

TECHNICAL MEMORANDUM

TO: Glencore Collinsville Open Cut (COL) **DATE:** April 30, 2026
FROM: Klohn Crippen Berger **FILE NO:** 14D10289A14
SUBJECT: Kerale Dam Seepage Assessment – Final

1 INTRODUCTION

Klohn Crippen Berger (KCB), operating as KCB Australia Pty Ltd, was commissioned by Glencore to assist Collinsville Open Cut (COL) in the hydrogeological conceptualisation of Kerale Dam as a designated Non-Use Management Area (NUMA) and a review of potential seepage from water that may be stored in the dam.

2 BACKGROUND

COL is authorised to conduct Environmental Relevant Activities (ERAs) under Chapter 5 of the *Environmental Protection Act* in accordance with their Environmental Authority (EA) EPML00332013, effective from 11 July 2024. The EA authorises ERAs within mining leases (MLs) ML1005, ML1006, ML1007, ML1008, ML1009, ML1015, ML1037, ML1064, ML10111, ML10250 and ML10333. Previous reporting (KCB 2026) provides supporting groundwater information for the Kerale Dam, and Pit 11 area and the associated groundwater system. As part of this review, it was identified that secondary seepage may occur from Kerale Dam towards downgradient receptors (with Pelican Creek lying more than 2 km to the south as the potential ultimate receptor). Figure 2-1 shows the location of Kerale Dam, an ephemeral creek to the south and the Pelican Creek.

COL operations extend across nine mining leases, with Kerale Dam located in the southeast of the site within ML1064. The dam comprises an embankment constructed across a natural drainage line west of mine and was designed to store neutralised mine-affected water, capturing upstream rainfall-runoff and seepage from the Pit 11 spoils¹. Although, no Terrestrial Groundwater Dependent Ecosystems (TGDEs) have been mapped near the COL site within the DETSI dataset; the Australian Government's Groundwater Dependent Atlas² indicates potential TGDEs may be associated with the unnamed ephemeral creek immediately south of Kerale Dam and along Pelican Creek, located on the mining lease boundary.

In recognition that water stored within Kerale Dam may seep towards downstream drainage features along the more permeable shallow alluvial zones, and potentially interact with these receptors, this memorandum reviews the hydrogeological conceptualisation of the Kerale Dam area and evaluates seepage potential, using the currently available data.

¹ Details of the Kerale Dam design and surface hydrology are contained in reports by WSP, 2026 and others.

² www.bom.gov.au/water/groundwater/gde/

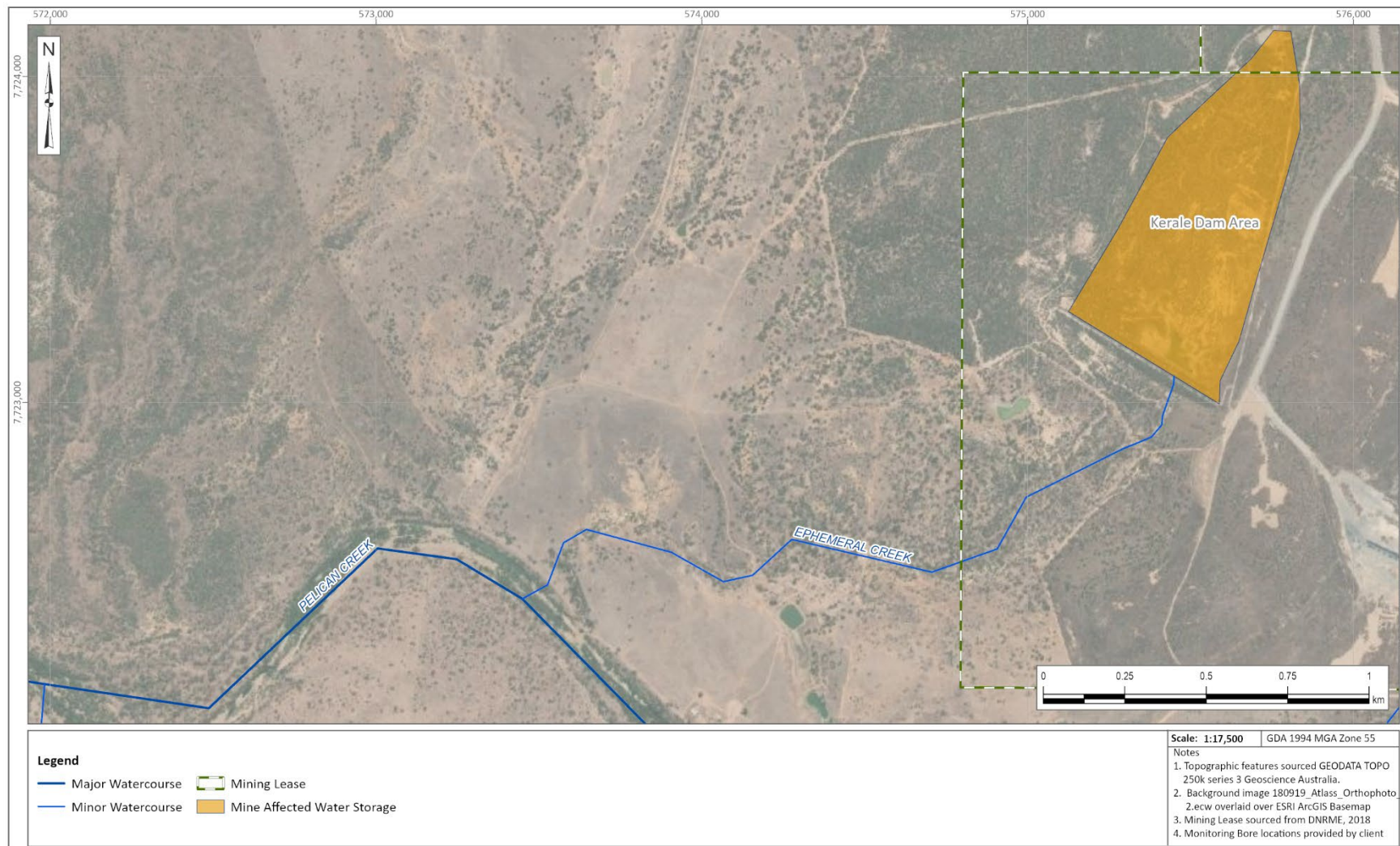


Figure 2-1 Kerale Dam, Unnamed Ephemeral Creek and Pelican Creek

3 HYDROGEOLOGICAL CONCEPTUALISATION

3.1 Topographic Setting

Kerale Dam was constructed in the early 1990s across a natural topographic low, west of the mining activities.

Design drawings illustrating the topography and location of Kerale Dam embankment are shown in Figure 3-1 and Figure 3-2 (Blain Johnson Pty Ltd 1991). These drawings show steeper terrain to the southeast, causing the dam to function as a sink for groundwater, surface runoff and spoil-derived seepage upgradient. Downgradient of the embankment, the terrain slopes towards a drainage line that reports to ephemeral watercourses (including an unnamed creek and Pelican Creek).

