generally of small magnitude (<0.5 m/s increase). A maximum velocity increase of approximately 1 m/s is predicted to occur at the toe of the levee.

The predicted velocities generally remain less than 1 m/s on the alluvial lands of the floodplain. This is consistent with the velocities in the area under existing conditions. This area is agricultural land with vegetation cover and there is no sign of geomorphic instability under current conditions. The predicted velocity changes are unlikely to change the existing geomorphic regime and would occur under the current approved design of the levee (that is, these changes are not specific to the Project).

Adjacent to the levee the maximum velocity is approximately 1.5 m/s, which can be readily managed through incorporation of scour protection in the detailed design of the levee.

The combination of appropriate design, scour protection on the levee and monitoring following large flood events (5% AEP or larger) is adequate to mitigate the risk of erosion due to construction of the already approved levee.

8 Groundwater impact assessment

8.1 Introduction

The potential impact of the Project on the groundwater regime has been assessed from an incremental (comparison between approved and proposed) and cumulative perspective (estimating the effects of historic approved, the Project and other planned mining activities).

To support the PERs (EMM 2026a and EMM 2026b), groundwater modelling has been undertaken to reflect the changes to the mine plan (EMM 2026c, Annexure A). This groundwater modelling uses the model developed by AGE (2022) and incorporates updates to the model parameterisation and simulated mining activities associated with the Project.

Discussion of potential post mining /long-term impacts is provided in Section 10, as this is inter-related with the final void water balance modelling completed by Engeny (2026).

The following sections summarise the groundwater modelling results presented in Annexure A (EMM 2026c).

8.2 Alluvial and watertable drawdown

8.2.1 Incremental drawdown

Figure 8.1 shows the proportional likelihood of incremental drawdown in the alluvium exceeding 0.2 m irrespective of time. The 0.2 m threshold was chosen for the alluvium given it hosts ecological receptors (terrestrial GDEs and stygofauna).

There is negligible incremental drawdown predicted across the groundwater study area, with small pockets where it is predicted that drawdown greater than 0.2 m is 'very unlikely' in the vicinity of:

- the existing LPBWs to the south of Carrington Pit and west of North Pit
- Pikes Creek to the north, near the HVLP and stockpile
- the east and north-east of the Lemington Road realignment
- the Hunter River alluvium where it meets the Wollombi Broom alluvium between Cheshunt Pit and SLP 1 (includes two extremely small areas of 'unlikely' drawdown).

LPBWs in the Alluvial Lands and Carrington Pit highwall (across the eastern arm of the paleochannel) were constructed to reduce the extent of drawdown in the alluvium. Depressurisation of the interburden and coal strata and associated vertical gradient between the Permian and the alluvium induces minor drawdown in the alluvium.

The Project is unlikely to cause additional significant impacts to the alluvium groundwater beyond what is currently approved.

Figure 8.2 shows the proportional likelihood of incremental drawdown in the watertable exceeding 2 m irrespective of time. The 2 m threshold was chosen for the watertable as this is the AIP minimum impact threshold for third-party water supply bores, which may also be present outside of the alluvium.

Three bores were identified as having 'likely' or 'very likely' likelihood of watertable drawdown exceeding 2 m. However, one of the bores (GW080516) is a test bore at Wambo Colliery; one is dewatering bore at Ravensworth Operations, owned by Glencore (GW080725) and the third is a stock bore at Wambo mining-owned land (GW017798).

The Project is not predicted to have a significant drawdown impact at third-party bores.

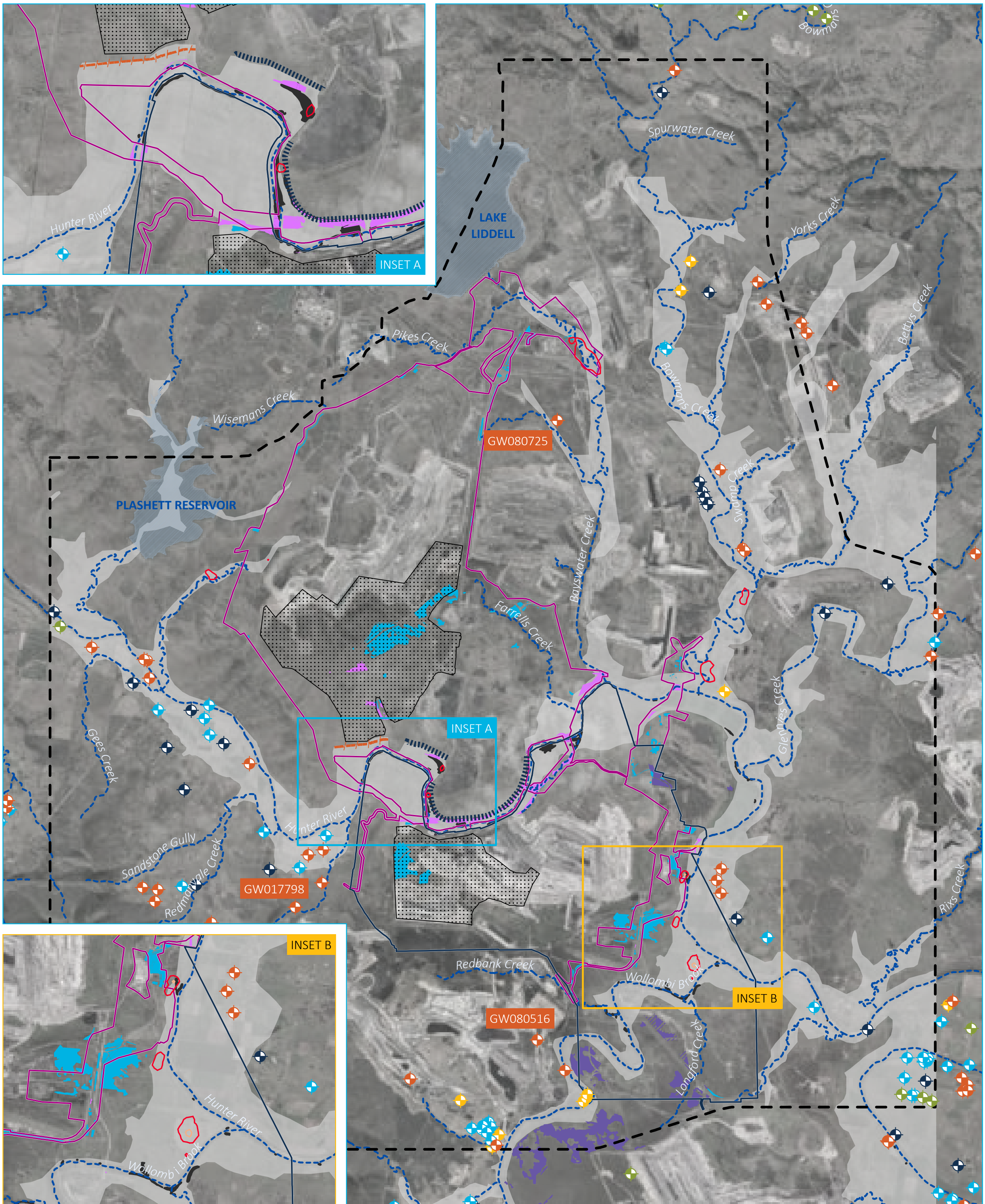
8.2.2 Cumulative drawdown

Figure 8.3 shows the maximum predicted cumulative drawdown in the alluvium irrespective of time (50th percentile, where it is as likely as not for cumulative drawdowns to be larger than the values predicted). This figure shows the drawdown predicted to occur due to the cumulative effect of historical approved and proposed mining at the HVO Complex and at other mining operations in the study area.

Most of the cumulative drawdown is predicted to occur along the alluvials to the north-east of the Project, due to the groundwater drawdown interactions with other existing mines that traverse these alluvial areas. As shown in Figure 8.1, the potential for incremental drawdown to occur (i.e. due to the Project) in these alluvial systems is very unlikely. Therefore, the Project is not predicted to contribute to cumulative drawdown in these areas.

In and around the Project itself, the cumulative maximum drawdown predicted in the Hunter River alluvium (less than 0.2 m, Figure 8.3) south of the Carrington Pit is due to depressurisation of the Permian hydrostratigraphy and an associated downward vertical gradient between the alluvial watertable and the Permian potentiometric surface. The depressurisation is related to mining at HVO North and HVO South.

In the Wollombi Brook alluvium, a maximum cumulative drawdown of up to 1 m is predicted in the area above the historical Lemington underground mine (Figure 8.3). The coal seams intersected by Lemington underground mine subcrop under parts of the Wollombi Brook alluvium. Drawdown is predicted due to downward vertical gradients associated with historical mining and the simulated continued use of Lemington underground as a water storage for operational water use for the MTW mining operation (as approved).



Source: EMM (2025); Glencore (2025); DCSSS (2024); GA (2009); Esri (2025); Umwelt (2025)

0 2.5 5 km

GDA2020 MGA Zone 56

N

KEY

- HVO North Action Area
- HVO South Action Area
- Mining area
- Model domain
- Alluvial extent (modelled)
- Low permeability barrier wall
- Carrington West Wing LPBW

Existing environment

- Named watercourse
- Named waterbody

Likelihood of exceeding 0.2m drawdown

- Unlikely
- Very unlikely

Bore type

- Water supply
- Commercial and industrial
- Irrigation
- Stock and domestic
- Unknown

Plant community type (PCT) (Umwelt, 2025)

- PCT 4089 | Namoi-Upper Hunter River Red Gum Forest
- River Red Gum (HVO, 2025)

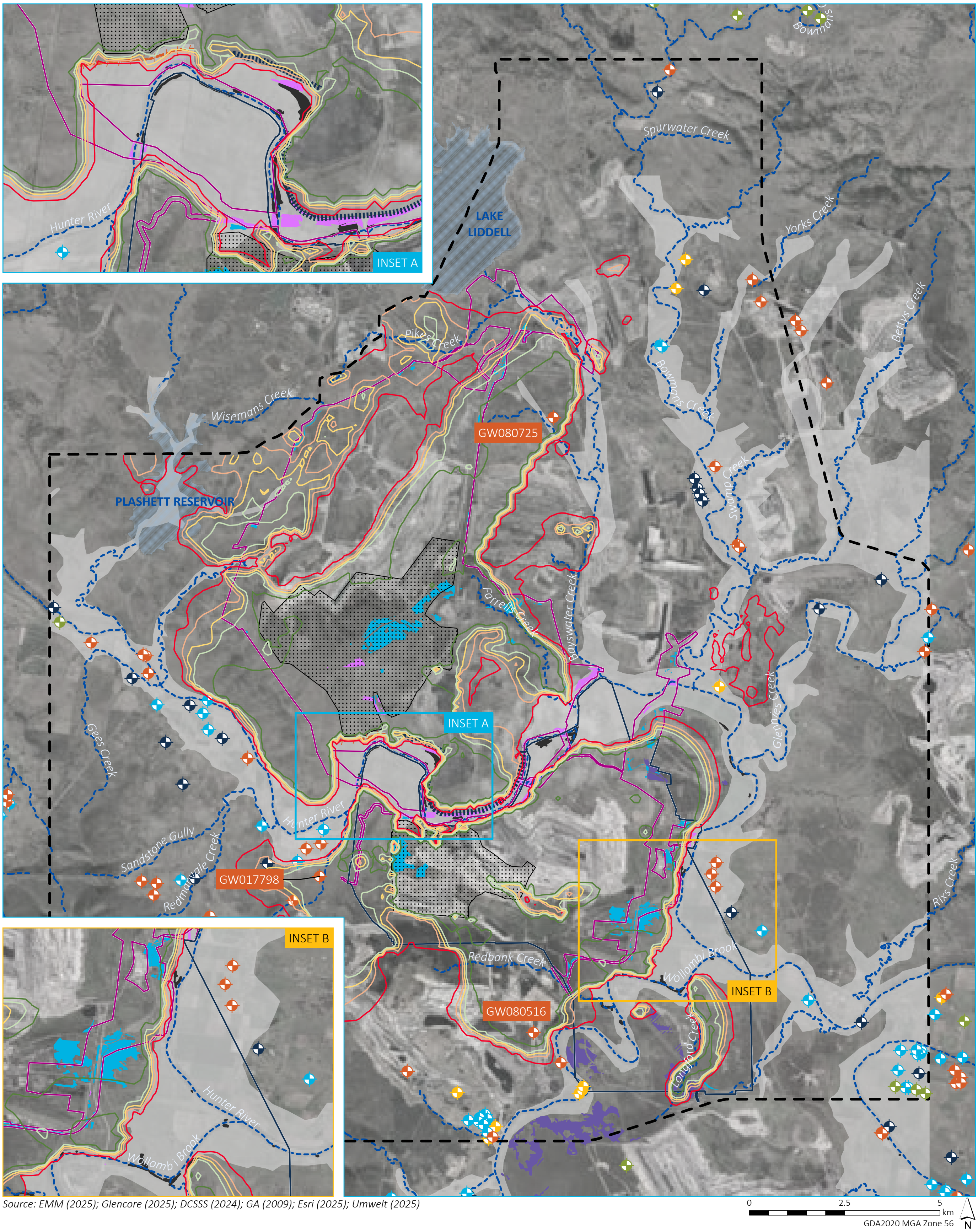
EPBC Act vegetation (Umwelt, 2025)

- Central Hunter Valley Eucalypt Forest and Woodland CEEC
- Warkworth Sands Woodland of the Hunter Valley CEEC
- Possible Warkworth Sands Woodland of the Hunter Valley CEEC

Proportional likelihood of exceeding 0.2 m incremental drawdown in alluvium irrespective of time

HVO Continuation Project
Water Resources Impact Assessment
Figure 8.1

EMM creating opportunities



Source: EMM (2025); Glencore (2025); DCSSS (2024); GA (2009); Esri (2025); Umwelt (2025)

KEY

- HVO North Action Area
- HVO South Action Area
- Mining area
- Model domain
- Alluvial extent (modelled)
- Low permeability barrier wall
- Carrington West Wing LPBW

Existing environment

- Named watercourse
- Named waterbody

Likelihood of exceeding 2m drawdown

- Very likely
- Likely
- As likely as not
- Unlikely
- Very unlikely

Plant community type (PCT) (Umwelt, 2025)

- PCT 4089 | Namoi-Upper Hunter River Red Gum Forest
- River Red Gum (HVO, 2025)

EPBC Act vegetation (Umwelt, 2025)

- Central Hunter Valley Eucalypt Forest and Woodland CEEC
- Warkworth Sands Woodland of the Hunter Valley CEEC
- Possible Warkworth Sands Woodland of the Hunter Valley CEEC

Bore type

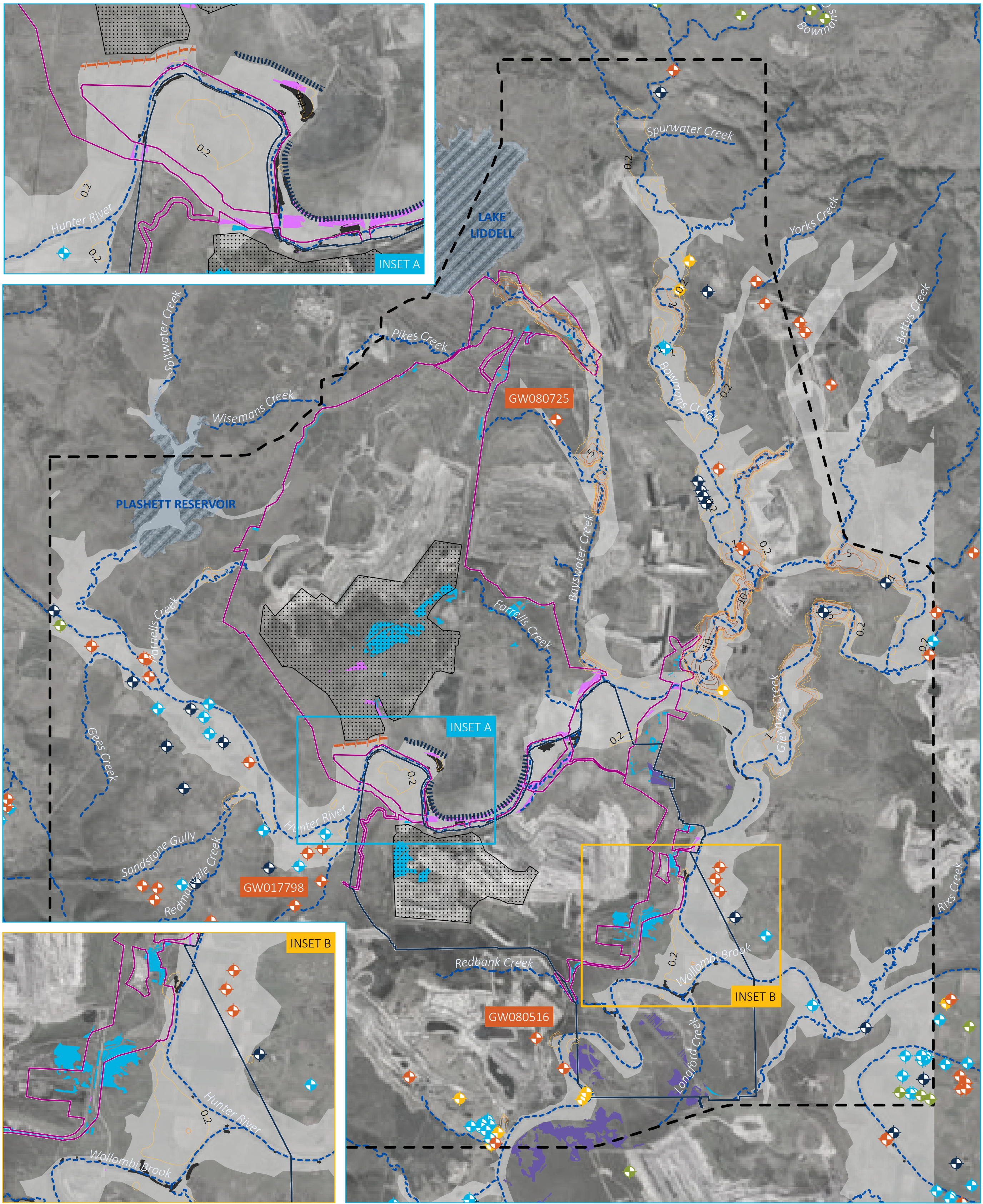
- Water supply
- Commercial and industrial
- Irrigation
- Stock and domestic
- Unknown

Proportional likelihood of exceeding 2 m incremental drawdown in the watertable irrespective of time

HVO Continuation Project
Water Resources Impact Assessment
Figure 8.2

EMM
creating opportunities

\\emm.local\xdrive\Secured\Divisions\H190408\GIS\02_Maps_2025WRIA\WRIA004_IncrProportionalLikelihood2mDDN\WRIA004_IncrProportionalLikelihood2mDDN_20251015_02.aprx 15/10/2025



Source: EMM (2025); Glencore (2025); DCSSS (2024); GA (2009); Esri (2025)

0 2.5 5 km
GDA2020 MGA Zone 56
N

KEY
HVO North Action Area
HVO South Action Area
Mining area
Model domain
Alluvial extent (modelled)
Low permeability barrier wall
Carrington West Wing LPBW
Existing environment
Named watercourse
Named waterbody

Modelled drawdown (m)
0.2
1
2
5
10
20

Plant community type (PCT) (Umwelt, 2025)
PCT 4089 | Namoi-Upper Hunter River Red Gum Forest
River Red Gum (HVO, 2025)
EPBC Act vegetation (Umwelt, 2025)
Central Hunter Valley Eucalypt Forest and Woodland CEEC
Warkworth Sands Woodland of the Hunter Valley CEEC
Possible Warkworth Sands Woodland of the Hunter Valley CEEC

Bore type
Water supply
Commercial and industrial
Irrigation
Stock and domestic
Unknown

Maximum predicted cumulative drawdown in alluvium irrespective of time (P50)

HVO Continuation Project
Water Resources Impact Assessment
Figure 8.3

EMM
creating opportunities

\\emm.local\xdrive\Secured\Divisions\H190408\GIS\02_Maps_2025WRIA\WRIA002_MaxCumDDNAllum\WRIA002_MaxCumDDNAllum_20251015_02.aprx 15/10/2025

8.3 Saturated thickness changes

Despite the minor drawdown predicted in the Hunter River alluvium, the alluvium will remain saturated largely due to leakage of surface water through the bed of the Hunter River and minor incremental drawdown.

