



Tāiko Critical Minerals Ltd

Report No: Z24011BTS-2-FIN

## **Barrytown South Mineral Sand Project – Hydrological Effects Assessment**

25 May 2026 FINAL-B

## **Kōmanawa:**

- 1. (verb) spring, well up (of water)**
- 2. (verb) to spring, well up (of thoughts, ideas)**

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## Executive Summary

Tāiko Critical Minerals Limited (TCM) propose developing a mineral sand mine in the central, coastal parts of the Barrytown Flats on New Zealand’s West Coast. The mineral sand deposits have accumulated as a series of raised beach deposits and strandlines in the Holocene epoch (i.e., the last 10,000 years before present), as a result of long-shore sediment drift from the south and concentration by wave action on strandlines. The economically exploitable mineral sand resource extends to a depth of approximately 10 metres, which coincides with the proposed depth limit of sand mining. TCM is seeking consent to undertake mineral sand mining over an area of approximately 280 ha (covered by Mining Permit MP 60785) within two blocks, owned by the farming companies known as Moir Farms Maimai Limited, Cargill Rd Barrytown Limited, Barrytown Farms Limited and Nikau Deer Farm along with a small portion of road reserve owned by the Grey District Council. This mineral sand project area is referred to as Barrytown South or the Southern Block (SB).

The proposed mining area encompasses a shallow, but stratified, coastal groundwater system replenished by creek infiltration and lesser soil drainage in overlying farmland. Much of the Barrytown Flats was cleared forest or back-dune wetlands and has also been subjected to gold dredging in the early part of the previous century. Measured hydraulic conductivity is variable according to sediment grain-size and texture, but ranges from 0.5 to 15 metres per day (m/d). Groundwater traverses the coastal groundwater system from east to west and discharges at farm drains, creeks, and into the Tasman Sea *via* submarine seepage. The chemical composition of groundwater in the Barrytown Flats coastal strip is fresh but enriched with dissolved metals as a result of low dissolved oxygen content of the water and reducing geochemical reactions in the presence of organic materials.

The proposed mining area occupies the coastal strip between Canoe Creek and Fagan Creek. In addition, several smaller creeks traverse the proposed mining area, including those of the Granite catchment. These creeks have their headwaters in the Paparoa Range with its summit at an elevation of 1,220 metres above mean sea level (AMSL) and steep bed gradients averaging 1 in 3.8. The Granite Creek main stem at the Little Granite Creek confluence is projected to have the following flow characteristics, plus flow statistics for surrounding creek catchments modelled for the coastline or eastern mining area margin –

Granite Creek Catchment at Confluence		Value				
Catchment Area (sq. km)		5.06				
Mean slope (ratio)		1 in 3.8				
1 in 10-year, 1 hour ARI Flood Flow (L/s)		8,730				
Mean Annual Flood, AEP of 0.633 (L/s)		5,290				
SB Creek Catchment	Catchment Area (km)	Mean (L/s)	Median (L/s)	MALF <sub>7d</sub> (L/s)	1-in-5 Year Low Flow (L/s)	FREQ3 (events/y)
Northern Ck @ Coast	0.672	26	14	43	2.7	31.7
Central Ck @ Coast	0.545	21	12	3.5	2.2	31.8
Clarke Ck @ margin	1.474	60	34	11	7.2	33.1
Little Granite Ck @ margin	1.574	141	76	20	15.7	31.3
Granite Ck @ margin	4.268	435	232	55	42.8	34.0
Wasabi Ck @ Coast	1.193	46	25	7.5	0	33.5

Creeks would be re-routed by temporary dogleg diversions around the active dredge pond as it passes. The Granite Creek main stem would not be disrupted by mining, instead the water course would truncate the mine path between the mining sections 1 and 2, with the active pit continuing from a starter pit at section 2 on the southern side of Granite Creek. This approach would maintain the flood-way of the Granite catchment across the coastal plain without interruption throughout the period of mining and restoration.

The proposed mineral sand mining operation would take 14 years to mine the Southern Block, allowing the 1 ha dredge pond to maintain a natural water level approximating the ambient water table height. Dewatering, the lowering of the water table to allow mining of mineral sand, would not be required. Despite the absence of dewatering, water surface rectification by the temporary pond and open water evaporation could slightly lower the dredge pond water level from that of the ambient water table. However, surcharging of the dredge pond with surplus returning water in the tailings deposition may mildly offset this potential water table lowering. Creeks and farm drains on the coastal plain are strongly connected to the underlying shallow groundwater system, which provides a degree of re-balancing of hydrological patterns surrounding the active dredge pond.

The proposal includes location of the Wet Concentrator Plant (WCP) on the eastern edge of the Southern Block, which has been separately authorised. The active mine void would be connected with the WCP by pressurised slurry lines crossing land between the two. The WCP would dispatch the processed Heavy Mineral Concentrate (HMC or Concentrate) with adherent moisture in trucks *via* the access road to SH6 and road route to Rapahoe. Mined and processed sand with mineral content below the cut-off becomes tailings, which would be returned *via* slurry lines to the back of the active dredge pond for spreading and back-filling of the mine void, ahead of eventual rehabilitation of the land.

The net effects of perturbation of the water table by sand mining operations would not give rise to the intrusion of seawater or brackish water into the groundwater system. Likewise, the penetration of fine sediments down to clay sized particles from the dredge pond or tailings would be limited to 40 metres lateral spread due to inherent filtration effects affecting the fine suspended particles. This substantially limits the extent to which dredging derived turbidity could be released to surrounding surface water *via* the subsurface. Long-term effects of the mining disturbance would also be negligible. Groundwater properties would not go through any significant changes following deposition of tailings to the mine void and land rehabilitation, so pre-existing groundwater flow patterns would re-establish in the wake of active sand mining. Geochemical effects have been assessed by Ecological Solutions, however combined assessments have included SPLP leachate analysis of bulk samples processed to emulate Run of Mine ore, tailings and heavy mineral concentrates, and modelling of ultimate concentrations. Lime dosing has also been trailed, which indicated that most of the metals and metalloids could be substantially reduced by the introduction of small doses of lime, particularly as crushed limestone, at sites of tailings deposition when they are emplaced in the tailings reception area.

Post closure rehabilitation would include remedying of the loss of 6.73 ha of natural inland wetland fragments throughout the mining area with at least 50 ha of constructed wetlands. Individual component areas of the wetlands to be constructed would be initially formed during the backfilling of tailings. The wetlands complex would include marshes and fens at a range of water depths from up to 2 metres, but including flaxlands, rushlands and expanses of raupo.

The upgradient Clarke Creek network would connect readily with open leads of fens and release net quantities of creek flow into water courses traversing rehabilitated dry land to the sea. Granite Creek including Little Granite Creek would be channelled through the wetland complex to the coast. Existing creek mouths and hāpua would be maintained from the pre-mining drainage patterns between the wetlands complex and coastline.

# Contents

Executive Summary.....	1
1 Background.....	9
1.1 Objectives.....	10
1.2 Report Structure .....	10
2 Site Setting Information .....	11
2.1 Information Sources.....	11
2.2 Location.....	11
2.3 Topography.....	12
2.4 Climate.....	13
2.4.1 Rainfall.....	13
2.4.2 Evaporation .....	15
2.5 High Intensity Rainfall.....	15
2.6 Geology.....	16
2.6.1 Regional & Basement Geology .....	16
2.6.2 Holocene Sedimentology .....	16
2.7 Hydrology.....	20
2.7.1 Setting .....	20
2.7.2 Previous Hydrometric Programmes .....	20
2.7.3 Additional Hydrological Estimations .....	24
2.7.3.1 Modelled Flow Statistics.....	24
2.7.3.2 Measured Nearby Flow Characteristics.....	26
2.7.3.3 Relevance of Collins Creek to Southern Block Creeks.....	26
2.7.3.4 Modelled High Flood Flows under High Intensity Rainfall.....	26
2.8 Groundwater Hydrology.....	29
2.8.1 Previous Studies .....	29
2.8.2 Aquifer Properties Determined in 1989.....	31
2.8.2.1 Pumping tests.....	31
2.8.2.2 Pneumatic Slug Tests .....	31
2.8.3 Hydrogeological Interpretation.....	34
2.8.4 Water Table and Surrounding Water Levels, 1989 - 1990.....	35
2.8.4.1 Horizontal Water Level Patterns .....	35
2.8.4.2 Barrytown South Horizontal Flow Rates .....	36
2.8.4.3 Vertical Water Level Patterns.....	37
2.8.5 Aquifer Properties Determined from 2022 and 2023.....	38

2.8.5.1	Pumping and Injection Tests.....	38
2.8.5.2	Slug Testing.....	41
2.8.5.3	Groundwater Level during 2022.....	42
2.8.5.4	More Recent SB Groundwater Measurements.....	44
2.9	Water Quality.....	45
2.9.1	Historic Water Quality Information.....	45
2.9.1.1	Groundwater Dissolved Metals.....	45
2.9.1.2	Metalliferous Sands Leachate Concentrations in the Southern Block.....	47
2.9.1.3	Salinity in Ground and Surface Water.....	47
2.9.2	Recent Water Quality Information.....	48
2.9.2.1	Granite Creek.....	48
2.9.2.2	Groundwater.....	48
2.9.3	2026 Lime Dosing Trial.....	51
3	Barrytown South Sand Mining Project – Project Description.....	52
3.1	Extent and Basic Description.....	52
3.2	Salient Water Management Aspects of the Proposal.....	55
3.2.1	Sand Mining.....	55
3.2.2	Water Supply.....	55
3.2.2.1	Canoe Creek Direct Take or Bank Infiltration Gallery.....	56
3.2.3	Mining Water Balance.....	57
3.2.4	Alterations to the Drainage Network.....	59
3.2.4.1	Creek diversions.....	60
3.2.5	Water Quality.....	61
3.2.5.1	Lime Dosing.....	61
4	Assessment of Hydrological Effects.....	62
4.1	Summary of Sand Mining Potential Effects.....	62
4.2	Summary of Water Supply Potential Effects.....	62
4.3	Summary of Alterations to the Drainage Network and Potential Effects.....	62
4.4	Summary of Shifts in Water Quality and Potential Effects.....	62
4.5	Dredge Pond Potential Effects.....	63
4.5.1	Void Permeability Change.....	63
4.5.2	Evaporation.....	65
4.5.3	Surcharged Dredge Pond.....	66
4.5.4	Disrupted Creek Network.....	66
4.5.4.1	East – West, sea-draining creek catchments.....	66
4.5.4.2	Granite Creek catchment.....	66

4.5.4.3	Flood Capacity.....	68
4.5.5	Changed Ground Properties and Volumes.....	69
4.5.5.1	Change in Grainsize .....	69
4.5.5.2	Compaction and Consolidation .....	69
4.5.5.3	Loss of Volume.....	69
4.6	Encountering Above-Ground Artesian Pressures .....	69
4.7	Water Quality Effects .....	70
4.7.1	Seawater Intrusion.....	70
4.7.2	Dredge Pond Turbidity.....	71
5	Effects Management.....	73
5.1	Avoidance, Minimisation and Remedies .....	73
5.1.1	Avoidance.....	73
5.1.2	Minimisation.....	73
5.1.3	Remedies .....	73
5.2	Management of Effects on Creeks .....	76
5.2.1	Clarke Creek and Granite Creek main stem .....	76
5.2.2	East – West Oriented Creeks.....	76
5.3	Management of Effects on Wetlands.....	77
6	Proposed Water Management.....	78
6.1	Context .....	78
6.2	Management Goals and Objectives .....	78
6.2.1	Hydrological Effect Goals.....	78
6.2.2	Water Management Objectives.....	78
6.3	Monitoring Envelope.....	79
6.3.1	Rainfall Monitoring .....	79
6.3.2	Creek Hydrological Monitoring .....	79
6.3.3	Groundwater Level Monitoring.....	80
6.3.4	Surface Water Monitoring (Water Quality).....	80
6.3.5	Mine Impacted Water Monitoring.....	82
6.4	Water Management Outcomes .....	82
7	Conclusions .....	83
8	References Cited .....	86
	Appendices.....	89
	Appendix 1. Groundwater Results from Nikau Deer Farm CB Block (09/11/2022).....	90
	Appendix 2. Collins Creek (“CC”) Upstream (“US”) & Downstream (“DS”) Dissolved Analysis Results from CB Block Water Bodies.....	91

Appendix 3. Canoe Creek Lagoon & Northern Boundary Drain Dissolved Analysis Results from CB Block .....	94
Appendix 4. Nikau Deer Farm, CB: HMC, Tails, Slimes and ROM water quality results.....	96
Appendix 5. Barrytown Farms Ltd: HMC, Tails, Slimes and ROM water quality results .....	97
Appendix 6. Unexpected Artesian Pressure Interception Protocol .....	99

## Figures

Figure 1: Location of Barrytown on the South Island West Coast.....	11
Figure 2: Barrytown South Project Area (shaded), main block and southern extension south of Cargill Road .....	12
Figure 3: NIWA map colour flood of median annual rainfall.....	14
Figure 4: Mapping of local geology and Nine Mile Formation deposits (Suggate, 1989).....	18
Figure 5: Mineral resource estimation and Holocene lithological domain profiles through the Barrytown South landform based on (Aldrich et al., 2023).....	19
Figure 6: Canoe Creek stage hydrograph 1 June 1990 to 8 November 1990, prior to rating curve correction .....	21
Figure 7: Canoe Creek flow hydrograph in litres per second after rating for the same period as Figure 6, above.....	21
Figure 8: Outline map of Barrytown Flats catchments reproduced from Coffey Partners (1991).....	22
Figure 9: Barrytown creek catchment boundaries of individual watersheds.....	25
Figure 10: Measured Collins Creek flow rate from 4 May to 8 November 2022 at the creek’s SH6 crossing .....	26
Figure 11: Granite catchment highlighted showing Granite, Little Granite & Clark creeks.....	27
Figure 12: Bed profile of Granite Creek (west to east).....	28
Figure 13: Time separated satellite images of middle Granite Creek showing flood damage from late 2022 .....	29
Figure 14: Location of Coffey Partners’ nearby test and observation bores across the Southern Block.....	30
Figure 16: Illustration of pneumatic test set-up, including the assembly clamped to bore casing .....	32
Figure 17: West – east hydrogeological cross-section line along the VA transect alignment.....	34
Figure 18: West – east hydrogeological cross-section line along the UK transect alignment.....	34
Figure 19: West – east hydrogeological cross-section line along the CAR transect alignment.....	35
Figure 20: Water table contours utilising 1989 AMSL groundwater levels from the shallow piezometers.....	36
Figure 21: Step filling and recovery of a sandy cobble gravel layer cut by a shallow trench or basin.....	40
Figure 22: Slug test displacement matching and result from falling head test on 32 mm piezometer PZ-841 .....	42
Figure 23: Slug test displacement matching from falling head test on 50 mm diameter bore CE-3m.....	42
Figure 24: Location of piezometers groundwater measurement points across the Nikau Deer Farm block (CB).....	43
Figure 25: Composite groundwater elevation plot of six continuous level hydrographs across Nikau Deer Farm .....	43

Figure 26: PZ-05 and -07 groundwater level over 5 day period, showing tidal signature.....	44
Figure 27: Groundwater elevation plot of three continuous level elevations across Barrytown South .....	44
Figure 29: Groundwater sampling bore CAR1 on the coastline (Coffey & Partners, 1991) .....	47
Figure 30: Location of the Southern Block mining areas (shaded) plus WCP .....	52
Figure 29: Lateral, coast-parallel progression of mine path, light pink is unmined .....	53
Figure 30: Schematic representation of the dredge pond and dredge in plan view (above) and profile (below).....	55
Figure 31: Location of proposed WCP water supply intake on Canoe Creek.....	56
Figure 32: Example of infiltration gallery construction [photo credits to Butt Drilling Ltd (buttdrilling.co.nz)] .....	57
Figure 33: Approximate water circuit transfer rates between dredge pond to WCP and back to the pond again .....	58
Figure 36: Detailed drainage network focusing on low-lying creeks .....	59
Figure 35: Schematic profile representation at exaggerated vertical scale of the ambient water table and void.....	63
Figure 38: Estimate of reduction in water table drop as a function of radius from the pond edge .....	65
Figure 39: Simplified mapping of creeks classed as rivers in terms of the RMA .....	67
Figure 41: Proposed post closure rehabilitation of the former mineral sand mining area in the SB with 51.7 ha of wetlands (Metcalf & Huxtable, 2025) .....	75
Figure 42: Mapping of the formation of 31 component wetland ponds before final rehabilitation .....	<b>Error!</b>
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Figure 43: 1990s-era Canoe Creek hydrological site at SH6 bridge pylon, including sight board and river stage sensor cables (Coffey & Partners, 1991) .....	80
Figure 44: Creek mouth monitoring sites for surface water and groundwater .....	81

## Tables

Table 1: Monthly & Annual Rainfall data for the period 1981–2010 (Macara, 2016).....	13
Table 2: Dry spell frequency, duration and seasonal distribution (Macara, 2016).....	14
Table 3: Seasonal distribution of Dry Spells (Macara, 2016) .....	15
Table 4: Median Evaporation / Evapotranspiration Measurements for Westport and Greymouth.....	15
Table 5: Instantaneous flow measurement data across the Barrytown Flats creek catchments (from Coffey Partners, 1991) .....	23
Table 6: Summary of hydrological data from NZ River Maps Flows for Barrytown Flats creek catchments .....	24
Table 7: HIRDS derivation of Granite and Little Granite at Confluence, Peak Flow Rate.....	28
Table 8: Coffey Partners (1991) Test bores along Sections within the Central and Southern Blocks .....	30
Table 9: Interpreted pumping test results for five Barrytown Flats test bores along Burke Rd, CB and SB31 .....	
Table 10: Summary of pneumatic slug test results closest to proposed sand extraction area at Barrytown South .....	32

Table 11: Comparison of pumping test and pneumatic slug test results (all Barrytown results) .....	33
Table 12: Interpretative assignment of hydraulic conductivities per formation/strata.....	33
Table 13: Estimation of SB Groundwater Flow Rates at three arbitrary Flow Fronts .....	37
Table 14: Summary of calculated vertical hydraulic gradients between paired shallow and deep piezometers or bores.....	38
Table 15: Combined Groundwater Properties from two sets of testing within the Nikau Deer Farm Block .....	39
Table 16: Nikau Deer Farm CB Groundwater quality screening assessment summary.....	46
Table 17: Nikau Deer Farm, deeper 16.5 m Injection Bore sampled (Sept. 2023) and analysed.....	46
Table 18: Process (Shake Test) water quality screening assessment summary .....	47
Table 19: Granite Creek catchment surface water quality results for samples taken 8 – 9 April 2024 .....	49
Table 20: SB groundwater water quality results for samples taken 8 – 9 April 2024 .....	50
Table 21: Synthetic Precipitation Leaching Procedure (SPLP) Leachate Test Results of Lime Dosing Trail .....	51
Table 22: Approximate Water Exchanges comprising a Water Balance for the SB Mining Operation.....	58
Table 23: Specified calculation parameters for estimating Water Table Drop .....	64
Table 24: Summary of NZ River Maps Hydrological Statistics for Barrytown Creeks .....	68
Table 25: Coffey Partners’ piezometers behind foredune at coastline with water levels on 30/08/1990 .	71
Table 26: Ngahere gold dredge (Thorpe, 1990) reduction in suspended particle size within groundwater .....	72
Table 27: Quantity of Mine Void Passes and Dogleg Diversions .....	77

# 1 Background

The Barrytown Flats in the Grey District, West Coast has a well-known mineral sand deposit (Suggate, 1989) with a history of exploration for minerals and metals, including ilmenite but especially gold mining in the early 20<sup>th</sup> century until 1941. Beach aggregate gold mining of modern beach sediments is also undertaken to the present day at Barrytown on Pakiroa Beach. Earlier in the 1980s, Westland Ilmenite, a division or subsidiary of North-BHP-Peko Pty Ltd, undertook significant resource assessment of the mineral sand resources across almost the entirety of the Barrytown Flats, including lodging water right applications under the Water and Soil Conservation Act (Coffey & Partners, 1991).

The current proponent, Tāiko Critical Minerals Ltd (TCM), took a more detailed and geographically focused set of sand mining activity applications under the Resource Management Act (RMA) to Grey District and West Coast Regional councils in 2022 to 2024, and the applications were granted consent to mine the Nikau Deer Farm Ltd block after a brief appeal to the Environment Court. The Nikau Deer Farm Block forms the bulk of the planned Central Block sand mining proposals, which are not the direct subject of this report but are referred to where the previous investigations are of relevance.

TCM is now requesting approvals to undertake mineral sand mining across the coastal flats between Canoe Creek and Fagan Creek, termed “Barrytown South” or the Southern Block (SB). The proposed mining approach would envisage a floating dredge excavating a groundwater filled dredge pond with the use of suction heads excavating the submerged flanks and base of the pond. The proposed sequence of sand mining would commence from north of Granite Creek and eventually progress to the south, terminating south of Cargill Road but before reaching Fagan Creek. The pit alignment would follow a sinuous north – south orientation of movement within three distinct blocks,

- Mining Section 1: North of Granite Creek,
- Mining Section 2: Between Granite Creek and Cargill Road, and
- Mining Section 3: South of Cargill Road.

The proposed duration of mining and rehabilitation would be 15 – 25 years. The mining proposal would also include the already consented Wet Concentrator Plant (WCP) to separate the mineral sand as Heavy Mineral Concentrate (HMC) from the sand below the grade cut-off, before dispatching the HMC by road to Rapahoe.

The Barrytown Flats are crossed by several creeks that could be classed as ‘rivers’ within the RMA, plus additional farm drains. These water courses conduct water from the Paparoa Range watershed in the east into Tasman Sea in the west. Chief among these in the vicinity of the Southern Block are Canoe, Clarke, Little Granite, Granite and Fagan creeks, plus three newly named creeks in the north and south of the SB. The Barrytown Flats also host a shallow groundwater system within *in situ* minerals sands and coarser alluvium. The water table is generally shallow under the coastal strip, augmenting several wetlands and in close hydrological connection with the aforementioned water courses. The Barrytown area is also a high rainfall zone, receiving moisture laden airstreams from the Tasman Sea. The rainfall pattern has a pronounced topographic tendency for increased rainfall intensity with rising ground to the east onto the Paparoa Range, feeding the headwaters with runoff following rain.

Shallow groundwater has an inherent load of dissolved metals / metalloids and nutrients. In addition, the mining process is markedly wet, using a saturated mining void and slurry lines prior to wet processing the suspended ore, primarily by water circulation means such as spirals. Therefore, sediment – water interaction may elevate natural concentration of the above constituents. Water quality controls would recognise the need for anticipating and monitoring constituent concentrations. Settling for suspended sediments and dosing with treatment reagents such as crushed limestone will be assessed.

The above background summarises the issues relating to the existing hydrological environment and the potential effects arising from the mining proposal. This report will outline the assessment of predicted effects and include steps formulated to avoid, minimise and otherwise manage the identified effects.

## 1.1 Objectives

The objectives of this document are tailored to provide the information required for assessing effects in terms of the Resource Management Act 1991 and the Fast-track Approvals Act 2024. The scope of required information was formerly set out in Schedule 4 of the Resource Management Act 1991 (now since 2013 titled 'Information required in application for resource consent') includes more or less the following:

- *A description of the proposal,*
- *A description of any possible alternative locations or methods, where an activity will result in significant adverse effects,*
- *An assessment of the actual or potential effects on the environment of the proposed activity;*
- *An assessment of any risks to the environment of an activity which includes the use of hazardous substances and installations,*
- *Where an activity includes the discharge of any contaminant, a description of the nature of the discharge, the sensitivity of the receiving environment, and possible alternative methods;*
- *A description of the mitigation measures to be undertaken,*
- *Identification of persons interested in or affected by the proposal, consultation undertaken if any, and response to the views of those consulted,*
- *How monitoring will be carried out if required and by whom, and*
- *Where a protected customary right is likely to be adversely affected by the proposed activity, the AEE must include a description of possible alternative locations or methods for the proposed activity unless written approval is given by the protected customary rights group.*

Accordingly, this technical assessment document focuses on the hydrogeology and hydrology disciplines and addressing some of the above information requirements, particularly the existing environment, potential effects and effects management. The specialist final assessments derived from the Assessment of Environment Effects (AEE) process are summarised and linked to detailed information provided in accordance with conventional documents of this type. The principal objectives of the assessments areas as follow:

- 1) To characterise the existing hydrological environment in and surrounding the Barrytown south area in the context of the current application for authorisations to mine parts of Barrytown Flats, within the following three discipline areas:
  - a) Groundwater and hydrogeology,
  - b) Surface water hydrology (not including Erosion and Sediment Control Planning), and
  - c) Water quality, in concert with environmental chemistry assessments of EcoLogical Solutions.
- 2) To outline proposed development and mining activities in the context of potential hydrological effects.
- 3) To undertake a technical assessment of potential effects in the context of site hydrology and proposed activities, including restoration or rehabilitation.
- 4) To examine possible management of effects in the context of avoiding, minimising or remedying such effects.
- 5) To carry opportunities for water management to recommendations within a water management plan.

## 1.2 Report Structure

This report is structured with Chapter headings as follow -

- Existing Environment
- Project Description
- Assessment of Hydrological Effects
- Effects Management
- Effects Monitoring
- Water Management arising

The rationale for each of these sections is covered in the discussion of objectives, above.

## 2 Site Setting Information

### 2.1 Information Sources

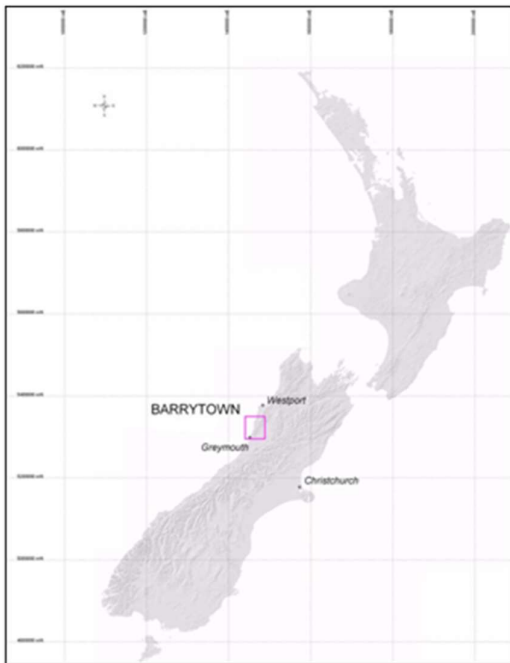
A set of existing information reporting was available for the Barrytown coastal flats project from the following sources –

- Inclusion of information from the Westland Ilmenite (Coffey & Partners, 1991) - Water Management Study,
- Review of the provisional hydrological assessment of sand extraction between Burke Road and Canoe Creek (Rekker, 2020), and
- Review of the more recent and definitive hydrological assessment for sand mining in the Central Block (Kōmanawa Solutions Ltd, 2024).

The assessments within other discipline areas, such as erosion & sediment control, environmental chemistry, ecology, and mine planning supported the description of proposed activities and included allied environmental assessments relevant to water management.

### 2.2 Location

Barrytown Flats are located on the South Island's West Coast, south of the Punakaiki River mouth. The flats lie to the west of State Highway 6 (SH6), which runs between the district centres of Westport and Greymouth. The Flats lie within Grey District, although the nearest locality of Punakaiki lies in Buller District, with the Punakaiki River marking the district boundary. Figure 1 shows Barrytown in the national context.



**Figure 1: Location of Barrytown on the South Island West Coast**

The Barrytown South Project (Southern Block, SB) areas comprise the following three sub-components:

- Mining Section 1: North of Granite Creek,
- Mining Section 2: Between Granite Creek and Cargill Road, and
- Mining Section 3: South of Cargill Road.

Figure 2 maps the location of the Southern Block, including the three mining sections and WCP.

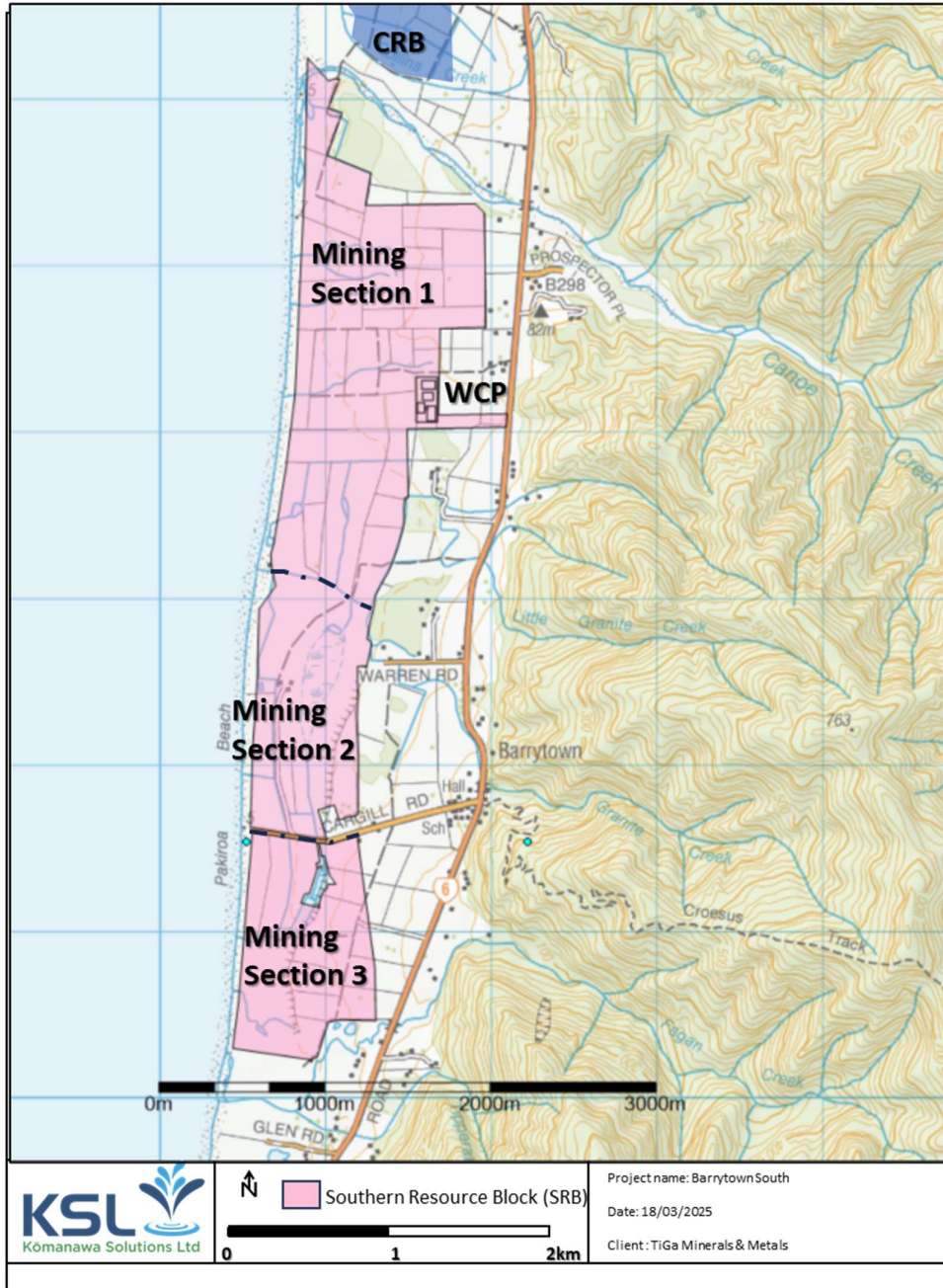


Figure 2: Barrytown South Project Area (shaded), Mining Sections 1, 2, and 3, plus WCP

### 2.3 Topography

The highest elevation within the project areas is approximately 25 metres AMSL, although the southern ⅓ of the project area and those parts included in the area to be mined, are generally at less than 10 metres AMSL. The coastal strip is tiered with one or two transgressive coastal terraces, although subdued alluvial fans of the main creeks overprint the land surface with soft swells. A single low terrace rise is visible approximately north of Cargill Road, half way between the coastline and hills. The topography of the Papanui Range is outlined in the surface hydrology sections.

## 2.4 Climate

The West Coast is New Zealand’s wettest region, and this may be attributed to its exposure to the predominant westerly airflow over the country combined with the orographic effect of the Southern Alps. Annual rainfall totals at relatively high elevations regularly exceed 10,000 mm (e.g., Cropp and Hokitika River headwaters), with low elevation coastal locations typically recording between 2,000 and 3,000 mm of rainfall annually. Temperatures in lowland areas remain mild throughout the year, with temperatures less than 0°C and greater than 25°C occurring very infrequently compared to most other regions of New Zealand (Macara, 2016).

In terms of local climate, the Barrytown Flats and hill watersheds are removed from the Main Divide that provides the backing to much of the West Coast. The area is thus insulated from the cold air drainage that flows down the Buller River and Grey River valleys to places such as Westport and Greymouth, especially during the cooler months (April to October), making the Barrytown area frost-free with mild winters moderated by the presence of the Tasman Sea.

### 2.4.1 Rainfall

Rainfall, in particular, is thought to be highly variable spatially in the coastal flats footing the Paparoa Range due to orogenic influences on the magnitude of rain falling at different sites across the area. The Barrytown Flats have been measured to have high rainfall and a high number of rain days. Moisture-laden air masses passing over the Tasman Sea are forced to rise over foothills and main Paparoa Range. The coastal plain fringing the Tasman Sea receives approximately 2,700 mm per annum while the peaks of the Paparoa Range slightly inland receive over 6,000 mm per annum.

In the Barrytown area, all rainfall stations are historic having not been continued to the present day. The last station at Punakaiki Rocks (F21132) ceased in March 2004. The closest continuing rainfall station from August 2002 is Greymouth Aerodrome Electronic Weather Station (EWS), approximately 30 km to the south. Greymouth at the aerodrome is in a similar topographic setting to the proposed mining area. The next closest rainfall and climate station is Westport Aerodrome (F11752 and F11754) at distance of 54.8 km to the northeast.

The Barrytown rainfall record of complete calendar years from 1973 to 1989 averaged 2,728 mm per annum. Punakaiki Rocks, 9.3 km to the north at the Pancake Rocks averaged 2,584 mm per annum from 1983 to 2003. A fragment of rainfall record at the Punakaiki River station 4 km away averaged 2,498 mm from 1962 to 1971. For the short six year-long period of overlap of simultaneous measurement at Barrytown and Punakaiki Rocks stations, the regression correlation coefficient  $R^2$  was 0.95 with Barrytown receiving on average 190 mm per annum more rainfall, possibly due to Barrytown being located at higher elevation (30 m AMSL) and closer to steep foothills. The Barrytown former rainfall station lay to the immediate east of the proposed mining area and within the Barrytown settlement. Rainfall is relatively evenly temporally distributed throughout the year as evident from the monthly mean totals at Westport and Greymouth sites in

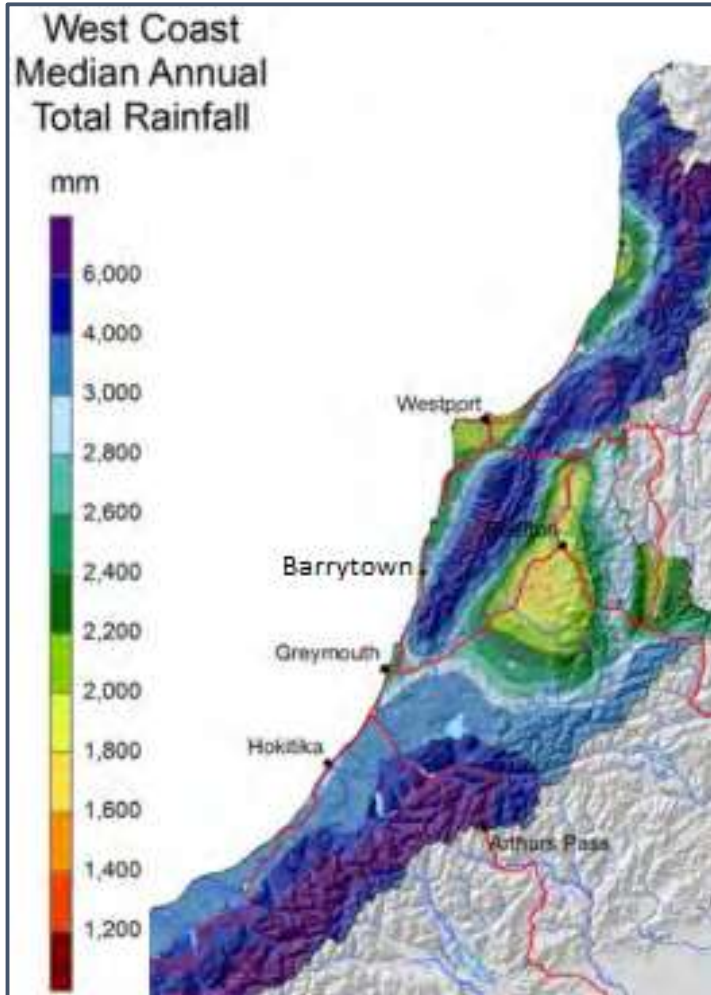
Table 1 below.