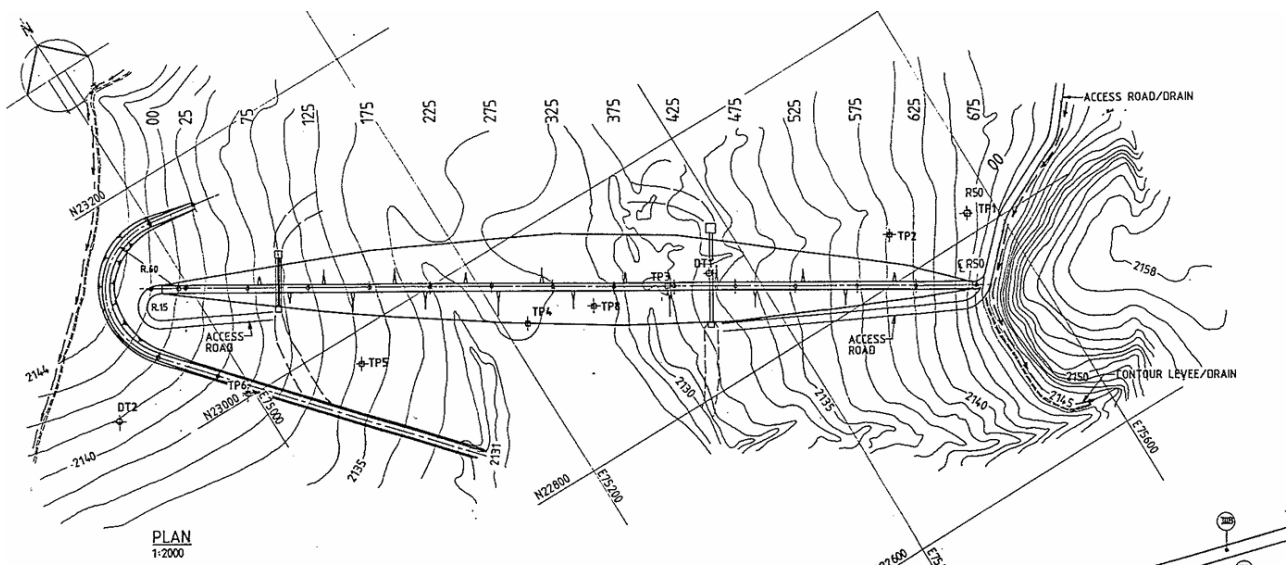


Figure 3-1 Elevation Change Across Kerale Dam Embankment (Blain Johnson Pty Ltd 1991)

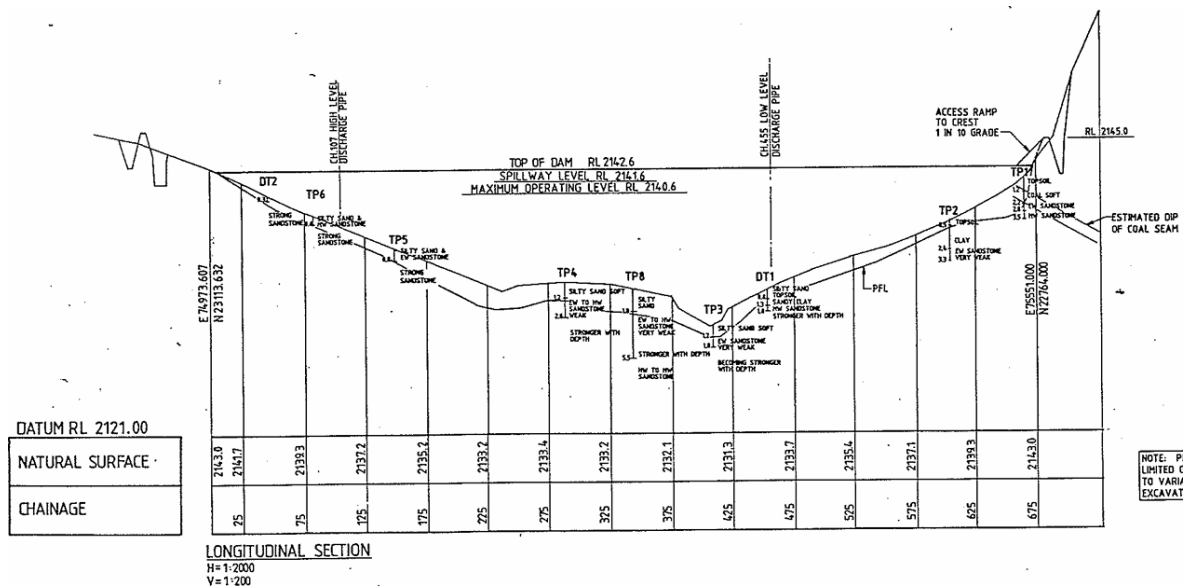


Figure 3-2 Cross-Section Drawing of Kerale Dam Embankment, Illustrating Change in Natural Surface Elevation, Northwest to Southeast (Blain Johnson Pty Ltd 1991)

The watercourses within the vicinity of the COL are ephemeral, flowing for a short time following episodic rainfall events, which typically occur during the wet season (December to March). As a result, the watercourses are considered to be ‘losing’ rather than ‘gaining’ and there is limited potential for groundwater to provide baseflow to the surface water system. As shown in Figure 2-1 there is an unnamed creek directly downgradient and south of the dam.

The valley geometry focuses surface and shallow subsurface flow toward the dam embankment and, downgradient, toward the adjacent drainage features, providing a primary control on the direction of potential seepage migration.

3.2 Site Geology

Kerale Dam is situated on Quaternary-age sediments (Qhh/m) overlying Permian-age units, including the Collinsville Coal Measures (Pbc). Immediately south of the dam, alluvial deposits (Qa), associated with Pelican Creek and its minor tributaries are mapped. The Quaternary-age sediments represent the shallow geological units most relevant to potential seepage migration beyond the dam footprint.

Alluvium (Qa and Qhh/m) are typically described as clay, silt, sand and gravel; flood-plain alluvium. Collinsville Coal Measures (Pbc) comprise Quartzose sandstone, conglomerate, siltstone, and coal.

Subsurface Conditions Beneath the Embankment

Figure 3-3 presents a cross-section through the valley beneath which the embankment was constructed. The drawing illustrates the subsurface conditions encountered during intrusive ground investigations, including test pits (TP) and dynamic tests (DT). The section reports the presence of silty sands overlying weathered sandstone of weak strength, indicating that shallow subsurface materials beneath the embankment are capable of transmitting groundwater.

The thickness of these deposits varies across the valley, being thinnest on the valley flanks (approximately 0.3 m at DT2) and increasing toward the valley centre, where a maximum thickness of 2.7 m was recorded at TP3. The sandstone is noted to increase in strength with depth; however, weathering remains evident (highly to moderately weathered) (TP8), indicating that shallow groundwater flow is likely confined to the upper weathered zone rather than deeper, less permeable rock. A low-grade weathered coal seam was encountered in the southeast in TP1, at a nominal thickness of <1 m and with significant weathering noted.

