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Ref: 9049

OCEANA GOLD (NEW ZEALAND) LIMITED
WAIHI NORTH PROJECT
GROUND SETTLEMENT REPORT

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EXECUTIVE SUMMARY

Engineering Geology Limited (EGL) was engaged by Oceana Gold (New Zealand) Limited (OGNZL) to assess the ground settlement effects from dewatering due to mining and access tunnel development for the Waihi North Project.

Assessment of ground settlement is based on both review of past settlement trends and theoretical calculations (where relevant). The large number of settlement observations at Waihi, spanning some 34 years, provides a reliable database for estimating likely future settlements associated with further dewatering.

Overall ground settlement effects are assessed to not cause damage to any structures if mitigations and recommendations are followed. The assessed ground settlement effects are summarised below, followed by the mitigations and recommendations.

<u>Assessment of ground settlement effects</u>

- The settlement effects for the Waihi North Project are summarised below:
  - Settlements can be expected around Gladstone Open Pit (GOP) (Figure 3) from dewatering of the younger volcanics and andesite near the pit in the order of 120 to 200mm (see Section 6.1.1). These settlement effects are on land near to Gladstone Open Pit owned by OGNZL.
  - South of the Ohinemuri River (Figure 3) additional settlements from the mining of GOP are assessed to be in the order of 10 to 50mm with low additional tilts (See 6.1.1) and therefore the residential dwellings in this area will not be damaged. Settlement monitoring is required in this area to confirm settlement effects are as expected.
  - The proposed Martha Underground (MUG) Decline (Figure 3) is expected to cause additional localised depressurisation of the andesite and additional settlements in the order of 10 to 50mm locally above the decline (See Section 6.1.2). There are no structures above the decline at risk. The proposed decline potentially intersects historic workings and the interface of the andesite with the younger volcanics. Drawdown of groundwater in the younger volcanics and historic workings present a risk, if not mitigated, of more notable settlement and tilt which could potentially extend to Moore Street, Boyd Road and Barry Road (Figure 3) where there are residential dwellings. Residential dwellings in Moore Street, Boyd Road and Barry Road that are not owned by the company are at least 190 m distance (in plan) from the proposed MUG Decline. Historic workings on record at the potential level of intersection only extend 90 m (i.e. part of the way) towards the dwellings in Barry Road. OGNZL owns the properties between the proposed MUG Decline and the non-company owned residential dwellings. There are mitigation options available that OGNZL will implement in response to evidence of groundwater drawdown or settlement of the younger volcanics as part of a specific Trigger Action

Response Plan. Additional settlement and groundwater monitoring is required in this area.

- The Wharekirauponga Access Tunnel decline (Figure 3) length, starting from the WUG Portal and extending north past Barry Road, potentially comes close to the younger volcanics. It could cause settlement effects affecting dwellings at Boyd Road and at the eastern end of Barry Road, if the potential for dewatering of the younger volcanics is not mitigated (See Section 6.1.3). OGNZL owns the land between Boyd Road and the proposed tunnel corridor and the land within the tunnel corridor immediately north and south of Barry Road. There are mitigation options available that OGNZL will implement in response to groundwater drawdown or settlement of the younger volcanics as part of a specific Trigger Action Response Plan. Additional settlement and groundwater monitoring is required in this area.

- The additional settlements from the Wharekirauponga Access Tunnel east of Waihi East (Figure 2) are expected to be in the order of 10 to 100 mm, depending on the geological structures it passes through. The tunnel east of Waihi East is to be located at depth in andesite rock and the shallow water table in the younger volcanics is not expected to be materially affected. Therefore, any additional tilts in this area will be very small (see Section 6.1.4) and the residential dwellings in this area will not be damaged. Additional settlement and groundwater monitoring is required in this area to confirm settlement effects are as expected.

- The settlements from the Willows Access Tunnel and Wharekirauponga Dual Tunnel (Figure 1) out to WUG are expected to be in the order of 10 to 100 mm depending on the geological structures. The tunnel is to be located at depth in andesite rock. There are no structures near to the Willows Access Tunnel and Wharekirauponga Dual Tunnel which could be affected (see Section 6.1.5).

- Settlements around the ventilation shafts (Figure 1) are expected to be on the order of 50 to 300 mm. These settlements would have no adverse effects on the farmland (Willows Ventilation Shaft) and forest area (WUG Ventilation Shafts) in which they would be located (see Section 6.1.6).

- Ground settlements at the WUG site (Figure 1) are expected to be unnoticeable as any change in level will occur gradually and be distributed over hundreds of metres resulting in small tilts or change in grade. This is because the settlement will be caused by dewatering generally at notable depth below the ground surface. In the middle of the settlement area, the settlements are estimated to reach up to 300 mm to 1,000 mm depending on the ground profile. Due to the hilly terrain at the WUG site, surface settlements of this magnitude are not expected to have any material effects on stream flows as the change in grade is notably less than the steepness of the terrain. As the tilt of the ground will be small, no noticeable impact on the forest environment is expected (see Section 6.1.7).

<u>MUG Decline development mitigations and recommendations</u>

- The MUG Decline could potentially dewater the shallow younger volcanics (ignimbrites and tuffs) and cause settlement effects in Moore Street, Boyd Road and Barry Road. EGL recommends that OGNZL mitigate this risk through:

    - Detailed assessment of the MUG Decline alignment.
        - Avoidance of the younger volcanics may be possible through refinement of the decline alignment and level, so to stay completely within the andesite.
        - Avoidance of historic workings may be possible.

    - Specific geotechnical and groundwater investigations to assist in determining the ground conditions and groundwater profile between the decline and closest properties. Such investigations can be undertaken on OGNZL property.

    - Monitoring of groundwater levels and ground surface settlement to detect possible effects.

    - Development of Trigger Action and Response Plans (TARPS) that set triggers and specific actions including mitigation measures if trigger levels are exceeded.

    - Mitigation of groundwater inflows into the decline (as required) during construction with grouting methods.

    - Mitigation of shallow groundwater drawdown by re-injection of captured groundwater back into the ground.

<u>Wharekirauponga Access Tunnel decline development mitigations and recommendations</u>

- The Wharekirauponga Access Tunnel decline from the WUG portal to Barry Road could potentially dewater the shallow younger volcanics (ignimbrites and tuffs) and cause settlement effects at Boyd Road and eastern end of Barry Road. EGL recommends that OGNZL mitigate this risk through:

    - Detailed assessment of the decline tunnel alignment to confirm options and risks.
        - Avoidance of the younger volcanics may be possible through refinement of decline alignment and level, so to stay completely within the andesite.

    - Specific geotechnical and groundwater investigations to assist in determining the ground conditions and groundwater profile between the decline and closest properties.

    - Monitoring of groundwater levels and ground surface settlement to detect possible effects.

- Development of Trigger Action and Response Plans (TARPS) that set triggers and specific actions including mitigation measures if trigger levels are exceeded.

- Mitigation of groundwater inflows into the tunnel decline (as required) during construction with grouting methods.

- Mitigation of shallow groundwater drawdown by the injection of captured groundwater back into the ground.

Wharekirauponga Access Tunnel development mitigations and recommendations

- EGL recommends that the Wharekirauponga Access Tunnel east of Waihi East is restricted to a minimum tunnel depth of 130 m, or 40 m (Ref. 7) minimum vertical offset from the top of the andesite/younger volcanic interface, whichever is deeper. The minimum depth reduces the risk of tilt at the ground surface and the minimum vertical offset reduces the risk of dewatering the younger volcanics which underlie Waihi East. This was a condition of the Correnso Underground mine which is directly beneath Waihi East that has been shown to be successful.

- EGL recommends that specific geotechnical and hydrogeological investigations along the Wharekirauponga Access Tunnel length east of Waihi East are undertaken to confirm the geotechnical and permeability conditions, and groundwater pressure profile, and to confirm the level of the tunnel to achieve the minimum offset to the younger volcanics. This can include surface drilled investigation boreholes, drilled boreholes ahead of the tunnel and/or geophysical surveys.

Surface borehole drilling mitigations and recommendations

- Where possible boreholes drilled from the surface should be sited away from structures to minimise settlement risk associated with leakage of shallow groundwater to deeper systems.

- Where possible boreholes should avoid intersecting underground workings.

- Grouting of all future surface-drilled holes to a depth below the top of the andesite.

General tunnel development mitigations and recommendations

- Avoid intercepting existing drillholes with the tunnel operation wherever possible.

- Avoid intercepting historical workings with the tunnel wherever practicable.

- Drilling ahead of the tunnelling operation, to inspect for geological structures or areas of ground that may make notable water inflows into the tunnel.

- Mitigation of sustained groundwater inflows through the use of grouting methods.

Dewatering and ground settlement monitoring recommendations

Monitoring of groundwater levels and ground settlements is required to check settlements are within estimates and there are no unforeseen effects. The dewatering and settlement monitoring plan will be updated for the Waihi North Project. Recommendations in regard to dewatering and ground settlement monitoring are summarised below:

- Continued monitoring of dewatering and settlement as required by the expired Mining Licence and resource consent 124860.

- The settlement monitoring zones and settlement trigger limits previously proposed for Project Martha are adjusted over the Favona Underground and locally around Gladstone Open Pit and Wharekirauponga Access Tunnel alignment for the Waihi North Project.

- The dewatering and settlement monitoring plan needs to be updated for the Waihi North Project.

- Groundwater monitoring piezometers provide the best early warning of potential adverse ground settlement effects such as tilt. This was evident in the situation which occurred in Gladstone Road related to borehole CDG008 as described in Section 5.3.3. EGL recommends that additional piezometers are installed along with the new settlement markers in areas where there are residential dwellings or other structures not owned by OGNZL.

- Recommended additional settlement monitoring markers and piezometers to measure potential settlement effects are summarised below and in Figure 66 to Figure 69:

    - Potential dewatering of the Gladstone vein south of GOP

        - Heath Road – Additional settlement points (Figure 67)
        - Clarke Street – Additional settlement points (Figure 67)

    - Additional settlement monitoring points around Gladstone Hill to provide an understanding of the settlement effects close to the pit.

    - Potential dewatering of the ignimbrite between the Wharekirauponga Access Tunnel decline and Boyd Road and Barry Road.

        - Boyd Road – Additional settlement points (Figure 68)

    - Potential additional dewatering of the andesite rock due to the proposed MUG decline in andesite beneath Moore Street.

        - Moore Street – Additional settlement points and a new piezometer borehole (Figure 67)

  - Potential dewatering of the andesite veins and rock mass not already dewatered by the development of the Wharekirauponga Access Tunnel east of Waihi East.

    - Barry Road – A new piezometer borehole adjacent to the houses in the tunnel corridor (Figure 68)
    - Mataura Road – Additional settlement points and a new piezometer borehole in the tunnel corridor (Figure 68)
    - Wenlock Street – Additional settlement points and a new piezometer borehole in the tunnel corridor (Figure 68)
    - State Highway 25 – Additional settlement points and a new piezometer borehole in the tunnel corridor (Figure 68)
    - Wharry Road – Additional settlement points and a new piezometer borehole in the tunnel corridor (Figure 68)

- Extension of the town settlement monitoring points out to the end of Willows Road, Highland Road, and Reservoir Road to cover the project extent near structures. (Figure 69)

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1.0 INTRODUCTION

Oceana Gold (New Zealand) Limited (OGNZL) proposes to develop a new mining project named the Waihi North Project (WNP) to extend the mine life in Waihi by developing a new open pit and underground mine (Ref. 1). OGNZL has engaged Engineering Geology Limited (EGL) to undertake this ground settlement assessment for the project elements which potentially have ground settlement effects. This assessment considers ground settlement effects caused by ground dewatering resulting in direct consolidation of soil and rock materials.

In this report ground "settlement effects" refer to both "settlement" and "tilt". The term "settlement" applies to the widespread and relatively minor vertical displacement of the ground surface caused by dewatering. The term "tilt" refers to differential settlements in the ground surface caused by dewatering (i.e. differences in settlement over short distances).

Extensive knowledge of ground settlement effects has been developed around Waihi through the monitoring undertaken for the effects associated with Martha Open Pit, and the Favona, Trio and Correnso Underground mines. This report reviews these past effects in assessing the settlement effects for the Waihi North Project.

1.1. Waihi North Project

The WNP elements (Ref. 1) are shown on Figure 1, Figure 2, and Figure 3 and comprises:

- The mining of a new open pit near the existing Processing Plant, centred over Gladstone Hill, the Gladstone Open Pit (GOP). This pit will be converted to a tailings storage facility once mining is complete;
- A new tailings storage facility to the east of existing Tailing Storage Facility (TSF) - Storage 1A (TSF1A), called Storage 3 or TSF3 in short;
- New rock stack (the Northern Rock Stack or NRS) at the Northern Stockpile area adjacent to the existing TSF – Storage 2 (TSF2);
- Reconsenting of the existing Water Treatment Plant (WTP) treated water discharge consents;
- Upgrading of the existing WTP to double the water treatment capacity;
- A new underground mine, the Wharekirauponga Underground Mine (WUG), located approximately 11km north-west of the current Processing Plant under

land administered by the Department of Conservation (DOC) (Coromandel Forest Park). WUG will comprise surface infrastructure, tunnel portals, a tunnelling system and the mine itself.
  - Site infrastructure supporting the mine will be located on OGNZL owned farmland located at the end of Willows Road, with only minimal surface features within the forest, in the form of fenced vent raises, on legal paper road owned by the Hauraki District Council;
  - Portal (Willows Portal) and a single tunnel (Willows Access Tunnel) at Willows Road to the edge of Coromandel Forest Park (1,300 m long);
  - Ventilation shaft on the Willows Road farm south of the Coromandel Forest Park (250 m long). This shaft will act as an exhaust during tunnel construction before being converted to an intake during mining operations;
  - Dual (access) tunnel (Wharekirauponga Dual Tunnel) from the edge of Coromandel Forest Park to the footwall of the Wharekirauponga orebody (5,500 m long);
  - Multiple declines as the dual tunnel approaches the top of WUG, for access to the lower portions of the orebody (500 – 1,200 m long);
  - Cross cuts at 200 m spacing along the length of the Wharekirauponga Dual Tunnel, providing a connection between the intake and exhaust tunnels (1,000 m total);
  - Portal (WUG Portal) and single ore transport tunnel (Wharekirauponga Access Tunnel) near the Processing Plant that connects with the dual tunnels at the Willows Road farm vent raise (approximately 5,000 m long);
  - New Martha Underground (MUG) decline from the cut for the WUG Portal to the existing Trio decline, passing under the south end of Moore Street; and
  - A link or bypass drive that connects the single Willows Access Tunnel to the single Wharekirauponga Access Tunnel from Waihi (270 m in length). This is to allow long term access between the two portals (Willows Portal and WUG Portal).
- Modifications to the existing overland and load out conveyors to allow waste rock loading and conveying to the NRS and return of rock to the plant for backfilling; and
- Upgrading of the existing Waihi Processing Plant to enable ore processing up to 2.25 million tonnes per annum (MTPA), up from 1.25 MTPA currently.

1.2. Project elements with potential ground settlement effects

Elements associated with the WNP that have potential ground settlement effects are:

- Gladstone Open Pit
- Willows Access Tunnel Willows Road Ventilation Shaft
- Wharekirauponga Dual Tunnel Up to 4 ventilation shafts at WUG
- WUG Mine drives, shafts and stopes
- Wharekirauponga Access Tunnel New MUG decline

The other elements of the projects are developed at the surface and do not have any notable potential ground settlement effects beyond their footprint and therefore do not require assessment as part of this report.

1.3. Consented ground settlement effects

This report extends the assessment of potential ground settlement effects due to ground dewatering for the current as-built and Life of Mine Plan (LoMP) for the open pit and underground mines already consented, which includes:

- Existing Martha Open Pit (MOP) (Ref. 2, 4, 10)
- Favona Underground (Ref. 3, 11, 12)
- Trio Underground (Ref. 5, 13, 14)
- Correnso Underground (including Slevin Underground) (Ref. 6, 15, 16)
- Martha Underground (MUG) (Ref. 7, 17, 18, 20)
- Martha Open Pit – Phase 4 (MOP4) (Ref. 7, 17, 18 , 20)

The last project consented was Project Martha (MUG and MOP4).

The settlement prediction approaches applied in these past assessments have provided estimates which have been on a similar magnitude as the measured ground settlements effects. Where there has been a difference between predictions and measured ground settlement effects, this has been explained within this report (see Section 5.3).

The elements and effects of the WNP interact with the existing as-built and consented projects.

1.4. Dewatering and settlement monitoring plan and annual reporting

As a requirement of the existing consents, a dewatering and settlement monitoring plan has been prepared by OGNZL (Ref. 8). This outlines the monitoring of groundwater and settlement and process in the event of unusual ground movement. This plan is certified by Waikato Regional Council and Hauraki District Council. This plan will be updated for the WNP.

As a requirement of the consent conditions, an annual dewatering and settlement report is prepared (Ref. 9). This reviews the six-monthly ground settlement survey data and the groundwater monitoring records. The monitored dewatering and settlement effects of the WNP will be included in this report annually.

1.5. Assessment limitations and management of risks

This assessment considers ground settlement effects (settlement and tilt) caused by ground dewatering resulting in direct consolidation of soil and rock materials. Other causes of potential ground settlement from the WNP are assumed to be less than minor or to have been assessed by others. This assessment assumes that OGNZL undertakes best practice mining methods that minimises any other potential ground settlement effects.

The extent of works covers a large area and the inferred ground conditions are based on a limited number of ground investigations. Unforeseen ground conditions can be expected. Uncertainty and risk around unforeseen ground conditions can be partially reduced by undertaking further ground investigations; however, risk will always remain and this risk will be managed by OGNZL.

While this assessment is for ground settlement effects that are caused by ground dewatering, this report is in no way to be taken as an assessment of effects on groundwater.

1.6. Report update

This report was originally issued in 2022. Only minor updates to text and figures have been made for the 2025 fast track application. The conclusions remain the same as in 2022.

2.0 GROUND SETTLEMENT OVERVIEW AT WAIHI

2.1. Ground settlement mechanism

Ground settlement effects at Waihi are predominately caused by dewatering within the ground, which arises because of lowering or local depressurisation of the groundwater around the mine open pits and underground workings and interconnected geological vein or fault structures. Lowering or depressurisation of the groundwater occurs within the defects and pores of the soil and the rock, resulting in a transfer of stress from the groundwater to the solid soil and rock material causing it to compress and settle.

The amount of settlement due to dewatering within the ground depends on the following:

1. The change in the compressive stresses in the ground from the pore water to the soil and rock material, which depends on the difference between the initial and final groundwater pressures;

2. The compressibility of the ground which is a natural property, and which varies depending on the type of soil and rock, and whether the ground has felt the same stress before; and

3. The thicknesses of the different types of soil and rock that underlie a site which undergo a change in pressure.

The rate of settlement depends on the permeability of the ground. Permeability is a measure of how easily water flows through a material. The presence of shafts and drives and other discontinuities in the ground increases the draining rate of water from the ground and hence increases the rate of settlement.

Settlement of the ground without notable tilt (i.e. settlement as a uniform surface) does not cause damage to structures founded on the surface. Tilt, which is differential settlement of the ground, can cause damage to structures if it occurs over short distances. This can affect the amenity of structures and in areas of very severe tilt potentially impact the structural integrity of brittle structures.

2.2. Geology and hydrogeology interpretation

The understanding of geology and hydrogeology is fundamental to understanding the observed settlement effects, and to allow estimates of future effects from extended and new projects. Different geological units beneath the ground surface present different settlement potential. The younger geological units made up of volcanic airfall, alluvial and lacustrine (lake) type deposits closer to the surface are more prone to ground settlement effects (both settlement and tilt) upon dewatering due to their shallower depth, higher permeability, and higher compressibility. The older andesite geological units around the Waihi township area are generally less prone to ground settlement effects due to their greater depth, lower permeability, and lower compressibility. Martha Open Pit intersects both the younger volcanics and older andesites. The underground mines are within the andesites. Dewatering caused by mining of the deeper andesite units causes settlement at the surface, however at Trio and Correnso Underground, due to their depth, tilt has generally not been an issue. Favona Underground is in an upper unit of the andesite with an overlay of hydrothermal breccia and tuff, and a thinner thickness of younger volcanics over the andesite. This area has experienced higher tilt, however there are no structures in this area for which the effects are consequential.

2.3. Historic mining operations

Historical mining in Waihi occurred from 1880 to the 1950s (Ref. 21). This included deep underground workings around the main gold bearing veins. The workings and dewatered reached approximately 660 m below the Waihi township. This would have caused settlement and consolidation of the ground. Settlement from historical mining was not surveyed.

After historical mining, partial rebound of the ground surface would have occurred. As a result of the historical consolidation of the ground in the areas of historical dewatering, settlement effects are reduced compared to areas of primary or first dewatering of the ground.

2.4. Modern mining operations

In 1988 open pit mining of Martha Hill began to form Martha Open Pit (Figure 2). This involved large scale excavation of both overburden soil and rock, and ore. Martha Hill was an area of extensive historic underground mining and some surface mining. Dedewatering of these areas has caused ground settlement, albeit of a lesser magnitude than historical mining, due to pre-consolidation of the soil and rock.

In late 2004 construction began on the decline (access tunnel) for the Favona Underground (Figure 2), with the extraction of ore in 2006 (Ref. 23). Favona Underground is 1.5 km southeast of Martha Open Pit. Before developing the Favona Underground the area already had some settlement from Martha Open Pit dewatering (Ref. 9). Favona Underground was extended to the south to include the Moonlight section of the vein system just to the west of the Processing Plant. Ore production from Favona Underground including the Moonlight development (Figure 2) was completed in 2014 (Ref. 22). Concurrently Trio Underground was developed to the west under Union Hill from 2010 (Ref. 23), with ore production beginning in 2012 and finishing in 2014 (Ref. 22).

Correnso Underground development began in 2014 and was close to complete in 2021. Correnso Underground was the first modern underground undertaken directly under private residential and commercial property not owned by the mining company.

Martha Underground development and underground bores were drilled for dewatering, beginning in July 2020. Martha Underground is currently being developed.

3.0 STUDY AREA GEOLOGY

3.1. Waihi to WUG geological setting

Brathwaite and Christie (Ref. 24) interpret the geology of the Waihi Basin as part of the Coromandel Volcanic Zone, a sub-aerial 8-million-year-old (late Miocene) to 1.5 million-year-old (early Pleistocene) andesite-dacite-rhyolite sequence that forms the Coromandel-Kaimai ranges. The basement rock (Manaia Hill Group sandstone, siltstone and conglomerate, Ref. 24) is assumed to be at considerable depth (~1 km). The Waihi Basin is a paleo-caldera (ancient large volcanic centre, like Lake Taupo) within the Coromandel Volcanic zone (Ref. 25) and the Coromandel Peninsula is located within an area of extensional tectonic faulting between the Taupo Volcanic Zone and the Hauraki Rift (i.e. Hauraki Plains and Firth of Thames). Faulting in the Waihi area trends approximately northeast-southwest.

The oldest volcanic formations outcropping in the Waihi area are andesites and dacites of the Late Miocene Waiwawa Subgroup of the Coromandel Group and includes the Waipupu Formation andesites and dacites which are 7.9-6.3 million years old (Ref. 24). These andesites outcrop at Gladstone, Union, and Martha Hill, and hills further to the northwest.

To the north of Waihi the Whitiroa andesite of the Waiwawa Subgroup comes in over the Waiwawa Formation andesite and dacites. The Whitiroa andesites are mapped out to the WUG site (Ref. 24).

The host rhyolites flows and pyroclasitc deposits at the WUG site are assigned to the Maratoto Rhyolite of the Coroglen Subgroup of the Whitianga Group (Ref. 24, 27, 29). The rhyolites form a dome complex that is partially overlain by rhyolitic tuffs of the Edmonds Formation (Ref. 24, 30, 31). The rhyolites at WUG are interpreted to overlie the older andesites of the Waipupu Formation or Whitiroa andesite (Ref. 27, 31). The older andesites and rhyolites are overlain by the Whakamoehau andesite (Ref. 31).

Dating (K-Ar) indicates a geological erosional time break of about 1 Ma (million years) between the andesites and dacites of the Waiwawa Subgroup and the eruption of andesites and dacites of the Kaimai Subgroup, which contains dacites belonging to the Uretara Formation which are 5.6-4.3 million years old. The dacites (Black Hill Dacite) of the Uretara Formation come in over the Waiwawa Formation andesites to the east of Waihi along the Ohinemuri River passing the TSF Development Site.

Of similar age to the Kaimai Subgroup are rhyolites of the Minden Rhyolite Subgroup within the Whitianga Group, which includes domes of Homunga Rhyolite which is 5.5-5.2 million years old and forms the hills of Ruahorehore Dome on which the existing TSFs are predominantly against.

The Waihi Basin caldera is infilled with Pliocene to early Pleistocene lacustrine (lake) sediments and ignimbrites of the Whitianga Group. At the base are lacustrine sediments of the Romanga Formation (4.5-3.0 million years old) part of the Coroglen Subgroup. Lacustrine sediments are also found around the current crest of the Martha Open Pit and in isolated locations at the TSF Development Site.

The overlying ignimbrites around Waihi are grouped into the Ohinemuri Subgroup consisting of Corbett ignimbrites at 2.9 million years old and Owharoa ignimbrites (late Pliocene) and Waikino ignimbrite at 1.5 million years old (early Pleistocene).

Eruptions of ash and pumice blanketed the Waihi area. Typical ash soils found in the area include the Waihi Ash series, the Hauparu Ash and the Rotoehu Ash. The ash mantle at WUG is likely to differ in origin.

3.2. Geology Martha Open Pit to Favona Underground and Gladstone Hill

With mining and exploration drilling a good understanding of the geology has been developed from Martha Open Pit to Favona Underground and Gladstone Hill.

Figure 5 to Figure 19 show geological maps and sections of the area around Martha Pit and proposed Gladstone Open Pit and Wharekirauponga Access Tunnel, including the various mineralised vein systems. Figure 5 includes the geological map of the area around the Martha Open Pit and proposed Gladstone Open Pit and the location of the cross-sections radiating out from the pits. The cross-sections are given in Figure 6 to Figure 17 and show that the mineralised andesite extends down to at least RL500m (m RL, Reduced Level in Mine Datum). For reference, the ground surface varies from approximately RL1080m to RL1180m around the pits.

Figure 19 shows the veins and workings in plan between the Martha and Favona fault and vein systems. Figure 18 shows an indicative geological cross-section from Martha Pit through the Correnso, Trio and Favona fault and vein systems along the same orientation as the lines A-A’ and B-B’ in Figure 19. The section in Figure 18 shows that the andesite (Waipupu Formation) made up of a lower quartz andesite and upper andesite outcropping at the horst (elevated) features of the former Martha Hill (Martha fault), Union Hill (Amaranth fault) and Gladstone Hill (Favona fault). The andesite rock extends to depths greater than 600m and below this a lower volcanic/volcaniclastic sequence is indicated, which is inferred to overlie the basement rock (Manaia Hill Group). The andesites are also host to the ore.

Along the top of the Favona fault and Favona and Gladstone vein systems are localised sequences of:

- Volcaniclastic deposits (tuffs) (Waipupu Formation)
- Hydrothermal (andesitic) vent breccia (Waipupu Formation)

See Figure 18. The hydrothermal breccia is encountered on the east side of Gladstone Open Pit. Above Favona Underground both the volcaniclastic deposits and hydrothermal breccia are present in the area where the Wharekirauponga Access Tunnel decline will pass.

The hydrothermal vent breccia and volcaniclastic deposits appear localised to the Favona and Gladstone vein systems based on the OGNZL geological model of Waihi (Ref. 26).

East from the Favona fault and Favona and Gladstone vein system is a sequence of:

- Rhyolite lava flows and tuff (Ruahorehore Rhyolite of Homunga Rhyolite)
- Dacite lava flows and breccia (Uretea Formation – Black Hill Dacite)

The Black Hill Dacite is present on the east side of Gladstone Open Pit, outcropping as Black Hill. The rhyolite lava flows and tuff associated with the Ruahorehore Rhyolite are too far to the east beneath the tailings storage facilities to be of interest for this study, however, are mentioned as there are rhyolitic lava flows and pyroclastic units also at WUG.

The Waipupu Formation andesite rocks (lower quartz andesite and upper andesite on Figure 18) around Waihi are extensively modified in places by weathering and hydrothermal alteration. An almost continuous cap of low permeability, highly weathered and altered material is present on the surface of the andesites around Waihi township.

The andesites are overlain by a series of younger volcanic deposits (post mineralisation) which are highly variable in thickness and composition. The younger volcanic deposits consist of rhyolitic tephras and ignimbrites in the form of flows, breccias and tuffs. On the sections (Figure 6 to Figure 17) these are shown as:

- Rhyolitic tuffs
- Sandy ignimbrites
- Welded ignimbrites

These younger volcanic deposits are exposed in the east and south walls of Martha Open Pit (Figure 38), however, blanket much of lower areas around Waihi, including Waihi East, Waihi South, lower slopes of Gladstone Hill, and the area over Favona Underground where the Wharekirauponga Access Tunnel decline is proposed.

Occasionally, paleosols (buried soils) and sedimentary deposits such as alluvium and boulder alluvium are present at the top of successive eruption sequences. The younger volcanic deposits underlie much of Waihi township to the east and south of the Martha Pit (Figure 5). They also overlie Favona Underground and the west and south of Gladstone Open Pit around the Ohinemuri River, however in a lesser thickness. A layer, up to approximately 8 m thick, of geological young ash soils, alluvium and completely weathered rhyolitic tephras blankets much of the younger volcanic deposits.

The younger volcanic deposits have some layers which are more compressible than the underlying andesite which means they have the potential to settle more when subjected to the same increase in stress. There are also some layers of welded ignimbrite which are very stiff which minimise tilt effects at the surface. The combined profile of the younger volcanic beneath Waihi township are up to 140 m deep in the Waihi East area.

3.3. Gladstone Open Pit

Gladstone Open Pit is centred over the Gladstone Hill and partially over the adjoining Winner Hill to the south. Gladstone Open Pit will intersect the veins within the andesite which extend to the Ohinemuri River to the south (Ref. 26, 37, and 40). It is possible that the veins do extend beneath the Ohinemuri River towards Heath Road. Surrounding Gladstone Hill are younger volcanic ignimbrite deposits (Ref. 26, 37, and 40) ignimbrites are present along the reach of the Ohinemuri River passing to the south of Gladstone Hill. In borehole GLD004D they are 16m deep. The andesite is highly weathered from approximately 16m to 24m deep and then abruptly changes to moderately to slightly weathered andesite, with quartz veining present. It is assumed that this weathered surface of the andesite will be of sufficiently low permeability to minimise drawdown of the ignimbrites above, as is found elsewhere around Waihi.

3.4. Wharekirauponga Access Tunnel geology

A high-level interpretation of the geology for the Wharekirauponga Access Tunnel by Golder (Ref. 27) is shown in long section in Figure 20. Sections from the OGNZL geology model (Ref. 26) in Figure 9, Figure 13, Figure 16, and Figure 17 also show the inferred geology. Behind the east end of the Waihi township the tunnel is indicated to pass through Waipupu Formation andesite (aw) which consists of andesitic flows, breccias, and tuffs, some of which are hydrothermally altered (Ref. 36). The tunnel will then pass through the younger andesite (inferred to be Whitiroa andesite by Golder Ref. 27), before returning back into Waipupu Formation andesite (Ref. 27).

The younger andesite present in the mid-section of the alignment is inferred to be on a down thrown block (graben) that is bounded by northeast regional scale faulting (Ref. 27). It is expected that there will be fracture zones associated with these faults and that ground conditions will be weaker than the general andesite rockmass (Ref. 36).

The WUG Portal entrance for the Wharekirauponga Access Tunnel is likely to be in andesites. However, the top of the cuts for the portal may intersect ignimbrites blanketing the hill.

The Wharekirauponga Access Tunnel decline alignment is slightly to the west of the current Favona Underground, however, will be notably shallower and may intersect both overlying ignimbrites and hydrothermal vent breccia before reaching the andesite again before passing behind Waihi East. PSM (Ref. 40) has produced an indicative section along the decline alignment which is included in Figure 21.

The existing Favona Underground vent shafts are approximately on the alignment of the decline (Figure 3). There is approximately 15m deep ignimbrites, with approximately 15m thickness of hydrothermal tuff (volcaniclastics) over hydrothermal vent breccia (Ref. 39) at this location. The hydrothermal vent breccia is 50m thick and overlies the upper andesites. The Favona Underground is within the upper andesites. Close interaction of the tunnel decline and the vent shafts present a potential risk of groundwater drawdown in the younger volcanics.

3.5. Willows Road site geology

The geology of the Willows Road site is summarised on Figure 22 and Figure 30, produced by GHD (Ref. 28). The site is noted to consist of a depth of primary weathered rock and/or pyroclastic deposits that are weathered to form clay and silt soils (Ref. 36). These soil materials are a few metres thick on the steeper slopes and in the gullies are around 7 to 15 m thick. Beneath these soils either lies relatively fresh andesite rock in the northern part of the site (Waipupu Andesite) or completely weathered tuff (Whiritoa Andesite) (Ref. 36) towards the portal and site infrastructure location. Golder (Ref. 38) infers the contact between the two units to daylight on the west side of Willows Road Farm and dip to the east. In the low-lying areas adjacent to the Mataura Stream, alluvial terrace deposits exist consisting of silty gravel and sands. These materials directly overlie the andesite (Ref. 36).

3.6. Wharekirauponga Dual Tunnel alignment

GHD (Ref. 28) has interpreted the available information along the Wharekirauponga Dual Tunnel from Willows Access Tunnel to WUG mine indicating that the tunnel passes at depth primarily through the Waipupu Formation andesite (aw) and Whiritoa andesite (ah), passing various geological lineaments or faults. The sections indicate that the Whakamoehau andesite (Ref. 31) overlies the Waipupu and Whitianga andesite over part of the alignment, however the tunnel is unlikely to intersect this unit at depth. This is shown on the plans in Figure 22 to Figure 26 and sections in Figure 27 to Figure 30. This mapping is based on the GNS 1:50,000 geological map (Ref. 24, 28).

3.7. WUG Mine geology

At WUG the host rock is assigned to the Maratoto Rhyolite (Ref. 24, 27, 29, 30, 31). The epithermal quartz veins occur in the rhyolite flow and breccias that form a dome complex (Ref. 31). The Maratoto rhyolites are overlain by tuffs of the Edmond Formation (24, 30, 31). The rhyolites infill a north-east trending graben (down thrown) structure (Ref. 30). The rhyolites overlie andesites of the Waipupu Formation or Whitianga Group andesites (Ref. 24, 27). The mineralised sequences are partially overlain by strongly magnetic, fresh andesite flows, rhyolitic tuffs and recent ash deposits (Ref. 22). The andesites are interpreted to be Whakamoehau andesite (Ref. 31). The fault structures of the graben trend approximately north-northeast (not inferred to be active) with a series northwest-striking faults interpreted to be cross-cutting the rhyolites (Ref. 30).

The geology at WUG is shown in a simplified form in Figure 31 and Figure 32, with a rhyolitic profile of pyroclastic deposits indicated to overlie a notable thickness of (lava) flow deposits, with pyroclastic deposits again beneath the flows before reaching the underlying andesites. The WUG Mine will be in the rhyolite flows and pyroclastic deposits. The ventilation shafts are positioned over the declines as they approach the mine from the south. They may be wholly within the Whitiroa andesite or pass through the Whakamoehau andesite at the surface and into the rhyolites at depth (26, 27). Further ground investigation is required to confirm the ground profile at these locations.

4.0 WAIHI DEWATERING AND GROUNDWATER LEVELS

4.1. Historical Dewatering

Extensive underground mining was undertaken at the Martha Mine from 1893 until 1952. The workings were generally in the area of Martha Hill, which is now Martha Open Pit and modern Martha Underground. Dewatering the original mine was required down to the full depth of workings, approximately RL540m. The historic dewatering occurred over many decades, longer than the recent phase of mining (1989-2021). By the time the recent phase of mining commenced in 1989 the groundwater levels had returned to near pre-mining levels.

4.2. Martha Open Pit, Favona, Trio and Correnso Underground Dewatering 1989-2024

Dewatering of the Martha Open Pit occurred progressively. Dewatering was achieved by installing pumps into the main shafts associated with historical underground mining beneath the pit. A record of the mine dewatering level over the life of the mine is shown in Figure 4. Reference reduced levels (RL) for key mine and geological features are also shown on Figure 4. Monitoring of dewatering levels was undertaken from shafts in the bottom of Martha Open Pit until 4 May 2015, when the slip occurred on the North Wall of the pit. Dewatering levels since 2015 are based on pumping levels in Correnso Underground and underground bores for MUG development.

The dewatering has been carried out at different rates during the period and sometimes the water level has been held near constant (refer to Figure 4). Records at Martha Open Pit begin with the groundwater at approximately RL1110m in 1989. The average rate of drawdown in the pit from 1989 to 1998 was about 16 m per year. Between 1998 and 2000 the groundwater level at the pit was at approximately RL970m. In 2000 and 2001 it was drawn down 30 m to RL940m. Between 2001 and 2003 the groundwater level at the pit was maintained between RL940m - RL960m. It was then lowered progressively 70m from RL960m to about RL890m from about May 2003 to December 2006, at an average rate of approximately 20 m per year. Groundwater levels beneath Martha Open Pit were held close to RL 890m until June 2009.

Concurrently, from 2004 the Favona Decline was developed, with the decline reaching near full depth early 2008 (see indicative depth of decline construction on Figure 4). The development of the decline is notable as the Favona vein system was understood to not be hydraulically connected to the Martha vein system and had not been dewatered historically. The decline for Favona was developed from the existing Favona Portal in Gladstone Hill (see Figure 3).

Martha Open Pit was dewatered a further 15 m to RL875m between June 2009 and December 2010 at an average rate of drawdown of approximately 10 m per year. The rate of dewatering was then increased to about 70 m per year from December 2010 to November 2011, with the water level was reduced from RL875m to RL807. It was slowly lowered to about RL790m from November 2011 to May 2015. Concurrently, Trio Underground was developed under Union Hill from 2010 (Ref. 23), with ore production beginning in 2012 and finishing in 2014 (Ref. 22). Correnso Underground development began in 2014. This was the first modern underground mine in Waihi undertaken under private residential and commercial property not owned by the mining company.

In 2015 there was the slip on the north wall of Martha Open Pit which prevented access to the dewatering pumps which were located in the pit in the old mine shafts. After this the dewatering was undertaken from the Correnso Underground. Slow dewatering continued to approximately November 2017, after which the dewatering rate was increased and the level was lowered at a rate of approximately 55 m per year to RL705m by Jan 2019. The level of the sump in Correnso (Gladstone Sump) remains at RL705m. Correnso Underground was close to complete in 2021 with the majority of the stopes mined and backfilled. Dewatering for Martha Underground commenced in July 2020 from two underground bores drilled below the RL800m exploration drives for MUG, which extend beneath Martha Open Pit. The bores are continuing to lower the groundwater level, which had reached RL662m as of December 2023.

4.3. Piezometer monitoring and interpretation

Monitoring wells, referred to as piezometers, have been installed at various locations surrounding the pit and undergrounds to monitor the effect of dewatering on groundwater levels as shown in Figure 33. The piezometers have been installed at different depths to enable the monitoring of groundwater levels or water pressures in the different geological units (alluvium, deeper younger volcanic deposits and andesite rock). The recorded levels are summarised on contour plans in Figure 34, Figure 36, and Figure 39.

The contours for the andesite in Figure 39 are indicative of the groundwater levels in the upper surface of the andesite. Groundwater levels in the deeper andesite will be lower. Figure 35, Figure 37, and Figure 40 group and present the recorded groundwater levels over time by geological unit for information.

GWS (Ref. 35) provides a detailed review of the site hydrogeology and the effect of pit dewatering on groundwater levels. Generally dewatering has resulted comparatively in much greater changes in groundwater levels in the deeper andesite rock than in the weathered surface of the andesite, younger volcanic deposits and alluvium. This is shown in Figure 42 and Figure 43 which present the recorded groundwater levels at monitoring location P2 and P8. At each location there are multiple devices recording groundwater levels in different geological units.

Generally, the groundwater can be drawn down in the andesite without affecting the shallow groundwater table, and only partially depressurising the younger volcanics at depth. In Figure 42 P2-1 and P2-2 tip (measurement) levels are in the andesite rock. They show the progressive drawdown of the andesite following the mine dewatering level. In Figure 43 P8-1 is located in andesite and also follows the mine dewatering. For all three piezometers (P2-1, P2-2 and P8-1) the groundwater levels have been drawn down below the tip and therefore they show a constant level as the mine dewatering continued. Notably the piezometer tips P2-3, P2-4, P8-3, and P8-4 in the alluvium and younger volcanic have not followed the same drawdown trend as the underlying andesite.

A shallow groundwater system associated with volcanic ash, alluvium and completely weathered rhyolitic tephra is present at shallow depth. The shallow groundwater system is controlled by rainfall infiltration. It is not affected by underground mine dewatering in the andesite and is only affected by the open excavations close to the pit. Both piezometers P2-4 (tip RL 1101m) and P8-4 (RL1111.8m) in the boulder alluvium do not show any notable drawdown.

The younger volcanic deposits are located within a transitional groundwater system. This groundwater system is not influenced significantly by either surface infiltration or underground dewatering of the andesite. It is, however, influenced by drawdown caused by the excavation of the pit walls. Figure 36 shows the contact of the deeper younger volcanics in the pit walls, showing the contact is lowest on the east side of the pit. Monitoring of groundwater levels indicates drainage primarily towards the open pit (see Figure 36). The response of piezometer P2-3 in Figure 42 and P8-3 in Figure 43 shows drawdown in the early stages of pit dewatering before a steady-state situation was reached in about 1996. This contrasts with the continuing drop in groundwater levels in the deeper andesite rock (P2-1, P2-2 and P8-1). Groundwater level changes and the associated consolidation of the varying thickness of the younger volcanic deposits, which are weaker and more compressible than the andesite, is responsible for much of the settlement that occurred in the early stages of dewatering close to the Martha Open Pit, however, as dewatering has transitioned to being predominantly in the andesite, compression of the andesite has become the more notable contributor for settlement.

The andesites host the mineralised veins. The veins are therefore located within the deep andesite groundwater system. The veins are directly affected by dewatering in Martha Open Pit and underground mines and respond rapidly to mine dewatering. The adjacent andesite rock responds slower than the veins due to its low permeability. The veins have good connection due to both their high permeability nature and the intersecting historical mining drives/adits and shafts.

Dewatering effects associated with the Martha Open Pit are abruptly attenuated to the north and west of the mine because of faulting. Dewatering extends to the south-west and east of Martha Pit. There is a connection between Martha, Correnso and Trio groundwater systems. The Favona vein groundwater system was originally thought to be hydrologically separate from Martha-Correnso-Trio groundwater system because of the groundwater levels in the andesite. Now the construction of Favona to Trio incline and decline provides a connection of the two systems above RL823m (Ref. 9). Some settlement (10 to 50 mm) had been observed at Favona prior to its development, hence the effects of deep dewatering of the andesite close to Martha Pit were having some minor effect at Favona.

Development of the Favona Underground caused significant local drawdown of groundwater in the andesite as indicated by piezometer P64-a on Figure 46, which is now dry below the screen depth 184 m below ground level (mbgl). The Favona Underground drives have reached RL766m (Figure 4), approximately 330 to 360 mbgl. Drawdown of the upper younger volcanic material in this area did not occur, as confirmed by piezometer P64-i (screen depth 30.5 mbgl) (Figure 46). However, some local drawdown of groundwater levels in the younger volcanics may have occurred temporarily during the ventilation shaft construction (Ref. 39). Piezometers P64-d was also drawn down dry during the development of Favona decline, with a screen depth at 53.6 mbgl. Drawdown has also occurred in the andesites south toward Gladstone Hill where the Moonlight Underground was developed. The dewatering reduces further south towards Gladstone Hill (Ref. 27) as shown on Figure 39 (Ref. 9) (see borehole GLD004) where the andesite groundwater levels at depth are close to the level of the Ohinemuri River.

4.4. Martha Underground dewatering

The Martha Underground dewatering will occur before and during the WNP. The effects may therefore occur concurrently with WNP.

The Martha Underground mine (Project Martha) extends to RL500m. Therefore, the water level will need to be lowered by 205 m below the previously held (Correnso) dewatering level (RL705m). Dewatering for Martha Underground is another 40 m deeper (RL500m) than historic mining. Dewatering will be achieved by the installation of stage pumping chambers within the mine that pump into the existing Correnso dewatering pumping system located at RL780m. Water will continue to be piped to the Water Treatment Plant. The MUG dewatering level is at RL662m at the end of 2023 (see Figure 4).

The observed response of veins within the Martha groundwater system to dewatering at Martha Mine means that the RL500m water level will also be developed in veins beneath Waihi, including Waihi East (Ref. 35). The existing multi-level piezometers P90 to P95 and P100 to P102 located in the Waihi East, shown in Figure 44, and Figure 45 indicate that the drawdown of the andesite is unlikely to have any notable drawdown effects on the shallower surficial alluvial and younger volcanic groundwater systems. These groundwater levels were recorded in August 2020. The groundwater level of the Martha vein system at that time was RL705m. The deepest piezometers in the boreholes are located in the upper andesite and show significant under drainage, however, the shallow piezometers in the younger volcanics show increasing groundwater pressure with depth indicating that they are maintaining a near hydrostatic profile.

Observation of groundwater levels and modelling by GWS (Ref. 35) indicate dewatering the Martha vein system from the current elevation (approximately RL705m) to RL500m is not expected to notably affect groundwater pressures within the younger volcanics. This is consistent with the long-term groundwater monitoring data which shows shallow groundwater pressures have remained relatively unchanged while dewatering has been ongoing. The groundwater pressures in the interconnected veins and other open rock defects connected to the veins are expected to drop nearly immediately in response to lowering of the groundwater level required for the Martha Underground. The groundwater pressures in the andesite rock mass are indicated to respond to dewatering of the veins.

The weathering profile depth within andesite rock does vary locally, resulting in a variation in thickness of the low permeability material that perches the shallow groundwater system. However, monitoring and modelling indicates that it is generally thick enough in the areas of works to date to maintain a perched water level in the overlying younger volcanics (Ref. 35). Martha Underground is located in areas of previous andesite watering.

Monitoring in the andesite is limited by the depth to which the piezometers have been installed. The lowest piezometers installed in the andesite are P92-156.3m at RL965m (beneath Waihi East) and P106-163m to RL974m (behind Martha Pit North Wall). Project Martha underground mines will be developed down to RL500m. Deeper dewatering of the andesites is interpreted to have very minor effect for structures at the surface. Dewatering levels in the interconnected veins are assumed to match the dewatering for the underground mines.

4.5. Waihi North Project dewatering

The groundwater drawdown effects for Waihi North Project have been assessed by GWS (Ref. 36) and GHD (Ref. 37). The following sections summarise the groundwater drawdown situations assumed for this ground settlement assessment for the various project elements.

4.5.1. Gladstone Open Pit

GHD (Ref. 37) has made assessment of the groundwater drawdown at Gladstone Open Pit. There is a shallow groundwater system in the younger volcanics overlying a deeper system in the andesite, similar to the rest of Waihi. However, the younger volcanics (sandy ignimbrite found up to 43.5 mbgl) are of a much more limited depth than Waihi East (up to 140 mbgl).

The Favona Underground dewatering is inferred to partially dewater the Gladstone vein system, with deeper piezometers in the andesite near to the vein system (P60 and P61) drawn dry on the north side of the pit. On the south side of the pit, piezometer GLD004 close to the inferred extent of the vein system shows slight vertical upward flows from the andesite to the ignimbrites. Piezometer P79 to the southwest of the pit indicates minor gradual drawdown of the andesites, however groundwater is still present in the monitored levels of the andesites. GLD004 indicates that the veins to the south may not be dewatered. P79 indicates partially dewatering in the andesites with limited hydraulic connection to the vein system is indicated by the lack of drawdown.

GHD (Ref. 37) expected that Stage 1 of the Gladstone Open Pit will already be fully dewatered in the andesites (near to the vein). Stage 2 which extends partially into Winner Hill, may only be partially dewatered along the vein, and in the andesites.

The pit is expected to have some drawdown effects in the shallow groundwater system around the pit, however these effects diminish away from the pit. The extent of the dewatering in younger volcanics is estimated by GHD (Ref. 37). The extent of dewatering effects in the shallow groundwater system is presented by GHD (Ref. 37) as distance drawdown graphs. In summary the groundwater drawdown at the edge of the pit varies between 3 to 8 m and the drawdown zone of influence extends up to 290 m. The Ohinemuri River is approximately 185m from the pit on its southwest extent. The Ohinemuri River is expected to control the shallow groundwater to the south of the river.

GHD (Ref. 37) has assumed that there will be a strong hydraulic connection along the Gladstone vein system which will allow the vein to dewater to the pit floor level of RL1005m. They consider that the drawdown extent will be similar to the extent indicated by P60 (fully drawn down) to GLD04 (not drawn down), however the maximum depth of drawdown will now shift 180 m to the southwest along the vein to the bottom of Gladstone Open Pit (RL1005m). GHD indicated no material reduction on the Ohinemuri River flows, attributed to the separation of the shallow and deep groundwater systems. They have indicated the likely extent of drawdown effects in the deeper andesite in Figure 3.14 of their report (Ref. 37). As there may be some drawdown of the vein system beneath at the Ohinemuri River they have assessed the effect on groundwater from vein dewatering. This is shown in Figure 3.13 of the GHD report (Ref. 37). This drawdown has been considered in the assessment of potential settlement effect in this report (Section 6.1.1).

4.5.2. Wharekirauponga Access Tunnel

GWS (Ref. 36) assessed the groundwater effects of the Wharekirauponga Access Tunnel from the Processing Plant to the start of the Wharekirauponga Dual Tunnel at Willows Farm. The tunnel will cause depressurisation of the andesite where not already depressurised by underground working. Where the Wharekirauponga Access Tunnel (decline) is passing Favona Underground in the andesite the ground water is indicated by monitoring to have been drawn down. No further drawdown effects are expected over the length of the decline in andesite.

Any sections of the decline which intersect the younger volcanic (ignimbrite) deposits can be expected to draw down the shallow groundwater system, which is not currently affected by the Favona Underground. OGNZL will use grouting methods at these sections of the decline to limit shallow groundwater inflow from the ignimbrites or undertake investigations to confirm any effects would not extend to reach any properties.

The proposed Wharekirauponga Access Tunnel corridor east of Waihi East is expected to pass at depth through andesite rock and therefore no notable drawdown of the overlying perched groundwater system in the younger volcanics is expected. Further investigation is required to confirm the tunnel will pass Waihi East within the andesite.

GWS highlighted (Ref. 36) the younger andesite is present in the mid-section of the tunnel alignment due to being in a down thrown block that is bounded by regional scale faults, and that it is expected that there will be fracture zones associated with these faults and that ground conditions will be weaker than the general andesite rockmass.

Where the tunnel passes these faults zones or veins in the andesite they may already be partially drained. EGL recommends installation of piezometers to determine the groundwater situation prior to the tunnel being drilled. These piezometers will follow the standard practice for Waihi East where piezometer tips are positioned in the shallow alluvium, deeper younger volcanics, weathered andesite and deeper andesite. They are also recommended to allow interpretation of the response of the groundwater system to tunnelling. If there is drawdown in the shallow groundwater systems, the tunnel will have to be pre-grouted with a curtain anywhere the tunnel is likely to draw considerable groundwater, which is most likely to be around faults or veins. If the weathered surface of the andesite was not present, much more extensive pre-grouting could be required, however, this is unlikely given the wider spread drawdown of andesite and monitoring to date in Waihi.

4.5.3. Willows Access Tunnel

GWS (Ref. 36) assessed the groundwater effects for the decline for the Willows Access Tunnel and Willows Ventilation Shaft based on ground investigations by Golder (Ref. 38) and GHD (Ref. 28). The site has relatively steep topography sloping down to the Mataura Stream. The wells indicated at higher elevations the water table is tens of meters below ground level. At lower elevations the depth to groundwater is between 1 to 5 m. Perching of groundwater is noted to occur in the shallow materials overlying the volcanic rockmass.

The portal cut will be at higher elevations and is expected to have only local drawdown in the rock which it is cut.

In-situ permeability testing was undertaken as part of the investigations by GHD and Golder (Ref. 38). GWS (Ref. 36) summarised that the andesite, which is the main geological unit the access tunnel is to be driven through, has a permeability of approximately 3.0×10^{-8} m/s and is similar to that adopted elsewhere in Waihi. GWS (Ref. 36) noted given the rockmass dewatered by the tunnel is of low permeability, any associated dewatering effects are expected to be limited. GWS (Ref. 36) assessed the potential groundwater drawdown profile above the tunnel. The estimated drawdown was 3.5 m above the tunnel with no discernible drawdown 600 m from the tunnel. They noted most of this effect would be within Willows Road Farm. The closest dwellings not owned by OGNZL are on Willows Road and Highland Road. Both are over 600 m from the decline access tunnel. The Willows Access Tunnel passes beneath the proposed Willows Rock Stack.

4.5.4. Wharekirauponga Dual Tunnel

The Wharekirauponga Dual Tunnel from Willows Access Tunnel to the WUG site is at depth (approximately 130m to 420m) within andesite rock.

GWS (Ref. 36) notes that any drainage effects will be localised to around the tunnel, and they will not manifest in the near surface due to the relative depth of the tunnel. They note no intrusive groundwater investigations along the tunnel alignment have been undertaken and this is considered justified based on the geology being similar to that at Waihi and the proposed mitigating tunnelling methodology that will ensure drainage effects are managed. This includes pre-grouting of any high inflow zones and allowing only rockmass drainage to occur. Geotechnical boreholes will be drilled ahead of the tunnel in advance to give prior warning of geotechnical and groundwater conditions.

4.5.5. WUG – Mine drives, shafts and stopes

The host rock at WUG is rhyolite flows and pyroclastic deposits. The rhyolite overlies andesite. Permeabilities within the rhyolites are currently understood to be higher than the andesites (Ref. 41). Detailed investigation and modelling will continue to develop this knowledge.

The current assumption is that the host rhyolites will be dewatered to the full depth of the WUG mine and shallow surficial groundwater systems will be protected with measures to avoid effects at the surface (restricting mining within a certain distance of the ground surface or geological units, grouting to restrict seepage).

4.5.6. Ventilation shafts

GWS (Ref. 41) assessed the potential for groundwater drawdown with distance from the ventilation shafts (at Willows Road and WUG) for the purposed of making a general assessment of ground settlement. The assessment assumes drawdown for 40 days until the ventilation shafts can be lined (with sprayed concrete). Estimated drawdown of the groundwater at the vent shafts ranged from 40 to 70 mbgl.

5.0 GROUND SETTLEMENT MEASUREMENTS AND PREDICTIONS

5.1. Settlement effects 1989 to 2024

Ground settlement measurements have been made around the Martha Open Pit and throughout Waihi since 1989. Six monthly surveys have been undertaken as required by condition 11 of the Mining Licence, condition 9 of Water Permit 971286 and conditions 5 to 7 of resource consent 124860. The locations of the settlement markers where settlement measurements are made are shown in Figure 47 to Figure 50.

Land Use Consent (No.97/98-015, Condition 3.30g) granted in 1999 refers to Figure 8 of the evidence presented by Dr R. Semple to the Environment Court in 1998 (Ref. 2). Seven zones (Zones 1 to 7) are identified in Figure 8 of this evidence and a copy of this figure is attached (refer to Figure 50 in this report). The seven zones are intended to represent areas of different magnitude of settlement. The zone boundaries were based on settlement monitoring up to 1997, site geology and distance from the pit. Generally, settlements within the different zones have been relatively consistent. However, there are some settlement markers that do not fit with the zones they are currently associated with. In 2018, EGL reviewed and updated the zonation for Project Martha taking into consideration of the monitoring data since 1997. This is shown in Figure 51.

The monitoring data show that some of the settlement markers indicate greater settlements than their zone category. These are noted in the annual dewatering and settlement report. The latest figure noting these locations is included in this report in Figure 52.

