R

APPENDIX R

Ground Settlement Assessment
(Engineering Geology Limited)

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OCEANA GOLD (NEW ZEALAND) LTD
PROJECT MARTHA

ASSESSMENT OF GROUND SETTLEMENT

25 May 2018

Prepared for:
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EXECUTIVE SUMMARY

1. Oceana Gold New Zealand Ltd (OGNZL) proposes to develop a new mining project named Project Martha for extending the mine life by developing open pit and underground mining comprising:

    - The Martha underground mine including the Rex lode
    - The Martha Phase 4 pit (MP4)

2. The groundwater level in Project Martha will have to be lowered to RL500m[1] to allow for the development of the Martha underground mine. This is approximately 200m below the existing consented dewatering level to RL700m of the Correnso underground mine. Dewatering will be achieved by the installation of stage pumping chambers within the mine that pump into the Correnso dewatering system at RL780m.

3. This report addresses the potential effects on ground settlement of the dewatering to RL500m, together with rebound that can be expected following closure when pumping ceases and groundwater levels rise. Settlement caused by dewatering arises as a result of lowering the groundwater and depressurisation of the water within the defects and pores within the ground. This results in increased stresses within the ground and compression resulting in settlement.

4. Monitoring of groundwater levels and settlement has been undertaken over a period of 28 years (1989-2017). The results indicate a very strong correlation between groundwater level and settlement.

5. This report builds on previous assessments proposed for dewatering required for the Martha, Favona, Trio and Correnso Mines. Settlement predictions have generally been shown to be accurate. Where there has been a difference between predictions and measured settlement, this has been explained in this report.

6. Over the life of the current mining operations, settlements due to dewatering at Waihi have been small. No damage to property or infrastructure has been attributed to settlement induced by mine dewatering.

7. The basement rock of the area surrounding Waihi is andesite and it extends to considerable depth. An almost continuous cap of low permeability, highly weathered and altered andesite is present on the surface of the andesite. The andesite rocks are overlain by a series of younger volcanic deposits which are highly variable in thickness and composition. A thin layer, up to about 8m thick, of geologically young ash soils, alluvium and completely weathered rhyolitic tephra blankets much of the younger volcanic deposits.

8. Groundwater drawdown associated with dewatering of Project Martha area is expected to be confined to the andesite bedrock. Groundwater levels in the overlying younger volcanic deposits are generally not expected to be affected. Minimal changes to the shallow groundwater system have resulted to date from 28 years of dewatering and none are expected. Full groundwater drawdown occurs in the mineralised veins. Partial drawdown occurs in the andesite rock mass, with drawdown reducing with distance from the veins.

[1] Levels are expressed as mine datum, which is approximately 1,000m below mean sea level (i.e. RL1,000m mine datum is approximately sea level).

9. Settlements due to the proposed dewatering have been assessed using two approaches. Firstly, an observational approach based on extrapolation of historic settlements assuming a simple linear relationship between settlement and time. Secondly, using numerical modelling. The numerical modelling covers dewatering since 1989 and allows assessment of tilt arising from the differential drawdown in groundwater about the veins. The numerical modelling demonstrates that settlements predicted using the observational approach are conservative and that ground surface tilts due to dewatering to RL500 will be acceptable.

10. Broad settlements due to the proposed dewatering to the target level of RL500m have been inferred from the observed settlements measured around Waihi arising from dewatering from the Martha Pit from RL975m to RL770m, which occurred over the period December 1999 to November 2017. Estimated settlements are summarised in Table 1 for both dewatering to RL700m to allow for development of the Trio and Correnso underground mine, which has already been consented, and from RL700m to RL500m to allow development of Project Martha. Additional settlement arising from dewatering now sought to be consented ranges from 24mm in Zone 1 to 140mm in Zone 7. Zones 1 to 7 represent different areas around Waihi in which settlements would be expected to be similar. The Land Use Consent granted in 1997 refers to these zones. The original zone boundaries are shown in attached Figure 15. We have reviewed and updated the zonation taking into consideration the monitoring data since 1997. The recommended new zone boundaries are shown in Figure 16.

11. Estimated settlements arising due to the proposed dewatering from RL700m to RL500m are considered acceptable and expected to occur within the andesite rock mass below the ground surface. Differential settlements, which are normally the concern for buildings and shallow buried services, if they occur, are expected to be very small (less than 1 in 1,000). This is because settlements are associated with the andesite rock mass and not the overlying younger volcanic deposit or surficial soils, and so damage potential is considered negligible.

12. We expect there will be a lag between dewatering and settlement occurring. This is because the andesite rock mass generally has low permeability and it will take time for the pore pressures within the rock mass to decrease.

13. When dewatering is no longer required, groundwater levels are expected to return to approximately their original levels. This will result in rebound of the ground. We estimate that rebound will be approximately 50 percent of the settlement that occurs during dewatering.

14. The Waihi area has already been subjected to ground dewatering to RL540m and for a longer duration during historical underground mining undertaken between 1893 and 1952 than will be required for the existing projects including the period of Project Martha. The historical dewatering will have resulted in pre-consolidation of the ground so that settlements associated with the current phase of mining would generally be expected to be of the same order or less than those that the area experienced between 1893 and 1952.

15. We recommend that the trigger levels in the Dewatering and Settlement Monitoring Plan (and within the resource consent) be reset considering the settlements expected because of the additional dewatering. The recommended revised trigger levels are provided in Table 2.

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ASSESSMENT OF GROUND SETTLEMENT

1.0 INTRODUCTION

Oceana Gold New Zealand Ltd (OGNZL) proposes to develop a new mining project named Project Martha for extending the mine life by developing open pit and underground mining comprising,

- The Martha underground mine including the Rex lode
- The Martha Phase 4 pit (MP4)

The project components are shown in Figure 1. Project Martha provides OGNZL with the opportunity to continue mining operations in Waihi for further 11 years beyond the existing life of mine (Correnso underground mine).

At its greatest depth Project Martha extends to RL500m[2] (up to 620 metres below the ground surface). This is 200m below the consented level for Correnso. Dewatering will be achieved by the installation of stage pumping chambers within the mine that pump into the Correnso dewatering system at RL780m. Water will continue to be pumped to the Water Treatment Plant for treatment and discharge in full accordance with existing conditions of consent.

This report addresses the potential effects on ground settlement of the additional dewatering to RL500m, together with rebound that can be expected following closure when pumping ceases and groundwater levels rise.

This report builds on the previous reports prepared for dewatering required for the Extended Martha, Favona, Trio and Correnso Mines, the predictions for which have generally been shown to be accurate. Where there has been a difference between predictions and measured settlement, this has been explained within this report.

In this report, the term "settlement" applies to the wide spread and relatively minor vertical displacement of the ground surface caused by dewatering. The term "tilt" refers

[2] Levels are expressed as mine datum, which is approximately 1,000m below mean sea level (i.e. RL1,000m mine datum is approximately sea level).

to where there are differential settlements (i.e. differences in settlement over short distances).

2.0 BASIS OF ASSESSMENT OF SETTLEMENT

Estimates of settlement have been based on the following data:

a) Settlement data over a period of 28 years (1989-2017) from surveys undertaken in the area around the Martha Pit as required by condition 11 of the now-expired Mining Licence 32 2388, condition 3 of the now-expired Water Permit 971286 and conditions 5 to 7 of resource consent 124860;

b) Groundwater level measurements over a period of 28 years (1989-2017) carried out in boreholes around the Martha Pit and dewatering water levels in the Martha Pit and Correnso underground;

c) Assessment of the likely groundwater conditions reported by GWS Ltd (Ref.1); and

d) Geology of the immediate mine area from earlier reports and the current geological model as recently updated by OGNZL.

3.0 GROUND SETTLEMENT AT MARTHA MINE

Settlement caused by dewatering arises as a result of lowering of the groundwater and depressurisation of the water within the defects and pores within the ground. This results in increased stresses within the ground. Various other physical processes can also give rise to settlement. They include shrink and swell as a result of changes in moisture content.

The amount of settlement due to dewatering/depressurisation of the groundwater depends on the following:

a) The increase in the compressive stresses within the ground, which depends on the difference between the initial and final groundwater levels;

b) The compressibility of the ground which is a natural property, and which varies depending on the type of soil and rock; and

c) The thicknesses of the different types of soil and rock that underlie a site which are depressurised.

The rate of settlement depends on the permeability of the ground (i.e. on how quickly soils can drain). Permeability is a measure of how easily water flows through a material. The presence of holes, tunnels and other discontinuities in the ground aid the draining of water from the ground and hence increase the rate of settlement.

Monitoring indicates a strong correlation between settlement and the depth of dewatering. Dewatering is necessary so that mining can be undertaken in dry conditions. Dewatering commenced at the Martha Pit in 1989. The water level in the pit was reduced from RL1100m to about RL790m in April 2015 when the pit was temporarily closed for operation due to pit wall instability blocking access to the base of the pit. Since then the mine has been dewatered from the Correnso underground mine. A graph of the depth of dewatering is shown in Figure 2.

Dewatering has also been undertaken since 2005 for the Favona underground mine, located south east of the Martha Pit. Monitoring indicates ground settlement in the vicinity of the Favona Mine is also strongly correlated to dewatering.

Over the life of the current mining operations, settlements due to dewatering at Waihi have been small, but have been observed over a large area. The largest settlements have occurred close to the Martha Pit because of dewatering of the more compressible surface soils. These settlements occurred early in the life of the project. Settlements have largely been in line with what was predicted, except for Favona. The reasons for the differences are explained later in this report.

Other than in connection with an incident in 2012 described below, no damage to property or infrastructure has been attributed to settlement induced by mine dewatering. This is not surprising because damage from settlement usually only occurs where there are high differential settlements (i.e. large differences in settlement over a short distance, also known as tilt). Settlement due to dewatering at Waihi is now primarily a result of settlement of deeper materials, not surface soils, so differential settlements (tilt) tend to be very small.

An incident occurred in 2012 when damage to some houses in Gladstone Road to the east of the Martha Pit was reported. Differential settlements were the cause of the damage. Investigations confirmed the settlement was a result of dewatering of younger volcanic deposits, and this was due to a deep geotechnical drillhole (CGD008) not being properly grouted rather than mine dewatering. Following re-grouting of the drillhole (CGD008) the original ground water levels were restored.

4.0 SITE GEOLOGY

The geology of the area is quite complex, but a better understanding has been possible as knowledge has increased in conjunction with mining and exploration drilling.

Figures 3 to 6 show geological maps and sections of the area around Martha Pit, including the various mineralised vein systems. Figure 3 includes the geological map of the area around the Martha Pit and the location of the cross-sections radiating out from the pit. The cross-sections are given in Figures 4 to 6 and show that the mineralised andesite extends down to at least RL500m below the Martha Pit.

Figure 7 is a plan that shows the vein system, workings and drillhole locations between the Martha and Favona system. Figure 8 is an indicative geological cross section from Martha Pit through the Correnso, Trio and Favona systems along the same orientation as Sections A-A' and B-B' in Figure 7. The section shows that andesite, the basement rock, outcrops on the former Martha Hill, to the north of the Martha Pit and on Union Hill. The andesite basement rock extends to depths greater than 600m. The andesite rocks are extensively modified in places by weathering and hydrothermal alteration. An almost continuous cap of low permeability, highly weathered and altered andesite (upper andesite) is present on the surface of the mineralised (quartz) andesite. The andesites are overlain by a series of younger volcanic deposits 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. 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 and outcrop to the east and south of the Martha Pit. A thin layer, up to about 8m thick, of geologically young ash soils, alluvium and completely weathered rhyolitic tephras blankets much of the younger volcanic deposits.

The younger volcanic deposits are more compressible than the underlying andesite which means they have the potential to settle more when subjected to the same increase in stress. Much of the dewatering induced settlement immediately adjacent to Martha Mine is associated with these deposits.

5.0 PIT DEWATERING AND GROUNDWATER LEVELS

5.1. Historical Dewatering

Extensive underground mining was undertaken at the Martha Mine from 1893 until 1952. The workings were generally in the area of the Martha Pit but extended to a much greater depth. Dewatering was required down to the full depth of workings, approximately RL540m. Dewatering for Project Martha is another 40m deeper (RL500m). The historic dewatering occurred over many years, much longer than the recent phase of mining (1989-2018). By the time the recent phase of mining commenced in 1989 the groundwater levels had returned to pre-mining levels.

5.2. Dewatering 1989-2017

Dewatering occurred from Martha Pit from 1989 until 4 May 2015. Since then it has been undertaken from the Correnso underground mine.

Dewatering of the Martha Pit occurred progressively. It was achieved by installing pumps into the main shafts associated with historical underground mining. A record of the mine dewatering level over the life of the mine is shown in Figure 2.

The dewatering has been carried out at different rates during the period and sometimes the water level has been held constant. The average rate of drawdown in the pit from 1989 to 2000 was about 16m per year. Between 2001 and 2003 the groundwater level at the pit was maintained between RL940 - RL960. It was then lowered progressively to about RL890 from about May 2003 to April 2006 and was held close to this until June 2009. The pit was dewatered further to

RL875 between June 2009 and December 2010. The average rate of drawdown in this period was about 10m per year. The rate of dewatering was then increased to about 60m per year from January 2010 and the water level was reduced from RL875m to RL807 in November 2011. It was lowered progressively to about RL790 from November 2011 to May 2015. After this the dewatering has occurred from the Correnso underground mine. The dewatering level has lowered to RL770 as at November 2017.

Monitoring of dewatering levels was undertaken from the bottom of Martha Pit until April 2015. Dewatering levels since then are based on pump levels in Correnso.

Monitoring wells, referred to as piezometers, have been installed at various locations surrounding the pit to monitor the effect of dewatering on groundwater levels as shown in Figure 9. The piezometers have been installed at different depths to enable the monitoring of groundwater levels or water pressures in the different geological units (alluvium, younger volcanic deposits and andesite rock). There were no piezometers installed in the Golden Link Project Area prior to 2011. As part of the investigations for the Golden Link Project, seven boreholes, P90 to P95 and CGD008 were drilled and their locations are shown in Figure 9. Piezometers were installed in different geological units to measure groundwater levels.

GWS (Ref.1) 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 overlying weathered andesite, younger volcanic deposits and alluvium as shown in Figures 10 and 11. In Figure 10, piezometer P2-1 and P2-2 are in andesite and in Figure 11, piezometer P8-1 is located in andesite.

A shallow groundwater system associated with volcanic ash, alluvium and completely weathered rhyolitic tephra is present at shallow depth. Monitoring indicates that it is unaffected by dewatering of the pit except immediately adjacent to the Martha Pit. Shallow groundwater levels are controlled, principally, by rainfall infiltration, low surface permeability and natural and assisted drainage to surface water systems. The response of piezometer P2-4 in Figure 10 is typical of the response of the shallow groundwater systems.

Younger volcanic deposits are located within the shallow groundwater system. Monitoring of groundwater levels indicates drainage primarily towards the open pit where the younger volcanic deposits are close to the Pit. The response of piezometer P2-3 in Figure 10 and P8-3 in Figure 11 is typical. Drawdown is evident 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. 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 Pit. The settlement was in accordance with predictions.

Groundwater levels in the mineralised andesite are directly affected by dewatering in Martha Pit. Groundwater levels in the vein system respond rapidly to mine dewatering with a slower response in the rock body (i.e. within the rock mass away from the veins) due to its low permeability. The veins have good connection due to both the high permeability nature and the historical mining. Monitoring indicates that the amount of groundwater drawdown in the andesite reduces with distance from the Pit. It also indicates that groundwater levels in the previously mined and mineralised andesite are very similar to the level of dewatering in the Pit, and that groundwater levels change quickly in response to changes in the Pit dewatering level. However, at increasing distance from the Pit, beyond the limits of historical underground mining and mineral vein system, groundwater drawdown occurs much more slowly, before it reaches an equilibrium between drainage and recharge. This is because of the lower permeability of the unmined and non-mineralised rock, which means it takes longer to drain.

Dewatering effects associated with the Martha 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 groundwater system was originally hydrologically separate from Martha-Correnso-Trio groundwater system. Now the construction of Favona to Trio inclines provides a connection of the two systems above RL823m (Ref.1).

Monitoring in the andesite is limited by the depth to which the piezometers have been installed. The deepest that a piezometer has been installed is at RL965m (P92 in East Waihi) while the Project Martha underground mines will be developed down to RL500m.

5.3. Dewatering associated with Project Martha

The Martha Underground mine extends to RL500m. Therefore, the water level will need to be lowered at least 200m below the currently consented level (RL700m). Dewatering will be achieved by the installation of stage pumping chambers within the mine that pump into the existing Correnso dewatering system located at RL780m. Water will continue to be piped to the Water Treatment Plant for treatment and discharge in full accordance with existing conditions of consent.

The observed response of veins within the Martha groundwater system (which does not include the separate Favona 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.1). The existing multi-level piezometers in Waihi East shown in Figures 12 and 13 are considered a good indication of the potential response to the additional dewatering at the location and over much of the developed Waihi area. The groundwater levels in boreholes P90 to P95 and P100 to P102 located in the Waihi East area are shown in Figures 12 and 13. These groundwater levels were recorded in November 2017. The groundwater level of the Martha vein system at that time is estimated to be approximately RL750m. The deepest piezometers in the boreholes are in the upper andesite and show significant under drainage.

Observation of groundwater levels and modelling by GWS (Ref.1) indicate dewatering the Martha vein system from the current elevation (approximately RL770m) to RL500m is not expected to significantly 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 on going. The groundwater pressures in the veins and other open rock defects connected to the veins are expected to drop 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 the deeper dewatering.

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 always thick enough to maintain a perched water level in the overlying younger volcanics (Ref.1).

6.0 GROUND SETTLEMENT MEASUREMENTS

Ground settlement measurements have been made around the Martha 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 14.

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. Seven zones (Zones 1 to 7) are identified in Figure 8 and a copy of this figure is attached (refer to Figure 15). The seven zones are intended to represent different areas in which settlements would be expected to be similar. 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 don’t fit with the zones they are currently associated with. Consequently, we have reviewed and updated the zonation taking into consideration monitoring data since 1997. The recommended new zonation map is shown in Figure 16. The same number of zones has been retained, and in many locations the zone boundaries have not been changed. The new zones are primarily based on examination of settlement data, but local geology has also been considered.

The monitoring data show that some of the settlement markers indicate greater settlements than their original zone category. This is more significant for settlements to the South and East of Waihi. This area is likely to be affected more by the Favona underground mine rather than the Martha, Trio and Correnso system. We have reshaped the boundaries of Zones 1, 2, 3, 4 and 5 in this area to provide consistency against the monitoring results to November 2017. We have also modified the boundaries of Zones

5 and 6 slightly around the Martha Pit. The new zoning around the pit provides a better transition and avoids localised, isolated zones. No changes have been made to the boundary of Zone 7.

The results of settlement monitoring for Zones 1 to 7 are presented in Figures 17 to 23 respectively. The settlement data indicate that there have been varying amounts of settlement but always over a large area and not resulting in unacceptable differential settlement (tilt). Settlement markers along the southern and south eastern perimeter of the pit have shown the greatest settlement. Generally, settlements decrease with distance from Martha Pit. Settlements near the perimeter of the pit are within the range of 30-290mm. Greater settlements have been recorded on the southern and eastern sides of the Pit compared to the northern and western sides. This difference is due to the presence of a greater thickness of the more compressible younger volcanic deposits on the southern and eastern sides.

Comparison of settlements with groundwater levels indicates a correlation. The amount of settlement is generally proportional to the drop in groundwater level. This is apparent in Figure 24 where settlement at 4A, which is relatively close to Martha Pit, has a similar trend to the groundwater level measured in the base of the pit. This same trend is evident in Figures 21 and 22 which show settlements in Zones 5 and 6 that are close to the pit.

The rate of settlement closer to the Martha Pit was generally higher during the initial stages of Pit dewatering and has reduced with time. Settlement markers in Zone 5 (Figure 21) and Zone 6 (Figure 22) show this. The curves are generally steeper in the early stages of mining, indicating a higher rate of settlement, than later. This is attributed to the higher compressibility of the younger volcanic deposits and the groundwater drawdown in these materials that occurred in the early stage of the mine life. In the early stages of the mine life Martha Pit dewatering resulted in changes in groundwater levels in both the younger volcanic deposits and underlying andesite rock. This can be seen in Figure 10. The changes in groundwater level in the ignimbrite (P2-3) were smaller than in the andesite, and equilibrium was reached in a shorter period. However, ignimbrite is more compressible than andesite and this is the reason why there were higher rates of settlements observed initially.

Settlements show a slower response to pit dewatering at increasing distance from the Martha Pit and underground mines, as shown by settlement measurements in Zones 2, 3 and 4 (refer to Figures 18, 19 and 20 respectively). At these locations settlements are much smaller and the rate of settlement is more uniform with time. Observations are in line with predictions. Smaller settlements are expected because groundwater drawdown away from the Martha Pit and underground mines is less and the rate of settlement is more uniform with time due to the slow rate of depressurisation of the andesite rock mass.

Settlements have continued to occur, albeit at very slow rates (typically 0.1-1mm year) during periods when mine water levels have not changed significantly (July 1998 to January 2000 and November 2006 to November 2010). We consider the most likely explanation is ongoing drainage of the mineralised andesite rock mass, with slow depressurisation occurring due to the low permeability of the rock mass away from the quartz vein system. The proposed further dewatering to RL500m will have minimal effect on any ongoing settlement in the upper andesite or younger volcanics. However, it will result in additional depressurisation of the mineralised andesite rock mass. There was a significant change in pit water level from November 2010 to November 2011. In general, settlement markers (refer Figures 17 to 23) 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.

The settlement measurements show cyclic patterns in some cases (refer to Figures 17 to 23). The cyclic variation is typically in the range of 5 to 15mm. The cyclical pattern is believed to be either due to seasonal effects resulting in differences between base and intermediate benchmark levels or due to errors in determining intermediate benchmark levels. Most settlements are measured from intermediate benchmark levels that are in turn checked against base benchmarks located away from the influence of mining activity. It is possible that seasonal effects (e.g. changes in groundwater levels resulting in differential settlements between the base and intermediate benchmarks or shrink/swell of the surficial soils on which the benchmarks are located) could result in seasonal differences between the base and intermediate benchmarks. The differences could also be due to errors in survey measurement. The cyclical variations are relatively small and are close to the level of accuracy expected from survey measurements.

Condition 7 of resource consent 124860 (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.2). Tilt gradients are generally very low, less than 1:1,000, which is well below the gradient that would give rise to concern for structures. Locations where tilt gradients are greater than 1:1000 are discussed in Section 9.

7.0 METHODS FOR ASSESSING SETTLEMENT

Open-pit mining at the Martha Mine commenced in 1987. Prior to commencement of mining, and subsequently again in 1997, theoretical predictions of the future ground settlements because of mine dewatering were made. Since then, throughout the life of the mine, ground settlements have been measured at 6 monthly intervals at 399 locations in Waihi. The large number of settlement observations, spanning some 28 years, provides a very reliable database for estimating likely future settlements associated with further dewatering. In fact, 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.

The proposed dewatering will result in an approximately 250m drop in the current groundwater levels in the andesite basement rock. Minimal effects on the shallow groundwater system and younger volcanic materials are predicted by GWS (Ref.1). This conclusion is based on review of monitoring data during mining of Martha Pit and the different underground mines and theoretical seepage analyses. Consequently, settlements caused by dewatering within the area of Project Martha will primarily be associated with the changes in groundwater levels in the andesite basement rock.

Estimates of settlement in the andesite have been made using two approaches. The first is an observational approach in which the settlement observations to date are used as a basis for predicting what might occur with the proposed dewatering. The second is a theoretical approach involving numerical modelling of seepage and deformation.

8.0 SETTLEMENT ESTIMATES

8.1. Observational Method

Estimates of settlements arising from further dewatering can be inferred from settlements recorded during the dewatering of the Martha Pit and the different underground mines. This is possible because:

(i) There is strong correlation between groundwater levels and observed settlement and

(ii) Studies by GWS Ltd (Ref.1) indicate that the dewatering to RL500m will not have any significant effect on the groundwater levels in the overlying younger volcanic deposits and much of the upper andesite immediately underlying the younger volcanic deposits, these being the layers most sensitive to dewatering and responsible for much of the settlement that has occurred to date.

The initial dewatering of the Martha Pit from January 1989 through to 1996-1999 caused depressurisation of some of the younger volcanic deposits and the andesite units as shown in Figure 10. After 1996, most of the piezometers in the younger volcanic deposits have shown no reaction to further dewatering of the mine. Piezometric levels have remained steady despite further dewatering of the pit suggesting that most of the observed settlement after 1996 was due to depressurisation of the andesite rock mass.

From December 1999 to November 2017, the water level in the Martha Pit was lowered by 205m from approximately RL975m to RL770m. The settlement measured during this time can be assumed to be due to settlement within the andesite rock mass. This period was selected because the water level was steady in the pit at about RL975m from June 1998 to December 1999 and at about RL770m from December 2011 to November 2017. It can be assumed that steady conditions were established at the start and end of the 205m drawdown.

As previously explained settlements measured around Waihi are grouped into seven zones (Zones 1 to 7). Observed settlements in each zone are presented in Figures 17 to 23. The average settlement for each zone over the period December 1999 to November 2017 is shown in their respective figure and is also summarised in Table 1. The average settlements due to 205m drawdown are estimated from the slopes of the settlement curves ignoring any obvious outliers.

The greatest average settlement occurred in Zone 7. It was approximately 143mm. This Zone is located near the Martha Pit. The higher rate of settlement in this area is likely due to greater depressurisation of the andesite rock mass and possibly also due to subsidence associated with the underlying historical Royal Lode workings.

Settlements in Zones 4, 5 and 6 over the period December 1999 to November 2017 averaged 38mm, 68mm and 96mm respectively. The distance from Martha Pit has a significant effect on the magnitude of the settlement observed. Areas further away from the Pit would have had less depressurisation of the underlying andesite rock mass and therefore less settlement. Zone 4 is further from Martha Pit than Zones 5 and 6. Zone 5 has more points farther from the Pit than Zone 6.

Average settlements in Zones 1, 2 and 3 are between 24mm and 27mm. These areas are least affected by drawdown.

As a check we have compared estimated settlements for the Trio Project (Ref.3) against the measured settlements associated with dewatering from RL875 to RL770 (approx. January 2011 to November 2017). The comparison showed that the estimated settlements are consistent with the monitored settlements. This confirms the observational method is a reliable predictor of future settlements.

Estimates of future settlement that will occur because of dewatering from the present level of RL770 to RL700 for the Trio and Correnso Projects have been inferred from the above observations. They have been made by scaling the observed settlements arising from the 205m reduction in water level from December 1999 to November 2017. Estimates based on this approach are summarised in Table 1. Estimates of settlements vary from 12mm in Zone 1 to 47mm in Zone 6. In Zone 7, settlement of 70mm is estimated. As noted above, the dewatering to RL700m for the Correnso Project has already been consented. The dewatering has continued from November 2017 and therefore some of these settlements have already occurred.

Estimates of additional settlements due to dewatering from RL700m to RL500m to allow for development of Project Martha are inferred from observations of historical settlements from December 1999 to November 2017. The estimated settlements are summarised in Table 1. Settlements range from 24mm in Zone 1 to 140mm in Zone 7. Estimates of settlements in Zones 3, 4, 5 and 6 range from 26mm to 94mm. These estimates are average estimates for the zones. At some locations settlements within each zone will be less and at others more.

The rate of drawdown of the groundwater level in the Martha Pit that started after November 2010 for the Trio Project is higher than the previous drawdown rates and associated with observations used to estimate the expected settlement as shown in Figures 17 to 23. It shows that the rate of drawdown has some effect on the rate of settlement, but it is not that significant. The average rate of dewatering from RL700m to RL500m will be at a faster rate than historical. However, the rate of drawdown is not expected to significantly affect the magnitude of the settlement based on observations to date and the numerical modelling. There could be a lag between dewatering and settlement occurring. This is because the andesite rock mass is of generally low permeability and it takes time for the pore pressures within the rock mass (i.e. groundwater level) to decrease.

8.2. Numerical Modelling

Two-dimensional de-coupled numerical modelling of seepage and deformation has been undertaken of an area to the east of Martha Pit. This area covers settlement Zones

4 and 5. The modelling provided estimates of settlements due to dewatering to RL770m associated with mining since 1989 and with the proposed additional dewatering to RL500m associated with Project Martha. The analyses have been undertaken using GeoStudio 2D finite element analysis (FEA) programs, SEEP/W (Ref.7) and SIGMA/W (Ref.8). The SEEP/W model of the ground and groundwater parameters was provided by GWS. Some small adjustments were made to the model for deformation modelling. The soil stiffness values were obtained from a geotechnical model developed by PSM (Ref.4). The assumptions and results of the modelling are presented in Appendix A.

The scope of modelling included:

i. Modelling of seepage and drawdown associated with dewatering of both single and multiple veins to various levels using SEEP/W.

ii. Deformation analyses using SIGMA/W with changes in stress due to dewatering to different levels predicted by the SEEP/W modelling.

iii. Comparison of the results of the numerical modelling with monitored settlements

Modelling was undertaken for three stages of dewatering:

i. Stage 1: Drawdown to the midpoint of the weathered andesite (RL975m at deepest).
ii. Stage 2: RL975m to RL770m (current level)
iii. Stage 3: RL770m to RL500m

The average modelled settlements for Stage 1 are 23mm for both single and multiple veins. The average modelled settlements for Stage 2 are 89mm for a single vein and 152mm for multiple veins. For Stage 3 the average modelled settlements are 26mm for a single vein and 66m for multiple veins.

Results of the modelling from the first two stages were compared with monitored settlements. The average modelled settlements for Stage 1 are generally smaller than monitored settlements (23mm compared to average monitored settlements of between 25mm and 45mm). The Stage 2 modelled settlements are greater. The average modelled settlements for Stage 2 are 89mm for a single vein and 152mm for multiple veins compared to average monitored settlements in Zones 4 and 5 of 38 and 68mm respectively. The differences between modelled and monitored settlements could be due to the assumption of a single stiffness value for the andesite rock mass. It is possible that the rock mass has a lower modulus at higher elevations with increasing modulus with depth.

The modelling indicates additional settlements due to Stage 3 dewatering (RL770m to RL500m) are considerably less than for Stage 2 (average modelled settlements of 26mm for a single vein and 66mm for multiple veins compared to 89mm and 152mm respectively for Stage 2). This is because groundwater drawdown and associated incremental stress in the rock mass is localised around the veins. It results in arching effects and lower settlements than if the rock mass was fully dewatered. Also, with Stage 3 the depth of rock mass that is affected by drawdown is less than Stage 2.

The modelling allows estimation of ground surface tilts. The estimated maximum tilts are associated with the multiple vein model and for Stages 1, 2 and 3 are 1 in 8,000, 1 in 4,600 and 1 in 3,800 respectively. The incremental change in tilt from Stage 2 to Stage 3 is very small and consistent with the relatively small increment in settlement predicted by numerical modelling. The measured tilts above the Correnso underground mine (which is largely within Zones 4 and 5) are generally smaller than the maximum tilt predicted by numerical modelling (1 in 4,600). This indicates the numerical model is conservative. The estimated maximum tilt following dewatering to RL500m (1 in 3,800) is considerably less than 1 in 1,000 which is the current trigger for notification of the Waikato Regional Council and for instigating additional monitoring.

