# Waihi North

## Groundwater Assessment
## WAI-985-000-REP-LC-0012_Rev2

Oceana Gold (New Zealand) Ltd

26 February 2025



→ The Power of Commitment

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# Executive summary

## Overview

GHD was commissioned by OGNZL to deliver a number of studies relating to groundwater for the Waihi North Project (WNP). This report provides the assessment of effects to groundwater and surface water of the proposed Gladstone Open Pit (GOP) and the new rock and tailings storage facilities of the WNP, which are proposed to include:

– GOP Tailings Storage Facility (TSF), to be emplaced within the GOP after closure.
– Northern Rock Stack (NRS), to be located north of the existing Tailings Storage Facility 2 (TSF2).
– Tailings Storage Facility 3 (TSF3), to be located east of the existing Tailings Storage Facility 1A (TSF1A).
– Willows Rock Stack (WRS), near the Wharekirauponga Underground Mine (WUG) access portal.

This assessment considers the potential for each individual component to influence groundwater flow and levels, baseflow in surface water and water quality. It is concluded that the potential effects to groundwater and surface water quality associated with development, operation and closure of these mine components may be measurable in localised areas, but are at most minor in nature. Each mine component is recommended to have a monitoring plan, outlining requirements for monitoring, site-specific trigger levels, and mitigation / contingency measures to manage unexpected adverse outcomes of undertaking the activities at each site.

The assessment conclusions and recommendations for each mine component are summarised below. This report is subject to, and must be read in conjunction with, the limitations set out in Section 1.5 and the assumptions and qualifications contained throughout the Report.

## Gladstone Open Pit and Tailings Storage Facility

Excavation of the Gladstone Open Pit (GOP) is proposed to comprise two conjoined pits over Gladstone Hill and Winner Hill. Following cessation of mining at GOP, the pit will be developed as a TSF, including partial backfilling with rock, installation of a geosynthetic liner to reduce discharges and a TSF drainage system to control groundwater. When underground mining ceases in Waihi dewatering will cease and deep groundwater levels will recover. The deep groundwater flow direction and levels are expected to be controlled by the Martha Pit Lake level. This rewatering of the deep groundwater system is assumed to occur during the period of TSF closure and be the background condition for the TSF in the long term.

Potential effects associated with the GOP are considered to relate to dewatering and loss of surface water catchment, which includes the lowering of groundwater levels, reduction in flow to surface water and depletion of water resources which may affect users of water. The effects associated with the GOP dewatering are assessed as follows:

– **Deep groundwater:** Existing mine dewatering activities are considered to have largely dewatered the vein system and andesite northeast of the proposed GOP. Dewatering during mining is predicted to result in this vein desaturation extending to the southwest and potentially a small distance beyond the Ohinemuri River. Desaturation of the host andesite outside of the veins is, however, expected to be limited, as seen elsewhere in Waihi. The effects to the deeper groundwater system are therefore considered to be limited.
– **Shallow groundwater:** The GOP excavation is predicted to result in only localised drawdown of the water table, with measurable changes only predicted immediately adjacent to the pit.
– **Surface water:** The change in groundwater flows and run-off to the Ohinemuri River, due to loss of catchment, are considered to be negligible in the context of river flow. Changes to groundwater flow to the Gladstone wetland is expected to be small and unmeasurable given the significantly greater influence of run-off in the wetland water balance.
– **Water users:** There are no groundwater users within the predicted zone of influence of GOP dewatering and the nearest groundwater and surface water takes are not expected to be adversely affected by dewatering.
– **Monitoring and management:** Monitoring of inflows to the pit and groundwater levels in both shallow and deep groundwater systems around the perimeter are recommended. In particular, monitoring effects within the veins southwest of the GOP will allow validation of the predicted extent of dewatering effects. Monitoring

of Gladstone wetland water levels is also recommended, with diversion of stormwater to the wetland proposed to mitigate the loss of catchment during GOP mining.

Potential effects associated with development of a TSF within the GOP relate to the discharge of contaminants to groundwater and surface water, impacting upon water quality and potentially affecting users of water. During operation of the TSF the deep groundwater is expected to remain dewatered by ongoing underground mining activities. No discharge of water from the tailings or rock backfill to the shallow groundwater system or surface water is predicted to occur. Seepage through the TSF liner is expected to percolate to the deep groundwater system, where it will migrate with groundwater towards the deeper underground mine dewatering locations.

On closure of the TSF, assuming cessation of all mine dewatering, deep groundwater levels will return to those similar to pre-mining conditions. Operation of the TSF drainage system is predicted to result in capture of upwelling groundwater and any seepages from the tailings, with inward hydraulic gradients effectively creating hydraulic containment of the TSF. Effects to groundwater and surface water during closure are therefore expected to be negligible. Closure of the TSF will also include installation of a capping layer, which will provide separation of stormwater from the tailings and be contoured to allow stormwater flow to Gladstone Wetland. This will effectively reinstate, and potentially expand, the wetland catchment from that prior to mining of GOP and operation of the TSF.

The long-term effects associated with the TSF, assuming drainage is no longer operated, are assessed as follows:

– **Shallow groundwater:** Discharge from the TSF is predicted to occur to the shallow groundwater system west of the Gladstone TSF, where it will ultimately flow to the Ohinemuri River. While only a small part of the water discharged from the TSF is expected to have contacted tailings, some minor change in shallow groundwater quality west of the TSF is conservatively predicted to occur in the long-term.
– **Surface water:** Changes to the Ohinemuri River water quality as a function of the TSF discharge, even when excluding potential attenuation of contaminants during migration to the river, is predicted to be negligible and within the receiving water quality criteria (RWQC). No groundwater or surface water users are predicted to be impacted by discharges from the TSF.
– **Monitoring and management:** It is expected that during and following mine closure the quality of water being discharged from the TSF and captured by the drainage network will improve. The assessment undertaken conservatively recognises these improvements in predicting long term effects to groundwater and surface water. Monitoring of water recovered from the TSF drainage system will allow validation of these assumptions and determination of when it is appropriate to cease operating the drains.

## Northern Rock Stack

Storage of rock from WNP mining activities is proposed at the Northern Rock Stack (NRS), with this to be constructed over the existing northern stockpile north of TSF2. Placement of a low permeability soil liner and installation of leachate and sub-soil collection drains is proposed to limit the potential for leachate to migrate to impact the receiving environment. Water impacted by mine rock that is captured by the drains will be conveyed to the WTP for treatment prior to discharge to the Ohinemuri River. Prior to closure, a portion of the rock will be used to backfill GOP and the underground mine. The remaining rock will then be covered with a low permeability capping layer and rehabilitated to reduce both water and oxygen infiltration, and corresponding leachate generation.

The effects associated with development of the NRS are assessed as follows:

– **Groundwater:** Increased groundwater recharge over the footprint of the NRS is predicted to occur during operation, with any changes in groundwater levels controlled by the sub-soil drains. Groundwater quality is expected to be affected by seepage through the NRS liner, however, the sub-soil drains are predicted to capture the majority of impacted water. The un-captured seepage is predicted to influence downgradient groundwater quality. Monitoring of existing storage facilities indicates that following closure, longer term impacts to water quality should reduce.
– **Surface water:** A reduction in direct groundwater discharge to the Ohinemuri River is likely to occur, however this is expected to be offset by discharge to the river from uphill diversion drains, treated water from the perimeter drains, and treated leachate and groundwater from the WTP. Minimal change in trace element concentrations and only a small increase in sulphate concentration in the Ohinemuri River is conservatively predicted as a result of NRS discharges.

– **Water users:** No groundwater or surface water users are predicted to be influenced by the development of the NRS.
– **Monitoring and management:** As with other rock storage facilities, monitoring of groundwater, surface water and drainage water quality is recommended to validate the assessment findings and identify potential issues associated with water quality.

## Tailings Storage Facility 3

Initial foundation works for the TSF3 will require removal of topsoil and excavation of compressible soils up to 20 m deep near the toe of the proposed embankment The excavation will be infilled with structural backfill prior to TSF3 construction. Dewatering is proposed to enable the excavation works.

The effects of construction dewatering have been assessed as follows:

– **Groundwater:** Dewatering will result in local decreases in groundwater levels, with the zone of influence of dewatering relatively limited. No groundwater users have been identified within this area.
– **Surface water:** Potential impacts to the Ruahorehore stream and Ohinemuri River flow during dewatering will be mitigated by diversion of abstracted groundwater to the stream. Use of appropriately sized sediment treatment basins or devices is expected to mitigate potential impacts to surface water quality.

On completion of the foundation works the starter embankment will be constructed. A network of sub-soil drains will be installed to control groundwater levels, and a low permeability soil liner and geosynthetic liner constructed over the base and side-slopes to control seepage from the tailings. A network of collector pipes and drains will be installed to collect seepage from the TSF. Following filling of the initial stage, the crest height will be raised and the low permeability soil liner extended up the side slopes to the final TSF3 height. The geosynthetic liner will only be utilised for the base and upstream face of the starter embankment.

Effects associated with development of TSF3 have been assessed as follows:

– **Groundwater:** Seepage from tailings and infiltration through the rock embankment is predicted to mix with groundwater and be captured by the TSF3 drainage network during the operational and closure periods. In the long term, after the sub-surface drains cease operating, groundwater impacted by a small amount of tailings seepage is predicted to migrate downgradient of TSF3 with deeper groundwater. Groundwater quality in the immediate vicinity of TSF3 is expected to show a minor influence of TSF3 discharges in the long-term. The spatial extent of this influence is expected to be constrained by attenuation and geochemical processes and only major ions, such as sulphate, are likely to demonstrate increased concentrations in downgradient groundwater.
– **Surface water:** The Ruahorehore Stream is not predicted to be a receptor of discharges from tailings or water infiltrating through the embankment, but may receive run off from the nearby collection pond buttress, or very minor amounts of leakage from the collection pond. Flows in the stream are expected to be maintained and potentially increased due to a small increase in groundwater levels. The stream quality is expected to remain within the RWQC.

  Groundwater sourced from the TSF3 is inferred to ultimately discharge to the Ohinemuri River. As with long term groundwater quality, minor increases in sulphate are conservatively predicted in the river in the long term. No water quality parameter concentrations are expected to exceed the RWQC as a direct result of the TSF3 groundwater discharges. Where the significant delay in flow to the river and attenuation reactions with groundwater flow are considered, it is unlikely that change in Ohinemuri river water quality resulting from TSF3 discharges to ground would be measurable.
– **Water users**: The changes to groundwater and surface water quality, where predicted to occur, are not expected to measurably impact any groundwater or surface water users.
– **Monitoring and management:** The monitoring and management approaches applied to the existing tailings storage facility are considered appropriate for application to TSF3.

## Willows Rock Stack

The WRS is proposed to be developed within a gully (WRS gully) through which flows an unnamed tributary of the Mataura Stream, which is a tributary of the Ohinemuri River. The WRS gully is steeply sided, with a low permeability residual soil/ash cover that is considered to be approximately equivalent to a low permeability soil liner. Clean water diversion drains will be constructed to divert run-off away from the WRS and collection drains will be installed within the WRS gully and shear key drain to collect seepage from the rock stack. The WRS is intended to be a short-term facility, with all of the rock to be returned to WUG as backfill. Following use, the site will be rehabilitated and largely returned to its natural configuration.

Effects associated with development of WRS have been assessed as follows:

– **Groundwater:** The majority of water infiltrating into the WRS will discharge to ground, however will subsequently be captured by the seepage drain system positioned at the base of the WRS gully with inward hydraulic gradients creating a high degree of hydraulic containment of the WRS. Localised increases in groundwater levels beneath the WRS is predicted to occur as a result of an increase in local seepage to the underlying andesite. Localised influence on groundwater quality is expected, however, given the temporary nature of the facility, the effects to groundwater quality are likewise considered to be temporary.
– **Surface water:** The flow from the WRS gully tributary will be captured as part of the WRS drainage system, and there will also be a reduction in groundwater discharge directly to the Mataura Stream. This is temporarily expected to reduce the flow of the Mataura Stream by a small amount. The amount is expected to be unmeasurable within the context of flow gauging error. A very small amount of seepage from the WRS will not be captured by the seepage drainage system and will flow with groundwater to the Mataura Stream. Small but measurable increases in major ion concentrations, such as sulphate, are conservatively predicted within the stream, with predicted trace elements increases not expected to be measurable. No parameter concentrations are expected to exceed the RWQC.
– **Water users:** No water users are expected to be measurably affected by the WRS seepage, owing to the minor discharge volume and significant dilution within surface water.
– **Monitoring and management:** As with other rock storage facilities, monitoring of groundwater, surface water and drainage water quality is recommended to validate the assessment findings and identify potential issues associated with water quality.

## Cumulative effects to surface water

The findings of this assessment of WNP mine components contributes to the assessment of cumulative effects of WNP discharges to the Ohinemuri River, which is provided in the GHD (2025a) Water Management Report.

# Contents

# Table index

# Figure index

## Appendices

# Glossary

| Term | Definition |
|---|---|
| Drains | For different definitions, refer to either: *Sub-soil Drains*, *Leachate Drains*, *TSF drainage system* |
| GHD | GHD Limited (the author) |
| GOP | Gladstone Open Pit mine |
| Leachate drains | Leachate drains are placed on top of the Zone A earth liner |
| MOP4 | Refer to Martha Phase 4 pit |
| mRL | Throughout this document, the elevations are provided in metres reduced level, with reference to Waihi Mine datum.<br>Note: the mine datum is 1,000 metres below sea level. |
| NAF | Non-acid forming materials sourced from rock. |
| NRS | Northern Rock Stack. A new rock stack at the Northern Stockpile area, adjacent to the existing TSF2, which will receive rock from the proposed Gladstone Open Pit. |
| NSPSP | Northern stockpile silt pond |
| OGNZL | Oceana Gold (New Zealand) Ltd (the client) |
| PAF | Potentially acid forming materials sourced from mine rock |
| Project Martha | Project Martha comprises two parts – the Martha Underground and the Martha North Wall (Martha Pit Phase 4 (MOP4)), a consented mining operation at Waihi beneath the existing open Martha pit and including remedying the north wall failure in the pit. Separate from WNP but incorporated into the OGNZL Life of Mine Plan. |
| RWQC | Receiving water quality criteria (as per original consent conditions) |
| Sub-soil drains | Sub-soil drains include sub-soil drains, upstream cut-off, initial toe drain and downstream toe drain. The drains are installed in the in-situ ground beneath Zone A, a low permeability layer constructed under placed rock and tailings storage facilities |
| GOP TSF | Tailings storage facility within Gladstone Open Pit (converted to TSF on closure) |
| TSF3 | Tailings Storage Facility 3. A new tailings storage facility to the east of existing TSF1A, which will receive rock and tailings from the proposed Gladstone Open Pit. |
| GOP TSF drainage system | Drainage system located beneath the geosynthetic liner at the base of the tailings in the Gladstone Open Pit TSF |
| Waihi North Project (WNP) | Proposed project that is the subject of this report. WNP will comprise the Wharekirauponga underground mine and associated surface facilities, Gladstone open pit, upgraded process plant, the Northern Rock Stack and TSF3. These components are linked and interact with each other to varying degrees as well as with the current Life of Mine Plan. |
| WRS | Willows Rock Stack |
| WTP | Water treatment plant |
| WUG | Wharekirauponga Underground Mine |
| ZOI | Zone of influence. This is defined in this assessment as the area nearest the proposed activity where groundwater level drawdown is greater than 0.5 m. This is adopted as the expected measurable range outside of seasonal fluctuations. |

# 1. Introduction

The current Waihi life of mine plan, including Project Martha, is to complete production by 2030. Studies conducted by Oceana Gold NZ Limited (OGNZL) have identified two new mining opportunities. The understanding of these opportunities has advanced to a point where OGNZL is ready to lodge resource consent applications for its next project, the “Waihi North Project” (WNP). The WNP is expected to extend the life of mine to at least 2042. It comprises development of a new open pit mine (the Gladstone Open Pit (GOP)), and a new underground development (the Wharekirauponga Underground Mine (WUG)). Additional tailings storage facilities and rock storage is also proposed.

GHD was commissioned by OGNZL to deliver a number of studies relating groundwater and surface water for the WNP. This report focuses on the hydrogeological (groundwater) aspects of GOP and the new rock and tailings storage facilities of the Waihi North Project. Hydrogeological (groundwater) assessment of the underground elements of the WNP are provided in WWLA (2025a; 2025b), Flo Solutions (2024a; 2024b) and Valenza Engineering (2022).

## 1.1 Background

### 1.1.1 WNP overview

The detailed description for WNP is provided in the Assessment of Environmental Effects prepared by Mitchell Daysh Limited (Mitchell Daysh, 2025). The general WNP project area is shown in Figure 1.1 and with the WRS site presented in Figure 1.2. The project components include:

– **Gladstone Open Pit (GOP):** A new pit near the existing processing plant and centred over Gladstone Hill. This pit will be converted to a tailings storage facility (TSF) once mining is complete.
– **Northern Rock Stack:** A new rock stack (Northern Rock Stack (NRS)) at the Northern Stockpile area, north of the existing Tailings Storage Facility 2 (TSF2). Rock sourced from Gladstone, surplus to the volume needed to construct the proposed Tailings Storage Facility 3 (TSF3) embankment and backfilling activities, will be stored at the proposed NRS.
– **Tailings Storage Facility 3:** A new tailings storage facility (TSF3) to the east of existing tailings storage facilities TSF2 and TSF1A. This new facility is to provide tailings storage for the WNP in addition to that provided by the proposed Gladstone open pit and existing TSFs.
– **Willows Rock Stack (WRS) at the new Wharekirauponga underground mine (WUG):** With associated surface infrastructure, including a WRS to be located on farmland (owned by OGNZL) at Willows Road (Willows Rock Stack; WRS), with underground access to the existing Processing Plant at Waihi.

Note: A new underground mine, Wharekirauponga, is proposed to be located approximately 11 km north-west of the current Processing Plant as part of the WNP (Figure 1.1). Site infrastructure supporting the mine will be located on private farmland located at the end of Willows Road. WUG surface infrastructure and tunnels from Willows Road are components of the WNP, but effects to groundwater from these aspects of WNP are not part of this assessment and are addressed by WWLA (2025a; 2025b).

### 1.1.2 Relationship to other mine activities

In February 2019, consents were granted for Project Martha, comprising the Martha Underground (MUG) Mine and a small cutback of the north wall of the Martha Open Pit called Phase 4 (MOP4). This project description assumes the following relationships between the previously consented Project Martha, TSF1A and 2, the Water Treatment Plant (WTP) and the WNP:

– MUG will operate in parallel with the WNP.
– Martha Open Pit 4 (MOP4) will be mined in parallel with the WNP. Rehabilitation of the Martha Pit after closure will comprise development of a pit lake and surrounding parkland facility for recreational use.
– Continued treated water discharge limits as per the existing discharge permit (AUTH971318).

- TSF1A is consented to 1,182 mRL. This results in a total proposed crest raise of 8 m from the current crest height of 1,174 mRL.
- TSF2 is consented to 1,160.7 mRL. The current TSF2 stage has been rehabilitated to 1,156 mRL. The final crest raise and final rehabilitation timing is yet to be determined, being based on conclusion of mining activities and any requirements for potential future tailings disposal.

TSF3 and the existing TSFs will receive tailings generated in the processing of ore from Gladstone, MUG MOP4 and the WUG.  Similarly, the NRS may store rock from Gladstone, MOP4 and the WUG.

A water management report prepared by GHD (2025a) as part of the WNP assesses the cumulative effects of the both the existing mine activities and the proposed WNP on the Ohinemuri River (refer to Table 1.1).

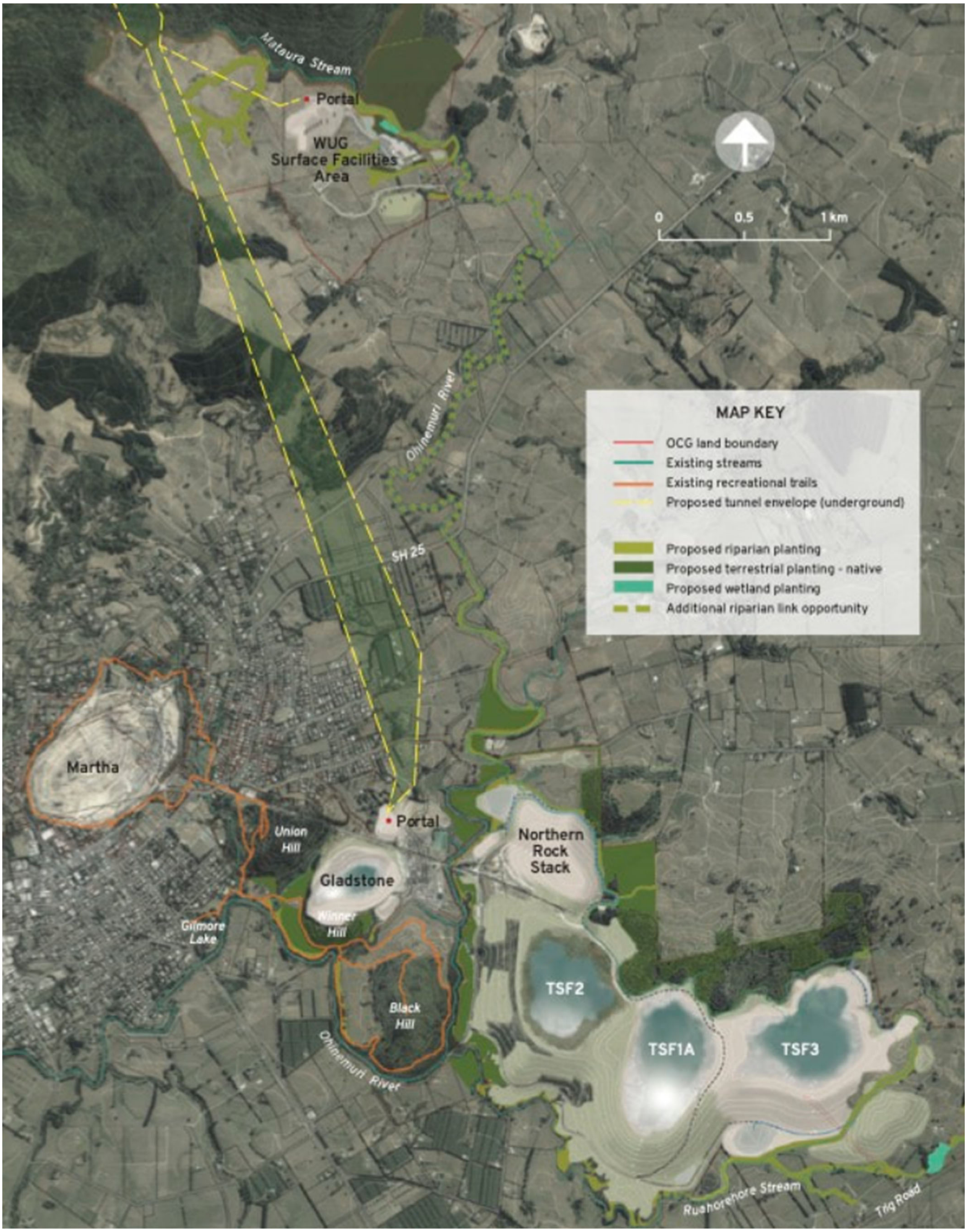


*Figure 1.1 Waihi North Project general project area (OGNZL, 2025)*

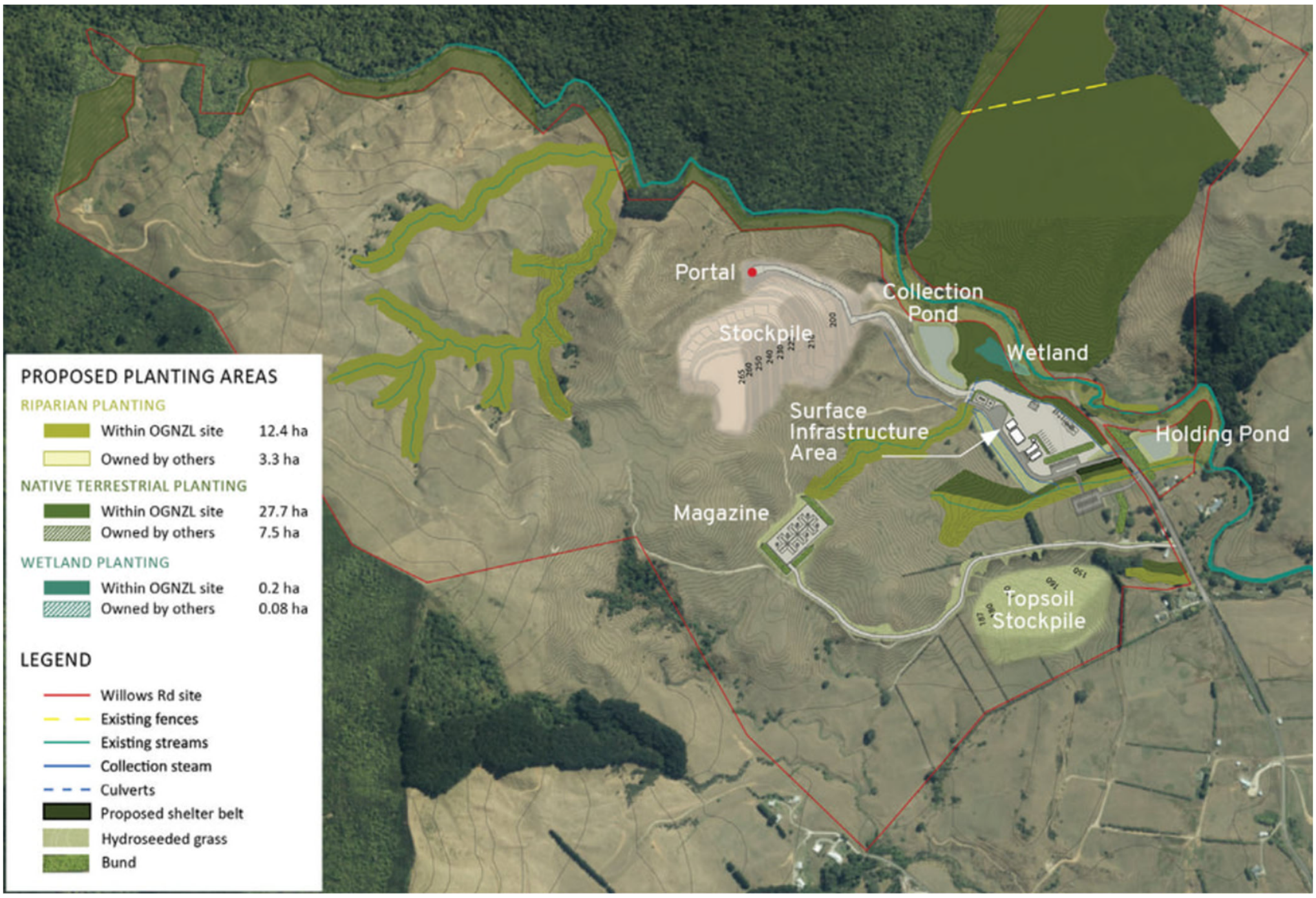


*Figure 1.2 Plan of Willows Road Farm surface infrastructure (OGNZL, 2025). (Note: elevations in figure not to mine datum +1,000 mRL).*

## 1.2 Purpose of this report

The NRS, Gladstone, TSF3 and WRS project components have each been the subject of various technical studies. This assessment focuses specifically on the individual hydrogeological, discharge quality and receiving environment water quality aspects of these four components. This report is provided as a supporting appendix to the Mitchell Daysh AEE.

The following reports are required to be read in conjunction with this groundwater assessment, particularly where referenced throughout this document:

*Table 1.1 Key reference documents*

| Key assessment description | Report Title and Reference |
|---|---|
| ***Surface water cumulative effects assessment:***<br>Management of minewater and the cumulative effects on the Ohinemuri River from all components of the WNP have been addressed in the Water Management Report. The outputs of the discharge quality analyses provided in Sections 3 - 6 are included in this report. | GHD, 2025a:<br>Waihi North Project Water Management Studies (WAI-985-000-REP-LC-0011) |
| ***Waihi North Project - Tunnel Elements:***<br>*Assessment of groundwater effects from the Wharekirauponga dual tunnel alignment.* | WWLA, 2025a.<br>Waihi North Project. Assessment of Groundwater Effects – Tunnel Elements. (WAI-985-000-REP-LC-0040) |

| Key assessment description | Report Title and Reference |
|---|---|
| ***Wharekirauponga Deposit:***<br>Assessment of groundwater effects from the Wharekirauponga underground mine. | WWLA, 2025b:<br>Assessment of dewatering effects – Wharekirauponga Deposit. 4 February 2025. |
| ***Geochemical Assessment Wharekirauponga underground mine***<br>Geochemical assessment of the proposed Wharekirauponga underground mine. | GHD, 2025ba:<br>Geochemical Assessment Wharekirauponga Underground Mine (WAI-985-000-REP-LC-0013) 5 February 2025. |
| ***Gladstone pit TSF design and civil engineering-related effects:***<br>Technical report prepared for resource consent, including GOP TSF design for the assessment of environmental effects | GHD, 2025c:<br>Gladstone Pit TSF Design Report (WAI-985-000-REP-LC-0010). 27 January 2025. |
| ***Gladstone Wetland Assessment Summary:***<br>*Technical memorandum summarising the assessment of effects on the Gladstone Wetland as a result of the proposed Gladstone Open Pit and development as a Tailings Storage Facility.* | GHD, 2022:<br>Gladstone Wetland Groundwater Assessment Summary Technical Memorandum. Rev B.<br>Provided in Appendix L of this report. |
| ***Mataura Wetland Assessment:***<br>*Technical memorandum presenting the assessment of effects on the Mataura Wetland as a result of the development of the Willows Rock Stack.* | GHD, 2025d:<br>Mataura Wetland Assessment Technical Memorandum. 24 February 2025.<br>Provided in Appendix M of this report. |
| ***NRS design and civil engineering-related effects:***<br>Technical report prepared for resource consent, including NRS design for the assessment of environmental effects | EGL, 2025a:<br>Tailings storage and rock disposal – Volume 4. Northern Rock Stack RL173 – Proposed rock disposal facility – Technical Report (WAI-985-000-REP-LC-0006) |
| ***Wharekirauponga design and geotechnical report:***<br>Assessment to characterise site conditions and includes WRS design. | Golder/WSP, 2022a:<br>Oceana Gold Waihi North Project – Wharekirauponga Underground Mine Willows Rock Stack and Surface Facilities Geotechnical Assessment (WAI-985-000-REP-LC-0037) |
| ***TSF3 design and civil engineering-related effects:***<br>Technical report prepared for resource consent, including preliminary TSF3 design for the assessment of environmental effects (including the potential for ground settlement associated with construction dewatering). | EGL, 2021:<br>Tailings storage and rock disposal – Volume 3. Proposed tailings storage facility – Storage 3 RL155 Technical Report (WAI-985-000-REP-LC-0004)<br>EGL, 2025b:<br>Tailings Storage and Rock Disposal Volume 3 – Proposed Tailings Storage Facility – Storage 3 RL155 Technical Report (WAI-985-000-REP-LC-0004) |
| ***WNP geochemistry analysis:***<br>Geochemical study of the ore, tailings, and overburden expected to be recovered from the proposed mine areas, and to assess the potential influence these materials may have on the environment. | AECOM, 2025:<br>Waihi North Project Geochemical Assessment – Geochemistry of Tailings and Overburden, Treatment and Mitigation (WAI-985-000-REP-LC-0038). |
| ***TSF3 geotechnical factual report:***<br>Extensive site investigations to characterise site conditions for TSF3. | EGL, 2018:<br>Waihi Mine Storage 3 – Geotechnical Factual Report (EGL ref. 8332, Draft Rev A) |
| ***NRS geotechnical factual report:***<br>Extensive site investigations to characterise site conditions for NRS. | EGL, 2019a:<br>Waihi Mine Northern Rock stack – Geotechnical Factual Report (EGL ref. 8332, Draft) |
| ***Willows Rock Stack geotechnical factual report***<br>Site investigations to characterise site conditions for WRS. | EGL, 2025c:<br>Waihi North Project Willows Rock Stack Geotechnical Factual Report (EGL ref: 9169) (WAI-983-080-REP-GT-0001) |

| Key assessment description | Report Title and Reference |
|---|---|
| ***Willows Rock Stack Technical Report:***<br>Technical report prepared for resource consenting. | EGL, 2025d:<br>Waihi North Project Willows Rock Stack Technical Report (EGL ref. 9169) (WAI-985-000-REP-LC-0074) |

## 1.3 Scope

The key objectives of this hydrogeological study are to:

1. **Understand dewatering requirements and effects:** Dewatering is required for TSF3 construction and a minor section of NRS construction. Excavation of the GOP will also result in groundwater drawdown within the surrounding groundwater system. The assessment provides potential inflows for water management considerations, and an assessment of potential dewatering effects on groundwater levels and surface water.
2. **Assess the life of mine and post-closure (long-term) influence on the environment:** WNP introduces new mine components that have the potential to influence groundwater and surface water through changes in groundwater levels, groundwater flow and/or water quality. An assessment relating to these potential effects has been undertaken (where applicable) for each of the key project components being considered. WRS is only considered for operational scenario, as it is intended to be a temporary storage facility.
3. **Inform monitoring and management requirements:** Where potential effects to the environment are identified in the assessment, appropriate monitoring and management approaches are provided as recommendations, for the purpose of allowing validation of the assessment predictions and monitoring of the potential for adverse outcomes.

The studies included a range of extensive site investigations to characterise existing environmental conditions.

## 1.4 Report structure

The body of this report provides summaries of key aspects of the assessment, with more detailed information and technical assessment provided in appendices. This report is structured as follows:

- **Section 2 – Background and environmental setting:** Broad overview of the site setting (geology, groundwater surface water) as it relates to the proposed activity.
- **Sections 3 to 6 – Assessment of each new mine component:** Separate hydrogeological assessment of each key project component (GOP, NRS, TSF3, and WRS, respectively). Supporting technical information for this assessment is provided in the following appendices.
  - Appendix A: Site investigation methodology
  - Appendices B-F: Outputs of the site investigation works (e.g. bore logs, groundwater levels, permeability data, water quality, water flow).
  - Appendix G: GOP and TSF detailed technical assessment.
  - Appendix H: NRS detailed technical assessment.
  - Appendix I: TSF3 detailed technical assessment.
  - Appendix J: WRS detailed technical assessment.
  - Appendix K: Potential water users considered in the effects assessment.
  - Appendix L: Gladstone Wetland Groundwater Assessment Summary
  - Appendix M: Mataura Wetland Assessment
- **Section 7 – Conclusions and Recommendations:** The potential effects identified within Sections 6 - 9 are summarised and discussed. Recommended monitoring and management measures are also presented where considered appropriate.
- **Section 8 – References:** All supporting data sources are listed.

## 1.5 Limitations

*This report has been prepared by GHD for Oceana Gold (New Zealand) Ltd and may only be used and relied on by Oceana Gold (New Zealand) Ltd for the purpose agreed between GHD and Oceana Gold (New Zealand) Ltd as set out in section 1 of this report. GHD otherwise disclaims responsibility to any person other than Oceana Gold (New Zealand) Ltd arising in connection with this report. GHD also excludes implied warranties and conditions, to the extent legally permissible.*

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

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

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

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

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*GHD has not been involved in the preparation of the Assessment of Environmental Effects (AEE), prepared by Mitchell Daysh and has had no contribution to, or review of the AEE other than in this technical report for groundwater assessment. GHD shall not be liable to any person for any error in, omission from, or false or misleading statement in, any other part of the AEE. The GHD document containing the disclaimer is to be included in any other document, the entirety of GHD's report must be used (including the disclaimers contained herein), as opposed to reproductions or inclusions solely of sections of GHD's report.*

# 2. Background and environmental setting

## 2.1 General setting

The site is located within the foothills of the Coromandel Range. The wider WNP is proposed both to the north and south of the Waihi Township.

To the southeast of Waihi, the landscape undergoes a transition into primary production lowlands adjoining the foothills of the Coromandel Range. This area is generally flat to gently undulating and comprises of pasture, shelter belts, clumps of exotic trees, horticultural lots, hedges and glasshouses. A series of steep dome-shaped volcanic hills extend to the east of Waihi and are shown within the context of existing site features in Figure 2.1; these include the vegetated forms of Union Hill, Gladstone Hill, Winner Hill and Black Hill

The WRS is located approximately 5 km north of the WTP, with the site setting shown in Figure 1.1.

The average annual rainfall adopted for this assessment is 2,110 mm/year (NIWA, 2019).

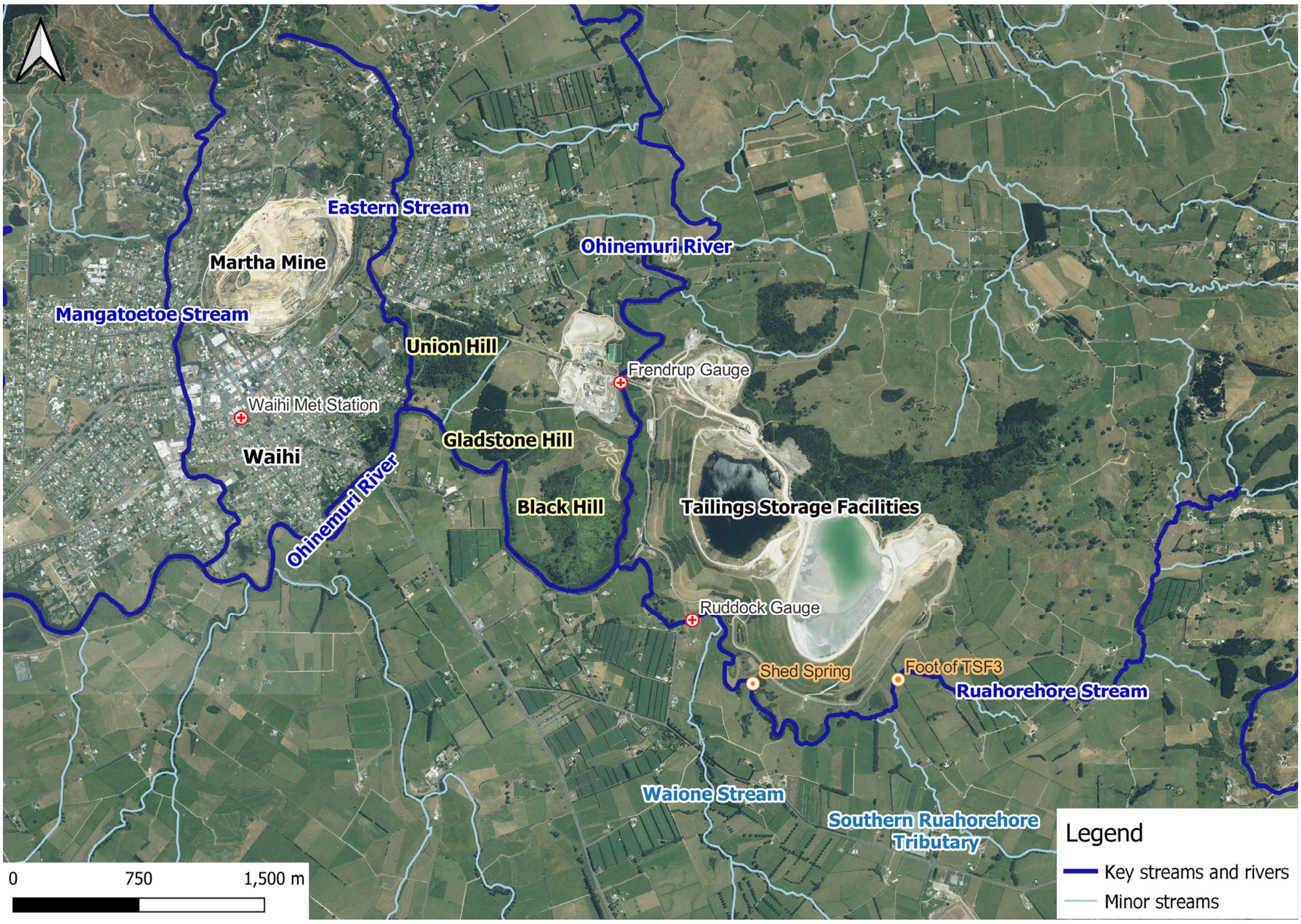



*Figure 2.1 Key geographic features of the southern WNP site*

## 2.2 Surface water

Where groundwater is in hydraulic connection with surface water, the effects of groundwater-related activities (such as construction dewatering on allocation limits) have been considered as part of this hydrogeological assessment. An overview of the hydrology is provided below, with detail provided as required in the respective technical assessments (Sections 3 - 6).

### 2.2.1 Regional hydrology

Waihi is located in the upper catchment of the Ohinemuri River, which has a total catchment area of 290 km$^2$. The eastern parts of the upper catchment consist of predominantly flat farmland. Numerous tributaries join the Ohinemuri River as it flows west, with the upper catchments becoming steep and forested further inland. The Ohinemuri River then flows through the Karangahake Gorge prior to joining the Waihou River near Paeroa.

OGNZL operates flow gauges along key surface water bodies (Figure 2.1) as part of daily compliance monitoring for the existing mining activities:

– **Frendrups gauge:** Measures flow on the Ohinemuri River between the mine site Processing Plant and northern stockpile. The river catchment at this location is approximately 50 km$^2$, with flow ranging from 15,300 – 3,180,000 m$^3$/day and a long-term median flow of 75,400 m$^3$/day.

  For this assessment, a median river flow of 63,200 m$^3$/day was adopted for the period that coincided with the site investigations (October 2017 – April 2020). This is conservatively lower than the long-term median provided above.

– **Ruddocks gauge:** Measures flow on the Ruahorehore Stream, which forms a significant tributary to the Ohinemuri River. The catchment at this location is approximately 20 km$^2$, with flow ranging from 1,850 – 1,500,000 m$^3$/day, and a median flow of 27,900 m$^3$/day.

### 2.2.2 Surface water allocation

Surface water allocation information was obtained from the Water Allocation Calculator (WRC, 2025a).

The WNP sites are located within the Ohinemuri River catchments presented in Table 2.1. For both catchments, the current level of cumulative allocation exceeds that catchment's allocation limits across all months of the year.

*Table 2.1 WRC surface water catchment information*

| Catchment | WNP sites | Catchment size | Combined primary and secondary allocable flow | Allocation status |
|---|---|---|---|---|
| Ohinemuri at Waihi Terrace | GOP, NRS, TSF3 | 74 km$^2$ | 0.12 m$^3$/s | Exceeds the allocation limits across all months of the year (primary and secondary) |
| Ohinemuri at Frendrups | WRS | 47 km$^2$ | 0.08 m$^3$/s | Exceeds the allocation limits across all months of the year (primary and secondary) |

## 2.3 Regional geology

The complex geology of the area is well documented by Brathwaite and Christie (GNS, 1996), in the Project Martha AEE (OGNZL, 2018 and GWS, 2018a), and in OGNZL annual compliance monitoring reports. An overview of the geology of the Waihi area is shown in Figure 2.3

The Waihi Basin is defined as a structurally controlled depression that is likely part of a former caldera structure. Basement rocks in the region comprise Coromandel Group andesite and dacite volcanic rocks which are present in the form of horst and graben structures (up thrown and down thrown blocks) due to past faulting (Figure 2.2).

The ore bodies mined by OGNZL to date, and proposed under WNP, comprise near-vertical quartz veining with elevated permeability within an andesite rock mass of relatively lower permeability. The andesite rock mass is overlain, in part, by younger volcanic materials comprising rhyolitic tephras and ignimbrite flows, breccias and tuffs. Paleosols and sedimentary deposits (alluvium "tm"; Figure 2.3) are occasionally interspersed or located at the base of these deposits. These deposits infill a paleo-valley system between the outcropping volcanic highs.

