Management Plan

Underground Void Management

Document ID: WAI-400-PLN-011

This is no longer a controlled document once printed.
This document must not be released outside of the company without permission of the Departmental Manager.

Department:	**Mining Underground**
Location/Site:	Waihi

	Position/Title	Name	Date
Authored by	Senior Geotechnical Engineer	P Keall	16/4/2019
Reviewed by	Underground Technical Services Supt	D Townsend	16/4/2019
Reviewed by	Underground Senior Engineer	T Page	17/4/2019
Reviewed by	Underground Senior Surveyor	M McKinnon	17/4/2019

	Position/Title	Name	Signature	Date
Approved by	Underground Mining Manager	Charles Gawith	C. Gawith	17/4/2019
Approved by	General Manager	Bernie O'Leary		18/4/2019

Document Approval –Version 5.0 Final

Prepared By: Peter Keall
Senior Technical Engineer

Reviewed By: David Townsend
Underground Technical Services Superintendent

Approved By: C Gawith ....

Charles Gawith
Underground Mine Manager

B O'Leary ....

Bernie O'Leary
General Manager

Certified By: 24/4/2019

Mark Buttimore
for Hauraki District Council

Document Issuance and Revision History

Procedure Name: **Underground Void Management**

Document ID: **WAI-400-PLN-011**

Revision No.	Revision Date	Section	Page	Description of Issuance or Revision	Effective Date
1.0	18 Nov 16			New document prepared for SUPA	19/11/2016
2.0	25 July 17	Various	Various	Document updated to reflect changed SUPA consent conditions and MDDP consent	26/7/2017
3.0	27 Feb. 18	various		Surface Monitoring (Section 6) and Scheduled update. Table 3 (probe drilling summary) replaced	9/3/2017
4.0	March 19	All		Updated for Mining in areas of historical workings Major review for Martha underground	25/03/19
5.0	April 19	All		Updated following review by HDC and minor edits – Final version	18/4/2019

Table of Contents

1 INTRODUCTION

The Martha Underground mine will involve the mining of remnant and virgin (areas that have previously been unmined) material in the area previously mined between 1887 and 1952 by the Waihi Gold Mining Company and Grand Junction Company (Figure 1). The information in this document details how the interaction between historical and future workings will be managed.

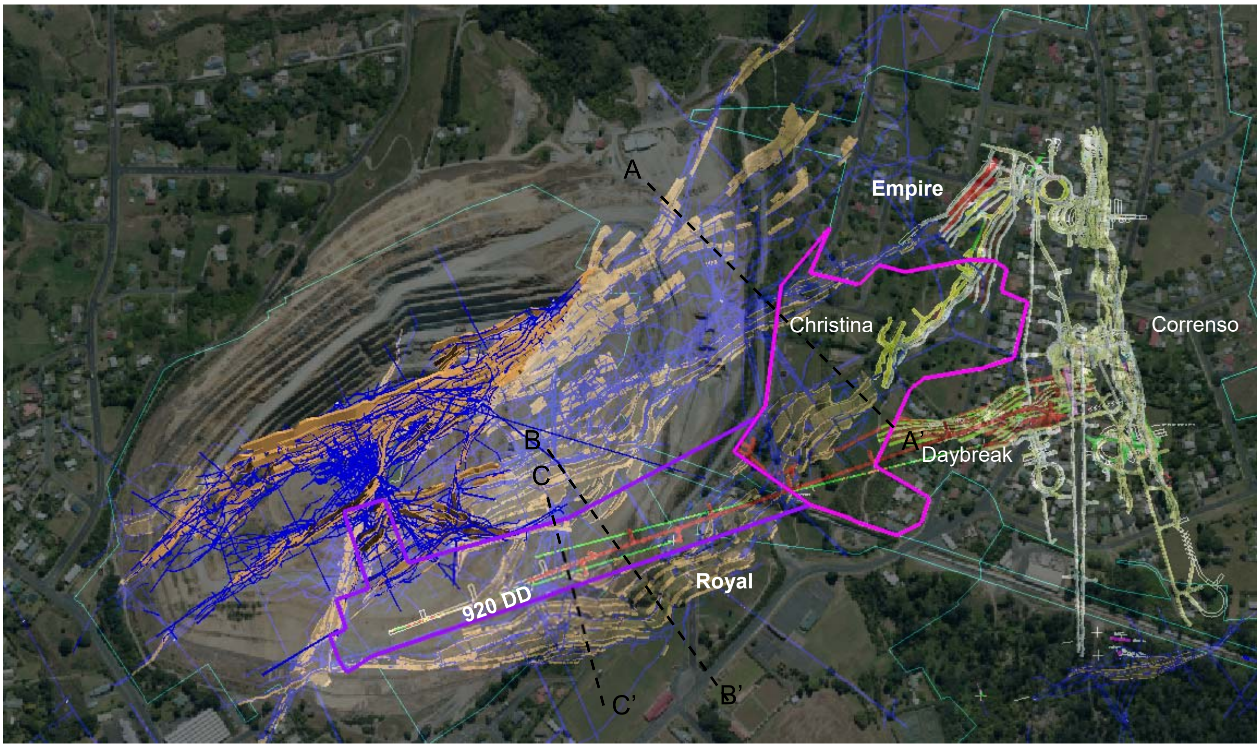

Figure 1. General overview of the Martha Underground Mine Area in relation to historical workings.

