Groundwater 9

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9 GROUNDWATER

9.1 INTRODUCTION

This section provides a summary of the key findings of the groundwater assessment undertaken for the Eastern Leases Project (the project). The groundwater assessment was undertaken by Australasian Groundwater and Environmental Consultants Pty Ltd and the detailed report is provided in the *Groundwater Report* (Appendix F).

The project site comprises the Eastern Leases and the proposed haul road corridor connecting them to the existing mine. The Eastern Leases consist of the Northern Eastern Lease (Northern EL) and the Southern Eastern Lease (Southern EL). The project site is shown on Figure 9-1.

The Environmental Risk Assessment presented in Section 4 identifies all potential project risks in relation to groundwater and determines the consequence and likelihood of each risk, and the overall risk rating. Risk ratings are provided for the risk both with and without the application of mitigation measures. The risk assessment has concluded that, with the application of the proposed mitigation measures, all risks associated with groundwater are low risk. This section provides further detail on the impacts on groundwater that have been identified for the project, as well as the mitigation measures that will be applied.

9.2 SCOPE OF WORK AND METHODOLOGY

The scope of work and methodology for the groundwater assessment included:

- Conceptualising the groundwater regime of the project site and surrounding area through:
  - Reviewing various groundwater, geotechnical and environmental reports from the project site and the existing mine in order to develop an appreciation of the hydrogeological setting of the project;
  - Reviewing relevant geological data including 3D geology models, databases and exploration drilling logs developed by the proponent for the project site, the existing mine and surrounding areas;
  - Reviewing hydrogeological data held on the Department of Land Resource Management (DLRM) Water Data Portal for existing water bores;
  - Undertaking a census of private (i.e. residential or commercial) water supply bores within a 5 km radius of the project site to confirm bore locations, usage and water quality;
  - Undertaking a field inspection of watercourses in order to identify interactions with the groundwater regime;
  - Installing dedicated monitoring bores and production bores for measuring groundwater levels, quality and hydraulic parameters. A total of 19 monitoring bores and 4 production bores were installed at ten locations across the Eastern Leases. The 19 monitoring bores comprise a combination of deep and shallow bores. The groundwater monitoring locations are shown on Figure 9-2;
  - Undertaking continuous groundwater level logging at each of the 19 monitoring bores to confirm groundwater level changes in response to rainfall;
  - Undertaking monthly field testing and laboratory analysis of groundwater samples at each of the 19 monitoring bores to confirm water quality. An extensive suite of groundwater quality parameters was investigated including physical chemistry, metals and metalloids, major ions, nutrients and petroleum hydrocarbons; and

  - Analysing the above listed data and using it to develop a conceptual groundwater model and describe the groundwater regime including recharge zones, direction of groundwater flow and discharge zones. The data was also used to gain an understanding of the environmental values of the groundwater.
- Developing a 3D numerical groundwater flow model for the project to simulate the existing conditions of the groundwater regime and provide predictions of the potential impacts of the proposed mining activities. The model integrated the hydrogeology (based on the conceptual groundwater model described above) and the proposed mine plan and schedule.
- Undertaking predictive modelling for the project to determine the mining effects on groundwater levels in the surrounding aquifers, and inform the assessment of groundwater impacts during mine operations and post closure.
- Assessing the groundwater impacts and developing feasible mitigation and management strategies in the event of potential adverse impacts being identified. Impacts assessed included:
  - Potential groundwater drawdown impacts on groundwater supply bores;
  - Potential groundwater drawdown impacts on watercourses;
  - Potential groundwater drawdown impacts on Groundwater Dependent Ecosystems;
  - Potential cumulative drawdown impacts with the existing mine; and
  - Potential impacts on existing groundwater quality during and post mining.
- Developing a groundwater monitoring program for the project.

A detailed compilation of supporting field data is provided in Appendix A of the *Groundwater Report* (Appendix F). This includes location and construction details on the bore network established for the project.

The modelling used conservative parameters and values and is considered to represent the worst case scenario for potential groundwater impacts resulting from the project. A detailed description of the modelling logic is provided in Appendix A of the *Groundwater Report* (Appendix F).

9.3 GROUNDWATER REGIME

The local surface geology is shown on Figure 9-3. Groote Eylandt was formed on a stable Proterozoic basement that outcrops to form hills and escarpments at the periphery of the project site. Between these hills and escarpments, the basement paleosurface is deeply incised and has been in-filled by subsequent sediment deposition resulting in a low-lying topography that is characterised by gently sloping valleys. Sediment deposits are thinner in the vicinity of basement high points and outcrops. Figure 9-4 provides a conceptual hydrogeological cross section illustrating the typical sedimentary geology within the project site between basement outcrops.

The hydrogeological units of the project site consist broadly of:

- A thin veneer of Quaternary sediments;
- A shallow, highly weathered and heterogeneous Tertiary laterite aquifer;
- A highly weathered and uniform Tertiary lateritic clay aquitard;
- A Cretaceous marine claystone aquitard that includes the manganese ore in the upper profile;
- A Cretaceous sandstone aquifer comprising marine sandstone and reworked basement materials; and
- An underlying Proterozoic basement aquitard.

The significant groundwater bearing units of the project site are:

- A shallow unconfined aquifer within the laterite near the surface; and
- A deeper confined aquifer within the Cretaceous sandstone.

Regional groundwater flow occurs from the elevated basement outcrops located in the centre of the island towards the ocean.

The hydrogeology of each key stratigraphic unit is described in the following sections.

9.3.1 Quaternary Sediments

Extensive, deep Quaternary sediments are typically absent from the project site, and are limited to localised alluvium associated with the Emerald River in the Northern EL and elevated palustrine deposits in the Southern EL (Figure 9-3). Beyond these localised areas, a thin surficial cover of Quaternary sands and silts that ranges from a few centimetres to 3 m thick has been deposited across the low lying valleys.

During the wet season a shallow and highly ephemeral water table may form at the base of the sands in localised low lying areas due to high rates of direct rainfall recharge. Any ephemeral groundwater present will recharge the underlying laterite through downward seepage or be rapidly lost to evapotranspiration. The Quaternary sediments dry quickly following rainfall events.

Groundwater within the Quaternary sediments is expected to be non-saline and exhibit low concentrations of dissolved minerals. The short residence time of ephemeral groundwater in these Quaternary sediments means that groundwater quality is likely to be comparable to that of rainfall.

9.3.2 Laterite

The Tertiary laterite blankets the low lying land between basement outcrops, forming a heterogeneous horizon of iron-cemented sediments that is distinct from the underlying lateritic clay. The laterite is typically thin adjacent to the basement outcrops and increases in thickness with distance from the basement. The thickness of this unit ranges from zero to 10 m across the project site.

