TAILINGS STORAGE FACILITY MONITORING PLAN

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Document Control

Author	WRC approver	Change	Date
		Second version	2004
		Third version	2010
M Graham	S Roa	Addendum. New GW sampling regime	2014
M Burroughs	S Roa	Fourth version. New Underdrainage sampling regime, trigger limits	Dec 2019

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1. Introduction

Water rights and resource consents for the Tailings Storage Facilities (TSF) Storage 1a and Storage 2 require the preparation, review and update (if necessary) of a Tailings Storage Facility Monitoring Plan (TSFMP) and shall provide such update Plan to Waikato Regional Council (WRC) annually (Condition 16 and 17). The Plan was updated in 2010 and again in 2014, however it was not approved. An addendum was subsequently approved. This plan is the fourth iteration.

This is plan will be updated every two years, or if any significant changes occur in the design or operation of the tailings storage facilities.

2. Consent and Water Rights

With respect to Storage 1A there are four consents that require a TSF Monitoring Plan:

- Discharge permit 971303 was granted to place waste rock and other material onto the ground to establish Storage 1A
- Discharge permit 971304 was granted to discharge tailings into Storage 1A
- Discharge permit 971305 was granted to discharge seepage from Storage 1A into the ground
- Water permit 971306 was granted to divert groundwater from within the footprint of storage 1A into subsoil drains

For Storage 2, Natural Water Rights prescribe monitoring conditions that are covered in this Plan:

- W1761 permits the discharge of natural water containing waste onto the land and into the ground beneath Storage 2 and the ‘holding’ pond. This water right contains conditions that are essentially the same as those for Storage 1A.

In addition water rights:

- W1749 permits damming of unnamed water courses within the area of Storage 2
- W1750 permits damming of unnamed water courses within the area for storage 1 (the consent is still active despite storage 1 being superceded by storage 1A)
- W1751 permits the damming unnamed water courses in order to construct a perimeter bond [sic] and access road around the north, west and south edges of the designated areas for storages 1 and 2 for waste and tailings disposal
- contain a condition that requires a management plan to describe sequencing of earthworks, runoff control facilities and rehabilitation necessary to meet the conditions of this right. The management plan will detail works and maintenance requirements for the following phases:
    a. construction
    b. operation of system while mining is taking place
    c. post operational requirements.

These conditions are met through the Operation, Maintenance and Surveillance Manual, Version 2018 (WAI-350-PLN-007 Operations Manual).

Also consents W1749 and W1750 condition 4, requires a contingency plan to minimise leachate to protect downstream users. Compliance with this condition is met in this Monitoring Plan.

The detailed water rights and resource consent conditions are provided in Appendix A. Specific conditions related to monitoring are outlined in the next section.

2.1 Background to Consent Changes

The monitoring plans for Storage 1a and Storage 2 were integrated in 2004 following a review and change to consent conditions.

Prior to the review of the Tailings Storage Facility Monitoring Plan in 2004, there were separate monitoring programmes for each tailings storage facility in accordance with their respective consents and management plans.

The operation and monitoring of Storage 2 was covered under resource consent W1761, and the monitoring programme has been developed under this consent since it was granted in 1987. The extended project resulted in additional consents relating to Storage 1A being granted in 1999. A change to the special conditions for the Storage 2 consent was sought in 2002, to align the conditions with those for Storage 1A. As a result the next step was to integrate the monitoring programmes for Storage 1A and Storage 2. This would allow greater ease of management and streamlining of monitoring and reporting processes.

Justification for a previously reduced, monitoring programme for the underdrainage and groundwater monitoring of both Tailings Storage Facilities was detailed in a 2003 report: Tailings Storage Facility – Review and Integration of the Underdrainage and Groundwater Monitoring Programmes for Storage 1A and 2 (TSF – Review 2003).

The WRC consent evaluation report for Storage 1A provides a review of changes. These proposed similar objectives and also to reduce the amount of monitoring required. Amendments were made to the monitoring required under conditions 22, 24 and 25 of consents 971303, 971304, 971305 and 971306, which are common conditions to each. These conditions provide the flexibility for monitoring to be detailed in the TSFMP and in the future, monitoring requirements could be reviewed simply through changes to the TSFMP (subject to WRC approval) rather than going through a formal consent change process. A revised TSFMP (version 2.0 February 2004) was prepared that reflected the various changes to the monitoring regime. The revised TSFMP also included proposals to amend the monitoring regime for the underdrainage system.

In May 2014 an extensive internal review of the TSF groundwater monitoring sampling frequency and network was undertaken by GWS Ltd. Requested changes were submitted as part of an Addendum to the plan and approved by peer reviewers James Pope and Chris Kidd and subsequently WRC (Appendix D). Changes implemented included:

- the number and frequency of wells routinely sampled were reduced
- biannual water level, pH and Electrical Conductivity measurements conducted
- annual water quality sampling in selected wells were considered adequate to identify trends
- special investigation wells for triggered wells or noted rising trends

In summary the groundwater sampling frequency was reduced. The quantity of groundwater samples taken was also decreased with wells defined as being either ‘scan’ or ‘scan and sample’ wells. These changes were implemented late 2014 after the annual peer review meeting.

Although reviewers agreed annual sampling of selected wells would suffice to identify any trends, OGNZL currently conducts bi-annual (winter and summer) sampling.

2.2 Monitoring Plan Requirements

2.2.1 Tailings Storage Facility 1A

Condition 16 of Storage 1A consents states that the Tailings Storage Facility Monitoring Plan must be designed to monitor and assess the effects of the tailings storage facility on the land, ground and groundwater resources. The Tailings Storage Facility Monitoring Plan shall address at least the following:

a. Completion of a risk management plan, as defined in the Australian/New Zealand Standard for Risk Management (AS/NZS 4360:1999) or any subsequent replacement standard. The purposes of the risk management plan shall be to:
   - identify and assess the operational risks relating to Storage1A,
   - develop risk reduction actions where assessed risks are not at an acceptable level, and,
   - develop an appropriate monitoring programme.

b. An overall description of the Tailings Storage Facility monitoring systems and the measures to be adopted to meet the objectives of the groundwater and surface water management system.

c. Details of the proposed structural integrity monitoring programme for the embankment of Storage 1A.

d. Details of the monitoring programme of Storage 1A effects on subsurface hydrogeology, including the establishment of monitoring bores for the purposes of detecting seepage escaping the underdrainage system, and to determine the representative groundwater quality for shallow and deeper groundwater around the perimeter of the waste disposal area (Area D) (Appendix F). These monitoring bores shall include:
   - background monitoring bores to be established up-gradient of Storage 1A to be used as control sites;
   - detection monitoring bores to be installed immediately down gradient of the embankment of Storage 1A for the purposes of gaining an early indication of any groundwater migration containing waste rock or tailings underdrainage;
   - compliance monitoring bores to be installed down-gradient of the detection bores and up-gradient to the receiving surface waters.

e. The measurement and monitoring of the liner and cover system integrity (by measuring drainage quality and flow from all underdrainage and surface collection systems) in order to verify the "as built" structure is achieving predicted design performance objectives.

f. In detailing the monitoring programmes the consent holder shall provide information on the monitoring methods proposed, the monitoring locations, parameters to be monitored, and the calibration and maintenance of monitoring equipment.

In the event of any conflict or inconsistency between the conditions of this consent and the provisions of the Tailings Storage Facility Plan, then the conditions of the consent shall prevail.

Condition 17 states that the Tailings Storage Facility Monitoring Plan shall be submitted to the Waikato Regional Council for approval at least one month prior to the exercise of this consent. The consent holder shall review and update (as necessary) the Plan and shall provide such updated Plan to the Waikato Regional Council annually.

2.2.2 Tailings Storage Facility 2

Condition 5 of W1761 was also amended to three conditions; 5A, 5B and 5C. Conditions 5A and 5C are exactly the same as conditions 16 and 17 for Storage 1A – effectively integrating the monitoring requirements for both tailing storage facilities.

Condition 4 in W1749 requires details of contingency plans to describe methods to be used to minimise the generation of leachate to protect downstream users and uses during construction, operation and post-operational phases. This Monitoring Plan incorporates a contingency plan to meet this condition.

Management plans are also required under Condition 1 in of permits W1750, and W1751 for the control of stormwater and suspended solids and to ensure the safe construction and control of the bund.

2.2.3 Exclusions

This Plan does not cover water rights or consent conditions relating to other management plans, rehabilitation plans or progressive rehabilitation.

2.3 Objectives of the Consent

Objectives of the consents that closely relate to the requirements of the TSF Monitoring Plan are captured in conditions 26, 27 and 29 of Discharge Permit 971303 (Appendix A).

Condition 26 requires that:

a. Seepage from S1A in combination with all other discharges authorised from the waste disposal area shall not cause an adverse environmental effect on adjacent surface waters, as indicated by the receiving water criteria in Table 2, or on users of this resource, or on aquatic biota, outside the footprint of S1A.
b. Seepage from S1A in combination with all other discharges authorised from the waste disposal area shall not cause an adverse environmental effect on groundwater or on users of this resource, outside the boundaries of Area D (Appendix F).

Condition 27 requires the provision of an annual TSF Monitoring Report to include the following information (summarised):

a. Data from monitoring undertaken during previous year
b. Identification of environmentally important trends

c. Interpretation and analysis of any change in ground water chemistry over the previous year and predictions of any future changes in groundwater or surface receiving water chemistry that may arise as a result of these trends. In addition the consent holder shall identify what contingency actions, if any, it proposes to take in response to these predictions.
d. Any contingency actions that may have been taken during the year.
e. Comment on compliance with all conditions and any reasons for non-compliance or difficulty in achieving conformance with the conditions of this consent.
f. A summary and analysis of complaints relevant to this consent, from the complaint log (refer Schedule 1).
g. Any works that have been undertaken to improve environmental performance or that are proposed to be undertaken in the forthcoming year to improve environmental performance in relation to activities permitted by this consent.

The report shall be forwarded in a format acceptable to the Waikato Regional Council.

Condition 29 states the discharges authorised by this (TSF) consent, in combination with all other discharges authorised for this site, shall not cause a significant adverse environmental effect on the receiving groundwater and surface water, or on users of these resources, or in the case of surface water, on aquatic biota. To that end discharges associated with the tailings and waste rock storage facility, either separately or in combination with other discharges, shall not cause the receiving water standards in Table 1 to be breached.

2.4 Other Consent Requirements

Other (TSF1A) consent conditions that relate to the monitoring and performance of the TSF are summarised below.

Condition 17:

- Review and update the Plan (as necessary) and shall provide such updated Plan to the Waikato Regional Council annually.

Condition 18:

- Measure and record the volume of storage provided by the available freeboard behind the embankment structure.

Condition 19:

- Establish and maintain an inventory of sources and estimated volumes of available inert material
- Update inventory at six monthly intervals and balanced against estimated future demand for inert material
- Prepare and implement contingency measures to ensure that proper control of geochemically active materials is maintained in the event a shortfall occurs or is identified in advance
- Report annually to Waikato Regional Council a summary of the inventory and details of any measures which have needed to be taken.

Condition 20:

- At monthly intervals collect a sample of tailings being discharged to the tailings pond, and shall determine its acid neutralising capacity (ANC), maximum potential acidity (MPA), and net acid generation (NAG) capacity. The date the sample is collected and the ANC, MPA and NAG results shall be reported to the Council annually.

Condition 21:

- Install groundwater quality monitoring bores downstream of the embankment structure for the purpose of detecting seepage escaping the underdrainage system, and to allow accurate and representative monitoring of discrete zones within the groundwater system.

Condition 22:

- Undertake "scan monitoring" in both shallow and deep aquifer systems, of water levels, pH, and conductivity in order to establish trends in the monitoring bores.
- Scan monitoring throughout the term of these consents in accordance with the requirements of the approved Tailings Storage Facility Monitoring Plan.
- Monitoring results forwarded to Waikato Regional Council at quarterly intervals.

Condition 23:

- Provide the Council within 12 months baseline monitoring data sufficient to characterise the groundwater regime in the Storage 1A catchment prior to placing PAF material.

Condition 24:

- Undertake a groundwater "compliance monitoring" programme in accordance with the requirements of the approved Tailings Storage Facility Monitoring Plan
- The compliance monitoring programme shall be undertaken at the baseline, detection and compliance monitoring bore locations.

Condition 25:

- At any time following completion of baseline monitoring, if monitoring results within the detection wells or the compliance wells differs from the relevant trigger level for that well over two consecutive readings, as defined in the approved Tailings Storage Facility Monitoring Plan, then the consent holder shall initiate the Contingency Plan detailed in the Tailings Storage Facility Monitoring Plan to characterise the change, assess the source of the change, and to determine what, if any, mitigation measures should be implemented to ensure that condition 26 is complied with at the down-gradient compliance bores. The trend and actions taken shall be detailed in the annual report to the Council.

Table 1 Groundwater Monitoring Parameters

Group 1 Parameters	Group 2 Parameters
Water levels	copper
pH	lead
Conductivity	nickel
Major cations (sodium, potassium, calcium, magnesium)	zinc
Major anions (bicarbonate, chloride and sulphate)	silver
Iron	cyanide
Manganese	ammonia
	nitrate

Note: All groundwater monitoring shall be based on the soluble test method, defined as the concentration of dissolved metals measured in that fraction which passes through a 0.45 µm filter.

Condition 28:

- Design and construction of all works is peer reviewed
- The purpose of the peer review is to ensure that the conditions of design, construction, operation and maintenance of Storage 1A are met and that such work is undertaken by appropriately qualified personnel, in accordance with best practice

Other (TSF2) consent conditions that relate to the monitoring and performance of the TSF are summarised below.

Condition 7:

- Carry out electrical geophysical survey of the perimeter outside the bund after construction of the bund and drainage systems, but before tailings deposition
- The survey to be repeated as directed following identification in the monitoring system of statistically significant (at p=0.05) seepage migration beyond the embankment at three year intervals
- Seek written approval to discontinue or reduce the frequency of surveys if it can be shown that they are no longer required

Condition 10:

~~There shall be no contamination of groundwater beyond a vertical line being the toe of the downstream face of the perimeter bund~~

(a) Seepage from Storage 2, in combination with all other discharges authorised from the Waste Disposal Area, shall not cause an adverse environmental effect on adjacent surface waters, as indicated by the receiving water criteria in Table

2, or on users of this resource, or on aquatic biota, outside the footprint of Storage 2.

(b) Seepage from Storage 2, in combination with all other discharges authorised from the Waste Disposal Area, shall not cause an adverse environmental effect on groundwater, or on users of this resource, outside the boundaries of Area D.

Condition 10A

The discharges authorised by this consent, in combination with all other discharges authorised for this site, shall not cause a significant adverse environmental effect on the receiving groundwater and surface water, or on users of these resources, or in the case of surface water, on aquatic biota. To that end discharges associated with the tailings and waste rock storage facility, either separately or in combination with other discharges, shall not cause the receiving water standards in Table 2 to be breached.

NB Refer to Table 17 in this TSFMP document

3. Overview of Operations

3.1 Tailings Storage Facility 2

TSF2 was constructed for the initial Martha Mine project. Tailings deposition ceased in August 2005. The underdrainage network continues to be operative and seepage waters are directed to the water treatment plant. The initial groundwater compliance bores were in place since commencement of the project and were re-classified as detection bores to integrate with the Storage 1A groundwater monitoring system. Eight new compliance bores were installed in January 2004. The new compliance bores are down-gradient and near Ohinemuri River and set in (or close to) former natural drainage features.

Structural monitoring comprises mainly a network of piezometers installed in the waste rock embankment to monitor hydrostatic levels. Deformation surveys are also undertaken periodically.

As PAF placement has ceased on Storage 2 there is no specific monitoring of waste rock materials (e.g PAF slurry tests). Surface geochemical behaviour of Storage 2 is monitored primarily at silt ponds; where water quality is monitored for compliance to consent conditions and is covered under the Water Management Plan. Underdrainage and groundwater monitoring continues to be conducted.

TSF2 embankment has been rehabilitated to the 156 mRL level. Further rehabilitation is required on some parts of the upper embankment and the capping of the tailings completed once the closure design is finalised.

In November 2007 approval was granted by Waikato Regional Council for the direct discharge of Storage 2 pond water to receiving water. Tailings pond water quality is monitored for compliance to receiving water quality standards and is covered under the Water Management Plan.

3.2 Tailings Storage Facility 1A

Construction of Storage 1A, since granting of consents in 1999, continues towards a consented height of 177.25 mRL. The current height is approximately 172 mRL at the time of this Plan's revision. Tailings deposition into TSF1A commenced in May 2001.

Structural monitoring comprises mainly a network of piezometers installed in the waste rock embankment to monitor hydrostatic levels. Deformation surveys are also undertaken periodically.

The comprehensive drainage and leachate collection network was installed to control seepage movement. Only short extensions are required to toe-drains, upstream cut-off drain and leachate drains, on the eastern side of the facility (Area 3).

Collection ponds are located in TSF1A and TSF2 to capture runoff from PAF areas which is then either pumped to the Water Treatment Plant for treatment prior to discharge or if water quality in the ponds is acceptable, direct discharged to the Ruahorehore Stream. Storage 1A collection ponds include South 3 (S3), South 4 (S4) and South 5 (S5). Storage 2 has only a small area of

PAF around on the eastern haul road and waste load-out station drains into the North Collection Pond. The management of these ponds is detailed in the Water Management Plan (WAI-200-PLN-001-0). Monitoring of waste rock properties is detailed in the geochemistry section of this Plan.

The groundwater monitoring system has been established since 2001. These consist of detection wells near the toe of the facility perimeter and compliance wells down-gradient. The monitoring wells are set in or near natural partially filled drainage features that existed prior to construction of the facility. For TSF1A, the majority of compliance wells were installed in November 1997; prior to the construction of the embankment. The majority of the detection bores were installed in May 2001 with monitoring beginning in August 2002. These wells, as discussed previously, have now been categorized as either 'Scan' wells or 'Scan and Sample' wells.

3.3 Continuous Improvement

The Annual Work Programme details specific work to be completed on an annual basis.

Activities that have the potential to directly impact on site geochemistry, underdrainage and receiving groundwater quality include ongoing construction of the Storage 1A embankment, the volume of storage of water in tailings and collection ponds, and the quality of waste rock material used in progressive rehabilitation.

In 2008 it was identified that the NAF stockpiles contained some PAF material, which resulted in poor water quality runoff to silt ponds. New drains were installed to divert runoff from affected parts of the stockpiles to collection ponds (NCP and S5). A QA/QC programme was put in place to ensure that stockpile materials were appropriately neutralised for later use in rehabilitated zones. The QA/QC programme is described in this Plan. The majority of the PAF material has now been removed with a small amount segregated and capped. The water quality in the ponds is now of direct discharge quality.

In general, future work includes constructing the embankment height to the consented 177.25 m RL. A rehabilitation cover will be constructed progressively in the summer months to pasture quality land use.

In addition, through the findings detailed in the Annual TSF Monitoring Report 2009, some bores around Storage 1A were required to be installed within the natural drainage features upstream or downstream of either compliance or detection bore respectively.

Some shallow bores around the site were installed with bladder pumps to enable undisturbed (sediment free) sampling of the bore water, however, many shallow bores have limited water depth and bailing is required.