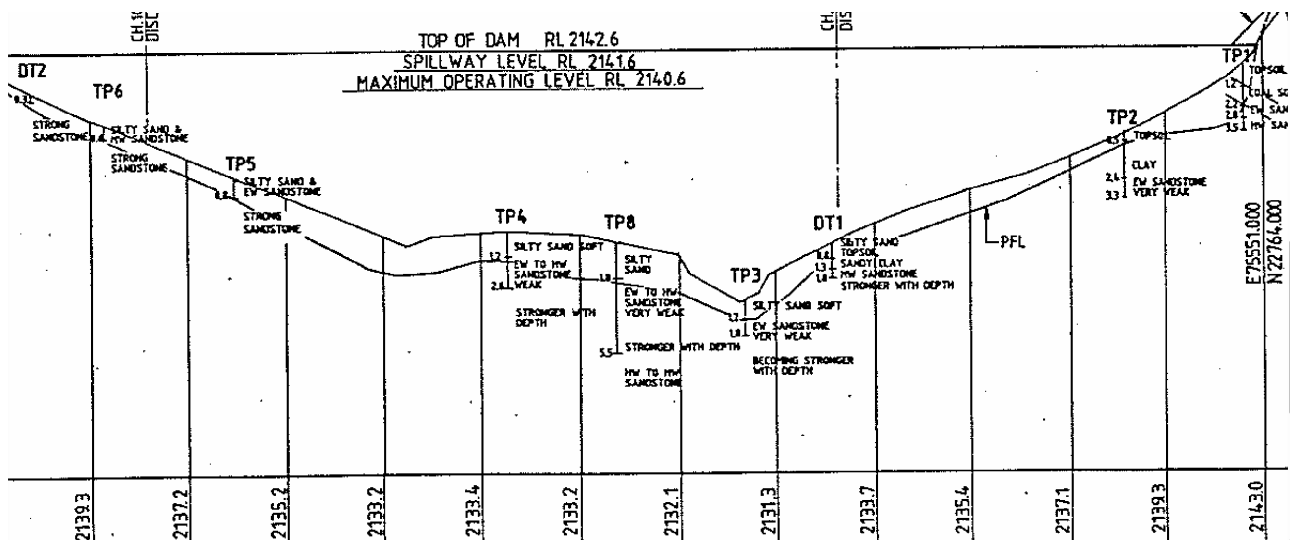


Figure 3-3 Cross-Section Drawing, Illustrating Ground Material Encountered Below the Embankment Northwest to Southeast (Blain Johnson Pty Ltd 1991)

This shallow system overlies the Collinsville Coal Measures which are a sequence of marine sedimentary rocks. The Collinsville Coal Measures comprise upper and lower members and contain sandstones, shales, mudstones, and coal seams. From the site characterisation undertaken in 2025, and the Blain Johnson (1991) descriptions, the shallow silts overlie a variable weathering profile, before the fresher sandstone is reached.

The unit of greatest interest for this document is the alluvium associated with the ephemeral creek to the south of Kerale Dam. This ephemeral creek system would have extended northwards in the current footprint of the Kerale Dam reservoir and the silty sand units around TP4 and TP8 (Figure 3-3) would provide the preferential pathway for water stored behind the embankment to seep into this narrow and shallow alluvial system.

The lithological units mapped regionally that are relevant around the Kerale Dam area are summarised in Table 3.1.

Table 3.1 Lithological Summary of Regionally Mapped Geology (DNRME 2019)

Age	Unit	Map Code	Lithological Summary
Quaternary	Alluvium	Qa and Qhh/m	Clay, silt, sand, and gravel; flood-plain alluvium.
Late Tertiary	Alluvium	T-Qa	Locally red-brown mottled, poorly consolidated sand, silt, clay, minor gravel; high-level alluvial deposits (generally related to present stream valleys but commonly dissected).
Late Permian	Blenheim Subgroup	Pbe	Carbonaceous and micaceous labile sandstone, siltstone, shale, and minor conglomerate.
Early Permian	Collinsville Coal Measures	Pbc	Quartzose sandstone, conglomerate, siltstone, and coal.

3.3 Local Hydrostratigraphy

Specifically in the vicinity of Kerale Dam, the hydrostratigraphic units of interest are:

- Quaternary Alluvium, Colluvium and Regolith.
- Underlying weathered Permian overburden.

Quaternary Alluvium, Colluvium and Regolith

Limited information is available on the characteristics and composition of the Quaternary deposits downgradient of Kerale Dam. As noted from the cross-section drawing of the Kerale Dam embankment, weathering of surficial deposits suggest they are capable of transmitting groundwater given the weak nature of the sandstone and weathering profile.

The higher permeability zone appears to be isolated to the shallow alluvial channel around the ephemeral creek. This is illustrated by the observations from bores such as RN 182866R that found a low permeability clay-rich unit dominating the profile. The two monitoring bores in the area K01 and K02 (RN 182622 and RN 182623) also indicate that the higher permeability would be associated to the close to the ephemeral creek where the sandy alluvial materials are present. Currently, K01, K02 and K03 are dedicated monitoring bores Kerale Dam with GLE01 further to the south targeting the deeper Glendoo sandstones for monitoring. Overall, this unit is estimated to be of low to moderate permeability³ and represents the primary unit through which seepage migrating downgradient of Kerale Dam would be transmitted.

Groundwater quality in alluvium across the mining area ranges between 4,000 and 16,000 mg/L, and pH is typically neutral.

Permian Overburden

This unit is estimated has variable thickness. Hydraulic tests have been undertaken (majority in Glendoo Sandstone) and indicate a low to moderate permeability, with a relatively high degree of variability.

Vertical movement of groundwater into the deeper hydrostratigraphic units is unlikely due to their comparatively low hydraulic conductivity.

³ Hydraulic Conductivity or Permeability: Very low: $<1 \times 10^{-9}$ m/s; Low: 1×10^{-9} to 1×10^{-7} m/s; Moderate: 1×10^{-7} to 1×10^{-5} m/s; High: 1×10^{-5} to 1×10^{-3} m/s; Very High: $>1 \times 10^{-3}$ m/s.