The predicted saturated thickness within the alluvial aquifer over the operational life of the Project is presented on Figure 8.4 for years 2027, 2035, 2040, and 2045 (i.e. at the planned end of mining at HVO North). The extent of the saturated areas remains largely unchanged over time and areas with potential GDEs are not predicted to be dewatered over the Project life.

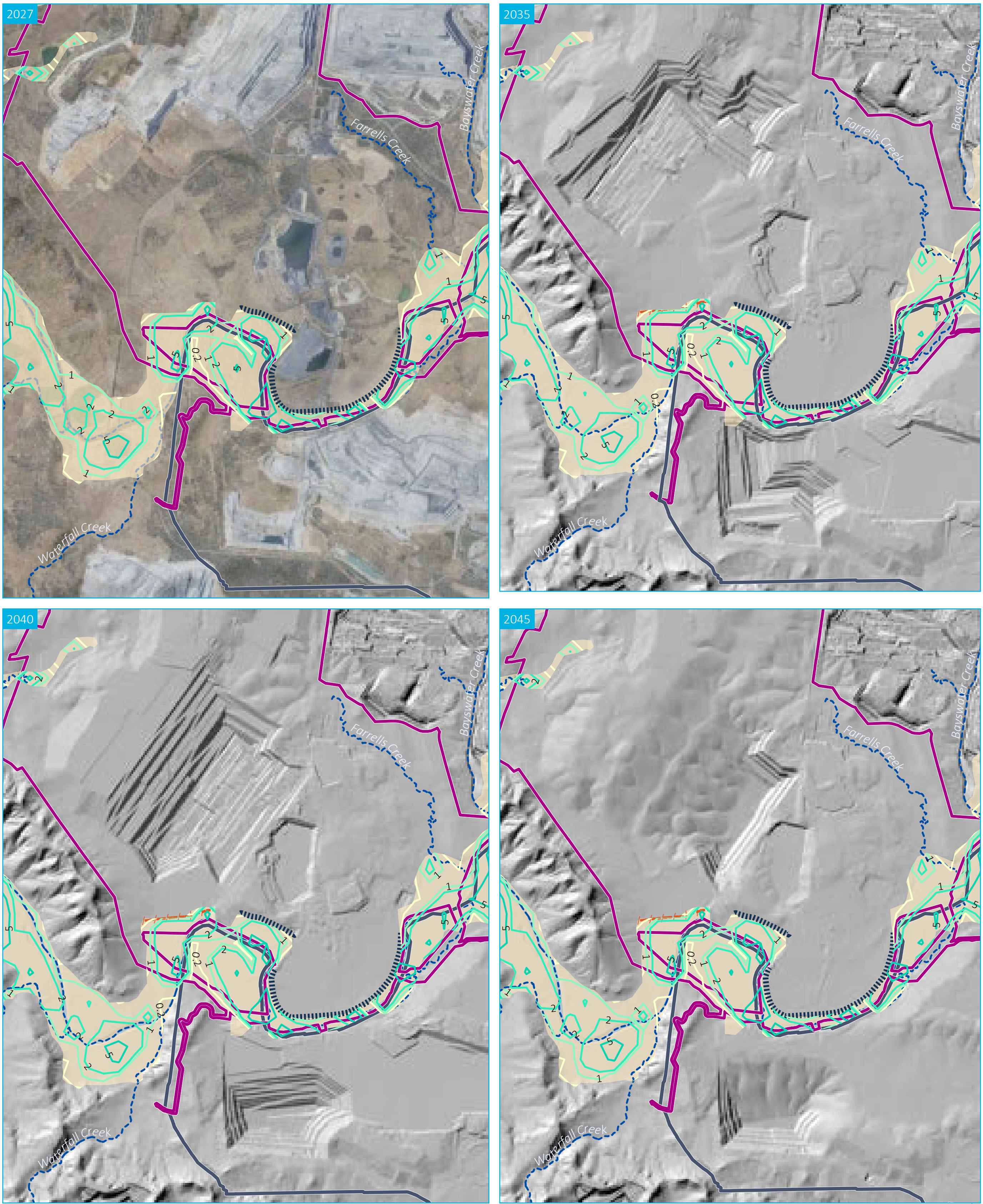
The potential impact of the Project on water dependent receptors is discussed in Section 9.

8.4 Groundwater inflows

The groundwater model has been used to predict annual volumes of groundwater intercepted by mining at HVO North and HVO South.

The median predicted inflow volume is predicted to peak at approximately 3,400 megalitres per year (ML/yr) in 2039, which is below HVO's existing water licence entitlement. The volume reduces when mining ceases at HVO South. Post mining, the groundwater model predicts the evaporative pumping effect of the pit lakes will stabilise at between about 1,600 ML/yr and 2,100 ML/yr and is within the entitlement held by HVO.

Further discussion on predicted groundwater inflows is provided in Annexure A.



Source: EMM (2025); Glencore (2025); DCSSS (2024); GA (2009)

0 2.5 5 km
GDA2020 MGA Zone 56
N

\\emm.local\xdrive\Secured\Divisions\H190408\GIS\02_Maps_2025ModelReport\MR016_SaturatedAlluviumThickness\MR016_SaturatedAlluviumThickness_20250820_03.aprx 8/10/2025

KEY

- HVO North Action Area
- HVO South Action Area
- Alluvial extent (modelled)
- Low permeability barrier wall
- Carrington West Wing LPBW

Existing environment

- Named watercourse

Modelled saturated thickness (m)

- 0.2
- 1
- 2
- 5

Modelled P50 alluvium saturated thickness at various times

HVO Continuation Project
Water Resources Impact Assessment
Figure 8.4

EMM
creating opportunities

8.5 Groundwater quality

The Project has the potential for groundwater quality changes as a result of the following:

- Exposure of acid sulphate soils: The Soil and Land Resources Assessment Report (Appendix P to the EIS; Minesoils 2022) assessed the potential risk associated with acid sulphate soils. The proposed action areas do not contain any of the five acid sulphate classes listed on the NSW Acid Sulphate Soil Planning Map. Based on the land elevation and distance from the coast, in conjunction with existing mapping for NSW, the potential for acid sulphate soils is considered a very low risk. Further, there is no evidence of acid sulphate soils indicators such as soil gleying, odour, marine sediments and organic materials recorded as part of the soils survey. As such, acid sulphate soils are not considered further in this report.

- Potential production of acid rock drainage and metalloid leachate during operations has been considered as part of the geochemistry assessment (Annexure D) and is discussed below.

- Seepage from backfilled emplacement areas to the alluvial watertable and Hunter River: The potential for seepage from mining areas backfilled with overburden and interburden material to the alluvial watertable and Hunter River has been considered in this report using outcomes from the groundwater model, site observations and geochemical characteristics reported by EGi (2022a).

- Potential seepage from mine water dams to alluvium: Discussed further below and uses observations from ongoing monitoring at the existing operation and dam design aspects.

- Changes to groundwater salinity (e.g. freshening) in the Hunter River alluvial aquifer: Discussed further below and uses observations from ongoing monitoring at the existing operation and consideration of change in groundwater flow directions predicted by groundwater modelling.

8.5.1 Acid rock drainage

i HVO Complex overall

The potential for acid rock drainage or metal leachate is low as the geochemical assessment for the Project (Annexure D) indicates the majority of rejects generated by the Project are likely to be NAF. Although 15% of the rejects samples tested were PAF, the thorough intermingling of rejects and overburden, and the excess acid neutralising capacity in the overburden, suggests that these bulk fill zones are unlikely to result in any significant acid rock drainage issues or effects on rehabilitation.

Waste material (overburden and interburden) will continue to be managed in accordance with current site management practices, including:

- isolation of acid rock drainage potential and saline waste through:
  - placement of PAF and saline material far from the Hunter River and alluvial sediments
  - encapsulation of PAF waste within low permeability NAF cell
  - blending of NAF and PAF overburden
- avoiding placement of PAF close to the surface to prevent leachate runoff
- seepage collection drainage and diversion drains.

These practices are effective, as observed in the surface water quality monitoring data, where water quality within the mine water system is generally neutral to alkaline, and salinity up to 5,170 mg/L TDS.

ii HVO South

There is no proposed change to waste management at HVO South from the existing approved operation. Therefore, the proposed operations at HVO South will have negligible impact on groundwater quality, including the social and environmental values of groundwater.

The final pit floors for the Cheshunt and Riverview pits will terminate at the base of the Bayswater Seam (as per the HVO South Approval), which will potentially expose pyritic Archerfield Sandstone. The implications of this on pit water quality was assessed in more detail with water quality modelling (EGi 2022b) and overall is expected to have no significant impact on water quality. Water quality monitoring of water pumped from active mine areas will be conducted during operations if this mine water is pumped out as part of the WMS.

8.5.2 Potential seepage from backfilled mining areas to the alluvial watertable and Hunter River

As mentioned, there is no proposed change to waste management and pit backfill at HVO South or HVO North from the existing approved operation. The only change at HVO North relates to the use of overburden and interburden material across the Jerrys Plains subgroup and Vane subgroup extracted in the area between West/Mitchell Pit and Carrington Pit area.

In contrast to the existing approved operation at HVO North, mining for the Project will occur as one main pit, advancing in a south-east direction towards the ultimate final void location north of the Carrington Pit void.

Consistent with the current approved operations, the mine plan (for HVO North and HVO South) involves progressively backfilling of mined areas with overburden and interburden waste material, followed by progressive rehabilitation.

During mining, the floor of the pit will be deep and intercepted groundwater will be actively managed as part of the mine WMS. This will result in depressurisation of the Permian strata and development of a steep hydraulic gradient towards the pit areas. Therefore, the active mining areas will be groundwater sinks.

Groundwater monitoring shows that groundwater levels in the rehabilitated Alluvial Lands area (at HVO North) are lower than the Hunter River alluvium (Section 4.6.4), supporting the conceptual understanding and modelling results that the potential for the watertable in the backfilled pit areas to rise to a similar or higher elevation than the alluvium is unlikely. Therefore, the potential for seepage to migrate towards the Hunter River alluvium is also very unlikely.

In 2022, AGE conducted sensitivity analysis to evaluate if changes to the hydraulic properties and recharge rates to the in-pit mine spoils at HVO could result in groundwater flow within the backfilled mine areas migrating towards the Hunter River alluvium rather than towards the voids.

A number of model scenarios were run with the hydraulic conductivity and storage properties of the spoil reduced and the rainfall recharge rate increased to enhance watertable mounding within the backfilled pit areas.

The outcomes of the sensitivity analysis (AGE 2022) predicts that the voids remain strong sinks and dominate the groundwater flow direction. The study found that the risk of seepage from the backfilled mine areas migrating through the existing and proposed LPBWs towards the Hunter River alluvium is negligible (AGE 2022).

In addition, updated history-matching conducted in 2025 included considerations of spoil hydraulic properties and recharge rates, with the history-matching results and predictive ensemble guided by the many years of groundwater monitoring at the HVO Complex and surrounds.

The IESC Advice raised the potential for preferential pathways to the Hunter River and associated alluvium, via remnant paleochannels, which are not accounted for in the groundwater modelling. The IESC notes that dilution effects are likely to occur between the backfill and the alluvium, and between the alluvium and Hunter River, but may not be effective in reducing risk if the seepage volume is higher than predicted.

Various field studies have been conducted since approximately 1999 to investigate and delineate the paleochannel including drilling and hydraulic tests. As part of detailed design of the Carrington West Wing LPBW, HVO will review field investigations conducted in the past and implement field investigations to fill data gaps and conceptual uncertainties as needed. In addition, the approved but not yet constructed LPBW will be designed and constructed to key into Permian strata (interburden or overburden) adjacent to and below the alluvial sediments.

Therefore, the Project, through the proposed mitigation measures, is predicted to have a negligible impact on groundwater quality in the HVO Complex area, including potential to adversely impact the social and environmental values of groundwater and connected surface water sources.

8.5.3 Potential seepage from mine water dams to alluvium

HVO has been operating (and will continue to operate) the mine WMS in accordance with the approved WMP, which includes segregating waters of different water quality (where practical).

As noted in the SWIA (Annexure B), seepage losses from out of pit storages and open cut pits are expected to be minor. In addition, potential seepage from the upgraded dams (Parnells Dam and Lake James) will be managed by an embankment filter, cut-off design and treatment of batters within the storages.

Parnells Dam is the only dam(s) located in an area of mapped alluvium.

The Parnells Dam area currently includes Dam 9W which receives saline mine water (constructed in 1993) and Dam 18W which contains clean water and works as part of the Parnells Creek diversion (constructed in approximately 2005). Parnells Dam (Dam 9W) receives (and will continue to receive) mine affected water diluted with water transferred from several sediment dams across the complex and a farm dam. As both Parnells Dam and Lake James are licensed HRSTS discharge points, water quality is managed to be of suitable quality to allow for discharging under the HRSTS and EPL limits.

Salinity at Parnells Dam (Dam 9W) averaged 3,288 µS/cm in 2023 (Umwelt 2024) which is within the historical range from 2,400 to 6,300 µS/cm noted by MER in 2003. Groundwater salinity monitoring at a shallow monitoring bore downstream of Parnells Dam (GW-100, screened in colluvial gravels) averaged approximately 10,800 µS/cm in 2023 (Umwelt 2024). The recorded salinity is within the historical range observed since monitoring commenced in 2013 and is much higher than the salinity measured at Parnells Dam or typical of the mine WMS. As such, the salinity observed at this shallow bore is not thought to be due to seepage from the mine WMS at HVO.

Based on historical monitoring, water management measures and proposed design, potential impacts to alluvial groundwater quality from potential seepage from dams are expected to be minor.

8.5.4 Potential changes to groundwater salinity in the Hunter River alluvial aquifer

Historical monitoring shows the groundwater salinity of the Hunter River alluvium ranges from approximately 117 to greater than 15,000 µS/cm (Section 4.6.5; AGE 2022; Umwelt 2024).

As mentioned in Section 4.6.5, the salinity of the paleochannel alluvium has, historically, been elevated, with freshening observed in areas close to the river where the effects of recharge and mixing are more evident (MER 2010). As reported in the HVO North West Pit EIS, groundwater salinity in the paleochannel ranged from 4,020 µS/cm to approximately 15,000 µS/cm (MER 2003).

Between 2023 and 2025, groundwater salinity in the Hunter River alluvium (in the Carrington West Wing area) ranged from approximately 909 µS/cm (4040P) to around 7,700 µS/cm (CGW45A). In the remnant area of paleochannel alluvium between the West Pit and Carrington Pit, groundwater salinity is high higher at around 9,400 µS/cm (GW-106; Section 4.6.5).

Realignment of Lemington Road and mining between West Pit and Carrington Pit at HVO North (as proposed), will result in removal of the remnant paleochannel material, which is disconnected from the Hunter River due to historical approved mining.

The mechanism for local changes to groundwater salinity in the Hunter River alluvium (due to mining at HVO) relates to construction of the currently approved (but not yet constructed) Carrington West Wing LPBW across the western arm of the paleochannel. The mine plan currently approved under the HVO North consent includes mining coal below alluvium in the Carrington West Wing area. The proposed disturbance and removal of alluvial material in this area is consistent with the mine plan currently approved under the HVO North Consent. Monitoring in the Carrington Pit alluvium and Alluvial Lands remnant alluvium, shows salinity has been relatively stable, freshening slightly (but remaining within historical observed ranges) in some areas during periods of high rainfall and streamflow, such as that observed in 2020 to 2022 (Umwelt 2024). Freshening of the alluvium has been observed since approximately 2011 in the northern extent of the western arm of the paleochannel (the portion in hydraulic connection with the river), for example at CGW39 (declining from ~7,700 µS/cm to 3,500 µS/cm over 15 years) and CGW45A (declining from ~7,500 µS/cm to ~4,000 µS/cm over 15 years). This is due to reduced groundwater flow from the Permian strata to the alluvium. Based on the stygofauna sampling, this gradual freshening has not had a detrimental effect on the stygofauna habitat.

Mining in the Carrington West Wing area and construction of the LPBW (as approved under the HVO North Consent), is unlikely to result in significant changes in alluvial groundwater salinity in the undisturbed alluvium due to:

- existing downward hydraulic gradient between the alluvium and Permian strata
- strong hydraulic connection with the Hunter River and existing groundwater salinities between 1,000 and 2,000 µS/cm.

9 Potential impacts on water dependent ecosystems

9.1 Groundwater dependent vegetation

This section focuses on river red gums and Central Hunter Ironbark Grassy Woodland (in the Hunter River riparian zone) as potentially groundwater dependent, and opportunistic users of alluvial groundwater in the study area. As noted in Section 4.8.3, the Central Hunter Ironbark Grassy Woodland conforms (or partially conforms) to the Central Hunter Valley Eucalypt Forest and Woodland CEEC.

Groundwater modelling predicts negligible incremental drawdown in the Hunter River alluvium near the riparian river red gum sites (Figure 8.1) with drawdown greater than 0.2 m considered very unlikely and no dewatering of the alluvium. Potential drawdown of the alluvial watertable is buffered by the leakage from the Hunter River, which has controlled flow through releases from Glenbawn Dam.

Up to 0.2 m of cumulative alluvial drawdown (P50) is predicted in the Carrington Billabong and river red gum vegetation area (Figure 8.3). In the Wollombi Brook alluvium area, the predicted maximum cumulative alluvial drawdown ranges from 0.2 to 1 m (Figure 8.3).

Cumulative groundwater drawdown is predicted in an area of mapped Central Hunter Valley Eucalypt Forest and Woodland CEEC along Pikes Creek to the north (Figure 8.3); however, this is in the disturbance footprint for the HVLP and stockpile. Therefore, cumulative groundwater drawdown impacts do not apply as the vegetation is located within the Biodiversity Impact Assessment Area.

Figure 9.1 shows predicted hydrographs at locations in the Hunter River alluvium south of the Carrington West Wing LPBW and near Carrington Billabong. It shows negligible predicted change in watertable elevation in the Hunter River alluvium in these areas.

During periods of drawdown, river red gums and Central Hunter Ironbark Grassy Woodland vegetation will continue to have access to shallow alluvial groundwater. In addition, the Project is predicted to have a negligible impact on Hunter River flow and flooding regime. Therefore, river red gum stands will continue to rely on flooding for germination.