8.3. Comments on Settlement Estimates

Estimates of the additional settlement due to dewatering from RL700m to RL500m (i.e. Martha Project) by the observational method in Zones 4 and 5 are greater than those by numerical modelling. The observational method gives values of 38-66mm. Estimates from modelling for dewatering from RL770m to RL500m (70m more than associated with Martha Project) are 26mm for a single vein and 66mm for multiple veins. For dewatering from RL975 m to RL770m the monitored settlements are lower than modelled, indicating that numerical modelling is conservative. Assuming the same applies to dewatering to RL500m it is conservative to adopt settlements from the observational approach for estimating the additional settlements associated with Project Martha. We consider that estimates based on the observational method are reliable because they are based on 28 years of monitoring. The numerical modelling estimates rely on assessed values of rock deformation modulus and the extent of drainage within the rock mass. There is considerable uncertainty associated with these assumptions. However, the numerical modelling does provide valuable insight with respect to the comparative difference between the different stages of dewatering and estimates of tilt that arise due to greater drawdown at the veins.

Local variations in settlement can be expected, as has been evident with current monitoring. The proposed dewatering could also result in an extension of the current zone of influence of dewatering. Settlements within the new areas of influence are likely to be very small based on monitoring of settlements within the current zone of influence.

The proposed dewatering to RL500m is expected to result in groundwater drawdown in the andesite rock mass, with no or minor impact on groundwater within the overlying younger volcanic deposits and shallow groundwater system. Predicted settlements in Zones 1 to 5 are small and are not expected to have any significant effect. Predicted settlements in Zones 6 and 7 are greater but still no damage to existing structures or infrastructure is expected.

Settlements at the ground surface are generally expected to follow those predicted in the andesite rock mass. Differential settlements (tilt), which are normally the concern for buildings and shallow buried services, are expected to be very small (less than 1 in 1,000) because settlements are associated with the andesite rock mass and not the overlying younger volcanic deposits or surficial soils, and so damage potential is considered negligible.

The total magnitude of the settlements is small and not considered significant because, as noted above, differential settlements are normally the concern for buildings and buried services. It is of interest to note that the Waihi area has already been subject to groundwater dewatering to a similar depth and greater duration during historical underground mining between 1893 and 1952 than required for the Project Martha. The historical dewatering will have resulted in pre-consolidation of the ground so that settlements associated with the current phase of mining would generally be expected to be of the same order or less than those that the area experienced between 1893 and 1952.

In some areas the total magnitude of settlement arising because of dewatering to RL500m will exceed the trigger levels derived for the Correnso Project. As recommended in Section 11, new trigger levels have been set to account for the effects of dewatering to greater depths for Project Martha.

9.0 EXCEPTIONS TO PREDICTIONS

Generally, settlements have been in-line with expectations. Where they have not they have been investigated and, in all cases, there have been explanations. They are discussed in the following sections.

9.1. Gladstone Road

An incident occurred in 2012 when damage to some houses in Gladstone Road to the east of the Martha Pit was reported. Differential settlements were the cause of the damage. Investigations confirmed the settlement was a result of dewatering of the younger volcanic deposits in this area, and this was due to a deep geotechnical drillhole (CGD008) not being properly grouted. Settlement was not directly related to mine dewatering. Following re-grouting of the drillhole the ground water was re-stored to the original levels and the land re-bounded close to original levels.

9.2. Slevin Street

Since May 2015 the tilt between marks 20C and 20D (Slevin Street) has been greater than 1:1,000. OGNZL believes the settlement is not related to dewatering associated with the current project, but to the weak nature of the ground and unfilled stopes that underlie the area (Ref.2). The area is near a high hazard zone identified by GNS Science (Ref.5). Slevin Park is a swampy area, historically infilled with weak material and slumping/subsidence has occurred previously. No damage to any residences has occurred. The closest residence to the affected area is 95m away.

9.3. Favona Underground Mine

Settlements at the Favona underground mine have been greater than originally predicted and have exceeded 1 in 1,000 at three locations. The locations are directly above the underground workings on farmland owned by OGNZL. No buildings have been affected. The original settlement estimates only considered settlements in the younger volcanic deposits (Ref.6). If allowance is made for settlement in the geologic units that underlie the younger volcanic deposits (i.e. unweathered ignimbrite, dacite units and both the upper and mineralised andesite rocks) then the observed settlements are considered realistic.

10.0 REBOUND

Dewatering for Project Martha Area will eventually stop once underground mining in the project area has ceased. The area will then be allowed to re-flood. The re-flooding will occur naturally but will be accelerated by the addition of water pumped from the Ohinemuri River. Re-flooding will result in the groundwater levels in the andesite and the younger volcanic materials rising back close 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 Pit involved dewatering of the ground to about RL540m; approximately 40m above the targeted RL500m for the Martha Underground. Following the cessation of mining in 1952 groundwater levels rose. Rebound will have occurred but was not monitored. We are unaware of any damage arising from re-watering.

Rebound of the ground to its original level because of rising groundwater levels is not expected. We estimate that rebound could be approximately 50% of the settlement that has occurred during modern mining. We consider that no damage is expected because of rebound.

11.0 MITIGATION AND RECOMMENDATIONS

Predicted settlements associated with additional dewatering to RL500m in Zones 1 to 5 are small and are not expected to have any significant effect. Predicted settlements in Zones 6 and 7 are greater but still no damage to existing structures or infrastructure is expected. This is because settlements are associated with settlement in the deeper andesite rock mass which underlies the younger volcanic deposits that blanket much of the area. Numerical modelling for Martha East (Zones 4 and 5) indicates incremental settlements and tilts associated with Project Martha are small and well within acceptable limits. Monitoring to date confirms this is the case, even in Zone 6. Consequently no mitigation measures are considered necessary. We recommend monitoring of settlement as required by the expired Mining Licence and resource consent 124860 should continue. Figure 14 shows that settlement markers within the area of the Martha Underground mine are closely spaced and therefore we believe it is not necessary to install any additional settlement markers for Project Martha.

We recommend that the trigger levels be reset considering the settlements expected because of the additional dewatering. The recommended revised trigger levels are provided in Table 2. The recommended trigger levels are based on estimates of the average settlement predicted for each zone. There is variation in observed settlements within each zone as can be seen in the settlement observations shown for each zone in Figures 17 to 23. There are a few reasons for this. They include the variation in thickness and compressibility of the different geologic units, variations in groundwater levels, the accuracy of the settlement surveys, variations in ground levels due to shrink/swell effects, local disturbance or damage to settlement markers and changes to groundwater levels due to new mining projects that have occurred following definition of the zones. The zones should be interpreted as only providing broad definitions of settlement response. Variations in settlements over distance are more likely to change gradually and so in reality the zones are not hard boundaries.

We also recommend that similar conditions as for the Correnso Underground be adopted to ensure that the groundwater regime affecting ground settlements is not adversely impacted. These include:

i) No stoping above defined levels in the andesite. This is to preserve the integrity of the top of the andesite that acts to maintain the perched groundwater level in the younger volcanics.
ii) Grouting of all future surface-drilled holes to a depth below the top of the andesite.
iii) Avoiding intercepting existing drillholes with mine workings.
iv) Grouting drillholes from underground where underground development intercepts holes that are making water or geological defects with significant and sustained water flows.

12.0 CONCLUSIONS

1. Dewatering of Project Martha will require a reduction in groundwater from the consented level of RL700m to RL500m. Dewatering is proposed to be achieved by the installation of stage pumping chambers within the Martha Underground that pump into the Correnso dewatering system at RL780m. Water will continue to be pumped to the Water Treatment Plant for treatment and discharge in full accordance with existing conditions of consent. Now dewatering is being undertaken down to RL700m for the Correnso Project. This dewatering is already authorised by existing resource consents. The groundwater level will then be lowered to RL500m for Project Martha. Drawdown is expected to be confined to the andesite rock. Groundwater levels in the overlying younger volcanic deposits are generally not expected to be affected. No changes to the shallow groundwater system are expected.

2. Settlements due to the groundwater drawdown to the target level of RL500m have been estimated by inference from observed settlement measurements and numerical modelling. The settlements inferred from observed settlements are greater than predicted by numerical modelling. They have been adopted as best estimates. They are likely to be conservative based on comparison with the results from numerical modelling. The numerical modelling provides useful insight into the comparative settlements associated with different stages of dewatering and provides estimates of ground surface tilt.

3. The inferred settlements have been based on the observed settlement measured around Waihi arising from dewatering from the Martha Pit from levels RL975m to RL770m which occurred over the period December 1999 to November 2017. Settlements due to dewatering from RL770m to RL700m to allow for the development of the Correnso underground mine are estimated to range from 12mm in Zone 1 to 47mm in Zone 6. Zone 7, which is around the pit, is

expected to have settlement of about 70mm. Additional settlement arising from the dewatering now sought to be consented for Project Martha (to RL500m) ranges from 24mm in Zone 1 to 94mm in Zone 6. Zone 7 is expected to have additional settlement of about 140mm.

4. Estimated settlements are small and are expected to occur within the andesite rock mass below the ground surface. Differential settlements (tilt), which are normally the concern for buildings as well as buried services, are expected to be very small and so damage potential is considered negligible.

5. We expect there will be a lag between dewatering and settlement occurring. This is because the andesite rock mass generally has low permeability and it will take time for the pore pressures within the rock mass to decrease.

6. When dewatering is no longer required, groundwater levels are expected to return to their original levels. This will result in rebound of the ground. We estimate that rebound will be approximately 50 percent of the settlement that occurs during dewatering.

7. We recommend that the trigger levels be reset considering the settlements expected because of the additional dewatering. The recommended revised trigger levels are provided in Table 2.

Report prepared by
ENGINEERING GEOLOGY LTD

C Wu (Geotechnical Engineer)

T Matuschka (CPEng)

REFERENCES

1. GWS (2018) ‘Project Martha Assessment of Groundwater Effects’.

2. OGNZL (2017) 'Dewatering and Settlement Monitoring Report 2017' Ref. WAI-200-REP-007-003.

3. EGL (2012) 'Newmont Waihi Gold, Golden Link Project Area, Assessment of Ground Settlement' Ref.6808.

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6. URS (2003) 'Favona Underground Mine - Assessment of Groundwater Issues', 14 March 2003.

7. GEO-SLOPE International Ltd (2007) ‘Seepage Modeling with SEEP/W: An Engineering Methodology’, GEO-SLOPE International Ltd.

8. GEO-SLOPE International Ltd (2007) ‘Stress and Deformation Modeling with SIGMA/W: An Engineering Methodology’, GEO-SLOPE International Ltd.

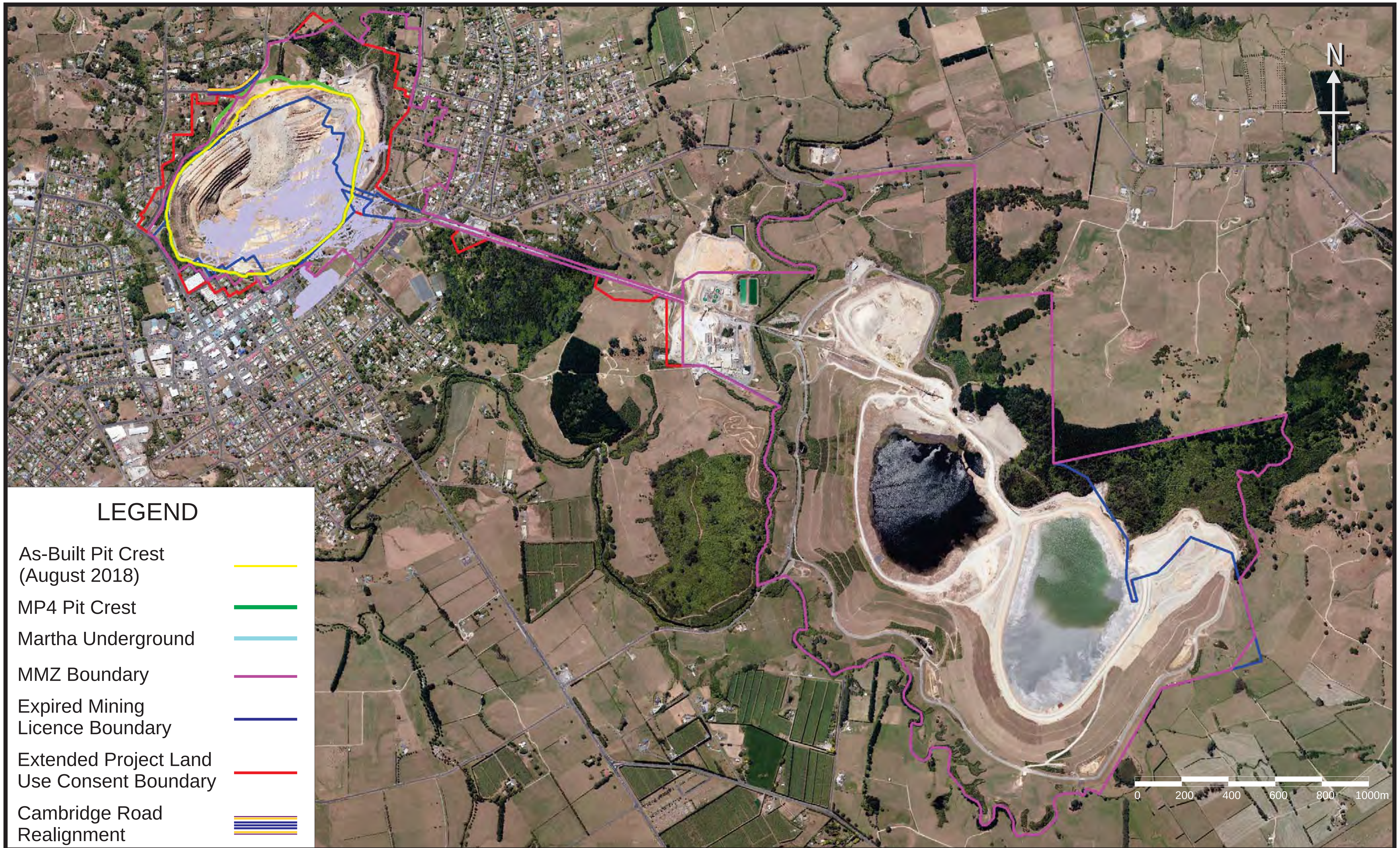
TABLE 1. SETTLEMENT ESTIMATES – OBSERVATIONAL METHOD

Zone	Typical Settlement Response to Dewatering from RL975m to RL770m (Dec 1999 to Nov 2017) (mm)	Estimated Settlement Response to Dewatering of Correnso Project from RL770m to RL700m [1] (mm)	Estimated Settlement Response to Dewatering of Project Martha from RL700m to RL500m (mm)
1	24	12	24
2	24	12	24
3	27	13	26
4	38	19	38
5	68	33	66
6	96	47	94
7	143	70	140

[1] The dewatering from RL770m to RL700m began in November 2017 and therefore some of the estimated settlement has already occurred

TABLE 2. RECOMMENDED NEW TRIGGER LEVELS FOR SETTLEMENT (mm)

Zone	Recommended New Trigger Levels for Settlement (mm)
1	55
2	65
3	95
4	160
5	260
6	340
7	540



OCEANAGOLD

Project Martha and Regulatory Boundaries

Figure 1

Date: 14 April 2018

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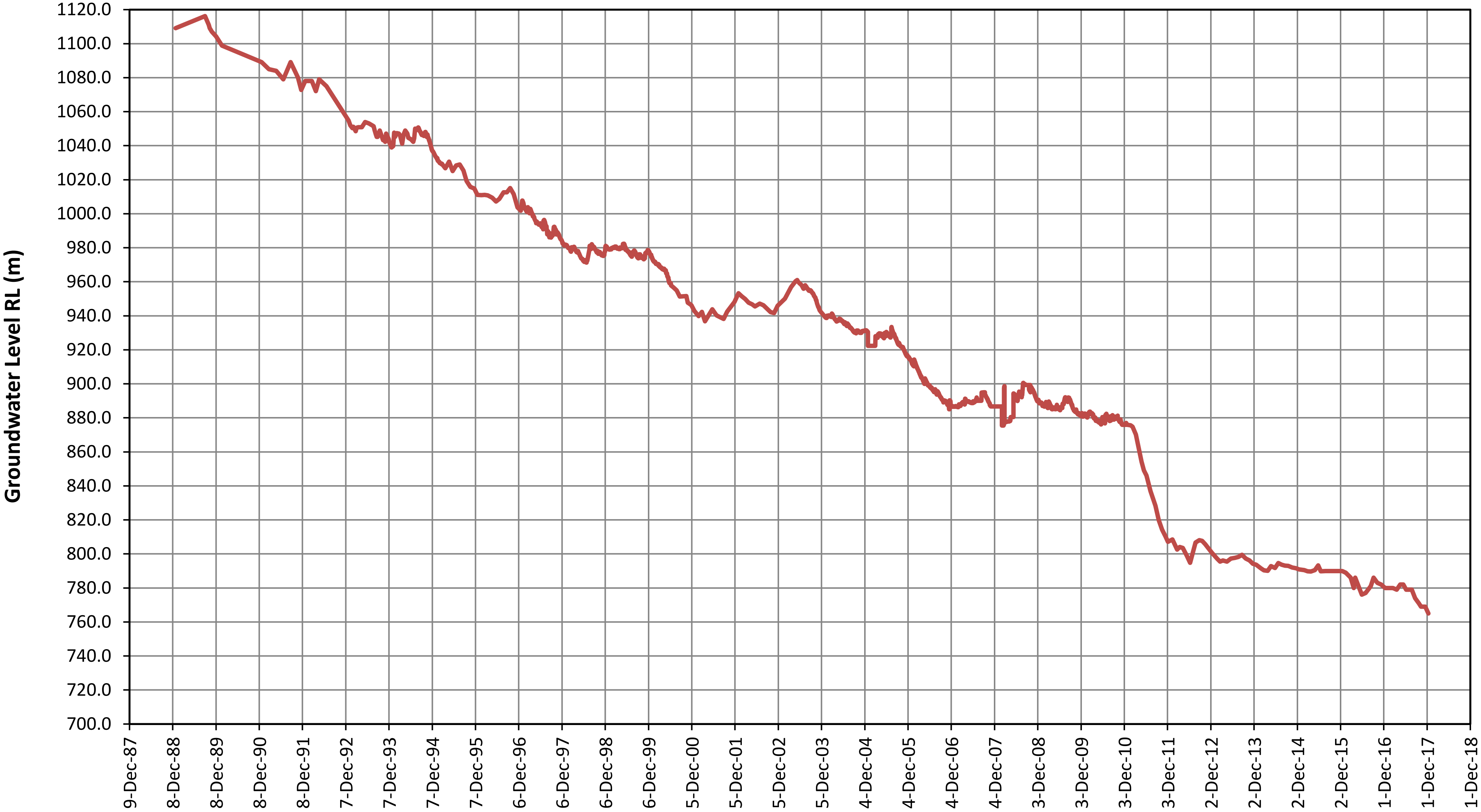

Figure 2

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OCEANA GOLD (NEW ZEALAND) LTD
PROJECT MARTHA

Mine Dewatering Level

Ref. No: 8332
Date: Jan 2018
Drawn: CW

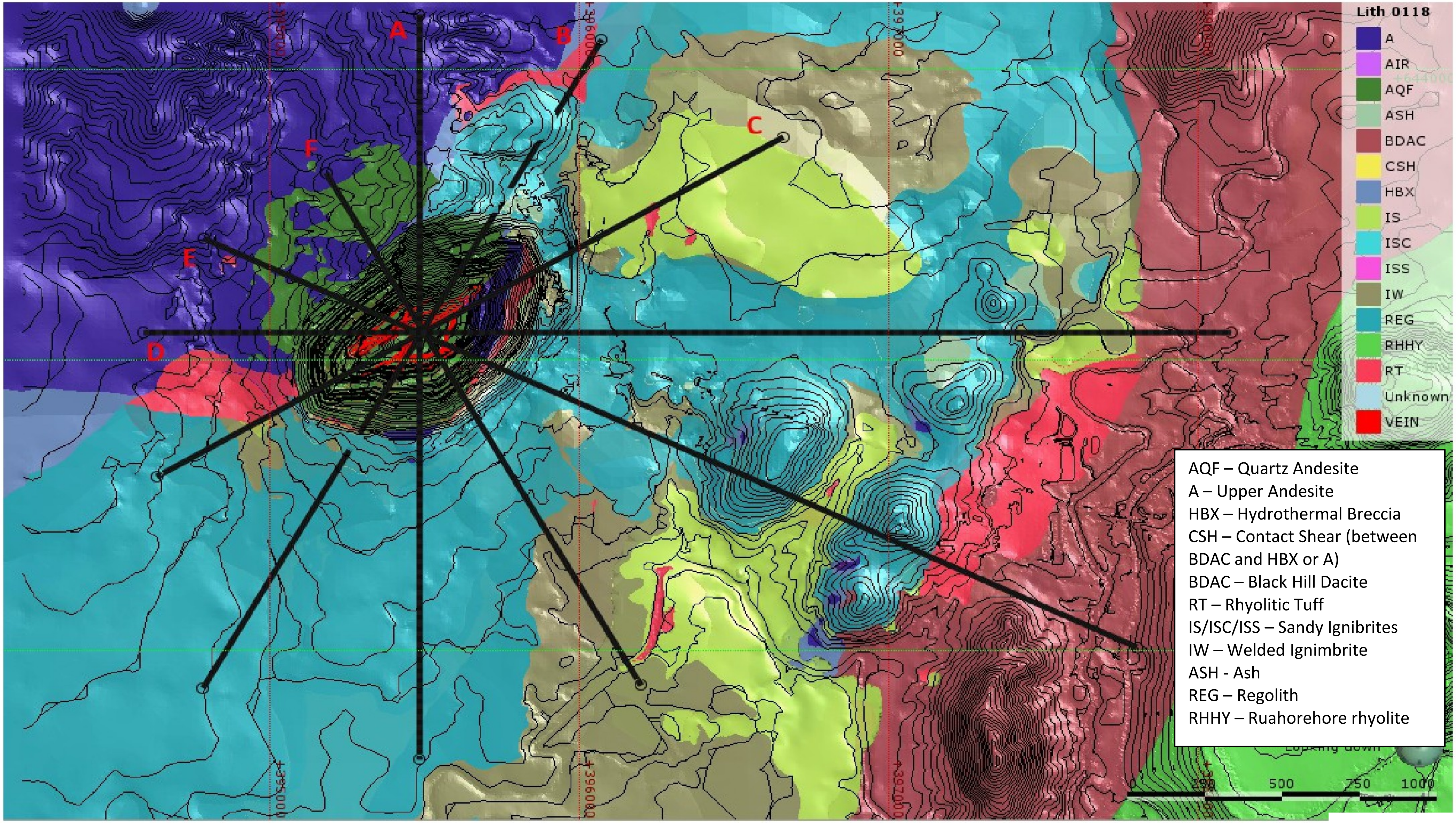

Figure 3

Engineering Geology Ltd
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OCEANA GOLD (NEW ZEALAND) LTD
PROJECT MARTHA

Geological Plan

Ref. No: 8332
Date: Jan 2018
Drawn: OGNZL

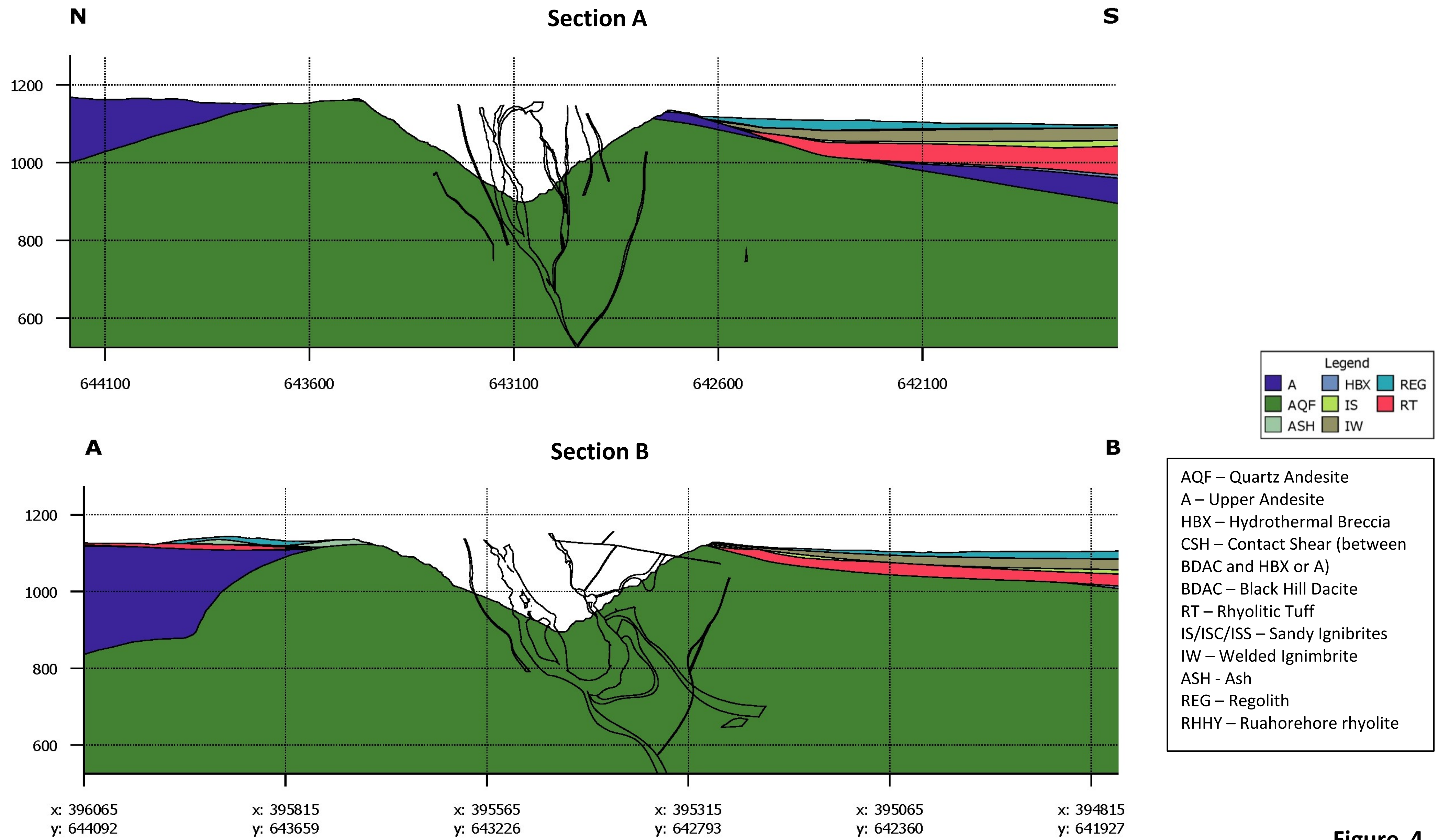

Figure 4

Engineering Geology Ltd Unit 7C, 331 Rosedale Rd, PO Box 301054, Albany, Auckland	**OCEANA GOLD (NEW ZEALAND) LTD** PROJECT MARTHA Geological Cross Sections A and B	Ref. No: 8332 Date: Jan 2018 Drawn: OGNZL