To the east of the Favona-Moonlight Graben, a thick sequence of post mineralisation dacite volcanics overlie the andesite rock, forming Black Hill (Figure 2.3). East of the Golden Valley Fault, a rhyolitic intrusion protrudes through the entire sequence to the east of Black Hill. This rhyolite forms the outcrops and topographic highs and is where the rock and tailings storage facilities are located.

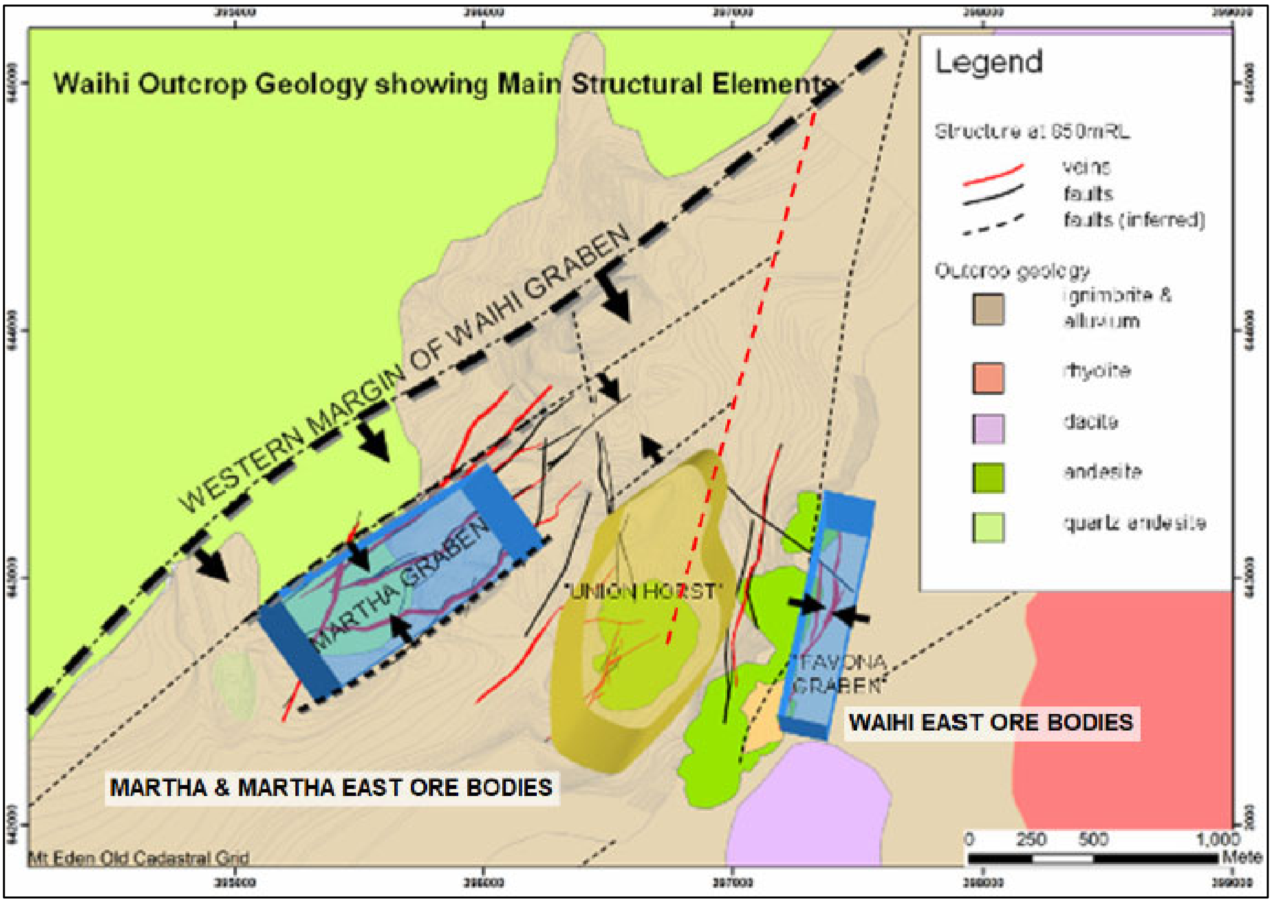



*Figure 2.2 Regional geology and structural domains (from GWS, 2018a)*

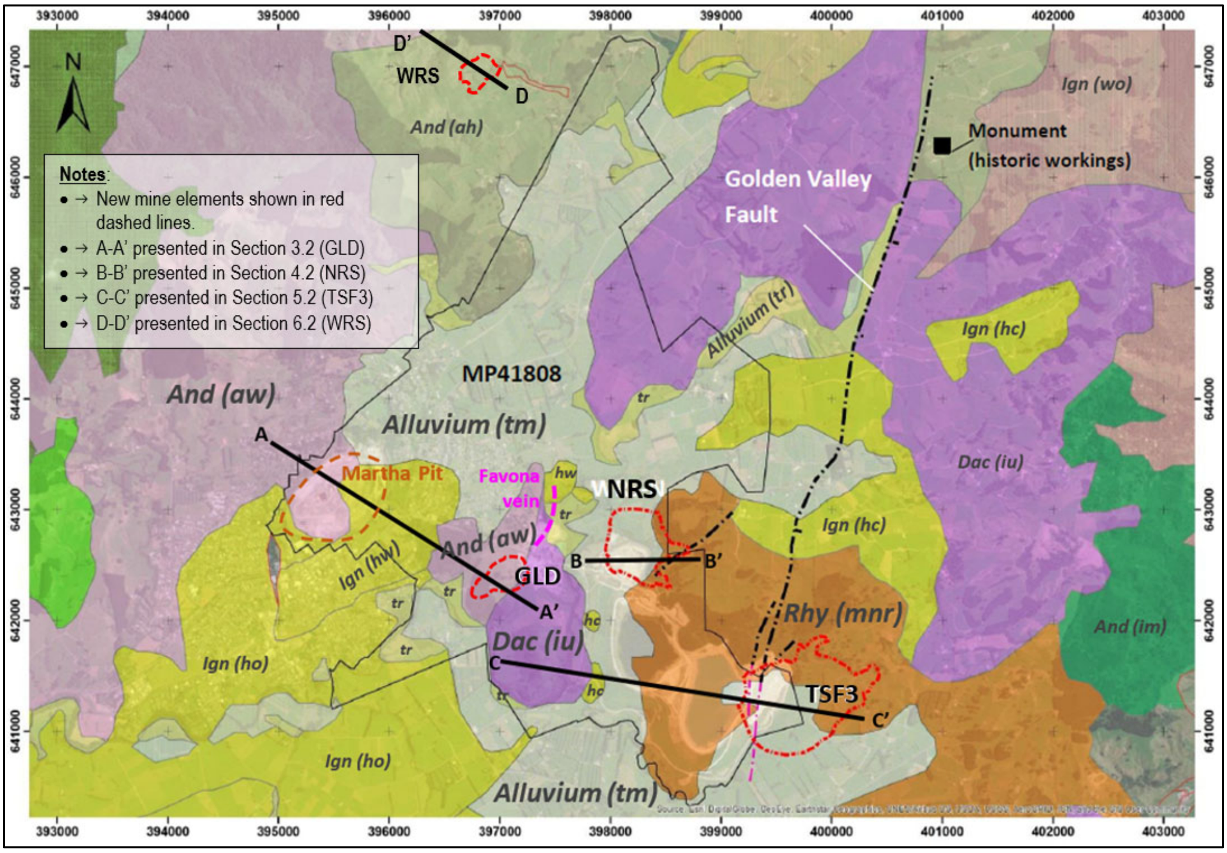



*Figure 2.3 Geology of the WNP area (OGNZL, 2017; GNS, 1996)**

*Table 2.2 Regional geology presented units in Figure 2.3*

| Group | Symbol | Geology | Unit Description |
|---|---|---|---|
| Tauranga | tr | Alluvium | Present day alluvium: Fluvial sand, gravel and mud of streams draining to the east of the Hauraki Lowlands. (Ruahihi Formation) |
| | tm | Alluvium | River deposits: Pumiceous, rhyolitic, and andesitic sand, gravel and silt. Minor lignite. (Matua Subgroup) |
| Whitianga Group | hw | Ignimbrite | Waikino Ignimbrite: Strongly welded, glassy ignimbrite. (Ohinemuri Subgroup) |
| | ho | Ignimbrite | Owharoa Ignimbrite: Welded, pumice rich ignimbrite. (Ohinemuri Subgroup) |
| | hc | Ignimbrite | Corbett Ignimbrite: Pumice-rich lithic-crystal ignimbrite. (Ohinemuri Subgroup) |
| | mnr | Rhyolite | Ruahorehore Rhyolite: Rhyolite Dome of the Homunga Rhyolite. (Minden Rhyolite SubGroup) |
| | wo | Breccia | Orokawa Breccia: Massive tuff breccia composed of andesite clasts in altered crystal-rich matrix, minor tuffaceous sandstone and siltstone. (Coroglen subgroup) |
| Coromandel Group | iu | Dacite | Uretara Formation: Andesitic and dacitic tuff breccias with minor volcanogenic siltstones. Andesite and dacite flows and domes. (Kaimai Subgroup) |
| | im | Andesite | Matangia Andesite: Fine grained, glassy andesite flows with minor tuff breccias. Local hydrothermal alteration. (Kaimai Subgroup) |
| | ah | Andesite | Whiritoa Andesite: Andesite and dacite flows and domes with tuff breccias and lithic-crystal tuff. (Waiwawa Subgroup) |
| | aw | Andesite | Waipupu Formation: Andesite and dacite. Minor tuff breccia, crystal tuff and lacustrine sediments. Extensive hydrothermal alteration. (Waiwawa Subgroup) |

# 2.4 Groundwater

## 2.4.1 Overview

The hydrogeology of the area has been previously described in Section 2.2 of the GWS (2018a) report and summarised in the Project Martha AEE (OGNZL, 2018).

Groundwater levels and directions are controlled by the presence and interconnections (where they occur) of the workings, vein systems and post mineralisation structures (faults and fracture zones). The shallow groundwater system in the Waihi area comprises groundwater flow through shallow soils, reworked young volcanics and weathered rock. The deep aquifer is regionally formed by andesite of the Coromandel volcanic group.

Near the Martha Pit, shallow groundwater in the younger andesite deposits is separated from the deeper groundwater in the andesite rock by a weathered lower permeability upper layer of the andesite rock mass. At the location of the key components of WNP relevant to this assessment (Gladstone, NRS, TSF3, WRS), groundwater has a different setting to Martha due to faulting. The local hydrogeology for each area is distinctly different with the respective conceptual groundwater models (CGMs) discussed in detail in Sections 3 to 6. Groundwater is discussed at a regional level below.

## 2.4.2 Regional hydrogeology

Groundwater recharge is from direct rainfall infiltration to the shallow groundwater. The recharge that remains in the shallow groundwater system, after some residence time in the aquifer, discharges locally as either springs and/or baseflow to streams or the Ohinemuri River.

Recharge to the deep groundwater system occurs where the deeper volcanic units (andesite, dacite, rhyolite) are exposed at the surface, usually in topographic highs such as ridges, as well as a small amount of leakage from the shallow groundwater system. The specific recharge rates to deeper versus shallow groundwater at the site are unknown, but typical values for shallow groundwater are expected to be in the order of 22% to 40% of annual average rainfall (WRC, 2025b), with deeper groundwater and less permeable aquifers in the area expected to be much less than this.

Groundwater flow direction through, and discharge from, the deeper volcanics of the Waihi Basin is not clearly documented. Multiple hydraulic divides are documented within the basin (Ling, 2003), with this interpretation expected to be a result of limited deep groundwater data, combined with the complex geology (grabens, faults) characteristics of the region. The Union Horst forms a paleo-topographic high that separates the Martha Graben from the Favona-Moonlight Graben (Figure 2.3). The Union Horst structure is considered to act as a physical barrier between the more structurally permeable areas of the Martha Graben and Favona-Moonlight Graben structures. Prior to the development of the underground mines, the connection of the systems was weak; these are now interconnected due to mine workings and dewatering of Martha underground (MUG) has been more recently used to control dewatering at Favona.

Although the site is located approximately 5 km from the east coast of New Zealand, the available data indicates that at the location of WNP, the intermediate to deep groundwater flow at this location is expected to be inland, to the west. For the purposes of this assessment, all groundwater is inferred to discharge to the Ohinemuri surface water catchment, with the volcanic hills to the east of Waihi inferred to provide a groundwater divide between the site and the coast, as defined by the Waihi Basin aquifer boundary on Figure 2.4.

## 2.4.3 Groundwater management levels

The majority of the site is located within the Waihi Basin (WRC WRP Aquifer Map 7; Figure 2.4). The WRS is located just north of the mapped WRC Waihi Basin extent, within an unmapped aquifer.

The Waikato Regional Plan aquifer management level for this aquifer is 6,000,000 $m^3$/year (WRC, 2025b), and the available groundwater is understood to be 30.8% (1,845,000 $m^3$/year) (pers. comm C. Harty, 23/11/2021). WRC treats groundwater and surface resources as being connected and a groundwater take will be considered to reduce the surface water flow downstream of the connected waterways. As noted in Section 2.2.1, the GOP, NRS and TSF3 sites are within the Ohinemuri at Waihi Terrace catchment, and WRS is within the Ohinemuri at Frendrups catchment; both of which are deemed overallocated.

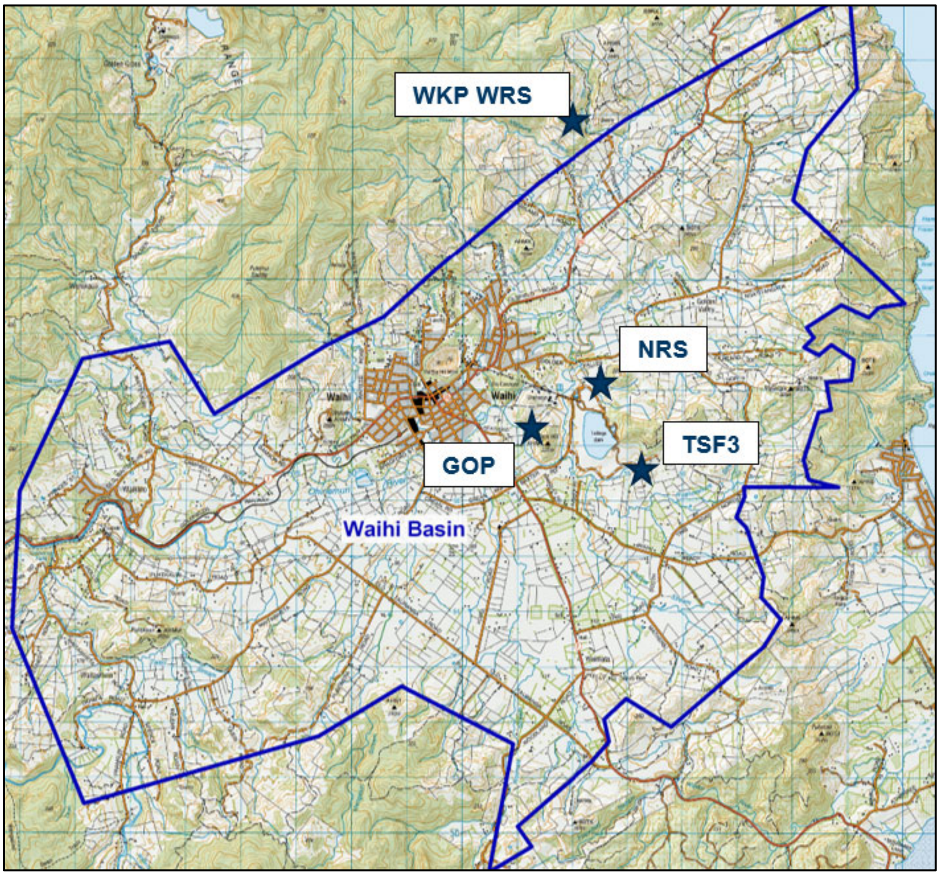



*Figure 2.4* *WRP Aquifer Map 7 (Waihi Basin)*

# 2.5 Water resource users

Registered bores, consented groundwater and surface water takes and any other identified water resource users have been considered within the individual assessments for GOP (Section 3; Figure 3.11), NRS (Section 4; Figure 3.11), TSF3 (Section 5; Figure 5.10) and WRS (Section 6; Figure 6.8).

It is noted that an assessment against the national environmental standards for sources of human drinking water (NES-DW, 2021) has not been included as there are no registered drinking water supplies (that provide for more than 501 people) located within the assessed envelope of effects for each of the proposed activities of the WNP.

# 2.6 Performance of existing TSFs

Seepage from the existing TSFs is authorised as part of the mining consents, subject to conditions. OGNZL undertakes extensive quality monitoring across the site, and the results are reviewed and interpreted by GWS (e.g. GWS, 2019 and 2020; OGNZL, 2020). Overall, the existing TSFs are reported by GWS to have generally demonstrated compliance with consent conditions:

– TSF2 operated between 1989 and 1999. Groundwater discharges from this facility are interpreted by to go to the Ohinemuri River.
– TSF1A was initiated in 2000 and is still in use. Groundwater discharges from this facility are inferred to go to the Ruahorehore Stream.
– Monitoring includes continuous or routine sampling of groundwater monitoring wells, TSF2 pond discharge, underdrain collection systems (including leachate) for the existing TSFs and surface water for each component of the mine site. The results are compared against trigger levels specific to each sampling location.
– Surface water monitoring locations are shown in Figure 2.5. The consent conditions for any watercourse (river, springs, wetlands) require that the water quality within the Ohinemuri River meets the receiving water

quality criteria (RWQC) as set out in Table 2.3 and defined in the existing site discharge consent (WRC, 1999).

A review of the data presented within the GWS (2019 and 2020) and OGNZL (2020) reports by GHD indicates the following:

– Some toe drain and monitoring well sample results periodically exceed trigger levels for some parameters, indicating a change from historical conditions. Periodic increases in parameters are not unexpected given the significant changes (i.e. mining activities) in the surrounding environment. These trends are expected to stabilise and water quality improve once active disturbance lessens. Ultimately, no trends are considered to indicate failure of containment of the tailings or rock facilities.
– Concentrations of trace elements in groundwater tend to decrease with increasing distance from the TSFs, which suggests that in-ground conditions promote attenuation such as the precipitation of iron hydroxide minerals and adsorption reactions. Such processes are key to limiting the extent to which contaminants released from mine tailings and mineralised rock may be seen in groundwater. As such, the area of impacted groundwater is limited to within OGNZL land.
– Long-term monitoring of the Ohinemuri River indicates that changes in the river water quality have occurred as result of the WTP discharge, primarily as changes in the major anions and cations (e.g. sulphate, bicarbonate, chloride) rather than trace element contaminants. It has been interpreted that river water quality remains unaffected by discharges to groundwater from the existing storage facilities.
– Periodic exceedances of the receiving water quality criteria (RWQC) (Table 2.3) have occurred along the Ohinemuri River (including upstream of the treated water discharge). However, these are infrequent events that do not indicate long-term exceedances as a result of mine related discharges.

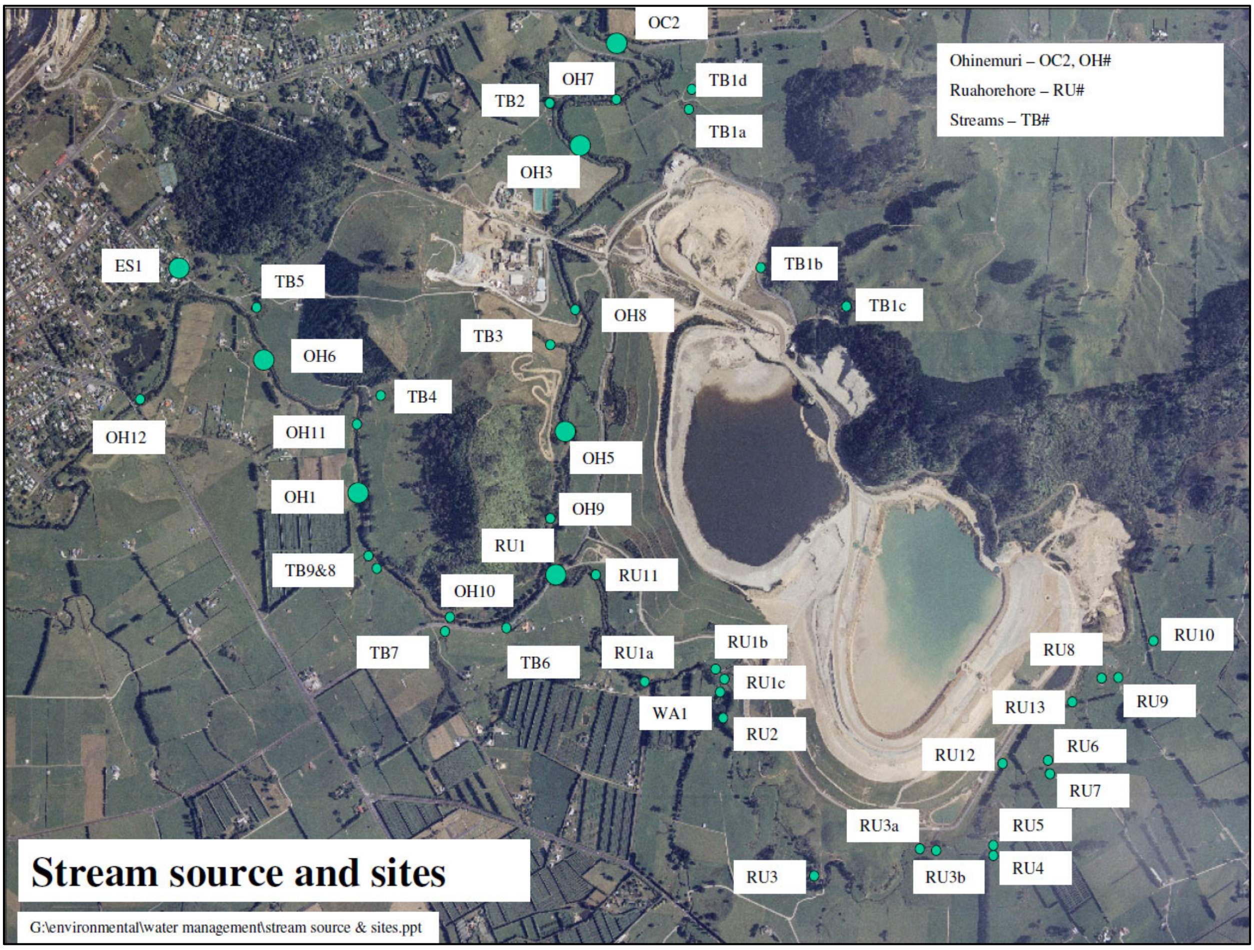



*Figure 2.5 OGNZL surface water monitoring network*

*Table 2.3 Existing consent compliance receiving water quality criteria (WRC, 1999)*

| Parameter | Receiving Water Concentration (2) | |
|---|---|---|
| (g/m$^3$ unless otherwise stated) | Hardness 20 g/m$^3$ $CaCO_3$ | Hardness 100 g/m$^3$ $CaCO_3$ |
| pH | 6.5 to 9.0 | 6.5 to 9.0 |
| Cyanide ($CN_{WAD}$)(1) | 0.093 | 0.093 |
| Iron | 1.0 | 1.0 |
| Manganese | 2.0 | 2.0 |
| Copper | 0.003 | 0.011 |
| Nickel | 0.040 | 0.160 |
| Zinc | 0.027 | 0.100 |
| Silver[1] | 0.0002 | 0.0024 |
| Total Ammonia | Refer Table 3 | Refer Table 3 |
| Antimony | 0.030 | 0.030 |
| Arsenic | 0.190 | 0.190 |
| Selenium | Refer Note (4) | Refer Note (4) |
| Mercury | 0.000012 | 0.000012 |
| Cadmium | 0.0003 | 0.001 |
| Chromium (VI) | 0.010 | 0.010 |
| Lead | 0.0004 | 0.0025 |

**Notes :**

*(1) Site specific derived criteria using US EPA (1985) methodology.*

*(2) Monitoring of metals shall be based on the soluble test method, defined as the concentration of dissolved metals measured in that fraction which passes through a 0.45 um filter except for mercury (Hg) which shall be based on acid soluble concentrations determined on unfiltered samples.*

*(3) Current analytical procedures for mercury have a practical quantification limit (PQL) of 0.0005 ppm. This PQL is acceptable for the purposes of reporting mercury concentrations. The reporting 'limit' for mercury concentrations shall be reviewed annually by the consent holder and shall be adjusted in line with improvements in analytical technology.*

*(4) The selenium concentration in the receiving water shall remain below the trigger limits of 0.02 g/m$^3$ 97% of the time on an annual basis, and 0.035 g/m$^3$ in any single analysis, based on monitoring undertaken pursuant to condition 16 of consent 971318. In the event that these limits are exceeded, the consent holder shall inform the Waikato Regional Council as soon as practicable and prepare a report, to the satisfaction of the Council, to demonstrate that continued discharges at concentrations exceeding the trigger limits will have no more than minor effects on the Ohinemuri River. This report shall be provided to the Council within two months of the consent holder becoming aware of the trigger exceedence.*

# 2.7 Proposed construction materials

Throughout this document, "NAF" (non-acid forming) and "PAF" (potentially acid forming) materials are discussed. These materials will be used for both backfill of the GOP and construction of tailings embankments. An overview of the geotechnical, structural and geochemical properties of these materials are provided in the EGL geotechnical reports (EGL, 2025a; 2025b). Detailed geochemical information of these materials is provided in the AECOM (2025) report.

In summary, PAF material, if exposed to oxygen for a period of time, can oxidise and generate low pH runoff. This can result in the release of heavy metals and poor discharge quality. PAF materials used in construction/backfill are encapsulated in low permeability NAF mine overburden material in specific zones to restrict both oxygen and water entry. AECOM has recommended that high mercury NAF is not used in NAF zones which perform a liner function or are exposed to the surface.

## 2.8 Climate change

The NIWA Our Future Climate New Zealand online mapping tool (NIWA, 2025) estimates changes in a number of climate variables as a result of increasing greenhouse gases in the earth's atmosphere. The estimated change in annual mean rainfall was considered using the six-model-average result, which uses the six global climate models (GCMs) used in the Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Report (AR5). The results indicate that between 1995 and 2090 annual mean rainfall is estimated to reduce between 0 – 5 % within the groundwater and surface water recharge areas of the WNP. This result remained consistent across all four representative concentration pathways (RCPs) for greenhouse gas included within the NIWA tool (2022) (RCP2.6, RCP4.5, RCP6.0 and RCP8.5). This range is considered to be within the existing natural climatic fluctuations already experienced within the WNP recharge area and is not expected to meaningfully impact the outcomes of this assessment.

# 3. Gladstone Open Pit and Tailings Storage Facility

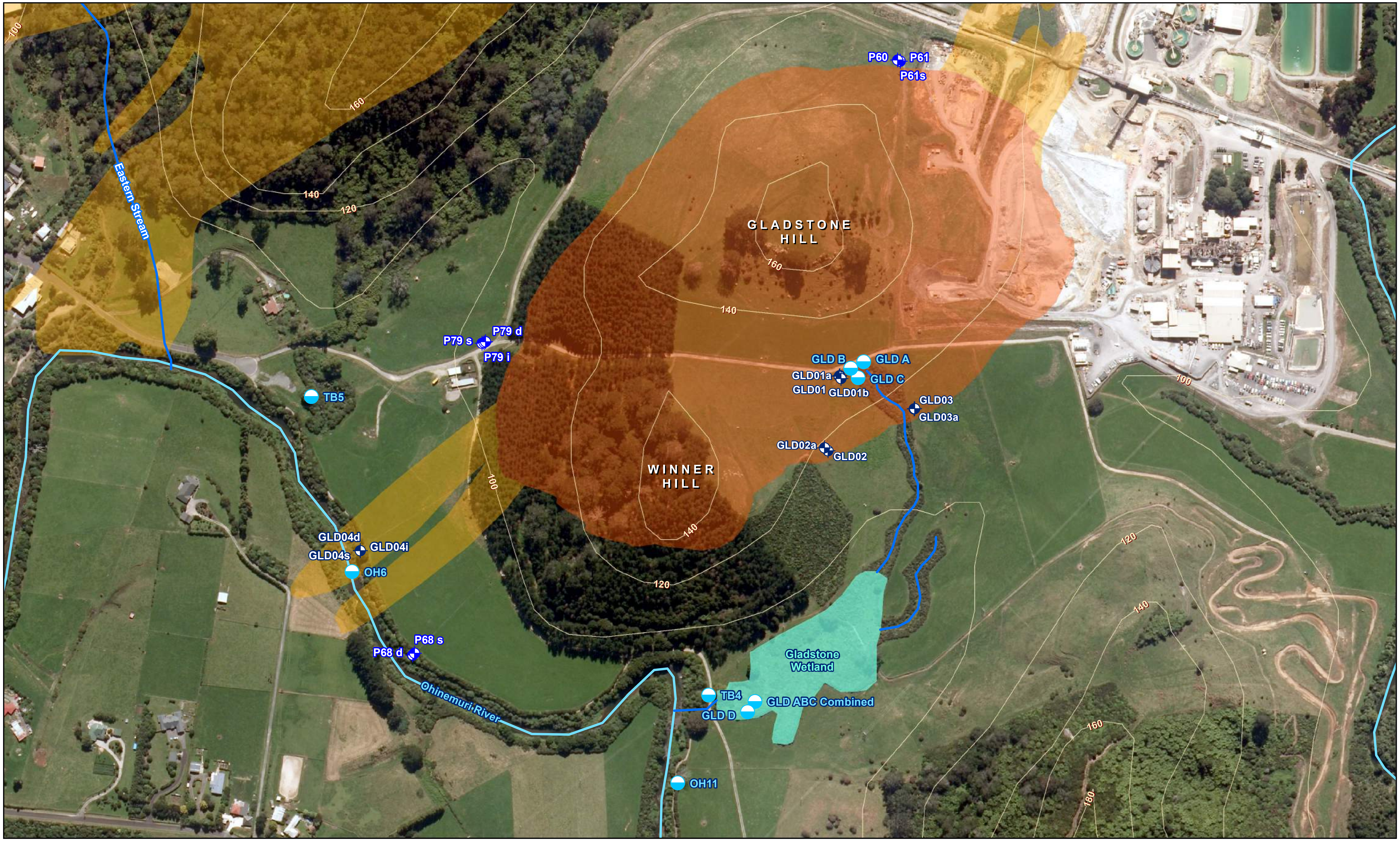
## 3.1 Site overview

### 3.1.1 General site setting

The Gladstone site location is located on Gladstone and Winner Hill, and between Union Hill and Black Hill (Figure 3.1). Land use currently comprises rolling farmland / pasture with a small pine plantation present on both Winner and Gladstone Hills. The Ohinemuri River is located southwest of the proposed GOP and GOP TSF (referred to as “TSF” throughout the remainder of Section 3). Farmland on the river flood plain and western flanks of Winner Hill separate the proposed pit from the river.

A tributary of the Ohinemuri River is present at the southern extent of the proposed Gladstone Pit. The tributary comprises two watercourses that feed a small wetland at the foot of the valley. The watercourses, up to approximately 200 m in length, flow in a relatively steep grade down the hillside. The watercourses upgradient of the Gladstone Wetland are intermittent, with no measurable baseflow during dry summer periods, but the area remains generally damp. Water discharged from the wetland flows to the southwest, with the tributary continuing its path through monitoring site TB4, and discharges to the Ohinemuri River (Figure 3.1).

Northwest of the proposed pit is a small valley which hosts an intermittent watercourse that discharges to the Ohinemuri River downstream of monitoring site TB5 (Figure 3.1). The watercourse is known to be dry for much of the year however provides drainage for stormwater from the surrounding catchment following high intensity rainfall events.




Paper Size A3

0 25 50 100

Metres

Map Projection: Transverse Mercator
Horizontal Datum: NZGD 2000
Grid: NZGD 2000 New Zealand Transverse Mercator

N

LEGEND

- Proposed Gladstone Pit
- Inferred mineralised vein system
- OGL Bores
- Quattro Bores
- Surface Water Locations
- Contour (20m)

**Ohinemuri River Tributary**

- River
- Stream
- Wetland

Oceana Gold Limited
Waihi North

| | |
|---|---|
| Job Number | 12552081 |
| Revision | 0 |
| Date | 13 Dec 2021 |

Gladstone site setting
and monitoring locations

Figure 3.1

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Level 3, 138 Victoria Street, PO Box 13 468, Christchurch 8141, New Zealand T 64 3 378 0900 F 64 3 378 8001 E chcmail@ghd.com W www.ghd.com



Data source: Aerial imagery - LINZ; General topo - LINZ; Bore locations - OGL. Created by:jrprice

### 3.1.2 Summary of proposed works

Gladstone Open Pit (GOP) is one of the components of the WNP works. The pit will comprise two conjoined pits sited over Gladstone Hill and Winner Hill and will subsequently be developed into a tailings storage facility (TSF). The proposed activity is described in detail in the Gladstone Pit TSF Design Report prepared by GHD (2022c). A high-level plan of the proposed GOP is provided in Figure 3.2.

A summary of the activity is provided below, with references to relevant plans in the GHD (2022c) design report provided in *italics*:

- **Preparation works:**
  - Earthworks (topsoil removal and stockpiling).
  - Establishment of clean water diversion drains.
- **GOP excavation:**
  - Mining of the GOP will disturb an area of approximately 23.2 ha, with the pit itself approximately 18.7 ha.
  - Excavation of the GOP to a maximum depth of 1,005 mRL (*GHD GOP DWG 12537997-C002*).
  - Groundwater dewatering (as needed) to enable mining excavation. It is understood that the walls of the GOP will be depressurised using horizontal drain holes which will generally be 20 m to 100 m long.
- **TSF Development** *(GHD GOP DWG 12537997-C003 – C007):*
  - Closure of the pit and installation of a drainage system to capture tailings seepage and reduce pore water pressure on the liner.
  - Backfill with rock (PAF and NAF) to a minimum elevation of 1,060 mRL to form a base upon which a liner subgrade and geosynthetic liner will be placed. All PAF will be lime treated to reduce ARD.
  - Emplacement of tailings to a maximum elevation of 1,103 mRL.
  - Water recovered by the drainage system will be diverted to the WTP. The drainage system will cease to be operated after water quality is considered to be sufficiently improved.
  - Following settlement of the tailings, a capping layer with a minimum thickness of 1 m of low permeability NAF weathered rockfill will be installed to provide a water shedding surface. The capping layer will be gently contoured to direct runoff towards the southern edge of the pit where the existing wetland is located.

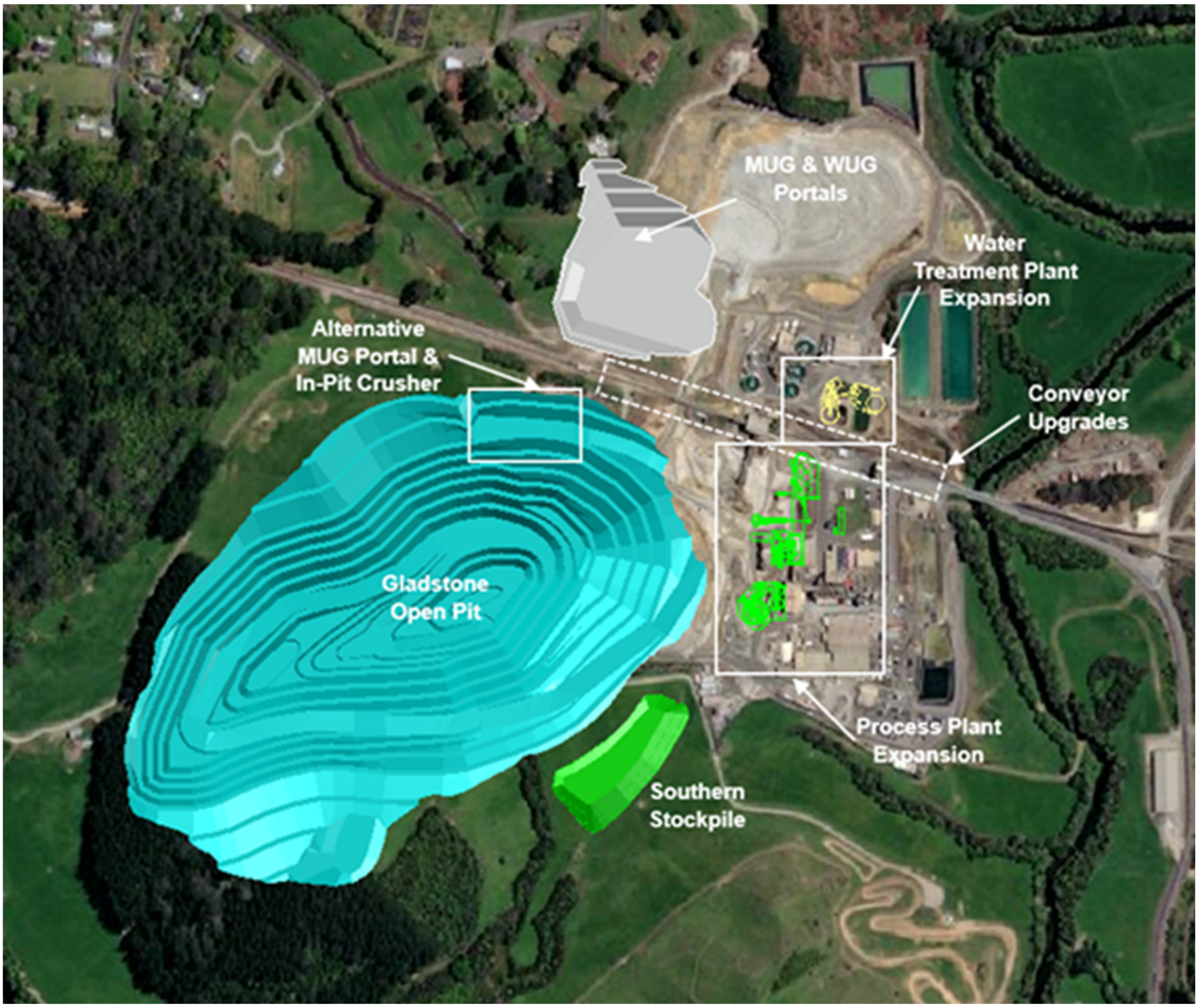


*Figure 3.2 GOP footprint and site layout (Mitchell Daysh, 2025)*

### 3.1.3 Potential influences on groundwater and surface water

Assessment of potential effects on groundwater and surface water has focused on the proposed GOP and TSF to influence:

- Shallow and deep groundwater levels and baseflow to surface water during excavation and dewatering of the GOP, including:
  - The Gladstone Wetland and the intermittent Ohinemuri tributary at TB4, south of the pit.
  - The intermittent Ohinemuri tributary at TB5, northwest of the pit.
  - The Ohinemuri River.
- Water quality, shallow and deep groundwater levels and changes to surface water baseflow during the following phases of the TSF:
  - Operational TSF
  - TSF closure
  - Long-term TSF

## 3.2 Local geology

The regional geology is presented in Section 2.3. The local geology for the Gladstone area is presented in Figure 3.3 and summarised in Table 3.1, which includes the local terminology applied to the Gladstone assessment. Key geological features are summarised below from GNS (1996) and site observations (Appendix A).

The proposed GOP is located in the andesite of Gladstone and Winner Hills (unit *aw*). It accesses the ore body referred to as the "Waihi East ore bodies" (Figure 2.2), which is located southwest of the Favona vein within the same andesite host rock. The geology in the vicinity of Gladstone is notable for weathering of the upper andesite and hydrothermal breccia between deposition events, and young volcanics on the eastern and southern flanks of Gladstone Hill (Figure 3.3).

Fractures and faults which strike southwest to northeast through the andesite of Gladstone Hill and the Favona mine are evident as mineralised veins, with the mineralised zone characterised in the OGNZL leapfrog model (2021) to extend beneath the Ohinemuri River as presented in Figure 3.1. Additional fracturing may continue in the same direction beyond the mineralised zone. These fractures acted as conduits for the hydrothermal waters and were likely connected to the explosion centre for the hydrothermal breccia which is evident in a number of boreholes at the site.

Subsequent volcanic activity resulted in the widespread deposition of dacite to the east and south of Gladstone Hill (Black Hill dacite; unit *iu*). The dacite infilled the paleo-valley present in the current day location of the Gladstone Wetland and Ohinemuri River. More recent ignimbrite materials (units *hw* and *ho*) and alluvial deposits associated with the Ohinemuri River overlie andesite to the north and west of Gladstone Hill (Figure 2.3).

Additional geological units included in the OGNZL leapfrog model (2021) that have also formed the basis of the analysis include:

- Ash cover and regolith materials. This is grouped with rhyolitic tuff (RT) in Table 3.1.
- Volcaniclastic sediments (VC), present as a discrete layer in places above the andesite or breccia, and underlying the dacite. For the purposes of the assessment these materials are assumed to have hydraulic properties generally consistent with the dacite.

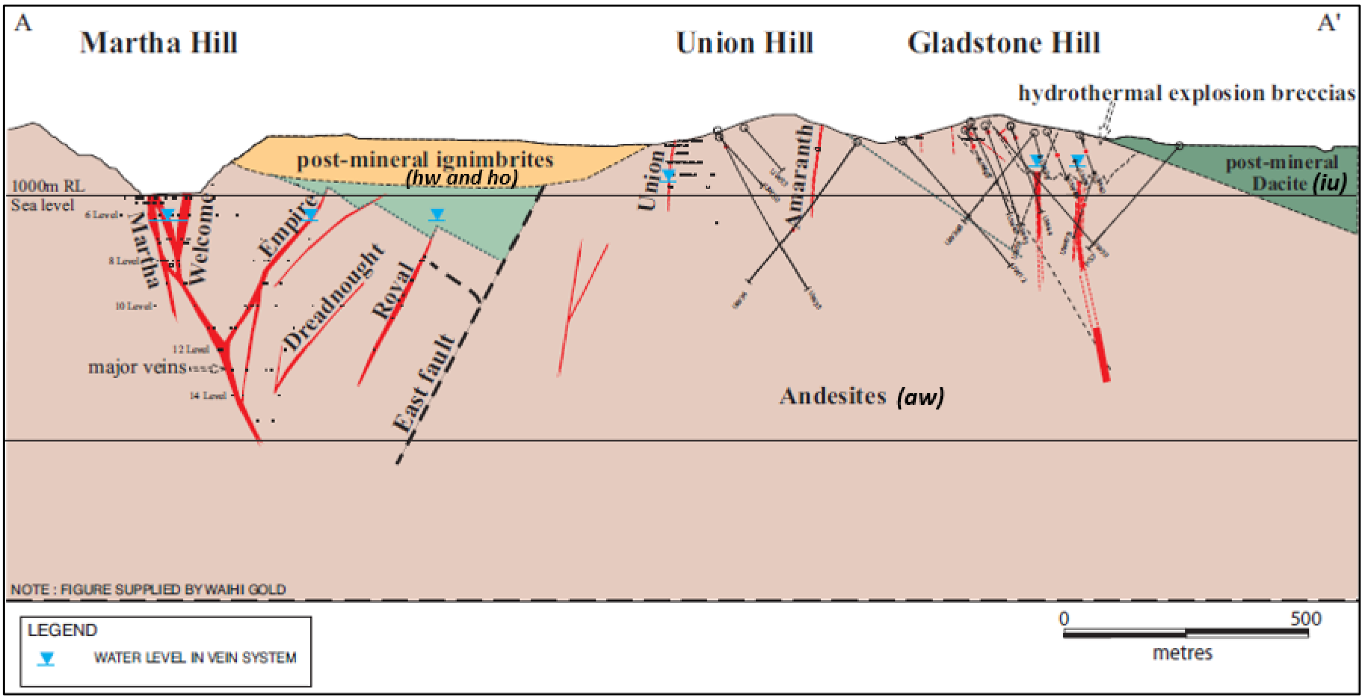


*Figure 3.3 Gladstone geological section (A-A' of Figure 2.3) (URS, 2003))*

*Table 3.1 Stratigraphy of the Gladstone area*

| Unit | Depth encountered (m bgl) *(thickness where present)* | Description |
|---|---|---|
| Topsoil | Surficial<br>*(0.25 – 3.4 m)* | Occurs across the site. |
| Ash/regolith[1] and RT (rhyolitic tuff) | 0.4 – 3.4<br>*(3.1 – 13.1 m)* | Occurs across the site, reducing in depth and thickness to the south where it overlies the dacite. |
| Sandy ignimbrite | 4.7 – 43.5<br>*(5.7 – 38.8 m)* | Occurs west of the proposed pit area. Typically separated from andesite by RT unit, however a small section is inferred to have direct contact with andesite beneath the Ohinemuri River west of the site. [1] |
| Dacite | 3.5 – 8.9<br>*(> 21.1 m)* | In the southeast of the proposed pit area, dacite separates the ash/regolith and RT units from the underlying breccia. |
| Hydrothermal breccia<br>(Coromandel Group) | 2.5 – 28.5<br>*(3.2 – 24.5 m)* | Overlies the andesite in the eastern and southern areas of the proposed pit. Not present in the northern and western areas of the proposed pit. |
| Andesite<br>(Coromandel Group) | 2.0 – 29.0<br>*(> 118 m)* | Andesite host rock. Encountered at shallowest depths beneath the central and western area of the proposed pit. Occasional outcrops of weathered altered andesite in elevated areas. |
| 1. OGNZL leapfrog model, 2021. | | |

# 3.3 Conceptual groundwater model (Gladstone CGM)

## 3.3.1 Overview

Two groundwater systems (shallow and deep) are inferred to be present at the Gladstone site, with this consistent with the broader Waihi area. The shallow system refers primarily to a series of units including surface sediments, ash layers, RT, VC and dacite. This system is characterised by rainwater infiltration, run-off and interactions with surface water. The deep system refers to groundwater within the andesite rock. The weathering of the andesite surface and hydrothermal breccia, prior to deposition of the dacite and other younger volcanics, provides hydraulic separation between the shallow and deep groundwater systems.