**Table 1: Monthly & Annual Rainfall data for the period 1981–2010 (Macara, 2016)**

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
Greymouth	209	161	177	195	197	238	198	192	209	225	197	252	2,452
Westport	158	128	136	142	171	230	139	192	184	209	168	190	2,046

**Note:** Month labels abbreviated to first three letters; “Ann” = Annual Rainfall.

Figure 3 illustrates the highly variable distribution that is not captured in comparing rainfall totals for the three population centres in Table 1. Westport and Greymouth lie near sea level, a similar topographic setting to the proposed Barrytown South sand mining area. These effects of orogenic influence and rain-shadowing in terms of modelled median annual rainfall totals as in colour flood shown in Figure 3 (Macara, 2016).



**Figure 3: NIWA map colour flood of median annual rainfall**

Long duration dry spells are quite uncommon (see Table 2) in most areas of the West Coast but can occur throughout the region when a persistent (blocking) anticyclone becomes established over the South Island. The rarity of dry spells contributes to the relative consistency of flow regime in rivers draining the Paparoa Range foothills as expanded on in the Hydrology section. In general, dry spells are more likely in autumn and winter as shown in Table 3.

**Table 2: Dry spell frequency, duration and seasonal distribution (Macara, 2016)**

Station location	Frequency	Mean duration (days)	Max. duration (days)	Max duration date
Greymouth	One every 19 months	17	39	6/2/2013 to 16/3/2013

**Note:** ‘dry spells’ are defined as periods of fifteen days or longer with less than 1 mm of rain on any day.

**Table 3: Seasonal distribution of Dry Spells (Macara, 2016)**

Seasonal distribution of Dry Spells	Summer	Autumn	Winter	Spring
Greymouth	25%	30%	35%	10%

## 2.4.2 Evaporation

Evaporation and evapotranspiration are measured and calculated at the Westport EWS and Greymouth EWS. Compared to the measured rainfall at these sites, the measured or calculated annual median evapotranspiration is small, as per Table 4.

**Table 4: Median Evaporation / Evapotranspiration Measurements for Westport and Greymouth**

Evaporation / Evapotranspiration Measurement	Westport 1996-2018 (mm/year)	Greymouth 2009-2018 (mm/year)
Total Penman Potential Evapotranspiration	816	839
Total Priestley-Taylor Potential Evapotranspiration	723	665
Total Penman Open Water Evaporation	750	826

Precipitation substantially exceeds evapotranspiration at Westport and Greymouth, and presumably also at Barrytown where precipitation totals are slightly higher. The imbalance in rainfall and evaporation leads to the tendency of the soil-moisture balance to remain in surplus (i.e., water-logged) which leads to soil draining laterally and vertically for lengthy durations of the hydrological year. This contrasts with soils on the east coast of the South Island, which display a distinct deficit period during summer and late summer - autumn. Such deficits relating to dry spells in Barrytown soils are brief and infrequent, even for low profile available water capacity (also known as field capacity) soils.

Indeed, the average duration of soil-moisture deficit for the period 1996 to 2018 were 3 days per year in Greymouth and 6 per year in Westport. Most of the West Coast region, including Barrytown, has an annual soil-moisture deficit mean period of less than 5 days in the average year. Extreme dry spells are considered to be rare at Barrytown. Using Greymouth airfield Electronic Measurement Station (EWS) site rainfall data, the longest consecutive dry spell in the period 1981 to 2010 (Macara, 2016) was 40 days (where daily rainfall was consistently less than 1 mm). The area’s soil water balance is most often in surplus with the resulting shedding of catchment water as indicated above. Rarely, the monthly soil water balance might fall into deficit in response to ‘dry spells’.

## 2.5 High Intensity Rainfall

High intensity rainfall over the Barrytown Flats in the vicinity of the Application Site has been modelled using HIRDS. The 5 year, 20 year, 50 year and 100 year recurrence interval 24 hour duration downpours are modelled to be 123, 158, 181, and 199 millimetres per day under historically recorded probabilities, respectively. For the downpour durations between 2 hours and 5 days, the Barrytown area is in approximately the 50<sup>th</sup> percentile (i.e., median) for downpour intensity in New Zealand. However, Barrytown Flats’ rainfall accumulations are considered high for a coastal setting, while elsewhere in New Zealand most high intensity rainfall areas are hill country or alpine.

Scientific projections utilising the general circulation models and regional circulation models of future climate suggest that high intensity rainfall at Barrytown Flats will increase. Both rainfall totals, including gentle and heavy rain, and high intensity rainfall downpours are very likely to increase. For example the 100 year recurrence interval, 24 hour duration rainfall would increase from historical levels of 199 millimetres to 213 millimetres in the representative concentration pathway 8.5 (RCP8.5) climate model, according to HIRDS.

## **2.6 Geology**

### **2.6.1 Regional & Basement Geology**

The backdrop hills to the Barrytown Flats are a geological composite of Cretaceous – Cenozoic marine sedimentary sequence and the northern West Coast bedrock strata (Nathan, 1974). The Canoe Fault is a significant local displacement, juxtaposing basement Carboniferous Karamea Batholith granitic intrusives plus late Palaeozoic Greenland Group meta-sediments against softer Tertiary sandstones such as the O’Keefe Formation (Blue Bottom Group). Two thirds of the Barrytown Flats are underlain by O’Keefe Formation muddy sandstone and the southern third is underlain by Karamea granitic basement. Granite Creek and Little Granite Creek have their headwaters in the Karamea granitic batholith rocks. In the far south of the foothills encompassing the landward flank of the coastal flats, the basement strata are primarily the Ordovician age Greenland Group indurated greenish-grey bedded sandstones and mudstones.

The Barrytown creeks north of Canoe Creek have their headwaters in softer, more erodible O’Keefe Formation silty sandstones. Scarce intersections with basement strata have been made in mineral resource or environmental drilling through the coastal flat deposits. Notably, O’Keefe Formation silty clay weathered basement was encountered at a depth of 24 m below ground at Burke Road, approximately 400 m west of SH6.

### **2.6.2 Holocene Sedimentology**

The mineral sands that are the focus of mining proposals comprise post-glacial coastal sand and gravel deposits grouped stratigraphically within the Nine Mile Formation (Suggate, 1989), also see Figure 4. The mineral sands are considered to have been set down in a series of north – south trending pro-grading strand lines. The sediment supply for deposition of the sands is inferred to have been marine long-shore drift originating from the south. The proposed sand extraction areas comprises a series of post-glacial strand lines extending from the foot of a Late Pleistocene sea cliff (coincident with SH6) and a staircase of up to three terraces that have extended seawards from the buried sea cliff, westward to the present-day coastline (Coffey & Partners, 1991). During the formation of strand lines, heavy minerals were concentrated within the surf-washed zone into lenticular black sand leads. These terraces and coastal gravelly sands are stratigraphically grouped within the Nine Mile Formation of Holocene to Late Pleistocene age (i.e., Recent to 14,000 years Before Present). The Nine Mile Formation contains marine placer mineral concentrations of ilmenite, gold and associated heavy minerals (epidote, garnet, titanomagnetite, zircon and trace monazite). The heavy minerals contain fractions with high magnetic susceptibility that were revealed in the Total Magnetic Intensity (TMI) channel of a recent airborne geophysical survey (Vidanovich, 2008).

Coffey Partners (1991) noted the following facies-related subdivisions within the Nine Mile Formation; Transgressive Beach Deposits, Elevated Beach Terraces, and Recent Foredune Deposits. The transgressive beach deposits tend to be more sand dominated but include gravel-sized grains in a fine to medium sand matrix. The transgressive beach deposits also tend to be found in the western, seaward portions of the coastal flats. Conversely, the elevated beach terraces tend to have higher proportions of gravel, while still being dominated by a sand matrix. The elevated beach terraces tend to be located parallel and in closer proximity to the eastern edge of the coastal flats. Suggate (1989) also noted the presence of Holocene alluvial Fans, which are evident and significant on the eastern edge of the Barrytown South area. Lobes of creek alluvium are mapped in Figure 4 draping over transgressive and elevated mineral sand/gravel deposits, including down-gradient of the Granite and Little Granite creeks discharging on the coastal plain

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from the Paparoa Range foothills. These were marked by Suggate (1989) and shown in Figure 4. A geological profile from the midst of the SB is shown in Figure 5.

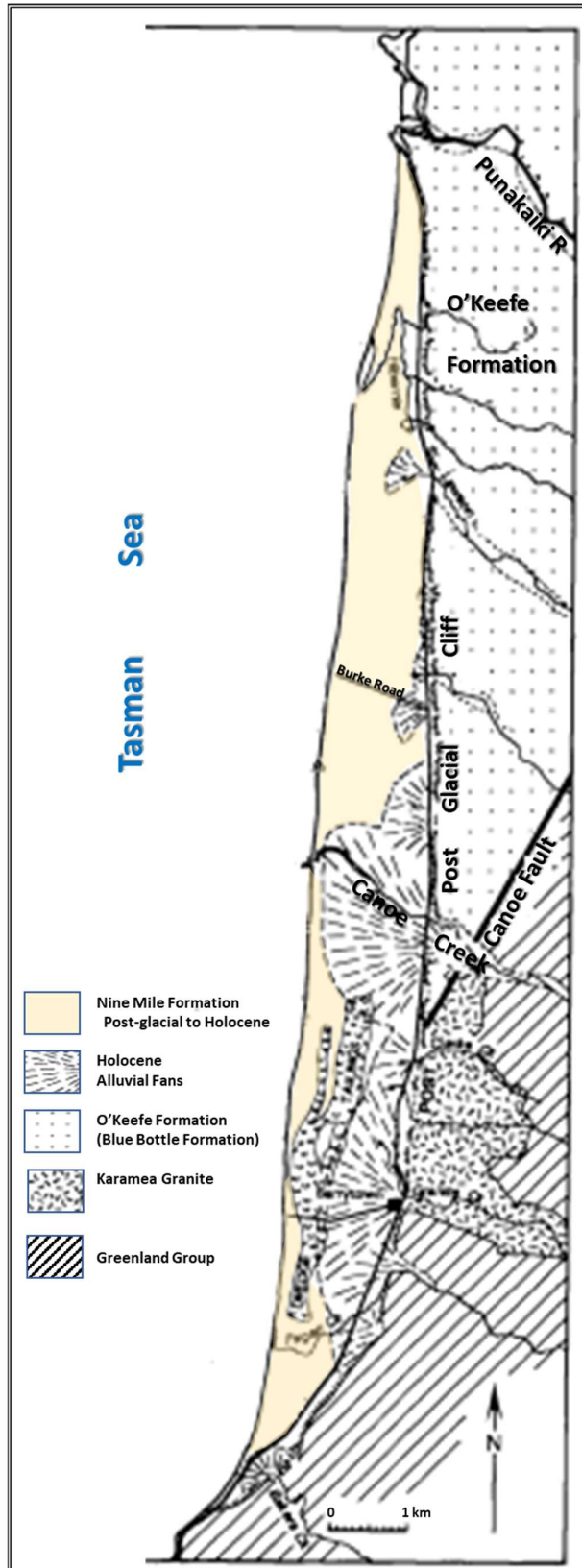


Figure 4: Mapping of local geology and Nine Mile Formation deposits (Suggate, 1989)

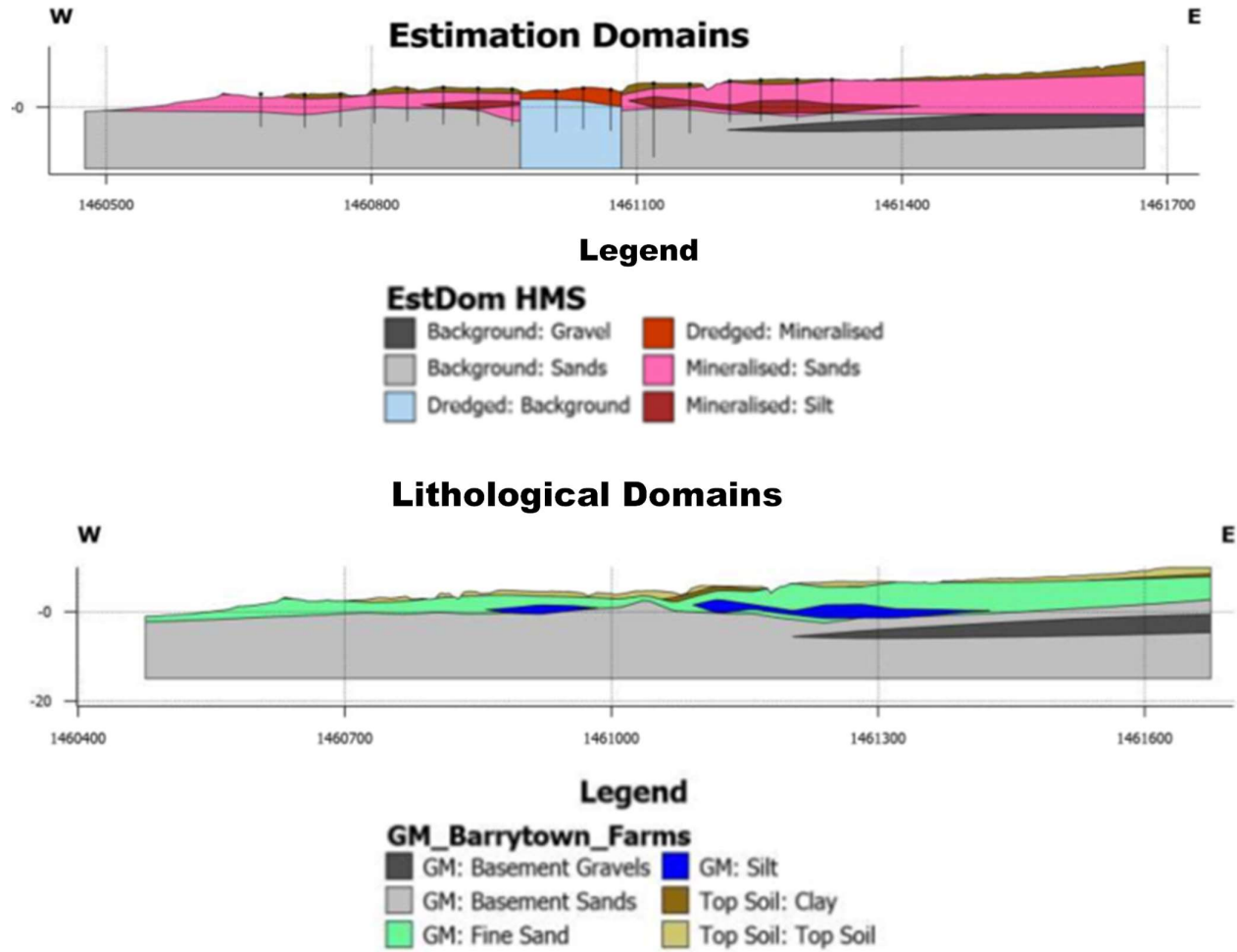


Figure 5: Mineral resource estimation and Holocene lithological domain profiles through the Barrytown South landform based on (Aldrich et al., 2023)

Figure 5 pairs sand resource and lithological domains determined in the 2022 mineral sand investigations using a dense network of logged and collated drill hole records (Aldrich et al., 2023). The east – west section line parallels Granite Creek’s path across the proposed SB mining area to the Tasman Sea. The cross-sections reveal a correlation between ‘mineralised sands’ and ‘fine sand’ lithology with the distribution of these units being identical in Figure 5. Figure 5 also highlights the fine grained silt and clay overburden (subsoil), plus the effect of the historic gold dredging in having stripped the overburden and raising the top of the mineral sands.

The depth of discovery for the RSC Geological Consultants’ drilling investigations across the Barrytown Farms Ltd land was largely limited to 12 metres below ground level. This depth of focus allowed the full delineation of mineralised sand, which extended to a maximum of 10 metres below ground level. Within and beneath the non-mineralised “basement” sand RSC Geological Consultants noted the top of the “basement”<sup>1</sup> gravel deposits, especially in the east of the Barrytown Farm Ltd block. Geological and hydrogeological follow-up studies at the CB found that alternating layers of sandy gravel and fine sand was located beneath the mineralised sands (Kōmanawa Solutions Ltd, 2024). The base of the Holocene – Pleistocene sequence and the expected geo-hydrological basement has only rarely been encountered in drill holes.

## 2.7 Hydrology

### 2.7.1 Setting

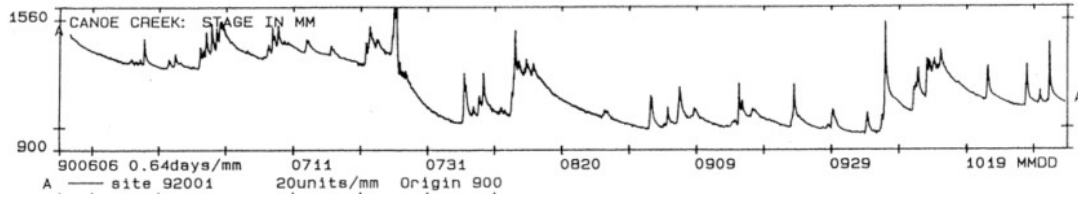
The hill backdrop to the Barrytown flats is dissected by 17 individual stream and creek catchments. Canoe Creek is the largest of these at 23.4 km<sup>2</sup> and has headwaters at the Paparoa Range crest to an elevation of 1,220 m AMSL. Granite Creek and Fagan Creek are the main catchments draining the face of the coastal range south of Canoe Creek and adjacent to the Barrytown settlement. Fagan Creek is notable as a very steep watercourse that adjoins headwaters with Canoe Creek on the flanks of the Paparoa Range peak, Mt Ryall near the Paparoa Range crest.

### 2.7.2 Previous Hydrometric Programmes

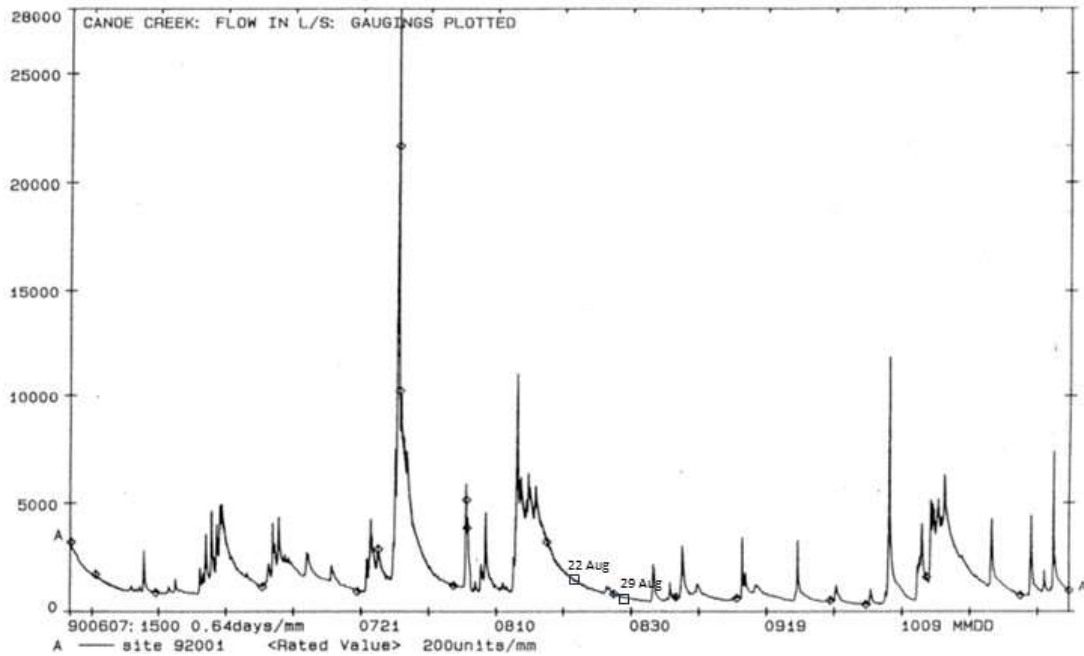
None of the creek catchments crossing the Barrytown Flats are currently routinely gauged, although spot gauging was undertaken on all creeks crossing SH6 in the winter and spring of 1990 (see Figure 8 Table 5) and a continuous recorder site was established on Canoe Creek at the SH6 crossing (see Figure 7). The DSIR Water Resources Survey and West Coast Regional Council shared the tasks in operating this relatively brief hydrometric programme for Westland Ilmenite reported in Coffey Partners (1991). This included the installation of flow measurement stations at Canoe, Waiwhero and Hibernia creeks at their respective crossings of SH6 in May 1990. The last recovered hydrometric flow data was taken in November 1990, indicating a brief period of recording of not quite six months. The Canoe Creek flow site was repeatedly gauged, correlated with creek water level (stage) to generate rating curves. The flow gauging and monitoring site is displayed as a photograph taken when the station was operational in 1990 (shown in Figure 40). As brief as this fragment of flow monitoring of Canoe Creek was, it provides a consistent characterisation of creek hydrology of the largest single Barrytown catchment.

The Canoe Creek stage and flow hydrographs have been compiled from 1 June 1990 to 8 November 1990 and the plots of these are displayed in Figure 6 and Figure 7, below. The hydrograph is annotated with the timestamps of 22 August and 29 August that are referred to in following text and Table 5.

<sup>1</sup> Basement in the geological mineral resource context means being beyond the extent of economic mineralization.



**Figure 6: Canoe Creek stage hydrograph 1 June 1990 to 8 November 1990, prior to rating curve correction**



**Figure 7: Canoe Creek flow hydrograph in litres per second after rating for the same period as Figure 6, above**

A mean flow for the six month period of 1,736 litres per second in Canoe Creek was indicated in Figure 7. The hydrograph of Canoe Creek in Figure 7 is consistent with a range-front creek of its physiography, the hydrograph is 'flashy', peaking in response to rainfall and dropping through a recession curve to baseflow. An instantaneous flow peak of approximately 28,000 litres per second was recorded on 26 July 1990. A period of baseflow averaging 700 litres per second was recorded from middle August 1990 to approximately 8 September 1990. Figure 8 maps the 17 creek catchments with estimated catchment areas upstream of SH6. Table 5 lists 17 instantaneous gaugings made on the same day (22 August 1990) which was preceded by five days of no rain and considered to approximate baseflow hydrological conditions in the smaller creeks by Coffey Partners (1991). This date was probably less representative of baseflow for Canoe Creek due to its longer characteristic recession coefficient.

Further delineation of Barrytown creek catchments was provided by Coffey Partners and reproduced in Figure 8. Spot gaugings were undertaken or attempted (in some cases no flow was visible to allow gauging) in each of the creeks crossing State Highway 6 on a few occasion, including on 22 August 1990. These spot gaugings extended the understanding gained from the three larger monitored creeks (Canoe, Waiwhero, and Hibernia) to the less significant creeks such as Little Granite Creek. Creeks not crossing the main road were not included in the survey.

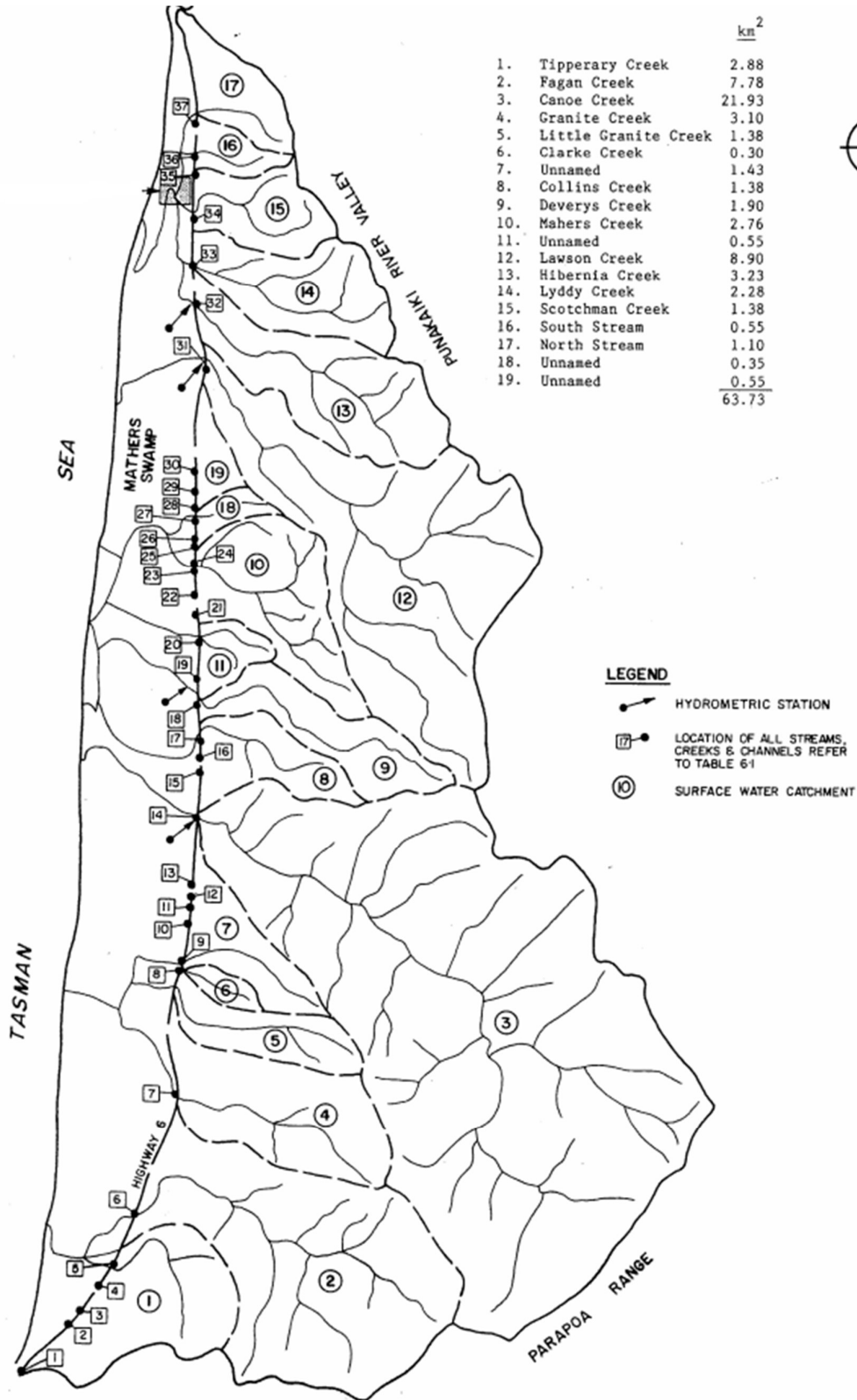


Figure 8: Outline map of Barrytown Flats catchments reproduced from Coffey Partners (1991)

**Table 5: Instantaneous flow measurement data across the Barrytown Flats creek catchments (from Coffey Partners, 1991)**

Catchment No. <sup>1</sup>	Catchment	Gauging Locality on SH6 <sup>2</sup>	Area (km <sup>2</sup> )	22/8/90* Campaign rates (L/s)	Gauging Flow	Instantaneous Specific Runoff (L/s/km <sup>2</sup> )
1	Tipperary Creek	@5	2.88	60		20.83
2	Fagan Creek	@6	7.78	0		0
3	Canoe Creek	@14	21.93	1,400 <sup>¥</sup>		63.84 <sup>¥</sup>
3	<i>Canoe Creek</i>	@14	21.93	660 <sup>§</sup>		30.1 <sup>§</sup>
4	Granite Creek	@7	3.1	10		3.23
5	Little Granite Creek	@6	1.38	0		0
6	Clarke Creek	@8	0.3	2		6.67
7	Unnamed Creek-7	@9	1.43	25		17.48
8	Collins Creek	@17	1.38	30		21.74
9	Deverys Creek	@18	1.9	50		26.32
10	Maher Creek	@23	2.76	18		6.52
11	Unnamed Creek-11	@20	0.55	3		5.45
12	Waiwhero Creek	@31	8.9	260		29.21
13	Hibernia Creek	@32	3.23	30		9.29
14	Liddy Creek	@33	2.28	10		4.39
15	Scotsman Creek	@34	1.38	8		5.80
16	South Creek	@36	0.55	3		5.45
17	North Creek	@37	1.1	2		1.82

**Note:** <sup>1</sup> Reproduced from Figure 15 and Table 6.1 of Coffey Partners (1991); \* 22 August 1990 preceded by 5-day period of no rain. <sup>2</sup> see Figure 8; Granite Creek and SB associated creeks adjoining the proposed sand extraction area, is shaded for emphasis. ¥ Canoe Creek remained at higher flow rather than base flow on 22 August 1990 due to its longer characteristic recession coefficient. § Canoe Creek measured on 29 August 1990, after creek flow had stabilised to base flow (see Figure 7).

The last column of Table 5 is instructive on the baseflow characteristics of the respective catchments. The spot gaugings were conducted following five days without rain, which is considered a dry period for this part of the West Coast as discussed previously in relation to Table 2. The two largest creek catchments, Fagan and Canoe creeks displayed strongly contrasting hydrological responses. Fagan Creek with a 7.78 km<sup>2</sup> catchment area upstream of SH6, granite bedrock and steep profile exhibited no flow on the day of gauging (22 August 1990). Canoe Creek with a 21.93 km<sup>2</sup> catchment area, variable geological strata and

significantly less steep profile exhibited flow of 1,400 litres per second, which may not have represented base flow (see Figure 1) for the flow hydrograph descending to a stable baseflow towards 29 August). Canoe Creek also has the highest calculated specific low flow runoff of 63.8 L/s/km<sup>2</sup> on 22 August, twice that of Waiwhero Creek despite being normalised for catchment area, which is likely to be an artefact of the creek flow having not recovered to baseflow on that date. Canoe Creek baseflow conditions seem only to be achieved by 29 August, when 660 litres per second was measured and this flow corresponded to a specific baseflow runoff of 30 L/s/km<sup>2</sup>. Being the largest Barrytown Flats creek catchment and reaching the highest Paparoa Range headwaters, Canoe Creek has the longest drainage course of the Barrytown Flats creeks. Canoe Creek also has a gravel traction load forming its bed while within the ranges, providing an alluvial hyporheic zone and groundwater reservoir buffering flow fluctuations and sustaining higher base flows as measured at SH6.

Low baseflow characteristics of the remaining creeks are associated with high gradient, quartzose or crystalline basement rock catchments on the West Coast, especially for Little Grante and Fagan Creek where no flows were measured during 22 August 1990 baseflow conditions. While lower gradient, sedimentary or alluvial accumulations in the upstream catchment are more commonly associated with higher baseflow and hence higher specific runoff values under baseflow conditions. Canoe Creek is an example of such natural hydrological reservoirs supporting a higher perennial base flow.

### 2.7.3 Additional Hydrological Estimations

#### 2.7.3.1 Modelled Flow Statistics

Auto-correlated hydrological indices for the Barrytown Flats catchments are contained within the NIWA (Whitehead & Booker, 2020) online national hydrological estimations, within both the New Zealand River Maps (Booker & Woods, 2014)) and the Ministry for the Environment GIS data coverage titled River Flows (Booker, 2015). These estimations attempt to extend measured hydrology from catchments with continuous flow recording to ungauged catchments.

Table 6 summarises low-flow, median and mean annual hydrology for the main Barrytown Flats creeks. The catchment areas differ in places to those listed in Table 5 due to the estimation point being differently placed. Estimation nodes do not necessarily coincide with each creek’s crossing of SH6, often placed at the nearest confluence of different branches of the creek network. In the cases of Maher Creek, Granite Creek and Fagan Creek the estimation node was measured at Maher Wetlands, coastal lagoon and coast, respectively. To this extent the creek catchments listed in Table 5 and Table 6 are not always comparable. It could be expected that the values contained within Table 6 would be internally consistent and broadly reflective of the long-term hydrological patterns. Table 6 and Figure 9 cover the creek catchments as formulated within the River Environmental Classification version 2 (REC2).

**Table 6: Summary of hydrological data from NZ River Maps Flows for Barrytown Flats creek catchments**

# and Creek	Catchment and measuring point	Catchment Area (km <sup>2</sup> )	1:5-year Low Flow (L/s)	MALF <sub>7</sub> d (L/s)	Median Flow (L/s)	Mean Flow (L/s)
8 Collins Creek	@SH6	2.15	11	16	47	94
3 Canoe Creek	Downstream of SH6	23.17	512	633	1,790	3,050
4 Granite Creek	@ Creek Confluence	5.06	75	98	407	762
2 Fagan Creek	@ SH6	8.06	179	215	636	1,090

**Note:** Creek numbering consistent with Table 5, Figure 8, and Figure 9.

The NZ River Maps modelled Fagan Creek low flows in Table 6 are demonstrably and artificially elevated in view of the negligible base flow measured in the creek in Table 5 (Coffey & Partners, 1991). Conversely, the modelled Canoe Creek Mean Annual Low Flow (MALF<sub>7d</sub>) of 633 litres per second in Table 6 is broadly in agreement with the inferred base flow measured at 660 litres per second in Table 5 as measured on 29 August 1990. The hydrological statistic of MALF<sub>7d</sub> is considered to fall on the lower end of nominal base flow.

The Barrytown Flats creek catchments in terms the River Environmental Classification system version 2 (REC2) is also shown in Figure 9. Creek catchments are however labelled in consistency with the numbering adopted by Coffey Partners (1991). The surrounding catchment, including the Punakaiki River, Moonlight Creek and Ten Mile (Waianiwaniwa) River are shown for orientation. Only the larger Canoe Creek backs onto the Grey River catchment tributaries, Moonlight and Blackball creeks at the crest of the Paparoa Range.