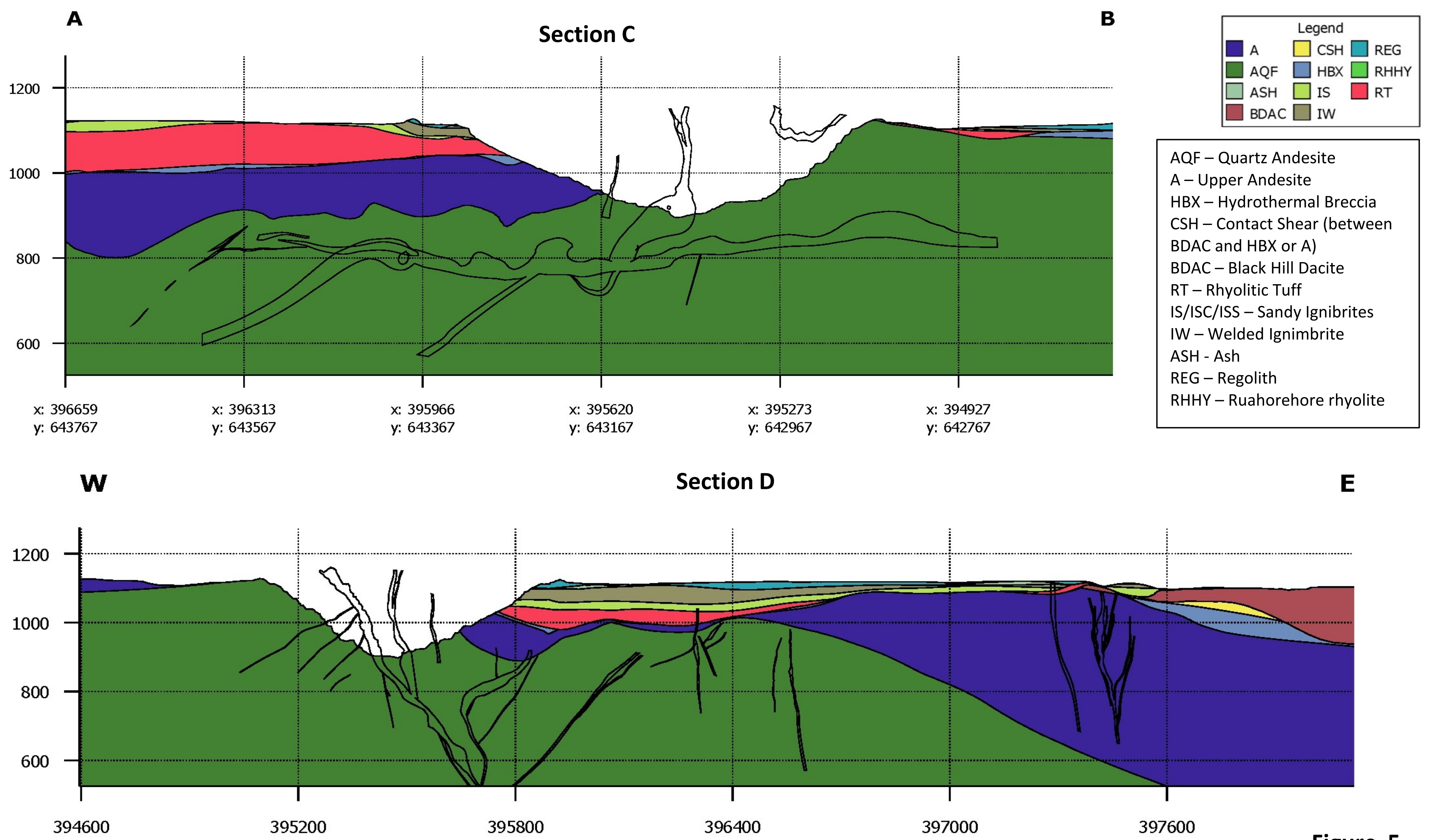

Figure 5

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OCEANA GOLD (NEW ZEALAND) LTD
PROJECT MARTHA

Geological Cross Sections C and D

Ref. No: 8332
Date: Jan 2018
Drawn: OGNZL

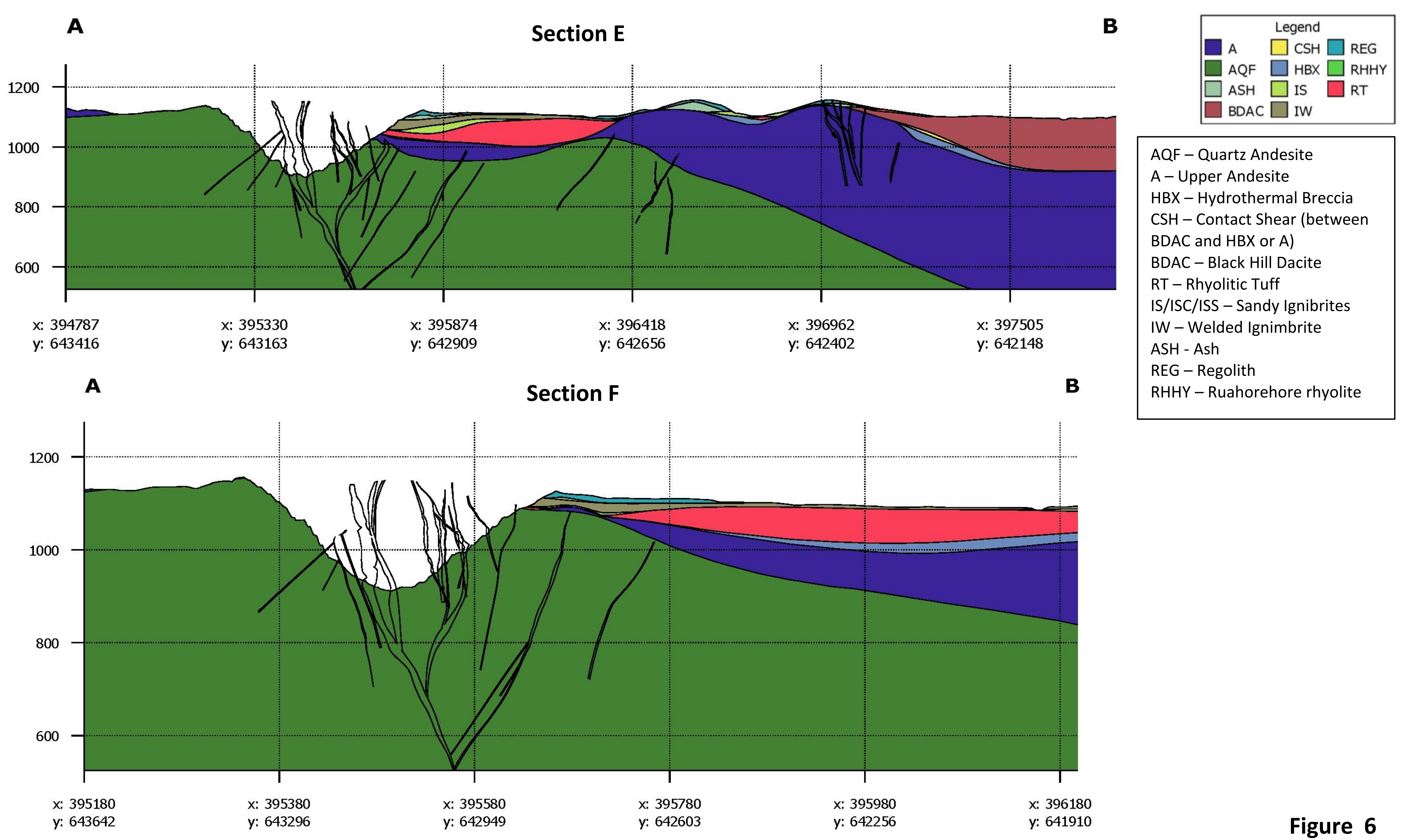

Figure 6

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OCEANA GOLD (NEW ZEALAND) LTD
PROJECT MARTHA

Geological Cross Sections E and F

Ref. No: 8332
Date: Jan 2018
Drawn: OGNZL

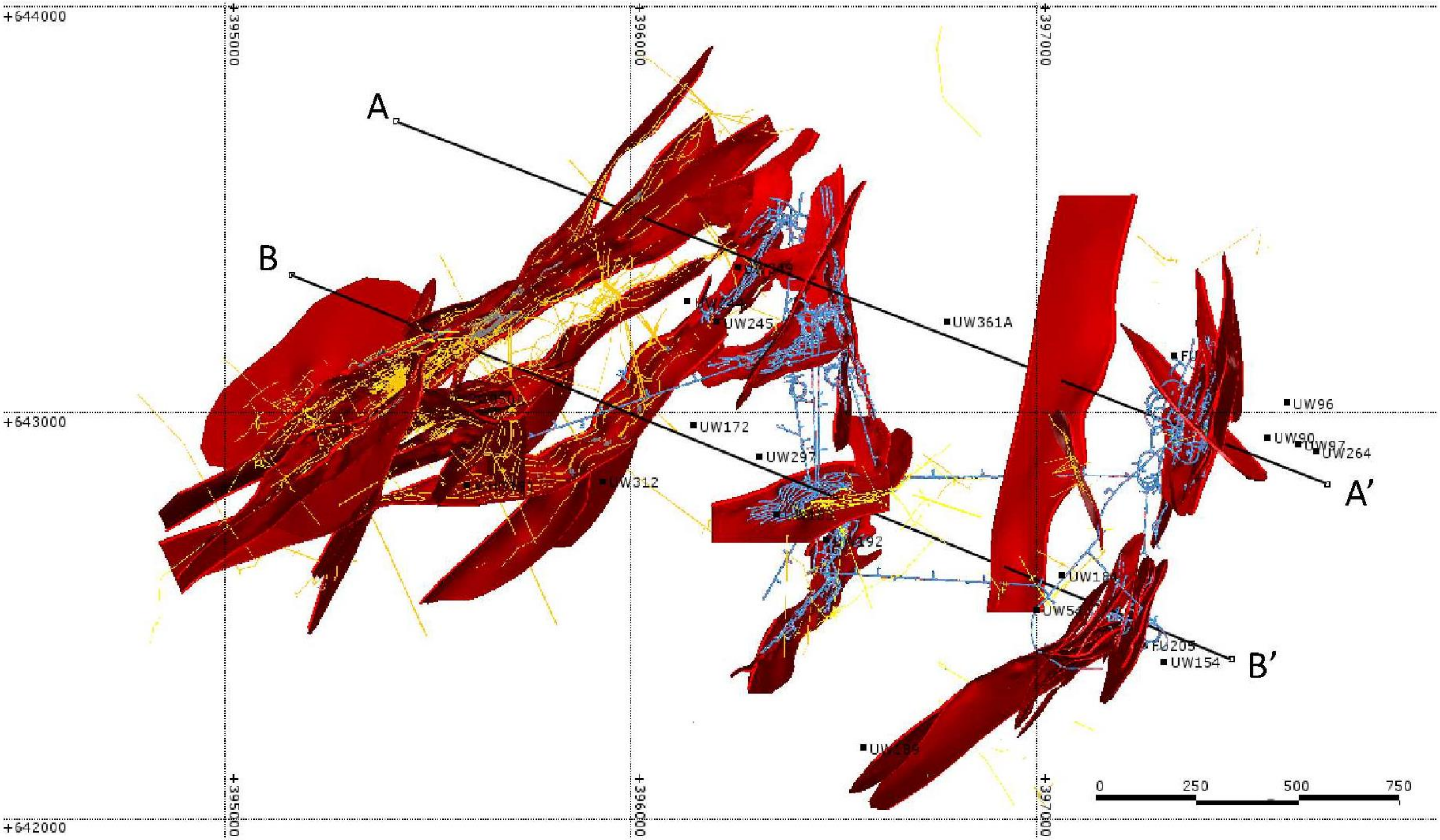

Figure 7

Engineering Geology Ltd Unit 7C, 331 Rosedale Rd, PO Box 301054, Albany, Auckland	**OCEANA GOLD (NEW ZEALAND) LTD** PROJECT MARTHA Plan of Martha, Union and Favona Systems	Ref. No: 8332 Date: Feb 2018 Drawn: OGNZL

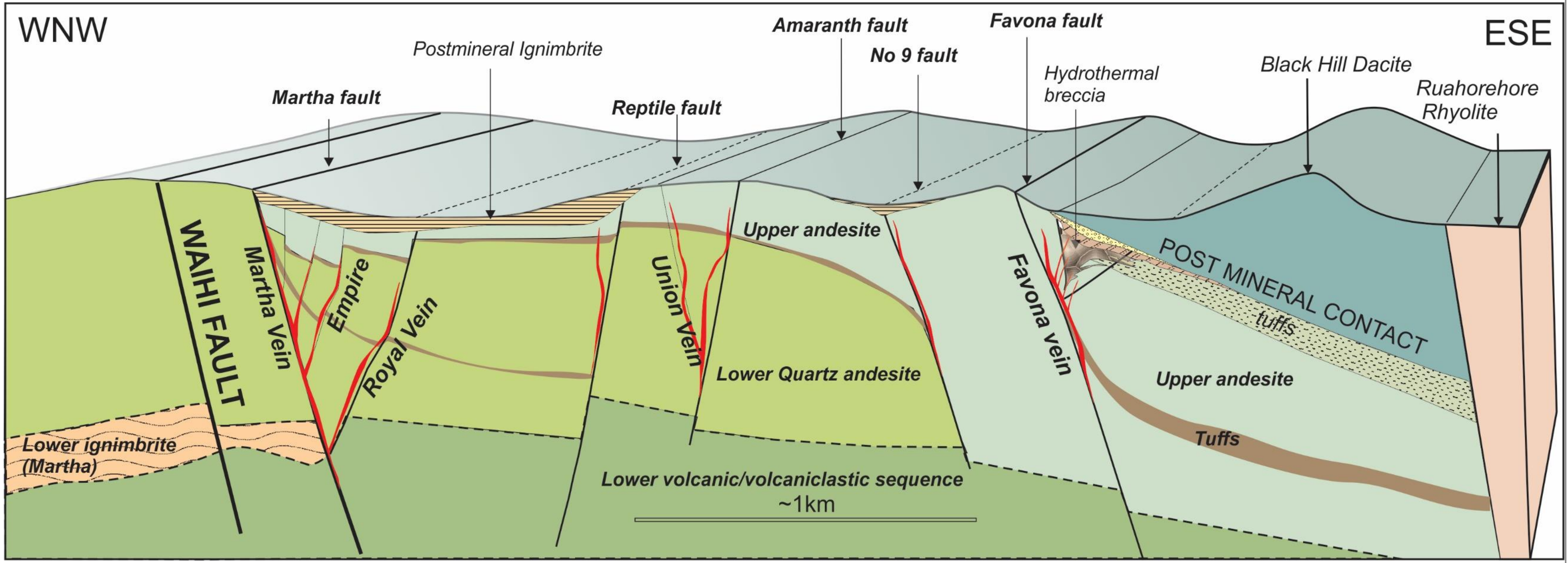

Figure 8

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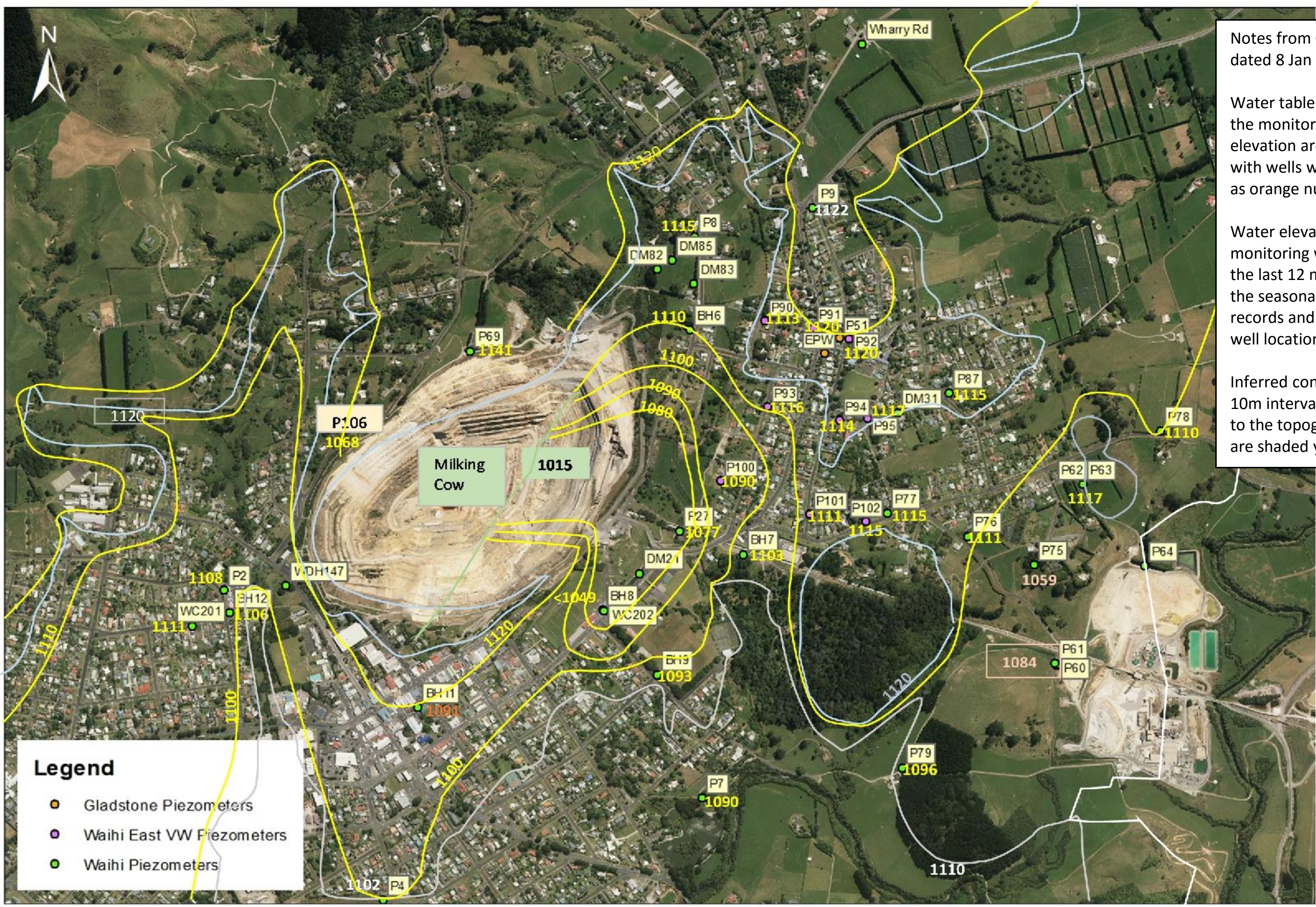
OCEANA GOLD (NEW ZEALAND) LTD
PROJECT MARTHA

Indicative Geological Section from Martha to Favona

Ref. No: 8332
Date: Feb 2018
Drawn: OGNZL



Notes from GWS Ltd Letter Report dated 8 Jan 2018

Water table elevation were plotted at the monitoring well location. The elevation are shown as yellow numbers with wells with uncertain values shown as orange numbers.

Water elevation data from shallow monitoring wells was averaged over the last 12 months (Jan-Dec 2017) given the seasonal fluctuations evident in the records and plotted at the monitoring well location.

Inferred contours of the water table at 10m intervals were drawn having regard to the topography. These contours are shaded yellow.

Figure 9

Engineering Geology Ltd Unit 7C, 331 Rosedale Rd, PO Box 301054, Albany, Auckland	OCEANA GOLD (NEW ZEALAND) LTD PROJECT MARTHA Location of Groundwater Monitoring Piezometers and Water Table Contours	Ref. No: 8332 Date: Jan 2018 Drawn: GWS LTD

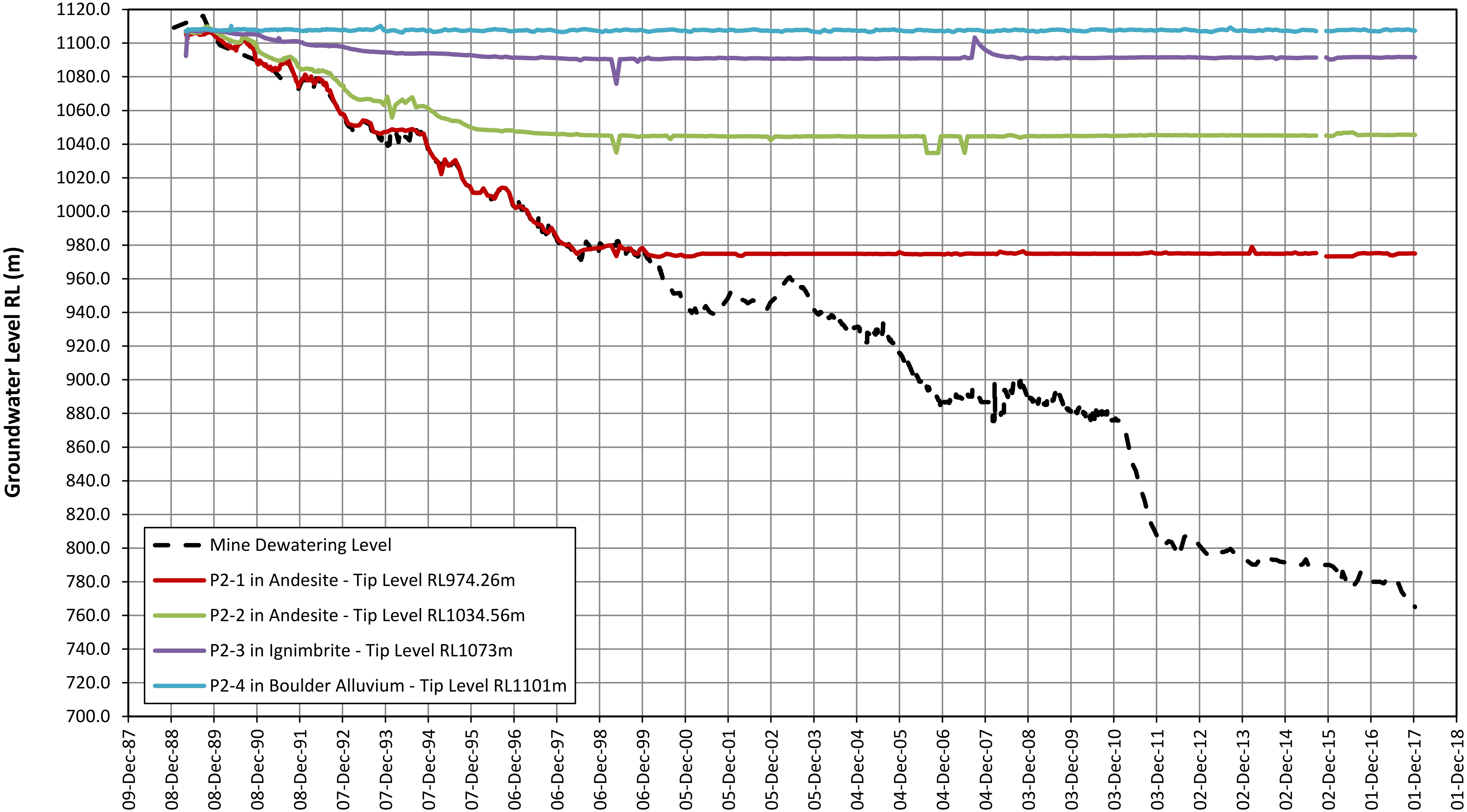


Figure 10

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OCEANA GOLD (NEW ZEALAND) LTD
PROJECT MARTHA

Piezometer Readings in Borehole P2

Ref. No: 8332
Date: Jan 2018
Drawn: CW

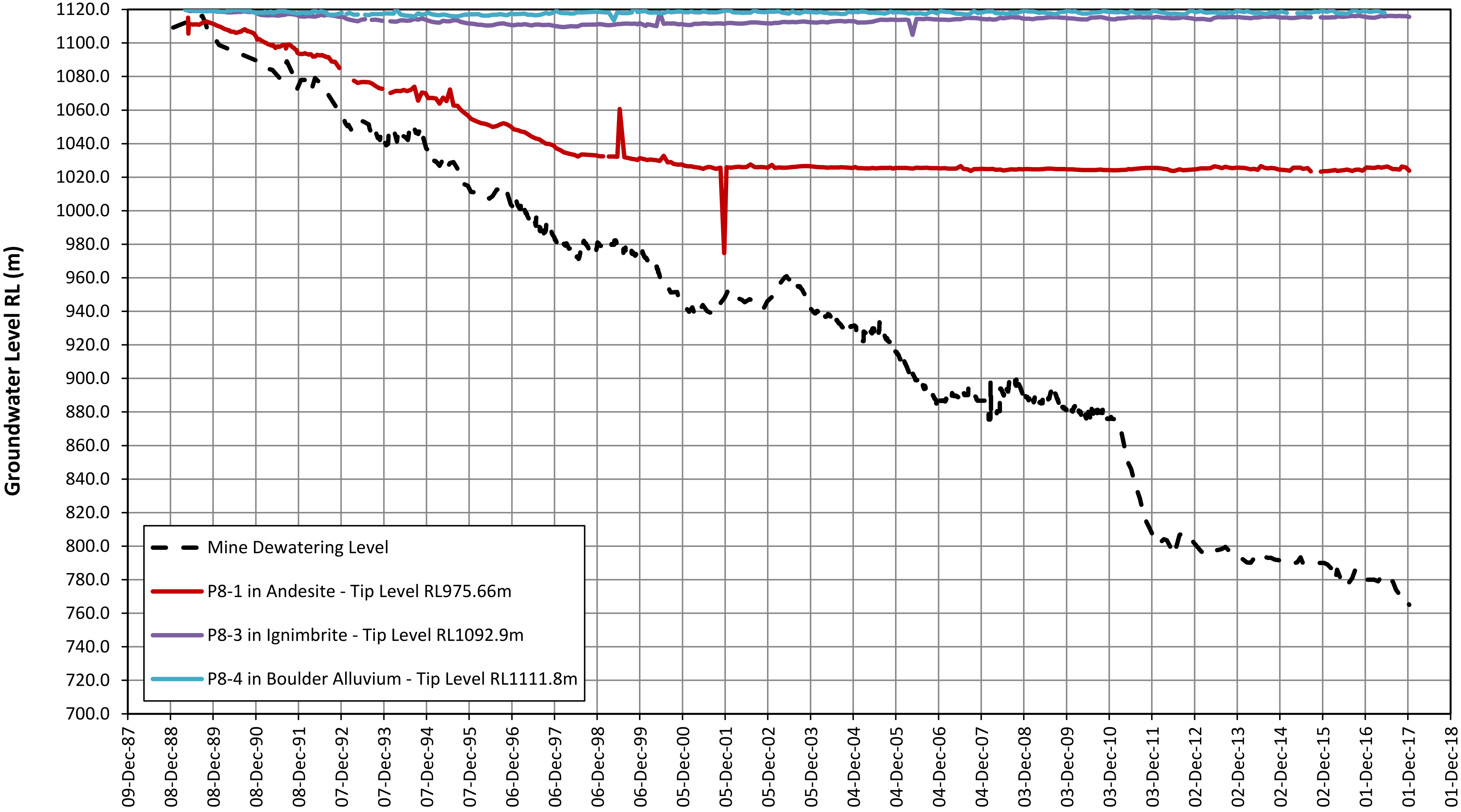

Figure 11

Engineering Geology Ltd Unit 7C, 331 Rosedale Rd, PO Box 301054, Albany, Auckland	**OCEANA GOLD (NEW ZEALAND) LTD** PROJECT MARTHA Piezometer Readings in Borehole P8	Ref. No: 8332 Date: Jan 2018 Drawn: CW

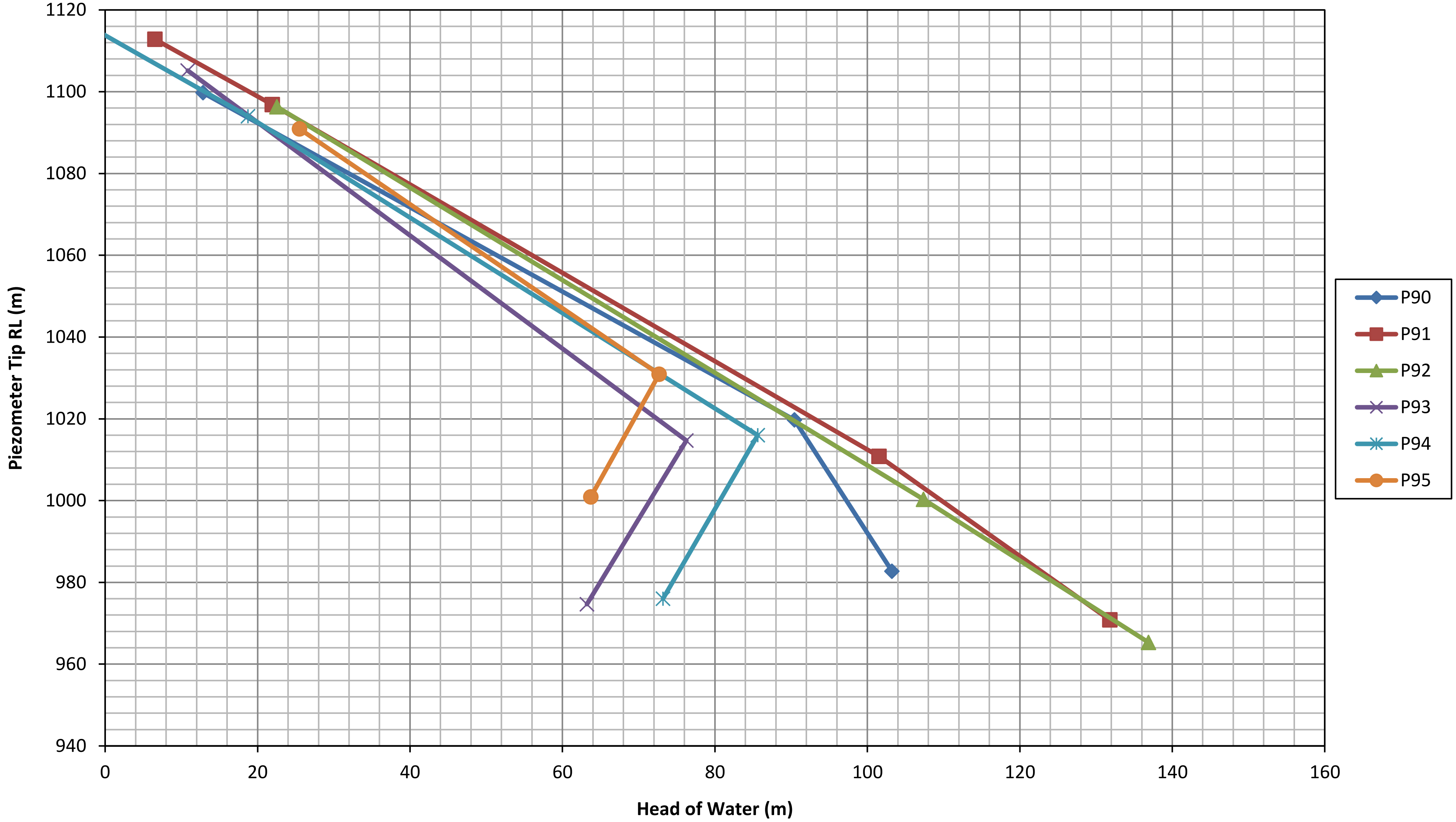

Figure 12

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Albany, Auckland

OCEANA GOLD (NEW ZEALAND) LTD
PROJECT MARTHA

Piezometer Readings in Boreholes P90 - P95

Ref. No: 8332
Date: Jan 2018
Drawn: CW

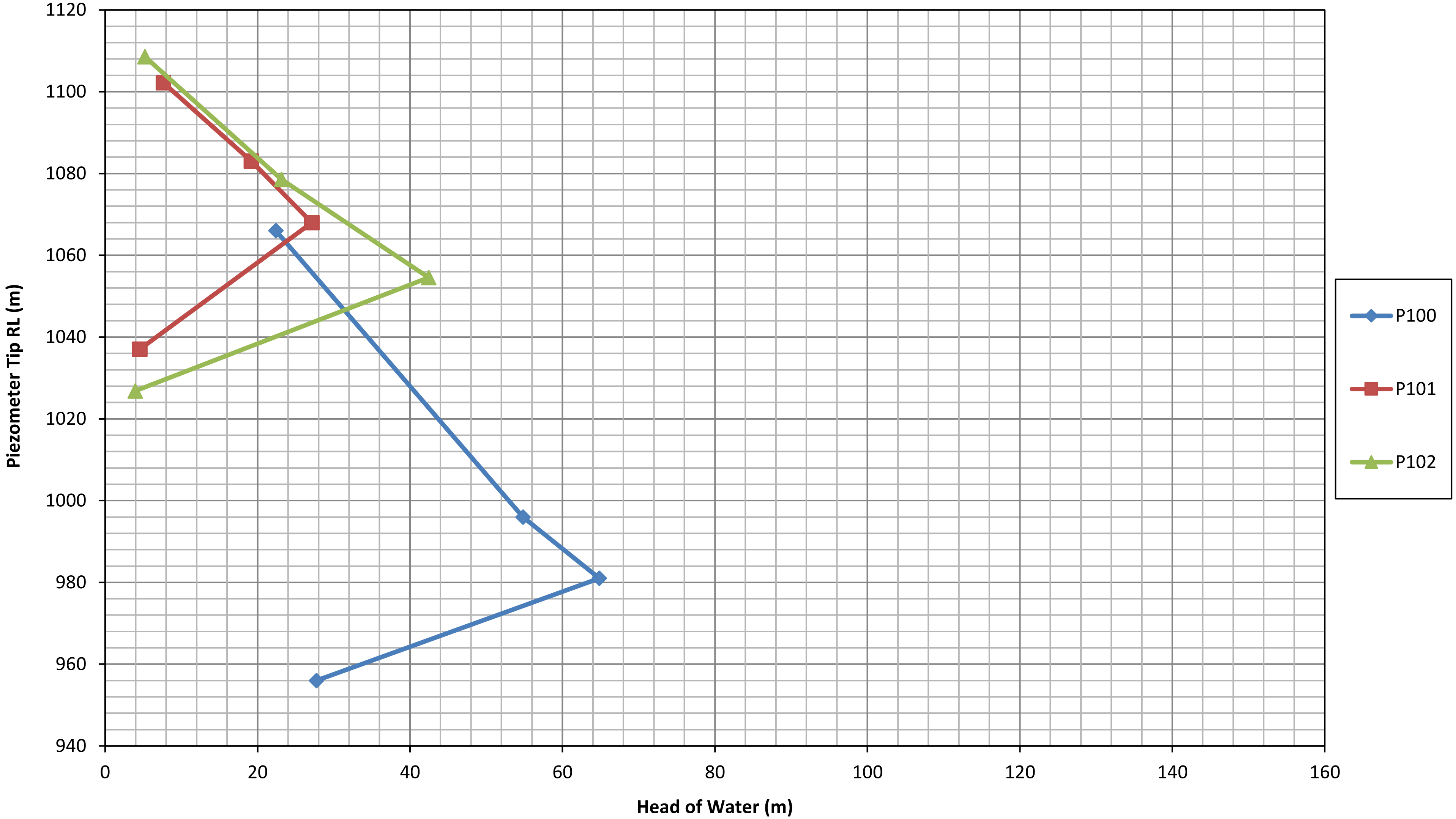
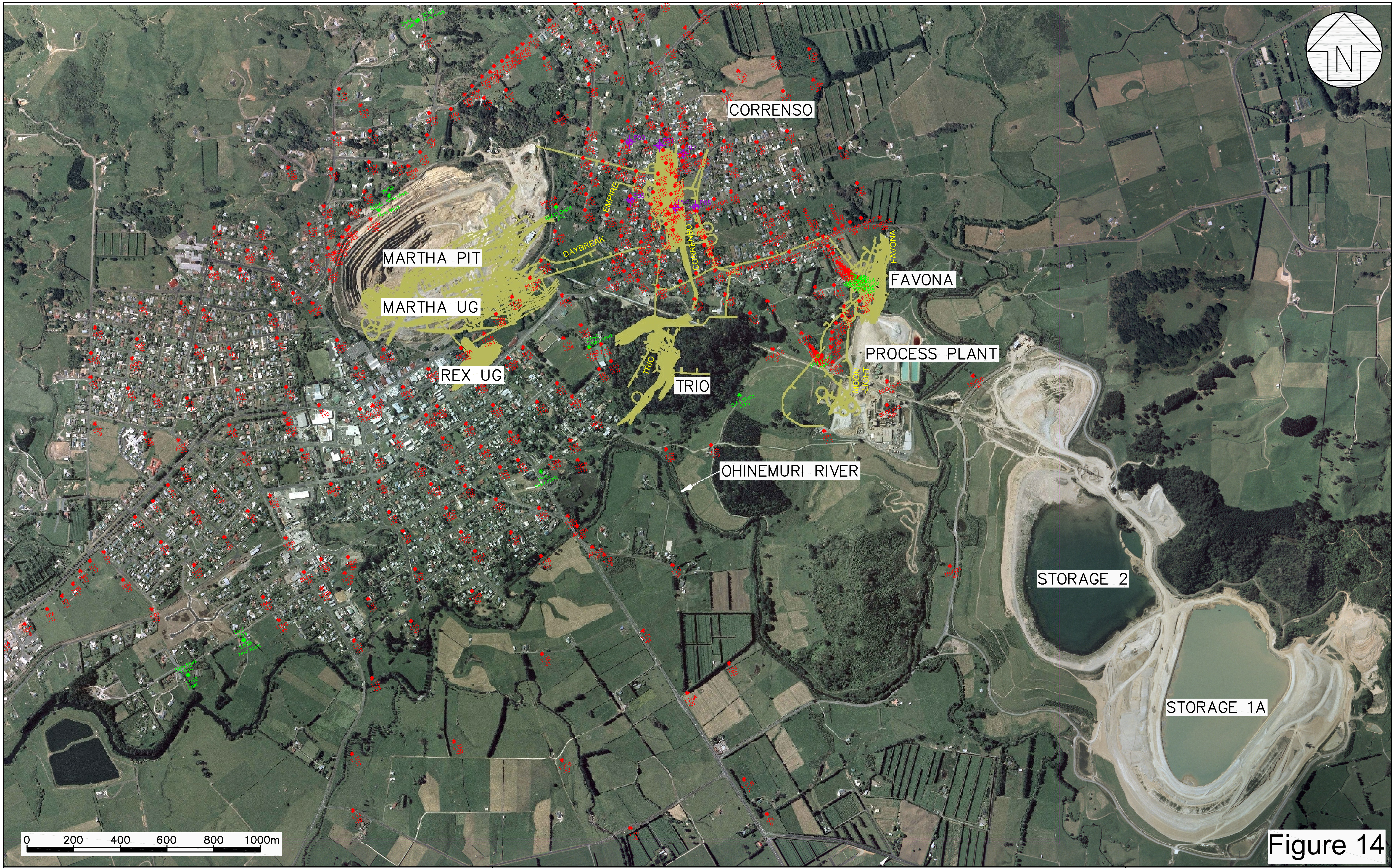