The river red gum community of the Hunter Valley is considered a threatened population under the BC Act, but at HVO it is highly disturbed so is classified as having a moderate ecological value (using the GDE Assessment Guidelines). Under the GDE Risk Matrix, the ecosystem is classified as D (moderate ecological value, low risk; ELA (2025)).

The aquatic ecology and GDE assessment (Annexure C) demonstrates that the predicted variation in the watertable will not prevent the long-term viability of the ecosystem and no significant impact on groundwater dependent vegetation is expected due to the Project.

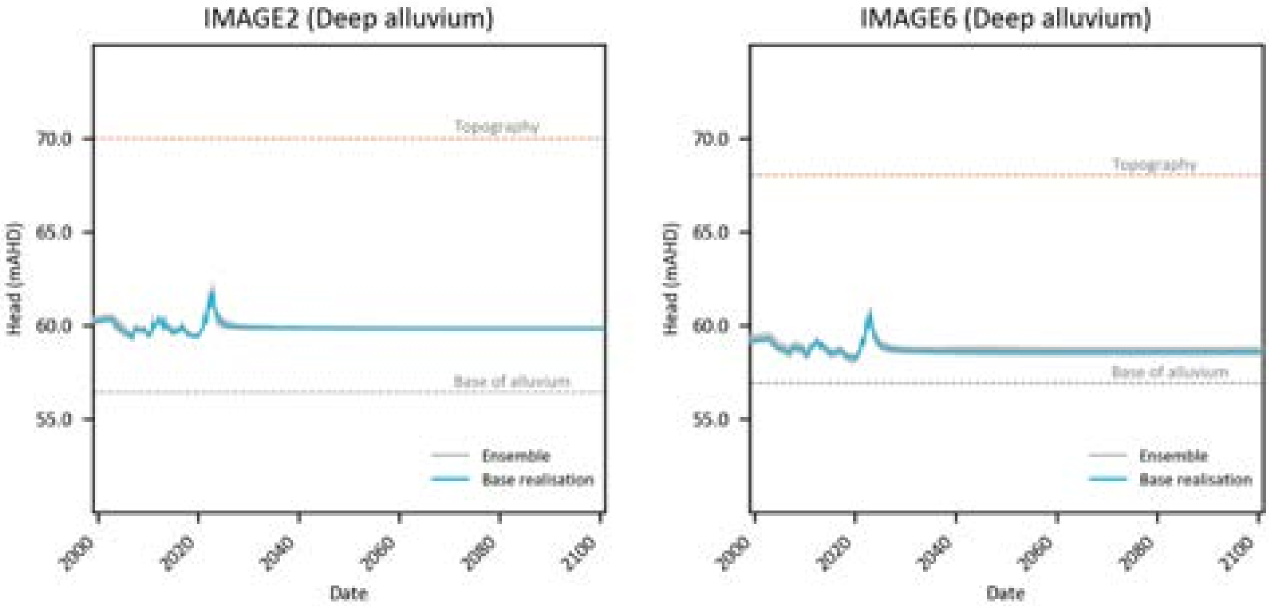


Figure 9.1 Hydrographs of predicted alluvial groundwater within the Carrington Billabong area

As discussed in Section 4.8.3, the watertable is greater than 20 mbgl (up to 80 mbgl) in the area where Central Hunter Valley Eucalypt Forest and Woodland CEEC is mapped in the HVO South MIA area and Lemington Road realignment area east of the HVO South mine. Therefore, the vegetation within the Central Hunter Valley Eucalypt Forest and Woodland CEEC are unlikely to access groundwater associated with the regional watertable and therefore are very unlikely to be impacted by the predicted incremental watertable drawdown presented on Figure 8.2.

9.2 Aquifer ecological communities

There is a good understanding of the stygofauna presence in the Hunter River (and tributary) alluvium due to many years of research and surveys. The Hunter River alluvium in the study area is a stygofauna habitat and hosts diverse stygofauna communities. As such, it is considered High Ecological Value. The stygofauna taxa within the study area are also known to be widespread throughout the Hunter Valley (ELA 2025).

9.2.1 Potential drawdown impacts

Groundwater modelling predicts minor incremental drawdown near the Carrington Billabong (very unlikely for alluvial drawdown to exceed 0.2 m; Figure 8.1). The cause of the drawdown relates to the extended mining duration compared to what is currently approved under the HVO North Consent. The small area of drawdown is due to an increased downward vertical gradient between the alluvial watertable and the Permian potentiometric surface.

The alluvial aquifer is predicted to remain saturated as downward leakage of water through the bed of the Hunter River will maintain aquifer saturation. Therefore, impacts from the Project on stygofauna communities are predicted to be minor.

The western arm of the paleochannel will be mined during the excavation of Carrington West Wing as part of approved operations. This will have an impact on the local stygofauna community in the paleochannel, as they will not be able to migrate out of the impact area prior to excavation. However, this impact is already approved as part of Carrington West Wing extension (HVO North Mod 3, MER 2010).

The risk to the stygofauna community associated with the Project is low. The cumulative impact to the stygofauna community from already-approved mining in the paleochannel is high and is categorised in the GDE Risk Matrix as C (High Ecological Value, High Risk; (ELA 2025)).

The aquatic ecology and GDE assessment demonstrates that the predicted watertable drawdown will not prevent the long-term viability of the ecosystem in the Hunter River alluvium in the study area, outside of the mining area. Therefore, it is predicted that the Project will not have a significant impact on stygofauna communities.

9.2.2 Potential impacts from changing salinity

As discussed in Section 8.5.4, historical monitoring shows the groundwater salinity of the Hunter River alluvium ranges from approximately 117 to greater than 15,000 µS/cm (AGE 2022; Umwelt 2024). Hancock and Boulton (2008) note that the optimal salinity range for stygofauna is less than 5,000 µS/cm; however stygofauna surveys at HVO has recorded stygofauna at bores with salinity up to 9,400 µS/cm (Annexure C), indicating stygofauna can tolerate higher salinities.

Based on current and historical measured groundwater salinity in the Carrington West Wing alluvial area and monitoring conducted in the Carrington Pit, Alluvial Lands and Cheshunt alluvial areas, the potential for changes to alluvial groundwater salinity due to the Project is expected to be unlikely. In addition, stygofauna has been collected from bores in the Hunter River alluvium where salinities range from approximately 800 to 9,400 µS/cm. Although the Project is unlikely to result in changes to alluvial salinity in the undisturbed alluvium, any potential changes will not have a detrimental impact on stygofauna communities given the large observed tolerance range to local groundwater salinity.

The Project is not expected to have a significant impact on stygofauna communities.

9.3 Aquatic ecology

Some species of fish living in the Hunter River require access to estuarine reaches to spawn. Such species of fish could be impacted if river levels reduce to an extent where this migration is impaired for long periods of time. Flow in the Hunter Regulated River is maintained and dominated by releases from Glenbawn Dam and inflow from tributaries, rather than from contribution from groundwater. The results of the streamflow analysis (summarised in Section 7.3 and discussed in detail in Annexure B), show minor to negligible change in streamflow and duration of dry days due to the Project.

The aquatic ecology and GDE assessment (Annexure C) included a survey where data was collected for sites upstream and downstream of HRSTS discharge sites. Differences in taxonomic richness were minor. SIGNAL scores were higher at the sites downstream of Farrells Creek and Lake James than for the upstream sites but were lower at the site downstream of Parnells Creek.

The findings of the aquatic ecology and GDE assessment (Annexure C) is that there will be no additional impact to aquatic ecology in the Hunter River, and with little significant impact to the aquatic ecology in the Hunter River tributaries due to the Project.

10 Final void assessment

10.1 Introduction

When the final landform is achieved, all operations will be complete, and the disturbance areas will be rehabilitated. As discussed in Section 2.2.4, the final landform will result in two voids at HVO North and a single void at HVO South.

In comparison to the approved operation, the HVO South void will remain largely unchanged; however, the HVO North Void is a reduction from three final voids (at West Pit, Mitchell Pit and Carrington Pit) to two voids (Mitchell Pit and Carrington Pit).

The voids have been designed to remain long-term sinks. As described in the SWIA (Annexure B), drainage systems will be established on rehabilitated overburden emplacement areas, as well as around the perimeter of the final voids to divert upstream catchment runoff away from the final voids and to downstream watercourses. As such, the final landform design minimises capture of surface water and thereby limits long-term impacts on streamflow.

Table 10.1 provides a comparison of the catchment areas of the approved final voids at the HVO Complex and the catchment areas of the proposed (indicative) final voids. An overall decrease in catchment area reporting to the voids across the HVO Complex will occur; this will result in increased catchment and surface runoff to the surrounding waterways, which is a positive change from the approved voids.

Table 10.1 Comparison of approved and proposed (indicative) final void catchment areas

Proposed void	Approved void	Catchment area of approved void (ha)	Catchment area of proposed void – Project (ha)	Change in catchment area (compared to approved; ha)
HVO South	Riverview Pit	1,145 [1]	570	-575
HVO North	West Pit	497 [2]	706	+55
	Mitchell Pit	154 [3]		
	Carrington Pit	120 [4]	324	+204
	Combined total	**1,916**	**1,600**	-316

Notes: 1. HVO South Mod 5 assessment (EMM 2017)
2. HVO North West Pit EIS (MER 2003)
3. Calculated (refer Chapter 3 of the EIS (EMM 2022))
4. HVO North Mod 3 (Carrington West Wing) (MER 2010)

10.2 Final pit lake recovery

Given the proximity of the HVO North and HVO South voids to each other and the groundwater connection through the Permian units between the voids, the final void hydrology and salinity modelling used inputs from the groundwater model where all three voids were simulated on the same scenario. The predicted pit lake recovery and salinity (from the final void hydrology and salinity modelling base case (i.e. most likely scenario; Engeny 2026) are presented for HVO North, Carrington Pit and HVO South proposed final voids in Figure 10.1, Figure 10.2 and Figure 10.3, respectively.

The HVO North Void pit lake level is predicted to reach an equilibrium level of approximately -17.8 metres Australian Height Datum (mAHD) after approximately 600 years, which results in a freeboard of approximately 100 m. For the Carrington Pit Void the model predicted a long-term pit lake level of 41.8 mAHD (within 100 years post closure), resulting in a freeboard of approximately 14.0 m.

Consistent with the Approved operation, the HVO North Void will act as a strong sink, stronger than the current approved voids at HVO North.

The HVO South pit lake level is predicted to reach an equilibrium level of approximately -29.7 mAHD after approximately 600 years, which leaves a freeboard of approximately 110 m. The assessment for HVO South Mod 5 (which relates to EPBC Act referral 2016/7641) estimated a long-term lake elevation of 30 mAHD and lake surface area of 337 hectares. The modelling completed for the Project indicates the HVO South pit lake will be considerably deeper than previously predicted, with the HVO South Void predicted to act as a regional sink. The difference in predicted long-term lake levels is likely be due to interaction with the proposed deep HVO North Void, reduced catchment area reporting to the HVO South Void (in comparison to the current approved landform) and greater evaporative losses from the proposed HVO North Void (in comparison to the current approved voids).

Salinity is expected to continue to increase over time in the pit lakes until solubility limits (subject to a range of factors including interspecies interactions) are reached (i.e. when precipitation of salts occurs). When the pit lake equilibrium levels are reached, the predicted pit lake salinity (TDS) for the HVO North, Carrington Pit Void and HVO South are 7,100 mg/L, 21,550 mg/L and 8,400 mg/L respectively.

Engeny (2026) conducted sensitivity analysis using ranges in measured salinity (low and high) for the host rock and other inputs and calculated the potential implications on pit lake salinity. At high salinities (as input values to the final void hydrology and salinity model), the pit lake salinity is still predicted to be less than 20,000 mg/L TDS for HVO North and HVO South voids and similar to seawater for the Carrington Pit void (see Annexure B for further discussion).

This is common for final voids in the Hunter Valley.

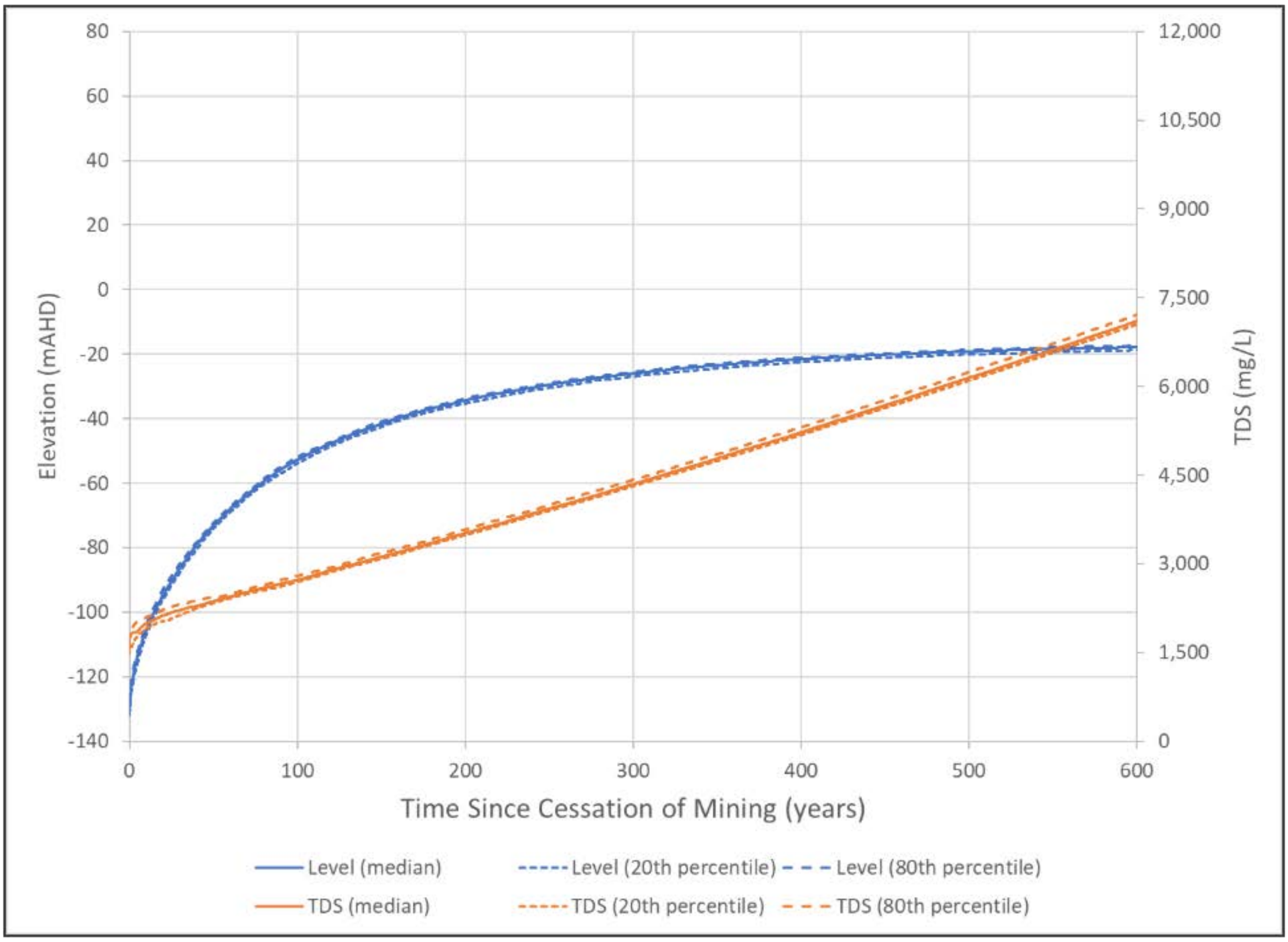


Figure 10.1 HVO North – North Void pit lake recovery and salinity (Engeny 2026)

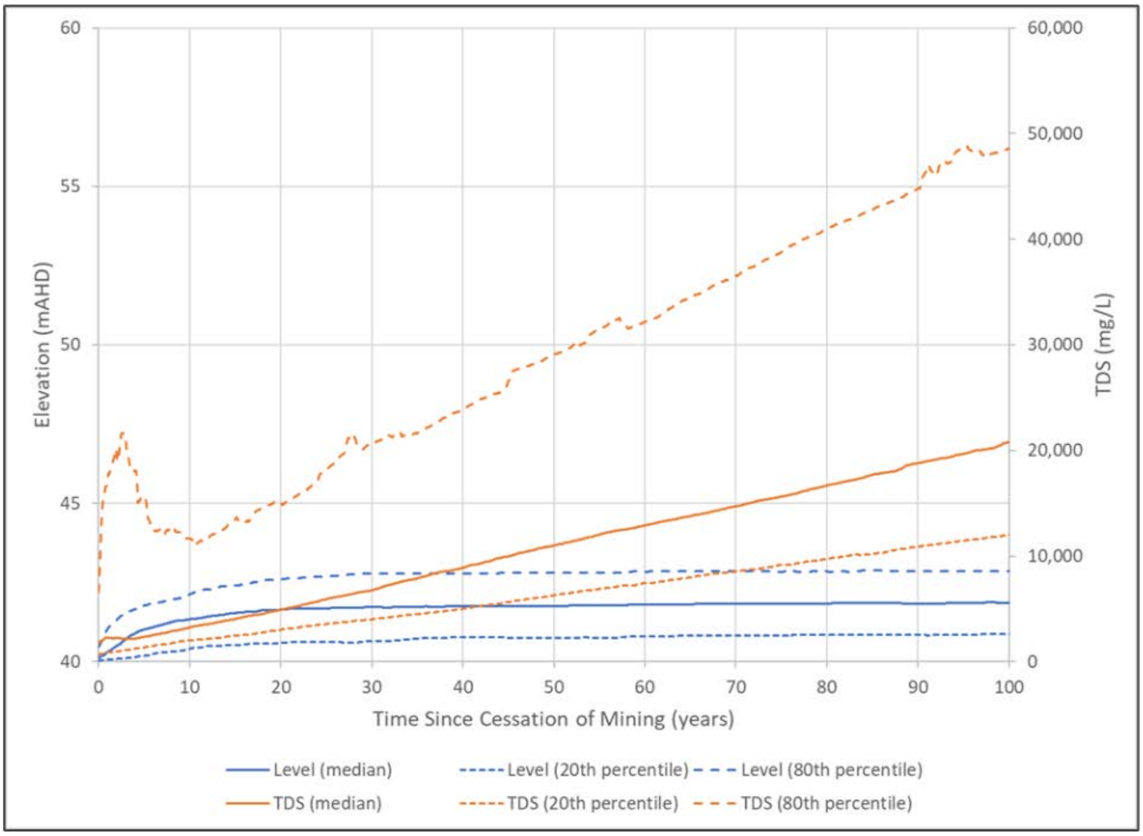


Figure 10.2 HVO North – Carrington Pit Void pit lake recovery and salinity (Engeny 2026)