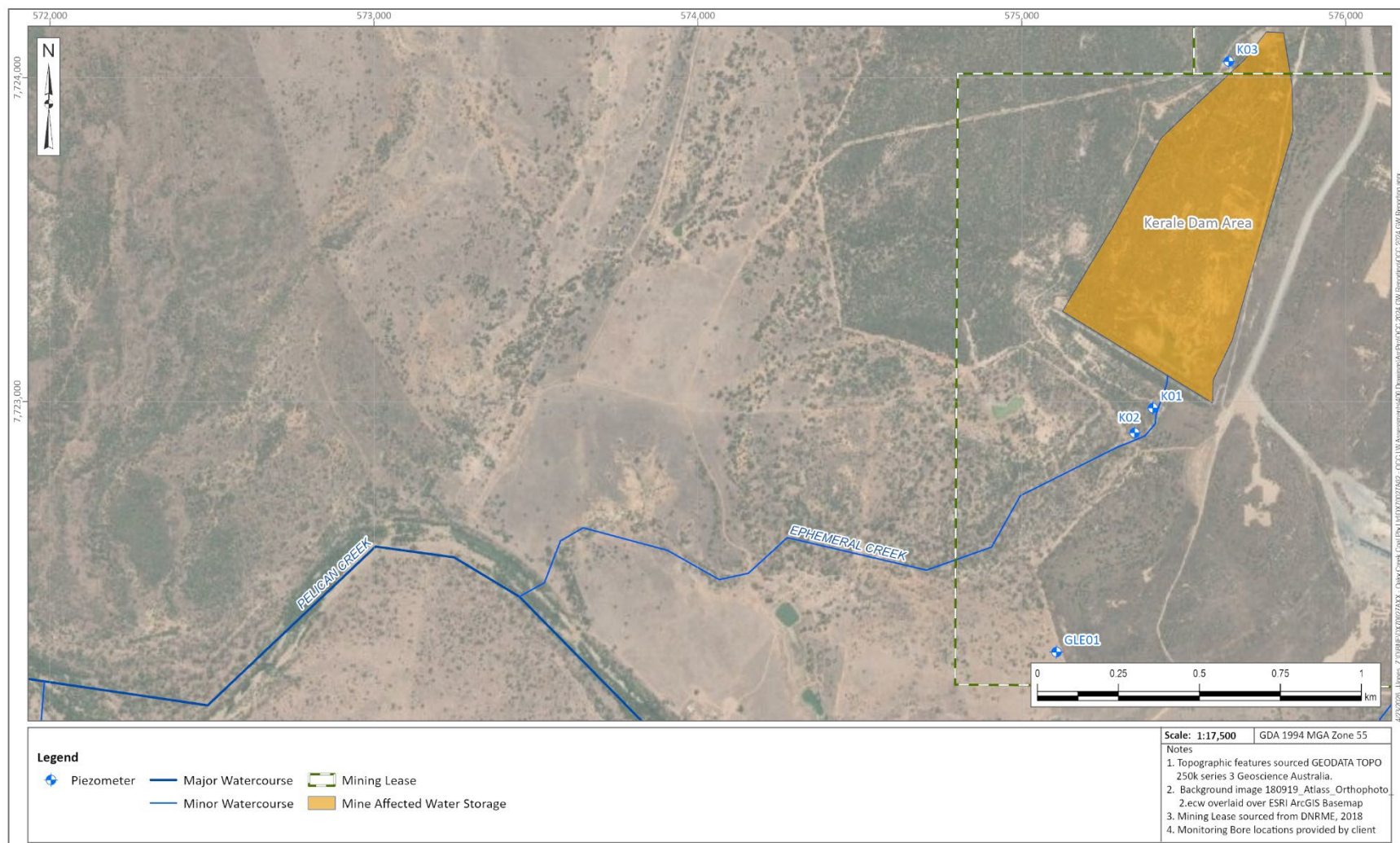


Figure 3-4 Groundwater Monitoring Bores in the Area of Interest

3.4 Dam Water Storage & Related Processes

Kerale Dam catchment areas is 64 ha, with an embankment crest height of 142 mRL (WSP, 2026).

WSP have completed a water balance for site including for Kerale Dam (WSP, 2026). WSP have reported the stored water elevation behind the embankment to vary between ~133.5 mRL and just above ~135 mRL.

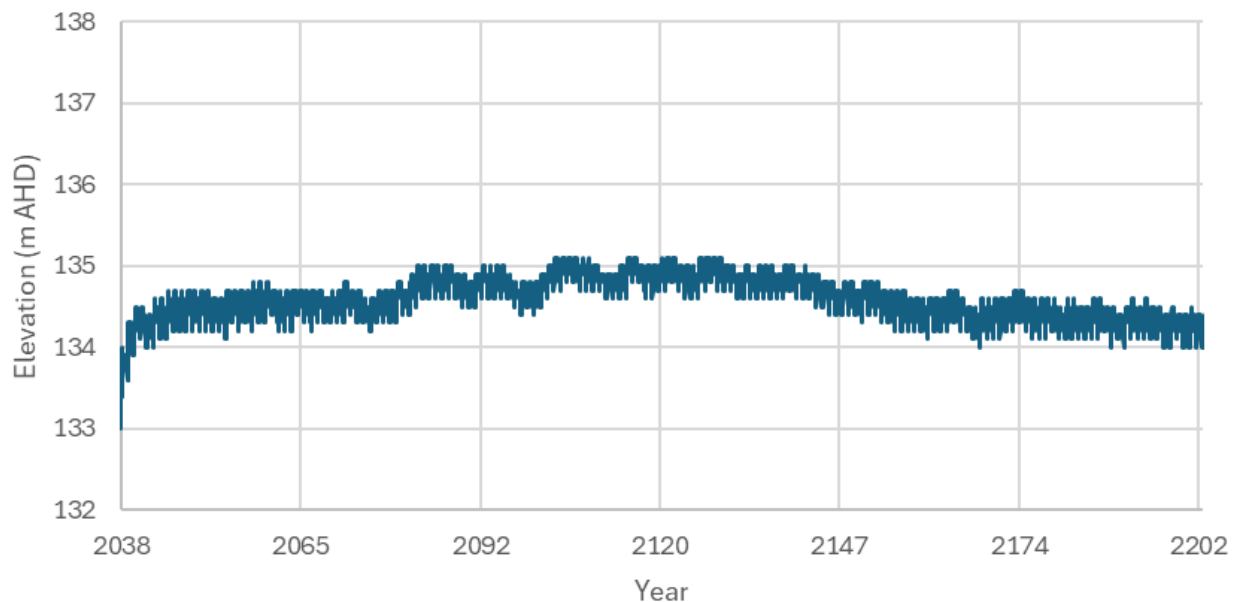


Figure 3-5 Predicted Water Level Elevations for Stored Kerale Dam Water for Full Closure Period (WSP, 2026)

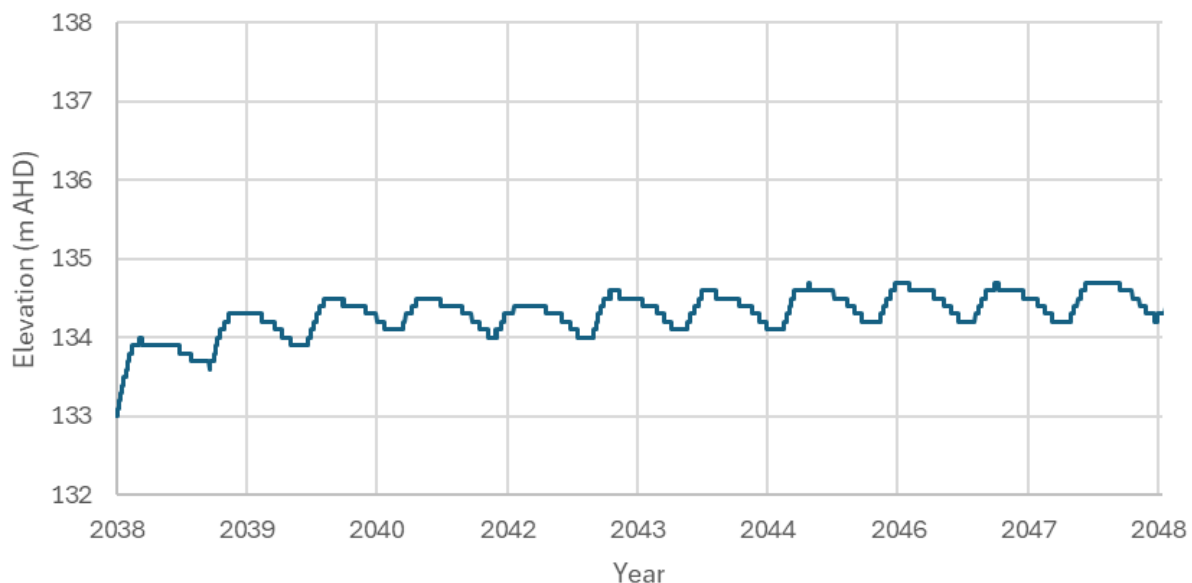


Figure 3-6 Predicted Kerale Dam Water Level Elevations 2038 to 2048 (WSP, 2026)

3.5 Groundwater Mechanisms and Seepage Migration

The system of interest in this memorandum is the connection between the stored water in the dam and the downgradient alluvium. As noted previously, the construction of the dam (without being keyed in or containing a low permeability base) and underlying subsurface material provide the opportunity for stored water to migrate through higher permeability sandy materials at the base of the embankment and into the weathered material or into the higher permeability alluvials associated with the ephemeral creek system (that now lies to the south of the dam).

Two VWP's are located downgradient of Kerale Dam, however data was not available during the writing of this report.