Figure 13

Engineering Geology Ltd Unit 7C, 331 Rosedale Rd, PO Box 301054, Albany, Auckland	**OCEANA GOLD (NEW ZEALAND) LTD** PROJECT MARTHA Piezometer Readings in Boreholes P100 - P102	Ref. No: 8332 Date: Jan 2018 Drawn: CW



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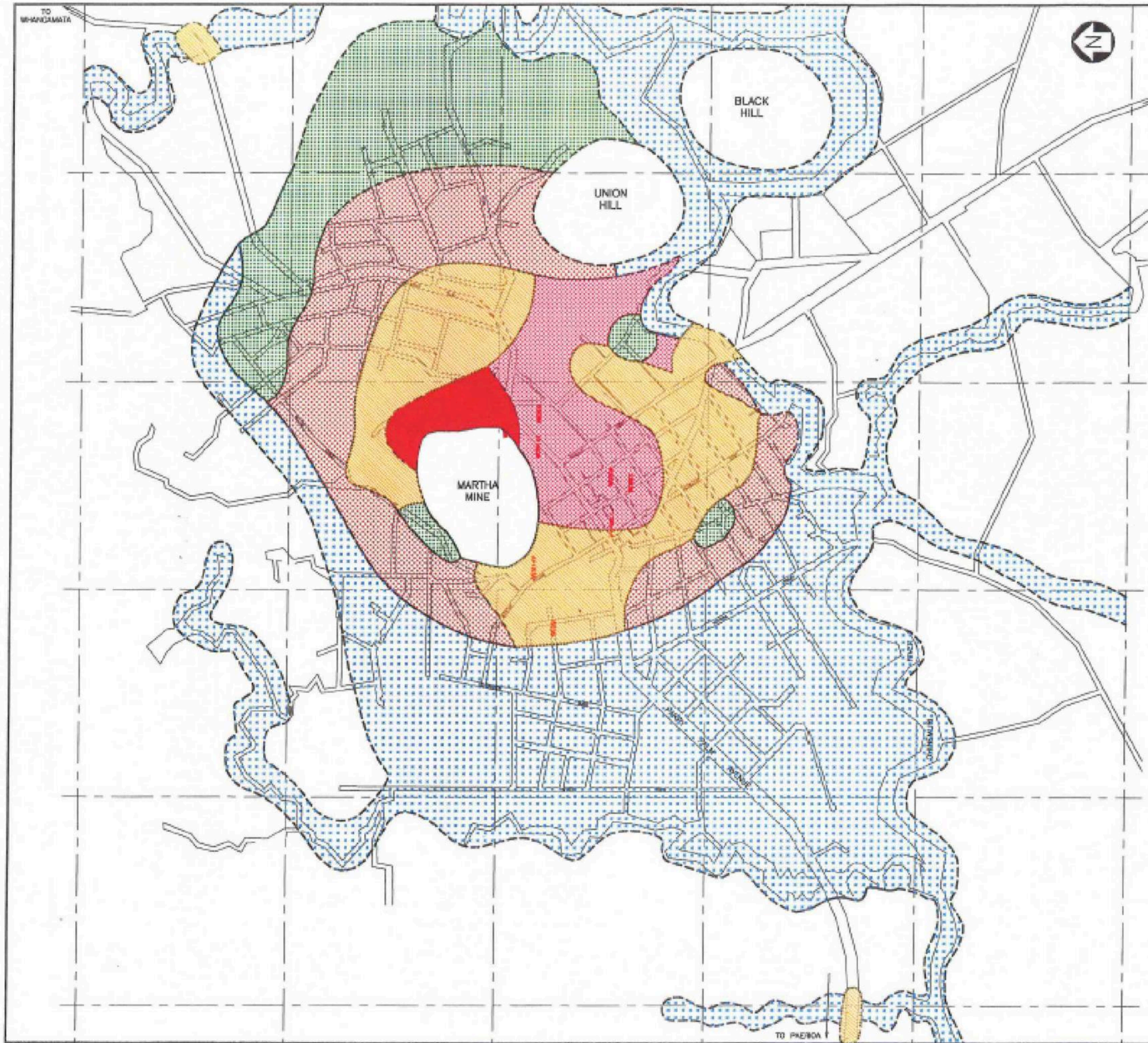
NEWMONT WAIHI GOLD
Golden Link Project - Correnso Proposal
Location of Ground Settlement Markers

Drawing No.	8332-Fig 14
Date:	1 Feb 2018
Drawn:	JL
Scale:	1:15000 (@A3)
Filename:	8332-Fig 14.dwg



KEY

	SETTLEMENT ZONE 1
	SETTLEMENT ZONE 2
	SETTLEMENT ZONE 3
	SETTLEMENT ZONE 4
	SETTLEMENT ZONE 5
	SETTLEMENT ZONE 6
	SETTLEMENT ZONE 7
	ZONE BOUNDARY
	ZONE BOUNDARY INFERRED

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	±8
5	−25 to −50	45	±9
6	−55 to −85	65	±8
7	−95 to −125	110	±9

* +ve indicates surface heave
−ve indicates surface settlement

Figure 15

REV	DESCRIPTION OF REVISION	BY	CHK	DATE
A	FINAL – RE-ISSUE OF DWG23205\05\01\8400\WA05R018	SCG		13NOV97

WAIHI GOLD COMPANY

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XREF FILES: WG50R52
VIEW NAME:
CAD FILE NAME: U:\~\0232\05\20\8400\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

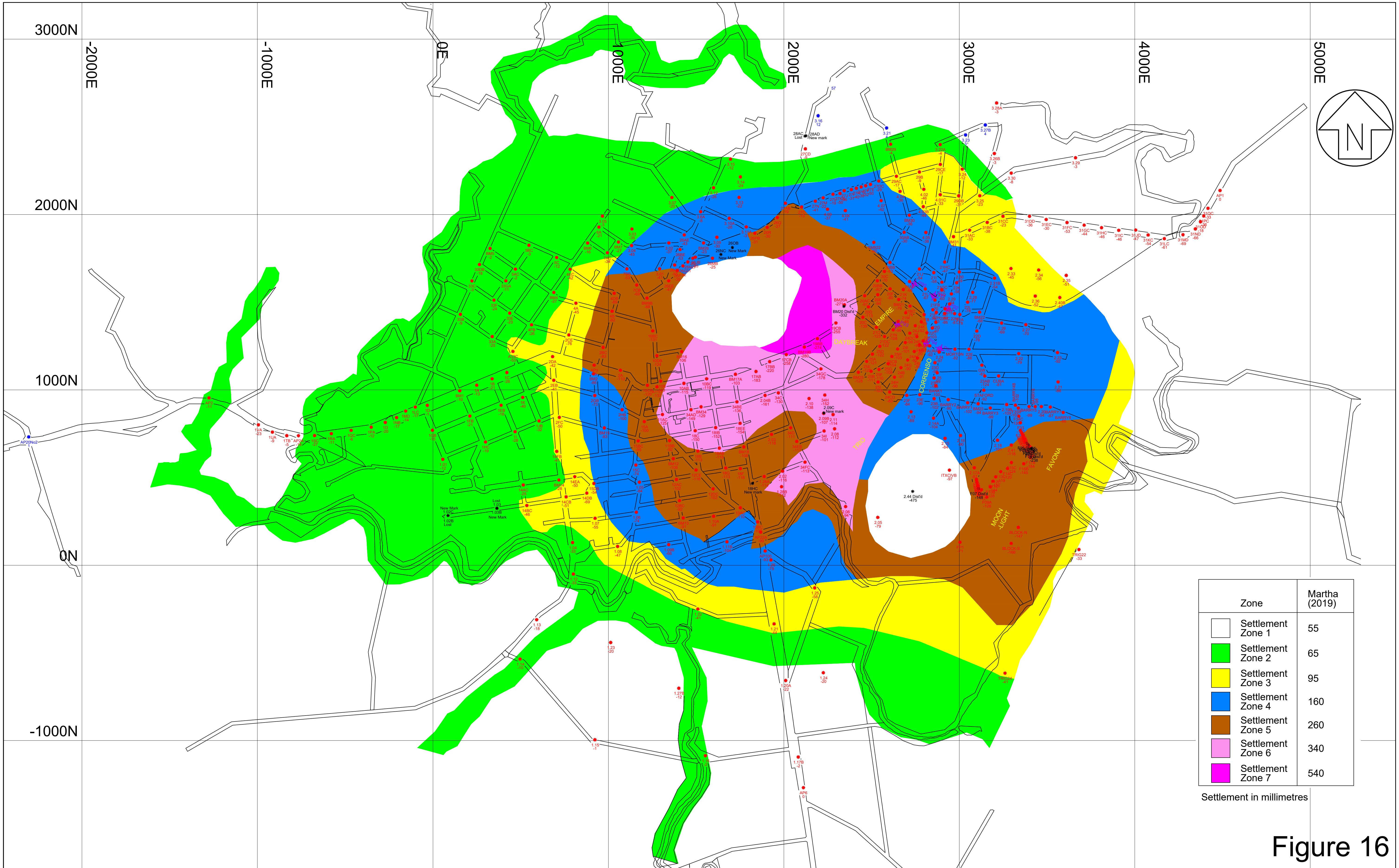

Figure 16

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OCEANA GOLD NZ LIMITED - WAIHI
Project Martha
Proposed Settlement Zones

Drawing No. 8332-Fig16
Date: 2 Feb 2018
Drawn: JL
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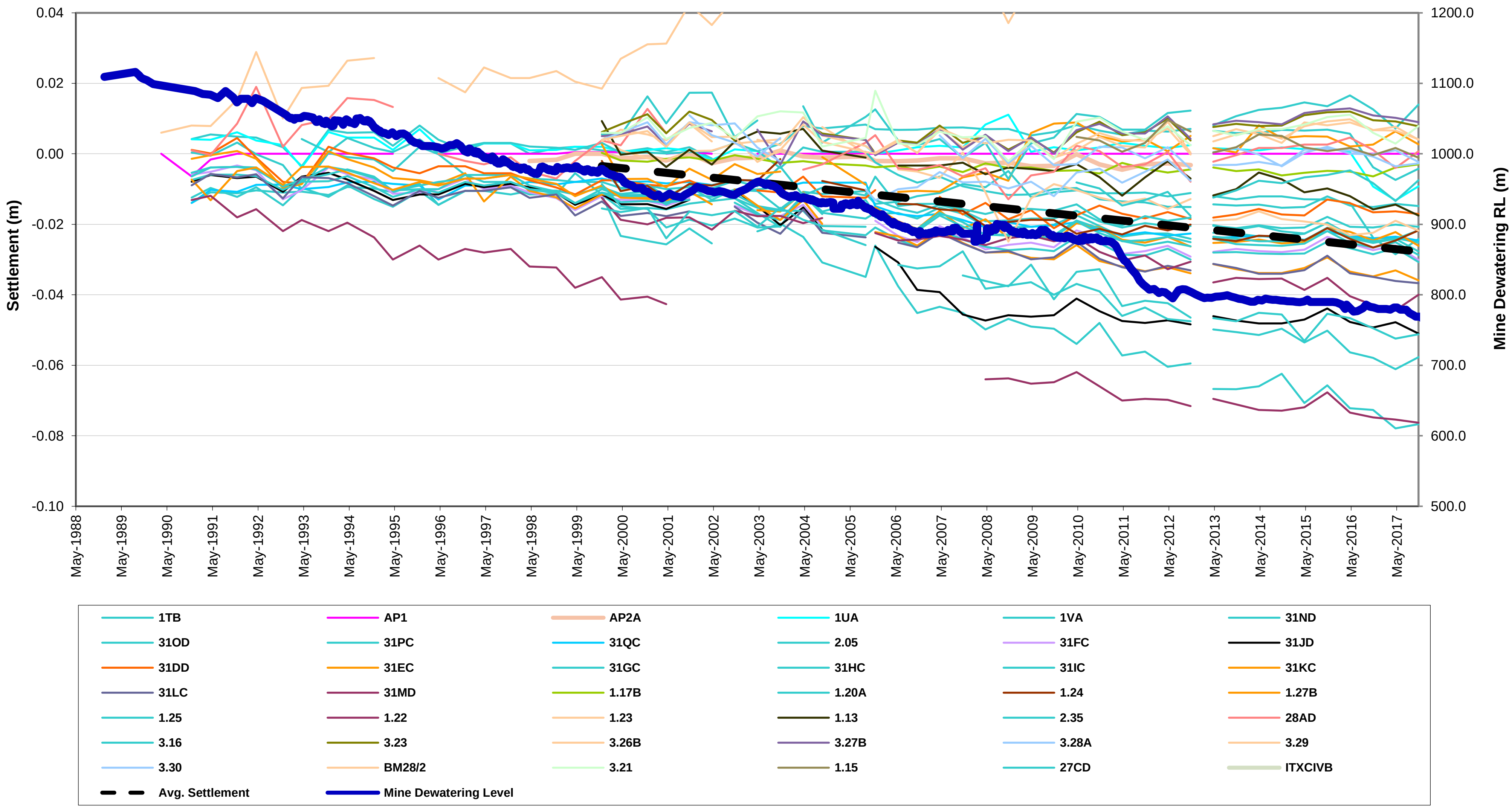

Figure 17

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OCEANA GOLD (NEW ZEALAND) LTD
PROJECT MARTHA

Ground Settlement - Zone 1

Ref. No: 8332
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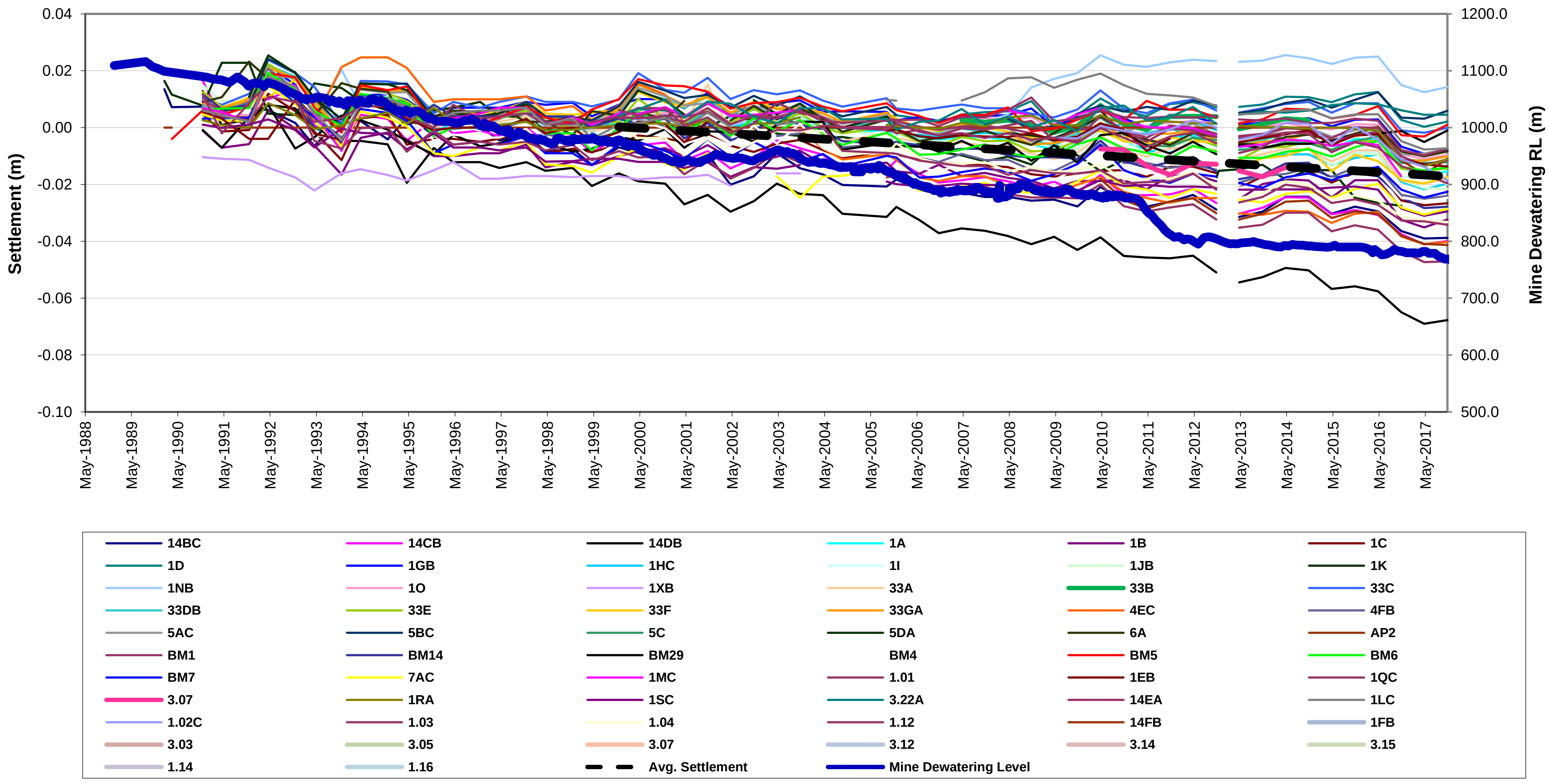

Figure 18

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OCEANA GOLD (NEW ZEALAND) LTD
PROJECT MARTHA

Ground Settlement - Zone 2

Ref. No: 8332
Date: Feb 2018
Drawn: CW

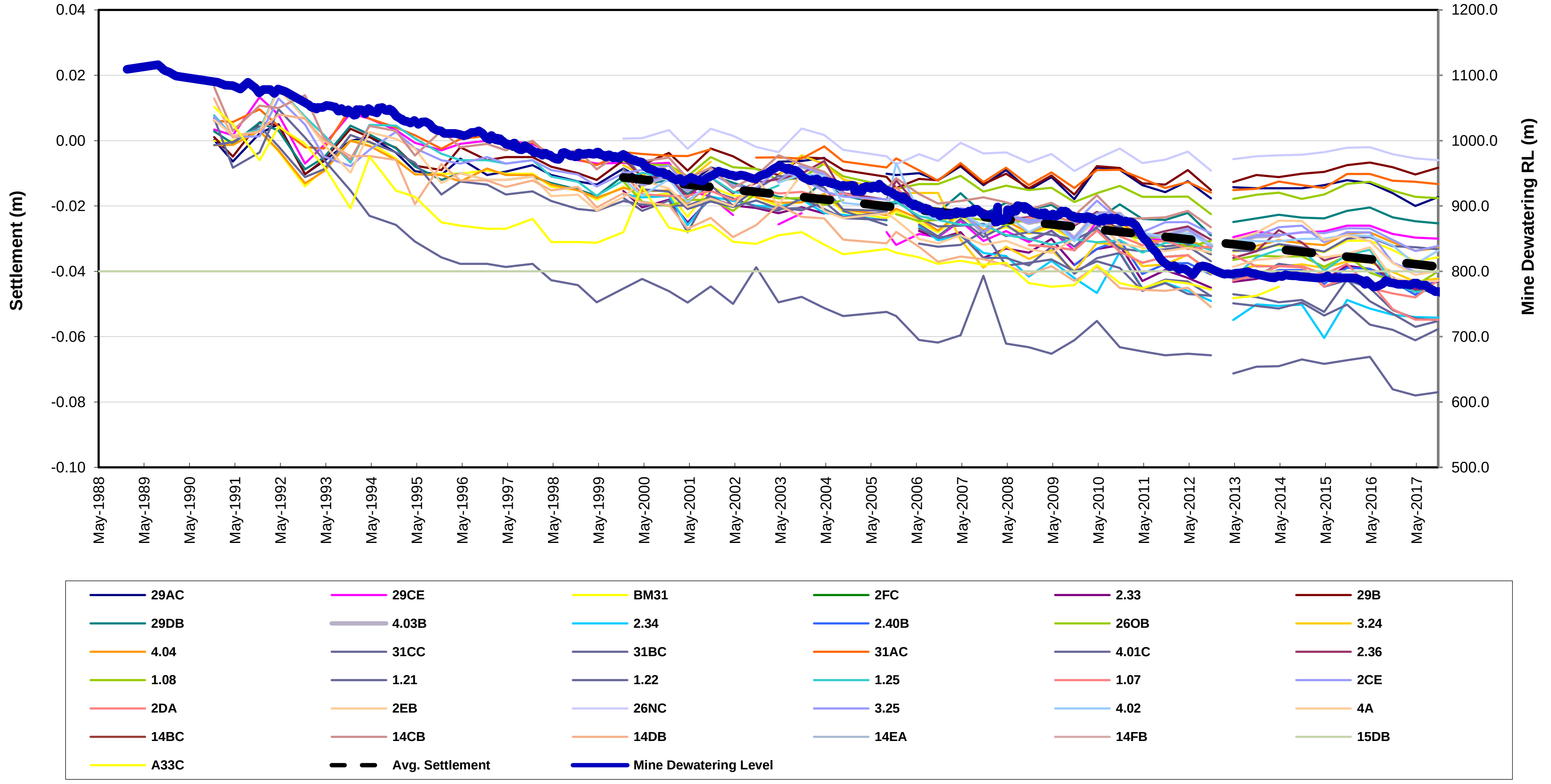

Figure 19

Engineering Geology Ltd Unit 7C, 331 Rosedale Rd, PO Box 301054,	**OCEANA GOLD (NEW ZEALAND) LTD** PROJECT MARTHA Ground Settlement - Zone 3	Ref. No: 8332 Date: Feb 2018 Drawn: CW

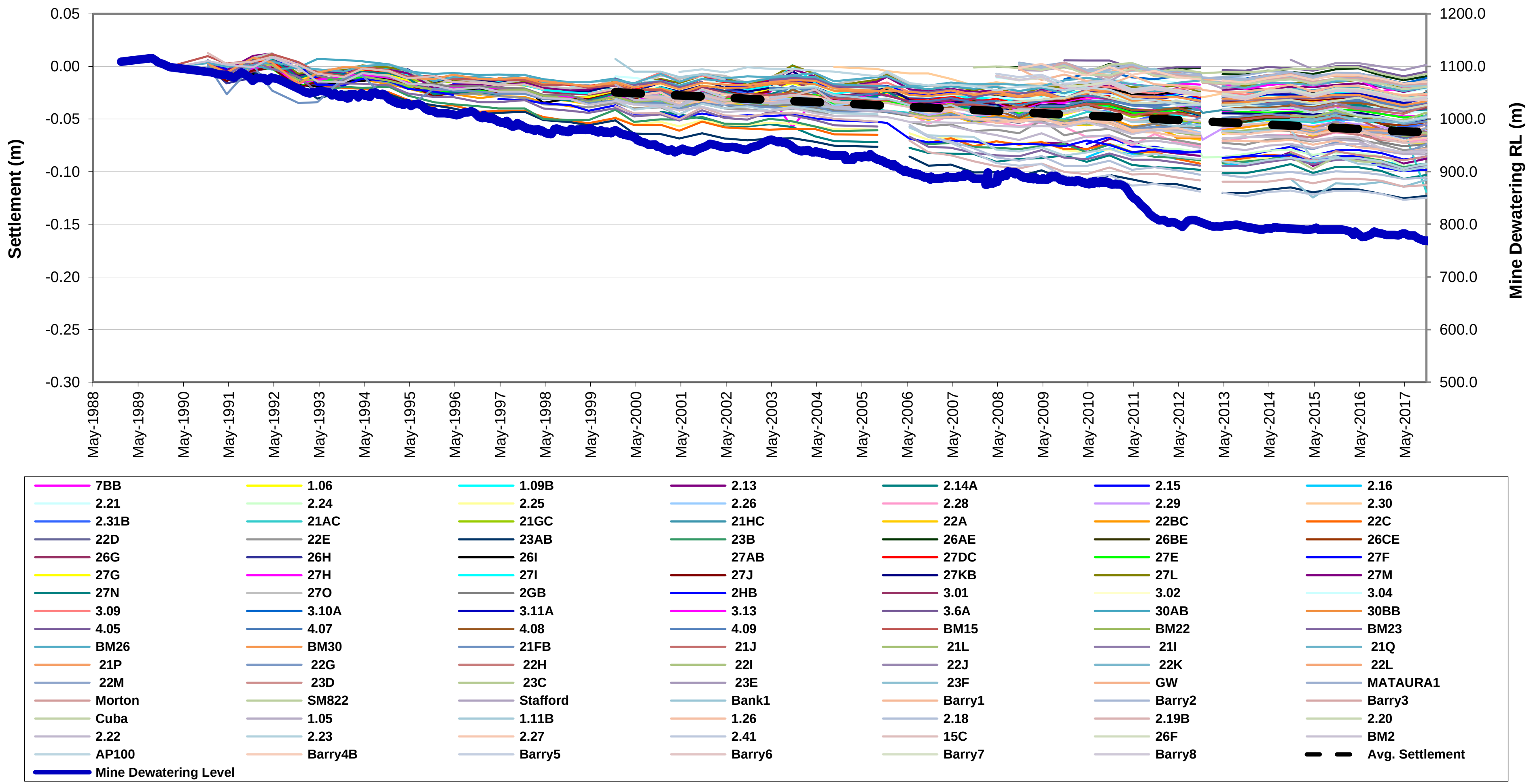

Figure 20

Engineering Geology Ltd Unit 7C, 331 Rosedale Rd, PO Box 301054,	**OCEANA GOLD (NEW ZEALAND) LTD** PROJECT MARTHA Ground Settlement - Zone 4	Ref. No: 8332 Date: Feb 2018 Drawn: CW