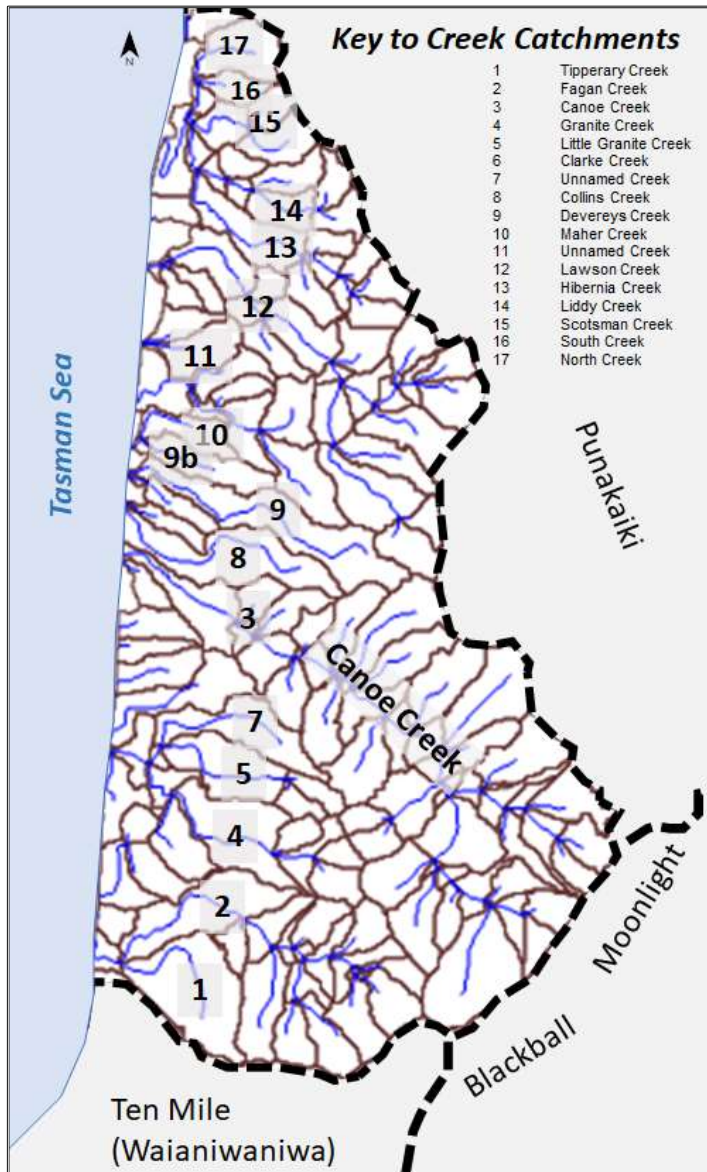
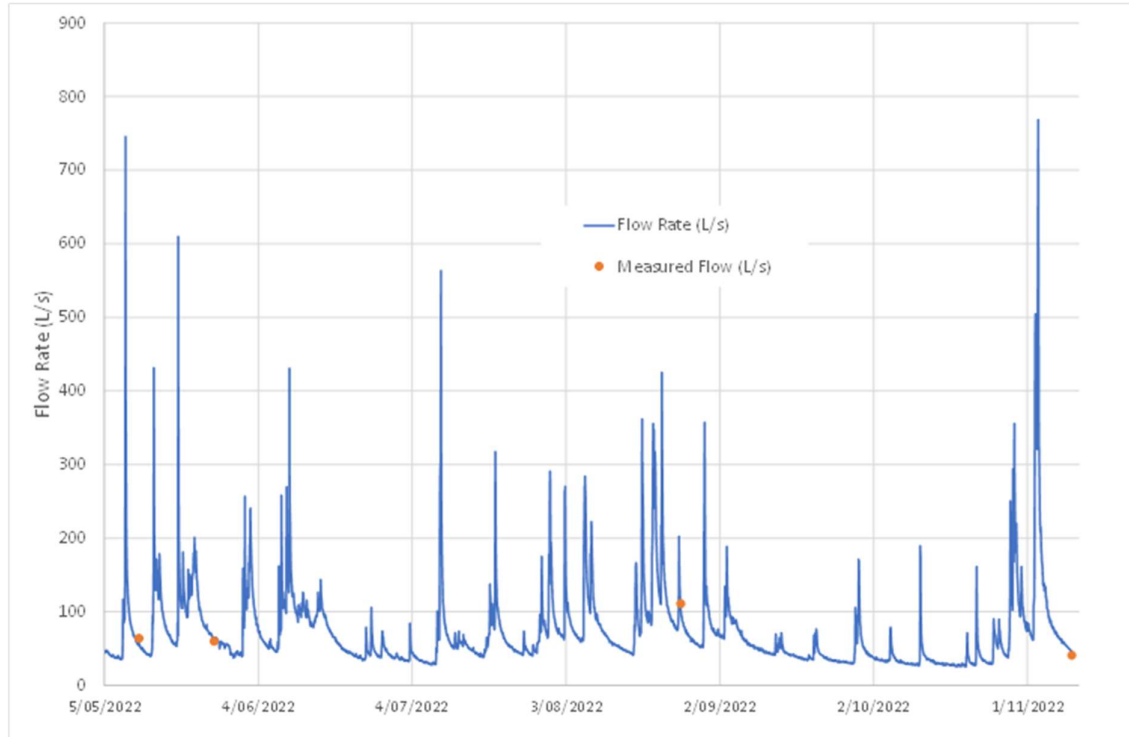


Figure 9: Barrytown creek catchment boundaries<sup>2</sup> of individual watersheds

<sup>2</sup> According to the River Environmental Classification version 2 (REC2)

### 2.7.3.2 Measured Nearby Flow Characteristics

Collins Creek (i.e., creek catchment No. 8 in Figure 8, Table 5, Table 6, and Figure 9) that passes over the coastal flats immediately to the north of the Barrytown South project area was also continuously gauged from early May to early November 2022 at a hydrological site managed by Kōmanawa Solutions and shown in Figure 10.



**Figure 10: Measured Collins Creek flow rate from 4 May to 8 November 2022 at the creek’s SH6 crossing**

Collins Creek is inferred to be broadly representative of the hydrology of small sized hill creek catchments of 1 to 2 square kilometre upstream of the SH6. Creek catchments of similar size such as Little Granite Creek discharge onto the Barrytown Flats and across the coastal plains and the Southern Block to the sea.

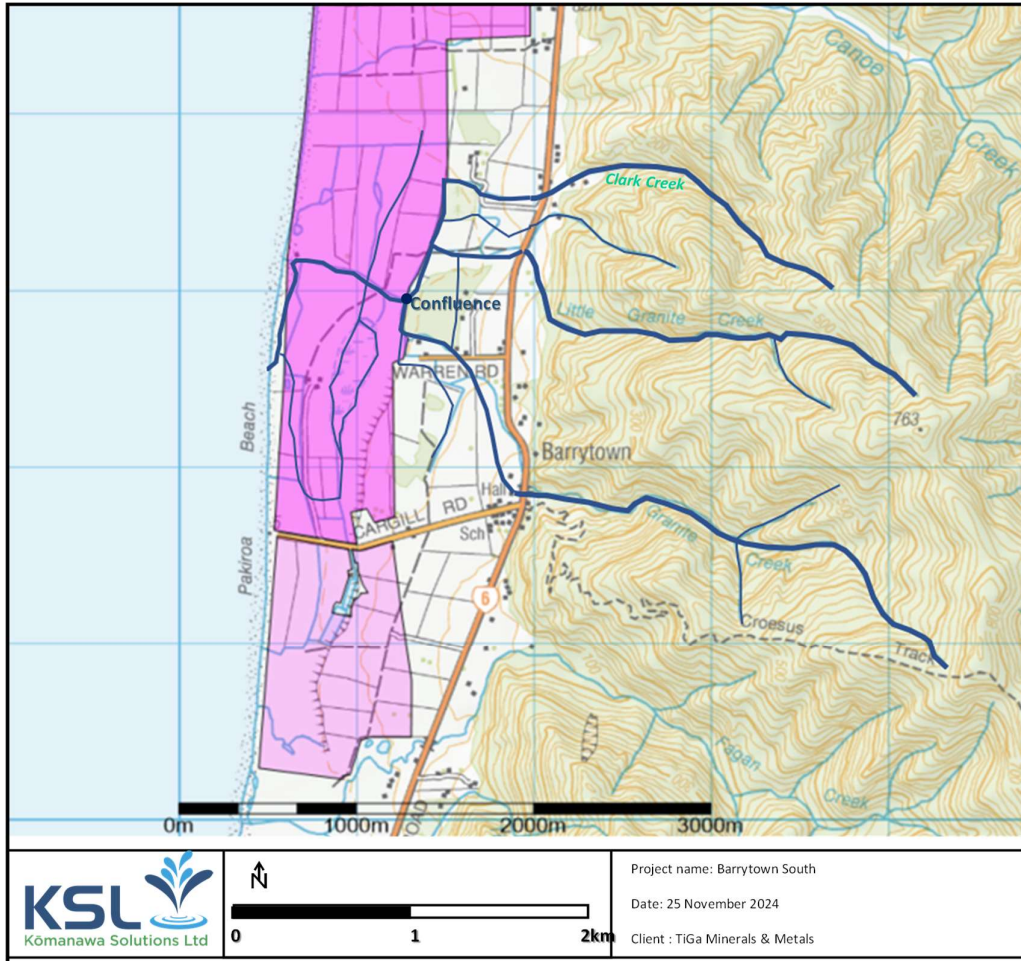
### 2.7.3.3 Relevance of Collins Creek to Southern Block Creeks

One of the differences between Collins Creek and Little Granite Creek is geology. The hill catchment geology of Collins Creek is Blue Bottom silty sandstone (O’Keefe Formation), while the hill catchment of Little Granite, as the name suggests, is composed of Karamea Batholith granitic rocks. The entire Granite hill catchment (Granite, Little Granite, and Clarke creeks) is granitic and steeper than that of Collins Creek. Therefore, given the observations of flashy, fresh flows and meagre baseflow from granitic catchments, Little Granite Creek is expected to display similar, but more accentuated flood peaks. The traction load in the beds of Little Granite and Granite creeks is highly visible granitic sand and cobbles, especially following significant flooding (see Figure 13).

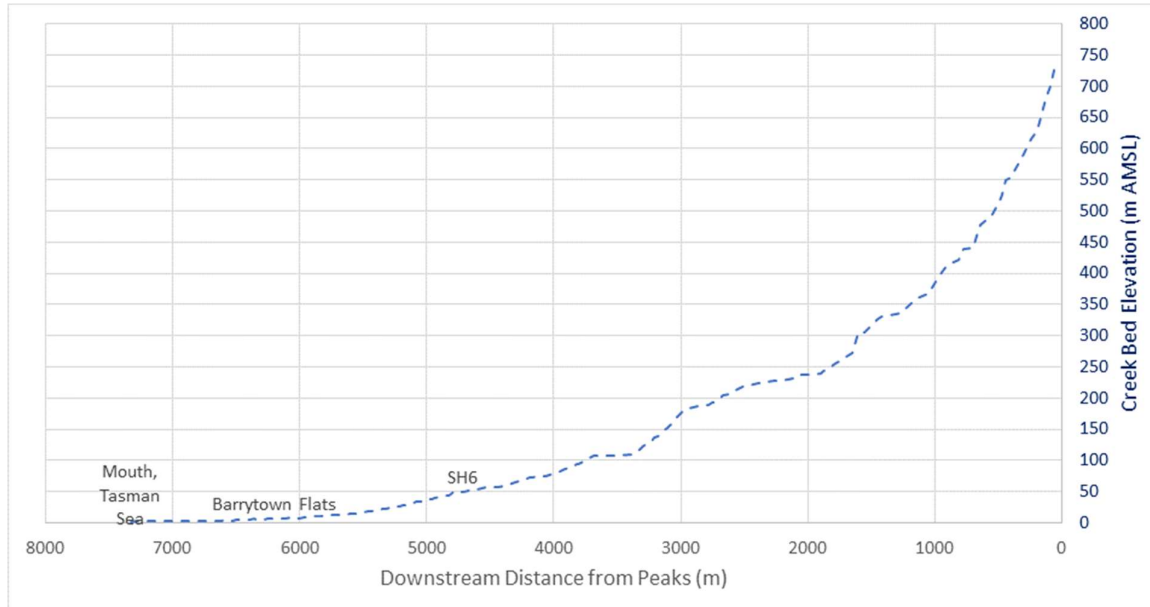
### 2.7.3.4 Modelled High Flood Flows under High Intensity Rainfall

The Granite Catchment comprising Granite Creek, Little Granite Creek and Clarke Creek each drain adjoining hill catchments of a combined area of 5.62 square kilometres as they cross State Highway 6 (SH6). After crossing SH6 the creek gradients slacken, and the creek channels meander and coalesce. The meandering creek channel characteristics have been modified by creek straightening and rectification

around paddocks. Wetlands such as fens have been drained in the interests of pastoral agriculture. The creek channel network is highlighted in Figure 11, while the profile of Granite Creek is plotted in Figure 12.



**Figure 11: Granite catchment highlighted showing Granite, Little Granite & Clark creeks**



**Figure 12: Bed profile of Granite Creek (west to east)**

High intensity rainfall falling on the Granite catchment, especially the hill catchment would cause a flow increase towards the peak flow rate within 1 hour (i.e., time of concentration is less than 1 hour). Table 7 lists the Average Recurrence Intervals, associated 1-hour rainfall intensities, and peak flow rates at time of concentration of approximately 59 minutes. The Rational Method (Pilgrim, 2001) was employed to estimate peak flow rates using a runoff coefficient of 0.15, which was selected on the basis guidelines for “(New Zealand) bush and scrub cover, with medium soakage” (Institute of Engineers, 1980).

**Table 7: HIRDS derivation of Granite and Little Granite at Confluence, Peak Flow Rate**

ARI	AEP	Hourly Downpour (1h)	Peak Flow (m <sup>3</sup> /s)	Peak Flow (L/s)
1.58	0.633	22.2	5.66	5,657
2	0.5	24.3	5.78	5,778
5	0.2	31.6	7.47	7,465
10	0.1	37.1	8.73	8,730
20	0.05	42.9	10.04	10,037
30	0.033	46.4	10.84	10,838
40	0.025	49	11.41	11,408
50	0.02	51	11.87	11,872
60	0.017	52.6	12.25	12,251
80	0.013	55.3	12.84	12,842
100	0.01	57.4	13.31	13,306
250	0.004	66.2	15.27	15,267

Note: ARI = Average Recurrence Interval in years. AEP = Annual Exceedance Probability as a decimal. Peak Flow = Rate at Time of Concentration,  $t_c$  in cubic metres per second (m<sup>3</sup>/s) of litres per second (L/s).

The Granite catchment, including Granite, Little Granite and Clarke creeks cross State Highway 6 (SH6) via short bridges and culverts. The creek beds of the steep and erodible catchments of granitic and metamorphic rocks upstream of SH6 in each case are prone to channel aggradation mainly through the build-up of granitic sand and gravel. Floods in these creeks are prone to blocking the associated bridge or culvert under the highway and surface flooding with pavement damage. Figure 13 compares Granite Creek bed load before and after a damaging 2022 flood.



**Figure 13: Time separated satellite images of middle Granite Creek showing flood damage from late 2022**

Figure 13 suggests that sediment deposition tapers off before reaching the SB mining area’s eastern boundary, presumably due to the reduction in creek channel gradient, falling water velocities, diminishing turbulence and lessening saltation of bed load or flood debris. Importantly, there was no sign in satellite image searches (31/12/1985 to 25/01/2023) that the creek crossing farmland within the SB proposed mining areas changed course due to this flooding and related damage.

## 2.8 Groundwater Hydrology

### 2.8.1 Previous Studies

The Coffey Partners (1991) report and appendices reported the installation of ten pumping test bores with paired observation bores at distances averaging 16.5 m apart. Test bores NBH9 to NBH10 were installed adjacent within or adjacent to the SB (see Table 8 and Figure 14 for details and locations). The CB and SB drilling investigations included ten bores of different depths, primarily bracketing ‘shallow’ (not far below the water table, generally 6 metres) and ‘deep’ (> 25 metres below ground).

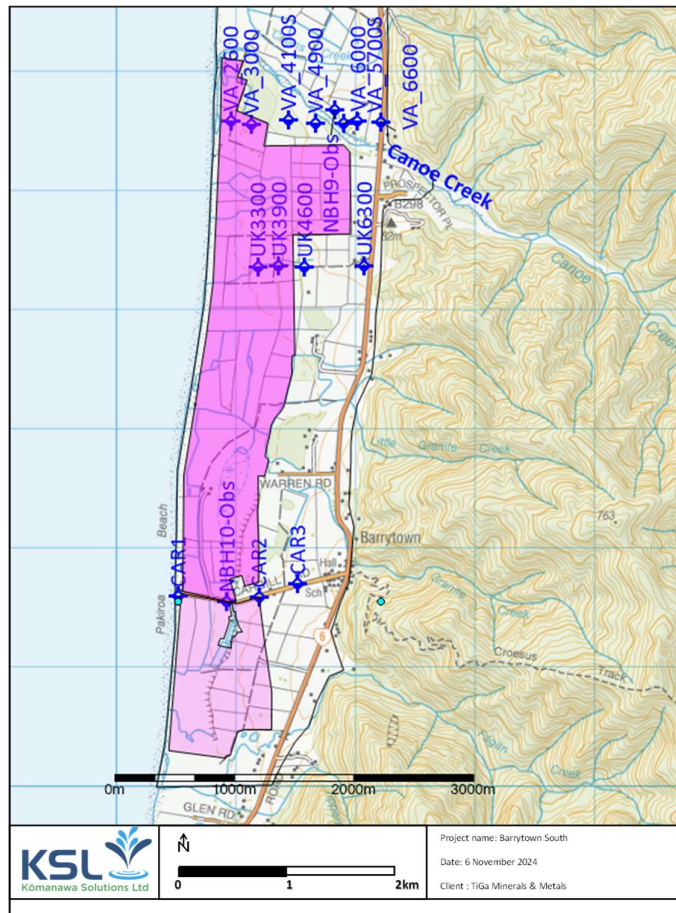
Each of the test bores from NBH6 to NBH10, including observation bores (“-Obs”), listed in Table 8 were test pumped at rates ranging between 0.2 and 2.3 L/s for durations ranging between 1 hour and 3¼ hours to determine aquifer properties using standard pumping test analysis methodologies such as the Theis Recovery Method (Theis, 1935) or Boulton Method (Boulton, 1963). **Error! Reference source not found.** maps the location of the two test bore sets that fell within or near the Southern Block (SB).

Coffey Partners also conducted 43 separate pneumatic slug tests on each available piezometer on the Barrytown Flats. These tests included eight pneumatic slug tests conducted on deep bores placed towards the base of the mineral sands and alluvial fans. The slug testing included 15 piezometers located adjacent to the proposed mining area. Pneumatic slug tests were also conducted in each of the pumping test observation bores (ending in the suffix ‘Obs’ in Figure 14) to allow comparison of the results in pumping tests and pneumatic slug tests. If the two methods were equivalent, it was more likely results would coincide.

**Table 8: Coffey Partners (1991) Test bores along Sections within the Central and Southern Blocks**

Bore #	NZTM_E	NZTM_N	Total Depth (m)	RL Collar (m AMSL)	SWL (m TOC)	SWL (m AMSL)
NBH6	1461897	5328021	8.5	8.92	2.83	6.09
NBH6-Obs	1461865	5328034	9.34	8.61	2.97	5.64
NBH7 (Deep)*	1461849	5328040	24.7	8.43	3.27	5.16
NBH7-Obs	1461863	5328034	26.95	8.62	3.02	5.6
NBH8	1461053	5328353	9.5	4.06	1.74	2.32
NBH8-Obs	1461053	5328331	9.3	4.57	2.56	2.01
NBH9 (Deep)	1461813	5325690	28.8	20.61	4.9	15.71
NBH9-Obs	1461827	5325669	31	20.62	4.75	15.87
NBH-10	1460915	5321549	9.32	10.4	0.08	9.19
NBH10-Obs	1460928	5321541	9.55	10.8	0.36	9.19

**Note:** NBH# = New Bore Hole (Number) for pumping and observation bores; Bore NBH1 was not tested by pumping test; \* NBH7 intersected bedrock. Obs = observation bore; NZTM = New Zealand Transverse Mercator (Easting / Northing); RL = Reference Level, essentially reference elevation; AMSL = Above Mean Sea Level; SWL = Static Water Level measured two days apart on 30 August and 1 September 1990; and blue shading indicates adjacent to proposed mining area.



**Figure 14: Location of Coffey Partners' nearby test and observation bores across the Southern Block**

Coffey Partners’ drilling programme installed logged boreholes along two East – West section lines within the proposed mining area (see Figure 14). Essentially, Coffey Partners included collection of hydrogeological data in the form of bore logs, pumping tests, pneumatic slug tests and corrected water level measurements. Efforts to re-visit and re-measure these bores and piezometers have been made. As far as can be determined, the bore heads have been removed and covered over by either Wetland Ilmenite or the adjoining land owners in the years subsequent to the installation in 1989.

## 2.8.2 Aquifer Properties Determined in 1989

### 2.8.2.1 Pumping tests

Coffey Partners (1991) undertook three aquifer tests in the vicinity of the Cowan Block, then conducted graphical (i.e. graph paper) semi-logarithmic fitting of data to type curves, which was the standard practice in the early 1990s. Residual drawdown from the recovery phase of the test was fitted to the Theis type curve and the resulting transmissivity or storage coefficient is also recorded in the Recovery column of Table 9.

**Table 9: Interpreted pumping test results for five Barrytown Flats test bores along Burke Rd, CB and SB**

Bore #	Duration (min)	Rate (m <sup>3</sup> /d)	T (m <sup>2</sup> /d)		K (m/d)		S	Formation Code (A-D)
			Dd	R	Dd	R		
NBH6-Obs	-----	-----	325	680	16.3	34.5	1 x 10 <sup>-2</sup>	B
NBH7 (Deep)	150	206	7.1 – 6.3	62.8	0.2 - 0.3	2.1	5 x 10 <sup>-4</sup>	B (Deep)
NBH7-Obs	-----	-----	–	337	–	11.2	2 x 10 <sup>-4</sup>	B (Deep)
NBH8	120	1.5	–	1.5	–	0.08	–	A
NBH8-Obs	-----	-----	–	29	–	1.5	–	A
NBH9 (Deep)	58	203	6	72	0.2	2.4	2 x 10 <sup>-4</sup>	C
NBH9-obs	-----	-----	–	54.6	–	1.9	–	C
NBH10	335	60	186	–	–	9.3	–	D
NBH10-Obs	-----	-----	163	–	–	8.1	–	D

**Note:** T = transmissivity, K = hydraulic conductivity, S<sub>y</sub> = specific yield, Dd = drawdown test, R = recovery test, NBH# = New Bore Hole (Number) for pumping and observation bores; Obs = observation bore; (Deep) in the Formation Code indicates bore screen was not shallow and was set at depth near base of deposit; S = Storativity values reported in instances where curve fits were feasible; and blue shading indicates within or immediately adjacent to proposed mining area. Formation Codes: A = Transgressive Beach Deposit; B = Elevated Terrace, C = Alluvial Fan, and D = Previously mined.

### 2.8.2.2 Pneumatic Slug Tests

Forty-three pneumatic slug tests in total were conducted on piezometers or observation bores with nominal casing diameters between 32 mm and 50 mm. Nineteen tests were conducted along the two closest transects to the CB or SB. The method of testing involved using a bore-head assembly to seal the bore into a pressure manifold with pressure gauge and pressure transducer – data logger suspended below the bore water level. The results of the above methodology and interpretation using the Hvorslev Method (Hvorslev, 1951) for the nineteen slug test analyses are listed in Table 10, which focuses on the piezometers closest to the proposed mining area.

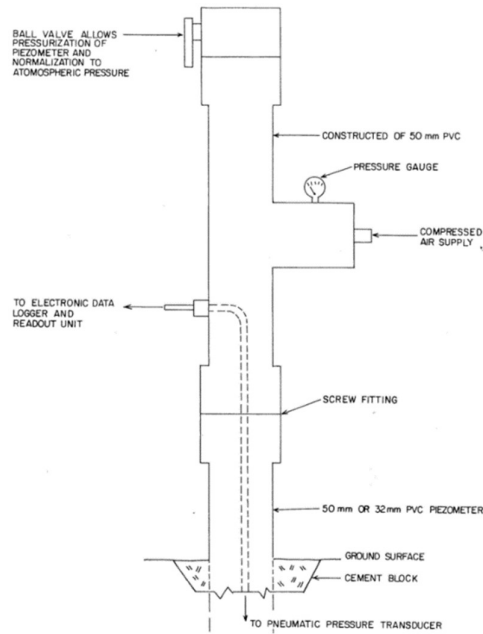


Figure 15: Illustration of pneumatic test set-up, including the assembly clamped to bore casing

Table 10: Summary of pneumatic slug test results closest to proposed sand extraction area at Barrytown South

Piezometer / Obs. Bore No.	Depth (m BGL)	Diameter (mm)	SWL (m ToC)	Basic Time Lag $t_0$ (seconds)	K (m/d)	Strata Code
WS_3200D	30.5	32	1.71	13.2	2.0	A
WS_3200S	9.6	50	0.9	60	2.2	F
WS_5000	8.95	50	1.65	8.4	7.0	B
WS_5500	9.3	50	2.19	19.0	3.1	B
WS_6000	6.6	32	2.11	26.0	2.3	B
WS_6300D	16.7	32	7.6	6.4	4.2	B
WS_6300S	6.65	32	2.91	24	1.1	B
UK2400	6.8	32	5.67	6.5	4.1	A
UK3000	11.65	32	8.96	5.8	4.6	C
UK3900	9.45	32	9.97	8.4	3.2	C
UK4500	8	32	15.75	8.8	3.0	C
UK6300	12.75	32	22.51	45	1.3	C
CAR1	5.67	50	3.66	5.8	10.2	D
CAR2	8.96	50	4.7	12.3	4.8	D
CAR3	9.97	50	7.83	9.0	6.6	D
NBH6-Obs	9.34	50	2.97	5.64	2.5	B
NBH7-Obs	26.95	50	3.02	5.6	2.4	B
NBH8-Obs	9.3	50	2.56	2.01	0.2	A
NBH9-Obs	31	50	4.75	15.87	7.0	C

**Note:** SWL = Static Water Level measured two days apart on 30 August and 1 September 1990 and in terms of depth to water from Top of Casing (ToC); refer to notes of Table 9 for Formation or Strata codes. A = Transgressive Beach Deposit; B = Elevated Terrace; C = Alluvial Fan; D = Previously Mined; and F = Recent Fore-dune.

A comparison of pumping test and pneumatic slug test results is possible by contrasting the pumping test observation bore results for both testing systems. Table 11 provides a comparison of ranges of hydraulic conductivity results within the separate drawdown and recovery phase-interpreted results for the entirety of the Barrytown Flats, plus the singular slug test results. Coffey Partners (1991) also aggregated aquifer and slug test data to advance a single value of horizontal hydraulic conductivity for each formation or strata in Table 12.

**Table 11: Comparison of pumping test and pneumatic slug test results (all Barrytown results)**

Bore #	Pumping Test Hydraulic Conductivity (m/d)		Slug Test Hydraulic Conductivity (m/d)	Strata Code
	Drawdown Phase	Recovery Phase		
NBH2-Obs	9	12.3	4.1	B
NBH3-Obs	0.7 – 0.8	4.9	0.9	B (Deep)
NBH4-Obs	2.6	7.1	8.8	A
NBH6-Obs	16.3	34.5	2.5	B
NBH7-Obs	–	2.1 - 11.2	2.4	B (Deep)
NBH8-Obs	–	1.5	0.2	A
NBH9-Obs	–	1.9 – 2.4	7	C (Deep)
NBH10-Obs	–	8.1 – 9.3	3	D

**Note:** NBH# = New Bore Hole (Number) for pumping and observation bores; Obs = observation bore; Strata or formation codes noted in Table 9; and green shading indicates within or immediately adjacent to proposed mining area. Formation or Strata codes. A = Transgressive Beach Deposit; B = Elevated Terrace; C = Alluvial Fan; D = Previously Mined.

**Table 12: Interpretative assignment of hydraulic conductivities per formation/strata<sup>3</sup>**

Code	Formation / Strata	Hydraulic Conductivity (m/d)	Comments Regarding Choice of Interpreted Value
A	Transgressive Beach	3	Relatively consistent results (1.5 – 7.1 m/d) throughout the transgressive beach deposits approximating 3 m/d.
B	Elevated Terrace	14	The mean of results was 16.4 m/d for shallow and 7.4 m/d for deep screened bores. The value of 14 m/d is a synthesis assuming that most flow occurs at shallow depths.
C	Alluvial Fan	3	Alluvial deposits are highly variable. A value of 3 m/d is consistent with the result for the Canoe Creek alluvial fan measured in test bore NBH9. Clay fraction and poor sorting are most likely limit on permeability.
D	Previously Mined	9	Based on a single set of results from NBH10 near Barrytown settlement. More emphasis on the pumping test results (8.1 – 9.3 m/d).
F	Recent Foredune	6	Based on slug test results in piezometers CAR1 and WS3200S. Nominated value reflects range of mean and median values.

<sup>3</sup> Taken from (Coffey & Partners, 1991)

The above formation or deposit singular hydraulic conductivities are interpretive and consider the wider Barrytown coastal flats' post-glacial to Holocene deposits. It might be noted that the sole pumping test determination of the permeability of historic mined mineral sand was at test bore NBH10 alongside Cargill Road.

### 2.8.3 Hydrogeological Interpretation

As outlined above, Coffey Partners sketched out a hydrogeological zonation that encompassed five depositional facies that grouped the hydro-stratigraphic units within the Holocene (Nine Mile Formation) as follows:

- Transgressive Beach Deposit,
- Elevated Terrace Deposit,
- Alluvial Fan Deposit,
- Previously Mined ground / shallow tailings, and
- Recent Foredune Deposit.

Coffey Partners drafted a number of hydrogeological cross-sections across the Barrytown Flats. Three of the cross-section transect lines cross the Barrytown South proposed mining area. The lines are aligned with the 1989 – 90 drill holes and piezometers prefixed “VA”, “UK”, and “CAR” (see Figure 16, Figure 17, and Figure 18). These lines are respectively aligned with northing orientations of 713550, 712330, and 709600 within the New Zealand Map Grid (NZMS260 series) coordinate system. The VA transect takes in the Canoe Creek sweep across the Barrytown Flats, including the Canoe Creek alluvial fan. The UK transect is also includes an alluvial surface and associated deposits probably related to unnamed creeks draining the hill flanks in the east. The CAR transect follows Cargill Road in the south of the SB.

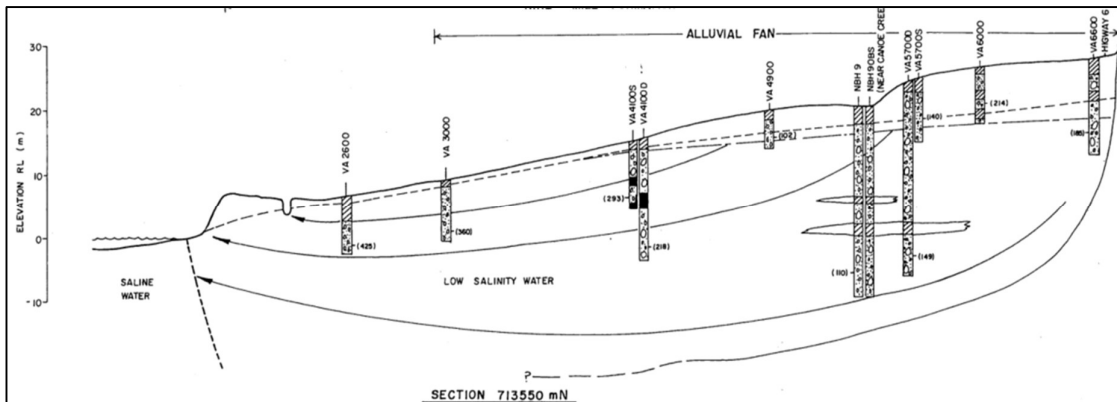


Figure 16: West – east hydrogeological cross-section line along the VA transect alignment

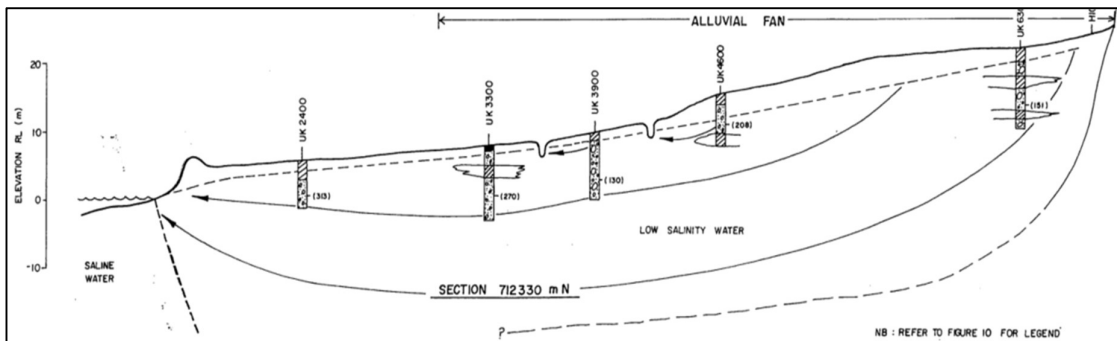
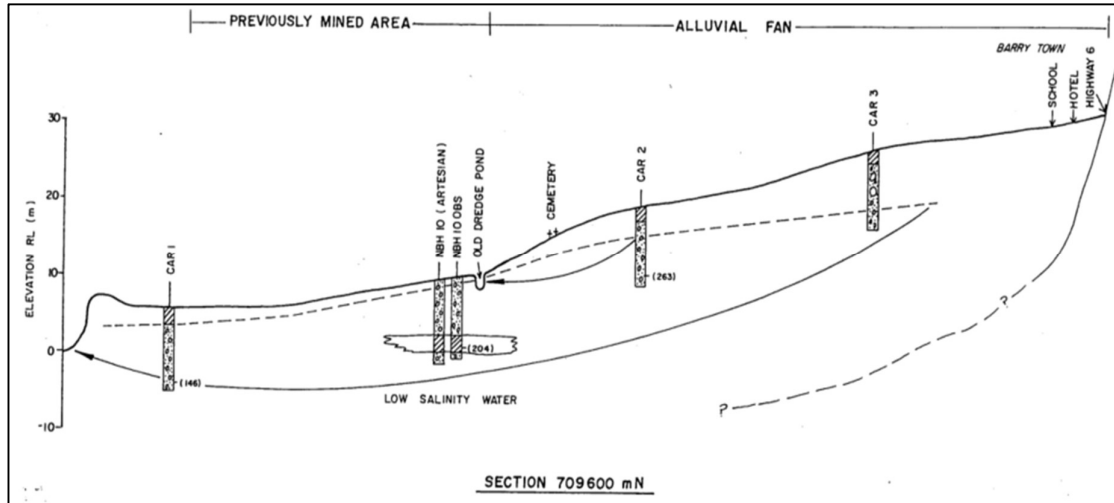


Figure 17: West – east hydrogeological cross-section line along the UK transect alignment



**Figure 18: West - east hydrogeological cross-section line along the CAR transect alignment**

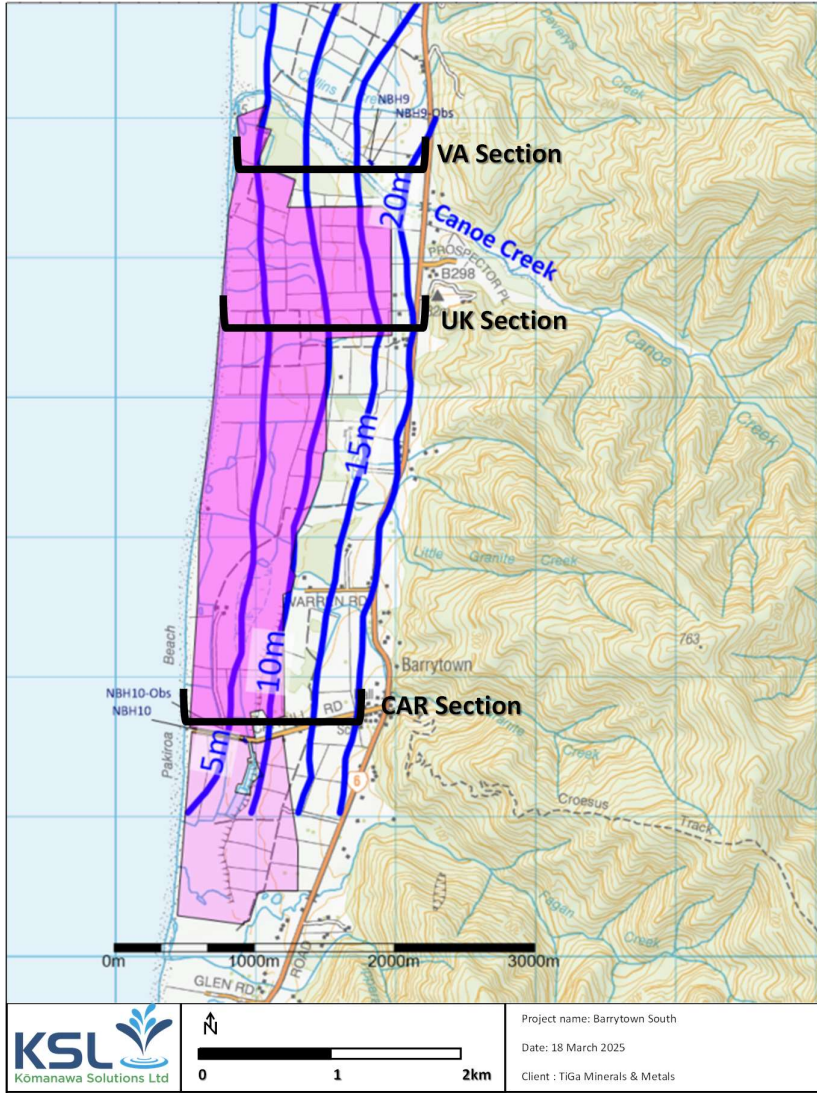
The CAR transect follows Cargill Road from the outskirts of Barrytown settlement to the Tasman Sea. The CAR transect hydrogeology reflects the earlier disturbance and re-working of sand deposits related to gold dredging that occurred in the first half of the 20<sup>th</sup> century. Despite these differences, the sections summarise general patterns of sand-dominated sediments down to depths of 15 – 20 metres beneath the Barrytown Flats, fresh ground water, and moderate hydraulic gradients perpendicular to the coastline.

## 2.8.4 Water Table and Surrounding Water Levels, 1989 - 1990

### 2.8.4.1 Horizontal Water Level Patterns

The Coffey Partners (1991) piezometer and test bore programme allowed the snap-shot and periodic measurement of groundwater levels within installed bores. On the whole, the contouring showed water table contours arranged sub-parallel to the coastline, with finer scale influences from wetlands and creeks on the coastal flats. However, the wide spacing of the transects (shown as WS, UK, and CAR section lines in Figure 19) used in the water table contour map covering the entirety of the Barrytown coastal flats diminishes the relevance of derived lateral water level patterns.