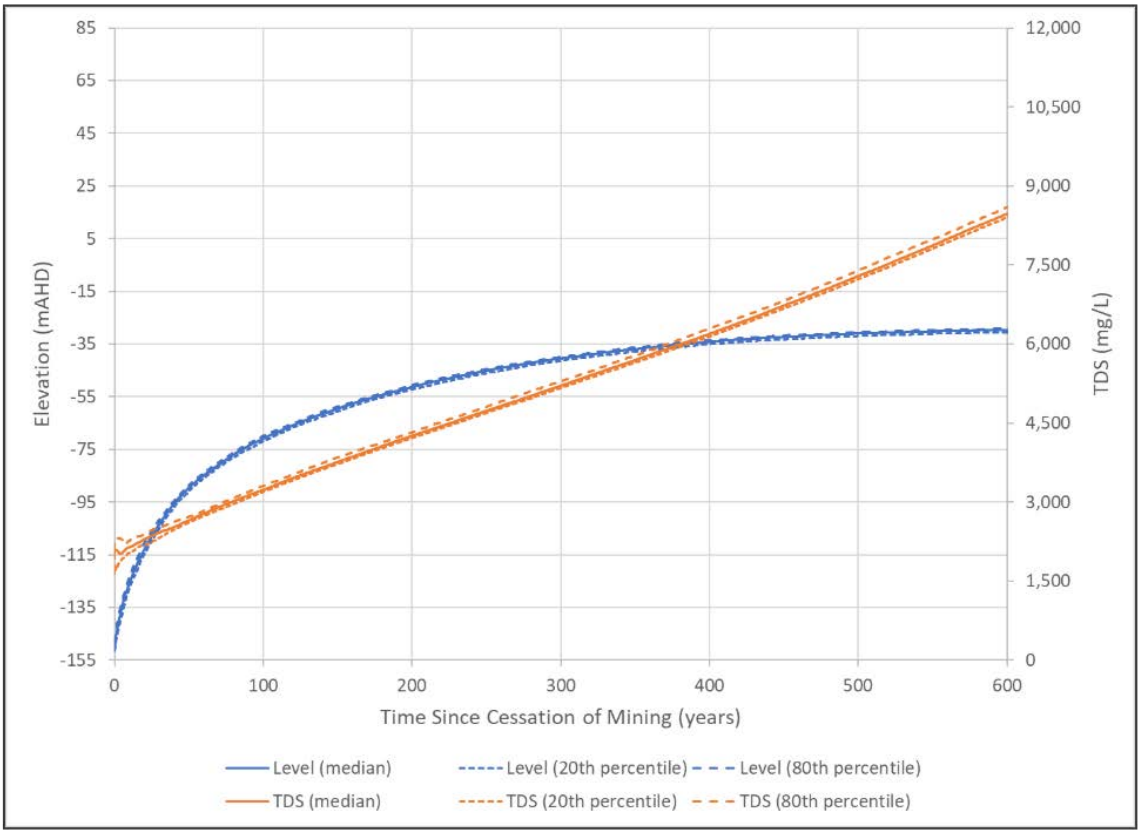
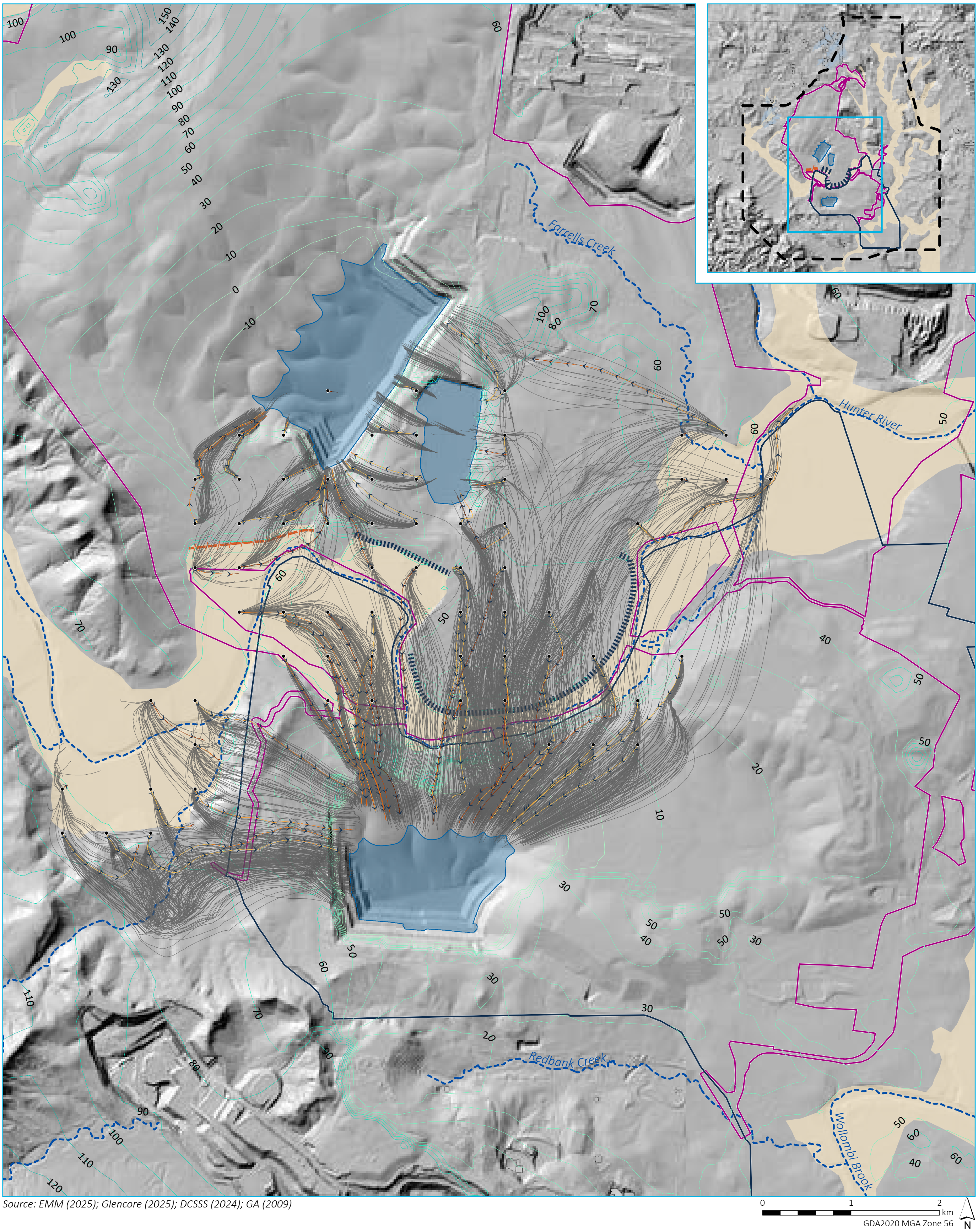


Figure 10.3 HVO South Void pit lake recovery and salinity (Engeny 2026)

10.3 Post closure groundwater levels and flow direction

The groundwater model (Annexure A) predicted recovery within the groundwater flow regime over a period of 1,000 years, simulating the pit lake recovery predicted by the final void hydrology model (Engeny 2026).

Advective particle tracking was performed to display the post mining groundwater conditions and long-term recovery. Particles were released at the watertable in early 2046 at regular spacing between HVO North and HVO South, and tracked to the end of the modelled recovery period. 50 realisations were randomly selected for particle tracking, and the results are presented in Figure 10.4 alongside base realisation modelled watertable contours 1,000 years post mining (note that the particle traces are 3-D, moving downwards as well as laterally). The final voids at HVO North and HVO South are predicted to be terminal sinks, with particles flowing towards and in some places under the Hunter River alluvium, terminating at, these locations. There is therefore a low potential for a shallow watertable to form within in-pit spoils and migrate to the Hunter River alluvial aquifer.



Source: EMM (2025); Glencore (2025); DCSSS (2024); GA (2009)

\\emm.local\xdrive\Secured\Divisions\H190408\GIS\02_Maps_2025ModelReport\MR026_ParticleTracking\MR026_ParticleTracking_20250918_03.aprx 8/10/2025

KEY

- HVO North Action Area
- HVO South Action Area
- Model domain
- Alluvial extent (modelled)
- Long-term pit lake
- Carrington West Wing LPBW
- Low permeability barrier wall
- Particle tracking (ensemble)
- Direction of travel
- Particle starting location

Year 2996 modelled watertable (mAHD)

- < -100
- -100 to -50
- -50 to 0
- 0 to 50
- 50 to 75
- 75 to 100
- 100 to 125
- 125 to 150
- 150 to 200
- > 200

Base realisation particle travel time (years)

- < 100
- 100 to 250
- 250 to 500
- 500 to 750
- 750 to 1000
- 1000 to 1500
- > 1500

Existing environment

- Named watercourse
- Named waterbody

Base realisation post-mining watertable and groundwater flow direction (particle tracking)

HVO Continuation Project
Water Resources Impact Assessment
Figure 10.4

EMM
creating opportunities

10.4 Potential impacts on water-dependent assets

Due to the depth of the HVO North and HVO South voids, the groundwater flux direction is predicted to remain into those voids and the lakes will act as strong groundwater sinks with no risk of overflows to the surface environment. Due to the proximity to the HVO North Void, water in Carrington Pit Void preferentially flows toward HVO North Void.

A conceptual cross section (approximately north to south) through the HVO North and HVO South voids is presented in Figure 10.5. It illustrates the outcomes and conceptual understanding discussed in Sections 10.2 to 10.4:

- post mining, the predicted watertable and pit lake levels are depressed, with groundwater flow directions towards the voids
- the Hunter River alluvium remains saturated due to the strong hydraulic connection with the Hunter River, as shown in Figure 10.6
- surface water drainage (rainfall runoff) towards the voids is reduced, to limit the potential long-term impact on streamflow
- evaporation is the dominant loss from the voids and the voids are predicted to remain groundwater sinks
- the long-term pit lake level is considerably deeper than the base of the alluvium and the base of weathering, therefore the risk of seepage from the pit lakes to shallow groundwater is negligible
- the risk of spill from the pit lakes to the environment is negligible.

Consistent with the predicted drawdown during operations, the post mining incremental alluvial drawdown is not predicted to have a significant impact on GDEs or surface water.

River red gums and other riparian vegetation that opportunistically use shallow groundwater will continue to have access to shallow alluvial groundwater. In addition, the Project is predicted to have a negligible impact on Hunter River flow and flooding regime post mining. Therefore, river red gum vegetation will continue to rely on flooding for germination.

The surface water, groundwater, aquatic ecology and GDE assessments demonstrate the proposed final voids are not predicted to have a significant impact on water resources and water-dependent assets (refer Figure 8.1, Figure 8.2 and Figure 9.1).

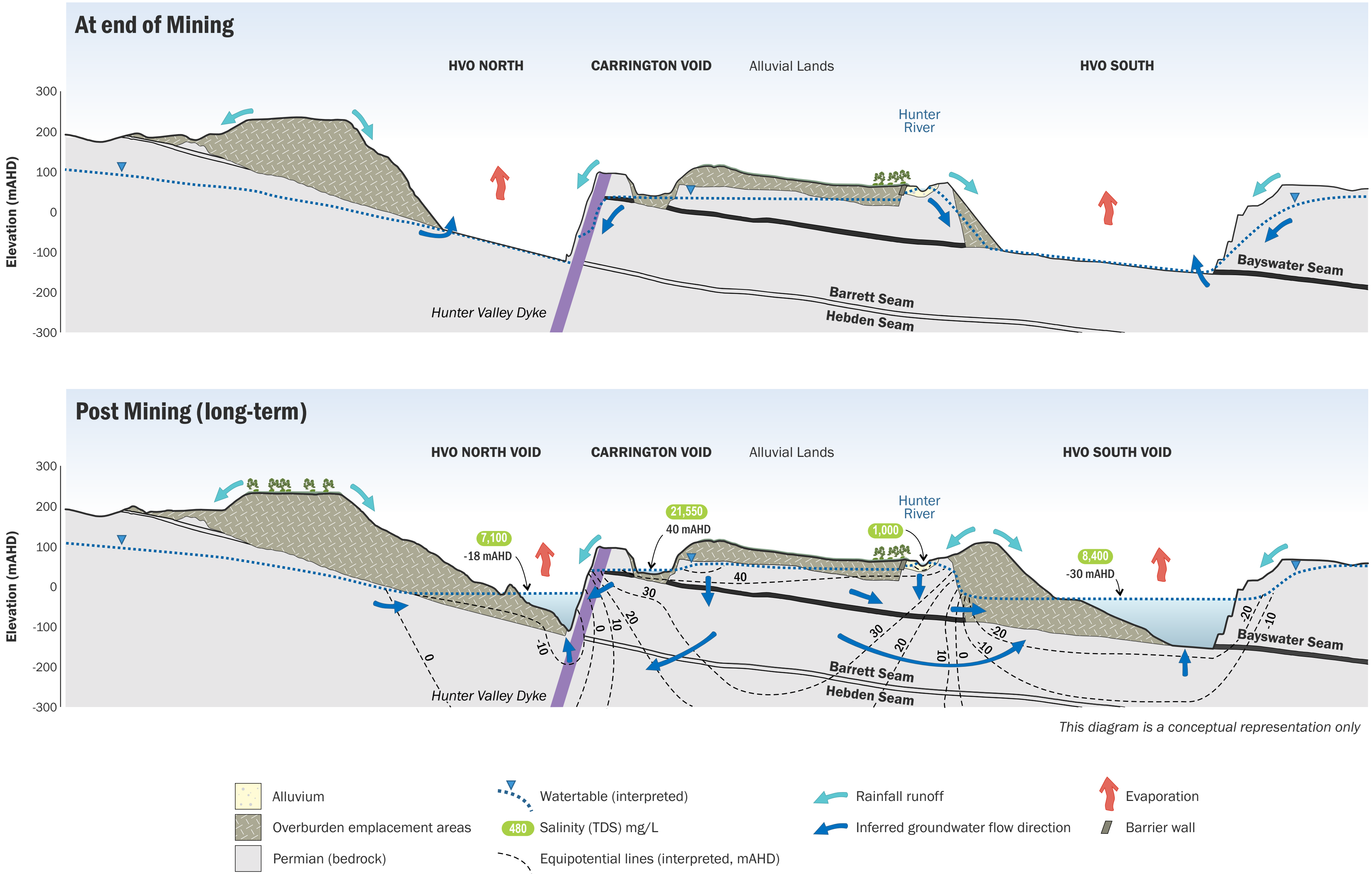
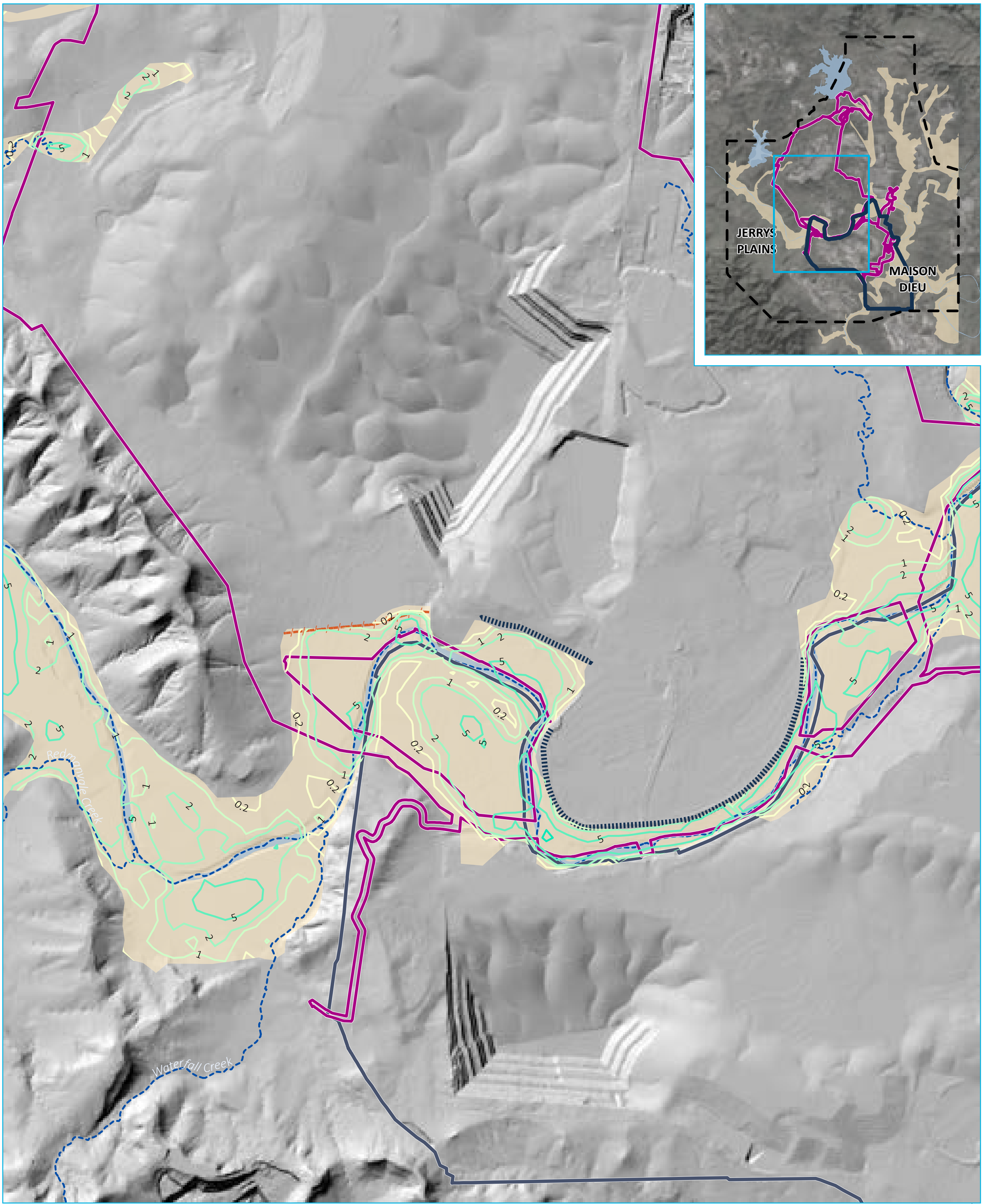


Figure 10.5 Mining and post-mining conceptual cross-section across the HVO Complex



Source: EMM (2026); Glencore (2025); DCSSS (2024); GA (2009)

\\emm.local\xdrive\Secured\Divisions\H190408\GIS\02_Maps_2025WRIA\WRIA007_SaturatedAlluviumLongTermPostMining\WRIA007_SaturatedAlluviumLongTermPostMining.aprx 10/03/2026

KEY

- HVO North Action Area
- HVO South Action Area
- Alluvial extent (modelled)
- Low permeability barrier wall
- Carrington West Wing LPBW

Existing environment

- Named watercourse
- Named waterbody

Modelled saturated thickness (m)

- 0.2
- 1
- 2
- 5
- 10
- 15
- 20
- 25
- 30

Modelled P50 alluvium saturated thickness long-term post-mining (2996)

HVO Continuation Project
Water Resources Impact Assessment
Figure 10.6

EMM
creating opportunities

10.5 Water quality

10.5.1 Overview

To meet the Project objectives to balance economic, environmental and social benefits, the landform has been designed to minimise the catchment reporting to the proposed voids. Evaporation from the void pit lakes will dominate, and the voids will remain strong long-term groundwater sinks.