In the vicinity of the basement outcrops, recharge to the laterite is limited to seasonal rainfall events over small catchment areas and the laterite is dry and unsaturated in these areas.

A water table forms within these sediments as they thicken in the low lying valleys between the basement outcrops. In these areas, focussed recharge occurs in areas where the laterite is exposed at the surface or in the bed of ephemeral drainage lines. Diffuse recharge occurs across the project site as seepage through the superficial Quaternary sediments. The water table within the laterite is unconfined and variable. Groundwater monitoring data, obtained as part of the EIS baseline monitoring program, indicates that the water level can fluctuate by up to 3.7 m between the wet and dry seasons.

Groundwater flows reflect both the natural topography and catchment boundaries, with discharge occurring predominantly via slow seepage to the underlying lateritic clay, marine claystone and manganese ore horizons. There is also potential for some limited discharge to watercourses. During the wet season, the water table may rise above the surface of channel beds forming shallow pools in depressions in the base of watercourses.

The laterite exhibits variable permeability due to the highly heterogeneous nature of this material. The more permeable granular materials form a locally significant aquifer with recorded permeability of up to 12 metres per day (m/d).

Groundwater monitoring data shows that the quality of groundwater in the laterite aquifer reflects the natural geological weathering and enrichment processes. Groundwater is typically non-saline due to the depleted mineral content, and is slightly acidic. The naturally acidic water results in naturally elevated concentrations of metals and metalloids, most notably manganese, copper and zinc. No private groundwater supply bores are known to target this aquifer in the vicinity of the project site.

9.3.3 Lateritic Clay

The lateritic clay underlies the laterite and comprises mottled clay with occasional sandy clay and silt. The distribution of the lateritic clay is similar to the laterite (i.e. typically thin adjacent to the basement outcrops and increasing in thickness with distance from the basement). This unit is up to 12 m thick within the low lying areas of the project site.

The lateritic clay is an aquitard and acts as a basal confining unit to the overlying laterite aquifer. This unit is characterised by cohesive, low porosity clays that exhibit low permeability and restrict groundwater movement. The measured permeability is lower than the overlying laterite and the underlying marine claystone. This unit does not yield sustained volumes of groundwater.

Recharge to the lateritic clay is limited to low rates of seepage from the overlying laterite. The groundwater flow direction follows the regional topography toward the west coast of the island. The lateritic clay slowly discharges into the underlying marine claystone.

Groundwater monitoring data shows that groundwater quality in the lateritic clay is typically non-saline, and slightly to moderately acidic (ranging from pH 6.9 to pH 5.9). However, this groundwater exhibits elevated salinity and dissolved minerals relative to the overlying laterite aquifer. The change in groundwater quality between these units confirms the relatively low permeability and long groundwater residency times associated with the lateritic clay.

The low permeability of this unit and long groundwater residency times are reflected in the concentrations of dissolved minerals (that reflect salinity) which, though low overall, are elevated in comparison to the local groundwater regime.

No private groundwater supply bores are known to target this groundwater in the vicinity of the project site.

9.3.4 Marine Claystone

The upper Cretaceous sedimentary sequence comprises a marine claystone with minor interbedded sandstone and siltstone. The marine claystone is up to 30 m thick in the low lying areas of the project site, and thins to less than 1 m in the vicinity of the basement outcrops. The upper profile of the marine claystone hosts the primary manganese ore. The manganese ore is described in detail in Section 3 – Project Description.

The marine claystone is an aquitard and acts as a confining unit overlying the Cretaceous sandstone aquifer. This unit exhibits a low primary porosity that restricts groundwater movement to fractures. Where fractures are intersected this unit shows slightly higher permeability, and conversely, where limited fractures are intersected this unit shows lower permeability associated with the primary porosity.

The low permeability of this unit is largely responsible for the steep vertical hydraulic gradient that characterises the local groundwater regime and results in a clear distinction between of the Cretaceous and laterite aquifers.

Recharge to the marine claystone is limited to extremely low rates of seepage from the overlying lateritic clay and the underlying confined Cretaceous sandstone. The groundwater flow direction follows the regional topography toward the west coast of the island where it slowly discharges into the coastal waters. However, discharge volumes are similarly very low due to the very low rates of groundwater recharge.

Groundwater monitoring data shows that groundwater quality is typically non-saline and slightly to moderately acidic and is therefore broadly comparable to the overlying lateritic clay. The low permeability of this unit and long groundwater residency times are reflected in the concentrations of dissolved minerals that are elevated in comparison to the underlying Cretaceous sandstone aquifer.

This unit yields extremely low volumes of groundwater and no private groundwater supply bores are known to target this groundwater in the vicinity of the project site.

9.3.5 Cretaceous Sandstone

The Cretaceous sandstone comprises quartz sandstone derived from reworking (i.e. erosion and redeposition) of the underlying older Proterozoic basement and subsequent deposition of a shallow marine sandstone. It is typically 10 to 40 m thick across the low lying areas of the project site.

The Cretaceous sandstone receives recharge from seepage from the overlying marine claystone (where present) and upward flow from the underlying Proterozoic basement. However, the main recharge zone occurs where the Cretaceous sandstone outcrops as a thin, unsaturated unit in the vicinity of the basement outcrops. In these areas, the rate of recharge is significantly enhanced by infiltration of runoff from seasonal rainfall events. Overall, the rate of recharge to this aquifer is very high.

A water table forms within this unit as it thickens with increasing distance from the basement outcrops. Where overlain by other sediments, this unit is generally uniformly saturated and confined. This saturated unit is characterised by high permeability and high porosity, resulting in a high transmissivity, high yielding aquifer with a large storage capacity. This aquifer is the most productive formation in the vicinity of the project site.

Groundwater associated with the Cretaceous sandstone flows in a westerly direction. The main discharge point for the Cretaceous sandstone is the marine waters of the Gulf of Carpentaria, approximately 9 km west of the Eastern Leases. The confined aquifer also provides baseflow to watercourses including the Amagula River and Emerald River, particularly in low lying coastal areas downstream of the project site where the overlying marine claystone aquitard thins and the aquifer subcrops beneath rivers.

Within the vicinity of the project site, this aquifer is intersected by a single bore at Yedikba Outstation, and another bore at Wurrumenbumanja Outstation (Figure 9-1). A bore census undertaken for the EIS confirmed that these bores were installed by the proponent as a water supply to the outstations. These outstations are not permanently occupied and receive varying levels of use, from occasional visitation to sporadic residency. The bore census indicated that drinking water supply at the outstations is preferentially sourced directly from local watercourses.