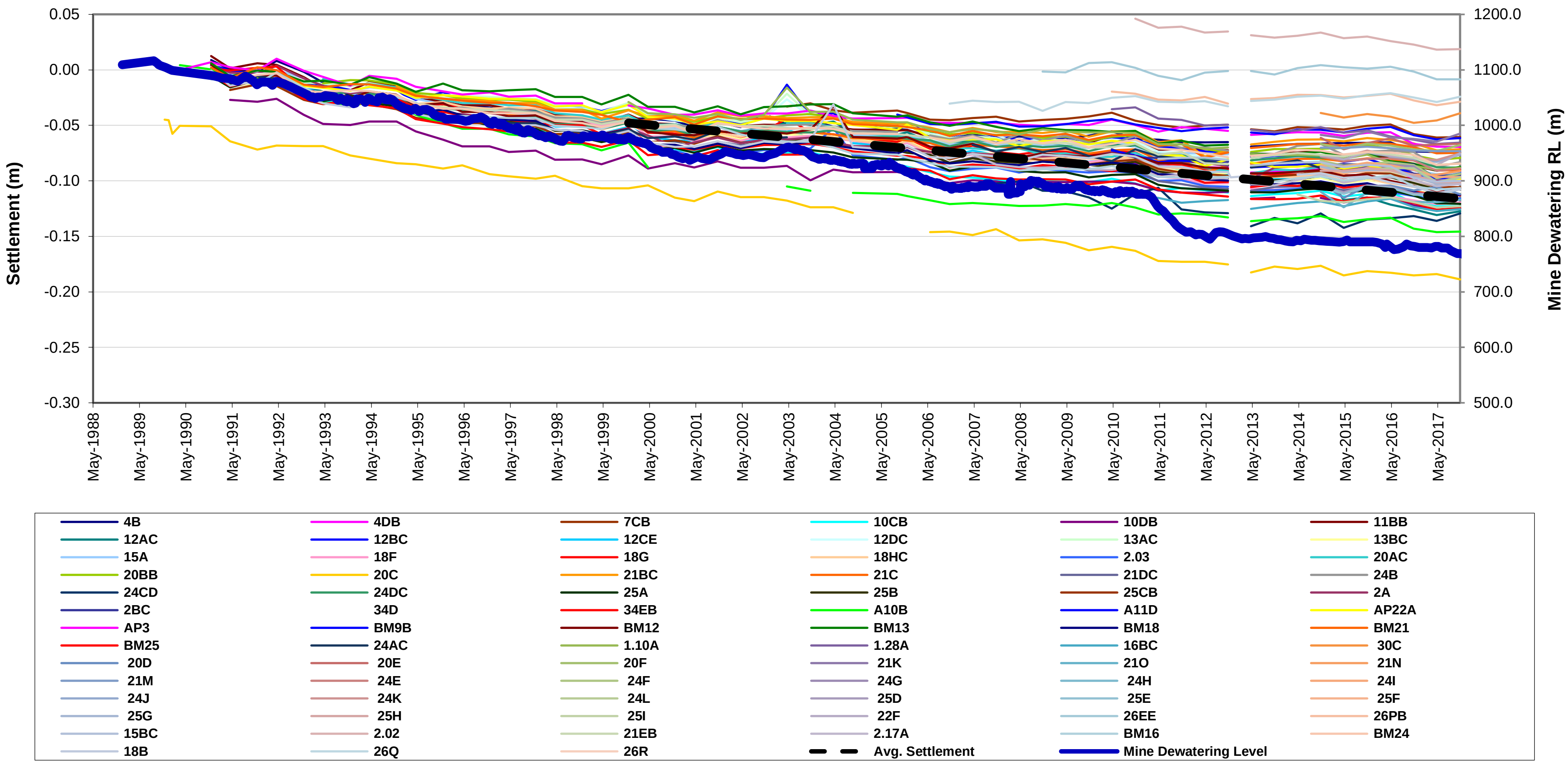

Figure 21

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OCEANA GOLD (NEW ZEALAND) LTD
PROJECT MARTHA

Ground Settlement - Zone 5

Ref. No: 8332
Date: Feb 2018
Drawn: CW

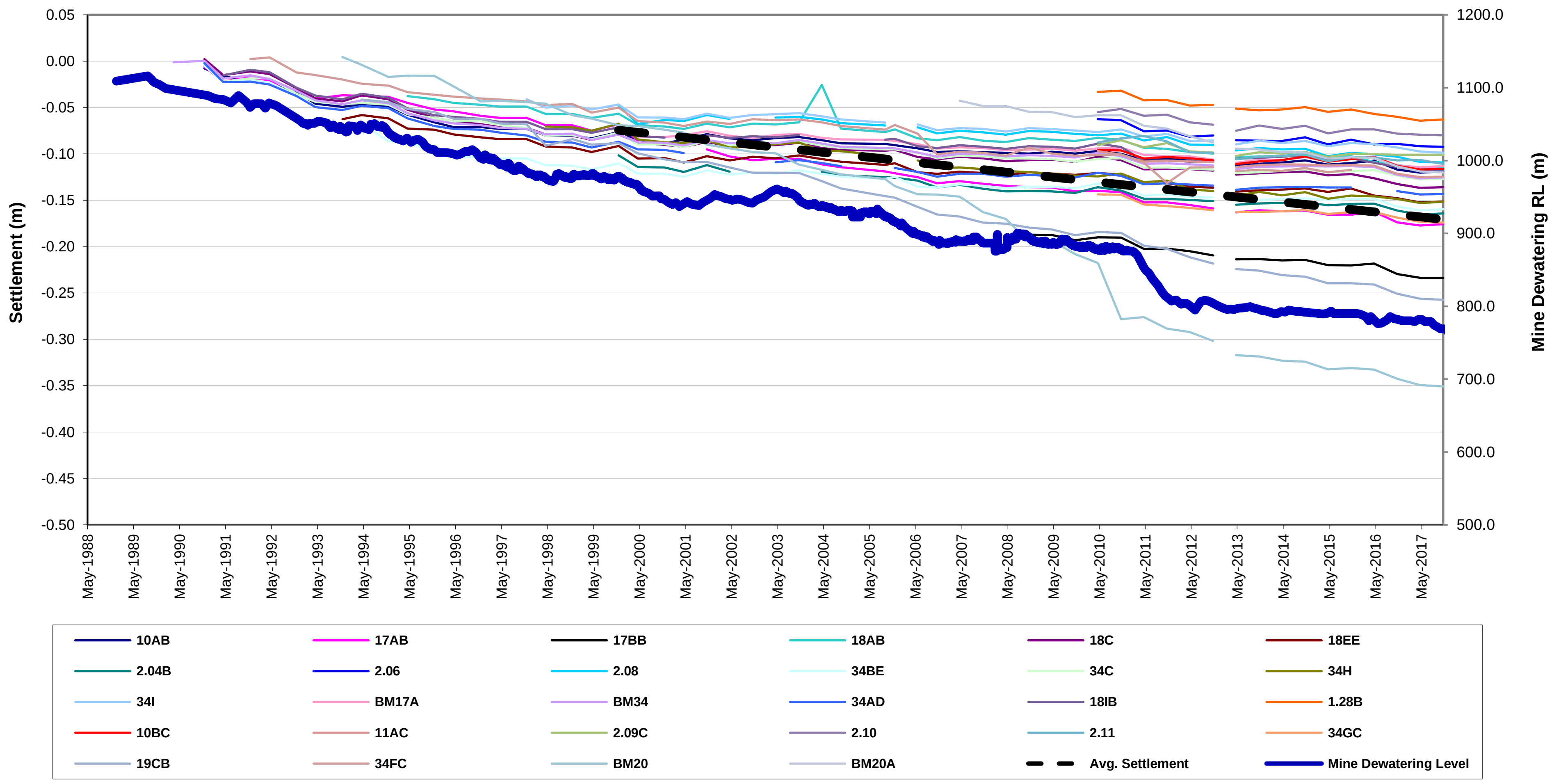

Figure 22

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OCEANA GOLD (NEW ZEALAND) LTD
PROJECT MARTHA

Ground Settlement - Zone 6

Ref. No: 8332
Date: Feb 2018
Drawn: CW

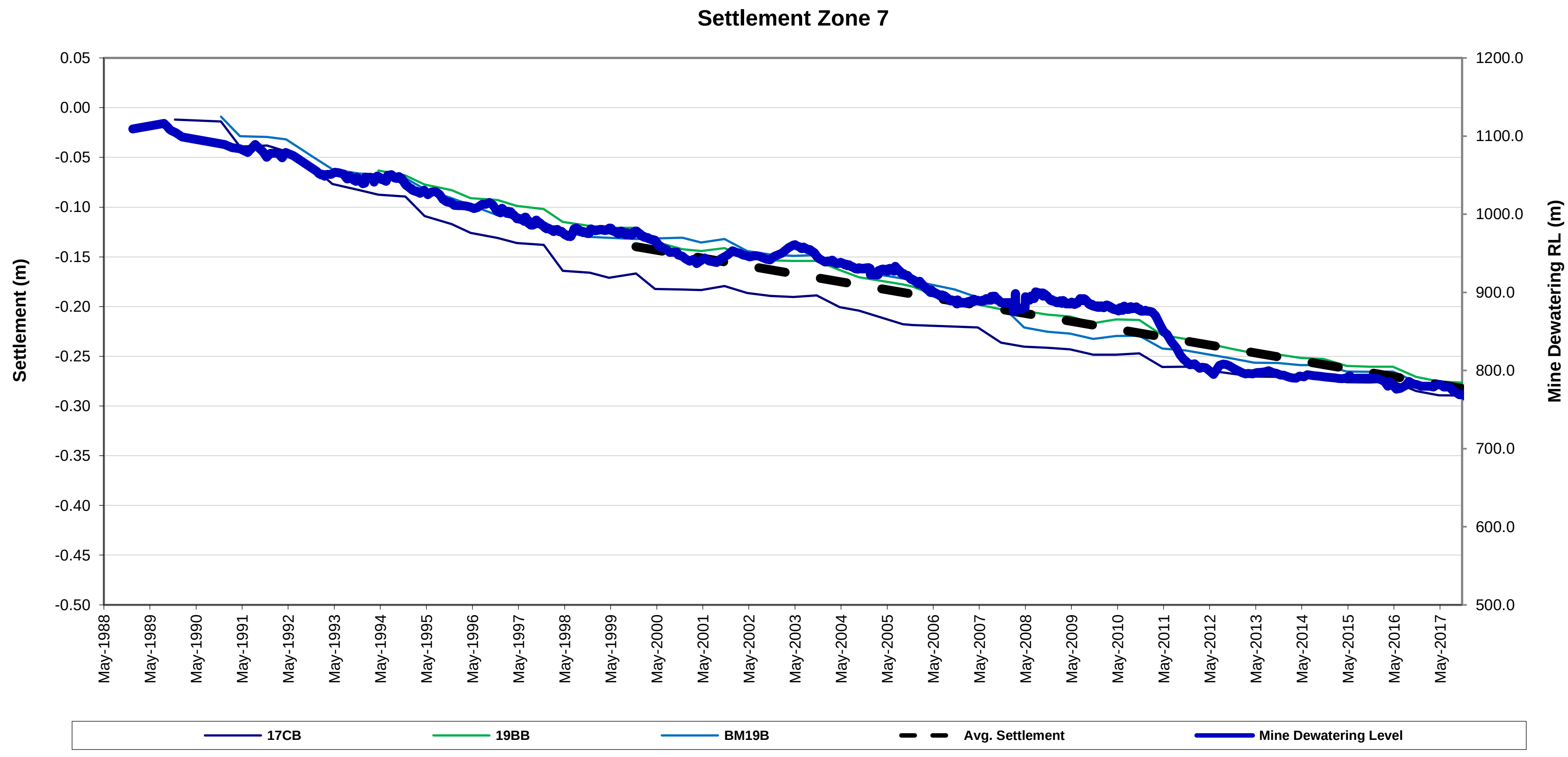


Figure 23

Engineering Geology Ltd Unit 7C, 331 Rosedale Rd, PO Box 301054,	**OCEANA GOLD (NEW ZEALAND) LTD** PROJECT MARTHA Ground Settlement - Zone 7	Ref. No: 8332 Date: Feb 2018 Drawn: CW

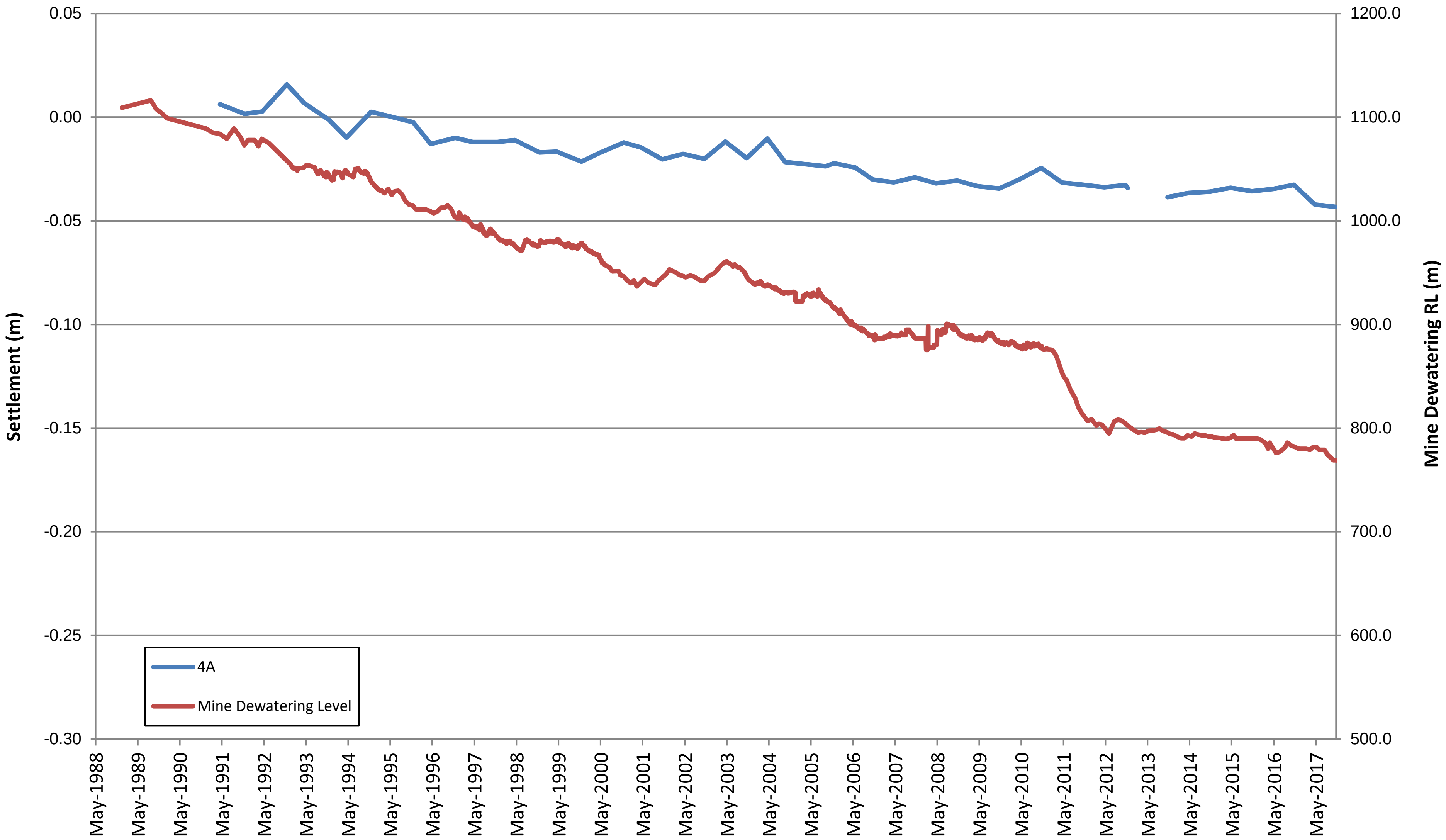


Figure 24

Engineering Geology Ltd Unit 7C, 331 Rosedale Rd, PO Box 301054, Albany, Auckland	**OCEANA GOLD (NEW ZEALAND) LTD** PROJECT MARTHA Ground Settlement of Marker 4A and Mine Dewatering Level	Ref. No: 8332 Date: Feb 2018 Drawn: CW

APPENDIX A
TWO DIMENSIONAL DECOUPLED SEEPAGE AND DEFORMATION NUMERICAL MODELLING

APPENDIX A
TWO DIMENSIONAL DECOUPLED SEEPAGE AND DEFORMATION NUMERICAL MODELLING

1.0 INTRODUCTION

This memorandum summarises the assumptions and results of two-dimensional (2D) seepage and deformation numerical modelling of the area to the east of the Martha Pit, referred to as Waihi East. The modelling was undertaken to enable estimates of settlements due to dewatering to RL770m associated with mining since 1989 and with Project Martha which will involve dewatering down to RL500m from the currently consented level of RL700m.

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 was provided by GWS Ltd (Ref.3). Some small adjustments were made to the model for deformation modelling.

2.0 SCOPE OF WORK

The scope of work has included:

i. Modelling of seepage and drawdown associated with dewatering of both single and multiple veins to various levels using SEEP/W.

ii. Deformation analyses using SIGMA/W with changes in stress due to dewatering to different levels predicted by the SEEP/W modelling.

iii. Comparison of the results of the numerical modelling with monitored settlements

3.0 SOIL PROFILE AND GROUND MODEL

Figure A1 provides the model geometry and the associated boundary conditions. The location of this section is also shown in Figure A1. 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 andesite rock mass in this document. The seepage modelling parameters within the GWS model have not been altered. The depth of andesite extended to RL400 in the GWS model. We have extended down to RL255. This is conservative for estimating deformations.

The parameters summarised in Table A1 have been adopted for SIGMA/W deformation analyses. These parameters are generally consistent with the parameters adopted in PSM's report (Ref.1). The only difference is we have adopted a Young's modulus of 2,000MPa for the weathered andesite. This number is only important for modelling settlements from January 1989 to December 1999. The settlements since December 1999 are believed to be mostly associated with the undisturbed andesite rock mass.

TABLE A1 Material Deformation Parameters

Unit	Unit Weight (kN/m^3)	Young's Modulus (MPa)	Poisson's Ratio
Younger Volcanics	25	8000	0.2
Weathered Andesite	20	2000	0.2
Andesite -Undisturbed (both Higher K and Lower K)	27	8700	0.2

4.0 MODELLING AND RESULTS

Decoupled seepage and deformation analyses using SEEP/W and SIGMA/W have been undertaken for three stages of groundwater drawdown. The SEEP/W model initially calculates the change in pressure at each stage of groundwater drawdown. The SIGMA/W model then calculates the ground deformation that is caused by the change in pressure.

4.1. Seepage Modelling

The SEEP/W model was used to undertake steady state seepage analyses for three stages of groundwater dewatering. The stages of the modelling are shown in Figure A2 and detailed described below.

Stage 1. Undertake groundwater dewatering to the Weathered Andesite (at approximately RL975 at it deepest). This approximately represents dewatering from January 1989 to December 1999.

Stage 2. Undertake groundwater dewatering from RL975 to RL770. This approximately represents dewatering from December 1999 to November 2017.

Stage 3. Undertake groundwater dewatering from RL770 to RL500. This approximately represents dewatering from November 2017 to 2031 (estimate ending time for Project Martha).

The average rate of groundwater drawdown for Stage 3 is greater than previous. However, we assume that dewatering of the andesite rock mass will achieve steady state conditions with the proposed drawdown rates that are shown in Figure A2.

Drawdown analyses for both single vein and multiple veins have been carried out. The results are presents in Figure A3 to A8. Figures A3 to A5 show the results of modelling for a single vein for Stages 1, 2 and 3 respectively. Figures A6 to A8 show the results of modelling for multiple veins.

4.2. Settlement Modelling

The SIGMA/W modelling has been undertaken to calculate the deformation induced by the pressure change associated with each stage of groundwater dewatering. The results are shown in Figures A9 to A14. Figures A9 to A11 show the results of modelling for a single vein for Stages 1, 2 and 3 respectively. Figures A12 to A14 show the results of modelling for multiple veins.

Seven settlement zones have been identified in the Waihi area in which measured settlements are relatively consistent. The modelling covers a section through Martha East which is covered mostly by Zones 4 and 5. Comparisons of the predicted settlements against measured settlements in Zones 4 and 5 are shown in Figures A15 and A16 respectively. Figures A17 and A18 show the ground surface settlements profiles for Stages 2 and Stage 3 of the model respectively. Results are shown for both single and multiple veins. The estimated average settlements are summarised in Table 2. These are the average of the settlements across the whole profile being modelled.

TABLE A2 Estimated Settlements

Stage	Single Vein		Multiple Veins	
	Average Settlement (mm)	Cumulative Settlement (mm)	Average Settlement (mm)	Cumulative Settlement (mm)
1	23	23	23	23
2	89	112	152	175
3	26	138	66	241

The average modelled settlements for Stage 1 are 23mm. The average modelled settlements for Stage 2 are 89mm for a single vein and 152mm for multiple veins. For Stage 3 the average modelled settlements are 26mm for a single vein and 66mm for multiple veins. The cumulative settlements are also provided in Table 2.

The modelling allows estimation of maximum ground surface tilts. They are summarised in Table 3. They have been obtained by selecting the maximum tilt from the surface profiles shown in Figures A17 and A18.

TABLE A3 Maximum Tilts

Stage	Tilts	
	Single Vein	Multiple Veins
1	1 in 8,000	1 in 8,000
2	1 in 10,000	1 in 9,000
3	1 in 30,000	1 in 18,000
1 and 2	1 in 5,500	1 in 4,600
1, 2 and 3	1 in 4,600	1 in 3,800

The estimated maximum tilts are associated with the multiple vein model and for Stages 1, 2 and 3 are 1 in 8,000, 1 in 4,600 and 1 in 3,800 respectively. Figure A17 show the incremental change in tilt from Stage 2 to Stage 3 is small. The measured tilts above the Correnso underground mine (which is largely within Zones 4 and 5) are generally smaller than the maximum tilt predicted by numerical modelling of Stages 1 and 2 (1 in 4,600). This indicates the numerical model is conservative.

5.0 DISCUSSION

The estimated settlements at the ground surface due to groundwater dewatering from RL975 to RL770 (Stage 2) are summarised in Table 2. They are 89mm for a single vein and 152mm for multiple veins. The monitored settlements in Zones 4 and 5 are lower, 38 to 68mm on average. The possible explanations for this difference are:

1. The adopted rock mass stiffness (Young's modulus) for the undisturbed andesite may be too low especially for andesite at greater depth.

2. The andesite rock mass has not fully depressurised to steady state condition.

Irrespective of the above reasons the results indicate that application of the numerical model to estimate deformation induced by dewatering from RL770 to RL500 (Stage 3) is likely to be conservative.

The results shown in Figures A17 and A18 and Table 2 indicate that the estimated ground surface surficial settlements in Stage 3 are significantly less than Stage 2. This is because of two reasons,

1. Soil arching effect reflects less surficial settlement due to deeper and more localised groundwater dewatering

2. The effective depth of andesite rock mass that are affected by drawdown reduces with increase in drawdown depth. The effective thickness affected by groundwater drawdown for Stages 2 and 3 are 720m (RL975 to RL255) and 515m (RL770 to RL255) respectively.

The tilts arising from settlement due to dewatering summarised in Table 3 show that the incremental tilt due to dewatering to RL500m are small. The maximum tilt for multiple veins is 1 in 3,800 which is well below the level that would give rise to any concerns with damage to structures or infrastructure.

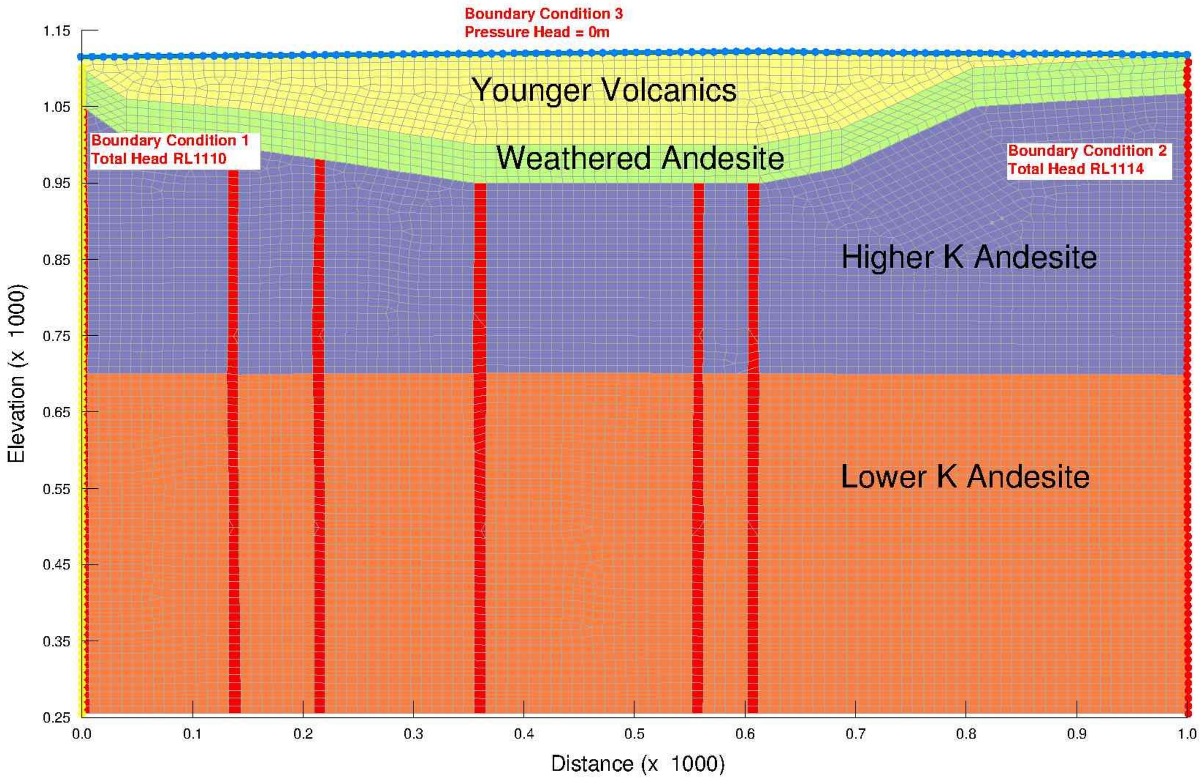
6.0 SUMMARY

The numerical modelling provides useful insight into the comparative settlements associated with different stages of dewatering and provides estimates of ground surface tilt. The results show that settlements due to groundwater dewatering from RL770m to RL500m (Stage 3) are lower compared to dewatering from RL975m to RL770m (Stage 2). This is because groundwater drawdown and associated incremental stress in the rock mass is localised around the veins. It results in arching effects and lower settlements than if the rock mass was fully dewatered. Also, with dewatering from RL770m to RL500m the depth of rock mass that is affected by drawdown is less than Stage 2.

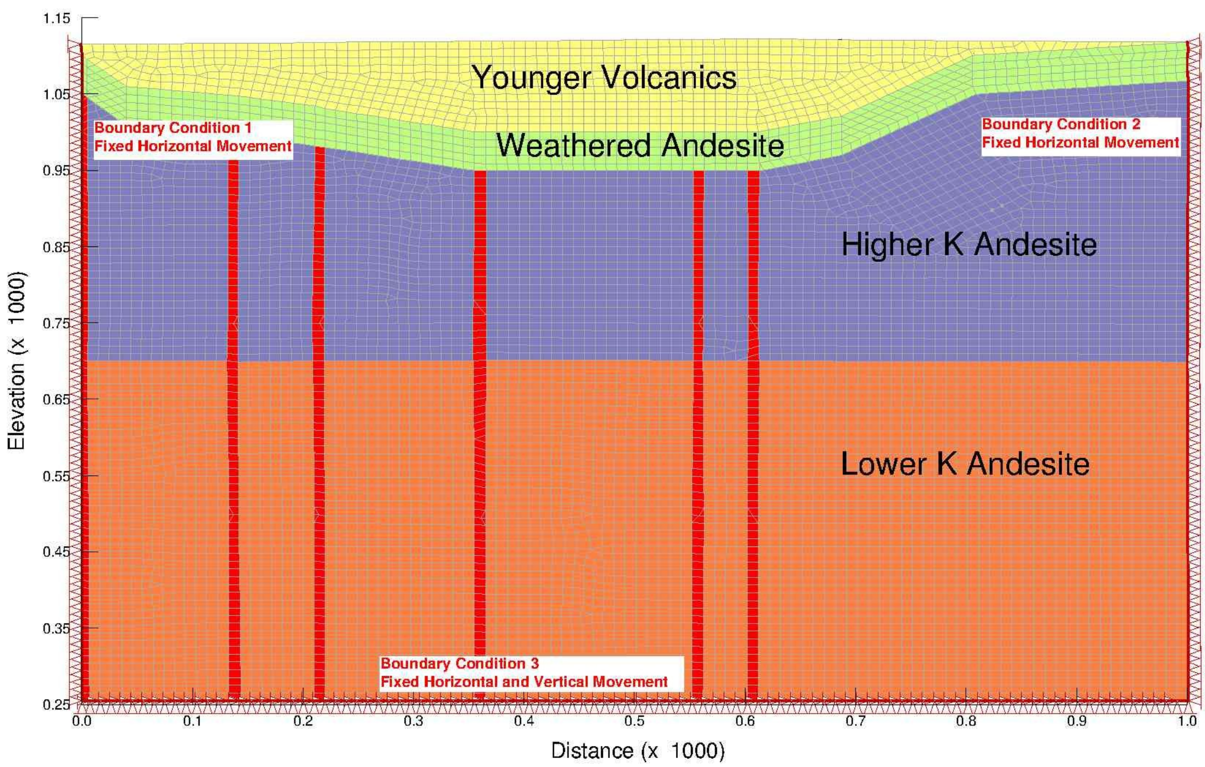
The numerical modelling allows estimation of ground surface tilts. The estimated maximum tilt following dewatering to RL500m is 1 in 3,800. This is well below the level that would give rise to any concerns with damage to structures or infrastructure. It is also considerably less than 1 in 1,000 which is the current trigger for notification of the Waikato Regional Council and for instigating additional monitoring.

The modelled section is for Waihi East which is largely covered by settlement Zones 4 and 5. However, the comparative results between Stage 2 and 3 would apply to the other settlement zones.