An approximate representation of measured shallow groundwater levels reduced to mean sea level reference is provided in Figure 19. The groundwater level contours suggest seaward groundwater gradient sustained by surface based replenishment (recharge) of the shallow aquifer under Barrytown Flats at creeks and the drainage of soils. The seaward bulge in groundwater level coinciding with the passage of Canoe Creek across the Barrytown Flats is a possible indication of an enhanced concentration of surface water recharge from the creek to the aquifer that is being expressed in the level measurements along the VA section line.



**Figure 19: Water table contours utilising 1989 AMSL groundwater levels from the shallow piezometers**

**2.8.4.2 Barrytown South Horizontal Flow Rates**

Knowledge as to the general groundwater properties (see Table 12), groundwater hydraulic gradient (see Figure 17, Figure 18, and Figure 19) and the width of the coastal aquifer across the groundwater flow direction within the Southern Block (see Figure 19) allow an estimate to be made as to the groundwater flow rates. The Southern Block is arbitrarily split into three sub blocks, North (north of Granite Creek), Central (Granite Creek – Cargill Road) and Southern (Cargill Road to Fagan Creek). The northern and central blocks relate to the transgressive beach deposits (marine sands) and alluvial fan deposits, which each have indicated hydraulic conductivity of 3 metres per day. These sub blocks can be attributed to the UK and CAR lines of piezometers and associated groundwater hydraulic gradients, respectively. The southern sub block south of Cargill Road is more exclusively composed of mine disturbed sand and gravel, so it is assigned a hydraulic conductivity intermediate between transgressive beach and previously mined deposits, i.e., 6 metres per day. It is also assigned the CAR transect groundwater hydraulic gradient.

The Darcy Equation, which provides a simplified means of calculating groundwater flow and pore velocity rates, which can be rearranged to the following equations:

Darcy Flow Equation  $Q = TiW,$

and the Darcy Velocity Equation:  $v = K/i n_e$

Where:

$Q$  = Mean frontal flow rate ( $m^3/d$ )

$T$  = Aquifer transmissivity ( $m^2/d$ )

$i$  = Hydraulic gradient ( $m/m$ )

$W$  = Width of flow front ( $m$ )

$v$  = Mean groundwater flow velocity ( $m/d$ )

$K$  = Hydraulic conductivity ( $m/d$ )

$n_e$  = Effective porosity (decimal)

The parameter assignment of the first flow equation for groundwater flow is provided in Table 13.

**Table 13: Estimation of SB Groundwater Flow Rates at three arbitrary Flow Fronts**

	Width, W (m)	Mean Gradient, i (m/m)	Hydraulic Conductivity (m/d)	Mean Depth (m)	Trans- missivity, T ( $m^2/d$ )	Gw Flow = TiW ( $m^3/d$ )	Gw Flow (L/s)
Flow Front North (m)	2,182	0.0138	3	15	45	1,352	15.7
Flow Front Centre (m)	1,558	0.0203	3	15	45	1,422	16.5
Flow Front South (m)	1,321	0.0203	6	15	90	2,411	27.9
Combined	5,061					5,185	60.1

The Darcy Velocity calculation is also able to be employed in the same methodology as Table 13. The main addition for calculating mean groundwater flow velocity. The range of mean flow velocity was derived as from 50 to 150 metres per year for each sub block, increasing to the south of the Southern Block. These mean estimated rates are approximations rather than precise values for these terms and these terms are subject to substantial heterogeneity. The above equations provide some order of magnitude estimates of the rate of horizontal subsurface flow and the pore velocities that solutes might be subject to.

### 2.8.4.3 Vertical Water Level Patterns

As mentioned previously, several paired shallow and deep piezometers or bores were installed within the Westland Ilmenite hydrology programme. This positioning allowed the estimation of vertical head difference and calculation of vertical hydraulic gradients.

Table 14 lists the paired piezometers and observation bores, some of which were within the proposed mining area. The largest level difference was 4.66 metres for piezometer WS6300 indicating a negative vertical gradient of -0.463 metre per metre ( $m/m$ ), i.e. strongly downwards. No positive (upward) vertical hydraulic gradients were observed, potentially due to the presence of Canoe Creek and infiltration in the higher permeability alluvial fan. The mildly (above ground) flowing artesian pressure at NBH10 would suggest that upward gradients could exist in areas closer to the Barrytown settlement.

**Table 14: Summary of calculated vertical hydraulic gradients between paired shallow and deep piezometers or bores**

Piezo or NBH No.	Easting	Northing	Depth (m BGL)	SWL (m AMSL)	Strata Code	Vertical Difference <sup>£</sup> (m)	Vertical Gradient (m/m)
VA_4100S*	1461441	5325585	9.7	13.95	C		
VA_4100D*	1461444	5325585	18.7	13.55	C	-0.40	-0.044
VA_5700S*	1461910	5325562	9.7	18.31	C		
VA_5700D*	1461907	5325566	30.9	17.5	C	-0.81	-0.038
WS_3200S <sup>¥</sup>	1461197	5328929	9.6	3.16	F		
WS_3200D <sup>¥</sup>	1461186	5328931	30.5	2.85	A	-0.31	-0.029
NBH6-Obs <sup>¥</sup>	1461865	5328034	9.34	5.64	B		
NBH7-Obs <sup>¥</sup>	1461863	5328034	26.95	5.6	B	-0.04	-0.0023
WS_6300S <sup>¥</sup>	1462144	5328960	6.65	10.04	B		
WS_6300D <sup>¥</sup>	1462144	5328964	16.7	5.38	B	-4.66	-0.463

**Note:** Bores generally measured on 30 August 1990. \* Along VA cross-section 713550 south of Canoe Creek; <sup>¥</sup> Along WS cross-section 716900 north of Burke Road; <sup>£</sup> Positive (+) difference equals upward, Negative (-) difference equals downward. Strata Codes: A = Transgressive Beach Deposit, B = Elevated Terrace, C = Alluvial Fan, F = Recent Foredune

The predominance of downward vertical gradients potentially indicates a pattern of shallow groundwater being recharged by soil drainage (i.e. land surface recharge) and surface water infiltration coupled with outflow of the Holocene aquifer's water at depth along the coastal boundary in the west. Such patterns of inflow and outflow alongside observed vertical gradients are common among unconfined coastal aquifers in moderate to high rainfall regions.

Although not listed in Table 14, but of note, is test bore NB-10 on Cargill Road. A 1-metre thick clay layer separates the deeper 8.0 to 11 metre silty sandy gravel from the shallow silty gravel above. As the bore was screened across the deeper gravel, it is notable that a mild above-ground artesian pressure is measured in bore NB -10. This is the sole measured indication of a positive vertical groundwater gradient and included ground historically mined to a depth of about 6 metres.

Elsewhere, upward vertical groundwater gradients in a coastal setting are more commonly associated with low permeability layers such pervasive silt, clay or peat beds between the shallow and deeper parts of the groundwater system. The balance of evidence would suggest that the vertical level differences measured in the Barrytown Flats area are the result of boundary effects and mild vertical stratification of a stratified aquifer between water table and silty sandstone basement. Later testing in the Central Resource Block found more indications of semi-confined, leaky water-bearing layers in the Holocene sediments (Kōmanawa Solutions Ltd, 2024).

## **2.8.5 Aquifer Properties Determined from 2022 and 2023**

### **2.8.5.1 Pumping and Injection Tests**

#### **November 2022 Pumping and Injection Tests**

Kōmanawa Solutions undertook a variety of groundwater permeability testing in 2022 and 2023, including pumping tests, slug tests and injection trials in relation to the Nikau Deer Farm hydrological assessments. Two sets of permeability testing using 125 mm diameter test bores (PB-1 and PB-2). The testing in November 2022 included step drawdown and constant rate tests with observation bores in PB-1, plus injection falling head tests in PB-2. The testing assessed two sedimentary facies; alluvial fan gravel deposits (PB-1), and fine sand with minor gravel (PB-2) as shown in Table 15.

**Table 15: Combined Groundwater Properties from two sets of testing within the Nikau Deer Farm Block**

Lithology in terms of broad Grain Size Distribution		
Property	PB-1 Variable & Constant Flow Tests Gravel with minor sand (Alluvial Fan, Type C) (semi-confined properties)	PB-2 Falling Head Test Mineral Sand with minor gravel (Transgressive Beach, Type A) (stratified)
Pump-out or Injection Flow Rate (L/s)	4.0	0.9
Transmissivity (m <sup>2</sup> /d)	290 - 388	15.5 - 85
Estimated Mean Hydraulic Conductivity (m/d)	58 - 78	3 - 17
PSD Correlated Hydraulic Conductivity (m/d)	-	11
Storativity	1 x 10 <sup>-3</sup> to 6.2 x 10 <sup>-4</sup>	<i>2.2 x 10<sup>-2</sup></i>
Specific Yield	-	0.35
Radius/Leakage Ratio, r/B	0.024 to 0.046	-
Leakage Coefficient, B (m)	208 to 361	-

**Note:** PSD = Particle Size Distribution with the representative diameters such as the 60% diameter (d<sub>60</sub>) and 10% diameter (d<sub>10</sub>) used in conversion to an estimated hydraulic conductivity. Values in italics are thought to be questionable and potentially subject to analysis artefacts; unconfined aquifer settings' storage coefficients are better defined by Specific Yield (comparable to drainable or effect porosity); semi-confined aquifer settings provided a range of leakage coefficients, of which the Leakage Coefficient (B) is the more universal and insensitive to the radius between pumping bore and observation bore.

## September 2023 Injection and Infiltration Trials

### Gravel with Sand Layer Pumping and Injection Trials

In September 2023, additional pumping and injection testing was undertaken in the Nikau Deer Farm block, along the CB's southern boundary near Collins Creek. Testing of a three metre thick gravel with sand layer between silty sand layers determined a transmissivity of 408 square metres per day and hydraulic conductivity of 135 metres per day. A storativity of  $7.8 \times 10^{-4}$  was also derived, while the overlying aquitard was determined to have a K'/B' leakage ratio of 0.027 (equivalent to hydraulic conductivity, K', of approximately 0.2 m/d). These gravel and sand layers were found to be semi-confined by clay bodies that tended to be follow the course of Collins Creek.

### Fine Mineral Sand Infiltration Trial

Infiltration testing was undertaken of an open trial section of trench in fine mineral sand lithology. The trench infiltration test of fine mineral sand determined an infiltration rate of 2.9 cubic metres per day per metre of trench ( $m^3/d/m$ ). The trial results were consistent with previous groundwater properties testing in the same lithology.

### Coarse Gravel Alluvium Infiltration Trial

An excavation was undertaken to form a shallow trench with base of 5.0 m, width 2.1 m, and the height to land surface 1.6 m. The trench was filled at a flow rate of 46 L/s to the brim, within 17 minutes. The pumping rate was adjusted down as soon as it was apparent that the trench would not sustain the higher pumping rate. The new pumping rate after 17 minutes was 25 L/s, as the trench began to lap over its edge. The pumping was held at 25 L/s, allowing the pumping to balance the pumped inflow with losses through its base for a further 43 minutes, after which flow was adjusted to 16 L/s for an hour resulting in a slight drop in pond water level below the lip. A further adjustment of pumping rate down to 10 L/s was held for a further hour, which also led to a further drop. The trench water level responded to each reduction in pumping rate by declining 0.07 m and 0.28 m from 25 - 16 L/s, and 16 - 10 L/s, respectively. Groundwater level responses were measured in a piezometer located 3.5 m from the edge of the trench end. The trench infiltration test of Canoe Creek alluvial cobble gravel was analysed using the method of Murdoch (Murdoch, 1994), and Gringarten & Witherspoon (Gringarten & Witherspoon, 1972) for water filled trench testing. Figure 20 shows the fitting of a curve conforming with the Murdoch (1994) generated type curves used to determine the hydraulic properties of the sandy cobble gravel.

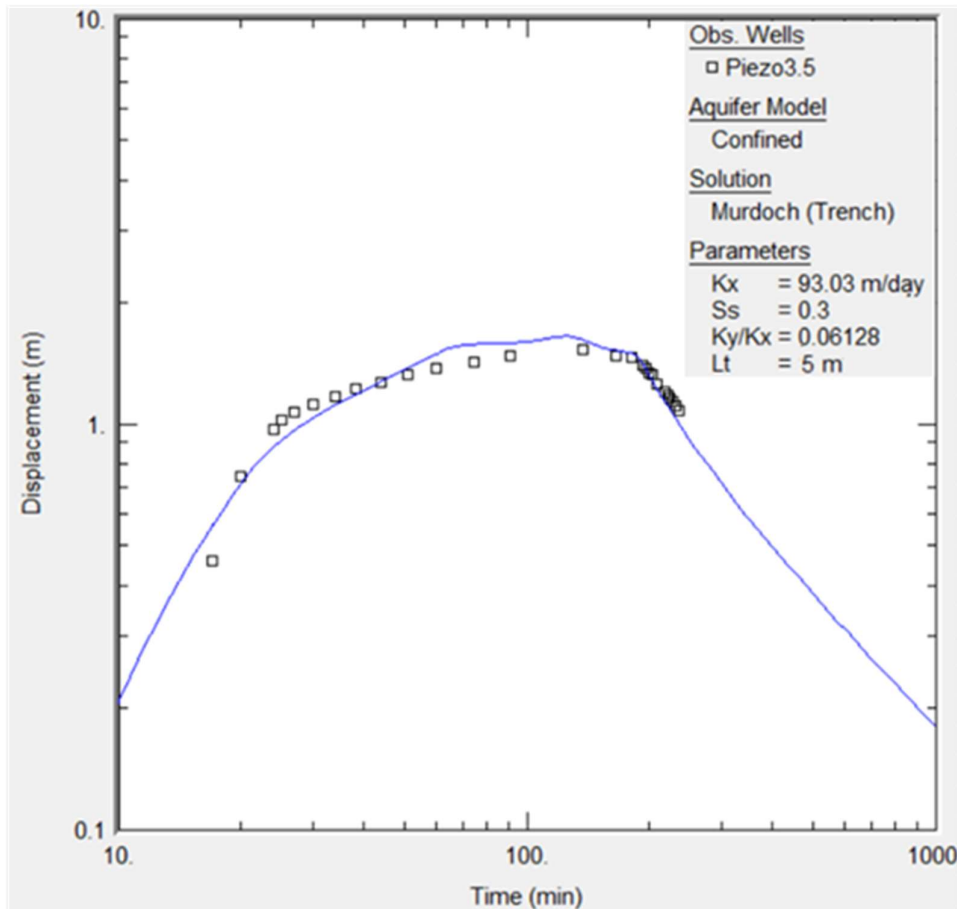


Figure 20: Step filling and recovery of a sandy cobble gravel layer cut by a shallow trench or basin

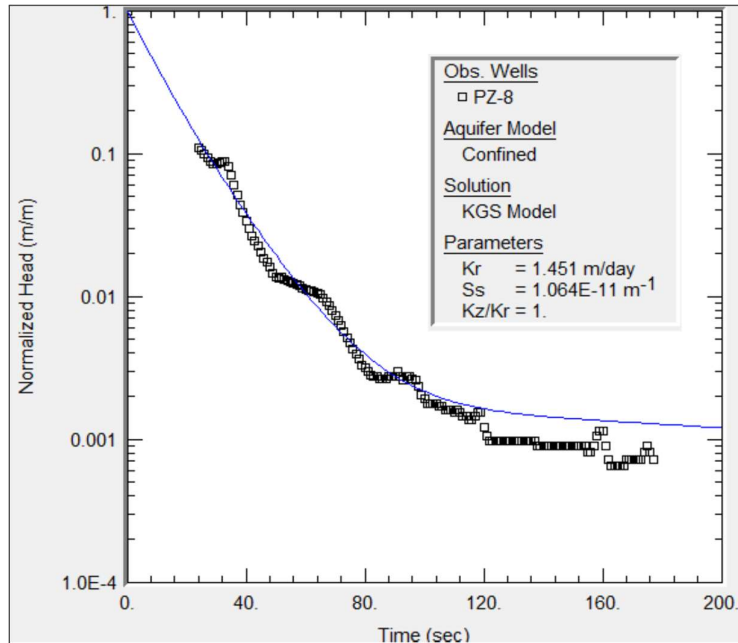
The derived hydraulic conductivity was 93 metres per day, while the storage coefficient was estimated at 0.3 (dimensionless). Both properties are consistent with a moderately to highly permeable, unconfined gravel. These hydraulic properties would have relevance to the Barrytown South project area only in the far north of the main block near the south bank of Canoe Creek. This area would not be approached by the proposed mine path and would also be less prospective in terms of mineral sand resource.

The consented Central Resource Block (CRB) water supply infiltration gallery would be installed into the Canoe Creek alluvium and have access to hydraulic conductivity in the realm of the value determined in the coarse gravel alluvium infiltration trial. It is proposed that the infiltration gallery would be tasked to supplying the WCP for the SB mining project.

### 2.8.5.2 Slug Testing

#### Fine Sand Slug Tests

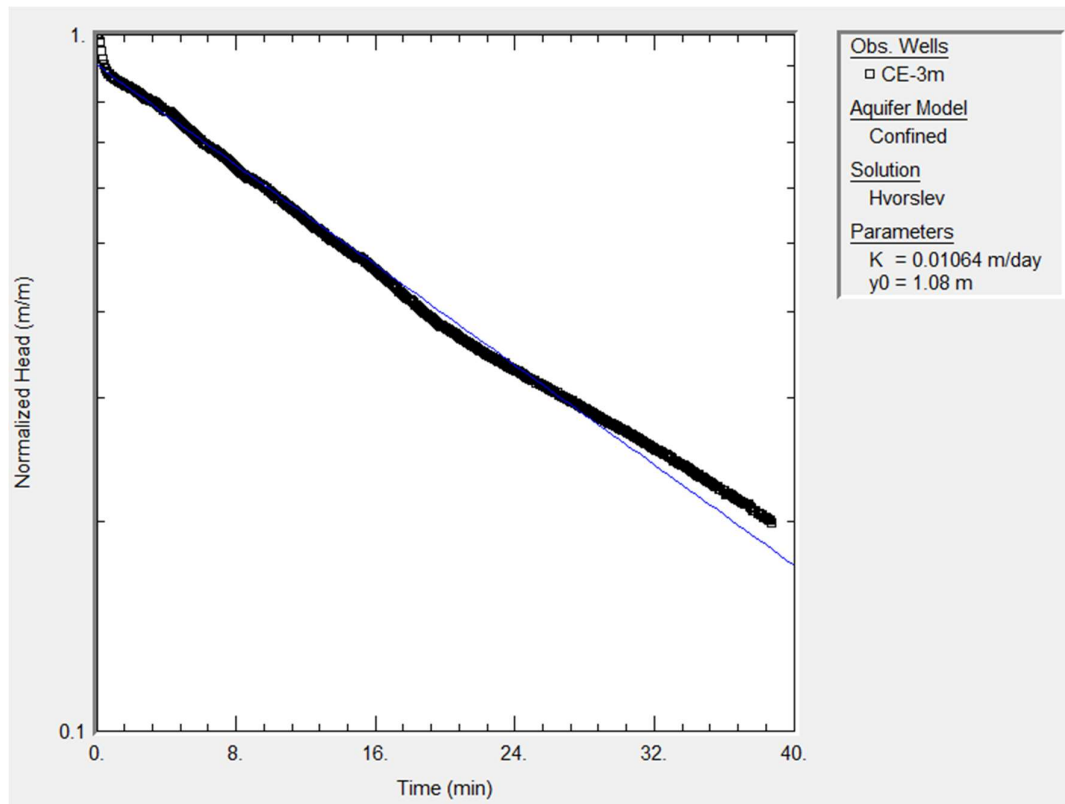
Slug tests were also undertaken in the Nikau Deer Farm in June 2022. However, the 32 mm diameter piezometers used in the block meant that slug testing was limited to added water, falling head tests, which in practise gave poor results. The sole test of note was taken with PZ-08 within grey, fine mineral sand near the Canoe Creek Lagoons. It determined a radial hydraulic conductivity ( $K_r$ ) of 1.4 metres per day (m/d). Figure 21 illustrates the plotted normalised head measured in the PZ-8 slug test and the derived hydraulic conductivity using Kansas Geological Survey (KGS) methodology.



**Figure 21: Slug test displacement matching and result from falling head test on 32 mm piezometer PZ-8**

#### Silty Clay Aquitard Layer Slug Test

Subsequently in September 2023, slug testing using added volume method was employed to test the properties of a silty clay layer of 7 metres thickness that intervened between Collins Creek and underlying mineral sand with gravel. Once again, falling head testing approach was taken by filling the 3.4-metre deep observation bore (50 mm diameter) with 1.2 metres of water being added instantaneously. The recovery to static water level after the displacement is plotted in Figure 22. The slug test analysis using the Hvorslev analysis method (Hvorslev, 1951) determined a hydraulic conductivity of 0.01 m/d (or  $1.15 \times 10^{-7}$  metres per second in units more commonly used for clays), which was at the lower end of the clay layer hydraulic conductivity determined in pumping and injection testing at the same site.



**Figure 22: Slug test displacement matching from falling head test on 50 mm diameter bore CE-3m**

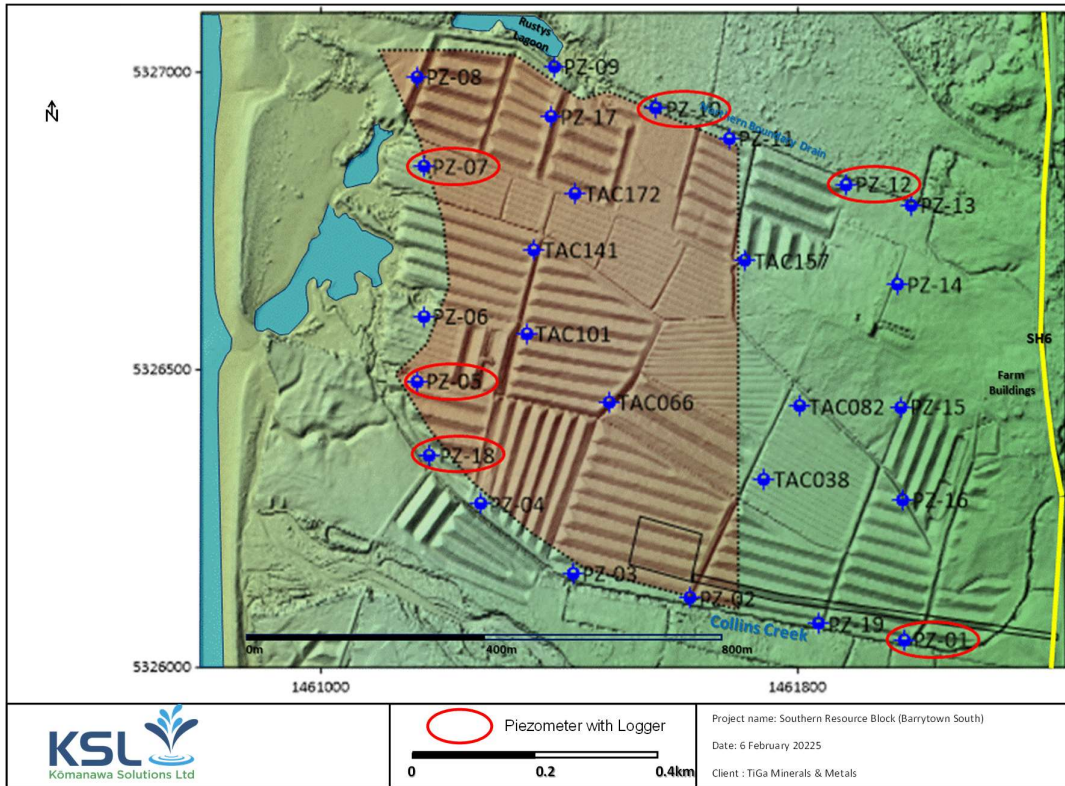
### 2.8.5.3 Groundwater Level during 2022

The CRB project installed 19 x PZ-## piezometers (32 mm diameter) plus seven TAC### (15 mm diameter) tube wells as part of groundwater characterisation (see Figure 23). Six piezometers (PZ- 1, 5, 7, 10, and 18) were fitted with electronic level loggers to collect a continuous record of groundwater level through time. The location of logger fitted piezometers are also mapped in Figure 23.

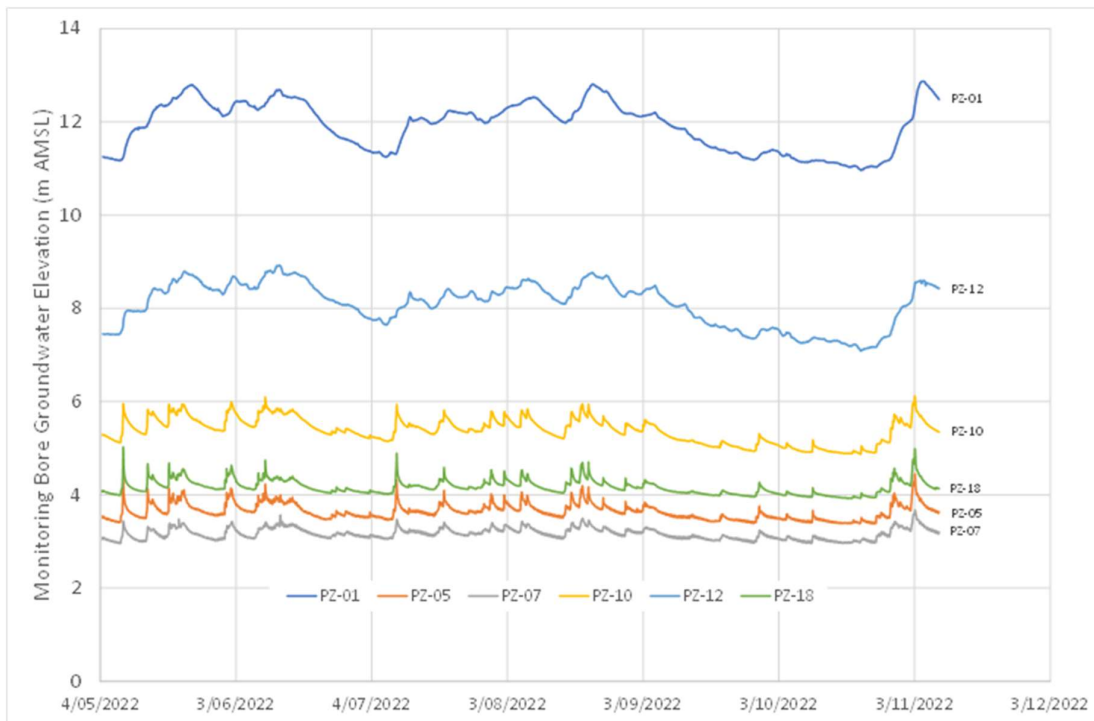
The level record of a 6.3 month period from May to November 2022 was plotted in Figure 24. The groundwater level trends exhibited correlations between groundwater level and the following environmental influences:

- The balance of rainfall and evapotranspiration (i.e., soil drainage), or
- Adjoining creek level fluctuations, or
- Variation in the level of coastal lagoons, and/or
- Sea tides in the piezometers furthest west.

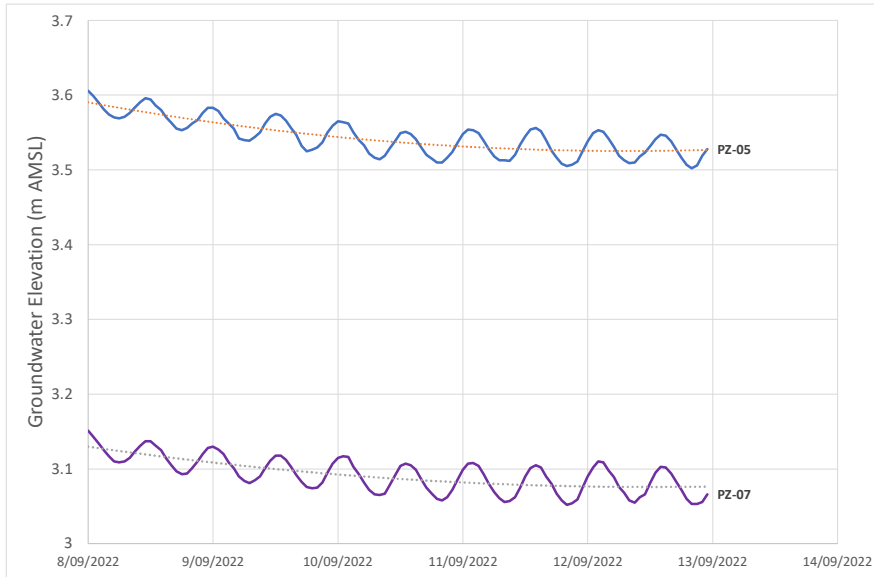
The very clear tidal influence is shown in Figure 25 for piezometers numbered PZ-07 and PZ-05 that were located closest to the coastline. Despite the proximity, the tidal influence is less than 0.05 metres (5 centimetres) while the corresponding tidal variation was up to 3 metres (300 centimetres), an approximate tidal efficiency of 0.0167 (1.67%). The intervening Canoe Creek Lagoons may be an explanation of the low degree of tidal influence. These lagoons exhibit little influence of tidal variation in their level. On balance the effect of tide on the groundwater system is minor and does not tangibly extend any further than 300 m from the landward edge of the coastal lagoons. Sampled groundwater from these piezometers and the coastal Lagoons was found to be fresh.



**Figure 23: Location of piezometers groundwater measurement points across the Nikau Deer Farm block (CB)**



**Figure 24: Composite groundwater elevation plot of six continuous level hydrographs across Nikau Deer Farm**



**Figure 25: PZ-05 and -07 groundwater level over 5 day period, showing tidal signature**

**2.8.5.4 More Recent SB Groundwater Measurements**

TCM instituted groundwater monitoring within the Barrytown Farms Limited property in the Reynolds dairy farm (Barrytown Farms Limited) north of Cargill Road. This farm lies within the Southern Block (SB). Figure 26 plots a selection of three groundwater level records within the Reynolds dairy farm with transducers installed in late July 2022. Piezometer PZ-103 is located inland on the banks of Granite Creek and exhibits relative stability in groundwater level. Piezometer PZ-101 is located at the farm milking shed in relative proximity of the coastline. Piezometer PZ-105 is located in the north of property and located between a farm drain and the coastline.



**Figure 26: Groundwater elevation plot of three continuous level elevations across Barrytown South**

Monitoring bore PZ-103 lies between a lowland reach of Granite Creek and a large wetland, therefore the degree to which the groundwater level within that bore may fluctuate is likely to be constrained by proximity to those two fixed heads. Bores PZ-101 and PZ-105 lie much closer to the coastline, 260 and 150 metres respectively. Bore PZ-105 in the northwest of the Reynolds dairy farm in low-lying coastal land appears to be more strongly influenced by coastal hydrological conditions, having a low standing water level and artefacts of tidal influence (approximately 5 centimetres, or a tidal efficiency of 1.7%). The influence of climate as soil drainage or creek and drain flow is evident in all piezometer hydrographs in the Barrytown South project area in Figure 26. Heavy and accumulating rainfalls were recorded in August and the period late October – early November 2022 and these correlate with spikey and elevated groundwater levels in all three hydrographs. A similar pattern of groundwater fluctuation was recorded in 2022 at the Nikau Deer Farm block, as illustrated in Figure 24.

## 2.9 Water Quality

### 2.9.1 Historic Water Quality Information

Field investigations in 2022 also included focused investigations of groundwater quality and groundwater composition. The Coffey Partners (1991) reporting of groundwater chemistry was limited, and the Barrytown area has not received attention from national, regional or local government groundwater investigations covering water quality in any way, i.e., NGMP<sup>4</sup>, LAWA<sup>5</sup> or WINZ<sup>6</sup> water quality databases. Groundwater and surface water sampling with analysis was undertaken in the Nikau Deer Farm Block from May 2022 to present. The results of these analyses is listed in tables provided in Appendix 1, Appendix 2, Appendix 3, and Appendix 4.

The water chemistry of the shallow groundwater throughout the Barrytown Flats was found to be of low dissolved oxygen content with low alkalinity although relatively dilute. The low oxygen content tends to allow the dissolution of metals/metalloids such as manganese in the shallow groundwater, which are represented in the shallow groundwater in moderate concentrations. Macro-nutrients, particularly nitrates or phosphates, are present at low to moderate groundwater concentrations in these bores, which is suggestive that the shallow pore spaces of Nikau Deer Farm groundwater were somewhat isolated from surface influences or nitrates were affected by assimilatory denitrification.

#### 2.9.1.1 Groundwater Dissolved Metals

Groundwater quality monitoring results from the nine groundwater sampling locations on the Nikau Deer Farm at locations indicated in **Error! Reference source not found.** were analysed for a range of dissolved constituents and compared to the Australian and New Zealand guidelines (ANZG) for fresh and marine water quality (2018 revision). The ANZG freshwater values are useful for preliminary screening for potential water quality issues because the receiving waters for discharges from the mine are fresh surface water bodies on and adjacent to the site. Drinking water standards are not relevant because the local groundwater resource on and downstream of the site is not used for drinking water supply.

The screening process identified the six parameters with concentrations above the ANZG 95% species protection values as per Table 16.

<sup>4</sup> National Groundwater Monitoring Programme is a database that provides a national perspective on Aotearoa New Zealand's groundwater quality through time run primarily by GNS Science with assistance from regional authorities.

<sup>5</sup> Land, Air, Water Aotearoa (LAWA) shares environmental data and information from a variety of environmental monitoring sources across the country and presents it in a layperson compatible format.

<sup>6</sup> Water Information New Zealand (WINZ) is a national database of public water supply water quality and composition developed by ESR for the Ministry of Health.

**Table 16: Nikau Deer Farm CB Groundwater quality screening assessment summary**

Parameter	ANZG 95% value	Max recorded	No of samples > ANZG	Samples exceeding ANZG
Aluminium	0.055	0.1	1	PZ-15
Arsenic	0.013	0.036	1	PZ-02
Chromium	0.001	0.0035	1	PZ-15
Copper	0.0014	0.0055	6	PZ-15, PZ-17, PZ-13, PZ-18, PZ-02, PZ-01
Nickel	0.011	0.122	2	PZ-18, PZ-01
Zinc	0.008	0.104	8	PZ-15, PZ-08 PZ-17, PZ-13, PZ-18, PZ-02, PZ-01, PB-01,

Note: Full analysis reproduced in Appendix 1 (Nikau Deer Farm)

These groundwater samples were taken from sampling bores with depths averaging 9 metres below ground level. Deeper drilling (> 16 metres BGL) and monitoring of groundwater quality associated with injection trials on the Nikau Deer Farm property found differing composition. Table 17 reproduces the analytical results for the deeper trial bore, which manifested less concentrated (dilute), more oxygenated (low iron and manganese), lower dissolved metals content.

**Table 17: Nikau Deer Farm, deeper 16.5 m Injection Bore sampled (Sept. 2023) and analysed**

	Units	Injection Well IW01 (16.5 m)	Guideline ANZG 95
Sum of Anions	meq/L	0.95	N/A
Sum of Cations	meq/L	0.94	N/A
Turbidity	NTU	0.26	N/A
pH	pH	7.3	N/A
Total Alkalinity	g/m <sup>3</sup>	35	N/A
Bicarbonate	g/m <sup>3</sup>	43	N/A
Total Hardness	g/m <sup>3</sup>	29	N/A
Electrical Conductivity	mS/m	10.1	N/A
Dissolved Calcium	g/m <sup>3</sup>	7.2	N/A
Dissolved Iron	g/m <sup>3</sup>	0.54	
Dissolved Magnesium	g/m <sup>3</sup>	2.6	N/A
Dissolved Potassium	g/m <sup>3</sup>	3.9	N/A
Dissolved Sodium	g/m <sup>3</sup>	5.7	N/A
Chloride	g/m <sup>3</sup>	6.6	N/A
Nitrite-N	g/m <sup>3</sup>	0.002	N/A
Nitrate-N	g/m <sup>3</sup>	0.012	N/A
Nitrate-N + Nitrite-N	g/m <sup>3</sup>	0.014	N/A
Sulphate	g/m <sup>3</sup>	2.9	N/A
Dissolved Organic Carbon	g/m <sup>3</sup>	<0.5	N/A
Dissolved Aluminium	g/m <sup>3</sup>	<0.003	0.055
Dissolved Arsenic	g/m <sup>3</sup>	0.0018	0.013
Dissolved Boron	g/m <sup>3</sup>	0.006	0.94
Dissolved Cadmium	g/m <sup>3</sup>	<0.00005	0.0002
Dissolved Chromium	g/m <sup>3</sup>	<0.0005	0.001
Dissolved Copper	g/m <sup>3</sup>	<0.0005	0.0014
Dissolved Lead	g/m <sup>3</sup>	<0.0001	0.0034
Dissolved Manganese	g/m <sup>3</sup>	0.027	1.9
Dissolved Nickel	g/m <sup>3</sup>	<0.0005	0.011
Dissolved Zinc	g/m <sup>3</sup>	0.0018	0.008

Note: **Bold** values indicate that they are in excess of the ANZG 95% protection guideline.