The results of settlement monitoring for Zones 1 to 7 are presented in Figure 53 to Figure 61. The settlement data indicate general trends, either showing gradual slow settlement over time or more notable response to specific stages of groundwater drawdown.

Figure 47 to Figure 49 show that generally, settlements decrease with distance from Martha Pit, except for the area of Favona Underground. Settlements are greatest near the perimeter of the pit on its east side where the younger volcanic are deeper. Settlements in this area (Zone 7) are currently up to approximately 300 mm (Figure

61). Settlement reduces away from the pit, however there is still recorded settlement greater than 20 mm up to 2.9 km from the pit indicating the depressurisation has some slight influence in the deep andesite for a notable distance. This slight depressurisation at depth is of no material effect.

Comparison of settlements with groundwater levels indicates that with ongoing dewatering, settlement has continued. The settlement typically follows a general trend rather than a rapid response to changes in the drawdown rate. However, Favona Underground dewatering has affected groundwater levels and settlement in its vicinity, at different rates than dewatering around the Martha vein system.

Dewatering at Favona Underground from 2005 to 2008 was notably faster than dewatering for Martha Open Pit over the same period. The dewatering of Favona Decline and Martha System are shown together on Figure 4 and Figure 59. Settlements in Zone 5 at Favona (Figure 59) were also at a greater rate than the rest of Zone 5 (Figure 58) over this time. Notably this rapid drawdown of groundwater at Favona Underground did not affect other areas of Zone 5, which were likely already drawdown to lower levels or were not connected to the Favona vein system.

There was a significant change in pit water level from November 2010 to November 2011. In general, settlement markers (refer Figure 53 to Figure 61) either showed no noticeable or only a very small increase in the rate of settlement. Where there was a change in rate of settlement it occurred either immediately or within one month following the change in pit water level. However, the rates of settlement reduced to their original levels in approximately six months.

Notably settlements continued at Favona until 2014 when underground mining of stopes was completed (see Figure 59). At this point the settlement rate slowed till November 2017.

Ground above Favona Underground (Figure 59) has shown a more notable settlement rate when water levels were further drawn down from Correnso Underground, approximately 75m, between November 2017 to January 2019. This indicates that there is now likely some connection between the andesite around the Martha veins and the Favona veins or underground. Dewatering of the Martha veins through the Martha Underground may result in further settlement at Favona, however, further monitoring data is required to confirm.

Settlements show a slower response to pit dewatering with increasing distance from the Martha Open Pit and underground mines, as shown by settlement measurements in Zones 1, 2 and 3 (refer to Figure 53, Figure 54, and Figure 55). At these locations settlements are much smaller and the rate of settlement is more uniform with time. Smaller settlements are expected because groundwater drawdown away from the Martha Open Pit and underground mines is less and the rate of settlement is more uniform with time due to the slower rate of depressurisation of the andesite rock mass away from depressurised veins.

Settlements have continued to occur, albeit at very slow rates (typically 0.1-1 mm per year), during periods when mine water levels have not changed significantly (July 1998 to January 2000 and November 2006 to November 2010). The most likely explanation is ongoing drainage of the andesite rock mass, with slow depressurisation of the rock away from the vein system occurring due to its low permeability.

Condition 7 of resource consent 12860 (and previously condition 10 of the Water Permit 971286) requires that tilt be assessed based on the six-monthly settlement survey data and reported in the Annual Dewatering and Settlement Monitoring report (Ref.6). Tilt gradients are generally very low, less than 1:1,000, in the area of the Waihi township. Tilt of less than 1:1,000 is well below the gradient that would give rise to concern for structures. Over Favona Underground there have been tilts with gradients greater than 1:1,000, however there are no structures in this area, so is not of concern. The area of greater tilts over Favona Underground appear to be limited, potentially by the Favona Fault on the west side of Favona Underground.

5.2. Project Martha settlement effects

The further dewatering to RL500m of the Project Martha underground will have minimal effect on any ongoing settlement in the upper andesite or younger volcanics. However, it will result in additional depressurisation and settlement of the deeper andesite rock mass. These settlement effects can be expected in the general areas of previously experienced settlement.

New settlement trigger levels for each settlement zone were set for Project Martha and are shown in Figure 51. These were determined by projecting observed settlements using the settlement trends determined using numerical models. These settlement trigger levels are also plotted on Figure 53 to Figure 61. The settlement trigger level for Zone 7 for Project Martha is 540 mm immediately east of Martha Open Pit. Around Favona and Gladstone, Zones 4 and 5 are specified with a settlement trigger level of 160 mm and 260 mm respectively.

5.3. Settlement exceptions to predictions

Generally, settlements have been in-line with expectations. Where there have been exceptions they have been investigated and in all cases there have been explanations. These are discussed in the following sections.

5.3.1. Gladstone Road

Settlement occurred in 2012 causing damage to some dwellings in Gladstone Road to the east of the Martha Open Pit. Differential ground settlements (tilts) were the cause of the damage, and investigations confirmed the settlement was a result of dewatering of the younger volcanic deposits in this area caused by a deep geotechnical drillhole (CGD008) not being properly grouted, which allowed groundwater to leak into the lower strata. Following re-grouting of the drillhole the ground water was restored to the original levels and the land rebounded quickly close to original levels.

5.3.2. Slevin Street

Since May 2015 the tilt between marks 20C and 20D (near Slevin Street) (Figure 49) has at times been greater than 1:1,000. OGNZL understands the settlement to be unrelated to dewatering associated with the current project. It is considered to be due to the weak nature of the ground and the presence of unfilled stopes in the old underground Martha Mine that underlie the area. The area is near a high hazard zone identified by GNS (Ref. 42). Slevin Park is a swampy area, historically infilled with weak material where slumping/subsidence has occurred previously. No damage to any dwellings has occurred. The closest dwelling to the affected area is 95 m away.

5.3.3. Correnso Area

Two tilt calculations greater than 1:1,000 in the Correnso South area were identified during the May 2020 survey and remain in the November 2021 survey. The tilts are between marks 23C/2.25 and 23C/BANK1 (Figure 49). Both tilts are due to a sharp increase in settlement of mark 23C in the May 2020 survey. The mark is noted by the surveyor as being near a watercourse. The mark may have been influenced by improved drainage nearby or may have been disturbed. The rate of settlement recorded at 23C in subsequent survey events has been similar to nearby marks, indicating that increased settlement at this point, if it were occurring, is not ongoing.

5.3.4. Favona Underground Mine

Settlements above the Favona Underground have been greater than originally predicted and tilts have exceeded 1 in 1,000 at five locations. The locations are directly above the underground workings and vein system on farmland owned by OGNZL. No buildings have been affected. The closest dwelling is on OGNZL owned land and is within 30 m of the recorded tilts. The nearest non-OGNZL dwelling is approximately 120 m from any tilts greater than 1:1,000. The original settlement estimates only considered settlements in the younger volcanic deposits (Ref. 3). If allowance is made for settlement in the geologic units that underlie the younger volcanic deposits (i.e. hydrothermal tuff, hydrothermal breccia, andesite and dacite) then the predicted settlements are closer to the measured settlements.

6.0 ASSESSMENT OF GROUND SETTLEMENT EFFECTS – WAIHI NORTH PROJECT

6.1. General

Prior to commencement of mining in 1987 and subsequently again in 1997 (Ref. 2), theoretical predictions of the future ground settlements due to mine dewatering were made. Since then, throughout the life of the mine, ground settlements have been measured at six-monthly intervals at hundreds of locations in Waihi township. The large number of settlement observations, spanning some 34 years, provides a reliable database for estimating likely future settlements associated with further dewatering. The monitoring undertaken at Waihi makes it one of the best monitored sites in New Zealand and provides an excellent database for predicting future settlements.

Assessment of ground settlement is based on both review of past settlement trends and theoretical calculations (where relevant).

Past assessment for Project Martha (Ref. 7) has set the ongoing settlement trigger levels for the seven settlement monitoring zones (refer to Table 1 and Figure 51). Settlement trigger levels are set to drive review of settlements which may be higher than expected, to check that there are no adverse effects occurring. Settlement predictions were based on the observed settlements trends extended for the potential dewatering effects of Project Martha. This approach follows two key steps:

1. First step is to set up simplified calculations/models to compare theoretical predictions with past recorded groundwater levels and ground settlement. Theoretical prediction models can then be adjusted to better match past predictions and to then aid future estimation of settlements, where the mechanisms involved are similar.

2. Second step is to use the adjusted theoretical models to estimate the settlement effects of dewatering caused by future developments.

The theoretical predictions are possible at Waihi because:

- There is strong correlation between groundwater levels and observed settlement which allows theoretical models to be essentially calibrated against the observed effects.

- Limited dewatering of the shallow groundwater and younger volcanics has occurred and limited future dewatering of these materials is predicted. Modelling of tilt due to changes in general groundwater profiles, depressurisation and geology can be broadly estimated, but cannot reliably predict notable tilts due to localised dewatering at shallow depths.

The additional settlement effects due to Waihi North Project have been assessed separately for:

- Potential dewatering of the Gladstone vein south of GOP
- Potential additional dewatering of the andesite rock due to the proposed MUG decline in andesite beneath Moore Street
- Potential dewatering of the ignimbrite between the Wharekirauponga Access Tunnel decline and Boyd Road and Barry Road
- Potential dewatering of the andesite veins and rock mass not already dewatered caused by the development of the Wharekirauponga Access Tunnel behind Waihi East
- Depressurisation around the Willows Access Tunnel
- Dewatering around ventilations shafts
- Dewatering due to the development of WUG

Calculations for the estimates of settlement have been undertaken using the GeoStudio 2D finite element analysis (FEA) programs, SEEP/W and SIGMA/W.

6.1.1. Gladstone vein dewatering south of GOP

Calculation of seepage and settlement has been undertaken for a representative profile south of the Gladstone Open Pit where there could be veins connected with the pit that may extend some limited distance beneath the Ohinemuri River. The assessment was undertaken to estimate the potential additional settlement and tilt around the Heath Road area.

The SEEP/W model of the ground and groundwater parameters for GOP were provided by GHD (Ref. 37). This assumes full vein drawdown to match the level of the pit floor (RL1005m). The change in groundwater is assessed against a current condition with the groundwater approximately at the river level with a slight upward flow from the andesite to the river indicated by GLD004 piezometers. The model assumes that the weathered andesite at the interface has a lower permeability than the overlying ignimbrites and fresher andesite rock beneath. The modelled drawdown of the groundwater in the ignimbrites by GHD is up to 4 m over the vein position. Depressurisation in the andesite is concentrated around the vein with a steep draw down profile modelled down to RL1005m or 80 m below the current water level in the vein.

The stiffness values used in the settlement calculations were selected by EGL. A stiffness value (young modulus) of 1,000 MPa was initially selected for ignimbrite profile which is the stiffness value used at Waihi East (Ref. 7) for softer rocks typical of the younger volcanics (for the purpose of estimating settlement). 2,000 MPa was used for the weathered andesite and 8,400 MPa for the slightly to unweathered andesite. The calculations are summarised in Appendix A. For the vein dewatering associated with Gladstone Open Pit excavation, the average modelled settlement was 36 mm, and the additional tilt effects were very low at 1:4800. Approximately 10 to 20 % of the calculated settlement is attributable to settlement in the ignimbrites and the remaining 80 to 90 % in the andesites. For the assessment of effects, settlement south of the Ohinemuri River can be expected to be in the order of 10 to 50 mm with very low additional tilts.

The settlement points (1.12A, 1.22, 1.25) south of GOP were reviewed against the trigger limits for monitoring plan zonation (Figure 62). The settlement in November 2021 in Zone 3 is between 45 and 75 mm. The settlement trigger limit for Zone 3 is 95 mm. The settlements in November are 47 to 78 % of the trigger level, with 73 % of the currently proposed drawdown in the Waihi vein systems undertaken.

The settlement (at points 1.26 and AP100) south of GOP in November 2021 in Zone 4 is approximately 110 mm (Figure 63). The settlement trigger limit for Zone 4 is 160 mm. The settlements in November 2021 were 69 % of the trigger level, with 73 % of the currently proposed drawdown in the Waihi vein systems undertaken.

Notably, settlements south of GOP have followed a relatively consistent trend with time as the Martha and Favona vein systems have been progressively dewatered, and the level of groundwater drawdown proposed for GOP is much less. The vein is indicated to have limited extent (Ref. 37), ending approximately at the Ohinemuri River. Overall, the extent of potential additional settlement from GOP is expected to diminish towards Heath Road and settlements associated with Martha dewatering are expected to continue.

For the Heath Road area it is proposed that the settlement zonation remains the same (Zone 3 and 4) and additional monitoring points be added near to the existing dwellings to provide forward warning of any unforeseen settlement effects. GLD004 piezometers are already in place close to the end of the Gladstone vein on the north side of Ohinemuri River to provide indication of dewatering effects in the ignimbrite and andesite. EGL recommends that additional settlement monitoring points are also included in Clarke Street to monitor for any effects southwest of GOP.

Settlements can also be expected close to GOP from dewatering of the younger volcanics and andesite close to the existing Gladstone Hill. Past settlements in this area have been on the order of 120 to 200 mm on the west and north sides of Gladstone Hill due to dewatering caused by Favona and Trio Underground developments. The areas to the north are already dewatered. Settlement around the south and east side of Gladstone Hill can be expected to be of a similar magnitude. The Processing Plant contains the only structures close to the pit and has experienced settlement due to the Favona dewatering. It is noted that on the west side of Gladstone Hill is a surficial landslide feature in extremely weak ignimbrites and tuffs which has recorded up to 540 mm of settlement. These settlements can be expected to continue and are likely a combination of surficial downslope movement and drawdown settlement. A series of additional settlement monitoring points around the remaining Gladstone Hill are recommended to provide an understanding of the settlement effects close to the pit, noting that the pit is proposed to become a TSF on closure (Ref. 1).

EGL recommends that the settlement zones around GOP and over Union Hill are adjusted to remove Zone 1. Zone 1 is no longer representative of the settlement levels in this area. Proposed adjustments are shown on Figure 66 and Figure 69.

6.1.2. Potential dewatering in the andesite by the MUG decline

The Gladstone Open Pit will require the existing Favona portal (access to MUG) and associated decline to be relocated. OGNZL is considering two options, one of which will be developed to provide a replacement portal in GOP, and a short length of new decline to link that portal to the existing underground workings to provide access to MUG. The other is a portal established just north of the existing conveyor, with the new decline running under the southern end of Moore Street linking into the existing development under Union Hill. This assessment considers the option of a portal north of the conveyor. The alternative portal and decline option, sited within the Gladstone Open Pit, remains south of the existing conveyor, and is not overlain by any built infrastructure. Any related settlement effects on privately or publicly owned property would therefore be of lesser effect than the portal north of the conveyor.

The area of the proposed MUG Decline option under Moore Street is partially depressurised in the andesite, possibly by the incline between Favona Underground and Trio Underground at RL823m, the Favona Underground, existing Favona Decline to the east, the existing Trio Decline to the South, or the dewatering of the interconnected Martha vein system. The proposed MUG Decline will be at RL1115m to RL1040m, a much shallower depth than the incline at RL823. The decline might intersect historic workings and also might intersect the top of the No. 9 fault/vein structure. The OGNZL geological model for the area indicates that the overlying younger volcanics (ignimbrites and tuffs) interface with the andesites at RL1074m. The proposed decline will come close to younger volcanics and historic workings which are interpreted to extend back to Moore Street, Boyd Road and Barry Road area. This presents a risk of dewatering the younger volcanics and this risk will be mitigated by OGNZL.

Mitigation includes grouting methods to limit groundwater inflows into the decline prior to construction and post-grouting if inflows continue at unacceptable levels Re-injection of captured groundwater can also be used as a mitigation option to maintain groundwater levels in the younger volcanics. Alternatively, it may be possible to avoid the younger volcanics completely be refining the decline alignment and level so to stay completely within the andesite.

Experience from the development of the initial section of the Favona Decline is that the additional settlements could be in order of 10 to 50 mm locally above the decline, if the decline remains in the andesite and assuming the younger volcanics are not drained.

Additional settlement monitoring points are recommended in Moore Street, to provide a closer network of points. Piezometers in borehole P75 and P76 already monitor groundwater levels in this area, however, an additional piezometer is recommended closer to the location of the decline to monitor the current groundwater levels above the decline and any future effects.

6.1.3. Wharekirauponga Access Tunnel decline behind Boyd Road and Barry Road

The location of the Wharekirauponga Access Tunnel decline (i.e. southern end of Wharekirauponga Access Tunnel) is above the Favona Underground. The andesite in this area is already dewatered and settlements and tilts have occurred, however, no dwellings are present in the area with greatest effects.

There is potential for the Wharekirauponga Access Tunnel decline to intersect the younger volcanics (ignimbrites) which potentially connect with ignimbrites at Boyd and Barry Road. The potential for intersection is illustrated by the cross section along the start of the decline shown on Figure 21 (Ref. 40), where the extended path of the top of the decline is close to the base of the younger volcanics (ignimbrites and tuffs). This could dewater the younger volcanics, and there is a risk this could cause settlement effects at Boyd Road and eastern end of Barry Road. This risk needs to be managed and where required mitigated by OGNZL.

Mitigation options includes grouting methods to limit groundwater inflows into the decline prior to construction and post-grouting if inflows continue at unacceptable levels. Re-injection of captured groundwater can also be used as a mitigation option to maintain groundwater levels in the younger volcanics. Alternatively, it may be possible to avoid the younger volcanics completely be refining the decline alignment and level so to stay completely within the andesite.

No calculations of potential settlements have been undertaken for the decline. Any effects from the decline can be limited to the existing settlement and tilt area above Favona Underground, through the mitigation measures discussed above.

Some settlement points over Favona Underground are starting to exceed the settlement trigger levels for Zone 5 (see Figure 59). Review of the settlement values over Favona Underground indicated an increase in settlement after the completion of mining at Favona in 2014. This is likely a delayed settlement response to the Correnso dewatering to RL705m. The settlement increased around 2017 and has slowed around 2020. This indicates some form of hydraulic link to dewatering of the Martha vein system.

EGL recommends that the area expected to exceed the Zone 5 trigger limits is redefined as Zone 6. Proposed adjustments are shown on Figure 66 and Figure 69. In this area, tilt greater than 1:1,000 occurs. No private structures are affected. This tilt is currently reviewed at six-month intervals. Continuing this review is prudent to make sure that the tilts do not extend to the privately owned dwellings in Boyd and Barry Road, with continued dewatering for Martha Underground and with the development of the Wharekirauponga Access Tunnel proposed.

Boyd Road and Barry Road are in settlement monitoring Zone 4. The settlement trigger level is 160 mm. Settlements in the area, away from the effects of Favona Underground, are typically 90 to 110 mm. The settlements in November 2021 were 56 to 69 % of the trigger level, with 73 % of the currently proposed drawdown in the Waihi vein systems undertaken. Keeping the Zone 4 settlement trigger level in this area is recommended.

Additional settlement monitoring points are recommended along Boyd Road to provide monitoring of any progression of tilts away from the Favona Underground.

6.1.4. Wharekirauponga Access Tunnel east of Waihi East

Calculations of potential seepage and settlement have been undertaken for a representative profile east of the Waihi Township where the Wharekirauponga Access Tunnel will be developed. This area covers settlement Zones 1, 3, and 4. The assessment was undertaken to estimate the potential additional settlement and tilt that could be expected.

The modelling provided estimates of settlements due to dewatering to RL940m, approximately the expected low point of the tunnel. In the model the tunnel is in the fresh andesite with a 50 m thick weathered andesite directly overtop which provides notable hydraulic separation from the younger volcanics. Two different situations were considered:

1. With the tunnel causing local depressurisation around the tunnel in the andesite rock mass
2. With the tunnel causing local depressurisation in multiple veins

The setup of these models is similar to the previous modelling done for Waihi East as part of Project Martha, however, they assume that there is no previous depressurisation of groundwater in this area. Settlement monitoring indicates there is some depressurisation in this area already, however it is not known to what extent. For the same conditions, the modelled groundwater depressurisation is likely to be greater than actual, and therefore the modelled settlements may be higher than actual, for this reason.

The average modelled settlements for the depressurisation around the tunnel in the general andesite rockmass is negligible at 8 mm.

The average modelled settlements from potential vein or fault drawdown due to seepage into the tunnel is 85 mm.

The additional tilt due to the Wharekirauponga Access Tunnel dewatering effects are very low (1:6,400 to 1:19,000) due to its depth and indicate any related potential for damage to structures is low.

For this assessment of effects settlements from the Wharekirauponga Access Tunnel east of Waihi East are expected to be in the order of 10 to 100 mm, depending on the length of the tunnel and the geological structures it passes. If the shallow water table is not affected, tilts will be very small.

EGL recommends that the Wharekirauponga Access Tunnel alignment remains in the andesite. Like Correnso Underground, a 40 m minimum offset from the interface between the top of the andesite and top of the tunnel workings could be required as a consent condition. Further investigation of the tunnel alignment would be required ahead of construction to confirm the offset is achieved.

Increased settlement monitoring and groundwater monitoring is recommended over the tunnel alignment. The increased monitoring reflects good practice in managing any risks associated with potential dewatering of the andesite and fault structures along the back of Waihi East.

Groundwater monitoring in the form of nested piezometers (like the P90 and P100 series holes in the area of Correnso Underground) is recommended at regular intervals along the tunnel alignment. Dewatering in the younger volcanics has been found in the past to be a good indicator of potential settlement issues (see Section 5.3.3).

The No. 9 Fault structure extends from the MUG decline to the Wharekirauponga Access Tunnel behind Waihi East (See Figure 39) and passes beneath privately owned dwellings. It is assumed that it is partially dewatered by the RL823m incline between Favona Underground and Trio Underground. A piezometer borehole in this area is recommended.

EGL recommends that Zones 2 and 3 are extended partially up SH2 as shown on Figure 66 and Figure 69 to allow for the additional settlement from the Wharekirauponga Access Tunnel at depth in the andesite rock.

6.1.5. Depressurisation around the Willows Access Tunnel and Wharekirauponga Dual Tunnel

The Willows Access Tunnel and Dual Access Tunnel to the WUG will be in andesite. Where the tunnel is at depth, average settlements and tilts at the surface are expected to be small. An assessment of potential magnitude of settlement was made for the tunnel when it is at 120 m depth. Most of the depressurisation is within the andesites. The stiffness applied to the regolith (alluvium, ash, residual soil) and weathered surface of the andesite was 1,000 MPa (this is a simplification assuming that the shallow groundwater is perched above the andesite), and the stiffness of the unweathered andesites was assumed to be 8,400 MPa. The calculated maximum settlement was 10 mm, and the tilt was 1:15,000. This is a small settlement owing to localised depressurisation in the tunnel at depth and the stiffness applied to the andesite. The stiffness of the andesite could be less. For example, if the stiffness was half the settlements would approximately double. This would still be a small settlement.

As a comparison the settlement calculated for the Wharekirauponga Access Tunnel in the andesite rock mass was 8 mm at the surface (see Section 6.1.4) for a tunnel depth of approximately 160 m. For the Wharekirauponga Access Tunnel the potential for the tunnel to drain multiple veins of fault structures and result in more widespread dewatering of the andesite was considered and this indicated 85 mm of settlement, with very low tilt. It is likely that the access tunnel will pass through vein and fault structures and settlements could be higher.

To conclude, settlements from the Wharekirauponga Dual Tunnel and Willows Access Tunnel to WUG are expected to be in the order of 10 to 100 mm, and if the shallow water table is not affected tilts will be very small. There are no buildings near to the access tunnel which could be affected by the effects of access tunnel and any settlement or tilt will not have any noticeable effect on farmland or forest environments.

A network of piezometers has already been installed at Willows Farm.

EGL recommends that the town settlement monitoring network is extended up Willows Road and Highland Road to the privately-owned dwellings at the end of these roads.

No settlement monitoring is required above the decline and access tunnel alignments, as it passes under farmland and forest. Any settlement is not expected to have any effects at the surface for these land uses.

6.1.6. Dewatering around ventilations shafts

Potential settlements around the vent shafts located at Willows Road and WUG can be expected due to construction or long-term seepage into the vents. The seepage could be from local drawdown of local perched water tables, and drawdown of deeper groundwater. Settlement effects are expected to be greatest close to the ventilation shafts where the drawdown profile is the greatest.

Simplified models of groundwater drawdown were developed by GWS, and EGL applied selected stiffness profiles to two profiles (see Appendix A). The two stiffness profiles considered were for the shaft at Willows Farm (Shaft 1 – 200 m deep) and the first shaft out at WUG (Shaft 2 – 320 m deep). Shaft 2 is the deepest at WUG and is the only shaft with current borehole information. The applied maximum drawdowns at the ventilation shafts were 50 to 65 mbgl. The calculated settlement was 75 mm at Shaft 1 and 140 mm at Shaft 2, with tilts between 1:8,200 and 1:1,400. These settlements are based on initial profiles, which pass through materials with rock stiffnesses. If the other ventilation shafts are located where soil is present the settlements could be greater. Based on the initial calculations, and observed settlements from dewatering adjacent to Martha Pit, settlements around the ventilation shafts are expected to be on the order of 50 to 300 mm. These settlements would have no adverse effect on the farmland and forest area in which they would be located. Any local depression around the ventilation shaft will only affect very local surface water flows around the shaft and this can be managed with minor ground profiling, so surface water does not pond against the shaft.

6.1.7. Dewatering due to the development of WUG

At WUG the drawdown of the deep groundwater will follow the underground mining development. The proposed mine development drives reach approximately RL850m (Waihi Mine Datum) at the East Graben Vein. The ground level above the East Graben Vein is between RL1260m and RL1120m. This is between 410 m and 270 m of potential drawdown.

An estimate of settlement for 380 m of drawdown was undertaken for an assumed geological ground profile of rhyolitic pyroclastics, rhyolite flows, and andesite flows (see Appendix A). The model was extended to a depth twice the depth of the proposed underground and the stiffness parameters used for the pyroclastics were assumed to be similar to the younger volcanic profile east of Waihi and given a Young’s modulus of 1,000MPa. The stiffness of the rhyolite and andesite flows was assumed to be 8,700MPa, which is similar to the unweathered andesite at Waihi. The calculated settlement is 700 mm. This calculation is undertaken to provide an understanding of the order of magnitude of possible settlement. Actual settlements will vary across the site.

For comparison, the maximum drawdown in Waihi in 2021 was around 450 m and the maximum settlement near to Martha Open Pit was 300 mm. However, this area had been subject to historic dewatering so the materials are already pre-consolidated. Further, the groundwater in the younger volcanic materials beneath Waihi East is only partially drawn down or depressurised, whereas for the calculation at WUG full drawdown has been assumed.

The Favona Underground area was subject to dewatering in the order of 350 m. The total settlement at Favona is around 300 mm. Favona is less likely to have had previous dewatering consolidation, however, the younger volcanics are less thick and not fully dewatered.

Based on the general order of magnitude of the settlement experience in Waihi, and the calculation undertaken and presented in Appendix A, for this assessment of effects we estimate settlements up to between 300 mm to 1,000 mm could be expected in the area of the WUG site.

Due to the hilly terrain at the WUG site, ground settlements in the order of 300 to 1,000 mm are not expected to have any material effect on stream flows or the forest environment. The flattest stream grade is approximately 1 in 30 over a 500 m length at the north end of the East Graben Vein, based on available topographic information. For a maximum settlement of 1m, occurring over a distance in the order of 200 m (i.e. estimated minimum distance from maximum to no settlement, based on the dewatering depths), this would result in a shallowing or steepening of grade in the order of 1 in

200. For a stream at 1 in 30, a 1 in 200 grade change is very minor. A 1 in 200 tilt is also unnoticeable in a forested environment.

In summary initial ground settlement estimates in the area of WUG could be on the order of 300 to 1000 mm, however, this is not expected to have any material effect on stream flows or the forest environment. EGL recommend that ongoing settlement monitoring is not required at the WUG site. Base survey of reference points at the ventilation shafts and any drill sites will be sufficient. Visual observation of the stream and forest environment as part of monitoring of other environmental effects would be sufficient to check for any unforeseen effects due to settlement.

6.1.8. Additional settlement and groundwater monitoring locations

We recommend additional monitoring (settlement points and piezometers located in boreholes). The locations are shown in Figure 66 to Figure 69. They will need to be reviewed and confirmed as part of the updates to the Dewatering and Settlement Monitoring Plan. This will depend on the final arrangement of the WNP elements i.e. confirm decline positions and depths and the final tunnel alignment in the Wharekirauponga Access Tunnel corridor.

7.0 REBOUND

Dewatering around the open pits and underground mines will eventually stop once mining in the area has ceased. The area will then be allowed to re-water. The re-watering will occur naturally, but for the areas near-Waihi, may be accelerated by the addition of water pumped from the Ohinemuri River. Re-watering will result in the groundwater levels rising back closer to their original levels. Rebound will occur as rising groundwater re-saturates the ground, resulting in a reduction in effective stress within the ground. As already noted, historical underground mining at Martha Open Pit involved dewatering of the ground to about RL540m; approximately 40 m above the targeted RL500m for the Martha Underground. Following the cessation of mining in 1952, groundwater levels rose back to near original levels before modern mining started in 1989. No damage arising from historical re-watering has been recorded.

Rebound of the ground to its original level because of rising groundwater levels is unlikely. It is expected that rebound could be in the order of 30 % to 90 % of the settlement that has occurred during modern mining depending on the area of town, and the level of previous dewatering. No damage from rebound is expected as, like settlement, it occurs relatively evenly across the same general areas. However, rebound must be monitored to confirm that there are no unforeseen effects. It is recommended this is continued until groundwater levels have stabilised, any rebound can be demonstrated to be 90 % complete, and there are no known issues unresolved.

8.0 SUMMARY OF EFFECTS, MITIGATIONS AND RECOMMENDATIONS

Overall ground settlement effects are assessed to not cause damage to any structures if mitigations and recommendations are followed. The assessed ground settlement effects are summarised below, followed by the mitigations and recommendations.

Assessment of ground settlement effects

- The settlement effects for the Waihi North Project are summarised below:

  - Settlements can be expected around Gladstone Open Pit (GOP) (Figure 3) from dewatering of the younger volcanics and andesite near the pit in the order of 120 to 200 mm (see Section 6.1.1). These settlement effects are on land near to Gladstone Open Pit owned by OGNZL.

  - South of the Ohinemuri River (Figure 3) additional settlements from the mining of GOP are assessed to be in the order of 10 to 50mm with low additional tilts (See 6.1.1) and therefore the residential dwellings in this area will not be damaged. Settlement monitoring is required in this area to confirm settlement effects are as expected.

  - The proposed Martha Underground (MUG) Decline (Figure 3) is expected to cause additional localised depressurisation of the andesite and additional settlements in the order of 10 to 50 mm locally above the decline (See Section 6.1.2). There are no structures above the decline at risk. The proposed decline potentially intersects historic workings and the interface of the andesite with the younger volcanics. Drawdown of groundwater in the younger volcanics and historic workings presents a risk, if not mitigated, of more notable settlement and tilt which could potentially extend to Moore Street, Boyd Road and Barry Road (Figure 3) where there are residential dwellings. Residential dwellings in Moore Street, Boyd Road and Barry Road that are not owned by the company are at least 190m distance (in plan) from the proposed MUG Decline. Historic workings on record at the potential level of intersection only extend 90 m (i.e. part of the way) towards the dwellings in Barry Road. OGNZL owns the properties between the proposed MUG Decline and the non-company owned residential dwellings . There are mitigation options available that OGNZL will implement in response to groundwater drawdown or settlement of the younger volcanics as part of a specific Trigger Action Response Plan. Additional settlement and groundwater monitoring is required in this area.

  - The Wharekirauponga Access Tunnel decline (Figure 3) length, starting from the WUG Portal and extending north past Barry Road, potentially comes close to the younger volcanics. It could cause settlement effects affecting dwellings at Boyd Road and at the eastern end of Barry Road, if the potential for dewatering of the younger volcanics occurs and is not mitigated (See Section 6.1.3). OGNZL owns the land between Boyd Road and the proposed tunnel corridor and the land within the tunnel corridor immediately north and south of Barry Road. There are mitigation options available that OGNZL will implement in response to groundwater drawdown or settlement of the younger volcanics as part of a specific Trigger Action Response Plan. Additional settlement and groundwater monitoring is required in this area.

  - The additional settlements from the Wharekirauponga Access Tunnel east of Waihi East (Figure 2) are expected to be in the order of 10 to 100 mm, depending on the geological structures it passes through. The tunnel east of Waihi East is to be located at depth in andesite rock and the shallow water table in the younger volcanics is not expected to be materially affected. Therefore, any additional tilts in this area will be very small (see Section 6.1.4) and the residential dwellings in this area will not be damaged. Additional settlement and groundwater monitoring is required in this area to confirm settlement effects are as expected.

  - The settlements from the Willows Access Tunnel and Wharekirauponga Dual Tunnel (Figure 1) out to WUG are expected to be in the order of 10 to 100 mm depending on the geological structures. The tunnel is to be located at depth in andesite rock. There are no structures near to the Willows Access Tunnel and Wharekirauponga Dual Tunnel which could be affected (see Section 6.1.5).

  - Settlements around the ventilation shafts (Figure 1) are expected to be in the order of 50 to 300 mm. These settlements would have no adverse effects on the farmland (Willows Ventilation Shaft) and forest area (WUG Ventilation Shafts) in which they would be located (see Section 6.1.6).

  - Ground settlements at the WUG site (Figure 1) are expected to be unnoticeable as any change in level will occur gradually over hundreds of metres resulting in small tilts or change in grade. This is because the settlement will be caused by dewatering generally at notable depth below the ground surface. In the middle of the settlement area, the settlements are estimated to reach up to 300 mm to 1,000 mm depending on the ground profile. Due to the hilly terrain at the WUG site, surface settlements of this magnitude are not expected to have any material effects on stream flows as the change in grade is notably less than the steepness of the terrain. As the tilt of the ground will be small, no noticeable impact on the forest environment is expected (see Section 6.1.7).

<u>MUG Decline development mitigations and recommendations</u>

- The MUG Decline could potentially dewater the shallow younger volcanics (ignimbrites and tuffs) and cause settlement effects in Moore Street, Boyd Road and Barry Road. EGL recommends that OGNZL manage and mitigate this risk through:

  - Detailed assessment of the MUG Decline alignment.
    - Avoidance of the younger volcanics may be possible through refinement of the decline alignment and level so to stay completely within the andesite.
    - Avoidance of historic workings may be possible.

  - Specific geotechnical and groundwater investigations to assist in determining the ground conditions and groundwater profile between the decline and closest properties. Such investigations can be undertaken on OGNZL property.

- Monitoring of groundwater levels and ground surface settlement to detect possible effects.

- Development of Trigger Action and Response Plans (TARPS) that set triggers and specific actions including mitigation measures if trigger levels are exceeded.

- Mitigation of groundwater inflows into the decline (as required) during construction with grouting methods.

- Mitigation of shallow groundwater drawdown by re-injection of captured groundwater back into the ground.

Wharekirauponga Access Tunnel decline development mitigations and recommendations

- The Wharekirauponga Access Tunnel decline from the WUG portal to Barry Road could potentially dewater the shallow younger volcanics (ignimbrites and tuffs) and cause settlement effects at Boyd Road and eastern end of Barry Road. EGL recommends that OGNZL mitigate this risk through:

  - Detailed assessment of the decline tunnel alignment to confirm options and risks.
    - Avoidance of the younger volcanics may be possible through refinement of decline alignment and level so to stay completely within the andesite.

  - Specific geotechnical and groundwater investigations to assist in determining the ground conditions and groundwater profile between the decline and closest properties.

  - Monitoring of groundwater levels and ground surface settlement to detect possible effects.

  - Development of Trigger Action and Response Plans (TARPS) that set triggers and specific actions including mitigation measures if trigger levels are exceeded.

  - Mitigation of groundwater inflows into the tunnel decline (as required) during construction with grouting methods.

  - Mitigation of shallow groundwater drawdown by the injection of captured groundwater back into the ground.

Wharekirauponga Access Tunnel development mitigations and recommendations

- EGL recommends that the Wharekirauponga Access Tunnel east of Waihi East is restricted to a minimum tunnel depth of 130 m, or 40 m (Ref. 7) minimum vertical offset from the top of the andesite/younger volcanic interface, whichever is deeper. The minimum depth reduces the risk of tilt at the ground surface and the minimum vertical offset reduces the risk of dewatering the younger volcanics which underlie Waihi East. This was a condition of the Correnso Underground mine which is directly beneath Waihi East that has been shown to be successful.

- EGL recommends that specific geotechnical and hydrogeological investigations along the Wharekirauponga Access Tunnel length east of Waihi East are undertaken to confirm the geotechnical and permeability conditions, and groundwater pressure profile, and to confirm the level of the tunnel to achieve the minimum offset to the younger volcanics. This can include surface drilled investigation boreholes, drilled boreholes ahead of the tunnel and/or geophysical surveys.

<u>Surface borehole drilling mitigations and recommendations</u>

- Where possible boreholes drilled from the surface should be sited away from structures to minimise settlement risk associated with leakage of shallow groundwater to deeper systems.

- Where possible boreholes should avoid intersecting underground workings.

- Grouting of all future surface-drilled holes to a depth below the top of the andesite.

<u>General tunnel development mitigations and recommendations</u>

- Avoid intercepting existing drillholes with the tunnel operation wherever possible.

- Avoid intercepting historical workings with the tunnel wherever practicable.

- Drilling ahead of the tunnelling operation, to inspect for geological structures or areas of ground that may make notable water inflows into the tunnel.

- Mitigation of sustained groundwater inflows through the use of grouting methods.

<u>Dewatering and ground settlement monitoring recommendations</u>

Monitoring of groundwater levels and ground settlements is required to check settlements are within estimates and there are no unforeseen effects. The dewatering and settlement monitoring plan will be updated for the Waihi North Project. Recommendations in regard to dewatering and ground settlement monitoring are summarised below:

- Continued monitoring of dewatering and settlement as required by the expired Mining Licence and resource consent 124860.

- The settlement monitoring zones and settlement trigger limits previously proposed for Project Martha are adjusted over the Favona Underground and locally around Gladstone Open Pit and Wharekirauponga Access Tunnel Alignment for the Waihi North Project.

- The dewatering and settlement monitoring plan needs to be updated for the Waihi North Project.

- Groundwater monitoring piezometers provide the best early warning of potential adverse ground settlement effects such as tilt. This was evident in the situation which occurred in Gladstone Road related to borehole CDG008 as described in Section 5.3.3. EGL recommends that additional piezometers are installed along with the new settlement markers in areas where there are residential dwellings or other structures not owned by OGNZL.

- Recommended additional settlement monitoring markers and piezometers to measure potential settlement effects are summarised below and in Figure 66 to Figure 69:
    - Potential dewatering of the Gladstone vein south of GOP
        - Heath Road – Additional settlement points (Figure 67)
        - Clarke Street – Additional settlement points (Figure 67)
    - Additional settlement monitoring points around Gladstone Hill to provide an understanding of the settlement effects close to the pit.
    - Potential dewatering of the ignimbrite between the Wharekirauponga Access Tunnel decline and Boyd and Barry Road.
        - Boyd Road – Additional settlement points (Figure 68)
    - Potential additional dewatering of the andesite rock due to the proposed MUG decline in andesite beneath Moore Street.
        - Moore Street – Additional settlement points and a new piezometer borehole (Figure 67)
    - Potential dewatering of the andesite veins and rock mass not already dewatered by the development of the Wharekirauponga Access Tunnel east of Waihi East.
        - Barry Road – A new piezometer borehole adjacent to the houses in the tunnel corridor (Figure 68)
        - Mataura Road – Additional settlement points and a new piezometer borehole in the tunnel corridor (Figure 68)
        - Wenlock Street – Additional settlement points and a new piezometer borehole in the tunnel corridor (Figure 68)
        - State Highway 25 – Additional settlement points and a new piezometer borehole in the tunnel corridor (Figure 68)
        - Wharry Road – Additional settlement points and a new piezometer borehole in the tunnel corridor (Figure 68)
- Extension of the town settlement monitoring points out to the end of Willows Road, Highland Road, and Reservoir Road to cover the project extent near structures. (Figure 69)

9.0 CONCLUSIONS

EGL was engaged by OGNZL to assess the ground settlement effects from dewatering for the Waihi North Project.

The large number of settlement observations at Waihi, spanning some 34 years, provides a reliable database for estimating likely future settlements associated with further dewatering.

Assessment of ground settlement is based on both review of past settlement trends and theoretical calculations (where relevant).

The assessed effects, mitigation actions and recommendations are summarised in Section 8.0. Overall, ground settlement effects are assessed to not cause damage to any structures, if the recommendations are followed, with appropriate mitigations where necessary.

Monitoring of groundwater levels (dewatering) and ground settlements is required to check settlements are within estimates and there are no unforeseen effects. The dewatering and settlement monitoring plan will be updated for the Waihi North Project. Trigger Action and Response Plans (TARPS) that set triggers and specific actions including mitigation measures if trigger levels are exceeded are recommended for the MUG decline and Wharekirauponga Access Tunnel.

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TABLES

Table 1: Settlement trigger levels

Settlement Zone	Range of Surface Movement (mm) Measured Dec. 1989 to May 1997	Measured Average Surface Settlement (mm) due to Mine Dewatering Dec. 1989 to May 1997	Predicted Range in Surface Settlement (mm) due to the Extended Mining Operations	Predicted Average Surface Settlement (mm) at cessation of the Extended Mining Operations	Trigger Levels for Settlement (including dewatering for Trio Development) (mm)	Maximum Total Settlement, incl Correnso Dewatering (mm)	Trigger Levels Project Martha/Waihi North Project
1	+2 to -10	0	0 to 10	0	25	35	55
2	+10 to -10	0	0 to 20	10	35	45	65
3	0 to -25	10	0 to 40	20	60	70	95
4	-15 to -35	25	30 to 80	45	110	125	160
5	-25 to -50	50	70 to 130	85	175	195	260
6	-55 to -85	65	100 to 180	120	220	240	340
7	-95 to -125	110	180 to 260	200	350	400	540

FIGURES

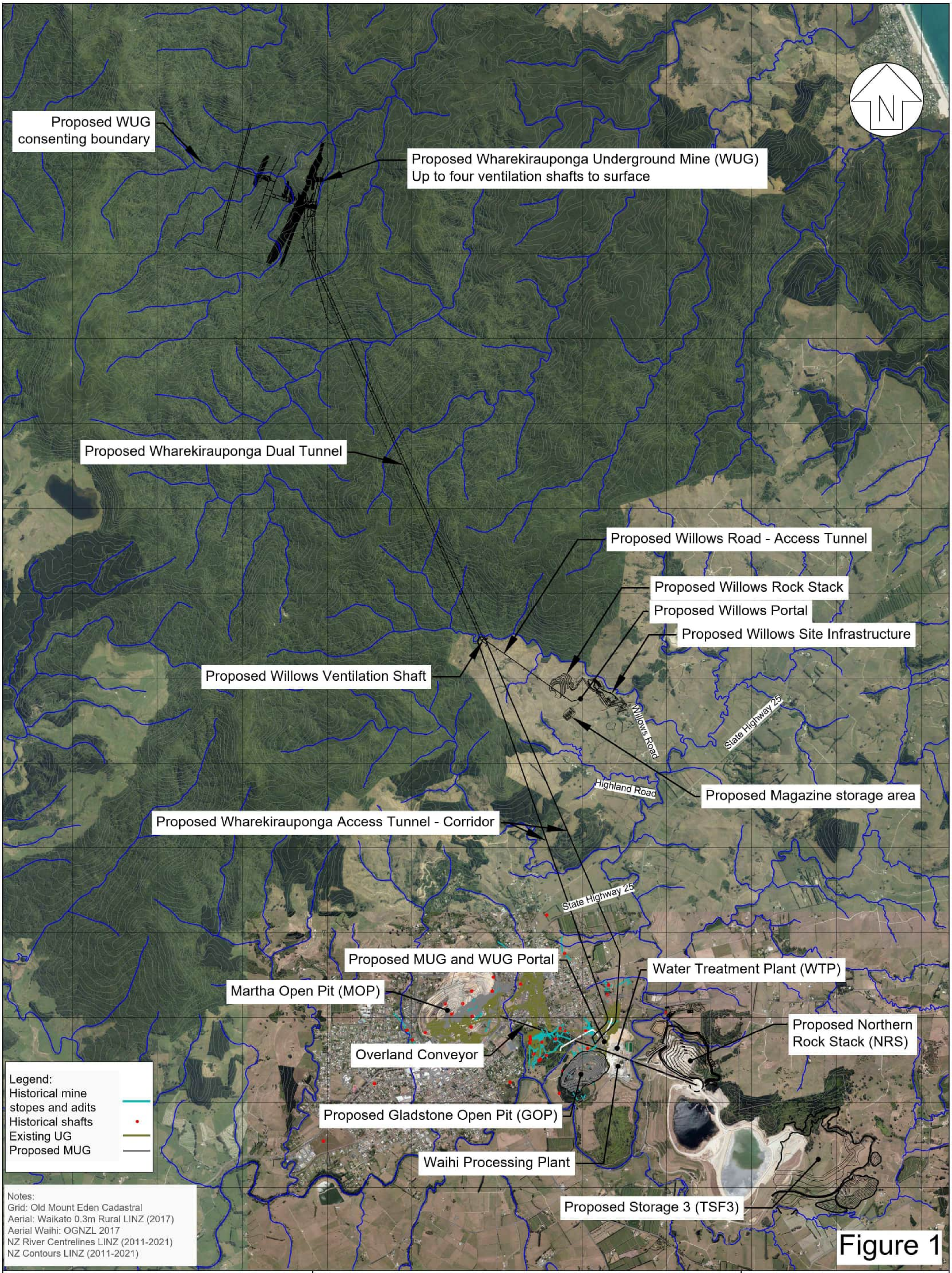

Figure 1

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Waihi: North Project
Site Plan 1:40,000

Drawing No.	9049–Fig1
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Drawn:	CL/ET
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Figure 2

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Waihi North Project
Site Plan 1:20,000

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Waihi North Project
Site Plan 1:7500

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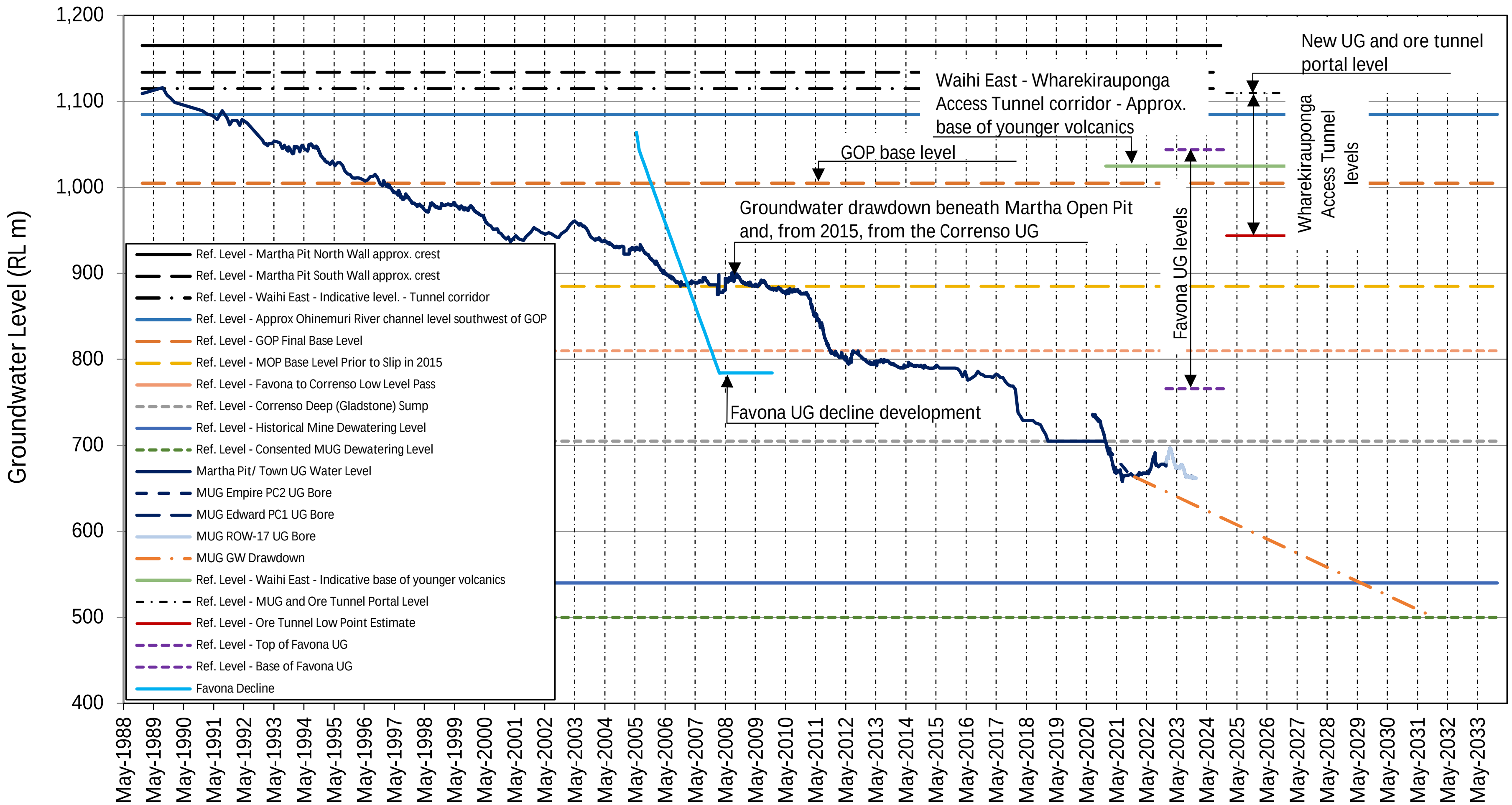

Notes:
RL in Mine Datum
Reference levels plotted are not time referenced

Figure 4

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WAIHI NORTH PROJECT

Waihi Town - Dewatering and Reference Levels

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Date: Feb 2025
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File: 9049-Settlement

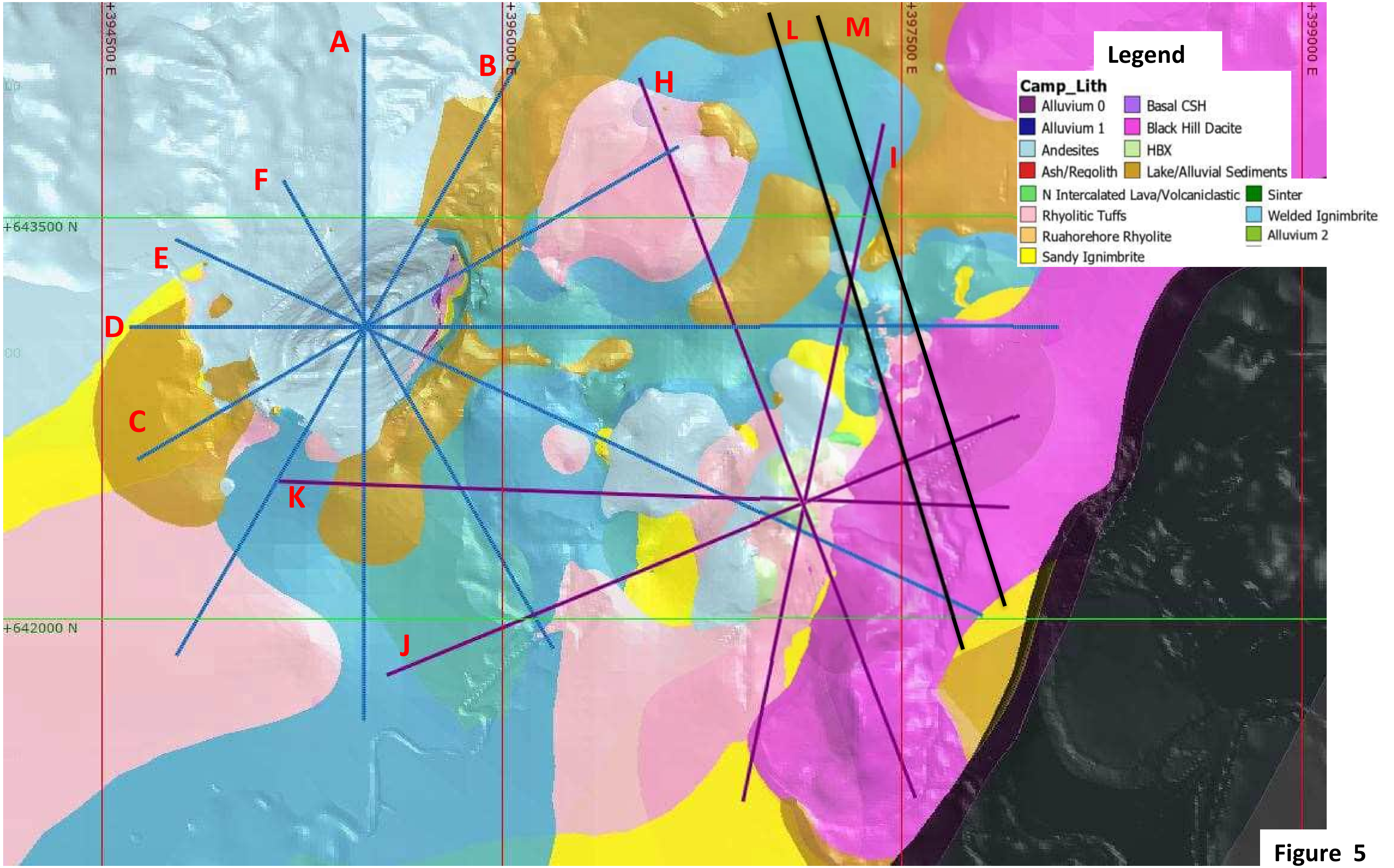

Figure 5

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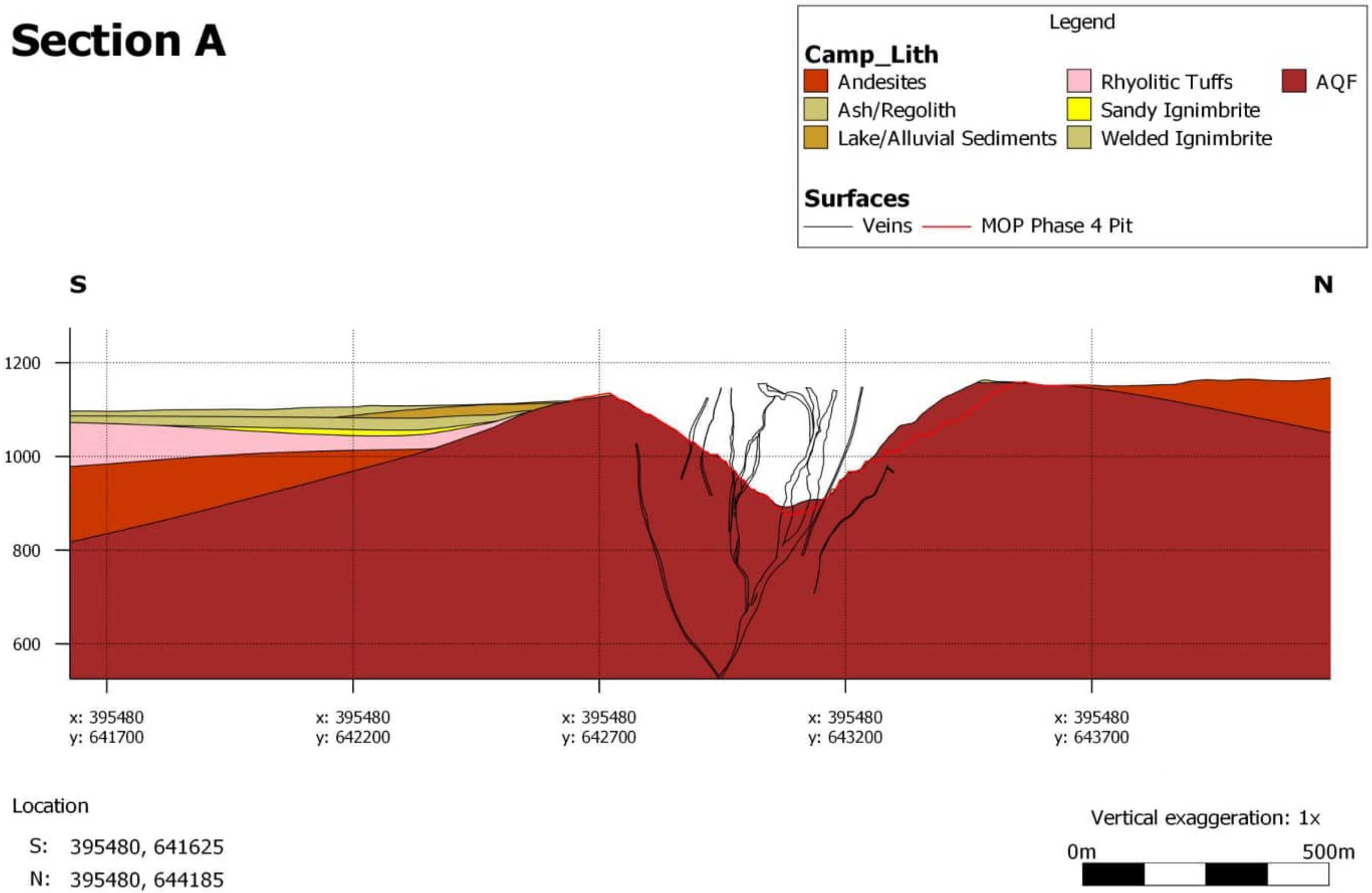
OCEANA GOLD (NEW ZEALAND) LTD
WAIHI NORTH PROJECT