2 PURPOSE AND SCOPE

This management plan covers any mining activities that are conducted within the Slevin Underground Project Area (SUPA), the Martha Drill Drive Project (MDDP) area, and the Martha Underground (MUG) project area.

The purpose of this document is to outline the management processes for dealing with mining activities in the areas of historical workings, to ensure surface stability. Whilst there are obvious overlaps between the risk to local and regional stability and worker safety, these hazards and controls associated with worker safety are covered by a series of detailed documents administered by WorkSafe New Zealand under the Health and Safety at Work (Mining and Quarrying Operations) Regulations 2016 and the Health and Safety at Work Act 2015.

This Void Management Plan will be read in conjunction with the Pit Slope Management Plan specifically conditions related to backfilling of old mine stopes

3 GUIDELINES, CONDITIONS AND LEGAL REQUIREMENTS

This Void Management Plan (VMP) has been written in accordance with, and with reference to, a number of other documents and legislative framework, namely:

1. Project Martha – Hauraki District Council. *Land Use Condition for land use consent* **LUC 202.2018.00000857.001.**
2. Principal Hazard Management Plan (PHMP) for Ground Control and Strata Instability.
3. The Waihi Underground Ground Control Management Plan (GCMP).
4. Principal Hazard Management Plan for Inundation and Inrush.

3.1 Land Use Condition for Land Use Consent LUC 202.2018.00000857.001

Specific consent conditions were agreed for Project Martha, one of those being the implementation of a VMP. Specific conditions/requirements of the VMP are detailed below and provide some of the framework for this document.

Page 19, *Condition #72. 30 working days prior to the commencement of any underground mining authorised by this consent, the consent holder shall provide to the Council for certification a Void Management Plan. If certification is not provided within 30 working days of Council's receipt of the Void Management Plan activities authorised by this consent may commence.*

The objective of the Void Management Plan is to confirm the location and shape of old unfilled and filled mined voids, and to identify the risks and controls required to ensure ground surface stability. The plan will include, but will not be limited to:

a. Proposed remnant mining methods;
b. The procedures / methods for the backfilling of stope voids (including historic stopes);
c. Modelling;
d. Probe Drilling;
e. Monitoring and operating procedures;
f. Specifications for construction and placement of stope pillars where required;
g. Conduct sufficient investigations to develop an adequate understanding of the ground conditions, and verify the location, status and extent of historical mine workings; and
h. Review the information from the investigations and adjust the mine design and stope design to ensure that there is a high level of confidence that the stopes will be stable prior to backfilling and in the long term.

The consent holder shall review and update the plan as necessary including whenever there is any change in the methods or procedures used for void detections monitoring or operating procedures and shall provide the updated plan to the council for certification.

Condition #73. The Void Management Plan shall include a procedure describing preventative and mitigation actions that would be implemented to ensure that the mining in the Rex Orebody does not drain the strata overlying the andesite via existing drill holes and structures. Preventative and mitigation actions may include:

a. *Avoid intercepting the drill holes with mine workings;*
b. *Grouting drills holes from underground where underground development intercepts holes into which water flows or geotechnical defects with significant and sustained waterflows; and*
c. *Undertake geotechnical investigations to demonstrate to the satisfaction of Council that draining of the drill hole (s) will not adversely affect surface stability.*

4 DEFINITIONS AND TERMINOLOGY

This document specifically relates to the identification and management of historical mine voids created during the mining of the historical Martha Underground Mine during mining activities from 1878 – 1953.

This document does not specifically cover the management of future/modern voids that will be created by mining of the MUG. These voids have been managed through conditions within the Land Use Consent LUC 202.2018.00000857.001. Voids that will be created by mining of the MUG may in some cases overlap or interact directly with historical voids, and in this instance will be managed under the Void Management Plan.

Historical voids relates to voids created during historical mining of the Martha deposit and may include:

- Development tunnels.
- Stopes, both filled and unfilled.
- Shafts such as haulage shafts (i.e. Number 2 Shaft), ore passes, waste passes and other such sub-vertical openings.

5 IDENTIFICATION OF VOIDS AND MANAGEMENT OF HISTORICAL VOID MODEL

The primary tool for the identifying the size, shape, condition, and the spatial location of historical workings is the void model. The void model is a 3-dimensional digital model of the historical workings, including stopes, drives, shafts, and other incidental historical mine workings.

The model is maintained by the survey department and is overseen by the Senior Surveyor.