Completion of rehabilitation is proposed on Storage 2, with the timing to be determined by conclusion of mining activities and any requirements for potential future tailings disposal.

4. Responsibilities and Authorities

The General Manager - Operations has overall responsibility for ensuring that the mine activities meet the conditions of the resource consents. Any non-compliance associated with the tailings and waste rock storage facility will be reported to the General Manager or his delegate.

To meet the consent requirement to retain the services of a registered Project Engineer who has recognised experience in the design of tailings storage facilities (the Project Engineer), Dr T. Matuschka (Engineering Geology Ltd) continues to be retained under contract with OGNZL Waihi to deliver such services. EGL annually report on the Structural aspects of the facility.

Construction supervision of the TSF and operation and maintenance of the lime facility and collection and silt ponds is the responsibility of the Site Services Manager.

Management of tailings discharges and water treatment plant operations is the responsibility of the Mill.

The HSE Manager is responsible for ensuring that the monitoring programmes are carried out as well as annual reporting on the geochemistry, underdrainage and groundwater components of the Plan. The HSE Manager ensures that the consent conditions are monitored and reported to the General Manager. GWS Limited continues to advise OGNZL Waihi on hydrogeology and water quality aspects and the preparation of reports.

All relevant employees of OGNZL will be made aware of this Plan, and the conditions of the resource consents held for activities at this site.

Construction activities are contracted and supervised by the Site Services Manager. Contracts are put in place to ensure compliance with the requirements of the design plans for the TSF and applicable resource consent conditions.

Hydrological equipment (in silt and collection ponds) are maintained and calibrated on a regular basis. This service is managed by the Mill Maintenance Department.

Table 2 identifies OGNZL Waihi operational departments with responsibilities to sections of this monitoring plan.

Table 2 Responsibilities Identified in the TSFMP

Section	Environmental	Site Services	Mill/Water Treatment
2 Consent and Water Rights	✓	✓	✓
3 Overview of Operations	✓	✓	
4 Responsibilities and Authorities	✓	✓	✓
5 Risk Assessment	✓	✓	✓
6 PART A – Structural Integrity	✓	✓	✓
7 PART B – Geochemistry	✓		✓
8 PART C – Underdrains	✓	✓	✓
9 PART D – Groundwater Monitoring	✓	✓	✓

5. Risk Assessment

5.1 Introduction

Consent Condition 16 a) and W1761 condition 5A a) requires completion of a risk management plan, as defined in the Australian/New Zealand Standard for Risk Management (AS/NZS 4360:1999) or any subsequent replacement standard. Waihi's risk management plan (WAI-300-PLN-016) can be found on SharePoint. The purpose of the risk management plan shall be to:

- Identify and assess the operational risks relating to Storage 1A and Storage 2,
- Develop risk reduction actions where assessed risks are not at an acceptable level, and,
- Develop an appropriate monitoring programme.

Reference is made to the AS/NZS Handbook HB 203:2004 Environmental risk management – principals and process. This guidebook is based on the generic process set out in replacement standard AS/NZS 4360:2004 Risk Management. The standard involves communicating and consulting with stakeholders, setting the context, identifying risks, and then analysing, evaluating, treating and monitoring risks. The entire risk management process is iterative. The process can be repeated many times with additional or modified risk evaluation criteria, leading to a process of continual improvement. The steps in the risk management process that are addressed in this section of the Plan are:

Step 1 Establish context
Step 2 Risk Identification
Step 3 Risk Assessment
Step 4 Risk Treatment
Step 5 Monitoring and Review

5.2 Risk Context

Establishing the context defines the basic parameters within which the risks must be managed and sets the scope for the rest of the risk management process. The context includes OGNZL Waihi's external and internal environment and the purpose of the risk management activity.

5.2.1 External Context

The views of stakeholders interested in, or concerned about, the effects of mining and in particular the risk associated with the potential environmental effects that a tailings storage facility could pose, are important in the consideration of the overall design, construction, operation and closure of the TSF. The aim of both the risk assessment and the Monitoring Plan is to ensure that the environmental performance of the Tailings Storage Facility continues to meet the expectations of stakeholders. Significant stakeholder issues are essentially inherent in the consent conditions and water rights. More information can be found in the Submissions and Evidence to consent applications and Environment Court hearings for the Extended Martha project. In this regard, initial identification of stakeholders includes representatives of:

- The Waihi Community
- Tangata whenua
- Landowners surrounding the tailings storage facility

- Communities and landowners downstream of Waihi; in the Hauraki-Thames-Coromandel region
- Non-government organisations
- Political parties and the NZ Government
- Regulatory authorities WRC and HDC
- Peer reviewers and consultants
- The global community including shareholders in OGNZL

The general and specific views of stakeholders are included as appropriate in the risk management process.

5.2.2 Internal Context

Risk management is an important facet of all areas of OGNZL Waihi's business. Risk assessment is an integral part of the Waihi mining operation from project development through to the operational phase. The views of internal stakeholders, such as OGNZL employees and contractors, site management teams, regional management teams and corporate, are equally important. Risk reviews are conducted at least annually.

The company maintains an Integrated Management System. The company operates under environmental and social responsibility policies that provide a framework to ensure that legal and other requirements are met, that there is engagement with stakeholders, and that systems are put in place to manage risk and prevent pollution. The policies are found on the OGNZL Waihi website. The OGNZL risk management approach is consistent with the AS/NZS standard.

5.3 Risk Evaluation Criteria

The risk evaluation step compares the risk against risk evaluation criteria or tolerability, and considers the costs and benefits. The risk criteria needs to be carefully chosen and a number of issues need to be considered such as what are appropriate end points, risk severity, determining acceptable risk, guidelines and regulations, best practice, and the form that the criteria should take (e.g. numerical levels).

The Resource Management Act sets the framework in Part II - Purpose and Principles. The risk criteria for the TSF are generally expressed in the consent conditions and have been developed through consultation with the regulator, experts and the public.

The company's proposals for the Extended Martha project were expected to have reduced the reasonably foreseeable environmental risks associated with its operations to acceptable levels. Given this, the remaining residual risks are relatively low, and the appropriate treatments are standard operating procedures, monitoring, and maintenance and where appropriate use of contingency plans when appropriate. Ultimately the risk criteria as set out in the consents ensure that there are likely to be no significant adverse environmental effects and that the receiving water standards are not breached.

5.4 Monitoring and Review

The objective of the 'monitor and review' stage of the risk management process is to assess the effectiveness of the risk management strategy and plan adopted, and to reassess their relevance from time to time. Condition 17 of the consent states that the Tailings Storage Facility Monitoring Plan shall be reviewed and updated (as necessary) and shall provide such updated Plan to the WRC annually.

Two functions of the monitor and review process are to:

- Monitor - the risks themselves, each step of the risk management process, risk treatment strategies, the effectiveness of communicating strategies, and the overall risk management system.
- Regularly repeat the risk management cycle. In particular the criteria need to be reviewed and if necessary updated.

5.5 Risk Review

Since the initial assessment the risks have been reviewed annually and maintained in the Waihi risk register. The risk reviews are usually team-based to ensure that there is identification of any new risks and agreement of the risk levels etc.

5.6 Risk Treatment

OGNZL Waihi adopts a hierarchy of controls for the treatment of risk; elimination, substitution, engineering, isolation, administration, and personal protective equipment. Engineering methods can be used to eliminate or substitute risks. Other controls may include barriers to isolate hazards, and passive or active alarm systems used to monitor the performance of engineered controls. Administration usually implies use of policies, management plans or procedures.

From recent reviews of the risks associated with the TSF, the following issues are identified:

Reduction in the storage capacity of collection ponds: Build-up of sediment resulted in overflows less than the design storm. The effects of these overflows are minor because of dilution afforded by the Ruahorehore Stream and Ohinemuri River. A pond cleaning programme was initiated in early 2009 and will continue on a regular basis to maintain storage capacity. Collection pond management is addressed in the Water Management Plan. This Plan addresses only the monitoring of ponds to evaluate geochemical performance of the waste rock materials on the embankment.

The 'catastrophic' release of tailings is a risk that will always be high in terms of the consequences. However, the likelihood is considered 'rare' because of the high standard of engineering design and construction supervision. Instrumentation (piezometers) to monitor water levels in embankment and periodic deformation surveys ensure management of this risk. These data are reported and peer reviewed annually. The risk of the tailings pond overflow is managed by frequent water level checks and ensuring placement of tailings within the impoundment.

The availability of adequate quantities of NAF material for the formation of liners and caps is met though adherence with Conditions 19 of the Tailings and Waste Rock Embankment consent. This consent requires six-monthly updates on the balance of inert material quantities, i.e. the volumes required against the volumes available. The condition requires the preparation and implementation of a contingency plan in the event that there is a shortfall of NAF material.

A potential risk is insufficient NAF material being available for the rehabilitation of the embankment and capping of the tailings. There is currently sufficient material available for rehabilitation and the risk is low. This aspect is reviewed annually so that the risk is managed. The reasonably foreseeable risks associated with Storage 1A and Storage 2 do not require any modification to the design or current operating practices and can be managed through appropriate monitoring and contingency planning.

Other risks include flood damage to the toe of the embankments and acid rock drainage issues. Overtopping risk is managed by the consent requirement to maintain a minimum freeboard. The annual construction programme also ensures crest levels are raised to meet tailing and water storage requirements if necessary. Frequent monitoring of waters levels ensures timely notification can be made. Minimum freeboard in Storage 1A is more at risk during the winter months. Water volumes in the dam in recent years have been higher than usual as a consequence of Cyanide Code requirements, however participation in the code has now ceased and water levels are able to be reduced. In Storage 2, water levels are maintained below the minimum freeboard with only the occasional incursion into the freeboard caused by significant rainfall events. The Storage 2 pond water quality has improved sufficiently to direct discharge by pumping to receiving waters. This has allowed better management of water levels in the pond. Continuous monitoring is also in place. The risk of flood erosion damage to the toe of the embankment may occur in exceptional circumstances (rare) and any damage could easily be repaired. The embankment foundations are well compacted providing resistance to erosion.

In the perimeter drain downstream of the vehicle wash-bay site, any potential PAF materials are removed on a regular basis.

The risk of tailings and/or waste rock seepage is similar to that identified in 1999. Seepage release is covered in Part C – Underdrainage of the TSF Monitoring Plan.

Spillage (e.g oil) from the contractor workshops during operations is low risk due to the infrequency of events. However, spills that do occur are most likely to be on hard surfaces and rapidly cleaned-up so that there is no release to soil or water. All workshop catchment areas drain to oil water separators. Workshop inspections are a regular activity.

All the other risks are considered negligible. Any dust control issues are addressed in the Air Quality Management Plan (for nuisance dust etc). Wildlife Monitoring procedures are also in place.

6. PART A – Structural Integrity

6.1 Introduction

The structural integrity of the embankment concerns all the zones of the embankment.

The zoning of the embankment provides for:

- Restriction of tailings seepage
- Safe long-term stability under both static and seismic loads
- Restriction on generation of acid drainage in the short and long-term
- Rehabilitation of the downstream shoulder to pasture and native plantings
- Collection of tailings seepage and waste rock leachate for treatment

Structural integrity is dependent on a number of factors. These include foundations, embankment fill properties, embankment pore pressures, groundwater pressures, surface drains, stored contents (tails and water) and significant environmental events such as extreme rainfalls and earthquakes. The liner system that acts to contain leachate associated with the waste rock that forms the embankments and to restrict tailings seepage consists of Zones A and B respectively. The cover system that acts to restrict infiltration of oxygen and water consists of Zones G and H. The integrity of the liner and cover are dependent on a number of factors. If the embankment were to deform significantly then this could affect the integrity of the liner and cover system. If the liner and cover systems do not perform their functions (i.e. control seepage and prevent infiltration of water and oxygen) then this could have an adverse effect on the structural integrity of the embankments due to excess pore water and internal erosion.

The risk of structural failure of the TSF's is very low due to their inherent conservative design, by adhering to the construction specifications, construction supervision by experienced civil engineering personnel, geotechnical testing during the construction phase, retention of the Project Engineer and due to a rigorous surveillance and monitoring programme (Conditions 2, 4, 5, 6, 9, 11, 12, 13, 15).

The Operations, Maintenance and Surveillance Manual for Storage 1A and Storage 2 is the main reference document for operating, maintaining and monitoring the performance of the TSF's and has been developed to conform to the NZSOLD (NZ Society of Large Dams) Dam Safety Guidelines.

Construction of the embankments is under the direct supervision of OGNZL Waihi site services personnel. The construction is assisted by surveyors and the Project Engineer, Trevor Matuschka (Engineering Geology Ltd), as necessary. There is a small residual risk that the integrity of the TSF's could be affected in some way by unforseen circumstances or extreme environmental events. It is normal practice to undertake surveillance and monitoring of large dams to ensure performance is in line with design assumptions and expectations. This provides confidence that the integrity of the facility is maintained.

This section provides details of the structural integrity monitoring programme for the embankments that form the TSF's (Storage 1A and Storage 2) as per the consent conditions 16 (c).

6.2 Structural Monitoring Objectives

The Structural Integrity monitoring aims to address primarily the conditions of the resource consent and any events that could damage the structure of embankment and of the liner and cover system viz:

- Overtopping - monitoring of minimum freeboard (Condition 9 & 18), storm events and water treatment activities
- Erosion - post-storm inspection and maintenance works (Condition 14) and water level monitoring in the tailings pond
- Rehabilitation cover failure – inspection and monitoring of land management activities, embankment groundwater water levels, tree root surveys
- Static and seismic stability - visual inspections, deformation surveys, measurement of piezometric levels and underdrainage flows
- Provide information on the monitoring methods, the monitoring locations, parameters to be monitored, and the calibration and maintenance of monitoring equipment (Condition 16(f)).
- Mitigation of any trends or processes that could adversely affect the structural integrity of the embankment and of the liner and cover system

In August 2018 a Failure Modes Effects Analysis (FMEA) workshop was carried out to identify potential failure scenarios for the TSFs, and conditions that could initiate such failures. OGNZL staff, the Project Engineer and a representative from the Peer Review Panel were present at the workshop. At the time of updating this Monitoring Plan the formal documentation of the FMEA had not been completed. The outcome of the FMEA will be used to review the operation, monitoring and surveillance of the TSFs to ensure that it is appropriate for the potential risks associated with the TSFs, and revise accordingly where any deficiencies are identified.

Monitoring of the structural aspects is a requirement of Resource Consents 971303, 971304, 971305 and 971306 for the Storage 1A and Water Permit W1761 for Storage 2. The scope of activities for structural monitoring includes:

- Measure and record available freeboard and volume of storage (Condition 18)
- An inventory of waste rock sources and volumes (Condition 19)

6.3 Structural Monitoring

6.3.1 *Review and Interpretation of Data*

The following is monitored and carried out to continually review and check the structural integriry of the embankment. Items (i) to (vi) are discussed in more detail under Section 6 and item (vii) in Section 8 of the Monitoring Plan.

i) Rainfall
ii) Pond water level and freeboard
iii) Management of tailings discharge
iv) Piezometers
v) Visual inspections
vi) Survey benchmarks
vii) Seepage

Trigger levels are assigned to the critical monitoring data to indicate any significant change in trend or potentially developing unsafe condition. Set procedures are followed should the trigger levels be exceeded (refer to the Contingency Plan in Section 6.3.12).

The critical monitoring data is forwarded to the Project Engineer every 6 months for review and comment. The data forwarded to the Project Engineer must be current, and not more than 5 days since the last reading. The Project Engineer must review and respond within 10 working days of receipt of the information.

6.3.2 Rainfall

Rainfall is measured at two locations; at the meteorological station (Met Station) on Barry Road at the entrance to the Martha Pit, and at the Water Treatment Plant (WTP).

The Met Station rain gauge is an automated telemetered system which is operated to the New Zealand hydrological recording standard (midnight to midnight) and is the official rainfall record.

The WTP rain gauge is read at midnight daily. The WTP rain gauge has been routinely inspected since April 2009 by Hydrologic Ltd. The Met Station is also serviced by Hydrologic Ltd. The gauges are calibrated biennially.

All documents and records are stored and maintained in the Environmental Department.

The met data is used to compare with changes in pond storage levels, underdrainage flows, and groundwater bore levels. It is also used for input into the site water balance model that is used to predict the likely volume of water stored in the TSF's under different operating conditions.

6.3.3 Pond Water Level and Freeboard

Condition 9 of the resource consents requires that the embankment structure incorporate at all times sufficient storage for the surface runoff arising from a PMP event, above all material in the tailing pond (solid and liquid), with 1.0 m additional freeboard.

Tailings water level is monitored daily at decant pumping stations and recorded electronically by Environmental Department staff. The electronic record is available for access by mill operations to review and update their own records as necessary. The electronic spreadsheet is also set-up to monitor the clearance of the pond water level from minimum freeboard. Water levels approaching minimum freeboard are reported to mill operators in a timely manner. The data is stored in drive S:\Enviro\TSF water levels – Storage 1A (or 2) freeboard.xls on a shared drive.

The minimum freeboard is calculated by the mine surveyor and updated (if necessary) as the height of the embankment crest progresses. The lowest elevation on the crest is used to calculate the minimum freeboard, the PMP volume, and the available storage. Other relevant levels and catchment/impoundment areas are estimated to calculate PMP etc. The data is stored in drive S:\Enviro\TSF water levels -TSF Pond Volumes BM.xls on a shared drive.

6.3.4 Tailings Management

The main purpose of tailings management is to achieve uniform deposition of tailings around the perimeter of the embankment and to prevent water ponding against the embankment. Sub-aerial deposition of tailings is preferred as far as possible. Sub-aerial deposition involves deposition of tailings above water. The advantages with sub-aerial deposition, compared to subaqueous deposition include:

- Evaporation from the beach surface dries and consolidates the tailings to a higher density, thereby maximising the available capacity of the impoundment (also evaporation results in greater strength of the tailings and this reduces the risks associated with a potential breach of the embankment; although it is noted the risk of a breach is considered extremely unlikely)
- Process water and stormwater runoff are not impounded directly against the embankment when tailings are discharged from the embankment and this significantly reduces hydraulic pressures on the embankment and seepage quantities.

Maintaining the maximum exposed area of the tailings has advantages with respect to maximising tailings density and strength, but does increase the risk of oxidation of sulphidic tailings which can result in poorer water quality and a greater hazard for bird life. Consequently a balance is required. Storage 1A is operated with a much smaller exposed beach area than was maintained at Storage 2 to reduce the risk of oxidation of the tailings and risk to bird life.

Tailings are deposited via spigot points along the upstream shoulders of the embankments. The tailings pipeline and spigots are raised ahead of the tailings. The spigots can be opened and closed as required to distribute tailings uniformly over different sections of the pond. In this way different sections of the pond can be progressively built up then rested to achieve the benefit of drying and compaction. Also the tailings beach can be shaped to direct water to the decant pumps. Mill operators are responsible for management of the tailings.

Tailing surveys are undertaken by the Mine surveyor in conjunction with pond water levels and freeboard. Surveyed data is retained in the surveyor's office and is provided at least annually to the Project Engineer for reporting purposes.