Geological Plan

Ref. No: 9049
Date: Mar 2022
Drawn: OGNZL/EGL

Section A



Location

S: 395480, 641625

N: 395480, 644185

Notes:
Section provided by OGNZL

Figure 6

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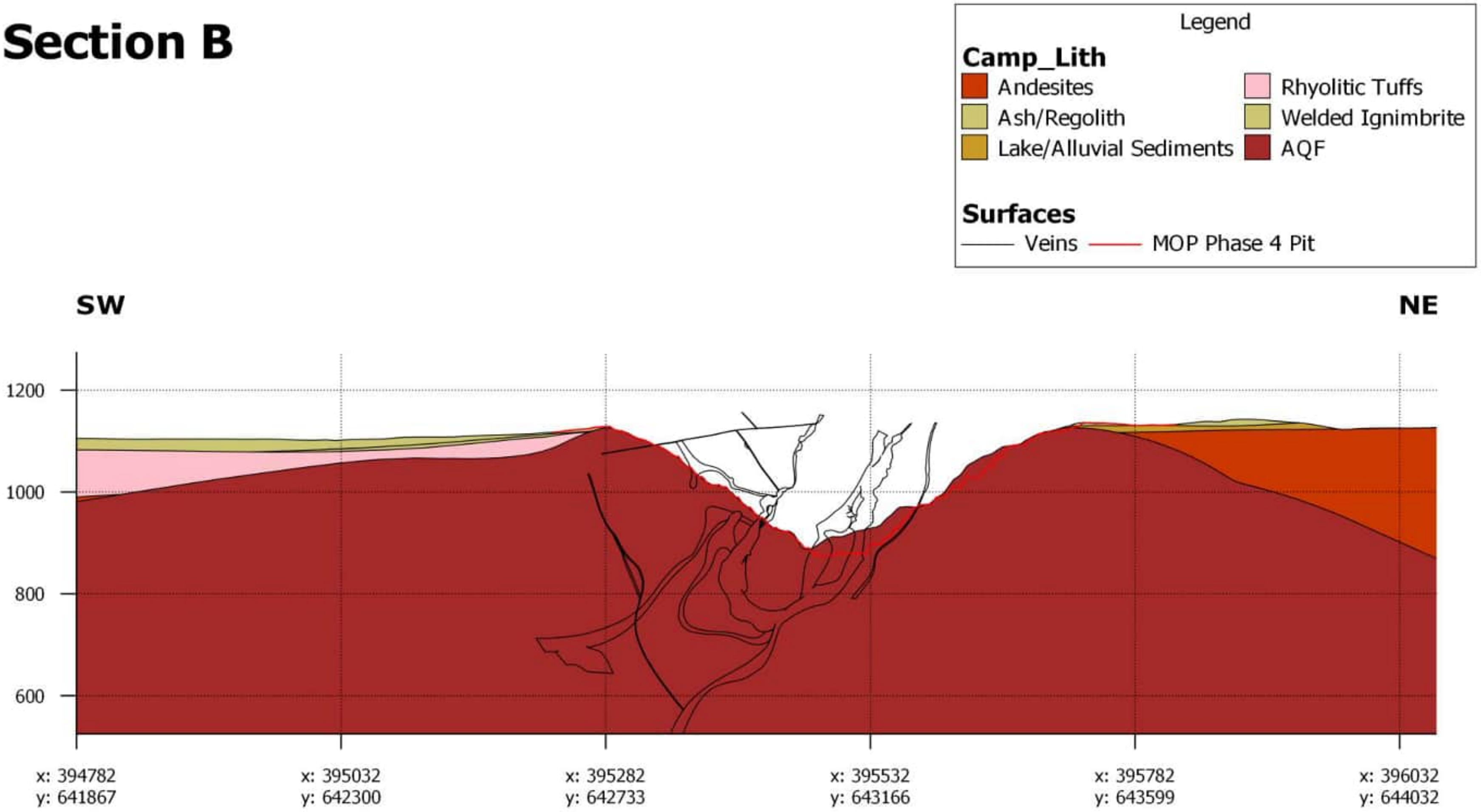
WAIHI NORTH PROJECT

Geological Cross Section A

Ref. No: 9049
Date: Jan 2022
Drawn: OGNZL

Section B



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Notes:
Section provided by OGNZL

Figure 7

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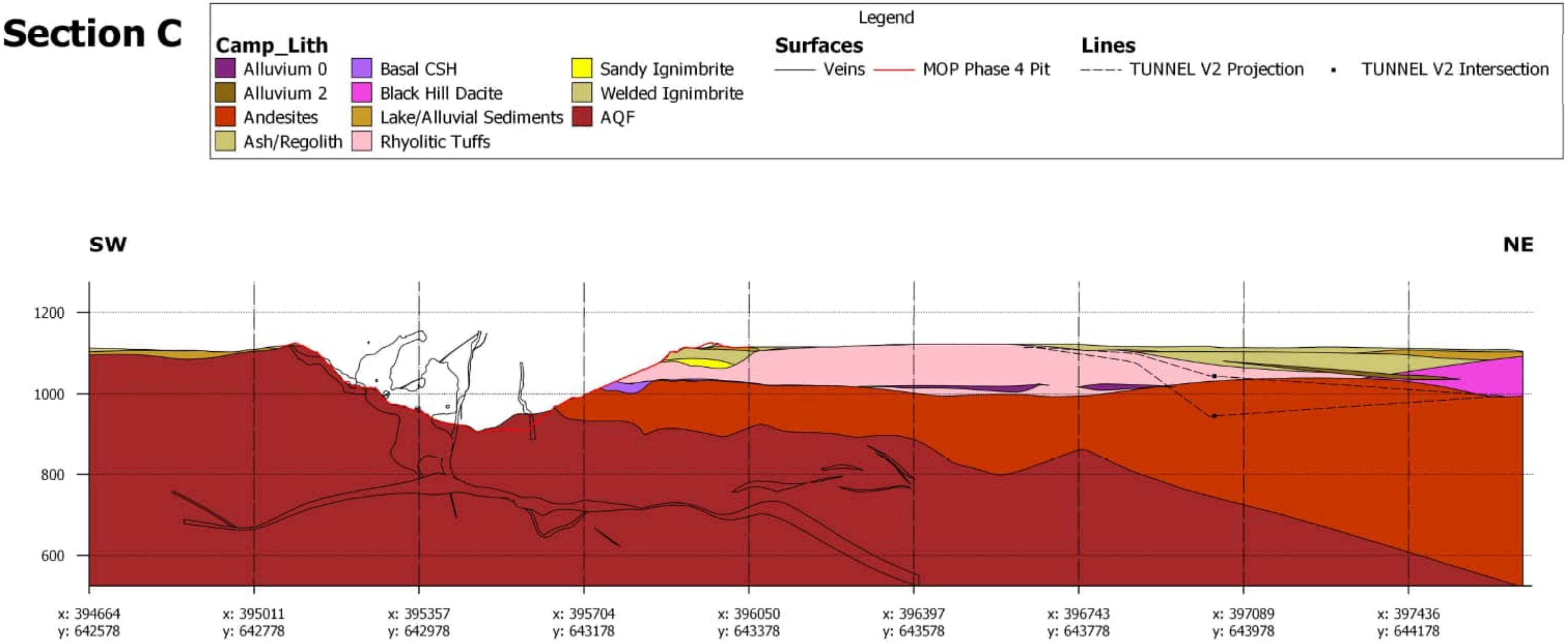
Geological Cross Section B

Ref. No: 9049
Date: Jan 2022
Drawn: OGNZL

Section C



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Notes:
Section provided by OGNZL

Figure 8

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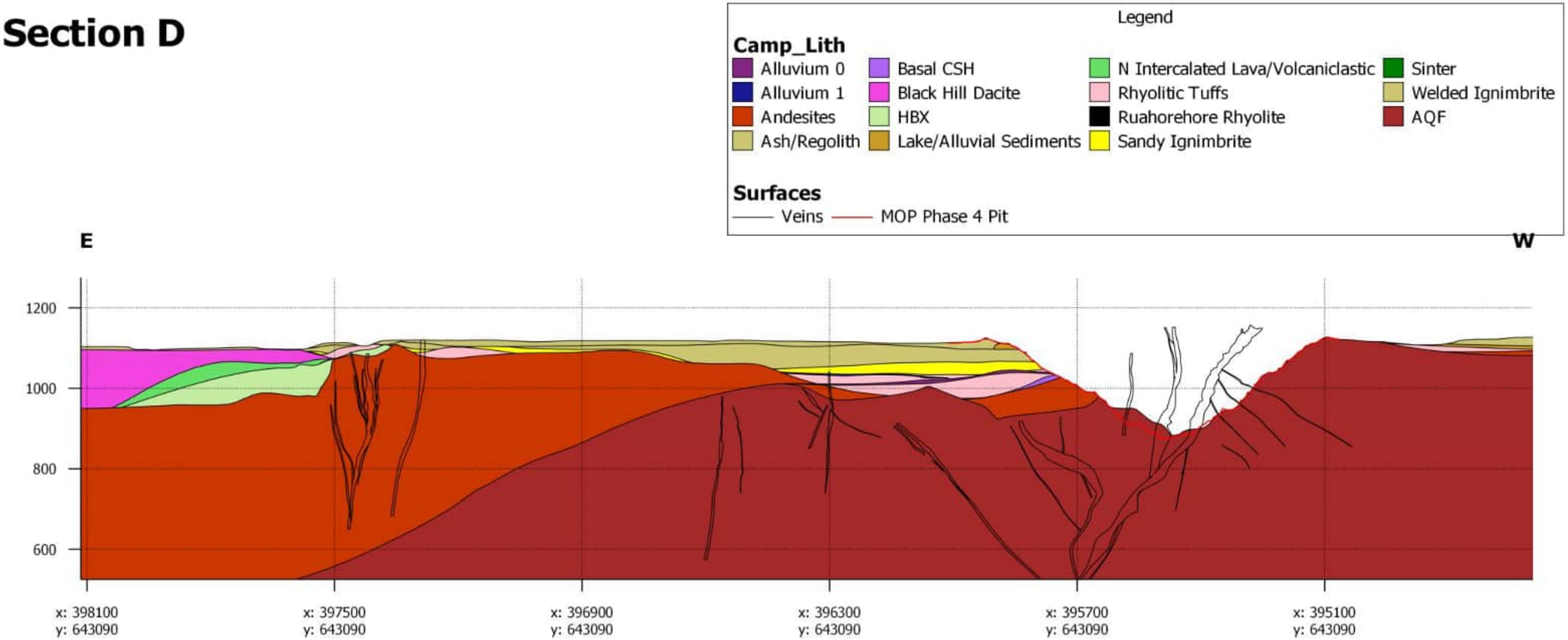
Geological Cross Section C

Ref. No: 9049
Date: Jan 2022
Drawn: OGNZL

Section D



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Scale: 1:10,000

Vertical exaggeration: 1x

0m 500m

Figure 9

EGL Geotechnical, Earthquake and Dam Engineers Engineering Geology Ltd +64 9 486 2546 info@egl.co.nz Unit 7C, 331 Rosedale Road, Albany, Auckland PO Box 301054, Albany, Auckland 0752 www.egl.co.nz	**OCEANA GOLD (NEW ZEALAND) LTD** WAIHI NORTH PROJECT Geological Cross Section D	Ref. No: 9049 Date: Jan 2022 Drawn: OGNZL

Section E

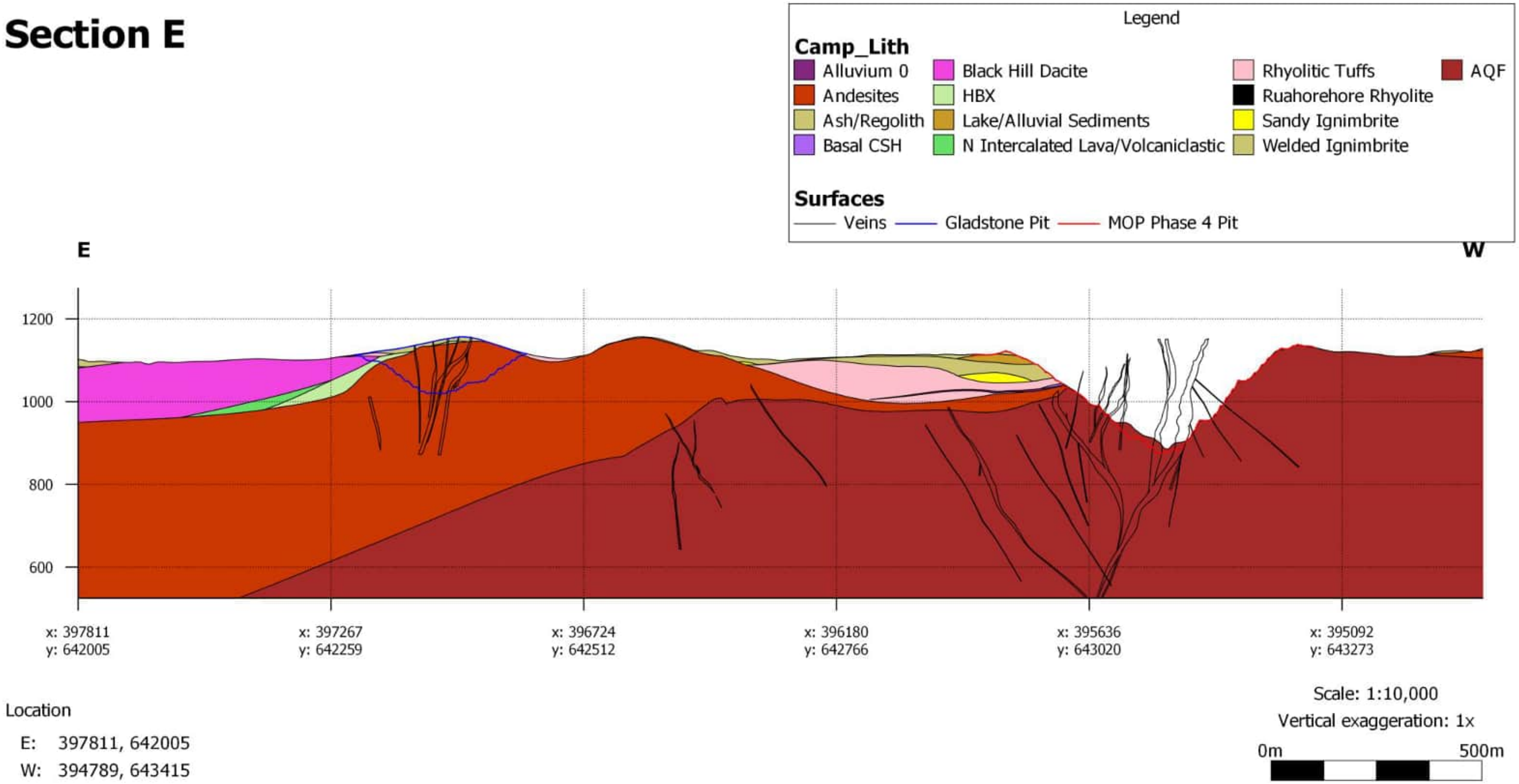

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Figure 10

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Geological Cross Section E

Ref. No: 9049
Date: Jan 2022
Drawn: OGNZL

Section F

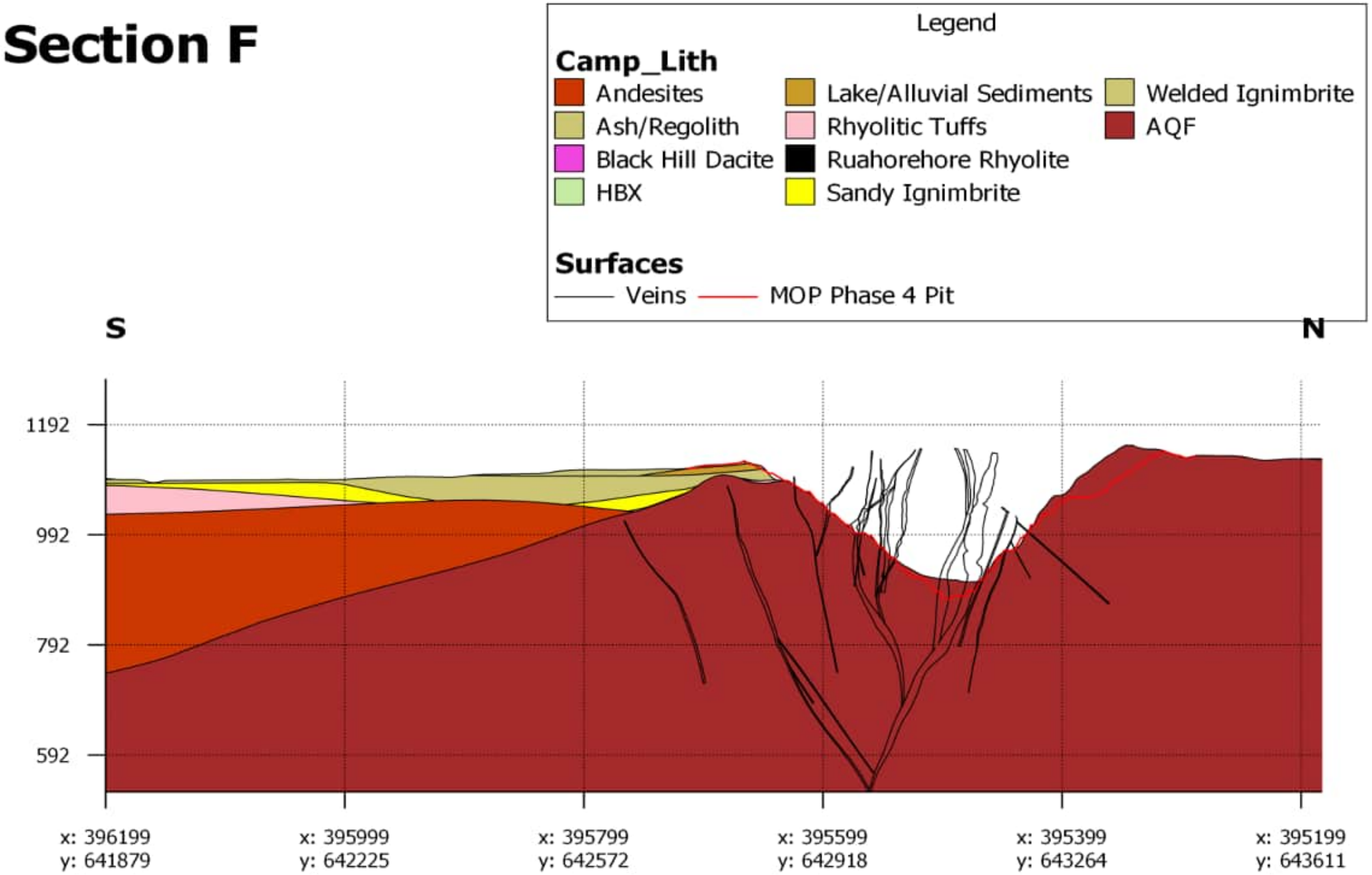

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Figure 11

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Geological Cross Section F

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Date: Jan 2022
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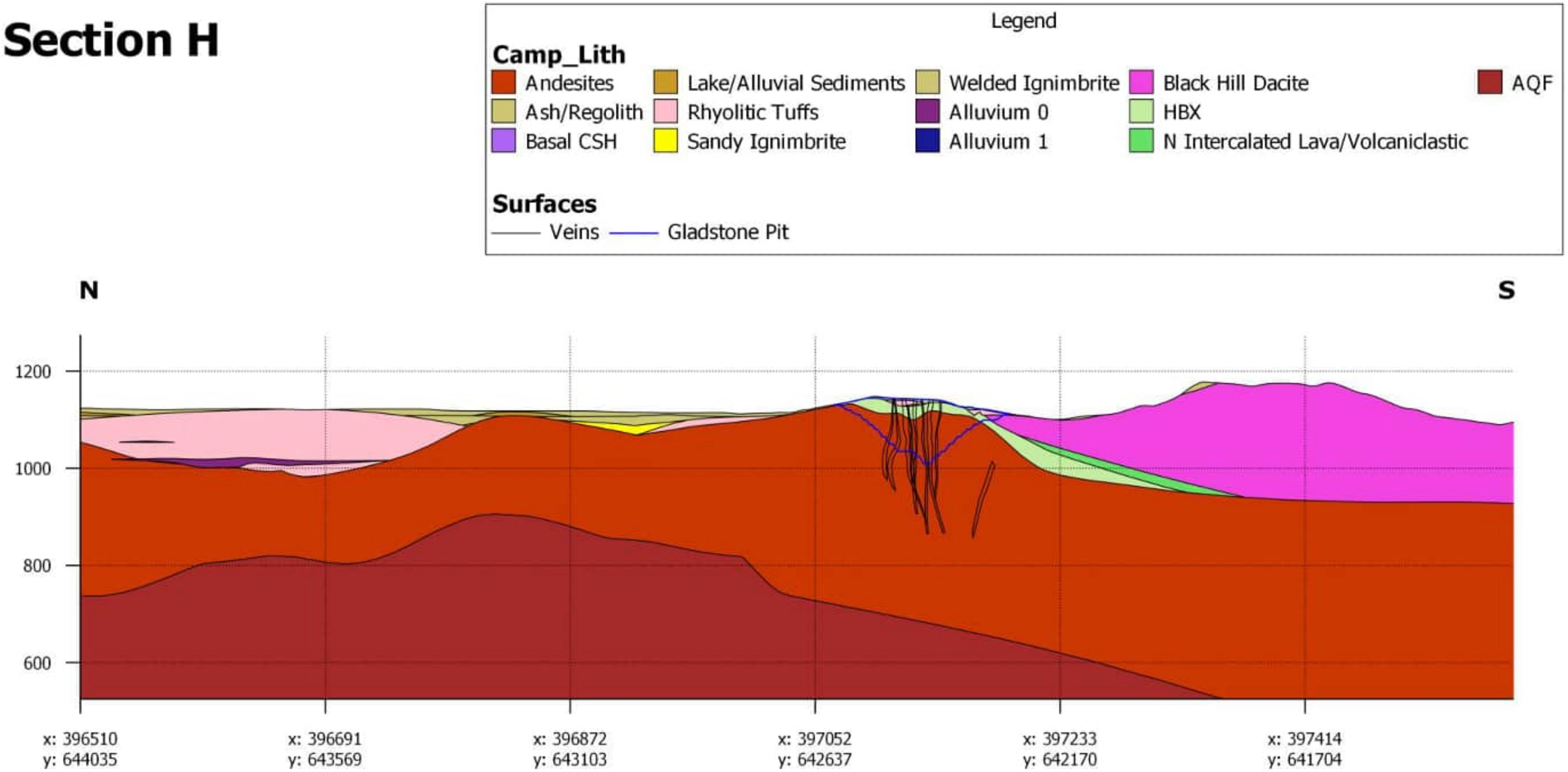
Section H



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0m 500m

Figure 12

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Geological Cross Section H

Ref. No: 9049
Date: Jan 2022
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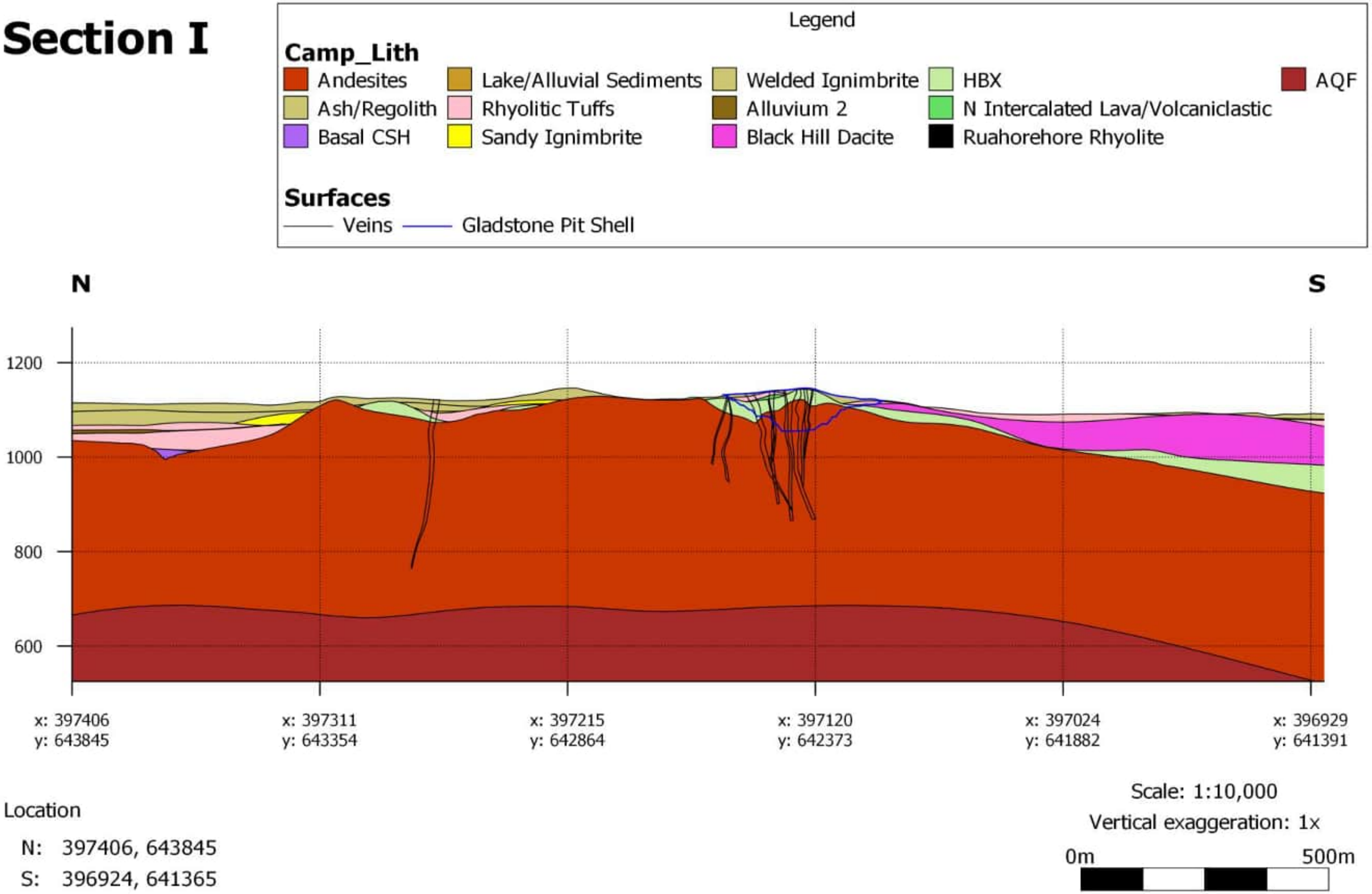
Section I



Location

N: 397406, 643845

S: 396924, 641365

Figure 13

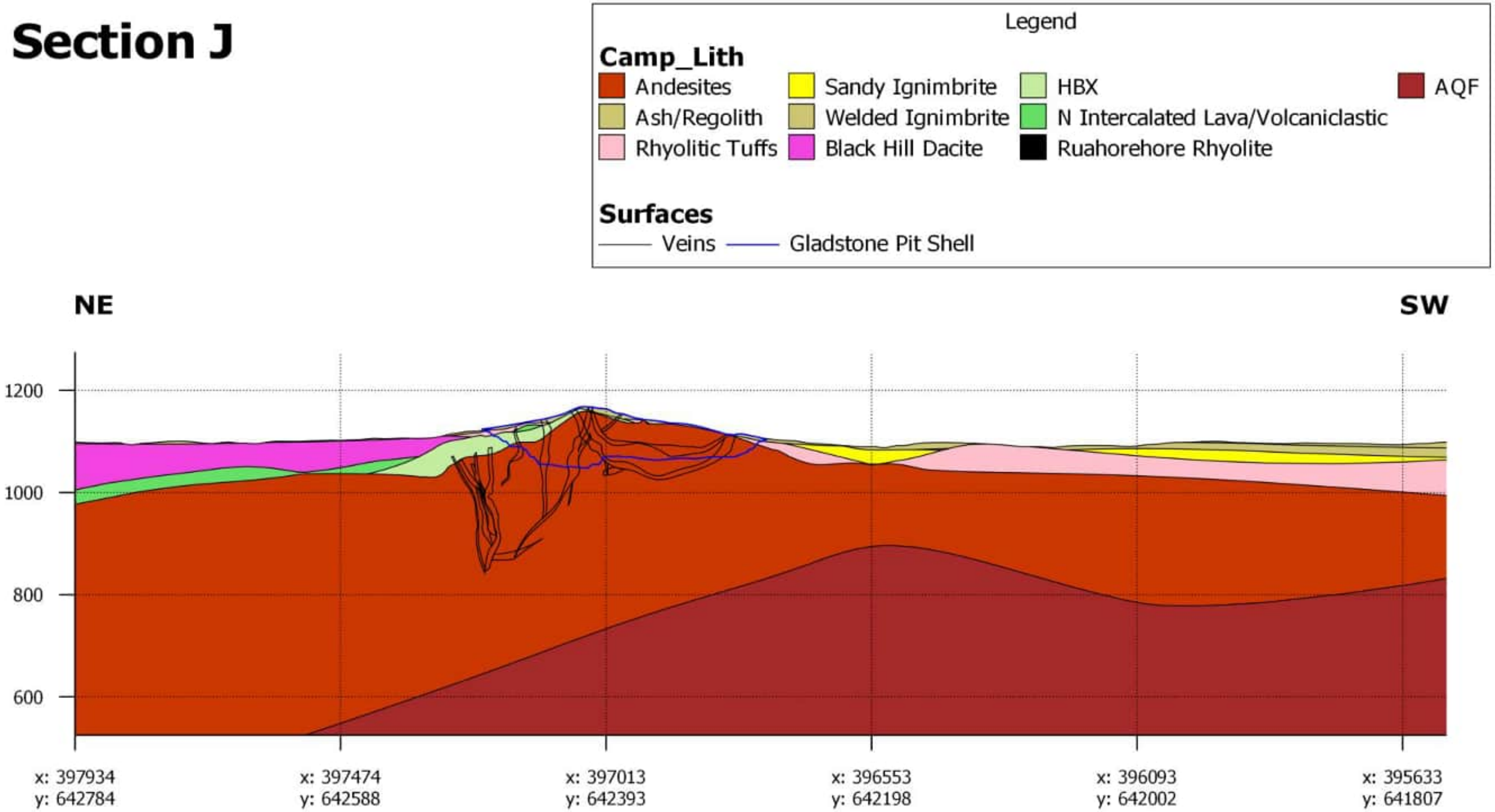
EGL
Geotechnical, Earthquake and Dam Engineers
Engineering Geology Ltd
+64 9 486 2546
info@egl.co.nz
Unit 7C, 331 Rosedale Road, Albany, Auckland
PO Box 301054, Albany, Auckland 0752
www.egl.co.nz

OCEANA GOLD (NEW ZEALAND) LTD
WAIHI NORTH PROJECT

Geological Cross Section I

Ref. No: 9049
Date: Jan 2022
Drawn: OGNZL

Section J



Location

NE: 397934, 642784

SW: 395556, 641774

Scale: 1:10,000

Vertical exaggeration: 1x

0m 500m

Figure 14

EGL
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OCEANA GOLD (NEW ZEALAND) LTD
WAIHI NORTH PROJECT

Geological Cross Section J

Ref. No: 9049
Date: Jan 2022
Drawn: OGNZL

Section K

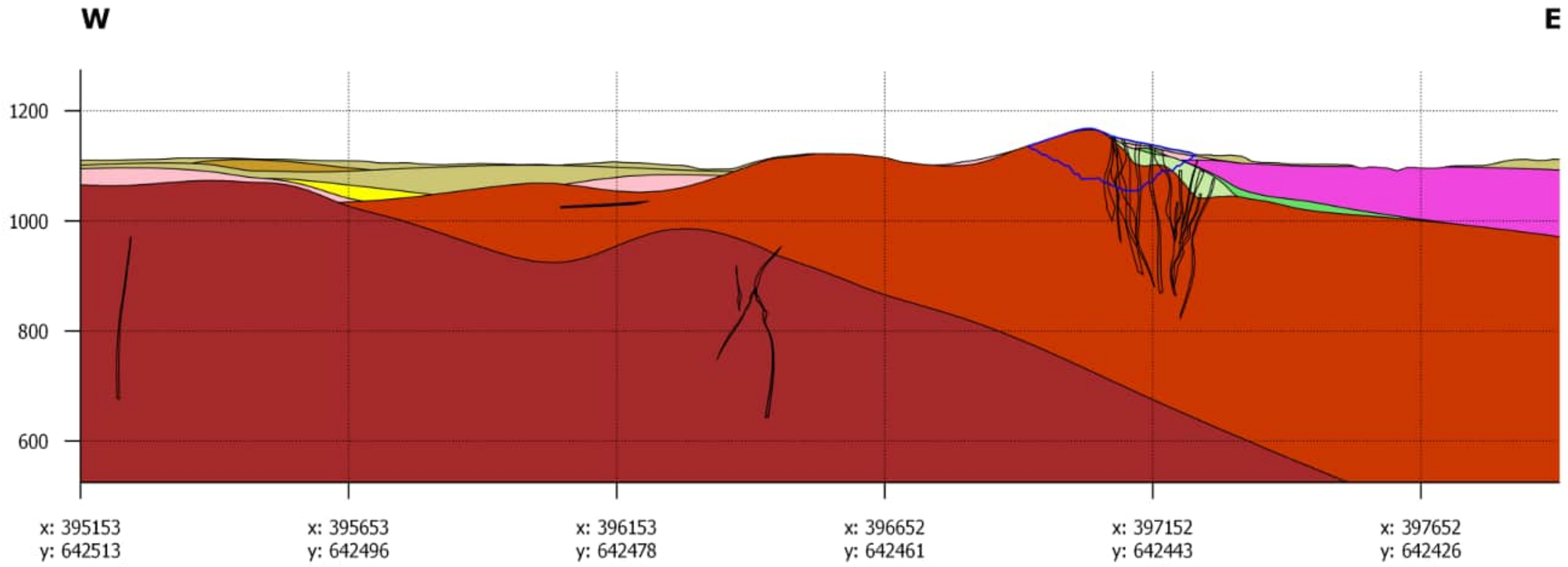
Legend

Camp_Lith

- Andesites
- Ash/Regolith
- Lake/Alluvial Sediments
- Rhyolitic Tuffs
- Sandy Ignimbrite
- Welded Ignimbrite
- Alluvium 1
- Black Hill Dacite
- HBX
- N Intercalated Lava/Volcaniclastic
- Ruahorehore Rhyolite
- AQF

Surfaces

- Veins
- Gladstone Pit Shell



Location

W: 395153, 642513

E: 397911, 642417

Scale: 1:10,000

Vertical exaggeration: 1x

0m 500m

Figure 15

EGL
Geotechnical, Earthquake and Dam Engineers
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WAIHI NORTH PROJECT

Geological Cross Section K

Ref. No: 9049

Date: Jan 2022

Drawn: OGNZL

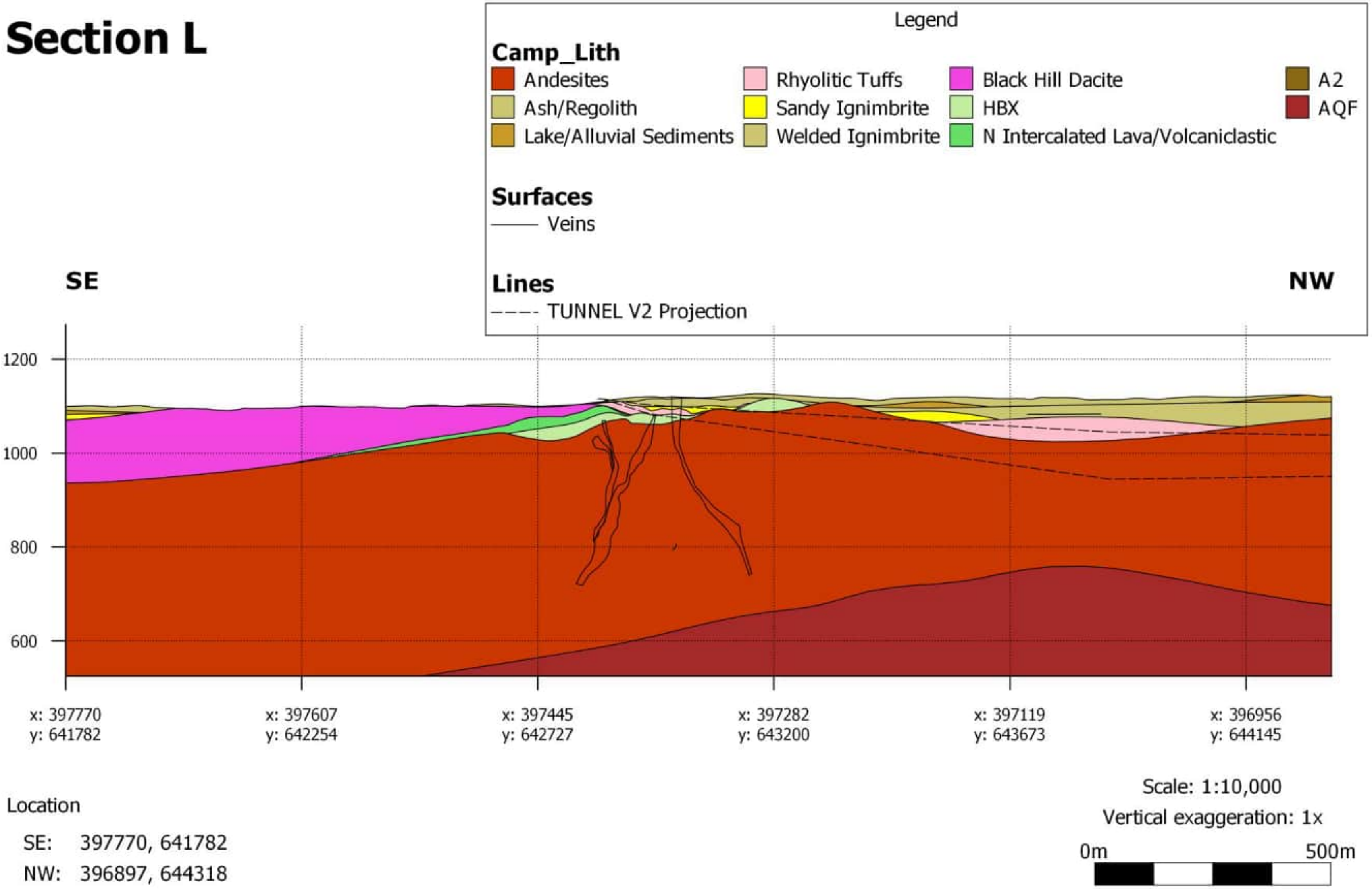
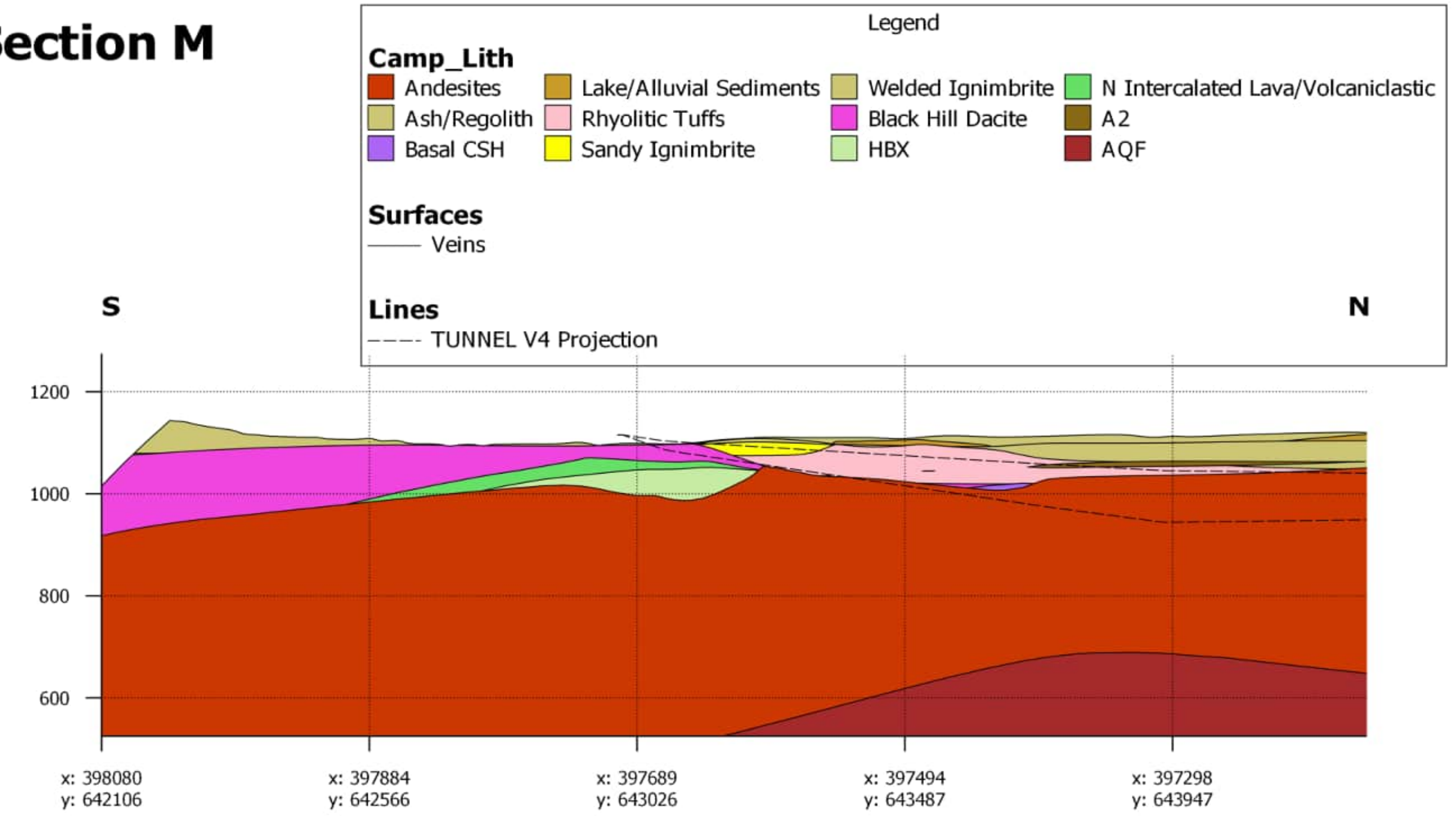


Figure 16

Engineering Geology Ltd +64 9 486 2546 info@egl.co.nz Unit 7C, 331 Rosedale Road, Albany, Auckland PO Box 301054, Albany, Auckland 0752 www.egl.co.nz Geotechnical, Earthquake and Dam Engineers	**OCEANA GOLD (NEW ZEALAND) LTD** WAIHI NORTH PROJECT Geological Cross Section L	Ref. No: 9049 Date: Jan 2022 Drawn: OGNZL

Section M



Location

S: 398080, 642106

N: 397156, 644281

Scale: 1:10,000

Vertical exaggeration: 1x

0m 500m

Figure 17

EGL Geotechnical, Earthquake and Dam Engineers

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OCEANA GOLD (NEW ZEALAND) LTD
WAIHI NORTH PROJECT

Geological Cross Section M

Ref. No: 9049
Date: Jan 2022
Drawn: OGNZL

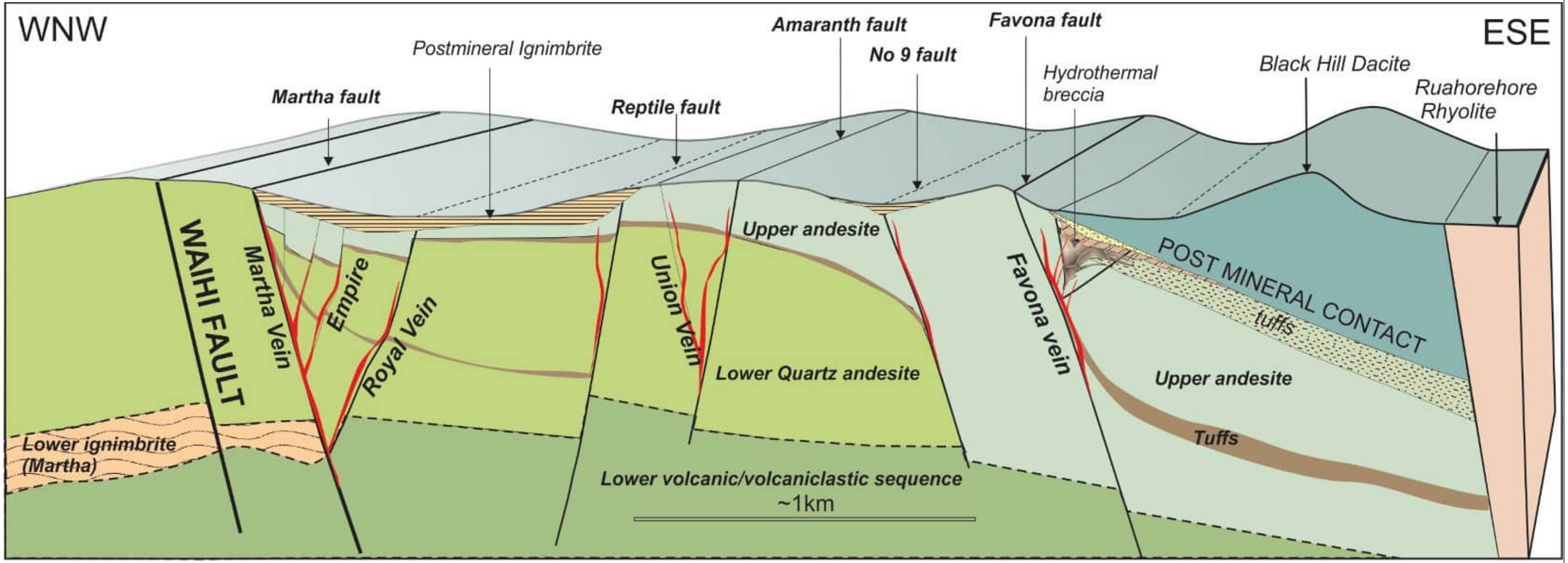

Figure 18

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OCEANA GOLD (NEW ZEALAND) LTD
WAIHI NORTH PROJECT

Indicative Geological Section from Martha to Favona

Ref. No: 9049
Date: Feb 2018
Drawn: OGNZL

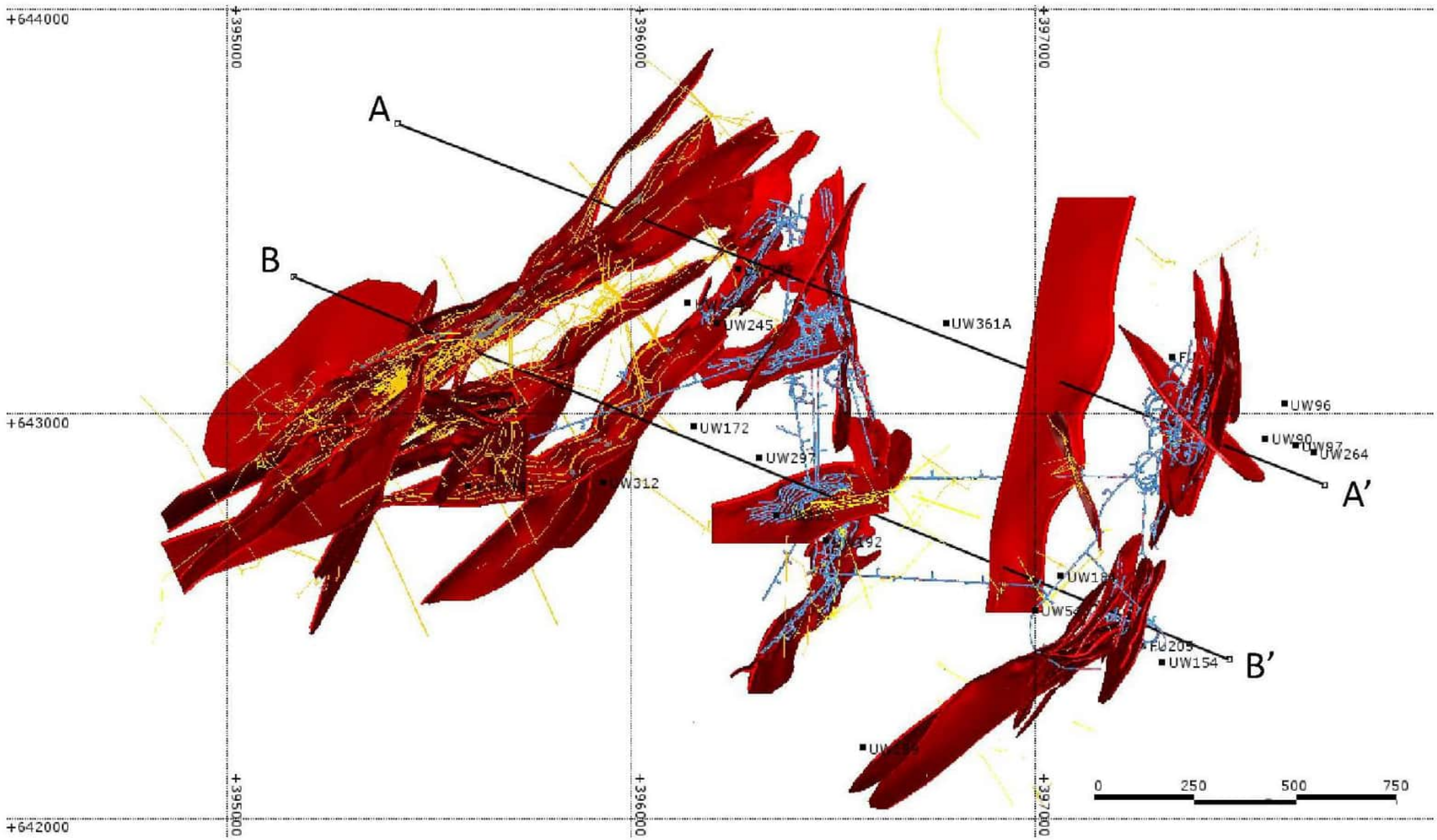

Figure 19

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Geotechnical, Earthquake and Dam Engineers

OCEANA GOLD (NEW ZEALAND) LTD
WAIHI NORTH PROJECT

Plan of Martha, Union and Favona Systems

Ref. No: 9049
Date: Feb 2018
Drawn: OGNZL

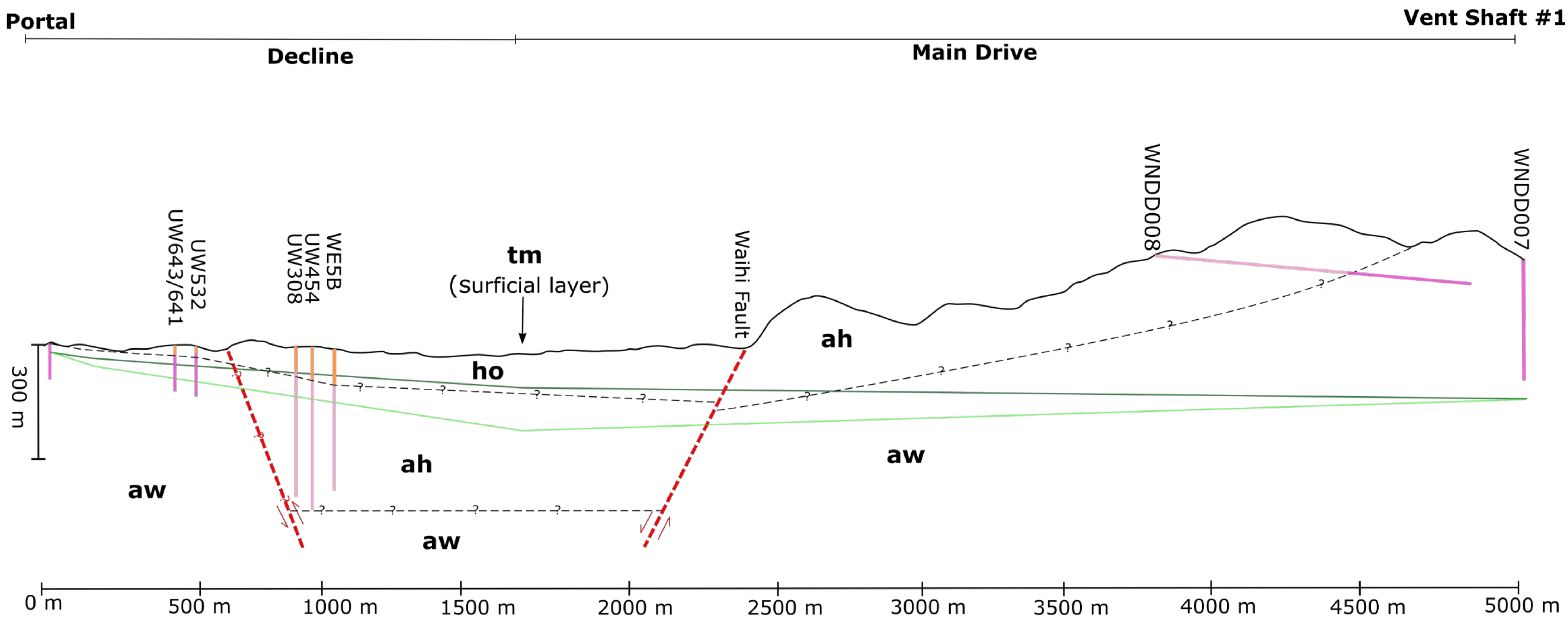

Figure 20

LEGEND

- Shallow Tunnel Alignment
- Deeper Tunnel Alignment
- **tm** - Matua Subgroup - Volcanigenic sediments alluvium
- **ho** - Ohinemuri Subgroup - tuff, ignimbrite, weak to strong
- **ah** - Whitiroa Andesite - andesitic flows, breccia and tuffs
- **aw** - Waipupu Formation Andesite - andesitic flows, breccias, tuffs, hydrothermally altered
- Faults
- Inferred contacts between formations