Groundwater monitoring data from the project site shows that groundwater quality is slightly to moderately acidic and non-saline with naturally elevated concentrations of metals. The pH levels and metal concentrations in this aquifer do not meet the recommended standards for drinking water (NHMRC & NRMMC, 2011).

9.3.6 Proterozoic Basement

The Proterozoic basement comprises a strongly jointed, massive, quartzite. The quartzite forms rugged, sparsely vegetated hills and scarps where it outcrops. Between the outcropping areas, the basement is typically overlain by the Cretaceous sandstone.

The basement outcrops are unsaturated to depths that correlate to groundwater levels in the Cretaceous sandstone aquifer.

Recharge occurs via direct rainfall infiltration on the outcropping areas. Recharge is likely to be via secondary porosity associated with the joint sets and any weathering which may have occurred in the upper profile of this unit. Joint planes are stained indicating preferential flow and recharge of groundwater along these structures. The Proterozoic basement exhibits very low primary porosity and hydraulic conductivity.

The hydraulic gradient is representative of the regional topography with flow from areas of higher elevation towards the coast. Discharge will occur into the overlying Cretaceous sandstone via jointing.

Due to the significant depth to groundwater and typically low yield of this unit, no bores or groundwater users are present.

The Proterozoic basement is not directly impacted by the project and lies beneath the target ore, marine claystone and Cretaceous sandstone aquifer. Any indirect impacts to the basement are therefore fully captured in the assessment of the overlying Cretaceous sandstone aquifer, and are therefore not discussed further in this assessment.

9.4 GROUNDWATER ASSESSMENT

9.4.1 Overview of Mining Activities

The project will make use of the same open cut mining methods that are currently used at the existing mine as described in Section 3 – Project Description. The overburden depth within the project site is up to 25 m, with an ore thickness of up to 5 m. These thicknesses and depths are variable across the project site. Similar to the existing mine, mining strips will be up to 1,500 m long and 40 m wide.

Overburden will ultimately be placed in mined quarries ensuring that there will be no final voids and no elevated overburden emplacement areas at the end of the mine life. There are, however, instances over the operating life of the project where it will not be feasible to directly place overburden in mined quarries, because of a lack of available capacity at the time. In these instances temporary out-of-pit overburden emplacements will be constructed.

The Northern EL is proposed to be developed first, with development of the Southern EL commencing several years later. Both areas will then be mined concurrently from approximately Project Year 7. Further detail on project scheduling is provided in Section 3 – Project Description.

The extents of the quarries over the life of the project are shown in Figure 9-2. The quarries will intersect several geological units including the laterite aquifer and the lateritic clay aquitard. The quarries will not intersect the marine claystone aquitard below the manganese ore, the Cretaceous sandstone aquifer or the Proterozoic basement.

9.4.2 Overview of Impacts

The process of open cut mining reduces groundwater pressures in the geological units surrounding the mining excavation. The extent and magnitude of the pressure reduction depends on the properties of the ore and other hydrogeological units. This zone is referred to as the zone of depressurisation, and is greatest adjacent to the mine excavation, gradually reducing with distance from the mining area. For the purposes of the EIS groundwater assessment, the limit of the zone of depressurisation is conservatively defined by a predicted lowering of the potentiometric groundwater surface by more than 1 m. A 1 m lowering of the potentiometric groundwater surface was adopted in defining the limit of the zone of depressurisation as it is within the range of natural groundwater pressure fluctuations between wet and dry seasons and also represents the reasonable limit of precision that can be inferred from groundwater modelling.

The mining sequence and mine plan will dictate the extent of groundwater depressurisation at each stage of the mine development. The project involves the staged development of numerous quarries.

The mine schedule will result in some quarries being completed (i.e. mined and backfilled) while other quarries are still active or have not yet been developed. Groundwater recovery will therefore commence in the completed quarries (e.g. those quarries in the Northern EL developed early in the mine life) while mining activities are ongoing in other areas (i.e. those quarries in the Southern EL developed late in the mine life). This sequencing has been captured in the groundwater modelling described in the following section.

Groundwater modelling was undertaken in order to assess the effects of mining on groundwater levels, and the associated impacts to groundwater users and the surrounding environment. Potential impacts include:

- Drawdown impacts on groundwater bores within the Cretaceous sandstone;
- Drawdown impacts reducing groundwater baseflow in watercourses;

- Drawdown of the water table and impacts on Groundwater Dependent Ecosystems; and
- Cumulative impacts (i.e. due to operation of the project and the existing mine) on groundwater bores, watercourses and ecosystems.

Section 9.4.3 describes the groundwater modelling that was undertaken and Sections 9.4.4 to 9.4.7 describe potential impacts related to predicted changes in groundwater levels.

The groundwater assessment also investigated potential impacts on groundwater quality including:

- Construction of overburden emplacements which have the potential to generate leachate and give rise to groundwater contamination; and
- Use of hydrocarbons and chemicals which have the potential to give rise to groundwater contamination.

These potential impacts are discussed in Section 9.4.8.

9.4.3 Overview of Modelling

Groundwater Model

A 3D numerical groundwater flow model was developed to predict the extents of depressurisation and the associated impacts on groundwater users and the surrounding environment. The groundwater model for the project was developed using MODFLOW-SURFACT. MODFLOW-SURFACT is the most widely used groundwater mode in Australia, and is considered to be industry standard. A detailed description of the groundwater model is provided in the *Groundwater Report* (Appendix F).

The groundwater model was constructed using a detailed geological model developed by the proponent from exploration data. It was further enhanced by inclusion of bore logs from groundwater monitoring bores and production bores installed at the project site, and all published lithological logs within the model extents. The model was calibrated to existing groundwater levels using reliable measurements from all representative local and regional bores within the model domain. Once calibrated, the model was used to predict the groundwater response to the project, including changes in groundwater levels and inflows to the proposed mining area.

The sensitivity of the model predictions to the input parameters was tested and analysed. The sensitivity analysis included varying model parameters and design features that could most influence the model predictions. The model parameters were adjusted to encompass the range of likely uncertainty in key parameters. Overall, the sensitivity analysis confirmed that there is a high degree of confidence in the model's calibration and predictions, and that the model is not likely to have under predicted any significant impacts.

Groundwater Level Predictions

The zone of depressurisation at the end of mining (i.e. Project Year 15) has been assessed as this represents the cessation of mine dewatering. This scenario also typically represents the maximum extent and/or magnitude of depressurisation associated with open cut mining. However, the groundwater regime in the vicinity of the project site experiences significant recharge and rapid recovery of groundwater levels that could mask the effects of early mining on groundwater. To ensure that the worst-case impacts on groundwater users and the water environment are assessed, the maximum overall life of mine zone of depressurisation has also been assessed.