After mining, the pit lake water will concentrate salts and become more saline over time due to evaporative losses. The following summarises the outcomes of the predicted long-term lake chemistry after mining from hydrogeochemical pit lake modelling completed by EGi (2022b) and Engeny's pit lake modelling:

- the pit lakes will be alkaline and brackish
- the salinity (TDS) will range from 3,000 to 9,000 mg/L (with sensitivity analysis by Engeny predicting a salinity up to ~35,000 mg/L TDS at Carrington Pit Void when equilibrium is reached)
- the dominant soluble salts will be sulphate, chloride and sodium
- there could also be slightly elevated concentrations (i.e. 0.1 to 1 mg/L) of some elements, including aluminium, boron, barium, manganese, nickel, selenium, and zinc, but other environmentally important metals and metalloids are predicted to occur at trace concentrations only
- the water quality of the pit lakes associated with the Project final voids will be similar to that of the Approved final voids, as both Project and Approved final voids are designed as groundwater sinks and will exist in the same hydrological, hydrogeological and geochemical environments. As time progresses the final voids will reach an "equilibrium" of salt species with inflows and interactions between salt species, such as precipitation, balancing.

For comparison purposes, the tolerance level for sheep to salinity in drinking water is up to 10,000 mg/L TDS without loss of production. Sheep can tolerate drinking water salinity up to 13,000 mg/L TDS for short periods or for extended periods if feeding on lush green feed (ANZECC & ARMCANZ 2000).

Further details of the pit lake recovery and salinity modelling is provided in Annexure B.

10.5.2 Potential water quality impacts

The predicted increasing salinity will not pose a risk to highly connected surface water sources, shallow groundwater or associated receptors, as:

- there is negligible risk of spilling from the pit lakes to the surface water environment
- the pit lake level will remain below the base of the alluvium and base of weathering (Figure 10.5)
- the voids will remain permanent sinks, creating a hydraulic gradient from the backfilled mine areas towards the void (Figure 10.4).

The potential for seepage to migrate from backfilled mine areas (such as in the Carrington West Wing area) has been assessed using the groundwater model for the Project (Annexure A).

Figure 10.4 shows potential infiltration of rainfall in the backfilled mine areas will gradually flow towards the pit lakes, as evidenced by the groundwater flow particle tracking completed as part of the groundwater modelling where particles that were released in the backfilled Carrington West Wing area travel to the HVO North Void (Figure 10.4). The risk of seepage from the backfilled mine areas migrating through the existing and proposed LPBWs towards the Hunter River alluvium is considered negligible.

Density variations in groundwater caused by elevated salinity can influence groundwater flow directions by creating hydraulic gradients that arise from differences in fluid density. To account for these effects and compare hydraulic heads within such variable-density environments, hydraulic head measurements are converted to equivalent freshwater head, which provides a consistent reference frame for interpreting groundwater flow. The IESC Advice recommended consideration of variable pit lake salinities (and salinity of groundwater inflows to the voids) and the implications of this increasing pit lake salinity on seepage salt loads to the Hunter River. To address this, EMM calculated equivalent freshwater head at the HVO North and Carrington Pit Void pit lakes, based on the calculated pit lake depth at equilibrium and the salinity ranges estimated as part of Engeny's modelling.

The equivalent freshwater head was calculated using the following equation (Post & Simmons 2022), which is applicable to groundwater head measured at a piezometer:

$$h_i = z_i + h_{p,i} = z_i + \frac{p_i}{\rho_i g}$$

Where $h_{p,i}$ represents pressure head for a piezometer at location *i* containing a water column with density ρ_i, so it is the height of the water column above the z_i coordinate, typically taken as the centre of the piezometer screen (Plate 10.1). This calculation has been used as being appropriately analogous to a pit lake of equivalent depth.

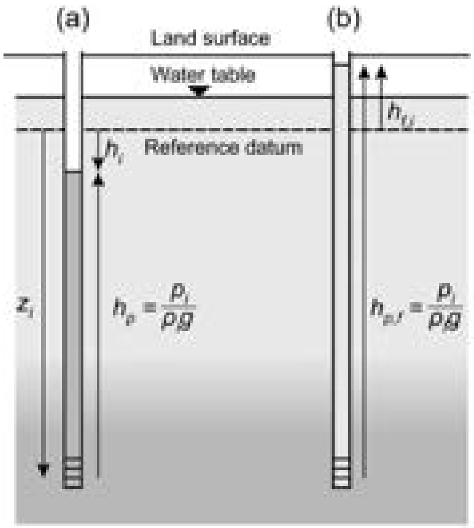


Plate 10.1 Piezometer filled with (a) water of the same density as the groundwater at the well screen, indicating point-water head and (b) freshwater, indicating equivalent freshwater head (Post & Simmons 2022)

The outcomes of the calculations are:

- The base case salinity of 7,100 mg/L TDS at the HVO North Void pit lake results in an equivalent freshwater head less than 1 m higher than the predicted equilibrium pit lake level of -18 mAHD (i.e. -17.3 mAHD). Using Engeny's estimated potential high salinity of 15,000 mg/L TDS, the equivalent freshwater head is -16.6 mAHD, which is still approximately 80 m below the Hunter River elevation.
- To reverse the hydraulic gradient, the HVO North Void pit lake would need to have a salinity greater than 600,000 mg/L TDS. Such a salinity value is implausible and above the saturation limit of water. Publicly available information reports that the highest salinity lake on Earth is recorded at 433,000 mg/L TDS (Perez and Chebude 2017).

- The base case salinity of 21,500 mg/L TDS at the Carrington Pit Void pit lake (which is predicted to have a very shallow lake depth) results in an equivalent freshwater head less than 0.1 m higher than the predicted equilibrium pit lake level of 41.8 mAHD. Using Engeny's estimated potential high salinity of 35,000 mg/L TDS, the calculated equivalent freshwater head is approximately 1 m higher, which is still greater than 20 m below the Hunter River elevation.
- To reverse the hydraulic gradient and direct seepage towards the Hunter River, the Carrington Void pit lake would need to have a salinity much greater than 600,000 mg/L TDS and capture a larger catchment of surface water to result in a much deeper pit lake. Therefore, the likelihood of that occurring is negligible.

The findings of the surface water and groundwater assessments demonstrate the potential impact of the Project on water quality is not significant and the Project is not predicted to impact the environmental, social and cultural value of the alluvial groundwater or connected surface water sources.

10.6 Climate change

The results of the final void hydrology model climate change scenarios suggest that in all but one of the climate change scenarios, the pit lake levels are predicted to be lower than in the base case and the salinity (TDS) is generally higher. The exception is the "RCP8.5 Higher" scenario that predicts higher pit lake levels and lower salinity in all final voids. Even in this scenario, the final voids are predicted to remain groundwater sinks.

A climate change scenario was also conducted as part of the groundwater modelling (Annexure A), simulating a scalar decrease to recharge and increase to potential evapotranspiration for the predictive period, representing a conservative "RCP8.5 Climate" scenario. The outcomes of the modelling show little difference in alluvial drawdown.

Detailed results are provided in the SWIA in Annexure B (Engeny 2026) and the GMR in Annexure A (EMM 2026c).

11 Risk assessment

11.1 Risk assessment and management framework

An evaluation of Project activities and potential incremental impacts on water resources and water-dependent assets, with consideration of the avoidance and mitigation measures listed in Section 6.2, has been completed.

The HVO risk assessment matrix has been used to quantify the potential risks of the Project on water receptors and is presented in Table 11.1.

Table 11.1 HVO risk assessment matrix

Basis of rating	Likelihood				
Consequence	**E – rare**	**D – unlikely**	**–C – possible**	**B – likely**	**–A - almost certain**
5 – catastrophic	15 (M)	19 (H)	22 (H)	24 (VH)	25 (VH)
4 – major	10 (M)	14 (M)	18 (H)	21 (H)	23 (VH)
3 – moderate	6 (L)	9 (M)	13 (M)	17 (H)	20 (H)
2 – minor	3 (L)	5 (L)	8 (M)	12 (M)	16 (M)
1 – negligible	1 (L)	2 (L)	4 (L)	17 (M)	11 (M)

Note: L: low | M: medium | H: high | VH: very high

The classification of likelihood and risk factors used for the risk assessment are defined in Table 11.2 and Table 11.3.

Table 11.2 Classification of likelihood

Likelihood factor	Description
A – almost certain	• may occur several times a year, or • expected to occur, or • has occurred several times within Glencore's operations
B – likely	• may occur about once a year, or • more likely to occur than not to occur, or • has occurred at least once within Glencore's operations
C – possible	• could occur more than once during a lifetime, • as likely to occur as not to occur, or • has occurred at least once in the mining/commodities trading industries
D – unlikely	• could occur about once during a lifetime, or • more likely not to occur than to occur, or • has occurred at least once in broader worldwide industry
E – rare	• unlikely to occur during a lifetime, or • very unlikely to occur, or • no known occurrences in broader worldwide industry

Table 11.3 Classification of consequence

Risk factor	Environmental impact	Compliance impact
5 – catastrophic	• unconfined and widespread • environmental damage or long-term effect (permanent; >10 years) • requires major remediation	• major litigation/prosecution at HVO corporate level • loss of licence to operate
4 – major	• long-term (2 to 10 years) impact • requires significant remediation	• major litigation/prosecution at department level
3 – moderate	• medium-term (<2 years) impact (typically within a year) • requires moderate remediation	• major litigation/prosecution at operation level
2 – minor	• near source • short-term impact (typically weeks) • requires minor remediation	• regulation breaches resulting in fine or litigation
1 – negligible	• near source and confined • no lasting environmental damage or effect (typically <day) • requires minor or no remediation	• regulation breaches without fine or litigation

11.2 Risk evaluation

The risks of potential impacts caused by the Project are summarised in Table 11.4. The risk evaluation assumes no additional controls (beyond those included as part of the Project design) are in place.

Table 11.4 Assessment of unmitigated potential impacts or events

Potential impact mechanism	Potential impact/event	Rating reasoning	Risk analysis	
			Environment	Compliance
Groundwater quantity: actual alluvial groundwater drawdown exceeds model predictions	Deteriorating groundwater quality at third-party bores	Landholder bores well outside the predicted drawdown extent (including uncertainty results); past studies and substantial available data increase model reliability/confidence.	1 (L)	1 (L)
	Potential long-term loss of water-dependent ecosystem viability (and thereby impacts on the tangible and intangible cultural values) beyond already approved impact	Past studies and substantial available data increase model reliability/confidence.	6 (L)	3 (L)
Groundwater quantity: predicted groundwater take exceeds licensed allocation	Unlicensed water take	Groundwater modelling shows groundwater takes well within existing entitlement; low uncertainty on results given substantial data available for the Project and surroundings.		5 (L)
Groundwater quality: enhanced mixing between aquifer units with different groundwater quality	Groundwater quality changes in alluvial aquifers and/or watercourses affect water users	Historically, upward leakage from the Permian to the alluvium occurred (and currently occurs in some areas). Minimal upward leakage from Permian brackish aquifers to the alluvium/watercourses is currently occurring within the study area. All model scenarios predict lowering of Permian heads as a result of the Project. Upward leakage from the Permian to the alluvium in the study area is unlikely.	3 (L)	
Groundwater quality: seepage of contaminated water from emplacement areas to alluvium and/or watercourses	Groundwater quality changes in alluvial aquifers and/or watercourses, adversely affecting water users, aquatic ecosystems and social and cultural values	Groundwater levels in the backfilled emplacement areas predicted to be well below the base of the alluvium – no seepage is predicted. Groundwater flow direction is predicted to be towards the pits/final voids (during and post mining); no seepage from backfilled emplacement areas to the alluvium predicted. Barrier walls exist and will be installed (as approved) in areas where overburden/interburden is adjacent to the alluvium; limiting seepage potential.	5 (L)	
Groundwater quality: seepage of saline void water to alluvium and/or watercourses	Groundwater quality changes in alluvial aquifers and/or watercourses (and changes to ecological habitat)	Final voids predicted to act as groundwater sinks in all model scenarios; seepage to the alluvium extremely unlikely.	6 (L)	

Potential impact mechanism	Potential impact/event	Rating reasoning	Risk analysis	
			Environment	Compliance
Groundwater quality: water quality of the pit lakes exceeds predictions (e.g. higher salinity or higher metalloid concentrations)	Changes to groundwater quality of Permian groundwater system	Pit lake modelling by Engeny (2026) included evaluating sensitivity to evaporation rates, rainfall and runoff (under climate change scenarios) various scenarios. Groundwater modelling and final void water balance modelling informed by considerable operational data and industry-standard approaches.	5 (L)	
Surface water and groundwater interaction: actual groundwater drawdown exceeds model predictions	Increased reduction in baseflow that affects streamflow and aquatic ecosystems, and having an indirect impact on social and cultural values	Minimal predicted reductions in streamflow in main watercourses (Hunter River and Wollombi Brook); model considered reliable. The Hunter River is a regulated system and HVO holds considerable entitlement for the predicted take. Therefore, any surface water take due to changes in groundwater interaction will be offset through existing high security entitlement. Some ephemeral minor tributaries are predicted to experience an increased duration of dry periods; however the impact will be negligible as these watercourses are typically dry for more than half the year.	5 (L)	
Surface water quantity: reduction in streamflow within watercourses	Streamflow impacted greater than predicted	The Project will not impact new catchments. Mining activities are mainly within the existing approved disturbance area / mining tenement. Modelling is based on considerable data and therefore has low uncertainty.	3 (L)	
Surface water quality: enhanced erosion and sediment runoff	Increased loads of suspended solids in site runoff	Continued operation of the HVO WMS in accordance with the WMP. Sediment and erosion controls will be implemented prior to disturbance; these sediment and erosion controls will be designed and constructed in accordance with Blue Book and existing management measures.	5 (L)	
Surface water quantity: predicted surface water take exceeds licensed allocation	Unlicensed water take	Predicted takes are based on robust modelling informed by substantial data available for the Project. Water balance modelling assessed water requirements under a range of climate scenarios. HVO holds considerable water entitlement in the water sources and water entitlements are available for trade, if needed.		5 (L)

Potential impact mechanism	Potential impact/event	Rating reasoning	Risk analysis	
			Environment	Compliance
Aquatic ecology: Restriction to fish passage within the Hunter River due to construction of the Hunter River Bridge resulting in changes to Hunter River flow regimes, and the potential for damming	Fish unable to migrate through Hunter River system; construction activities scheduled during native fish migratory season	Detailed engineering design and construction plan so that no change to flow regimes or damming occurs; construction works to avoid being scheduled during native fish migratory season.	5 (L)	
Less than adequate assessment of geological faults and structures in groundwater impact assessment and model	Groundwater inflows greater than predicted due to high hydraulic conductivity of geological structures; instability of pits	Geological structures in the study area are well known due to extensive investigations for historical mining and substantial dataset. At HVO North, mining will mainly involve mining deeper in previously excavated areas; uncertainty considered low.	3 (L)	
Cumulative impacts: multiple mining operations in proximity to Hunter River	Unacceptable increase of cumulative mining impacts on the Hunter River and Wollombi Brook systems. Regulator and community concern	The additional impact (contributing to the cumulative impact) due to the Project is minor, as predicted by robust modelling informed by substantial data available for the Project.	5 (L)	
Changes in flow velocity in the study area due to levee construction or upgrades	Channel stability adversely affected in the study area	The existing approved operations includes construction of levees, including the Carrington West Wing Levee (designed for 1% AEP as per condition 26 of the HVO North Consent), so the additional incremental change due to the Project is minor. Flood modelling (comparison between existing/baseline and the Project) shows low risk to channel stability.	5 (L)	

12 Monitoring, mitigation and management

12.1 Water management strategy

During operations, water will continue to be managed in accordance with the existing water management objectives to minimise fresh water usage, impacts on the environment and neighbours to the HVO Complex, and interference to mining production.

The above will be achieved through the Project design features, including:

- minimising clean water take via through the construction of the Mitchell clean water diversion[4]
- extension of existing WMS including the construction of flood levees to provide flood protection to mine workings during operations and immunity up to and including the Extreme Event for the residual pit lakes at closure, including Cheshunt Levee, Riverview Levee and the North Void TSF Levee 2 (southern levee).

Design of the WMS components will, during the detailed design stages, consider future increases in rainfall intensities associated with climate change. Any changes to government guidance will be incorporated, as required, into detail designs for construction of new WMS components as well as augmentation/management changes for existing WMS components.

Post mining, a key objective of the closure WMS is to limit runoff to the voids. Drainage lines will be compatible with the surrounding drainage network and will direct upstream catchment runoff towards downstream watercourses, including the Hunter River. As part of closure and rehabilitation planning, the final landform design would consider including drainage channel(s) so that potential daylighting of seepage from the backfilled mining areas (e.g. in the Carrington area) would be directed to the void.

In addition, the Carrington West Wing Levee will be partially removed and incorporated into the final landform at closure to reinstate floodplain storage in this area.

Mitchell East Levee will be established/incorporated into the final landform to provide flood protection for the HVO North Void.

As part of closure planning HVO will also undertake further detailed analysis and hydrogeochemical modelling to evaluate the final void water quality and any actions that could improve final void water quality (e.g. post mining beneficial uses).

12.2 Mine material management

HVO has developed a geochemical sampling program, which involves the continued retrieval and analysis of cores from across the HVO Complex. It is anticipated that all key units (including coal seams) will be identified and analysed as part of this ongoing sampling and analysis campaign. However, until this is complete a conservative approach that assumes a classification of PAF for all coal seam materials is being implemented, and the material managed accordingly.

The following provides a summary of the water-related recommendations in the geochemical assessment (Annexure D):

- Operational blending of NAF and PAF overburden/interburden together with the excess alkaline leachate from NAF materials prevent acid rock drainage and water quality impacts from PAF materials for the bulk of the waste rock dumps.

4 Note: this drain diverts upslope runoff away from mining and/or disturbance areas and is not a creek diversion

- Continued monitoring of the mine water system for indicators of acid mine drainage.

- Tailings will be deposited either below the base of weathering and alluvium, if present, or a seepage assessment will be undertaken to prevent the seepage to water resources and overtopping prior depositing above the base of weathering. In addition, tailings areas will be capped and designed to be free draining, limiting the potential for water ponding.

Overall, with the above management strategies implemented, the Project is expected to present a low risk with respect to acid rock drainage and metal leaching. The key focus of materials management will be to exclude any potentially problematic materials from the near surface region of overburden/interburden dumps and TSF capping layers, and control upward migration of salts to prevent impacts on rehabilitation. This will be readily achievable given the overall low proportion of problematic materials.

12.3 Carrington West Wing Low Permeability Barrier Wall

As noted by Timms et al (2013), low permeability barriers are being used across Australia and internationally to limit impacts of open cut mining on sensitive water resources (such as a creek or river).

Timms et al (2013) conducted a study on LPBWs used in mining across Australia and internationally, including the different types of barrier wall types, design and construction. The study lists the importance of:

- Characterisation of site conditions: Extensive drilling and hydrogeological characterisation of the paleochannel area has been conducted as part of earlier investigations and assessments (MER 2003, 2010). Additional drilling will be conducted to install additional monitoring bores, as agreed and approved by relevant NSW Government agencies (discussed further below).

- Design considerations: Considering preferential pathways such as through fractured and weathered rock; hydraulic, geomorphic and seismic stability; risk from blasting; and the bentonite/grout/clay/slurry mix. The aspects will be considered as part of the LPBW design, also meeting the requirements of the NSW Government and as listed in the HVO North Consent.

- Construction: With consideration of Australian Standard (AS) 3798-2007 and site-specific quality assurance and quality control measures.