CLIENT
OCEANAGOLD CORPORATION

PROJECT
WAIHI NORTH PROJECT: REVIEW OF EXISTING GEOLOGICAL INFORMATION FOR PROPOSED TUNNEL

TITLE
TUNNEL ALIGNMENT 4

CONSULTANT GOLDER

YYYY-MM-DD	2021-09-28
PREPARED	LT
REVIEW	TM
APPROVED	TM

PROJECT NO.	REPORT	REV.	FIGURE
20148384	012	0	B2

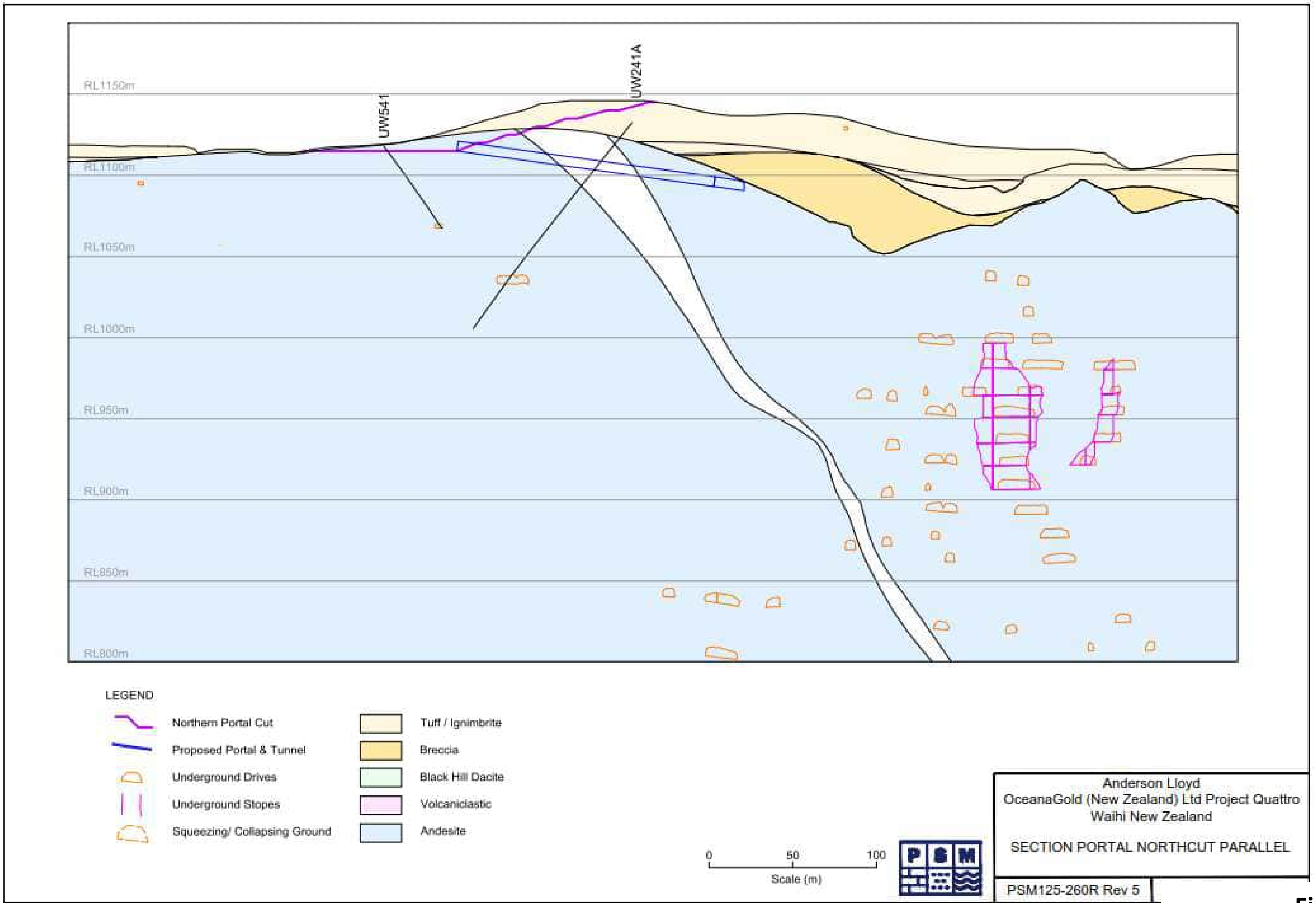

Figure 21

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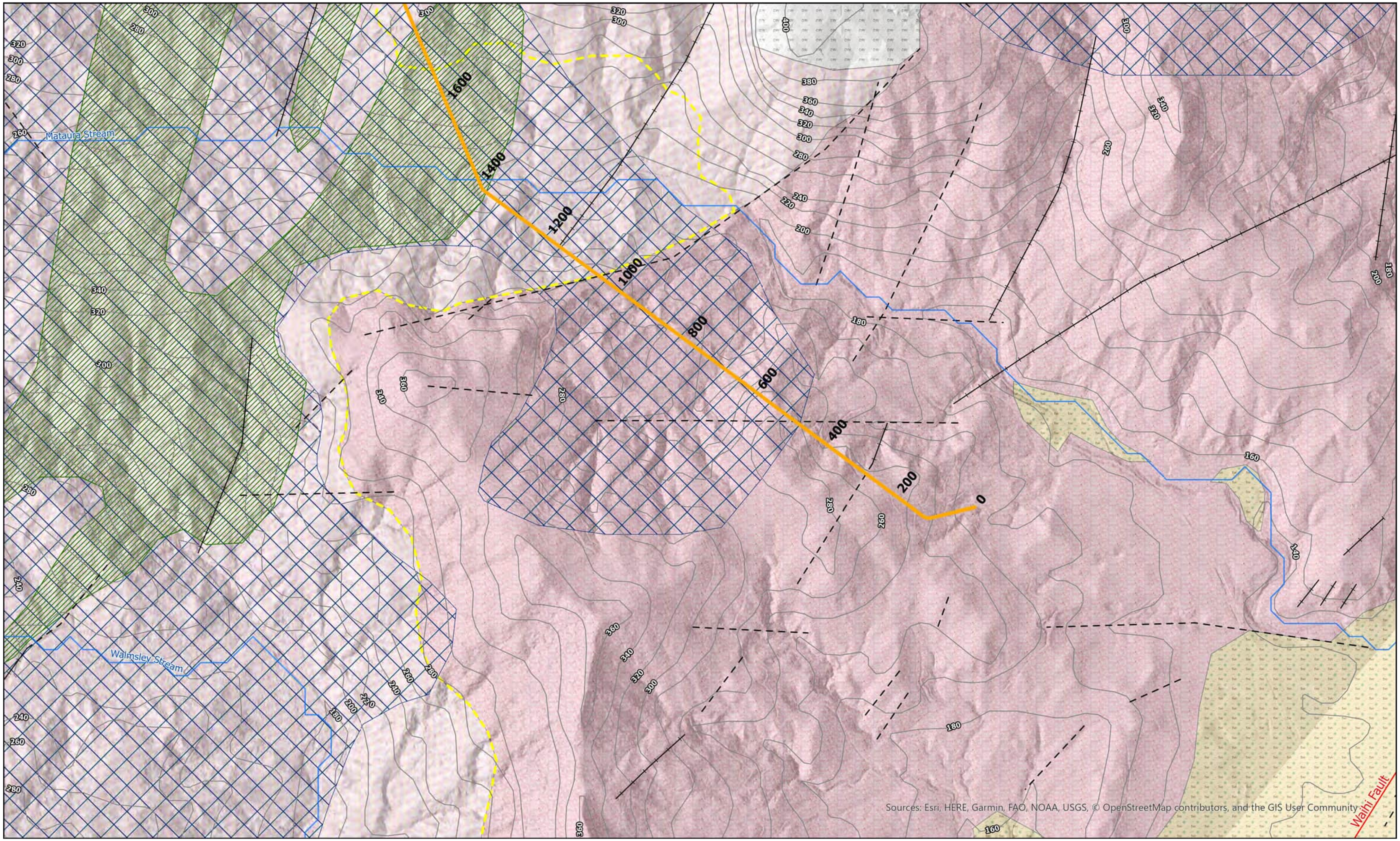
www.egl.co.nz

OCEANA GOLD (NEW ZEALAND) LTD
WAIHI NORTH PROJECT

Wharekirauponga Access Tunnel Geology Section (By PSM)

Ref. No: 9049
Date: June 2022
Drawn: PSM



Paper Size A3

0 50 100 200 300

Metres

Map Projection: New Zealand Map Grid
Horizontal Datum: New Zealand 1949
Grid: GD 1949 New Zealand Map Grid

N

LEGEND

GNS 1:50k geological lithological units

- Tauranga Group and Whitianga Group
- Ratarua Ignimbrite: Welded, dacitic ignimbrite
- Whakamoehau Andesite: Andesite and dacite with minor quartz phenocrysts. Andesite tuff breccias
- Whiritoa Andesite : Phyric andesite and dacite flows and domes with tuff-breccias and lithic crystal tuff
- Waipupu Formation : Andesite and dacite, locally with quartz phenocrysts. Minor tuff breccia, crystal tuff and lacustrine sediments

Geologic features

- Fault
- Inferred liniament
- Liniament
- GNS-mapped hydrothermal alteration zone
- Watercourse
- OGL tunnel centreline

OGL-mapped and GHD-inferred surface hydrothermal alteration

- Argilite Alt - Illite / Illite, Smectite
- Argilite Alt - Smectite Surficial
- Quartz Alt / Silicification

Oceana Gold
WKP Exploration Tunnel - Water Assessment

Conceptual Engineering Geological Model

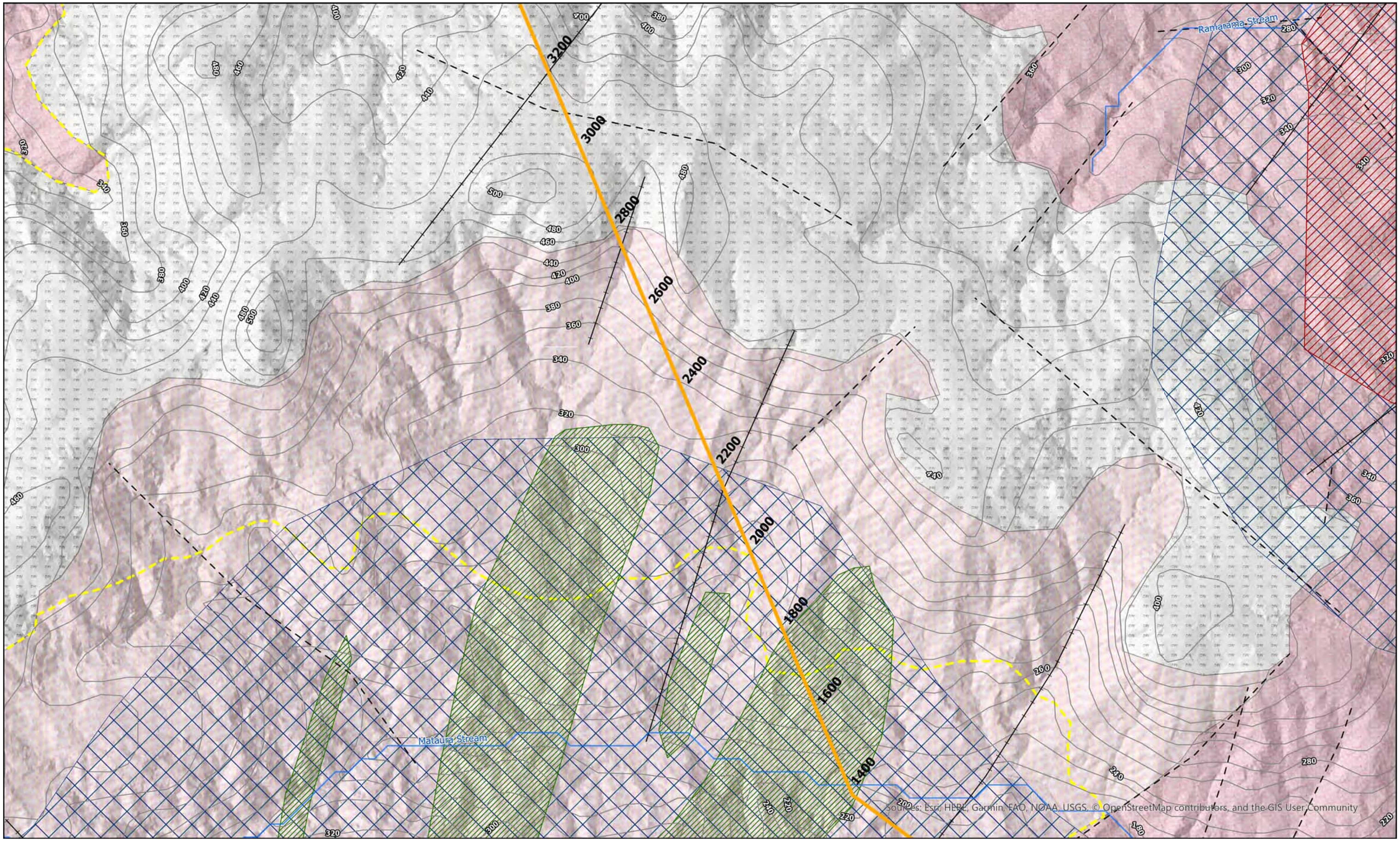
Job Number	125336958
Revision	0
Date	19 Aug 2020

Figure 22

N:\NZ\Christchurch\Projects\51\12533958\GIS\Maps\Deliverables\GeotechMapping\GeotechMapping.aprx

27 Napier Street Freemans Bay, Auckland 1010 **T:** 64 9 370 8000 **F:** 64 9 370 8001 **E:** aklmail@ghd.com **W:** www.ghd.com

Data source: ESRI: World topographic Map and World Hillshade; Oceanea Gold: DEMs (20190503); GNS: 1:50k 1996 Waihi Area map, pdf; Waikato Regional Council: REC named watercourses (20200715); LINZ: 1:50k contours (20200721); GHD: tunnel diagram (20200715) Created by:nrama



Paper Size A3

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Metres

Map Projection: New Zealand Map Grid
Horizontal Datum: New Zealand 1949
Grid: GD 1949 New Zealand Map Grid

N

LEGEND

GNS 1:50k geological lithological units

- Whakamoehau Andesite: Andesite and dacite with minor quartz phenocrysts. Andesite tuff breccias
- Whiritoa Andesite : Phyric andesite and dacite flows and domes with tuff-breccias and lithic crystal tuff
- Waipupu Formation : Andesite and dacite, locally with quartz phenocrysts. Minor tuff breccia, crystal tuff and lacustrine sediments

Geologic features

- Inferred liniament
- Liniament
- GNS-mapped hydrothermal alteration zone
- Watercourse
- OGL tunnel centreline

OGL-mapped and GHD-inferred surface hydrothermal alteration

- Argilite Alt - Illite / Illite, Smectite
- Argilite Alt - Smectite Surficial
- Quartz Alt / Silicification

GHD

OCEANAGOLD

Oceana Gold
WKP Exploration Tunnel - Water Assessment

Job Number 125336958
Revision 0
Date 19 Aug 2020

Conceptual Engineering Geological Model

Figure 23

N:\NZ\Christchurch\Projects\51\12533958\GIS\Maps\Deliverables\GeotechMapping\GeotechMapping.aprx

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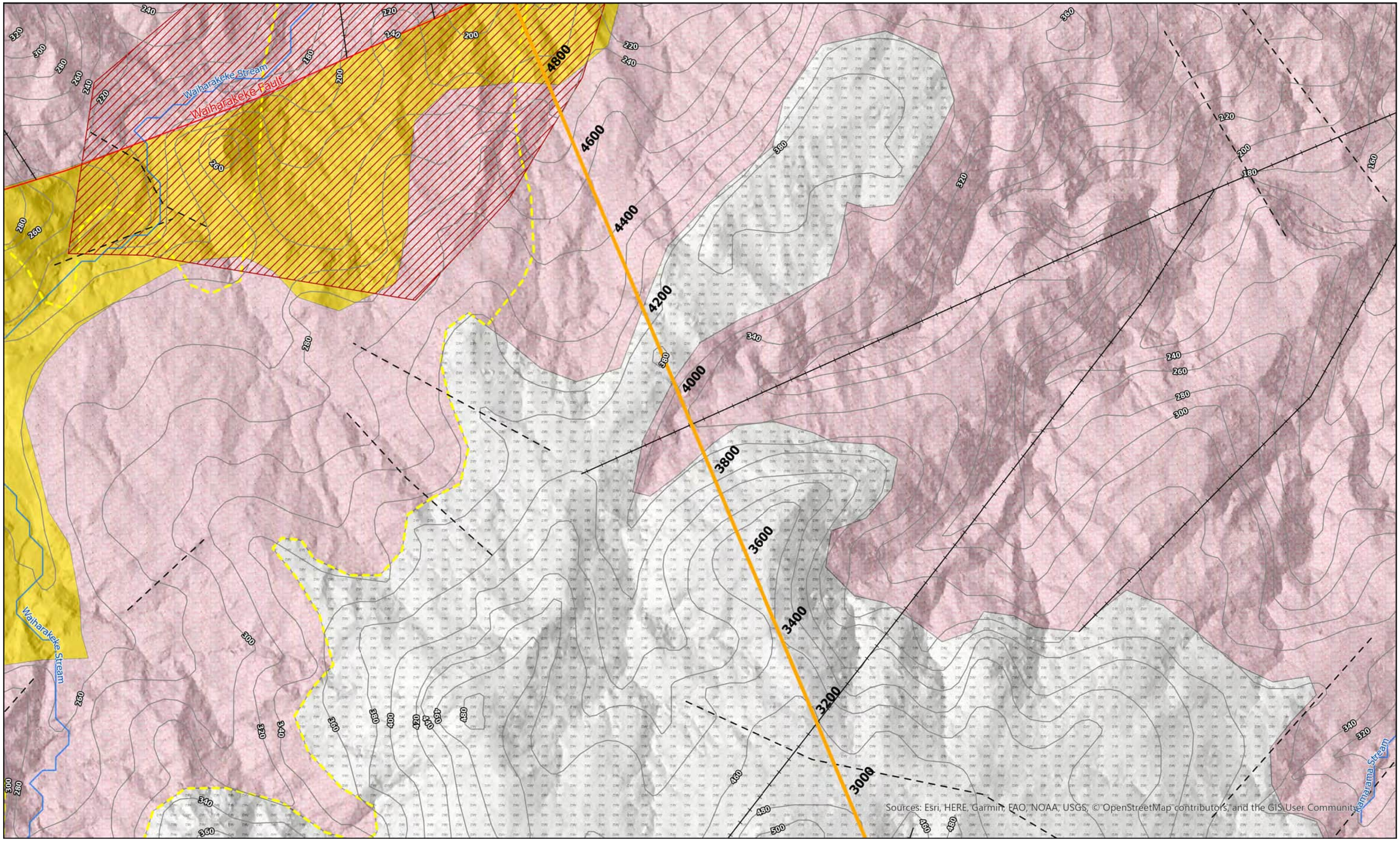
Data source: ESRI: World topographic Map and World Hillshade; Oceanea Gold: DEMs (20190503); GNS: 1:50k 1996 Waihi Area map, pdf; Waikato Regional Council: REC named watercourses (20200715); LINZ: 1:50k contours (20200721); GHD: tunnel diagram (20200715) Created by:nrama



Paper Size A3

0 50 100 200 300

Metres

Map Projection: New Zealand Map Grid
Horizontal Datum: New Zealand 1949
Grid: GD 1949 New Zealand Map Grid

N

LEGEND

GNS 1:50k geological lithological units

Whakamoehau Andesite: Andesite and dacite with minor quartz phenocrysts. Andesite tuff breccias

Whiritoa Andesite : Phyric andesite and dacite flows and domes with tuff-breccias and lithic crystal tuff

Waiharakeke Dacite : Dacite flows, tuff breccia and minor tuff. Local intercalated rhyolite flows and tuffs

Geologic features

Fault

Inferred liniament

Liniament

GNS-mapped hydrothermal alteration zone

Watercourse

OGL tunnel centreline

OGL-mapped and GHD-inferred surface hydrothermal alteration

Argilite Alt - Illite / Illite, Smectite

Argilite Alt - Smectite Surficial

Quartz Alt / Silicification

GHD

OCEANAGOLD

Oceana Gold
WKP Exploration Tunnel - Water Assessment

Job Number 125336958
Revision 0
Date 19 Aug 2020

Conceptual Engineering Geological Model

Figure 24

N:\NZ\Christchurch\Projects\51\12533958\GIS\Maps\Deliverables\GeotechMapping\GeotechMapping.aprx

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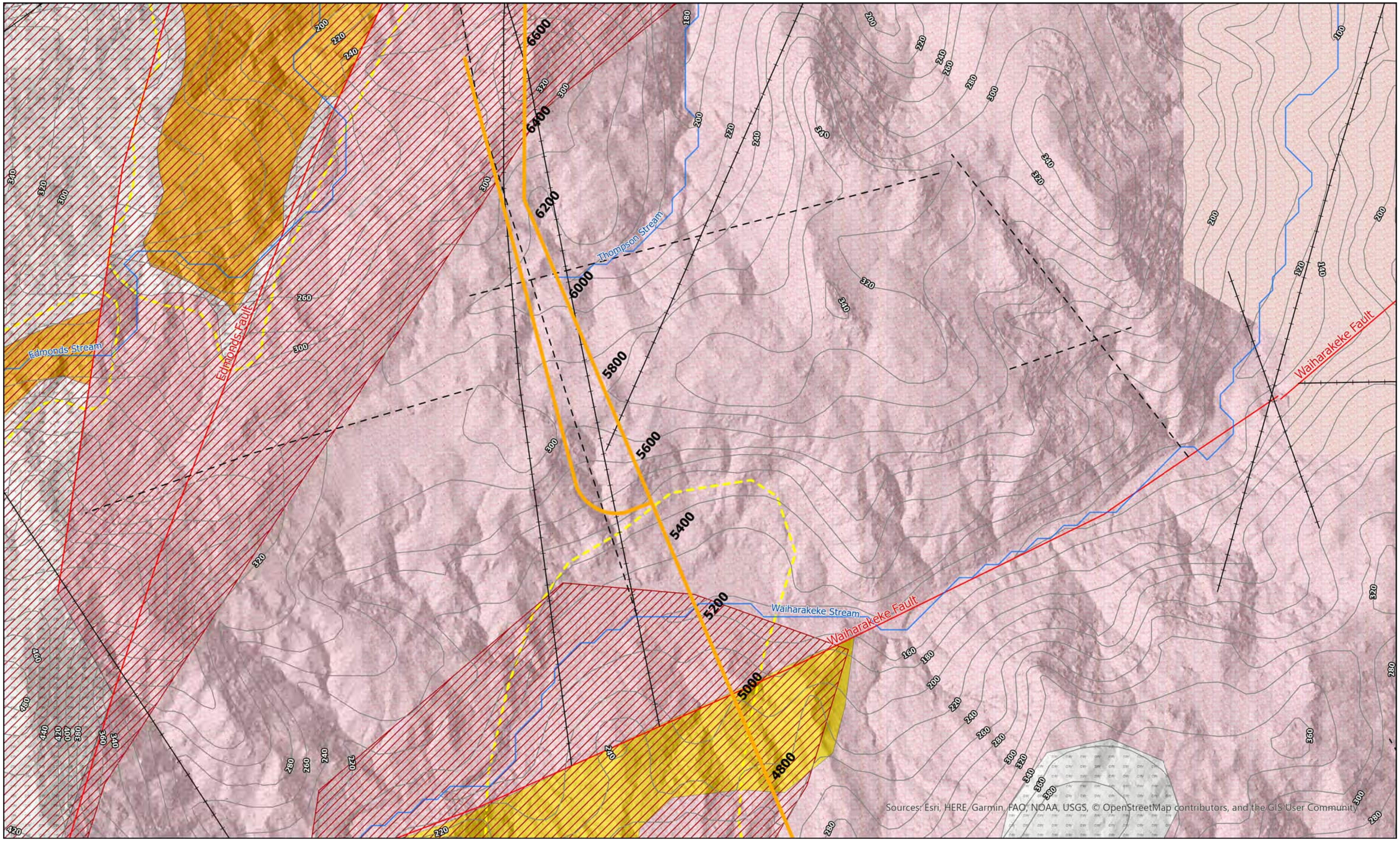
Data source: ESRI: World topographic Map and World Hillshade; Oceanea Gold: DEMs (20190503); GNS: 1:50k 1996 Waihi Area map, pdf; Waikato Regional Council: REC named watercourses (20200715); LINZ: 1:50k contours (20200721); GHD: tunnel diagram (20200715) Created by:nrama



Paper Size A3

0 50 100 200 300

Metres

Map Projection: New Zealand Map Grid
Horizontal Datum: New Zealand 1949
Grid: GD 1949 New Zealand Map Grid

N

LEGEND

GNS 1:50k geological lithological units

- Whakamoehau Andesite: Andesite and dacite with minor quartz phenocrysts. Andesite tuff breccias
- Whiritoa Andesite : Phyric andesite and dacite flows and domes with tuff-breccias and lithic crystal tuff
- Coroglen Subgroup : Rhyolitic tuff - crystal, lithic and lapille tuff
- Waiharakeke Dacite : Dacite flows, tuff breccia and minor tuff. Local intercalated rhyolite flows and tuffs

Geologic features

- Fault
- Inferred liniament
- Liniament
- GNS-mapped hydrothermal alteration zone
- Watercourse
- OGL tunnel centreline

OGL-mapped and GHD-inferred surface hydrothermal alteration

- Argillite Alt - Illite / Illite, Smectite
- Argillite Alt - Smectite Surficial
- Quartz Alt / Silicification

GHD

OCEANAGOLD

Oceana Gold
WKP Exploration Tunnel - Water Assessment

Job Number 125336958
Revision 0
Date 19 Aug 2020

Conceptual Engineering Geological Model

Figure 25

N:\NZ\Christchurch\Projects\51\12533958\GIS\Maps\Deliverables\GeotechMapping\GeotechMapping.aprx

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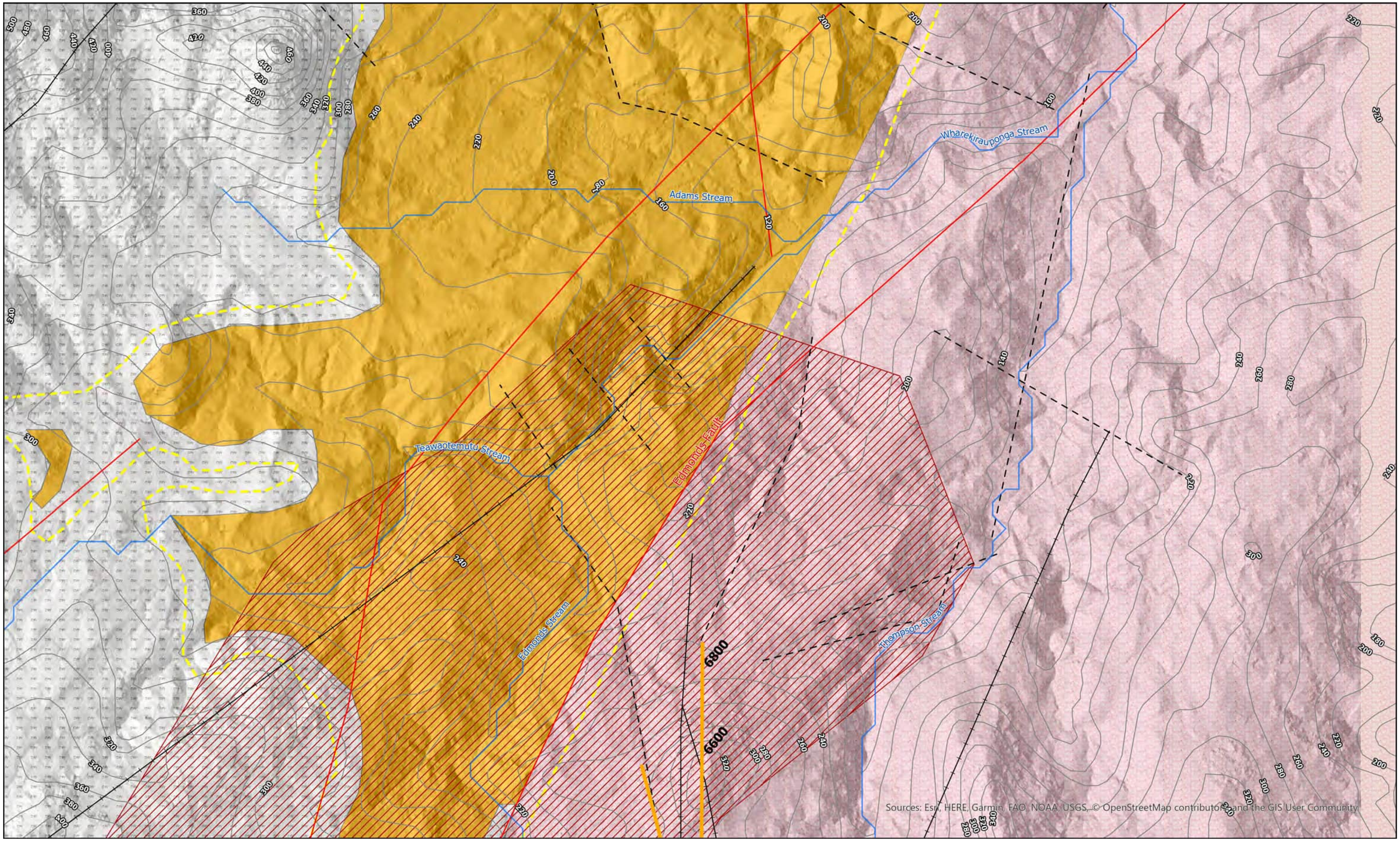
Data source: ESRI: World topographic Map and World Hillshade; Oceana Gold: DEMs (20190503); GNS: 1:50k 1996 Waihi Area map, pdf; Waikato Regional Council: REC named watercourses (20200715); LINZ: 1:50k contours (20200721); GHD: tunnel diagram (20200715) Created by:nrama



Paper Size A3

0 50 100 200 300

Metres

Map Projection: New Zealand Map Grid
Horizontal Datum: New Zealand 1949
Grid: GD 1949 New Zealand Map Grid

N

LEGEND

GNS 1:50k geological lithological units

Whakamoehau Andesite: Andesite and dacite with minor quartz phenocrysts. Andesite tuff breccias

Whiritoa Andesite : Phyric andesite and dacite flows and domes with tuff-breccias and lithic crystal tuff

Coroglen Subgroup : Rhyolitic tuff - crystal, lithic and lapille tuff

Geologic features

Fault

Inferred liniament

Liniament

GNS-mapped hydrothermal alteration zone

Watercourse

OGL tunnel centreline

OGL-mapped and GHD-inferred surface hydrothermal alteration

Argilite Alt - Illite / Illite, Smectite

Argilite Alt - Smectite Surficial

Quartz Alt / Silicification

GHD

OCEANAGOLD

Oceana Gold
WKP Exploration Tunnel - Water Assessment

Job Number	125336958
Revision	0
Date	19 Aug 2020

Conceptual Engineering Geological Model

Figure 26

N:\NZ\Christchurch\Projects\51\12533958\GIS\Maps\Deliverables\GeotechMapping\GeotechMapping.aprx

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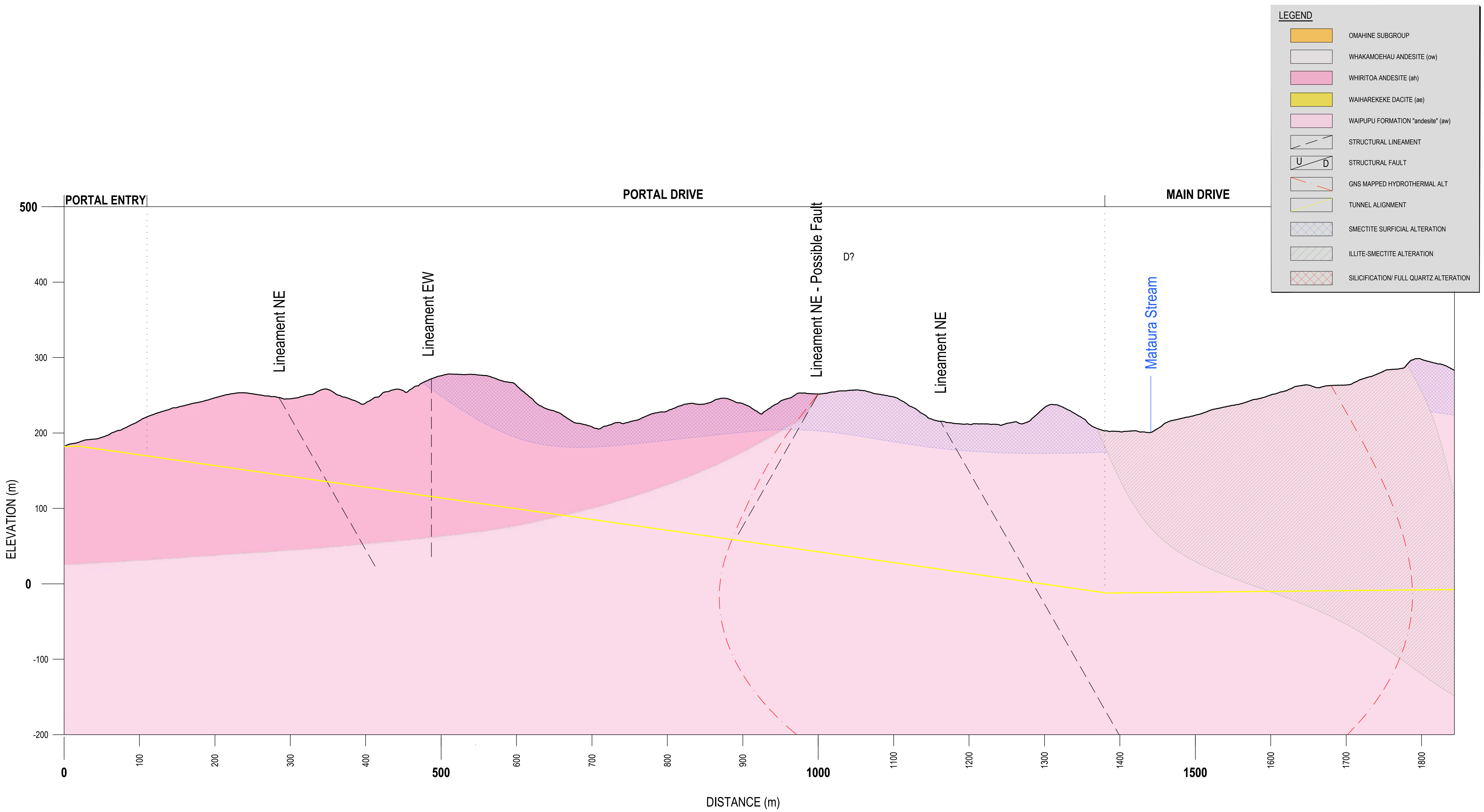
Data source: ESRI: World topographic Map and World Hillshade; Oceanea Gold: DEMs (20190503); GNS: 1:50k 1996 Waihi Area map, pdf; Waikato Regional Council: REC named watercourses (20200715); LINZ: 1:50k contours (20200721); GHD: tunnel diagram (20200715) Created by:nrama



LONGSECTION 1 - CH 0 TO CH 1844

SCALE 1:2500

0 25 50 75 100 125m

SCALE 1:2500 AT ORIGINAL SIZE

Figure 27

PRELIMINARY

No	Revision	Drawn	Job Manager	Project Director	Date
A	CONCEPTUAL	NB	TM	NE	082020Y

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Drafting Check DM | Design Check NE
Approved (Project Director) NE
Date 17082020
Scale 1:2500 @ A1
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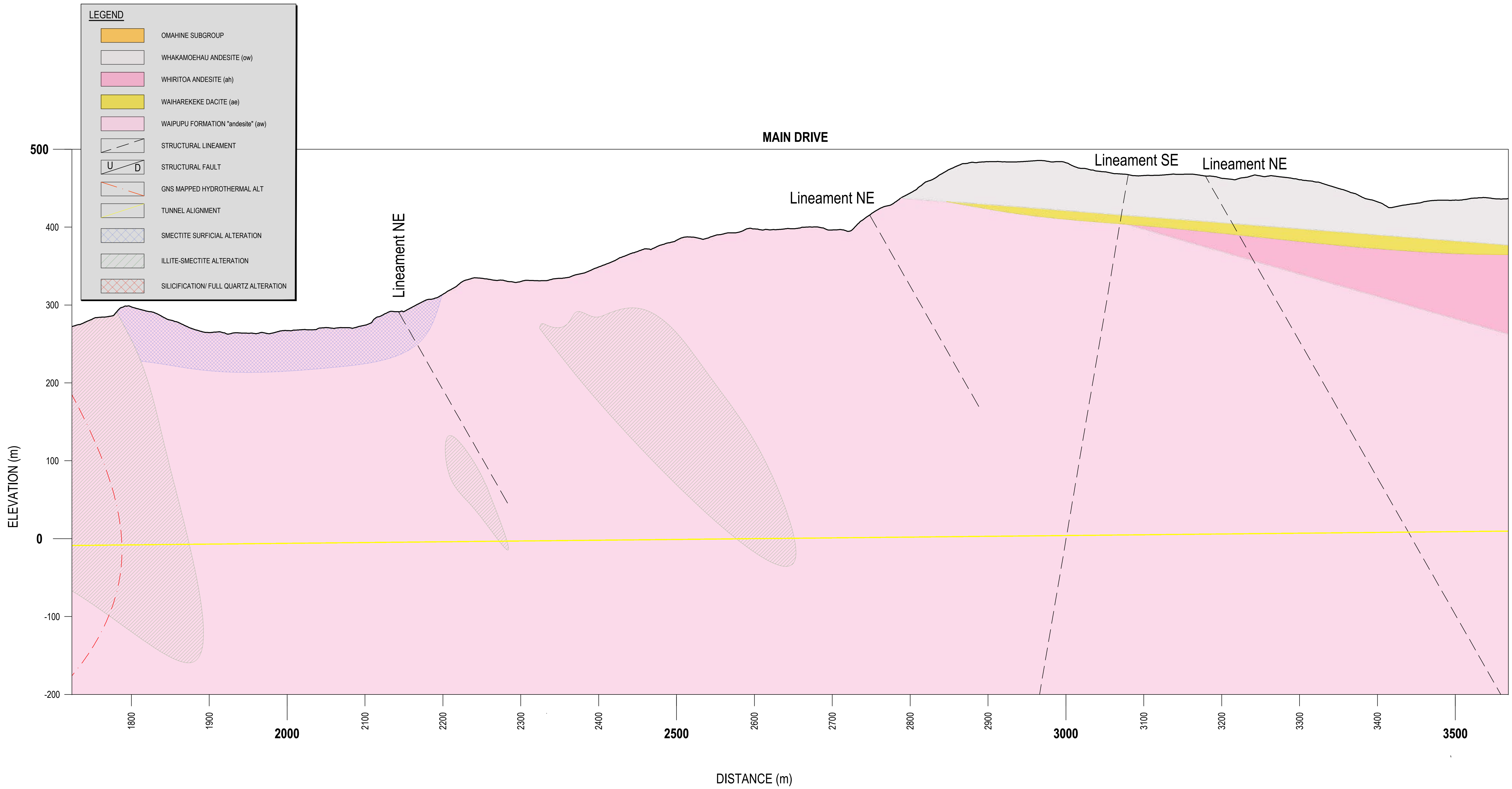
Client **OCEANA GOLD LIMITED**
Project **WKP EXPLORATION TUNNEL - WATER ASSESSMENT**
Title **CONCEPTUAL GEOLOGICAL LONGSECTION DRAFT 17082020**

Original Size **A1** Drawing No: **Q001** Rev: **A**

Plot Date: 17 August 2020 - 2:31 PM Plotted by: Nick Burke Cad File No: C:\Users\nburke\Desktop\WKP C drive\master_section_newalignment.dwg



LONGSECTION 2 - CH 1723 TO CH 3567

SCALE 1:2500

Figure 28

0 25 50 75 100 125m

SCALE 1:2500 AT ORIGINAL SIZE

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Designer NICK BURKE
Drafting Check DM
Design Check NE
Approved (Project Director) NE
Date 17082020
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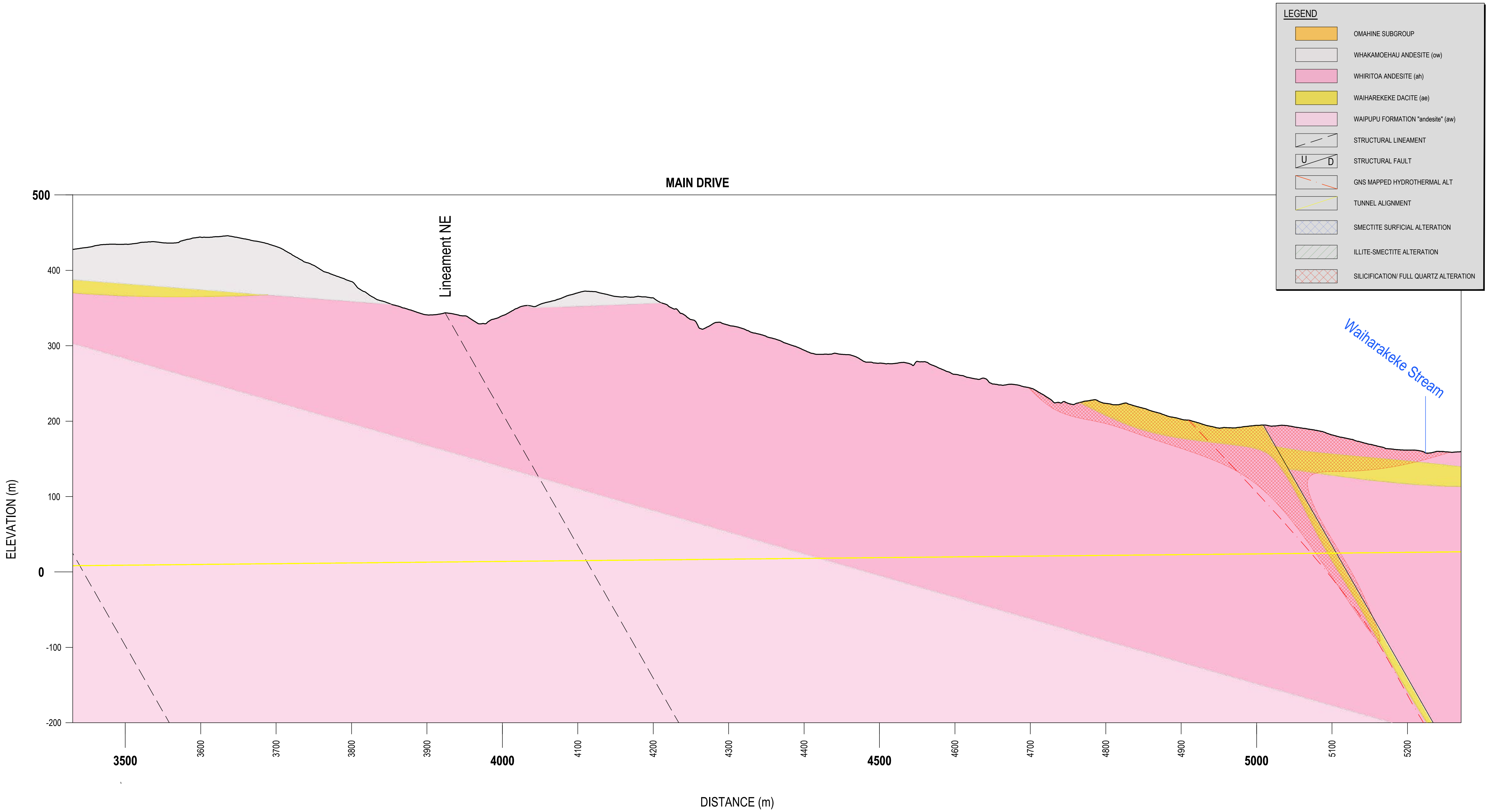
Project **WKP EXPLORATION TUNNEL - WATER ASSESSMENT**
Title **CONCEPTUAL GEOLOGICAL LONGSECTION DRAFT 17082020**

Original Size **A1** **Drawing No: Q002** **Rev: A**

Plot Date: 17 August 2020 - 2:31 PM Plotted by: Nick Burke Cad File No: C:\Users\nburke\Desktop\WKP C drive\master_section_newalignment.dwg



LONGSECTION 3 - CH 3430 TO CH 5271

SCALE 1:2500

Figure 29

0 25 50 75 100 125m

SCALE 1:2500 AT ORIGINAL SIZE

PRELIMINARY

No	Revision	Drawn	Job Manager	Project Director	Date
A	CONCEPTUAL	NB	TM	NE	082020Y

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Approved (Project Director) NE
Date 17082020
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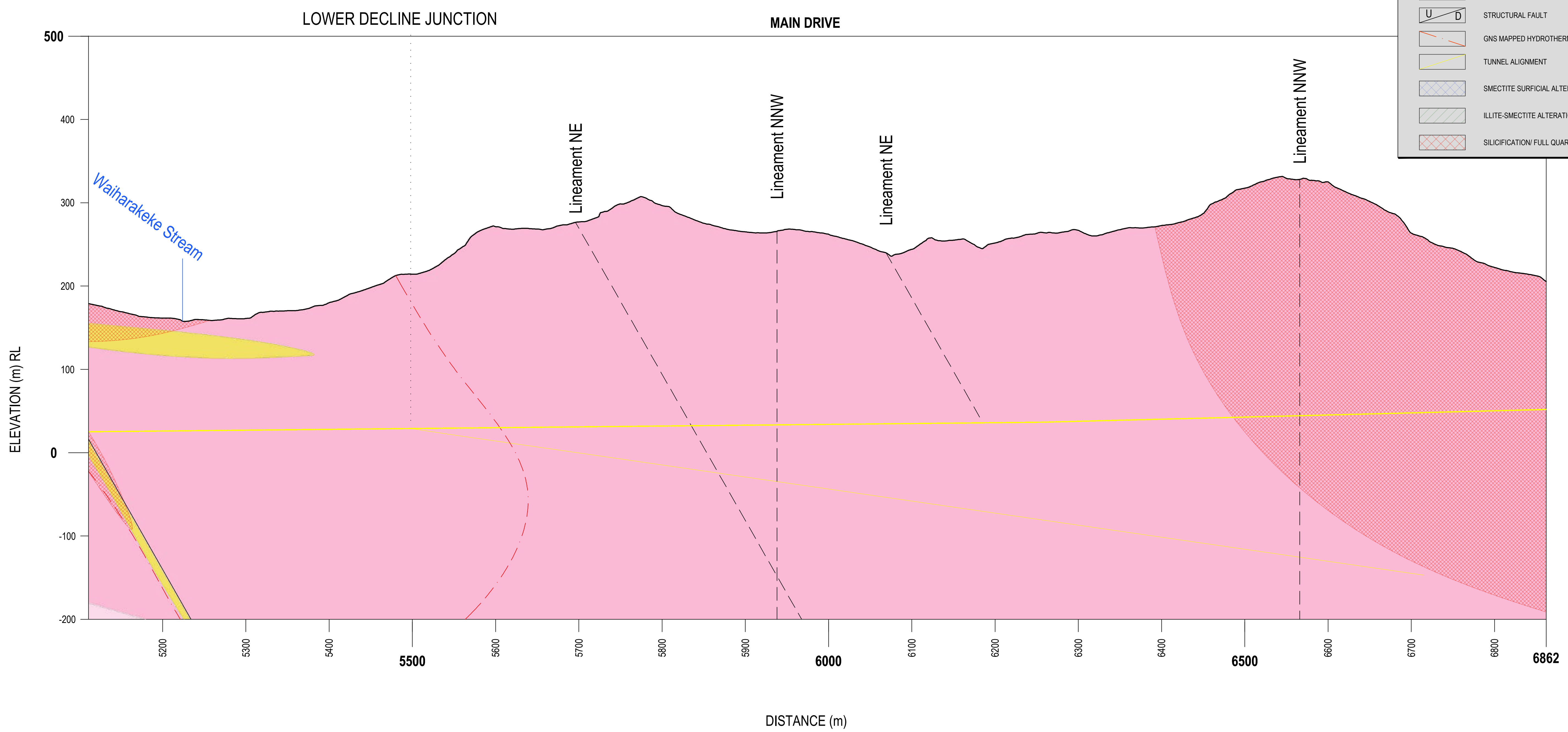
Title **CONCEPTUAL GEOLOGICAL LONGSECTION DRAFT 17082020**

Original Size A1 Drawing No: **Q003** Rev: **A**

Plot Date: 17 August 2020 - 2:32 PM Plotted by: Nick Burke Cad File No: C:\Users\nburke\Desktop\WKP C drive\master_section_newalignment.dwg



LEGEND

- OMAHINE SUBGROUP
- WHAKAMOEHAU ANDESITE (ow)
- WHIRITOA ANDESITE (ah)
- WAIHAREKEKE DACITE (ae)
- WAIPUPU FORMATION "andesite" (aw)
- STRUCTURAL LINEAMENT
- STRUCTURAL FAULT (U D)
- GNS MAPPED HYDROTHERMAL ALT
- TUNNEL ALIGNMENT
- SMECTITE SURFICIAL ALTERATION
- ILLITE-SMECTITE ALTERATION
- SILICIFICATION/ FULL QUARTZ ALTERATION

LONGSECTION 4 - CH 5112 TO CH 6862

SCALE 1:2500

Figure 30

0 25 50 75 100 125m

SCALE 1:2500 AT ORIGINAL SIZE

PRELIMINARY

No	Revision	Drawn	Job Manager	Project Director	Date
A	CONCEPTUAL	NB	TM	NE	082020Y

Note: * indicates signatures on original issue of drawing or last revision of drawing

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Drafting Check	DM	Design Check	NE
Approved (Project Director)	NE		
Date	17082020		
Scale	1:2500 @ A1	This Drawing must not be used for Construction unless signed as Approved	

Client: **OCEANA GOLD LIMITED**
Project: **WKP EXPLORATION TUNNEL - WATER ASSESSMENT**
Title: **CONCEPTUAL GEOLOGICAL LONGSECTION DRAFT 17082020**

Original Size: A1 | Drawing No: **Q004** | Rev: **A**

Plot Date: 17 August 2020 - 2:32 PM Plotted by: Nick Burke Cad File No: C:\Users\nburke\Desktop\WKP C drive\master_section_newalignment.dwg

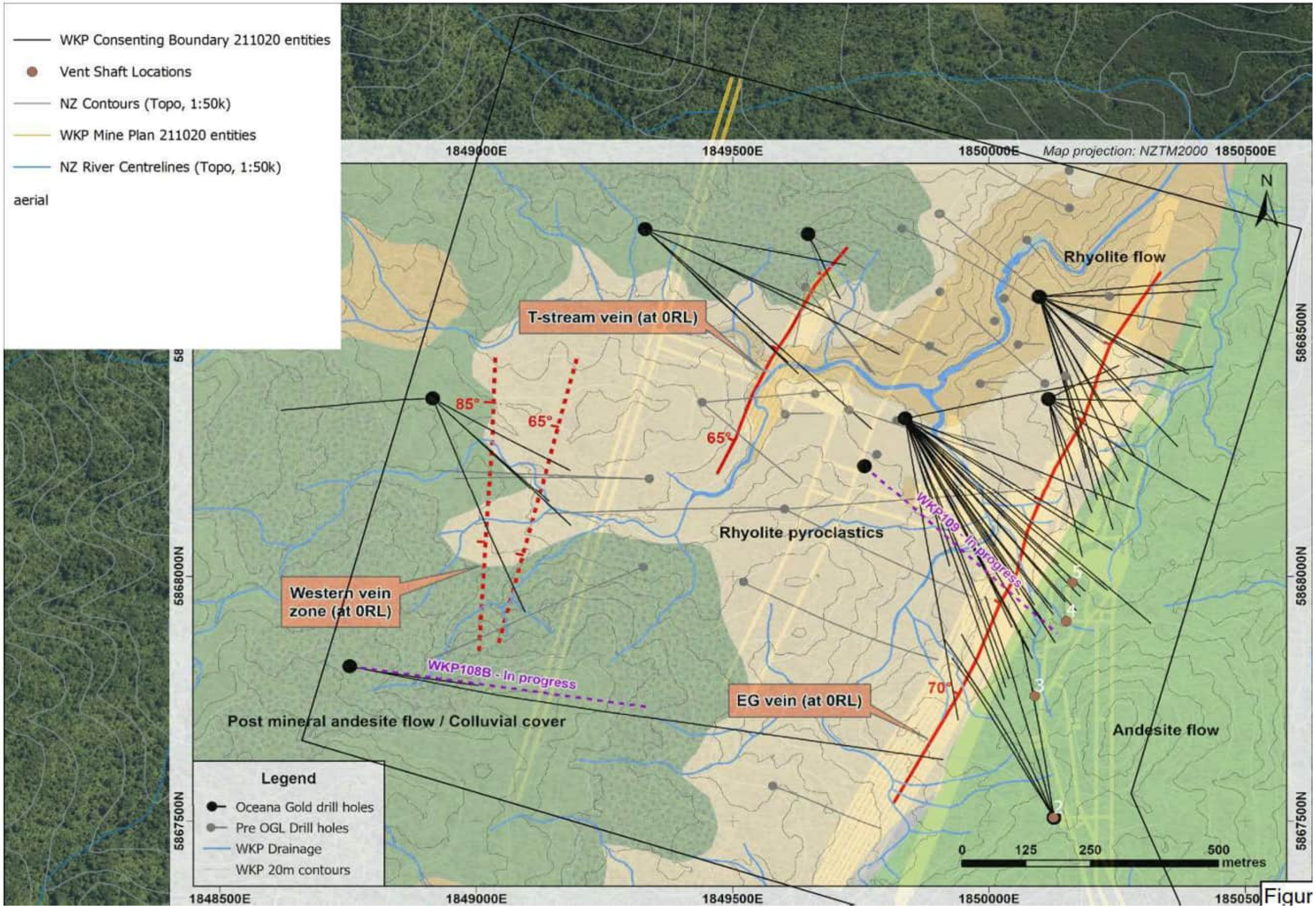

Figure 31

EGL Geotechnical, Earthquake and Dam Engineers Engineering Geology Ltd +64 9 486 2546 info@egl.co.nz Unit 7C, 331 Rosedale Road, Albany, Auckland PO Box 301054, Albany, Auckland 0752 www.egl.co.nz	**OCEANA GOLD (NEW ZEALAND) LTD** WAIHI NORTH PROJECT WUG Geology Plan	Ref. No: 9049 Date: Feb 2022 Drawn: OGNZL/EGL