A summary of the conceptual model from information presented above is as follows:

Source of Water:

Upstream runoff is captured by the Kerale Dam catchment and upstream sources (described in more detail in concurrent reports from WSP, 2026 and ERM, 2026). From the groundwater perspective the dam acts as a sink which contributes a very small portion of the water balance. Due to the seasonality of rainfall around COL, the stored water volumes and elevations also follow a seasonal pattern (see in the more detailed period provided by WSP - Figure 3-6). Once water ponds in the dam, the head increases and this allows intermittent pulses to be released as function of the changing gradient between the stored water and the downgradient alluvials (which are the higher permeability zones, hydraulically connected via the sandy units underlying the embankment).

The quality of the water stored in the Kerale Dam will be variable and will likely follow an inverse relationship between the elevation. A more detailed assessment of the water quality of this stored water and the surface water flows is provided by the concurrent ERM 2026 report.

Pathways:

- A hydraulic connection is likely to exist between the unlined dam and underlying weathered and unconsolidated Quaternary deposits. This connection and the increased permeability of the sands and alluvials allowing water to migrate down gradient. Depending on the elevation of the stored water in the dam, the hydraulic gradient will vary.
- Lateral seepage migration from the dam will predominantly occur through the surficial alluvials associated with the ephemeral creek. While detailed site assessment of the alluvials in this minor system have not been undertaken, the properties of the alluvials around the site are fairly consistent. To allow a more conservative assessment of potential seepage rates, the local presence of more clay-rich units (reported from the dam design test pits and from the bores drilled more distal to the ephemeral creek).
- The alluvial deposits south (downgradient) of the dam are not well defined, but direction of groundwater movement is likely to flow towards the natural topographic low and along the drainage line.

Gradients for assessment of potential seepage rates have been based on the range of predicted water levels in the Kerale Dam and the drop in topography along the ephemeral creek drainage line.

Receptors:

- Alluvial deposits and by proximity, the unnamed creek.
- Pelican Creek will be the ultimate receptor.

Mechanisms:

Figure 3-8 to Figure 3-9 present high-level conceptual (schematic) cross-sections developed for the Kerale Dam area and downgradient towards the unnamed creek and can be used to explain the likely seepage mechanisms. Surface water is stored upgradient of the Kerale Dam embankment, with stored water elevations and associated hydraulic gradients varying seasonally in response to rainfall and drawdown conditions. The presence of higher-permeability sandy materials beneath the embankment provides a hydraulic connection between stored water and the downstream alluvial sediments. Seepage is therefore expected to occur at low rates, with migration velocities varying over time in response to changes in hydraulic gradient.

In the absence of stored water within Kerale Dam, the drainage line immediately south of the embankment would remain entirely ephemeral. The presence of stored water may result in intermittent flow within the section of the drainage line closest to the embankment; however, the small channel capacity and high rates of evaporation and evapotranspiration within the Collinsville Open Cut area mean that the majority of the creek system remains ephemeral. Flow is expected to occur only when supported by sufficient surface runoff, groundwater seepage, and/or direct rainfall. Even during these periods, groundwater levels are anticipated to fluctuate, and intervals will occur where the water table falls below the channel bed, resulting in recharge of underlying groundwater by surface water.

Any seepage plume arising from interaction between Kerale Dam and the downstream alluvial system is expected to migrate slowly, at rates on the order of a few metres per year. As seepage migrates downgradient along the drainage line, it will be subject to evaporative losses, with groundwater levels commonly remaining below the creek bed surface during drier periods. Progressive migration will be accompanied by seasonal interaction with surface water derived from catchment runoff and dam-related flows, resulting in dilution of the groundwater component. During the dry season, elevated evaporation rates are expected to further limit migration and may result in near-surface evapoconcentration of dissolved constituents, consistent with observations in other ephemeral drainage lines at the site. Where temporary accumulation of salts occurs within shallow soils, subsequent transport is expected to be dominated by surface water processes during wet-season flow events.

Overall, the magnitude of subsurface groundwater flow within the alluvial drainage system is expected to be minor relative to wet-season surface water flows, resulting in limited potential for sustained off-site transport via groundwater pathways.

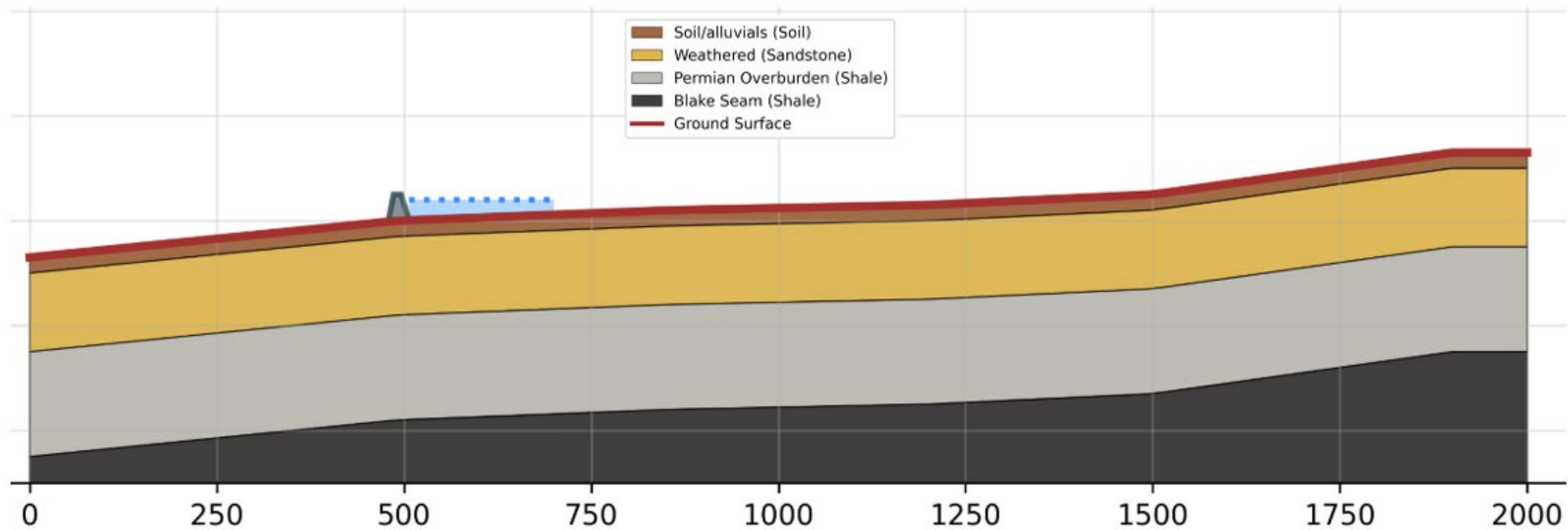


Figure 3-7 Schematic Cross-Section Kerale Dam Extent Across with Alluvial System (Not to Scale)