The implication of the groundwater quality characterisation at the CRB mine area during 2022 - 2023 suggested any wholesale mobilisation of the deeper groundwater within the sandy gravel would reduce metals / metalloids concentrations in an active sand extraction pit by dilution with less concentrated deeper groundwater.

### 2.9.1.2 Metalliferous Sands Leachate Concentrations in the Southern Block

Drill hole samples taken and stored during the 2022 investigations of the Barrytown Farms Ltd block within the Southern Block were re-sampled and sent for a re-analysis technique termed 'shake testing'. Of most interest in reviewing the results are the metalliferous constituents. Samples were thus sorted into subsets following physical agitation sorting into 'Slimes' (fine sediments), 'Tails' (tailings), 'ROM' (Run Of Mine ore), and 'HMC' or 'Cons' (Heavy Mineral Concentrate). The chemical analyses sampled the water decanted from each representative component of the mineral sands mining and processing chain. The sole dissolved metals that triggered exceedance of the ANZG 95% ecological guideline were mercury, aluminium, chromium, cobalt, copper, lead, nickel and zinc, as listed in Table 18 (see also Appendix 5).

**Table 18: Process (Shake Test) water quality screening assessment summary**

Toxicant (dissolved unless otherwise stated)	Units	ROM	Slimes	Tails	Cons	ANZG 95
Mercury	g/m <sup>3</sup>	<0.00008	0.0003	0.0022	0.00014	0.0006
Aluminium	g/m <sup>3</sup>	0.52	1.13	0.68	0.97	0.055
Chromium	g/m <sup>3</sup>	0.0035	0.0164	0.0084	0.0118	0.001
Cobalt	g/m <sup>3</sup>	0.0038	0.0107	0.0011	0.0013	0.0014
Copper	g/m <sup>3</sup>	0.0079	0.034	0.0094	0.0086	0.0014
Lead	g/m <sup>3</sup>	0.0024	0.00196	0.0032	0.005	0.0034
Nickel	g/m <sup>3</sup>	0.0085	0.33	0.0041	0.0108	0.011
Zinc	g/m <sup>3</sup>	0.064	0.122	0.029	0.025	0.008

### 2.9.1.3 Salinity in Ground and Surface Water

For unconfined groundwater systems in humid climates, such as the Barrytown Flats, there tends to be a net surplus of freshwater outflowing to the coast. Coffey Partners' electro-magnetic surveys (Coffey Partners, 1991) along the foredune and beach zones of the Barrytown coastline found no evidence of low resistivity (i.e., high electrical conductivity) indicative of saline groundwater, including water samples taken at the coastline (see Figure 27).



**Figure 27: Groundwater sampling bore CAR1 on the coastline (Coffey & Partners, 1991)**

Coastal lagoons and creek mouths were also uniformly freshwater despite being a beach-width from the Tasman Sea [refer to water quality results in (Coffey & Partners, 1991) and (Kōmanawa Solutions Ltd, 2024), and Appendix 3 of this report]. These appear to also serve as a freshwater screen against the entry of saline wedges into the coastal lagoons and creek estuaries. Indeed, the a classic mixed sand/gravel beach, (MSGB) the dominant feature of which is a gravel bund barrier would serve to prevent landward movement of seawater or brackish water by any process except ‘wash-over’ by large sea waves (Tear, 2026). The relatively high topographic gradient of Barrytown Flats to the Tasman Sea also assists in preventing the penetration salinity inland to any extent. Within the SB proposed mining areas, the most seaward groundwater sampling bores (VA-2600, UK-2400, and CAR1) all returned electrical conductivity measurements less than 430 micro-Siemens per centimetre ( $\mu\text{S}/\text{cm}$ ), i.e., less than 0.86% of full seawater salinity (Coffey & Partners, 1991). These seaward sampling bores were mostly close to the Mean High Water Springs datum of the coastline.

## **2.9.2 Recent Water Quality Information**

Groundwater samples were taken from five piezometers and ten surface water positions in the SB on 8 and 9 April 2024 as part of reconnaissance field investigations at that time. Table 19 lists the results of analysis for selected samples taken from Granite Creek (upstream of Confluence) and Little Granite Creek (upstream of Confluence, plus two groundwater sampling bores listed in Table 20.

### **2.9.2.1 Granite Creek**

Selected water samples taken at Granite Cree main stem and the Little Granite Creek tributary, which includes Clarke Creek contributions), were sampled immediately the creek confluence at the Reynolds farm ford on the coastal plain. Table 18 lists the full results of analysis of Granite Creek waters for standard water quality analytes. Surface water exceeded ANZG 95% species protection (McDowell et al., 2013) for dissolved aluminium, copper, iron, manganese and nickel. The influence of the groundwater seepage into coastal plain surface water is hinted at with the similarity of cation and anion concentrations plus hardness / alkalinity and electrical conductivity. Turbidity is plausibly higher in both surface waters due to the sources of suspended solids or colour in creek waters.

### **2.9.2.2 Groundwater**

The groundwater sampled in the unconfined piezometer (PZ-101) and the semi-confined flow artesian piezometer (PZ-104) show contrasts in the composition of indicator constituents. Piezometer PZ-104 is unusual in manifesting high turbidity at 1,500 NTU. However, the elevated turbidity in a groundwater sample may be explained by the elevated total iron content of the same piezometer of 104 grams per cubic metre. Highly reducing geochemical conditions are more often encountered in semi-confined pressure conditions. It is likely that the elevated total iron reflects the presence of ferric precipitate flocculation being suspended in the sample water once it came into contact with atmospheric oxygen. Groundwater exceeded ANZG 95% species protection (McDowell et al., 2013) for iron and nickel. The SB groundwater dissolved metal concentrations stand out as being generally lower than that of the CB Nikau Deer Farm Block (compare Table 16 above with Table 20 below).

Nickel is the sole non-ferrous groundwater dissolved metal exceedance of the ANZG95 guideline in the groundwaters, which is curious placed alongside the surface water exceedances for dissolved aluminium, copper, iron, manganese and nickel. There is a possibility that the basement rock geochemistry in the upper catchment was the contributor of aluminium, copper and nickel, while iron and manganese had their source in microbial-mediated reduction in the presence of dissolved organic carbon derived from buried vegetation in coastal plain sediments.

**Table 19: Granite Creek catchment surface water quality results for samples taken 8 – 9 April 2024**

Sampling Site		Granite Ck	Little Granite Ck	Detection Limit	ANZG 95
Sum of Anions	meq/L	1.11	1.23	0.07	N/A
Sum of Cations	meq/L	1.12	1.61	0.05	N/A
Turbidity	NTU	5.9	1,080	0.05	N/A
pH	pH Units	6.7	6.1	0.1	N/A
Total Alkalinity	g/m <sup>3</sup> as CaCO <sub>3</sub>	32	31	1	N/A
Bicarbonate	g/m <sup>3</sup> at 25°C	39	37	1	N/A
Total Hardness	g/m <sup>3</sup> as CaCO <sub>3</sub>	34	34	1	N/A
Electrical Conductivity (EC)	mS/m	11.9	14	0.1	N/A
Total Suspended Solids	g/m <sup>3</sup>	3	1,270	3	N/A
Total Dissolved Solids (TDS)	g/m <sup>3</sup>	78	98	10	N/A
Dissolved Calcium	g/m <sup>3</sup>	9.1	10.2	0.05	N/A
Total Iron	g/m <sup>3</sup>	1.24	118	0.021	N/A
Dissolved Magnesium	g/m <sup>3</sup>	2.6	2.1	0.02	N/A
Dissolved Mercury	g/m <sup>3</sup>	< 0.00008	< 0.00008	0.00008	0.0006
Total Mercury	g/m <sup>3</sup>	< 0.00008	< 0.0021	0.0021	N/A
Dissolved Molybdenum	g/m <sup>3</sup>	< 0.0002	0.0002	0.0002	0.034
Dissolved Potassium	g/m <sup>3</sup>	1.05	2.7	0.05	N/A
Dissolved Silver	g/m <sup>3</sup>	< 0.00010	< 0.00010	0.0001	N/A
Dissolved Sodium	g/m <sup>3</sup>	9.1	12.1	0.02	N/A
Chloride	g/m <sup>3</sup>	13.3	19.5	0.5	N/A
Total Ammoniacal-N	g/m <sup>3</sup>	0.094	0.36	0.01	N/A
Nitrite-N	g/m <sup>3</sup>	0.005	< 0.002	0.002	0.9
Nitrate-N	g/m <sup>3</sup>	0.3	< 0.002	0.001	N/A
Nitrate-N + Nitrite-N	g/m <sup>3</sup>	0.31	< 0.002	0.002	N/A
Total Kjeldahl Nitrogen (TKN)	g/m <sup>3</sup>	0.19	3.6	0.1	N/A
Dissolved Reactive Phosphorus	g/m <sup>3</sup>	< 0.004	< 0.004	0.004	N/A
Total Phosphorus	g/m <sup>3</sup>	0.012	2.2	0.002	N/A
Sulphate	g/m <sup>3</sup>	3	3.4	0.5	N/A
Total Organic Carbon (TOC)	g/m <sup>3</sup>	2.3	12.2	0.5	N/A
Dissolved Aluminium	g/m <sup>3</sup>	0.005	<b>0.169</b>	0.003	0.055
Dissolved Arsenic	g/m <sup>3</sup>	0.0017	0.0042	0.001	0.013
Dissolved Boron	g/m <sup>3</sup>	0.011	0.01	0.00005 - 0.008	0.94
Dissolved Cadmium	g/m <sup>3</sup>	< 0.00005	< 0.00005	0.001	0.0002
Dissolved Chromium	g/m <sup>3</sup>	< 0.0005	0.0055	0.0005	0.001
Dissolved Cobalt	g/m <sup>3</sup>	0.0002	0.0009	0.0002	0.0014
Dissolved Copper	g/m <sup>3</sup>	-	<b>0.0021</b>	0.0005	0.0014
Dissolved Iron	g/m <sup>3</sup>	<b>0.62</b>	<b>7.7</b>	0.00005 - 0.02	0.0034
Dissolved Lead	g/m <sup>3</sup>	< 0.00010	0.00055	0.0001	1.9
Dissolved Manganese	g/m <sup>3</sup>	<b>0.065</b>	<b>0.26</b>	0.00005 - 0.002	0.011
Dissolved Nickel	g/m <sup>3</sup>	< 0.0005	<b>0.0024</b>	0.0005	0.00005
Dissolved Zinc	g/m <sup>3</sup>	0.0016	0.0023	0.001	0.008

Note: ANZG95 = Aust. & NZ Guidelines for Fresh & Marine Water Quality e.g. (McDowell et al., 2013), 95% species protection. **Bold** indicates exceeds ANZG95.

**Table 20: SB groundwater water quality results for samples taken 8 – 9 April 2024**

Sampling Site		PZ-101	PZ-104 (Artesian)	Detection Limit	ANZG 95
Sum of Anions	meq/L	1.38	1.28	0.07	N/A
Sum of Cations	meq/L	1.49	1.29	0.05	N/A
Turbidity	NTU	3.5	1,500	0.05	N/A
pH	pH Units	7.5	6.2	0.1	N/A
Total Alkalinity	g/m <sup>3</sup> as CaCO <sub>3</sub>	34	34	1	N/A
Bicarbonate	g/m <sup>3</sup> at 25°C	41	41	1	N/A
Total Hardness	g/m <sup>3</sup> as CaCO <sub>3</sub>	42	40	1	N/A
Electrical Conductivity (EC)	mS/m	15.5	13.9	0.1	N/A
Total Suspended Solids	g/m <sup>3</sup>	10	3,400	3	N/A
Total Dissolved Solids (TDS)	g/m <sup>3</sup>	97	100	10	N/A
Dissolved Calcium	g/m <sup>3</sup>	12	9.6	0.05	N/A
Total Iron	g/m <sup>3</sup>	1.82	106	0.021	N/A
Dissolved Magnesium	g/m <sup>3</sup>	2.9	3.8	0.02	N/A
Dissolved Mercury	g/m <sup>3</sup>	< 0.00008	< 0.00008	0.00008	0.0006
Total Mercury	g/m <sup>3</sup>	< 0.00008	< 0.0021	0.0021	N/A
Dissolved Molybdenum	g/m <sup>3</sup>	< 0.0002	< 0.0002	0.0002	0.034
Dissolved Potassium	g/m <sup>3</sup>	2.7	1.65	0.05	N/A
Dissolved Silver	g/m <sup>3</sup>	< 0.00010	< 0.00010	0.0001	N/A
Dissolved Sodium	g/m <sup>3</sup>	12.6	10.4	0.02	N/A
Chloride	g/m <sup>3</sup>	24	11.6	0.5	N/A
Total Ammoniacal-N	g/m <sup>3</sup>	< 0.010	< 0.010	0.01	N/A
Nitrite-N	g/m <sup>3</sup>	< 0.002	< 0.002	0.002	0.9
Nitrate-N	g/m <sup>3</sup>	< 0.002	1.79	0.001	N/A
Nitrate-N + Nitrite-N	g/m <sup>3</sup>	< 0.002	1.79	0.002	N/A
Total Kjeldahl Nitrogen (TKN)	g/m <sup>3</sup>	0.51	4.4	0.1	N/A
Dissolved Reactive Phosphorus	g/m <sup>3</sup>	< 0.004	0.013	0.004	N/A
Total Phosphorus	g/m <sup>3</sup>	0.047	8.6	0.002	N/A
Sulphate	g/m <sup>3</sup>	1.6	7.2	0.5	N/A
Total Organic Carbon (TOC)	g/m <sup>3</sup>	6.3	10.2	0.5	N/A
Dissolved Aluminium	g/m <sup>3</sup>	< 0.003	0.029	0.003	0.055
Dissolved Arsenic	g/m <sup>3</sup>	0.0011	< 0.0010	0.001	0.013
Dissolved Boron	g/m <sup>3</sup>	0.01	0.016	0.00005 - 0.008	0.94
Dissolved Cadmium	g/m <sup>3</sup>	< 0.00005	< 0.00005	0.001	0.0002
Dissolved Chromium	g/m <sup>3</sup>	< 0.0005	< 0.0005	0.0005	0.001
Dissolved Cobalt	g/m <sup>3</sup>	< 0.0002	< 0.0002	0.0002	0.0014
Dissolved Copper	g/m <sup>3</sup>	< 0.0005	0.001	0.0005	0.0014
Dissolved Iron	g/m <sup>3</sup>	<b>0.86</b>	<b>0.05</b>	0.00005 - 0.02	0.0034
Dissolved Lead	g/m <sup>3</sup>	< 0.00010	0.00015	0.00010	1.9
Dissolved Manganese	g/m <sup>3</sup>	<b>0.026</b>	0.0024	0.00005 - 0.002	0.011
Dissolved Nickel	g/m <sup>3</sup>	<b>0.0006</b>	< 0.0005	0.0005	0.00005
Dissolved Zinc	g/m <sup>3</sup>	0.0013	0.0025	0.001	0.008

Note: **Bold** indicates exceeds ANZG95.

### 2.9.3 2026 Lime Dosing Trial

A trial was undertaken by EcoLogical Solutions during February 2026 to examine the efficacy of dosing returned tailings with lime prior to the tailings' deposition at the tailings reception area. Hydrated lime was used in the trial although it is envisaged that that crushed limestone with similar properties would be employed for operational lime dosing. Crushed limestone rather than hydrated lime would add a more desirable pH shift and more hardness following dosing. The use of crushed limestone would provide a more protective role of hardness in lime dosing, especially in the case of copper and zinc. The active parts of the limestone composition would be dissolved or suspended carbonates in the dosing process. The lime dosing trial involved mixing dry-washed tailings and hydrated lime in set ratios from no lime and 3,520:1 to 750:1 across six trail samples that added lime. Approximately 100 grams of tailings were mixed with six weights of lime, from the highest lime weight of 0.1112 grams (0.11%) to 0.0287 grams (0.02%). The seventh trial contained no lime and served as a control sample. Deionised water was used as an aqueous extraction solution and the leachate captured for analysis. The leachate simulated the composition of the pore water in contact with tailings and dosing lime. The results are listed in Table 21.

Analysis of the leachate by the SPLP<sup>7</sup> laboratory method determined that hardness concentrations and pH increased proportionally from 9.9 to 29.5 gCaCO<sub>3</sub>/m<sup>3</sup>, and 7.6 to 10.5 pH units, respectively. The hardness and pH shift from sample to sample was generally proportional to lime content. Tailings without lime had low hardness (10.2 g/m<sup>3</sup>, as CaCO<sub>3</sub>) and slightly alkaline pH (8.4) in SPLP leachate analysis. Chromium, iron, manganese and nickel components of the tailings displayed significant reductions in aqueous concentrations in proportion to the lime dose ratio. Aluminium had reduction responses to lime dose at low lime contents but increased aluminium concentrations at the highest lime contents. The assessment of zinc in tailings was hampered by the unhelpfully high detection limit (<0.011 mg/L) resulting in nil significant zinc concentrations in any sample.

EcoLogical Solutions' report considered that augmentation (i.e., dosing) with lime showed promise for treating of tailings and slimes for deposition at the proposed tailings reception area within the SB. Contradictions and some trail sample variance was caused by the use of hydrated lime and high zinc detection limits were noted, so further field-based testing with crushed limestone at larger scale was recommended.

**Table 21: Synthetic Precipitation Leaching Procedure (SPLP) Leachate Test Results of Lime Dosing Trail**

Sample Number Tailings : Lime Ratio	1 3520:1	2 1670:1	3 2770:1	4 1210:1	5 750:1	6 885:1	7 (Control)
pH (unitless)	7.6	9.7	8.7	10.0	10.5	10.1	8.4
Hardness (as CaCO <sub>3</sub> )	9.9	16.1	10.7	16.4	29.5	19.6	10.2
Aluminium	0.68	0.73	0.79	0.92	0.95	0.90	0.82
Chromium	0.0031	0.0025	0.0033	0.0030	0.0021	0.0027	0.0035
Copper	0.0024	0.0025	0.0025	0.0026	0.0024	0.0027	0.0025
Iron	1.05	0.71	1.09	0.78	0.35	0.63	1.23
Manganese	0.0141	0.0090	0.0139	0.0095	0.0038	0.0074	0.0155
Nickel	0.00120	0.00087	0.00116	0.00089	0.00054	0.00082	0.00125
Zinc	<0.011	<0.011	<0.011	<0.011	<0.011	<0.011	<0.011

Note: All results generally in g/m<sup>3</sup>. **Green shaded** analytes are those that responded in a discernible way to lime addition in the trials (aluminium has a dose threshold at approximately 2770:1). The high SPLP zinc detection limit resulted in less than threshold results and hampered the ability to discern response to lime dosing even at concentrations above the ANZG 95 ecological guideline of 0.008 g/m<sup>3</sup>.

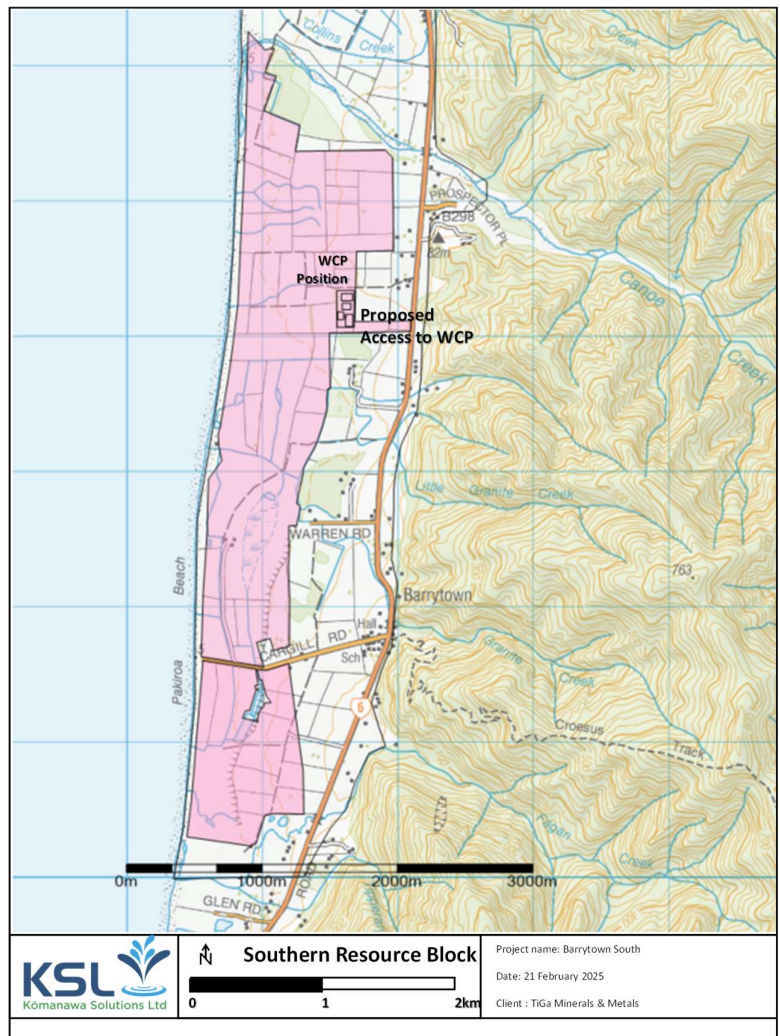
<sup>7</sup> Synthetic Precipitation Leaching Procedure, US EPA SW-846 Test Method 1312

### 3 Barrytown South Sand Mining Project – Project Description

#### 3.1 Extent and Basic Description

TCM is seeking consent to undertake mineral sand mining and processing to obtain ilmenite, garnet and other minerals over an area of approximately 280 ha (covered by Mining Permit MP 60785) within two blocks owned by Moir Farms Maimai Limited, Cargill Rd Barrytown Limited, Nikau Deer Farm Ltd and Barrytown Farms Limited. This area is referred to as Barrytown South or the Southern (Resource) Block (SB). The Central Block has been substantially consented to permit sand mining as part of TCM’s application covering the Nikau Deer Farm block processed and heard between April 2023 to October 2024 and the Central Block is not part of this assessment document.

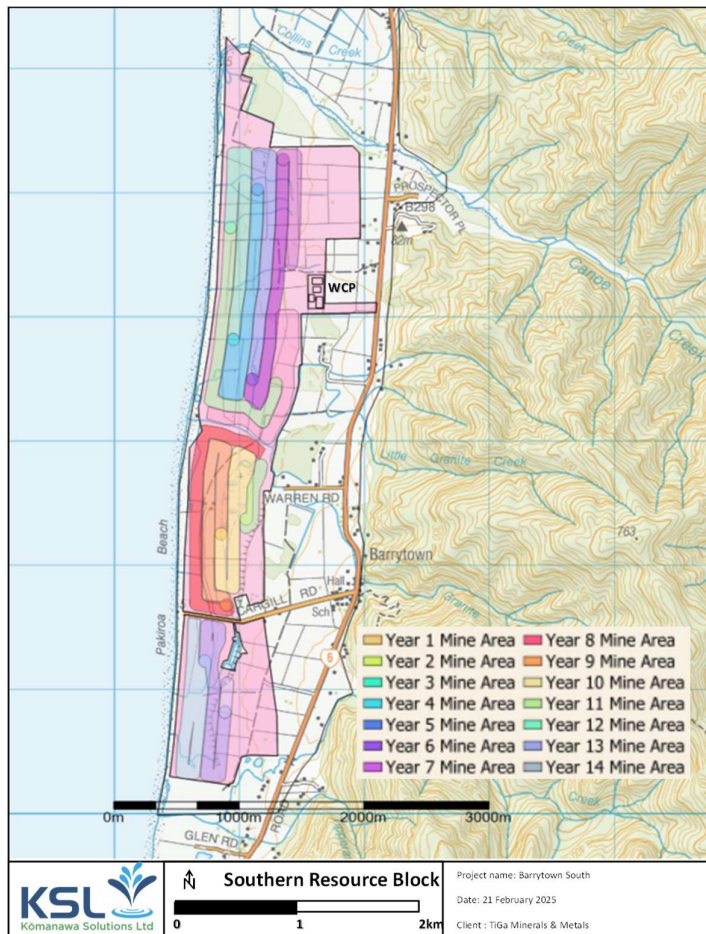
The Southern Block would include the mining of sand between Canoe Creek (south of the Canoe Creek Scenic Reserve on the creek’s south bank) and Fagan Creek along a coastal strip occupying low-lying farmland west of the state highway. Mining, including a full rehabilitation of the SB, is proposed to take approximately 18-24 years. A 35 year term of consent is being sought. This will allow for any contingencies which may arise during mining or in the completion of rehabilitation to provide operational certainty. A Wet Concentrator Plant (WCP), including Mine Water Facility and Access Road will be constructed on the SB adjacent to the mining disturbance area, which has been consented through a conventional RMA process. The access road, linking the WCP to SH6 is shown in Figure 28.



**Figure 28: Location of the Southern Block mining areas (shaded) plus WCP**

Mining of the SB is proposed to progress in strips (as shown in Figure 29, covering the main block). The representative dimensions of the strips are 100m wide and 300m in length. The mine pit will be approximately 3 ha, including 0.5 ha of stripping occurring ahead, and 0.5 ha of active rehabilitation occurring behind, the mine pit. Approximately 1 ha of contoured ground behind the rehabilitation area will be seeded in grass. 20 metre mining setbacks will apply for the proposed SNA PUN-49 and the other property boundaries. A 50 metre mining setback will apply from the Mean High Water Spring (MHWS). Temporary water course diversions will be required for the existing, and ephemeral, water bodies on the site with the exception of Granite Creek. The proposed mining activity will involve the removal and stockpiling of topsoil via the use of excavators and mine trucks.

The dredge will float in an approximate 1 ha mine void excavated to below the shallow water table. The suction cutter on the dredge arm will cut away at the void sides as mining progresses. Processed sand material will be pumped back to the active mine area following processing. Tailings will be deposited behind the dredge as it advances *via* dewatering hydro-cyclones. Overburden and topsoil will be placed back over the tailings periodically completing the mining sequence. The total disturbed area of the mine will be approximately 8 ha in area. A total of 16 ha of disturbed area at any one time is being sought as part of the application. Figure 29 demonstrates the progression of mining which is to progress across the application area commencing in the north of Granite Creek block, progressively moving parallel to the coastline within 100m wide strips. Mining along the mine path will progress in three blocks: north of Granite Creek, Granite Creek to Cargill Road, and south of Cargill Road (Southern Extension) employing the setbacks.



**Figure 29: Lateral, coast-parallel progression of mine path, light pink is unmined**

Once the pre-mining, preparatory activities are complete, mining will progress as follows:

- Approximately 0.2 - 0.6 metre in depth of topsoil and overburden in advance of mining will be removed and stockpiled for rehabilitation using an 85 tonne excavator and 30 tonne articulated trucks. The area of this activity will be approximately 1 ha.
- Approximately 1 ha of sand ore will be exposed as a bench where the mining field unit and desliming unit are located on skids. The rate of mining advance will be approximately 10 metres per day (70 metres per week).
- The sand ore will be mined via a floating dredge in a 1 ha pond in the mining pit to a maximum depth of 10 metres.
  - The slurry will pass through a trommel and desliming circuit before being pumped to the WCP.
  - Reject large material from the trommel and slimes will be returned to the mine pit for rehabilitation.
- Total mining along the mine path is projected to take 14 years to complete, half of that time in the north of Granite Creek block
- Mined mineral sand will be pumped to the WCP to extract Heavy Mineral Concentrate (HMC). As mined mineral sand will be collected at a faster rate than it can be processed, it will be stored at the WCP each day and processed overnight. This will result in the WCP running continuously.
- HMC will be separated from the mined sand ore using a water and gravity circuit, drained of excess moisture and stored at the WCP for dispatch to Rapahoe.

The mining pit will be progressively filled as the mine pit progresses forward with 1 ha of the mining void actively receiving tailings pumped back from the WCP following processing. The material to be returned to the mine void following screening or de-sliming, includes clay slimes less than 53 micron ( $\mu\text{m}$ ) diameter, and gravel, woody material and rock greater than 2 mm diameter. The tailings are to be delivered by slurry lines that suspend sand in a liquified suspension, dewatered and deposited to the tailings reception area *via* hydro-cyclones<sup>8</sup>. The tailings will be allowed to naturally 'beach out' (i.e., spread). The hydro-cyclone will be moved as required to distribute the tailings evenly across the tailings reception area. Following dewatering of sands, tailings will be levelled and contoured with the use of excavator(s) and bulldozer(s) ready to receive the pre-stripped overburden and soil.

Mined strips will be progressively rehabilitated as the mining void advances. The material identified above, will be levelled and contoured to reinstate the land to a similar, or improved, pre-mining landform of contoured dairy grazing pasture or other land uses to be determined. Any other stockpiled topsoil will be spread out and used as a growing medium. Mined land will be removed from the disturbed area calculation once vegetative cover (i.e. sowing of grass) has reached 80% vegetative cover. To achieve a smooth landform and minimise ground level reduction at the western end of the mine, initial vegetative cover will be established as soon as practicable (potentially using hydroseeding) to minimise any erosion potential. This will be followed by the establishment of longer term, permanent pasture species. Final wetland design and landform will be designed in conjunction with the owner. In terms of water management, the dredge used in sand mining will float on the ground water within the mining void and excavate to a maximum depth of 10 metres. Processing water will be sourced from the existing water take location on the CB. Consent GDC-3154-23 / WCRC-2023-0046 authorises the abstraction of water for processing CB-mined material at the WCP for a 12 year duration. A new consent is being sought via this Application to ensure the water take is available to the newly located WCP, and to support mining of both the CB and SB.

Figure 30 sketches out a representative cross-section of the active dredge pond, excavating face, and tailing back-fill zones (also known as the tailings reception area).

<sup>8</sup> A hydro-cyclone is a device that uses centrifugal forces to classify solid particles, in a liquid stream, by size and/or density. Such cyclones are employed to separate solids, in this case sand, from the suspending water following emergence of the slurry from slurry lines.

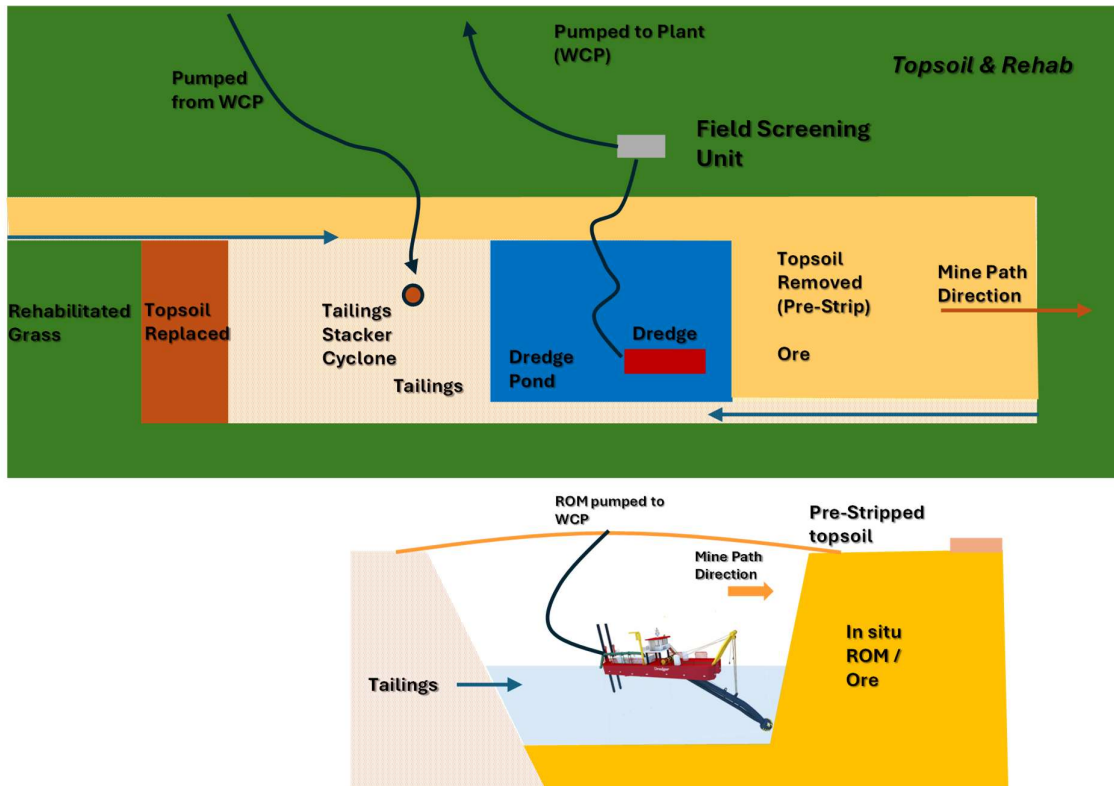


Figure 30: Schematic representation of the dredge pond and dredge in plan view (above) and profile (below)

## 3.2 Salient Water Management Aspects of the Proposal

### 3.2.1 Sand Mining

Groundwater would be relied on to float the mining dredge as a platform for suction of sand ore by an extendable and cantilevered arm. As the tailings and suspending water from the WCP would be returned to the dredge pond at much the same rate as the rate of ore and water extraction for the slurry transfer to the WCP, the dredge pond water level is not expected to alter appreciably as a consequence of the balanced outflows and inflows.

### 3.2.2 Water Supply

A water supply would be required for the WCP. A water supply for the WCP has already been consented within the consents of the CB. The following maximum rates of take and annual volume are set out below as the consent would need to be extended for the SB mining phases:

- Instantaneous 63 L/s (244 m<sup>3</sup>/hour)
- Daily: 5,400 m<sup>3</sup>/d (equivalent to 62.5 L/s)
- Monthly: 162,000 m<sup>3</sup>/month
- Annually: 1,400,000 m<sup>3</sup>/year

Water supply would be obtained from a gallery installed in the alluvial bed of Canoe Creek. Abstraction of Canoe Creek using a bank infiltration gallery on the edge of the river or a direct river intake. A gallery intake would draw clean water even when Canoe Creek was turbid due to the filtration effect of water passage through river gravels.

### 3.2.2.1 Canoe Creek Direct Take or Bank Infiltration Gallery

A bank infiltration gallery would be established in the north bank / bed of Canoe Creek adjacent to the farm track terminus in the creek bed shown in Figure 31 (labelled “Location of Gallery Well Field”). The maximum daily rate of take would be 62.5 L/s, which is 10% of the MALF<sub>7d</sub> corresponding to Canoe Creek. The infiltration gallery option would encompass a horizontal slotted pipe lain in a trench and backfilled with coarse graded gravel to maximise entry rates for groundwater as shown in Figure 32. Being installed in the Canoe Creek gravel fan in proximity to the active creek channel(s), the gallery would draw in creek water. The chief benefits in using this approach would be relative invulnerability to flood damage by being buried and outside of the active creek bed combined with the treatment of water moving through creek bed gravel in removing suspended sediments or turbidity.