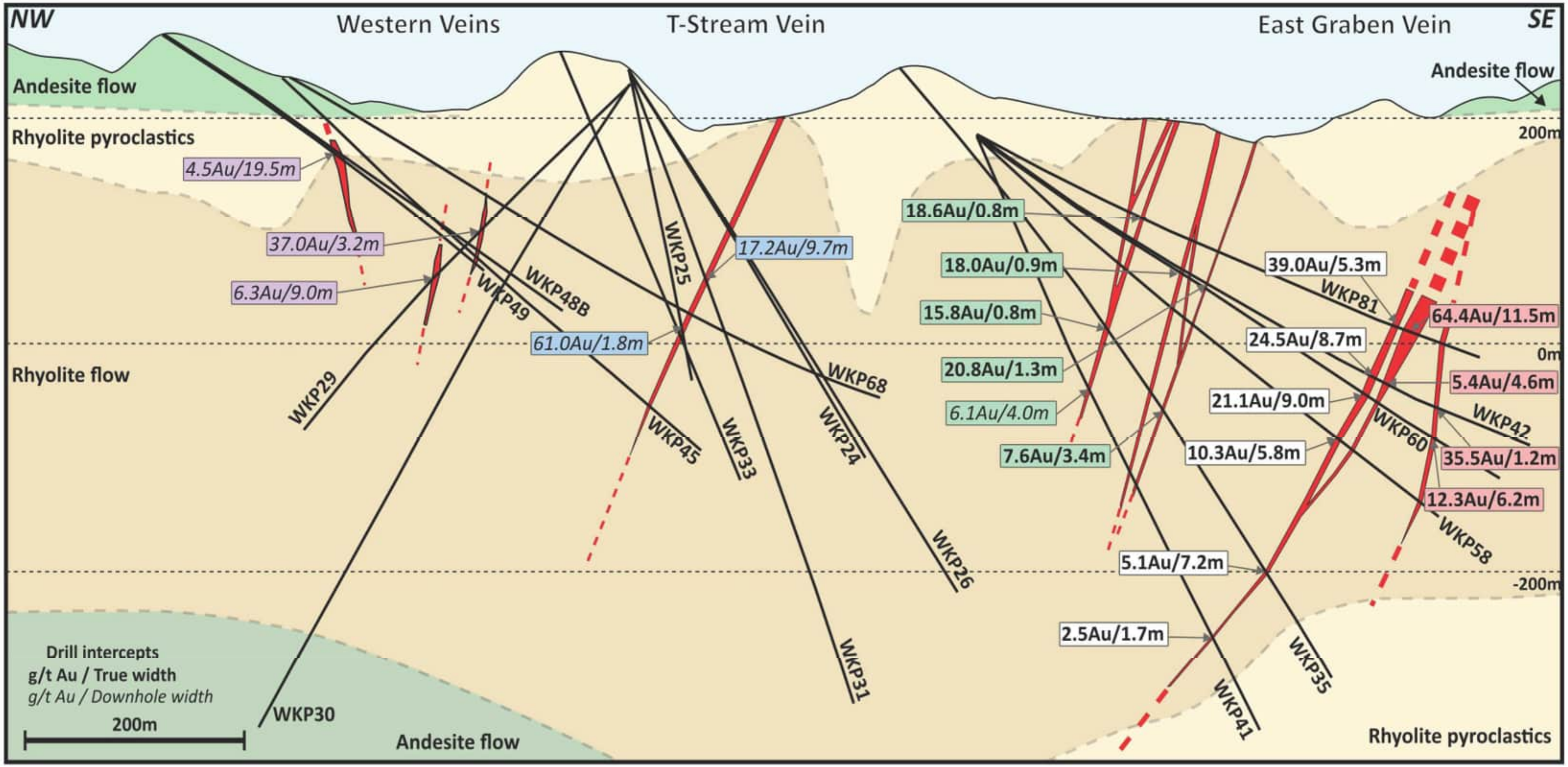

Figure 32

EGL Geotechnical, Earthquake and Dam Engineers Engineering Geology Ltd +64 9 486 2546 info@egl.co.nz Unit 7C, 331 Rosedale Road, Albany, Auckland PO Box 301054, Albany, Auckland 0752 www.egl.co.nz	**OCEANA GOLD (NEW ZEALAND) LTD** WAIHI NORTH PROJECT WUG Geology Cross Section	Ref. No: 9049 Date: Feb 2022 Drawn: OGNZL

Figure 33

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WAIHI NORTH PROJECT

Waihi Piezometer Network 2023

Ref. No: 9049
Date: Feb 2025
Drawn: OGNZL

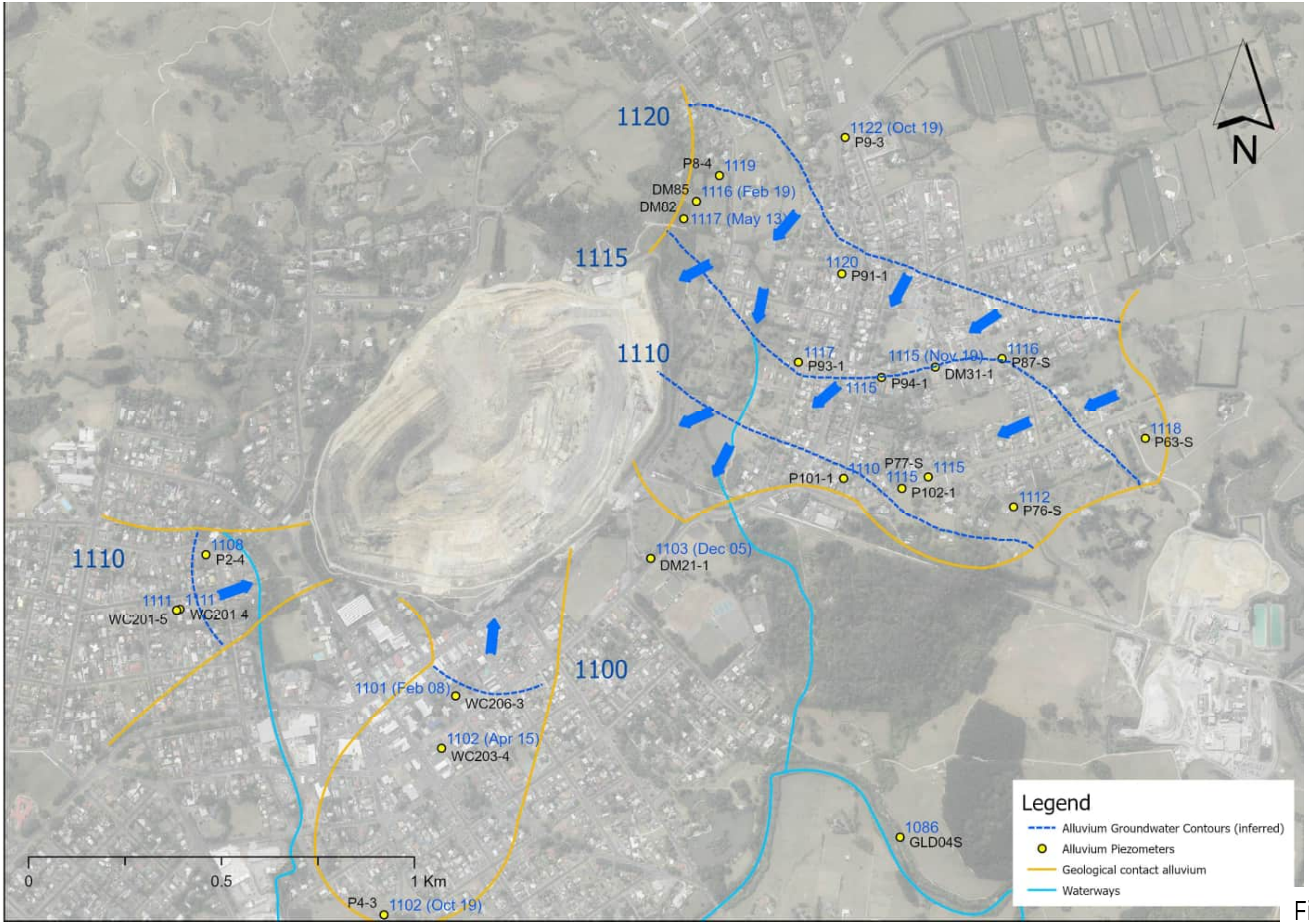

Figure 34

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WAIHI NORTH PROJECT

Alluvium water level contours

Ref. No: 9049

Date: Mar 2024

Drawn: OGNZL

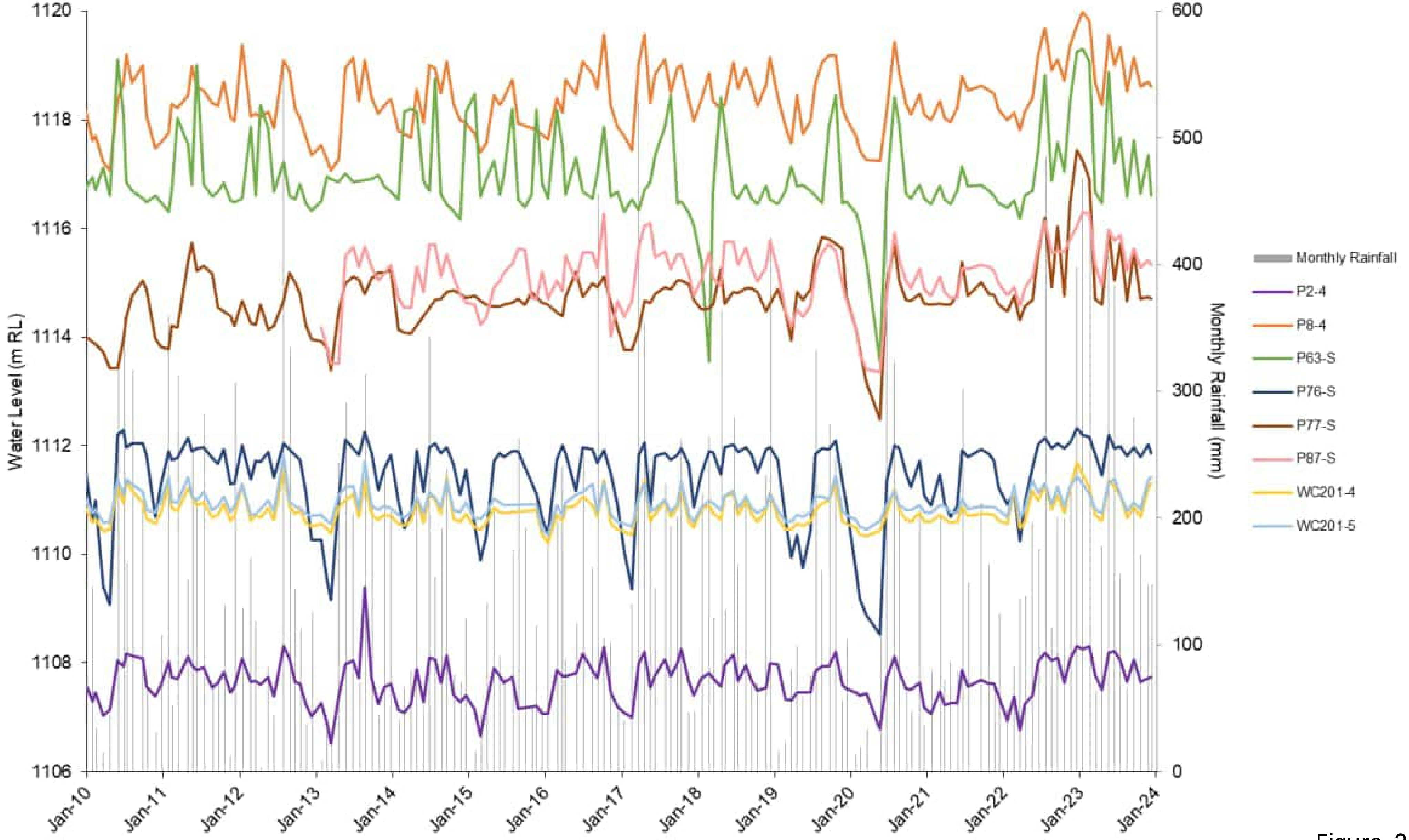

Figure 35

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OCEANA GOLD (NEW ZEALAND) LTD
WAIHI NORTH PROJECT
Groundwater Levels Trends - Shallow Groundwater (Alluvium & Weathered Contact of Young Volcanics)

Ref. No: 9049
Date: Mar 2024
Drawn: OGNZL

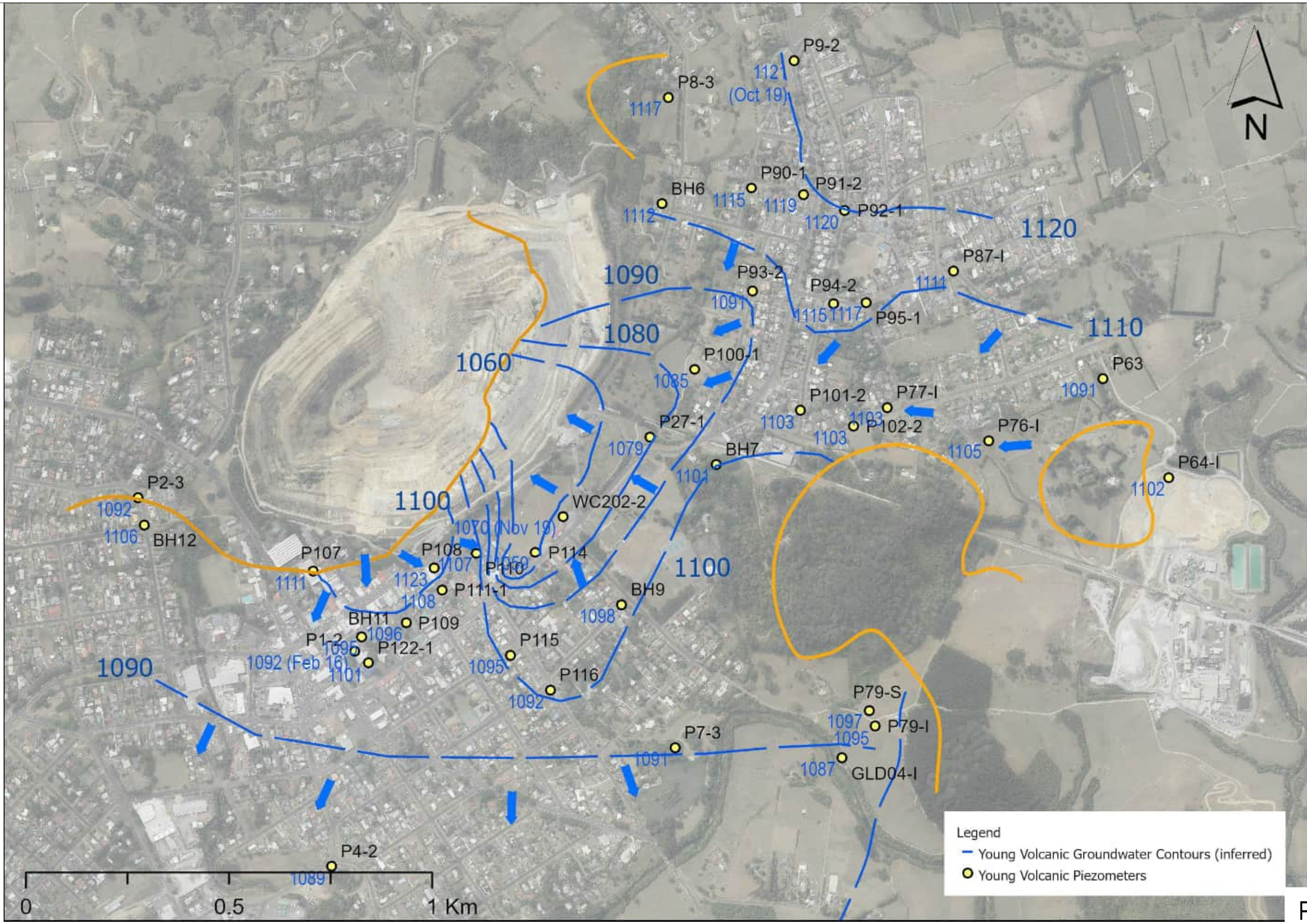

Figure 36

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OCEANA GOLD (NEW ZEALAND) LTD
WAIHI NORTH PROJECT

Deeper Younger Volcanics Water Level Contours

Ref. No: 9049
Date: Mar 2024
Drawn: OGNZL

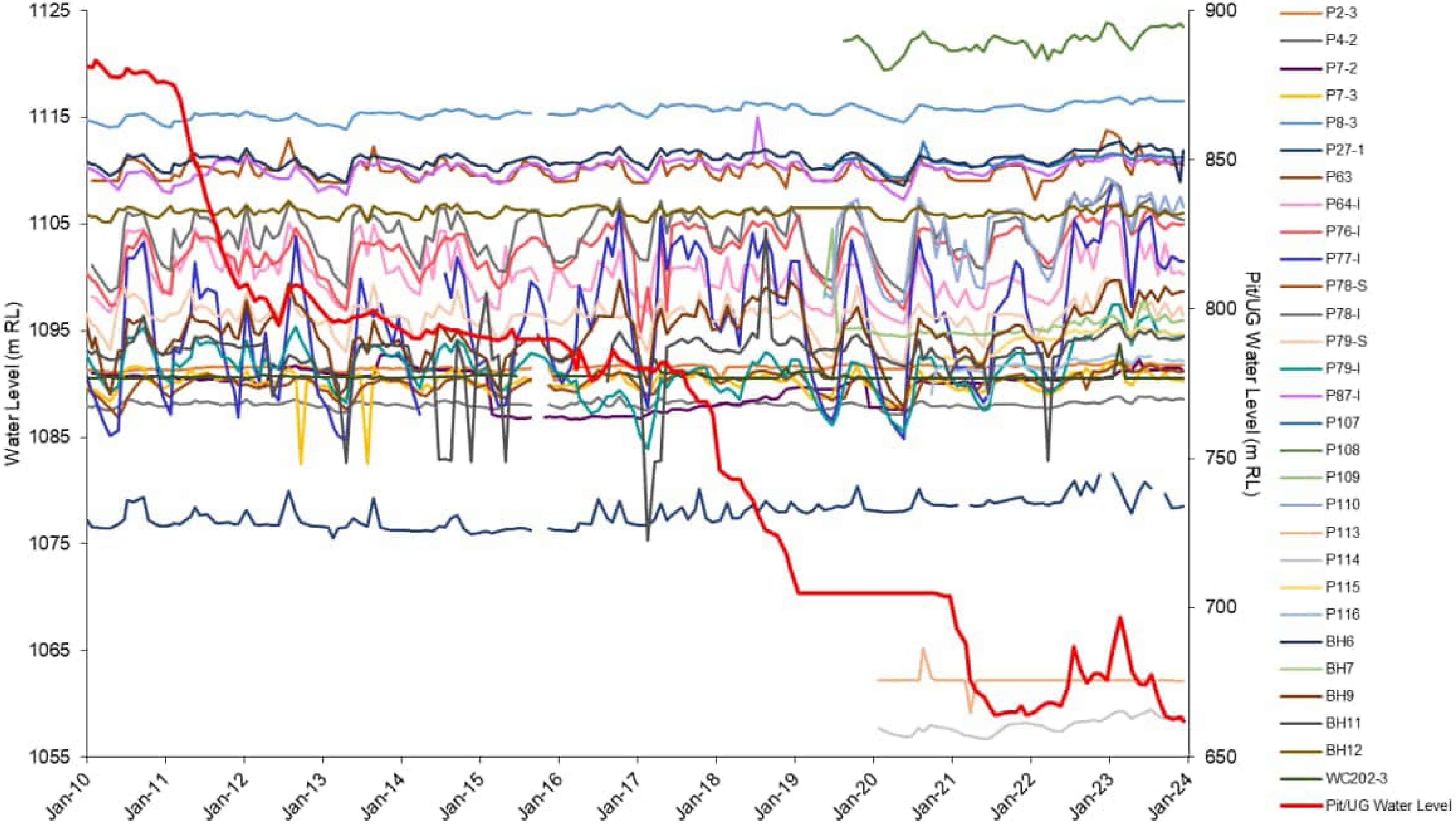

Figure 37

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WAIHI NORTH PROJECT

Groundwater Level Trends - Deeper Younger Volcanic Materials

Ref. No: 9049
Date: Mar 2024
Drawn: OGNZL

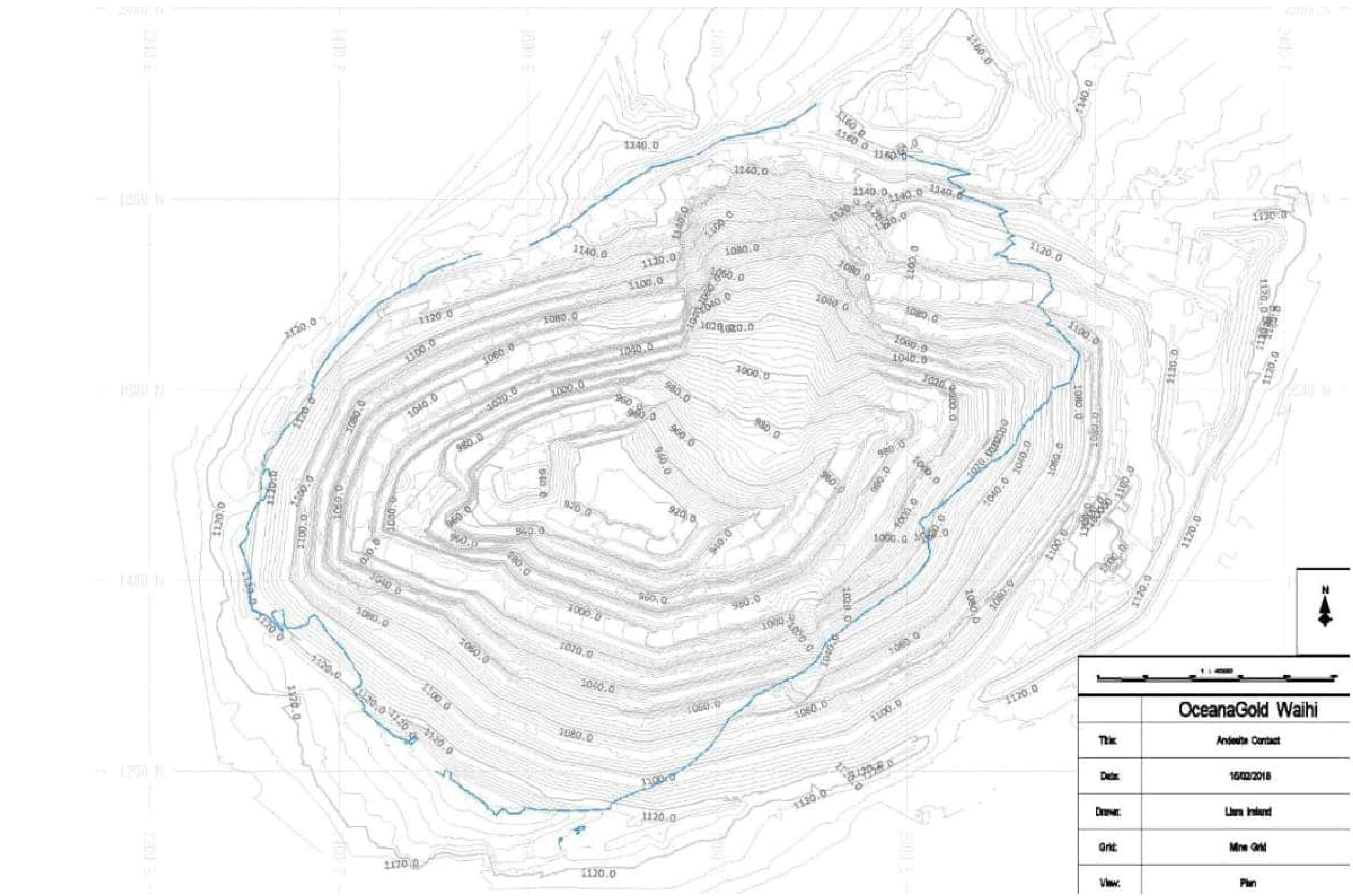

Figure 38

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WAIHI NORTH PROJECT

Andesite Younger Volcanic Materials Contact in Martha Pit

Ref. No: 9049
Date: Mar 2022
Drawn: OGNZL

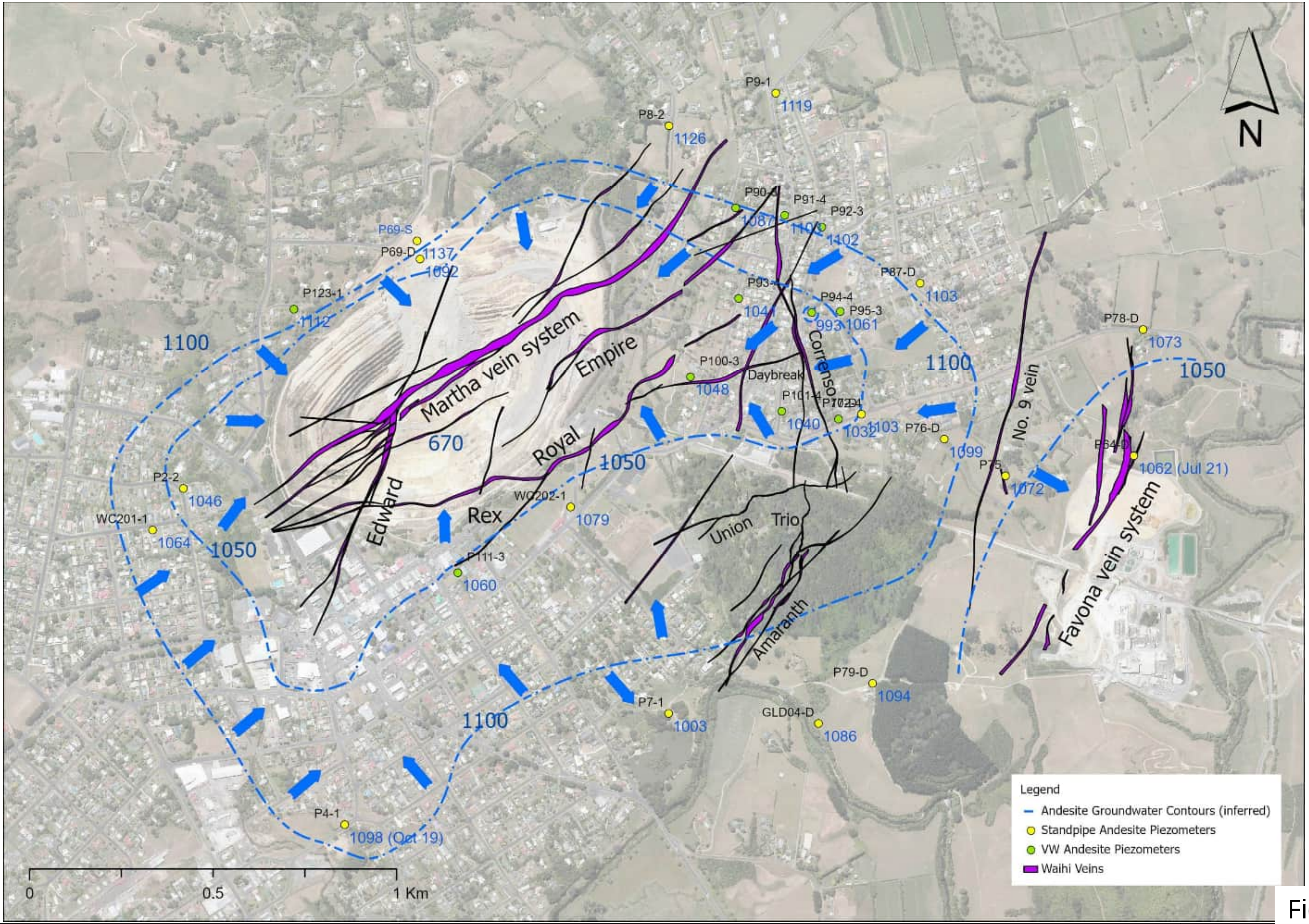

Figure 39

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WAIHI NORTH PROJECT

Andesite water level contours

Ref. No: 9049
Date: Mar 2024
Drawn: OGNZL

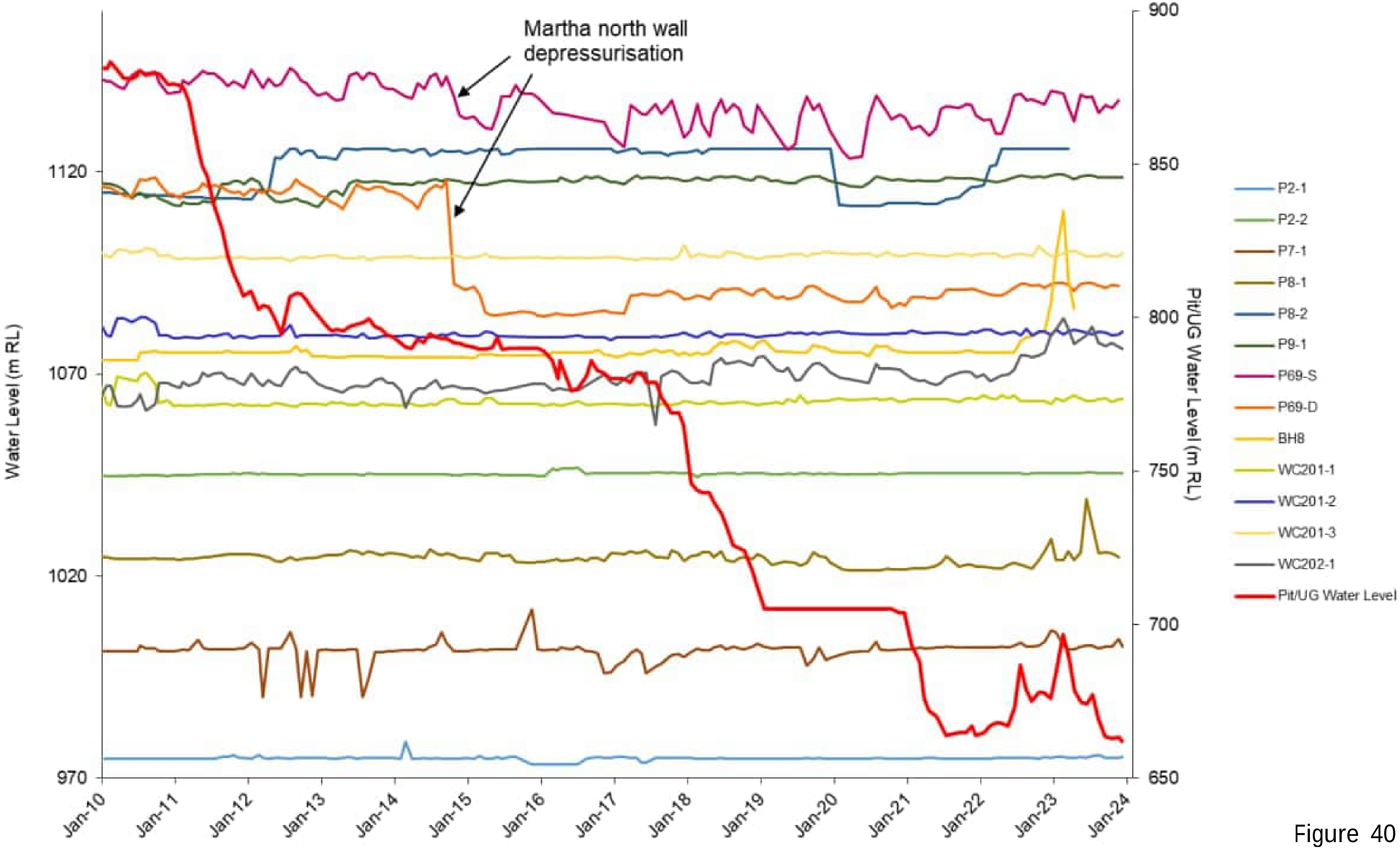

Figure 40

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WAIHI NORTH PROJECT

Groundwater Level Trends - Martha Andesite

Ref. No: 9049
Date: Mar 2024
Drawn: OGNZL

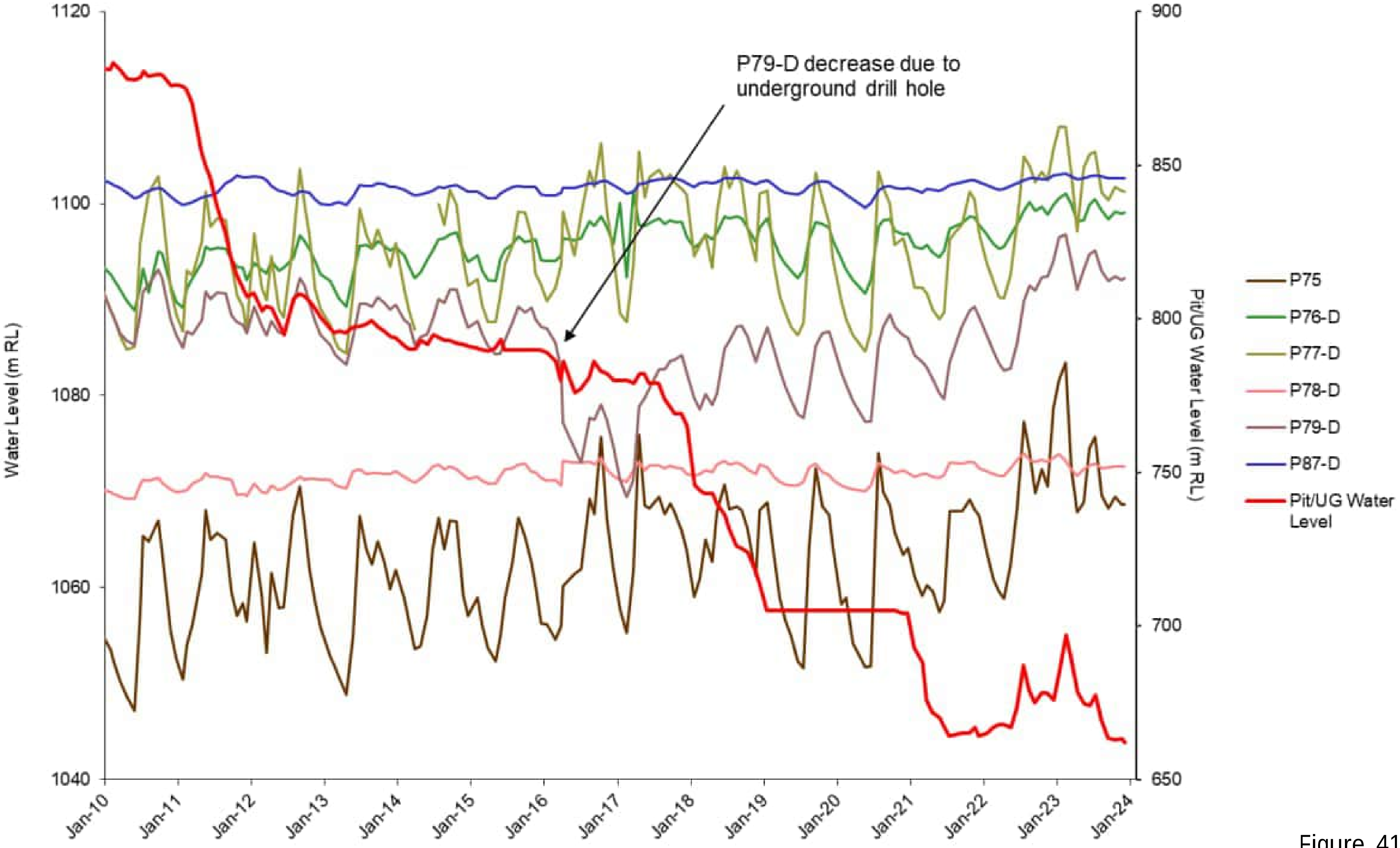

Figure 41

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WAIHI NORTH PROJECT

Groundwater Level Trends - Favona Andesite

Ref. No: 9049
Date: Mar 2024
Drawn: OGNZL

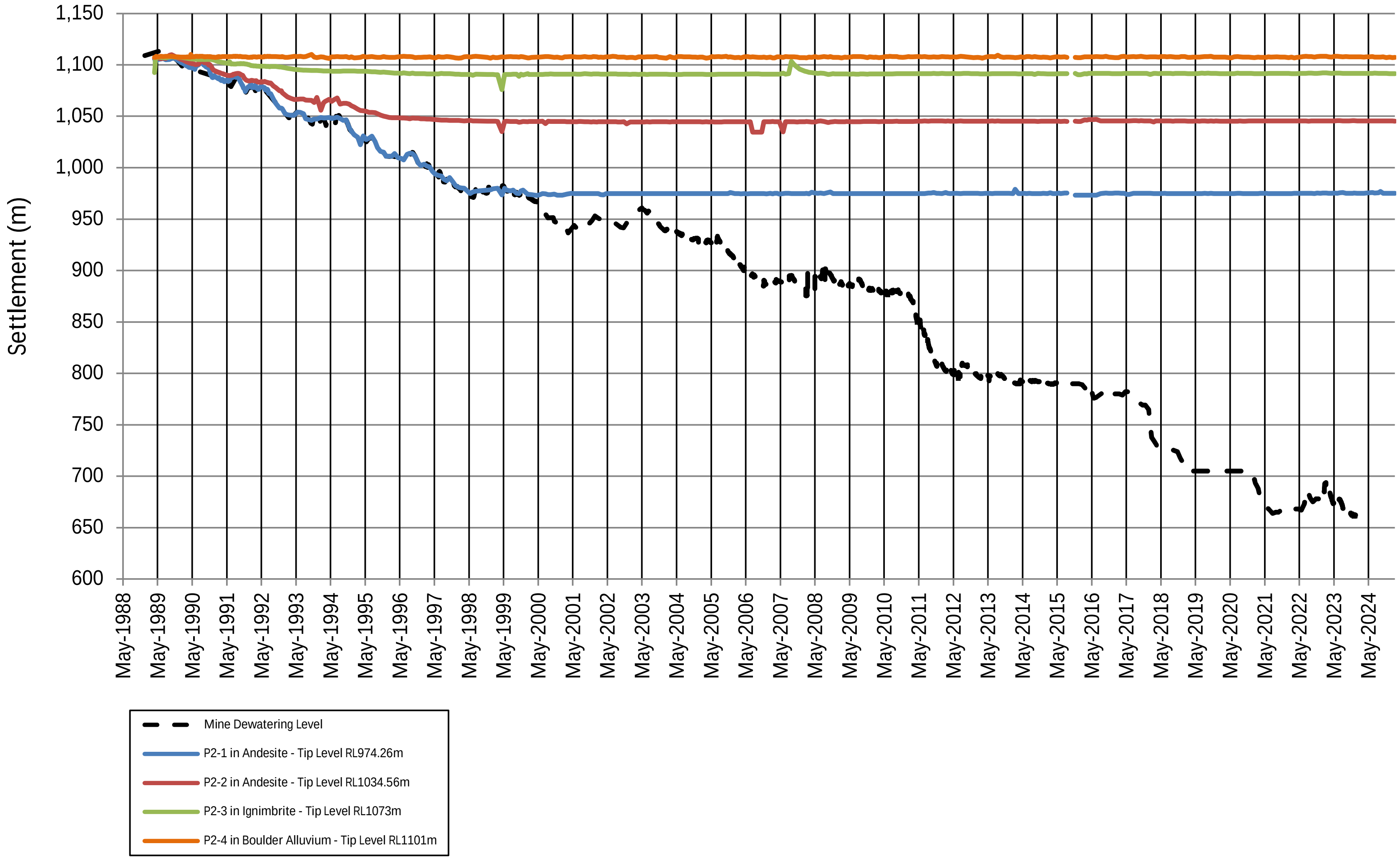

Figure 42

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OCEANA GOLD (NEW ZELAND) LTD
WAIHI NORTH PROJECT

Piezometer Readings in Borehole P2

Ref. No: 9049
Date: Feb 2025
Drawn: MC/CM
File: 9049-Piezometer

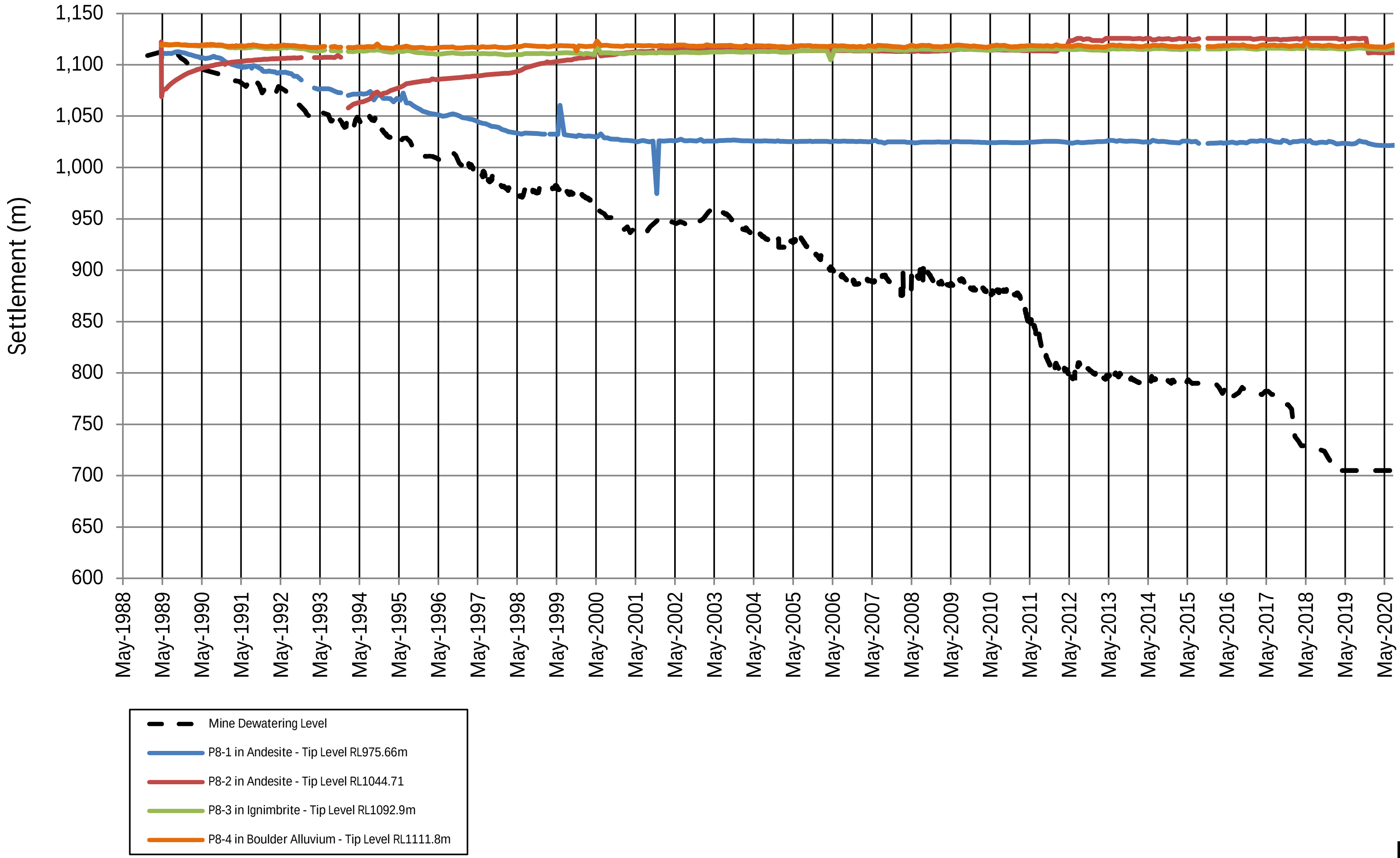
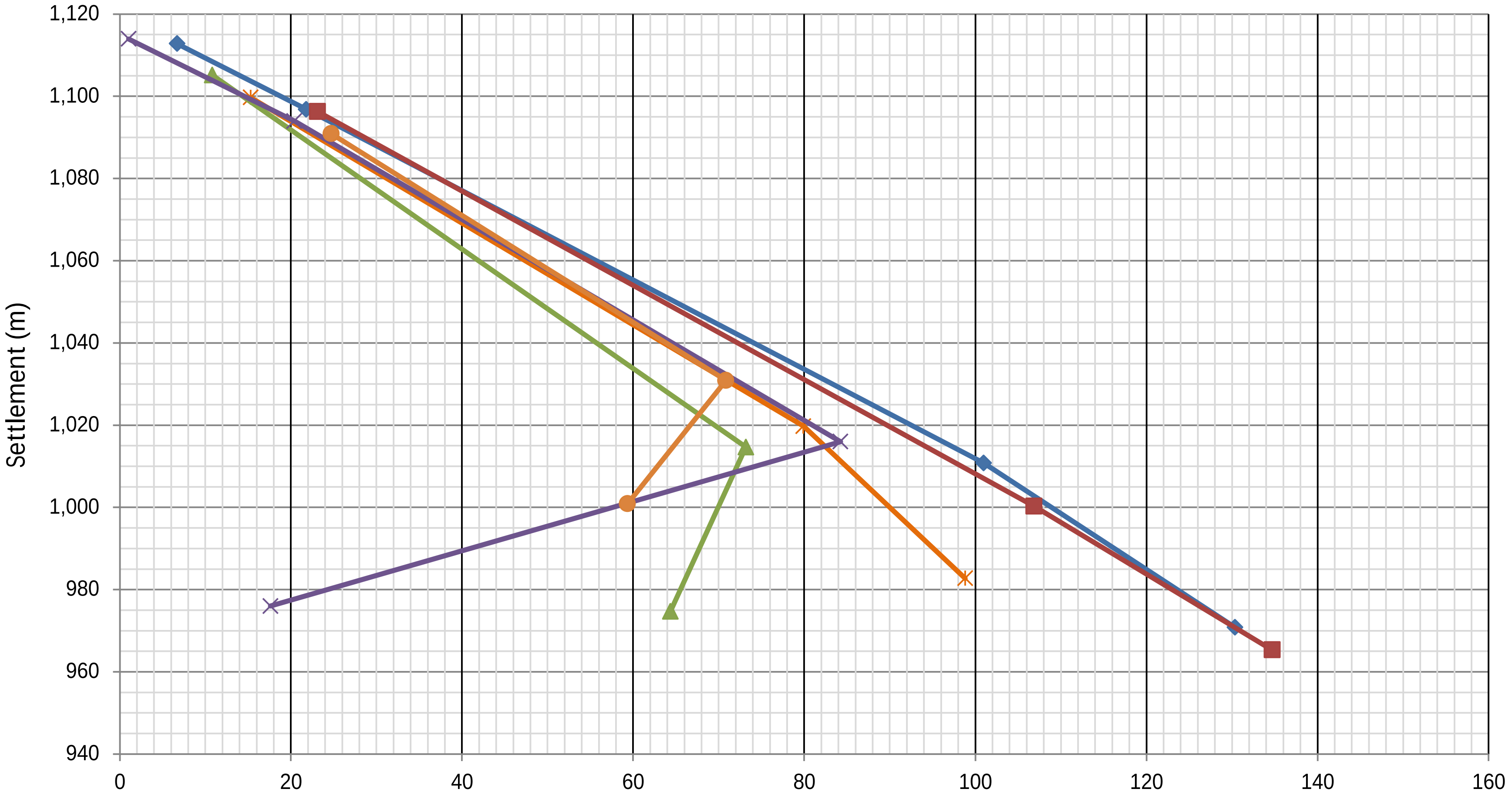


Figure 43

EGL Engineering Geology Ltd Geotechnical, Earthquake and Dam Engineers +64 9 486 2546 info@egl.co.nz Unit 7C, 331 Rosedale Road, Albany, Auckland PO Box 301054, Albany, Auckland 0752 www.egl.co.nz	**OCEANA GOLD (NEW ZELAND) LTD** WAIHI NORTH PROJECT Piezometer Readings in Borehole P8	Ref. No: 9049 Date: Feb 2025 Drawn: MC/CM File: 9049-Piezometer



Note: Data 11/02/2025

Figure 44

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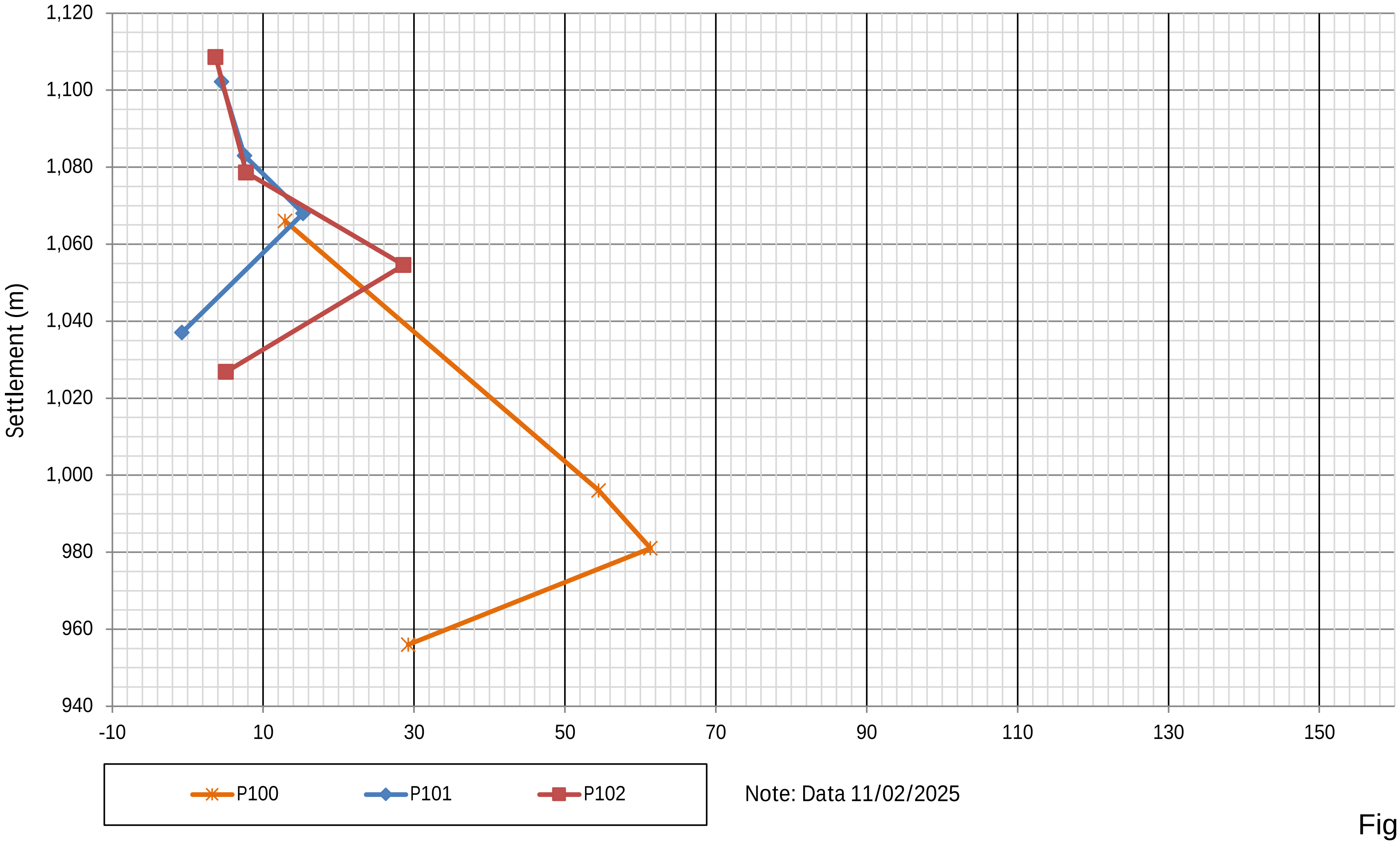
WAIHI NORTH PROJECT

Piezometer Readings in Boreholes P90-P95

Ref. No: 9049
Date: Feb 2025
Drawn: MC/CM
File: 9049-Piezometer



Note: Data 11/02/2025

Figure 45

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Piezometer Readings in Boreholes P100-P102

Ref. No: 9049
Date: Feb 2025
Drawn: MC/CM
File: 9049-Piezometer

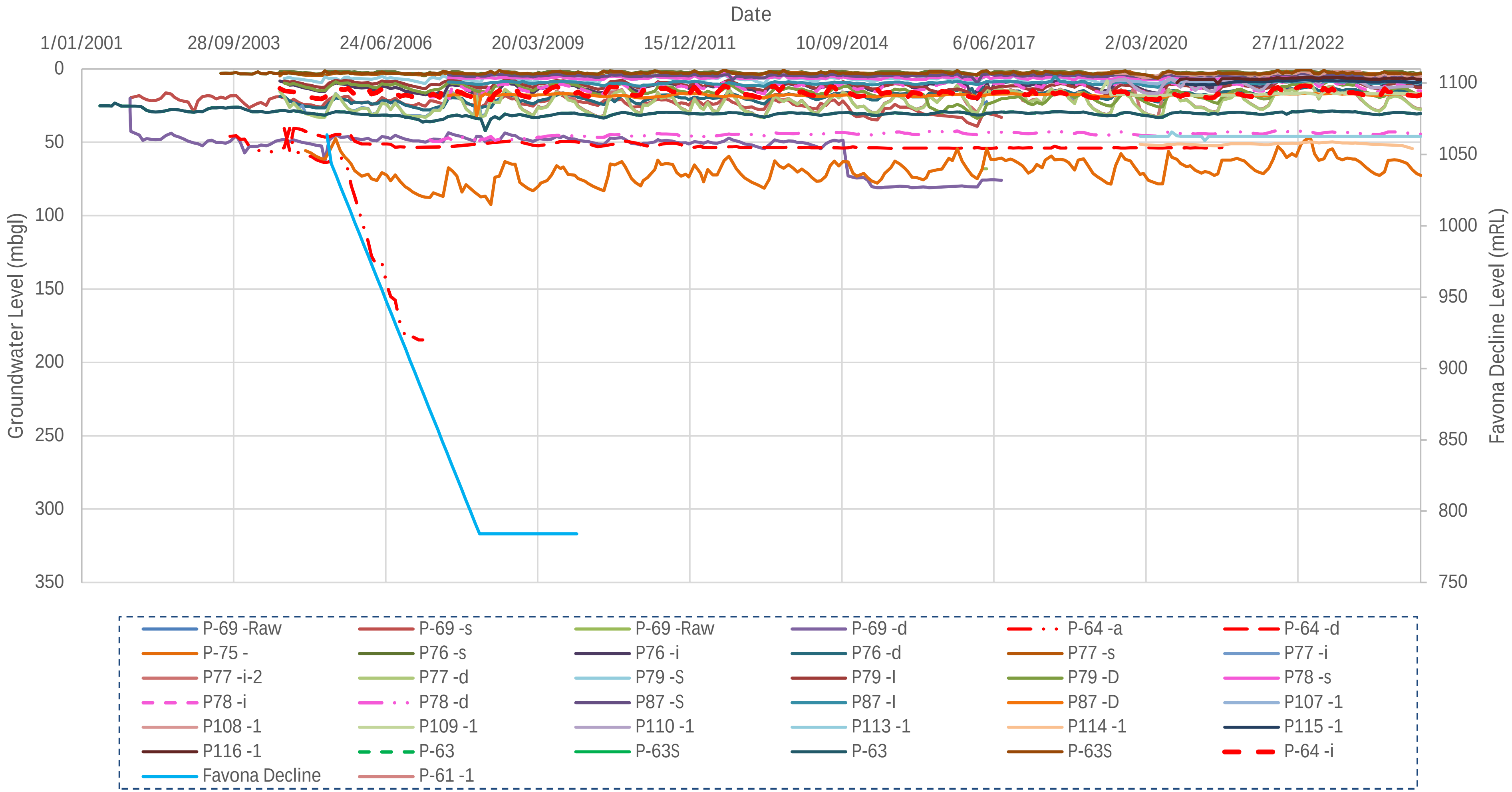

Figure 46

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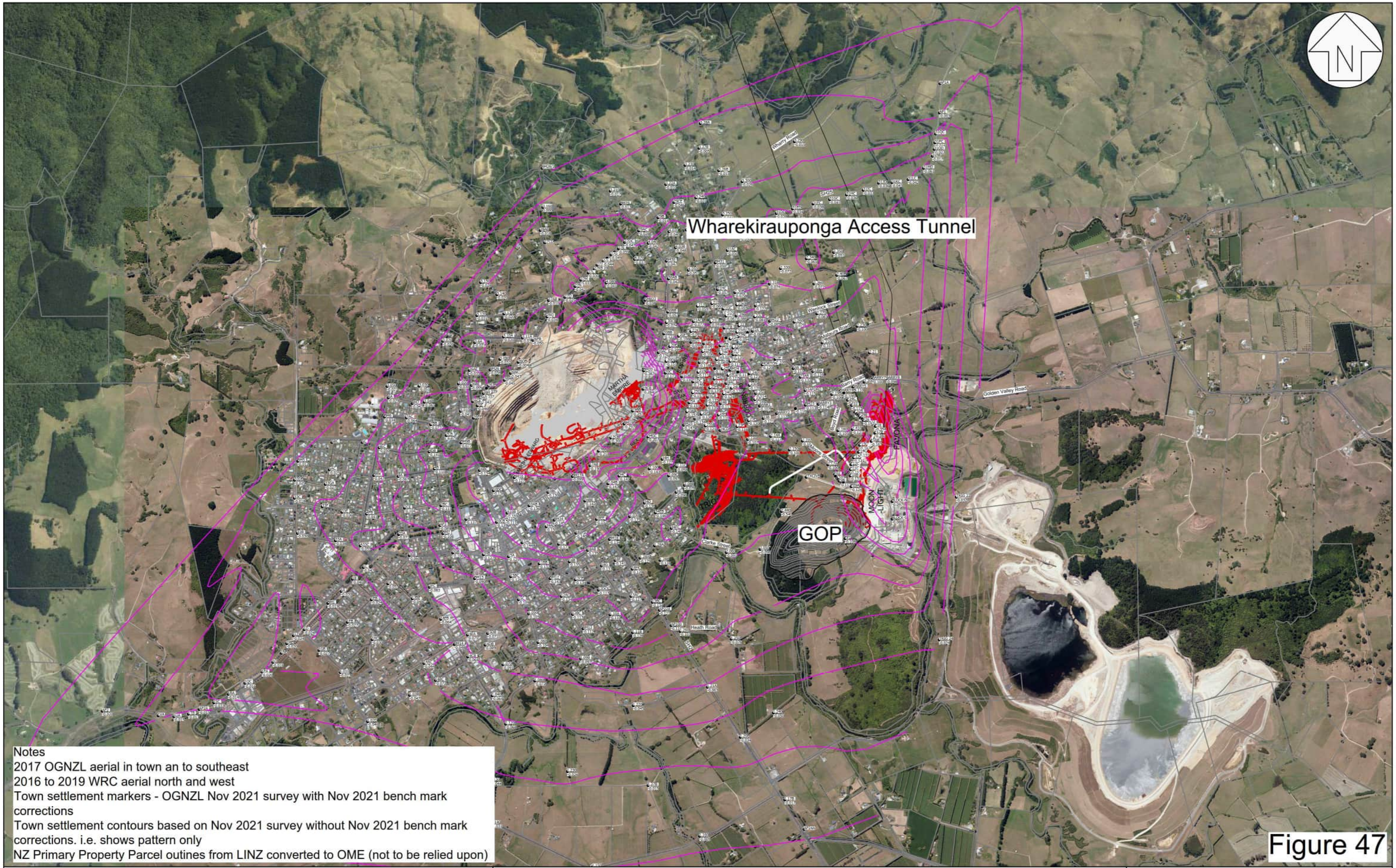
WAIHI NORTH PROJECT