The existing Favona portal infrastructure is constructed in the andesite rock and intersects the shell of the proposed GOP. Dewatering of the andesite currently occurs to enable underground mining, which extends to an approximate depth of 800 mRL (OGNZL, 2019). Complex faulting in the area has the potential to provide either conduits or barriers to groundwater flow between ore bodies, with these demonstrating a southwest-northeast orientation. Dewatering of Favona mine commenced in 2005, with further mining in the Waihi area providing hydraulic connection between the Martha area to the northwest and the Favona-Moonlight-Gladstone area. The dewatering for Favona mine, and ongoing dewatering for Correnso and MUG mine activities, has resulted in the andesite in close proximity to the veins and underground workings being dewatered, with the shallow groundwater system being locally under-drained. The low permeability of weathered andesite and breccia has allowed maintenance of a shallow groundwater system. This situation is evident across Waihi, where mining and dewatering is occurring at depth.

The Ohinemuri River to the southwest of the GOP has demonstrated losing conditions, suggesting loss of water to shallow groundwater. These losing conditions have occurred concurrently alongside upwards vertical hydraulic gradients from the deep andesite adjacent to the river, providing evidence of the hydraulic separation of the shallow and deep groundwater systems local to the proposed GOP.

The Gladstone CGM is presented in the following cross-sections (Figure 3.4 to Figure 3.6).


Paper Size A3

0 50 100 200

Metres

Map Projection: Transverse Mercator
Horizontal Datum: NZGD 2000
Grid: NZGD 2000 New Zealand Transverse Mercator

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LEGEND

- Proposed Gladstone Pit
- Inferred mineralised vein system
- Cross section locations
- Contour (20m)

**Ohinemuri River Tributary**

- River
- Stream
- Tributary
- Wetland

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Revision 0
Date 13 Dec 2021

Gladstone cross-section locations (N-S and W-E)

Figure 3.4

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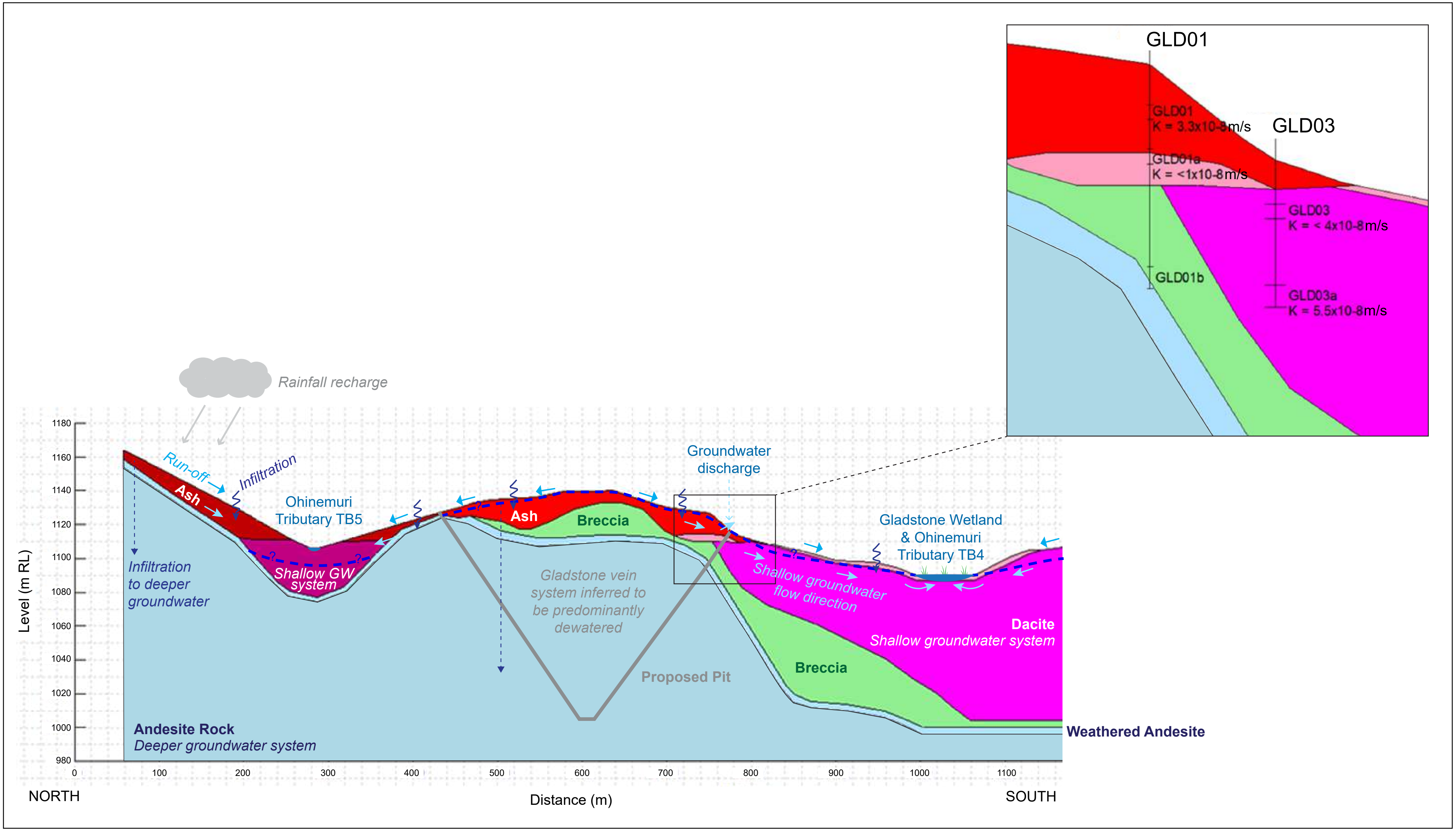
Level 3, 138 Victoria Street, PO Box 13 468, Christchurch 8141, New Zealand T 64 3 378 0900 F 64 3 378 8001 E chcmail@ghd.com W www.ghd.com



Data source: Aerial imagery - LINZ; General topo - LINZ; Bore locations - OGL. Created by:jrprice




LEGEND

- Andesite
- Ash / Regolith (N)
- Ash / Regolith (S)
- Dacite
- Hydrothermal Breccia
- RT (N)
- RT (S)
- Weathered Andesite
- Proposed Gladstone Pit
- Potentiometric groundwater level
- Groundwater Recharge
- Shallow Groundwater Flow Direction
- Rainfall Runoff
- Wetland / tributary

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North - South
Model Cross Section

| | |
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| Job Number | 12552081 |
| Revision | 0 |
| Date | 07 Dec 2021 |

Figure 3.5

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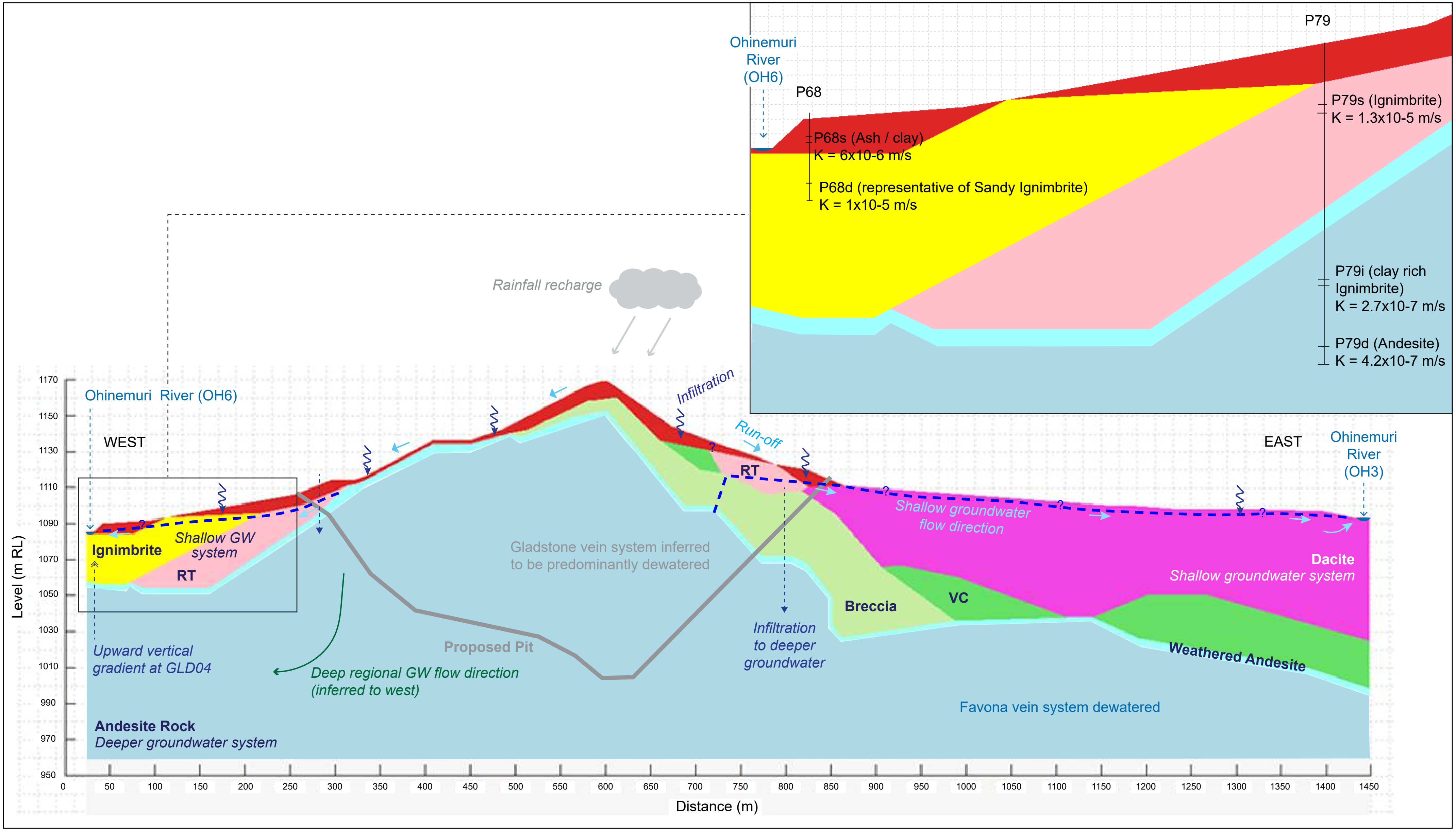
Level 3, 138 Victoria Street, PO Box 13 468, Christchurch 8141, New Zealand T 64 3 378 0900 F 64 3 378 8001 E chcmail@ghd.com W www.ghd.com



Data source: GHD. Created by:jrprice




LEGEND

| | | | |
|---|---|---|---|
| Andesite | RT | Proposed Gladstone Pit | Rainfall Runoff |
| Ash / Regolith | Sandy Ignimbrite | Potentiometric groundwater level | Wetland / tributory |
| FVN Dacite | Volcaniclastic | Groundwater Recharge | |
| Hydrothermal Breccia | Weathered Andesite | Shallow Groundwater Flow Direction | |

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Waihi North

Job Number 12552081
Revision 0
Date 07 Dec 2021

West - East
Model Cross Section

Figure 3.6

N:\NZ\Christchurch\Projects\51\12526951\GIS\Maps\Deliverables\12552081\12552081_Z003_GladstoneHYD_EastWest.ai

Level 3, 138 Victoria Street, PO Box 13 468, Christchurch 8141, New Zealand T 64 3 378 0900 F 64 3 378 8001 E chcmail@ghd.com W www.ghd.com



Data source: GHD. Created by:jrprice

## 3.3.2 Shallow groundwater system

The shallow groundwater system at Gladstone comprises groundwater flow through shallow soils, reworked young volcanics and highly weathered rock on the flanks and surrounds of Gladstone and Winner Hills. The presence of the Gladstone wetland on the southern flanks of Gladstone Hill results from groundwater recharge into the shallow groundwater system, while the intermittent watercourses are also expected to be connected to the shallow groundwater system at times.

On-going weathering, erosion and fracturing of andesite where it outcrops on Gladstone Hill has provided a material with more porous characteristics than the deeper, less-weathered andesite, and a surface through which rainwater infiltration, whilst low, is expected to occur. The change in properties and desaturation of deeper andesite limits the volume of recharge that can infiltrate, promoting flow of infiltrating water radially away from Gladstone Hill into the younger volcanics of the shallow groundwater system.

### Hydraulic Properties

Hydraulic conductivity (K) testing of the dacite and rhyolitic tuff (RT) at the locations of the GLD bore series installed on the southern flank of Gladstone Hill indicates very low permeabilities, as summarised in Table 3.2 (detailed permeability results are provided in Appendix D). This is generally consistent with the observed residual weathering, which presents as clay-like materials. The low permeability of these materials results in high groundwater levels (shallow water table), supporting the wetland to the south of the proposed Gladstone Pit.

In contrast, the higher permeability of the rhyolitic tuff (RT) to the north and west of Gladstone Hill provides greater drainage, lower groundwater levels and more rapid flow of groundwater in comparison to the conditions to the south. The typically dry conditions of the intermittent tributary at monitoring location TB5 reflect the higher permeability of the materials to the north and west, which can dissipate high water levels faster than in lower permeability areas following rainfall events.

***Table 3.2 Hydraulic Conductivity of geological units in shallow groundwater system***

| Geological Unit | Geomean hydraulic conductivity (m/s) |
|---|---|
| Ash/regolith south of pit<br>(GLD01) | $3.3 \times 10^{-8}$ |
| Ash/regolith west of pit<br>(P68s[1]) | $6.0 \times 10^{-6}$ |
| RT (rhyolitic tuff) south of pit<br>(GLD01a) | $<1 \times 10^{-8}$ |
| RT (rhyolitic tuff) north of pit<br>(P61s[1]) | $2.5 \times 10^{-6}$ |
| RT (rhyolitic tuff) west of pit<br>(P79i) | $2.7 \times 10^{-7}$ |
| Sandy Ignimbrite<br>(P79s & P68d[1]) | $1.2 \times 10^{-5}$ |
| Dacite<br>(GLD03 & GLD03a) | $4.8 \times 10^{-8}$ |
| 1. URS, 2003. | |

### Shallow groundwater levels

Groundwater levels in the GLD bore series installed on the southern flank of Gladstone Hill are presented in Figure 3.7. Groundwater levels within the shallow system appear to respond to infiltration during rainfall events, with downward hydraulic gradients typically evident. However, higher groundwater levels are recorded to occur immediately following rainfall events at GLD02a, where an increase in groundwater pressures in the hydrothermal breccia unit is likely to have occurred due to differing recharge pathways and hydraulic conductivity in comparison to the overlying shallow volcanics. This provides upwards vertical hydraulic gradients following rainfall events that result in groundwater discharge to the intermittent watercourses upgradient of the Gladstone Wetland. More typical downward hydraulic gradients indicate that some minor recharge of the deep groundwater system is occurring. Under-drainage of the shallow aquifer is most evident in the GLD01 series of monitoring wells, where the deepest well (GLD01b), screened within breccia/weathered andesite (separating the shallow and deep groundwater system), is typically found to be dry.

Piezometric maps for the Gladstone site are provided in Appendix C, presenting groundwater levels in the shallow water table bores installed in the ash/regolith and dacite units, and piezometric contours within the RT and deeper section of the dacite unit. Vertical hydraulic gradient directions and flow/discharge locations in relation to the Ohinemuri River and its tributaries are included in both figures.

All groundwater monitoring wells in the shallow groundwater system are installed within 33 m of the ground surface, typically within weathered, fractured volcanic flows and/or volcaniclastic sediments.

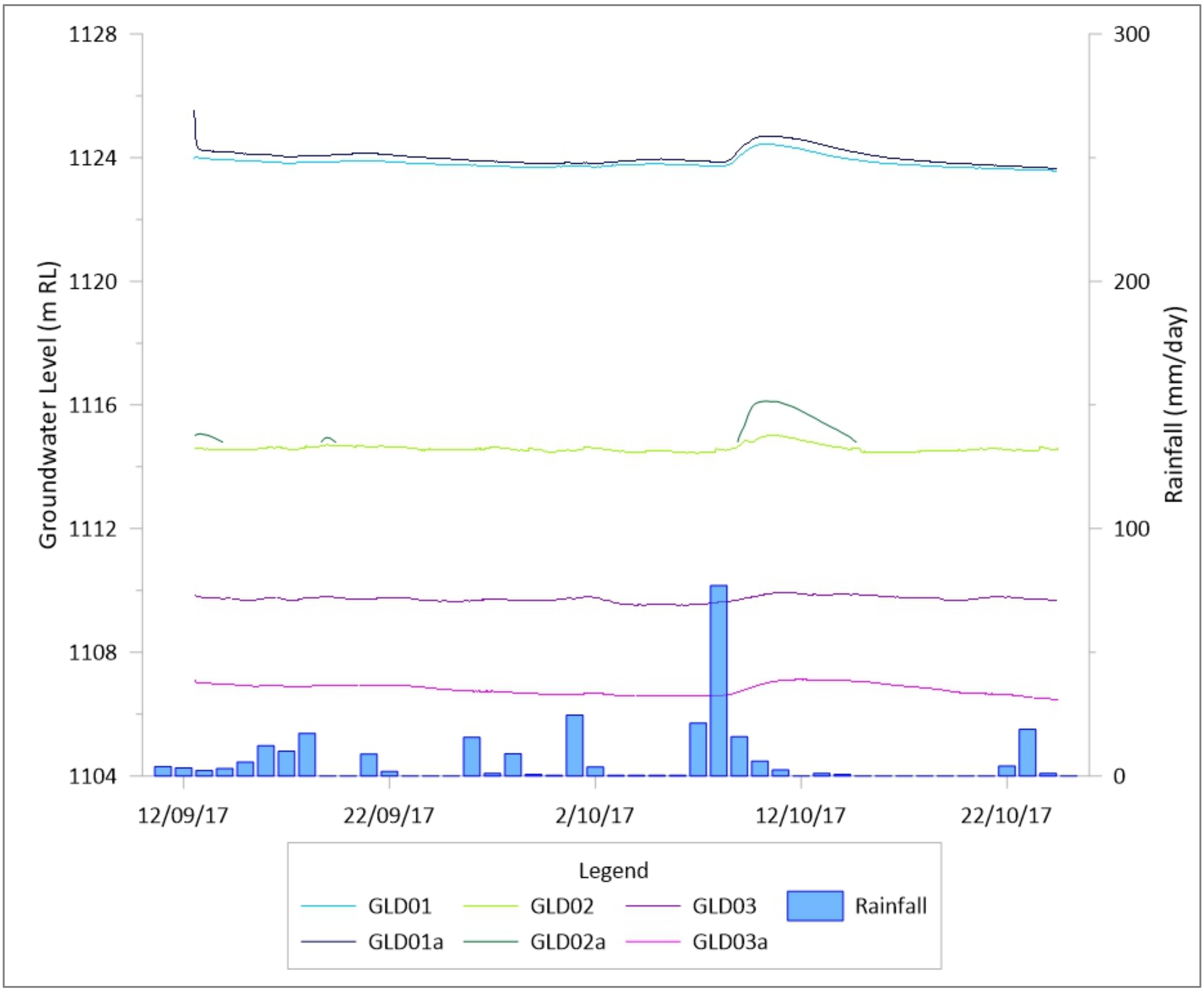



***Figure 3.7 Groundwater levels in the shallow system on southern flank of Gladstone Hill****

** The pressure transducer in GLD02a was not installed below the water table during the full monitoring period.*

### 3.3.3 Deep groundwater system

Groundwater flow within the andesite rock underlying the shallow groundwater system is predominantly through secondary porosity features, with the vein system providing sub-vertical conduits for groundwater movement (URS, 2003). Away from fault zones and vein systems, the deep rock mass has very low permeability resulting in limited hydraulic connectivity between fault zones.

## Deep groundwater levels

Water levels in the deep groundwater system have been recorded as below and are summarised in Table 3.3. Well locations are presented in Figure 3.8.

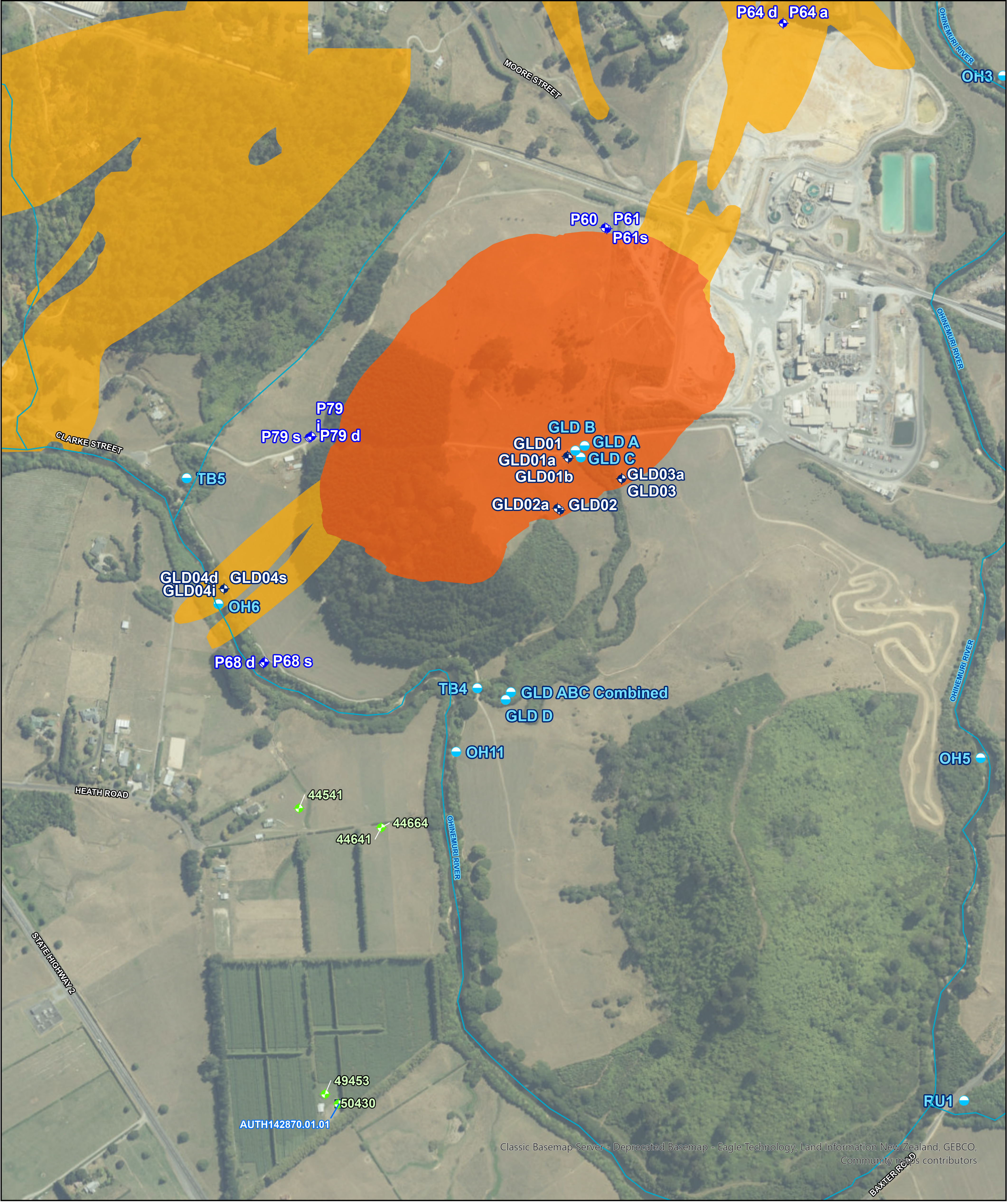
– A groundwater level range of 1,064 – 1,089 mRL was recorded in the monitoring wells in Table 3.3 prior to dewatering of the Favona system, with downward vertical hydraulic gradients recorded in areas of elevated topography as the shallow groundwater provides recharge to the deep groundwater system (Figure 3.9).
– Upward vertical hydraulic gradients between the shallow and deep system have been recorded at lower topographic elevations adjacent to the Ohinemuri River (GLD04 well series). This well series was installed to replace the P68 well series due to damage and concerns regarding well integrity. Previous groundwater levels recorded at P68, prior to dewatering of the Favona vein system, recorded a downwards vertical hydraulic gradient between the shallow and deep system.
– Deep groundwater piezometers within and/or immediately adjacent to mineralised vein zones north and north-east of the proposed Gladstone Pit (P64D, P64A, P60) are dry, reflecting the influence of local mine dewatering.
– Immediately west of the proposed Gladstone Pit, and slightly offset from the Gladstone vein system (P79 series), the deep groundwater shows gradual, long-term reductions in levels, reflective of a minor influence of dewatering. Figure 3.9 provides the long-term water level record for the P79 well series illustrating this response.
– Deep groundwater levels and flow directions from 1983 are presented in Figure 3.8, indicating that deep groundwater levels in the vicinity of Gladstone were approximately 1,100 mRL with a flow direction towards the west.

Groundwater level data and vertical hydraulic gradients are presented in Appendix C.

*Table 3.3 Deep groundwater system well properties*

| Piezometer | Screen (mRL) | Hydraulic conductivity (m/s) | Approximate water level (mRL) | Comments |
|---|---|---|---|---|
| P60 | 1,043 – 1,029[1] | $5 \times 10^{-7}$ [1] | 1,065 prior to Favona dewatering.[1] Recorded as dry from 2005. | Installed in altered andesite west of Favona vein system to monitor for dewatering effects. Collapsed 2011. |
| P61 | 1,089 – 1,076.5[1] | $7 \times 10^{-9}$ [1] | 1,084 | Installed in altered andesite west of Favona vein system to monitor for dewatering effects. No impacts have been observed from dewatering. Obstructed 2019. |
| P64I[2] | 1,086 – 1,085.5[1] | - | 1,098.5 | Installed in shallow groundwater system above Favona vein system. |
| P64D | 1,069 – 1,063[1] | $6 \times 10^{-9}$ [1] | 1,078 prior to Favona dewatering.[1] Dry from 2006. | Installed in altered andesite to monitor Favona vein system. |
| P64A | 960 – 930 (open hole) | $5 \times 10^{-4}$ [1] | 1,064 prior to Favona dewatering.[1] Dry from 2006. | Installed within Favona vein structure. No significant water loss occurred during drilling of this well until deep into the vein system. |
| P79d | 1,050 – 1,047 | $4 \times 10^{-7}$ | 1,078 – 1,094. Declining average conditions. | Installed in altered andesite to monitor effects from Moonlight vein system. |
| GLD04d | 1,027 – 1,021 | - | 1,085 | Installed in andesite along Gladstone vein strike adjacent to Ohinemuri river. Andesite highly fractured. |

1. URS, 2003.
2. This bore is not installed in the deep groundwater system but has been included to assist with CGM discussion.




LEGEND

- OGL Bores
- Quattro Bores
- Surface Water Locations
- Registered bores (WRC Well ID) - excluding OGL bores

**Authorised Takes - excluding OGL takes**

- Groundwater take (AUTH = WRC consent ID)
- Proposed Gladstone Pit
- Inferred mineralised vein system
- Rivers (LINZ)

Paper Size A3

0 50 100 200

Metres

Map Projection: Transverse Mercator
Horizontal Datum: New Zealand 1949
Grid: NZGD 1949 Mount Eden Circuit

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GHD

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Waihi North

Gladstone registered bores, groundwater takes and mineralised vein system

| | |
|---|---|
| Job Number | 12590241 |
| Revision | 1 |
| Date | 13 Feb 2025 |

Figure 3.8

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Level 3, 138 Victoria Street, PO Box 13 468, Christchurch 8141, New Zealand T 64 3 378 0900 F 64 3 378 8001 E chcmail@ghd.com W www.ghd.com



Data source: Aerial imagery - LINZ; General topo - LINZ; Bore locations - OGL. Created by:nrama

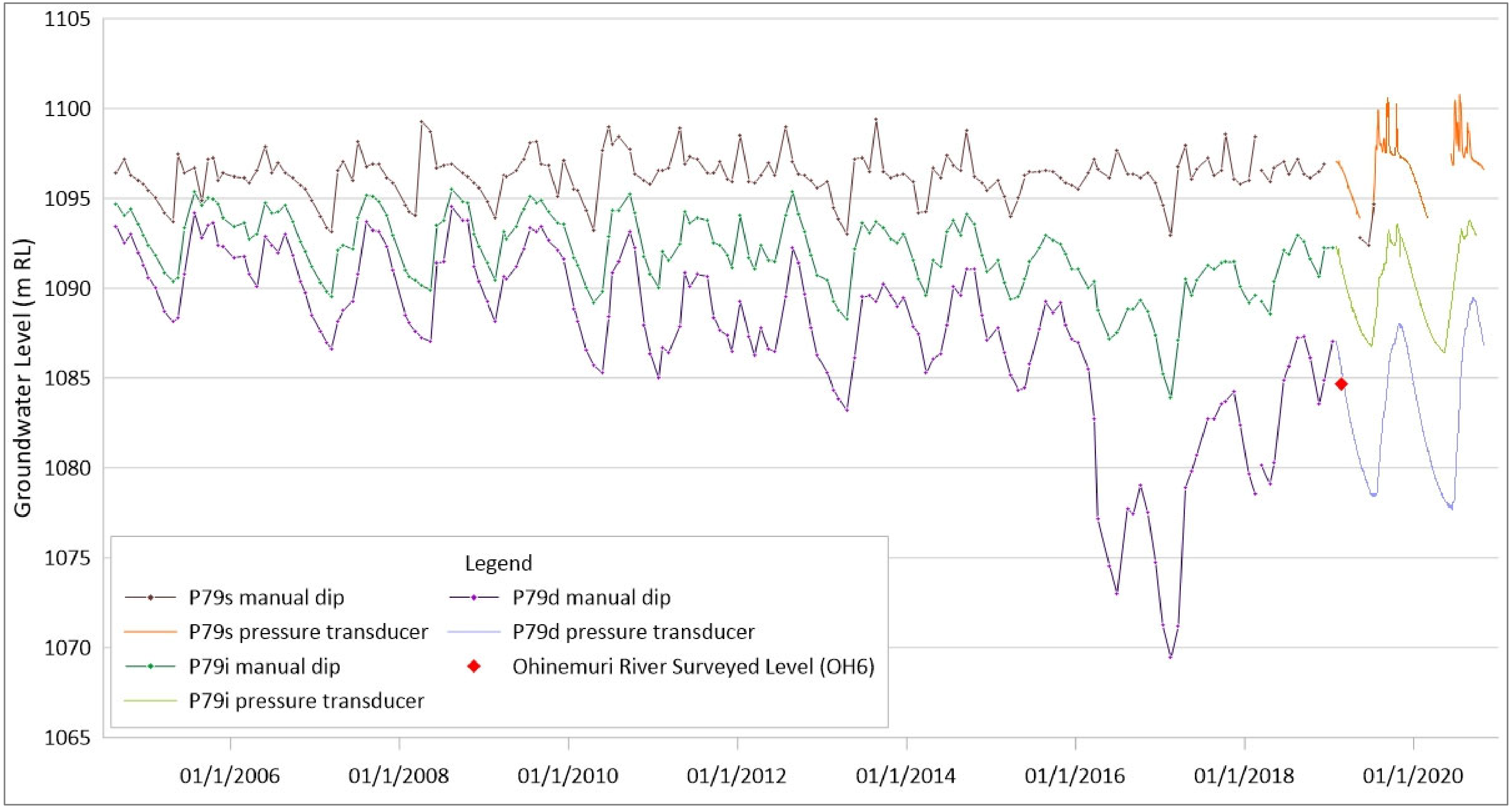


*Figure 3.9* ***Groundwater levels in the shallow (P79s & P79i) and deep (P79d) systems southwest of Gladstone Hill and surveyed Ohinemuri River level at OH6***

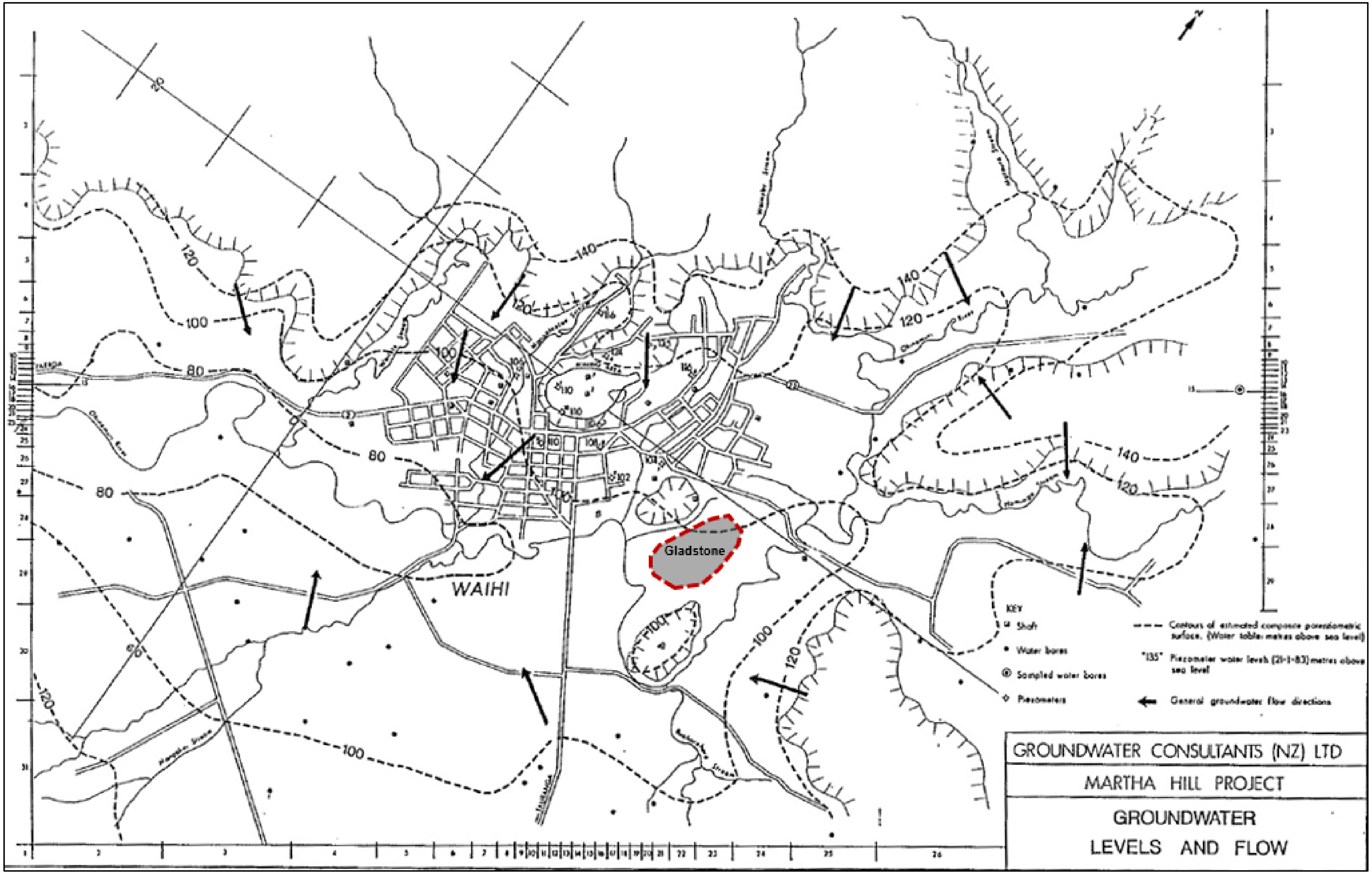


*Figure 3.10* ***Deep groundwater levels (m above mean sea level) and flow direction recorded in 1983 (GCNZ; year unknown - modified to show approximate Gladstone location)***

### Hydraulic connection to Favona

The influence of the Favona mine dewatering on the Gladstone vein system has been constrained to areas that have a strong hydraulic connection with the Favona system, with this connection inferred to reduce along the strike between wells P60 and GLD04. The degree to which the Gladstone deep groundwater is currently dewatered due to Favona mine workings is not well defined, however it is expected that the vein system at the location of the proposed GOP is predominantly dewatered.

Given the dry conditions recorded to at least 1,029 mRL in P60 immediately north of the proposed GOP (Figure 3.8), and 1,097 mRL at GLD01b within the southern GOP boundary, it is considered likely that the north-eastern section of the proposed GOP is fully dewatered to the maximum proposed pit depth (1,005 mRL). However, the south-western section of the GOP, where the proposed maximum pit depth is shallower (approximately 1,025 – 1,040 mRL), may be dewatered to a lesser degree.

The interpreted hydraulic connection between the Favona and Gladstone vein systems is supported by the data presented in Table 3.3, and is summarised as follows:

– P64 well series: Three piezometers were installed to target the Favona vein system (Figure 3.8). Monitoring indicates that after dewatering of Favona commenced in 2005, water levels reduced in the two piezometers installed in the deep andesite system (P64D and P64A) and became dry in 2006. The piezometer installed in the shallow groundwater system (P64I) did not record a response to dewatering, as a result of the hydraulic separation between the shallow and deep systems.

– P60 and P61 well series: These wells were installed to differing depths adjacent to one another to monitor dewatering effects to the west of the Favona vein system, and immediately to the north of the proposed GOP (Figure 3.8). P60 was recorded as dry since 2005, with no change in water levels recorded in the shallower P61. The apparent difference in response between these piezometers, and variability in hydraulic conductivity, is reflective of the highly localised influence of the dewatering on surrounding groundwater levels and potentially the shallower elevation of the P61 piezometer.

– P79 well series: Deep groundwater levels at P79d have been gradually declining since 2005, with a more significant reduction in 2016 reported by OGNZL (2019) as likely due to water loss during drilling of a nearby horizontal bore (Figure 3.9). The drill hole was plugged, with no further water loss reported. However, the declining trend in water levels in P79d and shallower piezometer P79i are considered to be reflective of a minor and delayed response to dewatering effects from Favona. Although the andesite at this location is fractured, only a limited hydraulic connection is interpreted to exist between the local country rock and the vein system.

– GLD01b is installed to approximately 1,097 mRL within hydrothermal breccia/weathered andesite above the andesite hosting the Gladstone vein system and has been recorded as dry since installation. The dry conditions at this piezometer may be attributed to dewatering of the underlying andesite. Groundwater levels in nearby P79d indicate a typical range between 1,077 – 1,094 mRL (Figure 3.9), approximately 50 m offset from the inferred Gladstone vein system.

– GLD04d is installed adjacent to the Ohinemuri River and screened at an elevation similar to the proposed maximum GOP depth (1,005 mRL). Despite the andesite encountered in GLD04d being highly fractured and in close proximity to the inferred location of the Gladstone vein system, deep groundwater at this location has not been dewatered. An upward vertical hydraulic gradient between the deep and shallow groundwater systems has been recorded. P68d and P68s however recorded a downward vertical hydraulic gradient prior to dewatering of the Favona system. In comparison to the 1983 deep groundwater levels presented in Figure 3.10, groundwater levels in the andesite are interpreted to have reduced slightly as a result of mine dewatering, however the influence of dewatering to the southwest of the proposed Gladstone Pit may be limited.

## 3.3.4 Groundwater quality

Detailed groundwater chemistry data recorded in the Gladstone monitoring wells between 2017 – 2020 is presented in the tables and piper plots in Appendix E.

The chemistry of the groundwater in shallow monitoring wells generally changes with depth and location, with this interpreted to be a function of land-use and degree of local mineralisation. Near surface groundwater, as recorded in GLD02 and GLD03, typically demonstrates aerobic conditions, with the presence of nitrate, low trace element concentrations and low dissolved solids content.

Moving deeper through the shallow profile and closer to the mineralised breccia in the south and eastern extents of the proposed GOP, groundwater demonstrates elevated sulphate and trace element concentrations, characteristic of sulphide mineral oxidation. This is most evident in GLD02a, and to a lesser extent GLD01a, which demonstrate elevated arsenic, antimony, nickel, sulphate, and zinc relative to shallower monitoring wells. Towards the Ohinemuri River, distant from the breccia, shallow groundwater remains relatively low in dissolved solids and indicators of mineralisation influence, as represented by water quality results from GLD04s.

Deep groundwater within the andesite to the north and southwest of the proposed GOP, as represented by monitoring wells P79d and GLD04d, respectively, typically reports higher iron, manganese and sulphate concentrations than the shallow groundwater system, but notably less influence of mineralisation than in monitoring wells interpreted to be influenced by breccia.

### 3.3.5 Surface water-groundwater interactions

#### Tributaries of the Ohinemuri River

The results of flow gauging of the Ohinemuri River and its tributaries, including the intermittent watercourses present south and north of the proposed GOP (TB4 and TB5), are presented in Appendix F. The monitoring locations are presented in Figure 3.1.

The intermittent watercourses south of Gladstone Hill that flow towards the Gladstone Wetland are typically recorded as dry during summer, with the downgradient tributary at monitoring location TB4 found to have very shallow ponded and stagnant water during these summer conditions (21 March 2019; Opus, 2019). However, following rainfall and during periods of higher groundwater levels, the headwaters of the TB4 tributary is inferred to receive groundwater discharge. A culvert passing beneath the road at this location is expected to provide water level and discharge control on the wetland. The following observations recorded during a site visit by GHD in June 2017 suggest that the watercourses become losing downstream of the groundwater discharge, before gaining again prior to the confluence with the Ohinemuri River:

– Flowing water (approximately 50 to 100 mL/s) in the upper headwaters.
– Boggy conditions with no flowing water 200 m downstream of the headwaters, and downward vertical hydraulic gradient measured in the wells at GLD03.
– Flow upstream of the Ohinemuri confluence measured at approximately 5 L/s.
– Changing water chemistry as the springs flow to the wetland (Appendix E).

Further discussion of the Gladstone Wetland is provided in the GHD (2022) Gladstone Wetland Groundwater Assessment Summary Technical Memorandum, which is appended to this report as Appendix L.