Mining Operations

Localised depressurisation is predicted in the laterite aquifer around the proposed quarries. Depressurisation of the laterite aquifer is predicted to be greatest in the Southern EL, where proposed quarries are deepest. This aquifer is predicted to experience up to 14 m of depressurisation in this area. The zone of depressurisation is predicted to extend less than 1 km from any quarry. The potential impacts of groundwater depressurisation on existing groundwater users and watercourses are discussed in Sections 9.4.4 and 9.4.5.

The thick marine claystone aquitard that underlies the manganese ore body and forms the floor of the quarry excavations limits the potential for any significant groundwater gradient from the Cretaceous sandstone towards the mining areas. Any negligible depressurisation of the Cretaceous sandstone due to mining will be readily offset by the very high recharge rate and storage capacity of this unit which effectively buffer any potential minor losses from the aquifer. The Cretaceous sandstone aquifer is not predicted to be significantly depressurised by the project.

Post Closure

Predictive modelling was undertaken to simulate groundwater recovery post mining. This simulation removes all drain cells used to simulate dewatering from the quarries during active mining operations, thus allowing the groundwater levels in the water-bearing strata to recover.

The modelling indicates that quarries that have been backfilled with overburden will gradually fill with water over time. This process will reduce the hydraulic gradient and magnitude of depressurisation immediately surrounding the mined area.

Post mining groundwater levels in the laterite aquifer are predicted to recover rapidly following completion of mining. 80% of the drawdown is predicted to recover within 5 years of mining. Almost total recovery of groundwater levels (i.e. to pre-mining levels) is expected to be achieved within 20 years of mine closure.

9.4.4 Impact on Existing Groundwater Users

A bore census was carried out to identify water supply bores surrounding the project site that could potentially be impacted by the project. The census drew upon information gathered through advice from the proponent, a search of the DLRM Water Data Portal. A representative from GEBIE (an incorporated body funded by the Anindilyakwa Land Council) accompanied the groundwater consultant during the inspection of bores.

The bore census was targeted towards bores that could potentially be impacted by the project due to their proximity to proposed mining activities. The local hydrogeology was also taken into account in planning the bore census. A conservative search radius of 5 km beyond the project site boundary was used in areas that could potentially be impacted by the project.

Only two water supply bores were identified at outstations during the bore census (Figure 9-1). These bores are located 2.2 km west of the Southern EL at Yedikba Outstation, and 3.5 km south of the Southern EL at Wurrumenbumanja Outstation. Neither was found to be in use. The bore census indicated that bores are installed within the Cretaceous sandstone aquifer. These bores are only sporadically used.

The project is not predicted to impact groundwater levels in the Cretaceous sandstone aquifer within which these bores are installed. Furthermore, as noted in Section 9.4.3, depressurisation in the laterite aquifer is not predicted to extend more than 1 km from any quarry and would not extend to either of these bores. Therefore, the project will not impact groundwater levels or yield in either of these bores.

Groundwater monitoring will be conducted over the life of the mine to confirm the actual extent of groundwater impacts and validate the conservative drawdown predictions. The groundwater monitoring program is described in Section 9.5.

9.4.5 Impact on Watercourses

The project site is predominantly drained by the Emerald River, Amagula River and their tributaries. The catchment and drainage setting of the project is described in Section 10 – Surface Water.

The watercourses that are in the upper catchments of the Angurugu, Emerald and Amagula Rivers are generally small watercourses that are seasonally dry.

The majority of watercourses in the vicinity of the project site are ephemeral and contain surface water flows or standing water during and immediately after the wet season. During the dry season, surface water is restricted mainly to remnant pools isolated by dry river or stream beds.

Sections of watercourses are predicted to receive groundwater inflows which contribute to surface water baseflow. Figure 9-5 shows the sections of watercourses that have been mapped as perennial, based on the results of the aquatic ecology impact assessment, groundwater modelling predictions, and from general observations made during the monthly baseline monitoring program.

Drawdown in the laterite is predicted to temporarily extend to ephemeral reaches of the Emerald River – Main Channel during mining. The predicted drawdown in this area is of a limited magnitude and duration. During the dry season, this will have no material effect on surface water baseflow due to the ephemeral nature of surface water flows in this watercourse. During the wet season, groundwater levels in the laterite are elevated and contribute to surface water flows. The limited duration and magnitude of drawdown is further offset by the high recharge in the laterite aquifer, and results in a very minor overall reduction in surface water baseflow. The total predicted decrease in baseflow over the 13 years of mining is 39 ML or 2.6 ML/a averaged over the life of the project. This represents approximately 0.2% of annual average baseflow in the Emerald River at station G9290211 (Figure 9-2) and is negligible in terms of total surface water flows in the river. This change would be imperceptible in downstream locations.

Drawdown in the laterite is also predicted to temporarily extend to ephemeral reaches of the Amagula River – Tributary 1 and Tributary 2 during mining. However, the magnitude of drawdown is significantly less than that predicted in the Emerald River and the affected tributaries are located at a greater distance (in excess of 1 km) from the nearest perennial watercourse. The predicted drawdown is not predicted to result in a net reduction in downstream baseflow. Leske Pools, a popular swimming hole, is not predicted to experience any reduction in flow.

The post mining final landform will not contain any final voids and the lack of final voids will allow pre-mining groundwater levels to re-establish. The extent of groundwater drawdown will retract around the rehabilitated quarries as groundwater levels recover post mining. Once groundwater levels fully recover, approximately 20 years post mining, groundwater contribution to baseflow in watercourses will be restored to pre-mining levels.

Overall, no significant adverse impacts on surface water values are predicted to arise from predicted changes in baseflow.

9.4.6 Impacts on Groundwater Dependent Ecosystems

Groundwater Dependent Ecosystems within or in proximity to the project site are discussed in Section 7 – Terrestrial Ecology.

9.4.7 Cumulative Impacts

The existing approved mine impacts the groundwater environment in the region and therefore requires consideration in relation to potential cumulative impacts it may have with the project.

The numerical groundwater model considered all approved future mining activities at the existing mine south of the Angurugu River. Mining areas beyond the Angurugu River are located over 5 km from the project site and are well beyond the limit of predicted impacts from the project (Figure 9-1). The numerical groundwater model was used to assess the cumulative groundwater impacts associated with the approved future operations in these areas. The numerical model included progression of the existing mine areas concurrently with the project.