Favona - Graben and Horst Piezometers

Ref. No: 9049
Date: Feb 2025
Drawn: CM/CL/ET
File: 9049-Settlement



Notes
2017 OGNZL aerial in town an to southeast
2016 to 2019 WRC aerial north and west
Town settlement markers - OGNZL Nov 2021 survey with Nov 2021 bench mark corrections
Town settlement contours based on Nov 2021 survey without Nov 2021 bench mark corrections. i.e. shows pattern only
NZ Primary Property Parcel outines from LINZ converted to OME (not to be relied upon)

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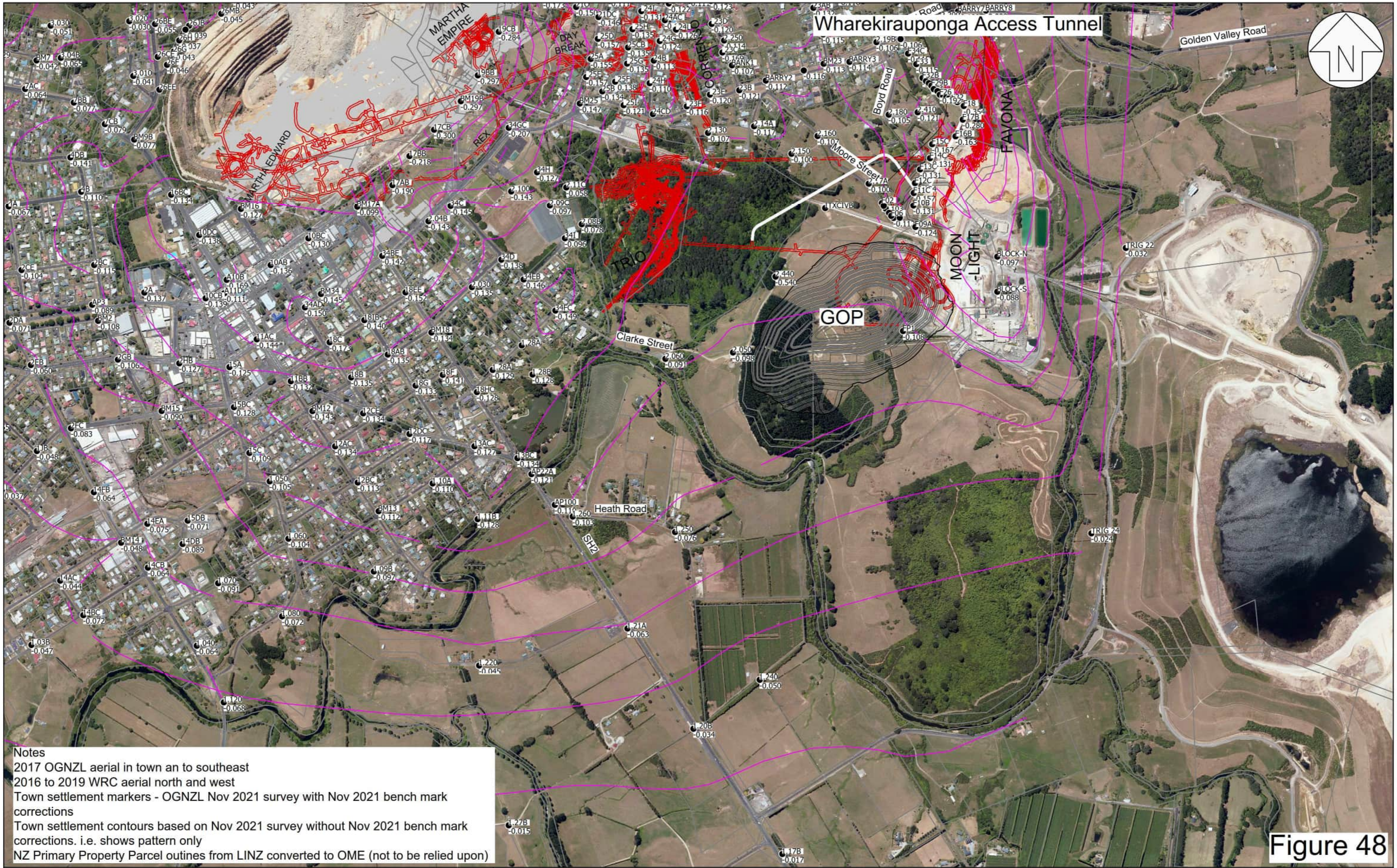
OCEANA GOLD (NEW ZEALAND) LIMITED
Waihi North Project
Ground Settlement Markers and Contours - Waihi Town Plan

Drawing No.	9049–Fig 47
Date:	13 June 2022
Drawn:	ET
Scale:	1:20000 (@A3)
Filename:	9049–Fig 47.dwg



Notes
2017 OGNZL aerial in town an to southeast
2016 to 2019 WRC aerial north and west
Town settlement markers - OGNZL Nov 2021 survey with Nov 2021 bench mark corrections
Town settlement contours based on Nov 2021 survey without Nov 2021 bench mark corrections. i.e. shows pattern only
NZ Primary Property Parcel outines from LINZ converted to OME (not to be relied upon)

Figure 48

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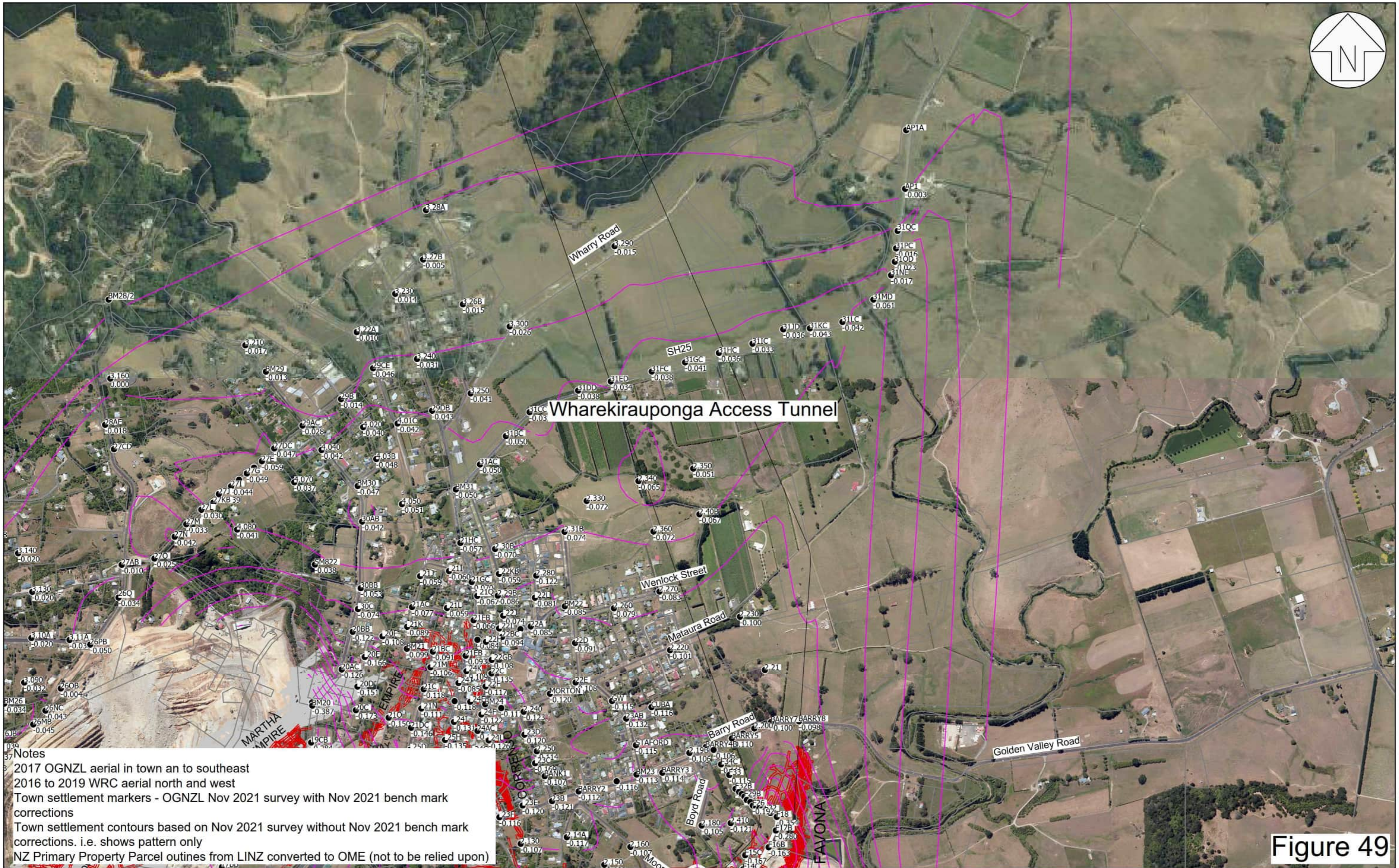
OCEANA GOLD (NEW ZEALAND) LIMITED
Waihi North Project
Ground Settlement Markers and Contours - Waihi Town Plan

Drawing No.	9049–Fig 48
Date:	13 June 2022
Drawn:	ET
Scale:	1:10000 (@A3)
Filename:	9049–Fig 47.dwg



Notes
2017 OGNZL aerial in town an to southeast
2016 to 2019 WRC aerial north and west
Town settlement markers - OGNZL Nov 2021 survey with Nov 2021 bench mark corrections
Town settlement contours based on Nov 2021 survey without Nov 2021 bench mark corrections. i.e. shows pattern only
NZ Primary Property Parcel outines from LINZ converted to OME (not to be relied upon)

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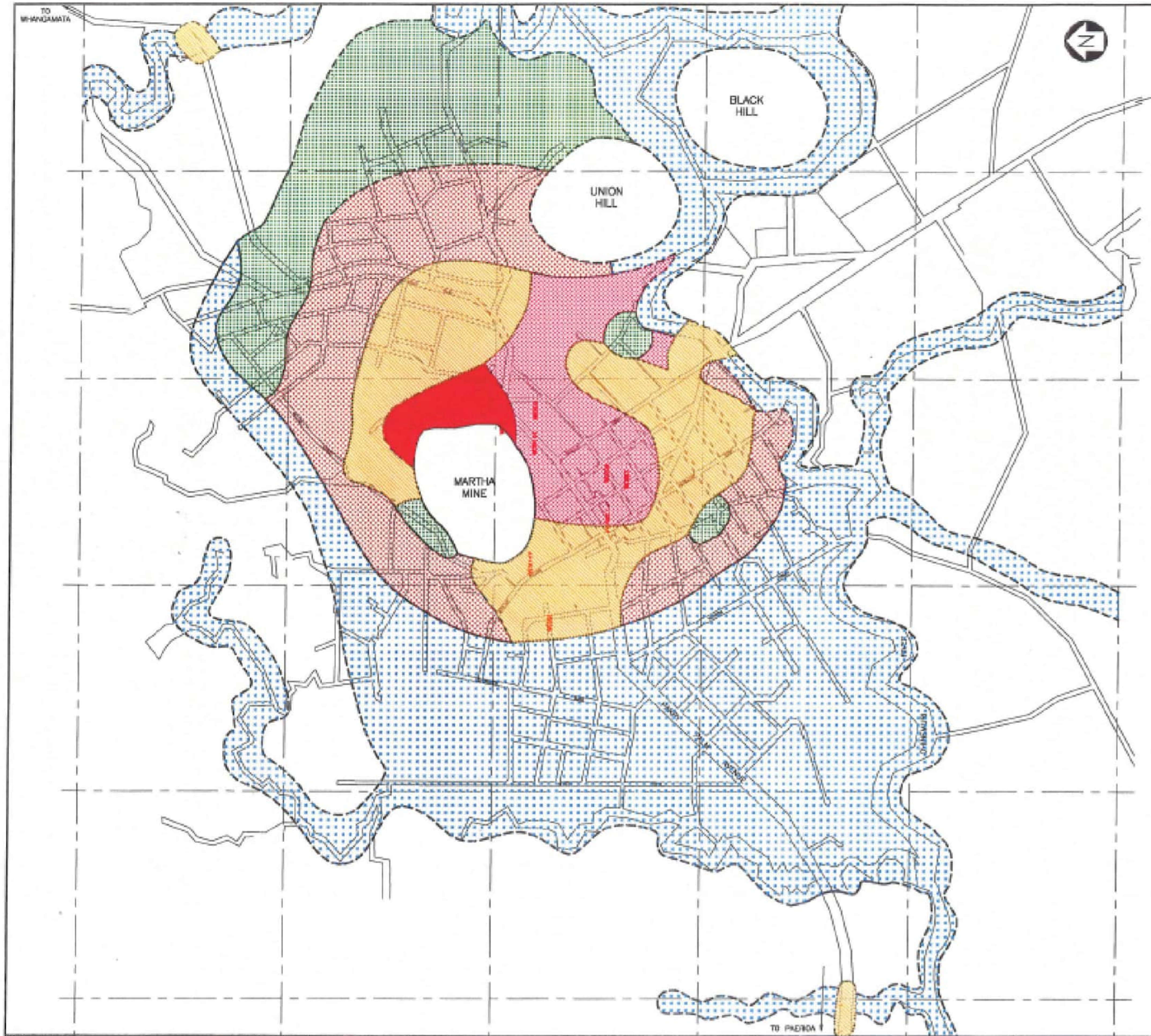
OCEANA GOLD (NEW ZEALAND) LIMITED
Waihi North Project
Ground Settlement Markers and Contours - Waihi Town Plan

Drawing No.	9049–Fig 49
Date:	13 June 2022
Drawn:	ET
Scale:	1:10000 (@A3)
Filename:	9049–Fig 47.dwg



SUMMARY OF THE MEASURED SETTLEMENT WITHIN THE SEVEN SETTLEMENT ZONES.

ZONE	RANGE OF SETTLEMENT (mm) MEASURED TO MAY 1997.	AVERAGE NET SETTLEMENT (mm) MEASURED TO MAY 1997.	MEASURED CYCLIC FLUCTUATION IN GROUND SURFACE (mm)*
1	+2 to −10	0	±3
2	+10 to −10	0	±10
3	0 to −25	15	±5
4	−15 to −35	25	±6
5	−25 to −50	45	±9
6	−55 to −85	65	±6
7	−95 to −125	110	±9

* +ve indicates surface heave
−ve indicates surface settlement

Figure 50

REV	DESCRIPTION OF REVISION	BY	CHK	DATE
A	FINAL − RE-ISSUE OF DWG2J205\05\01\6400\WA05R016	SCG		13NOV97

WAIHI GOLD COMPANY

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ENGINEERING & ENVIRONMENTAL CONSULTANTS
Woodward-Clyde (NZ) Ltd
385 QUEEN STREET
AUCKLAND, NEW ZEALAND
phone: (09) 379 3515 fax: (09) 379 7550

XREF FILES: WG50R52
VIEW NAME:
CAD FILE NAME: U:\~\0232\05\20\6400\WA05R107
MILLIMETRES WHEN PRINTED FULL SIZE
SCALES: 1:10 000(A1) 1:20 000 (A3)
DESIGNED / DRAWN / CHECKED / PEER REVIEWED / PROJECT MANAGER / DATE

MARTHA MINE, WAIHI

PLAN OF SETTLEMENT ZONES WITHIN WAIHI TOWNSHIP AS AT DECEMBER 1995

STATUS: FINAL
REVISION: A
DRAWING NUMBER: Figure 8

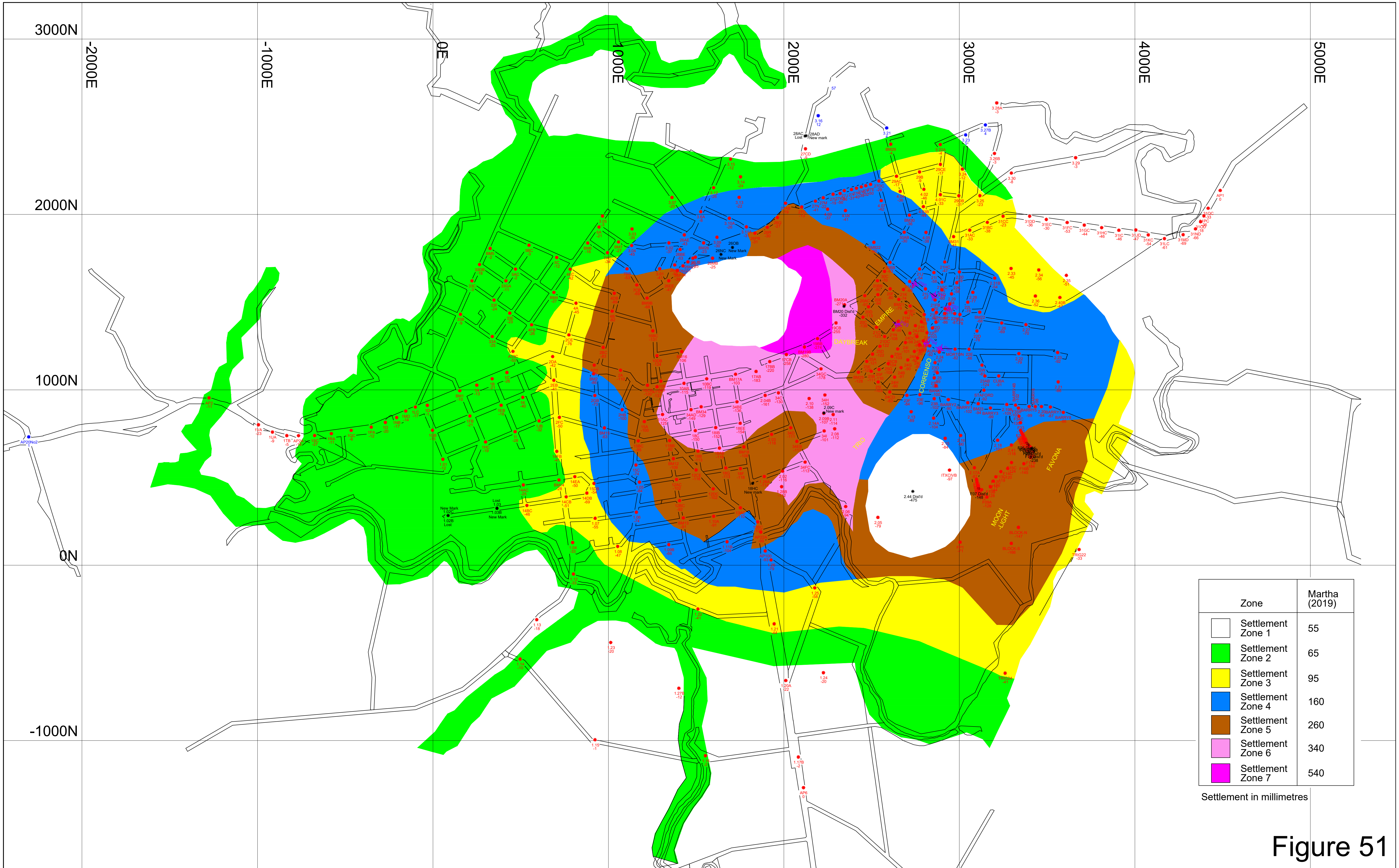

Figure 51

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OCEANA GOLD NZ LIMITED - WAIHI
Project Martha
Settlement Zones

Drawing No.	8332–Fig16
Date:	2 Feb 2018
Drawn:	JL
Scale:	1:20000 (@A3)
Filename:	8332–Fig16.dwg

Figure 52

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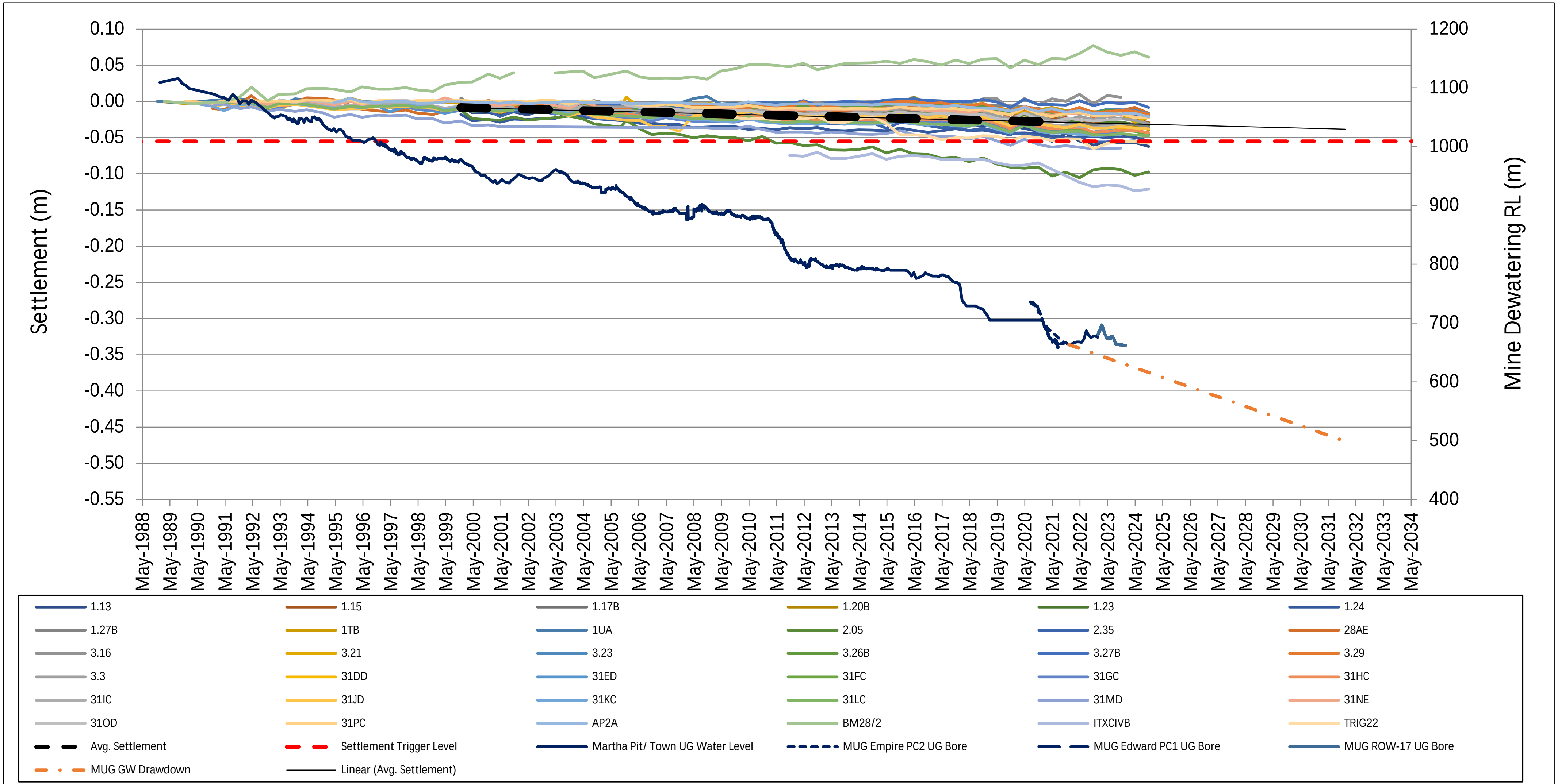
OCEANA GOLD (NEW ZEALAND) LTD
WAIHI NORTH PROJECT
Settlement marks exceeding Project Martha trigger levels in November 2023

Ref. No: 9049
Date: Feb 2025
Drawn: OGNZL



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WAIHI NORTH PROJECT

Ground Settlement - Zone 1

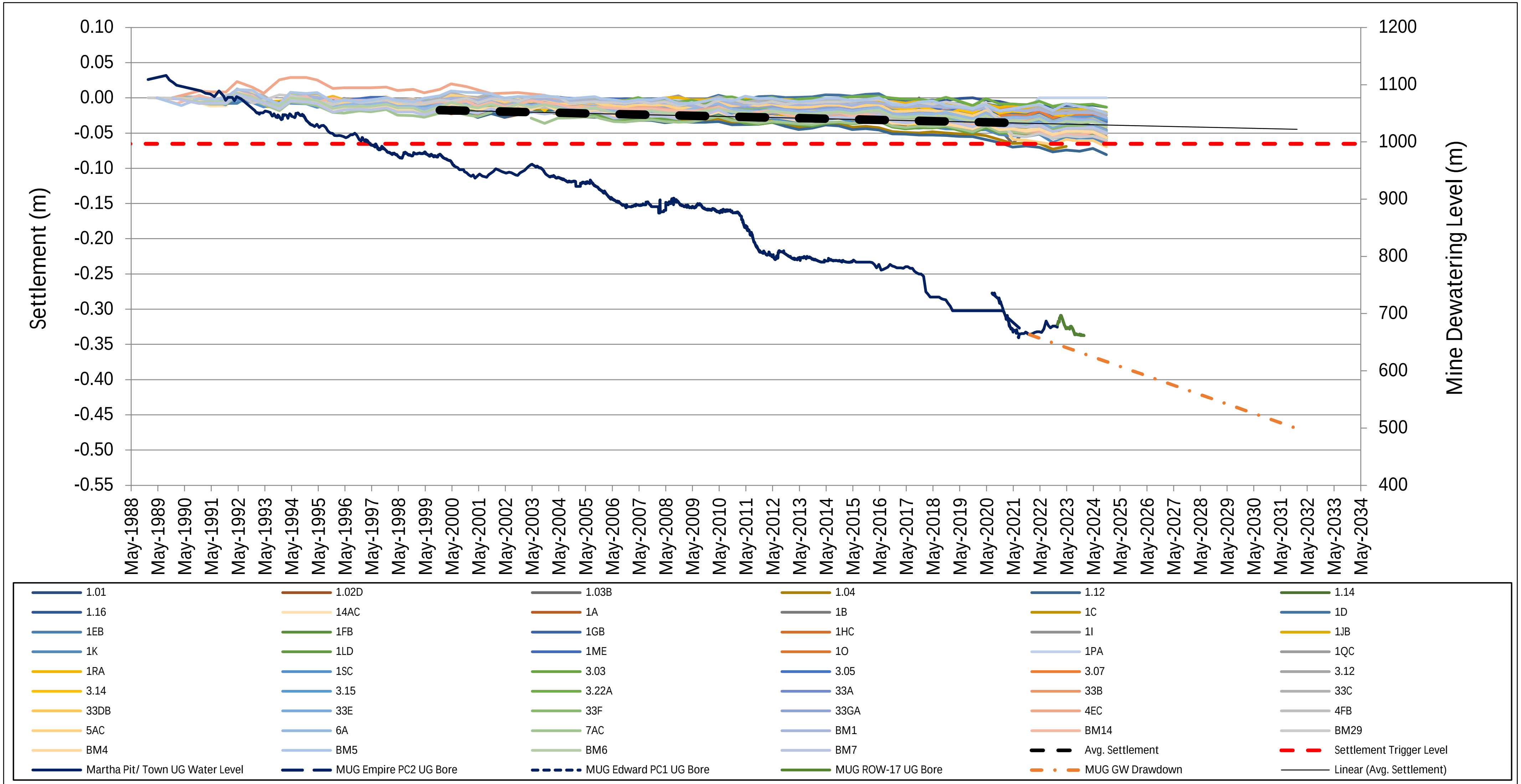
Settlement Trigger Level 55mm

Figure 53

Ref. No: 9049

Date: Feb 2025

Drawn: CM/CL/ET



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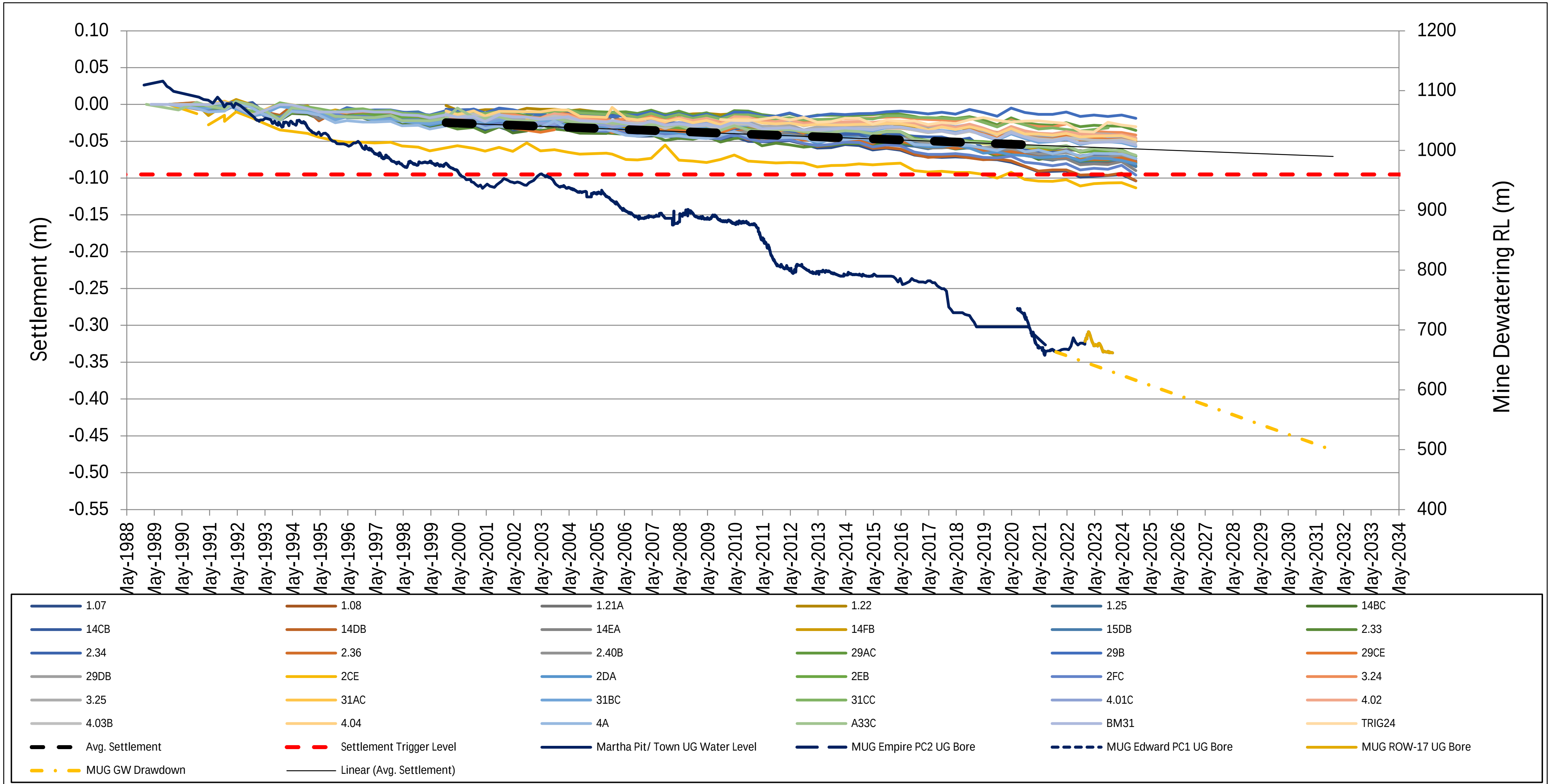
OCEANA GOLD (NEW ZELAND) LTD
WAIHI NORTH PROJECT
Ground Settlement - Zone 2
Settlement Trigger Level 65mm

Figure 54
Ref. No: 9049
Date: Feb 2025
Drawn: CM/CL/ET



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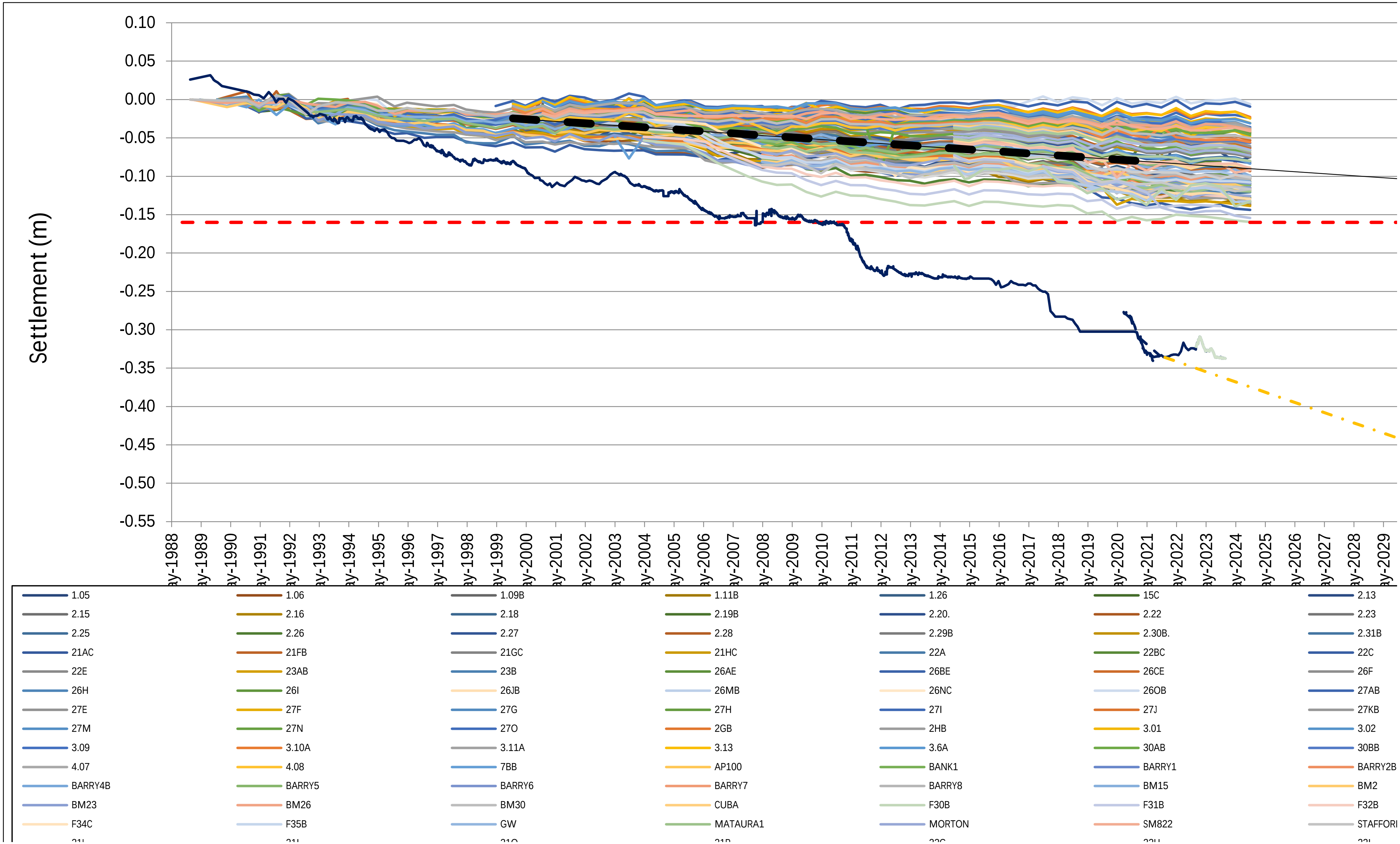
OCEANA GOLD (NEW ZELAND) LTD
WAIHI NORTH PROJECT
Ground Settlement - Zone 3
Settlement Trigger Level 95mm

Figure 55
Ref. No: 9049
Date: Feb 2025
Drawn: CM/CL/ET



Settlement (m)
0.10
0.05
0.00
-0.05
-0.10
-0.15
-0.20
-0.25
-0.30
-0.35
-0.40
-0.45
-0.50
-0.55
ay-1988
ay-1989
ay-1990
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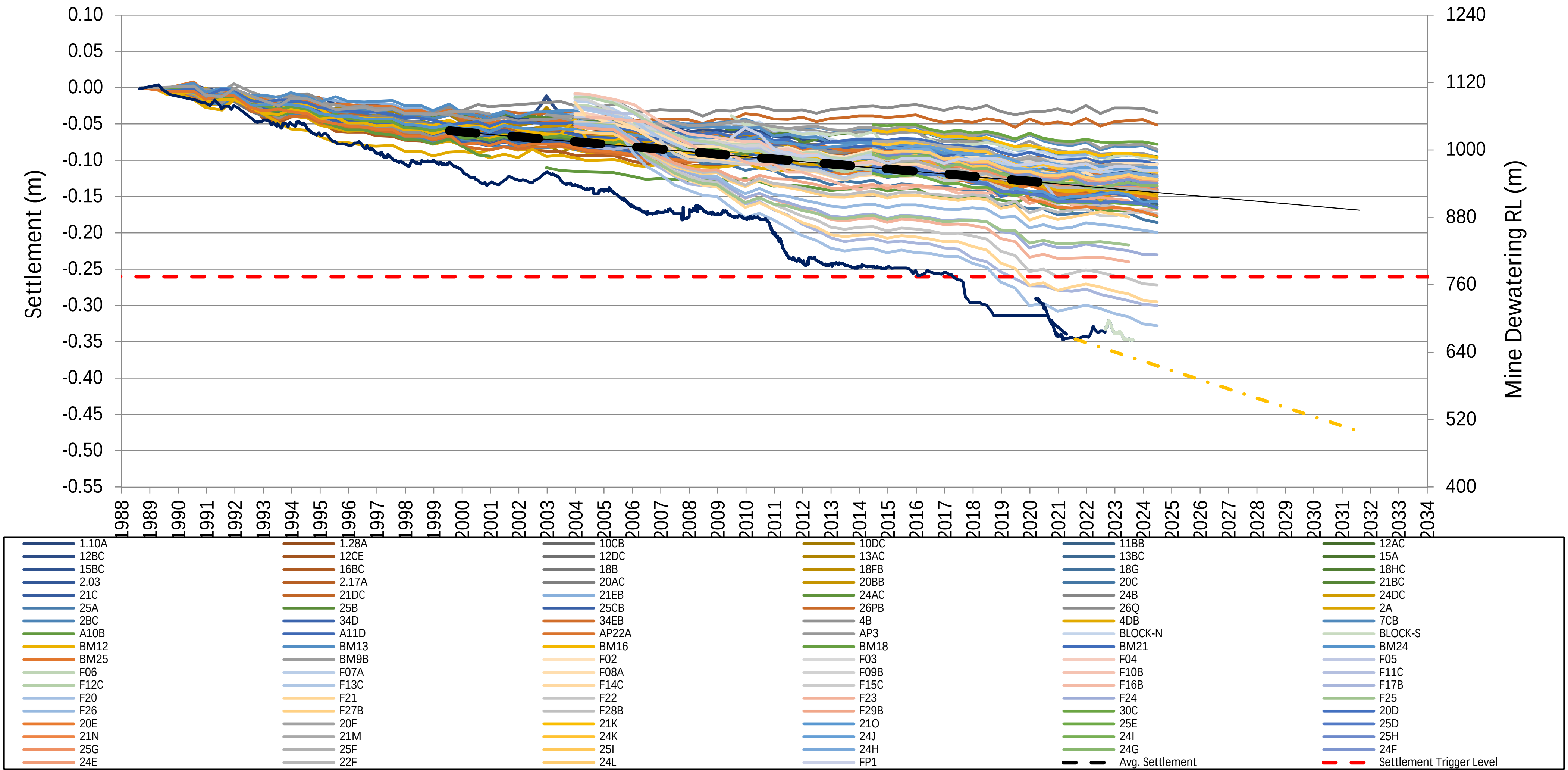
ay-2028
ay-2029
1.05
1.06
1.09B
1.11B
1.26
15C
2.13
2.15
2.16
2.18
2.19B
2.20.
2.22
2.23
2.25
2.26
2.27
2.28
2.29B
2.30B.
2.31B
21AC
21FB
21GC
21HC
22A
22BC
22C
22E
23AB
23B
26AE
26BE
26CE
26F
26H
26I
26JB
26MB
26NC
26OB
27AB
27E
27F
27G
27H
27I
27J
27KB
27M
27N
27O
2GB
2HB
3.01
3.02
3.09
3.10A
3.11A
3.13
3.6A
30AB
30BB
4.07
4.08
7BB
AP100
BANK1
BARRY1
BARRY2B
BARRY4B
BARRY5
BARRY6
BARRY7
BARRY8
BM15
BM2
BM23
BM26
BM30
CUBA
F30B
F31B
F32B
F34C
F35B
GW
MATAURA1
MORTON
SM822
STAFFORI



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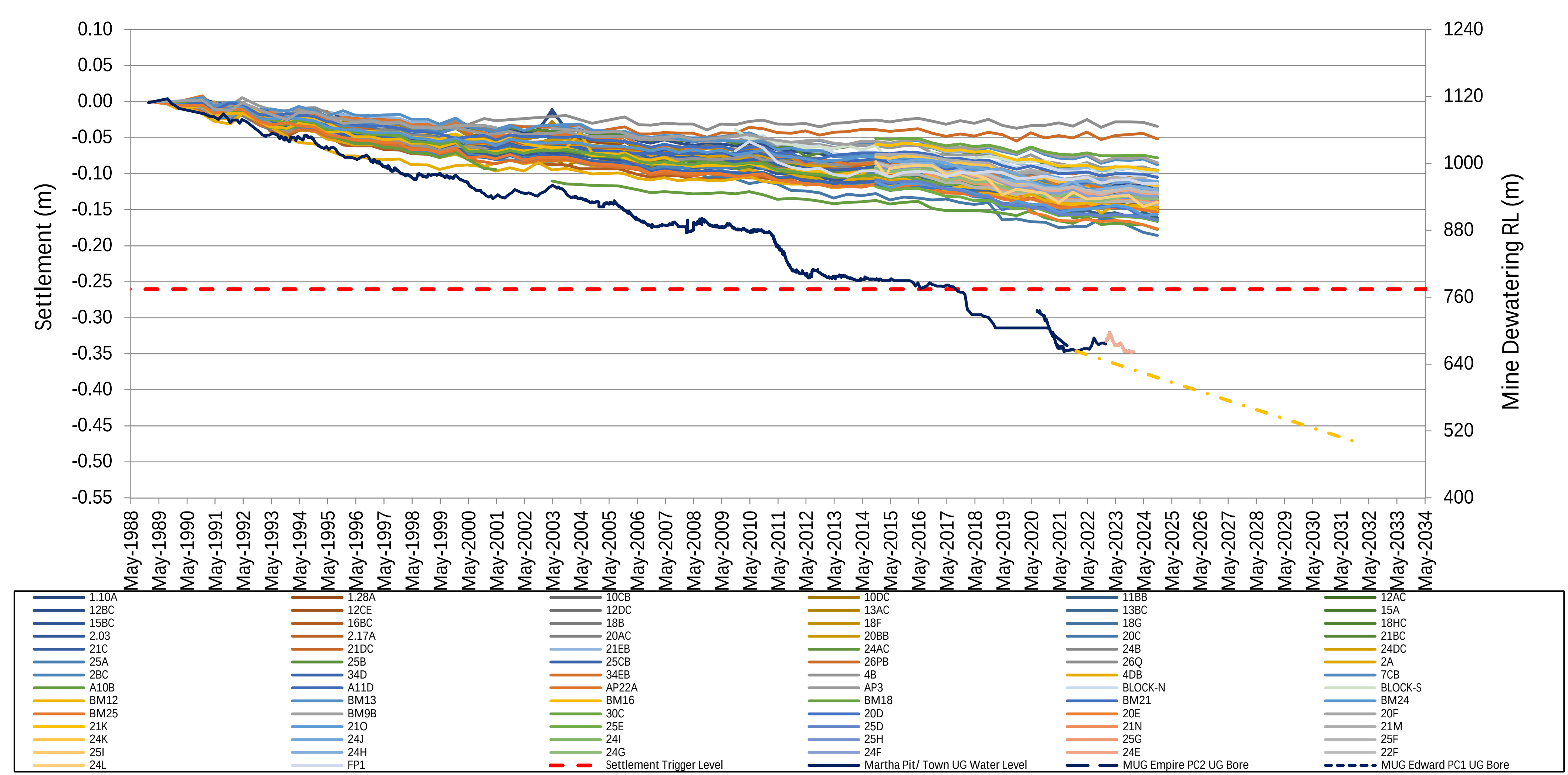
OCEANA GOLD (NEW ZELAND) LTD
WAIHI NORTH PROJECT
Ground Settlement - Zone 5

Figure 57
Ref. No: 9049
Date: Feb 2025
Drawn: CM/CL/ET



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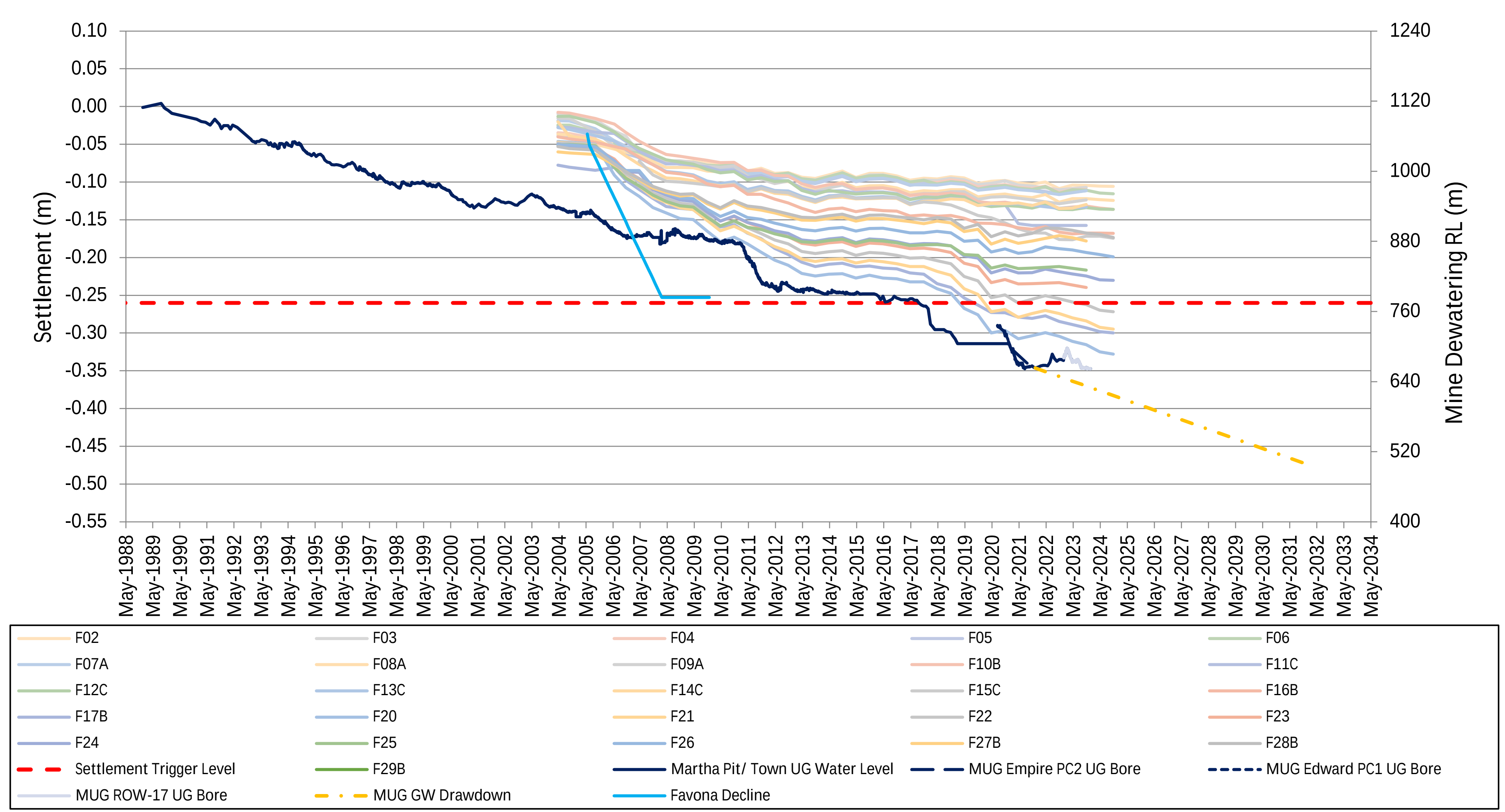
OCEANA GOLD (NEW ZELAND) LTD
WAIHI NORTH PROJECT
Ground Settlement - Zone 5 (Excl. Favona Points)

Figure 58
Ref. No: 9049
Date: Feb 2025
Drawn: CM/CL/ET



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WAIHI NORTH PROJECT

Ground Settlement - Zone 5 (Favona Points Only)

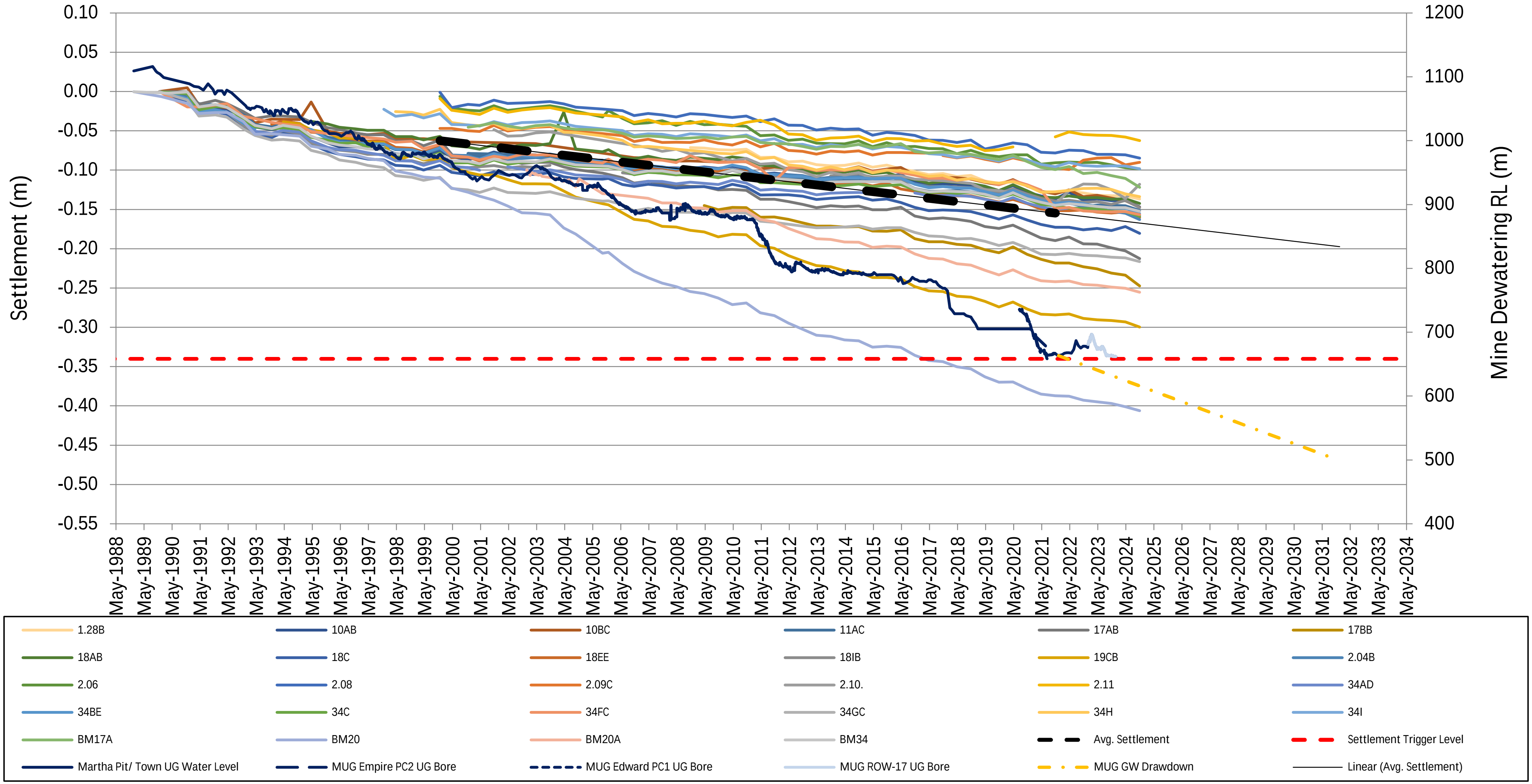
Settlement Trigger Level 260mm

Figure 59

Ref. No: 9049

Date: Feb 2025

Drawn: CM/CL/ET



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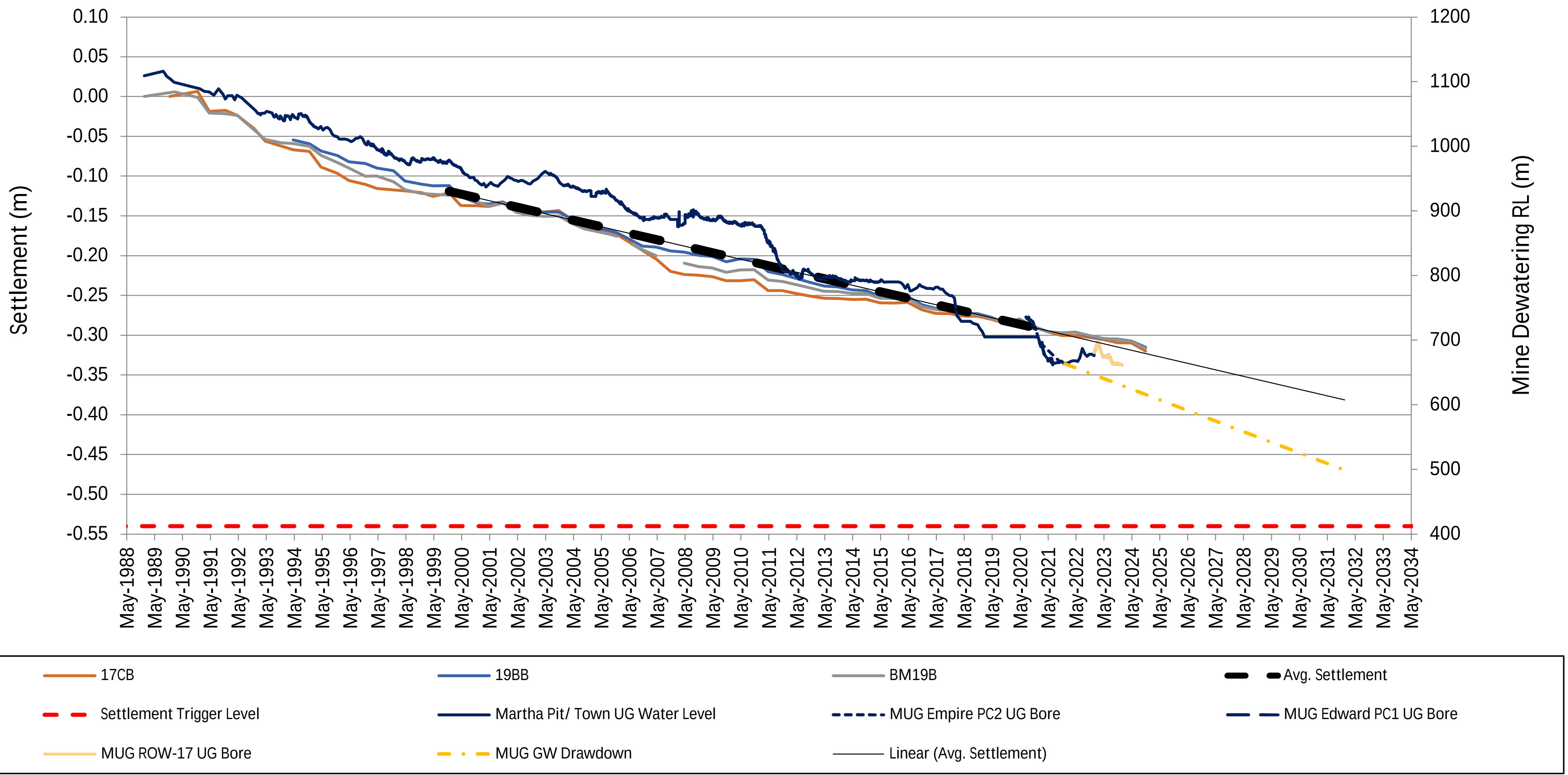
OCEANA GOLD (NEW ZELAND) LTD
WAIHI NORTH PROJECT
Ground Settlement - Zone 6
Settlement Trigger Level 340mm