SEEP/W Model



SIGMA/W Model



SEEP/W and SIGMA/W Model	Figure A1

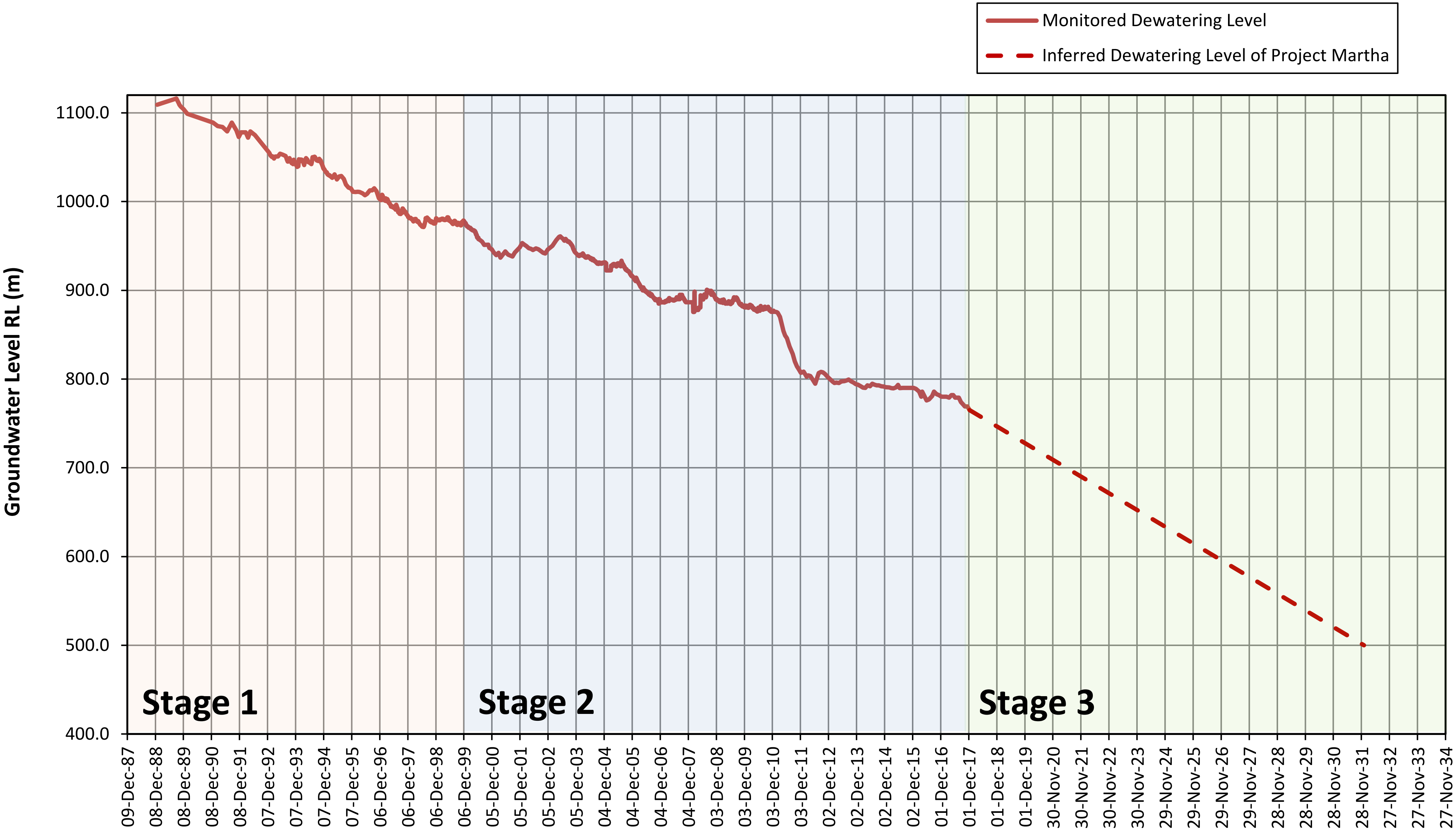
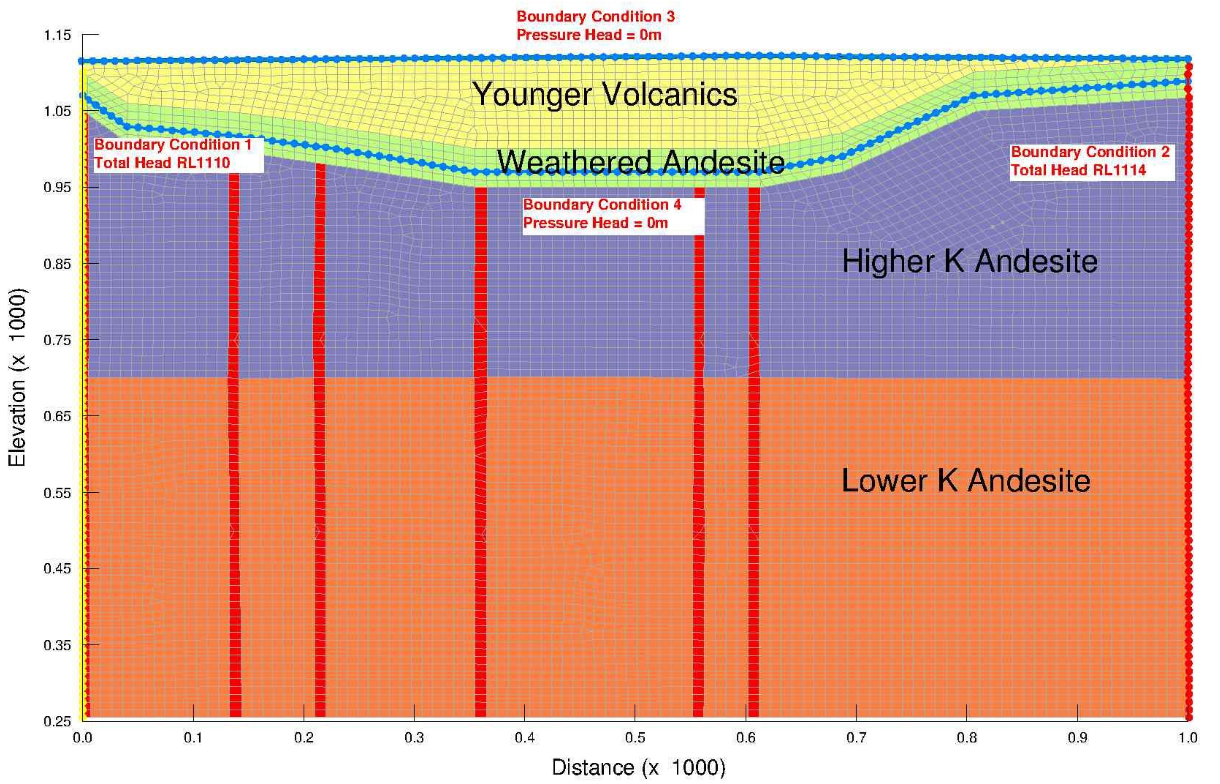


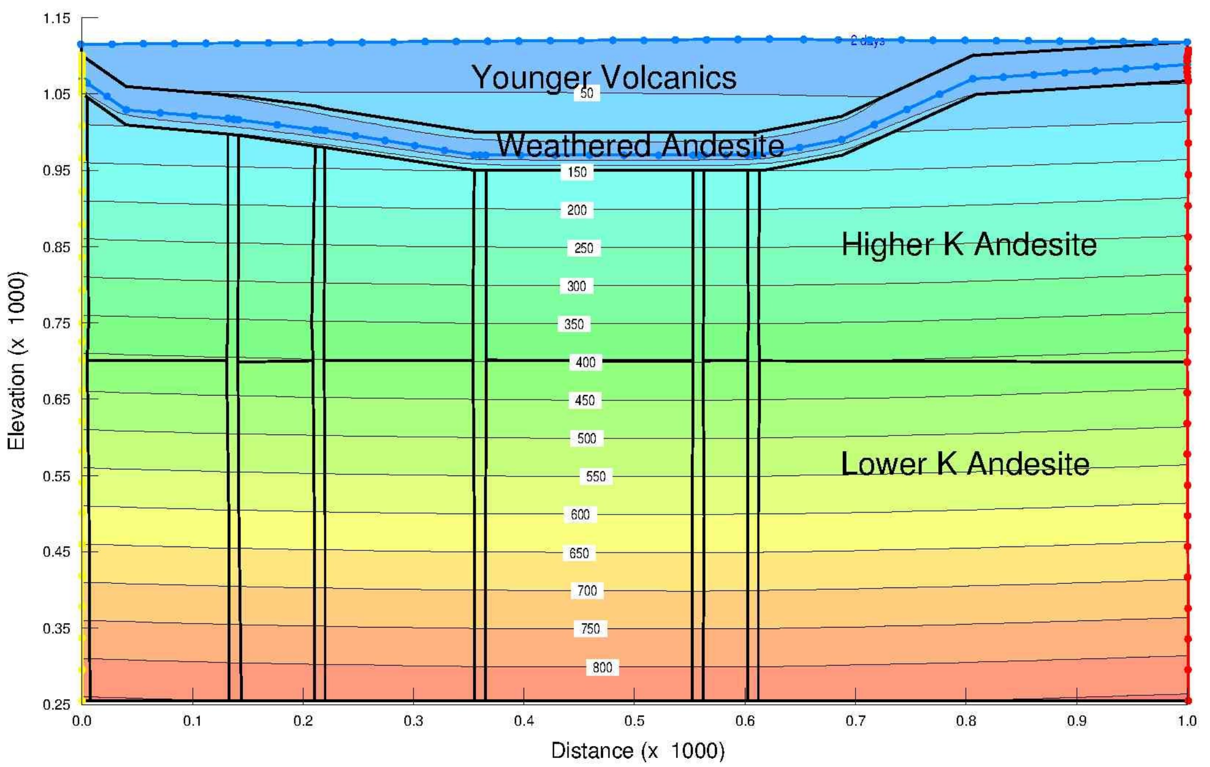
Figure A2

Engineering Geology Ltd Unit 7C, 331 Rosedale Rd, PO Box 301054, Albany, Auckland	**OCEANA GOLD (NEW ZEALAND) LTD** PROJECT MARTHA Mine Dewatering Level	Ref. No: 8332 Date: May 2018 Drawn: CW