The Ohinemuri tributary TB5 does not appear to receive groundwater baseflow, and only flows after significant rainfall events. With the exception of the September 2019 gauging event, it has been recorded as dry during all flow gauging events in 2019 and 2020 (Appendix F). A rainfall measurement of 132 mm was recorded over the two weeks prior to the September 2019 flow gauging event, suggesting that the flow in the TB5 tributary at this time was derived from stormwater runoff and interflow.

#### Ohinemuri River

Flow in the Ohinemuri River during baseflow conditions ranges between 0.2 and 0.5 $m^3$/sec between the Martha Process area and Gladstone Hill (Appendix F).

Flow gauging recorded losing conditions between monitoring locations OH11 and OH6 adjacent to the proposed Gladstone Pit in June 2019 and January 2020 (Appendix F). As discussed in Section 3.3.3, upwards vertical hydraulic gradients are recorded between the deep and shallow groundwater systems adjacent to the river (GLD04 well series). This provides further evidence of the separation of the shallow and deep groundwater systems in the vicinity of the Ohinemuri River.

### Surface water quality

Surface water quality data recorded at TB4 and its upstream headwaters, TB5 and the Ohinemuri River (OH6) between 2017 – 2020 is presented in tables and piper plots in Appendix E. The water chemistry is summarised as follows:

– The chemical composition of the sample from the intermittent watercourse TB5 is similar to that of the intermittent watercourse at GLD A and the Ohinemuri River at OH6. These samples are likely to be representative of surface water runoff and interflow.
– Concentrations of sulphate and calcium increase along the flow path of the intermittent watercourse at GLD B and C, suggesting the inflow of groundwater influenced by mineralisation.
– Surface water within the wetland (GLD D) has a similar water chemistry to the Gladstone shallow groundwater system (GLD01a and GLD03), confirming that the intermittent watercourses and wetland receive shallow groundwater discharge. The water quality of the wetland also demonstrates an influence of mineralisation, with elevated trace element concentrations.
– The TB4 water chemistry is similar to that of the wetland (GLD D), confirming that the wetland contributes to the downstream tributary flow.

The water quality recorded in the Ohinemuri River at the location of OH6 complies with the RWQC throughout the available data set (excluding mercury due to the laboratory limit of detection being greater than the criteria).

While the concentrations of some trace elements are naturally elevated in groundwater flowing from the Gladstone shallow system due to the natural geological setting, the influence on the Ohinemuri River quality is expected to be negligible owing to the relatively small contribution of local groundwater to baseflow of the river.

## 3.3.6 Water resource users

Registered bores within proximity of the proposed Gladstone Pit are presented in Figure 3.11; WRC, 2025c). A full list of water users is provided in Appendix K. A summary is provided below and in Table 3.4:

– The closest registered bores (Well IDs 44641, 44664 and 44541) are located approximately 430-440 m south of the proposed GOP (Figure 3.8).
– The closest consented groundwater take (AUTH142870, Well ID 50430) is located at Black Hill Orchard approximately 820 metres south of the proposed GOP (Figure 3.8).
– There are no registered bores or water takes located between the proposed GOP and the Ohinemuri River.
– All registered bores presented in Figure 3.8 are interpreted to be installed within andesite to a maximum depth between 72-350 mbgl.
– There are no surface water takes within 1 km of the proposed GOP. The nearest downstream Ohinemuri River take (AUTH141637 for frost protection) is located approximately 10 km downstream of the WNP area and is not shown on the report figures.

*Table 3.4 Groundwater takes and registered bores in the vicinity of the proposed Gladstone Pit*

| Registered Well ID (Completion year) | Property | Consented groundwater take (year granted) | Depth (m) | Approximate distance from Gladstone Pit (m) |
|---|---|---|---|---|
| 44641 (1999) | Mullan D | - | 72 | 430 |
| 44664 (2000) | | - | 85 | 430 |
| 44541 (2000) | | - | 126 | 440 |
| 49453 (1965) | Black Hill Orchard | - | 183 | 810 |
| 50430 (2018) | | AUTH142870 (2021) | 350 | 820 |


Paper Size A3

0 400 800

Metres

Map Projection: Transverse Mercator
Horizontal Datum: NZGD 2000
Grid: NZGD 2000 New Zealand Transverse Mercator

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LEGEND

- Registered bores (WRC Well ID) - excluding OGL bores

**Authorised Takes - excluding OGL takes**

- Groundwater take (AUTH = WRC consent ID)
- Surface water take (AUTH = WRC consent ID)
- Shed Spring
- Farm pond
- Rivers (LINZ)

Oceana Gold Limited
Waihi North

| | |
|---|---|
| Job Number | 12590241 |
| Revision | 1 |
| Date | 13 Feb 2025 |

## Gladstone surface water and groundwater takes

Figure 3.11

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Data source: LINZ (cc-by): Aerial imagery (NZ - Imagery: Classic Basemap Server - Deprecated Basemap - Eagle Technology, Land Information New Zealand, GEBCO, Community maps contributors), Roads - 20200216; GHD: Bores_Gladstone, Bores_Gladstone_New_20211123,, Consents_Gladstone. Created by:nrama

URS (2003) reported that monitoring of groundwater levels at the Black Hill Orchard bore (Well ID 50430) had not identified any effects from dewatering of the Martha Mine. Testing of groundwater from the bore and completion of a pumping test in 2017 (GWS, 2018b) suggests that the Black Hill Orchard bore is unlikely to be in hydraulic connection with the Gladstone area, with this indicated by:

– A four-hour pumping test provided a transmissivity (T) for the andesite aquifer at this location of 53 $m^2$/day for early time testing (the first hour). A boundary effect is obvious in later test time, resulting in a lower T of 18 $m^2$/day. This boundary is inferred to be a lower permeability unit estimated within 500 m of the bore. The inferred transmissivity and boundary effect suggest that the aquifer is of limited extent and with impaired hydraulic connection.
– A comparison of groundwater quality from the Black Hill Orchard Bore with that of deep groundwater from monitoring wells installed near Gladstone indicates that the water type is different with the Black Hill Orchard Bore being relatively uninfluenced by mineralisation. The Black Hill Orchard Bore is a sodium bicarbonate type water with low dissolved solids and a neutral to high pH (7.6), with elevated alkalinity. The water has low sulphate (<5 mg/L), with comparatively higher sodium and chloride. In general, dissolved mineral content is low and water chemistry does not show a notable influence of mineralisation. By comparison, groundwater from monitoring bore GLD04d has a mixed water type that corresponds most closely with a calcium sulphate water type. Groundwater from the andesite at this location has a slightly lower pH (6.8), elevated sulphate of 78 mg/L, lower chloride, and elevated dissolved zinc (0.17 mg/l), indicating some influence of mineralisation that is not present in the groundwater at Black Hill Orchard.

## 3.4 Gladstone Open Pit and Tailings Storage Facility assessment methodology

Potential impacts on groundwater and surface water associated with the proposed GOP and TSF were assessed using conceptual interpretation, supported by the use of 2D numerical groundwater models and analytical models. The assessment comprised:

1. **Conceptual groundwater model development** (Section 3.3): Understanding of the current geological and hydrogeological environment using site investigation data (Appendix A) and OGNZL leapfrog model (2021).
2. **GOP and TSF assessment:**
   a. Development of two steady-state cross-section models (GeoStudio 2021 SEEP/W finite element numerical modelling software) representing existing shallow groundwater flow paths that extend radially from Gladstone Hill. These models were used to predict changes in groundwater levels and flow and estimate discharge of tailings porewater to the TSF drainage system and the receiving environment. The north-south cross section was adopted to assess the effects to shallow groundwater between the GOP and local tributaries (TB4 and TB5) and the Gladstone wetland. The east-west cross section was adopted to assess the effects to shallow groundwater between the GOP and the Ohinemuri River. The alignment of the east-west section includes the locations where the pit shell intersects with the lowest elevations of the adjacent shallow groundwater systems. The model set-up considers a situation where the shallow groundwater system is currently under-drained as a result of existing mine dewatering (Section 3.3.3). The assessment modelled the following sequential scenarios:
      i. **Current conditions:** Calibrated base model representing the existing environment.
      ii. **GOP excavation:** Excavation of the GOP to maximum proposed depth.
      iii. **Operational TSF:** Pit backfill with rock and tailings, presence of a tailings pond and TSF drainage system prior to rewatering of the deep groundwater system.
      iv. **TSF closure:** Drainage of the tailings pond, placement of a capping layer and continued operation of TSF drainage system, subsequent to rewatering of the deep groundwater system
      v. **Long-term TSF:** No further operation of the TSF drainage system.
   b. Development of a groundwater recharge model to estimate changes in groundwater recharge area for each of the assessment scenarios. This analytical solution was used as a comparative analysis to provide a degree of further confidence in the numerical model calibration.

3. **Gladstone vein dewatering assessment:**
   a. Development of a steady-state cross-sectional model (Geostudio 2021 SEEP/W finite element numerical modelling software) representing existing shallow and deep groundwater systems and the Gladstone vein system. The model was orientated perpendicular to the strike of the Gladstone vein system where it passes beneath the Ohinemuri River southwest of the proposed GOP. The model was used to predict groundwater drawdown within the shallow and deep groundwater systems, and potential changes in Ohinemuri River flow. The model set-up considers a situation where the deep groundwater system southwest of the proposed GOP is not currently dewatered as a result of current mine dewatering (Section 3.3.3). The assessment modelled the following scenarios:
      i. **Current conditions:** Base model representing the existing environment.
      ii. **Gladstone vein dewatering:** Dewatering of the Gladstone vein system to maximum proposed GOP depth (1,005 mRL).
   b. Existing data recorded during mine dewatering of the Favona system was used qualitatively to predict groundwater inflow rates from the deep groundwater system during excavation of the GOP. This assessment considered a scenario where the deep groundwater system southwest of the proposed GOP is not currently dewatered as a result of mine dewatering.
4. **Surface water catchment assessment:** Development of a surface water catchment model to predict changes in catchment area following excavation of the proposed GOP and capping of the TSF.
5. **Water quality assessment:** Development of a contaminant mass mixing model to predict impacts to groundwater and surface water quality after operation of the TSF drainage system is discontinued (long-term TSF scenario). Results from AECOM (2021b) geochemical equilibrium modelling to generate a groundwater quality equilibrated for mineral saturation for the TSF discharge were used alongside the predicted groundwater flows from the long-term TSF assessment and existing water quality data in a mixing model to provide fully mixed water quality predictions for the Ohinemuri River. No water quality assessment was required for the GOP excavation and operational and TSF closure scenarios, as no discharges to the environment are predicted to occur. Discharge of dewatered groundwater and stormwater from the GOP during excavation, and groundwater discharged from the TSF drainage system during operation and TSF closure scenarios, will be treated at the WTP prior to discharge to the Ohinemuri River (further discussed in the Water Management Studies Report (GHD, 2025a)).

Refer to Appendix G for detailed descriptions of the assessment methodologies.

# 3.5 GOP excavation analysis results

The below sections provide summarised assessment results, with additional detail provided in Appendix G.

## 3.5.1 Groundwater levels and flow

### Shallow groundwater levels

The predicted groundwater drawdown of the shallow water table from current conditions at the edge of the pit in the GOP excavation assessment scenario is presented in Table 3.5. Groundwater drawdown at the edge of the pit is expected to range between 3-8 m, with a drawdown zone of influence (ZOI) extending up to approximately 290 m. The magnitude of drawdown corresponds with the depth of the saturated material of the shallow groundwater system exposed at the pit rim. Distance drawdown graphs and the predicted groundwater water table with distance from the pit are presented in Appendix G. Predicted shallow groundwater levels and groundwater flow paths for the GOP excavation scenario are also presented in the cross sections in Figure 3.12. Groundwater levels at the Gladstone Wetland are predicted to reduce by approximately 0.5 m.

*Table 3.5 Predicted change in groundwater table compared to current conditions and ZOI for GOP excavation*

| Direction from pit | Groundwater level change at edge of pit (m) | Drawdown zone of influence (m)* |
|---|---|---|
| North | -3 | 60 |
| East | -6 | 155 |
| South | -8 | 290 |
| West | -6 | 210 |
| Notes:<br>* Where drawdown > 0.5 m<br>- Considering model uncertainty, results are rounded. | | |

Shallow groundwater inflow and stormwater runoff is likely to be captured and discharged to the WTP during excavation of the GOP, however if the deep groundwater system is under-drained, seepage to the andesite may occur. After reaching saturated conditions, the seepage will migrate with deep groundwater flow to underground mine dewatering systems.

The Gladstone vein dewatering assessment modelled a maximum of 0.04 m of groundwater drawdown of the shallow water table from current conditions during pit excavation and dewatering at the location of the Ohinemuri River southwest of the pit (Figure 3.13). The model results also reported a reduction in Ohinemuri River baseflow of 1.5 $m^3$/day southwest of the proposed GOP in response to vein dewatering to 1,005 mRL (Table 3.6). The low magnitude of expected groundwater drawdown and change in river flow is an expression of the separation of the shallow and deep groundwater systems. Potential impacts to the Ohinemuri River as a result of excavation of the pit and resulting changes in the shallow groundwater system are discussed in Section 3.5.2.

*Table 3.6 Predicted change in Ohinemuri River flow compared to current conditions in Gladstone vein dewatering scenario*

| Surface water body | Predicted change in Ohinemuri River flow ($m^3$/day) |
|---|---|
| Ohinemuri River | -1.5 |

## Deep groundwater levels

As presented in Table 3.5, the influence on shallow groundwater is expected to be constrained to within 290 m of the Gladstone Pit, and within this area a slight loss of recharge to the deep groundwater system. This reduction is likely small in magnitude and expected to have an insignificant influence on deep groundwater levels.

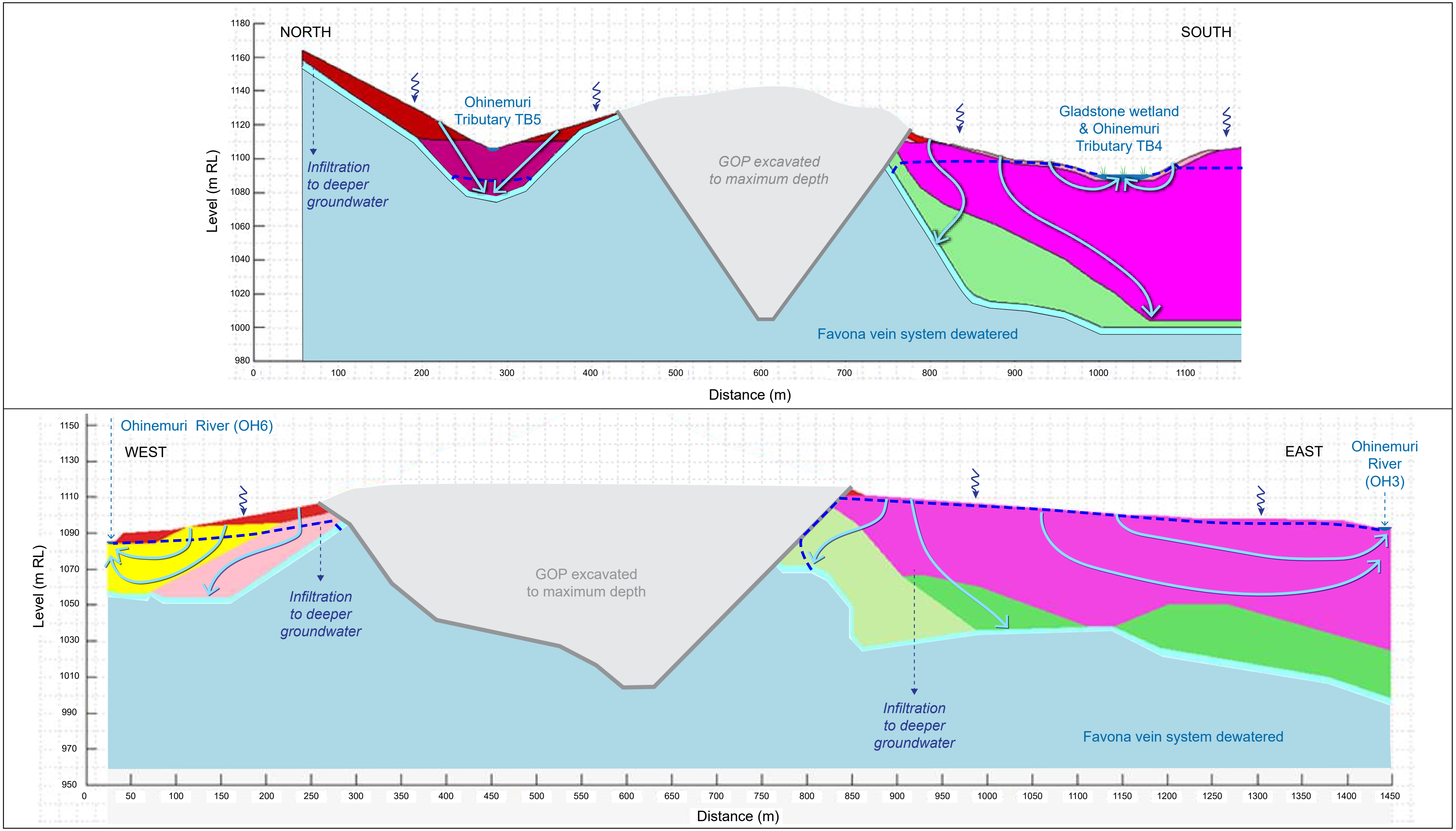
The Gladstone vein dewatering assessment assumes that a strong hydraulic connection is present along the vein system between the GOP and the Ohinemuri River, which will allow the vein system to dewater to an elevation of 1,005 mRL to model the maximum potential groundwater drawdown and resulting influence on the river. The predicted extent of unsaturated andesite perpendicular to the Gladstone vein where it is dewatered to the maximum depth of 1,005 mRL is presented in Table 3.7.

*Table 3.7 Deep groundwater drawdown from current conditions and ZOI for Gladstone vein dewatering*

| Direction from vein system | Predicted extent of unsaturated andesite within deep groundwater system (m from Gladstone vein)* |
|---|---|
| Northwest | 80 (with additional 20 m extent of unsaturated conditions approximately 180 – 200 m from the Gladstone vein) |
| Southeast | 230 |
| Notes:<br>* Where pore water pressure is less than zero<br>- Considering model uncertainty, results are rounded. | |

The likely upper bound of the extent of unsaturated andesite in the deep groundwater system is presented in plan view in Figure 3.14. The maximum extent perpendicular to the vein system was informed by the results presented in Table 3.7, while the assessment of the extent along the strike of the vein considered:

- The interpreted site setting using existing groundwater monitoring levels, and the impacts experienced during dewatering of Favona. It is assumed that groundwater within the veins and surrounding andesite at Gladstone will respond in a similar manner to that at Favona.
- Favona mine dewatering is predicted to have resulted in an upper bound drawdown extending from P60, which is fully dewatered, to GLD04 where the effects of dewatering are not detectable.
- During excavation and dewatering of the GOP, the maximum point of drawdown will be the centre of the pit approximately 200 m southwest of P60. The predicted upper bound drawdown has therefore been extended the same distance southwest of GLD04.




LEGEND

- Andesite
- Ash / Regolith
- Dacite
- Hydrothermal Breccia
- RT
- Sandy Ignimbrite
- Volcaniclastic
- Weathered Andesite
- Proposed Gladstone Pit
- Potentiometric groundwater level
- Groundwater Recharge
- Groundwater Flow Direction
- Wetland / tributary

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Waihi North

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| Job Number | 12552081 |
| Revision | 0 |
| Date | 07 Dec 2021 |

GOP Excavation Results

Figure 3.12

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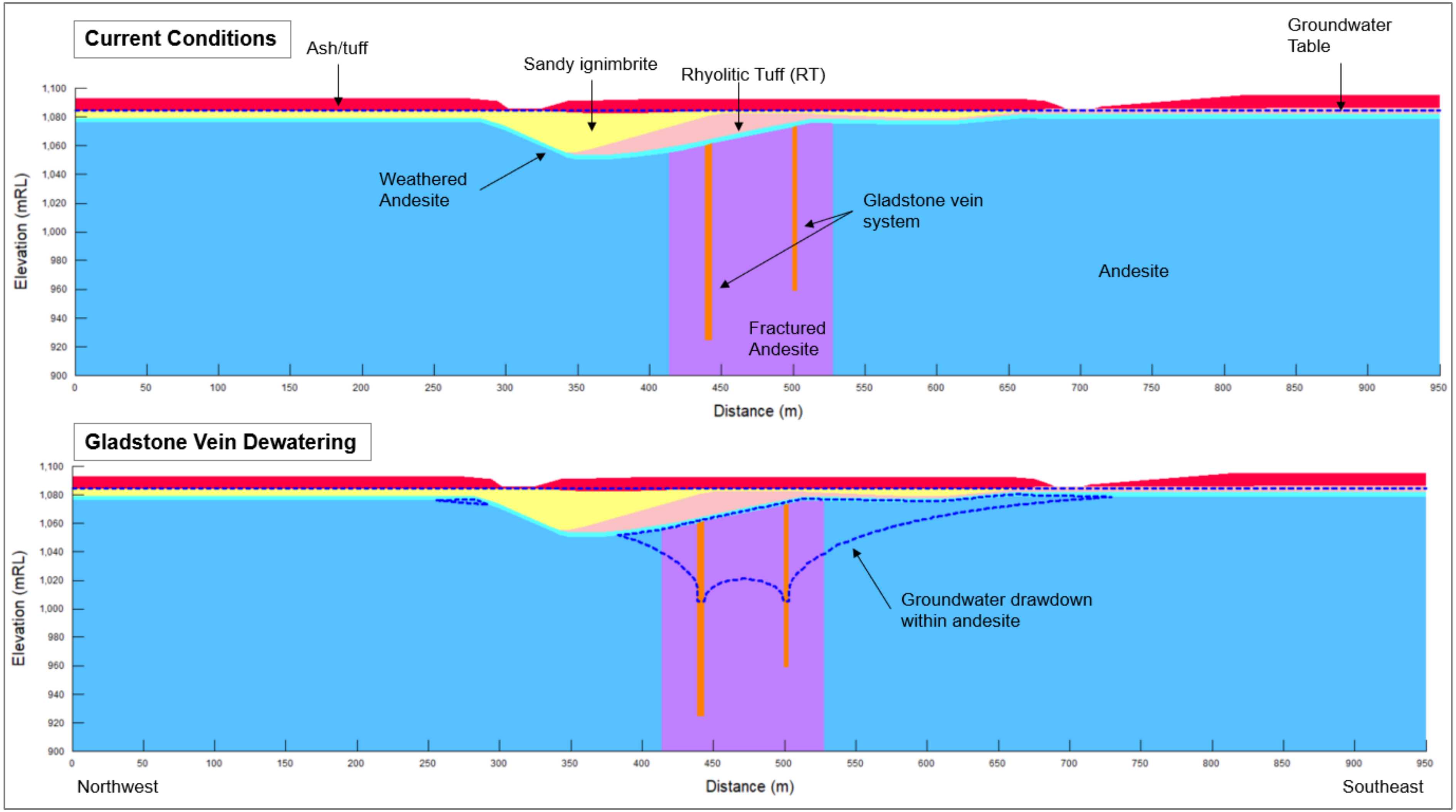
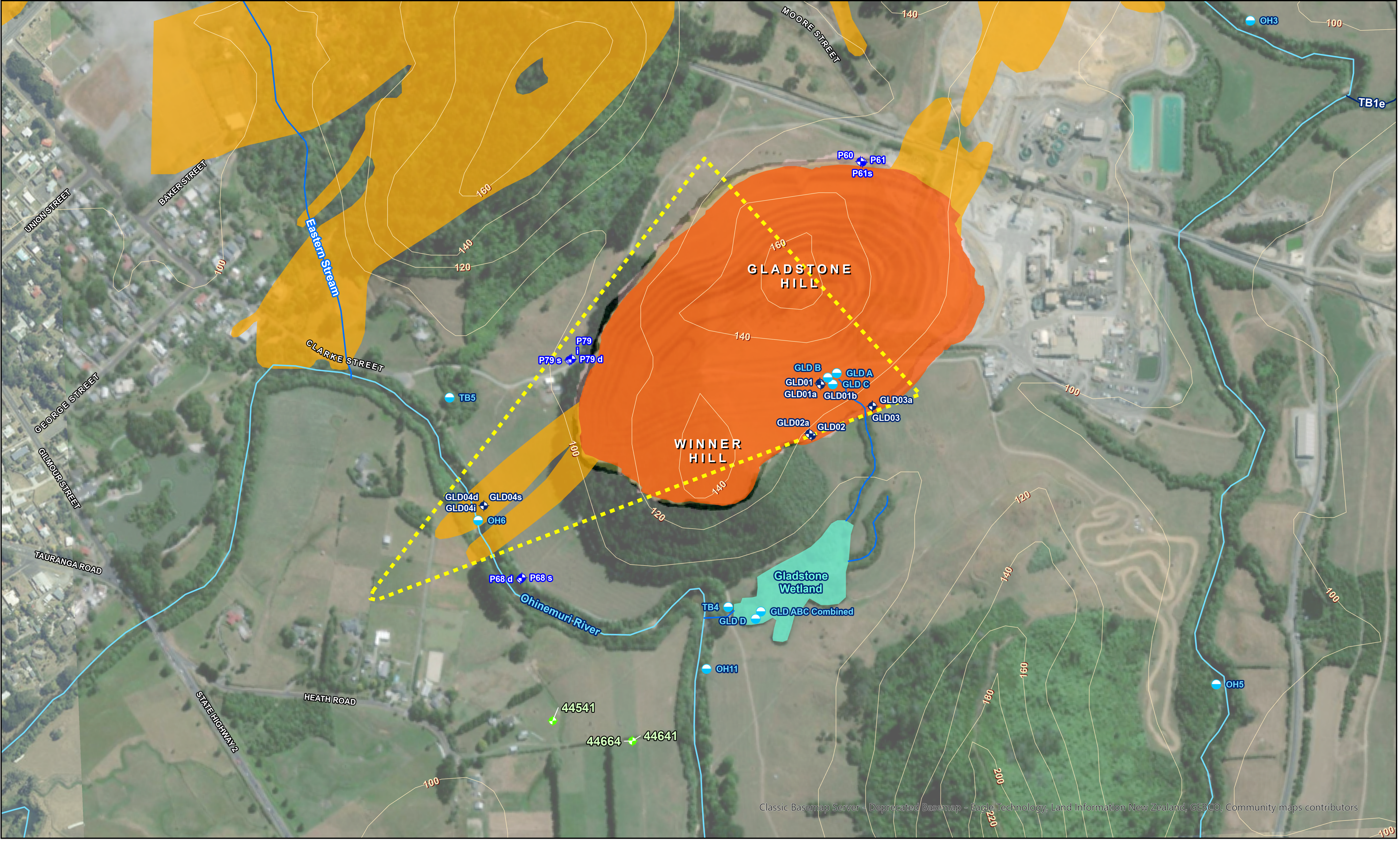



*Figure 3.13 Gladstone vein dewatering assessment perpendicular to vein strike – groundwater levels for current conditions and Gladstone vein dewatering scenarios*




Paper Size A3

0 50 100 200

Metres

Map Projection: Transverse Mercator
Horizontal Datum: NZGD 2000
Grid: NZGD 2000 New Zealand Transverse Mercator

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LEGEND

- OGL Bores
- Quattro Bores
- Surface Water Locations
- Registered bores (WRC Well ID) - excluding OGL bores
- Likely upper bound for zone of unsaturated andesite in deep groundwater system
- Proposed Gladstone Pit
- Inferred mineralised vein system

**Ohinemuri River Tributary**

- River
- Stream
- Tributary
- Wetland
- Contour (20m)

GHD

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Gladstone dewatering zone of unsaturated andesite

| | |
|---|---|
| Job Number | 12590241 |
| Revision | 1 |
| Date | 13 Feb 2025 |

Figure 3.14

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Data source: Aerial imagery - LINZ; General topo - LINZ; Bore locations - OGL. Created by:nrama

## GOP groundwater inflow

Groundwater inflows to the open pit from the shallow groundwater system in the GOP excavation scenario have been modelled for four sections around the pit and with the results presented in Table 3.8.

The following is noted:

– Greater inflow rates from the shallow groundwater system than those presented in Table 3.8 are likely to be observed during the initial excavation period, as higher groundwater levels will generate strong groundwater gradients towards the pit.
– Inflows from the north, south and west are negligible as groundwater modelling indicates that the water table won't intercept the pit wall where the shallow materials are exposed during this phase of works (Figure 3.12).

*Table 3.8 Estimated inflows to GOP from shallow groundwater system during GOP excavation*

| Pit section | Shallow groundwater inflow (m$^3$/day) |
|---|---|
| North | Negligible |
| East | 9 |
| South | Negligible |
| West | Negligible |
| **Total** | **9** |
| Notes:<br>- Considering model uncertainty, results are rounded. | |

Historical dewatering activities in the vicinity of Gladstone, including for the Favona-Moonlight system, is considered to provide a reasonable approximation for the likely rate of groundwater inflow to the proposed GOP from the deep groundwater system. The average daily discharge recorded during dewatering of the Favona underground is presented in Figure 3.15, alongside mine (dewatering) depth and estimated groundwater inflow (GWS, 2018a). During initial mine dewatering groundwater discharge includes water sourced from storage within the connected vein systems as well as groundwater inflow to the vein systems from the surrounding rockmass. After the groundwater from storage has been depleted, the groundwater inflows reach an equilibrium, considered by GWS (2018a) to have occurred in 2014 (Figure 3.15). This results in maximum groundwater discharge rates occurring between the commencement of mining and shortly after the maximum mine depth is reached.

Prior to dewatering of the Favona system, there was no hydraulic connection to the Martha ore bodies to the west due to structural barriers to groundwater flow (Figure 2.2). Groundwater discharge in Figure 3.15 was therefore sourced from the connected vein system and surrounding rockmass within the 'Waihi East' area. In contrast, inflows to the proposed GOP are only anticipated to be sourced from a much smaller, currently disconnected section of the Gladstone vein system to the southwest of the pit. The qualitative assessment of groundwater inflow to the proposed GOP during excavation has conservatively assumed similar groundwater inflow rates as those recorded during mining of Favona to 1,005 mRL (the proposed GOP depth), however reduced by 50% considering the Gladstone vein system immediately northeast of the proposed GOP is recorded as dewatered (Section 3.3.3) with inflows only considered to occur from the southwest. The results of the qualitative assessment are presented in Table 3.9.

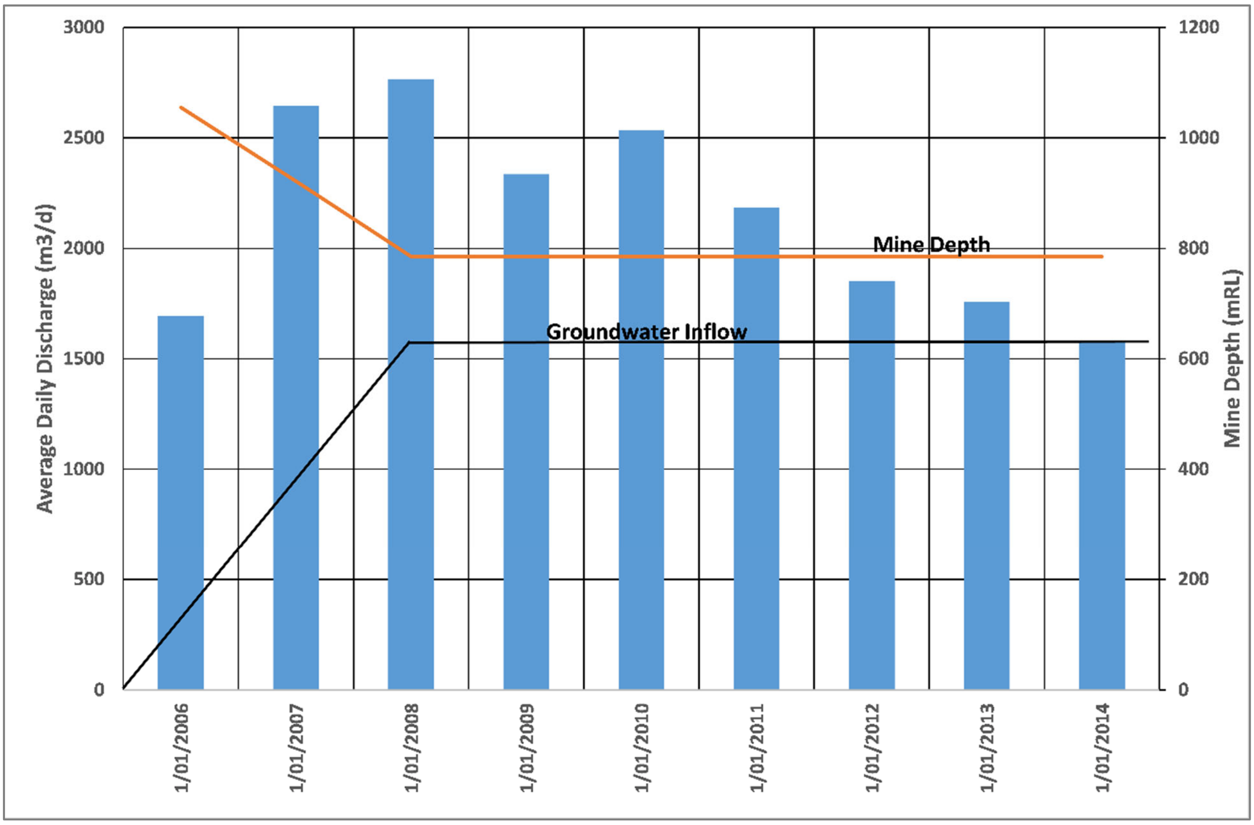



*Figure 3.15 Favona pumping discharge plotted alongside mine depth and estimated groundwater inflow (GWS, 2018a)*

*Table 3.9 Recorded Favona groundwater discharge and predicted GOP groundwater discharge*

| GOP phase of excavation | Average daily groundwater discharge ($m^3$/day) | |
|---|---|---|
| | Recorded during Favona dewatering ($m^3$)(1) | Predicted during GOP excavation |
| Initial excavation to maximum depth | 2,200(2) | 1,100 |
| Long-term groundwater inflow | 650(3) | 325 |

Notes:
1. Favona discharge based on results presented in Figure 3.15.
2. Average of 2006 and 2007 daily discharge, as mine depth of 1,005 mRL was reached at the end of 2006.
3. Groundwater inflow estimated by GWS (2018a) when mine depth reached 1,005 mRL.

The results from the groundwater model developed for the Gladstone vein dewatering assessment indicate that approximately 11 $m^3$/day of long-term groundwater inflow will occur from each 1 m section where maximum groundwater drawdown to 1,005 mRL occurs within the Gladstone vein. Assuming a linear relationship of drawdown with distance, and using the predicted groundwater inflow derived from the Favona data, this indicates that unsaturated andesite along the strike of the vein will extend approximately 60 m. This is a smaller extent than predicted in Figure 3.14 and demonstrates the conservatism of the groundwater modelling assessment. The actual inflow rates likely to be experienced are notably lower than 11 $m^3$/day per 1 m section along the strike of the vein. The extent of unsaturated andesite perpendicular to the vein strike modelled during the vein dewatering assessment (Table 3.7 and Figure 3.14) is therefore also considered to represent an upper bound.

### 3.5.2 Groundwater flow to receiving environment

During GOP excavation and dewatering, loss of recharge and reduction in shallow groundwater levels is predicted to reduce shallow groundwater flow to surface water to a small degree, with the predicted changes summarised in Table 3.10.

No changes in shallow groundwater flow to the north, towards the Ohinemuri tributary TB5, are predicted to result from GOP excavation. This is because the existing groundwater catchment area and groundwater gradients within the catchment are not predicted to be impacted.

*Table 3.10 Predicted groundwater discharge to surface water during GOP excavation*

| Surface water body | Estimated groundwater discharge to surface water body ($m^3$/day) | | Percentage change in groundwater discharge | Percentage change in groundwater catchment area |
|---|---|---|---|---|
| | Current conditions | GOP excavation scenario | | |
| Gladstone wetland / Ohinemuri tributary (TB4) | 1.0 | 0.7 | -30% | -20% |
| Ohinemuri River east of Gladstone (OH3) | 50 | 50 | <-1% | -10% |
| Ohinemuri River west of Gladstone (OH6) | 215 | 160 | -30% | -20% |
| Notes:<br>- Considering model uncertainty, results have been rounded. | | | | |

### 3.5.3 Surface water catchments

The reduction in the surface water catchment areas due to GOP excavation is predicted to reduce runoff and interflow, and hence peak flow in the tributaries. The predicted change in catchment areas are presented in Table 3.11.

*Table 3.11 Predicted change in surface water catchment areas during GOP excavation*

| Surface water catchment | Percentage change in catchment area |
|---|---|
| Gladstone Wetland / Ohinemuri Tributary (TB4) | -26% |
| Ohinemuri Tributary (TB5) | -16% |
| Ohinemuri River west of Gladstone (OH6)[1] | -20% |
| Ohinemuri River east of Gladstone (OH3)[1] | -20% |
| 1. Constrained to the area between the Gladstone Pit and Ohinemuri River | |

## 3.6 Gladstone TSF analysis results

The below sections provide summarised assessment results, with additional detail provided in Appendix G.

### 3.6.1 Groundwater levels and flow

The predicted groundwater drawdown from current conditions at the edge of the pit after development of the TSF and the drawdown ZOI are presented in Table 3.12. The predicted groundwater table with distance from the pit is presented for all scenarios in Appendix G. Predicted groundwater levels and groundwater flow paths for each TSF scenario are also represented in the cross sections in Figure 3.16, Figure 3.17 and Figure 3.18.

*Table 3.12 Predicted change in groundwater table compared to current conditions and drawdown ZOI after development of the TSF*

| Orientation from pit | Operational TSF | | TSF closure | | Long-term TSF | |
|---|---|---|---|---|---|---|
| | Groundwater level change at edge of pit (m) | Zone of influence (m)* | Groundwater level change at edge of pit (m) | Zone of influence (m)* | Groundwater level change at edge of pit (m) | Zone of influence (m)* |
| North | -3 | 56 | -3 | 36 | -2 | 28 |
| East | -6 | 155 | -6 | 120 | -5 | 99 |
| South | -8 | 288 | -8 | 88 | -7 | 69 |
| West | -6 | 212 | -5 | 124 | +2 | - |
| Notes:<br>* Where drawdown > 0.5 m<br>- Considering model uncertainty, results are rounded | | | | | | |

The following is noted regarding influence on groundwater levels during various phases of Gladstone TSF assessment:

– During development of the TSF (operational TSF scenario) the groundwater drawdown adjacent to the pit, and the drawdown of the groundwater table with distance from the pit, is predicted to be very similar to that during GOP excavation (discussed in 3.5.1). This is because no additional recharge to the shallow groundwater system is predicted to occur during this early phase of the TSF development. Instead, tailings pore water not recovered at surface as decant is predicted to discharge through the base of the pit to the deep groundwater system, with no connection to the adjacent shallow groundwater system (Figure 3.16).

– After rewatering of the deep groundwater system (TSF closure and long-term TSF scenarios) as a result of cessation of mine dewatering and formation of Martha Pit Lake, the greater pressure in the deep system is expected to reduce or reverse the local downward vertical hydraulic gradients between the shallow and deep groundwater systems (Figure 3.17 and Figure 3.18). This in turn reduces the predicted groundwater drawdown at the edge of the pit and the drawdown zone of influence (Table 3.12).

– In the TSF closure scenario the groundwater table to the north and south (Figure 3.17) of the pit is predicted to rise in comparison to current conditions. This is again due to the changes in vertical hydraulic gradients as a result of rewatering of the deep groundwater system. In addition, the groundwater table to the west of the pit is also predicted to increase in comparison to current conditions in the long-term TSF scenario (Figure 3.18) as a result of increased recharge to this catchment in the form of groundwater discharge from the TSF (further discussed in Section 3.6.2).

– Excavation of the GOP will remove the upper sections of the intermittent TB4 tributary. In the TSF closure and long-term TSF scenarios, groundwater discharge is expected to re-establish in the lower reaches approximately 115 - 125 m downstream of the headwaters, with a predicted rise in the shallow groundwater table of approximately 3 m in the vicinity of the wetland due to reduced or reversed downwards vertical hydraulic gradients.

The predicted total groundwater flow to surface water bodies for each TSF scenario is presented in Table 3.13*,* Table 3.14 and Table 3.15*.* An increase in total groundwater discharge to surface water in comparison to current conditions is predicted in the TSF closure and long-term TSF scenarios as a result of increased groundwater levels and changes in vertical hydraulic gradients.

With the exception of the Ohinemuri River to the east (OH3), an additional increase in discharge to surface water is predicted in the long-term TSF scenario in comparison to the TSF closure scenario, which is due to discontinued operation of the TSF drainage system allowing groundwater levels in close proximity to the pit to increase, also reflected in the further reduction of groundwater drawdown at the edge of the pit (Table 3.12). The reason why there is no change to the discharge to the Ohinemuri River to the east (OH3) is that the TSF drainage system is predicted to have little effect on this catchment due to a large thickness of low permeability breccia separating the deep and shallow groundwater systems and no discharge from the TSF predicted to the east in the long-term TSF scenario.