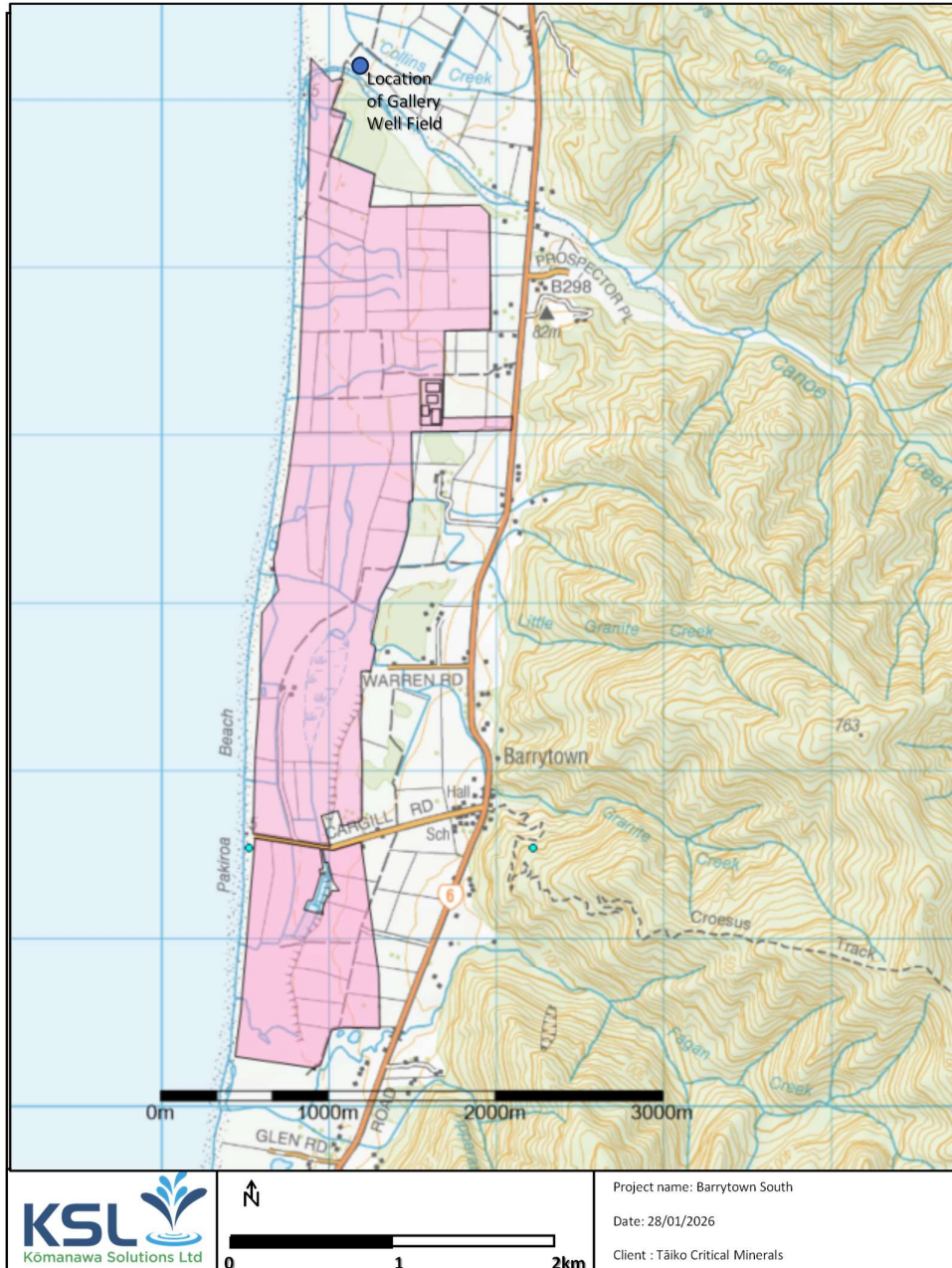


Figure 31: Location of proposed WCP water supply intake on Canoe Creek



**Figure 32: Example of infiltration gallery construction [photo credits to Butt Drilling Ltd (buttdrilling.co.nz)]**

### **3.2.3 Mining Water Balance**

The operational water balance meshes the dredging, water supply and WCP processing operations linked by pipelines or slurry lines. The WCP has a Mine Water Facility (MWF) for conditioning the water circulating through the processing circuits. Water is also taken from the MWF to transport tailings as a slurry back to the tailings reception area. Sand transport within slurry lines requires approximately 50% of the tonnage of mass carried in order to suspend the necessary sand material from the dredge pond to the WCP.

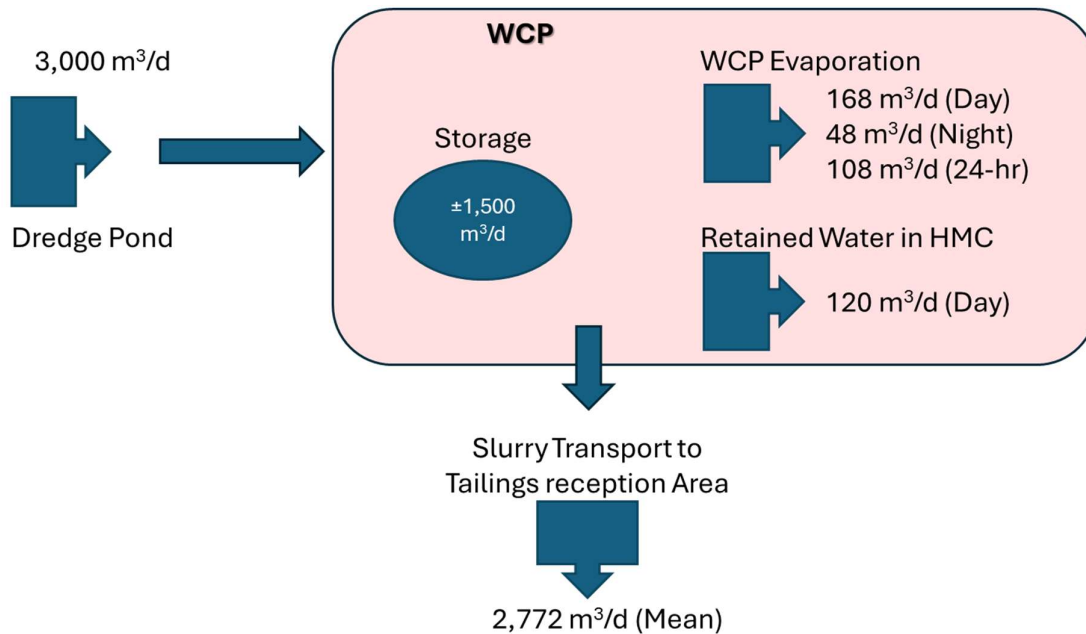
Within the WCP, the losses of adherent moisture and *in situ* evaporation would be made-up with compensating water supply from the Canoe Creek gallery. Table 22 and Figure 33 set out an approximation of the operational water balance.

The principal balance node in sand mining operations would be the dredge pond and ability of the connected groundwater system to buffer minor surpluses and deficits. The dredge pond would have an air space buffer volume of ranging from 45,000 to 60,000 cubic metres between the standing water level defined by the upper shoreline of the dredge pond. Furthermore, the capacity of the connected groundwater system to buffer water flux shocks is related to the drainable porosity and transmissivity of the mineral sand aquifer. Between the air space able to absorb surpluses and aquifer capacity to buffer any deficits or surpluses, the dredge pond hydraulic dynamic capacity to absorb water shocks is considerable.

The variable water take from the Canoe Creek allows the water balance to be tuned. The dredge pond would not produce an obligate surplus to be absorbed or discharged. Instead, the mining method of dredging using a floating dredge plant would allow the dredge pond water level to find a level consistent with the surrounding water table. In the case that the dredge pond water level departs from the surrounding groundwater level, the extent of that departure would be limited by consent conditions to less than 20% of baseline dredge pond water depth, as set out in proposed condition 22.1(b). The water control measures to support that proposed condition includes the manipulation of the Canoe Creek infiltration gallery water supply. An upward departure in the dredge pond water level from the surrounding could be managed by curtailing pumping from the infiltration gallery, while a deficit in dredge pond water level could be management by increasing water supply pumping.

**Table 22: Approximate Water Exchanges comprising a Water Balance for the SB Mining Operation**

	Daily Tonnage Rates	
Rate of Advance (m/d)	6 - 10	-
ROM Mining Rate (t/d)	~ 6,100	-
Slurry Line Water Content or Concentration (% by weight)	50% ± 10%	-
	Daily Water Rate (m <sup>3</sup> /d)	Mean Water Rate (L/s)
Mean Slurry Line Water Content (To & From WCP)	3,000	35
Water Losses from WCP and MWF	230	2.65
Water Losses from Dredge Pond	70	0.8
Mean Make-Up Water Supply Requirement	300	3.5



**Figure 33: Approximate water circuit transfer rates between dredge pond to WCP and back to the pond again**

### 3.2.4 Alterations to the Drainage Network

Sand mining would cross the existing drainage channels as creeks and farm drains. A faithful representation of drainage network crossing the Southern Block is provided in Figure 34, drafted in 1990 studies (Coffey & Partners, 1991).

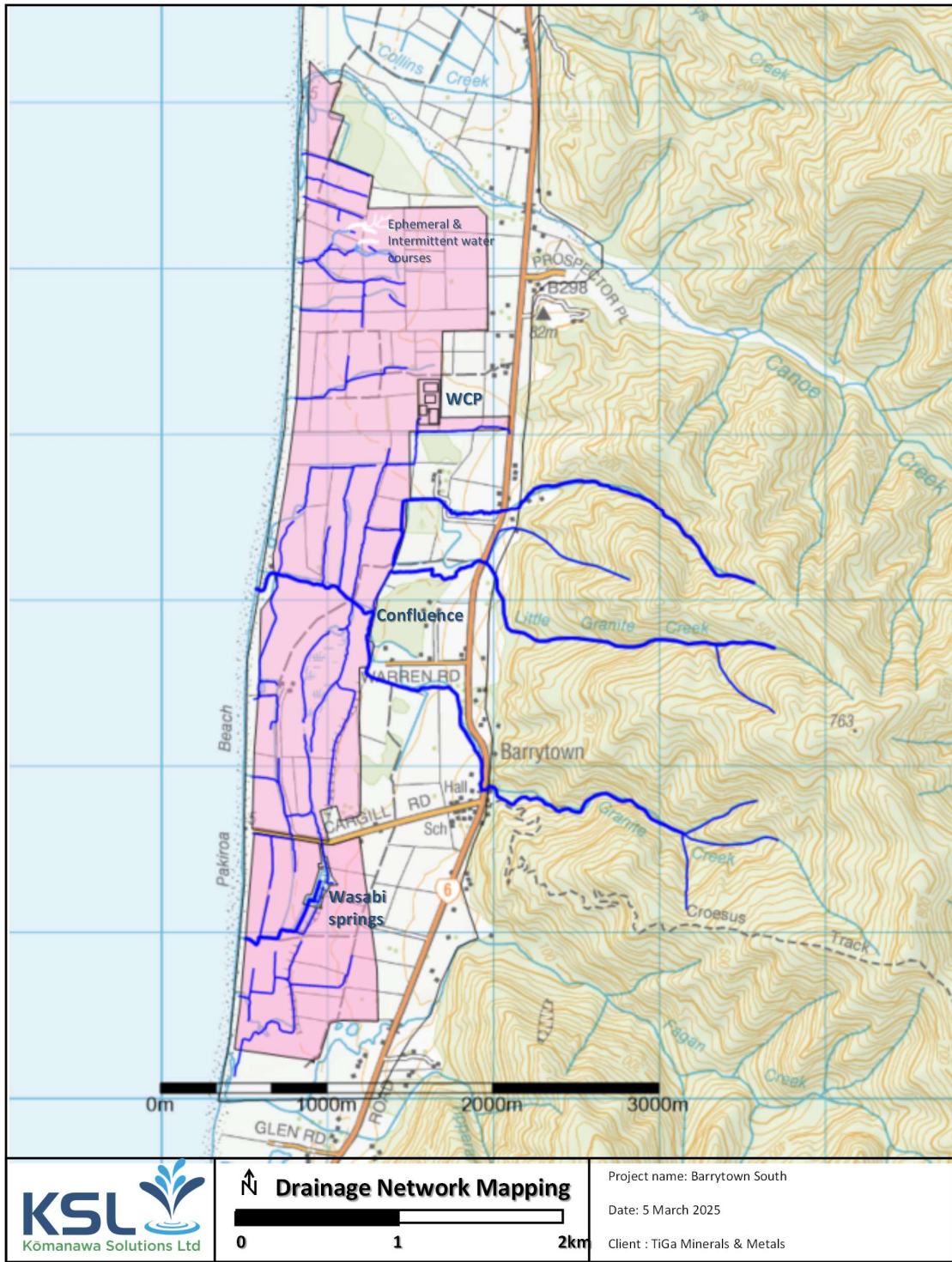


Figure 34: Detailed drainage network focusing on low-lying creeks

### **3.2.4.1 Creek diversions**

Diversions to the existing drainage network would be required to facilitate sand mining. Cut-offs between the dredge pond and the existing drainage would be driven by the need to maintain fish habitat or fish passage requirements, plus Erosion and Sediment Control or turbidity control objectives. The existing creek, and to a lesser extent farm drain channels, would also require reinstatement following the passage of the dredge pond, including preserving hydraulic grade, armouring and replacing riparian vegetation.

In circumstances where creek systems intersect the mine path, as a general approach as mining moves into an area to be constructed into the wetland the following steps will be undertaken:

1. Creeks will be diverted around the mining activity, as detailed in Section 4.8 of the WMP document, to allow mining to continue.
2. Creek channels will be reformed in the permanent diversion location and developed at the same level as that existing prior to mining activity. This also enables full stabilisation of these creek diversions including riparian vegetation planting.
3. Surrounding the creek formation (at a lower level based on the rehabilitation process) the wetland ponds and shape will be established. These areas will be fully stabilised as part of the rehabilitation vegetation establishment.
4. As the mine path progresses and the wetland formation advances, the final wetland infill planting programme will also continue to advance.

Overall, from a water management perspective the wetland establishment will utilise the mining void to divert any dirty water runoff and will ensure that there is minimal, if any, surface water discharges. At all times the wetland establishment earthworks form part of the maximum 16ha exposed area limit.

#### **Granite Creek**

Granite Creek would not be diverted. The mining of two strips surrounding the crossing of Granite Creek would be truncated, and a third strip would be shortened to permit the creek bed to be retained in its current alignment. A starter pit would be established on the south bank of Granite Creek following the transportation of dredge plant from the terminus of Mining Section 1 across Granite Creek. The banks of Granite Creek would be maintained at full pre-existing strength, as would the creek bed and hydraulic gradient. Minor north-south oriented creeks or farm drains running parallel to the mining area's eastern boundary but outside of the land affected by mining such as Clarke Creek and Little Granite Creek including a farm drain flowing north to Granite Creek at the Confluence, would continue in this hydrological function during the mining of Mining Sections 1 and 2. Offset distances from these water courses and the Granite Creek main stem would be placed for the continuation of the existing channel arrangement throughout operational and post-mining phases of the activity.

### **3.2.5 Water Quality**

Suspended sediment and turbidity impacts of mining are dealt with by the Erosion and Sediment Control Management Plan prepared by Ridley Dunphy Environment, and by the geochemistry and water quality assessments of EcoLogical Solutions. These surface water effects are therefore outside the scope of water quality effects considered herein. Because the minerals processing is mechanical and does not involve the addition of chemicals to the process water, the potential for water quality changes in the water circulating through the processing plant (some of which will be discharged back to the mine excavation within the separated sand deposits) is limited. However, the potential for the gravity sorting process at the WCP has some potential for liberating minerals and other substances into solution from the ore sand. These liberated or elevated dissolved contaminants may enter the groundwater or surface water system initiating the need to assess potential effects on water quality.

Screening of groundwater quality in 2022 and 2023 at the Nikau Deer Farm block identified that six metallic elements and up to eight out of eight groundwater monitoring bores exceeded the relevant ANZG 95% guideline. In surface water monitoring four metallic elements and up to three water body sampling sites (mostly influenced by groundwater seepage) exceeded the ANZG 95% guideline. The full analytical results are provided in Appendix 4. Therefore, the baseline water quality characterisation indicated the presence of exceedances of the relevant ecological guidelines, primarily for metallic elements in groundwater and surface water. Inferences were made that low oxygen content groundwater and the presence of electron donors from organic matter provided conditions for dissolved metals or metalloids to achieve significant concentrations. These dissolved metals / metalloids also enter down-gradient of parts of the shallow groundwater system in seepage, affecting surface water composition. The question of water quality effect is covered in the EcoLogical Solutions assessment of project water quality baseline, geo-chemistry, and water quality effects.

#### **3.2.5.1 Lime Dosing**

Dosing of the returned tailings ('tails') is proposed as an approach for managing the effects of elevated metals, metalloids and nutrients. A laboratory scale trial of lime dosing has been undertaken and further field trials are recommended. It is envisaged that dosing of the whole tailings and suspending water would raise the pH and hardness levels inducing the complexing to solids and immobilisation of metals, metalloids and nutrients.

The laboratory trial of lime dosing (see Section 2.9.3) found that dosing raised pH and hardness while leading to significant reductions in aluminium, chromium, iron, manganese and nickel. Copper did not respond in the laboratory trial, although EcoLogical Solutions considered that the use of crushed limestone with its inherent greater hardness raising property would result in copper reduction (M. Fitzpatrick, personal communication, February 25, 2026). Nutrients such as dissolved phosphorus are known from literature to respond to the addition of lime in studies of constructed wetlands with reduced phosphorus concentrations (Ballantine & Tanner, 2010).

It is proposed that crushed limestone emulsion would be introduced either at the MWF – WCP before tailings are injected to the return slurry lines or alternatively before the tailings are discharged at the tailings reception area. It is anticipated that reactions to reduce or immobilise metals, metalloids and nutrients would occur in the tailings deposit pore water or within downstream groundwater.

## 4 Assessment of Hydrological Effects

### 4.1 Summary of Sand Mining Potential Effects

The direct hydrological impulses and their potential effects impinging on the groundwater and surface water systems are summarised as follow:

- **Void permeability:** The temporary dredge pond void would have infinite hydraulic conductivity and as such flatten the water table profile in the immediate vicinity of the dredge pond at the time.
- **Evaporation:** Exposing the water table to the atmosphere and evaporative losses.
- **Surcharged Dredge Pond:** Given the added water supply to the WCP there is a possibility that slightly more water volume will be returned the dredge pond than taken from it.
- **Altered creek and wetlands networks:** The mining void will interrupt the course of farm drains and creeks crossing the low-lying farmland within the mining area, thus re-arranging hydrological profile as diversions are placed, shifted and removed during the operational phase of mining.
- **Changed ground properties and volumes:** Returning tailings to the wake of the mining void would bring slightly changed hydrological properties of the emplaced sand barren of minerals, plus the removal of minerals into HMC that is removed to Rapahoe would significantly reduce the volume of sand returned to the mined areas as tailings.
- **Water quality:** The possibility of seawater being mobilised and displacing freshwater would be examined. The water returned with tailings plus the solution of contaminants from tailings would be examined by EcoLogical Solutions Ltd in the water quality and geochemistry assessment document.

These hydrological impulses would be examined in turn and in tandem to determine the net effect on hydrological condition during mining operations and subsequently as operational impacts dissipate.

### 4.2 Summary of Water Supply Potential Effects

The direct hydrological effect of taking water for WCP make-up water supply, include the following:

- **Surface Water Take or Depletion:** Alteration to the pore water levels within the Canoe Creek alluvium leading to the interception of water that directly originates from Canoe Creek.

### 4.3 Summary of Alterations to the Drainage Network and Potential Effects

The hydrology of the Barrytown coastal strip associated with the Southern Block mining area would be temporarily altered, including the hydrological processes up-gradient and down-gradient of the active dredge ponds passing along mine strips.

- **Alteration to Gradient:** The pre-existing hydrological gradients of water courses and water table would be re-arranged by diversions around the dredge pond during the operational phase.

### 4.4 Summary of Shifts in Water Quality and Potential Effects

Individual or cumulative alterations to the previous hydrological gradient may give rise to a reversal of the gradient pushing fresh water across the coastline.

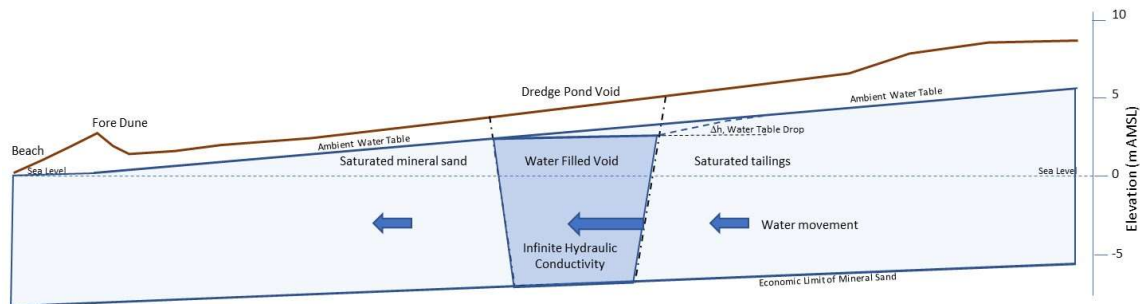
- **Seawater Intrusion:** The displacement of fresh groundwater or estuary water by sea water leading to brackish water quality conditions within groundwater or surface water.
- **Turbidity:** The liberation of silt and clay from in situ fine sediment within the water-filled dredge pond would create turbid water that would penetrate for at least a short distance into the groundwater system.
- **Liberation of Metals, Metalloids and nutrients:** The agitation, abrasion and circulation of sediments, including organic components would change the water chemistry, including elevating dissolved concentrations in groundwater and down-gradient surface water.

## 4.5 Dredge Pond Potential Effects

As has already outlined the proposed sand mining method is a floating dredge with a hinged cutter and suction arm with a depth range up to 10 metres below water level. Since the water table across 90% of the SB mining area is shallower than 1.5 metres, the water table could be exposed by the pre-stripping of soil and subsoil / overburden. The dredge excavation would temporarily create a void abreast and immediately ahead of the operational dredge until the deposition of tailings fills the water filled void from behind. This equipment, and the approach devised to utilise it, would avoid the need to lower the ambient water level by pumping or wellpoint extraction, so the excavation would remain water-filled. By avoidance of dredge pond lowering the potential effects normally related to dewatering the potential effects of drawdown, surface water depletion, or seawater intrusion are also avoided or minimised.

### 4.5.1 Void Permeability Change

The excavation of the travelling dredge pond would create a void of up to 300 metres long, 100 metres wide and 10 metres deep to the economic base of the mineral sand ore, at any one time. The mean length of dredge pond perpendicular to the groundwater hydraulic gradient would be 100 metres. The 250,000 to 270,000 cubic metre temporary void would quickly fill with groundwater at near infinite hydraulic conductivity. The dredge pond void would no longer exclusively adhere to the prevailing groundwater gradient that existed prior to the excavation of the dredge pond as the pond water surface must be flat. Instead, the water level on the upgradient side of the void would be lower than existed prior to excavation as illustrated schematically in Figure 35.



**Figure 35: Schematic profile representation at exaggerated vertical scale of the ambient water table and void**

The basic throughflow equation based on measured hydraulic gradient is as follows –

$$\begin{aligned} \Delta \text{ Water Table} &= W \times i \\ &= 100 \text{ m} \times 0.010 \text{ m/m} \\ &= 1.0 \text{ m (the maximum, against pond margin)} \end{aligned}$$

Where:

$$\begin{aligned} W &= \text{Width of Dredge Pond} \\ &= 100 \text{ metres} \\ i &= \text{Horizontal hydraulic gradient across the Barrytown Flats} \\ &= \Delta h / \Delta L \\ &= 10.1 \text{ m} / 725 \text{ m} \\ &= 0.01 \text{ m/m} \end{aligned}$$

Therefore, due to the relatively steep groundwater hydraulic gradient up to 1 metre of decline in the water table might be experienced at the upstream side of the dredge pond as a result of excavation. The effect would be temporary but would follow the upstream edge of the dredge as it traverses the nominated mine path. Importantly, the water level decline would always remain on the landward side of the excavation, therefore as the mining approaches the 50 metre set-back from the coastline the water level decline due to the above mechanism closest to the coastline would be close to nil.

The Theis Equation (Theis, 1935), which provides a simplified means of calculating water table drop radiating from the landward sides of the dredge pond, which can be rearranged to the following equation:

Theis Equation  $s = QW(u) / 4pT$   
 Where:  $u = r^2S / 4Tt$

Where also:

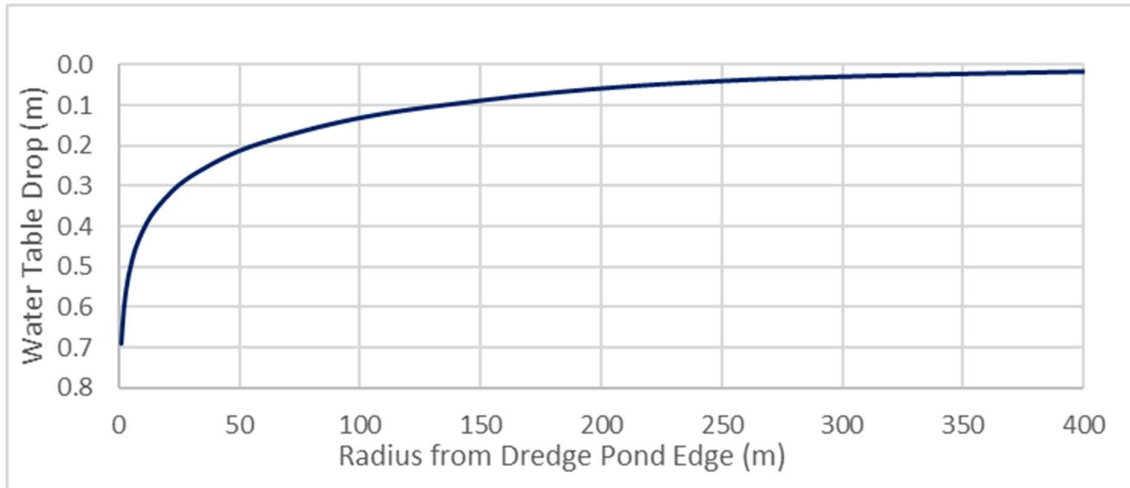
- s = Water table drop (m)
- Q = Groundwater flow rate (m<sup>3</sup>/d)
- T = Aquifer transmissivity (m<sup>2</sup>/d)
- S = Specific yield or Storativity of the aquifer (m/m)
- r = Distance from the dredge pond edge (m)
- t = Time or duration of pumping (d)
- K = Hydraulic conductivity (m/d)
- W(u) = Well function approximated by the Taylor series:  
 $-0.5772 - \ln(u) + u - 2/2.2! + u^3/3.3! - \dots$

The following values of parameters in Table 21 were used with the Theis Equation to estimate the water table drop around the landward margins of the dredge pond as a consequence of void permeability effects.

**Table 23: Specified calculation parameters for estimating Water Table Drop**

Computational Parameter	Value	Notes
Sand Layer Hydraulic Conductivity, K (m/d)	6	Composite of disturbed ground and transgressive beach deposit, Table 12 (Coffey & Partners, 1991)
Sand Layer Thickness, b (m)	15	Consistent with Table 13
Sand Layer Transmissivity, T (m <sup>2</sup> /d)	90	T = Kb
Sand Layer Storativity, S (dimensionless)	1 x 10 <sup>-1</sup>	Consistent with an unconfined sand aquifer
Duration of pumping, t (d)	60	

Placing 60 days as the most reasonable computational period and a 1 metre water level decline on the edge of the dredge pond (0.1 metre allowing for a mud cake on the inside of the pond), the estimable induced groundwater flow rate was 0.8 litres per second. The Theis Equation also allowed the calculation of the reduction in water table drop as a function of radius from the pond edge. Figure 36 illustrates the decay curve in water table drop to negligible values at a radius of 400 metres of the pond edge.



**Figure 36: Estimate of reduction in water table drop as a function of radius from the pond edge**

As the measured seasonal variation in groundwater level in the mineral sand groundwater system is in the order of 1.25 metres (see Figure 26 for piezometers PZ-101 and -105), the estimated water table rectification effect applied by the passage of the dredge pond would represent a negligible effect on groundwater levels.

#### 4.5.2 Evaporation

The excavation of the travelling dredge pond and wetted tailings reception area would expose a water surface of up to a maximum of 300 metres long, 100 metres wide where the water table is directly exposed to evaporation. Evaporative loss of groundwater would result, which would become a long-term, albeit low rate of groundwater abstractive induced in the presence of the atmospheric evaporation across the water surface. The calculation below indicates the derivation of the mean annual dredge pond open water evaporation rate. The derived estimate of evaporative losses are approximately 67 cubic metres per day (m<sup>3</sup>/d) or 0.78 litres per second (L/s). Such evaporative losses would be affected by air temperature, solar radiative intensity and wind such that the rate would rise. On a daily basis, the evaporative losses would also fall back to negligible rates during the hours of darkness. Mean annual Penman daily evaporative loss rates would smooth these fluctuations out across the hydrological year such that the annual volume of evaporative loss based on the calculation below could be estimated as 24,455 cubic metres per year.

$$\begin{aligned}
 \text{Evaporative Loss} &= A \times E \\
 &= (300\text{m} \times 100\text{m}) \times 0.002235\text{m/d} \\
 &= 67 \text{ m}^3/\text{d} \text{ based on annual average rate of open water evaporation}
 \end{aligned}$$

Where:

$$\begin{aligned}
 E &= \text{Rate of evaporation (m/d)} \\
 &= 816 \text{ mm/a (from section 2.4.2, Table 4 Penman evaporation)} \\
 &= 0.002235 \text{ m/d} \\
 A &= \text{Area of dredge pond water surface, L x W (m}^2\text{)} \\
 L &= \text{Length of dredge pond (m)} \\
 W &= \text{Width of dredge pond (m)}
 \end{aligned}$$

The estimated mean daily and annual rates of losses from the active dredge pond due to evaporation of 67 m<sup>3</sup>/d (0.8 L/s) and 24,455 m<sup>3</sup>/a, respectively, are relatively small compared to ambient groundwater system discharges. Peak daily evaporative losses could be assessed in terms of the assumed peak evaporation rate of 5 mm per day (0.005 m/d), therefore peaking at 150 m<sup>3</sup>/d (1.74 L/s). Furthermore, the calculatable water table lowering due to the above evaporation groundwater extraction would also be small relative to the seasonal variation in the ambient water table.

The mean evaporation loss of dredge pond water of 0.8 L/s coincides with the estimated groundwater flow equivalent to void permeability effect (see section 4.5.1). It is important to note that the evaporation and void permeability effects on groundwater would not be additive, i.e., the 1 metre maximum water table rectification and water table lowering due to evaporative loss would not stack atop each other. Instead, the evaporative losses may induce a mild generalised lowering of surrounding water table height surround the total pond perimeter, in addition to the void permeability effect.

### **4.5.3 Surcharged Dredge Pond**

The tailings slurry may deliver back more water, after decanting from tailings, than was taken out of the dredge pond in suctioning the ore away to the WCP. The source of such surcharge would be the additional water obtained from the infiltration gallery and used in wet processing. Surcharging of the pond would raise the water table by an amount proportional to the rate of surcharge and groundwater hydraulic properties of the affected groundwater system.

Trials of infiltration into fine mineral sand in the CB found rates of infiltration in the order of 3 cubic metres per metre of infiltration trench, suggesting the 100 metre long dredge pond void would infiltrate at least 300 cubic metres per day (3.5 L/s) relating to pond surcharge without undue rises in pond water level (Rekker, 2023). Any surcharge effect would also serve to oppose and correct water table decline induced by flattening of the water table surrounding the void, or losses of water due to evaporation.

### **4.5.4 Disrupted Creek Network**

Figure 37 shows the project area, the eastern margin of mining and creeks that would be classified as rivers in terms of the RMA in a simplified map. This map shows that Clarke Creek could be removed from contact with the area of mining by connecting Clarke Creek and Little Granite Creek by a 265 metre long interconnecting creek channel along the gap between the project boundary and the eastern margin of the actual mining area. Such an interconnection between Clarke Creek and Little Granite Creek would remove the requirement to undertake ad hoc diversions for the passage of the mine void in Year 1 and 2 of the eight year Section 1 zone.

#### **4.5.4.1 East – West, sea-draining creek catchments**

The other mostly east – west oriented would be subject to diversion ahead of and behind the passing of the Northern, Central, Wasabi and Southern Creeks, which are mostly of wholly encompassed by mining the Section 1 and Section 3 mining areas. Following final passage of the mining void through each of these east – west oriented creeks, rehabilitation would begin and ultimately integrate the hydrological function of the rehabilitated land and water courses.

#### **4.5.4.2 Granite Creek catchment**

With interconnection of Clark Creek, all Granite Creek catchment sub catchments would cross the mining area to the coastline in the Granite Creek main stem. As has been mentioned Granite Creek from the creek confluence to the sea would be removed from any mining activity with a 20 metre buffer set to either side of the creek banks. Mining activity would stop and start short of the Granite Creek buffer meaning that no diversions of Granite Creek catchment water course would be required.

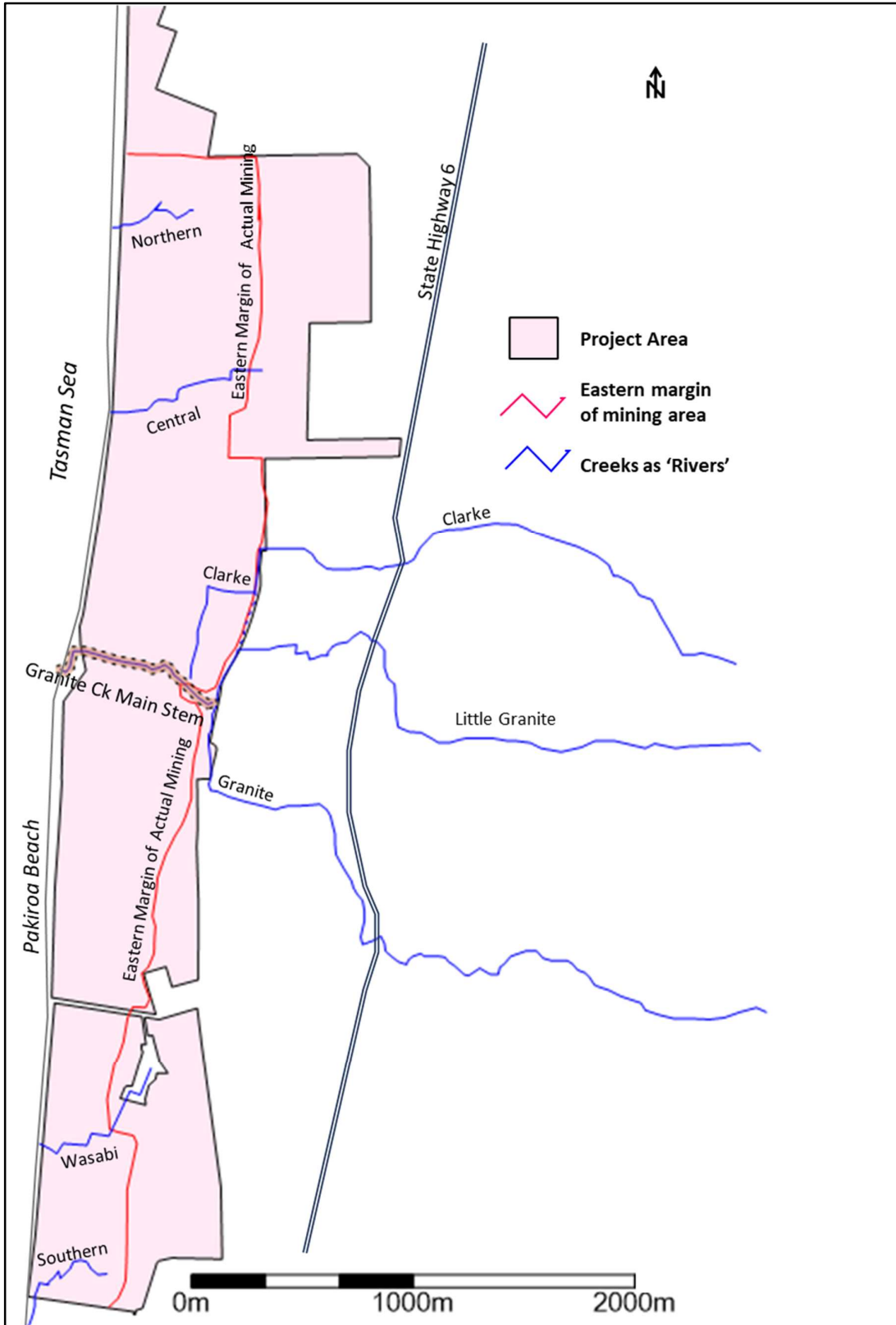


Figure 37: Simplified mapping of creeks classed as rivers in terms of the RMA

The hydrological statistics of these creeks is summarised in Table 24, listing the existing creek flow quantities needing to be managed and maintained during operational mining activities affecting the creek catchments concerned.

**Table 24: Summary of NZ River Maps Hydrological Statistics for Barrytown Creeks**

Catchment	Catchment Area (km)	Mean (L/s)	Median (L/s)	MALF <sub>7d</sub> (L/s)	1-in-5 Year Low Flow (L/s)	FREQ3 (events/y)
Northern Creek @ Coast	0.672	26	14	43	2.7	31.7
Central Creek @ Coast	0.545	21	12	3.5	2.2	31.8
Clarke Creek @ margin	1.474	60	34	11	7.2	33.1
Little Granite Creek @ margin	1.574	141	76	20	15.7	31.3
Granite Creek @ margin	4.268	435	232	55	42.8	34.0
Wasabi Creek @ Coast	1.193	46	25	7.5	0	33.5
Southern Creek* @ Coast	0.231	-	-	-	-	33.6

Note: NZ River Maps data from <https://shiny.niwa.co.nz/nzrivermaps/>; \* Southern Creek catchment extent below the threshold for characterisation of hydrological statistics; FREQ3 The average number of events per year that exceed three times the median flow (events/year). Green shading indicates flows that would be transferred to the coastline within Granite Creek main stem.