6.3.5 Water Level Management – TSF1A

The structural integrity of the Zone B embankment face needs to be maintained by:

- Ensuring water levels are kept low by pumping decant for water treatment.
- Ensuring there is adequate exposed tailings beach to buffer against wave action. This is achieved by ensuring that spigots discharging tailings are frequently rotated around the perimeter of the impoundment. This is the responsibility of the mill operators. Environmental or Site Services/Mining operations personnel also monitor and report when spigot discharge needs to be changed.
- Alternatively, earth fill is sometimes placed in areas where erosion is evident.

6.3.6 Water Level Management – TSF2

TSF2 no longer receives tailings. Water is not directed to the water treatment plant but is pumped directly to receiving waters under water quality protocols approved by WRC.

The management of pond water levels is a balance between ensuring minimum freeboard is maintained (below 153.28 mRL) and preventing excessive periods of exposure to the tailings surface (above 152.80 mRL). As of October 2016, the calculated Probable Maximum Precipitation (PMP) + 1m freeboard was 3.12m.

The Water Treatment Plant Operators liaise with the Environmental Department to ensure target pond water levels are maintained.

6.3.7 Piezometers

Piezometers measure water pressure and provide information necessary to assess the stability of the embankments and to evaluate the impact of the TSF's on groundwater conditions. Piezometers are installed both in the embankments and the underlying foundations.

Embankment piezometers (Figure 1 & 2) are installed progressively by Site Services contractors (Geotechnics) to meet the design specifications set out in Storage 1A Embankment Instrumentation Section drawings (Engineering Geology Ltd, 1998; Drawing No. 98/1/DS-C-89 A-D) and as amended by the Project Engineer. The Storage 2 embankment has been instrumented with 76 pneumatic piezometers that were installed progressively as the embankment was constructed, commencing in 1989. As of 2018 only 22 pneumatic piezometers are operational as the others have malfunctioned in the preceding 28 years. Storage 2 also has 12 vibrating wire piezometers installed within the tailings beneath the current capped area around the perimeter of the TSF and 23 standpipe piezometers within the embankment (Figure 1), of which 17 are still operational. The measured water pressures in the piezometers in Storage 2 have remained very stable with little change.

A review of monitoring frequency was conducted by the Project Engineer in 2016 and the piezometers continue to be read monthly.

Vibrating wire piezometers are installed in Storage 1A (Figure 2). A total of 106 piezometers have been installed to date. These piezometers are also read monthly. Monitoring of the water pressure in the piezometers to date show that the TSF is performing satisfactorily.

Water levels in piezometers are measured by Environmental Department personnel using procedure WAI-200-PRO-003 TSF Piezometer Data Collection (Appendix E).

Data is updated immediately and checks undertaken for trends in the data. In addition r_u values are computed and recorded. r_u values are defined as being a function of measured water level, fill thickness, and material density. High r_u values can be of concern in zones that could be vulnerable to instability (e.g. Zone B). To date the measured piezometric levels and the calculated r_u values have not exceeded unacceptable levels. Records are provided annually to the Project Engineer (Engineering Geology Ltd) for the Structural Integrity report or whenever an unusual response is measured.

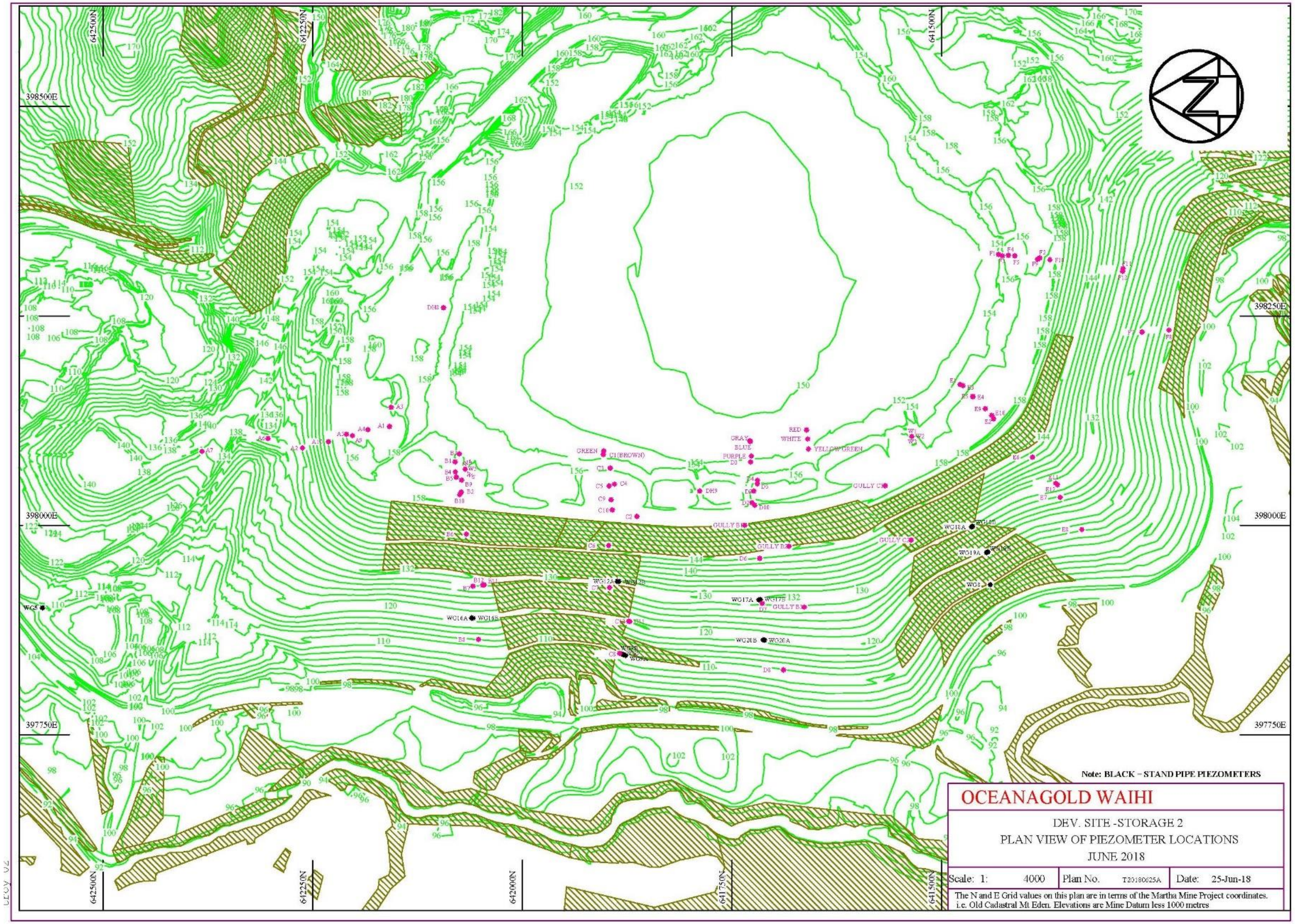

Figure 1 TSF2 Piezometers

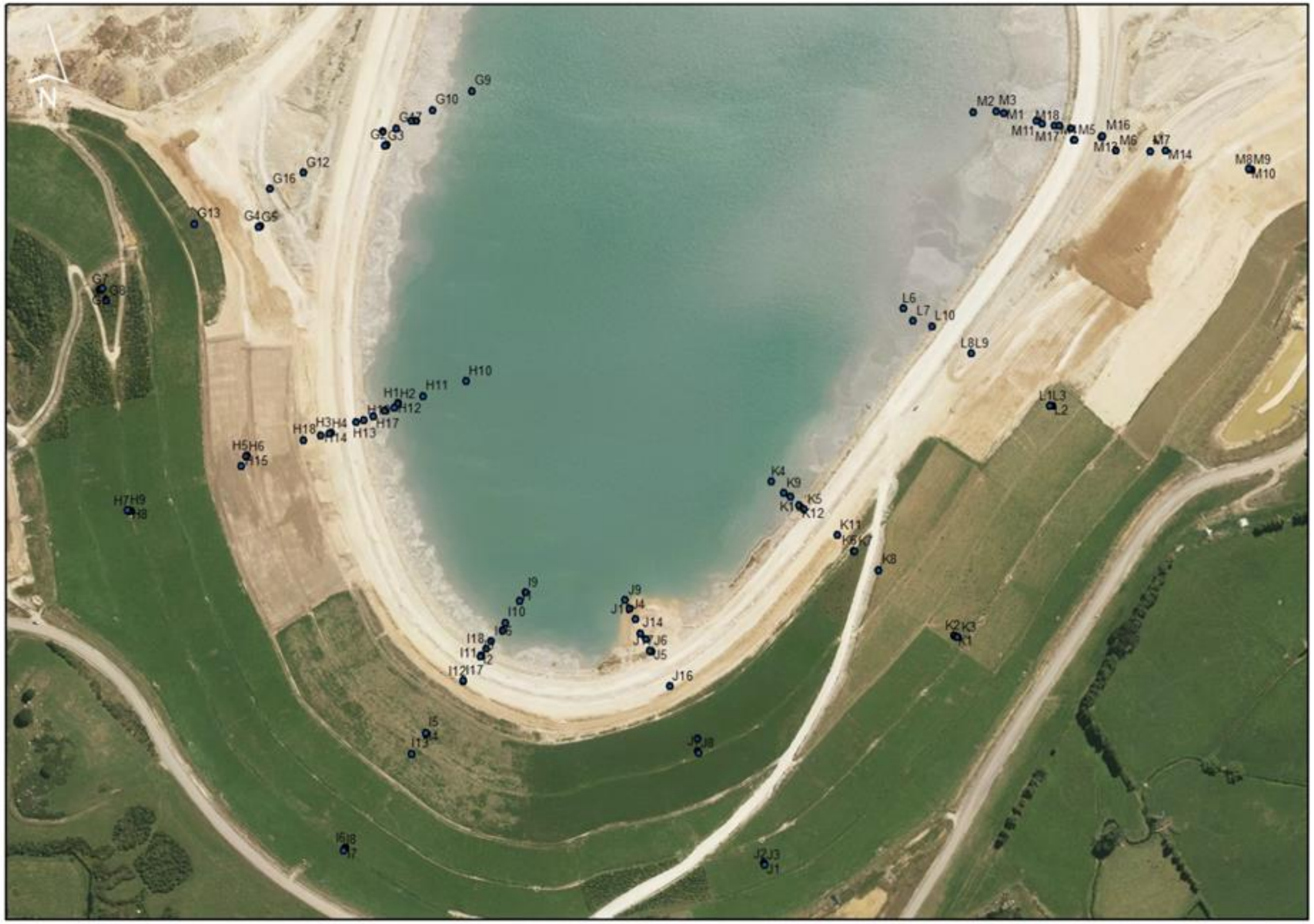

Figure 2 TSF1A Vibrating Wire Piezometers

Trigger levels

The Operations, Maintenance & Surveillance Manual, 2018 defines the following alert and alarm trigger levels for piezometers (Tables 3.1 and 3.2). If the alert or alarm trigger levels are exceeded the Contingency Plan is initiated (see section 8, OMSM). Alert trigger levels are set at levels to draw attention to a changing trend in piezometric level being monitored, and are below which would be a safety concern. Alarm trigger levels are set at levels to indicate a significant change in the parameter being monitored requiring investigation. In some cases the alarm trigger level could indicate a less than normally accepted performance standard.

Table 3.1 Piezometer Trigger Levels for Storage 2

Pneumatic Piezometers			
Piezometer ID	**Tip Level**	**Alert Level**	**Alarm Level**
	RL	**RL**	**RL**
A1	No longer working		
A2	111	119.0	125.0
A3	No longer working		
A4	126.41	140.0	TBC
A5	125.42	140.0	146.0
A6	No longer working		
A7	No longer working		
A9	No longer working		
A10	No longer working		
B1	No longer working		
B2	No longer working		
B3	No longer working		
B4	No longer working		
B5	No longer working		
B6	112.25	119.0	125.0
B7	110.989	116.5	122.5
B8	104.251	106.5	112.5
B9	No longer working		
B10	No longer working		
B11	119.003	125.5	131.5
B12	111.211	115.5	119.5
C1	No longer working		
C2	104.55	107.5	113.5
C3	No longer working		
C4	No longer working		
C5	124.934	127.0	133.0
C6	No longer working		
C7	No longer working		

C8	101	103.0	109.0
C9	No longer working		
C10	No longer working		
C11	113.98	116.5	118.5
C12	106.43	108.5	114.5
Blue	No longer working		
Yellow/Green	No longer working		
Red	No longer working		
White	No longer working		
Grey	No longer working		
Brown	No longer working		
Green	No longer working		
Purple	No longer working		
D2	No longer working		
D4	No longer working		
D5	124.174	140.0	143.0
D6	No longer working		
D7	No longer working		
D8	98.263	100.5	106.5
D9	No longer working		
D10	No longer working		
E1	No longer working		
E2	No longer working		
E3	No longer working		
E4	No longer working		
E5	No longer working		
E6	No longer working		
E7	106.1	109.0	115.0
E8	100.89	103.0	109.0
E9	No longer working		
E10	No longer working		
E11	No longer working		
E12	No longer working		
F1	No longer working		
F2	No longer working		
F3	No longer working		
F4	No longer working		
F5	No longer working		
F7	111.788	114.0	119.0
F8	101.757	105.5	110.0
F9	No longer working		
F10	No longer working		

F11	125.369	127.5	129.0
F12	118.286	120.5	126.0
GullyB1	103.15	108.0	114.0
GullyB2	No longer working		
GullyB3	No longer working		
GullyC1	No longer working		
GullyC2	No longer working		
Standpipe Piezometers			
Piezometer ID	**Tip Level**	**Alert Level**	**Alarm Level**
	RL	**RL**	**RL**
WG1	Removed/grouted for TSF1A		
WG2	Removed/grouted for TSF1A		
WG3	Removed/grouted for TSF1A		
WG4	Removed/grouted for TSF1A		
WG5	79.539	103.0	108.0
WG6	Removed/grouted for Northern Stockpile		
WG8	84.984	99.0	104.0
WG9	87.258	93.0	98.0
WG9a	96.592	99.0	104.0
WG9b	104.866	108.0	113.0
WG12a	120.82	124.0	TBC
WG12b	113.02	119.0	TBC
WG15	Removed/grouted for TSF1A		
WG16a	105.961	113.0	118.0
WG16b	113.672	117.0	122.0
WG17a	121.911	123.5	128.5
WG17b	109.714	117.0	TBC
WG18a	122.421	125.0	130.0
WG18b	114.321	117.5	122.5
WG19a	105.255	108.5	113.5
WG19b	112.949	115.0	120.0
WG20a	105.841	109.0	TBC
WG20b	113.854	117.5	122.5
Vibrating Wire Piezometers			
Piezometer ID	**Tip Level**	**Alert Level**	**Alarm Level**
	RL	**RL**	**RL**
BH1-W01	135.01	150.0	153.0
BH1-W02	144.81	153.0	155.0
BH1-W03	149.81	154.0	156.0

BH3-W04	135.94	150.0	153.0
BH3-W05	145.74	153.0	155.0
BH3-W06	150.74	154.0	156.0
TSF2-1-VW1	151.12	154.0	156.0
TSF2-1-VW2	141.12	153.0	155.0
TSF2-1-VW3	131.12	150.0	153.0
TSF2-2-VW4	149.85	154.0	156.0
TSF2-2-VW5	142.85	153.0	155.0
TSF2-2-VW6	136.85	150.0	153.0

Note: TBC-No alarm trigger level set as piezometer shows significant historical variation.

Table 4.2 Piezometer Trigger Levels for Storage 1A

Vibrating Wire Piezometers			
Piezometer ID	**Tip Level**	**Alert Level**	**Alarm Level**
	RL	**RL**	**RL**
G2	114.459	115.5	119.5
G3	110.372	115.5	119.5
G4	111.775	111.0	115.0
G5	101.487	113.0	117.0
G6	108.982	108.0	112.0
G7	111.163	110.5	114.5
G8B	110.135	110.5	114.5
G9	130.23	150.0	154.0
G10	130.06	134.0	138.0
G11B	133.13	134.5	138.5
G12	130.2	131.5	135.5
G13	129.905	132.0	136.0
G14	152.941	163.5	167.5
G15	144.845	144.0	148.0
G16	145.004	146.0	150.0
G17	162.365	168.5	171.5
G18	Proposed to be installed		
H1	No longer working		
H2	104.15	109.5	113.5
H3	101.86	105.0	109.0
H4	103.38	108.5	112.5
H5	101.48	105.0	109.0
H6	102.92	107.0	111.0
H7	99.37	103.5	107.5
H8	97.57	100.0	104.0
H9	88.15	101.0	105.0

H10	114.8	143.0	147.0
H11	132.24	161.0	165.0
H12	129.72	130.5	134.5
H13	130.12	133.5	137.5
H14	127.72	129.5	133.5
H15	125.036	125.0	129.0
H16	151.059	163.5	167.5
H17	145.02	149.0	153.0
H18	140.218	141.5	145.5
H19	162.075	164.5	168.5
H20	Proposed to be installed		
I1	118.57	119.0	123.0
I2	No reading from Apr 2014		
I3	118.35	119.5	123.5
I4	110.55	111.5	115.5
I5	113.01	114.0	118.0
I6	94	107.5	111.5
I7	102.81	106.5	110.5
I8	104.78	108.0	112.0
I9	129.91	146.0	150.0
I10	129.7	128.5	132.5
I11	130.4	131.5	135.5
I12	130.34	131.0	135.0
I13	124.912	128.0	132.0
I15	150.486	165.5	169.5
I16	145.063	146.5	150.5
I17	145.007	146.0	150.0
I18	162.094	168.5	171.5
I19	Proposed to be installed		
J1	113.19	115.0	119.0
J2	110.84	112.0	116.0
J3	101.5	108.5	112.5
J4	126.1	129.0	133.0
J5	123.84	125.0	129.0
J6	126.44	127.5	131.5
J7	114.97	116.0	120.0
J8	117.68	116.0	120.0
J9	134.005	158.5	162.5
J10	130.03	131.0	135.0
J12	129.942	131.0	135.0
J14	150.948	163.5	167.5
J15	No reading from Oct 2017		
J16	145.106	148.5	152.5

J17	161.591	166.0	170.0
J18	Proposed to be installed		
K1	115.77	117.0	121.0
K2	112.499	113.0	117.0
K3	104.7	110.5	114.5
K4	132.01	132.5	136.5
K5	130.92	132.0	136.0
K6	126.56	127.0	131.0
K7	128.06	129.5	133.5
K8	129.793	130.5	134.5
K9	150.798	163.0	167.0
K10	145.26	146.5	150.5
K11	145.259	146.5	150.5
K12	162.055	168.5	171.5
K13	Proposed to be installed		
L1	119.36	121.0	125.0
L2	127.59	129.0	133.0
L3	130.56	131.0	135.0
L6	135.38	136.5	140.5
L7	152.439	163.5	167.5
L8	139.12	142.0	146.0
L9	145.167	146.0	150.0
L10	161.139	166.5	170.5
L11	Proposed to be installed		
M1	114.65	117.0	121.0
M2	121.482	136.5	140.5
M3	129.98	144.0	148.0
M4	116.65	118.0	122.0
M5	120.48	121.5	125.5
M6	115.186	117.0	121.0
M7	118	121.5	125.5
M8	104.686	114.0	118.0
M9	112.171	114.5	118.5
M10	116.325	117.5	121.5
M11	129.758	131.0	135.0
M12	129.815	131.0	135.0
M13	130.05	131.5	135.5
M14	130.05	131.0	135.0
M15	No longer working		
M16	144.97	150.5	154.5
M17	144.74	146.5	150.5
M18	161.831	167.0	171.0

M19	Proposed to be installed

6.3.8 *Embankment Survey Benchmarks*

Benchmarks are located on the completed downstream shoulders and are surveyed to determine horizontal and vertical movements in the embankment. The accuracy of survey measurements is estimated to be +10mm horizontally and +5mm vertically.