SEEP/W Model

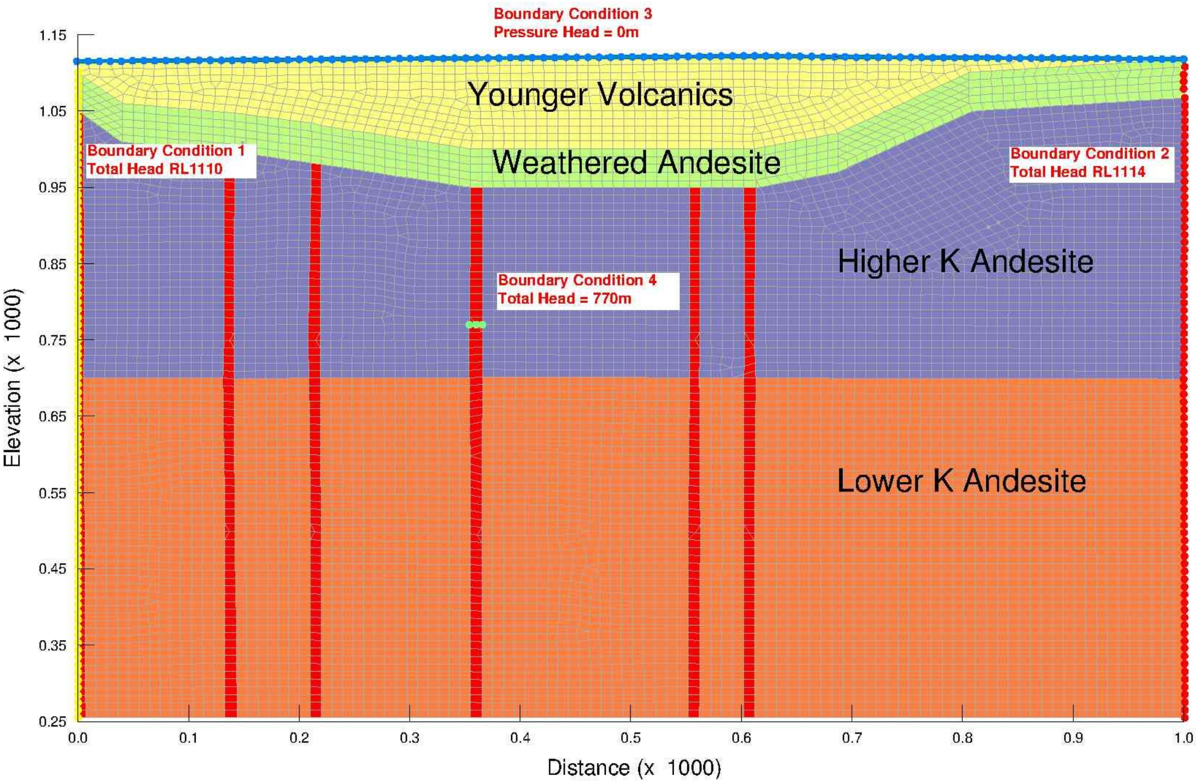


SEEP/W Steady State Pressure Head Distribution, Unit: metre

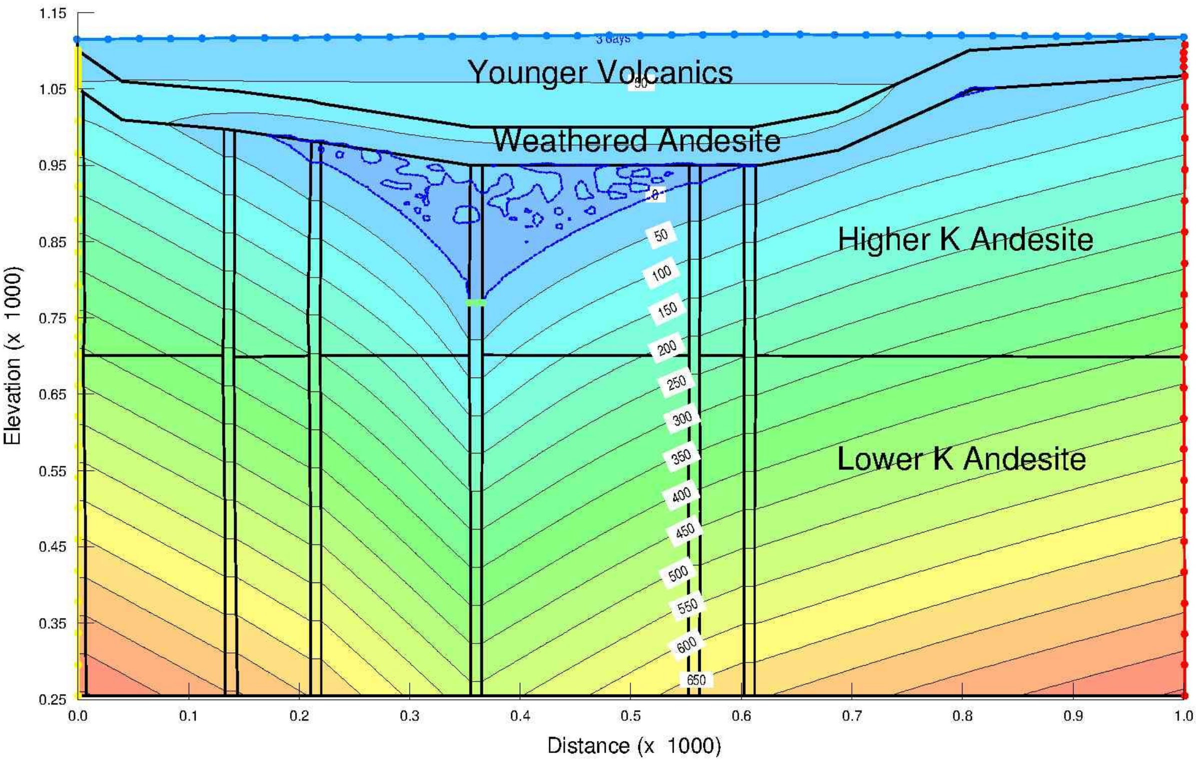


Single Vein Drawdown Stage 1 SEEP/W Model and Results	Figure A3

SEEP/W Model

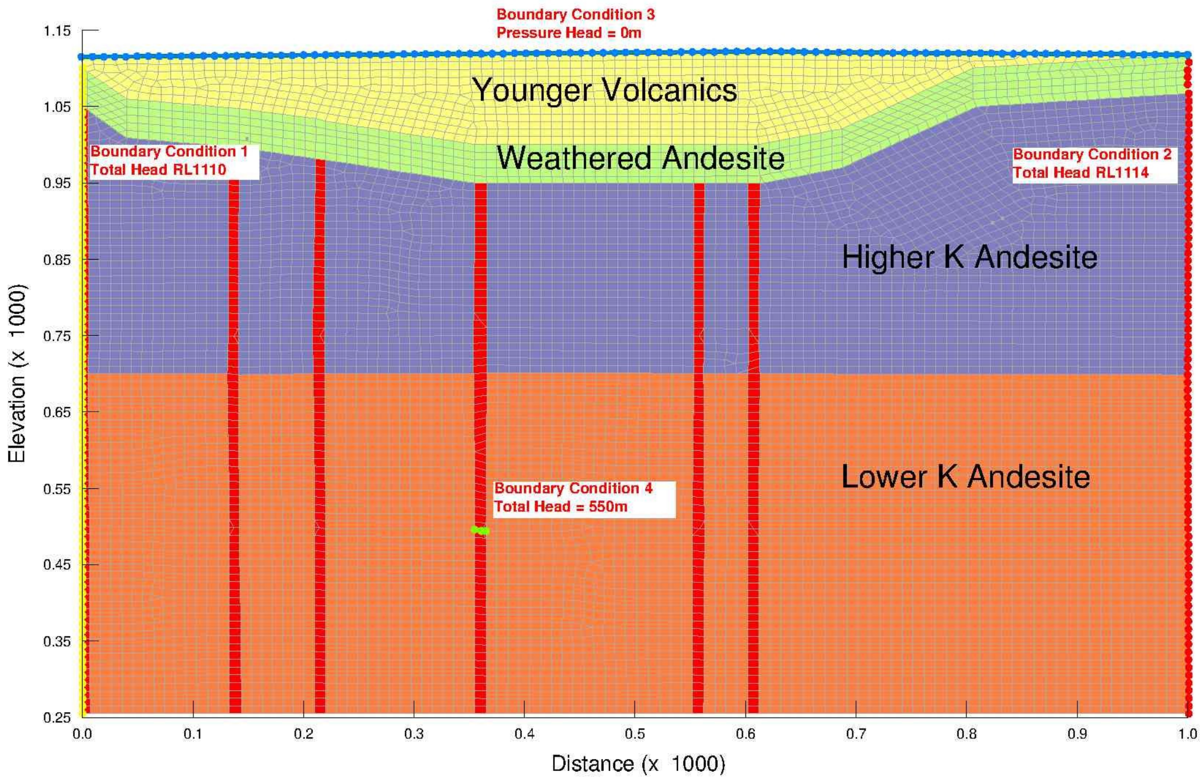


SEEP/W Steady State Pressure Head Distribution, Unit: metre

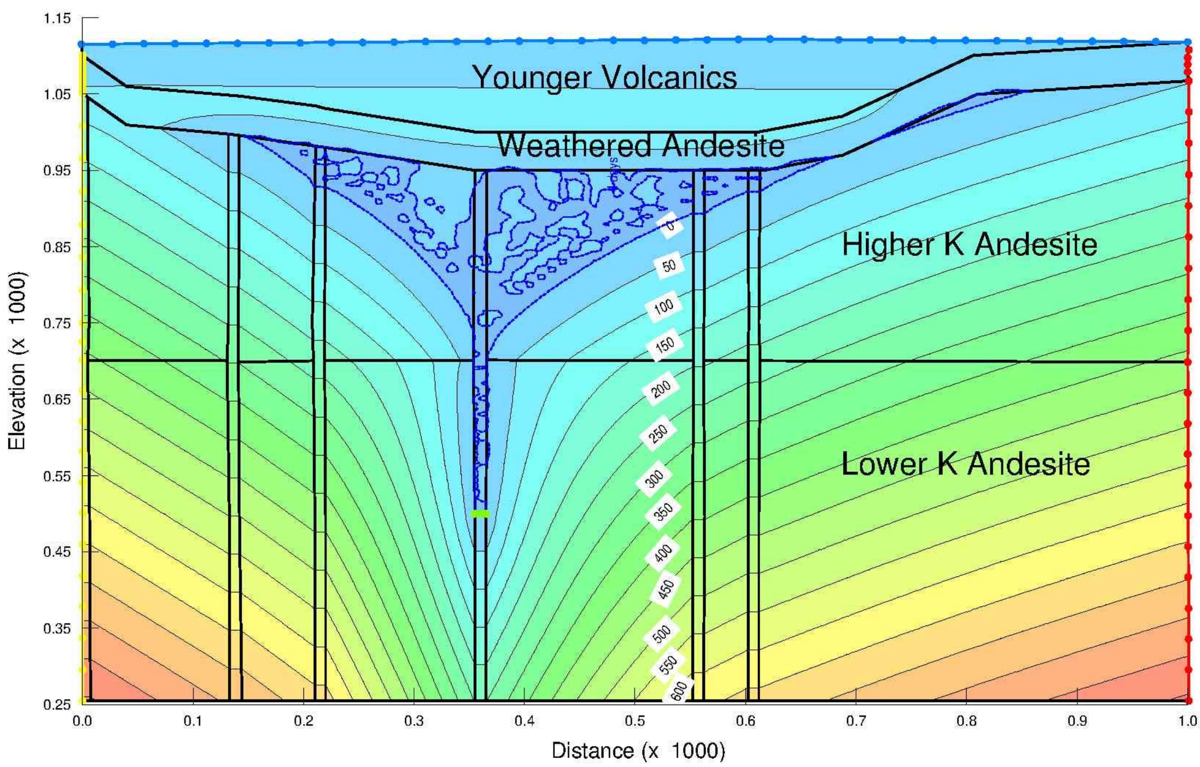


Single Vein Drawdown Stage 2 SEEP/W Model and Results	Figure A4

SEEP/W Model

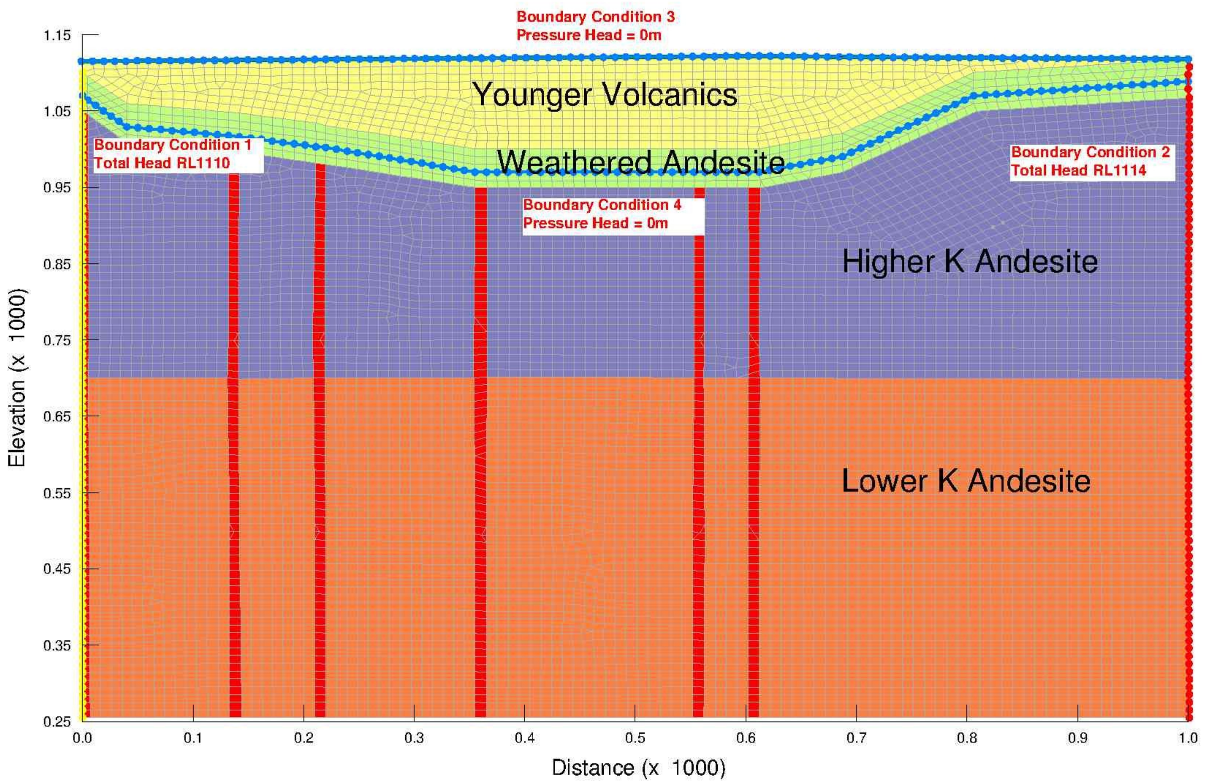


SEEP/W Steady State Pressure Head Distribution, Unit: metre

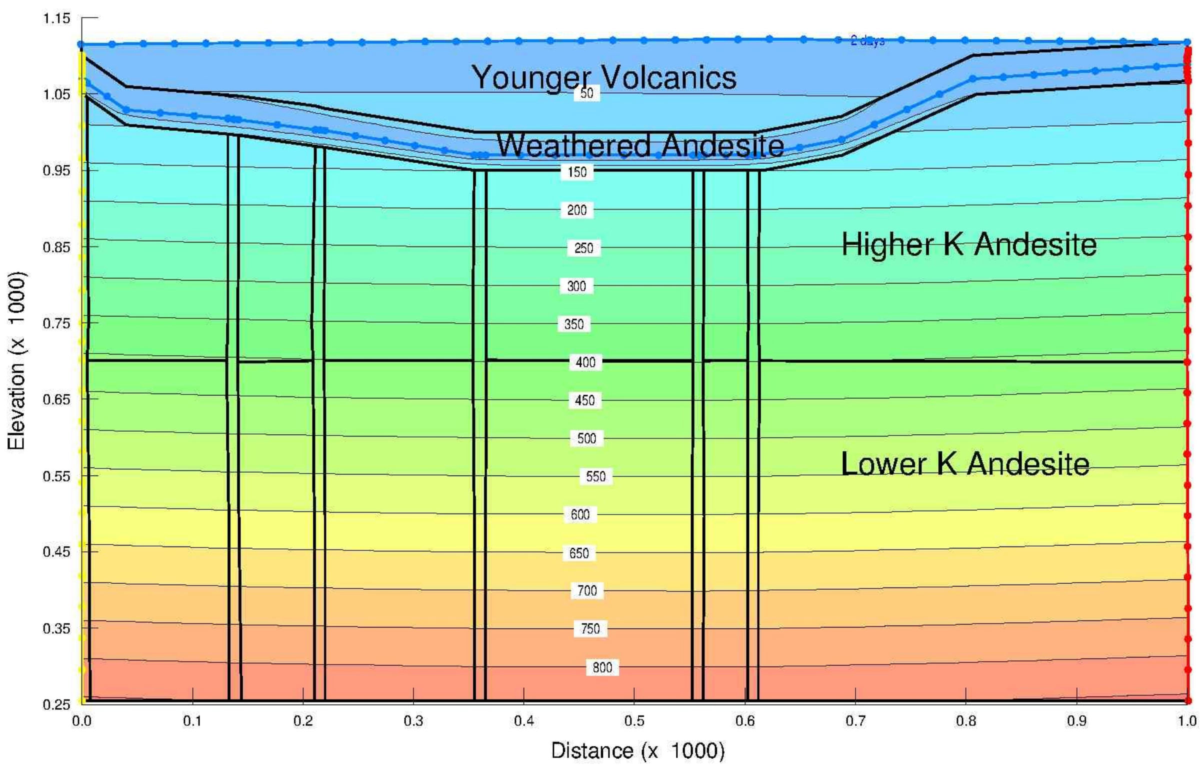


Single Vein Drawdown Stage 3 SEEP/W Model and Results | **Figure A5**

SEEP/W Model

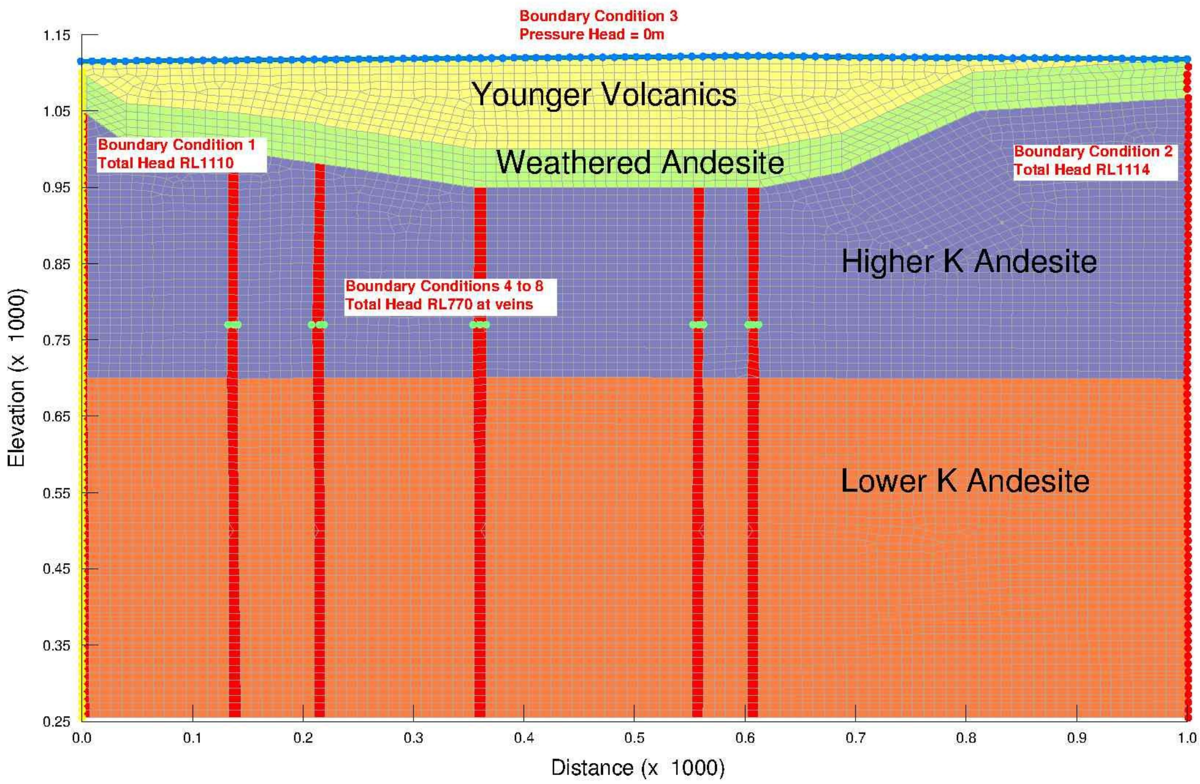


SEEP/W Steady State Pressure Head Distribution, Unit: Metre

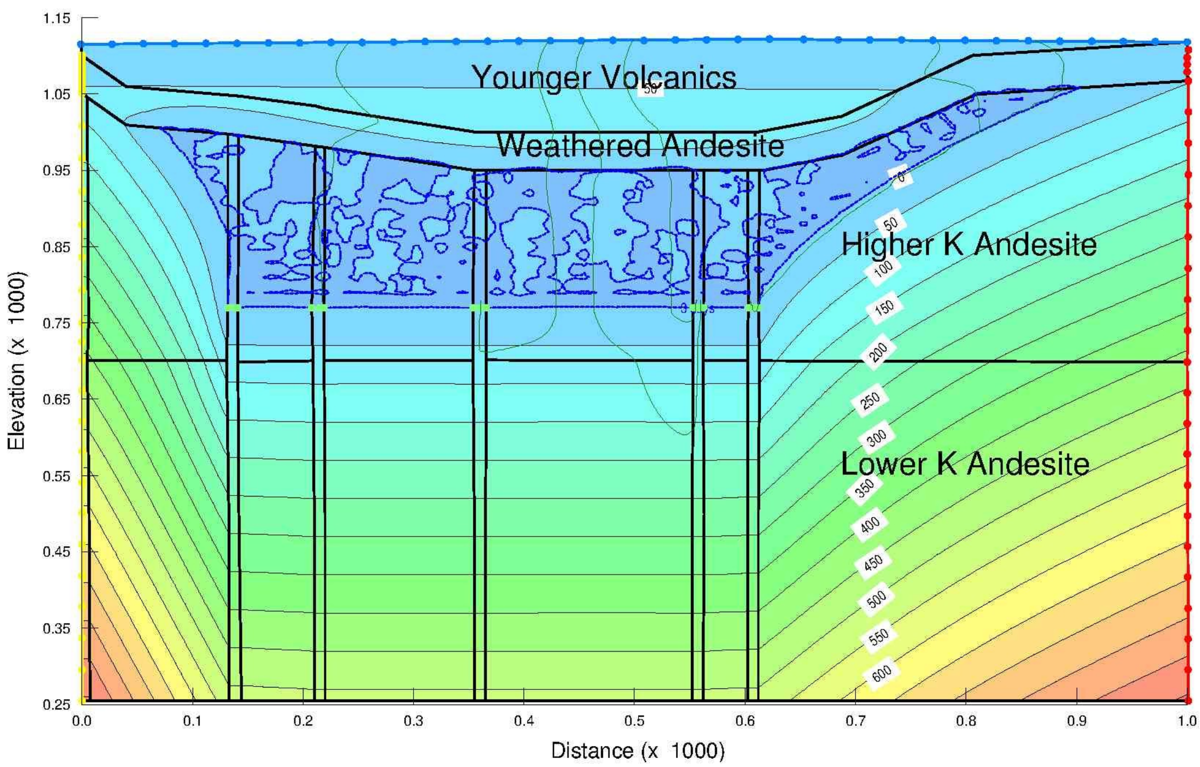


Multi Veins Drawdown Stage 1 SEEP/W Model and Results	Figure A6

SEEP/W Model

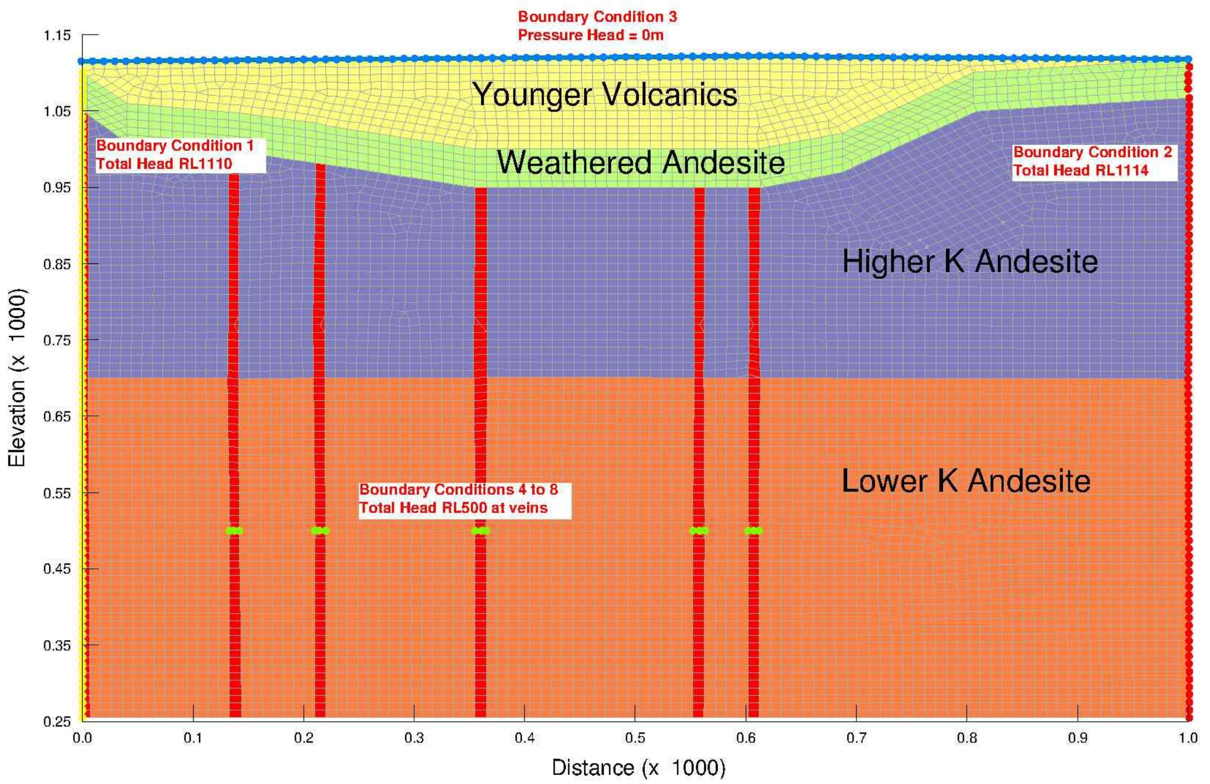


SEEP/W Steady State Pressure Head Distribution, Unit: metre

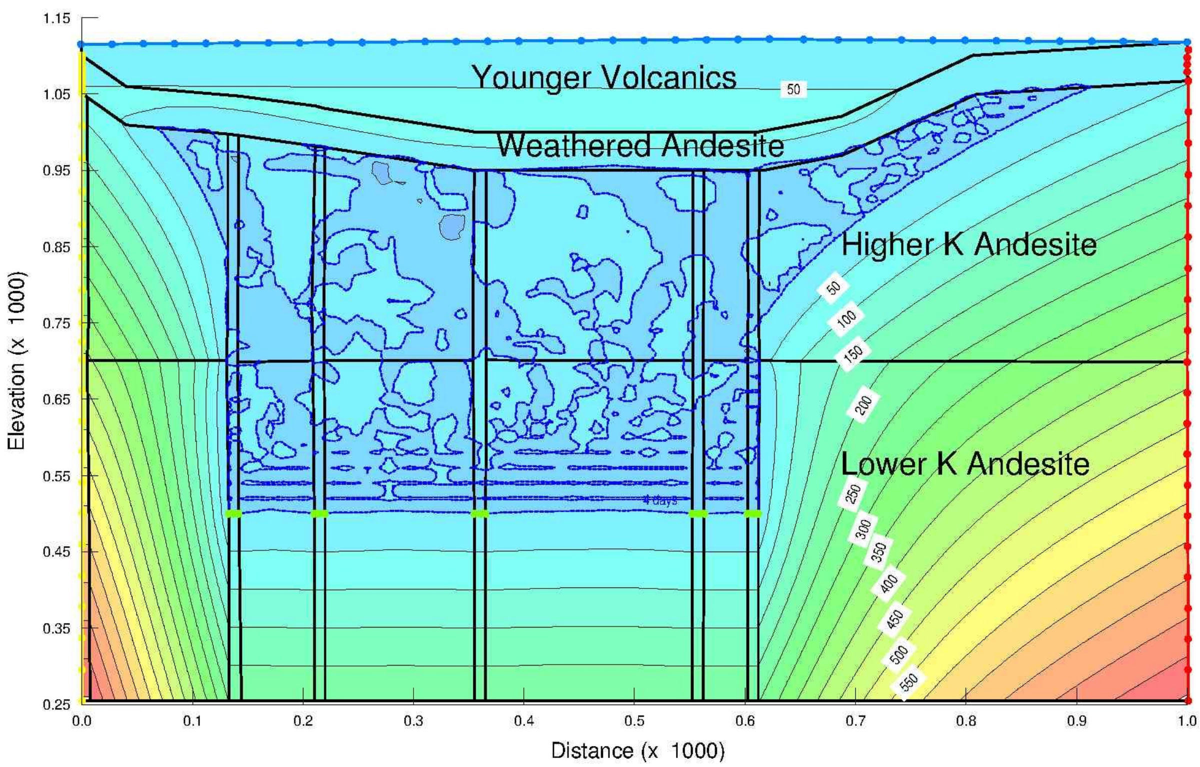


Multi Veins Drawdown Stage 2 SEEP/W Model and Results	Figure A7

SEEP/W Model

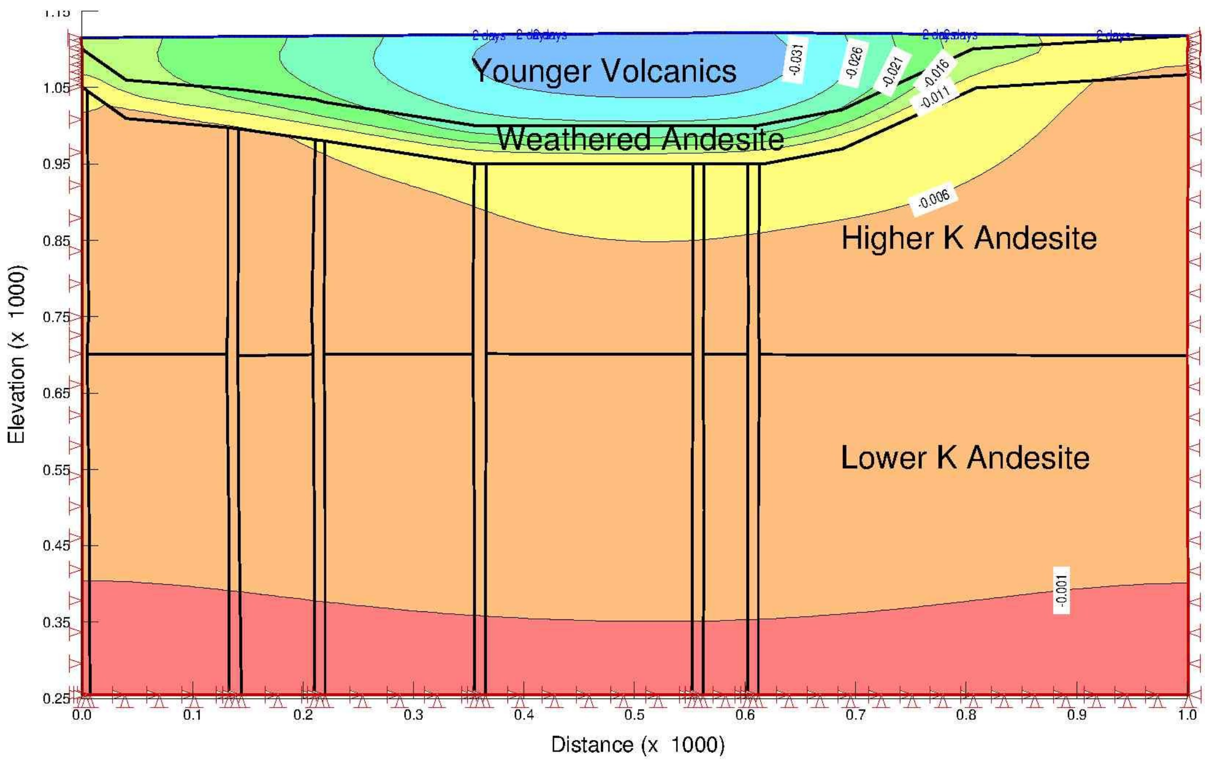


SEEP/W Steady State Pressure Head Distribution, Unit: metre

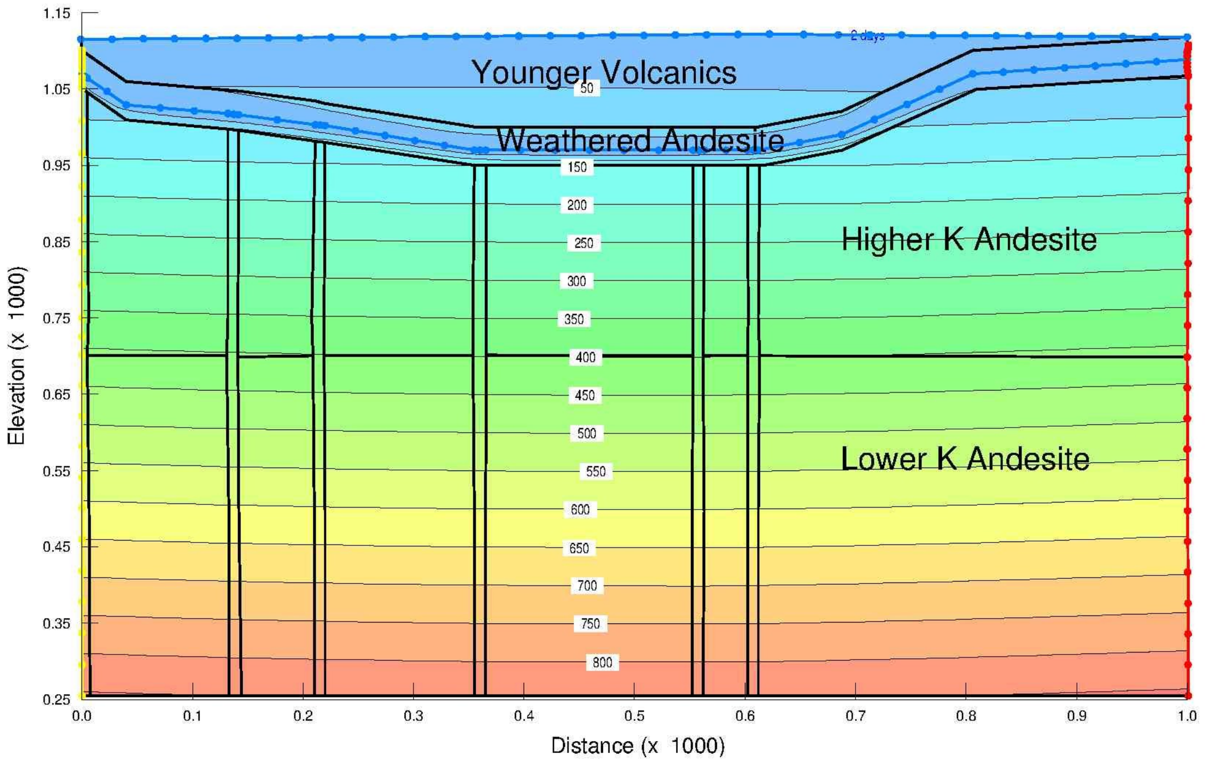


Multi Veins Drawdown Stage 3 SEEP/W Model and Results	Figure A8

SIGMA/W Single Stage Vertical Settlements, Unit: metre

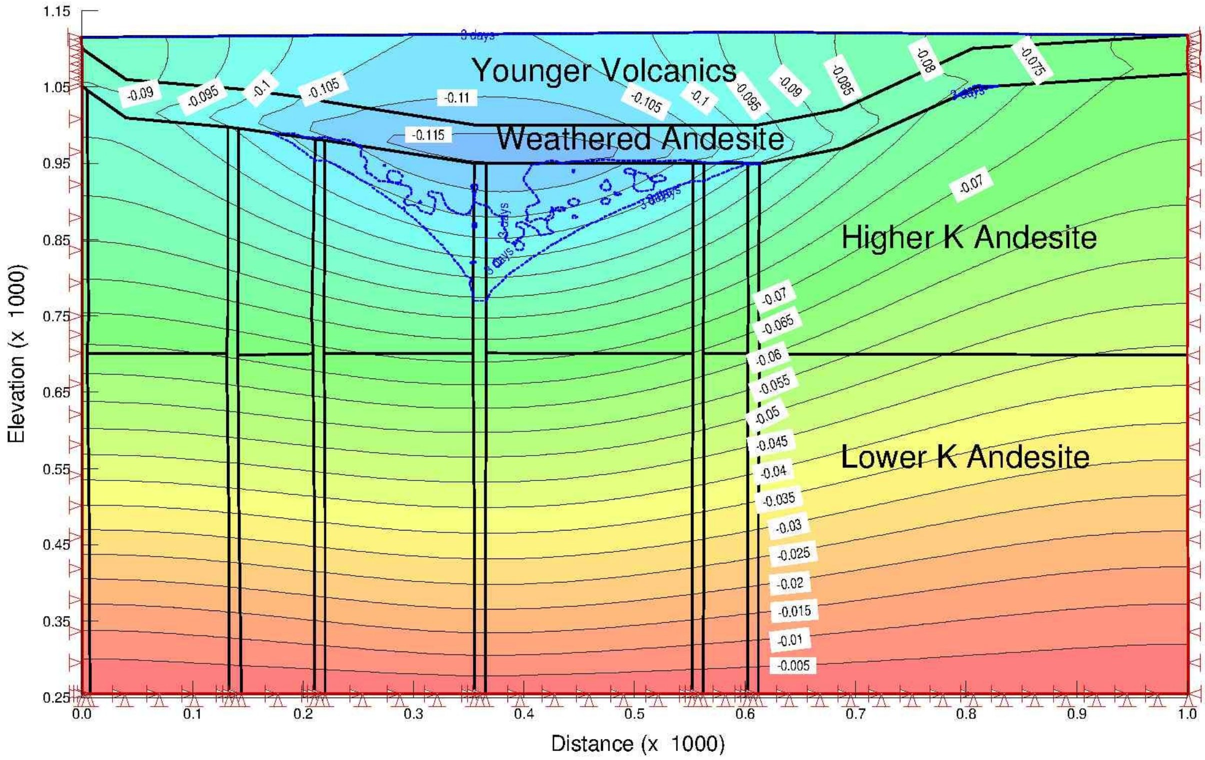


SEEP/W Steady State Pressure Head Distribution, Unit: metre (for reference)

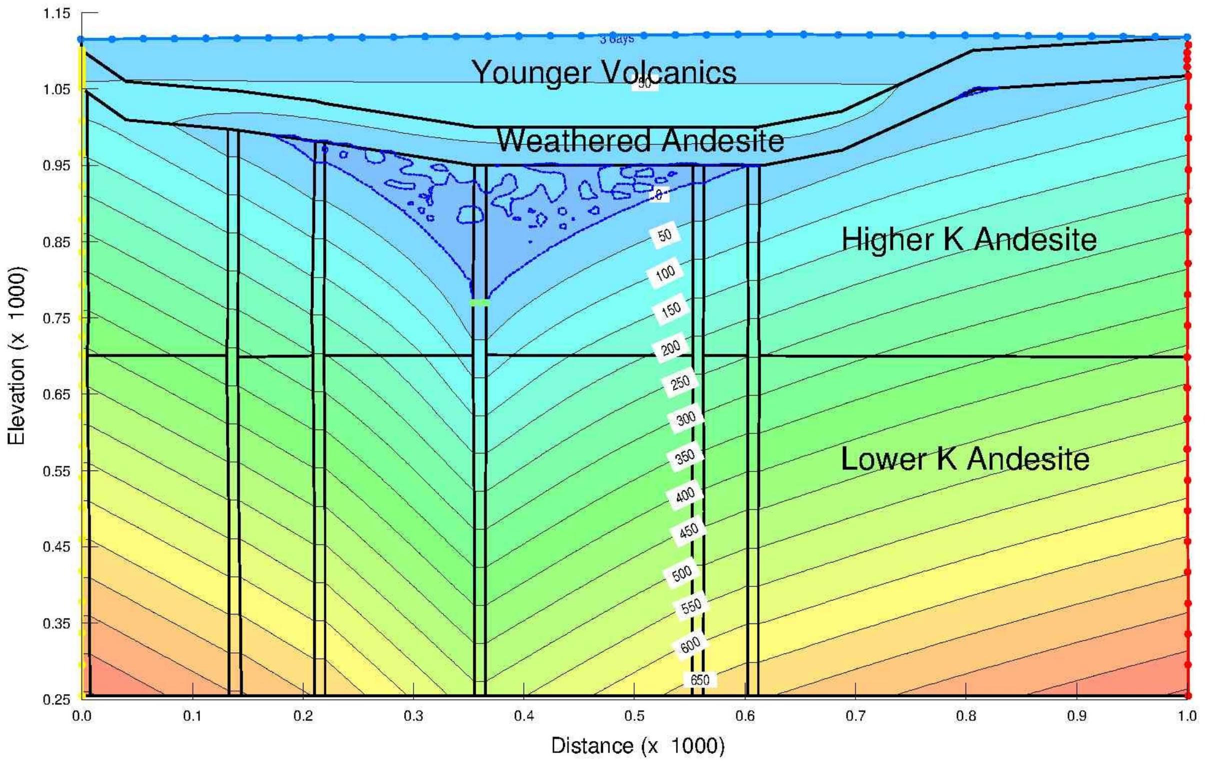


Single Vein Drawdown Stage 1 SIGMA/W Settlements	Figure A9

SIGMA/W Single Stage Vertical Settlements, Unit: metre

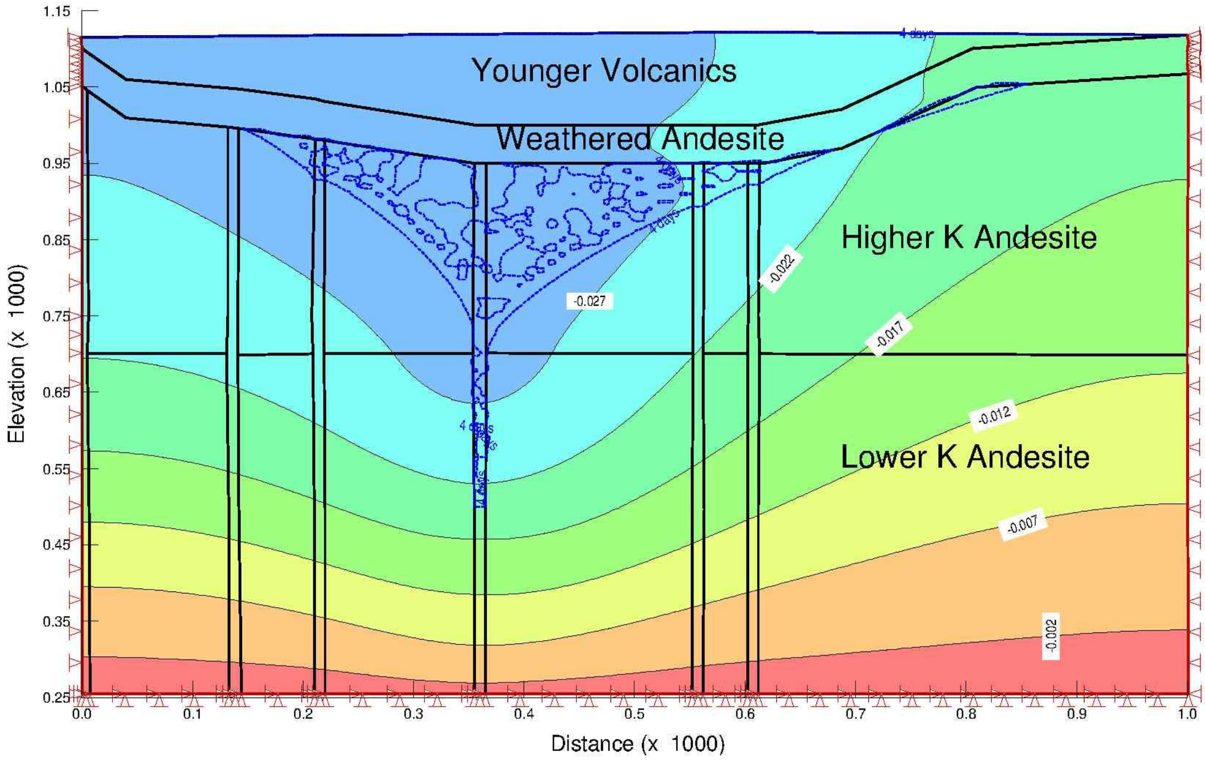


SEEP/W Steady State Pressure Head Distribution, Unit: metre (for reference)

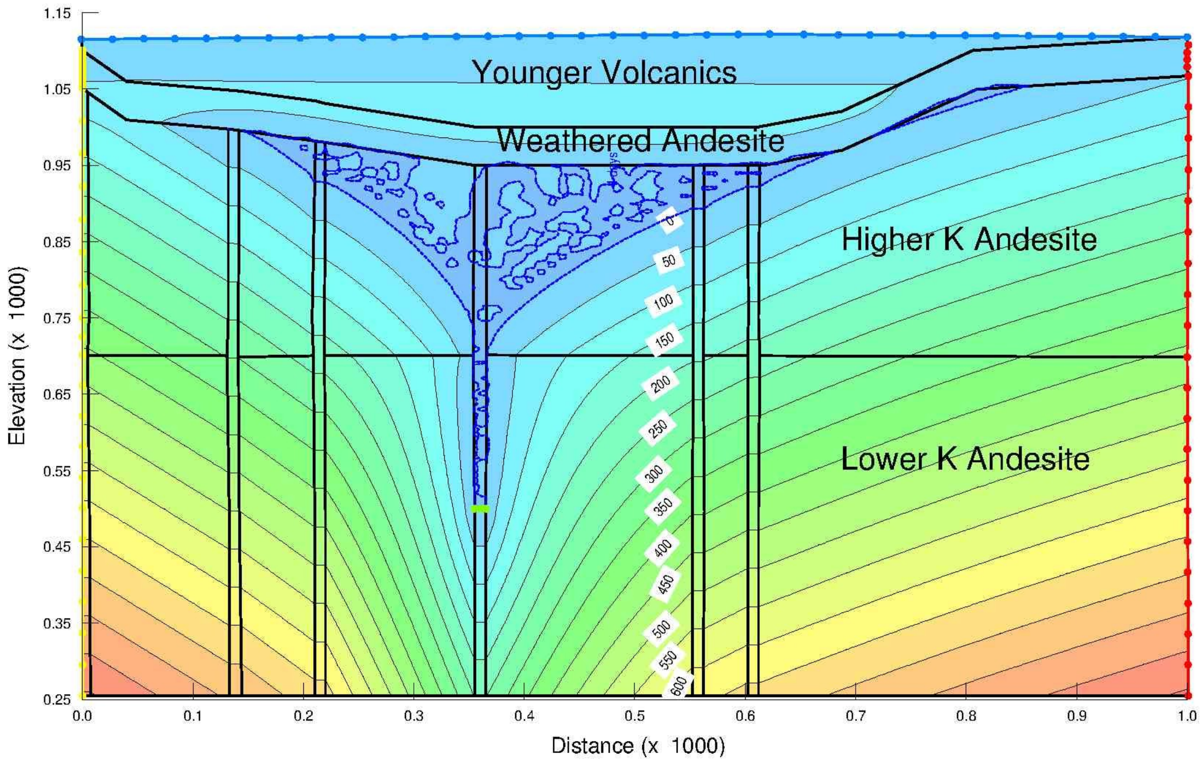


Single Vein Drawdown Stage 2 SIGMA/W Settlements	Figure A10

SIGMA/W Single Stage Vertical Settlements, Unit: metre

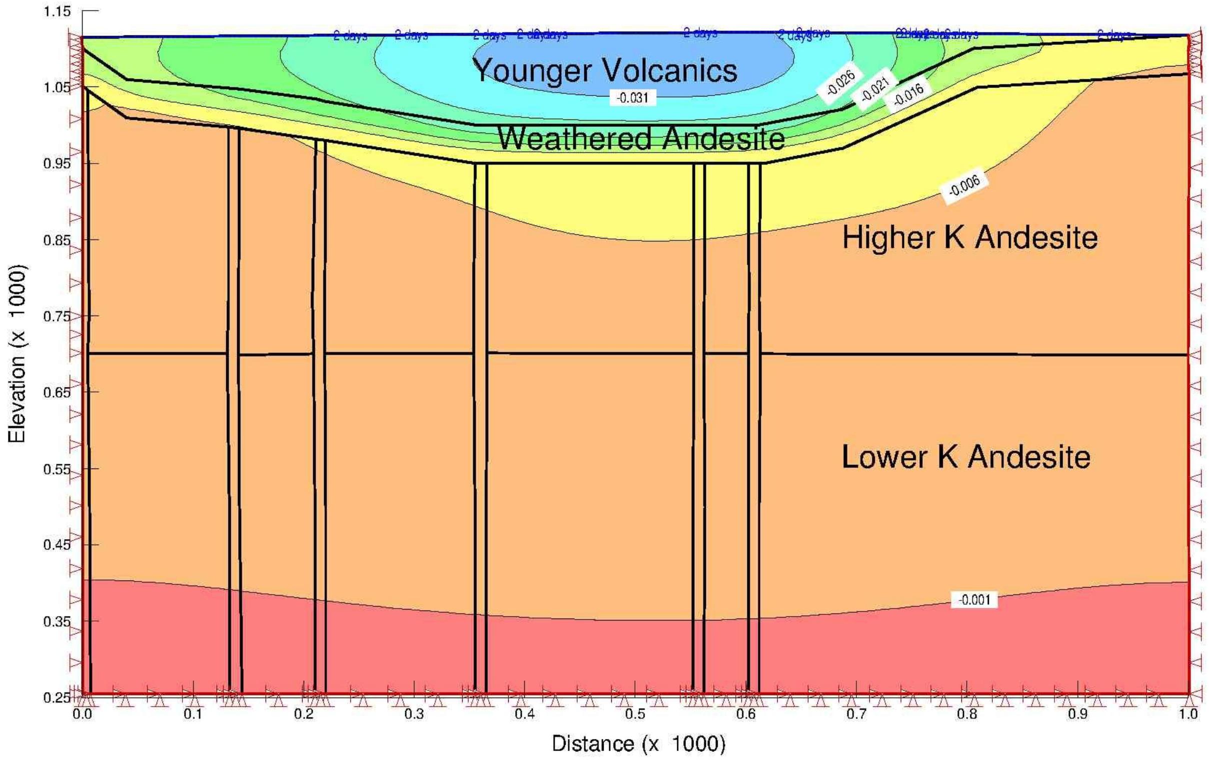


SEEP/W Steady State Pressure Head Distribution, Unit: metre (for reference)

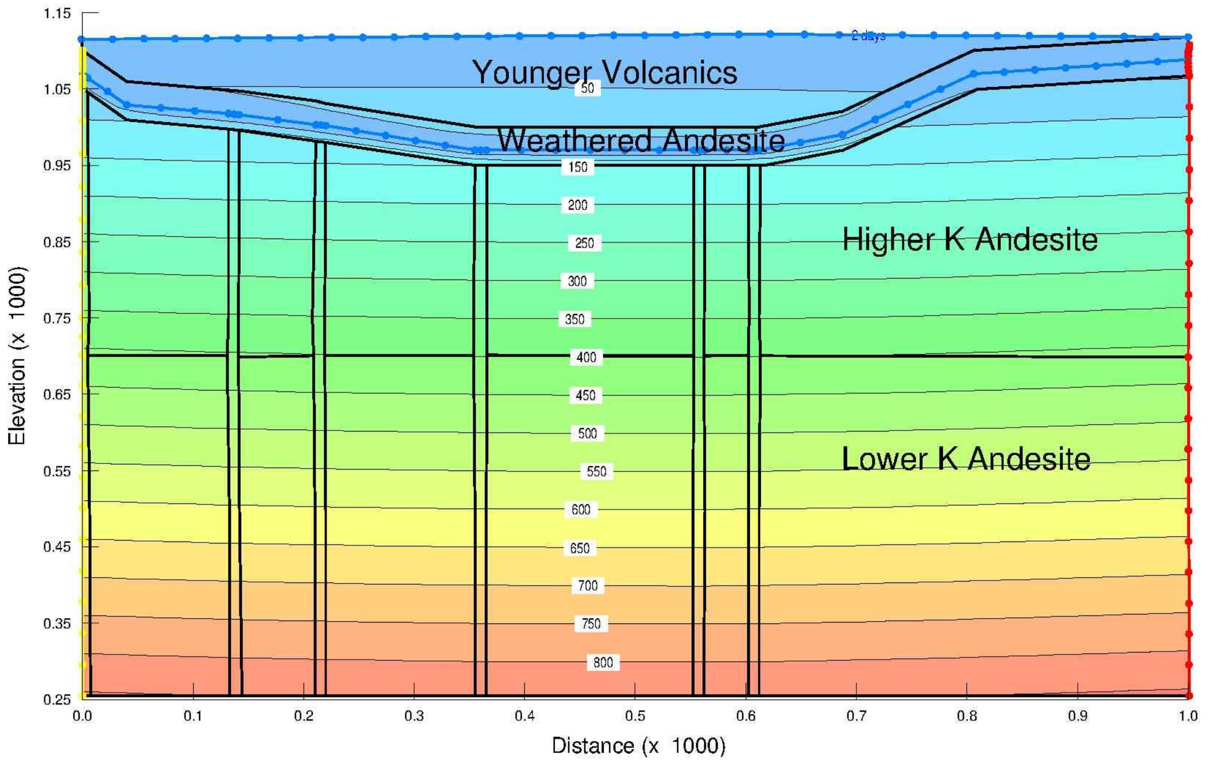


Single Vein Drawdown Stage 3 SIGMA/W Settlements | **Figure A11**

SIGMA/W Single Stage Vertical Settlements, Unit: metre

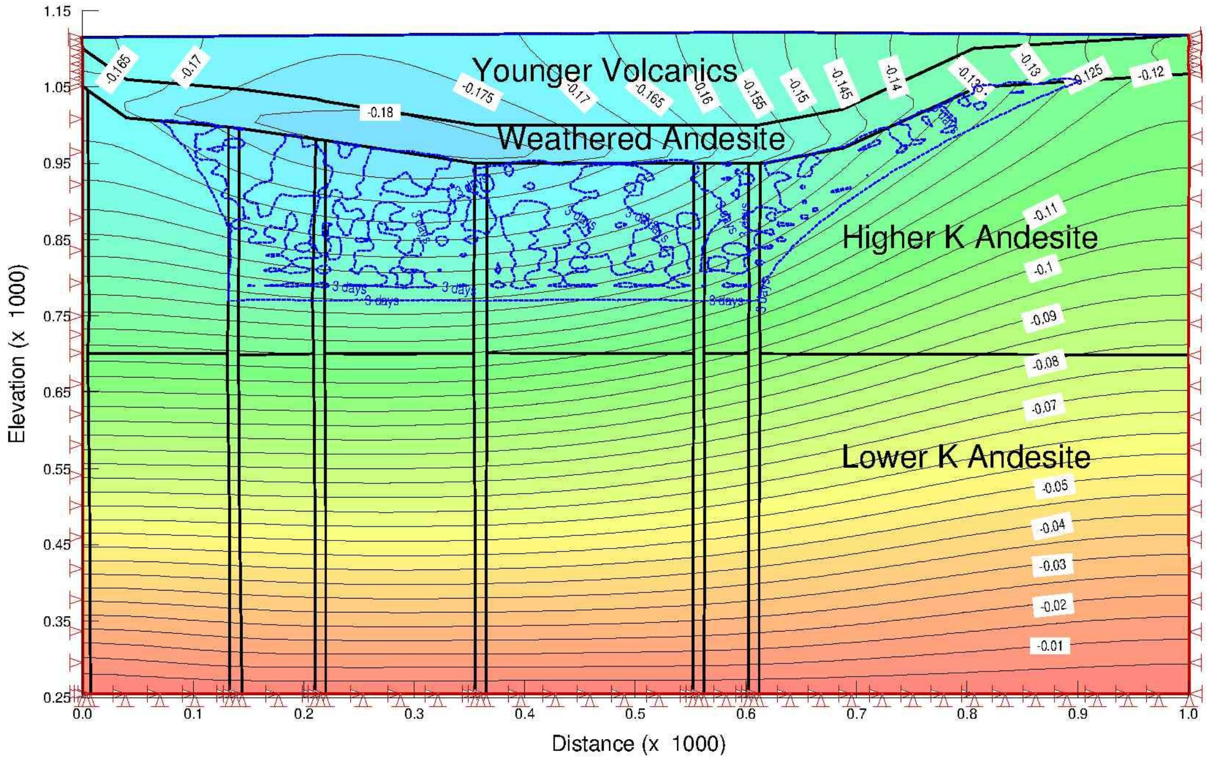


SEEP/W Steady State Pressure Head Distribution, Unit: metre (for reference)