- Testing and monitoring (before, during and after construction): Including consideration of maintenance, and possibly repair, that may be required through the mine life, and post closure of the site. This will be captured in the LPBW management plan discussed further below.

HVO has successfully constructed two LPBWs at the HVO Complex (Alluvial Lands in 1995 and Carrington Pit in 2010) in accordance with design requirements by the NSW Government, with design and construction by appropriately qualified and experienced engineers and contractors.

Condition 23 of the HVO North Consent lists specific design requirements for the Carrington West Wing LPBW, including:

- detailed design by a suitably qualified and experienced expert(s)

- the design endorsed by the NSW Government prior to construction

- the design achieves the relevant performance measures including:

    - applicable permeability of 10^{-8} m/s or less

    - applicable AS 3798-2007

- hydraulic, geomorphologic and seismic stability which will withstand any blasting-related vibrations, mining operations, fluvial and weather events, decay corrosive and biological attack.

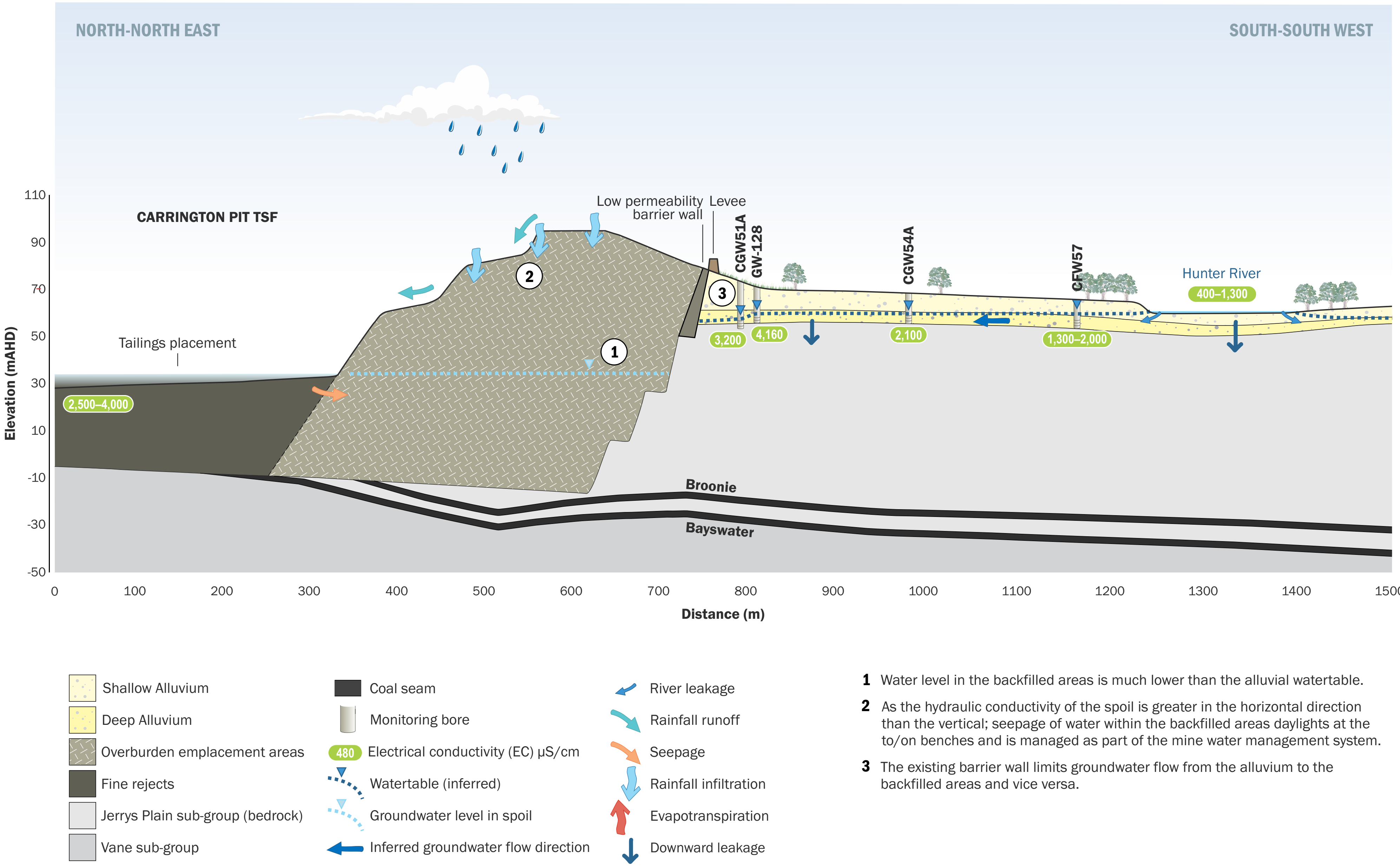
Consistent with the approaches for the Carrington and Alluvial Lands LPBWs, the Carrington West Wing LPBW will be conservatively designed, through consultation with relevant NSW Government agencies, and constructed to meet the consent requirements.

Historical monitoring in the Carrington Pit alluvium and Alluvial Lands remnant alluvium (near the existing LPBWs), shows groundwater levels and salinity have been relatively stable, except following high rainfall and/or streamflow events when levels fluctuate due to infiltration or interaction with the Hunter River. There is no indication of deterioration of either LPBW.

Illustrations of the hydrogeological understanding of the existing environment in and around the existing LPBWs near Carrington Pit and Alluvial Lands is presented on Figure 12.1 and Figure 12.2. The diagrams illustrate the deeper groundwater elevations in the backfilled mine areas and shallow and relatively flat hydraulic gradient in the alluvial aquifer.

The proposed Carrington West Wing LPBW is an accepted, industry standard, engineered mitigation approach.

Section 12.6 discusses the proposed monitoring and management plans associated with the Carrington West Wing LPBW, and other management and monitoring strategies.



1 Water level in the backfilled areas is much lower than the alluvial watertable.

2 As the hydraulic conductivity of the spoil is greater in the horizontal direction than the vertical; seepage of water within the backfilled areas daylights at the to/on benches and is managed as part of the mine water management system.

3 The existing barrier wall limits groundwater flow from the alluvium to the backfilled areas and vice versa.

This diagram is a conceptual representation only

Figure 12.1 Conceptual cross section – Carrington LPBW area

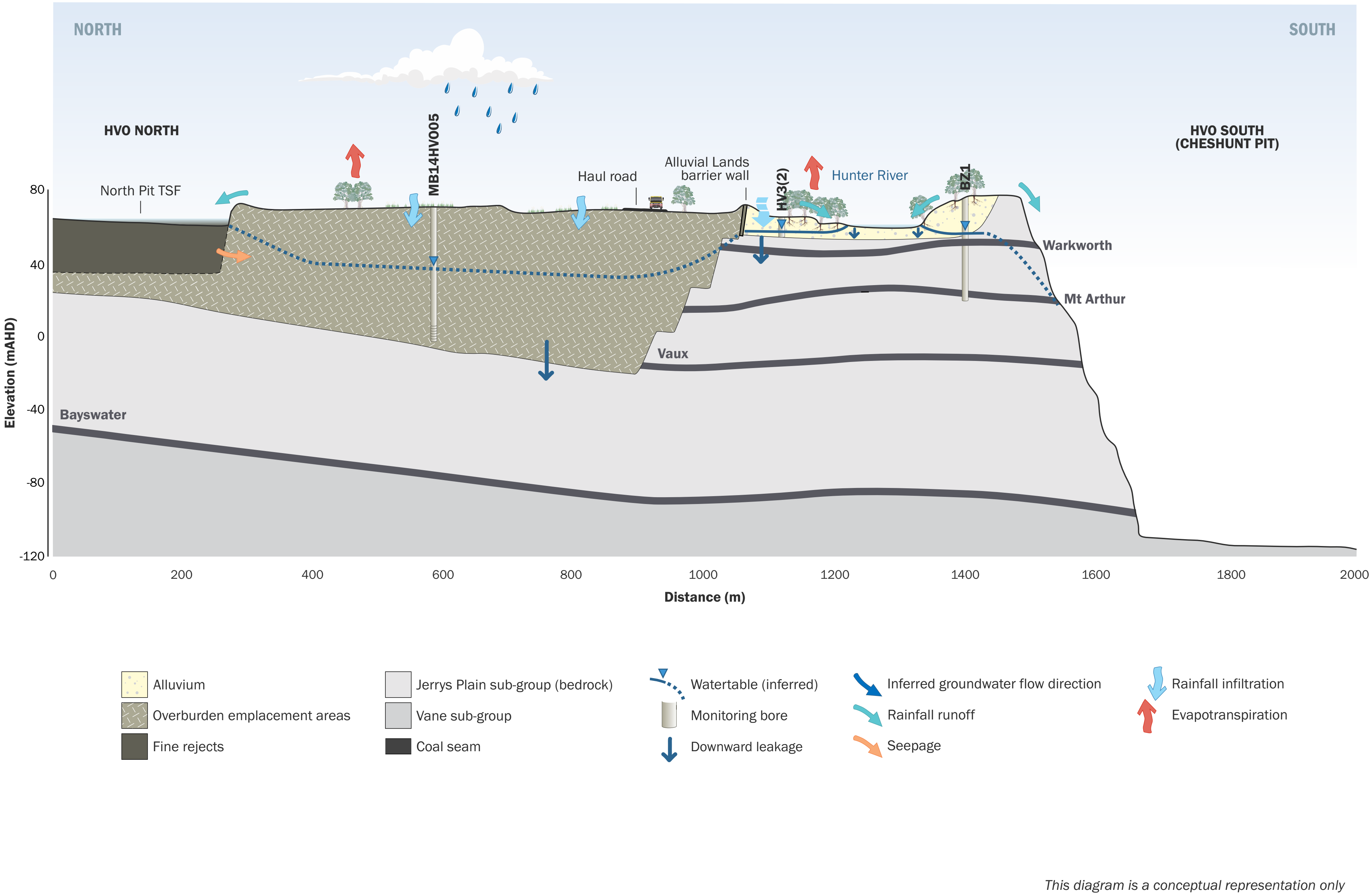


Figure 12.2 Conceptual cross section – Alluvial Lands LPBW area

12.4 Erosion and sediment control measures

All sediment dams are sized based on the HVO Erosion and Sediment Control Protocol and the Blue Book (Landcom 2004).

Consistent with existing management and mitigation measures, HVO will implement erosion and sediment control measures:

- during construction, and design of scour protection measures during detailed design phase
- where works are within the areas defined as waterfront land (i.e. the bed of a watercourse and the land on each side within 40 m of the bank), to minimise the impact of the works on the watercourse and adjoining land.

During operations, erosion and sediment control will continue to be undertaken in accordance with an ESCP which forms part of the WMP. This is discussed further in Annexure B.

12.5 Monitoring program

12.5.1 Water take

HVO is committed to comply with the rules of the applicable WSPs, acts, regulations and associated policies. Methods for measuring and metering water take will be included in the updated WMP for the Project. This will include for example, commitment to continue to meter pumped transfer between storages and pumped volumes from the open cut pits. Where interception of water cannot be practically metered, HVO will use monitoring data and modelling to predict and report take. Examples where interception of water cannot be practically metered include:

- runoff volumes
- rainfall on a dam surface
- leakage from watercourses to groundwater
- evaporation from surfaces of dams.

HVO will conduct the following to assist with calculating and reporting water intercepted by the Project:

- continue to monitor rainfall at the site
- continue to measure and record pumping between storages
- measure and record pumped volumes from the open cut pit
- continue groundwater level monitoring at existing monitoring locations and new locations that will be agreed with NSW DCCEEW
- continue surface water level monitoring in the Hunter River
- use of monitoring data to calibrate the water balance model
- use of monitoring data to review and verify groundwater model predictions, including estimates of river leakage to groundwater (an indirect take).

12.5.2 Surface water quality

HVO has a comprehensive existing water quality monitoring program in accordance with the approved WMP (refer Section 4.4.2). This program is suitable for ongoing use to monitor the performance of the WMS and initiate investigations and corrective actions if required.

The surface water monitoring program covers all three water category areas within the HVO Complex (i.e. clean, sediment and mine water systems). The program will continue in accordance with the approved WMP. Following approval of the Project, HVO will implement increased frequency of comprehensive analysis from annually to six monthly for all sites.

As documented in the WMP, HVO uses the following performance indicators to initiate site specific investigations regarding surface water quality:

- professional judgement to determine that the single deviation or a developing trend could result in environmental harm
- three consecutive measurements of EC or pH exceed trigger values
- one measurement of TSS exceeds the trigger value.

A summary of the surface water monitoring results will continue to be provided in the HVO Annual Review, as required under the development consents. In addition, any significant findings regarding the implementation of the WMP will be reported in the Annual Review and will document reviews and feedback relating to the maintenance and performance of the WMS.

12.5.3 Groundwater

HVO has an established substantial groundwater monitoring network to monitor groundwater levels/pressures and quality at the HVO Complex, as shown on Figure 4.6 and detailed in the WMP. The WMP describes groundwater monitoring requirements for evaluating:

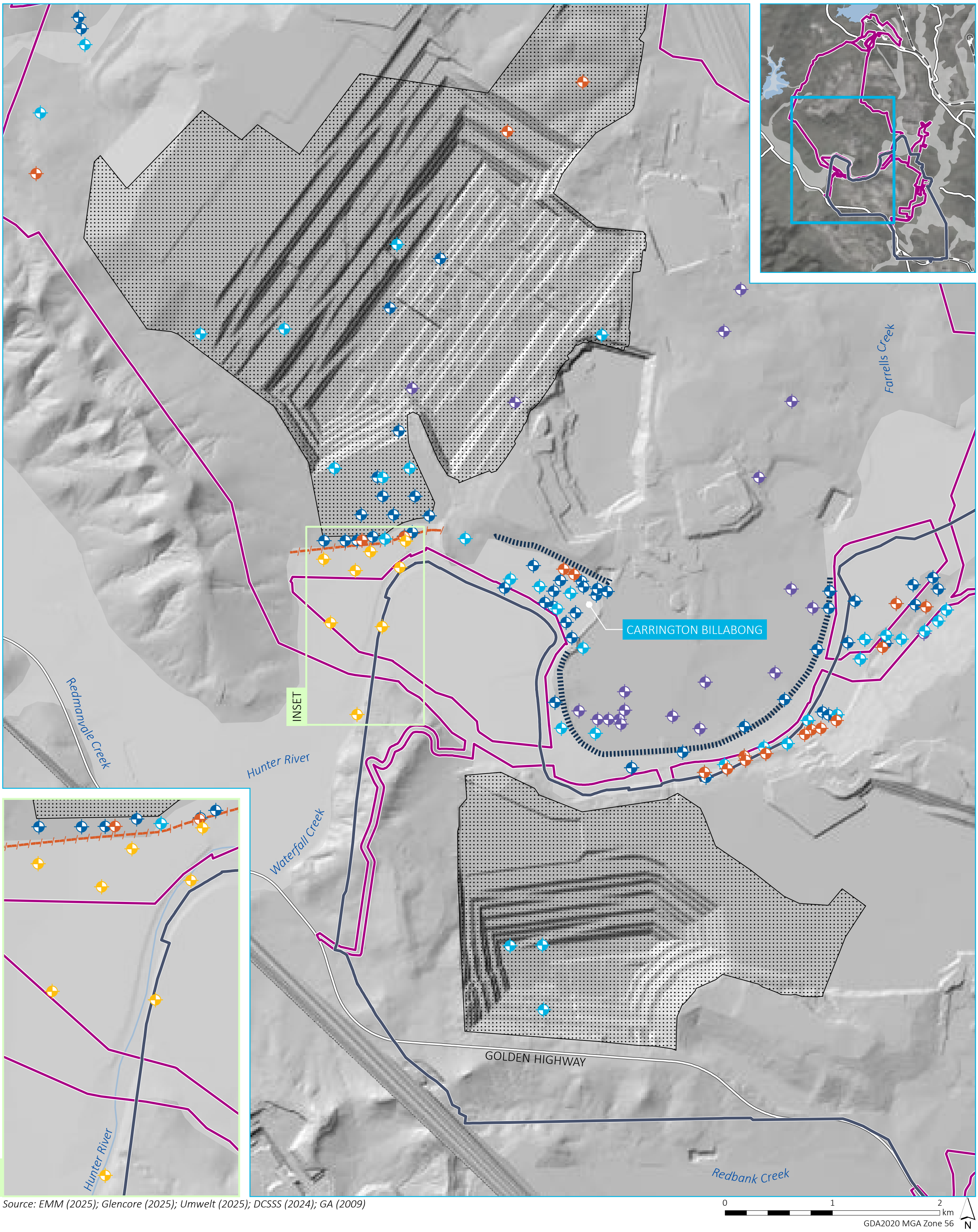
- water take from water sources
- effectiveness of the LPBWs
- impacts on privately-owned bores
- impacts on water-dependent assets
- seepage/leachate from water storages
- Alluvial Lands area management
- validation of the groundwater model.

Additional monitoring bores (to augment the existing monitoring network) will be installed in the Hunter River alluvium south of the Carrington West Wing LPBW to monitor for potential impacts in this area (Figure 12.3).

A network of six to eight nested monitoring bores will be installed in this area, with separate bores screened with the alluvium and Permian strata. The bores will be equipped with pressure transducer data loggers to record changes in groundwater pressure, the records of which will calibrated with regular (e.g. quarterly) manual measurements of depth to groundwater level. The bores will be installed approximately one year prior to mining commencing in the remnant paleochannel to allow collection of background groundwater level trends prior to the effects of mining.

In addition, piezometers will be installed downstream of the Carrington West Wing LPBW, consistent with the approach used for the Carrington Pit LPBW. The purpose of the piezometers would be to monitor for changes in salinity (as EC) and pressure.

In addition to groundwater monitoring in the Carrington West Wing alluvial area, a review of the groundwater monitoring network and monitoring equipment will be conducted as part of updates to the WMP (discussed further in Section 12.5.5). This would consider installation of additional pressure transducer data loggers at other monitoring bores to increase the monitoring frequency.



Source: EMM (2025); Glencore (2025); Umwelt (2025); DCSSS (2024); GA (2009)

KEY

- HVO North Action Area
- HVO South Action Area
- Mining area
- Alluvial extent (modelled)
- Existing low permeability barrier wall
- Carrington West Wing LPBW

Existing environment

- Rail line
- Major road
- Named watercourse

- Proposed monitoring bore

Existing groundwater monitoring location (HVO)

Lithology

- Alluvium
- Spoil
- Regolith

Permian

- Coal seam
- Interburden

Proposed additional groundwater monitoring – Carrington West Wing area

HVO Continuation Project
Water Resources Impact Assessment
Figure 12.3

12.5.4 River red gum health monitoring and management

Mitigation measures for the river red gum stands at the Carrington Billabong and along the Hunter River are given in detail in the *River Red Gum Rehabilitation and Restoration Strategy* (HVO 2022). Restoration and rehabilitation strategies will be continued and adapted as required over the life of the Project. Current controls focus on terrestrial aspects of the river red gum communities, rather than on groundwater, and include:

- Fencing and stock access control: establish and maintain fencing to exclude stock and support the expansion of the vegetation over time.
- Passive regeneration: passive regeneration actions will be carried out to support the natural recruitment of river red gum stands. This includes removal of stock, restriction of access by stock, vehicles and people, weeding and control of feral animals.
- Assisted revegetation: assisted regeneration is necessary to establish a diverse, native understorey and groundcover in the river red gum vegetated area. This includes supplementary planting of native grasses, forbs and shrubs tubestock and seeds. It may also include ripping the soil and weed control.
- Weed and pest control: implementation of an appropriate weed and pest control program, with selection of targeted species informed by the results of ecological monitoring.
- Ecological Monitoring: design and implement an updated ecological monitoring program that will assess the success of the rehabilitation and restoration strategy going forward, as well as inform ongoing management actions.