*Table 3.13 Estimated groundwater discharge to surface water bodies during operational TSF scenario*

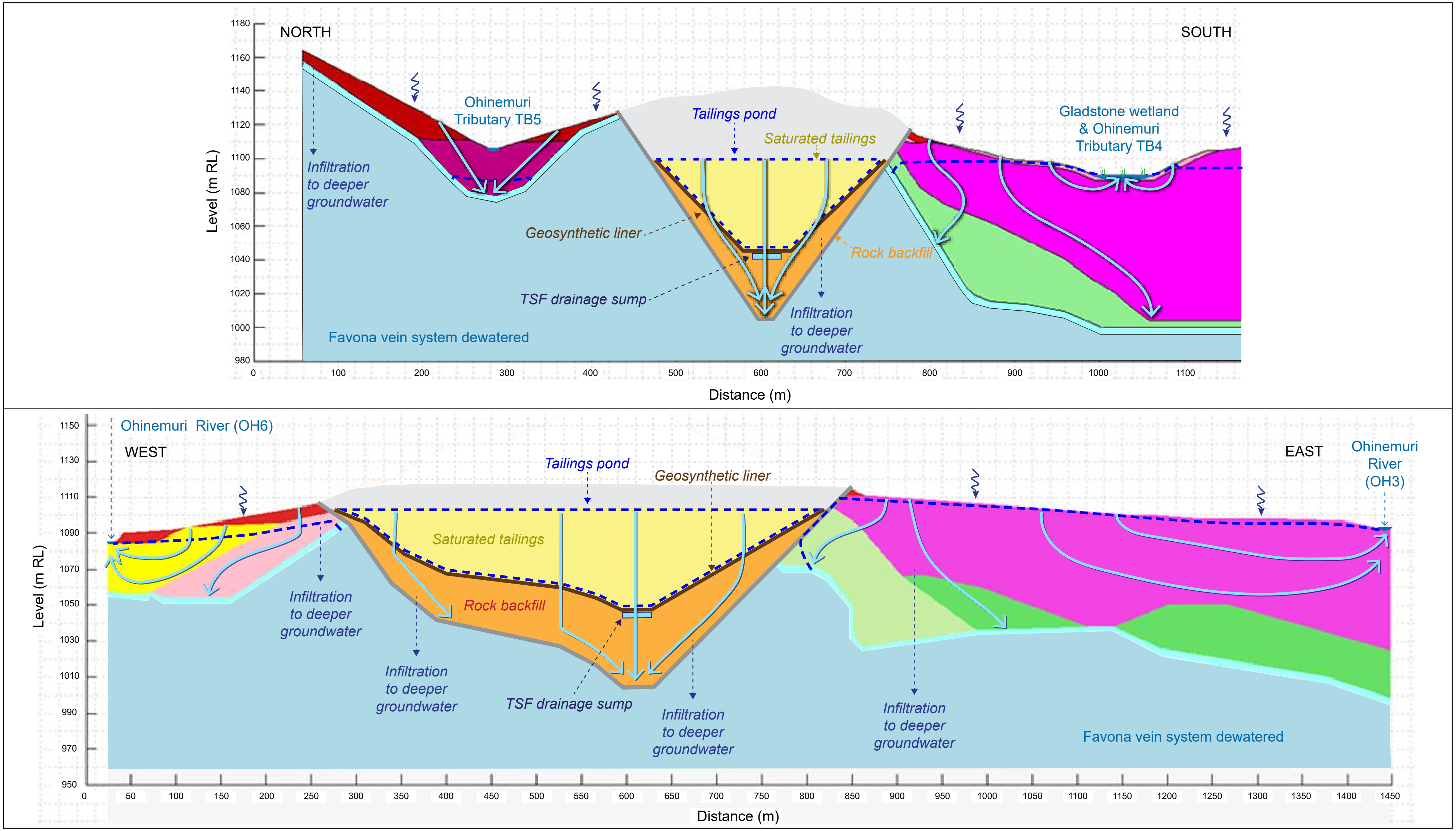
| Surface water body | Estimated groundwater discharge to surface water body ($m^3$/day) | Percentage change in groundwater discharge from current conditions | Percentage change in groundwater catchment |
|---|---|---|---|
| Gladstone Wetland / Ohinemuri tributary (TB4) | 0.5 | -33% | -22% |
| Ohinemuri tributary (TB5) | 0 | 0% | 0% |
| Ohinemuri River east of Gladstone (OH3) | 50 | -<1% | -12% |
| Ohinemuri River west of Gladstone (OH6) | 160 | -27% | -19% |
| Notes:<br>- Considering model uncertainty, results have been rounded. | | | |

*Table 3.14 Estimated groundwater discharge to surface water bodies during TSF closure scenario*

| Surface water body | Estimated groundwater discharge to surface water body ($m^3$/day) | Percentage change in groundwater discharge from current conditions | Percentage change in groundwater catchment |
|---|---|---|---|
| Gladstone Wetland / Ohinemuri tributary (TB4) | 2.5 | +156% | +84% |
| Ohinemuri tributary (TB5) | 0 | 0% | 0% |
| Ohinemuri River east of Gladstone (OH3) | 55 | +15% | +10% |
| Ohinemuri River west of Gladstone (OH6) | 210 | -2% | -7% |
| Notes:<br>- Considering model uncertainty, results have been rounded. | | | |

*Table 3.15 Estimated groundwater discharge to surface water bodies during long-term TSF scenario*

| Surface water body | Estimated groundwater discharge to surface water body ($m^3$/day) | Percentage change in groundwater discharge from current conditions |
|---|---|---|
| Gladstone Wetland / Ohinemuri tributary (TB4) | 3 | +197 |
| Ohinemuri tributary (TB5) | 5 | NA* |
| Ohinemuri River east of Gladstone (OH3) | 55 | +15% |
| Ohinemuri River west of Gladstone (OH6) | 315 | +46% |
| Notes:<br>- Considering model uncertainty, results have been rounded.<br>* Calculation not undertaken as no groundwater baseflow predicted during current conditions | | |




LEGEND

| | | | |
|---|---|---|---|
| Andesite | RT | Proposed Gladstone Pit | Wetland / tributary |
| Ash / Regolith | Sandy Ignimbrite | Potentiometric groundwater level | TSF drainage sump |
| Dacite | Volcaniclastic | Groundwater Recharge | Geosynthetic liner |
| Hydrothermal Breccia | Weathered Andesite | Groundwater Flow Direction | Saturated tailings / rock backfill |

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Date 08 Dec 2021

Operational TSF Results

Figure 3.16

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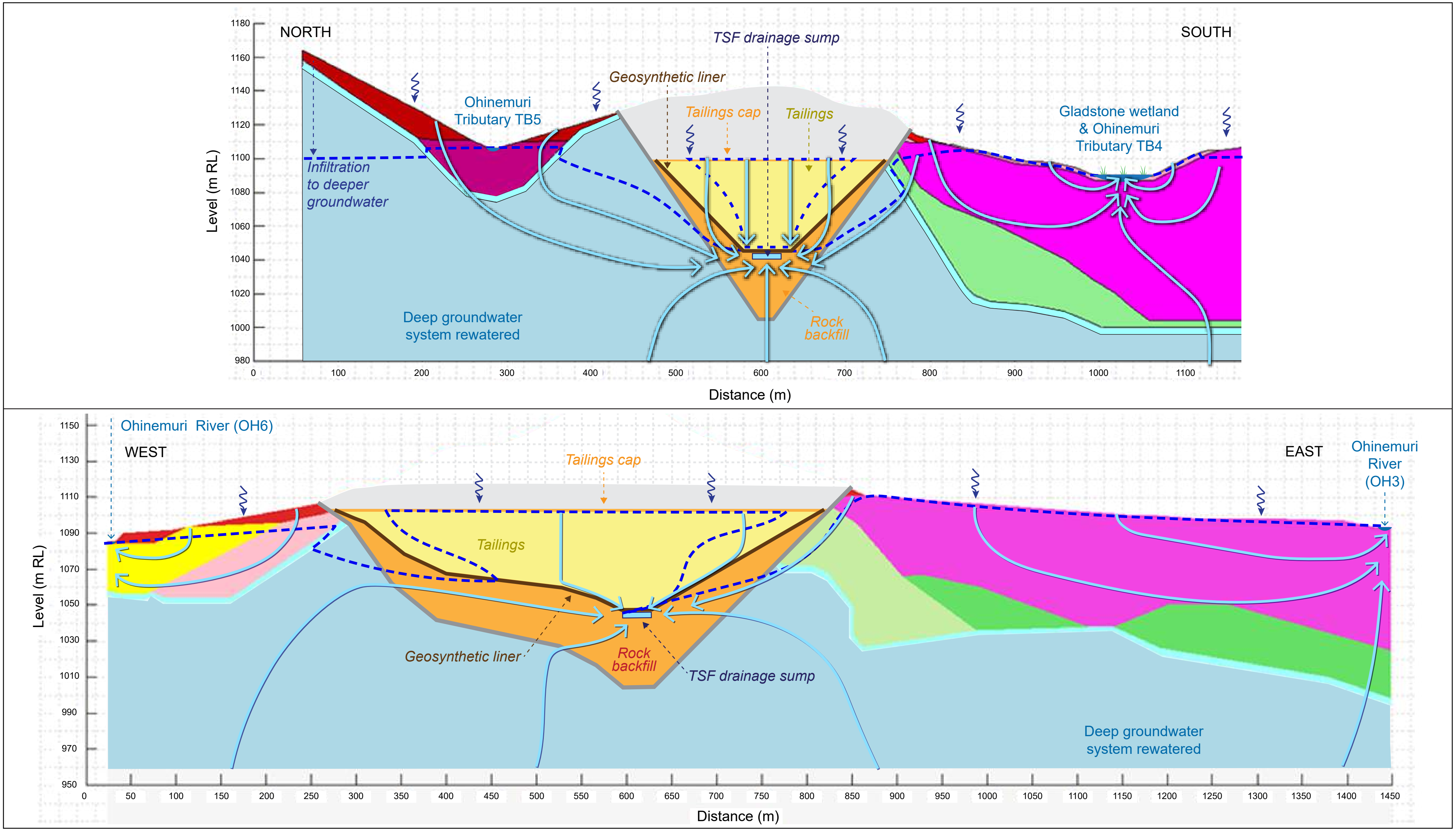


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| | | |
|---|---|---|
| Andesite | RT | Proposed Gladstone Pit |
| Ash / Regolith | Sandy Ignimbrite | Potentiometric groundwater level |
| Dacite | Volcaniclastic | Groundwater Recharge |
| Hydrothermal Breccia | Weathered Andesite | Groundwater Flow Direction |
| Wetland / tributary | TSF drainage sump | Geosynthetic liner |
| Tailings / rock backfill | | |

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Long-term TSF Results

Figure 3.17

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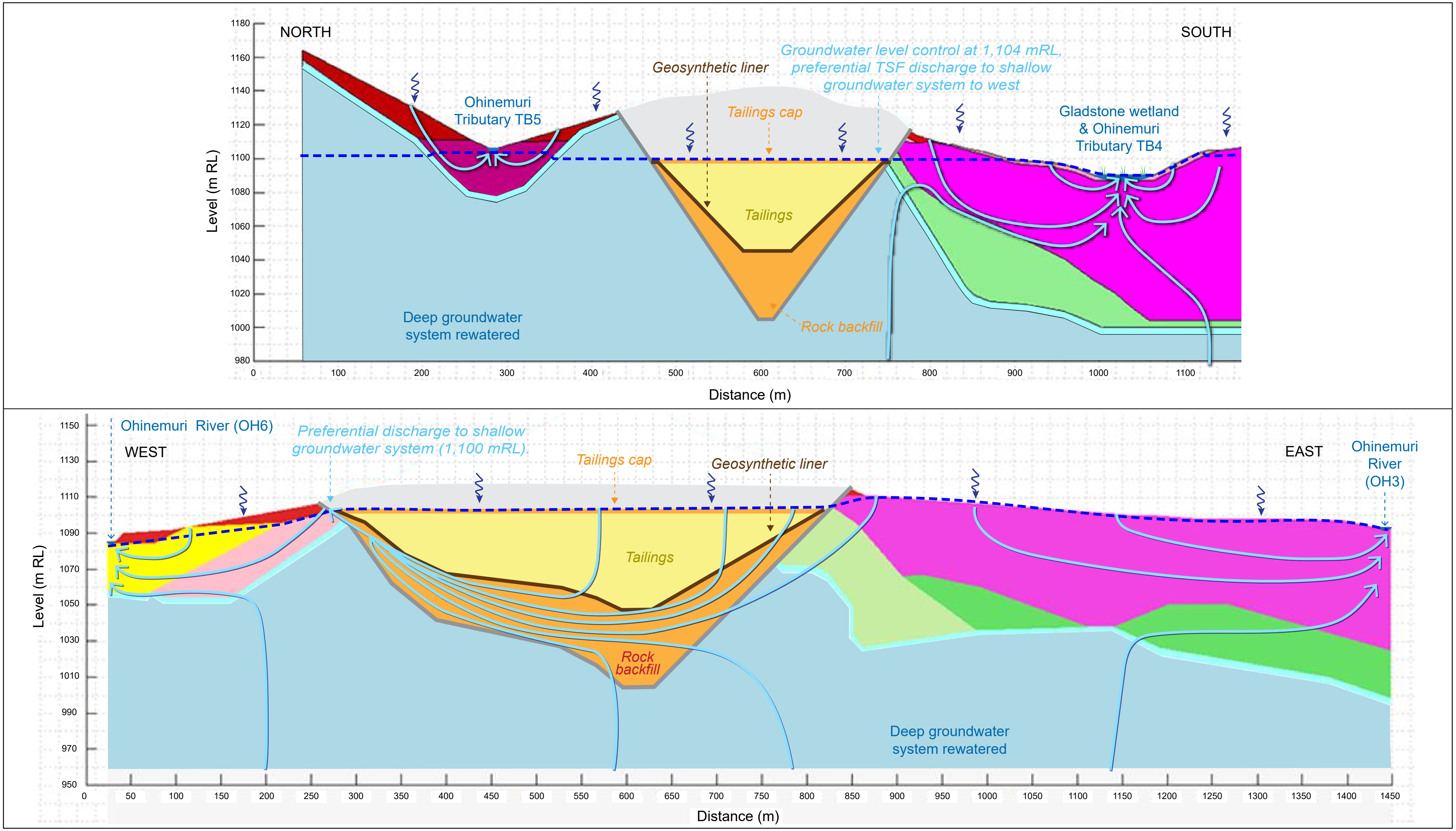


LEGEND

| | | | |
|---|---|---|---|
| Andesite | RT | Proposed Gladstone Pit | Wetland / tributary |
| Ash / Regolith | Sandy Ignimbrite | Potentiometric groundwater level | Geosynthetic liner |
| Dacite | Volcaniclastic | Groundwater Recharge | Tailings / rock backfill |
| Hydrothermal Breccia | Weathered Andesite | Groundwater Flow Direction | |

Oceana Gold Limited
Waihi North

Job Number 12552081
Revision 0
Date 08 Dec 2021

TSF Closure Results

Figure 3.18

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Level 3, 138 Victoria Street, PO Box 13 468, Christchurch 8141, New Zealand T 64 3 378 0900 F 64 3 378 8001 E chcmail@ghd.com W www.ghd.com



Data source: GHD. Created by:jrprice

### 3.6.2 Gladstone TSF discharge to receiving environment

Discharge of groundwater that is predicted to migrate to a surface water body from the TSF is presented in Table 3.16.

*Table 3.16 Estimated discharges from the pit area to surface water in the current conditions scenario, and from the TSF in the operational, TSF closure and long-term TSF scenarios*

| Pit section | Estimated groundwater discharge to surface water bodies ($m^3$/day)* | | | |
|---|---|---|---|---|
| | Current conditions | Operational TSF | TSF closure | Long-term TSF |
| North (TB5) | 0 | 0 | 0 | 0 |
| East (OH3) | 0 | 0 | 0 | 0 |
| South (TB4) | 0 | 0 | 0 | 0 |
| West (OH6) | 4 | 0 | 0 | 65 (5 - tailings porewater) |
| **Total** | **4** | **0** | **0** | **65** |
| Notes:<br>- Considering model uncertainty, results are rounded | | | | |

Estimated groundwater discharge from the proposed Gladstone Pit area (current conditions) that is predicted to migrate to a surface water body is only 4 $m^3$/day to the Ohinemuri River (OH6). This relatively low flow is primarily due to the limited thickness and saturation of the shallow groundwater system across the elevated Gladstone Hill and Winner Hill areas. Leakage to the deep groundwater system due the downwards hydraulic gradients also removes a small amount of shallow groundwater which would otherwise flow to surface water (Figure 3.5 and Figure 3.6).

During development of the TSF (operational TSF scenario), there is no predicted discharge of groundwater from the TSF to the shallow groundwater system, as all recharge through the TSF is predicted to discharge to the deep groundwater system (Figure 3.16).

In the TSF closure scenario, groundwater flux into the TSF is from groundwater upwelling following rewatering of the deep groundwater system, with rainwater infiltration through the capping layer also contributing water to the TSF. However, the TSF is hydraulically contained by the drainage system which generates a groundwater gradient towards the base of the tailings (Figure 3.17), again resulting in no discharges to the shallow groundwater system.

In the long-term TSF scenario, the TSF drainage system is no longer operational which allows groundwater to flow into the TSF and discharge to the adjacent shallow groundwater system where it migrates to surface water bodies (Figure 3.18). The relatively permeable rock backfill which forms the TSF sub-grade provides a preferential flow path for groundwater upwelling from the deep groundwater system with limited contact with the tailings, while infiltration through the capping layer migrates towards the pit rim in rock backfill placed above the tailings. As such, only a small volume of water migrating through the TSF to the shallow groundwater system is predicted to be influenced by tailings.

Discharge from the TSF in the long-term TSF scenario is predicted to occur through the western area of the pit. The maximum rock backfill and TSF capping layer elevation of 1,107 mRL means that the TSF only contacts the relatively permeable young volcanics that host the shallow groundwater system at the western edge of the pit. To the west the shallow groundwater system extends as low as approximately 1,100 mRL at the pit boundary. In the long-term TSF scenario, the groundwater level with the TSF is predicted to be higher than this, creating saturated flow outwards from the TSF towards the Ohinemuri River (OH6). To the north and south, the TSF is only in contact with lower permeability andesite and/or breccia. To the east, a hydraulic divide is predicted close to the pit boundary, creating inwards hydraulic gradients from the shallow groundwater system towards the TSF, inhibiting discharge in this direction.

### 3.6.3 Surface water catchments

The reduction in the surface water catchment areas in the operational TSF scenario is predicted to reduce runoff and interflow, and hence peak flow in the tributaries. After capping of the TSF (TSF closure and long-term TSF scenarios) the proposed gently contoured surface will direct stormwater run-off. It is expected that this will restore, or increase, surface water contribution to the catchment to the south (TB4 catchment). The predicted change in surface water catchment areas in all TSF scenarios are presented in Table 3.17.

*Table 3.17 Predicted change in surface water catchment area after TSF development*

| Surface water catchment | Percentage change in surface water catchment area from current conditions | |
|---|---|---|
| | Operational TSF | TSF Closure / Long-term TSF |
| Ohinemuri Tributary (TB5) | -16% | -16% |
| Ohinemuri River west of Gladstone (OH6)[1] | -20% | -20% |
| Ohinemuri River east of Gladstone (OH3)[1] | -20% | -20% |
| Ohinemuri Tributary (TB4) | -26% | Up to +74% |
| 1. Constrained to the area between the Gladstone Pit and Ohinemuri River | | |

### 3.6.4 Deep groundwater drainage to WTP

The predicted flow of water impacted by the backfilled rock and tailings and the flow of deep groundwater as a result of operation of the TSF drainage system in the operational and TSF closure scenarios is presented in Table 3.18.

*Table 3.18 Predicted flow to the deep groundwater system and TSF drainage system in the operational TSF and TSF closure scenarios*

| Deep groundwater receptor | Flow ($m^3$/day) | |
|---|---|---|
| | Operational TSF | TSF Closure |
| ***Assumed deep groundwater levels*** | ***Below TSF drain levels*** | ***Above TSF drain levels*** |
| Deep groundwater system | 187 (tailings porewater) | 0 |
| Gladstone TSF drainage system | 0 | 1,252 total<br>(58 tailings porewater)<br>(1,194 deep groundwater) |

No discharge is predicted through the TSF drainage system when deep groundwater levels are at an elevation below the proposed drains, as the materials surrounding the drainage sump will remain unsaturated, preventing the migration of tailings porewater discharge towards the drains. Where groundwater levels are at an elevation above the proposed TSF drainage system the drainage sump will be saturated allowing the generation of a groundwater gradient towards the drains. These conditions are anticipated to provide hydraulic containment of the tailings porewater, with no discharges predicted to either the deep or shallow groundwater systems. Water impacted by the backfilled rock and tailings that has discharged through the TSF drainage system will be directed to the WTP for treatment.

For a situation where the deep groundwater system at Gladstone is currently dewatered as a result of mine dewatering to an elevation lower than the proposed TSF drainage system, as represented by the operational TSF scenario, then the tailings porewater from the TSF is predicted to discharge into the deep groundwater system. The tailings porewater is then anticipated to migrate with groundwater towards other (deeper) underground mine dewatering systems where it will be captured and directed to the WTP. In the event that the impacted groundwater is not captured prior to cessation of mine dewatering, new groundwater gradients would either direct the groundwater back towards the TSF drainage system, or towards the Martha Pit Lake (1,104 mRL proposed level).

For a situation where the deep groundwater system at Gladstone is not currently fully dewatered, and groundwater levels are at a higher elevation than the proposed TSF drainage system, the tailings porewater is anticipated to be hydraulically contained. This alternative operational TSF scenario would have similar results to the TSF closure scenario, which considers a situation where full rewatering of the deep groundwater system has occurred after mine dewatering has ceased.

Operation of the TSF drainage system will be discontinued after a sufficient improvement in water quality of the discharge has been recorded (long-term TSF scenario). Discharges of tailings porewater to the receiving environment in the long-term TSF scenario are discussed in Section 3.6.2.

### 3.6.5 Water quality

Following development of the TSF interaction of groundwater with rock backfill/tailings will influence groundwater quality. In the long-term TSF scenario the drainage system will no longer be operational and groundwater discharge is expected to the west of the pit (Section 3.6.2). Groundwater flowing through the TSF will interact with the NAF weathered rock capping layer, the backfilled PAF rock and tailings pore water, however the concentration of trace elements will be influenced by the rate of leaching, which will be many orders of magnitude lower through the consolidated tailings than through the rock backfill.

The water quality assessment has therefore considered the following groundwater flow pathways when assessing TSF discharge:

- Groundwater interaction with tailings impacted porewater.
- Groundwater recharge through the NAF weathered rock capping layer.
- Deep groundwater flow through leached PAF and NAF rock backfill.

The results of equilibrated TSF discharge, which considered the above flow pathways, with shallow groundwater (AECOM, 2021a) have then been used to undertake a mixing model with the Ohinemuri River. The predicted effects to the receiving water quality for the long-term TSF scenario are provided in Table 3.19.

The results indicate that elevated concentrations of number of parameters associated with tailings discharge are likely within the shallow groundwater west of the Gladstone pit during the long-term TSF scenario. This includes iron, mercury and zinc which are predicted to exceed the receiving water quality criteria. Mercury is typically immobile in groundwater due to volatilization and/or precipitation processes and has not been reported in significant persistent concentrations by OGNZL (2020). It is not a parameter of concern for these reasons. Although zinc is also predicted to exceed the receiving water quality criteria in the shallow groundwater in the long-term TSF scenario, the concentration represents a reduction from existing conditions recorded in GLD04s (Table 3.19).

Impacts to the Ohinemuri River water quality following mixing with the discharged groundwater are predicted to be negligible and within the RWQC.

*Table 3.19 Predicted receiving water quality in the Long-term TSF scenario (values in mg/L)*

| Parameter | Existing shallow groundwater quality (GLD04s) | Predicted values after equilibration of TSF discharge with shallow groundwater (AECOM, 2021a) | Existing Ohinemuri River quality (OH6 median) | Predicted values after mixing with Ohinemuri River | Receiving water quality criteria |
|---|---|---|---|---|---|
| pH | 6.8 | 7.7 ↑ | 7.1 | - | 6.5 – 9.0 |
| Al | 0.088 | 0.07 | 0.016 | 0.016 | |
| As | 0.001 | 0.0012 ↑ | 0.0010 | 0.0010 | 0.19 |
| Ba | 0.14 | 0.109 | 0.038 | 0.038 | |
| Total Alkalinity | 65 | 42 | 15.4 | 15.6 ↑ | |

| Parameter | Existing shallow groundwater quality (GLD04s) | Predicted values after equilibration of TSF discharge with shallow groundwater (AECOM, 2021a) | Existing Ohinemuri River quality (OH6 median) | Predicted values after mixing with Ohinemuri River | Receiving water quality criteria |
|---|---|---|---|---|---|
| Ca | 10.5 | 79 ↑ | 43.5 | 43.8 ↑ | |
| Cd | <0.00005 | 0.0001 ↑ | <0.00005 | <0.00005 | 0.0003 |
| Cl | 9 | 11 ↑ | 16.4 | 16.4 | |
| Co | 0.017 | 0.04 ↑ | 0.0009 | 0.0011 ↑ | |
| Cr | <0.0005 | <0.0005 | <0.00050 | <0.00050 | 0.01 |
| Cu | 0.0014 | 0.0008 | 0.0005 | 0.00050 | 0.003 |
| Fe | 0.03 | ***2.2*** ↑ | 0.09 | 0.098 ↑ | 1 |
| Hg | ***<0.00008**** | ***0.00011*** ↑ | ***<0.00008**** | ***<0.00008**** | 0.000012 |
| K | 3.5 | 6 ↑ | 3.6 | 3.6 | |
| Mg | 2.8 | 12 ↑ | 3.1 | 3.1 | |
| Mn | 0.43 | 1.5 ↑ | 0.019 | 0.024 ↑ | 2 |
| Na | 24 | 27 ↑ | 17.1 | 17.2 ↑ | |
| Ni | 0.0089 | 0.007 | 0.0005 | 0.00053 ↑ | 0.04 |
| Pb | <0.0001 | <0.0001 | <0.0001 | <0.0001 | 0.0004 |
| SO4 | 17 | 263 ↑ | 148.0 | 149.0 ↑ | |
| Sb | 0.0002 | 0.0007 ↑ | 0.00055 | 0.00055 | 0.03 |
| Se | <0.001 | <0.001 | <0.001 | <0.001 | 0.02 |
| Zn | ***0.13*** | ***0.12*** | 0.0024 | 0.0028 ↑ | 0.027 |

*Notes:*
Receiving water quality criteria values for hardness 20 g/m$^3$ $CaCO_3$
Values in **bold** indicate an exceedance of the receiving water quality criteria
* The mercury (Hg) criterion is lower than available laboratory detection limits
↑ Denotes a predicted increase from existing groundwater / surface water quality

# 3.7 Gladstone effects summary and discussion

The predicted influence on key environmental aspects is summarised in the following sections.

## 3.7.1 GOP excavation summary and discussion

The key potential effects of the GOP excavation are a lowering of shallow groundwater levels locally, a reduction in flows to surface water and discharge of any dewatered groundwater to the receiving environment via the WTP. The potential effects and recommendations for management or monitoring are discussed below.

### Shallow groundwater

It is anticipated that the shallow groundwater table will be intercepted during excavation of the GOP, with total inflows to the pit estimated to be low (approximately 9 m$^3$/day under steady state conditions) due to the low permeability of the deposits (Table 3.8). This is considered to be minimal in the context of stormwater run-off. The complexity of the geology and topography adjacent to the pit means that the predicted dewatering ZOI is not radial. The dewatering of the shallow groundwater system is predicted to result in groundwater table drawdown of 3 m on the northern pit boundary, increasing up to 8 m on the southern pit boundary where the ZOI extends 290 m from the pit rim (Table 3.5). Groundwater drawdown at the Gladstone Wetland is predicted to be approximately 0.5 m.

A negligible reduction in shallow groundwater levels adjacent to the Ohinemuri River due to dewatering of the Gladstone vein system southwest of the GOP is anticipated, with a reduction in Ohinemuri River baseflow of approximately 1.5 $m^3$/day (Table 3.6). Changes in shallow groundwater discharge to the Ohinemuri River as a result of pit excavation are further discussed in the groundwater discharge to receiving environment section below.

The conceptual groundwater model (Section 3.3) presents evidence that the shallow groundwater system is already under-drained as a result of dewatering of the deep groundwater system, with no adverse effects recorded to date. Abstraction of groundwater during excavation of the GOP is therefore not expected to adversely impact groundwater quality. While there may be some localised changes in soil moisture in close proximity to areas of earthworks and dewatering, no impacts are expected beyond the immediate vicinity of the GOP. Intermittent wetting by rainfall is considered to provide the greatest influence on soil moisture levels across the Waihi North Project area.

## Deep groundwater

The Gladstone vein system and mineralised fault zone extends in a northeast – southwest direction through Gladstone Hill and has been interpreted by OGNZL geological model (2021) to extend beneath the Ohinemuri River at the approximate location of GLD04 (Figure 3.8). Groundwater levels in GLD04d likely represent water pressures within the south-western extent of the Gladstone vein system and indicate that the full extent of the mineralised fault does not have a strong hydraulic connection to existing dewatered areas. This suggests that whilst permeable, there are hydraulic disconnects within the veins, and this situation can be expected further along the southwest alignment. In addition, continued saturated conditions in monitoring locations P79d and P61, which are installed within andesite country rock in close proximity to the mineralised vein system, confirm the limited drawdown influence laterally from the vein as a result of Favona dewatering (Figure 3.8). Historical dewatering records for Favona are considered to provide reasonable approximations for inflow rates to the GOP during excavation in the event that the vein southwest of the pit is not dewatered (Table 3.9), and could be in the order of:

– 1,100 $m^3$/day of deep groundwater discharge to the GOP during initial excavation until after the maximum depth of 1,005 mRL is reached.
– 325 $m^3$/day long-term groundwater inflow after dewatering has reached steady state conditions.

The groundwater inflow rates are considered to represent an upper bound given the limited extent of the ore body southwest of the GOP and the generally limited hydraulic connection outside of the immediate vein system.

Groundwater drawdown within the deep groundwater system has been modelled to result in unsaturated andesite extending up to 230 m perpendicular to the vein strike (Table 3.7), however the very low permeability of the surrounding country rock is expected to limit the extent of the influence on the deep groundwater system. The expression of dewatering along strike of the veins (Figure 3.14) is anticipated to be limited by hydraulic connectivity in the vein network similar to the contrasting deep groundwater levels currently observed northeast and southwest of the proposed GOP.

## Groundwater discharge to the receiving environment and changes to surface water catchments

The small reduction in shallow groundwater levels as a result of excavation of the proposed GOP is predicted to result in locally reduced groundwater flow to nearby surface water receiving environments. The ZOI is expected to be constrained to within 290 m of the Gladstone Pit (Table 3.5), with no measurable effects to shallow groundwater levels predicted to extend beyond the Ohinemuri River.

The surface area of the proposed pit (18.7 ha) currently contributes runoff and interflow to the surface water catchments of the Ohinemuri River and its tributaries. Excavation of the pit is therefore predicted to also reduce surface water runoff and interflow, with this including the removal of the upper sections of the intermittent watercourses above the Gladstone Wetland.

The following changes in discharges to surface water bodies are predicted (Table 3.10 and Table 3.11):

– Groundwater discharge to the Ohinemuri River west of the proposed Gladstone Pit (OH6) is predicted to reduce by approximately 55 $m^3$/day, however groundwater discharge to the Ohinemuri River to the east

(OH3) is predicted to reduce by <1 $m^3$/day. However, these changes are likely to be unmeasurable within the river which has a median flow of 63,200 $m^3$/day (Frendrups gauge) and significantly higher peak flows. Stormwater runoff and interflow from the GOP area towards both OH3 and OH6 locations is also predicted to reduce by approximately 20%. This reduction in flow from these sub-catchments (currently an area of approximately 30 ha) is again considered to be very small in the context of the total Ohinemuri River catchment (29,000 ha).

– No change is predicted to groundwater levels and gradients within the catchment of the Ohinemuri tributary north of the pit (where TB5 is located). This is because the existing groundwater catchment area is not anticipated to be impacted by GOP excavation. Removal of surface area is predicted to reduce surface water runoff and interflow from the GOP area by approximately 16% for TB5.
– Groundwater flow to the Gladstone wetland (TB4 tributary) is predicted to reduce to approximately 0.7 $m^3$/day from the current scenario of 1.0 $m^3$/day. Removal of surface area in the TB4 catchment is also predicted to reduce surface water runoff and interflow to the Gladstone wetland by approximately 26%.

Despite these predicted reductions in discharge to surface water receptors, all dewatered groundwater and rainfall runoff captured within the Gladstone Pit during excavation will be directed towards the WTP and subsequently discharge back into the Ohinemuri River. This is expected to result in a net neutral or gain to the Ohinemuri River flow.

The effect to tributary TB5 from the reduction in stormwater runoff and interflow is expected to be negligible, given that it is inferred to form a drainage channel, rather than a groundwater fed watercourse.

As the effect to the wetland water balance is anticipated to be small but measurable, managing flow to the wetland will reduce the potential effect of the proposed activity. In the event that effects to the wetland are greater than predicted, it is anticipated that stream augmentation or stormwater diversion can be used to mitigate the adverse effects. Further discussion of the Gladstone Wetland is provided in the GHD (2022) Gladstone Wetland Groundwater Assessment Summary Technical Memorandum, which is appended to this report as Appendix L.

## Groundwater users

Within the shallow groundwater system drawdown from the pit dewatering is predicted to produce a zone of influence that extends up to 290 m south of the pit boundary, and 210 m west (Table 3.5). There are no registered groundwater users located within these areas nor in alignment of the veins extending to the southwest of Gladstone pit (Figure 3.11). The nearest bore user is recorded 430 m south of Gladstone and is not expected to be impacted during excavation of the Gladstone Pit (Figure 3.8).

The extent of dewatering influence on the deep groundwater system is expected to be constrained to within close proximity of the Gladstone vein system by the low permeability country rock. This inference is supported by the limited extent that Favona mine dewatering has on groundwater levels offset from the alignment of the vein system, as indicated by monitoring at locations P79d and P61.

Existing groundwater users located south of the Gladstone Pit are not expected to be in hydraulic connection with the Gladstone vein system due to the low permeability of the andesite country rock and large separation from the alignment of the mineralised veins. For the groundwater take at the Black Hill Orchard bore, this is supported by the lack of response to dewatering of the Martha mine (URS, 2003), pumping test results (GWS, 2018b) and a comparison of groundwater quality with GLD04d (Section 3.3.6).

It is acknowledged that there may be a slight loss of recharge to the deep groundwater system as a result of initial dewatering of Gladstone Pit and any small ongoing inflows, which would otherwise provide recharge to the deeper system. However, this reduction is expected to be small in magnitude and expected to have negligible influence on the groundwater users outlined in Section 3.3.6.

## Surface water users

The nearest downstream take from the Ohinemuri River (frost protection; AUTH141637) is located approximately 10 km downstream of the WNP area. It is expected there will be no effects to this user in terms of surface water flow reductions, where there is predicted to be no net decrease in surface water flow due to GOP excavation. Similarly, there are no predicted effects to surface water quality as a result of groundwater dewatering.

### 3.7.2 TSF summary and discussion

#### Final landform

After mining of GOP ceases, the pit is proposed to be developed into a TSF. The excavated pit will be backfilled with PAF and NAF rock to a minimum elevation of 1,060 mRL to form a base for placement of a liner subgrade and geosynthetic liner. Tailings will then be placed to a maximum elevation of 1,103 mRL. After settlement of the tailings, the tailings pond will be drained and the tailings then covered with a capping layer with a minimum of 1 m low permeability NAF weathered rockfill. Limestone will be added to the backfilled rock at appropriate rates to provide mitigation of mine rock drainage, while the cover will control long term sulphide oxidation and potential acid generation.

#### Groundwater

During development of the TSF the deep groundwater system is anticipated to continue to under-drain the shallow groundwater system due to ongoing dewatering of the Favona mine. Predicted groundwater drawdown and groundwater levels in this scenario are similar to those in the GOP excavation scenario as the tailings pond and recharge to the tailings is not expected to influence the adjacent shallow groundwater system. Instead, tailings pore water not recovered at surface as decant is expected to percolate downwards, ultimately discharging to the deep groundwater where it will contribute to flow being captured by Favona mine dewatering.

Following capping of the TSF and cessation of underground mine dewatering, represented by the long term TSF scenario, rewatering of the deep groundwater system will result in elevated groundwater levels within the deep groundwater system. As a result of this downwards vertical hydraulic gradients currently recorded between the shallow and deep system are predicted to reduce or reverse. This reduces the predicted zone of influence of the groundwater drawdown, and groundwater levels are predicted in a number of locations to be greater than current conditions, including in the vicinity of the Ohinemuri tributary to the north (TB5) and the Ohinemuri River (OH3). Groundwater levels in the vicinity of the Gladstone Wetland (TB4) are predicted to increase by approximately 3 m in comparison to current conditions.

The modelling assessment indicates that the greatest influence on groundwater levels within the receiving environment is the elevation of the TSF drainage system and rewatering of the deep groundwater system (TSF closure and long-term TSF scenario). The proposed Martha Pit Lake level (1,104 mRL) is expected to impose a water level control on the connected mine workings.

Hydraulic containment of the tailings and rock backfill is anticipated to be achieved by the TSF drainage system, with the drain predicted to capture both tailings pore water generated from infiltrating rainwater (approximately 58 $m^3$/day) and deep groundwater (approximately 1,194 $m^3$/day), upwelling from the deep groundwater system (Table 3.18).

After the TSF drainage system is no longer operated (long-term TSF scenario), groundwater discharge from the TSF (approximately 65 $m^3$/day (Table 3.16)) is predicted to be predominantly west towards the Ohinemuri River (OH6). This dominant flow path results from the presence of the relatively permeable young volcanics on the western pit face at an elevation that allows contact with the saturated rock backfill. Water being discharged from the TSF is predicted to be primarily groundwater upwelling through the rock backfill, and rainwater infiltrating the cover and migrating above the tailings towards the pit rim. Only a relatively small proportion of water is expected to be influenced by tailings (less than 10%), due to the low permeability of consolidated tailings relative to emplaced rock backfill.

#### Surface water

Prior to complete rewatering groundwater flow to surface water during TSF operation is expected to be consistent with that for GOP excavation. Likewise, during this time it is predicted that there would be no groundwater discharges from the TSF to surface water. However, the changes in groundwater levels and hydraulic gradients after complete mine rewatering are expected to result in the development of flow paths from the TSF to shallow groundwater to the west and the Ohinemuri River (OH6), with this also increasing net groundwater flow to the river.

Approximately 65 $m^3$/day of groundwater is predicted to discharge from the TSF and migrate to the surface water receiving environment in the long-term TSF scenario; compared to 4 $m^3$/day that is predicted to flow to surface water currently from the proposed pit area (Table 3.16).

After rewatering of the deep groundwater system an additional 100 $m^3$/day is predicted to discharge the Ohinemuri River from the catchment area west of Gladstone (OH6 Table 3.15). The additional flow to the Ohinemuri River from the Gladstone area is not likely to be distinguishable from additional flow anticipated to result across the wider Waihi area due to rewatering of the deep system.

The capping layer on the TSF is proposed to be graded for stormwater runoff, with at least some of the discharge, if not all, being directed to the south. The surface water catchment area for the Gladstone Wetland (TB4) will therefore be restored, with a potential increase by up to74% compared to current conditions (Table 3.17). This is expected to provide additional flow to the Gladstone Wetland. Further discussion of the Gladstone Wetland is provided in the GHD (2022) Gladstone Wetland Groundwater Assessment Summary Technical Memorandum, which is appended to this report as Appendix L.

## Water quality

Groundwater discharge from the TSF to the surface water receiving environment in the long-term TSF scenario is predicted to be in the order of 65 $m^3$/day to the west of the pit (Table 3.16). Of this discharge, approximately 5 $m^3$/day is predicted to comprise tailings porewater, with the remainder being groundwater and infiltrated rainwater that has migrated through rock backfill to the point of discharge from the pit. Shallow groundwater quality following mixing and geochemical equilibrium (AECOM, 2021a) is predicted to result in an increase in the concentration of iron and mercury within the shallow groundwater to levels exceeding the receiving water quality criteria. The water quality assessment also considered dilution of the flux of potential contaminants within the Ohinemuri River, with the impact to the river predicted to be negligible.

It is important to note that the water quality results (Table 3.19) do not allow for attenuation of key contaminants with aquifer materials during groundwater flow. It is noted that the trace metal contaminants in particular are expected to have a strong affinity for binding to clay minerals within the shallow aquifer and iron minerals within the deeper aquifer. These adsorption processes are seen in other mine areas (such as TSF1A and rock stacks) to significantly attenuate contaminant migration in groundwater.

## Groundwater users

Consistent with the interpretation for GOP excavation scenario, development of a TSF is not expected to influence existing groundwater users owing to the lack of hydraulic connection with groundwater users. Rewatering of the deep groundwater system is expected to return groundwater levels to approximately the same level as pre-mining levels in the vicinity of the Gladstone pit.

Away from the influence of the TSF drainage system (operational TSF and TSF closure scenarios), groundwater flow paths within the deep groundwater system are expected to be towards the current Favona underground mine dewatering. When the TSF drainage system ceases operation (long-term TSF) and the Favona underground mine dewatering ceases, groundwater flow paths within the deep groundwater system will either be towards the TSF where discharge to the shallow groundwater system is predicted, or towards the Martha Pit Lake. Shallow groundwater flow in the vicinity of the TSF is anticipated to be intercepted by the Ohinemuri River. Therefore, no impact to the groundwater quality at the location of the existing groundwater users south of Gladstone is expected.

## Surface water users

The nearest surface water user on the Ohinemuri River (AUTH141637) is located approximately 10 km downstream of the WNP area. The changes to the shallow groundwater regime as a result of rewatering of the deep groundwater system may result in minimal increases in groundwater discharge to the Ohinemuri River and associated increased river flow. Discharges to the river from the TSF are, however, interpreted to have negligible influence on water quality with no predicted exceedance of the adopted receiving water criteria. As such, surface water users are not expected to be adversely impacted by groundwater discharge from the TSF in any of the TSF scenarios.

### 3.7.3 Monitoring recommendations

Monitoring is recommended as a condition of consent, as per other mining activities at Waihi. This section provides only a high-level overview of monitoring recommendations. Specific requirements should be detailed in an overarching Gladstone Water Monitoring and Contingency Plan. The plan should include requirements for baseline monitoring (for comparative analysis to provide a degree of confidence in the assessment), trigger levels, and contingency measures to manage any potential exceedances.

- **GOP excavation:**
  - **Pit inflow:** Monitoring of pit inflow rates should be undertaken during the excavation and dewatering works. This will assist with understanding the potential connection of the shallow groundwater system and the current degree of dewatering within the deep groundwater system as a result of existing mine dewatering.
  - **Water quality**: Monitoring of groundwater and surface water should be undertaken to assess potential impacts to the receiving environment during excavation and dewatering of the pit. It is recommended that this includes the nearest private bore users, if amenable to the owners. In addition, discharges from the excavated pit should be monitored to inform treatment requirements at the WTP.
  - **Groundwater levels:** Monitoring of shallow and deep groundwater levels should be undertaken at selected monitoring wells, including a network of piezometers installed around the perimeter of the pit. Monitoring of groundwater in wells connected to the Gladstone vein and adjacent to it, southwest of the site, is also recommended to confirm the extent of drawdown along strike of the vein.
  - **Flow monitoring:** Surface water flow gauging of the Ohinemuri River and its tributaries should be undertaken prior to and during the pit excavation and dewatering works.
- **TSF development:**
  - **Water quality:** Monitoring of groundwater and surface water should be undertaken to assess potential impacts to the receiving environment during and after development of the TSF.
  - **Groundwater levels:** Monitoring of shallow and deep groundwater levels should be undertaken at selected monitoring wells during development of the TSF and rewatering of the deep groundwater system.
  - **Flow monitoring:** Surface water flow gauging of the Ohinemuri River and its tributaries should be undertaken prior to, during and after development of the TSF, and prior to, during and after rewatering of the deep groundwater system.

# 4. Northern Rock Stack

## 4.1 Site overview

### 4.1.1 General site setting

The current site setting of the proposed NRS is presented in Figure 4.1. The existing topography at the site slopes from the elevated rhyolite dome in the east towards the Ohinemuri River in the west. Current land use comprises the existing northern storage area (also known as the northern stockpile) and workshop in the south, with pastoral farming in the north. A Significant Natural Area (SNA) defined by the District Plan, is located east of the site beyond the mining licence boundary, which sits between the NRS and proposed TSF3.

The proposed footprint of the NRS will be positioned over an existing perennial stream and its intermittently flowing tributaries, which currently discharges into the Ohinemuri River. The Ohinemuri River itself is located west of the site and flows approximately north to south.

### 4.1.2 Summary of proposed activity

The NRS facility is proposed to be located north of the existing storage of TSF2. The NRS will be built over the existing northern storage area and workshop and extend further to the north. The existing tributary of the Ohinemuri River within this area will require diversion. A plan of the proposed NRS is provided in Figure 4.2.

The proposed activity for NRS is described in the NRS geotechnical report prepared by EGL (2025a). Both NAF and PAF materials are proposed to be stored at the NRS to a maximum elevation of 1,173 mRL. Some of the rock will subsequently be used to backfill other mining facilities reducing the maximum elevation of the stack to 1,148 mRL. During closure, any unused rock will be capped with NAF and the NRS would be progressively rehabilitated in accordance with the surrounding area.