The expected trend in the measurements is for a reduction in movement over time as consolidation progresses within the embankment fill. Maximum recorded movements in Storage 2 have been up to 43mm horizontal movement and 133mm vertical settlement. These movements may include a component of creep in the outer lightly compacted plant growth zone (Zone H). These settlements are not significant and expected due to consolidation of the fill (T Matuschka, 1997; OGNZL Evidence).

The benchmarks established on Storage 1A have recorded a maximum of 40mm horizontal movement and 93mm vertical settlement. These deformations are also not considered significant.

Trigger Levels

Surveying accuracy is 10mm horizontal and 5mm vertical. The Operations, Maintenance & Surveillance Manual, 2018 define trigger levels for TSF2 (Table 5) and TSF1A (Table 6). The trigger level for each mark given in Table 4 and 5 refers to the total resultant horizontal and vertical movement. An annual incremental alert trigger level of 30mm for the horizontal and vertical deformation has also been set to monitor the ongoing performance of the embankments. The annual incremental alert trigger level is set at a level to draw attention to a changing trend in deformation being monitored, and is below which would be a safety concern.

The locations of 35 benchmarks on Storage 2 are shown in Figure 3. The locations of 41 benchmarks on TSF1A are shown in Figure 4. The benchmarks are monitored from 'control' marks located clear of the embankment footprint. Surveys are undertaken at annual intervals by the Mine Surveyor (a registered surveyor).

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Table 5 TSF2 Benchmark Trigger Levels

Benchmark	Total Depth of Fill	Alert Trigger Level for Total Movement	
		Horizontal	Vertical
	M	mm	mm
B100	0.3	-	-
B110	7.6	38	58
B120	15.2	61	91
B130	24.5	98	147
B140	35.9	144	216
B156	48.7	195	292
C99	-0.1	-	-
C110	10.8	43	101
C120	18.7	75	148
C130	29.0	116	174
C140	43.2	173	259
C156B	52.2	209	313
D99	-0.1	-	-
D100	4.7	-	-
D110	10.1	42	87
D120	18.1	73	114
D130	27.8	111	167
D140	42.4	170	255
D156	53.2	213	319
Z100	4.3	-	-
Z110	11.2	48	67
Z120	18.9	76	113
Z130	26.8	107	161
Z140	42.2	169	253
Z156	51.0	204	306
E99	-0.1	-	-
E100	-0.3	-	-
E110	8.8	35	53
E120	19.1	76	115
E130	27.2	109	163
E140	38.8	155	233
Y99	0.8	-	-
Y100	2.1	-	-

Y110	9.1	56	68
Y120	15.3	61	92
Y130	21.2	85	127
Y140	32.3	129	194
F100	3.6	38	-
F110	14.9	60	90
F120	20.6	83	124
F130	21.6	86	130

Table 6: TSF1A Benchmark alert trigger levels for total movement

Benchmark	Total Depth of Fill	Trigger Level for Total Movement	
		Horizontal	Vertical
	M	mm	mm
G120	10.1	40	42
G130	23.0	64	92
G140	31.3	88	125
G150	39.2	110	157
H104	5.0	43	34
H120	21.5	60	86
H130	29.3	82	117
H140	38.3	107	153
H150	50.2	140	201
I108	0.2	-	-
I120	18.1	54	73
I130	25.8	72	103
I140	30.8	86	123
I152	39.8	111	159
I165	51.0	143	204
J120	9.0	40	36
J130	17.3	48	69
J140	25.6	72	103
J152	35.0	98	140
J165	42.6	119	170
K120	10.7	35	43
K130	19.1	53	76
K140	25.6	72	102
K152	30.7	86	123

K165	37.0	104	148
L120	2.3	-	-
L130	7.9	34	32
L140	13.8	43	55

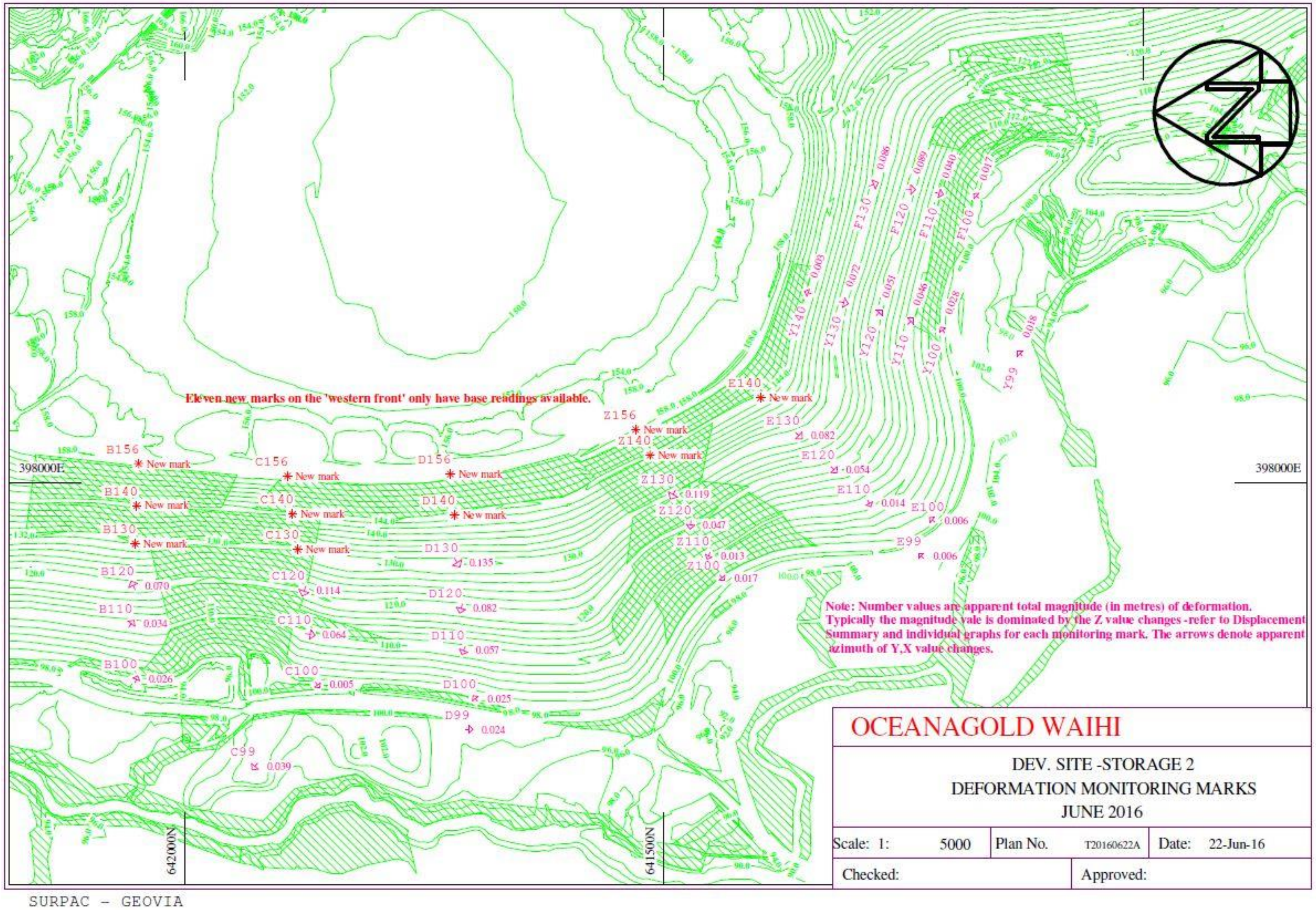

Figure 3 TSF2 Benchmark Network

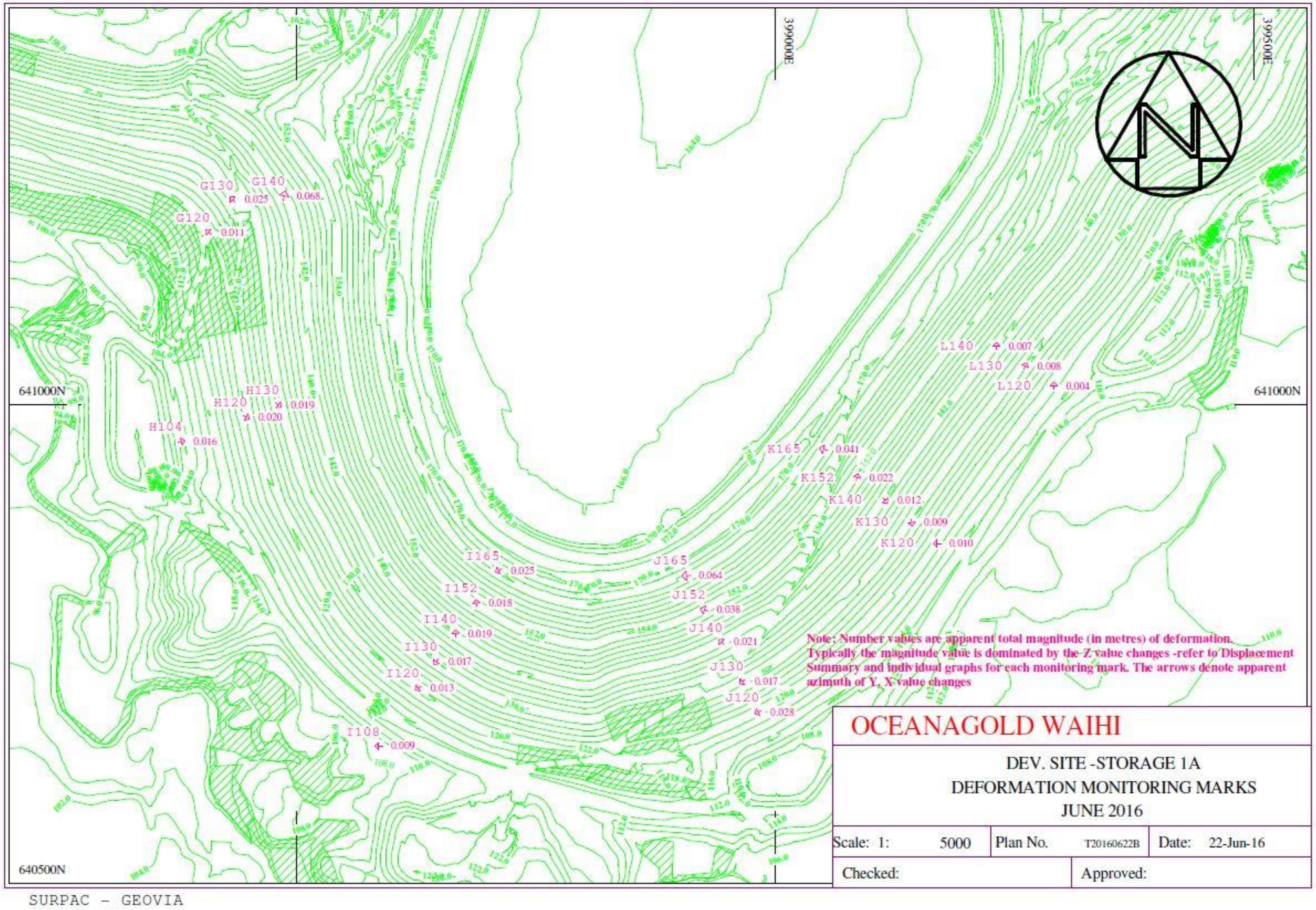

Figure 4: TSF1A Benchmark Network

6.3.9 Inventory of Materials

Construction of the Storage 1A embankment and associated structures primarily involves the use of mine waste rock. A small quantity of fill is obtained from foundation stripping. Topsoil underlying the various structures is stripped and stockpiled for later use for rehabilitation purposes. Excavated unsuitable foundation material is stockpiled separately.

Various quantities of PAF and NAF mine waste material have been excavated from the open pit. Underground waste rock is not used on the TSF. When construction activities are operating, an inventory of waste rock materials for the various construction zones is maintained and reported by Site Services on a monthly basis.

This information is presented in the Annual Inspection Report (Structural Integrity) by the Project Engineer (Engineering Geology Ltd). The report also comments on the availability of the material for completing construction and rehabilitation on Storage 1A and Storage 2.

6.3.10 Calibration of Equipment

Surveying

Calibration of the theodolite is required to achieve consistency in the measurements. Calibration of the equipment will be undertaken prior to each annual benchmark survey.

Other factors that influence accuracy of measurement are vertical ‘plumbing’ differences at the control and monitoring marks, and atmospherics at the time of each measurement event. These differences were allowed for when setting the benchmark triggers set out in Tables 4 and 5.

Piezometer

The Geokon (Model GK403) instrument used to measure vibrating wire piezometers does not require calibration.

The pneumatic piezometer readout instrument is calibrated annually.

6.3.11 Visual Inspections

Many parts of the construction and operation of the TSF’s are observed daily on an informal basis by staff involved in ongoing construction and operation. Inspections identify issues like erosion, seepages, cracking, debris or infrastructure repair that may require remediation.

Detailed formal inspections are carried out every six months by the Site Services Department. A visual inspection is also carried out following an unusual event. An unusual event is defined as:

- Large rainfall (greater than 100mm in 24 hrs)
- Landslide in ground above impoundments or on shoulders of embankment
- Earthquake shaking felt at the site
- Power supply interruption
- Break in tailings delivery or return water pipelines

Records of six monthly inspections are based on a template (G:\Environmental\Monitoring Data\Development Site\Other\Visual Inspection Template 100316.xls) and archived in G:\Development\Ops Monitoring & Surveillance\6 Monthly Visual Inpections.

6.3.12 Contingency Plan

If piezometer or benchmark trigger levels are exceeded the following steps must be undertaken:

1. Confirm readings are accurate.
2. Alarm Level Exceeded
   i) Refer immediately to the Principal Control Plan (PCP) Waihi Emergency Management for response.
   ii) The severity of the alarm must be categorized to Level 1, Level 2 or Level 3, as given in the Emergency Action Plan, then follow the corresponding notification and action procedures in the Emergency Action Plan.
   iii) Notify the Project Engineer immediately.
3. Alert Level Exceeded.
   i) Notify the Project Engineer within 24 hours.
   ii) Investigate the possible cause for exceeding the alert level and whether it has occurred previously, and how frequent the exceedence.
   iii) Undertake further investigations, if necessary, to determine whether mitigation measures are required, or the alert trigger level needs to be reviewed and possibly revised by the Project Engineer.
   iv) If mitigation measures are required then notify PRP and WRC Resource Use Directorate.
   v) Design mitigation measures.
   vi) Implement mitigation measures.
   vii) Prepare Mitigation/Investigation Report and forward to PRP and WRC Resource Use Directorate.

7. PART B – Geochemistry

7.1 Introduction

The geochemical related risk events (refer to Section 5 for risk details) pertain primarily to tailings and waste rock seepage bypassing the underdrainage system or perimeter bund, inability to meet liner permeability specifications, and insufficient NAF material for rehabilitation. The management of these risks have been through application of earth-dam engineering design standards for the embankment, construction supervision (ensuring underdrainage and liner specifications are met), and annual review of material in stockpiles.

The geochemistry of surface materials and water contained in tailings, waste rock and collection ponds can influence the geochemistry and performance of the underdrainage system and potentially the groundwater system.

Reducing the potential for acid rock drainage during the construction phases of the TSF embankment is important for control of water quality in the underdrainage system in the medium to long term and of surface runoff to collection ponds in the short term. Currently, underdrainage and some collection pond water is pumped and treated before discharge. Additional geochemical stability can be provided through the addition of limestone to the waste rock materials. Limestone application is undertaken via a hopper over the conveyor belt near the mill and by surface application. Consent condition 7 requires that the pH of the waste rock is controlled until capping is complete. The quality of collection pond water is an indicator of the performance of the surface limestone application.

The geochemical stability of tailings is an important aspect for closure with respect to the design of the capping layers. Tailings exposed for any length of time will oxidise and become acidic. Knowledge of the acid generation and neutralising capacity of the tailings will enable the design of a suitable rehabilitation cover. Both solid and water covers are suitable to control oxidation.

The ‘geochemical stability’ of tailings pond water has not been addressed in previous Monitoring Plans. Discharge of Storage 2 water commenced in late 2007 after the water quality was demonstrated to meet receiving water quality criteria. The discharge was approved by WRC under resource consent 971223. Condition 2 (d) of the consent stipulates to ‘fix the tailings pond outlet such that during the post-closure period the tailings pond water level will be maintained so that the downstream toe of the tailings cap is submerged during a year of average rainfall’; mainly to prevent oxidation of the tailings surface. Currently water is discharged by pumping and results in periodic exposure of the tailings surface. The exposed tailing surface on the north side of the pond was treated with limestone in 2015. A rehabilitation cover trial was developed in 2011 and the tailings have subsequently been partially capped around the northern and western perimeter of the TSF. The final capping details for Storage 2 have not yet been finalized.

7.2 Geochemical Monitoring Objectives

Monitoring of the geochemistry of tailings, waste rock and associated runoff is a requirement of Resource Consents 971303, 971304, 971305 and 971306 for the Storage 1A and Water Permit

W1761 for Storage 2. Collection ponds associated with Storage 1A are covered by consent 971312 (Appendix A). The scope of activities for geochemical monitoring includes:

1. Testing tailings solids for potential acid rock drainage (Condition 20)
2. Testing PAF waste rock materials for potential acid rock drainage (Condition 7)
3. Monitoring surface water quality in collection ponds around Storage 1A (Condition 16(e) and 12 (971312))
4. Provision of information on the monitoring methods, the monitoring locations, parameters to be monitored, and the calibration and maintenance of monitoring equipment (Condition 16(f))
5. Mitigation of any trends or processes that could adversely affect geochemistry stability
6. Rehabilitation cover failure – monitor tailings, and quality and quantity of waste rock materials (new)
7. Monitoring of Storage 2 pond water and tailings surface

7.3 Geochemical Monitoring

7.3.1 Tailings

Tailings deposition into Storage 1A commenced on the 12th May 2001. Tailings are delivered to the tailings pond using two dedicated pipelines and discharge spigots are set at between 25m to 50m intervals around the pond perimeter. Approximately five spigots are open at a time and open spigots are periodically relocated to ensure a constant deposition of tailings along the pond edge. Tailings are sampled monthly using procedure WAI-200-PRO-029 Discharging Tailings and Supernatant Sampling. Tailings samples are submitted to SGS laboratories in Waihi whereas supernatant samples are sent to RJ Hill. Analyses determine the tailings acid neutralising capacity (ANC), maximum potential acidity (MPA), and net acid generation (NAG) capacity, and sulphate (Table 7) and these procedures are detailed in Appendix E). Results of this testing are forwarded to EGi for analysis and reporting (Appendix C).