Figure 60
Ref. No: 9049
Date: Feb 2025
Drawn: CM/CL/ET
File: 9049-Settlement



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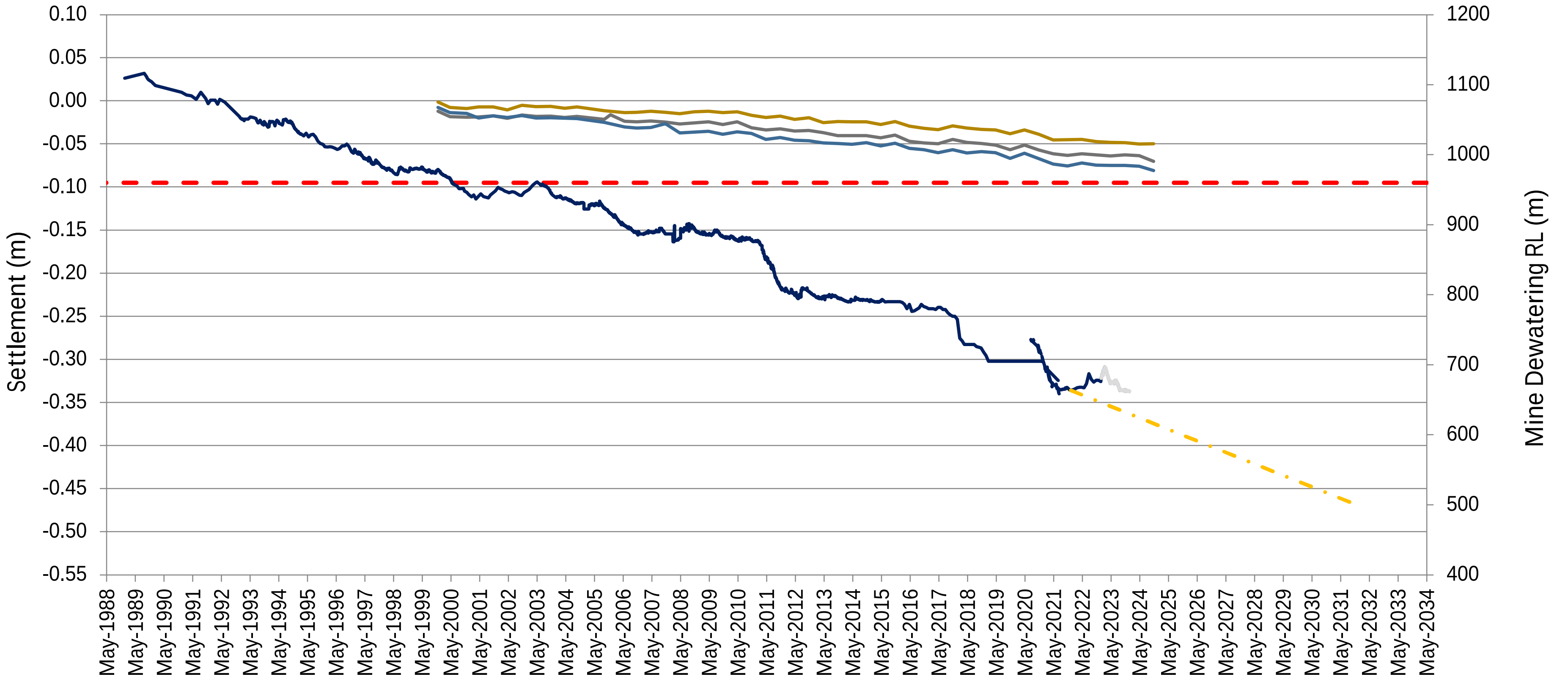
OCEANA GOLD (NEW ZELAND) LTD
WAIHI NORTH PROJECT
Ground Settlement - Zone 7
Settlement Trigger Level 540mm

Figure 61
Ref. No: 9049
Date: Feb 2025
Drawn: CM/CL/ET
File: 9049-Settlement



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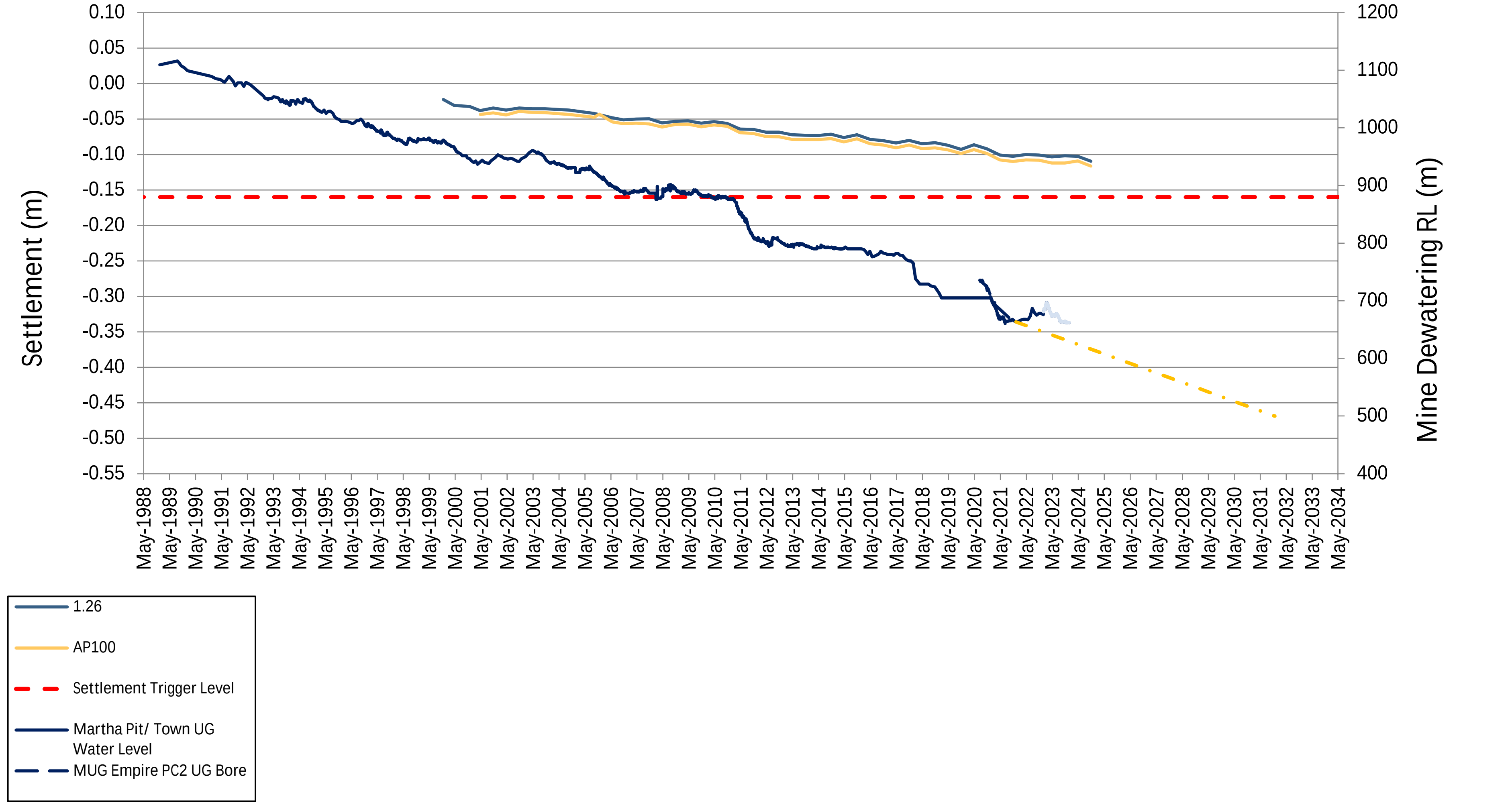
OCEANA GOLD (NEW ZELAND) LTD
WAIHI NORTH PROJECT
Ground Settlement - Zone 3 - South of GOP
Settlement Trigger Level 95mm

Figure 62
Ref. No: 9049
Date: Feb 2025
Drawn: CM/CL/ET
File: 9049-Settlement



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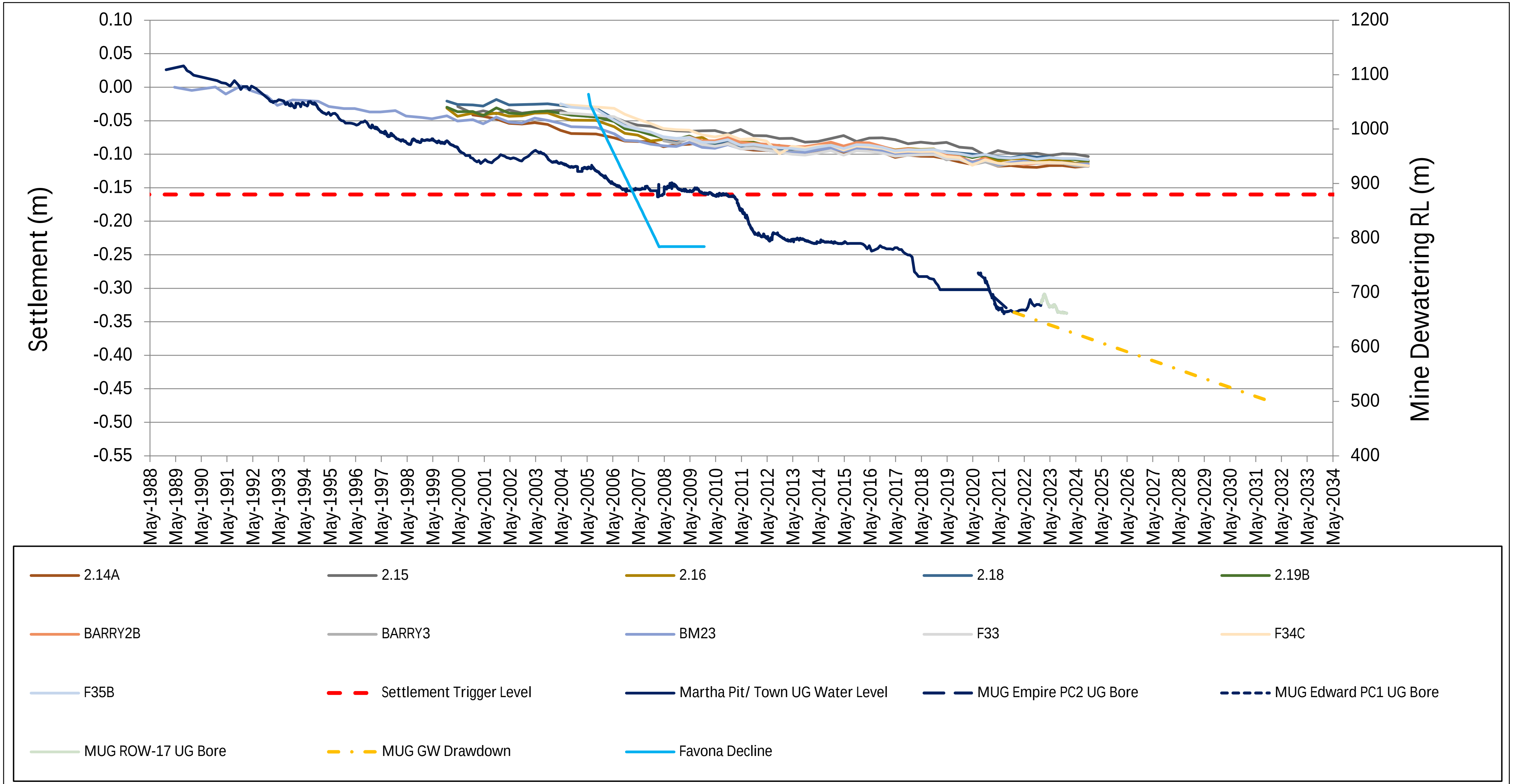
OCEANA GOLD (NEW ZELAND) LTD
WAIHI NORTH PROJECT
Ground Settlement - Zone 4 (South of GOP)
Settlement Trigger Level 160mm

Figure 63
Ref. No: 9049
Date: Feb 2025
Drawn: CM/CL/ET



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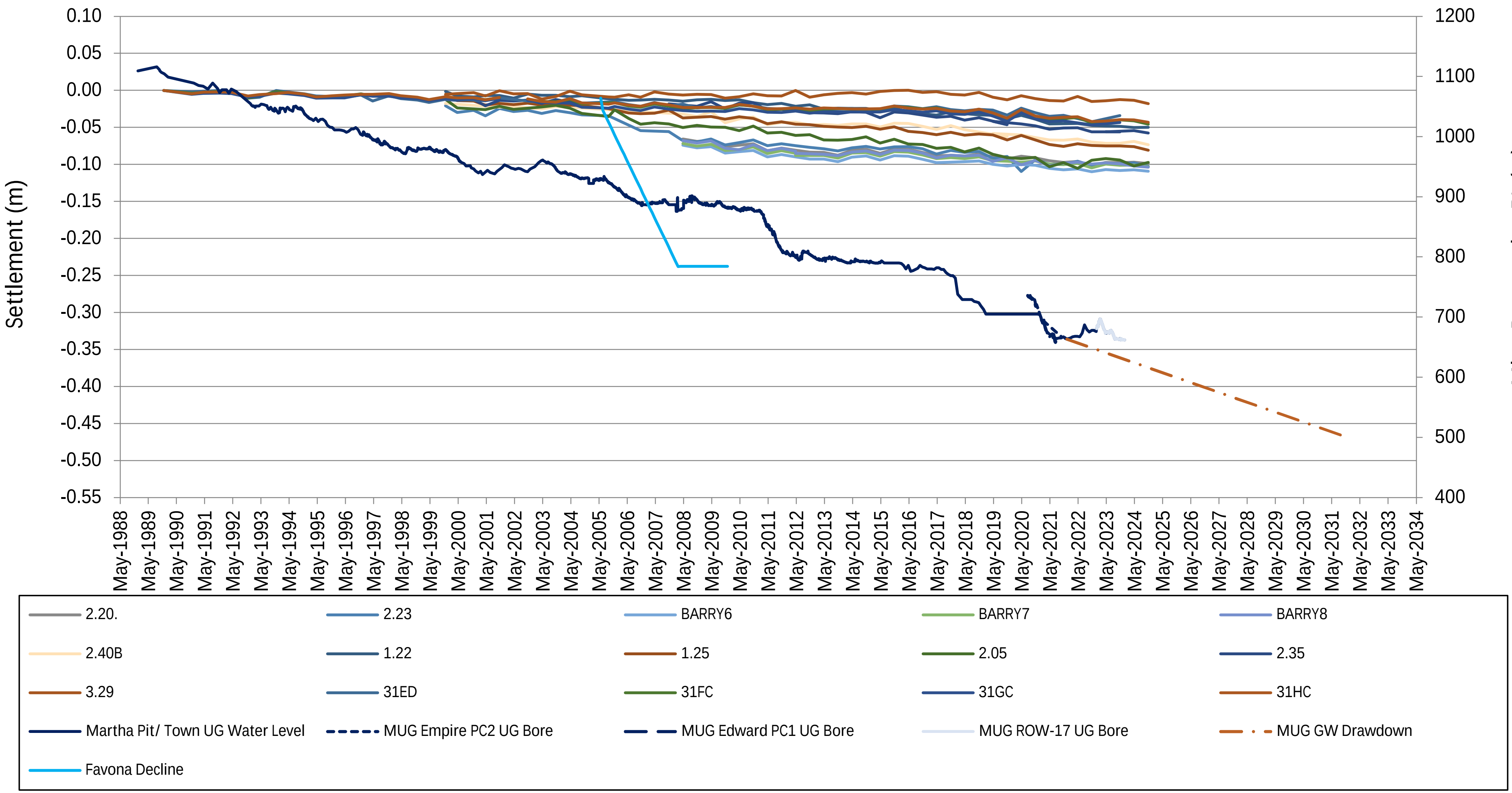
OCEANA GOLD (NEW ZELAND) LTD
WAIHI NORTH PROJECT
Ground Settlement - Zone 4 (Moore Street & Boyd Road Area)
Settlement Trigger Level 160mm

Figure 64
Ref. No: 9049
Date: Feb 2025
Drawn: CM/CL/ET
File: 9049-Settlement



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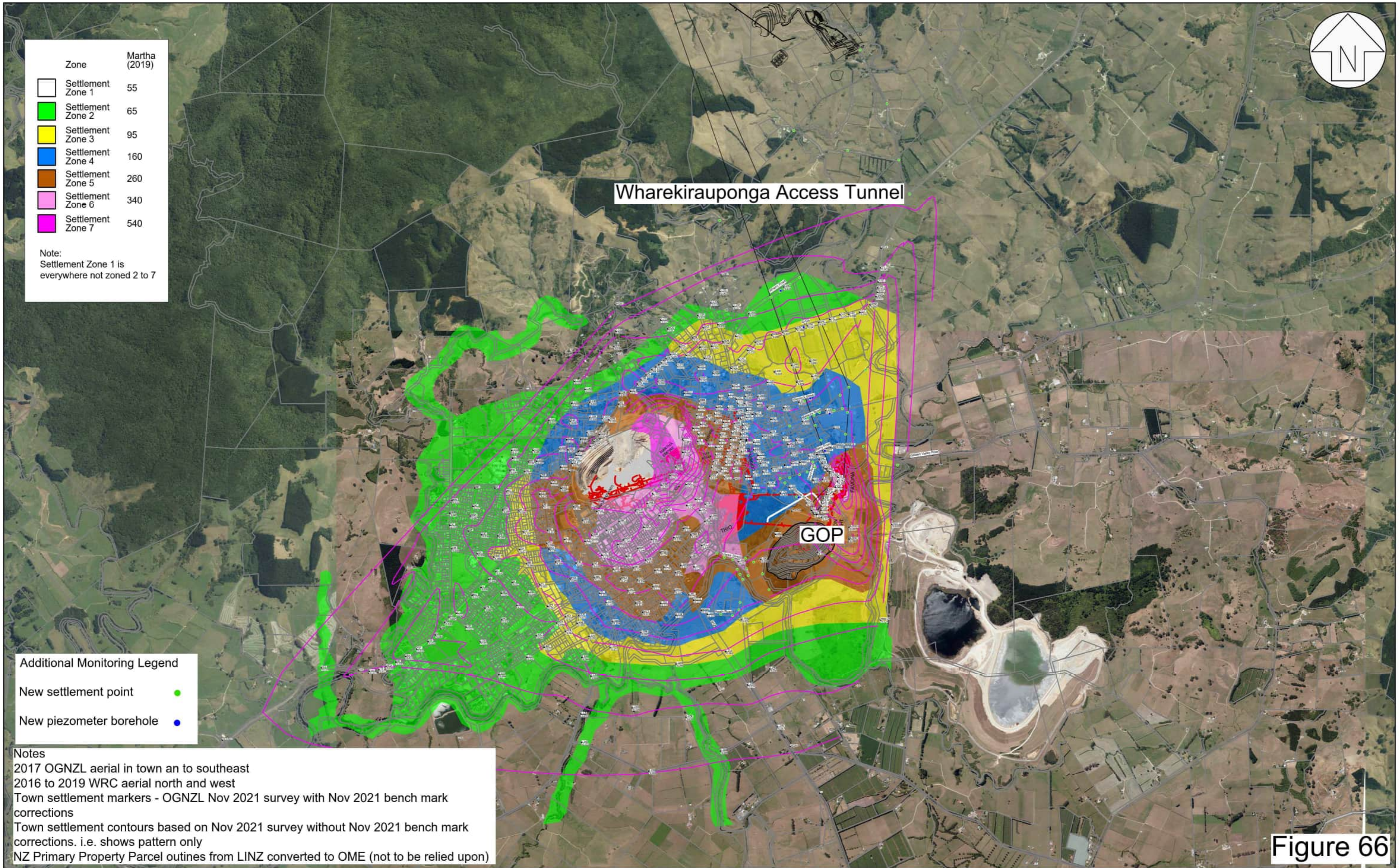
OCEANA GOLD (NEW ZELAND) LTD
WAIHI NORTH PROJECT
Ground Settlement - Points in proposed Wharekirauponga Access Tunnel

Figure 65
Ref. No: 9049
Date: June 2025
Drawn: CM/CL/ET
File: 9049-Settlement



Notes
2017 OGNZL aerial in town an to southeast
2016 to 2019 WRC aerial north and west
Town settlement markers - OGNZL Nov 2021 survey with Nov 2021 bench mark corrections
Town settlement contours based on Nov 2021 survey without Nov 2021 bench mark corrections. i.e. shows pattern only
NZ Primary Property Parcel outines from LINZ converted to OME (not to be relied upon)

Figure 66

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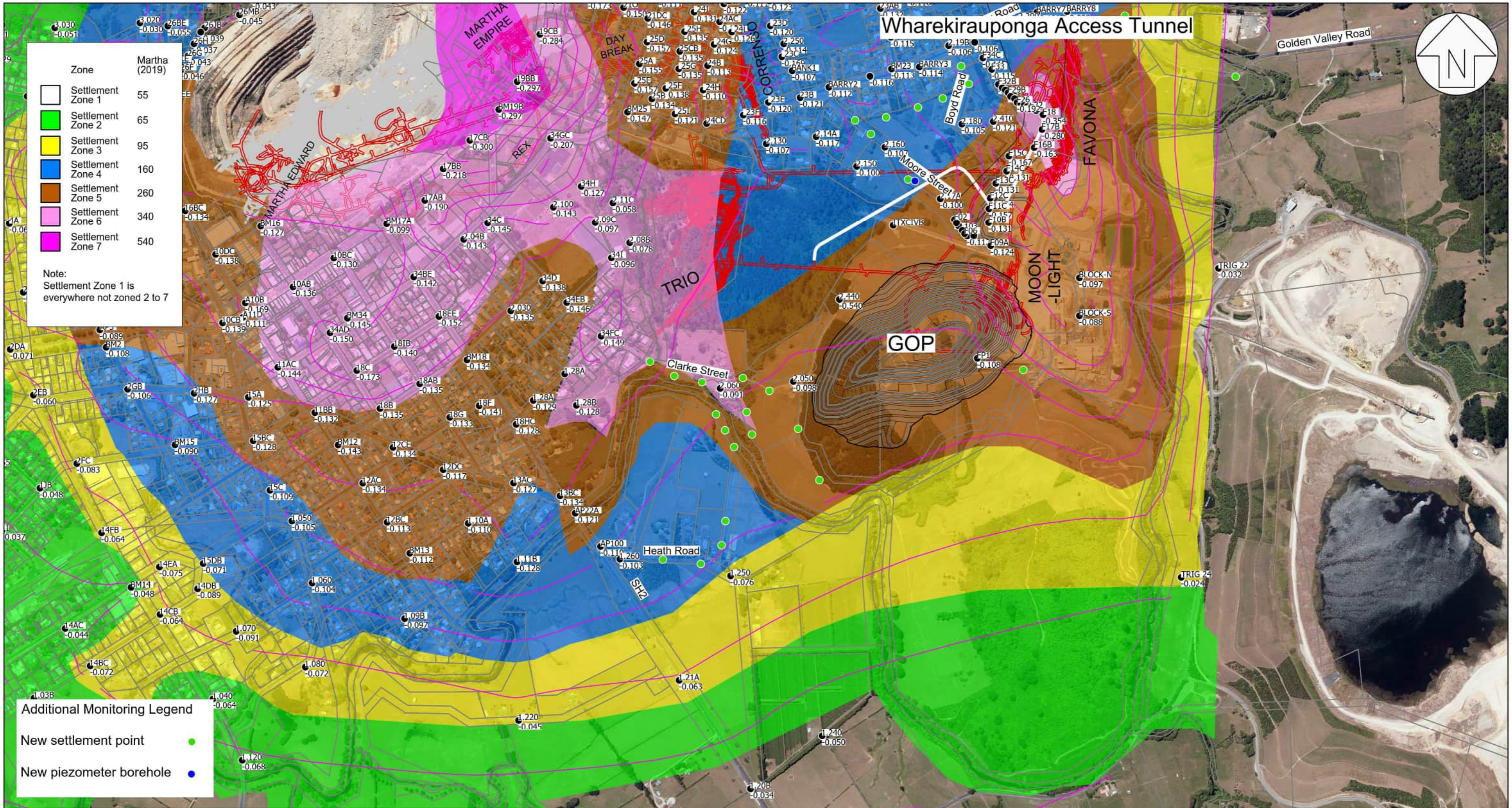
OCEANA GOLD (NEW ZEALAND) LIMITED
Waihi North Project
Draft arrangement of proposed additional monitoring locations

Drawing No.	9049–Fig 66
Date:	13 June 2022
Drawn:	ET
Scale:	1:30000 (@A3)
Filename:	9049–Fig 47.dwg



Notes
2017 OGNZL aerial in town an to southeast
2016 to 2019 WRC aerial north and west
Town settlement markers - OGNZL Nov 2021 survey with Nov 2021 bench mark corrections
Town settlement contours based on Nov 2021 survey without Nov 2021 bench mark corrections. i.e. shows pattern only
NZ Primary Property Parcel outines from LINZ converted to OME (not to be relied upon)

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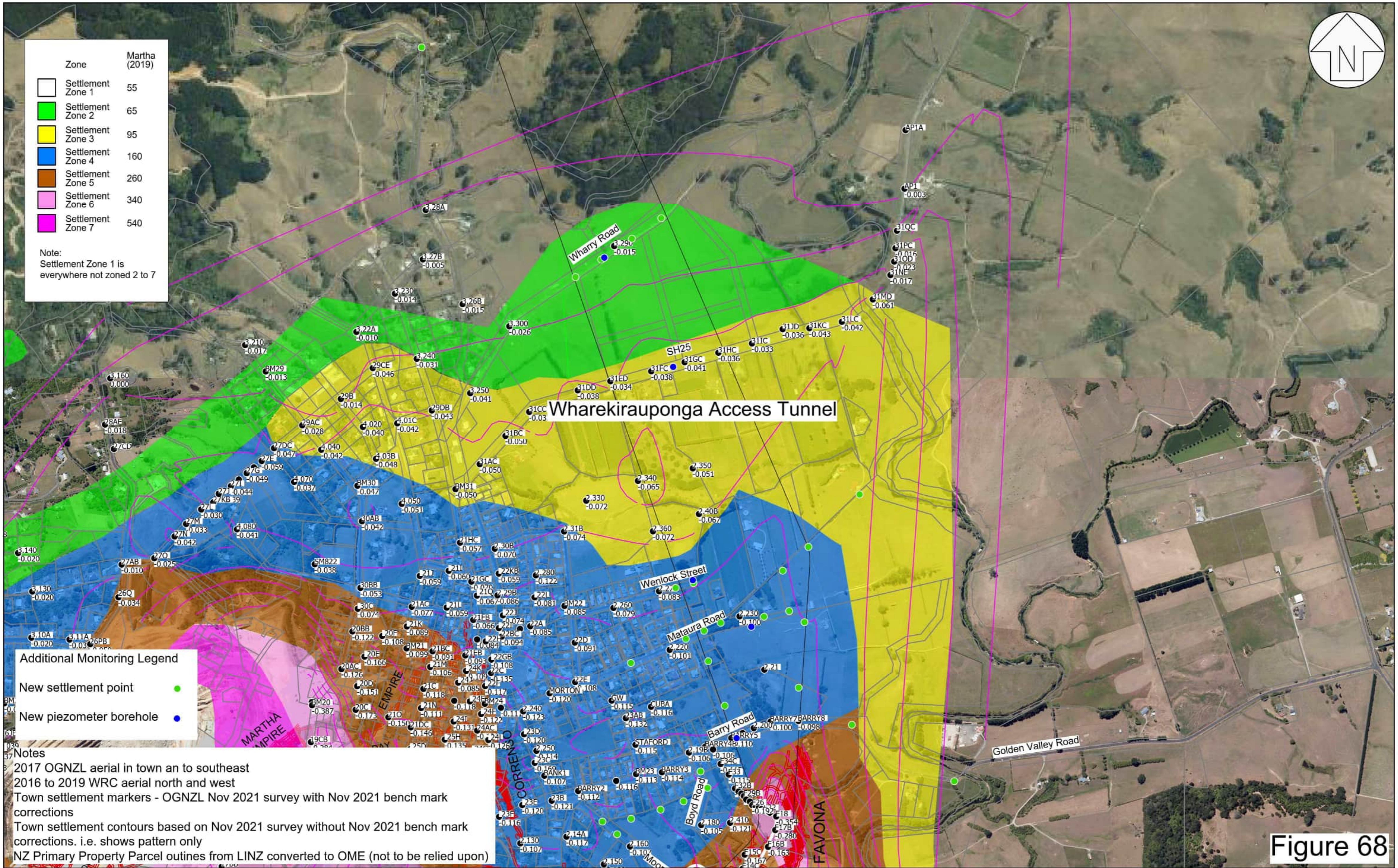
OCEANA GOLD (NEW ZEALAND) LIMITED
Waihi North Project
Draft arrangement of proposed additional monitoring locations

Drawing No.	9049–Fig 67
Date:	13 June 2022
Drawn:	ET
Scale:	1:10000 (@A3)
Filename:	9049–Fig 47.dwg



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OCEANA GOLD (NEW ZEALAND) LIMITED
Waihi North Project
Draft arrangement of proposed additional monitoring locations

Drawing No.	9049–Fig 68
Date:	13 June 2022
Drawn:	ET
Scale:	1:10000 (@A3)
Filename:	9049–Fig 47.dwg

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OCEANA GOLD (NEW ZEALAND) LIMITED
Waihi North Project
Draft arrangement of proposed additional monitoring locations

Drawing No.	9049–Fig 69
Date:	13 June 2022
Drawn:	ET
Scale:	1:10000 (@A3)
Filename:	9049–Fig 47.dwg

Appendix A
Settlement Calculations

Memorandum

Ground settlement and tilt estimates for GOP cross vein and Wharekirauponga Access Tunnel dewatering

A1.0 INTRODUCTION

This memorandum summarises the assumptions and results of two-dimensional (2D) seepage and deformation numerical modelling of GOP cross vein and Wharekirauponga Access Tunnel dewatering. The modelling was undertaken to enable estimates of settlements due to dewatering.

The analyses have been undertaken using Geostudio 2D finite element analysis (FEA) programs, SEEP/W and SIGMA/W (Refs. 1 and 2). The SEEP/W model of the ground and groundwater parameters for GOP cross vein assessment were provided by GHD (Ref. 4). The Wharekirauponga Access Tunnel model is based on work undertaken by EGL for MUG and MOP4 (Ref. 3).

A2.0 SCOPE OF WORK

The scope of work has included:

i. Modelling of seepage and drawdown associated with dewatering of deep groundwater systems from the depressurisation around the Wharekirauponga Access Tunnel using SEEP/W.

ii. Modelling of seepage and drawdown associated with cross vein dewatering caused by the Gladstone Open Pit excavation as modelled by GHD (Ref. 37)

iii. Deformation analyses using SIGMA/W with changes in stress due to vein dewatering and tunnel depressurisation estimated by the SEEP/W modelling.

A3.0 SOIL PROFILE AND GROUND MODEL

Figure A1a and Figure A1b provides the model geometry and the associated boundary conditions for the Wharekirauponga Access Tunnel assessment base condition (i.e. before tunnelling). The model was constructed as four layers. From the surface these layers were: younger volcanic rocks, weathered andesite, and undisturbed andesite comprising higher permeability (K) andesite and lower K andesite. The higher K and lower K andesite are both referred to as undisturbed andesite rock mass in this document. The model base extends down to RL255.

Figure A4a and A4b provides the model geometry for settlement estimations caused by the Gladstone Open Pit excavation dewatering of the veins. The model was constructed as three layers. From the surface these layers were: younger volcanic rocks, weathered andesite, and undisturbed andesite. The model base extends down to RL900.

The parameters summarised in Table A1 have been adopted for SIGMA/W deformation analyses for both the depressurisation around the Wharekirauponga Access Tunnel and the Gladstone Open Pit vein dewatering.

TABLE A1 Material Deformation Parameters

Unit	Unit Weight (kN/m^3)	Young's Modulus (MPa)	Poisson's Ratio
Younger Volcanics	25	1,000	0.2
Weathered Andesite	22	1,000	0.2
Andesite -Undisturbed (both Higher K and Lower K)	27	8,700	0.2

A4.0 MODELLING AND RESULTS

Decoupled seepage and deformation analyses using SEEP/W and SIGMA/W have been undertaken for both the Gladstone Open Pit vein dewatering and the Wharekirauponga Access Tunnel. The SEEP/W model calculates the change in pressure associated with dewatering and depressurisation. The SIGMA/W model then calculates the ground deformation that is caused by the change in pressure.

Two separate geometries were used to model ground deformations, one for the Gladstone Open Pit and one for the Wharekirauponga Access Tunnel. The tunnel geometry was modelled for two different scenarios. The first scenario is the case where the tunnel intersects veins which may cause dewatering shown in Figure A2, and the second scenario is modelled for where the tunnel intersects no veins and local depressurisation occurs shown in Figure A3. The Gladstone Open Pit geometry was only modelled for vein dewatering shown in Figure A4.

A4.1. Settlement Modelling

The SIGMA/W modelling has been undertaken to calculate the settlement and tilt induced by the pressure change.

Figure A2b shows the settlement from the potential groundwater drawdown in veins intersecting the tunnel.

Figure A3b shows the settlement for groundwater depressurisation around the tunnel where no veins are interected.

The settlements for the potential drawdown in the modelled intersecting veins for Gladstone Open Pit are shown in Figure A5.

The estimated average settlements are summarised in Table A2 and A3. These values are the average of the settlements across the whole profile modelled.

TABLE A2 Estimated Settlements from the Wharekirauponga Access Tunnel

Analysis	Average Settlements (mm)
Depressurisation around Tunnel	8
Tunnel Vein Drawdown	85

TABLE A3 Estimated Settlements from the Gladstone Open Pit excavation

Analysis	Average Settlements (mm)
GOP Vein Drawdown	36

The average modelled settlements for the depressurisation around the tunnel is 8 mm. The average modelled settlements from potential vein drawdown due to leakage into the tunnel is 85 mm. i.e. ineffective lining or sealing of the tunnel at vein location presents a greater potential for settlement.

For the vein drawdown associated with Gladstone Open Pit excavation, the average modelled settlements is 36 mm.

The modelling allows estimation of ground surface tilts caused by the additional effects from the tunnel or GOP. They are summarised in Table A4 for the Wharekirauponga Access Tunnel and Table A5 for the Gladstone Open Pit vein dewatering. They have been obtained by selecting the maximum tilt from the surface settlement profiles shown in Figure A2b, A3b and A5.

The additional tilt settlements due to the Wharekirauponga Access Tunnel and Gladstone Open Pit vein dewatering effects are very low and indicate the increased potential for damage to structures is low.

TABLE A4 Estimation of additional tilts from the Wharekirauponga Access Tunnel

Analysis	Tilts
Depressurisation around Tunnel	1:6400
Vein Dewatering	1:19000

TABLE A5 Estimation of additional tilts from the Gladstone Open Pit vein dewatering

Analysis	Tilts
Vein Dewatering	1:4800

REFERENCES

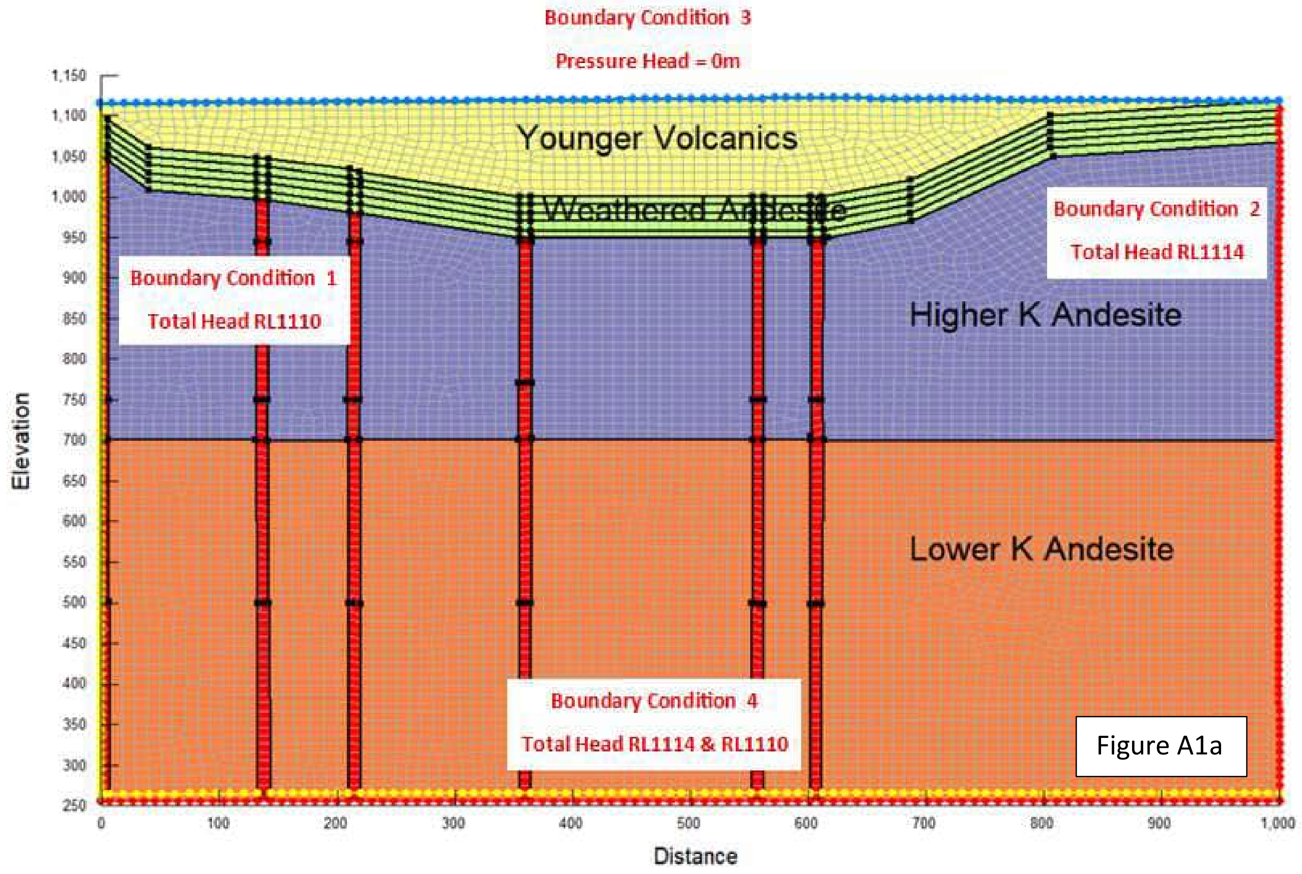
1. Geoslope International Ltd (2020) ‘Heat and Mass Transfer Modeling with GeoStudio’

2. Geoslope International Ltd (2020) ‘Stress-Strain Modeling with GeoStudio’

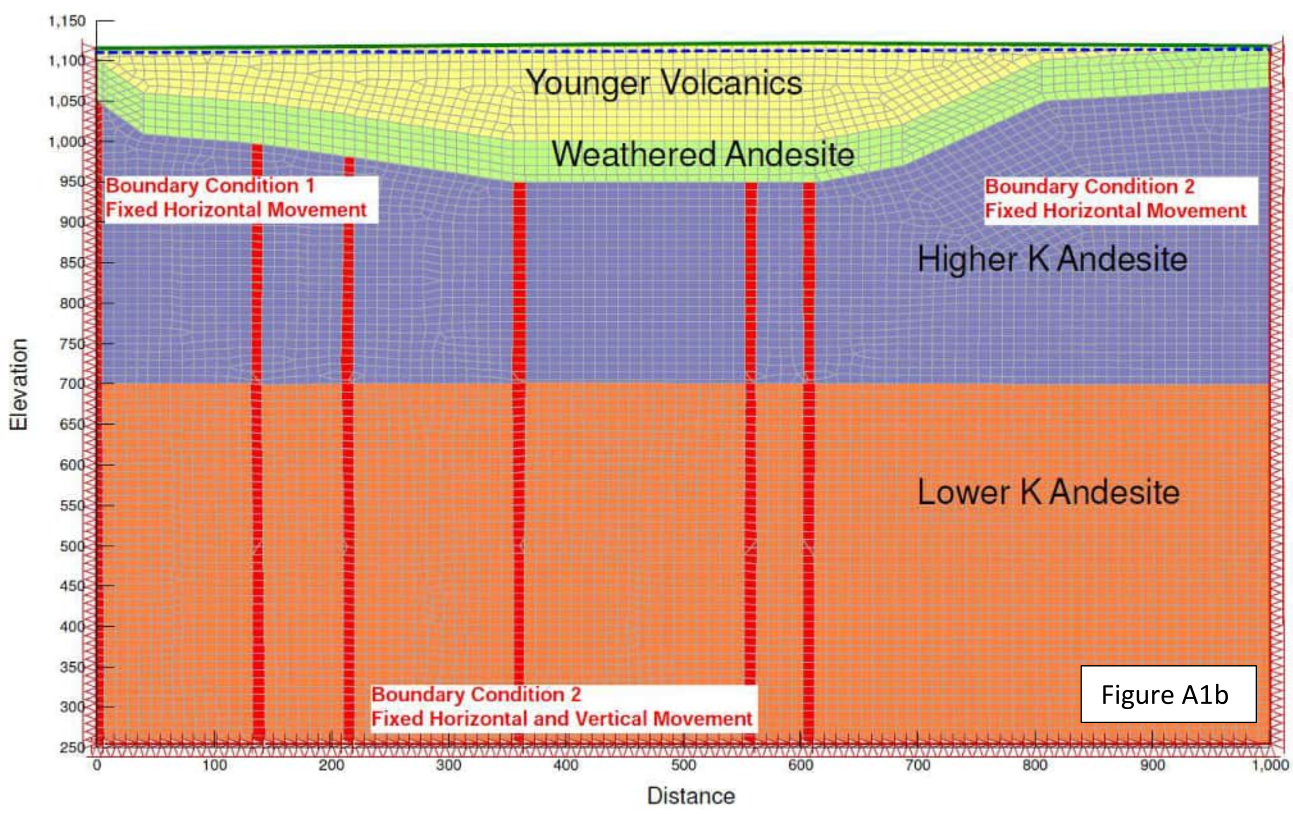
3. Engineering Geology Ltd (2018) ‘Oceana Gold (New Zealand) Ltd Project Martha Assessment of Ground Settlement’ Ref. 8332.

4. GHD (2021) ‘Waihi North Project – Hydrogeology and Mine Dewatering Report’ Draft.

SEEP/W Model

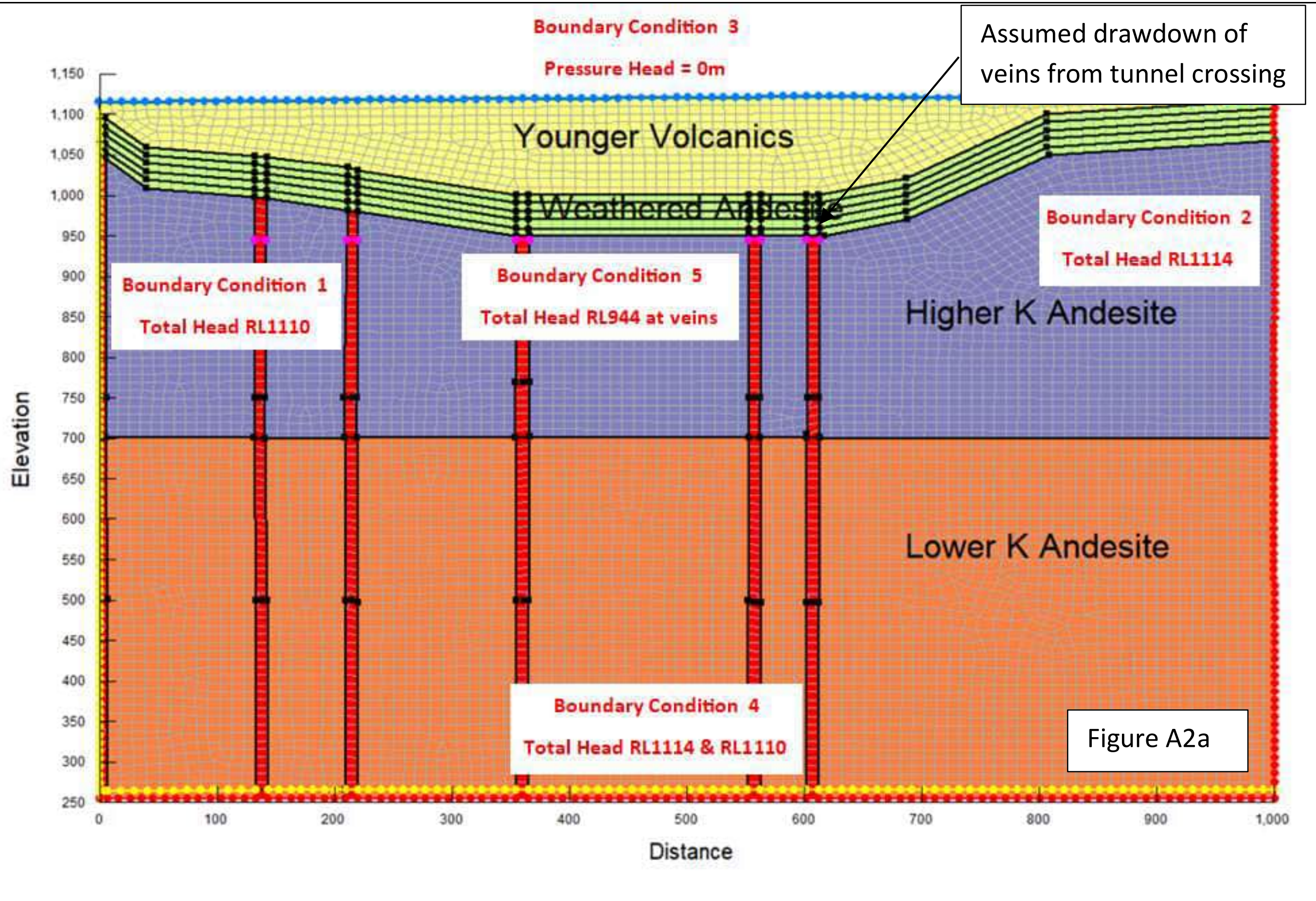


SIGMA/W Model

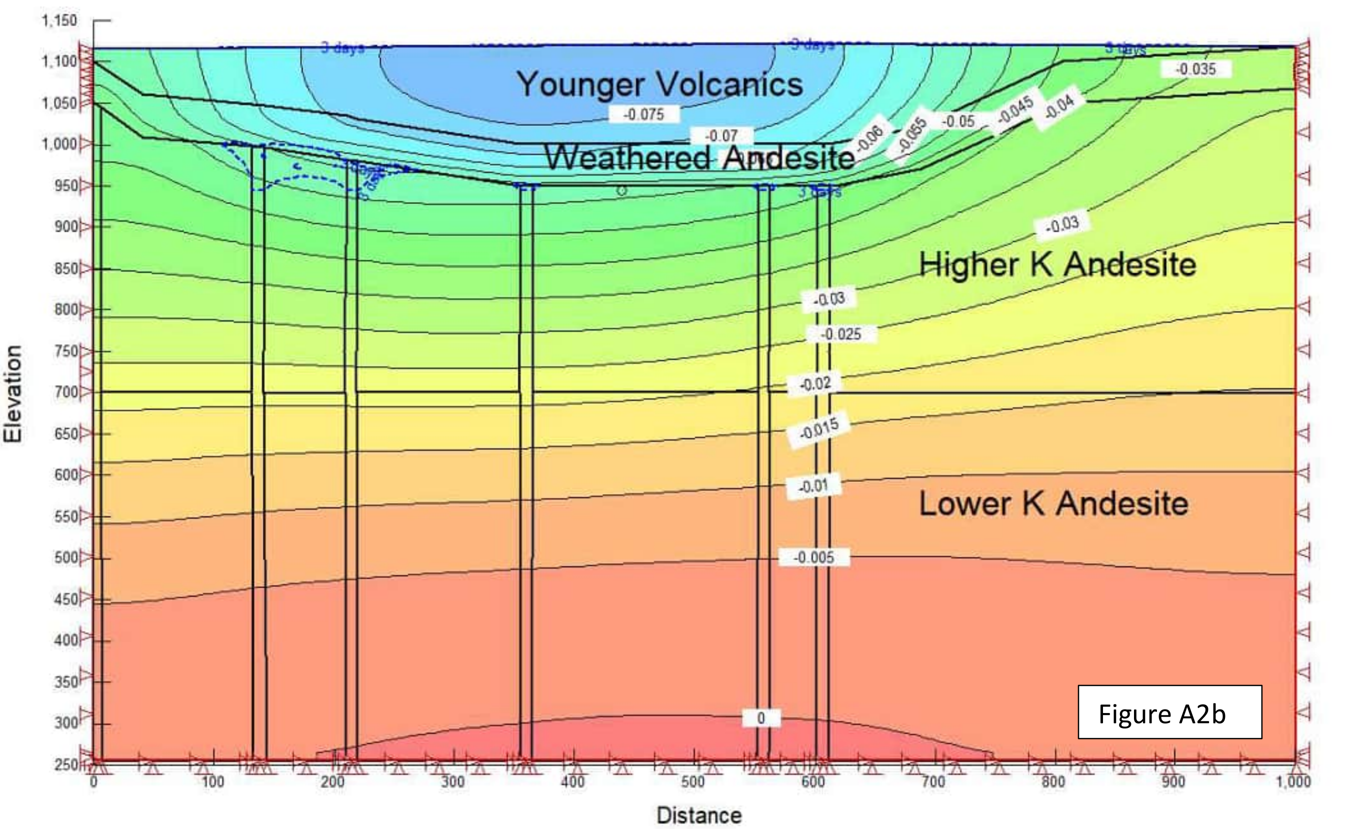


SEEP/W and SIGMA/W Model	**Figure A1**

SEEP/W Model

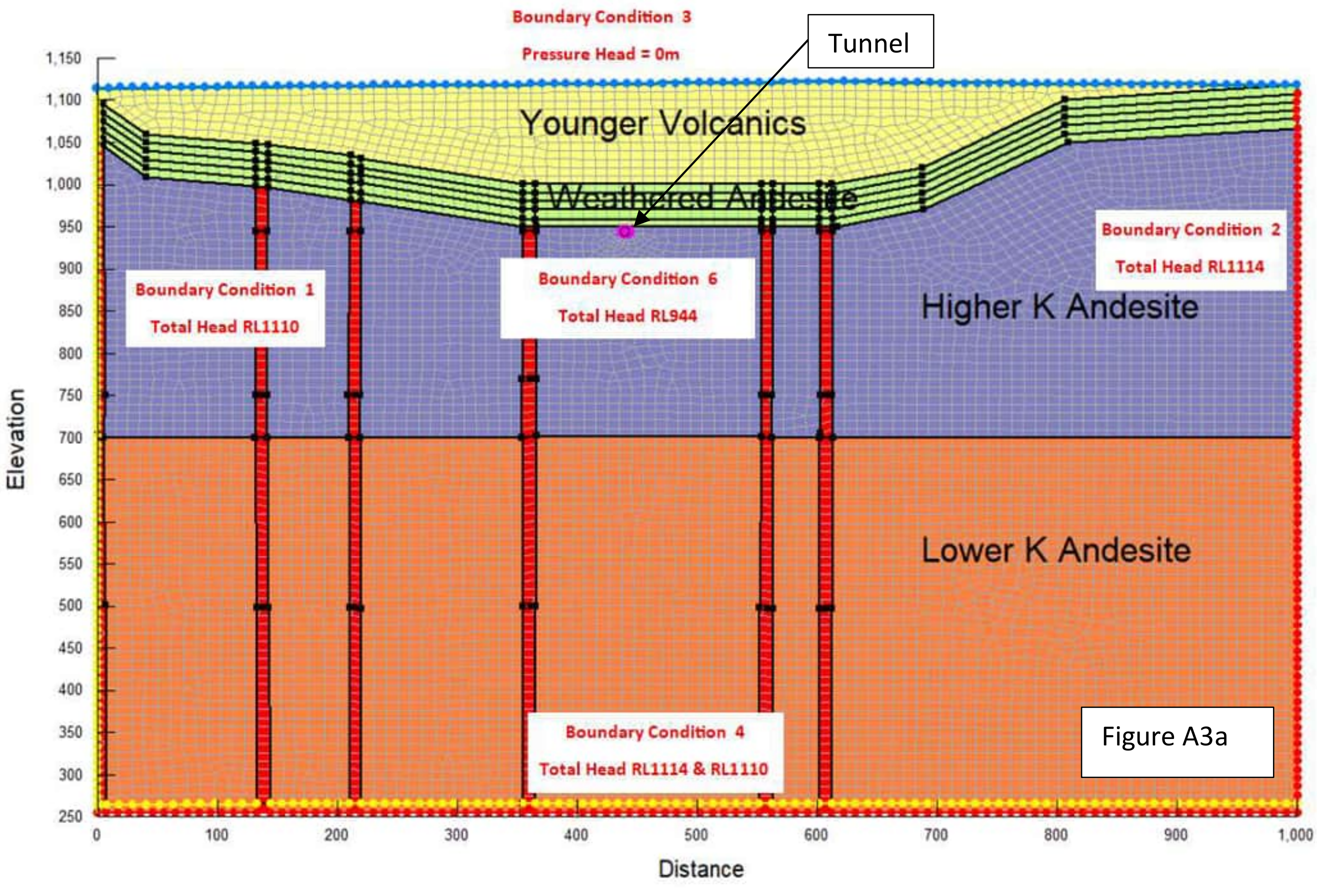


SIGMA/W Model

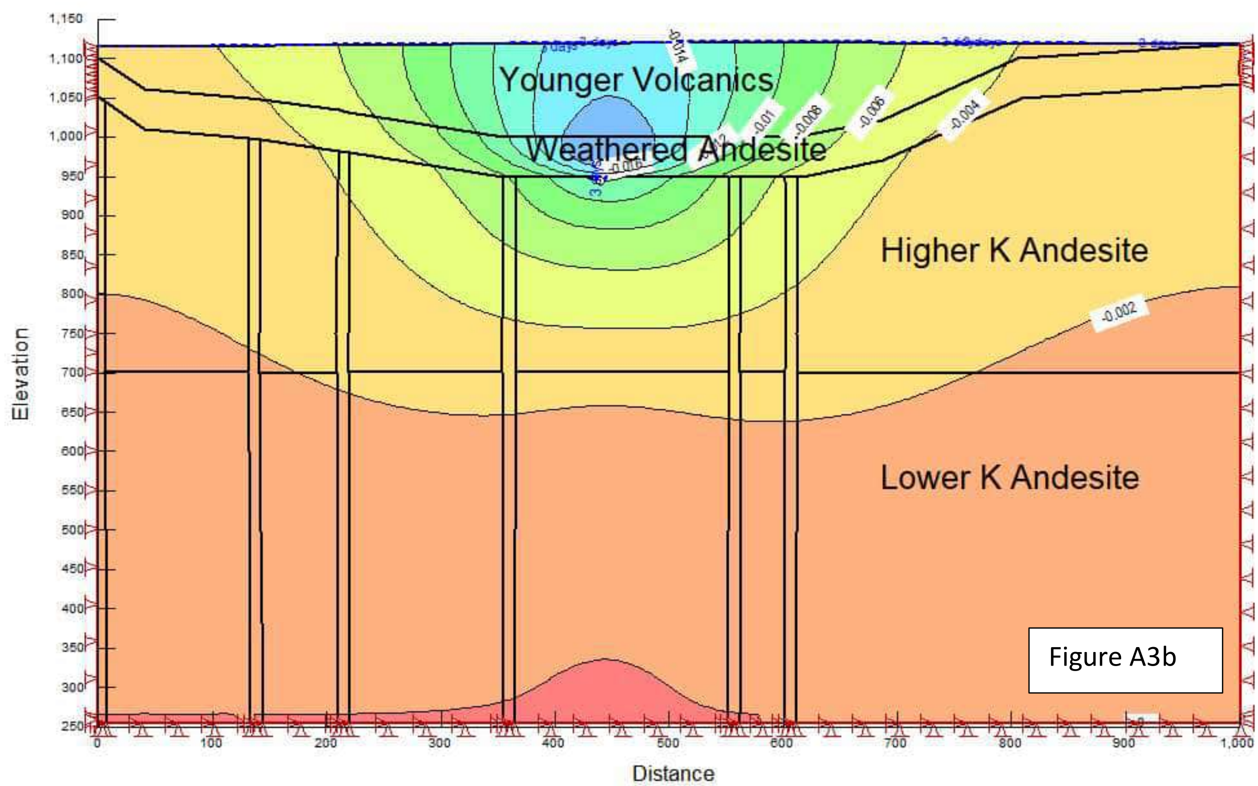


SEEP/W, SIGMA/W Model and Settlement Results for Multiple Veins **Figure A2**

SEEP/W Model

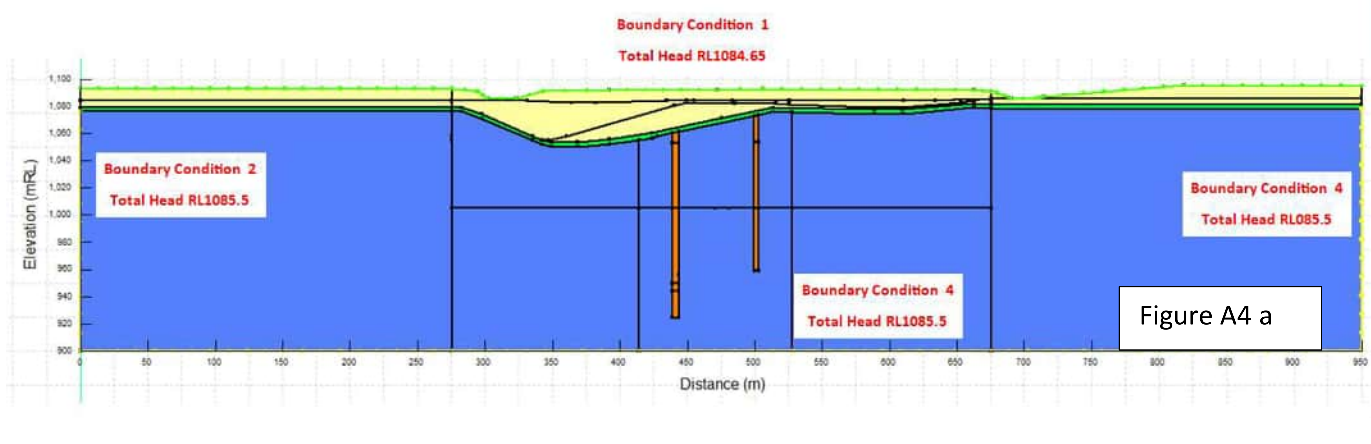


SIGMA/W Model

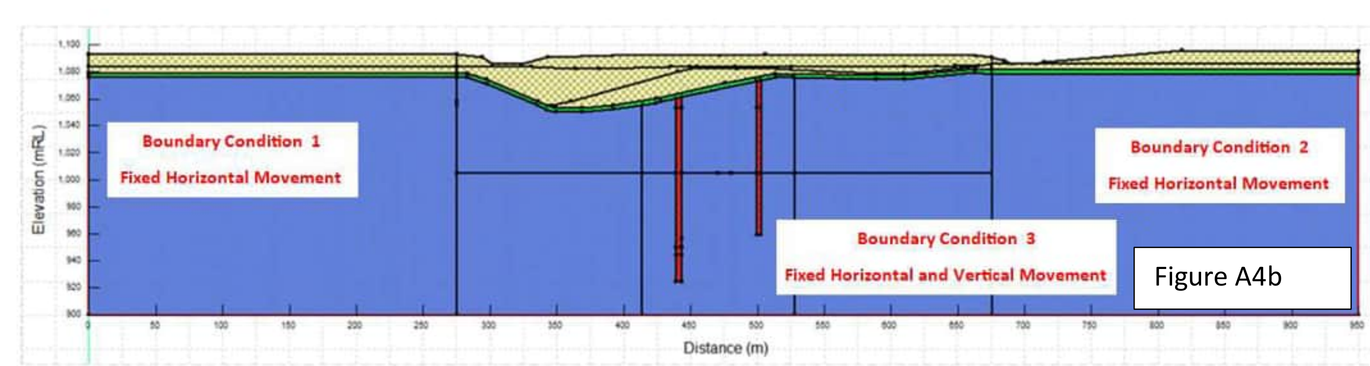


SEEP/W, SIGMA/W Model and Results for Wharekirauponga Access Tunnel **Figure A3**