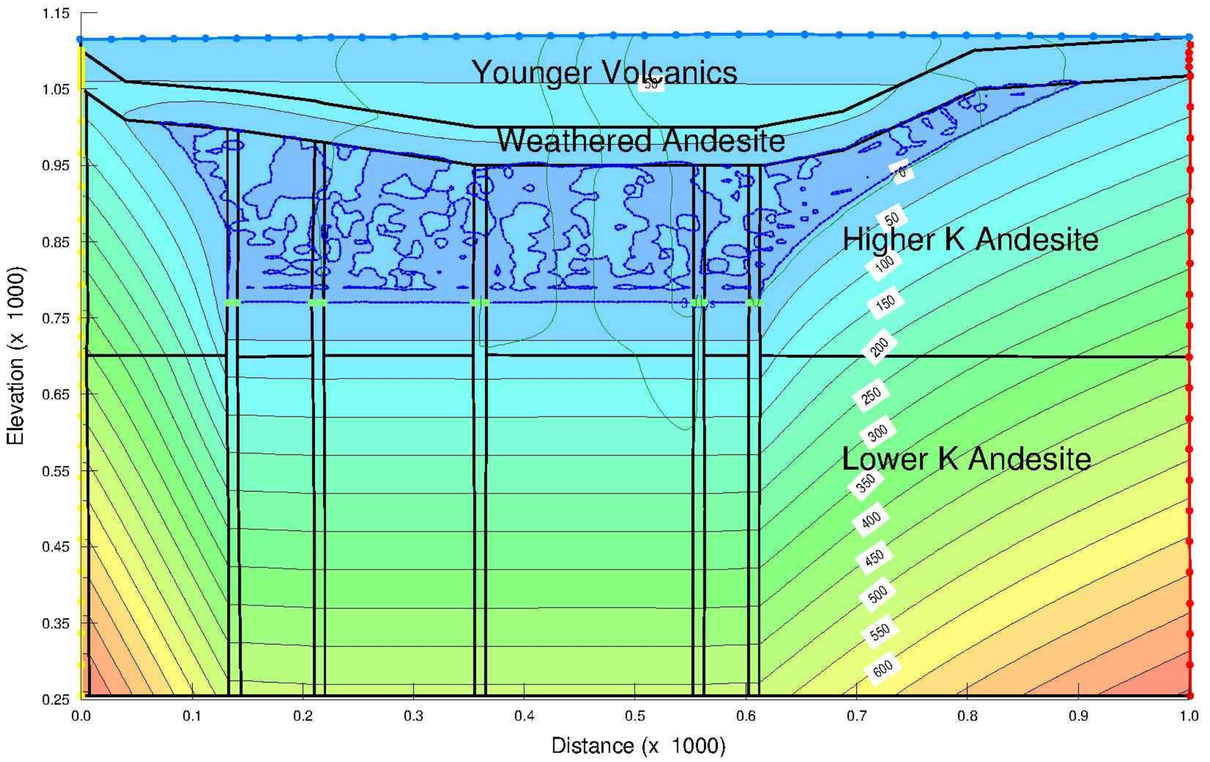


Multi Veins Drawdown Stage 1 SIGMA/W Settlements	Figure A12

SIGMA/W Single Stage Vertical Settlements, Unit: metre

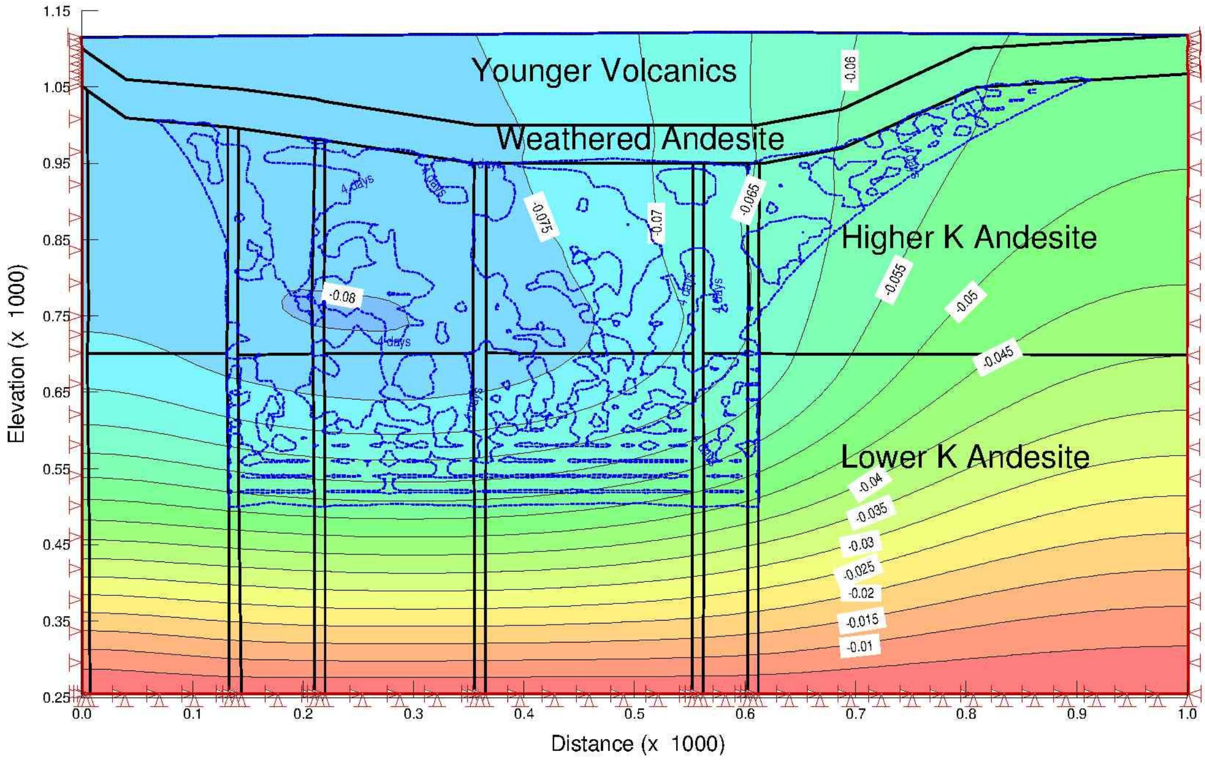


SEEP/W Steady State Pressure Head Distribution, Unit: metre (for reference)

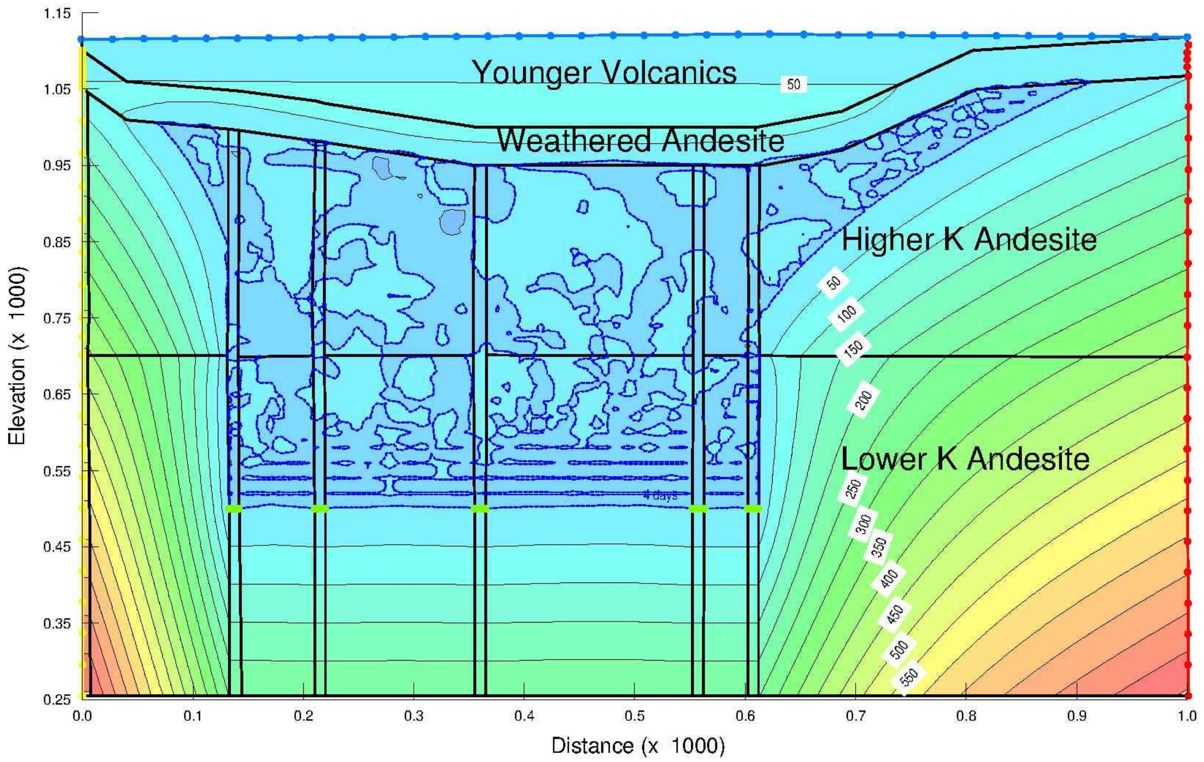


Multi Veins Drawdown Stage 2 SIGMA/W Settlements | **Figure A13**

SIGMA/W Single Stage Vertical Settlements, Unit: metre



SEEP/W Steady State Pressure Head Distribution, Unit: metre (for reference)



Multi Veins Drawdown Stage 3 SIGMA/W Settlements	Figure A14

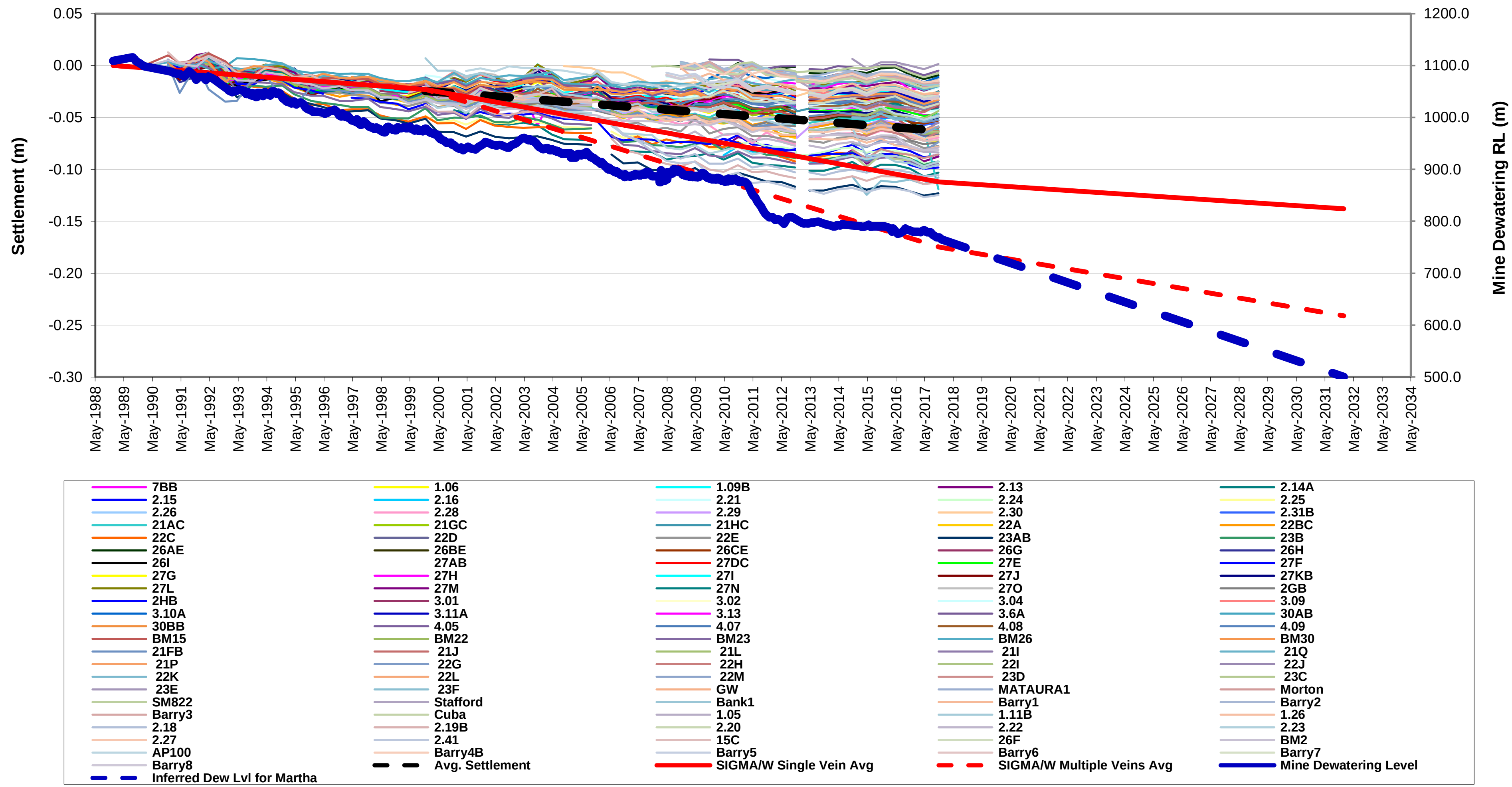


Figure A15

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PROJECT MARTHA

Comparison of SIGMA/W Settlement with Observed Settlement - Zone 4

Ref. No: 8332
Date: May 2018
Drawn: CW

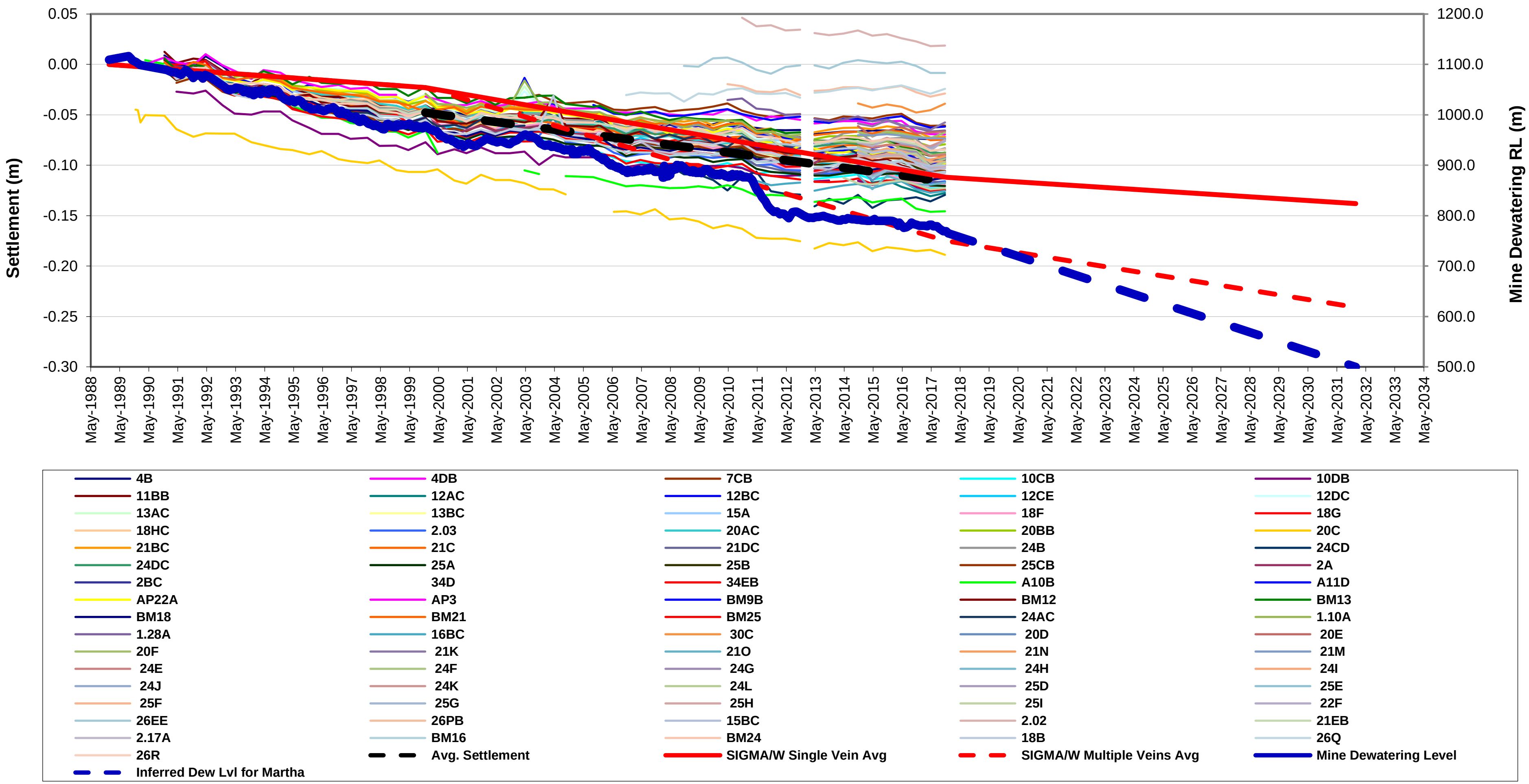

Figure A16

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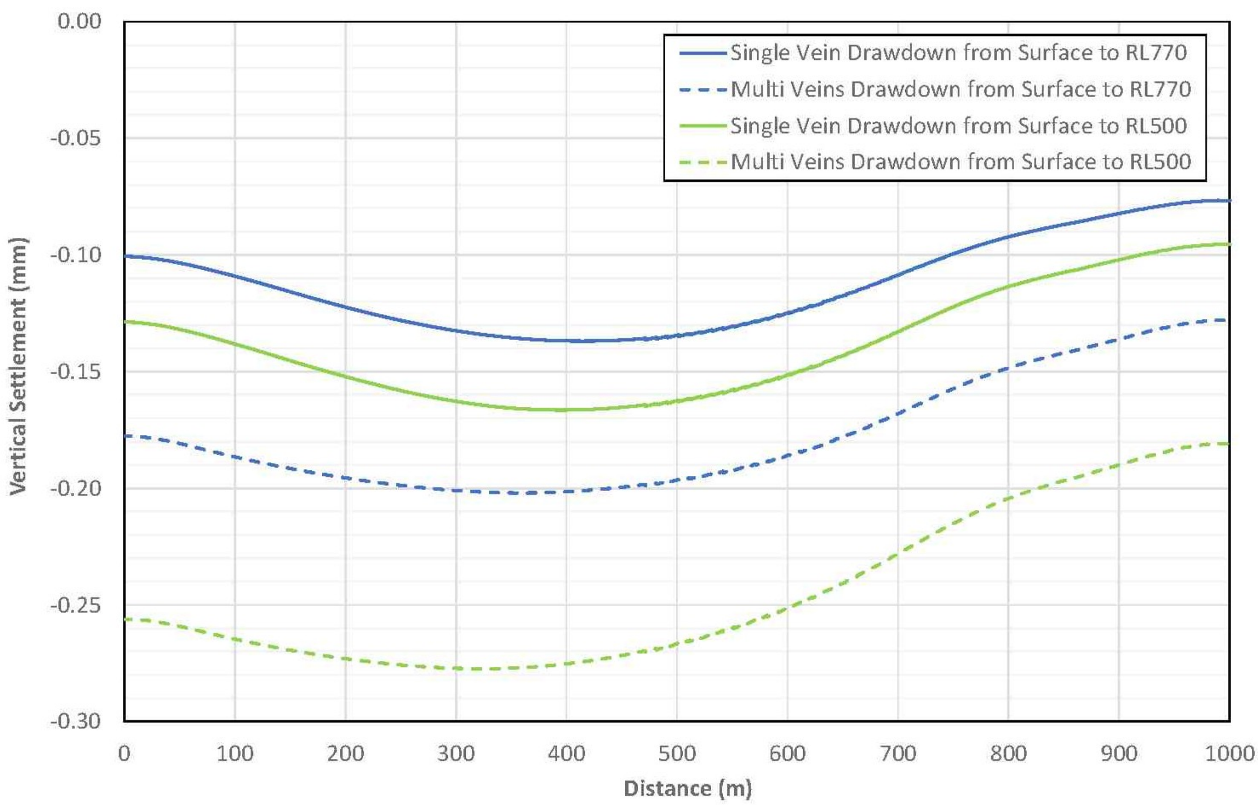
OCEANA GOLD (NEW ZEALAND) LTD
PROJECT MARTHA

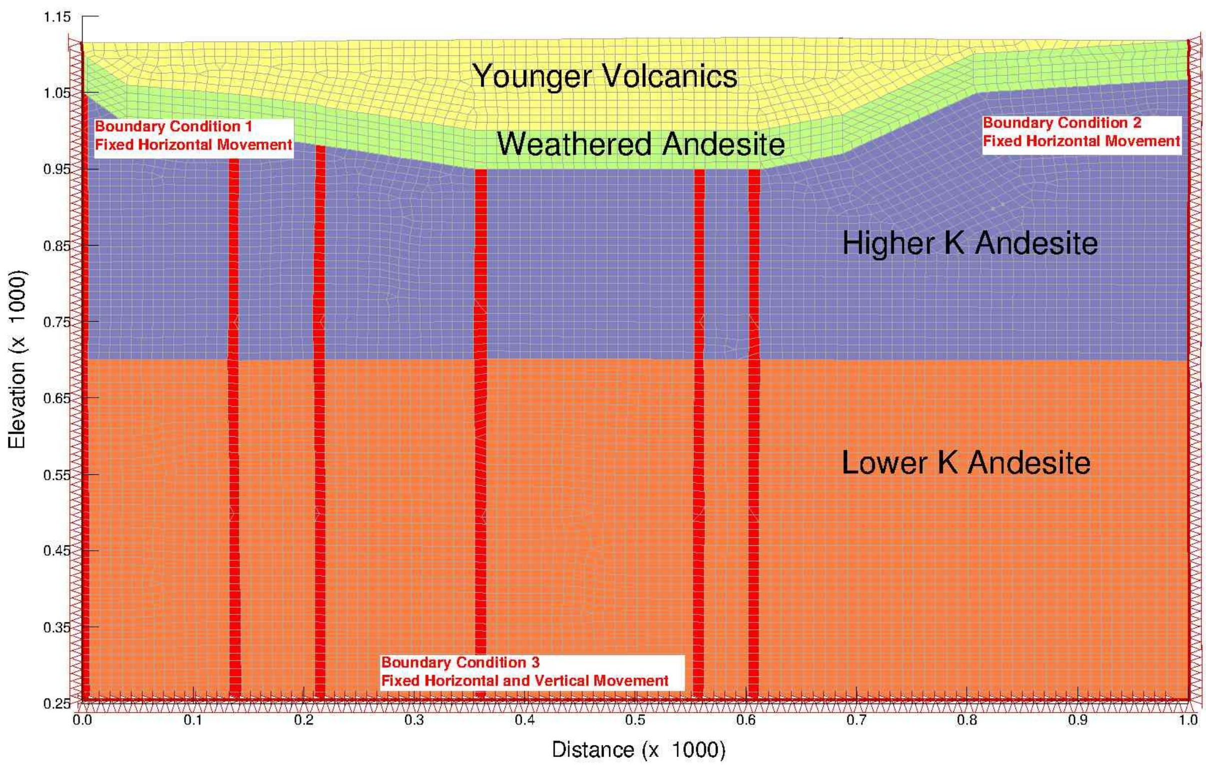
Comparison of SIGMA/W Settlement with Observed Settlement - Zone 5

Ref. No: 8332
Date: May 2018
Drawn: CW

SIGMA/W Vertical Surficial Settlements, Unit: metre

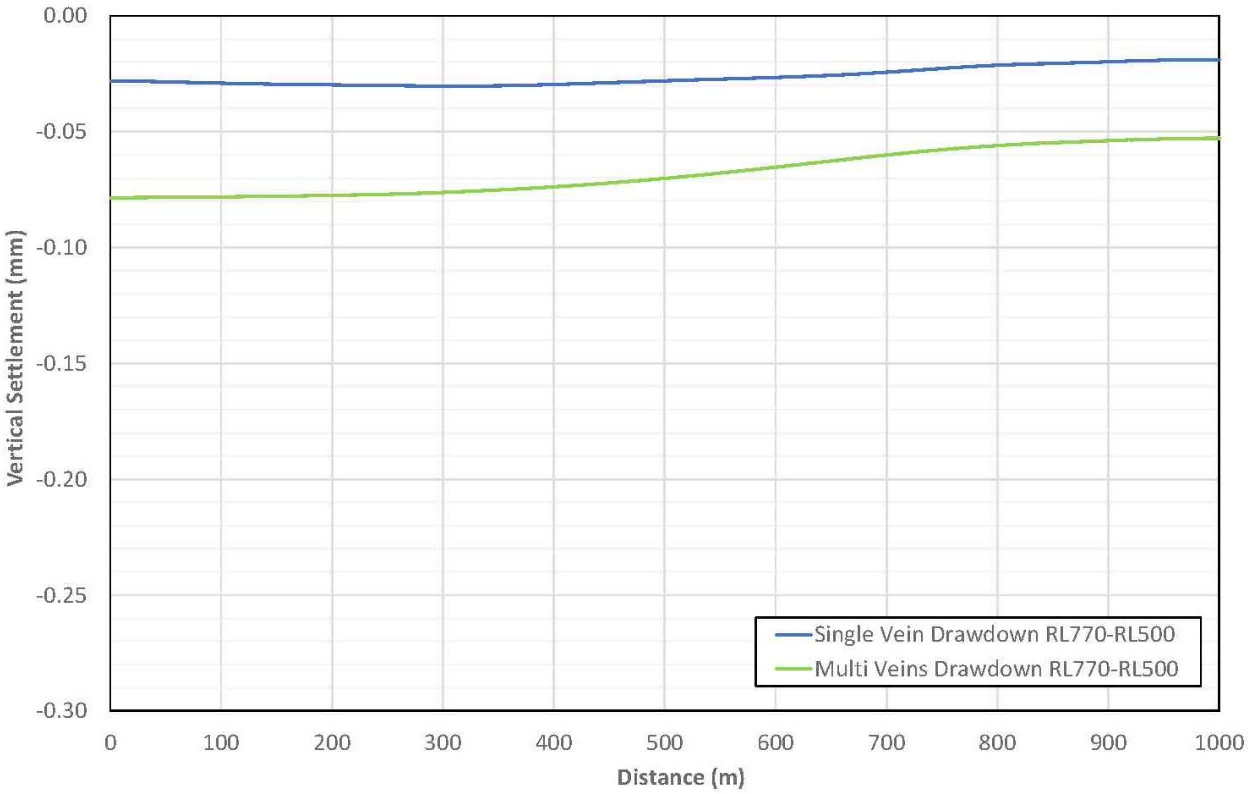


SIGMA/W Model

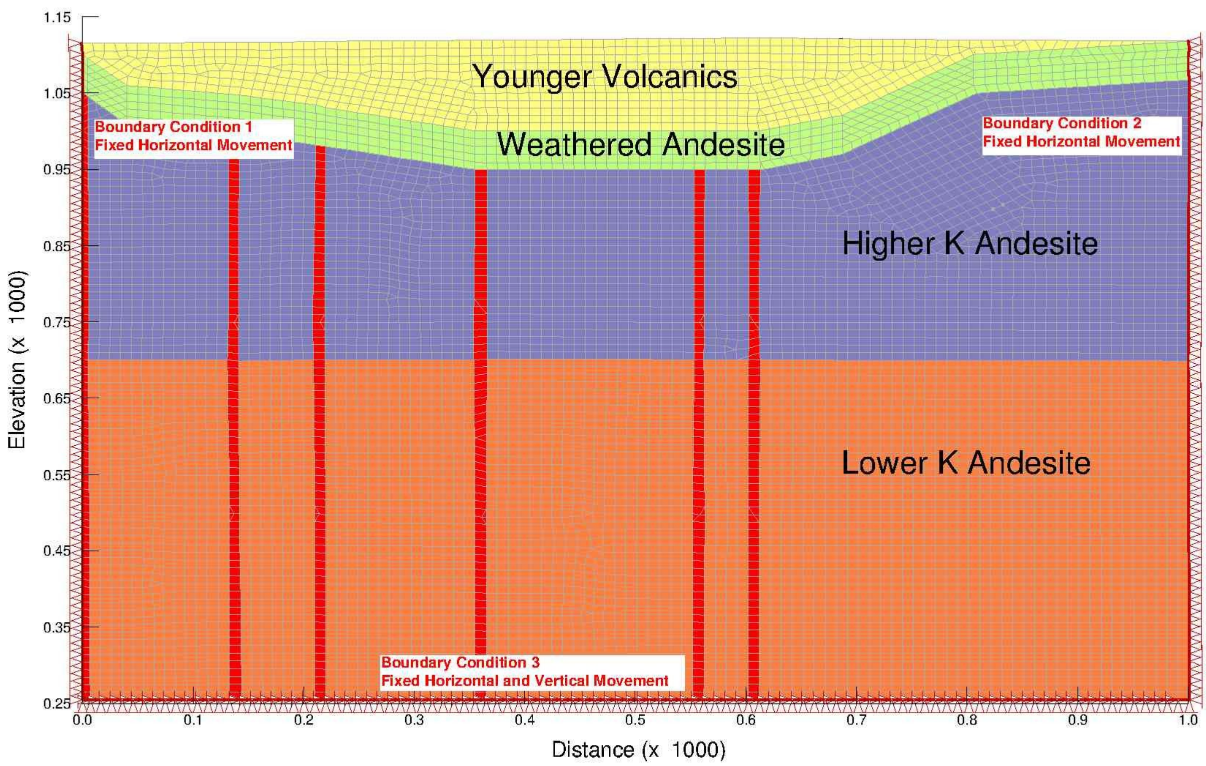


SIGMA/W Surficial Settlements (Cumulative)	Figure A17

SIGMA/W Vertical Surficial Settlements, Unit: metre



SIGMA/W Model



SIGMA/W Surficial Settlements Stage 3	Figure A18