Paper Size A3

0 25 50 100

Metres

Map Projection: Transverse Mercator
Horizontal Datum: NZGD 2000
Grid: NZGD 2000 New Zealand Transverse Mercator

N

LEGEND

- Existing northern stockpile
- Workshop
- OGL Bores
- Quattro Bores
- Surface Water Locations
- Contour (20m)

**Ohinemuri River Tributary**

- River
- Tributary

Oceana Gold Limited
Waihi North

NRS site setting
and monitoring locations

| | |
|---|---|
| Job Number | 12552081 |
| Revision | 0 |
| Date | 08 Dec 2021 |

Figure 4.1

N:\NZ\Christchurch\Projects\51\12526951\GIS\Maps\Deliverables\12552081\12552081_Z011_NRSSiteSetting.mxd

Level 3, 138 Victoria Street, PO Box 13 468, Christchurch 8141, New Zealand T 64 3 378 0900 F 64 3 378 8001 E chcmail@ghd.com W www.ghd.com



Data source: Aerial imagery - LINZ; General topo - LINZ; Bore locations - OGL. Created by:jrprice

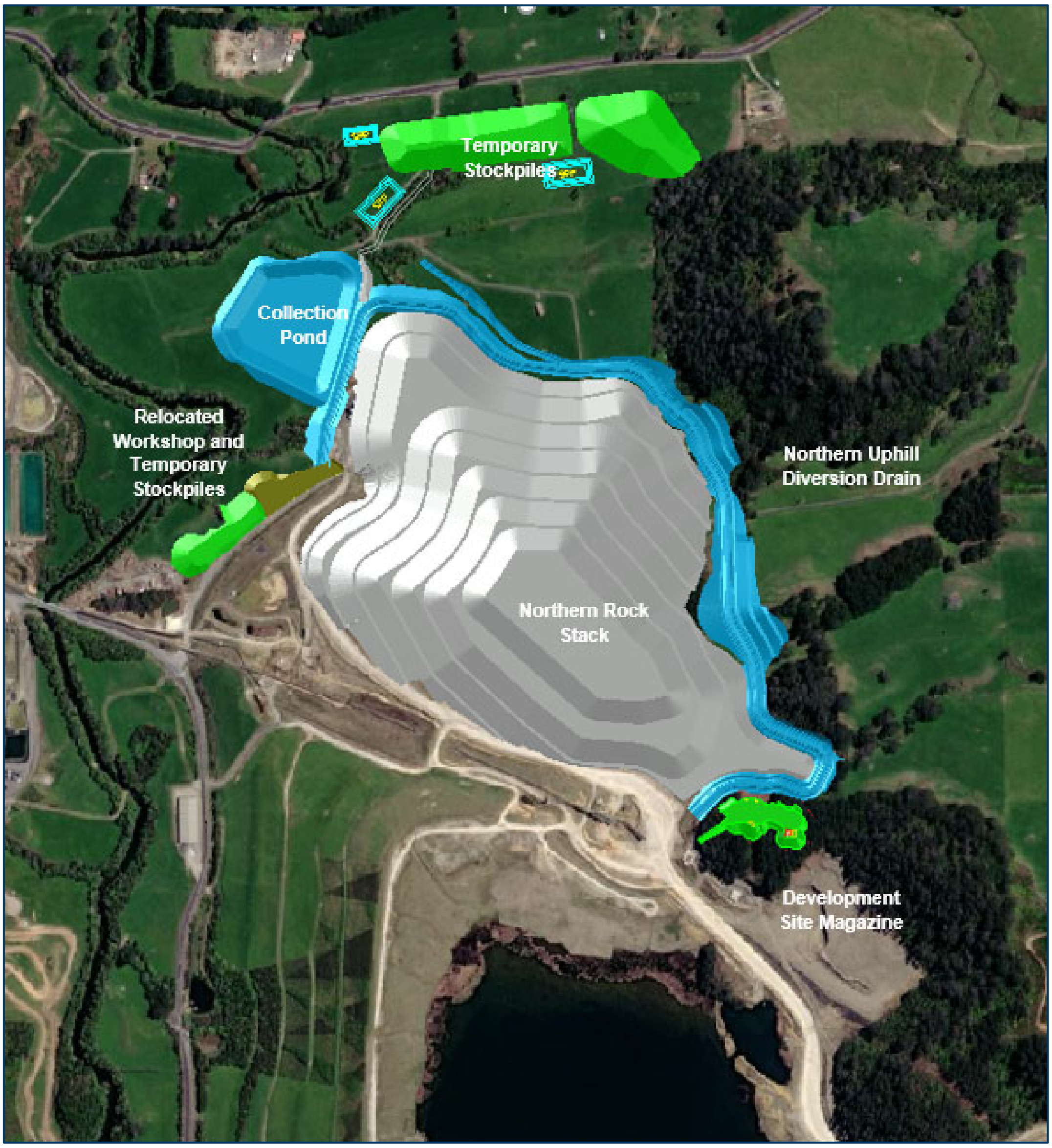



*Figure 4.2 NRS proposed location and greatest extent during operation (Mitchell Daysh, 2025)*

### 4.1.3 Potential influences on groundwater and surface water

In addition to the rock stack, the proposed NRS will include a number of soil stockpiles and a collection pond (Figure 4.2) within a catchment contributing surface water and groundwater to the Ohinemuri River.

Assessment of potential effects on groundwater and surface water has focused on the potential for the proposed NRS to influence:

– Groundwater levels and baseflow to the Ohinemuri River during operation and after closure.
– Groundwater and river water quality resulting from leachate seepage from the NRS, and the extent to which this may be mitigated by a liner and engineered sub-soil drainage.

## 4.2 Local geology

The regional geology is presented in Section 2.3. Cross sections of the geology for the NRS area are presented in Figure 4.3 and Figure 4.4. A detailed description of the geology is provided in EGL NRS Geotechnical Factual Report (GFR; EGL, 2019a).

The NRS site is located west of the Golden Valley fault (and a smaller conjugate fault), through which the Ruahorehore Rhyolite has intruded to the surface. The proposed rock stack is located within an alluvial gully, which is underlain predominantly by Black Hill Dacite (unit *iu)*. Dacite outcrops across the site, present up to 300 m in thickness (to 800 mRL), with the Ruahorehore rhyolite (*mnr)* overlying the dacite along its eastern edge. Where present, ignimbrite overlies the dacite unit and has a thickness of up to 30 m in the west of the existing northern storage area (EGL bore WG5).

The regional andesite rock (*aw)* underlies the site at depth and has been confirmed from sterilisation drilling to have no mineralisation at this location.

The shallow geology is summarised as follows:

– A discontinuous ignimbrite flow is located in a paleo-channel that runs north to south across the site, roughly aligned with an existing tributary flowing north to the Ohinemuri River (Tributary TB1, located between surface water monitoring locations TB1a and TB1f on Figure 4.1). The ignimbrite is occasionally underlain by clast-supported boulder and cobble alluvium, which is likely to be related to the erosional surface of the dacite.
– A paleo-channel in the southern section of the site appears to be aligned with the location of the tributary prior to construction of the existing northern storage site (EGL bore MW5S/D), with the historical channel location inferred from original site topography (EGL, 2019a Figure 3).
– Ohinemuri River alluvium (organic clay to fine/medium gravels) overlie the ignimbrite and dacite across the majority of the NRS site. A discontinuous volcanic ash layer overlies the uppermost units.

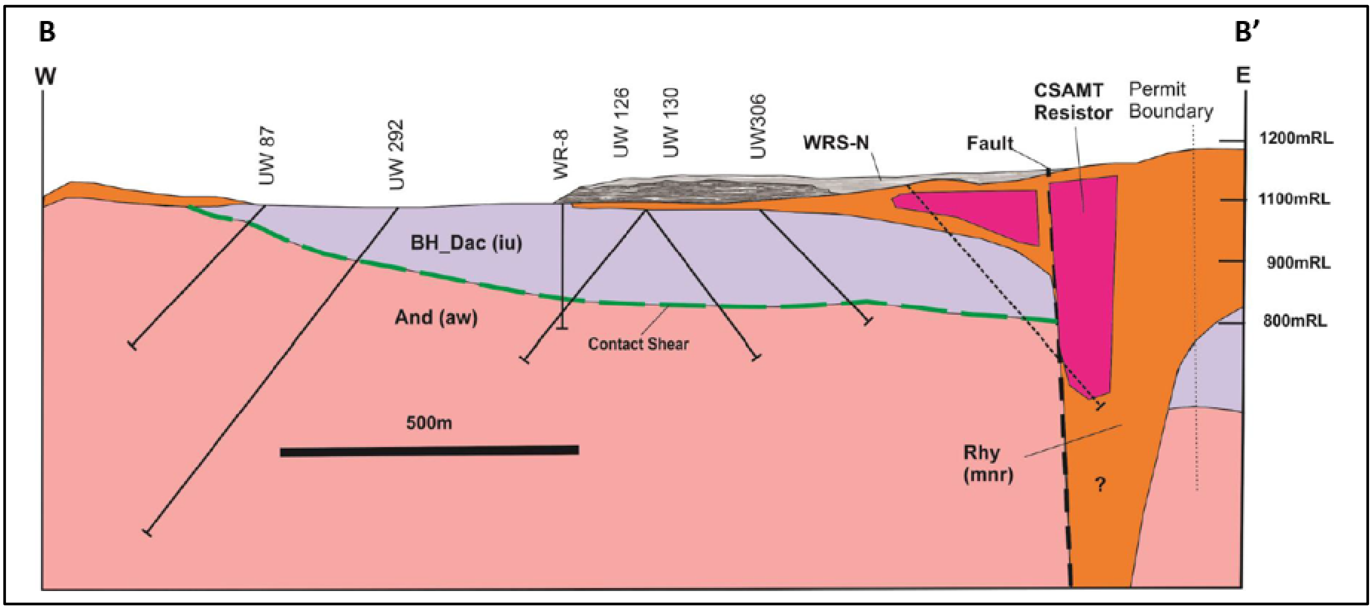



*Figure 4.3 NRS geological cross-section (B-B' of Figure 2.3) (OGNZL, 2017)*

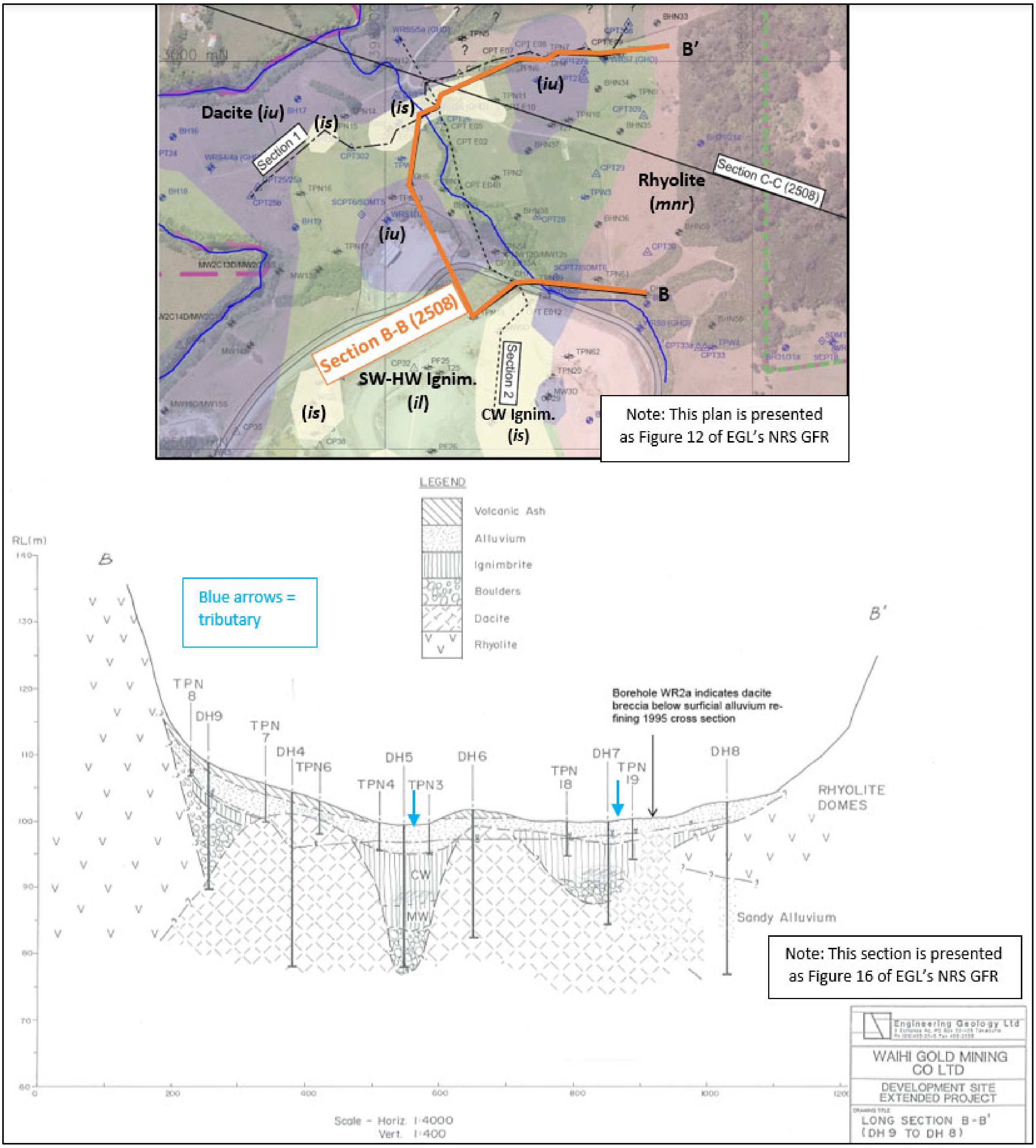



*Figure 4.4 NRS geological long-section B-B (2508) from EGL (2019a)*

# 4.3 Conceptual groundwater model (NRS CGM)

## 4.3.1 Overview

The geology at the NRS is notably different to that at Gladstone and TSF3, with no clear separation of shallow and deeper groundwater systems. This is due to the presence of multiple alluvial paleo-channels within and overlying variable volcanics (ignimbrite, dacite and rhyolite). The deep andesite, which outcrops to the west of the Ohinemuri River, is present below 200 m depth at NRS due to the dip of the unit and faulting (Golden Valley Fault). All groundwater monitoring wells at NRS are installed in the shallow system, with some paired between the water table and deeper within the shallow system (up to 25 m bgl; referred to as "deeper" wells / groundwater in this section), to provide an understanding of vertical hydraulic gradients beneath the site.

Overall, whilst slight differences in groundwater are recorded between the shallow and deeper monitoring wells, it is interpreted that the system is hydraulically connected and collectively discharges to the Ohinemuri River west of the NRS. The NRS CGM discussion is focused around the shallow system to 25 m depth; any reference to the deep regional andesite aquifer is clarified as such where discussed.

## 4.3.2 Shallow groundwater system

Monitoring wells installed at the proposed NRS site are located between 100 m to 770 m east of the Ohinemuri River (Figure 4.1). The majority of monitoring wells at NRS have recorded groundwater levels at less than 5 m bgl, with some locations within 10 m bgl (1,095 – 1,106 mRL). The well pair located at the foot of the rhyolite dome (WRS03 and WRS03a) 770 m east of the river, record groundwater at much higher elevations than the other NRS monitoring wells (approximately 1,130 mRL) due to their elevated location.

Groundwater recharge is expected to occur from rainfall infiltration over the elevated rhyolite dome, as well as across the alluvial river plain. Recharge to the elevated rhyolite drives upward vertical hydraulic gradients at the base of the hill, east of the proposed NRS footprint. Groundwater and surface water levels recorded in a number of locations across the site are presented in Figure 4.5 and Figure 4.6, alongside rainfall. The following is noted:

– When comparing groundwater levels within shallow monitoring wells, those nearest to the Ohinemuri River and tributary show the greatest response to rainfall. The rapid response of groundwater is likely to be due to the higher permeability of the shallow geological units (completely weathered to residual volcanics in wells WRS04, WRS05, WRS08).

– The deeper groundwater levels near tributary location TB1a demonstrate a greater response to rainfall when compared to the water table (DH05/DH05a/WRS06; Figure 4.5). This is considered to be a function of the close proximity to the ignimbrite paleo-channel and underlying boulder and cobble alluvium at depth, these providing a preferential groundwater flow pathway and allowing transmission of recharge from higher in the catchment. The water table and deeper groundwater piezometric contours (Appendix C) demonstrate the influence that this preferential pathway has on groundwater flow directions.

– Downward vertical hydraulic gradients are recorded in close proximity to the Ohinemuri River and along the tributary, with deeper groundwater inferred to be recharged in these areas. The strongest downward vertical gradients during summer baseflow conditions are observed near the existing northern storage area. Milder downward gradients are observed closer towards the Ohinemuri River, where groundwater levels and vertical gradients suggests that both shallow and deeper groundwater is discharging to the river (WRS04 and WRS05).

– A delayed and more muted response to rainfall occurs at the foot of the rhyolite dome in the east of the site (WRS07/DH09 and WRS03/WRS03a). Mild to moderate upward vertical hydraulic gradients occur at these locations, which indicates that the upper reaches of the tributary (near WRS TB) are likely spring fed.

Groundwater levels and gradients typically follow topography, with a steeper gradient at the base of the rhyolite dome to the east (0.1), becoming gentler across the alluvial flats (0.03). The shallow groundwater flow direction is approximately west to northwest, following the site topography towards the perennial tributary (TB1f to TB1a) and the Ohinemuri River.

The presence of the higher transmissivity ignimbrite and alluvium paleo-channel along a similar alignment to the stream is expected to provide a preferential groundwater flow pathway for shallow groundwater from the NRS site towards the Ohinemuri River (demonstrated in piezometric groundwater contours in Appendix C).

The deep aquifer within the andesite in the vicinity of the NRS is inferred to flow to the west and is sufficiently deep to be hydraulically separate from the proposed NRS facility.

The shallow groundwater system is comprised of permeable alluvium, as well as lower permeability ignimbrite and dacite units. Permeability generally decreases with depth (Table 4.1) as the degree of weathering reduces and flow relies more on secondary porosity (fracturing) rather than primary porosity.

*Table 4.1 Permeability of NRS geological units*

| Groundwater System | Geological Unit | Geomean Permeability (m/s) |
|---|---|---|
| Shallow (water table) | Alluvium | $>1 \times 10^{-4}$ |
| | Ignimbrite (completely weathered) | $3.5 \times 10^{-6}$ |
| | Dacite (completely weathered) | $1.0 \times 10^{-6}$ |
| Deeper (up to 25 m) | Ignimbrite (highly weathered) | $1.1 \times 10^{-6}$ |
| | Dacite (moderately – highly weathered) | $8.5 \times 10^{-7}$ |

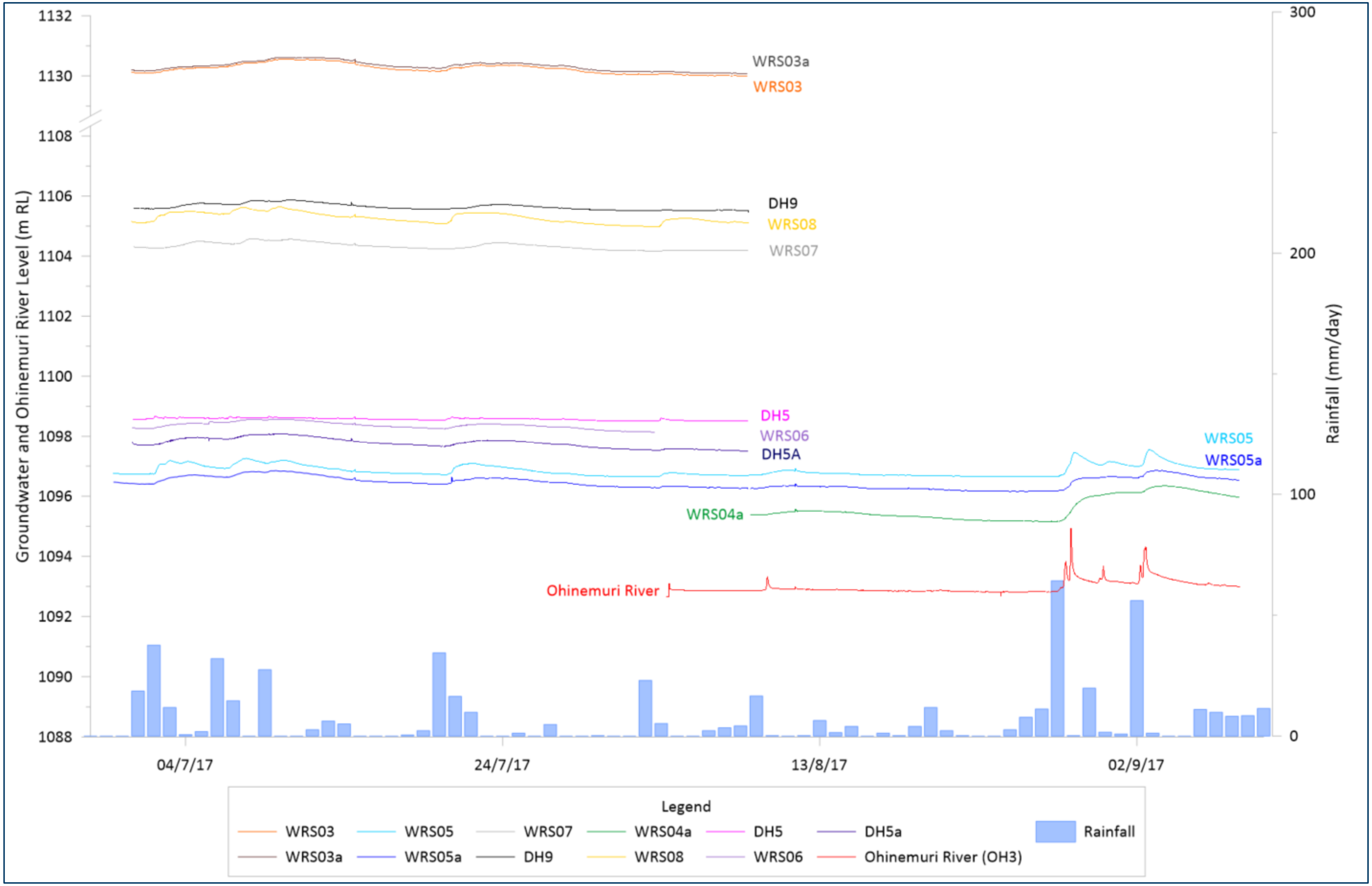



***Figure 4.5*** ***NRS 2017 groundwater and Ohinemuri River (OH3) levels and rainfall (CLIFLO Athenree 2 station 18638). Monitoring locations presented in Figure 4.1.***

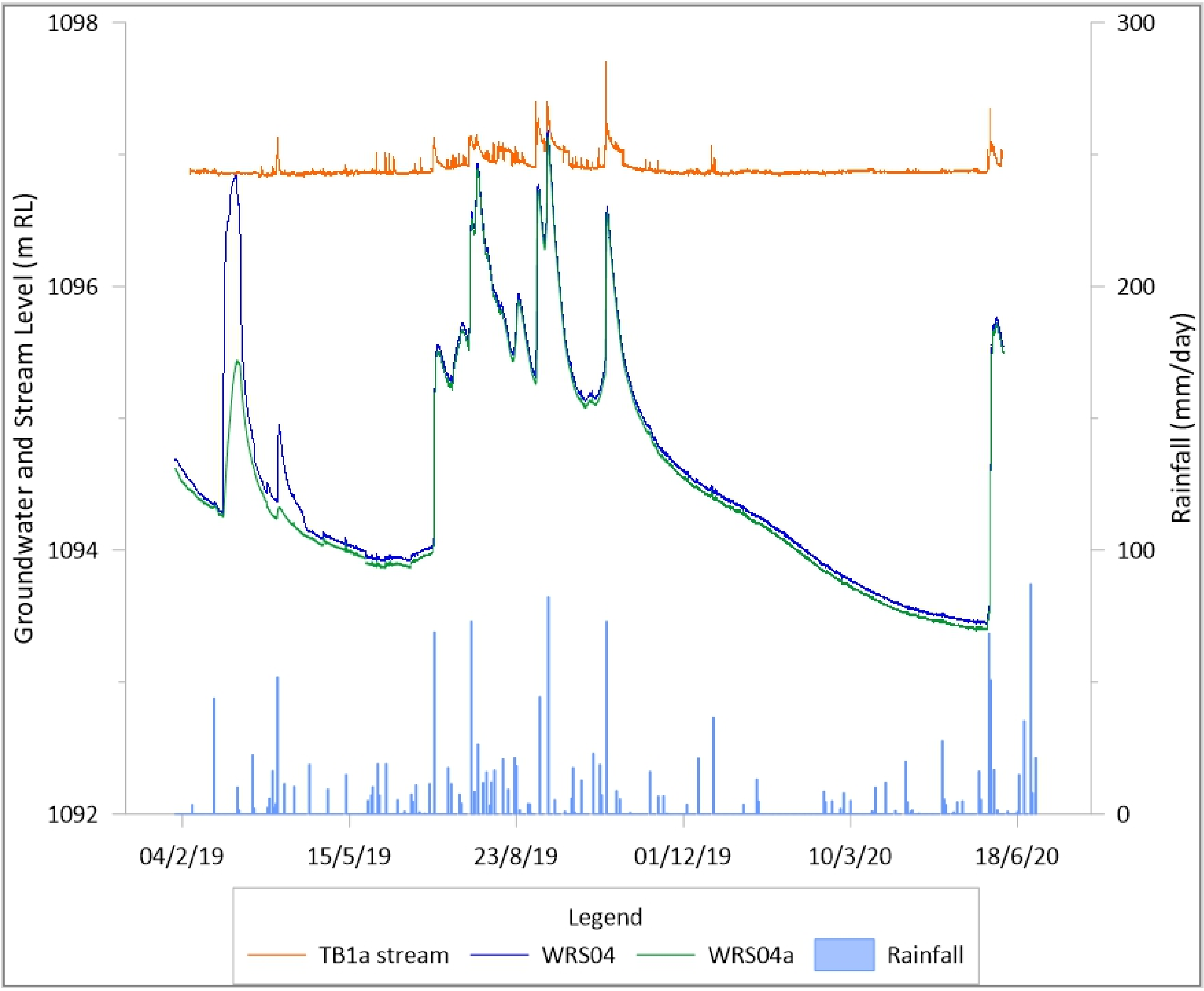



*Figure 4.6* *NRS 2020 groundwater and TB1a stream levels and rainfall (CLIFLO Athenree 2 station 18638). Monitoring locations presented in Figure 4.1.*

## 4.3.3 Surface water-groundwater interactions

The Ohinemuri River flows roughly north to south past the proposed NRS site (Figure 4.1). Flow in the Ohinemuri River during baseflow conditions is typically recorded to be less than 0.3 $m^3$/sec (23,200 $m^3$/day) at the Frendrups flow gauge southwest of the NRS site (Figure 2.1). Neutral flow conditions have been recorded between flow gauging stations located up and down stream of the NRS site (Appendix F), however groundwater levels, flow directions, vertical hydraulic gradients, alignment of the paleochannel and water quality results all infer that groundwater discharge is occurring, albeit small relative to river flow and likely within the range of error of the flow gauging measurement. Should neutral or losing conditions occur along this reach, groundwater is anticipated to flow south following topography and the alignment of the river before discharging to the River further downstream.

Ohinemuri tributary TB1 flows from southeast to northwest, from the existing northern storage area across the proposed NRS site, before discharging into the Ohinemuri River (Figure 4.1). The surface water catchment area of TB1 is approximately 112 hectares, with the upper reaches being spring fed (WRS TB) as discussed in Section 4.3.2. The northern storage area is inferred to be situated over historical flow path(s) of the tributary, moving the current alignment further to the east (TB1b) (Figure 4.1).

Flow gauging along tributary TB1 (Appendix F) indicates that although groundwater spring discharges form the headwaters of the tributary, the stream is typically recorded as neutral under base flow conditions. This indicates a close hydraulic connection with groundwater across the site, with gaining and losing sections likely to occur along its length. Gaining conditions were recorded following a high rainfall period in September 2019, which is likely to be due to increasing runoff and interflow between gauging locations as well as greater groundwater discharge. Typical groundwater flow at TB1a (Figure 4.1) is approximately 3 L/s (Appendix F).

A separate tributary TB1E (Figure 4.1), described by OGNZL as a small field drain, has remained dry during all flow gauging events (Appendix F).

### 4.3.4 Groundwater and surface water quality

A summary of the groundwater and surface water chemistry data recorded in the locations presented in Figure 4.1 between 2017 – 2019 and representative piper plots are presented in Appendix E.

#### Groundwater quality

The chemistry of the groundwater differs to a small degree between the shallow and deeper monitoring wells, with the latter generally indicating a greater proportion of calcium and bicarbonate and a lower proportion of chloride and sulphate.

Most monitoring wells at the NRS site typically record low trace element concentrations, however, elevated concentrations of trace elements recorded in WRS02 (mercury, manganese, iron) and DH05a (zinc, manganese, iron, lead) demonstrate a degree of influence of mineralisation and anaerobic conditions.

#### Influence of existing storage facilities

The existing northern storage stockpile located in the south of the proposed NRS site is part of TSF2, which commenced construction in 1987 (Figure 4.7). It is an active stockpile, which was constructed to only receive NAF rock, however it understood that at least some PAF was also stored at this location. The northern stockpile silt pond (NSPSP) is positioned to collect run off from the stockpile and discharge directly to tributary TB1 when the water quality is suitable. Leachate drains are installed beneath the existing northern stockpile to capture leachate generated, and sub-soil and toe drains are installed to intercept potentially impacted groundwater. The toe drains installed at the northern boundary of the northern stockpile demonstrate a rock storage influence with Ca-Mg-$SO_4$ type water indicated by piper diagrams (OGNZL, 2016). GHD has undertaken a high-level review of available toe drain water quality data (OGNZL, 2016). A summary of the rock storage influence recorded in the toe drains is presented below:

– Toe drain location T13: This location is installed south of GHD sample location TB1e (Figure 4.1). This drain demonstrates the greatest rock storage influence with the elevated concentrations of sulphate and dissolved iron, and elevated electrical conductivity. This is likely to be either due to T13 capturing a higher proportion of leachate compared to groundwater, or due to toe drain T13 receiving discharge from a larger rock thickness and catchment area than contributes flow to drains T12 and T14. Peak sulphate (3,170 mg/L) and dissolved iron (23 mg/L) concentrations coincided with the minimum recorded pH (3.3) between 1996 and 1999. The concentrations have continued to decline and pH increased through to 2020. This suggests a timeframe of 9 years from construction for the peak PAF rock influence to be realised at this location.
– Toe drain locations T12 and T14: Both locations indicate fluctuating trends over the operation of the existing rock storage, with pH (4.3 – 6.8), electrical conductivity (15 – 210 mS/m), sulphate (40 – 3,400 mg/L) and dissolved iron (0.01 – 16 mg/L) confirming collection of rock storage leachate.
– Groundwater: Monitoring of wells downgradient of the northern stockpile (OGNZL wells MW12S/D and MW2C13S/D (OGNZL,2020)) indicate very little impact of rock storage leachate to groundwater quality. One-off elevated concentrations of electrical conductivity, sulphate and iron have been recorded, however there are no trends that indicate any ongoing influence from tailings or rock storage.

The water quality results from WRS02/WRS02a and WRS08/DH08 indicate a rock storage influence, as demonstrated by sulphate (up to 155 mg/L) and dissolved iron (up to 2.6 mg/L), as a result of being situated on the periphery of the existing northern storage area (Figure 4.1). Elevated concentrations of iron and a number of other parameters, also infer a rock storage influence at DH05a, which is installed in the alluvium at the base of the paleo-channel (an inferred preferential groundwater flow pathway) down-hydraulic gradient of the northern storage area. The absence of sulphate in DH05a is likely attributed to a more anaerobic condition within the groundwater recharge zone for the paleo-channel in the centre of the northern storage area. Infiltration of rock storage seepage is likely to be occurring into the up-hydraulic gradient section of the paleo-channel, which is aligned with inferred historical location of Ohinemuri tributary TB1. These results indicate that although complete containment of leachate impacted groundwater is not being achieved, the leachate and drainage systems are reducing the flux of contaminants that are migrating offsite. Dilution and attenuation in groundwater is also likely to be reducing the contaminant concentrations measured in the groundwater monitoring wells.

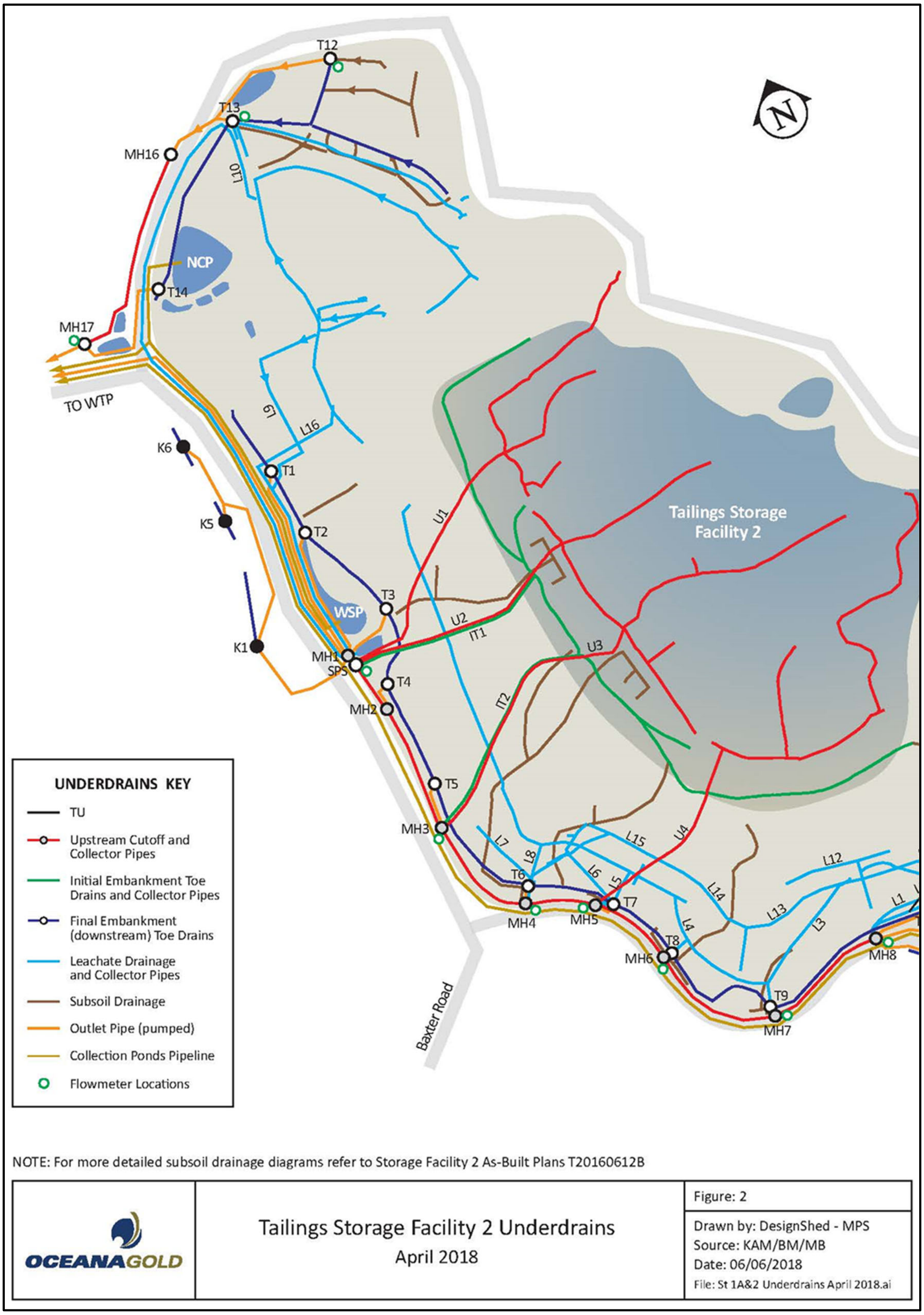



*Figure 4.7 TSF2 and existing northern stockpile underdrains and sampling locations (OGNZL, 2016)*

Overall, the exceedance of statistical trigger levels and analysis of groundwater quality trends does not suggest any developing or ongoing failure of containment or encapsulation of rock at the existing rock storage facility. A key aspect of interpretation relates to the concentrations of iron in groundwater around the existing rock storage facility; concentrations of iron in groundwater are greatest nearest to the embankment and within the paleo-channel (WRS08/DH08 and DH05a). Compared with predicted rock storage infiltration quality (up to 300 $g/m^3$; Section 6.3.1 of AECOM, 2025) this is a significant reduction in concentrations within just metres of the facility, with further reduction with distance away from the northern stockpile. This suggests that in-ground conditions continue to promote the precipitation of iron hydroxide minerals (such as ferrihydrite and goethite), which are key to attenuating trace element contaminants released from mineralised rock through adsorption and co-precipitation reactions. The occurrence of such attenuating processes is likewise expected to mitigate contaminant discharge from the NRS, which is expected to have discharge and groundwater conditions generally consistent with the existing rock storage facility.

#### Surface water quality

Surface water quality under baseflow conditions indicates little change in chemistry as tributary TB1 flows towards the Ohinemuri River. Under these conditions the chemistry of the tributary was recorded to be relatively similar to NRS groundwater samples, confirming a close hydraulic connection between surface water and groundwater. After large rainfall events, a difference in chemistry is recorded between surface water samples along the stream (TB1a, TB1f and TB1b) in comparison with the groundwater fed headwaters (WRS TB) and the Ohinemuri River (OH3) (Figure 4.1 and Appendix F). This is likely to be a result of surface water runoff and interflow.

The surface water quality of the Ohinemuri River at sampling point OH3 appears similar to that of deep piezometer WRS04a which is located approximately 100 m to the east of the river (Figure 4.1).

### 4.3.5 Water resource users

There are no registered bores located within approximately 800 m of the proposed NRS (WRC, 2025c), including the area between the proposed NRS site and the Ohinemuri River (Figure 3.11).

The closest surface water take is presented in Table 4.2. This take is from the Ohinemuri River upstream of the proposed NRS site. The closest downstream surface water take from the Ohinemuri River is approximately 10 km downstream of the WNP area and is not shown on the report figures.

***Table 4.2 Water takes in the vicinity of the proposed NRS***

| Property/user | Consented take (year granted) | Type | Approximate distance from NRS |
|---|---|---|---|
| Ohinemuri River take (Waihi water supply) | AUTH130392.03.01 (2014) | Surface water take | 300 m upstream |

## 4.4 NRS assessment methodology

Potential impacts on groundwater and surface water associated with the proposed NRS were assessed using a variety of methodologies to predict the rate of seepage infiltration through the Zone A soil liner and subsequent effects to the receiving environment during operation and after closure of the proposed NRS. Consideration has been given to the longer-term impacts, owing to the short timeframe for NRS construction and closure, relative to groundwater travel times. The assessment comprised:

1. **Conceptual groundwater model development** (Section 4.3): Understanding of the current geological and hydrogeological environment using site investigation data (Appendix A).
2. **Groundwater flow:** Development of an analytical groundwater model to predict existing groundwater flow across the NRS site and baseflow discharge to the Ohinemuri River.
3. **Construction dewatering assessment:** Development of an analytical groundwater drawdown model to provide analysis of groundwater inflow and drawdown resulting from the installation and operation of the uphill

diversion drains along the south-eastern boundary of the NRS (where groundwater is anticipated to be intercepted).

4. **NRS assessment**: Development of a steady-state cross-section model (developed within GeoStudio 2021 SEEP/W finite element numerical modelling software) to predict the rate of leachate capture and seepage through the Zone A liner. The assessment modelled the following scenarios:
    a. **NRS Operation**: Rock stack to proposed maximum operational capacity.
    b. **NRS Closure**: Final proposed elevation of rock stack including capping layer.
5. **Water quality assessment:** Development of a contaminant mass mixing model to predict impacts to groundwater and surface water quality from leachate seepage to the receiving environment. Results from AECOM (2021c) geochemical equilibrium modelling to generate a groundwater quality equilibrated for mineral saturation for the NRS leachate were used alongside predicted groundwater and leachate flow from the above assessments and existing surface water quality data to provide water quality predictions for the surface water receiving environment.

Refer to Appendix H for detailed description of the assessment methodology.

# 4.5 NRS assessment results

## 4.5.1 Construction dewatering and groundwater flow

Groundwater flow at the base of the Rhyolite Dome, upgradient of the proposed NRS site, has been estimated using Darcy's Law (Darcy, 1856) to be approximately 720 $m^3$/day (see Appendix H for detailed calculations). Taking into consideration additional groundwater recharge under existing conditions as groundwater flows across the alluvial flats (450 $m^3$/day) total groundwater discharge to the Ohinemuri River is estimated to be in the order of 1,170 $m^3$/day.

Groundwater is anticipated to be intercepted during construction of the uphill diversion drains at the south-eastern boundary of the NRS. Construction of the drains will involve excavation of rhyolite rock in this area, with dewatering likely to be required where the design invert levels of the uphill diversion drain are below the existing groundwater table. Initial groundwater inflow rates and distance of influence of groundwater drawdown predicted during excavation and dewatering for the installation of the uphill diversion drains presented in Table 4.3.

The following is noted:

– The inflow rates determined assume that the full length of excavation required will be undertaken at the same time, however it is likely that the excavation will be progressively advanced. These results are therefore considered to be conservative.
– Groundwater inflow rates are predicted to reduce over time as groundwater levels and gradients towards the uphill diversion drains reduce as the system equilibrates to the change in conditions.

*Table 4.3 NRS groundwater inflow rates and distance of influence of dewatering for uphill diversion drain construction*

| Uphill Diversion Drain Dewatering Assessment | Result range |
|---|---|
| Initial groundwater inflow rate ($m^3$/day) | 10 – 70 |
| Distance of influence (m) | 1 – 10 |
| - Considering assessment uncertainty, results are rounded. | |

## 4.5.2 Rock stack leachate

The predicted rate of leachate capture within leachate collection drains, and rate of leachate seepage through the Zone A liner is presented in Table 4.4, predicted leachate and groundwater capture within sub-soil drains is presented in Table 4.5 and the predicted leachate flow within groundwater that is anticipated to migrate to the Ohinemuri River is presented in Table 4.6. The results represent steady state conditions during average rainfall conditions, and present predicted seepage results for 30% and 50% rainfall recharge in recognition of uncertainty in rainwater infiltration to the rock stack for the operational NRS operation scenario, and the predicted recharge through the Zone G & H capping layer for the NRS closure scenario (AECOM, 2020).

The proportion of leachate captured in leachate collection drains, captured in sub-soil drains and predicted to discharge to the Ohinemuri River is presented in Figure 4.8. The breakdown of groundwater and leachate captured in the sub-soil drains is presented in Figure 4.9.

Rock stack leachate and groundwater flow paths modelled for the NRS operation and NRS closure scenarios are presented in Figure 4.10 and Figure 4.11, respectively.