Granite Creek is considered to be better left without diversion during the mining process so it would continue to hold its current course, including creek banks from the entry to the SB mining area to the creek's estuary (hāpua) onto the Tasman Sea. The floating dredge crossing would require earthworks to provide a floatable channel accommodating the 0.6 metre minimum draught of the dredge plus a passage through the creek banks, which would be restored immediately following the passage. Accordingly, Little Granite Creek and Clarke Creek post-diversion into Little Granite Creek would also enter Granite Creek upstream of the eastern margin of actual mining.

The remaining east- west oriented creeks crossing the mining area would be as follows:

- Northern Creek
- Central Creek,
- Wasabi Creek, and
- Southern Creek.

Temporary diversions to maintain surface flows in these east-west flowing creeks would be set up to allow the mine void to pass through the creek lines followed by creek bed restoration. These schematic plans are included in the WMP.

#### 4.5.4.3 Flood Capacity

The key water course to the maintenance of flood capacity and flood passage relates to the main stem, Granite Creek. Granite Creek would be unaltered by mining activities and so retain capacity to carry flood flows within its current parameters. Lesser creeks and farm drains would be diverted around the active dredge pond and tailings zone in constructed diversion channels with cross-sections, freeboard and gradient with flood carrying capacity exceeding the existing channels. The existing channels are essentially farm drains excavated into overburden clays.

#### **4.5.5 Changed Ground Properties and Volumes**

In addition to the change in groundwater properties imparted by the passage of the dredge pond void, the re-filling of the pond by tailings would to some extent, change the physical properties of the restored ground left in the wake of mining.

##### **4.5.5.1 Change in Grainsize**

Essentially the same geologic materials would be emplaced as tailings into the mine void. Oversize material such as gravel clasts, rocks, tree bases and other woody material would be screened out at the side of the dredge pond as part of pre-processing before the ore is added to slurry lines for transfer to WCP. The oversize material would be returned to the tailings by excavator and truck transfer. The mineral sand being taken off as HMC as part of basic refinement and not left in tailings are expected to be fine, heavy sands. Non-mineral sands and mineral sands of insufficient economic mineral purity would be slurry lined back to the tailings cyclone for deposition on the tailings “beach” (see Figure 30). These understandings as to the lithological composition of the tailings provides the information that the tailings should be close to the grain size distribution of the original transgressive beach deposits as they were mined.

##### **4.5.5.2 Compaction and Consolidation**

It is relevant to compaction and consolidation that significant areas of the proposed mining area have been dredged previously by mechanical bucket dredge to recover gold until the 1940s. Compaction and consolidation may be expected to have occurred in the undertaking of historic gold mining. The level of compaction and/or consolidation of tailings could be lower than the original transgressive beach deposits prior to mining. This is expected to give rise to progressive water loss, where above the water table, and compaction following emplacement in the dredge pond void.

##### **4.5.5.3 Loss of Volume**

The overall volume of tailings emplaced in the mined area would be less than the original deposits due to the ore processing removal of Heavy Mineral Concentrate, containing magnetite, ilmenite, garnet and other trace minerals, as the economic resource motivating the mining. Projections of the proportions of HMC and tailings returned to the mining area suggest the HMC percentage by volume being 18% of whole mineral sand (Aldrich et al., 2023), leaving 82% by volume as non-economic waste material to be returned to the void as tailings.

#### **4.6 Encountering Above-Ground Artesian Pressures**

With the depth range of the suction dredge up to 10 metre below ground, the dredge pond could potentially breach aquitard layers and encounter above-ground, artesian pressure<sup>9</sup> conditions. Such conditions could flood the dredge pond with groundwater until the pressure heads within the dredge pond and the breached water-bearing layer equalise. Above-ground artesian pressures were measured in 1989 along Cargill Road (Coffey & Partners, 1991). Another zone of above-ground artesian pressure was measured at a piezometer (PZ-104) on the eastern edge of the proposed mining area within Mining Section 1 and near Clarke Creek. Artesian groundwater pressures were also measured on the southern flank of the Central Resources Block (Rekker, 2023).

Impacts of encountering above-ground or near-ground artesian conditions would be the loss of water level freeboard within the dredge pond and possible overflow of groundwater at the point of lowest elevation to the rim of the mine void. Effects of flooding of the pond or overflow could include less workable to unsafe working conditions for operations immediately outside of the mine void, including the management of the hydro-cyclones in the tailings reception area. Overflows of groundwater may flood depressions in

<sup>9</sup> Above-ground artesian pressure occurs when groundwater is confined under such high pressure beneath impermeable or semi-permeable layers (like clay) that pressure rises above the land surface, causing the water to flow freely should the impermeable layer be breached by a well or excavation. All aquifers with pressures that rise above the aquifer top are “artesian,” but they are only “flowing” if the pressure is strong enough to push water above the ground surface.

surrounding farm land and potentially cause erosion along a path to the nearest water course. In the medium term depressurisation may have effects of depleting surrounding water bodies.

An Unexpected Artesian Pressure Interception Protocol would be refined and maintained as part of the Water Management Plan. This would recognise that artesian conditions may not be encountered or not eventuate into problematic conditions. However, should latent geological conditions give rise to unexpected artesian pressures, the protocol would include key contingency measures, including immediate actions on break-through, emergency sealing measures, monitoring and assessment, adjustments to mining water management such as curtailing the project water supply and revised excavation controls to be included in the recertified Water Management Plan. Appendix 6 contains a draft of the proposed Protocol.

## **4.7 Water Quality Effects**

### **4.7.1 Seawater Intrusion**

The excavation of a dredge pond into the in situ mineral sands by itself does not give rise to conditions leading to seawater intrusion. The preconditions for seawater intrusion are as follow:

- Coastal proximity,
- Permeability to allow the flow of groundwater across the coastline,
- If groundwater flow direction is seawards, the reversal of the pre-existing flow orientation and shift landwards of the freshwater – saline water transition zone,
- Low groundwater gradient,
- Brackish river mouths or estuaries that loop behind the coastal strip, or
- The presence of a relict seawater or brackish water body at depth, with the risk of up-coning.

The SB mining areas have proximity to the coast and shallow permeability that allows by-directional groundwater flow across the coastline. The groundwater flow direction is seawards and there are no indications that this flow orientation reverses temporarily or on occasion. The groundwater flow gradient towards the sea is relatively strong, at least 0.01 metres per metre. All creek mouths on the Barrytown Flats have been measured to be freshwater. Estuaries or drowned river mouths do not penetrate inland from the coastline to any extent. Past deeper groundwater exploration has so far failed to encounter brackish or saline groundwater. The presence of the Blue Bottom (O’Keefe) Formation or Karama Batholith granite is known to occur at moderate depth beneath the Barrytown Flats, limiting the ability of saline groundwater bodies to be emplaced or persist.

Thus the basic preconditions of exposure to seawater and groundwater flow continuity across the coastline are valid, but the remaining pre-conditions are less valid without the reversal of groundwater gradients by a change to the overall water balance of the groundwater system. The penetration of saline wedges along the coastal creeks is negligible, primarily restricted to high seas and wave wash-over of the beach barrier into the lowest reaches of Barrytown Flats creeks. All indications considered in the Existing Environment section relating to groundwater quality point to fresh groundwater extending to the coastline, and possibly beyond.

As outlined in the foregoing effects assessments relating to sand mining activities, dewatering of the dredge pond is not required. Other impacts of sand mining such as the flattening of the water table surrounding the pond void or evaporative losses are not capable of inducing a significant change in groundwater flow pattern, let alone a reversal of the ambient groundwater flow orientation. The Wet Concentrator Plant (WCP) water supply infiltration gallery operations would induce groundwater drawdown in a defined zone of the Canoe Creek alluvium but the zone would be restricted to the area between Canoes Creek bed and the gallery. The potential that this specific groundwater abstraction would contribute to seawater intrusion can be related to the magnitude of drawdown that is projected to extend to the immediate coastal zone, which would be slight and resulting risk low.

Baseline groundwater levels in the coastal zone of the SB were measured to be above mean sea level in August 1990, as listed in Table 24. The maximum depth of the piezometers was 10.01 metres, thus within

the shallow, unconfined mineral sands compartment of the groundwater system. The groundwater level behind the foredune in the unconfined aquifer ranged between 1.50 m and 5.57 metres AMSL. These were indications that a considerable groundwater level ramp existed at the coastline.

**Table 25: Coffey Partners’ piezometers behind foredune at coastline with water levels on 30/08/1990**

PIEZOMETER NUMBER	NORTHING mN	EASTING mE	TOTAL DEPTH (m, TOC)	CASING DIA (m)	RL GROUND (m)	STICK UP (m)	RL COLLAR (m)	DEPTH TO S.W.L.	DATE	GROUND SURFACE (m, RL)	STRATIGRAPHIC UNIT
VA 2600	713566.20	280651.48	9.60	32	6.80	0.20	7.00	1.43	30/8	5.57	A
UK 2400	712350.74	280547.09	6.80	32	5.50	0.17	5.67	2.98	30/8	2.69	A
CAR 1	709582.46	280145.63	10.07	50	5.08	0.08	5.16	3.66	30/8	1.5	F

Note: ‘RL COLLAR’ equates to the elevation of the bore collar. ‘DEPTH TO S.W.L.’ equates to depth to the static water level. Therefore, ‘GROUND SURFACE (m,RL)’ equates to groundwater elevation, i.e., the static water table elevation with respect to mean sea level.

The static groundwater elevation at the alluvium infiltration trial in September 2023, near the proposed site of the WCP water supply infiltration gallery averaged 5.0 metres AMSL. In view of the measured 5.0 metres above sea level, the Ghyben-Herzberg Principle (Veruijt, 1968) would indicate that the implied minimum depth of fresh water beneath the Canoe Creek infiltration gallery is 200 metres (i.e., 198 metres below sea level).

#### 4.7.2 Dredge Pond Turbidity

The proposed mineral sand project has an Erosion and Sediment Control Plan (ESCP) covering the suspended sediment and turbid water discharges from disturbed surfaces involved in sand mining operations. As part of ESCP measures the top soil and subsoil / overburden would be stripped ahead of the advancing dredge pond excavation. This would prevent the soils dropping into the dredge pond and adding to turbidity,

The foremost and applicable observation-based assessment of turbidity movement through outwash gravels comparable to the silty sand with gravel deposits at the site is the Department of Scientific & Industrial Research (DSIR) investigation of the operational Ngahere gold dredge operated by the then Grey River Gold Mining Company Ltd (Thorpe, 1990). The dredging activity at Ngahere was markedly different to that proposed at Mananui, however the point in referring to the DSIR research was the in situ investigations of the penetration of fine sediment into the groundwater system adjacent to the dredge pond. The dredging area at Ngahere was investigated in 1988 to 1989, including intensive piezometer installation, surface geophysics, brine / dye tracing, and multi-level low-rate groundwater sampling.

The dredge pond in 1989 and 1990 was 300 m wide and 150 m long with cross-pond conveyors backfilling the void directly from the dredge. The maximum depth of excavation was 20 m BGL. The gold-bearing ‘wash’ zone lay beneath the barren overburden and comprised the clay-rich “Old Man conglomerate”. The overburden through which most of the saturated groundwater flow was occurring, was characterised as a sandy, cobbly gravel with a  $d_{50}$  of approximately 20 mm, hydraulic conductivity of approximately 1,250 m/d, groundwater flow velocity of 10 m/d, hydraulic gradient of 0.002 m/m (1 in 500) and effective porosity of 0.25. The DSIR investigation determined each of these parameters independently for the purposes of the study of turbidity movement in groundwater.

Operation of the dredge produced measured total suspended solids (TSS) generated in water within the dredge pond ranging from 3,400 g/m<sup>3</sup> to 20,250 g/m<sup>3</sup>, measured from the surface at 0 m to pond bottom at 20 m depth. A reasonable estimate of average TSS would be 4,000 g/m<sup>3</sup>. The inferred source of the suspended fine sediment as silts, clays and colloids was the basal Old Man Conglomerate fine sediment groundmass. So, suspended fine sediment was produced by disturbance of the wash zone and groundwater

flowed through the dredge pond within the overlying, coarser overburden sandy gravels under more or less natural groundwater hydraulic gradient of 1 in 500.

Sampling bores were installed from as shallow as 2.0 m depth in the overburden and as deep as 20 m in the wash, plus two or three intermediate depths in each monitoring bore nest. The ambient groundwater flow direction was determined, as was the groundwater flow velocity, through a combination of hydraulic gradients, tracer studies and resistivity tracking of injected brine plumes. Rhodamine dye tracer experiments determined the water was leaving the dredge pond and passing the monitoring bores through all monitored depths (i.e., from 2 m to 20 m BGL). It can be noted that the groundwater was measured to be flowing from one side of the dredge pond at a known rate and under a natural gradient, and turbid water was partially pulled into the aquifer at all depths while filtration of coarser (clay sized) particles was active.

The main observation of the groundwater monitoring was that the principal size of particles decreased as the groundwater flow drew turbid water into the aquifer, which was clear evidence of filtration effects. Table 25 lists the decline in suspended particle size measured in down-gradient groundwater monitoring points observed in the Ngahere Gold dredging trials.

**Table 26: Ngahere gold dredge (Thorpe, 1990) reduction in suspended particle size within groundwater**

Distance	Median (d <sub>50</sub> ) Particle Size (µm)	Descriptive Particle Size (typical size range in µm)
Pond	2.5 – 15	Clay – silt (Silt 3.9–62.5 µm)
8 m into aquifer	3.5	Clay (0.98–3.9 µm)
35 m into aquifer	0.4	Colloid (0.00095–0.977 µm)

Note: 1 µm = 1/1000 mm.

Points can be made as to the applicability of Ngahere gold dredge groundwater travel distance and entrained turbidity to mineral sand extraction at SB –

- Hydraulic conductivity of the mineral sand at Barrytown is lower than at Ngahere (3 – 9 m/d versus 1,250 m/d),
- Hydraulic conductivity of the sandy gravel is lower than Ngahere (50 – 200 m/d versus 1250 m/d),
- Effective porosity would probably be similar to both sites,
- Natural groundwater gradients would be similar to both sites,
- The quantity of fine sediment as clay and colloidal particles with the mineral sands would be less than the weathered “Old Man conglomerate”, and
- Turbidity would be more likely to be lower and penetrate less distance in groundwater moving laterally than measured at Ngahere due to the lower hydraulic conductivity of materials.

The observed turbidity – distance relationships and empirical relationships developed from the Ngahere research provides the most useful basis for assessing the potential effects of dredge pond turbidity. Since the Ngahere research has broad parallels with what is proposed at Barrytown, and given that the hydrogeological environment has strong similarities, the coefficients developed there should have good currency in the Barrytown setting than on a purely theoretical basis. More sophisticated theoretical approaches are unlikely to be matched with the heterogenous setting of the groundwater environment at Barrytown.

Applying the Ngahere research findings to the Barrytown SB, we find that it is unlikely that any significant turbidity would extend further than 40 m into the aquifer. Any particles in suspension beyond 40 m would be substantially less than a micron (<1 µm) in size, while any particles beyond 20 metres would be fine clay with a median diameter of only 3.5 micron (µm). Any changes in groundwater borne turbidity beyond 20 metres of travel would be in terms of colour and clarity rather than sediments that could coat fish gills, etc. The potential for turbidity changes in the receiving environment is low, even without accounting for dilution in the creek and filtration in the fine substrate of the creek bed.

## 5 Effects Management

### 5.1 Avoidance, Minimisation and Remedies

Effects management has been built into the mining proposal from the beginning, including in the choice of the mining area boundaries, mining method, ore handling configuration, etc.

#### 5.1.1 Avoidance

The chief mitigation has been avoidance of proximity to sensitive receptors. In the water management context, the choice has been made to restrict the mining area of the SB to farmland under existing dairy or dairy support land use, which has largely all been subjected to historical clearance, pasture conversion, and drainage. Pockets of the subject land has been humped and hollowed, a form of drainage to maximise pasture production in areas of adverse saturation and soil conditions. The mining area borders but avoided inclusion of an area of significant indigenous biodiversity, namely the proposed Significant Natural Area SNA-PUN-49. The only other area of vegetation is a small cluster of old man pine (*Pinus sp.*) on the banks of Little Granite Creek towards the centre of the SB. The Canoe Creek wetland reserve north of the SB is also excluded from the mining area. Fagan Creek is not directly affected or encroached on by mining section number 3 of the SB.

Cargill Road and dwellings / structures will be excluded from mining activities. A 50 metre buffer, excluding mining is imposed between the mining strips against the coastal marine area delineated by Mean High Water Springs (MHWS) or the foredune crest. The existing lawful activity of beach mining Pakiroa Beach for gold would not be affected by the TCM sand mining activities since these existing mining practices are restricted to the sand and gravel beach barrier, between MHWS and strand line that lies outside of the proposed SB mining area.

#### 5.1.2 Minimisation

Minimisation of potential water management effects was tangibly chosen in selection of the suction dredge mining technology using a floating platform and submerged excavation elements. This allows mineral sand ore to be taken to a maximum depth of up to 10 metres without an air-filled pit that would require dewatering or well-pointing and the pumping of groundwater for normal mining operations. Instead, it is proposed that the dredge void would be filled with groundwater to the height of the ambient water table, without recourse to pond water pumping. The ore sand would be extracted as a water-borne slurry, but the diversion of the entrained water would be balanced by the cyclone separation of water and sand as part of tailings deposition at the tail end of the dredge pond.

The direct impact of the dredge mining through each of the creek reaches and farm drains being crossed by the mining strips would be remedied and minimised by the temporary nature of the excavation until restoration and rehabilitation returns full hydrological function and habitat values of the affected water courses.

#### 5.1.3 Remedies

Remedying arises from the mining through of water bodies (creeks and wetlands). The lengths of pre-mining and post-closure rehabilitation of creeks and wetlands are listed as follows:

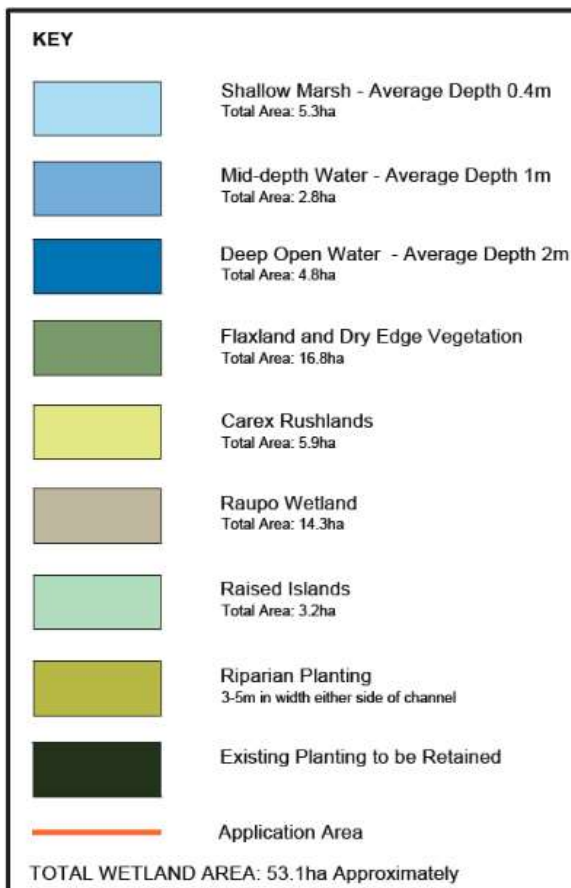
- Approximately 3,825 metres of modified creek with potential habitat affected by mining,
  - Replaced by at least 3,825 metres of rehabilitated and enhanced creek length.
- Approximately 18 ha of wetland fragments affected by mining,
  - Replaced by at least 53 ha of constructed and rehabilitated .

The historic establishment of farm drains, often as rectification or modification of existing creeks in order to conform with the farm paddock layouts has resulted in the formation of many drains arranged north to south, and some aligned east to west. Cross connection between north – south drains are also a feature of

the existing hydrologic arrangement (see Figure 34). The intervals between existing north – south farm drains across parts of the SB are approximately equivalent to the mine-path widths.

In some instances it may be practicable to avoid or minimise the effect of mining and ancillary activities. One instance is the wetland within the Mining Section 2, north of Cargill Road. Given the ability for mineral sand mining to engineer depressions in the land surface and the net deficit in the volume of sand to be emplacement as tailings, an intentional constructed wetland-like landform is proposed as part of the restoration process within the SB mining area, aligned north – south along the eastern boundary of the mining-disturbed area. This specific aspect of restoration would be intended as direct remedy for the loss of the fragmentary natural inland wetlands according to the definition(s) of such within the National Policy Statement Freshwater Management 2020 (NPS-FM 2020).

Plans have been developed to rehabilitate the post closure former mining area with a complex of wetlands. The composition of the wetlands complex is listed in Figure 38. Figure 39 illustrates the wetlands rehabilitation proposal. At least 53 hectares of wetland areas, which includes open water wetland marshes and fens with water depths up to 2 metres, flaxlands, rushlands, expanses of raupo, and raised islands amidst the wetlands complex is proposed to be constructed. Figure 39 shows a wetlands complex hugging the eastern boundary of the former mining area, in a hydrological zone where the base of wetlands would receive sustaining groundwater seepage. The water table in these areas are shallow to within 0.25 metres of the land surface and may in fact have above ground water pressures measured at depths of 1 to 2 metres below ground. Accordingly, it is anticipated that the replenishment of freshwater would be sustained by surface water inflows from Clarke Creek, other minor terrace drainages and groundwater seepage from the underlying coastal groundwater system.



**Figure 38: Key to wetland complex component areas displayed in Figure 39**



**Figure 39: Proposed post closure rehabilitation of the former mineral sand mining area in the SB with >50 ha of wetlands (Glasson Huxtable, 2026)**

## 5.2 Management of Effects on Creeks

Creeks classed as rivers include the following:

- Northern Creek,
- Central Creek,
- Clarke Creek,
- Granite Creek, including flows of Little Granite Creek,
- Wasabi Creek, and
- Southern Creek.

### 5.2.1 Clarke Creek and Granite Creek main stem

Clarke Creek currently crosses the eastern margin of the mining area into Year 1 and Year 2 mine paths. A management of the effect of mining would be for an intentional diversion of Clarke Creek from immediately upstream of the mining area margin to Little Granite Creek. The diversion would have sufficient head to facilitate gravity flow from Clarke Creek to Granite Creek and could become a long-term feature of surface water flow, until post-mining rehabilitation is undertaken. The Rehabilitation Plan includes the former course of Clarke Creek after diversion within a constructed wetland complex.

Little Granite Creek would receive the normal and flood flows of the Clarke Creek catchment. Therefore, the Little Granite Creek water course running along the eastern margin would be deepened and strengthened to receive the additional flow rate increase. Following rehabilitation of the wetlands complex between Cargill Road and the former WCP, Clarke Creek would be returned a course similar to its pre-mining alignment. However, instead of passing through farmland, Clarke Creek would pass through the wetlands complex and form part of hydrological function of the complex. In particular, Clarke Creek would have the following morphological features:

- A meandering pattern flowing through the northern lobe of the wetland complex to Granite Creek.
- The creek would convey clean water from the upstream hill catchment.
- Clarke Creek would be formed contemporaneously with wetland formation, including run, riffle and pool habitats; however, pool habitats would predominate as the creek crosses the low-gradient wetlands complex.
- Clarke Creek would occupy a creek facies and have a variety of substrates, however fine organic substrates would dominate the pool habitat area as it crosses the low gradient wetlands complex.

### 5.2.2 East – West Oriented Creeks

The Northern, Central, Wasabi and Southern creeks are essentially east-west oriented creeks that would be overtaken and mined through by the proposed mining activity. Temporary diversions are proposed to manage the effect of these creeks being mined through. ‘Dogleg’ diversion channels would bridge across two mine paths north and south of the original creek bed to allow creek flow to be maintained while sections of the original creek are being mined through. Restoration of the creek beds would fall into three classes:

- Class 3: temporary diversion of creek flow in dogleg diversion channels,
- Class 2: medium term or interim restoration of the original creek bed following diversion, and
- Class 1: long-term rehabilitation of the creek bed in line with rehabilitation plan, including naturalisation of creek channels and final rehabilitation of the central wetlands complex, which affects Central Creek.

Indeed, Northern and Central creeks would be mined through by six passes of the mine void. Wasabi creek would be mined through by three passes of the mine void, while Southern Creek would be mined through four times. The number of mine void passes doubles the number of temporary dogleg diversion channels (see Table 27).

**Table 27: Quantity of Mine Void Passes and Dogleg Diversions**

Creek	Number of Mine Path Passes	Number of Dogleg Diversions	Rehabilitation Solution
Northern	6	12	Restored creek in largely the same form.
Central	6	12	Restored creek in largely the same form, plus sinuosity.
Wasabi	3	6	Restored creek in largely the same form, plus sinuosity.
Southern	4	8	Restored creek in largely the same form.
<b>Totals</b>	19	38	

### 5.3 Management of Effects on Wetlands

A large, centralised wetlands complex would be created within the Mine Sections 1 and 2, essentially between the WCP and Cargill Road. The wetland complex would be born from the restoration of the eastern mine paths in those Mine Section and initially comprise 31 individual ponds.

The formation of the beds of the 31 component wetland ponds is an initial step towards final wetland complex rehabilitation works. The east-west segregation of initial ponds allows for the later formation of deep water, open water fens and marshes. This includes a midline running down part of the line of the future wetlands allowing for further excavation linking the wetland ponds from west to east and linking low gradient creeks internal to the wetland complex.

The ultimate wetland complex includes the following notable hydrological features:

- Creeks: Clarke Creek and Granite Creek main stem **enter** the wetland from the east at elevations between 6 and 7 metres AMSL,
- Granite Creek main stem water course would be maintained somewhat hydrologically separate from the wetland complex by the original banks and bed gradient, slightly perched above that of the wetlands bounding the creek course,
- Water depths greater than 1 metre and less than 2 metres across 5.3 hectares equates to at least 50,000 cubic metres of water storage buffer within the open water leads of the wetland complex,
- Additional flow buffering will be held within shallower leads of water and porous beds of the wetlands,
- Due to the buffering of different storage reservoirs combined, the creeks draining the wetland complex will maintain a more consistent flow regime than under the previous flow characteristics of farmland networked with rectilinear farm drains.

Overall, the progressive and final rehabilitation of the east flats affected by mining and converted to a zoned wetland complex would retain and enhance the hydrological functioning compared to the existing environment.

## 6 Proposed Water Management

### 6.1 Context

This document is intended to foreshadow the Water Management Plan; Monitoring and Effects Management Plan (WMP – MEMP), which is a comprehensive assessment of the hydrological conditions at Barrytown and environs providing context for the assessment of effect arising from the proposed mining activities. This document and the WMP are distinct from the Erosion and Sediment Control Plan (ESCP), which relates to stormwater and site runoff management particularly for the materials borrow areas that will have ESCP measures deployed to manage runoff from disturbed areas up to 2 ha at a time. For the same token, the WMP sits alongside the Ecological Management Plan (EMP) plus its water chemistry and geochemistry aspects. The rehabilitation plans detail land surface reformation, revegetation and water body restoration, which. This section of the hydrological effects assessment is intended to foreshadow the WMP and proposed consent conditions.

### 6.2 Management Goals and Objectives

#### 6.2.1 Hydrological Effect Goals

The specific goals associated with avoiding hydrological effects are:

- I. The flow in Granite Creek or Canoe Creek not reduced by more than 10% of its MALF in long-term operation (i.e., over more than 7 days).
- II. The quality of water discharged to receiving waters will not cause adverse impacts on stream ecology or turbidity.
- III. Potential adverse water quality (including ecological) impacts associated with discharge of naturally present toxic metals and phosphorus in downgradient surface waters are avoided or remedied.
- IV. The pre-mining surface drainage patterns are restored such that the catchment areas for Clarke Creek, Granite Creek and other smaller creeks are not changed to any significant extent, albeit the 53 ha of wetland is established across these named catchments.

#### 6.2.2 Water Management Objectives

The water management goals will be achieved via the following actions:

- A. The groundwater level in the dredge pond will not be manipulated to materially lower or raise pond water levels beyond 20% of the total pond depth.
- B. Pumping of groundwater will be minimised by avoiding dewatering and water table lowering while excavating saturated material by dredging within the mine void down to the economic mineral grade limit or maximum reach depth of 10 metres.
- C. Water pumped from the pit will be conveyed to the WCP. Water will be ordinarily pumped back to the dredge pond tailings zone, thereby achieving the avoidance of dewatering and meeting objective A.
- D. The quality of any groundwater that could enter surface water or coastal water will be monitored to confirm that it meets standards which are consistent with Hydrological effects goal II above and the concentration thresholds within the appropriate proposed consent conditions.
- E. Detailed design information for the water management system shall be issued to WCRC for review and comment at least 16 weeks prior to the start of mining operations. Design information will include design drawings of the infiltration trenches and basin. Changes to the Water Management Plan would require certification.
- F. The rate of take of water from the water supply gallery will be monitored in accordance with the Resource Management (Measurement and Reporting of Water Takes) Regulations and the pumping rate will be restricted to 63 L/s instantaneous rate, and 5,400 m<sup>3</sup>/d on a daily basis. This maximum rate of take is anticipated to be required for infrequent periods of up to 7 days. It is also anticipated that for periods beyond 7 days the long-term abstraction rate would be less at 9.5 L/s.

- G. The rehabilitated mine area will provide for the establishment of a large wetlands complex in the east of the former mining area, connecting to the sea with rehabilitated creeks restored with realignment and riparian plantings.

## **6.3 Monitoring Envelope**

### **6.3.1 Rainfall Monitoring**

Rainfall on the coastal plain is a necessary monitoring task for water management during the consent term. Rainfall is a key driver of the hydrological process in hill catchment creeks, lowland creeks, groundwater and wetlands of the coastal strip. Variations in rainfall also directly affects the soil moisture levels, impacting on the ability to work with soil, and the generation of turbidity in stormwater, particularly in relation to activities in the borrow areas (see ESC Plan).

Therefore, continuous monitoring of Barrytown rainfall totals and perhaps pluviographic rainfall intensity would assist the environmental management of Project in terms of water, erosion and sediment control, water quality and terrestrial ecology. However, it is not envisaged that rates of rainfall indicating extremes of intensity would become formal triggers for water management actions.

### **6.3.2 Creek Hydrological Monitoring**

The principal creeks crossing and affecting the SB mining areas are in the Granite catchment, although Canoe Creek and Fagan Creek are also found at the extreme northern and southern ends of the mining area while not crossed by those creeks. The recommendation is that flow gauging sites are established and maintained on the following:

- Clarke Creek, and
- Canoe Creek.

The sites of flow measurement are marked in Figure 41. Canoe Creek has proven in 1990 that a stage and flow hydrological site can be established at the state highway bridge (see Figure 40). Given the water management goals and objectives to maintain certain flows in Canoe Creek, a hydrological site to record creek stage and flow rate could be justified.



**Figure 40: 1990s-era Canoe Creek hydrological site at SH6 bridge pylon, including sight board and river stage sensor cables (Coffey & Partners, 1991)**

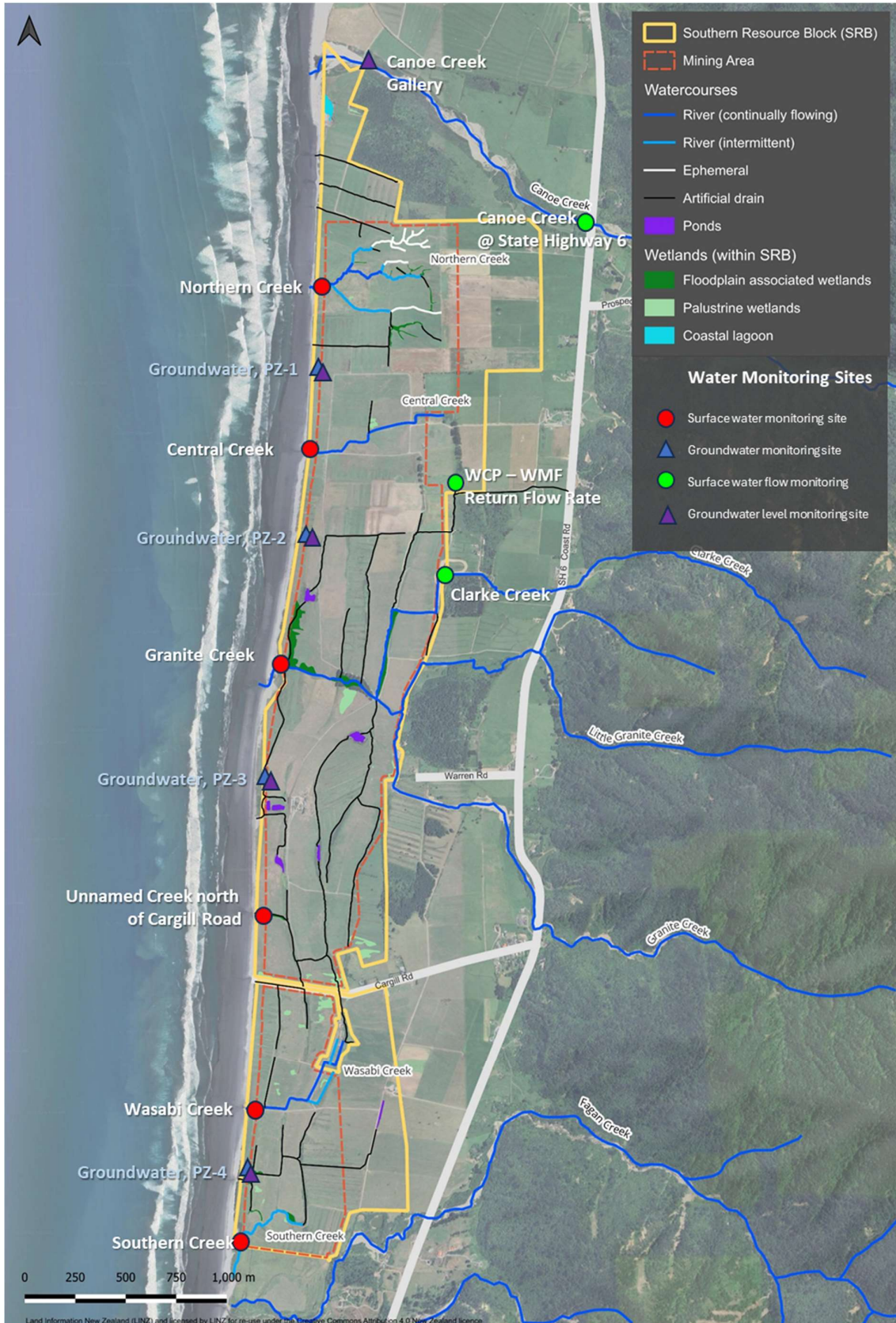
### **6.3.3 Groundwater Level Monitoring**

Among the priorities to be used in selection of existing or new groundwater monitoring bores would be the following priorities:

- Delineation of groundwater profiles across the SB mining area (perpendicular to the coastline),
- Monitoring of the effect of water supply gallery operation in terms of pore water level, and
- Monitoring of the ground water level and electrical conductivity at the coastline.

### **6.3.4 Surface Water Monitoring (Water Quality)**

The SB spans a coastline distance of 5 kilometres from the vicinity of the southern bank of Canoe Creek to the mouth of Fagan Creek. Along this coastal frontage there are eight creek mouths, including six more significant creek mouths that would merit routine water quality monitoring as shown in Figure 41. In addition to the sites indicated in Figure 41, water quality monitoring would be undertaken at the active mine void as it move along the proposed mine path (see Section 6.3.5).



**Figure 41: Creek mouth monitoring sites for surface water and groundwater**

Monitoring of surface and groundwater quality / composition in accordance with the analytical list in the proposed condition 24.2, Suite A.

### **6.3.5 Mine Impacted Water Monitoring**

In addition to these sites, the travelling mine void and particularly the tailings reception area will be the point of discharge for the mine water circuit. Samples of decanted water returning with tailings slurry as MIW would be taken at the point of discharge in accordance with proposed conditions of consent.