SEEP/W Model

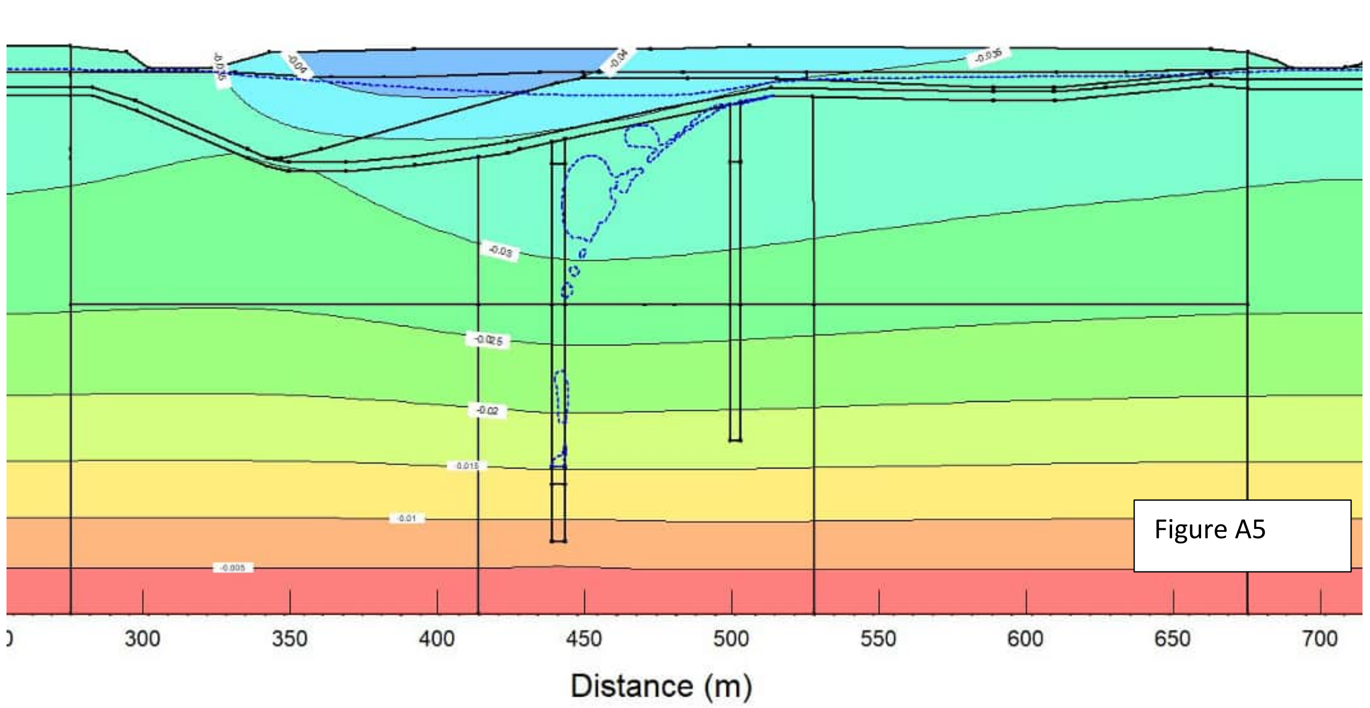


SIGMA/W Model



SEEP/W and SIGMA/W Model | **Figure A4**

SIGMA/W Model



SEEP/W and SIGMA/W Model | **Figure A5**

Memorandum

Ground settlement and tilt estimates for Wharekirauponga Vent Shafts, Mine and Tunnel.

A1.0 INTRODUCTION

This memorandum summarises the assumptions and results of two-dimensional (2D) seepage and deformation numerical modelling of Wharekirauponga Mine (WUG), Vent Shafts and Tunnel. The modelling was undertaken to enable estimates of settlements due to dewatering and depressurisation.

The analyses have been undertaken using Geostudio 2D finite element analysis (FEA) programs, SEEP/W and SIGMA/W (Refs. 1 and 2). The SEEP/W model of the ground and groundwater parameters for the vent shafts and tunnel (at Willows Road Farm) were provided by GWS.

A2.0 SCOPE OF WORK

The scope of work has included:

i. Deformation analyses using SIGMA/W with changes in stress due to the depressurisation of the tunnel at Willows Road Farm, estimated by the SEEP/W modelling.

ii. Deformation analyses using SIGMA/W with changes in stress due to potential seapage of groundwater into the vent shafts, estimated by the SEEP/W modelling.

iii. Deformation analyses (total settlement) using SIGMA/W with changes in stress due to dewatering from the Wharekirauponga mine.

A3.0 SOIL PROFILE AND GROUND MODEL

A3.1 Willows Farm Tunnel Section

Figure A1a and Figure A1b provides the model geometry and the associated boundary conditions for the tunnel assessment base condition (i.e. before tunnelling). Figure A2a and A2b provides the model geometry and associated boundary conditions after tunnelling. The Willows Road Farm tunnel section replicates a general drawdown profile in a typical weathered andesite rock mass. The drawdown condition assumed one set of permeability condition for the full profile in SEEP/W. The SIGMA/W deformation model applied three different stiffness layers. From the surface these layers were: regolith, weathered andesite, and unweathered andesite. The model extends from RL370m down to a base level at RL10m.

The parameters summarised in Table A1 have been adopted for SIGMA/W deformation analyses for the depressurisation around the tunnel (at Willows Road Farm).

TABLE A1 Material Deformation Parameters

Unit	Unit Weight (kN/m^3)	Young's Modulus (MPa)	Poisson's Ratio
Regolith	18	1,000	0.2
Weathered Andesite	22	1,000	0.2
Unweathered Andesite	27	8,700	0.2

A3.2 Vent Shafts

There are 5 vent shafts in total and are identified as shafts 1 - 5. Vent shafts 2 – 5 are located at WUG and shaft 1 is located at Willows Road Farm. This section includes both models at Willows Road Farm and WUG. The vent shafts were modelled as axis-symmetric, large diameter wells. The depths of the vent shafts are provided in Table A2.

TABLE A2 Vent Shaft Depths

Vent Shaft N.o	Depth (m)
1 WUG	200
2 WUG	320
3 WUG	220
4 WUG	150
5 WUG	195

Only Vent Shafts 1 and 2 are modelled in SEEP/W and SIGMA/W. Vent shaft 1 is modelled for Willows Road Farm and Vent Shaft 2 is modelled as the deepest vent shaft at WUG.

Figure A3a and Figure A3b provides the model geometry and the associated boundary conditions for the Willows Road Farm vent shaft assessment base condition (i.e. before vent shaft construction). The seepage SEEP/W analysis assumed one permeability condition. SIGMA/W deformation model was applied as three different stiffness layers. From the surface these layers were: regolith, weathered andesite, and undisturbed andesite. The model base extends from RL225m down to RL-275m.

The parameters summarised in Table A3 have been adopted for SIGMA/W deformation analyses from the dewatering of the vent shaft at Willows Road Farm.

TABLE A3 Material Deformation Parameters for Shaft 1

Material Layer	Unit Weight (kN/m^3)	Young's Modulus (MPa)	Poisson's Ratio
Regolith	18	30	0.2
Weathered Andesite	22	1,000	0.2
Undisturbed Andesite	27	8,700	0.2

Figure A5a and Figure A5b provides the model geometry and the associated boundary conditions for the WUG vent shaft assessment base condition (i.e. before vent shaft construction). The model was constructed as five layers. From the surface these layers were:

regolith, very strong (VS) andesite, very weak (VW) andesite, strong (S) andesite and weak (W) rhyolite. The model base extends down to RL-300m from RL340m.

The parameters summarised in Table A4 have been adopted for SIGMA/W deformation analyses from the dewatering of the vent shaft at WUG.

TABLE A4 Material Deformation Parameters for Shaft 2

Material Layer	Unit Weight (kN/m^3)	Young's Modulus (MPa)	Poisson's Ratio
Regolith	18	30	0.2
Very Strong Andesite	27	8,700	0.2
Very Weak Andesite	27	1,000	0.2
Strong Andesite	27	8,700	0.2
Weak Rhyolite	25	8,700	0.2

A3.3 Wharekirauponga (WUG) Mine

Figure A7 provides the model geometry and the associated boundary conditions for the mine assessment base condition (i.e. before dewatering). The SIGMA/W deformation model was applied as four different stiffness layers. From the surface these layers were: regolith, rhyolite pyroclastics, rhyolite flow and andesite flow. The model base extends down to RL-600m from RL200m.

The parameters summarised in Table A5 have been adopted for SIGMA/W deformation analyses for the depressurisation at WUG.

TABLE A5 Material Deformation Parameters for WUG Mine settlement estimate

Material Layer	Unit Weight (kN/m^3)	Young's Modulus (MPa)	Poisson's Ratio
Regolith	18	30	0.2
Rhyolite Pyroclastics	25	1,000	0.2
Rhyolite Flow	27	8,700	0.2
Andesite Flow	27	8,700	0.2

A4.0 MODELLING AND RESULTS

Decoupled seepage and deformation analyses using SEEP/W and SIGMA/W have been undertaken for both the vent shafts at (Willows and WUG) dewatering and the tunnel section (at Willows Road Farm). The SEEP/W model calculates the change in pressure associated with dewatering and depressurisation. The SIGMA/W model then calculates the ground deformation that is caused by the change in pressure.

Four separate geometries were used to model ground deformations, Vent Shaft 1, Vent Shaft 2, tunnel section at Willows Road Farm and the WUG mine (simplified 1d profile). The vent shaft geometry was modelled for drawdown caused from potential seepage into the vent shafts. The tunnel section modelled local depressurisation into the andesite. The WUG mine geometry is simplified and replicates geology at the mine to estimate the settlement caused from full drawdown to RL-180m.

A4.1. Settlement Modelling

The SIGMA/W modelling has been undertaken to calculate the potential settlement and tilt induced by the pressure change.

Figure A2b shows the settlement for groundwater depressurisation around the tunnel at Willows Road Farm.

Figure A4b and A6b shows the settlement from the potential groundwater drawdown caused from potential seapage into Vent Shafts 1 and 2.

The estimated settlement for the potential full drawdown caused by dewatering of the WUG mine is shown in Figure A8.

The estimated maximum settlements are summarised in Table A6, A7 and A8. These values are the maximum settlements across the whole profile modelled.

TABLE A6 Estimated maximum settlements from the tunnel at Willows Road Farm

Analysis	Maximum Settlements (mm)
Depressurisation around Tunnel	10

TABLE A7 Estimated maximum settlements from the vent shafts

Analysis	Maximum Settlements (mm)
Vent Shaft 1 – Willows Farm Road	75
Vent Shaft 2 - WUG	140

TABLE A8 Estimated settlements from the WUG Mine.

Analysis	Maximum Settlements (mm)
WUG Mine Drawdown	700

The maximum modelled settlements for the depressurisation around the tunnel is 10 mm. The maximum modelled settlement from potential drawdown due to seepage into the vent shaft at Willows Road Farm and WUG is 75mm and 140mm, respectively. For the drawdown associated with WUG mine dewatering, the maximum modelled settlement is 700 mm.

The modelling allow an estimation of ground surface tilts caused by the additional effects from the tunnel or vent shafts. They are summarised in Table A9 for the tunnel at Willows Road Farm tunnel section and Table A10 for the vent shafts at Willows Road Farm and WUG. They have been obtained by selecting the maximum tilt from the surface settlement profiles shown in Figure A2b, A4b and A6b.

TABLE A9 Estimation of additional tilts from the tunnel at Willows Road Farm.

Analysis	Tilts
Depressurisation around tunnel	1:15000

TABLE A10 Estimation of additional tilts from the vent shafts.

Analysis	Tilts
Vent Shaft 1	1:1400
Vent Shaft 2	1:8200

No assessment of tilt was made for the WUG profile.

REFERENCES

1. Geoslope International Ltd (2020) 'Heat and Mass Transfer Modeling with GeoStudio'
2. Geoslope International Ltd (2020) 'Stress-Strain Modeling with GeoStudio'

SEEP/W Model

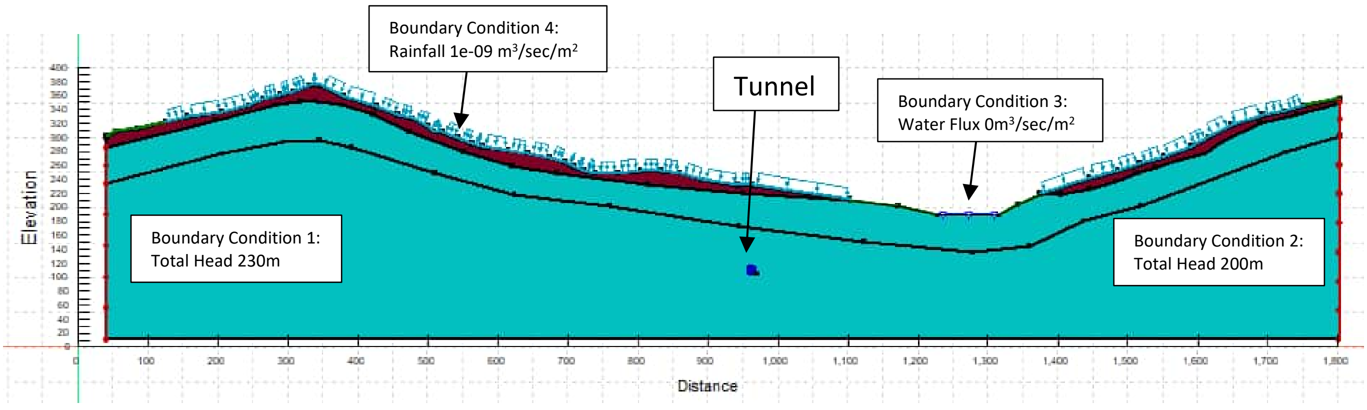


Figure A1a

SIGMA/W Model

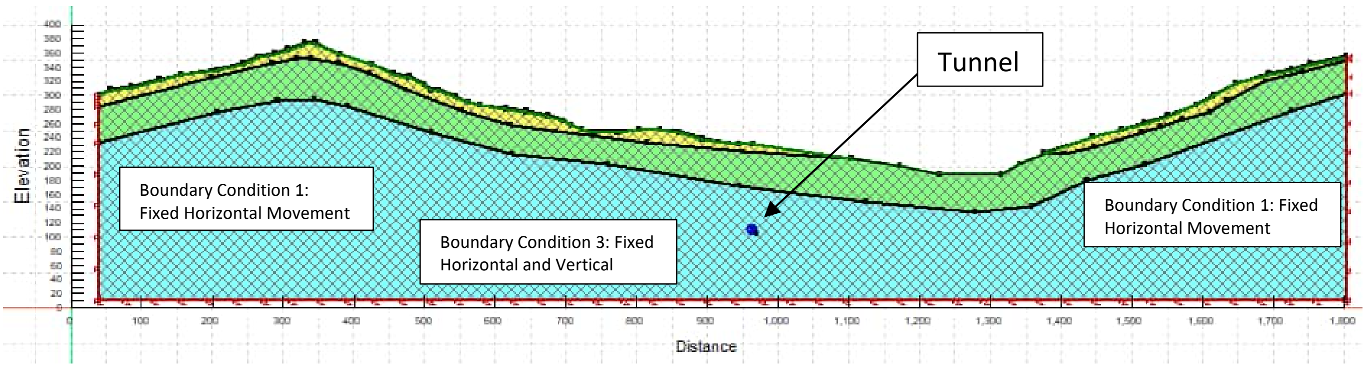


Figure A1b

SEEP/W and SIGMA/W Model	Figure A1

SEEP/W Model

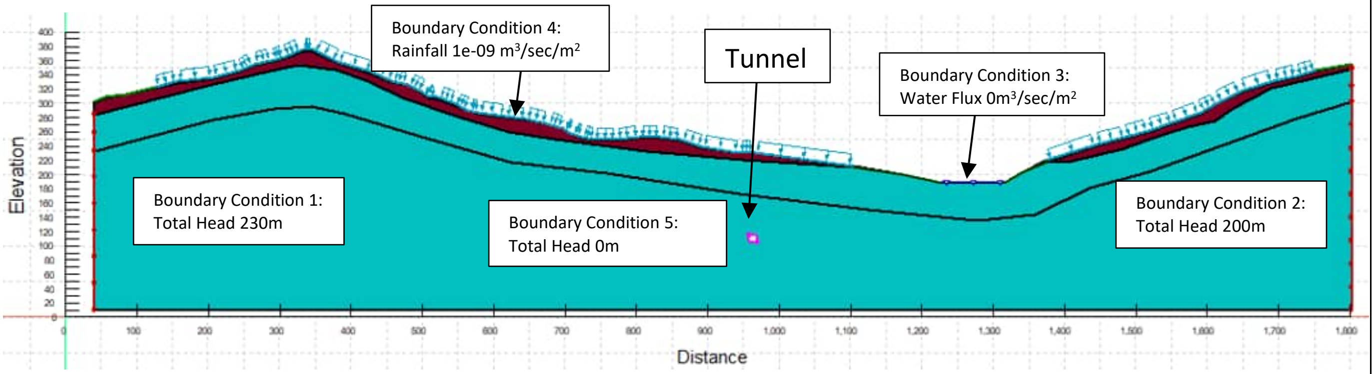


Figure A2a

SIGMA/W Model

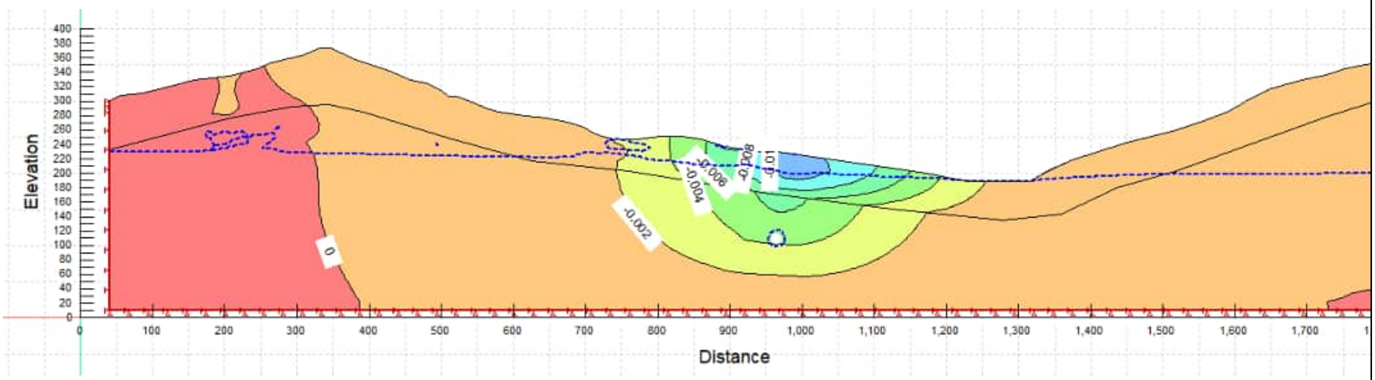


Figure A2b

Note: Settlement contours in meters

SEEP/W and SIGMA/W Model | **Figure A2**

SEEP/W Model

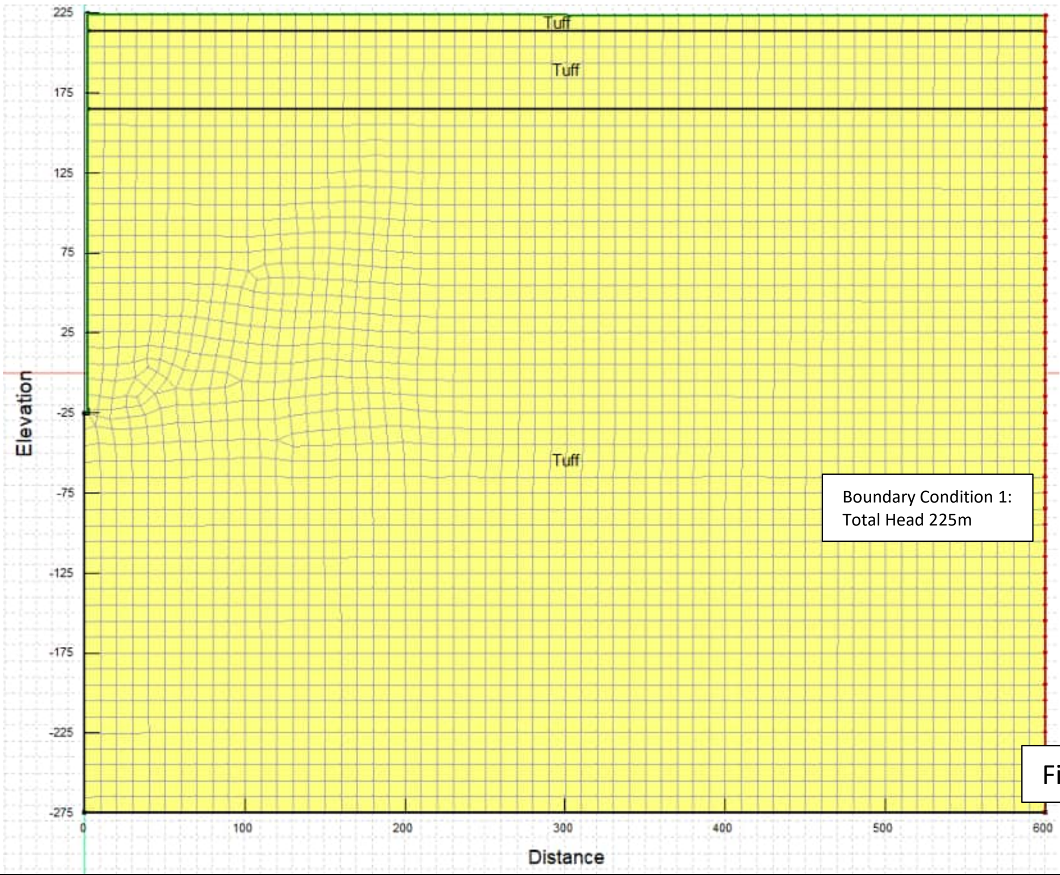


Figure A3a

SIGMA/W Model

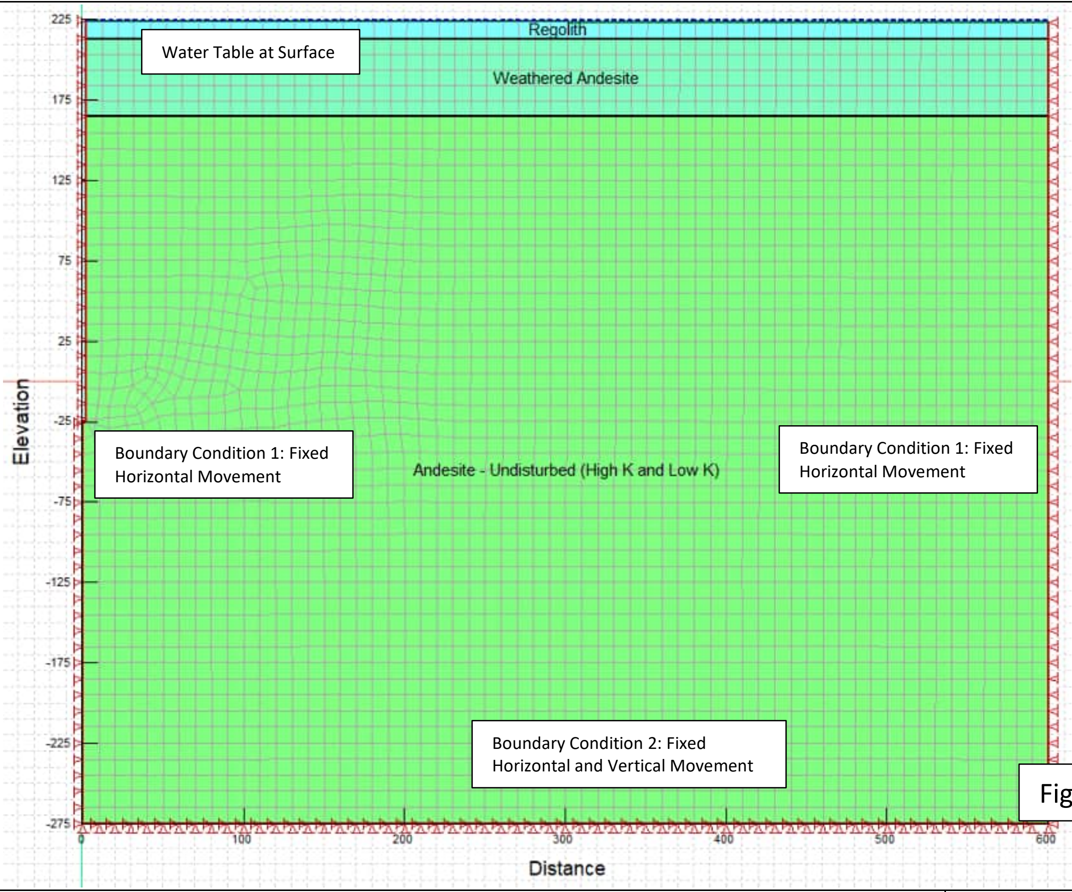
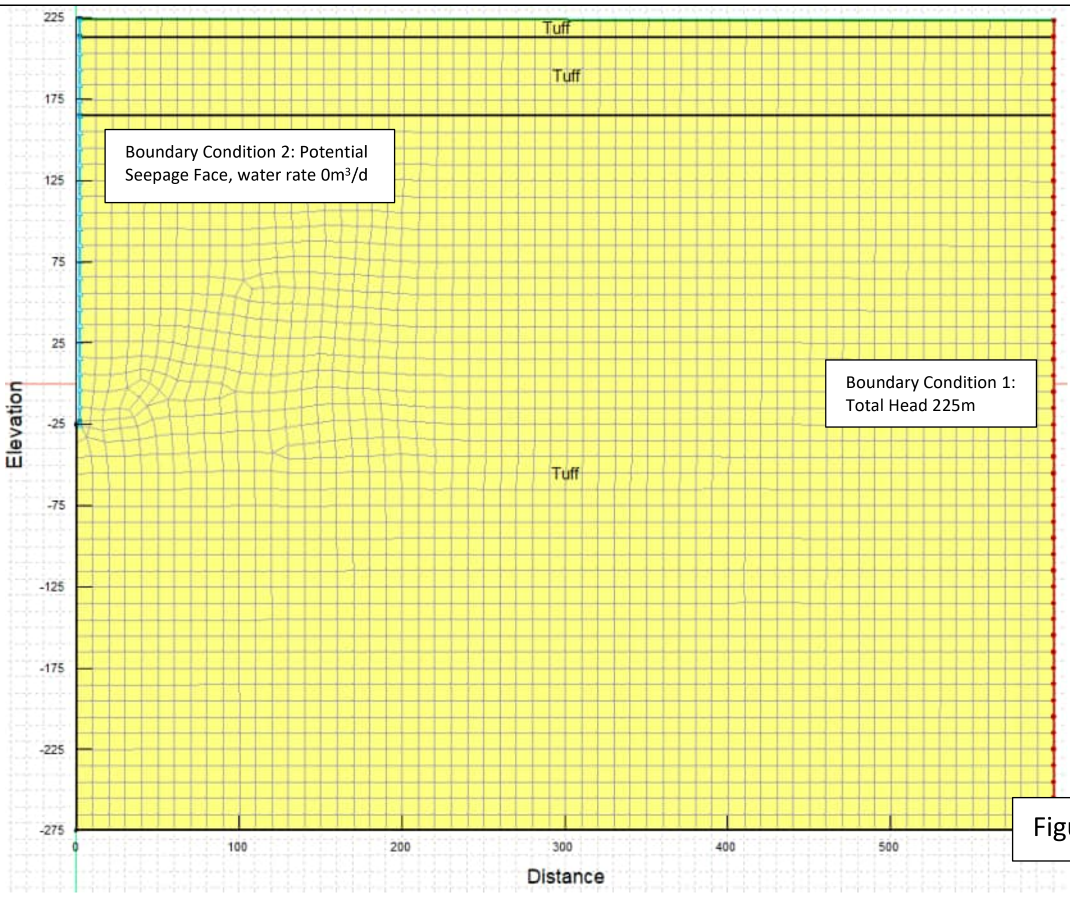


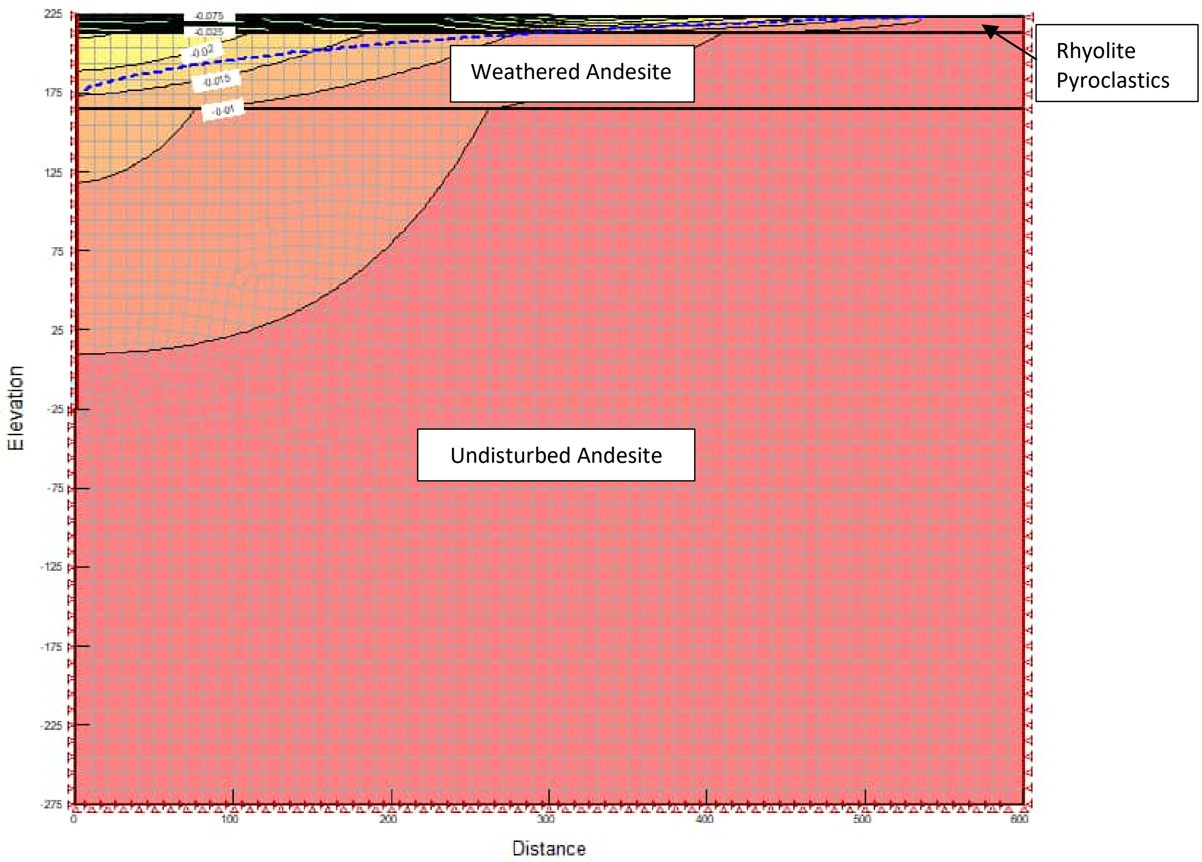
Figure A3b

SEEP/W and SIGMA/W Model for Shaft 1 | **Figure A3**

SEEP/W Model



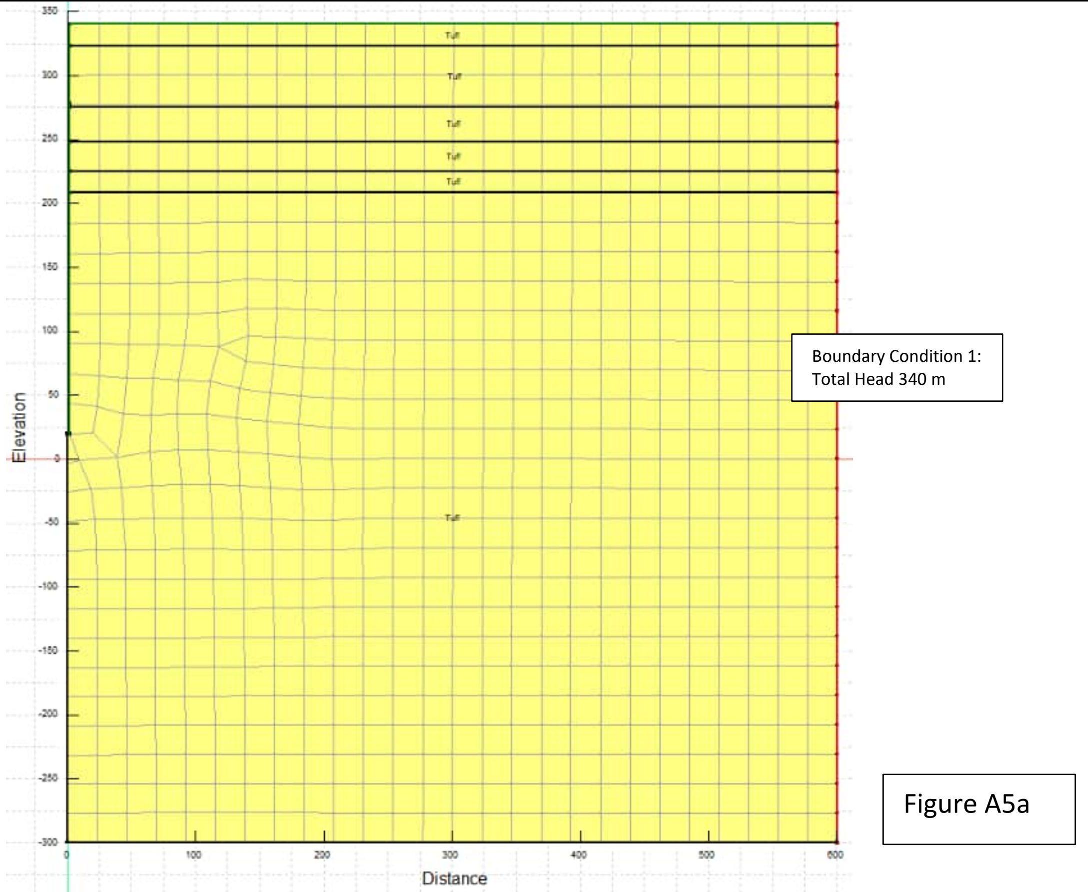
SIGMA/W Model



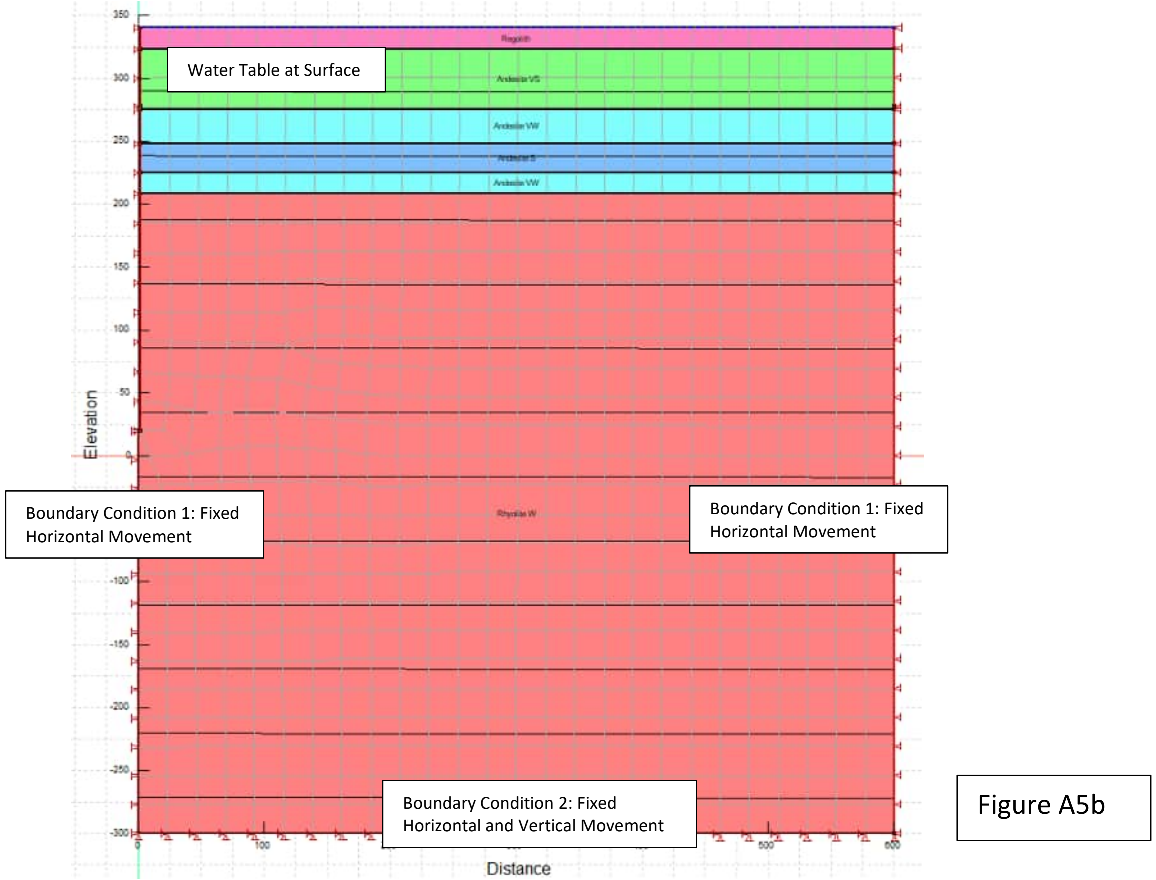
Note: Settlement contours in meters

SEEP/W, SIGMA/W Model and Settlement Results for Shaft 1	**Figure A4**

SEEP/W Model

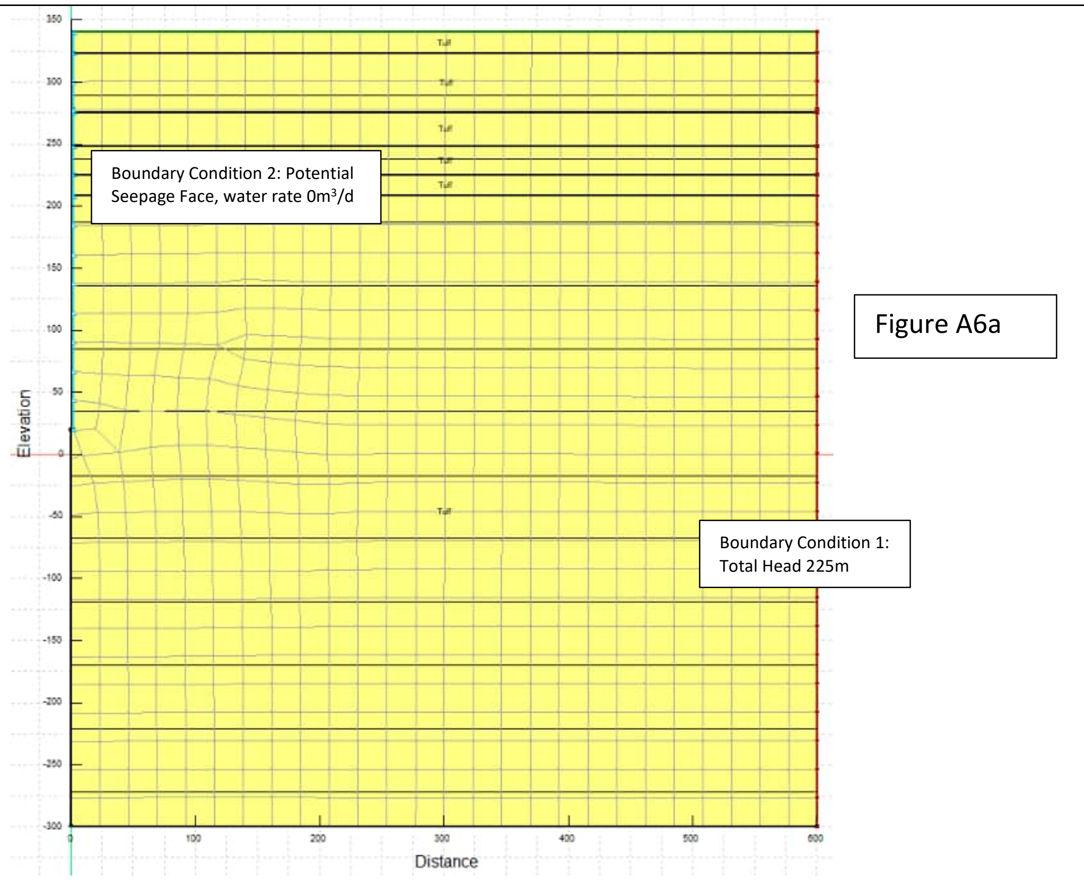


SIGMA/W Model

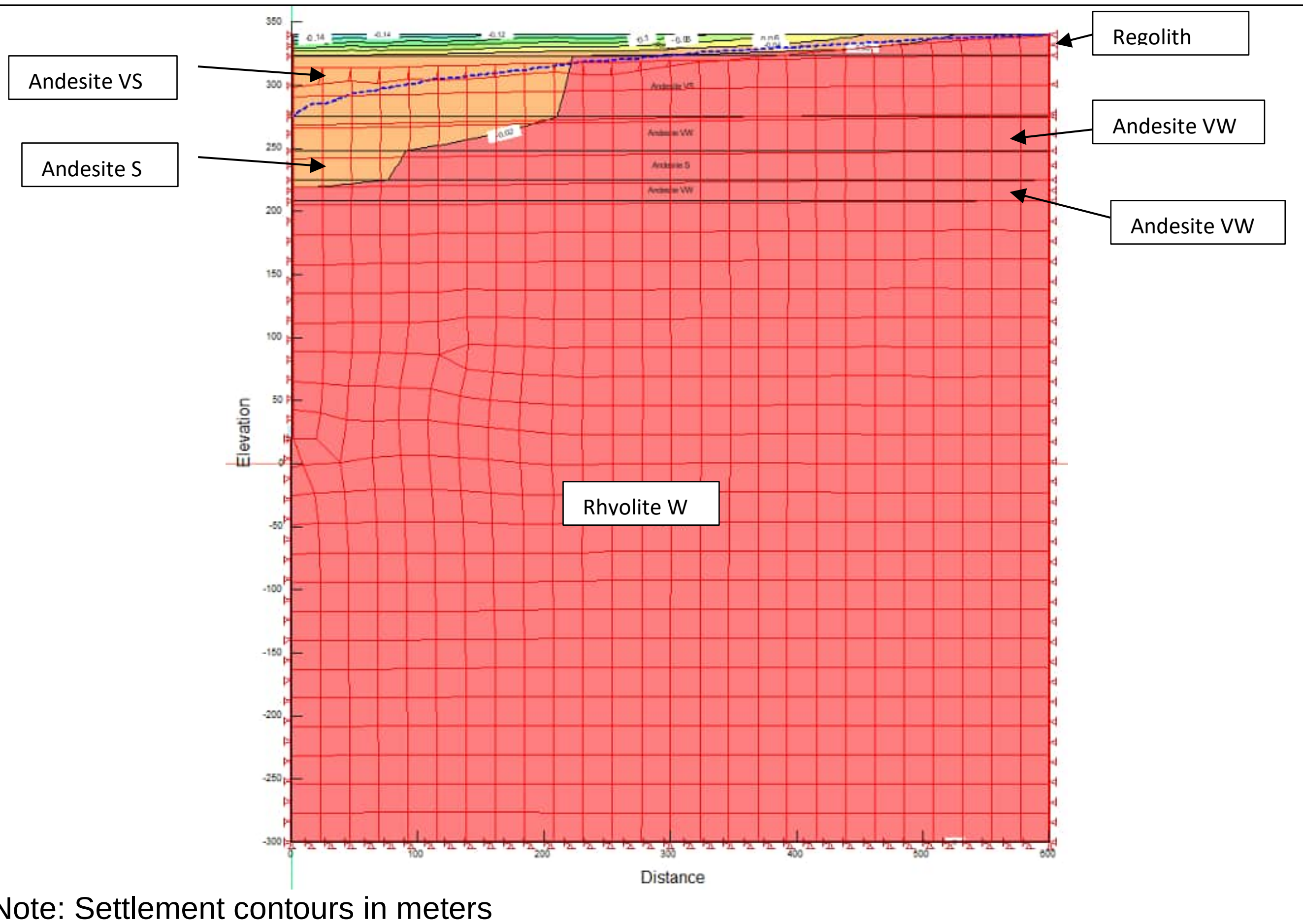


SEEP/W and SIGMA/W Model for Shaft 2 | **Figure A5**

SEEP/W Model



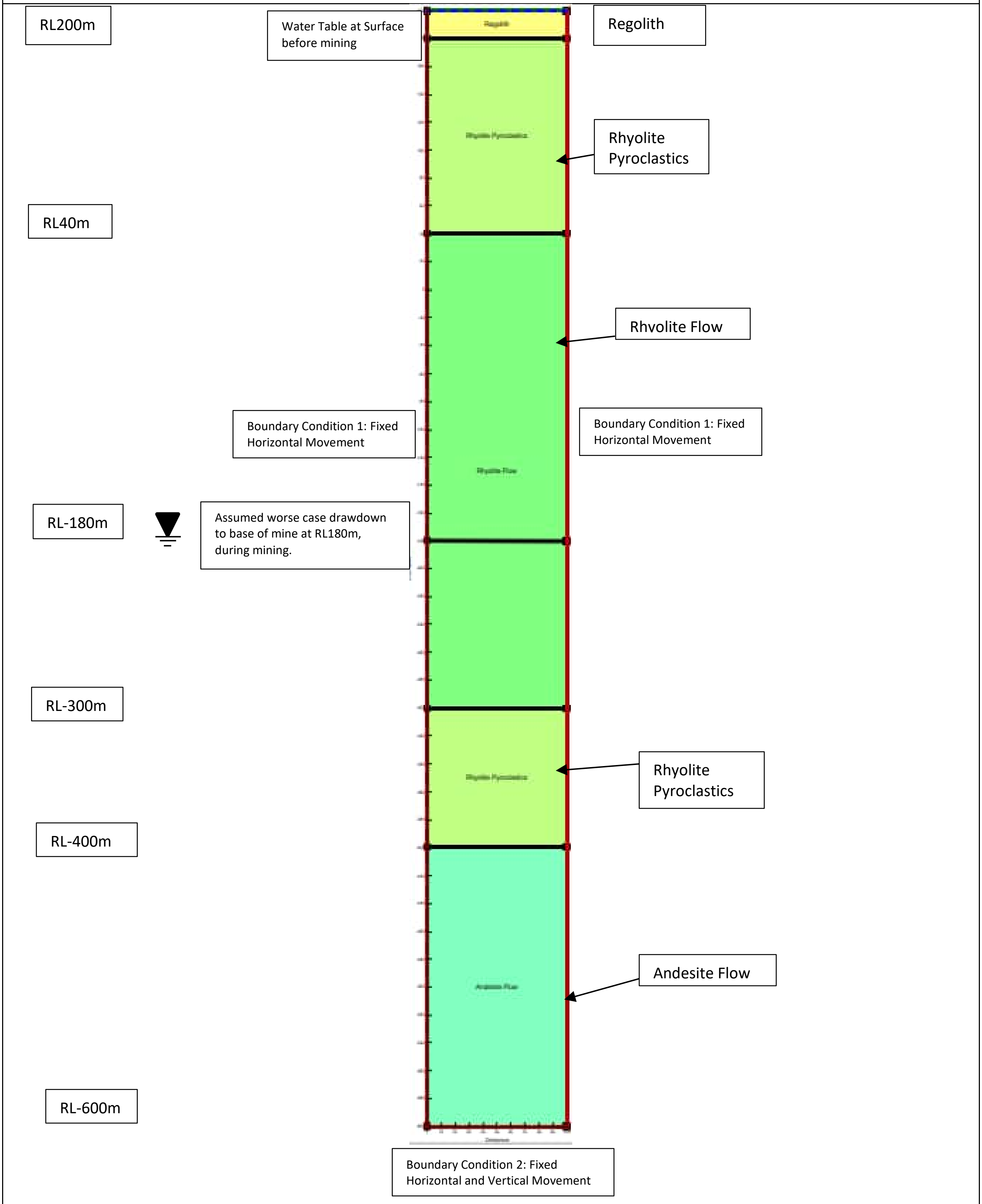
SIGMA/W Model



Note: Settlement contours in meters

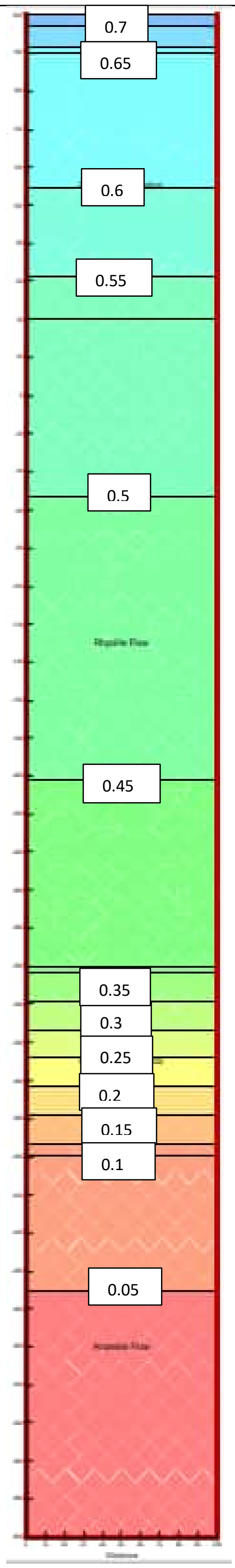
SEEP/W, SIGMA/W Model and Settlement Results for Shaft 2 | **Figure A6**

SIGMA/W Model



SIGMA/W Model for WKP Mine Dewatering | **Figure A7**

SIGMA/W Model



Note: Settlement contours in meters

SIGMA/W Model and Settlement Results for WKP Mine Dewatering | **Figure A8**