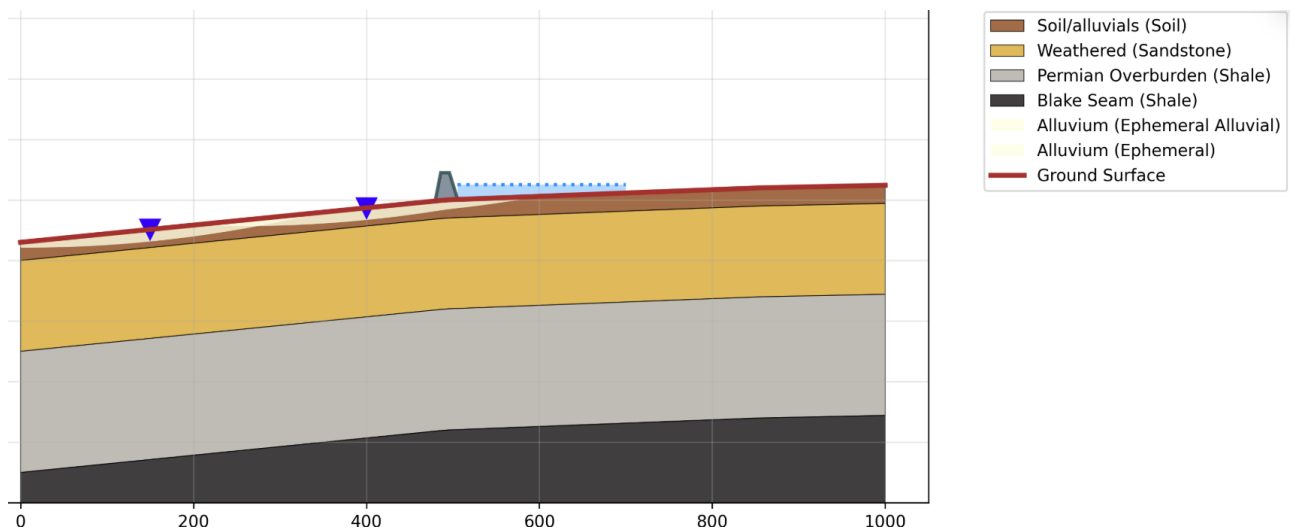


Figure 3-8 Local Scale Schematic Cross-Section Kerale Dam Alluvial System (Not to Scale)

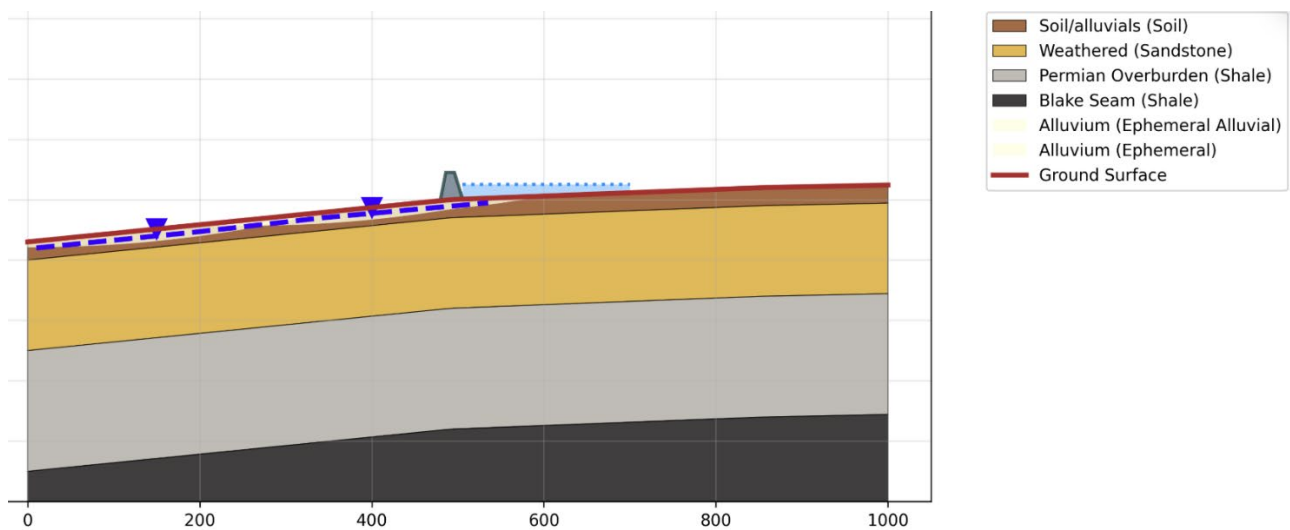


Figure 3-9 Local Scale Schematic Cross-Section Kerale Dam with Inferred Groundwater Levels in Downstream Alluvial System (Not to Scale)

4 ASSESSMENT OF SEEPAGE POTENTIAL

4.1 Embankment Details

Kerale Dam was constructed in 1991 and design drawings from Blain Johnson Pty Ltd (1991) provide information on embankment geometry. Figure 4-1 presents a cross-section through the embankment, illustrating a central clay core, with a sand filter on the downstream side, interpreted as a downstream filter or toe drain. Sandy fill is shown on the upstream face beneath a layer of rockfill. The drawing indicates stripping of vegetation and topsoil prior to construction, however, as these drawings do not represent as-constructed records, this information cannot be verified.

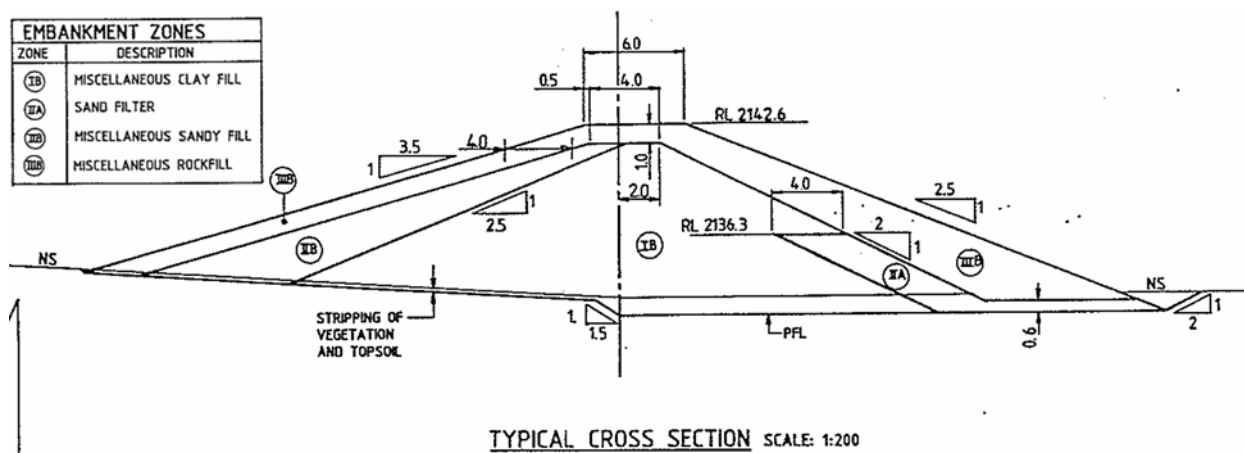


Figure 4-1 Kerale Dam Embankment Drawing (Blain Johnson Pty Ltd 1991)

4.2 Seepage Rate Estimation

The expected gradient for contaminant transport was based on the elevation of the stored water provided by WSP's water balance and the elevation of the alluvial in the creek adjacent to monitoring bore K02. WSP's water balance provides elevations of water stored in Kerale Dam to be between RL 134 m and RL 135 m. Groundwater flow velocity is the fundamental driver of advective contaminant transport. The Darcy flux (specific discharge) q [m/day] is given by Darcy's Law:

$$q = K * i$$

where K [m/day] is the saturated hydraulic conductivity and i [-] is the hydraulic gradient.

Solute transport occurs only through the connected pore space. The effective seepage velocity (seepage velocity) v [m/day] is:

$$v = q / n = (K * i) / n$$

where n [-] is the effective porosity.

Estimates used for the calculations are below:

- Hydraulic Conductivity (K) 0.5000 m/day.
- Effective Porosity⁴ 0.2500.
- Hydraulic Gradient (i) 0.01.

From this, an average effective seepage velocity of ~0.02 m/day was calculated.