Table 7 Parameters Monitored in the Tailings Discharge

Parameter
Sulphur (%)
Acid Neutralising Capacity (ANC)
ANC (Fizz Rating)
ANC (kgH_2SO_4)
ANC ($\%CaCO_3$)
Reaction kinetics between time ranges (Slow/Fast)
Net Acid Generation (NAG)
NAG pH
NAG at pH 4.5 (kgH_2SO_4/tonne)
NAG at pH 7 (kgH_2SO_4/tonne)

The tailings NAG analysis is conducted monthly as per the consent requirement. A discretionary sample, CN_{WAD}, is also sampled monthly.

7.3.2 Tailings Supernatant Water

Monitoring of tailings pond water quality has been conducted monthly for many years. For Storage 2 the regime reverted to monthly in November 2008 following a review of the (now stable) water chemistry trends. The objective of the monitoring programme is to:

1. Assess water quality in Storage 2 against the receiving water quality criteria in order to be able to commence direct discharge (Condition 4; Consent 971223)
2. Assess the changes in chemistry in Storage 1A tailings water associated with processing of different ore types (e.g Favona antimony, Martha selenium).

At the time of writing, TSF1A supernatant is sampled fortnightly with a comprehensive sampling suite taken monthly. TSF2 is also sampled monthly.

TSF2 Discharge Management

All discharges from TSF2 are pumped and managed by the Water Treatment Plant operators. The discharge pump is located on a raft which floats on the decant pond. The pump intake is approximately 500mm below the surface of the water. The rafts are designed so that the pontoon will rest on the bottom of the pond before the suction hose. This system keeps the pump out of the main impoundment where tailings have settled and above silt within the pond itself.

The objective of the management regime is to maintain the water level of the tailings pond within a relatively small range defined by a lower level sufficient to ensure that the tailings beach remains largely covered and an upper level being the minimum freeboard requirement set in consent conditions (see section 6.3.5).

Continuous metering was installed at the end of 2007, with an automatic override that shuts the pumps off in the event of trigger values for pH, conductivity or turbidity being reached. Self-imposed trigger values are:

- $6.5 \leq pH \leq 9$
- Turbidity ≤ 30 NTU
- EC ≤ 80 mS/m

In addition to these parameters, temperature and flow are also continuously metered. The probes are currently cleaned weekly and calibrated monthly by mill operators. A comprehensive suite of analytes is tested monthly by the Environmental Department as recommended by URS (2007) and EGi (2010).

Trigger Levels

For pH the receiving water quality criteria is used for trigger levels.

The trigger values for turbidity and electrical conductivity are based on the relationship with three key metals - Mn, Cu and Se monitored from November 2007 to July 2008 (NWG-WAT-TSF2 Discharge Review-L080905).

The highest copper and manganese concentrations corresponded with elevated turbidity and retention of this measure was adopted with the level defined at 30 NTU.

The highest conductivity readings corresponded with the highest copper and manganese concentrations and the trigger value of 80 mS/m was reached once, and a series of high conductivities (50-80 mS/m) corresponded to maximum concentrations for copper and manganese of between 80% and 90% of compliance.

Correlation of turbidity with suspended solids indicated that turbidity provided a more conservative measure as suspended solids concentrations increase. The receiving water criterion for silt pond discharge is 100 g/m^3. The adoption of the turbidity trigger levels avoids missing opportunities to discharge from TSF2. This trigger value will be reviewed again when sufficient additional data is available.

Frequency of Analysis

The frequency of sampling and analysis of TSF2 water is based on:

1. Results demonstrating that the water quality has remained within receiving water quality standards since early 2007, and for the most part concentrations have been substantially less than those standards.
2. The monitoring period has included several high rainfall and high wind events, events that could potentially lead to increased turbidity with resulting decrease in water quality, without resulting in an exceedance of any of the receiving water quality standards.
3. The results of the continuous monitoring of the discharge quality indicate that the management process is appropriate.

In addition, when TSF2 begins discharging, reassurance sampling is taken of the discharge.

7.3.3 Waste Rock

To determine the potential for acid generation and sulphate release from waste rock, Condition 7 of the Discharge to Land - Waste Rock consent (971303) states:

"Until final capping is complete, the consent holder shall ensure that the pH of a slurry of one part solid (less than 4mm size fraction) to two parts deionised water, of the surface of exposed PAF rock (after liming) remains greater than or equal to pH 5.5. Unless Waikato Regional Council agrees to an alternative sampling programme in writing, samples shall be collected on a grid pattern of not more than 50m and within 1 week of placement of the PAF rock and then at intervals not exceeding 4 weeks."

OGNZL find it difficult to sample within a week of placement due to operational and/or weather restrictions, however sampling is conducted monthly. In general sampling is conducted on berms and haul roads in a single line at 50m intervals with scattered sampling from stockpile areas, not in a grid as detailed in Condition 7. The procedure has been approved by WRC (Appendix D).

When slurry results report less than pH 5.5 lime is spread over the affected waste rock area to bring the pH over 5.5. This contingency measure ensures that acid rock drainage is mitigated until final encapsulation. The PAF pH slurry testing Standard Operating Procedure (WAI-200-PRO-031) was last reviewed in June 2017 (Appendix E).

The location of waste rock placement and pH slurry results are plotted on aerial photos for reporting.

7.3.4 Rehabilitation Cover

The water quality of silt ponds was compromised in 2008 as a result of runoff from NAF stockpiles (North and Surplus Soil). Investigations found PAF material had been inadvertently placed on the stockpiles. While the runoff and acid generating potential of these stockpiles have been mitigated (by diversion drains and limestone application) there was a potential shortfall of these materials for future use in the rehabilitation covers (Zones G and H). As a result of this issue a methodology, rational and recommendations were outlined by EGi (2008): Geochemistry Review – Site Visit Report Contamination of NAF Stockpiles.

The concept of lime addition to increase acid neutralising capacity has been previously used at Waihi and other operations. The basis of success at Waihi is that the Potentially Acid Forming (PAF) material in the Non Acid Forming (NAF) stockpiles has a low capacity to produce acid. This PAF material could effectively be rendered NAF following the addition and mixing of limestone.

The success of the strategy is dependent on:

1. Understanding the PAF capacity to determine the amount of limestone addition (limestone is only added to PAF Low Capacity material and any other PAF material is to be removed) and

2. Determining the waste rock pH after lime addition to ensure adequate addition and mixing.

The following procedures were established to manage this aspect (Appendix E): WAI-350-PRO-017 Waihi Lime Addition Facility and associated Control of Acid Rock Drainage and WAI-200-PRO-031 PAF pH Slurry Testing.

The later procedure is conducted for both Zone G and H and requires sampling of the placed stockpile material on the embankment.

7.3.5 Collection and Silt Ponds

Monitoring of collection and silt pond water quality provides a measure of the performance of the cover system integrity (Condition 16e). Water quality will indicate the effectiveness of either limestone application to areas of exposed waste rock or the effectiveness of established rehabilitation covers.

Surface runoff from the Storage 1A embankment is diverted to Collection Ponds at South 3 (S3), South 4 (S4) and South 5 (S5) from where it is either discharged directly or pumped to the WTP if the water quality is not suitable.

On Storage 2 the North Collection Pond (NCP - western side of Northern Stockpile) collects runoff from the north tip of Storage 2, the haul roads, and the Waste Load-out area. The NCP periodically overflows during storm events into the perimeter drain which reports to West Silt Pond (WSP). South 1 (S1) silt pond (next to S3 collection pond) captures runoff from the rehabilitated area behind it. Runoff from the central stockpile waste rock area on Storage 1A is prevented from entering S1 by a rock spine drain (which directs runoff to S3).

A silt pond (NSPSP) at the northern end captures runoff from the Northern Stockpile. This water is directy discharged to a tributary of the Ohinemuri if the water quality is suitable.

Collection ponds are managed under resource consent 971312. Condition 12 of the resource consent requires monitoring of the discharge from each collection pond overflow event. Management of ponds and pond overflows is detailed in the Water Management Plan.

Typically ponds are continually kept low to maintain capacity and only sampled if there is an overflow event. Overflow event sampling uses procedure WAI-200-PRO-018 Collection & Silt Pond Management (Appendix E). The parameters are listed in Table 8.

Table 8 Collection Pond Sample Monitoring Parameters

Overflow Monitoring Parameters
pH
Conductivity
Suspended solids
Cyanide (WAD)
Total ammonia
Iron, manganese, copper, nickel, zinc, silver, antimony, arsenic, selenium, cadmium, chromium (VI), lead, mercury.
Other - discretionary
Hardness - Calcium, Magnesium
Sulphate

The consented collection pond monitoring programme for metals is for ‘acid-soluble’ concentrations determined on unfiltered samples. At the time of writing a Code 65, which analyzes the required parameters in Table 8, is requested from RJ Hill.

Continuous monitoring equipment has been installed at the following collection & silt ponds: NSPSP, WSP, S1, S3, S4 and S5 (and Storage 2 decant pond). If the ponds are within set parameter limits they are allowed to be direct discharged. Discharge parameters are pH 6.5 – 9.0 and NTU <110.

Performance indicators

For silt ponds the compliance limits or pH (6.0-9.0 units) and total suspended solids (100 g/m^3) must be met (Condition 7; 971311).

Key water quality targets for geochemical control were identified by Dr S Miller in evidence submitted to the Environment Court hearing for the Extended Martha project 1999. These were:

1. To meet the NZ drinking water standard for SO_4 = 250 g/m^3. This was calculated to be double the worst case estimate for the release of the acid rock drainage measure of 10kg SO_4 /ha/d.
2. Achieve the receiving water quality standard in consents for Mn = 2 g/m^3
3. Achieve a pH of 6 units for minimising Mn release and control of Al and Cu

Ultimately, before collection pond water can be directly discharged they must be able to meet or exceed the receiving water quality criteria on a sustainable and continuous basis, and not adversely affect downstream users of ground or surface water, or aquatic biota (Condition 13; 971312).

7.3.6 Laboratory Analysis

Water samples are sent to either RJ Hill Laboratories in Hamilton or SGS laboratory in Waihi. IANZ accreditation (International Accreditation New Zealand) is held by both companies. QA/QC is conducted on every batch of samples; this includes the use of certified control standards, duplicates, spike recoveries, reagent blanks and calibration of instrumentation in accordance with manufacturer's specification. If any out of spec results are received re-tests are requested and an investigation instigated.

All water quality analysis is performed using the procedures described in APHA "Standard Method for the Examination of Water and Wastewater, 20th edition (1998).

7.3.7 Calibration of Equipment

Field meters, either handheld Eutech PC300 units or a Micro Purge MP20 flow cell unit are calibrated for pH and electrical conductivity prior to commencing field sampling. In addition the instruments are serviced and calibrated once a year by a manufacturer approved service provider.

Endress and Hauser continuous monitoring instrumentation for pH, NTU, EC and Temperature (where applicable) are maintained weekly and calibrated every month by Mill staff.

8. PART C – Underdrains

8.1 Introduction

The underdrainage monitoring programmes for Storage 1A and 2 were integrated in 2004 under a revised Tailings Facility Monitoring Plan. At that time Storage 2 and Storage 1A were monitored under separate plans. Storage 2 had been operating for some 17 years prior and a comprehensive monitoring database existed for the drainage and groundwater chemistry of that structure. Storage 1A has been designed in a similar manner to Storage 2 but has additional features to further protect groundwater and surface water quality. Consents for both Storage 1A (971303, 971304, 971305, 971306) and 2 (W1761) were integrated after the granting of consents for the extended project, to reflect the same conditions in relation to both annual monitoring reports and monitoring plans for the tailings storage facilities. Integration of the two monitoring programmes has simplified management and reporting of these programmes.

8.2 Underdrain Monitoring Objectives

Monitoring of the underdrains aim to address primarily the conditions of the resource consent that relate to tailings and waste rock seepage processes. The objective of the underdrainage monitoring programme is primarily to meet Condition 16(e) and (f) of the Storage 1A consents and Water Permit W1761 for Storage 2 viz:

1. Seepage release – monitor tailings and waste rock seepage flows and water quality
2. Verify that the "as built" structure is achieving predicted design performance
3. Provide information on monitoring methods, monitoring locations, parameters to be monitored, and the calibration and maintenance of monitoring equipment
4. Develop a comprehensive database for use in geochemical modelling and to assist in defining closure criteria
5. Determine trends in flows and chemistry
6. Define trigger limits for unexpected or unacceptable monitoring results
7. Detail contingency measures to mitigate unacceptable drainage conditions
8. Detail methods to evaluate effects on groundwater

8.3 Overview of Underdrainage System

The underdrainage system comprises a network of subsurface drains that collect migrating water from tailings, the waste rock embankment and natural groundwater (Figures 5 and 6). The principal features of the underdrainage system are as follows.

Tailings Underdrains

Tailings Underdrains are laid along natural drainage features at the base of the ash materials beneath the TSFs. The ash materials serve as a blanket drain to the tailings and collect tailings seepage. As the tailings consolidate over time it is expected that the seepage of tailings pore water will slow considerably and this has proven to be the case.

Upstream Cut-Off Drains

These drains collect tailings water along the upstream toe of the embankment and assist consolidation of tailings.

Initial Toe Drains

The Initial Toe Drains collect waters moving through the initial embankment to capture any potential seepage which bypasses the upstream cut-off drains.

Leachate Drains

Leachate drains collect waters migrating from the encapsulated un-oxidised, potentially acid forming (PAF) waste rock within the embankment.

Sub-Soil Drains

The sub-soil drains underlie the Zone A clay liner in TSF1A and drain un-impacted groundwater in the natural paleo-gullies beneath the structure. Sub-soil drain waters are directed to the toe drains.

Toe Drains

Toe drains are located along the downstream toe of the waste rock embankment. Toe drains are located around the toe of the current embankment to collect upwards moving groundwater and groundwater moving down-gradient through the shallow soils beneath the waste site. The drains may potentially intercept tailings water mixed with groundwater.

Collector Sumps

Collector sumps are located at low points around the perimeter of the TSFs to collect underdrain flows. At TSF2, toe drains, leachate drains, sub-soil drains and underdrains reported to the 'T' series collector sumps prior to 1994. These were then disconnected and/or re-routed to either manholes or the perimeter drain depending on water quality. TSF1A collector sumps receive leachate drain discharges from leachate sumps.

The 'K' series of collector sumps run along the perimeter of the TSF2 embankment and receive waters from to drains. Drains K5 and K6 were installed in 2007 as a contingency action in response to changes in proximal groundwater chemistry.

Manholes

Manholes collect drain flows including discharges pumped from the 'T' series collector sumps and/or leachate drains. The Manholes are connected in a series via gravity-fed pipework. All underdrain flows are pumped from the manholes to a central manhole or sump (MH17 and SPS at TSF2; MH11 at TSF1A) from where the water is directed to the Water Treatment Plant (WTP) for treatment prior to discharge or to the Processing Plant for reuse.

Manholes are constructed so as to serve as sampling portals for the various drains, as required. Underdrain inputs to the individual manholes are presented for TSF2 in Table 9 and in Table 10 for TSF1A.

Gravity Outlets

Gravity outlets were installed in preparation to allow water from the TSF1A toe drain sumps to discharge clean groundwater and drainage water directly to surface water in the future. These outlets are permanently closed until underdrainage waters are of suitable quality to allow direct discharge.

Table 9 TSF2 Underdrain Nomenclature

Manhole Riser	Site Name	Type of Drain
MH1	IT1 U1 & U2	Initial toe drain Underdrains
MH2	T4	Toe drain
MH3	IT2 U3 T5	Initial toe drain Underdrain Toe drain
MH4	L8 SS T6	Leachate drain Subsoil drain Toe drain
MH5	L5 & L6, L15 U4 T7	Leachate drain Underdrain Toe drain
MH6	L4, L14 T8	Leachate drains Toe drain
MH7	L3 T9	Leachate drain Toe drain
MH8	L1, L2, L11, L12, L13, L16 K2 & K3 T10	Leachate drains Cutoff drains Toe drain
MH9[1]	K3 & K4 T11B	Cutoff drains Toe drain
MH10[2]	T11 & T11A	Toe drains
MH16	T12 & T13 (combined)	Toe drains
MH17	T12 & T13 (combined), T14	Toe drains
SPS	L9, L10, L16 K1, K5 & K6 (combined) T1, T2 & T 3	Leachate drains Cutoff drains Toe drains

Schematics drawings of individual manholes and collector sumps are provided in Appendix B.

[1] MH9 was capped and covered in 2004 as part of the TSF embankment development. Infrastructure is still in place and operates passively, with outflows reporting to the Seepage Pump Sump via MH10.

[2] MH10 was capped and covered in 2004 as part of the TSF embankment development. Infrastructure is still in place and operates passively, with outflows reporting to the Seepage Pump Sump via T13 & T14.

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Table 10 TSF1A Underdrain Nomenclature

Manhole Riser	Collector Sump	Site name	Individual drains
MH11	MH11	MH11-I	Subsoil drain
	TU	TU	Tailings Underdrain
	UCD	UCD	Upstream Cutoff Drain
	LD6	LD6	Leachate Drain
	T15		Combined discharge
		T15-C	Initial Toe drain west (ITD)
		T15-D	Gully subsoil drain (SSG)
		T15-E	S2 subsoil drain (SSS2)
		T15-F	Toe drain north (TDN)
		T15-G	Subsoil drain (SS1)
		T15-H	Toe drain south (TDS)
	LM1	LM1a	Leachate Drain
		LM1b	Subsoil drain
		LM1c	Subsoil drain
MH12	LD7	LD7	Leachate Drain
	T16	T16-A	Toe drain
	LM2	LM2	Leachate Drain
MH13A	LD8	LD8	Leachate Drain
	T17		Combined discharge
		T17-B	Subsoil drain
		T17-D	Toe drain
	LM3	LD13	Leachate Drain
		LM3A	Leachate Drain
MH14	LD9	LD9	Leachate Drain
	T18		Combined discharge
		T18-A	Toe drain
		LD11	Leachate Drain
		LD12	Leachate Drain
	LM4	LM4	Leachate Drain
	T21 & stock tank overflow	S5 SUB	Subsoil drain
		WG1	Spring
MH15	T19		Combined discharge
		T19-C	Toe drain
		T19-D	Subsoil drain
		T19-E	Initial toe drain
	LM5	LM5	Leachate drain
		S3 SUB	Subsoil drain
		S4 SUB	Subsoil drain
	T22	T22	Subsoil drain

LM1, LM2, LM3, LM4, have separate pumps installed and pump directly to MH11, MH12, MH13A and MH14 respectively. LM5 is pumped directly to MH15. This allows the water from the leachate drains to be separated from the downstream toe drain system.