*Table 4.4 Predicted leachate capture and leachate seepage through zone A liner*

| Infiltration conditions | Leachate captured by leachate collection drains (m3/day) | Leachate seepage through Zone A liner ($m^3$/day) |
|---|---|---|
| **NRS Operation** | | |
| 30% rainfall[1] | 29 | 413 |
| 50% rainfall[1] | 109 | 605 |
| **NRS Closure** | | |
| 5-year average cap infiltration (369 mm/year)[2] | 2 | 262 |
| 1. Based on an average annual rate of 2.11 m/year<br>2. AECOM, 2020.<br>- Considering model uncertainty, results are rounded. | | |

*Table 4.5 Predicted groundwater and leachate captured in sub-soil drains*

| Infiltration conditions | Groundwater captured by sub-soil drains ($m^3$/day | Leachate captured by sub-soil drains ($m^3$/day) | Total sub-soil drains capture ($m^3$/day) |
|---|---|---|---|
| **NRS Operation** | | | |
| 30% rainfall[1] | 744 | 342 | 1087 |
| 50% rainfall[1] | 736 | 508 | 1244 |
| **NRS Closure** | | | |
| 5-year average cap infiltration (369 mm/year)[2] | 751 | 212 | 963 |
| 1. Based on an average annual rate of 2.11 m/year<br>2. AECOM, 2020.<br>- Considering model uncertainty, results are rounded. | | | |

*Table 4.6 Predicted groundwater and leachate captured in sub-soil drains*

| Infiltration conditions | Leachate flow to Ohinemuri River ($m^3$/day) |
|---|---|
| **NRS Operation** | |
| 30% rainfall[1] | 71 |
| 50% rainfall[1] | 97 |
| **NRS Closure** | |
| 5-year average cap infiltration (369 mm/year)[2] | 49 |
| 1. Based on an average annual rate of 2.11 m/year<br>2. AECOM, 2020.<br>- Considering model uncertainty, results are rounded. | |

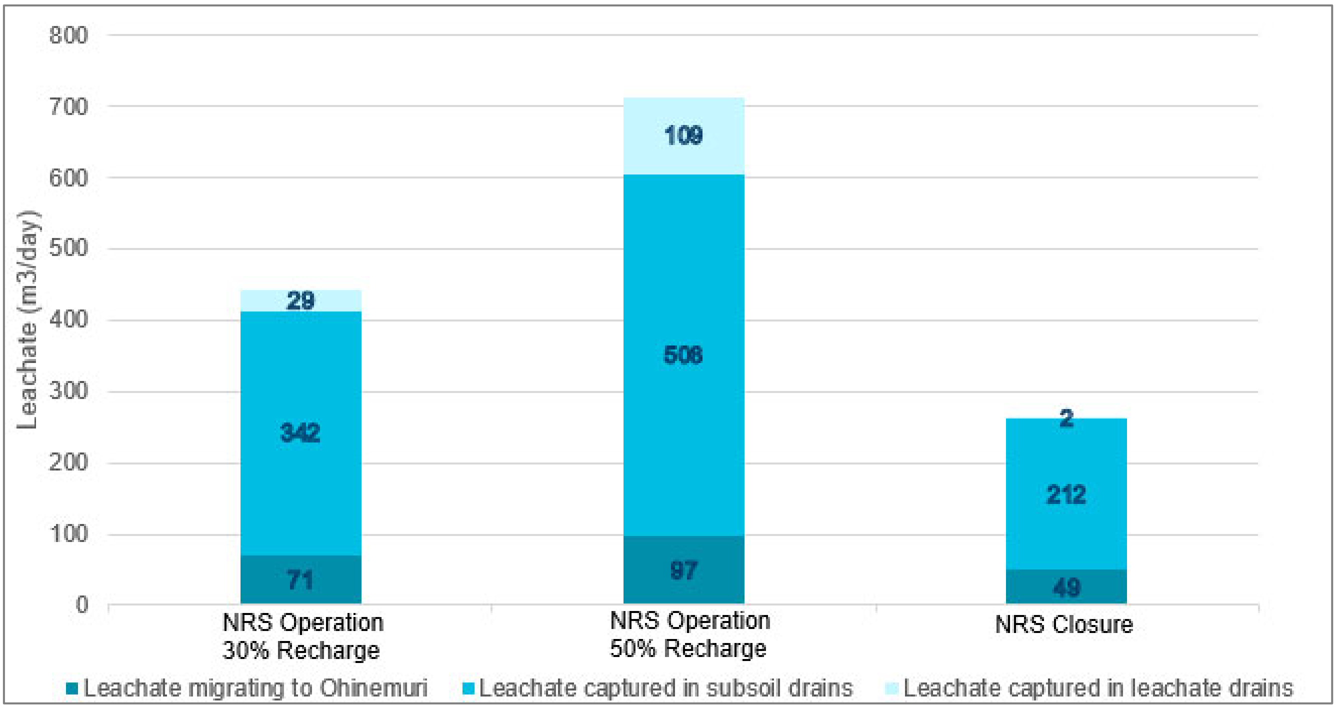



*Figure 4.8* *NRS leachate balance*

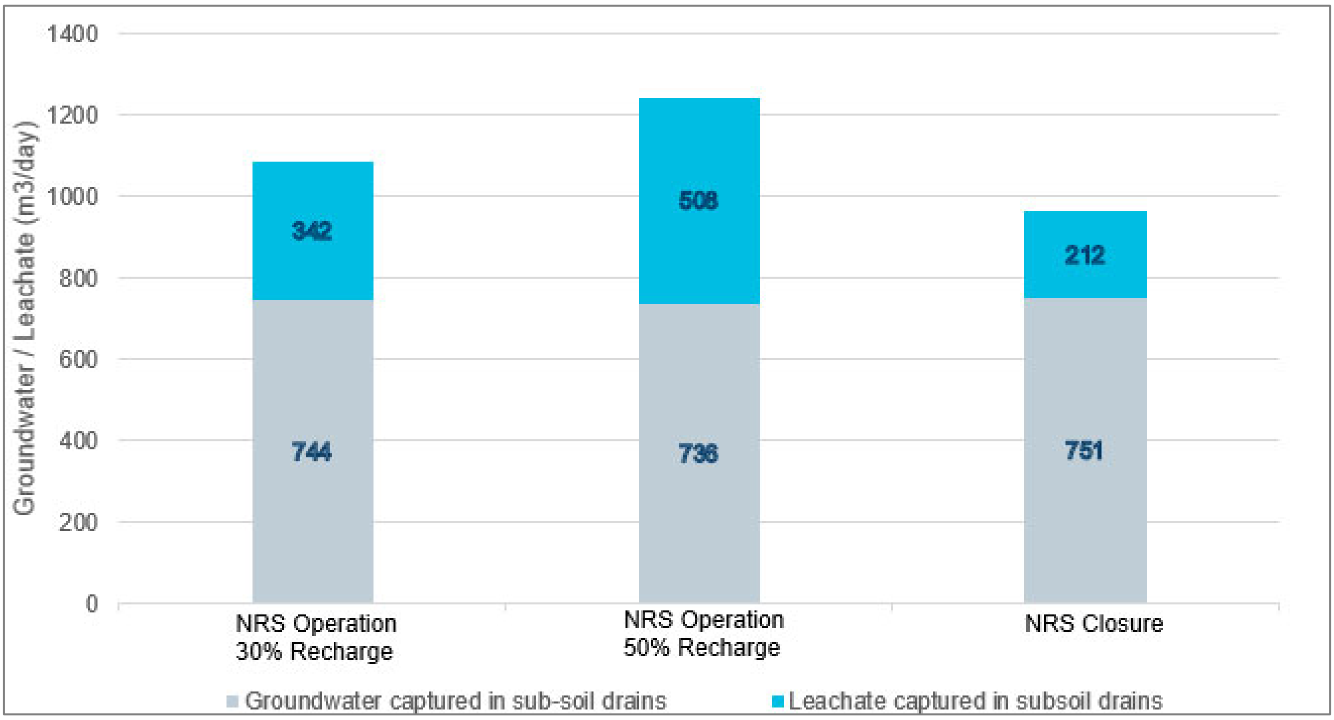



*Figure 4.9* *NRS groundwater and leachate captured in sub-soil drains*

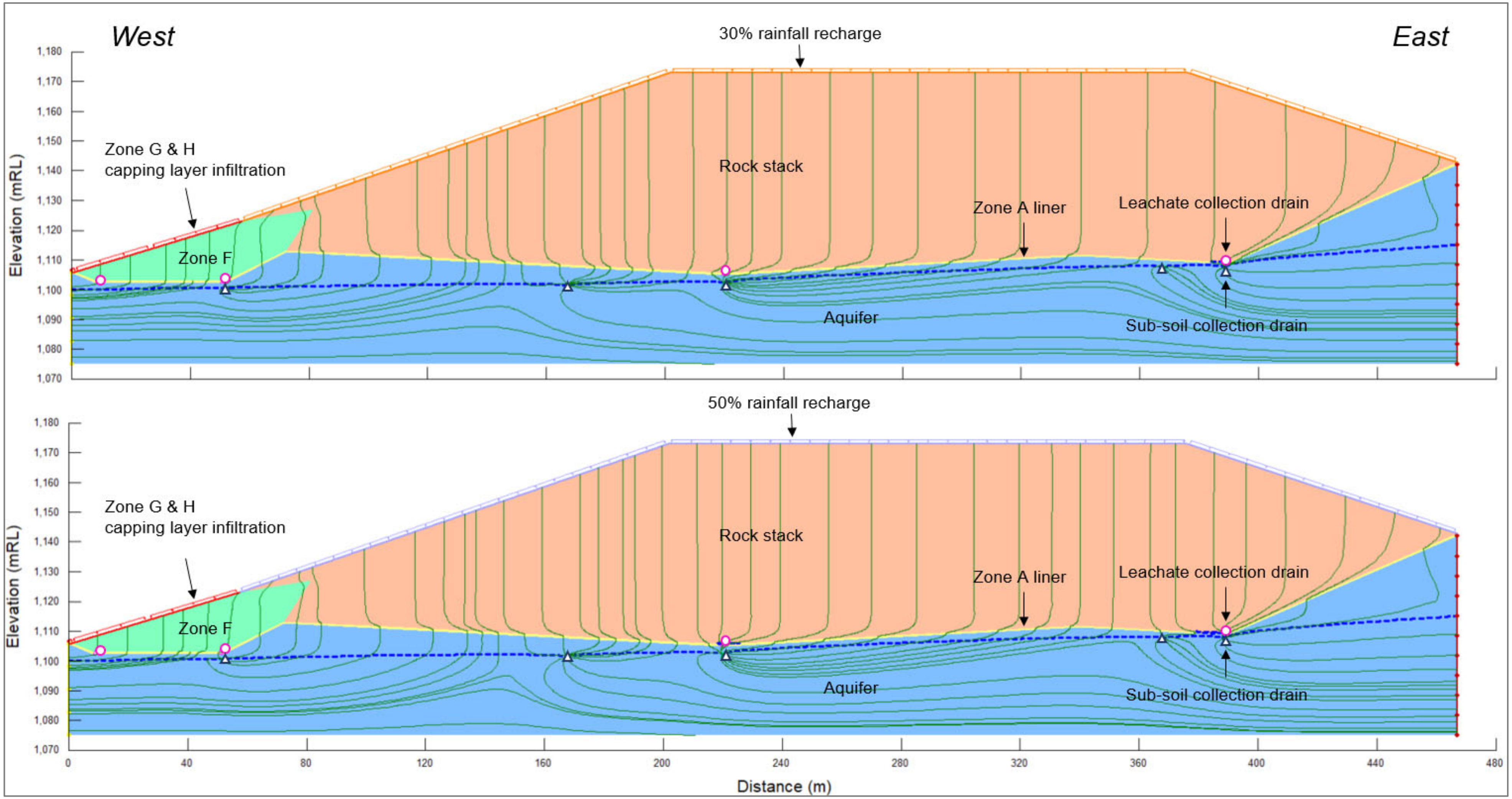



*Figure 4.10 NRS operation scenario predicted leachate and groundwater flow paths for 30% and 50% rainfall recharge*

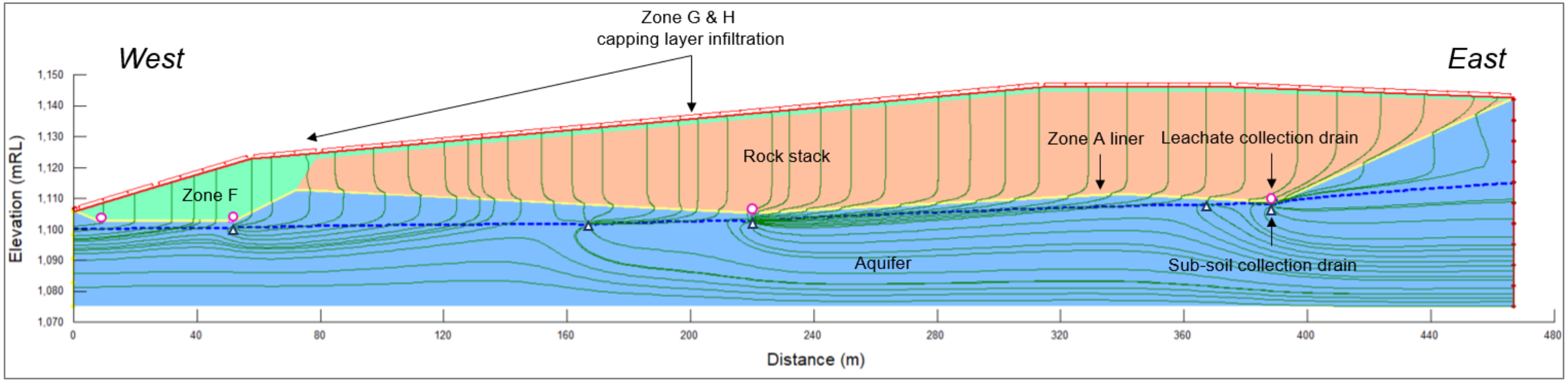



***Figure 4.11 NRS Closure scenario predicted leachate and groundwater flow paths***

## 4.5.3 Water quality

Emplacement of rock at the NRS will result in leachate generation during both operation and after closure that will percolate downwards through the rock stack. Quality of leachate is expected to improve over time (AECOM, 2025). Where not captured by leachate drains the leachate will seep through the underlying Zone A soil liner until groundwater is encountered. A significant volume of impacted groundwater will be captured by the sub-soil drains and diverted for treatment. The remaining leachate impacted groundwater will migrate to the Ohinemuri River.

The potential effects of the leachate seepage on the receiving environment have been predicted for the NRS closure scenario and compared against the existing water quality of the groundwater and the Ohinemuri River (Table 4.7).

The water quality assessment provides a highly conservative prediction of potential impacts as the methodology does not allow for attenuation, which would otherwise significantly reduce many of the concentrations provided in Table 4.7. Attenuation is expected to occur through interaction with the soil profile and adsorption reactions with groundwater flow, with only residual soluble components then migrating from the point of discharge with groundwater flow.

The predicted concentrations of mercury are greater than the RWQC as the laboratory detection limit of this parameter is greater than the criterion. As discussed previously, mercury is typically immobile in groundwater due to volatilization and/or precipitation processes and has not been reported in significant persistent concentrations by OGNZL (2020). It is not a parameter of concern for these reasons.

The following is summarised from the water quality assessment:

– Overall, concentrations of several parameters associated with rock storage are predicted to increase within the groundwater in the NRS closure scenario, with iron and manganese exceeding the receiving water quality criteria.
– The large catchment of the river results in significant dilution of groundwater discharging from the NRS to the Ohinemuri River, so that predicted increases in Table 4.7, with the exception of sulphate, are expected to be unmeasurable within laboratory error and natural variations in the river. Parameter concentrations within the river are predicted to remain below the adopted receiving water criteria.
– The mass flux of NRS leachate and groundwater discharging to Ohinemuri River during operation of the NRS is provided in Table 4.8. These values are presented for inclusion in the Water Management Report for the assessment of cumulative effects to the Ohinemuri River catchment and are not discussed further in this report. It is noted that these results are highly conservative as they are for the 50% rainfall recharge scenario during NRS operation and do not consider geochemical equilibration of the leachate with the shallow groundwater or attenuation.

*Table 4.7 Predicted receiving water quality in the NRS closure scenario (values in mg/L)*

| **Parameter** | **Existing shallow groundwater quality** (DH05a median) | **Predicted values after equilibration of NRS leachate with shallow groundwater (AECOM, 2021b)** | **Existing Ohinemuri River quality** (OH3 median) | **Predicted values after mixing with Ohinemuri River** | **Receiving water quality criteria** |
|---|---|---|---|---|---|
| pH | 6.5 | 7.4 ↑ | 7.2 | - | |
| Al | 0.003 | 0.011 ↑ | 0.013 | 0.013 | |
| As | 0.0096 | <0.001 | <0.0010 | <0.0010 | 0.19 |
| Ba | 0.67 | 0.02 | 0.027 | 0.027 | |
| Ca | 2.7 | 116.0 ↑ | 3.1 | 3.6 ↑ | |
| Cd | <0.00005 | 0.000010 | <0.00005 | <0.000050 | 0.0003 |
| Co | 0.041 | 0.020 | <0.00020 | 0.00028 ↑ | |

| Parameter | Existing shallow groundwater quality (DH05a median) | Predicted values after equilibration of NRS leachate with shallow groundwater (AECOM, 2021b) | Existing Ohinemuri River quality (OH3 median) | Predicted values after mixing with Ohinemuri River | Receiving water quality criteria |
|---|---|---|---|---|---|
| Cr | <0.0005 | <0.0005 | <0.0005 | <0.00050 | 0.01 |
| Cu | <0.0005 | 0.000060 ↑ | <0.0005 | <0.00050 | 0.003 |
| Fe | ***6.8*** | ***21.0*** ↑ | 0.10 | 0.19 ↑ | 1 |
| Hg | ***<0.00008**** | ***<0.00008**** | ***<0.00008**** | ***<0.00008**** | 0.000012 |
| K | 2.3 | 3.0 ↑ | 2.0 | 2.0 | |
| Mg | 1.2 | 28.0 ↑ | 1.9 | 2.0 ↑ | |
| Mn | 1.5 | ***4.0*** ↑ | 0.010 | 0.027 ↑ | 2 |
| Na | 9.9 | 11.0 ↑ | 9.2 | 9.2 | |
| Ni | 0.0051 | <0.003 | <0.0005 | <0.00051 ↑ | 0.04 |
| Pb | 0.00016 | <0.0001 | <0.0001 | <0.0001 | 0.0004 |
| SO4 | 5.0 | 338.0 ↑ | 5.0 | 6.4 ↑ | |
| Sb | <0.0002 | 0.00030 ↑ | <0.0002 | <0.00020 | 0.03 |
| Se | <0.001 | <0.001 | <0.0002 | <0.00020 | 0.02 |
| Zn | 0.016 | <0.003 | 0.0019 | 0.0019 | 0.027 |

*Notes:*
Receiving water quality criteria values for hardness 20 $g/m^3$ $CaCO_3$
Values in **bold** indicate an exceedance of the receiving water quality criteria
* The mercury (Hg) criterion is lower than available laboratory detection limits
↑ Denotes a predicted increase from existing groundwater / surface water quality

*Table 4.8 Predicted mass flux to the Ohinemuri River during operation of the NRS (50% rainfall recharge)*

| Parameter | Mass flux (kg/day) to Ohinemuri River |
|---|---|
| Al | 1.2 |
| As | 0.00054 |
| Ba | 0.026 |
| Ca | 46.7 |
| Cd | 0.00068 |
| Co | 0.19 |
| Cr | 0.00012 |
| Cu | 0.0026 |
| Fe | 29.3 |
| Hg | 0.000013 |
| K | 1.4 |
| Mg | 11.2 |
| Mn | 1.6 |
| Na | 10.2 |
| Ni | 0.076 |

| Parameter | Mass flux (kg/day) to Ohinemuri River |
|---|---|
| Pb | 0.000025 |
| SO4 | 139.9 |
| Sb | 0.00020 |
| Se | 0.00023 |
| Zn | 0.12 |

# 4.6 NRS potential effects summary and discussion

The predicted influence on key environmental aspects is summarised in the following sections.

## 4.6.1 Uphill diversion drain construction dewatering

Placement of the NRS is predominantly anticipated to be above the existing range of groundwater level fluctuations at the site. The exception to this is in the south-eastern boundary, where excavation into the elevated rhyolite dome is proposed to allow installation of the uphill clean water diversion drain.

The dewatering assessment to estimate the influence of this drainage was highly conservative, assuming that the groundwater would be encountered along the full 240 m length of the excavation section. The predicted inflow rates are also those expected at the commencement of dewatering (10 – 70 $m^3$/day) and are likely to reduce over time as groundwater levels reduce in response to the change in conditions. The dewatering required for installation, and the ongoing influence of the uphill diversion drains throughout operation and closure, is predicted to have a zone of influence of up to approximately 10 m and is therefore not likely to have a significant impact on groundwater gradients and flow across the remainder of the NRS site. Whilst localised changes may occur in the immediate vicinity of the dewatering, the minor volume is not expected to significantly influence the wider groundwater and surface water flow regime. Abstraction of groundwater during construction dewatering is also not expected to adversely impact groundwater quality.

While there may be some localised changes in soil moisture in close proximity to areas of earthworks and dewatering, no impacts are expected beyond the immediate vicinity of the works. Intermittent wetting by rainfall is considered to provide the greatest influence on soil moisture levels across the Waihi North Project area.

## 4.6.2 Rock stack assessment, groundwater levels and flow

### Final landform

After rock stored at the NRS has been used to backfill Gladstone Open Pit and various underground mining stopes, the proposed final maximum elevation of the NRS is 1,148 mRL. This includes a rock capping layer (Zone F, G and H materials) to limit oxygen and water ingress. The capping layer is proposed to be covered with topsoil and contoured.

### Groundwater levels and flow

Groundwater flow to the Ohinemuri River has been estimated at approximately 1,170 $m^3$/day. This represents only a small proportion (< 1%) of Ohinemuri River flow as it passes the NRS site (averaging 63,200 $m^3$/day), with this supported by unmeasurable changes in river flow recorded between up- and down-gradient flow gauging sites.

The potential reduction of direct rainwater recharge to the groundwater system due to placement of the NRS is predicted to be offset or increased by seepage of leachate through the liner. The results of the assessment indicate that between 415 – 605 $m^3$/day of leachate is predicted to seep through the liner and discharge into the groundwater beneath the rock stack during the NRS operation scenario, reducing to approximately 260 $m^3$/day in the NRS closure scenario.

Only small changes to groundwater levels are predicted to occur due to placement of the NRS, however groundwater discharge to the Ohinemuri River is expected to reduce as a large component of groundwater flow will be captured by the sub-soil drains. Existing rainfall recharge will be intercepted by the rock stack and the perimeter drains, however this is expected to be offset or increased by seepage of leachate through the NRS soil liner.

Although there is the potential for groundwater mounding to occur beneath the NRS where the rate of leachate seepage exceeds that of the existing rainfall recharge, groundwater levels are expected to be largely controlled by the elevation of the sub-soil drainage system. The results of the assessment indicates that between 1,090 – 1,245 $m^3$/day of combined leachate and groundwater may be captured by the sub-soil drains during NRS operation, reducing to approximately 965 $m^3$/day following NRS closure.

Where mounding of groundwater occurs, the likelihood of saturated conditions being present within the rock increases, driving horizontal flow within the rock towards the leachate collection drains and reducing the proportion of leachate that may seep through the soil liner. This is demonstrated in the results of the sensitivity analysis (Appendix H), where groundwater levels up- and down-gradient of the NRS were both tested within the SEEP/W model. Furthermore, interception of elevated groundwater by the sub-soil drains and diversion for treatment is anticipated to reduce the contaminant flux that may migrate within groundwater beyond the NRS footprint and discharge into the Ohinemuri River.

Regardless of the degree to which leachate infiltration generates mounding, groundwater flow to the receiving environment is not expected to be significantly changed as a result of the proposed NRS. This is supported by monitoring of existing storage facilities which indicates that water levels remain similar to existing conditions.

Former gullies and permeable material across the site, including the boulder and cobble alluvium and weathered ignimbrite in the paleo-channel beneath the NRS footprint, have the potential to act as preferential pathways for groundwater flow, providing a conduit for groundwater discharge to the Ohinemuri River where not captured by sub-soil drains. Elsewhere, depending on the hydraulic gradients, and the elevations of the NRS liner and sub-soil drains, seepage may infiltrate deeper in the shallow groundwater system and ultimately discharge to the Ohinemuri River via existing groundwater flow paths.

## Surface water

The footprint of the proposed NRS and associated features are located within the surface water catchments of the Ohinemuri River and tributary TB1. At present, surface water runoff and interflow discharges directly to these surface water features. During operation of the rock stack, clean water diversion drains will capture stormwater and interflow which will be discharged directly to the Ohinemuri River. During operation of the NRS, rainfall that is intercepted by the rock stack will either evaporate or generate leachate. After closure of the NRS, a degree of recharge to the rock stack will still occur through the capping layer and continue to generate leachate. Runoff from the rock during operation, or from the capping layer after closure, will be collected within perimeter drains and diverted to the collection pond for treatment, after which it will be discharged to the Ohinemuri River.

During both operation and closure of the NRS, the leachate generated within the rock stack has three potential pathways:

1. Capture by leachate collection drains, treatment and discharge to the Ohinemuri River.
2. Seepage through the NRS soil liner into groundwater, capture by sub-soil or toe drains, followed by treatment and discharge to the Ohinemuri River.
3. Seepage through the NRS soil liner into groundwater, followed by migration and discharge to the Ohinemuri River.

Although the pathways of runoff, interflow and groundwater will change, and may be intercepted during operation and after closure of the NRS, the Ohinemuri River will remain as the final receiving environment. As no additional water is proposed to be introduced to the NRS system by way of a dam or pond (i.e. as with TSF3), the volume of discharge to the river is therefore expected to remain similar to those under existing conditions. Changes to surface water flow and levels in the Ohinemuri River during operation and after closure of the NRS are therefore expected to be unmeasurable.

## Rock stack leachate and water quality

The proposed NRS has the potential to influence the water quality within the receiving environment due to seepage of rock leachate through the base of the Zone A liner. Between 415 – 605 $m^3$/day of leachate is predicted to seep through the liner and discharge into the groundwater beneath the rock stack in the NRS operation scenario, reducing to approximately 260 $m^3$/day following NRS closure.

The leachate will mix with the groundwater and any residual soluble mass, following attenuation, will either be captured by the sub-soil drainage system or migrate to the Ohinemuri River with groundwater flow. The assessment results indicate that between 70 – 100 $m^3$/day of leachate is predicted to migrate to the Ohinemuri River in the NRS operational scenario, reducing to approximately 50 $m^3$/day in the NRS closure scenario.

The results of the water quality assessment considered dilution of contaminant mass predicted to discharge to groundwater and predicted to migrate to the Ohinemuri River. Adsorption of contaminants to aquifer materials along the groundwater flow path has not been considered and in this regard, the prediction of effects to groundwater and Ohinemuri River quality are considered to be highly conservative.

Monitoring of existing storage facilities indicates that following closure longer term impacts should reduce, with these considered more relevant to the Ohinemuri River water quality owing to groundwater travel times and contaminant adsorption.

Following dilution and mixing of groundwater with the Ohinemuri River, the assessment indicates given the length of the flow path and expected attenuation, changes to Ohinemuri River water quality are expected to be minimal. Sulphate is predicted to increase between 1 – 2 mg/L which may be measurable within the river, however this increase is considered to be small in the context of the downstream water quality changes.

Under baseflow conditions, the Ohinemuri Tributary (TB1) at the NRS site displays neutral results during flow gauging, and a similar chemical signature to nearby piezometers. This indicates that this stream is in close connection with the shallow groundwater system. Placement of sub-soil drainage along the alignment of TB1 therefore has the potential to capture a large proportion of leachate seepage occurring in the eastern portion of the proposed NRS. This presents the opportunity to identify potential issues with discharges and reduce the flux to the receiving environment.

The presence of the paleo-channel along the same alignment of TB1 is considered to provide a preferential groundwater flow pathway towards the Ohinemuri River. The greatest permeability is likely to be within the boulder and cobble alluvium in the base of the paleo-channel, therefore there is the potential for leachate seepage from the NRS to by-pass the sub-soil drains, as already appears to be occurring from the northern stockpile. In the event that groundwater flow to the sub-soil drainage system does not eventuate, monitoring within the paleo-channel provides an alternative means of identifying and responding to unforeseen conditions.

Meaningful changes in groundwater and river levels are not anticipated as a result of the proposed NRS. However, if the Ohinemuri River immediately adjacent to the NRS site becomes neutral or losing due to changes in groundwater levels and flow regime as a result of placement of the NRS and capture of groundwater within sub-soil drains, the following is noted with regards to potential fate and transport:

– Groundwater would likely flow south, following topography and alignment of the Ohinemuri River before discharging to the River further downstream.
– While estimated groundwater quality considers equilibration of NRS leachate with shallow groundwater, adsorption of contaminants to aquifer materials along the groundwater flow path has not been considered. As discussed in Section 2.6, concentrations of trace elements in groundwater tend to decrease with increasing distance from the TSFs, which suggests that in-ground conditions promote attenuation. As such, the area of impacted groundwater is limited to within OGNZL land. Section 4.3.4 also notes that comparison of water quality results between the existing northern storage toe drains and groundwater monitoring wells indicate that dilution and attenuation of leachate from the existing rock storage is likely to be reducing the contaminant concentrations measured in groundwater, with these concentrations also reducing with distance from the stockpile. This suggests that in-ground conditions promote attenuation of trace element contaminants released from mineralised rock through adsorption and co-precipitation reactions. The occurrence of such attenuating processes is likewise expected to mitigate contaminant discharge from the NRS, with significant attenuation continuing if the groundwater flow path is longer prior to discharge to the river.

– While the location and alignment of paleochannels at the NRS site, and the drain proposed to be installed along the alignment of the existing tributary, will influence the shape of a leachate plume, the fate of any impacted groundwater will be similar to that described above, with discharge to the Ohinemuri River occurring either in close proximity to the site or further downstream to the south.

#### Water users

No current or anticipated groundwater users have been identified within 800 m of the NRS. Any changes to groundwater levels or quality are likely to have a negligible effect on the groundwater receiving environment. Although minor reductions in groundwater levels have been recorded around the existing northern storage and TSF2, the levels remain within historical range, providing supporting evidence for the above interpretation.

### 4.6.3 Monitoring recommendations

Monitoring is recommended as a condition of consent, as per other mining activities at Waihi. This section provides only a high-level overview of monitoring recommendations. Specific requirements should be detailed in an overarching NRS Water Monitoring and Contingency Plan. The plan should include requirements for baseline monitoring (for comparative analysis to provide a degree of confidence in the assessment), trigger levels, and contingency measures to manage any potential exceedances.

– **Construction dewatering:** Monitoring of groundwater inflow rates and groundwater levels should be undertaken during the excavation and dewatering works to assist with understanding groundwater response.
– **NRS operation and closure:**
  - **Groundwater levels:** Monitoring of groundwater levels should be undertaken at selected monitoring wells prior to and during installation of the Zone A liner, placement of the rock and capping of the rock.
  - **Flow monitoring:** Surface water flow gauging of the Ohinemuri River and its tributaries should be undertaken prior to, during and after construction of the NRS.
  - **Water quality:** Monitoring of groundwater and surface water should be undertaken to assess potential impacts to the receiving environment during and after development of the NRS. This should include targeting groundwater within paleo-channels.

# 5. Tailings Storage Facility Three

## 5.1 Site overview

### 5.1.1 General site setting

A high-level site layout plan of the proposed TSF3 is provided in Figure 5.1. It will extend over a short valley, approximately 700 m wide, covering existing farmland, which comprises surficial alluvium and underlying weathered rhyolite deposits. The hills surrounding the site are remnants of the ancient Ruahorehore Volcanic Dome, which has a maximum elevation of 1,260 mRL. The valley runs approximately from northeast to southwest, down to 1,109 mRL at the toe of the proposed TSF. At this location, the Ruahorehore Stream has a large catchment (580 ha), extending to the east and is heavily altered to form a drainage channel for farming purposes.

The site is characterised by generally poorly drained soils (observed boggy surface and surface water ponding in winter). A series of short upper valley branches extend into the hills to the north (Figure 5.2), with two spring-fed streams forming the Ruahorehore Tributary. The tributary flows from the hills via farm drains to the Ruahorehore Stream to the south. The farm drains are shallow with typically very low to no flow baseflow. The Ruahorehore stream will require diversion at the toe of the embankment as indicated on Figure 5.1.

The transition from farm drain to stream occurs in the area west of the red catchment marked on Figure 5.1. Shed Spring is located downgradient of TSF3 and immediately south of TSF1A. This spring provides a significant portion of the flow to the Ruahorehore Stream at this location (discussed further in Section 5.3.5).

Drainage water from TSF1A toe (GWS, 2019; 2020), springs and farm drains are also inferred to report to Ruahorehore stream downstream of the TSF3 site.

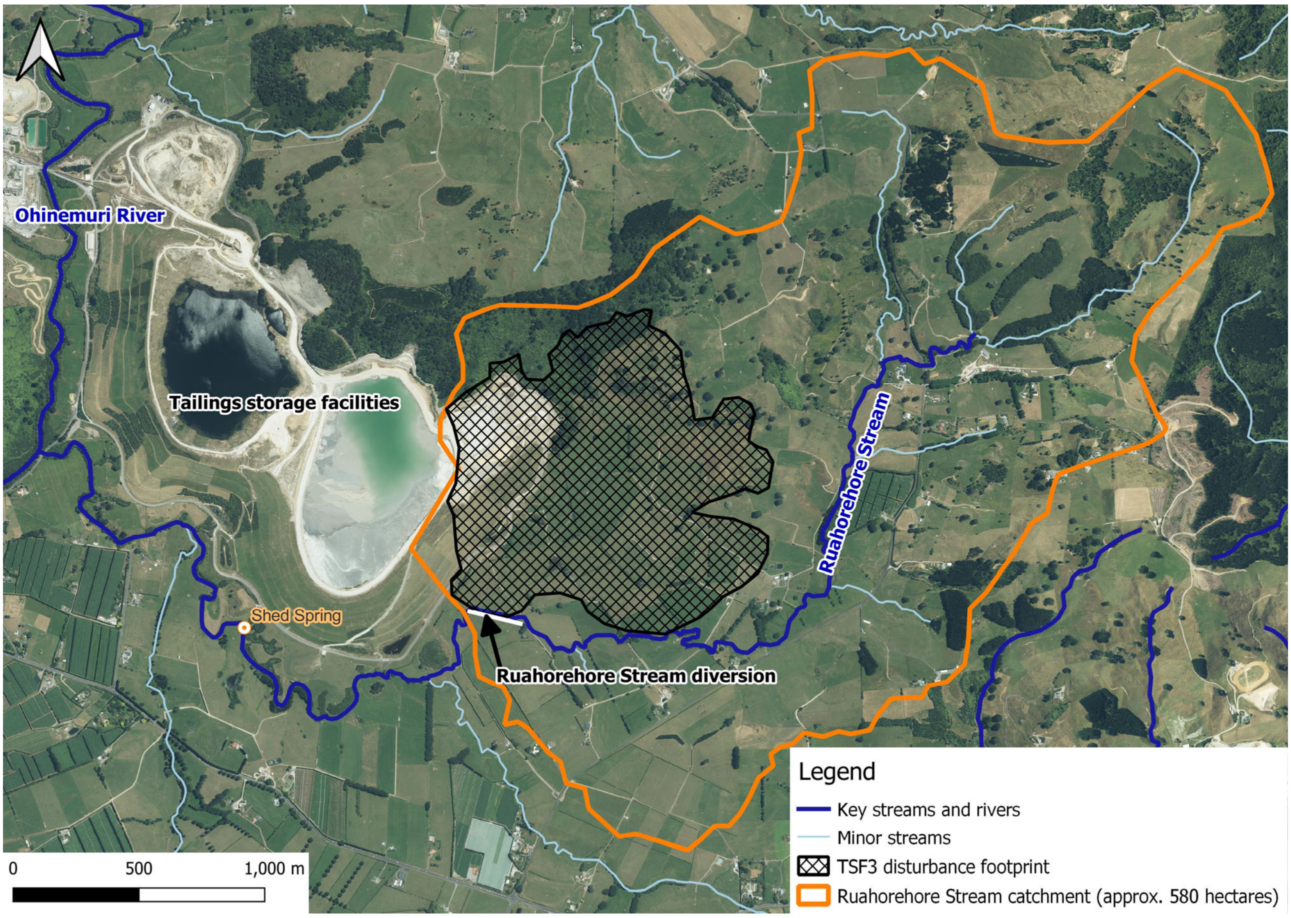
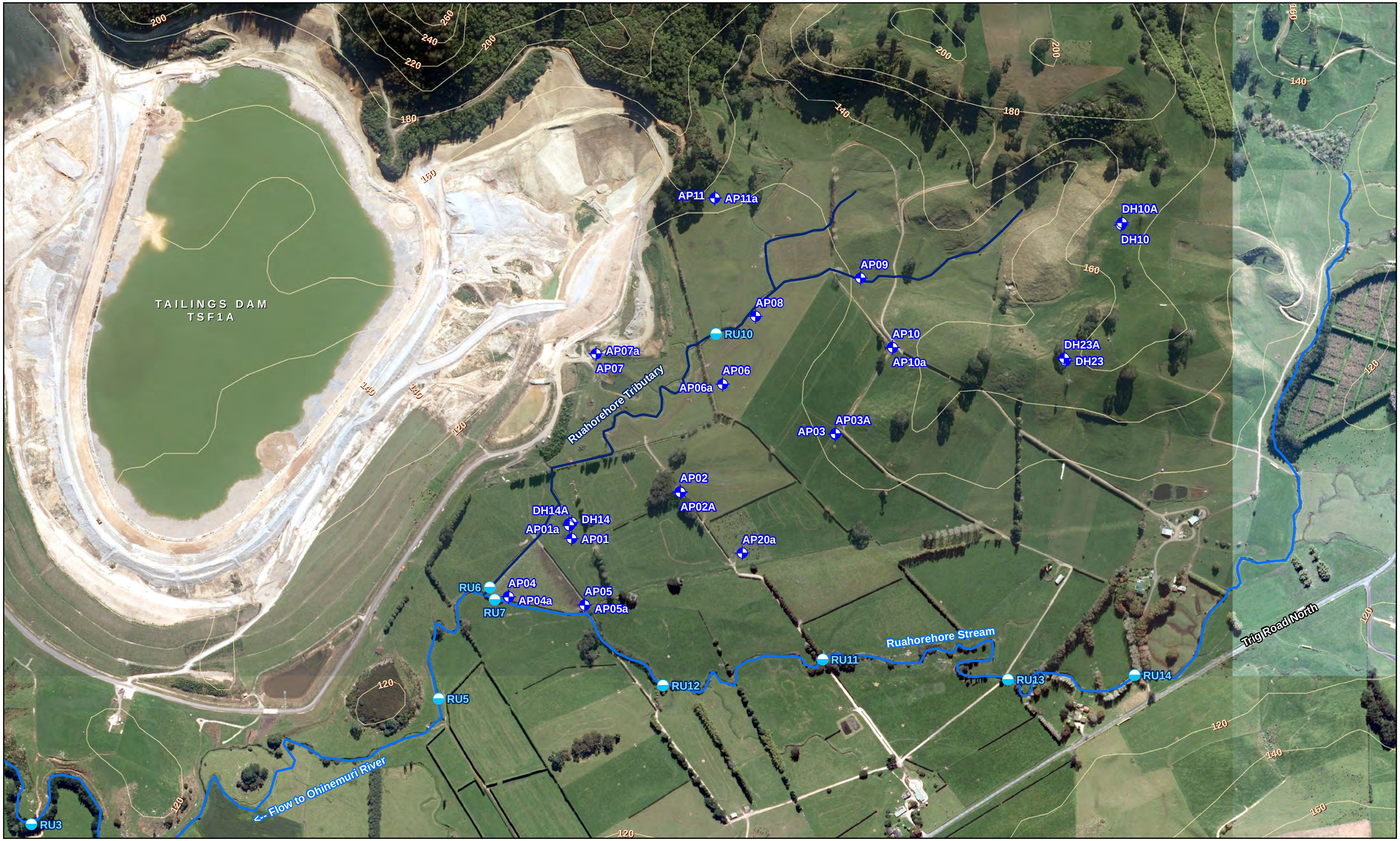



*Figure 5.1 TSF3 site layout plan showing the Ruahorehore Steam Catchment upstream of the TSF3 embankment toe*




Paper Size A3

0 50 100 200

Metres

Map Projection: Transverse Mercator
Horizontal Datum: NZGD 2000
Grid: NZGD 2000 New Zealand Transverse Mercator

N

LEGEND

OGL Bores

Surface Water Locations

**Ohinemuri River Tributary**

Stream

Tributary

Contour (20m)

Oceana Gold Limited
Quattro

TSF3 Site Setting
and Monitoring Locations

| | |
|---|---|
| Job Number | 51-37083 |
| Revision | A |
| Date | 23 Dec 2020 |

Figure 5.2

N:\NZ\Christchurch\Projects\51\37083\GIS\Maps\Deliverables_Hydrogeo_SiteSetting\51_37083_Z005_TSF3SiteSetting.mxd

Level 3, 138 Victoria Street, PO Box 13 468, Christchurch 8141, New Zealand **T** 64 3 378 0900 **F** 64 3 378 8001 **E** chcmail@ghd.com **W** www.ghd.com



Data source: Aerial imagery - LINZ; General topo - LINZ; Bore locations - OGL. Created by:jrprice

### 5.1.2 Summary of proposed activity

The proposed TSF3 will be an earth and rockfill embankment structure, like TSF1A and 2, forming an impoundment to store the discharged tailings slurry pumped from the Processing Plant. At its northern extent, the TSF abuts the steeply sloping hillside, comprising rhyolite and its western extent abuts TSF1A (Figure 5.3). The proposed TSF3 is described in detail in the TSF3 Technical Report prepared by EGL (2025b). A plan of proposed TSF3 at 1,155 mRL is provided in Figure 5.3 (below).

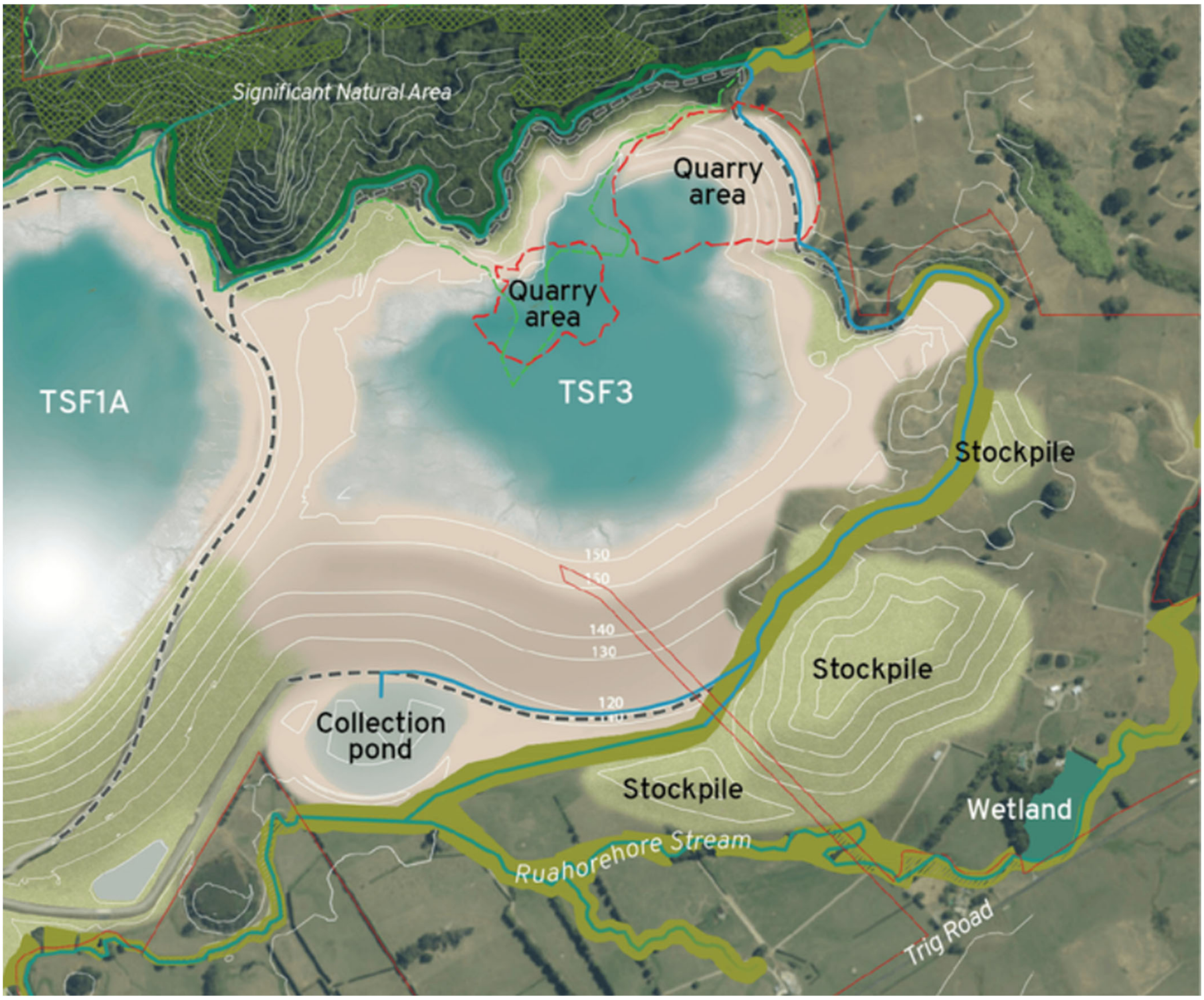



*Figure 5.3 TSF3 layout plan to 1,155 mRL (OGNZL, 2025). (Note: elevations in figure not to mine datum +1,000 mRL).*

A summary of the key aspects as it relates to this assessment is provided below (EGL, 2025b):

– **Foundation works**:
  - Removal of topsoil and stockpiling.
  - Excavation of quarry/borrow areas to provide a source of NAF fill (Figure 5.3).
  - Drainage works to intercept groundwater flow immediately beneath the impoundment (subsoil drains installed up the centre of the gullies, initial embankment upstream cutoff drain and initial toe drain, and a main embankment downstream toe drain).
  - Diversion works (including a section of the Ruahorehore Stream).