Based purely on advective transport assumptions, this translates to groundwater movement of approximately 7 m/year along the inferred downgradient flow path using the assumptions above. Since the gradient would vary over time and the properties of this alluvial system have not been characterised in detail for this specific reach, a stochastic approach was taken to estimate potential seepage velocities. 10,000 realisations were simulated in GoldSim to provide an envelope of potential rates of seepage that may occur per year.

- 10% 2.21 m/year.
- 25% 3.28 m/year.
- 50% 4.73 m/year.
- 75% 6.49 m/year.
- 90% 8.54 m/year.
- Mean 5.12 m/year.

An alternative assessment was undertaken (Figure 4-2) using expected variances rather than specific ranges. This provided a similar outcome in terms of expected seepage velocity.

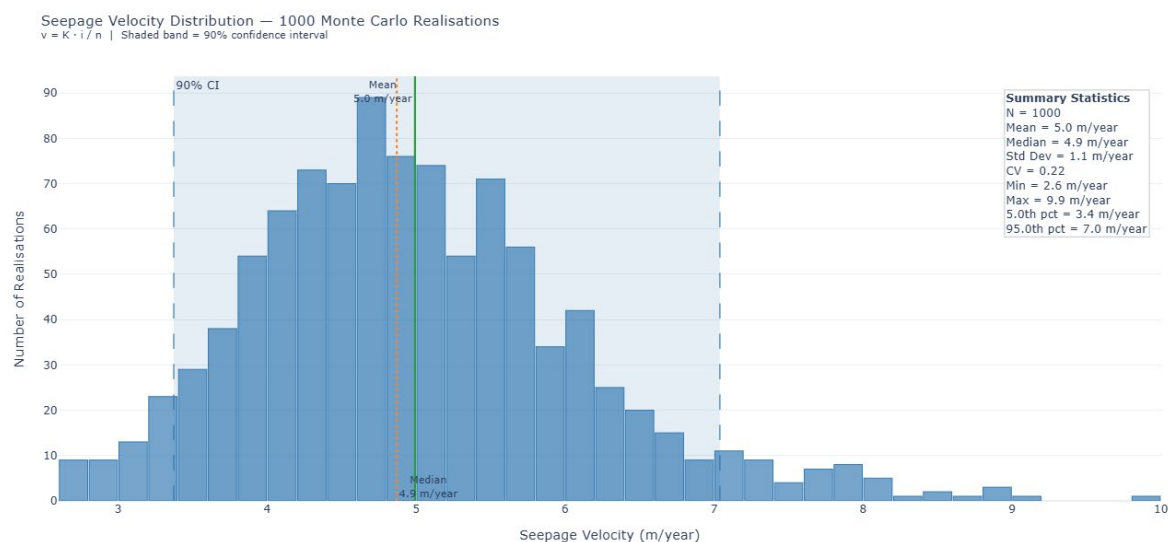


Figure 4-2 Stochastic Estimates of Seepage Velocity in the Ephemeral Alluvials as a Result of Stored Water in Kerale Dam

⁴ Based on porosity ranges summarised by Davis (1969) in (Freeze and Cherry 1979), sand/silt porosity (n) ranges 25-50 %

4.3 Analytical Contaminant Transport Assessment

Plume migration from Kerale Dam is predicted to be slow and limited in spatial extent, with transport constrained to shallow regolith and alluvial pathways. Interaction with deeper hydrostratigraphic units is unlikely due to their comparatively low hydraulic conductivity, which is consistent with the conceptual hydrogeological model. Model results indicate gradual plume migration toward a minor drainage feature located south of Kerale Dam, with transport times on the order of centuries for any plume moving directly south before potential interaction with Pelican Creek.

Since the transport along the alluvial system in this ephemeral creek would be associated with significant mixing with other sources of runoff, it can be expected that the plume would be progressively diluted.

The Domenico (1987) analytical equation was used to simulate three-dimensional contaminant transport in a homogeneous, isotropic aquifer under steady-state flow conditions. The model accounts for advection and hydrodynamic dispersion (longitudinal, horizontal transverse and vertical transverse) from a finite-area continuous source.

Contaminant transport in saturated porous media is governed by the Advection-Dispersion Equation (ADE), which describes the combined effects of advective transport (bulk movement with groundwater), hydrodynamic dispersion (mechanical mixing and molecular diffusion), and any source/sink terms. In three dimensions, for a conservative solute under steady, uniform flow in the x-direction, the ADE takes the form:

$$dC/dt = D_L*(d^2C/dx^2) + D_{th}*(d^2C/dy^2) + D_{tv}*(d^2C/dz^2) - v*(dC/dx)$$

where C [mg/L] is concentration, t [days] is time, v [m/day] is seepage velocity, and D_L , D_{th} , D_{tv} are the longitudinal, horizontal transverse, and vertical transverse dispersion coefficients respectively.

Analytical solutions to the ADE are possible under idealised boundary and initial conditions. The Domenico (1987) solution is one of the most widely applied, offering a closed-form expression for a continuous, finite-area source.

A Monte Carlo stochastic analysis using the Domenico approach was performed using 1,000 realisations. Parameter uncertainty was characterised using triangular probability distributions. Concentration profiles were computed at the following time points: 365 days (1 year), 730 days (2 years), 36525 days (100 years), 182625 days (200 years), 73050 days (500 years).

For this assessment, it was assumed that a 500 m transport length down the alluvial sediments associated with the ephemeral was appropriate. The analysis point is located 500 m downgradient of the source and to represent the source a value of “100” was used so that a percentage of source concentration could be estimated.

The calculations show that under the specified conditions the plume could migrate significant distances, but that rate of mass transfer would be low, resulting in significant reduction in

concentrations (depending on specific combinations and distributions selected in the assessment, the concentration reaching the observation point ~ 500 m from the Kerale Dam embankment would reach between ~ 10% to 30% of the source).

An example is provided in Figure 4-3 where a 500-year simulation with 1,000 realisations and a triangular distribution of input parameters has been assumed (as indicative of the process). Figure 4-4 shows all Monte Carlo simulation results with a peak mean concentration of ~ 19% (i.e. ~ 20% of the Kerale Water Dam concentrations).

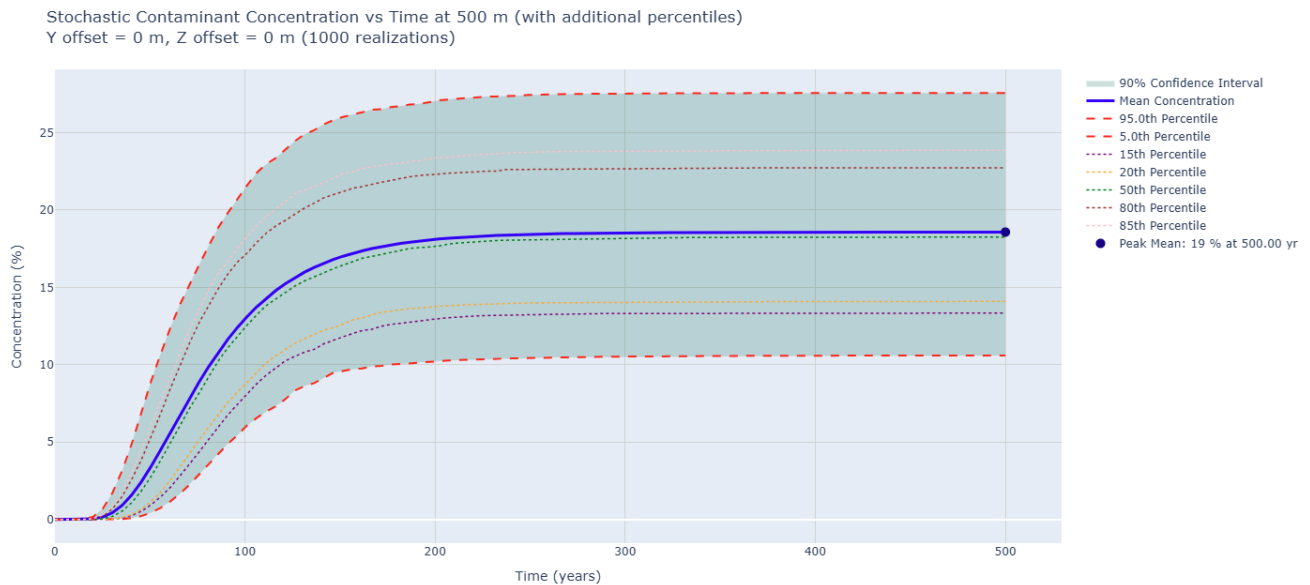


Figure 4-3 Domenico Estimate of Contaminant Transport from Kerale Dam (Concentrations are Relative to the Concentration in Kerale Dam)