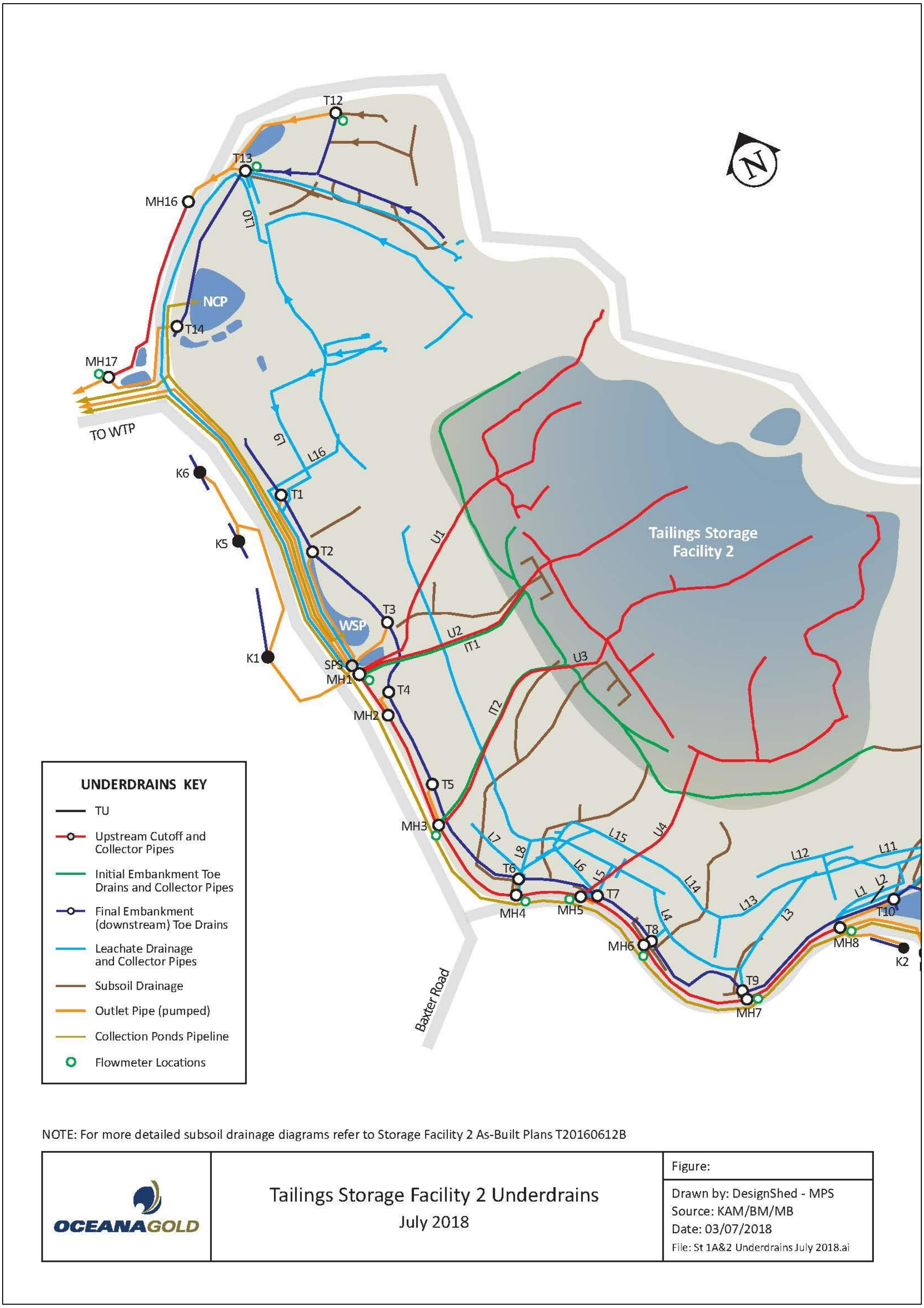

Figure 5 Schematic of Underdrainage Network for TSF2

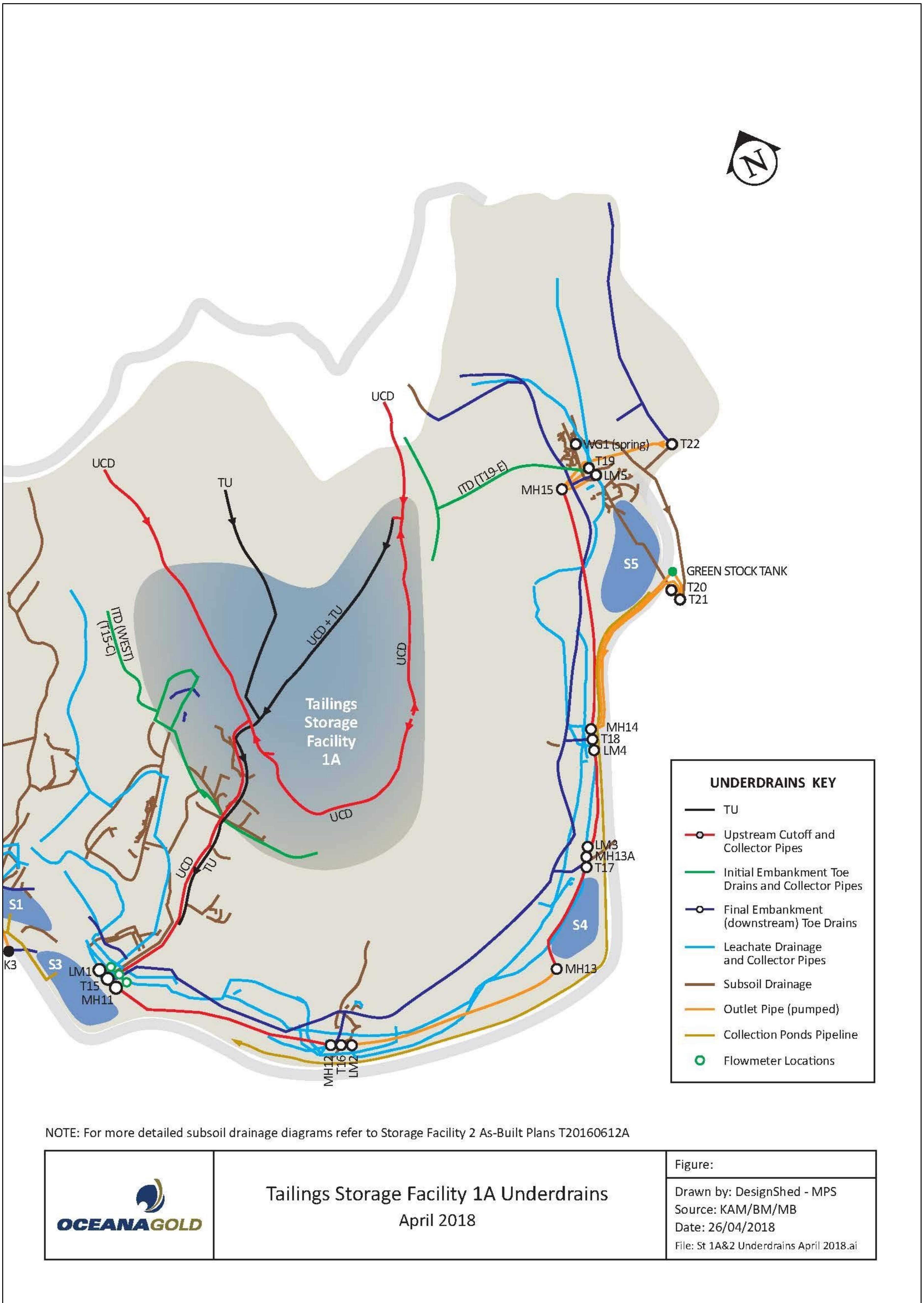

Figure 6 Schematic of Underdrainage Network for TSF1A

8.4 Underdrainage System Monitoring

The scope of the underdrainage monitoring programme is to:

- Sample the underdrains beneath the TSF to determine chemical composition;
- Define and assess compliance of samples with trigger limits;
- Undertake contingency monitoring and/or mitigation measures in the event of unexpected or unacceptable responses; and,
- Report annually on underdrainage monitoring results and system performance.

8.4.1 Underdrain Flows

TSF2 underdrain flows are metered and are read approximately every second week. Flow meters are located at IT1, IT2, U1, U2, U3, and U4. Most toe drains, leachate drains and cut-off drains are metered and read weekly.

Most TSF1A underdrains do not have flow meters and flow is measured if flowing at the time of sampling using a bucket and stopwatch.

The tailings underdrain (TU) and upstream cut-off drain (UCD) are read manually with bucket and stopwatch. Leachate drain LM1 has a flow meter that is read every second week. For TSF1A, total underdrainage flow is recorded weekly via a meter installed on the MH11 outlet pump line. TSF2 has two total flows; the MH17 outlet pump (North TSF2 drain network) and SPS (South TSF2 drain network flow). SPS data is available via the SCADA system.

Flow trigger levels have been developed for underdrains in Storage 2 and Storage 1A (Table 12 and Table 13). The monitoring data are checked against the specified trigger levels for the respective drain flow. A contingency plan is activated when a flow trigger level is exceeded or a flow changes abruptly.

8.4.2 Water Quality Sampling

TSF2 drains can be sampled with relative ease, as sampling spigots are located on each drain. However, TSF1A drains are located at the bottom of the toe drain sumps. To sample these individually the sampler must enter the manhole with a harness using confined space entry procedures. Sampling of individual drains was discontinued in recent years as part of risk-reduction initiatives. Such detailed monitoring was not considered necessary in light of all underdrainage water being collected and sent to the WTP for treatment regardless of quality. Combined (sump) discharges are sampled and flow measured when safe to do so (during low drain flows). During high flows, which submerge the individual drains, a combined sample is taken.

To measure the drainage quality (as required by Condition 16(e)), the parameters listed in Table 1 of Consent Condition 25 have been used as a minimum (see Table 11).

The underdrains are sampled quarterly for key parameters of pH and EC. Trigger levels are developed for pH (acid conditions) and electrical conductivity (dissolved metals and sulphates). The data reveal a strong correlation between electrical conductivity and sulphate, manganese, iron, and a weak correlation with copper. For other metals there is an indication that metals tend to increase as conductivity increases though correlations vary for different metals.

A review of the trigger limits was conducted by GWS Ltd in 2016. Universal trigger limits have been proposed at 4.5 pH lower limit and EC 450 mS/m upper limit. These trigger levels would indicate an incidence of AMD may be developing. If one of these parameters is triggered the procedure is to resample to confirm the result. If the trigger is still breached, a full analysis will be taken. Contingency measures are outlined in Section 8.5.5.

Field parameters (Table 11) are taken each quarter and full analysis sampling undertaken annually, except at the TSF composite sampling sites TSF2 SPS and TSF1A MH11. These are sampled quarterly.

In addition to the Underdrain sampling, “Shed Spring” is currently sampled. Located south of TSF1A, the spring is believed to discharge water from the deeper structures under and around the TSF. The spring is considered to provide sampling of a large area beneath TSF1A (see Section 9.3).

Parameters used in the full analysis monitoring have been selected to ‘categorise’ the drainage water. Included in this list are parameters identified by EGi (in a review of the monitoring in 2010). The inclusion of alkalinity and acidity provide a better indication of the strength of a trend in the pH of the drainage waters. From a geochemical perspective only dissolved parameters are necessary, however for closure related purposes acid soluble analysis is added to the full annual analytical suite.

Table 11 Drain Sampling Parameters

Annual Full Analysis Parameters (dissolved and acid soluble)		Quarterly Categorising Parameters
pH (field and lab)		pH (field, lab)
Conductivity (field and lab)		Conductivity (field, lab)
Ca, K, Mg, Na	Sum of cations	
Cl, HCO_3, SO_4	Sum of antions	
Acidity/ Total Alkalinity	Pb	
Ag	Sb	
Al	Se	
As	Si	
Cd	Tl	
CN_{WAD}	TSS	
Co	U	
Cr	Zn	
Cr (VI)	Free ammonia (NH3)	
Cu	Total ammoniacal (NH_4-N)	
F	Nitrate-N (NO3N)	
Fe	Nitrate-N + Nitrite-N (NOxN)	
Hardness	P - Total	
Hg + Hg Total		
Mn		
Ni		

Sampling is in accordance with the standard operating procedures WAI-200-PRO-034 Underdrain Sampling & Flow Measurement.

Discretionary sampling is undertaken of other parameters and includes dissolved and acid soluble concentrations. The annual monitoring suite also includes other elements identified in the tailings column leachate trials by Dr Stuart Miller (EGi) where the Global Abundance Index or GAI is greater than 3. In 2015 some analytes were removed after a long period of little to no detection. B, Ba, Mo, Sn, Sr and Th were excluded (Appendix D).

8.4.3 Laboratory Analysis

Water samples are sent to RJ Hill Laboratories (RJH) in Hamilton. International Accreditation New Zealand (IANZ) accreditation is held by both companies. Quality Assurance and Quality Control (QA/QC) procedures are applied to all samples; this includes the use of certified control standards, duplicates, reagent blanks and calibration of instrumentation in accordance with manufacturer's specification. If any out of specification results are received re-tests are requested and an investigated instigated.

All water quality analysis is performed using the procedures described in APHA “Standard Methods for the Examination of Water and Wastewater, 20th edition (1998). Acid soluble analyses include a particulate matter component and can have adsorbed dissolved metals.

8.4.4 Data Management

All water quality results are automatically imported from the relevant laboratory into the Water Quality Database (InViron). Trigger levels are included in the database which is linked to an automatic email notification system to alert relevant site personnel to any non-conformances recorded.

InViron is able to:

- Store large amounts of data
- Generate sample numbers and CoC sheets
- Notify by e-mail trigger level events
- Produce generic or site specific reports
- Export large amounts of sample data

8.5 Contingency Plan

The consents do not define water quality criteria for drains. However Condition 4 in W1749 requires details of contingency plans to describe methods to be used to minimise the generation of leachate to protect downstream users and uses during construction-operation, and post-operational phases.

One of the objectives of monitoring for Storage 1A and 2 is to verify that the "as built" structure is achieving predicted design performance objectives. As detailed in Section 8.3 the key functions of the tailing storage facility in terms of underdrainage are to:

1. Intercept tailings seepage.
2. Ensure safe long-term stability under both static loads; by reducing seepage forces acting on the embankment. This is provided by various drains.
3. Intercept acid drainage generated by PAF waste rock in the short and long-term.
4. Collect tailings seepage and waste rock leachate for treatment.

At present chemically significant underdrainage flows are pumped to the water treatment plant before discharge to the river.

When underdrain flows are of a quality to be directly discharged to receiving waters, consent condition 26 requires that seepage waters will not cause an adverse environmental effect on adjacent surface waters, as indicated by the receiving water criteria in Table 2 of the conditions (Appendix A); on groundwater; on users of the resource; or on aquatic biota. At this time no discharge to receiving water occurs from sumps or manholes.

To warn of adverse trends that may indicate failure of the liner, structural zones and/or underdrainage system, monitoring results are checked against trigger levels developed for flow, pH and electrical conductivity.

8.5.1 Flow Trigger Limits

Flow alert trigger levels were revised and updated by T. Matuschka in 2018 (Table 12 & Table 13). Some trigger levels are lower than in the previous Plan reflecting the generally lower flows emanating from the drains at this time. Additionally new triggers have been created where previously there were none. Alert trigger levels are set at levels to draw attention to a changing trend in the flow being monitored, and are below which would be a safety concern.

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Table 12 Storage 2 Underdrainage

Manhole Riser	Site Name	Gravity, Pumped or Metered	Type of Drain	Previous Flow Rate Trigger (l/S)	Flow Rate Alert Trigger Level (L/s)
MH1	IT1	Gravity	Initial toe drain	1.0	1.0
	U1	Gravity	Underdrain	2.0	2.0
	U2	Gravity	Underdrain	0.5	0.5
MH2	T4	Pumped & metered	Toe drain		0.5
MH3	IT2	Gravity	Initial toe drain	0.5	0.5
	U3	Gravity	Underdrain	0.5	0.5
	T5	Pumped & metered	Toe drain		1.5
MH4	L08	Gravity & metered	Leachate drain		0.5
	SS	Gravity	Subsoil drain		-
	T6	Pumped & metered	Toe drain		0.5
MH5	L05	Gravity & metered	Leachate drain		0.5
	L06	Gravity & metered	Leachate drain		0.5
	L15	Gravity	Leachate drain		0.5
	U4	Gravity	Underdrain	0.5	0.5
	T7	Pumped & metered	Toe drain		0.5
MH6	L04	Gravity & metered	Leachate drain		0.5
	L14	Gravity	Leachate drain		0.5
	T8	Pumped & metered	Toe drain		1.0
MH7	L03	Gravity & metered	Leachate drain		0.5
	T9	Pumped & metered	Toe drain		0.5
MH8	L01 & L02	Gravity & metered	Leachate drain		0.2
	L11, L12 & L13	Gravity & metered	Leachate drains		0.5
	K02	Pumped & metered	Cutoff drain		1.0
	K03	Pumped & metered	Cutoff drain		0.5
	T10	Pumped & metered	Toe drain		1.5
MH16	T12 & T13 (combined)	Pumped & metered	Toe drains		2.0
MH17	T12 & T13 (combined)	Gravity	Toe drains		2.0
	T14	Pumped & metered	Toe drain		0.5
SPS (Seepage Pump Sump)	L09 & L10	Gravity & metered	Leachate drains		1.0
	K01, K05 & K06 (combined)	Pumped & metered	Cutoff drains		2.0
	T1	Pumped & metered	Toe drain		1.0
	T2	Pumped & metered	Toe drain		0.5
	T3	Pumped & metered	Toe drain		0.5
T1	L16	Gravity	Leachate		-

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Table 13: Storage 1A Underdrainage

Manhole Riser	Collector Sump	Site name	Individual drains	Previous Flow Rate Trigger (l/S)	Flow Rate Alert Trigger Level (l/s)
MH11	TU	TU	Tailings Underdrain	1.0	1.0
	UCD	UCD	Upstream Cutoff Drain	0.5	0.5
	LD6	LD6	Leachate Drain		2.0
	T15		Combined discharge		
		T15-C	Initial Toe drain west (ITD)	0.5	0.5
		T15-D	Gully subsoil drain (SSG)		0.5
		T15-E	S2 subsoil drain (SSS2)		0.5
		T15-F	Toe drain north (TDN)	0.5	0.5
		T15-G	Subsoil drain (SS1)		0.5
		T15-H	Toe drain south (TDS)	0.5	0.5
	LM1	LM01a	Leachate Drain		-
		LM01b	Subsoil drain		-
		LM01c	Subsoil drain		-
MH12	LD7, LD10	LD7, LD10	Leachate Drain		0.2
	T16		Combined discharge		
		T16-A	Toe drain	0.5	0.5
		LD10	Leachate drain		0.3
	LM02	LM02	Leachate Drain		-
MH13A	LD8	LD8	Leachate Drain		0.2
	T17		Combined discharge		
		T17-B	Subsoil drain		-
		T17-D	Toe drain	0.5	0.2
	LM03	LM03A	Leachate Drain		-
		LD13	Leachate drain		0.3
MH14	LD9	LD9	Leachate Drain		0.3
	LD11	LD11	Leachate drain		0.3
	LD12	LD12	Leachate drain		0.3
	T18	T18-A	Combined discharge		
			Toe drain		0.2
	LM04	LM04	Leachate Drain		-
	T21	WG1	Spring		3.5
		S5 SUB	Subsoil drain		1.5
MH15	T19		Combined discharge		
		T19-C	Toe drain	0.5	0.5
		T19-D	Subsoil drain		0.3
		T19-E	Initial toe drain	0.5	0.2
	T22	T22	Toedrain		-
	LM05	LM05	Leachate drain		1.0
		S3 SUB	Subsoil drain		0.5
		S4 SUB	Subsoil drain		0.5
Springs		Shed	Spring to Ruahorehore		-
		Sth Gully	Green stock tank		-

8.5.2 Flow Contingency Procedures

When a flow alert trigger level is exceeded on two consecutive occasions or the flow changes abruptly, either increasing or decreasing, then the flow contingency procedures will be initiated to investigate the cause and if necessary implement mitigation actions. The procedures to be followed are:

1. Confirm readings are accurate
2. Check for reticulation faults (pipe connections, valves, and flow meters)
3. Review recent on-site activities
4. Correct any minor faults in reticulation system.
5. Complete incident report and identify preventive or corrective actions
6. Notify the Project Engineer and if necessary a Geotechnical Peer Reviewer(s)
7. If no plumbing faults, investigate other causes; consult Project Engineer and Peer Reviewer geochemist/hydrogeologist
8. If cause identified and significant mitigation likely notify PRP and WRC
9. Design mitigation measures
10. Notify PRP and WRC
11. Implement mitigation measures
12. Complete Investigation/Mitigation Report to PRP and WRC

If any visual observations give cause for concern regarding the safety of the tailings dams (e.g. increased surface seepage, slumping/movement of the embankment etc) then the Project Engineer must be notified immediately (see Section 8 OMSM).