The maximum predicted extents of depressurisation for the existing mine and the project were compared in order to determine whether any areas could potentially be depressurised by both operations. This approach provides a conservative assessment of the potential worst-case cumulative impacts in terms of changes to groundwater levels. The detailed results of the cumulative assessment are provided in the *Groundwater Report* (Appendix F).

The model predictions indicate that there will be no cumulative depressurisation impacts during the operations phase of the project, or post-mining. The localised drawdown in the laterite aquifer due to the project will not intersect the zone of depressurisation associated with the existing mine. The project is not predicted to depressurise the Cretaceous sandstone aquifer and therefore cumulative depressurisation of this aquifer is precluded.

9.4.8 Impacts on Groundwater Quality

Key potential sources of groundwater contamination are seepage from:

- Overburden emplacement areas; and
- Hydrocarbon and chemical storage.

Overburden Emplacement Areas

The open cut mining area will be actively dewatered during mining operations. Mine dewatering will create a hydraulic groundwater gradient and induce groundwater flow towards the dewatered quarry. Any water leaching through the overburden emplacements and into the underlying geology will also therefore migrate towards the dewatered mining area. Groundwater inflows to the mining areas will be managed as part of the proposed mine water management system described in Section 10 – Surface Water.

Post mining groundwater levels within the overburden emplacement areas are predicted to recover and stabilise at levels consistent with pre-mining groundwater levels. During the recovery period, the mined areas will continue to behave as a groundwater sink until groundwater levels fully recover. Once stabilised, groundwater levels will fluctuate around the pre-mining levels in response to rainfall recharge and the mined areas will not act as a permanent groundwater sink. Post recovery, groundwater including any water leaching through the backfilled quarries, would flow through the project site, consistent with the regional groundwater flow regime.

Geochemical testing concluded that the bulk overburden materials are likely to generate low salinity, low acidity leachate with extremely low concentrations of dissolved minerals and soluble metals, with the exception of naturally occurring manganese. These results are consistent with the highly weathered nature of the overburden materials that are largely leached of minerals. The overburden leachate quality results are similar to the existing groundwater quality reported in Section 9.3. The geochemical testing program is described in the *Geochemistry Report* (Appendix A).

Any leachate movement away from the overburden emplacements in the post mining phase is therefore unlikely to result in significant change to surrounding water quality.

Hydrocarbon and Chemical Storage

The project is an additional mining area that will be operated as part of the existing mine, rather than an independent mine. There will consequently be very limited infrastructure on the project site and storage of diesel and chemicals will be limited to small scale, portable containers.

Section 18 – Health and Safety describes the measures that will be adopted to prevent contamination from the transport, handling and storage of diesel or chemicals. Given the limited activities proposed on the project site, and the controls that will be adopted, the project has a very limited potential to give risk to groundwater contamination as a result of hydrocarbon and chemical contamination.

9.5 MONITORING

The established groundwater monitoring network comprises 19 monitoring bores at ten locations across the Eastern Leases to establish baseline groundwater levels and quality (Figure 9-2). The details of the proposed groundwater monitoring network are provided in Table 9-1.

The groundwater monitoring network established as part of EIS groundwater investigations will continue to be utilised throughout the life of the project. Any monitoring bores that are removed by mining during the life of the project will be replaced, where necessary.

Recording of groundwater levels from existing monitoring bores will continue and will enable natural groundwater level fluctuations (such as responses to rainfall) to be distinguished from potential water level impacts due to depressurisation resulting from mining activities.

Groundwater quality monitoring will continue until 24 contiguous months of baseline data is collected. This will establish a robust, long-term groundwater quality baseline that can be used to detect any changes in groundwater quality during and post mining.

Once 24 months of baseline data has been collected, groundwater quality monitoring frequency will revert to quarterly intervals for physical parameters (pH, electrical conductivity, total dissolved solids, salinity, temperature, dissolved oxygen), hardness and alkalinity, major ions (Ca, Mg, Na, K, CO_3, HCO_3, Cl, SO_4) and metals and metalloids (Al, As, B, Ba, Be, Cd, Cr, Co, Cu, Fe, Hg, Mn, Ni, Pb, Se, U, V, Zn), with annual monitoring of nutrients (ammonia, nitrite, nitrate, total phosphorus) and total hydrocarbons.

The groundwater monitoring data will be reviewed annually and the groundwater monitoring program revised, as necessary.

Table 9-1 Groundwater Monitoring Program

MONITORING POINT REFERENCE	EASTING (GDA94)	NORTHING (GDA94)	GEOLOGICAL UNIT
EL-N-MB01S	664017	8447502	Laterite / Lateritic Clay
EL-N-MB01D	664017	8447502	Reworked Basement / Marine Sandstone
EL-N-MB02S	664120	8448622	Laterite / Manganese Ore / Marine Claystone
EL-N-MB02D	664120	8448622	Marine Sandstone
EL-N-MB03S	664986	8447701	Laterite / Manganese Ore / Marine Claystone
EL-N-MB03D	664986	8447701	Reworked Basement
EL-N-MB04S	665744	8449493	Lateritic Clay
EL-N-MB04D	665744	8449493	Reworked Basement
EL-S-MB05	664495	8442763	Marine Claystone
EL-S-MB06S	663563	8442620	Quaternary Sediments / Laterite
EL-S-MB06D	663563	8442620	Reworked Basement
EL-S-MB07S	665215	8441005	Laterite / Manganese Ore
EL-S-MB07D	665215	8441005	Reworked Basement / Marine Sandstone
EL-S-MB08S	667488	8440496	Laterite / Lateritic Clay
EL-S-MB08D	667488	8440496	Marine Claystone
EL-S-MB09S	665875	8440131	Marine Claystone / Manganese Ore
EL-S-MB09D	665875	8440131	Reworked Basement
EL-S-MB10S	668233	8441997	Laterite / Lateritic Clay
EL-S-MB10D	668233	8441997	Marine Claystone

Monitoring Point Reference nomenclature describes the bore and its location as follows:

EL-N – Northern EL
EL-S – Southern EL
MB01 – Monitoring Bore 01
S or D – Shallow or Deep Bore