- Initial excavation and dewatering of compressible soils. Up to 20 m of weak compressible soil in the paleo-gully area will require removal and backfill with NAF structural fill.
  - Construction of a low-permeability NAF soil liner (Zone A material) across the tailings footprint.
  - Installation of leachate collector drains above the Zone A liner, within the embankment.
- **Starter embankment**:
  - Construction of TSF3 is expected to commence in advance of MOP and GOP, therefore the starter embankment will initially be constructed using material from the borrow areas and the existing East Stockpile. The starter embankment will be constructed to an elevation of 1,135 mRL.
  - Emplacement of HDPE liner to 1,135 mRL.
  - The collected drainage will be pumped from the leachate collection system and sent to the WTP.
- **Stages operational through to closure:**
  - Crest lifts in stages, including to 1,145 mRL.
  - Lift to the final facility height of 1,155 mRL.
  - Capping of the embankment to minimise oxygen ingress (closure).

At 1,155 mRL (Figure 5.3, above), TSF3 will:

- Have a new footprint of 100 ha. Of the total footprint (approximately 120 ha), 20 ha is already part of the existing footprint of TSF1A and East Stockpile.
- Have an embankment crest 20 m-wide and a total length of 1,000 m.
- Have three lined (HDPE) collection ponds (S4, S6 and S7) downgradient of the facility.
- Be 46 m in height above the toe at 1,109 mRL.
- Contain up to 6.7 $Mm^3$ of tailings material.

To achieve the design objectives of TSF3 (outlined in the EGL technical report (EGL, 2025b)) the rock embankment will be designed as a zoned structure. The primary functions of the different zones are summarised in Table 5.1.

*Table 5.1 Description of TSF3 construction materials*

| Material name | Description |
|---|---|
| Zone A | Low permeability zone (earth liner) underneath the full facility that restricts seepage from mine overburden material into underlying ground |
| Zone B | Low permeability upstream zone that restricts seepage from the tailings |
| Zones C1 and C2 | Structural fill zones that provide support to Zone B and provide a transition between the finer grained material in Zone B and the coarser material in Zones D2 and D3 |
| Zones D2 and D3 | Bulk fill zones with less restrictive requirements than other zones. Zone D2 has a higher strength specification than Zone D3. |
| Zone E | Specified zones for the weakest material |
| Zone F | Structural fill zone on outside shoulder that also provides a transition between the coarser material in Zone D and finer material in Zone G. Also provides a drainage path for leachate. |
| Zone G | Outer sealing layer of the embankment that restricts entry of oxygen and water |
| Zone H | Plant growth layer |
| Zone I | Structural fill forming downstream section of the perimeter road where it is in fill |

Notes:
PAF mine overburden material is not permitted for use in Zones A, G, H and I.
Refer to EGL (2025b) Technical Report drawings for further detail of these zones.

### 5.1.3 Potential influences on groundwater and surface water

TSF3 will be positioned within the Ruahorehore Stream catchment (Figure 5.1). The removal of unsuitable materials from the TSF3 footprint will require stream and spring diversion and construction dewatering, whilst the TSF design requires sub-surface drainage to control groundwater pressure. The assessment of potential effects to groundwater and surface water associated with TSF3 has focused on the following:

– Construction dewatering required for the excavation of sensitive soils and the potential dewatering effects on the Ruahorehore Stream.
– The potential leachate and contaminant discharges from TSF3 and whether engineered underdrainage is likely to mitigate adverse impacts to groundwater and surface water.
– The potential influence on groundwater and the Ruahorehore Stream in the event that the proposed underdrainage system does not provide effective interception of contaminants, e.g.. drainage failure.

## 5.2 Local geology

The regional geology is presented in Section 2.3. The local geology for the TSF3 area is presented in Figure 5.7 and Table 5.2 below, which includes the local terminology applied to this TSF3 assessment. Material descriptions not previously used prior to 2018 include the sensitive/redeposited tuff and froth flow within the primary rhyolite unit. These terms have been introduced by EGL in the Geotechnical Factual Report (GFR; EGL, 2018), which provides a detailed description of the local geology and origins (including from GNS (1996)).

Cross-sections of the geology beneath the proposed TSF3 are provided in Figure 5.4 (E-W) and Figure 5.6 (NE-SW). This site is located within a surficial alluvial gully (defined as 'the paleo-gully') dipping to the southwest, and surrounded by rhyolite ridges of the Ruahorehore Rhyolite (unit *mnr*). Both the paleo-gully and rhyolite ridges form significant features at the proposed TSF3 site. Key geological features are summarised below:

– Whilst Coromandel Group dacite (unit *iu*) and regional andesite rock (*aw*) underlie the site at depth, these units are separated from the Waihi East ore bodies (including Gladstone) by the Golden Valley Fault.
– The Golden Valley Fault, which separates TSF3 from TSF1A and TSF2, provided a conduit for the Ruahorehore Rhyolite (a dome of the Homunga Rhyolite), which intruded through the andesite and dacite. The original rhyolite dome is deeply eroded beneath the proposed TSF3 site, and the shallow geology demonstrates an extensive weathering profile (Figure 5.5). The dome remnants form the topographic highs that bound the paleo-gully and will form the northern, eastern and western bounds of TSF3 (Figure 2.3). The rock below the site has been confirmed from sterilisation drilling to have no mineralised veins.
– The TSF3 paleo-gully appears to be infilled with remnants of a complex mixture of rhyolite tuffs, pyroclastic flows and gaseous lava flows (Figure 5.6; refer to EGL (2018) for further detail). The surface geology comprises alluvium/colluvium, and/or volcanic ash up to a few metres thick. These materials are unsuitable for use in the TSF3 foundation and are required to be excavated and backfilled, including the redeposited tuff to a depth of 20 m.

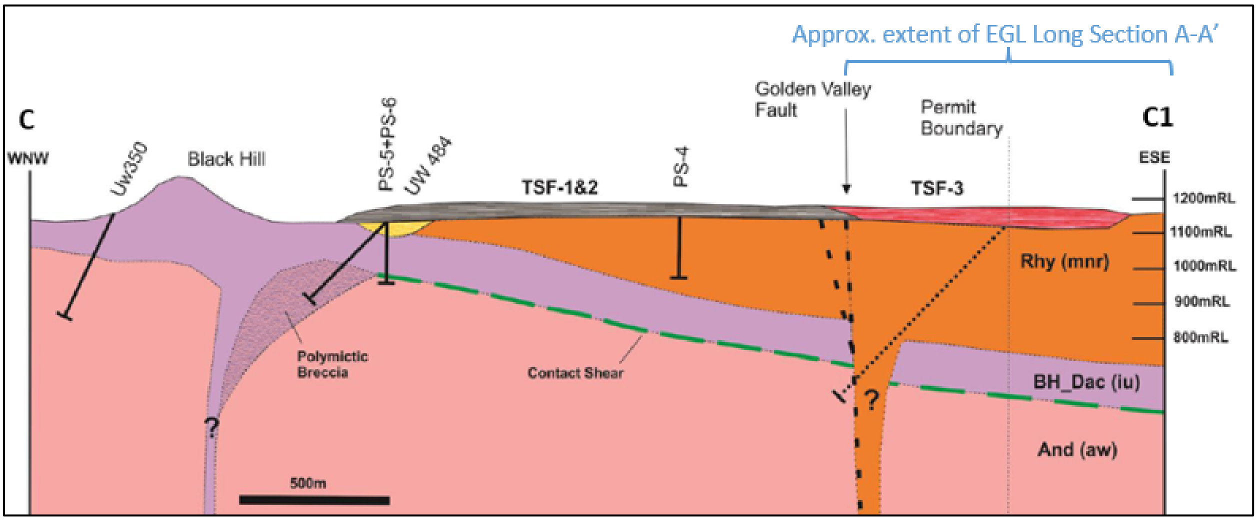



*Figure 5.4 TSF3 geological section (C-C' of Figure 2.3) (from OGNZL, 2017)*

*Table 5.2 Stratigraphy of the TSF3 area*

| Unit | Depths encountered<br>*(thickness where present)* | | Description |
|---|---|---|---|
| Topsoil | Surficial<br>*(0.01 to 0.7 m)* | | Occurs across the site, thickest near gully features.<br>Fill is present at some locations. |
| Volcanic Ash | Surficial (typically)<br>*(< 2.2 m; averaging 1.1 m)* | | Three ash units occur (Waihi, Hauparu, Rotoehu). The ashes are slightly variable, but typically comprise yellow-brown sandy silts.<br>Ash occurs across the site, particularly in the hills, and is absent across the lower valley floor. Ash often overlies colluvium or alluvium, however in some locations more recent alluvium and colluvium may lie over the ash. |
| Colluvium | Surficial – hills<br>*(<3.3 m)* | | Colluvium is typically sandy or gravelly silt with some cobbles. |
| Alluvium | Surficial – valley, gullies<br>*(0 to > 5 m)* | | Alluvium is derived from the erosion of the surrounding rhyolite hills and is highly variable across the TSF3 site, from gravelly and sandy to clayey. There are also some buried organic or peaty layers<br>A key zone identified is the highly plastic, low permeability, saturated clayey layers encountered near the drainage ditches in the lowest lying area of the TSF3 site (in the vicinity of AP1 and AP4). |
| Rhyolite | Redeposited Tuff | 2.4 to 35 m bgl<br>*(1.7 to 30 m)* | Also referred to as "sensitive tuff", this fine-grained rhyolite tuff material is likely to have been reworked by gravity or water, and infills a paleo-gully beneath the lower valley floor. This material is significantly weaker than welded crystal tuffs and tuff breccias at TSF3. |
| | Tuff | 1.2 to > 42 m bgl<br>*(1 to > 32 m)* | Crystal tuff (weakly to moderately welded) is typically encountered in the upper valley floor and around the west paleo-ridge line. Tuff breccia refers to coarse tuff where particles are greater than 4 mm. |
| | CW–HW Flow<br><br>MW-SW Flow | 0.7 to > 27 m bgl<br>*(2 to 23 m)*<br><br>0.5 to 125 m bgl | Two types of flows were observed at TSF3:<br>Flow rhyolite: Observed on site is described as flow banded phenocrystic, sometimes spherulitic, rhyolite lava, which shows various degrees of weathering typically from the surface (completely weathered near surface, to slightly weathered with depth). At depth, flow rhyolite has also been observed to be brecciated.<br>Froth flow: A form of flow rhyolite which is partially vesiculated and likely derived from a gaseous lava flow or froth, which has been described as froth flow rhyolite (AP17a and AP20a). |
| | Ash and Tuff | 125 – 156 m bgl | Observed in the GT020 drill hole at depth. Rhyolitic ash and tuff deposits, possibly representing the initial phase of the rhyolitic eruption. |
| Dacite – Tuff Breccia | >156 m bgl | | Observed in the GT020 drill hole at depth. This is the dacite unit that outcrops to the west of the Ohinemuri River at Gladstone. The dacite dips to the south west, and does not outcrop at TSF3. |
| Andesite – Tuff and Lava Flow | >191 m bgl | | Observed in the GT020 drill hole at depth. This is the andesite unit that hosts the ore body at Favona, Gladstone and Martha. The andesite at TSF3 is separated from the mined andesite areas by faulting and does not outcrop at TSF3. |

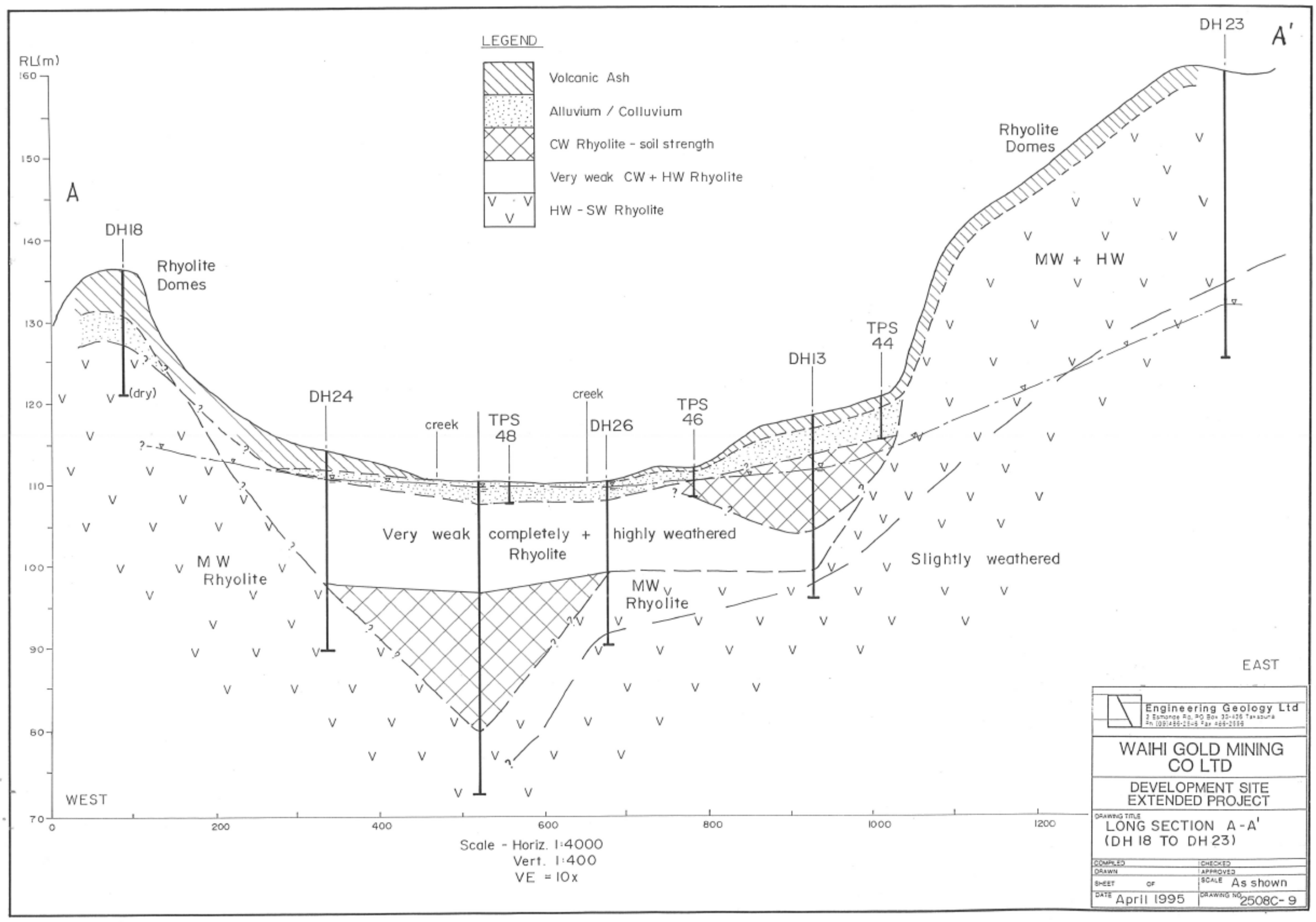



***Figure 5.5*** ***East-west cross section of paleo-gully beneath the TSF3 site (EGL 1996 Long-section A-A'; refer to Figure 5.4)***

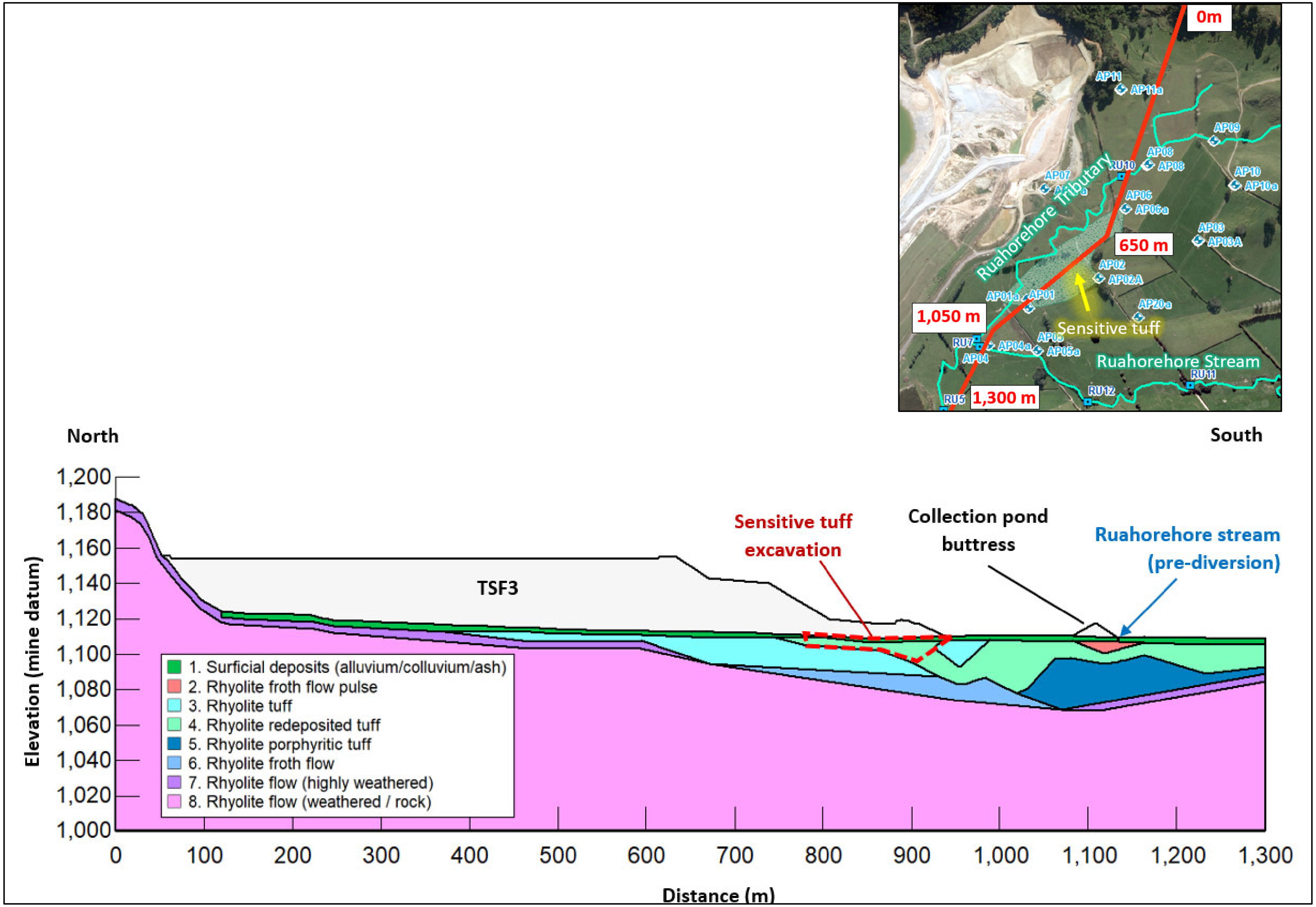



*Figure 5.6 Northeast-southwest cross section of paleo-gully beneath the TSF3 site (scale is approximately only)*

## 5.3 Conceptual groundwater model (TSF3 CGM)

### 5.3.1 Overview

Groundwater beneath the TSF3 site is interpreted to be present as a subdued expression of topography, with recharge occurring in the hills to the north/northeast and groundwater flow toward the Ruahorehore Stream to the south.

Two groundwater systems at the TSF3 site (shallow and deeper) are referred to in this assessment:

– The shallow system refers primarily to alluvial/colluvial/ash layers at the site and any perched water in the hills. This system is influenced by farm drainage and the Ruahorehore Stream.
– The "deeper system refers to groundwater within rhyolite units (lava, tuff) that flow beneath the proposed TSF3 site.

Trace elements in groundwater are naturally detectable due to the natural catchment conditions (e.g. aluminium, iron, zinc; refer to tabulated water quality data in Appendix E).

The conceptual understanding of TSF3 is in general agreement with that of TSF1A and TSF2 provided by GWS (2019), which is shown in Figure 5.7 below and modified to represent TSF3.

### 5.3.2 Shallow groundwater

Shallow groundwater is present within shallow volcanic ash/alluvium/colluvium including within the paleo-gully. Shallow groundwater is recharged from run-off from the hills and from direct rainwater infiltration. Shallow groundwater discharges near the rhyolite foothills, which produces the springs encountered in gullies (refer to the locations of the Ruahorehore Tributary head waters in Figure 5.2).

Shallow groundwater levels within the lower permeability alluvium in the lower valley (near wells AP01 and AP04; Figure 5.8) are at ground level during high rainfall (winter) conditions, creating boggy ground conditions for a few months each year. Recharge rates to the shallow system are expected to be limited, with recharge unlikely to occur in the lower lying areas, indicated by upward vertical hydraulic gradients between well pairs (Appendix C), limited vadose zone and poor drainage. Rainfall is inferred to predominantly generate run-off to the farm drains and the Ruahorehore Stream across the majority of the TSF3 footprint.

The low permeability of the surficial ash and alluvial units provides limited transmissivity for directing flow to streams. The Ruahorehore Stream is relatively neutral in flow, changing from losing to gaining and back again along its length (Figure 5.8). It is considered to be in connection with shallow groundwater in its immediate vicinity but receives only a small proportion of groundwater flow as interflow (Figure 5.7). This is consistent across the catchment (580 ha), which typically has only a small number of low-flow surface water features but has a high water table. This suggests a limited groundwater catchment for the Ruahorehore Stream at the proposed TSF3 site.

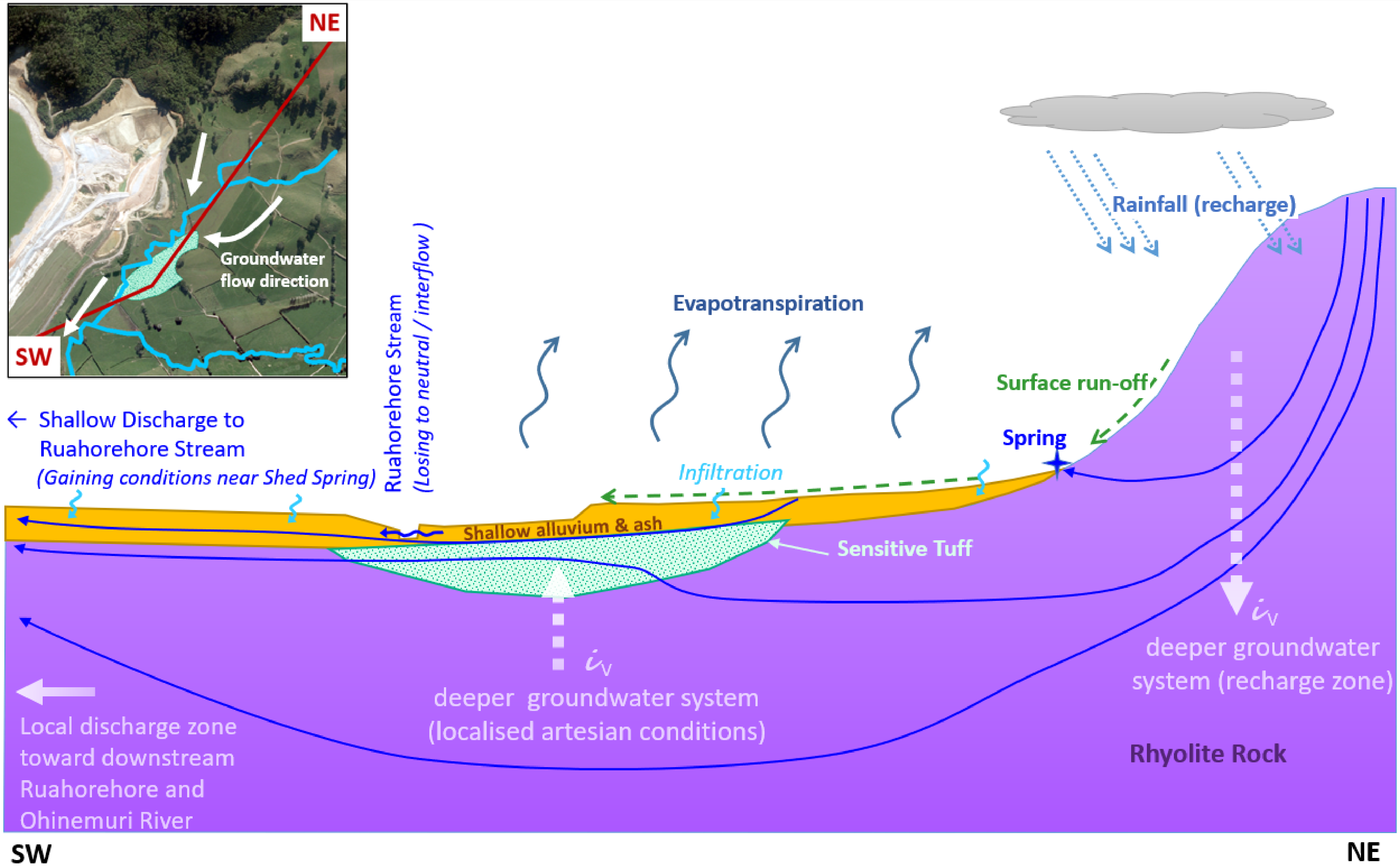



*Figure 5.7 Conceptual hydrogeological cross-section through the TSF3 paleo-gully*

## 5.3.3 Deeper groundwater

The deep groundwater system is located within the deeper weathered and fractured rhyolite rock and tuff units underlying the shallow system. This is considered to form the primary aquifer beneath TSF3.

Groundwater levels vary at TSF3; groundwater levels and vertical gradients in the deeper system were measured as follows:

– Maximum measured water level of 1,160 mRL in the hills, to 1,108 m RL in the lower valley near the Ruahorehore Stream (e.g. well AP04; Figure 5.8).
– Strong vertical downward gradients were measured in the hills (wells DH10, DH23 and AP10). These conditions gradually change to upward vertical gradients toward the lower valley floor. Mild flowing artesian conditions are reported near the Ruahorehore Stream (wells AP01, AP04, AP05, DH14).

The localised artesian conditions are inferred to be caused by a combination of the low permeability of the alluvium relative to the underlying tuff (Table 5.3). Welded tuff is locally present at some locations, underlying sensitive tuff within the paleo-gully (EGL, 2018). Anisotropy of the tuff units are also likely to contribute to occurrence of artesian conditions and separation of shallow and deeper groundwater.

Deeper groundwater is inferred to be predominantly recharged via rainwater infiltration into competent, fractured rhyolite in the ridge areas, where strong downward gradients are present, and which is considered to form the local groundwater divide. The rates of recharge are expected to be higher than those of the shallow groundwater system as indicated by strong downward vertical hydraulic gradients in the ridges and higher permeability of the rhyolite lava units (Section 5.3.4).

## 5.3.4 Hydraulic conductivity

Interpreted hydraulic conductivity (K) value based on site testing (Appendix A and Appendix D) are presented in Table 5.3. The K across the site is highly variable both spatially and vertically on small scales; refer to plans presented in Appendix D. This is attributed to multiple factors such as differing geological units, mode of deposition, anisotropy, reworking and weathering.

***Table 5.3 Summary of hydraulic conductivity Values for TSF3***

| Groundwater System | Geological Unit | Geomean K (m/s) | K Range (m/s) |
|---|---|---|---|
| Shallow | Alluvium / Ash | $4.5 \times 10^{-8}$ | $3.2 \times 10^{-9}$ to $8.5 \times 10^{-7}$ |
| Deeper (Rhyolite) | Redeposited Tuff | $2.8 \times 10^{-6}$ | $3.2 \times 10^{-9}$ to $1.0 \times 10^{-4}$ |
| | Tuff | $4.8 \times 10^{-8}$ | $5.7 \times 10^{-10}$ to $1.5 \times 10^{-5}$ |
| | CW-MW Flow Rhyolite | $1.3 \times 10^{-7}$ | $1.2 \times 10^{-9}$ to $1.0 \times 10^{-4}$ |
| | MW-SW Flow Rhyolite | $5.0 \times 10^{-6}$ | $1.0 \times 10^{-8}$ to $1.0 \times 10^{-4}$ |
| | Froth Flow Rhyolite | $2.8 \times 10^{-7}$ | $3.2 \times 10^{-9}$ to $2.4 \times 10^{-5}$ |

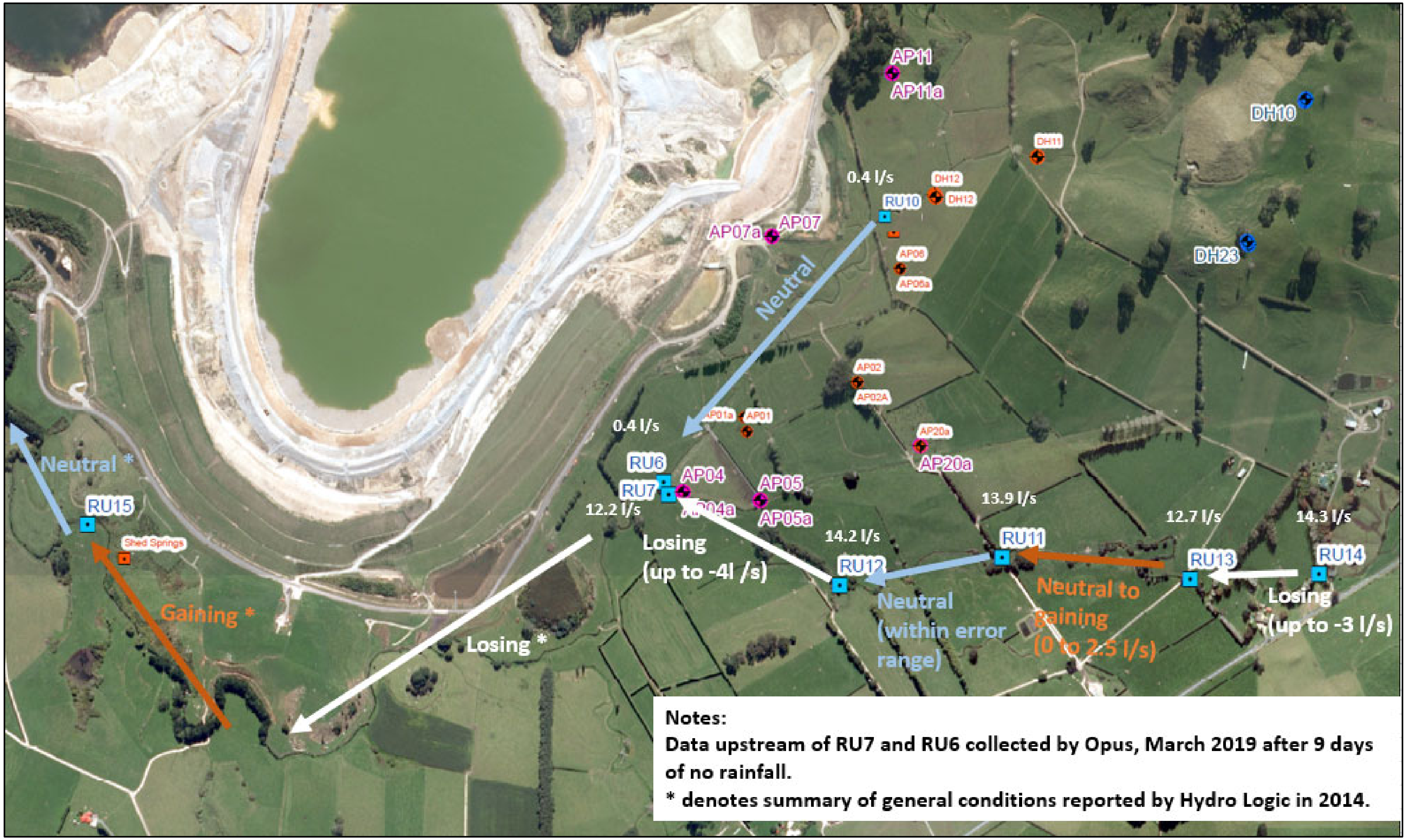



*Figure 5.8 Summary of baseflow conditions at TSF3*

## 5.3.5 Surface water-groundwater interactions

Groundwater flow direction in both the shallow and deeper aquifers is inferred to be generally to the southwest, along the paleo-gully, toward and along the Ruahorehore Stream (refer to inset on Figure 5.7) and ultimately to the Ohinemuri River.

The site has shallow surface water flow paths and farm drains that extend from north to south across the TSF3 area. These drains/channels are within the shallow alluvium/ash surface material, and receive small rates of spring flow from the rhyolite hill areas (refer to spring locations in Figure 5.2), but predominantly convey run-off and receive some shallow groundwater as discussed in Section 5.3.2.

Baseflow gauging (Appendix F) results at the proposed TSF3 site indicate that sections along the Ruahorehore Stream vary between losing and gaining conditions, and are predominantly neutral to losing (Figure 5.8). This supports the above inferences that the groundwater catchment is small and is separated from deeper artesian aquifer at this location.

Hydro Logic New Zealand Ltd (Hydro Logic) data from 2014 to 2015 indicates strong gaining conditions upstream of RU15, with localised spring-fed conditions occurring at Shed Spring, approximately 1.5 km downstream of TSF3. Conditions return to neutral conditions downstream of Shed Spring (Figure 5.8), suggesting limited groundwater contribution along this stretch of the stream.

The Ruddock gauge (Figure 2.1) has measured daily flow on the Ruahorehore Stream since 2000. This gauge is located approximately 850 m downstream of Shed Spring (Figure 2.1). The catchment at this location is approximately 20 km$^2$, with flow ranging from 1,850 to 1,500,000 m$^3$/day, and a median flow of 27,900 m$^3$/day. The total flow at this location is summed from:

- **Ruahorehore Stream:** The catchment size at TSF3 toe is 5.8 km$^2$ (Figure 5.1). Flows gauged during this assessment to typically vary between 540 m$^3$/day and 3,600 m$^3$/day (Appendix F), with a median of 1,340 m$^3$/day. The lower end of the flow range is considered to represent baseflow and is in the order of 1 L/s/km$^2$ (supporting a limited groundwater catchment). In terms of water quality, trace elements within the stream are not notably different from the Ohinemuri River adjacent to the other mine components. However, major ion concentrations (such as calcium, chloride, magnesium, sodium and sulphate) are considerably lower in the Ruahorehore Stream.
- **Ruahorehore Stream - southern tributary:** Approximately 2.8 km$^2$ in size, this catchment is located south of the site as shown on Figure 2.1. Base flow has not been measured but downstream measurements by Hydro Logic suggests that this tributary does not provide meaningful contribution to the Ruahorehore Stream flow (Figure 5.8).
- **Shed Spring**: Located 1.5 km downstream of the TS3 footprint, has flow ranging from 90 to 4,950 m$^3$/day, with a median flow of 430 m$^3$/day (OGNZL 2015 and 2017 daily gauging data). This spring is interpreted from water quality data (Appendix E) and the geological setting to discharge from a fracture system in the rhyolite rock that extends beneath TSF1A (inferred to extend in the general direction of faults to the north/northeast, Figure 2.3). The western rhyolite ridge bounding TSF3 extends beneath TSF1A as shown in Figure 5.9. This ridge is interpreted to form a topographic and structural geological divide between the spring and groundwater of the TSF3 site. The Shed Spring source is therefore interpreted to be within a separate groundwater catchment to the TSF3 site.
- **Waione Stream**: Based on the information above compared against Ruddocks Gauge, it is estimated that the Waione Stream catchment size is less than 12 km$^2$ and the flow contributed during low flow periods is less than 1,300 m$^3$/day. This equates to 1 L/s/km$^2$ from the Waione catchment to the measured Ruddocks flow. This, again, supports limited groundwater contribution to baseflow along this section of the stream.

The following conclusions are made regarding groundwater discharge from the TSF3 site, based on this CGM:

- The Ruahorehore Stream has only a small groundwater catchment and predominantly provides conveyance of run-off during rain events.
- The deeper groundwater in weathered /reworked volcanics is inferred to flow through the subsurface, influenced by paleo-gullies and deep geological structures. The actual discharge location of deeper groundwater is unknown but is expected to be distant, diffuse and difficult to pinpoint. For the purposes of this assessment, all deeper groundwater is inferred to discharge into the Ohinemuri River.

– The Southern Ruahorehore Tributary, Shed Spring and Waione Stream are interpreted to be located within separate groundwater catchments and outside the predicted envelope of effects of the TSF3 activity. These are not assessed further in this report

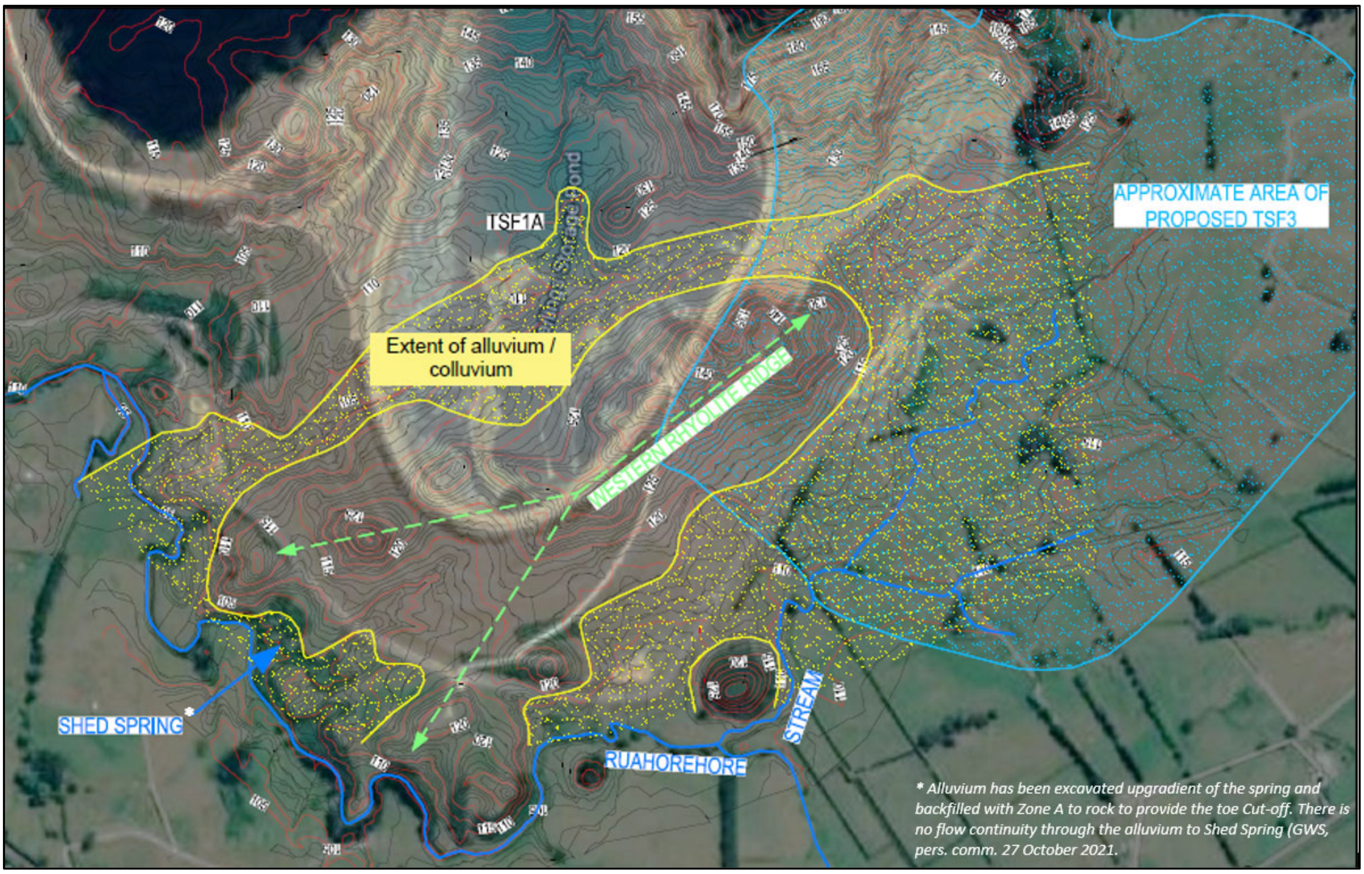



*Figure 5.9 TSF3 original topography showing western rhyolite ridge*

## 5.3.6 Water resource users

Registered bores and water take consents within proximity of the TSF3 are presented on Figure 5.10 (WRC, 2025c). A full list of water users is provided in Appendix K. A summary is provided below and in Table 5.4 and Table 5.5:

– One registered bore is located within 1 km of TSF3 (Well ID 56609). This bore is associated with groundwater take AUTH131303 and is located 450 m cross-gradient from the edge of the proposed TSF3 facility, and 750 m from the deepest point of the excavation to be dewatered.
– The nearest down-gradient bore user (Well ID 56607) is just over 1 km away.
– Three surface water takes are registered, between 1 and 2 km from TSF3. Water permit AUTH125719 authorises water take from a tributary of the Ruahorehore located to the south and is topographically separated by a rhyolite ridge that bounds the proposed TSF3 site. Water permit AUTH120591 authorises water take from the Ruahorehore Stream 1.7 km downstream of TSF3 for horticultural and frost protection purposes. Water permit AUTH146708 authorises water take from a surface water pond on the south side of the Ruahorehore Stream approximately 1.8 km downstream of TSF3 for frost protection purposes.
– An additional unregistered water user has been identified and included in the assessment; a farm pond located approximately 830 m east of the deepest excavation point (Table 5.5 and Figure 5.10). The farm pond appears to be bunded.

*Table 5.4 Nearest TSF3 groundwater users*

| WRC Well ID (associated water permit, if any) | Depth | Approx. Distance from TSF3 | Direction | Bore use |
|---|---|---|---|---|
| 56609 (AUTH131303) | Unknown | 450 m | Southeast (cross-gradient) | Agriculture farming - dairy |
| 44385, 44107, 38557 (cluster; no permits) | 116 – 140 m | 1,000 – 1,100 m | South (cross-gradient) | Unknown |
| 44283 (AUTH139076) | 48 m (Casing to 26 m) | 1,200 m | South (cross-gradient) | Horticulture/cropping |
| 56607 (AUTH131201) | 30 m | 1,000 m | Southwest (downgradient) | Agriculture farming - dairy |

*Table 5.5 Nearest surface water users*

| WRC Take ID | Approx. Distance from TSF3 and direction | Water body | Use |
|---|---|---|---|
| n/a | 830 m (east) | Farm pond | Unknown |
| AUTH125719 | 1,200 m (south-east) | Unnamed tributary of Ruahorehore Stream | Agriculture farming - dairy |
| AUTH120591 | 1,700 m (west (downstream)) | Ruahorehore Stream | Frost-protection (250 m3/day, up to 10,000 m3/year) |
| AUTH146708 | 1,800 m (west (downstream)) | Surface water pond south of Ruahorehore Stream | Frost protection |