## **6.4 Water Management Outcomes**

The following water management outcomes would be met by the proposed Water Mitigation, Monitoring and Management Plan:

1. Hydrological function within and surrounding the SB mining areas is retained and enhanced through operations, and particularly following mine closure and rehabilitation.
2. Water levels and flow rates within and surrounding the SB mining areas are maintained within historical ranges, and significant departures are as a result of natural forcings rather than mining operations.
3. That hydrological function, water levels and water flows are adequately delineated and backed up by monitoring of key indicators of hydrological function.
4. The water levels and creek flows are maintained for adequate ecological (aquatic habitat, fish passage, and saturation) conditions for the SB mining areas and surrounds.
5. Water quality in terms of low turbidity, salinity and dissolved metals / metalloids, and nutrients are maintained within bounds that avoid transgressing the ecotoxicological thresholds recommended by EcoLogical Solutions and included in proposed conditions of consent.

## 7 Conclusions

The following conclusions are drawn in preparing this hydrological effect assessment:

1. The Barrytown Flats is underlain by sequences of fine mineral sand, silt/clay, gravel alluvium and minor peat, which is saturated by fresh groundwater to moderate depth above mudstone or granitic rock basement.
2. The resulting groundwater system is a freshwater coastal aquifer, meeting the Tasman sea at Pakiroa Beach. Evidence of the absence of landward groundwater salinity indicates that groundwater is fresh laterally to at least Mean High Water Springs on the coastline.
3. Three distinct periods of hydrogeological investigation since 1989 have defined the groundwater properties and hydraulic gradients of the Barrytown-South, Southern Block
  - a. Groundwater permeability as hydraulic conductivity ranges between 0.5 and 15 metres per day.
  - b. Groundwater hydraulic gradients have values ranging between 0.01 and 0.02 metres per metre.
4. The Southern Block is crossed by creeks of the Granite Creek catchment and a few lesser lowland creeks. The Granite and Little Granite creeks' hydrology has been correlated with neighbouring creeks such as Canoe and Collins Creek, with indications that both are steep and flashy and having negligible baseflow until leaving the hill catchments and discharging onto the coastal flats with an underlying granular groundwater system.
5. Mining proposals by Tāiko Critical Minerals (TCM) for mining of Barrytown Flats' mineral sand deposits, include liquifying the mineral sand using a floating suction dredge. The dredging would excavate a 100 x 100 metre mine void of up to 10 metres depth using a suction arm cantilevered below the dredge pontoon. The ambient water table would not be pumped down by any means due the ability to mine the mineral ore sub-aqueously, i.e., there would be little or no dewatering of the resulting dredge pond.
6. TCM's other mining infrastructural proposal for the Southern Block is the construction of the Wet Concentrator Plant on the central eastern edge of the Block and supplying the Plant with filling and make-up water from the Canoe Creek alluvium infiltration gallery. The establishment of the Wet Concentrator Plant has been authorised by the relevant councils *via* resource consents.
7. The Wet Concentrator Plant (WCP) would receive ore pumped in slurry lines and return tailings after processing to the tailings reception area at the rear of the active dredge pond. The slurry circuit would be mostly neutral in terms of the depletion or accumulation of dredge pond water, other than the diurnal difference between dredge (12 hours per day) and WCP operation (24 hours per day).
8. A hydro-cyclone to separate water and sand would deposit tailings sand as free of saturation as possible to build up a backfilling of tailings within a tailings reception area for subsequent consolidation and rehabilitation as a land surface or as the base of a wetland pond.
9. The dredge is proposed to float in a travelling pond filled with groundwater from the surrounding mineral sand aquifer and would have largely neutral effect on the level of the water table beyond minor rectification of the water table surface and open water evaporation through the surface being exposed to the atmosphere.
10. The mining activities beginning in the north of the Southern Block would move generally in north to south mining strips in three discrete geographic blocks while slowly progressing south, stopping only for Granite Creek and Cargill Road before terminating north of Fagan Creek's closest approach, within the southern extension area.
11. The main stem of Granite Creek would be crossed by the dredge pontoon as a transportation event between the Section 1 and Section 2 mining blocks; however, the main stem of Granite Creek would not be mined through and existing banks would be retained.
12. Other, flowing water bodies classed as 'rivers' within the mining area, bounded by the offset distances to coastal foredune and property boundaries, would be mined through. These would be

temporarily diverted into diversion channels to maintain through flow and re-established in prescribed form in the wake of the restoration of the dredge pond void with consolidated tailings and targeted rehabilitation, albeit not necessarily in exactly the same morphology.

13. The water table within the affected groundwater system would not be depressed by intentional dewatering and is assessed to be largely unaffected despite temporary and localised flattening of the hydraulic profile on the landward side of the dredge pond, including minor evaporative losses from the dredge pond surface.
14. The taking of groundwater would be largely non-consumptive, meaning that the sole consumption of pumped groundwater would be the transportation of adherent moisture in Heavy Mineral Concentrate *via* the trucking route, plus evaporation of water being held in the dredge ponds and water storage ponds adjacent to the WCP. These losses would drive the requirement for the water supply as make-up water.
15. The Wet Concentrator Plant water supply would be taken at the Canoe Creek from an infiltration gallery buried within the Canoe Creek alluvium in a location already authorised by the neighbouring Central Resource Block consents. The term of the existing authorisation would require extension for the life of the SB mining operations.

#### **Effects, Effects Management Hierarchy, and Management of Certainty**

16. Each of the principal effects attached to the proposed activities have been assessed and a level of effect assigned:
  - a. **Water take:** The taking of Canoe Creek water via the Canoe Creek alluvium in an infiltration gallery at peak rates less than ten percent of MALF<sub>7d</sub> in Canoe Creek (proposed maximum take is 63 litres per second), therefore less than minor.
  - b. **Mining:** The dredging of mineral soils to 10 metres below ground level followed by back-filling with processed sands is groundwater level neutral and therefore has effects less than minor.
  - c. **Backfilling with Tailings:** The ultimate water-bearing and water transmission properties of the backfilled mine strips would be broadly the same as the original ground therefore effects would be less than minor.
  - d. **Water contamination:** The dredging of mineral soils to 10 metres below ground level followed by back-filling with processed sands has mild effects in terms of elevating turbidity, dissolved metals liberation, and nutrient mobilisation. After *in situ* attenuation and any remedial limestone dosing the water quality effects on groundwater and down-gradient surface water will be less than minor.
  - e. **Stream network disruption:** The diversion, restoration, and rehabilitation of the Barrytown Flats across the life of the Southern Block mineral sand mine would have medium and long-term effects that are in aggregate less than minor.
  - f. **Wetlands:** The mining-out of wetland fragments by the Southern Block operations would temporarily have an adverse effect on those inland natural wetlands, remedied by restoration into wetland ponds and subsequently rehabilitation to a larger wetland complex between Clarke Creek and Cargill Road.

17. The Effects Mitigation Hierarchy (avoid, minimise or remedy) was also included in the Water Management Plan, and Monitoring & Effects Management Plan. All effects must first be avoided, then minimised, and then remedied where effects remain and measures are practicable. Any residual effects remaining must be offset then compensated for in such a manner that there is no net loss, or preferably a net gain, for creeks or wetlands in the affected area.
- a. Once the mining plan determined there was a functional need for the surface mining of mineral sands in the Southern Block, mine-path measures to (as far as practicable) avoid mining through wetlands were employed.
  - b. For those remaining wetlands surrounding the mine path, a mining method was selected that minimised dewatering and the consequent altering of groundwater levels and/or creek flow disruption.
  - c. Sand dredging with a travelling dredge pond would minimise any lowering of the water table and minimise realignment of surface water flows through targeted diversions.
  - d. For those wetland fragments within the mine path that would be mined out, rehabilitation remedying this loss by restoring a larger extent within the post-mining wetland complex has been planned and will be implemented as part of a rehabilitation plan.
  - e. The creek network following wetland rehabilitation would need to mesh with a partly artificial set of creek alignments and profiles. These residual effects would be remedied by rehabilitating creek alignments and channel morphology to a more natural character with enhanced habitat and amenity values, but in a way which retains existing hydrological functioning while enhancing aquatic habitat values.
18. The level of certainty that is held for these assessments may be summarised as follows:
- a. The existing environment and hydrological conceptual model has allowed a high level of certainty to be obtained for the affected surface water and groundwater systems.
  - b. The compilation of assessments was feasible for all potential effect classes with a moderate to high level of certainty.
  - c. The evaluation of remedial measures in managing the effects also had a moderate to high level of certainty.
19. No significant adverse effects are assessed as arising in the hydrology and water quality discipline areas. Effects management options are available for responding to the results of water monitoring, particularly for dissolved metals and nutrients in ground and surface water. Disturbance of creek water courses and wetlands have rehabilitation responses that remedy those disturbance effects. The rehabilitation responses are multidisciplinary, and include input from hydrological, ecological and landscape disciplines.

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# Appendices

## Appendix 1. Groundwater Results from Nikau Deer Farm CB Block (09/11/2022)

	<i>Sample Name:</i>	PZ-15	PZ-08	PZ-17	PZ-13	PZ-06	PZ-18	PZ-02	PZ-01	PB-01
Sum of Anions	meq/L	1.86	0.98	0.99	1.15	0.89	0.94	0.87	1.43	1.41
Sum of Cations	meq/L	2	0.95	1	1.1	0.86	0.93	0.87	1.4	1.85
Turbidity	NTU	240	880	22	118	75	176	1.45	166	121
pH	pH Units	7.4	7.7	7.6	7.5	7.6	7.6	7.6	7.6	7.3
Total Alkalinity	g/m <sup>3</sup> as CaCO <sub>3</sub>	55	34	35	36	31	33	31	57	51
Bicarbonate	g/m <sup>3</sup> at 25°C	67	41	42	43	38	40	38	70	62
Total Hardness	g/m <sup>3</sup> as CaCO <sub>3</sub>	47	30	31	33	25	28	29	43	40
Electrical Conductivity (EC)	mS/m	20.6	10.7	11	12.3	9.5	10.2	9.7	14.8	14.9
Total Suspended Solids	g/m <sup>3</sup>	610	1,440	112	183	880	640	60	310	19
Total Dissolved Solids (TDS)	g/m <sup>3</sup>	131	64	63	71	56	62	58	85	106
Dissolved Aluminium	g/m <sup>3</sup>	0.1	0.005	0.005	< 0.003	0.012	0.008	0.009	0.007	< 0.003
Dissolved Boron	g/m <sup>3</sup>	0.014	0.008	0.007	0.009	0.006	0.006	0.006	0.009	0.011
Dissolved Calcium	g/m <sup>3</sup>	13.7	7.6	7.7	9.2	5.7	6.7	8.4	10.6	11.7
Dissolved Cobalt	g/m <sup>3</sup>	0.0011	< 0.0002	0.0002	0.0009	0.0002	0.0011	0.0002	0.0009	0.0006
Dissolved Iron	g/m <sup>3</sup>	3.2	< 0.02	0.16	< 0.02	0.03	0.02	0.03	0.04	11.1
Dissolved Magnesium	g/m <sup>3</sup>	3.1	2.6	2.7	2.5	2.6	2.7	1.87	3.9	2.6
Dissolved Manganese	g/m <sup>3</sup>	0.29	0.0076	0.059	0.031	0.11	0.0183	0.0105	0.11	0.29
Dissolved Mercury	g/m <sup>3</sup>	< 0.00008	< 0.00008	0.00008	0.00008	0.00008	0.00008	< 0.00008	0.00008	0.00008
Dissolved Molybdenum	g/m <sup>3</sup>	0.0012	0.0004	0.0003	0.0002	0.0004	0.0153	0.002	0.003	0.0002
Dissolved Potassium	g/m <sup>3</sup>	6.3	2.8	2.8	1.68	4.1	4.5	1.86	2	2
Dissolved Silver	g/m <sup>3</sup>	0.0001	< 0.00010	0.0001	0.0001	0.0001	0.0001	< 0.00010	0.0001	0.0001
Dissolved Sodium Chloride	g/m <sup>3</sup>	15.8	6.6	7.1	8.7	5.7	5.9	5.5	9.9	12.6
Total Ammoniacal-N	g/m <sup>3</sup>	1.17	< 0.010	< 0.010	0.106	< 0.010	0.022	0.087	0.73	0.72
Nitrite-N	g/m <sup>3</sup>	0.24	< 0.002	< 0.002	0.004	< 0.002	< 0.002	0.017	0.004	< 0.02 #1
Nitrate-N	g/m <sup>3</sup>	1.18	0.29	0.33	0.76	0.029	0.022	0.183	0.048	< 0.02
Nitrate-N + Nitrite-N	g/m <sup>3</sup>	1.42	0.29	0.33	0.77	0.03	0.023	0.2	0.052	< 0.02 #1
Total Phosphorus	g/m <sup>3</sup>	0.7	1.07	0.081	0.27	0.129	0.27	0.04	0.25	0.181
Sulphate	g/m <sup>3</sup>	1.5	3.1	2.1	3.6	2.6	2.9	1.4	0.9	1.6
Total Organic Carbon (TOC)	g/m <sup>3</sup>	6.7	2.4	0.8	1.1	2.2	1.2	1.4	3	4.7
Dissolved Arsenic	g/m <sup>3</sup>	0.0091	0.0106	0.0021	0.0021	0.0017	0.0010	0.036	0.0025	0.0081
Dissolved Cadmium	g/m <sup>3</sup>	< 0.00005	< 0.00005	0.00005	0.0001	0.00005	0.00005	< 0.00005	0.00005	< 0.00005
Dissolved Chromium	g/m <sup>3</sup>	0.0035	< 0.0005	0.0005	0.0005	0.0005	0.0005	0.0008	0.0005	0.0005
Dissolved Copper	g/m <sup>3</sup>	0.0019	0.0014	0.0017	0.0018	0.0005	0.0055	0.0026	0.002	0.0005
Dissolved Lead	g/m <sup>3</sup>	0.00113	< 0.00010	0.0003	0.0001	0.00038	0.00017	0.00023	0.00013	0.0001
Dissolved Nickel	g/m <sup>3</sup>	0.0104	< 0.0005	0.0006	0.0019	0.0005	0.045	0.0053	0.122	0.0012
Dissolved Zinc	g/m <sup>3</sup>	0.068	0.0151	0.039	0.074	0.0012	0.0198	0.104	0.046	0.0122

## Appendix 2. Collins Creek (“CC”) Upstream (“US”) & Downstream (“DS”) Dissolved Analysis Results from CB Block Water Bodies

Toxicant (dissolved)	Units	CC US 28/07/22	CC US 23/08/22	CC US 21/09/22	CC US 01/11/22	CC DS 28/07/22	CC DS 23/08/22	CC DS 21/09/22	CC DS 01/11/22	ANZG 95
Sum of Anions	meq/L	1.16	1.03	1.07	0.99	0.95	0.88	0.82	0.89	N/A
Sum of Cations	meq/L	1.16	1.06	1.14	1	0.94	0.9	0.88	0.92	N/A
Turbidity	NTU	0.95	0.6	1.19	0.82	3.7	6.6	1.07	1.35	N/A
pH	pH units	7.8	7.6	7.7	7.6	7.6	7.3	7.5	7.3	N/A
Total alkalinity	g/m <sup>3</sup> as CaCO <sub>3</sub>	34	28	33	29	28	25	25	28	N/A
Bicarbonate	g/m <sup>3</sup> at 25°C	41	35	40	35	34	30	31	33	N/A
Total hardness	g/m <sup>3</sup> as CaCO <sub>3</sub>	34	32	33	30	28	26	26	27	N/A
EC	mS/m	12.6	12	12.5	11.1	10.3	10.3	9.5	10	N/A
TSS				< 3	< 3			< 3	4	N/A
TDS	g/m <sup>3</sup>	72	61	74	65	57	56	54	64	N/A
Aluminum	g/m <sup>3</sup>	0.024	0.029	0.029	0.044	0.01	0.018	0.011	0.028	0.055
Boron	g/m <sup>3</sup>	0.01	0.011	0.012	0.011	0.007	0.009	0.01	0.009	0.94
Calcium	g/m <sup>3</sup>	9.9	9.2	9.4	8.3	7.9	7.3	7.1	7.3	N/A
Cobalt	g/m <sup>3</sup>	< 0.0002	< 0.0002	< 0.0002	< 0.0002	0.0003	< 0.0002	< 0.0002	< 0.0002	0.0014
Iron	g/m <sup>3</sup>	0.09	0.05	0.12	0.09	0.21	0.16	0.25	0.22	N/A
Magnesium	g/m <sup>3</sup>	2.4	2.3	2.3	2.2	2.1	2	1.91	2.1	N/A

<b>Toxicant</b>	<b>Units</b>	<b>CC US</b>	<b>CC US</b>	<b>CC US</b>	<b>CC US</b>	<b>CC DS</b>	<b>CC DS</b>	<b>CC DS</b>	<b>CC DS</b>	<b>ANZG 95</b>
<b>Manganese</b>	g/m <sup>3</sup>	0.0115	0.0049	0.0116	0.0073	0.034	0.0169	0.024	0.021	1.9
<b>Mercury</b>	g/m <sup>3</sup>	< 0.00008	< 0.00008	< 0.00008	< 0.00008	< 0.00008	< 0.00008	< 0.00008	< 0.00008	0.0006
<b>Molybdenum</b>	g/m <sup>3</sup>	< 0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0002	0.034
<b>Potassium</b>	g/m <sup>3</sup>	1.11	0.99	1.09	0.97	1.06	0.99	1	1.03	N/A
<b>Silver</b>	g/m <sup>3</sup>	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	0.00005
<b>Sodium</b>	g/m <sup>3</sup>	10	8.8	10.3	8.7	7.9	7.6	7.6	7.8	N/A
<b>Chloride</b>	g/m <sup>3</sup>	14.4	14	12.5	12.5	12.2	11.7	9.7	10.5	N/A
<b>Total Ammoniacal-N</b>	g/m <sup>3</sup>	< 0.010	< 0.010	< 0.010	0.016	0.04	0.026	< 0.010	0.065	0.9
<b>Nitrite-N</b>	g/m <sup>3</sup>	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	N/A
<b>Nitrate-N</b>	g/m <sup>3</sup>	0.036	0.036	0.023	0.025	0.147	0.149	0.058	0.092	N/A
<b>Total phosphorus</b>	g/m <sup>3</sup>	0.008	0.005	0.081	0.006	0.008	0.007	0.008	0.009	N/A
<b>Sulphate</b>	g/m <sup>3</sup>	3.5	3	3	2.7	2.2	2.4	1.8	1.9	N/A
<b>Total organic</b>	g/m <sup>3</sup>	2.6	1.9	2	3.3	1.6	1.5	2	3.3	N/A
<b>Arsenic</b>	g/m <sup>3</sup>	< 0.0010	< 0.0010	< 0.0010	< 0.0010	< 0.0010	< 0.0010	< 0.0010	< 0.0010	0.013
<b>Cadmium</b>	g/m <sup>3</sup>	< 0.00005	< 0.00005	< 0.00005	< 0.00005	< 0.00005	< 0.00005	< 0.00005	< 0.00005	0.0002
<b>Chromium</b>	g/m <sup>3</sup>	< 0.0005	< 0.0005	< 0.0005	< 0.0005	< 0.0005	< 0.0005	< 0.0005	< 0.0005	0.001
<b>Copper</b>	g/m <sup>3</sup>	< 0.0005	< 0.0005	< 0.0005	< 0.0005	< 0.0005	< 0.0005	< 0.0005	0.0006	0.0014

<b>Toxicant</b>	<b>Units</b>	<b>CC US</b>	<b>CC US</b>	<b>CC US</b>	<b>CC US</b>	<b>CC DS</b>	<b>CC DS</b>	<b>CC DS</b>	<b>CC DS</b>	<b>ANZG 95</b>
<b>Lead</b>	g/m <sup>3</sup>	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	0.00011	< 0.00010	0.0034
<b>Nickel</b>	g/m <sup>3</sup>	< 0.0005	< 0.0005	< 0.0005	< 0.0005	< 0.0005	< 0.0005	< 0.0005	0.0005	0.011
<b>Zinc</b>	g/m <sup>3</sup>	< 0.0010	< 0.0010	< 0.0010	< 0.0010	< 0.0010	< 0.0010	< 0.0010	< 0.0010	0.008

Note: ANZG 95 = Australia New Zealand (Default) Guideline value at 95% species protection

CC Canoe Creek

EC Electrical Conductivity

TDS Total Dissolved Solids

TSS Total Suspended Solids

### Appendix 3. Canoe Creek Lagoon & Northern Boundary Drain Dissolved Analysis Results from CB Block

Toxicant (dissolved)	Units	Lagoon	Lagoon	Northern Drain	Northern Drain	Northern Drain	ANZG 95
		23/08/2022	21/09/2022	23/08/2022	21/09/2022	1/11/2022	
Sum of Anions	meq/L	1	1.37	0.68	0.92	0.69	N/A
Sum of Cations	meq/L	1.09	1.54	0.7	1.03	0.73	N/A
Turbidity	NTU	10.1	7.6	6.2	4.4	2.7	N/A
pH	pH units	7.1	7.4	6.7	7.3	6.5	N/A
Total alkalinity	g/m <sup>3</sup> as CaCO <sub>3</sub>	24	30	14.2	32	14	N/A
Bicarbonate	g/m <sup>3</sup> at 25°C	30	36	17.3	39	17.1	N/A
Total hardness	g/m <sup>3</sup> as CaCO <sub>3</sub>	27	35	18.1	34	17.6	N/A
EC	mS/m	12	16.8	8.2	10.8	8.4	N/A
TSS			6		< 3	5	N/A
TDS	g/m <sup>3</sup>	72	95	47	70	58	N/A
Aluminium	g/m <sup>3</sup>	0.055	0.017	0.096	0.043	0.131	0.055
Boron	g/m <sup>3</sup>	0.011	0.015	0.007	0.009	0.008	0.94
Calcium	g/m <sup>3</sup>	7.1	8.6	4.7	10.2	4.2	N/A
Cobalt	g/m <sup>3</sup>	< 0.0002	0.0004	0.0013	0.0005	0.0016	0.0014
Iron	g/m <sup>3</sup>	1.15	0.88	0.12	1.01	0.29	N/A
Magnesium	g/m <sup>3</sup>	2.3	3.2	1.55	1.96	1.76	N/A
Manganese	g/m <sup>3</sup>	0.0071	0.097	0.031	0.046	0.043	1.9
Mercury	g/m <sup>3</sup>	< 0.00008	< 0.00008	< 0.00008	< 0.00008	< 0.00008	0.0006
<b>Molybdenum</b>							
Molybdenum Potassium	g/m <sup>3</sup>	< 0.0002	< 0.0002	< 0.0002	< 0.0002	< 0.0002	0.034

Toxicant (dissolved)	Units	Lagoon	Lagoon	Northern Drain	Northern Drain	Northern Drain	ANZG 95
		23/08/2022	21/09/2022	23/08/2022	21/09/2022	1/11/2022	
Potassium Silver	g/m <sup>3</sup>	1.33	2	0.9	1.19	1.04	N/A
Silver Sodium	g/m <sup>3</sup>	< 0.00010	< 0.00010	< 0.00010	< 0.00010	< 0.00010	0.00005
Sodium Chloride	g/m <sup>3</sup>	10.5	17.2	6.9	6.6	7.5	N/A
Chloride	g/m <sup>3</sup>	15.7	25	10.5	8.3	10.7	N/A
Total Ammoniacal-N	g/m <sup>3</sup>	0.103	0.15	0.027	0.052	0.023	0.9
Nitrite-N	g/m <sup>3</sup>	0.005	0.005	0.002	0.008	< 0.002	N/A
Nitrate-N	g/m <sup>3</sup>	0.107	0.068	0.26	0.057	0.128	N/A
Total phosphorus	g/m <sup>3</sup>	0.075	0.056	0.018	0.078	0.053	N/A
Sulphate	g/m <sup>3</sup>	2.8	3.3	4.1	1.9	4.9	N/A
Total organic carbon	g/m <sup>3</sup>	8.8	4.3	4.6	7.8	8.1	N/A
Arsenic	g/m <sup>3</sup>	0.0012	< 0.0010	< 0.0010	< 0.0010	0.0011	0.013
Cadmium	g/m <sup>3</sup>	< 0.00005	< 0.00005	0.00008	< 0.00005	0.00005	0.0002
Chromium	g/m <sup>3</sup>	0.0008	< 0.0005	< 0.0005	< 0.0005	< 0.0005	0.001
Copper	g/m <sup>3</sup>	0.0014	0.0018	0.0027	0.0014	0.0029	0.0014
Lead	g/m <sup>3</sup>	0.00028	0.00012	0.00028	0.00019	0.0004	0.0034
Nickel	g/m <sup>3</sup>	0.0013	0.0006	0.0021	0.0013	0.0025	0.011
Zinc	g/m <sup>3</sup>						

Note: ANZG 95 = Australia New Zealand (Default) Guideline value at 95% species protection. EC = Electrical Conductivity. TDS = Total Dissolved Solids. TSS = Total Suspended Solids  
**0.0151** indicates that the ANZG 95 guideline is exceeded.

#### Appendix 4. Nikau Deer Farm, CB: HMC, Tails, Slimes and ROM water quality results

Toxicant (dissolved)	Units	Slimes	Tails	ROM	HMC	ANZG 95
pH	pH units	6.9	6.9	6.9	6.8	N/A
Total alkalinity	g/m <sup>3</sup> as CaCO <sub>3</sub>	134	29	31	5.8	N/A
Bicarbonate	g/m <sup>3</sup> at 25°C	163	35	38	7.1	N/A
Total hardness	g/m <sup>3</sup> as CaCO <sub>3</sub>	3800	39	310	3.7	N/A
EC	mS/m	8.7	2.3	2.5	1	N/A
TDS	g/m <sup>3</sup>				35	N/A
Aluminium	g/m <sup>3</sup>	0.12	0.2	0.12	0.39	0.055
Arsenic	g/m <sup>3</sup>	< 0.02	< 0.02	< 0.02	< 0.0010	0.013
Boron	g/m <sup>3</sup>	< 0.10	< 0.10	< 0.10	0.008	0.94
Cadmium	g/m <sup>3</sup>	< 0.0010	< 0.0010	< 0.0010	< 0.00005	0.0002
Calcium	g/m <sup>3</sup>	310	4.6	23	1.13	N/A
Chloride	g/m <sup>3</sup>				< 0.5	N/A
Chromium	g/m <sup>3</sup>	< 0.0010	< 0.0010	< 0.0010	0.0036	0.001
Cobalt	g/m <sup>3</sup>	< 0.004	< 0.004	< 0.004	0.0004	0.0014
Copper	g/m <sup>3</sup>	0.012	< 0.010	< 0.010	0.0055	0.0014
Iron	g/m <sup>3</sup>	< 0.4	< 0.4	< 0.4	0.5	N/A
Lead	g/m <sup>3</sup>	< 0.002	< 0.002	< 0.002	0.00148	0.0034
Magnesium	g/m <sup>3</sup>				0.2	N/A
Manganese	g/m <sup>3</sup>	0.12	< 0.010	0.026	0.0199	1.9
Mercury (inorganic)	g/m <sup>3</sup>	< 0.00008	< 0.00008	< 0.00008	< 0.00008	0.0006
Molybdenum	g/m <sup>3</sup>	< 0.004	< 0.004	< 0.004	0.0008	0.034
Nickel	g/m <sup>3</sup>	< 0.010	< 0.010	< 0.010	0.0016	0.011
Nitrate-N	g/m <sup>3</sup>				0.042	N/A
Nitrite-N	g/m <sup>3</sup>				0.005	N/A
Potassium	g/m <sup>3</sup>	2	< 1.0	1.6	0.64	N/A
Silver	g/m <sup>3</sup>	< 0.002	< 0.002	< 0.002	< 0.00010	0.00005
Sodium	g/m <sup>3</sup>	4.9	1.8	1.4	0.74	N/A
Sulphate	g/m <sup>3</sup>				< 0.5	N/A
Total Ammoniacal-N	g/m <sup>3</sup>				< 0.010	0.9
Total organic carbon	g/m <sup>3</sup>	45	3.6	9.6	3.4	N/A
Total phosphorus	g/m <sup>3</sup>	60	< 0.42	3.9	0.22	N/A
Zinc	g/m <sup>3</sup>	< 0.02	< 0.02	< 0.02	0.006	0.008

Note: 'Slimes' relates to fine sediments. 'Tails' relates to tailings. 'ROM' relates to Run Of Mine ore. 'HMC' or 'Cons' relates to Heavy Mineral Concentrate. ANZG 95 = Australia New Zealand (Default) Guideline value at 95% species protection. EC = Electrical Conductivity. TDS = Total Dissolved Solids. TSS = Total Suspended Solids.

## Appendix 5. Barrytown Farms Ltd: HMC, Tails, Slimes and ROM water quality results

### Southern Block (Barrytown South)

Toxicant (dissolved unless otherwise stated)	Units	ROM	Slimes	Tails	Cons	ANZG 95
Sum of Anions	meq/L	0.46	0.68	0.21	0.14	
Sum of Cations	meq/L	0.6	1.13	0.37	0.33	
Turbidity	NTU	2000	9700	530	410	
pH	pH units	5.4	5.6	5.6	5.9	
Total alkalinity	g/m <sup>3</sup> as CaCO <sub>3</sub>	3.6	10	3.2	3.5	
Bicarbonate	g/m <sup>3</sup> at 25 deg C	4.4	12.2	3.9	4.2	
Total hardness	g/m <sup>3</sup> as CaCO <sub>3</sub>	16.7	36	6.6	5	
EC	mS/m	6.3	10.4	2.9	1.7	
TSS	g/m <sup>3</sup>	4100	11600	380	240	
TDS	g/m <sup>3</sup>	77	158	58	45	
Calcium	g/m <sup>3</sup>	4.3	11.2	1.81	1.49	
Total Iron	g/m <sup>3</sup>	156	400	28	18.1	
Magnesium	g/m <sup>3</sup>	1.46	1.85	0.5	0.32	
Mercury	g/m <sup>3</sup>	<0.00008	0.0003	0.0022	0.00014	0.0006
Total Mercury	g/m <sup>3</sup>	< 0.0021	0.024	0.04	0.00063	
Molybdenum	g/m <sup>3</sup>	< 0.0002	0.0003	0.0003	0.0003	0.034
Potassium	g/m <sup>3</sup>	1.66	2	0.88	0.77	
Silver	g/m <sup>3</sup>	0.92	0.00068	0.103	0.039	
Sodium	g/m <sup>3</sup>	2.8	3.8	1.93	1.03	
Chloride	g/m <sup>3</sup>	0.6	4.8	1.6	0.9	
Total Ammoniacal-N	g/m <sup>3</sup>	0.111	0.39	0.102	0.08	0.9
Nitrite-N	g/m <sup>3</sup>	0.08	0.057	0.004	0.007	
Nitrate-N	g/m <sup>3</sup>	1.4	0.062	0.35	0.091	
Nitrate-N + Nitrite-N	g/m <sup>3</sup>	1.41	0.119	0.36	0.098	
TKN	g/m <sup>3</sup>	2.9	5	1.21	0.94	
DRP	g/m <sup>3</sup>	0.014	0.0056	0.005	0.014	
Total phosphorus	g/m <sup>3</sup>	1.65	5.4	0.48	0.45	
Sulphate	g/m <sup>3</sup>	13.1	15.8	3.7	1.6	
TBOD	g O <sub>2</sub> /m <sup>3</sup>	<2	24	3	3	
TOC	g/m <sup>3</sup>	23	56	<20	< 20	
Aluminium	g/m <sup>3</sup>	0.52	1.13	0.68	0.97	0.055
Arsenic	g/m <sup>3</sup>	0.0025	0.0029	0.002	0.0024	0.013
Boron	g/m <sup>3</sup>	0.015	0.029	0.014	0.013	0.94
Cadmium	g/m <sup>3</sup>	< 0.00005	0.00007	< 0.00005	< 0.00005	0.0002
Chromium	g/m <sup>3</sup>	0.0035	0.0164	0.0084	0.0118	0.001
Cobalt	g/m <sup>3</sup>	0.0038	0.0107	0.0011	0.0013	0.0014

Toxicant (dissolved unless otherwise stated)	Units	ROM	Slimes	Tails	Cons	ANZG 95
<b>Copper</b>	<i>g/m<sup>3</sup></i>	0.0079	0.034	0.0094	0.0086	0.0014
<b>Iron</b>	<i>g/m<sup>3</sup></i>	0.73	0.95	1.09	1.33	
<b>Lead</b>	<i>g/m<sup>3</sup></i>	0.0024	0.00196	0.0032	0.005	0.0034
<b>Manganese</b>	<i>g/m<sup>3</sup></i>	0.135	0.38	0.048	0.049	1.9
<b>Nickel</b>	<i>g/m<sup>3</sup></i>	0.0085	0.33	0.0041	0.0108	0.011
<b>Zinc</b>	<i>g/m<sup>3</sup></i>	0.064	0.122	0.029	0.025	0.008

Note: 'Slimes' relates to fine sediments. 'Tails' relates to tailings. 'ROM' relates to Run Of Mine ore. 'HMC' or 'Cons' relates to Heavy Mineral Concentrate. ANZG 95 = Australia New Zealand (Default) Guideline value at 95% species protection. EC = Electrical Conductivity. TDS = Total Dissolved Solids. TSS = Total Suspended Solids.

## Appendix 6. Unexpected Artesian Pressure Interception Protocol

Key contingency measures may include:

- **Immediate Action on Breakthrough:** If an artesian inflow from an aquifer is unexpectedly intercepted, the mine manager must cease all work in the area immediately and assess next steps.
- **Emergency Sealing Procedures:** Measures to stop the flow include installing a "capping layer" of impermeable material to plug the breach, effectively restoring the confining layer.
- **Monitoring and Assessment:** Operators must monitor, document, and report whether the flow is increasing and if it is confined to the excavation area.
- **Below Water Table Excavation Controls:** Plans must account for groundwater levels and any new knowledge on the disposition of artesian conditions. Excavations are often limited in terms of depth or extent to prevent tapping into higher-pressure water-bearing layers or aquifers.
- **Precautionary Pressure Monitoring:** In some scenarios, operators must use extended vertical pipes to monitor the height of the artesian pressure head ahead of the travelling mine void for the anticipation of higher-pressure before the excavation encounters them.

### Unexpected Artesian Aquifer Interception

1. In the event of an accidental interception or unanticipated levels of artesian flows, all practicable measures shall be undertaken to remedy or mitigate any change in aquifer pressure, water quality or temperature. This shall include but not be limited to:
  - a. The mine manager shall immediately cease all works within the immediate area of excavation that caused the interception of the artesian flows;
  - b. The return of tailings slurry from the WCP should also be curtailed and consideration given to halting the pumping of make-up water from the Canoe Creek infiltration gallery as a means of easing any water surplus accumulations in the Mine Water Facility.
  - c. The mine manager shall determine and document whether the flow is constant or increasing, if the turbidity is constant or increasing and if the flow is confined to the excavation;
  - d. The mine manager shall notify the mine manager and environmental officer and/or other appropriate personnel to determine the emergency measures required to arrest the artesian flow. Emergency measures shall include, but not be limited to:
    - i. the installation of impermeable material to the extent required to reform a capping layer over the aquifer breach; or
    - ii. inserting a pressure relief system to control discharge and minimise overflow from the dredge pond.
  - e. Appropriate erosion and sediment control measures shall be installed to minimise the sediment entrained in any artesian flow from entering surface water or the Coastal Marine Area;
  - f. The West Coast Regional Council shall be notified as soon as practicable but no later than two working days after the interception; and
  - g. Upon remediation and arresting of flow from the aquifer interception, the design of the mining works and dredging methodology shall be reconsidered and, if required, revised

to avoid future interceptions of the aquifer. The revisions may be included in the Water Management Plan for recertification by the Consent Authority.

2. There shall be no seepage of artesian flows from an aquifer beneath the excavated and backfilled areas following the completion of the remedial works outlined in Condition (1)(c). If seepage does occur, further remedial actions shall be taken to cease or minimise the seepage of artesian flows to the satisfaction of the West Coast Regional Council.

**Dewatering Management Plan**

3. At least 10 working days prior to commencing the works, the Consent Holder shall submit a Dewatering Management Plan (DMP) to the West Coast Regional Council. The DMP shall be prepared in accordance with the appropriate Erosion and Sediment Control Plan. The DMP shall contain the following:
  - a. The methodology for dewatering, including:
  - b. A map showing the location of areas that are likely to require dewatering;
  - c. A programme of works, including an indicative timeframe.
4. The DMP may be amended at any time. Any amendments shall be:
  - d. Only for the purpose of improving the efficacy of dewatering; and
  - e. Consistent with the conditions of this resource consent; and
  - f. Submitted in writing to the West Coast Regional Council.