9.6 GROUNDWATER LICENSING AND REPORTING

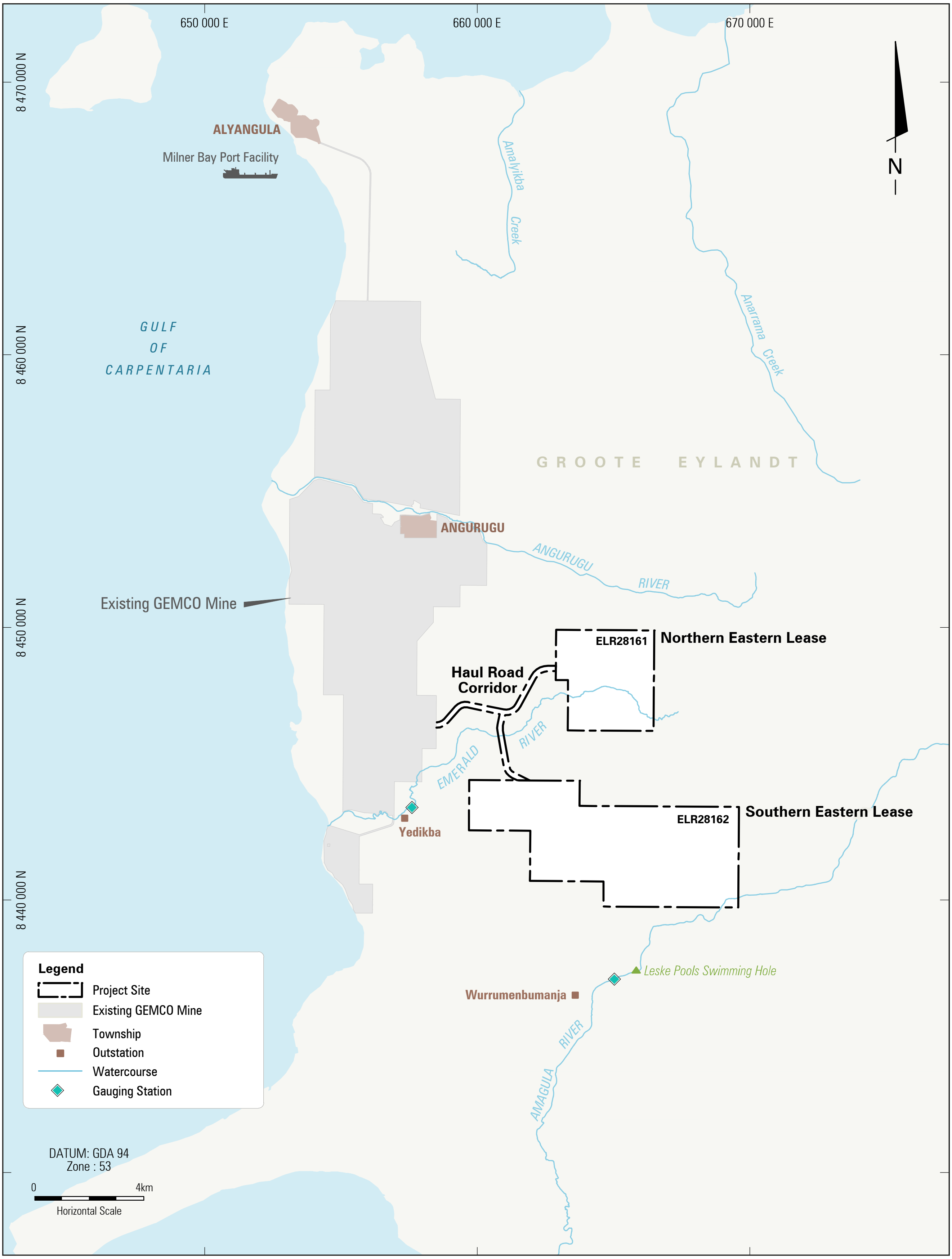
The NT *Water Act* and subordinate *Water Regulations* are the primary legislation regulating groundwater resources in the NT and are administered by the DLRM. A wide range of groundwater activities are regulated under the *Water Act*, including the licensing of groundwater extraction and recharge, and the authorisation of releases to groundwater.

Mining activities are exempt from these requirements of the *Water Act* where groundwater is managed under the *Mining Management Act* (administered by the Department of Mines and Energy). As the project will be regulated under the *Mining Management Act*, licences or authorisation under the *Water Act* will not be required in relation to groundwater management. The proponent will obtain the necessary authorisations under the *Mining Management Act* before the project commences.

Underground waste arising from mining activities may be regulated under the *Water Act* in situations where underground waste or contaminated groundwater migrates off site. The project will not involve unconfined waste or contaminated groundwater migrating beyond the project site.

The proponent will consult with the NT government in relation to any obligations under the above legislation, and will comply with all applicable requirements.

FIGURES



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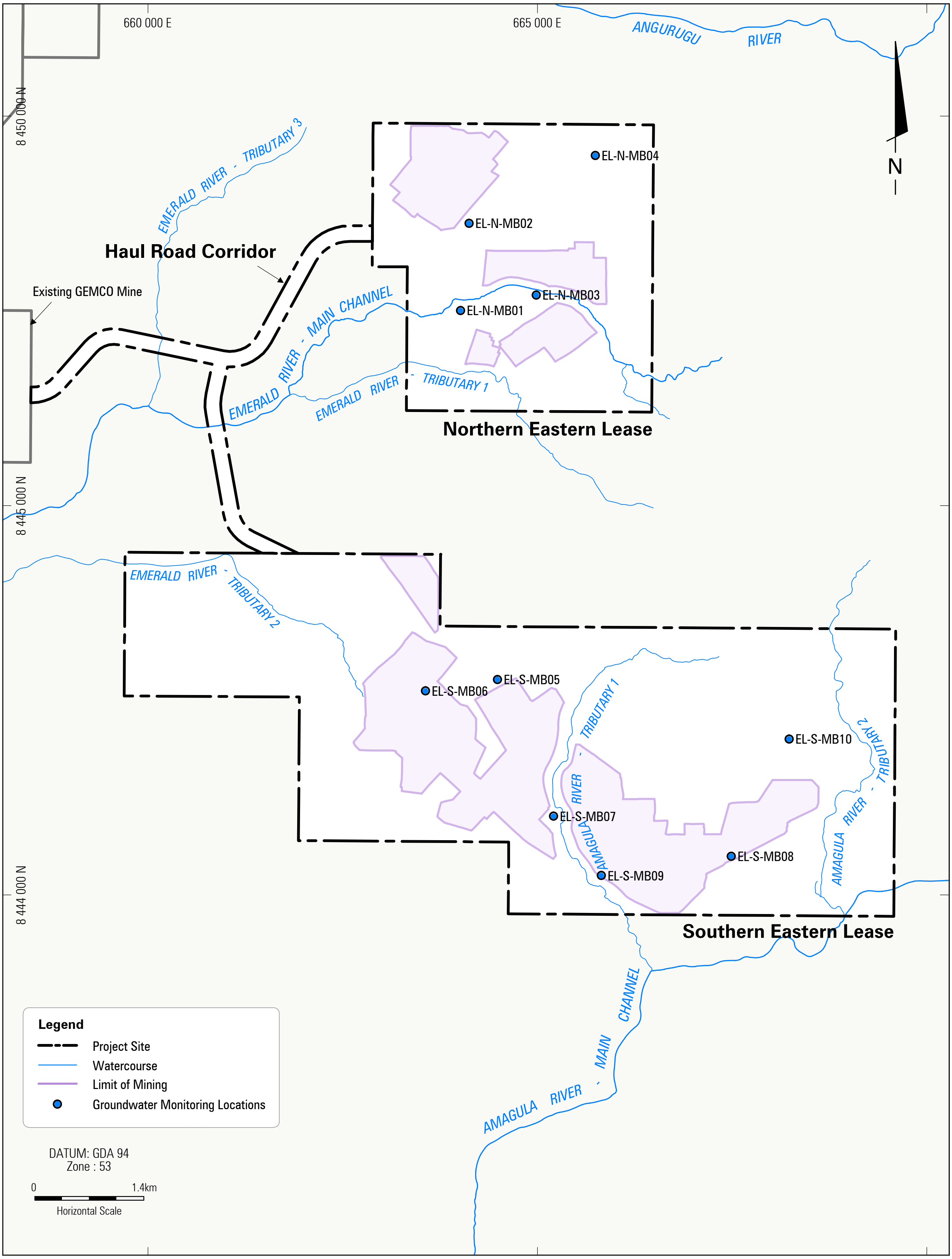
Local Setting