Further investigations may involve but not necessarily include:

- Detailed analysis of the drain flow hydrographs and correlations with rainfall and site works.
- Review of local construction records.
- Review of the drain chemistry data.
- Review of the groundwater head and chemistry data.
- Installation of additional monitoring wells.

8.5.3 Chemical Trigger Limits

The trigger levels provide an early indicator of changes occurring in the drain chemistry that could be associated with increasing acid rock drainage from either waste rock or tailings. When consecutive monitoring results exceed trigger levels the contingency plan is activated.

8.5.4 Chemical Evaluation for Reporting

Drain water can be evaluated using other geochemical techniques, beyond that of trigger level assessment. This is useful to assist with interpretation of any groundwater chemistry trends. The drain waters can be evaluated using:

- Key chemistry indicators and their trends (pH, electrical conductivity (EC), sulphate, cyanide, iron, manganese.
- Piper Tri-linear Diagrams to characterise the chemical water type using major cations and anions
- Stiff diagrams – proportion of major cations and anions

- Hardness/EC ratio - where there have been insufficient parameters to construct Piper diagrams, (e.g. early collection pond data) to allow comparison with other types of water.
    - For natural groundwater, that is groundwater not affected by the TSF structure, the Hardness/EC ratio is typically <1 to approximately 2
    - Waters with a waste rock influence have Hardness/EC ratios of approximately 5-6 (for silt/collection ponds) and 6-9 (for leachate drains).

8.5.5 Drain Chemistry Contingency Procedures

The procedure for when the trigger level is breached on two consecutive occasions or chemistry trends indicating acid rock drainage is:

- Check for errors in database if results triggered
- Check analytical results are correct
- Check sampling procedures and laboratory procedures
- When confirmed pH or EC results have been triggered on two consecutive rounds:
- Check scan parameters on two consecutive days
- Initiate weekly scan monitoring if results confirmed
- Consult geochemist/hydrogeologist and the Project Engineer
- A persistent potentially adverse trend e.g. after one month of weekly monitoring , will initiate an investigation into the source of the trend
- Inform WRC and the Peer Reviewer(s); depending on rate and magnitude of chemical change observed
- A series of decisions are to be taken as to whether further investigations are warranted and whether mitigation is needed
- Sampling continues until a trend is reversed, stabilised and to an acceptable level (determined by geochemist)

Further investigations may involve but not necessarily include:

- Detailed analysis of drain chemistry data
- Establish whether correlation exists with rainfall and site works
- Review of drain flow data
- Review of groundwater levels in piezometers embankment and surrounds, and chemistry data
- Recalibration of geochemical models to check transient responses
- Use of geophysical and /or tracer test to further investigate changes in groundwater chemistry
- Installation of additional monitoring facilities, if required, to check water and air conditions within the deposits

A flow chart has been developed in Figure 7.

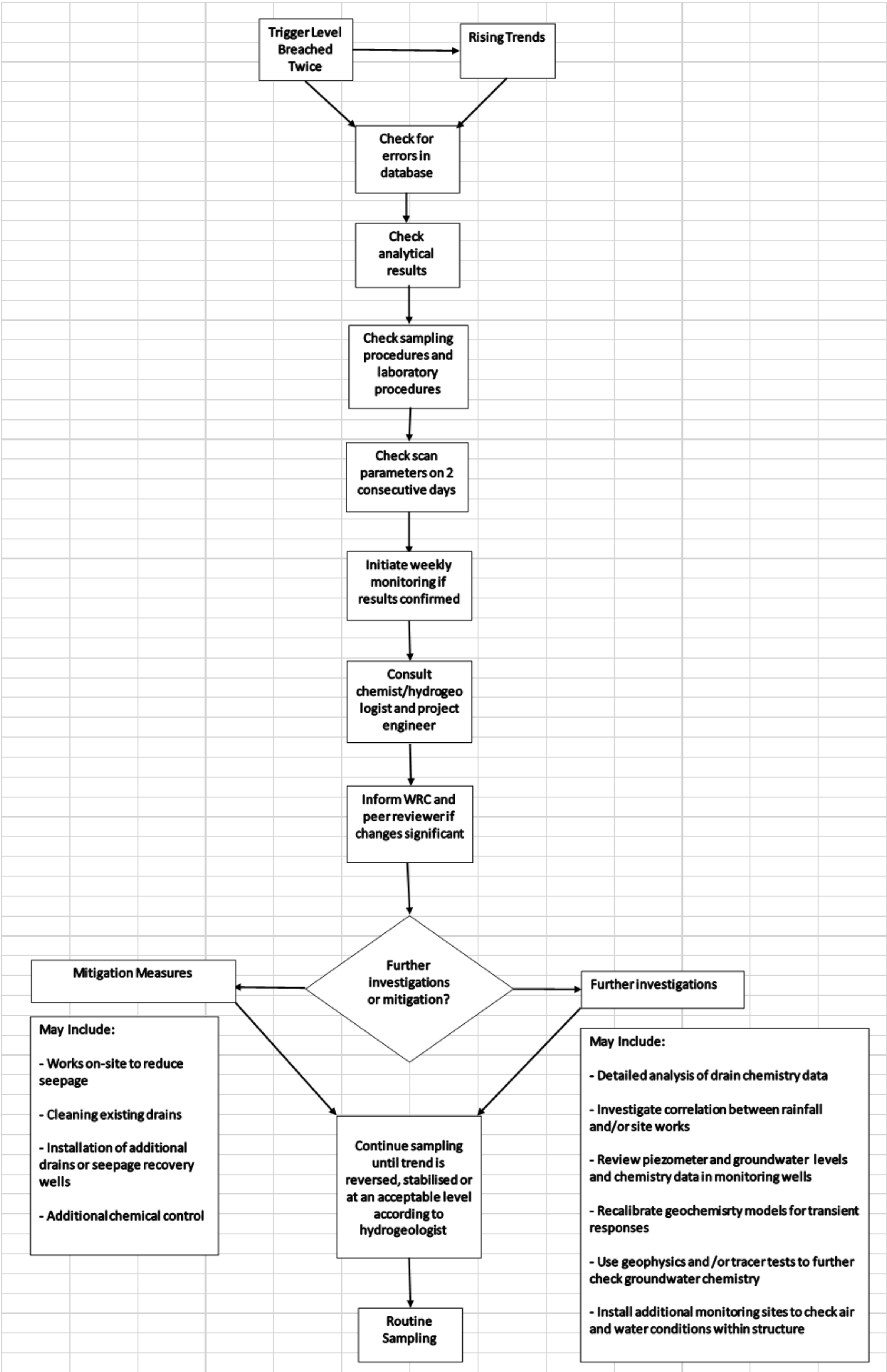

Figure 7 Underdrainage Contingency Measures

8.5.6 Contingency Measures

Breach of trigger levels could indicate a range of performance issues.

Mitigation measures, if considered necessary, would be designed on the basis of specific conditions at each location and may involve, but not necessarily include:

- Works on-site to reduce seepage
- Cleaning existing drains
- Installation of additional drains or seepage recovery wells
- Additional chemical control

Zone A

Although Zone A is a design measure it also serves as a contingency measure by restricting leachate from entering the groundwater. It's a low permeability fill and the structure allows any leachate to report to the leachate drain. In the event of any leachate filtering through Zone A of the embankment the natural groundwater system is expected to dilute and divert waters to the downstream toe drain.

9. PART D – Groundwater Monitoring

9.1 Introduction

The groundwater monitoring programmes for Storage 1A and 2 were revised in 2014. This section describes the hydrogeological system, the groundwater monitoring system, contingency plans and the measures to be adopted to meet the objectives for groundwater and surface water management.

9.2 Groundwater Monitoring Objectives

The groundwater monitoring plan has the following objectives:

1. To satisfy consent conditions;
2. To develop a monitoring programme to determine the effects of the Tailings Storage Facility on subsurface hydrogeology, specifically:
   a. Avoid any significant adverse environmental effect on groundwater or users of groundwater beyond the site;
   b. Protect the Ohinemuri River and Ruahorehore Stream from effects of seepage of waste rock or tailings components through the groundwater system;
   c. Detect early movement of seepage to allow mitigation measures to be implemented if required.
3. Monitoring methods, monitoring locations, parameters to be monitored, and the calibration and maintenance of monitoring equipment.

Monitoring of groundwater around the perimeter of Storage 1A and Storage 2 includes:

- Overview of hydrogeology.
- Groundwater monitoring network – well locations.
- Well construction details.
- Description of sampling methods and protocols.
- Records and data management.
- Sampling frequency and sampling parameters.
- Defined trigger limits and assessment of compliance of samples with trigger limits.
- Contingency measures if monitoring indicates unexpected or unacceptable responses.
- Reporting.

9.3 Overview of Hydrology

The footprint of TSF2 and TSF1A is located in an area of land between the Ohinemuri River and a tributary - the Ruahorehore Stream - and a block of unnamed hills on the eastern side (Figure 8). The hills comprise rhyolite forming part of the Ruahorehore Rhyolite dome complex. The 160 ha area beneath the tailings storage facility was once low-lying topography overlain by layers of volcanic ash, colluvium and alluvial filled palaeo-channels. These natural gullies and swamp filled depressions, reminiscent of the pre-mining topography, are still evident around the perimeter of the waste rock embankments.

The conceptual model of the site indicates that the greater part of the deeper groundwater flow in the rock mass is moving through fractured rhyolite underlying lower permeability weathered rhyolite.

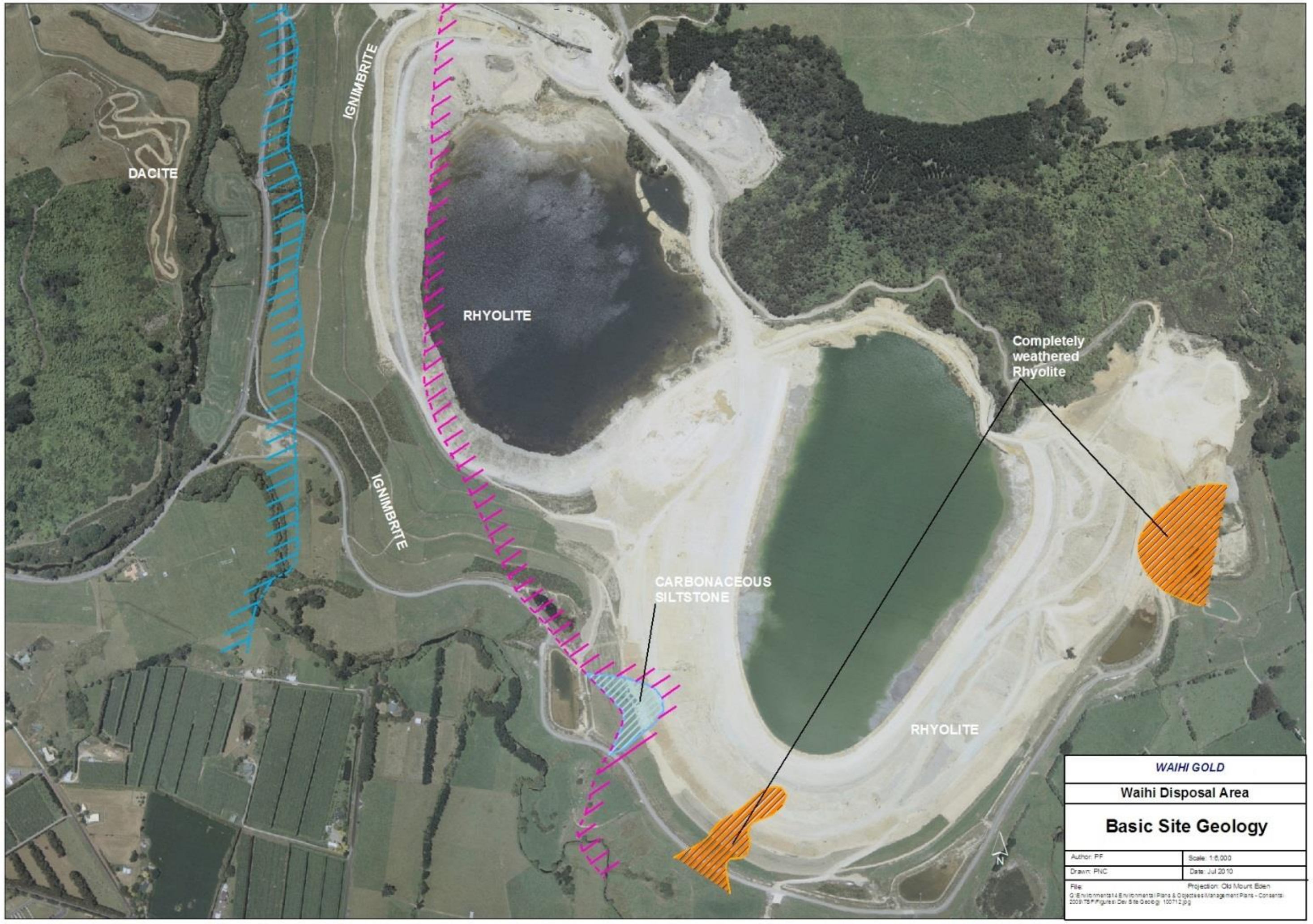

Figure 8 General geology underlying the Tailings Storage Facility and surrounds[3]

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[3] Adapted from Engineering Geology Ltd Site Geology, Dwg 2508C-5A, 1996

In the original siting of compliance well sites (WWC, 1996), site 8 is a spring, now referred to as Shed Spring. This site has the potential to provide a sample of a large volume of the groundwater system. The spring is situated at the south-western end of a north-easterly aligned gully and ridge (corresponding to the completely weathered rhyolite near the bottom of Figure 8), suggesting the presence of a structural trend within the underlying bedrock.

9.4 Groundwater Monitoring Network

9.4.1 Background

The Storage 2 groundwater monitoring network was established in 1988. Control wells were established in the hill behind Storage 2 and compliance wells along the foot of the perimeter bund. Some of these wells were disestablished as a consequence of the Extended Martha Project.

Between 1996 and 1998, substantial groundwater monitoring was undertaken at the Storage 1A site prior to construction. This included the monitoring of wells constructed as investigation drill holes (DH series). Additional monitoring wells were established around the Storage 1A site in 1997 close to the Ruahorehore Stream and monitoring undertaken as part of the proposed compliance monitoring regime; and monitoring of the DH series bores ceased.

With the granting of consents relating to Storage 1A in 1999 the groundwater monitoring network was expanded to meet condition 16(d); detection bores were established upstream of the compliance wells and new control bores installed in the hill behind the tailings storage facility in 2000/2001.

Detection wells provide an early warning of groundwater change before any change is identified at the compliance wells. The area between the detection wells and the compliance wells would allow time to investigate the cause to the change and if necessary implement mitigation measures to avoid non compliance with Condition 26.

The location of each set of detection and compliance wells was designed, in particular for the shallow wells, to lie within areas of visible natural drainage systems (gullies or swales) and/or known palaeo-channels (Appendix F). The natural movement of shallow groundwater is towards depressions such as the palaeo-channels which ultimately connect to streams and rivers.

Recognising the need for a similar monitoring regime for Storage 2, a variation to the natural water rights was applied for, and granted in 2003.

The current groundwater monitoring system was finally completed in 2010 (Figures 9 and 10).

In 2007, two bores were installed near the northeast upstream slope of Storage 1A to allow measurement of water levels affected by the tailings pond. The two rhyolite hill control bores are frequently dry because they were not drilled deep enough, and two old site investigation bores (Orchard’s Farm) were added in 2008 to the monitoring programme.

In 2010 three deep detection bores (MW1D – 15, -16, -17) were established on the uphill diversion drain road behind Storage 1A. These bores were established to provide an understanding of the hydrogeology behind the dam, however they are frequently dry, probably because the wells were not drilled deep enough

9.4.2 Current Situation

OGNZL's groundwater monitoring network at its Tailings Storage Facilities comprises 94 wells including four control wells, 48 detection wells, and 42 compliance wells. An extensive review of the well chemistry in 2014 resulted in a revised groundwater monitoring programme that was approved in December 2014 through an addendum to the Tailings Storage Facility Monitoring Plan (2004).

For the purpose of monitoring, the wells have been divided into either scan or scan and sample wells (Figure 9 and 10, Table 14). Scan wells are wells that have historically shown little or no change in their chemistry. Water level, pH and EC are measured annually. Scan and sample wells are sampled six-monthly for key parameters (Table 15).

Should any scan or scan and sample well show a change in a parameter (primarily pH, EC or sulphate), a special investigation occurs which involves increased frequency of sampling to assist in understanding the anomaly. External geochemical advice is sought also.

Additionally each year peer reviewers may recommend changing the status of wells. As such Table 14 and Figures 9 and 10 can be considered indicative.

The review of the groundwater data undertaken in 2014 by GWS Ltd indicated that seepage through the groundwater is minimal and, where it does occur, is generally from transient sources related to early site construction or to on-going construction activities immediately adjacent to the site of detection. WG1 and Shed Spring may both be structurally controlled seepage zones.