12.5.5 Stygofauna monitoring

Prior to mining commencing in the western arm of the paleochannel at HVO North, HVO will conduct additional stygofauna sampling at the proposed additional groundwater monitoring bores mentioned in Section 12.5.3 and at existing groundwater monitoring within the Hunter River alluvium, in the Carrington West Wing area. This will allow collection of additional baseline data, both within the impact area and upstream of impact areas.

A stygofauna monitoring program will be incorporated into the groundwater monitoring program, which will be described in the updated WMP that will be developed through consultation and with approval from relevant government authorities.

12.6 Management plans

Following approval of the Project, if granted, the WMP would be updated to address contemporary NSW and Commonwealth approval conditions in consultation with the relevant NSW Government and Commonwealth agencies. The updated WMP would address any specific development consent or licence conditions and will include:

- proposed mitigation and management measures for the Project
- objectives and performance criteria including trigger levels for investigating any potentially adverse impacts associated with the Project, including groundwater level and quality trigger levels for the Carrington Billabong area and Hunter River alluvium south of the Carrington West Wing LPBW (discussed further below)
- details of monitoring, inspection and maintenance programs
- reporting procedures for the results of the monitoring program

- plans to respond to any exceedances of the performance criteria and indicators.

The WMP will be updated to include the addition of dissolved organic carbon (DOC) in the surface water and groundwater monitoring suites to enable appropriate comparison of dissolved copper, nickel and zinc concentrations to the pending new water quality guidelines.

Trigger action response plans (TARPs), which define contingency plans and remedial measures, would be reviewed as part of the update to the approved WMP.

Performance criteria are detailed in the approved WMP, and HVO has developed the following performance indicators to initiate site specific investigations regarding groundwater levels and quality:

- professional judgement determines that the single deviation or a developing trend could result in environmental harm

- three consecutive measurements of EC, pH or groundwater level exceed trigger values.

The primary objective of trigger levels is to provide an early indication of potential impacts to receptors and initiate a management response. They are not intended to be an instrument to assess 'compliance' and should not be used in this capacity (ANZG 2018).

The outcomes of the investigation are reported in the Annual Review.

12.6.1 Low permeability barrier monitoring and management plan

In accordance with condition 25 of the HVO North Consent, HVO will develop a low permeability barrier monitoring and management plan (LPB MMP) following Project approval, if granted, and in consultation with NSW DCCEEW.

The LPB MMP would include the following:

- Identification and design of dedicated groundwater monitoring bores in the area shown on Figure 12.3 that will be installed approximately one year prior to mining in the remnant paleochannel.

- Monitoring requirements and methodologies, including monitoring of groundwater levels/pressures and salinity at a suitable frequency (such as daily records at alluvial monitoring bores using level temperature conductivity (LTC) data loggers), and sampling for comprehensive laboratory water quality analysis at a suitable frequency, to evaluate the efficacy of the Carrington West Wing LPBW.

- Additional monitoring requirements to inform stability and effectiveness of the LPBW following construction.

- Identification and design of piezometers to be installed downstream of the Carrington West Wing LPBW during construction.

- Summary of the Carrington West Wing LPBW construction methodology and design requirements.

- Identification of other monitoring requirements or adjustments, such as at the Hunter River and/or river red gum stands.

- Selection of trigger levels, and appropriate action response plan(s), for groundwater level and salinity in the Hunter River alluvium south of the Carrington West Wing LPBW so that groundwater level and quality is adequately managed.

- Summarising reporting commitments that will evaluate multiple lines of evidence for assessing potential impacts at receptors, including groundwater quality, groundwater levels/pressures, mining activity, climate (rainfall and temperature), streamflow, surface water quality and riparian vegetation health monitoring. This is because changes to groundwater (quantity or quality) are likely to precede any impacts to the biological indicators associated with GDEs (termed secondary impacts by Serov et al (2012)) and should be used as early indicators of possible receptor impact.

Groundwater quality performance triggers for the Carrington West Wing LPBW area will be reviewed as baseline data is collected (ahead of mining in the remnant paleochannel). The performance triggers will be based on statistical analysis of the recorded ranges in baseline concentrations of selected leading indicators (e.g. salinity and sulphate concentrations). Groundwater level (as elevation or trends) performance triggers will be based on a combination of baseline data for selected monitoring bores as well as comparison of measured and model predicted levels/heads for different stages of the Project.

As part of closure planning, the LPB MMP will be reviewed to inform the closure management plan regarding any monitoring and management measures (including triggers and contingency actions) to manage potential future failure/degradation of the barrier walls.

12.7 Groundwater model validation

Continuous improvements to the groundwater model will be undertaken as and when new data become available, particularly where there is a divergence of observed groundwater system response from that predicted by the model. Groundwater monitoring data will be used to validate and verify the groundwater model predictions. New data may require a revision and update of the conceptual hydrogeological model prior to updating and recalibrating the numerical model and re-running of predictive scenarios. Where this is deemed necessary, the WMP may also require updating depending on any changes to the conceptualisation and model predictions.

As mining progresses, a need for further model updates will be assessed every three years based on evaluation of groundwater monitoring data and findings of impact verification.

12.8 Residual risk assessment

Risk evaluation in Section 11.2 were re-assessed considering the recommended controls and management measures outlined above. A revised risk assessment is provided in Table 12.1.

Table 12.1 Assessment of residual risk of potential impacts or events

Potential impact mechanism	Potential impact/event	Management or mitigation	Residual risk	
			Environment	Compliance
Groundwater quantity: actual alluvial groundwater drawdown exceeds model predictions	Potential long-term loss of water-dependent ecosystem viability beyond already approved impact	Additional groundwater monitoring bores to be installed in the alluvium south of the Carrington West Wing LPBW and LPB MMP to be developed in consultation with DCCEEW, including development of early warning trigger levels and response plan. Ecohealth monitoring at Carrington Billabong to continue.	3 (L)	

Potential impact mechanism	Potential impact/event	Management or mitigation	Residual risk	
			Environment	Compliance
Groundwater quantity: predicted groundwater take exceeds licensed allocation	Unlicensed water take	Monitoring and measurement of take. Model review and validation to be conducted every three years to re-evaluate model predictions (including predicted take).		3 (L)
Groundwater quality: seepage of contaminated water from emplacement areas to alluvium and/or watercourses	Groundwater quality changes in alluvial aquifers and/or watercourses (and changes to ecological habitat)	Detailed design of the Carrington West Wing LPBW will be conducted by an appropriately qualified and experienced expert, and will meet the requirements of the NSW Government, including AS 3798-2007. Construction will include appropriate QA/QC measures. Additional groundwater monitoring bores to be installed in the alluvium south of the Carrington West Wing LPBW and LPB MMP to be developed in consultation with DCCEEW, including development of early warning trigger levels and response plan.	3 (L)	
Groundwater quality: seepage of saline void water to alluvium and/or watercourses	Groundwater quality changes in alluvial aquifers and/or watercourses (and changes to ecological habitat)	Review groundwater model predictions as part of periodic groundwater model validation and during closure planning. Revisit pit lake recovery modelling (including water quality) as part of detailed closure planning, which would be developed within five years of cessation of mining.	3 (L)	
Groundwater quality: water quality of the pit lakes exceeds predictions (e.g. higher salinity or higher metalloid concentrations)	Changes to groundwater quality of Permian groundwater system	Review groundwater model predictions as part of periodic groundwater model validation and during closure planning. Revisit pit lake recovery modelling (including water quality) as part of detailed closure planning, which would be developed within five years of cessation of mining.	3 (L)	
Surface water and groundwater interaction: actual groundwater drawdown exceeds model predictions	Increased reduction in baseflow that affects streamflow and aquatic ecosystems	Additional groundwater monitoring bores to be installed in the alluvium south of the Carrington West Wing LPBW and LPB MMP to be developed in consultation with DCCEEW, including development of early warning trigger levels and response plan. Review groundwater model predictions as part of periodic groundwater model validation.	3 (L)	
Surface water quantity: reduction in streamflow within watercourses	Streamflow impacted greater than predicted	Continued operation of the WMS in accordance with the WMP. Review groundwater model predictions as part of periodic groundwater model validation.	3 (L)	
Surface water quality: enhanced erosion and sediment runoff	Increased loads of suspended solids in site runoff	Continued operation of the HVO WMS in accordance with the WMP. Implement erosion and sediment control measures in accordance with HVO’s sediment and erosion control protocol.	3 (L)	

Potential impact mechanism	Potential impact/event	Management or mitigation	Residual risk	
			Environment	Compliance
Surface water quantity: predicted surface water take exceeds licensed allocation	Unlicensed water take	Monitoring and measurement of take.		3 (L)
Aquatic ecology: Restriction to fish passage within the Hunter River due to construction of the Hunter River Bridge resulting in changes to Hunter River flow regimes, and the potential for damming	Fish unable to migrate through Hunter River system; construction activities scheduled during native fish migratory season	Operate the WMS (including dam construction and diversions) in accordance with the approved WMP and WMS objectives. Accounting for surface water take (including indirect take due to watertable drawdown) via HVO's existing entitlements in the Hunter Regulated River water source (ensuring adequate releases from Glenbawn Dam).	5 (L)	
Less than adequate assessment of geological faults and structures in groundwater impact assessment and model	Groundwater inflows greater than predicted due to high hydraulic conductivity of geological structures; instability of pits	Revisit conceptual hydrogeological understanding as monitoring data is collated and reviewed, and using observations during mining. Periodic groundwater model review and validation.	3 (L)	
Cumulative impacts: multiple mining operations in proximity to Hunter River	Unacceptable increase of cumulative mining impacts on the Hunter River and Wollombi Brook systems; regulator and community concern	Groundwater model validation and ongoing monitoring to review predictions.	3 (L)	
Changes in flow velocity in the study area due to levee construction or upgrades	Channel stability adversely affected in the study area	Implement erosion and sediment control measures in accordance with HVO's sediment and erosion control protocol, including scour protection measures. Channel stability monitoring during/following large streamflow events.	3 (L)	
Failure of Carrington West Wing LPBW	Long-term leakage from the Hunter River alluvium towards the HVO North final void, inducing increased leakage from the Hunter River and potentially resulting in unsaturated areas of the alluvium (away from the river)	Detailed design by appropriately qualified and experienced expert; meeting requirements of NSW Government and AS 3978-2007; QA/QC measures during construction; additional monitoring and implementation of the LPB MMP.	5 (L)	

13 Conclusions

The water impact assessments for the Project, including groundwater, surface water, aquatic ecology and GDE studies, considered potential impacts on water resources and water-dependent assets that could result from the Project during construction, operations and after closure.

The assessments show the Project can operate within and meet the requirements of the water regulatory framework. Key results are summarised below.

13.1 Surface water impacts

Key outcomes of the SWIA (Annexure B) and aquatic ecology assessment (Annexure C) are summarised as follows:

- Impacts on Hunter River and Wollombi Brook streamflow will be negligible.
- Minor changes in streamflow are predicted for three ephemeral watercourses during operations. The predicted change in streamflow will have a minor impact on the number of dry days, as many of these ephemeral watercourses are dry (on average) for more than half of the year under current conditions. Post mining, potential streamflow impacts are expected to be negligible.
- Potential impacts on surface water downstream users will be negligible as no changes in streamflow regimes are predicted in the Hunter River, given it is a regulated system and HVO hold sufficient entitlement for the predicted reduction in streamflow due to the Project.
- No impacts are predicted on the aquatic ecology of the Hunter River, particularly as flow will be mitigated through regulated releases from Glenbawn Dam, and only minor impacts to the aquatic ecology in the tributaries to the Hunter River are predicted.
- The proposed WMS for the Project is predicted to maintain a sufficient water supply for the operation and discharge capacity to prevent flooding of operational areas of the mine.
- Potential impacts on surface water quality are expected to be minimal and will continue to be mitigated through an appropriately sized, designed and operated WMS, including release from sediment dams in accordance with their design and discharge of mine water in accordance with approved EPL requirements. Modelling indicates that the impact of approved HRSTS discharges will have a negligible impact on water quality. Concentrations of key analytes are predicted to remain within the existing ranges observed in the Hunter River.
- Water balance modelling indicates that overflows from sediment dams (not mine water dams) is predicted to occur at the HVO Complex when rainfall events exceed the design rainfall depths of the sediment dams. However, based on the conservative WMS design standards implemented and their proposed adaption with climate change, it is considered that the risk of sediment dam overflows will continue to be the same as the existing operations with the likelihood of overflows driven by the NSW design standards (the Blue Book (Landcom 2004)).
- The flood modelling for the Project indicates no impact on the use of the land (grazing and cropping or Crown land).
- The proposed realignment of Lemington Road will significantly improve flood immunity of this road adjacent to the Hunter River.
- The Project is not predicted to change the flood hazard categories, or have an impact on use of the land, public safety or emergency management.

- Changes in velocity are presented to be localised around Project infrastructure and will remain within the existing ranges experienced, with a low likelihood of causing scour.

- HVO holds more than sufficient entitlement to account for the predicted direct and indirect surface water take during operations.

- During the closure period:

  - Take associated with runoff captured from storages on non-minor streams within the Jerry Water Source (Jerrys management zone) during the transition period that exceeds HVO's existing entitlement will be sourced from the open market (including trade, in accordance with the WSP rules). There is adequate share entitlement within the Jerrys Water Source for the predicted take. In addition, the Hunter Unregulated and Alluvial WSP allows for trade (permanently and temporarily) into the Jerrys Water Source from several (17) other upstream water sources. This demonstrates there is sufficient entitlement within the water source and upstream water sources for HVO to obtain additional entitlement via the open market.

  - HVO will apply to convert sufficient aquifer entitlements to unregulated river entitlements for the predicted peak take associated with dams on non-minor streams in the Lower Wollombi Brook Water Source during closure.

The potential impact of the Project on surface water resources and aquatic ecology is insignificant.

13.2 Groundwater impacts and groundwater dependent ecosystems

Key outcomes of the groundwater modelling and GDE assessment are summarised as follows:

- Potential groundwater level drawdown impacts at third-party groundwater bores are predicted to be negligible.

- The proposed HVO North Action and HVO South Action are predicted to result in minor increased drawdown in the alluvial aquifer(s), as mining will largely occur in areas previously mined or approved for mining under the existing approvals (e.g. Carrington West Wing area). In addition, construction of the approved (but not yet constructed) Carrington West Wing LPBW will be an effective mitigation measure to limit drawdown in the Hunter River alluvium and the potential for seepage from the backfilled mine areas to the alluvium. The potential impact on water quality is minor. In addition, a LPB MMP will be developed, including development of TARPs, identifying mitigation measures to manage potential unexpected effects.

- Minimal drawdown (less than 0.2 m) is predicted in the Hunter River alluvium near mapped river red gum stands in the Carrington Billabong and dewatering will not occur. This predicted drawdown will be buffered by leakage through the riverbed. Therefore, no significant impact in ecological receptors is predicted.

- No additional drawdown in the Wollombi Brook alluvium is predicted during operations. In contrast, the avoidance measure of removing mining in the RSEE, SLP 1 and 2 area from the mine plan is predicted to result in a reduction in potential drawdown in the Wollombi Brook alluvium (in comparison to the mine plan currently approved at HVO South).

- HVO holds sufficient entitlement to account for the predicted groundwater take over the Project life and beyond in most water sources. Where the indirect take is predicted to exceed HVO's existing entitlement, HVO will either apply to convert sufficient existing unregulated river entitlements to aquifer entitlements or purchase additional entitlement required via the open market to account for the small predicted indirect take, prior to the take occurring.

- The potential for acid rock drainage or metal leachate is low as the majority of rejects generated by mining at the HVO Complex are likely to be NAF. Thorough intermingling of rejects and overburden, and the excess acid neutralising capacity in the overburden, suggests that emplacement areas are unlikely to result in any significant acid rock drainage issues or effects on rehabilitation.
- The potential for seepage from backfilled mining areas to the alluvial watertable and Hunter River is very unlikely because:
  - there is no proposed change to waste management and pit backfill at HVO South or HVO North from the existing approved operation
  - during mining, the floor of the pit will be deep and intercepted groundwater will be actively managed as part of the mine WMS, resulting in depressurisation of the Permian strata and development of a steep hydraulic gradient towards the pit area. Therefore, the active mining areas will be groundwater sinks
  - groundwater monitoring shows that groundwater levels in the rehabilitated Alluvial Lands area (at HVO North) are lower than the Hunter River alluvium, supporting the conceptual understanding and modelling results that the potential for the watertable in the backfilled pit areas to rise to a similar or higher elevation than the alluvium is unlikely.
- Seepage losses from out of pit storages and open cut pits are expected to be minor. In addition, potential seepage from the upgraded dams (Parnells Dam and Lake James) will be managed by an embankment filter, cut-off design and treatment of batters within the storages. Based on historical monitoring (including at dams in the mine WMS and bores in alluvium downgradient from existing dams), water management measures and proposed design, potential impacts to alluvial groundwater quality are expected to be minor.
- Potential for seepage from tailings areas to alluvial (or other shallow) groundwater systems is unlikely, as tailings will be stored in pit areas and the main voids will act as groundwater sinks.
- No changes to the environmental, community and cultural values referenced in Sections 4.4.4 and 4.6.6 are predicted.
- The risk to the stygofauna community associated with the HVO North Action is low because there will be no additional excavation in the alluvium beyond what is approved under the HVO North Consent. The cumulative impact (including that associated with the mine plan currently approved) to the stygofauna community in the paleochannel is high and is categorised in the GDE Risk Matrix as C (High Ecological Value, High Risk; Annexure C). However, the aquatic ecology and GDE assessment demonstrates that the predicted watertable drawdown will not prevent the long-term viability of the ecosystem in the Hunter River alluvium outside of the HVO North Action area. Therefore, it is predicted that the Project will not have a significant impact on stygofauna communities in the study area.

The potential impact of the Project on groundwater resources and receptors, including ecological receptors, is not significant.

13.3 Final void

Key outcomes of the final void assessment are:

- the predicted long-term watertable and pit lake level will be depressed, with groundwater flow directions towards the HVO North Void and HVO South Void

- the runoff area contributing to the voids is sufficiently small so that evaporation dominates, and the voids remain as strong long-term groundwater sinks thereby attracting seepage from the surrounding strata (at a very low rate)

- infiltration of rainfall in the backfilled mine areas will gradually flow towards the pit lakes, as evidenced by the groundwater particle tracking completed as part of the updated groundwater modelling (Annexure A), and the risk of seepage from the backfilled mine areas migrating through the existing and proposed barrier walls to the Hunter River alluvium is negligible

- the long-term pit lake level is considerably deeper than the base of the alluvium and the base of weathering, therefore the risk of seepage from the pit lakes to shallow groundwater is negligible

- salinity is expected to continue to increase over time in the pit lakes until solubility limits are reached (i.e. when precipitation of salts occurs) and an "equilibrium" of salt species with inflows and interactions between salt species is achieved

- the risk of spill from the pit lakes to the environment is negligible

- the Project is predicted to have a negligible impact on Hunter River flow and flooding regime post mining

- the Hunter River alluvium is predicted to remain saturated due to the strong hydraulic connection with the Hunter River.