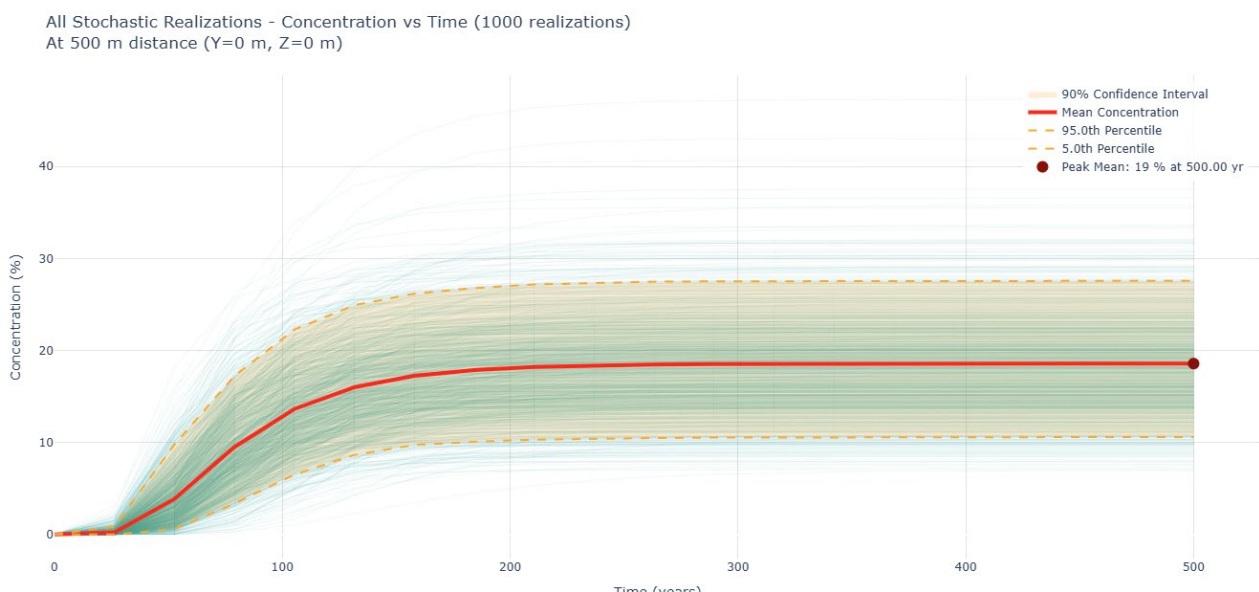


Figure 4-4 All Monte Carlo Simulation Results

4.4 Limitations and Uncertainty

The following points have been identified as limitations and uncertainties in this review:

- The water quality profile of the stored Kerale Dam is not yet defined.
- While hydraulic properties of alluvial are available across the site, a targeted site investigation of the alluvials in the ephemeral channel south of Kerale Dam has not been completed to provide an understanding of the extent, depth and variability in this material.
- The depth to intact rock beneath the embankment is inferred from the design drawings and the test pits undertaken at the time. No as-built drawings are available.
- The assessment has based the hydraulic gradient on the projected water elevations in the dam and the topographical information related to the ephemeral creek. The seasonal depth of surface and subsurface water levels in this zone which is expected to act as preferential pathway is not well understood and there are dedicated instruments to measure these levels have not yet been installed.
- The analytical approach is subject to several inherent limitations too. The Domenico analytical solution is an approximate analytical model with the following key assumptions and limitations:
 - ◆ Steady-state, uniform flow - Constant, spatially uniform groundwater velocity. Transient flow, recharge zones, or heterogeneous K fields are not represented (to account for these, the stochastic approach has been included in this memorandum).
 - ◆ Continuous, constant-concentration source - Source maintains constant C_0 for the whole simulation. This means that the pulse source nature of the Kerale Dam interactions is not accurately considered; the analytical constant/continuous concentration likely overestimates the plume migration from Kerale Dam.
 - ◆ Conservative solute mass transport is assumed. The estimated plume migration included in this report does not include solubility constraints, retardation (sorption), biodegradation or other transformation processes. The Domenico approach will likely overestimate concentrations for reactive contaminants.
 - ◆ Contaminant migration is assumed to occur in a homogeneous, isotropic medium and dispersivity values are constant throughout the domain.

Despite these limitations, the Domenico solution provides a rapid, transparent, and defensible screening-level estimate of contaminant plume behaviour. It is widely accepted by regulatory agencies for preliminary risk assessment and natural attenuation evaluations (USEPA, 1998; ASTM, 1998).

5 OVERALL CONCLUSION

The hydrogeological conceptualisation and seepage assessment indicate that groundwater movement associated with Kerale Dam is predominantly shallow, slow, and controlled by local topography and surficial alluvial materials. Predicted seepage rates and transport modelling, undertaken using conservative assumptions, predict that any downgradient migration along the unnamed ephemeral creek would occur over extended timeframes and would be subject to substantial seasonal dilution from runoff and surface water. Although, the ephemeral creek represents the preferred flow path, extending approximately 2.7 km before reaching the Pelican Creek, slow migration rates combined with system seasonality and expected dilution (to be confirmed by the concurrent surface water quality study being completed by ERM) suggest that potential impacts would be limited, likely extending no more than several hundred metres from the dam embankment.

6 CLOSING

We would like to thank you for the opportunity to work on this assignment. Should you have any questions, please do not hesitate to contact the undersigned.

This memo is an instrument of service of Kohn Crippen Berger (KCB). The report has been prepared for the use of COL (Client) for the specific application to the Kerale Dam NUMA submission, and it may not be relied upon by any other party without KCB's written consent.

KCB has prepared this report in a manner consistent with the level of care, skill and diligence ordinarily provided by members of the same profession for projects of a similar nature at the time and place the services were rendered. KCB makes no warranty, express or implied.

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2. The observations, findings and conclusions in this report are based on observed factual data and conditions that existed at the time of the work and should not be relied upon to precisely represent conditions at any other time.
3. The report is based on information provided to KCB by the Client or by other parties on behalf of the Client (Client-supplied information). KCB has not verified the correctness or accuracy of such information and makes no representations regarding its correctness or accuracy. KCB shall not be responsible to the Client for the consequences of any error or omission contained in Client-supplied information.
4. KCB should be consulted regarding the interpretation or application of the findings and recommendations in the report.

Yours truly,

KLOHN CRIPPEN BERGER



Brent Usher, PhD, RGeo
Senior Hydrogeochemist, Principal
Project Manager

RC:BU/SW

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