Table 14: Well categorisation

TSF1A Shallow		TSF1A Deep		TSF2 Shallow		TSF2 Deep	
Scan + Sample	**Scan**	**Scan + Sample**	**Scan**	**Scan + Sample**	**Scan**	**Scan + Sample**	**Scan**
MW1C1S	MW1D3S	MW1D3D	MW1C1D	MW1S	MW2S	MW2D	MW1D
MW1D2S	MW1C3S	MW1D5D	MW1D2D	MW2C7S	MW2C2S	MW6D	MW2C2D
MW1C2S	MW1D4S	MW1D7D	MW1C2D	MW2C8S	MW4S	MW2C6D	MW4D
MW1C4S	MW1D5S	MW1D9D	MW1C3D	MW15S	MW2C4S	MW2C15D	MW2C4D
MW1C7S	MW1C5S	MW1C9D	MW1D4D		MW6S		MW2C7D
MW1D8S	MW1C6S	MW1D11D	MW1C4D		MW2C6S		MW2C8D
MW1C9S	MW1D6S	MW1C12D	MW1C5D		MW7S		MW12D
MW1D11S	MW1D7S	MW1D18D	MW1D6D		MW8S		MW2C13D
MW1D18S	MW1C8S	MW1DSPD	MW1C6D		MW12S		MW2C14D
MWCT3S	MW1D9S	MW1CSpD	MW1C7D		MW13S		MW15D
	MW1D10S	MW1Cspring[1]	MW1D8D		MW2C13S		
	MW1C10S	WG1 Spring[2]	MW1C8D		MW14S		
	MW1C11S		MW1D10D		MW2C14S		
	MW1C12S		MW1C10D		MW2C15S		
	MW1CSpS		MW1C11D		WSP1		
	MW1DSPS		MW1D13D		WSP2		
	MWR4DS		MW1D15D				
			MW1D16D				
			MW1D17D				
10	**16**	**12**	**19**	**4**	**16**	**4**	**10**

[1] MW1Cspring, or Shed Spring, is included as a key monitoring site for deep groundwater as this spring is believed to be derived of groundwater flowing beneath the TSF structures.
[2] WG1 Spring is included based on the same reasoning, as well as elevated Mercury concentrations detected throughout the historical monitoring record.

Figure 9 Current Network of Scan and Sample Wells

Figure 10: Current Network of Scan Wells

9.5 Groundwater Monitoring

9.5.1 Baseline Monitoring

Consent condition 23 required 12 months baseline monitoring data sufficient to characterise the groundwater regime prior to placing PAF material within Storage1A.

Baseline monitoring was undertaken at the Storage 1A compliance well sites from November 1997 and December 1998. Monitoring was also conducted for the DH series bores that existed prior to construction of the embankment construction and commencement of monitoring of the compliance bores.

During the operational period background monitoring is undertaken from control bores located up-gradient of the Tailings Storage Facility and behind the rhyolite hill-block, currently only MWCT3S is not dry. (Figure 9).

Trigger levels are established each year for the water levels, scan conductivity and pH values. These are based on three standard deviation from the mean of the historic data. EC has a high value trigger whereas pH has a low value. Water level only requires a high level trigger to indicate whether possible seepage from the TSF area/ponds has occurred.

Assessment and exceedence notification can occur when the field data is entered into the InViron system.

9.5.2 Operational Monitoring

Groundwater sampling is carried out in accordance with procedure - Groundwater Monitoring WAI-200-PRO-012 (Appendix E).

Table 1 of consent condition 25 for Storage 1A identifies the groundwater monitoring parameters (Table 15). The Storage 2 water right (Appendix A) does not identify specific monitoring parameters; rather condition 5A states that a TSF Monitoring Plan must be designed to assess effects of the Storage 2 on the groundwater resources. To this end the parameters defined for Storage 1A are applied to Storage 2.

Table 15 Groundwater Monitoring Parameters (Consent Condition Table 1)

Group 1 Parameters	Group 2 Parameters
Water levels pH Conductivity Major cations (sodium, potassium, calcium, magnesium) Major anions (bicarbonate, chloride and sulphate) Iron Manganese	copper lead nickel zinc silver cyanide ammonia nitrate

All groundwater samples are analysed to determine the concentration of dissolved metals measured in a fraction which passes through a 0.45 µm filter.

Consent condition 22 requires “scan monitoring” in both shallow and deep bores. Scan monitoring encompasses measurement of water levels and key water quality indicators - pH and conductivity in order to detect changes in water quality. The scan monitoring is required throughout the term of the consents.

Condition 24 requires “compliance monitoring” in accordance with the requirements of this Plan (and described in the next section). The compliance monitoring programme is undertaken at the baseline (control bores), detection, and compliance monitoring bore locations.

9.5.3 Monitoring Frequency

Biannual scan monitoring of designated scan wells includes pH, conductivity and water level. Analysis is conducted by trained staff at a purpose built OGNZL Waihi lab. A decrease in pH and increase in conductivity could indicate the onset of acid sulphate conditions. Conductivity is closely correlated to sulphate and is the surrogate parameter which is easily measured in the field (along with pH) and for which results can be readily assessed. Measurement of changes in bore water levels will indicate seasonal groundwater behaviour and/or a change in groundwater flow regime (e.g. depletion or increase in groundwater in an area). Monthly special investigation monitoring of ‘categorising’ parameters (Table 16) is initiated when a parameter is triggered on two consecutive occasions at an affected site. Site based trigger levels have been developed for pH and EC to initiate the Contingency Plan (section 9.6).

The six monthly scan and sample category (Table 16) is designed to meet the ‘compliance’ monitoring required in condition 24 and confirm the scan monitoring results. The parameters include Group 1 and 2 parameters identified in Table 15 and additional discretionary parameters.

The cations, anions and metals will enable characterisation of groundwater having constituents with waste rock or tailings characteristics or characteristics of natural and other sources (e.g organic materials).

Table 16 Monitoring Parameters and Frequency

Scan and Sample Parameters Six monthly (RJH Code 40)		Scan Parameters Six monthly	Special Investigation Parameters Monthly (if a well is triggered)
pH (field and lab)		pH (field, lab)	pH (field and lab)
Conductivity (field and lab)		Conductivity (field, lab)	Conductivity (field and lab)
Ca, K, Mg, Na	Sum of cations		Water level
Cl, HCO_3, SO_4	Sum of anions		Ca, K, Mg, Na
Total Alkalinity	Mn		Cl, HCO_3, SO_4
Ag	Ni		CN_{WAD}
Al	Pb		Co
As	Sb		Fe
Cd	Se		Mn
CN_{WAD}	TSS		(or other analytes as required)
Co	U		
Cr	Zn		
Cu	Free ammonia (NH3)		
F	Total ammoniacal (NH_4-N)		
Fe	Nitrate-N (NO3N)		
Hardness	Nitrate-N + Nitrite-N (NOxN)		
Hg			

Note: From a geochemical perspective only dissolved concentrations are necessary.

The groundwater analytical suite was revised by GWS Limited in 2018. The aim was to include receiving water quality criteria parameters and analytes required for Piper Trilinear analysis. The comprehensive nitrogen suite relates to CN breakdown. Some analytes that have historically recorded below or near detection or considered unneccessary have been removed from the suite. These include: Acidity, Bicarbonate Alkalinity, acid soluble Antimony, acid soluble Mercury, acid soluble Selenium, dissolved Sulphur, dissolved Thallium, Nitrite-N and Reactive Silica.

Equipment, Calibration and Maintenance

Water levels in the groundwater wells are measured using an electrical dipper. The water dipper probe and cable are routinely cleaned with ‘decon’ followed by a deionised water rinse. The cleaned probe is stored in a specific purpose-built container.

The water dipper is calibrated annually by Hydrologic Ltd.

To sample groundwater deep wells are micro-purged and sampled using dedicated bladder pumps. Samples are taken off the pump discharge. Although some of the shallow bores have had dedicated bladder pumps installed to enable undisturbed (sediment free) sampling the remainder of the shallow bores have shallow water levels and require manual volumetric purging with a disposable bailer to remove water sitting in the well and to bring in water from the formation surrounding the well.

On-site filtration is undertaken on samples for metals analysis. The filtration kit is used one per sample. Samples are transported in a chilli bin containing frozen cool packs.

Field equipment is regularly checked to ensure good working order. Calibration results assist with identifying when individual probes need replacement or an instrument needs servicing. Thermo Fisher Scientific Ltd (Enviroequip Division, Auckland) carry out instrument servicing and annual calibration and performance inspection of the handheld and flow-cell instruments.

Analytical Laboratories and Methods

SGS New Zealand Ltd (SGS) based in Waihi and RJ Hill Laboratories Hamilton (RJ Hill) provide analytical services to OGNZL Waihi.

Both companies hold accreditation under International Accreditation New Zealand (IANZ). QA/QC is conducted on every batch of samples; this includes the use of duplicates, reagent blanks and calibration of instrumentation in accordance with manufacturer’s specification. If any out of spec results are received re-tests are requested and an investigation instigated.

Field scan analyses are undertaken at OGNZL Waihi’s purpose-built laboratory. The laboratory uses a Hach 2100Q module capable of assessing pH, conductivity, temperature and turbidity. The laboratory and testing methodology have been independently assessed and approved by Golder Associates NZ Limited.

Laboratory probes are calibrated before and after analysis. The pH instrument is calibrated against appropriate standards (pH 4.01 & 7.0) following manufacturers operating instructions. Electrical conductivity instrument (EC) calibration is undertaken either daily or weekly prior to a sample run and this exceeds manufacturer requirements. Two sets of probes are used – one for groundwater and the other underdrain samples. RJ Hill provide analytical services when field results are outside trigger limits and for routine analyses.

All water quality analyses are performed in accordance with APHA "Standard Method for the Examination of Water and Wastewater, 20th edition (1998). Dissolved rather than acid soluble forms of metals are measured in groundwater.

RJ Hill report the results of ion balance checks for all OGNZL Waihi water samples where analyses have been performed to reasonably cover the major ions present. The minimum suite of analytes requested in order to report an ion balance will be; Calcium, Magnesium, Sodium, Potassium, pH, Total Alkalinity, Chloride and Sulphate.

9.6 Contingency Plan

9.6.1 Objectives

Storage 1A and Storage 2 Condition 25/5C requires initiation of a Contingency Plan if monitoring results within the wells differs from the relevant trigger levels for that well over two consecutive readings.

The objective of the contingency plan is to:

- Characterise the change,
- Assess the source of the change, and to determine what, if any, mitigation measures should be implemented to ensure that condition 26 is complied with at the down-gradient compliance bores.

The trend and actions taken are to be detailed in the annual report to the Council.

This Contingency Plan defines the trigger levels and the actions to be taken to meet the objectives.

9.6.2 Trigger Levels

Trigger levels have been developed to assist as an early warning indicator of potential changes of groundwater quality. Trigger levels for pH, conductivity, and water levels have been developed from the scan monitoring data for Storage 1A and Storage 2 and applied to all the groundwater bores.

Condition 29 of the consent requires (in part) that discharges associated with the tailings and waste rock storage facility, either separately or in combination with other discharges, shall not cause the receiving water standards in Table 17 to be breached. The condition also states that discharges shall not cause a significant adverse environmental effect on the receiving groundwater and surface waters.

If the monitoring results fall outside the relevant upper and/or lower trigger level within the detection or the compliance wells, over two consecutive readings, then the contingency plan is initiated as detailed below.

The trigger levels for Storage 2 and Storage 1A wells are based on historical data. When pH is less than the lower trigger level outside of three standard deviations of the historic data then the contingency plan is initiated as more acidic conditions are indicated. When conductivity is greater than the upper level outside of the three standard deviations the contingency plan is actioned as more sulphate and possibly metals are indicated in the groundwater. A rise in water level above the upper level could indicate increasing groundwater flows from a new source or ground deformation. Greater flows of contaminants would be of greater concern if they were to discharge to a stream or river. Reduced bore water levels may indicate a depletion of groundwater and result in a change in water quality. However, there is a lower risk of groundwater contaminants (if any) discharging to receiving water. Trigger levels are revised each year based on the historic results.

9.6.3 Contingency Actions

Data Checks

Data checks are to be undertaken when the scan parameters pH and EC are triggered once:

1. Initial check that data is correct
2. Check equipment and calibrations
3. Check with another field measurement (next day)
4. Accept result if cause is not readily explainable and undertake next scan sample (or quarterly if scheduled)

Monitoring

Monitoring to be undertaken when the scan parameters are triggered twice:

1. Monthly sampling and analysis of categorising parameters (Table 16)
2. If after another two consecutive sampling rounds the trend has not reduced or stabilized a series of decisions are to be taken as to whether further investigations are warranted and whether mitigation is needed
3. The hydro-geochemist, Peer Reviewer(s), WRC, Project Engineer and/or other advisers are to be informed

Investigations or Assessments

Investigations may involve but not necessarily include:

- Extending sampling to drains, surface runoff from the waste rock, or collection ponds
- Installation of pits, trenches or additional wells with logging, surveying, sampling and analyses to investigate the shallow groundwater system
- Use of geophysics and/or tracer tests to further investigate changes in groundwater chemistry
- Installation of additional wells to investigate the deeper groundwater system
- Review of as-built drawings and construction testing data
- Falling head tests to verify groundwater hydraulic conductivity around the well site
- Bore integrity tests

Assessment will be necessary to identify the likelihood of an offsite effect; that is to determine compliance against the requirements of condition 26 and 29 of the consent in regard to:

1. Seepage outside the footprint of Storage 1A
2. Seepage, outside the boundaries of Area D (Appendix F)
3. Compliance with receiving water standards (Table 9-4)

4. A significant adverse environmental effect on the receiving groundwater and surface waters

Effects Assessments

Effects assessment may include:

- Sampling of river and stream margins during low flows at the suspected point of groundwater discharge
- Sampling of springs
- Review of contaminated groundwater flow path(s), mass load, and migration rate
- Calculation of the dilution available in river or stream

The Ruahorehore Stream bounding Storage 1A will be more sensitive to any possible seepage/water quality issues due to the relatively lesser flow. If an off-site effect is assessed as likely and mine related, appropriate mitigation measures will be undertaken.

Mitigation Measures

Mitigation measures, if considered necessary, would be designed on the basis of the specific conditions at each location may involve, but not necessarily include:

- Groundwater interception and recovery systems
- Treatment or removal of any surface contaminants if practicable
- Chemical treatment systems in surface runoff or groundwater

Expert advice should be sought for design and implementation of mitigation measures if necessary.

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Table 17 Receiving Water Quality Criteria

Parameter	Receiving Water Concentration [(2)]	
(g/m^3 unless otherwise stated)	Hardness 20 g/m^3 $CaCO_3$	Hardness 100 g/m^3 $CaCO_3$
pH	6.5 to 9.0	6.5 to 9.0
Cyanide (CN_{WAD})[(1)]	0.093	0.093
Iron	1.0	1.0
Manganese	2.0	2.0
Copper	0.003	0.011
Nickel	0.040	0.160
Zinc	0.027	0.100
Silver[1]	0.00025	0.00284
Total Ammonia	Refer Table 3	Refer Table 3
Antimony	0.030	0.030
Arsenic	0.190	0.190
Selenium	~~0.005~~ Refer Note (4)	~~0.005~~ Refer Note (4)
Mercury	0.000012	0.000012
Cadmium	0.0003	0.001
Chromium (VI)	0.010	0.010
Lead	0.0004	0.0025

Notes :

20/9/05

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

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

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

(4) The selenium concentration in the receiving water shall remain below the trigger limits 0.02 g/m3 97% of the time on an annual basis, and 0.035 g/m3 in any single analysis, based on monitoring undertaken pursuant to condition 16 of consent 971318. In the event that these limits are exceeded, the consent holder shall inform the Waikato regional Council as soon as practicable and prepare a report, to the satisfaction of the Council, to demonstrate that continued discharges at concentrations exceeding the trigger limits will have no more than minor effects on the Ohinemuri River. This report shall be provided to the Council within two months of the consent holder becoming aware of the trigger exceedance.

Criteria For Total Ammonia 18/09/08

Chronic Criterion - g/m³ as Ammonia							
Temp °C / pH	0	5	10	15	20	25	30
6.50	3.0	2.8	2.7	2.5	2.5	2.5	2.4
6.75	3.0	2.8	2.7	2.6	2.5	2.5	2.5
7.00	3.0	2.8	2.7	2.6	2.5	2.5	2.5
7.25	3.0	2.8	2.7	2.6	2.5	2.5	2.5
7.50	3.0	2.8	2.7	2.6	2.5	2.5	2.5
7.75	2.8	2.6	2.5	2.4	2.3	2.3	2.4
8.00	1.82	1.70	1.62	1.57	1.55	1.55	1.59
8.25	1.03	0.97	0.93	0.90	0.90	0.91	0.94
8.50	0.58	0.55	0.53	0.53	0.53	0.55	0.58
8.75	0.34	0.32	0.31	0.31	0.32	0.35	0.38
9.00	0.195	0.189	0.189	0.195	0.21	0.23	0.27

Note: To convert these values to mg/l as nitrogen, multiply by 0.822

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10. Definitions

ANC	Acid Neutralising Capacity
ARD	Acid Rock Drainage
EGI	Environmental Geochemistry International
IANZ	International Accreditation New Zealand
ICMC	International Cyanide Management Code
LAF	Lime Addition Facility
Memo	Technical Memorandum
MPA	Maximum Potential Acidity
NAF	Non Acid Forming
NAG	Net Acid Generation
NAPP	Net Acid Production Potential
NCP	North Collection Pond
NSPSP	North Stock Pile Collection Pond
NWG	Newmont Waihi Gold
NZ	New Zealand
OGNZL	OceanaGold New Zealand Limited
OMSM	Operations, Maintenance and Surveillance Manual
PAF	Potentially-Acid Forming
“Part B”	Tailings Storage Facility Monitoring Report: Part B – Geochemistry
PCP	Principal Control Plan
Piper diagrams	Piper Trilinear Diagrams
QA/QC	Quality Assurance and Quality Control
“the Report”	Tailings Storage Facility Monitoring Report
SSSP	Surplus Soil Stockpile
TSF	Tailings Storage Facility
TSF1A	Tailings Storage Facility One-A
TSF2	Tailings Storage Facility Two
TSFMP	Tailings Storage Facility Monitoring Plan
WLO	Waste Load Out
WRC	Waikato Regional Council
WSP	West Silt Pond
WTP	Water Treatment Plant

11. References & Associated Documents

Item	Title	Location
	WWC, 1996	
	T Matuschka, 1997; OGNZL Evidence	
Consent	Resource Consent 971303	OGNZL Consent Register and Legal Database
Consent	Resource Consent 971304	OGNZL Consent Register and Legal Database
Consent	Resource Consent 971305	OGNZL Consent Register and Legal Database
Consent	Resource Consent 971306	OGNZL Consent Register and Legal Database
Water Right	Natural Water Right W1749	OGNZL Consent Register and Legal Database
Water Right	Natural Water Right W1750	OGNZL Consent Register and Legal Database
Water Right	Natural Water Right W1751	OGNZL Consent Register and Legal Database
Water Right	Natural Water Right W1761	OGNZL Consent Register and Legal Database
Manual	NWO-DAM-003-SYS-M1 Operations Manual	OGNZL database
	EGi (in a review of the monitoring in 2010	
Consent	EWDOCS-#882633-v1 Consent Change Evaluation Report	OGNZL Consent Register and Legal Database
	EGi (2008): Geochemistry Review – Site Visit Report Contamination of NAF Stockpiles.	
	Smith and Mudder, 1991	
	Dr J. Webster-Brown (2003)	
	APHA “Standard Method for the Examination of Waterand Wastewater, 20th edition (1998).	
	(NWG-WAT-TSF2 Discharge Review-L080905)	