River red gums and riparian vegetation that opportunistically use shallow groundwater will continue to have access to shallow alluvial groundwater. Alluvial drawdown is not predicted to have a significant impact on GDEs or surface water resources. Additionally, as mentioned above, the Hunter River flow and flooding will not be impacted by the Project, thereby river red gum communities will continue to rely on flooding for germination.

The potential post mining impacts of the Project on water resources is not significant.

References

Australasian Groundwater and Environmental Consultants (AGE) 2022, *HVO Continuation Project EIS - Groundwater Impact Assessment*, prepared for EMM Consulting Pty Limited.

ANZECC and ARMCANZ 2000, *Australian and New Zealand guidelines for fresh and marine water quality*. Agriculture and Resource Management Council of Australia and New Zealand and the Australian and New Zealand Environment and Conservation Council.

ANZG 2018, *Australian and New Zealand Guidelines for Fresh and Marine Water Quality*. Australian and New Zealand Governments and Australian state and territory governments, Canberra ACT, Australia.

Ball J, Babister M, Nathan R, Weeks W, Weinmann E, Retallick M, Testoni I (Editors) 2019, *Australian Rainfall and Runoff: A Guide to Flood Estimation*, Commonwealth of Australia (Geoscience Australia).

Barnett B, Townley LR, Post V, Evans RE, Hunt RJ, Peeters L, Richardson S, Werner AD, Knapton A and Boronkay A 2012, *Australian Groundwater Modelling Guidelines*, Waterlines report, National Water Commission, Canberra, June 2012.

Commonwealth of Australia 2024. *Information Guidelines Explanatory Note: Using impact pathway diagrams based on ecohydrological conceptualisation in environmental impact assessment*. Report prepared for the IESC on Unconventional Gas Development and Large Coal Mining Development through DCCEEW, Commonwealth of Australia, Canberra.

DCCEEW 2022, *Significant Impact Guidelines 1.3: Coal seam gas and large coal mine developments – impacts on water resources*, Department of Climate Change, Energy, the Environment and Water, Canberra. CC BY 4.0.

Department of Planning, Infrastructure and Environment (DPIE) 2021, *State Significant Development Guidelines*. First published July 2021.

Department of Primary Industries – Water (DPI – Water) 2017, *Water Sharing Plan for the Hunter Regulated River Water Source Background Document*. First published March 2017.

Doody TM, Hancock PJ, Pritchard JL 2019, *Information Guidelines Explanatory Note: Assessing groundwater-dependent ecosystems*. Report prepared for the IESC on Coal Seam Gas and Large Coal Mining Development through the Department of the Environment and Energy, Commonwealth of Australia.

Eco Logical Australia (ELA) 2025, *Hunter Valley Operations Continuation Project* - *aquatic ecology and groundwater dependent ecosystems assessment,* prepared for EMM Consulting Pty Ltd on behalf of HV Operations Ltd.

EGi 2022a, *HVO Continuation Project EIS - Geochemical Assessment*, prepared for HV Operations Ltd.

2022b, *Hunter Valley Operations – Continuation Project, Water quality predictions for final pit voids*, prepared for HV Operations Pty Ltd.

EMM Consulting Pty Ltd (EMM) 2017, *Hunter Valley Operations South - Modification 5 Environmental Assessment*, prepared for HV Operations Pty Ltd. Reference J15013.1

2022, *Hunter Valley Operations Continuation Project Environmental Impact Statement*, prepared for HV Operations. Reference H190408.4

2023a, *Hunter Valley Operations Continuation Project, Submissions Report*, prepared for HV Operations Pty Ltd, November 2023. Reference H190408.9

2023b, *HVO North Continuation Project, Amendment Report*, prepared for HV Operations Pty Ltd, November 2023. Reference H190408.11

2025a, *HVO Continuation Project, Amendment Report*, prepared for HV Operations Pty Ltd, August 2025. Reference H190408.18

2025b, *HVO Continuation Project - Amendment, Water Assessment*, prepared for HV Operations Pty Ltd. Reference H190408

2025c, *HVO Continuation Project Amendment, Groundwater Modelling Report*, prepared for HV Operations Pty Ltd. Reference H190408

2026a, *HVO North Open Cut Coal Continuation Project (EPBC 2023/09651), Draft Public Environment Report*, prepared for HV Operations Pty Ltd. Reference H190408

2026b, *HVO South Open Cut Coal Continuation Project (EPBC 2023/09652), Draft Public Environment Report*, prepared for HV Operations Pty Ltd. Reference H190408

2026c, *HVO Continuation Project, Groundwater Modelling Report*, prepared for HV Operations Pty Ltd. Reference H190408

Engeny Water Management (Engeny) 2018, *HVO Environmental Constraints Surface Water Management and Water Balance*, prepared for HV Operations Pty Ltd.

2022, *HVO Continuation Project – Surface Water Impact Assessment*, prepared for EMM Consulting Pty Ltd on behalf of HV Operations Pty Ltd.

2025, *HVO Continuation Project Amendment – Surface Water Impact Assessment*, prepared for EMM Consulting Pty Ltd on behalf of HV Operations Pty Ltd.

2026, *HVO Continuation Project – Surface Water Impact Assessment*, prepared for EMM Consulting Pty Ltd on behalf of HV Operations Pty Ltd.

EPA 2013, *Hunter Catchment Salinity Assessment – final report*. NSW Environmental Protection Authority.

2025, *NSW Guide for Large Emitters – Guidance on how to prepare a greenhouse gas assessment as part of NSW environmental planning processes*. NSW Environmental Protection Authority.

Gardner WB 1854, *Volume 02: Production and Resources of the Northern and Western Districts of New South Wales*, 1854 [ca. 1842-1858].

Hancock PJ and Boulton AJ 2008, Stygofauna biodiversity and endemism in four alluvial aquifers in eastern Australia. *Invertebrate Systematics* 22, 117-126.

Hunter Valley Operations (HVO) 2018, *Hunter Valley Operations Water Management Plan*, Hunter Valley Operations.

2022, River Red Gum Rehabilitation and Restoration Strategy.

IESC 2024, *Information guidelines for proponents preparing coal seam gas and large coal mining development proposals*, Commonwealth of Australia.

Landcom 2004, *Managing Urban Stormwater: Soils and Construction*, the 'Blue Book'. Volume 1, 4th edition

McVicar TR, Pinetown KL, Hodgkinson JH, Barron OV, Rachakonda PK, Zhang YQ, Dawes WR, Macfarlane C, Holland KL, Marvanek SP, Wilkes PG, Li LT and Van Niel TG 2015, *Context statement for the Hunter subregion. Product 1.1 for the Hunter subregion from the Northern Sydney Basin Bioregional Assessment.* Department of the Environment, Bureau of Meteorology, CSIRO and Geoscience Australia, Australia.

Mackie Environmental Research (MER) 2003, *Hunter Valley Operations, West Pit Extension and Minor Modifications - Surface and Groundwater Management Studies*, prepared for Coal & Allied, September 2003.

2009, *Groundwater management studies – Ravensworth Operations Project*, prepared for Umwelt.

2010, *Carrington West Wing modification groundwater assessment*, prepared for EMM Consulting Pty Ltd.

Minesoils Pty Ltd (Minesoils) 2022, *Hunter Valley Operations Continuation Project - Soils and Land Impact Assessment Report*, prepared for EMM Consulting Pty Ltd. Reference MS-029.

Murray TA and Power WL 2021, *Information Guidelines Explanatory Note: Characterisation and modelling of geological fault zones*. Report prepared for the Independent Expert Scientific Committee on Coal Seam Gas and Large Coal Mining Development through the Department of Agriculture, Water and the Environment, Commonwealth of Australia 2021.

NOW 2012, *NSW Aquifer Interference Policy, NSW Government Policy for the licensing and assessment of aquifer interference activities*, NSW Department of Primary Industries - Office of Water.

Peeters LJM and Middlemis H 2023, *Information Guidelines Explanatory Note: Uncertainty analysis for groundwater modelling*, A report prepared for the Independent Expert Scientific Committee on Coal Seam Gas and Large Coal Mining Development through the Department of Climate Change, Energy, the Environment and Water, Commonwealth of Australia 2023.

Post VEA and Simmons CT 2022, *Variable-Density Groundwater Flow*, published by the Groundwater Project, Guelph, Ontario, Canada 2022.

Serov P, Kuginis L, Williams JP 2012, *Risk assessment guidelines for groundwater dependent ecosystems*, *Volume 1 – The conceptual framework*, NSW Department of Primary Industries, Office of Water, Sydney.

Timms W, Liu H and Laurence D 2013, *Design of Low Permeability Barriers to Limit Subsurface Mine Seepage*. Water in Mining Conference, Brisbane 26-28 November 2013.

Threatened Species Scientific Committee (TSSC) 2015, Approved Conservation Advice (including listing advice) for the Central Hunter Valley eucalypt forest and woodland ecological community.

Umwelt 2024, *Hunter Valley Operations – 2023 Groundwater Annual Review, prepared for Hunter Valley Operations Pty Ltd*, March 2024.

2026a, *Hunter Valley Operations North Continuation Project Biodiversity MNES Assessment Supporting the Draft Public Environment Report*, prepared for HVO Operations Pty Ltd.

2026b, *Hunter Valley Operations South Continuation Project Biodiversity MNES Assessment Supporting the Draft Public Environment Report*, prepared for HVO Operations Pty Ltd.

Pérez E & Chebude Y 2017, *Chemical analysis of Gaet'ale, a hypersaline pond in the Danakil Depression (Ethiopia): New record for the most saline water body on Earth.* Aquatic Geochemistry, 23(2), 109–117. https://doi.org/10.1007/s10498-017-9312-z

Wafer J 2014 "Placenames as a Guide to Language Distribution in the Upper Hunter, and the Landnám Problem in Australian Toponomastics." In *Indigenous and Minority Placenames: Australian and International Perspectives*, eds. Ian D. Clark, Luise Hercus, and Laura Kostanski. Canberra, ACT: ANU Press, 57–82.

Glossary

Term	Definition
Alluvium	Unconsolidated sediments (clays, sands, gravels and other materials) deposited by flowing water. Deposits can be made by streams on riverbeds, floodplains, and alluvial fans.
Aquifer	A geological structure, formation or group of formations; able to receive, store and transmit significant quantities of water. A geological structure or formation, or an artificial landfill, that is permeated with water or is capable of being permeated with water (NSW Water Management Act 2000 definition).
Aquifer, confined	Aquifer overlain and underlain by an impermeable or almost impermeable formation.
Aquifer, unconfined	Saturated water-bearing formation which has a watertable.
Aquitard	A geological formation that may contain groundwater but is not capable of transmitting significant quantities of it under normal hydraulic gradients. May function as a confining unit.
Baseflow	The component of streamflow supplied by groundwater discharge.
Bore	A hole drilled in the ground, either lined (e.g. with steel or PVC) or unlined (open hole) used to access groundwater. May be used for observation of groundwater (including groundwater level or quality).
Calibration	Process of adjusting the values of model parameters within physically defensible ranges until the model performance adequately matches observed historical data from one or more locations represented by the model (i.e. a match is obtained that is robust and fit for purpose).
Catchment	The land area draining to a point of interest, such as a water storage or monitoring site on a watercourse.
Conceptual model	Simplified representation of a real situation, described by diagrams, flow charts, governing relationships or natural laws.
Confining unit	Low permeability strata that may be saturated but will not allow water to move through it under natural hydraulic gradients.
Confluence	The location where two or more watercourses join or intersect.
Dewatering	Removal of water from an aquifer as part of the construction phase of a development or part of ongoing activities to maintain access, serviceability and/or safe operating conditions. (NSW AIP).
Direct effect	Changes to the physical and/or quality aspects of groundwater as a consequence of an activity, or changes to the physical characteristics of aquifer affected by a development activity. Examples include changes in groundwater levels, changes in groundwater chemistry.
Drawdown	The decline in groundwater level (hydraulic head) compared to the original (or static) groundwater level. It is a change in groundwater level and is reported in metres.
Ecosystem	A dynamic complex of plant, animal and micro-organism communities and their non-living environment interacting as a functional unit.
Electrical conductivity (EC)	Electrical conductivity (EC) measures dissolved salt in water. The standard EC unit is microSiemens per centimetre (µS/cm) at 25 °C.
Ephemeral	Something which only lasts for a short time. Typically used to describe rivers, lakes and wetlands that are intermittently dry.
Evapotranspiration	Quantity of water evaporated and transpired from the soil and the vegetative cover.
Groundwater	The water contained in interconnected pores within rocks and sediments below the ground surface in the saturated zone, including perched systems above the regional watertable.

Term	Definition
Groundwater dependent ecosystems	Natural ecosystems that require access to groundwater to meet all or some of their water requirements so as to maintain their communities of plants and animals, ecological processes and ecosystem services.
Groundwater discharge	The process by which groundwater is released into the environment usually either via baseflow or evapotranspiration.
Groundwater level	The groundwater elevation in an aquifer, typically measured in a bore. In the case of an unconfined aquifer, the groundwater level is equal to the watertable level.
Potentiometric surface	A surface representing the hydraulic head of groundwater in a confined aquifer.
Groundwater recharge	The process which replenishes groundwater, usually by rainfall infiltrating from the ground surface to the watertable and/or by surface water infiltrating to the watertable from a stream. Other forms of recharge include flooding and irrigation, and artificial recharge can also occur through various means, including bore injection.
Hydraulic conductivity	A coefficient of proportionality describing the rate at which water can move through a medium.
Hydraulic connection	Degree of hydraulic interaction between aquifers, between different parts of the same aquifer, and between groundwater and surface water systems.
Hydrogeology	The study of the interrelationships of geologic materials and processes with water, especially groundwater.
Hydrograph	A graph showing the surface level, discharge, velocity, or some other feature of water, with respect to time.
Hydrostratigraphic unit	The subsurface is divided into hydrostratigraphic units that have similar properties from the point of view of storage and transmission of groundwater. Units that store significant amounts of water and transmit this water relatively easily are called aquifers. Units that offer a high resistance to flow are called aquitards, or confining units.
Infiltration	The process by which water on the ground surface enters the soil profile.
Low permeability barrier	Engineered structure to reduce the transmission of water from the receiving environment into mining areas.
Mitigation	Action taken to reduce the impact that a project may have on a receptor or water source.
Mounding	The increase in groundwater level compared to the original (or static) groundwater level. It is a change in groundwater level and is reported in metres.
Nested monitoring site/bore	Two or more monitoring bores installed at one location at varying depths to allow monitoring of different aquifers or depth intervals.
Permeability	The measure of the ability of a rock, soil or sediment to transmit a fluid. The magnitude of the permeability depends largely on the porosity and the connectedness of pores spaces.
pH	Value that represents the acidity or alkalinity of an aqueous solution. It is defined as the negative logarithm of the hydrogen ion concentration of the solution.
Porous rock	Material containing interstices that are usually connected and which above a certain scale may be considered continuous with respect to its hydraulic properties.
Porosity	The proportion of open space within a rock or deposit, comprised of intergranular space, pores, vesicles and fractures.
Riparian	An area or zone within or along the banks of a stream or adjacent to a watercourse or wetland; relating to a riverbank and its environment, particularly to the vegetation.
Salinity	Concentration of dissolved salts in water.

Term	Definition
Saturated zone	The soil and geological layers below the land surface where all spaces between soil/sediment/rock particles are filled with water. It encompasses all the soil and geological layers below the watertable.
Seep	A moist or wet location where groundwater reaches the land surface.
Seepage	The infiltration of water from streams, irrigation channels, water storages, farm dams, natural surface water features and septic tanks into the groundwater system. It is a form of surface water–groundwater interaction and groundwater recharge. The term can also apply to low volumes of groundwater discharge.
Sensitivity	The degree to which numerical model outputs are affected by changes in selected input parameters.
Spring	A location at the land surface where groundwater discharges creating a visible flow.
Storage parameters	Specific yield: The amount of water that a unit volume of saturated permeable rock will yield when drained by gravity. Storativity: The amount of water that a unit volume of saturated permeable rock will release from storage per unit decline in hydraulic head.
Streamflow	The flow of water in streams, rivers and other channels.
Stygofauna	Aquatic animals found in groundwater; sometimes used as a synonym of stygobite.
Surface runoff	Water from precipitation or other sources that flows over the land surface.
Surface water	Water that flows over or is stored on the surface of the earth that includes: water in a watercourse, lake or wetland and any water flowing over or lying on land: after having precipitated naturally or after having risen to the surface naturally from underground.
Total Dissolved Solids	The total amount of dissolved solid matter found in a sample of water.
Uncertainty	A state of lack of confidence to exactly describe the current or future condition of a system when limited knowledge of that system is available. Uncertainty is often categorised into two main types (AGMG; Barnett et al. 2012): • deficiency in our knowledge of the natural world (including the effects of error in measurements) • failure to capture the complexity of the natural world (or what we know about it) in a model. Formal definition from AS/NZS ISO 310000:2009: Uncertainty is the state, even partial, of deficiency of information related to the understanding or knowledge of an event, its consequence, or its likelihood.
Unsaturated zone	The soil between the land surface and the regional watertable in which the pore space contains both air and water.
Water balance	The flow of water into and out of, and changes in the storage volume of, a surface water system, groundwater system, catchment or specified area over a defined period of time.
Water quality	The physical, chemical and biological characteristics of water. Water quality compliance is usually assessed by comparing these characteristics with a set of reference standards. Common standards used are those for drinking water, safety of human contact and the health of ecosystems.
Water sharing plan	A legislated plan that establishes rules for managing and sharing water between ecological processes and environmental needs of the respective water source (river/aquifer). It manages WALs, water allocation and trading, water extraction, operation of dams, management of water flows, and use and rights of different water users.
Watertable	The surface between the unsaturated and saturated zones of the subsurface at which the hydrostatic pressure is equal to that of the atmosphere.
Validation	Where observations and model simulations are compared using data that were not part of the model calibration.
Verification	Verification involves comparing the predictions of the calibrated model to a set of measurements that were not used to calibrate the model, in order to confirm that the model is suitable for use as a predictive tool.

Australia

SYDNEY
Level 10 201 Pacific Highway
St Leonards NSW 2065
T 02 9493 9500

NEWCASTLE
Level 3 175 Scott Street
Newcastle NSW 2300
T 02 4907 4800

BRISBANE
Level 1 87 Wickham Terrace
Spring Hill QLD 4000
T 07 3648 1200

CANBERRA
Level 2 Suite 2.04
15 London Circuit
Canberra City ACT 2601

ADELAIDE
Level 4 74 Pirie Street
Adelaide SA 5000
T 08 8232 2253

MELBOURNE
Suite 8.03 Level 8 454 Collins Street
Melbourne VIC 3000
T 03 9993 1900

PERTH
Suite 9.02 Level 9 109 St Georges Terrace
Perth WA 6000

Canada

TORONTO
2345 Younge Street Suite 300
Toronto ON M4P 2E5

VANCOUVER
60 W 6th Ave Suite 200
Vancouver BC V5Y 1K1

linkedin.com/company/emm-consulting-pty-limited

emmconsulting.com.au