FIGURE 9-1



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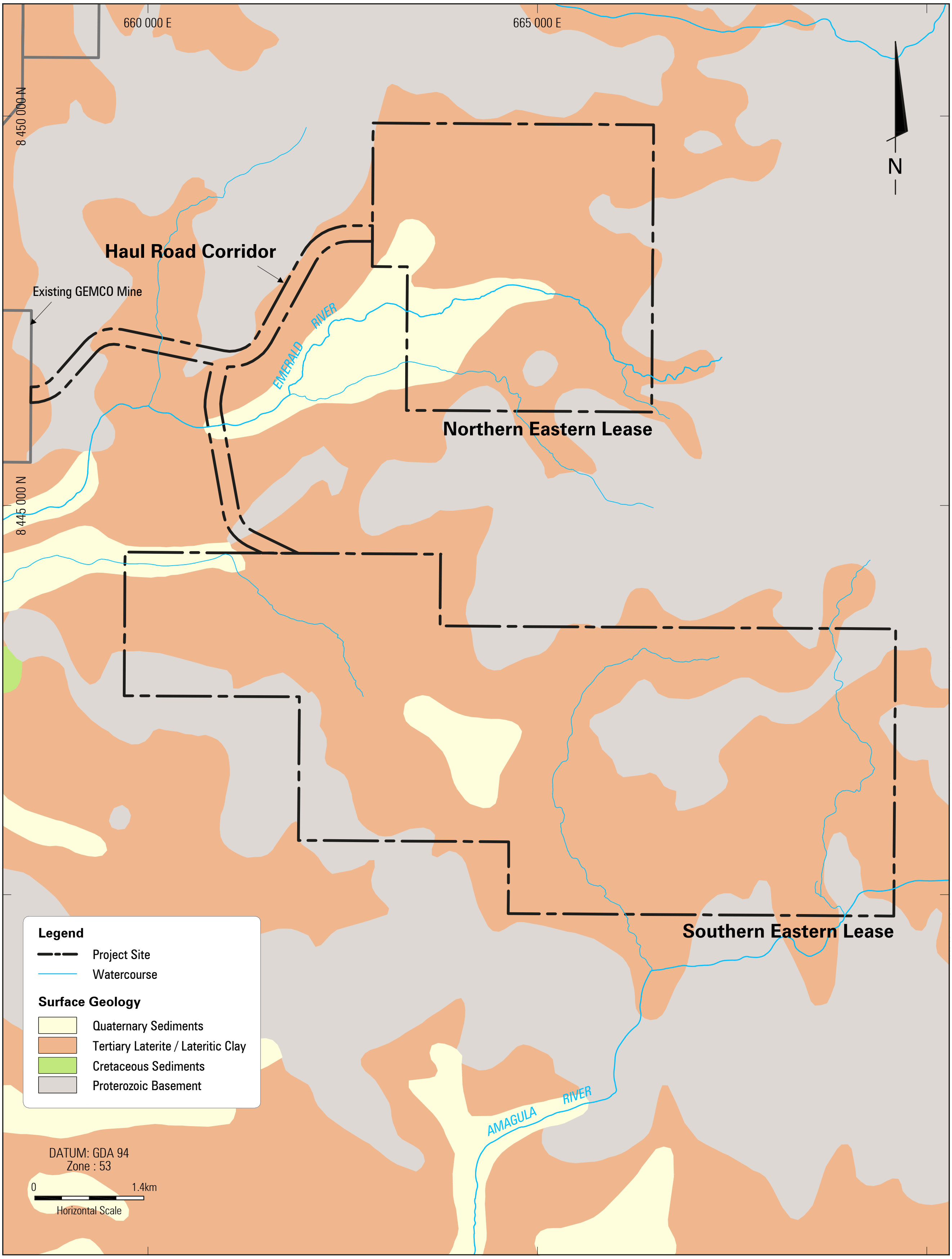
Groundwater Monitoring Locations

FIGURE 9-2



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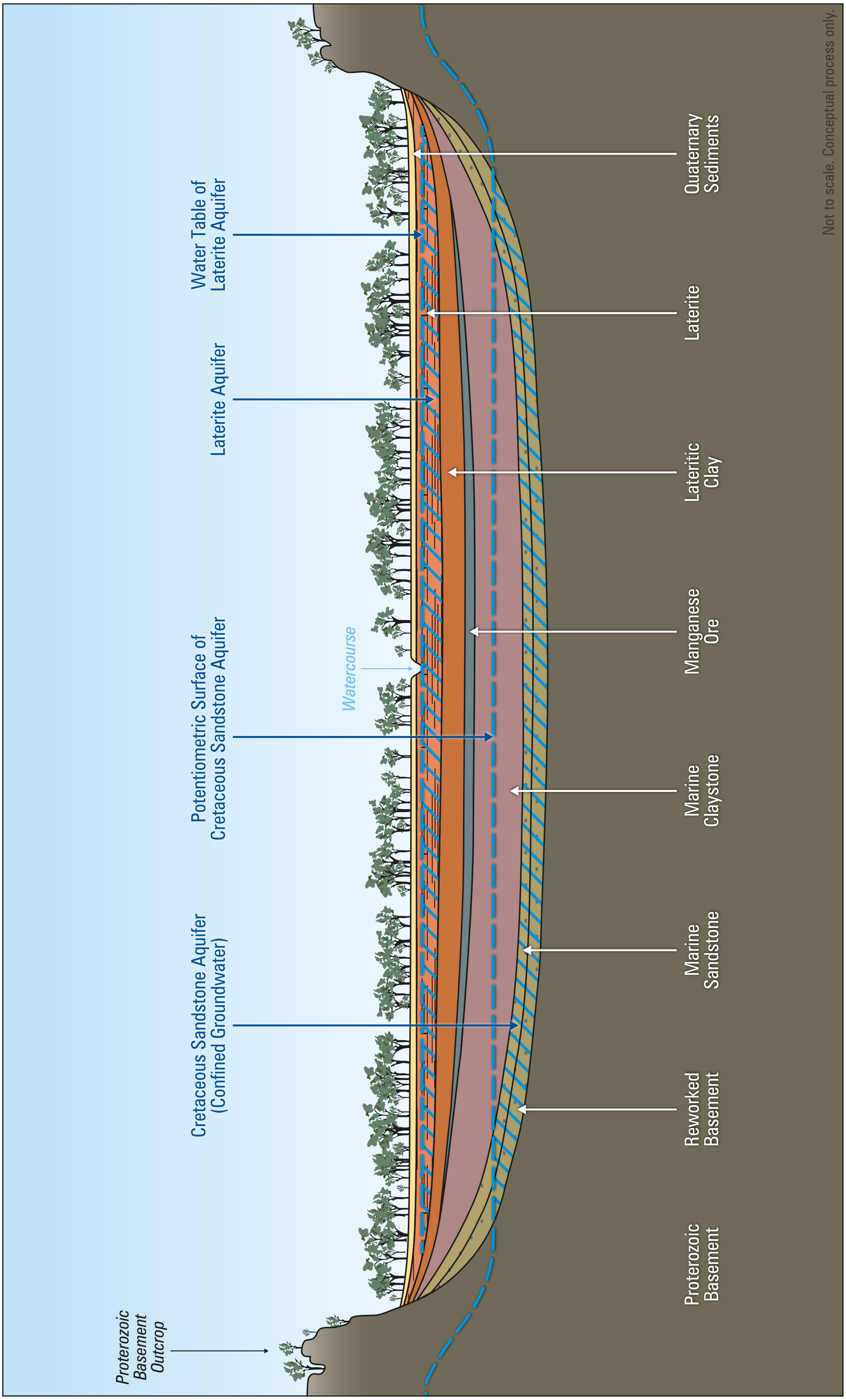
Surface Geology

FIGURE 9-3



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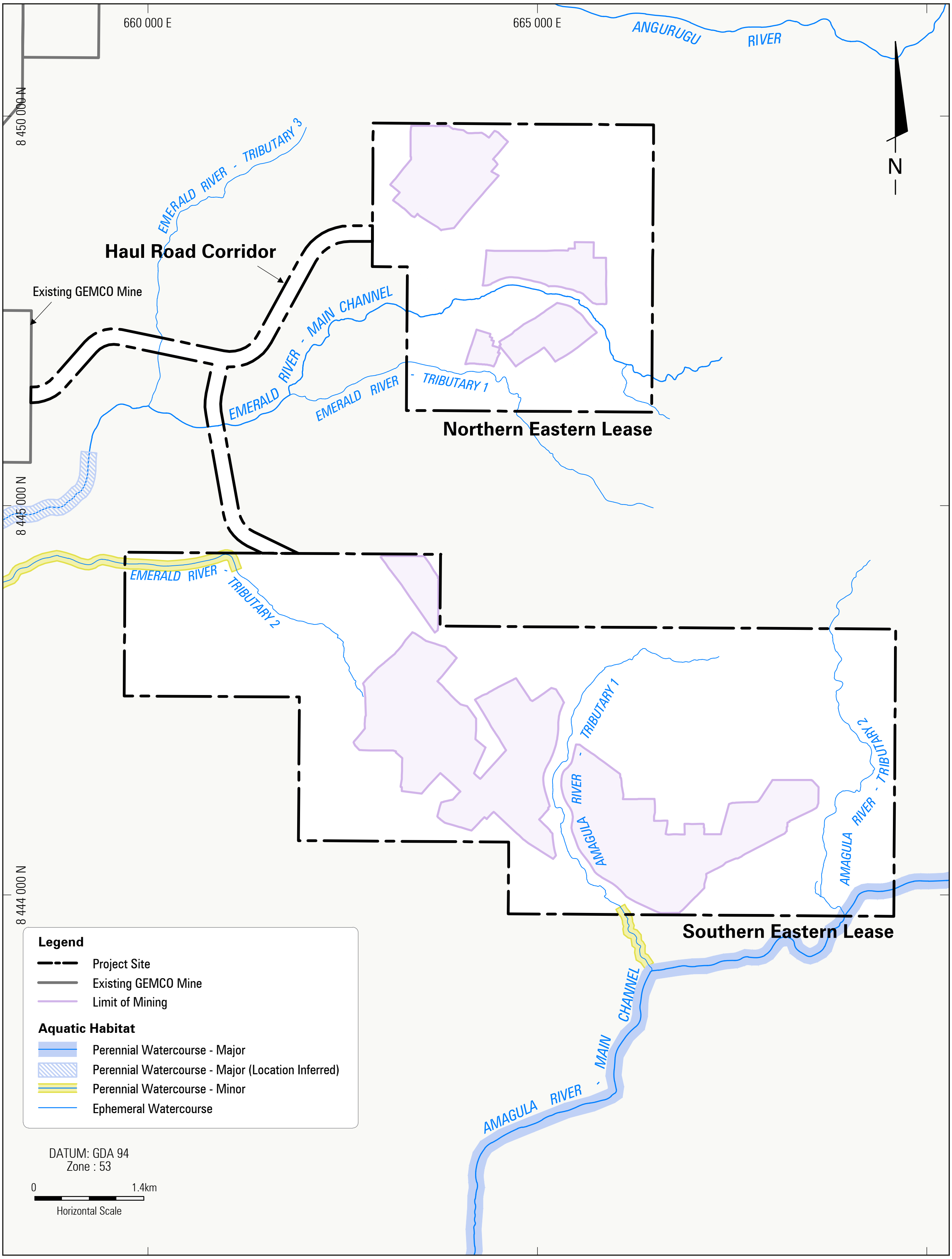
Conceptual Hydrogeology Cross-section

FIGURE 9-4



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Local Drainage Setting

FIGURE 9-5