The model is updated and maintained as per the site guidelines. Information that is used to inform and update the void model comes from multiple sources such as 2-dimensional historical maps, diamond drilling, probe drilling, planned intersections with historical workings, and survey scans.

As per the site guidelines, this model must be updated regularly and be made available to other stakeholder departments such as geotechnical, mine planning, and operations. Site processes and procedures require that the latest version of the Void Model be used when designing, reviewing, or adjusting any mining activities in proximity to historical voids.

6 PLANNING AND DESIGN OF INTERACTIONS WITH HISTORICAL VOIDS

Interaction of the proposed MUG with historical workings is inevitable due to the extensive nature of the historical workings, and the intention of the project to recover gold from materials left behind by historical activities.

The main types of interactions foreseen to occur between the Martha underground mining and historical workings includes:

- Proposed development and historical development.
- Proposed development and historical stopes (filled and unfilled).
- Proposed development and historical shafts.
- Proposed stoping and historical development.
- Proposed stoping and historical stopes (filled and unfilled).

- Proposed stoping and historical shafts.

Proposed shafts (such as vent shafts and ore/waste passes) will be planned to avoid all historical workings unless approved by the Underground Mining Manager.

As previously discussed mining in the Martha underground project area will be interacting and intersecting historic workings. Historic development drives are too small to represent any significant cave propagation / surface instability risk. Similarly stopes that have been backfilled do not constitute a significant caving hazard. The Stability Assessment Process outlines the processes used to assess and manage the risks of surface instability. Two resolutions of assessment are employed in the process:

- an annual review of the rolling three-year mine plan, and
- an assessment of each development design as they are issued.

The annual review requires stakeholder departments (particularly mine planning, geotechnical engineering and surveying) to review the upcoming three years of mining and provide documented assessments on any areas of concern. The assessment and feedback from the Geotechnical Department, amongst other things, will focus on maintaining regional stability and ensuring the planned mining activities will not cause surface instability. Interaction of the Martha open pit and the underground workings will also be a major component of this yearly review and assessment.

The development design review is a detailed assessment of each individual level design considers not only the planned level development, but also the intended use of the development, ie stoping above, or mining of a skin. It is an iterative process that requires the design to be assessed by Mine Planning, Survey, and Geotechnical Engineering. During this process all potential interactions with historical workings are identified and controls are implemented to mitigate any potential ground instability risks that could result from mining interactions. These controls may include avoiding the potential interaction, varying standoff distances, multiple stops for probe drilling, and trigger points for survey scans.

Once the design has been assessed and controls agreed upon, the design is approved by all relevant stakeholders and the authorisation to commence development is issued. The documentation of all this assessment and subsequent controls are filed for future reference.

7 GEOTECHNICAL ASSESSMENTS AND MANAGEMENT OF VOIDS

Geotechnical review and reporting is an integral part of the void management planning process. As part of the stability assessment process a geotechnical checklist is completed prior to any development within proximity to historical workings. As mining activities progress, ongoing and regular geotechnical inspections and assessments will be an important part of ensuring the rockmass around historical voids remains stable.

The initial and ongoing geotechnical assessment of voids incorporates multiple steps and methodologies. These may include but are not limited to:

- Initial assessment based on spatial location of void in relation to other mine workings – both historical and current.
- Assessment of interaction potential i.e. induced stress affects.
- Review of drill logs and core photos.
- Rock mass characterization based on drill holes and mapping:
    - Q-determinations;
    - Rock Mass Rating (RMR);
    - Geological Strength Index (GSI);
    - domain modelling; and.
    - numerical modelling plus on-going rock property test work.
- Review of all mapping and other information relevant to the void to determine:
    - significant discontinuities;
    - orientations;
    - jointing;
    - nature of veining; and

  - previous history.
- Stability assessments are carried out using the above information. These assessments will include:
  - Mathews Potvin stability graph;
  - 2D Numerical modelling;
  - UNWEDGE as appropriate;
  - advanced 3D numerical modelling.
- Caving potential and whether there is a propagation risk.
- C-ALS information where it can be obtained. Taking multiple C-ALS surveys of historical open voids will provide precise data on the effect that mining activities may be having on the historical voids.
- Other monitoring, near-field and far-field using pit monitoring network:
  - near-field monitoring will include MPBX and clock its, plus SMART bolts and Slough meters above potential cave areas;
  - open pit monitoring of the prism station network and on-going pit-slope monitoring by radar.
- Options for backfilling:
  - optimum locations;
  - type of fill (cemented or run of mine waste).
- Team-based risk assessments to identify and formalize appropriate controls.
- Team-based back analysis.

8 VOID MANAGEMENT, MONITORING AND MITIGATION OF RISKS

Following the assessment process, there will be historical voids that are identified as requiring some form of ongoing management, monitoring, or risk mitigation to ensure long term stability. These steps can be broken into different areas and are outlined below.

8.1 Void Management

The management of void's stability will principally be undertaken through use of the following measures:

1. Appropriate mining method selection.
2. Backfilling of voids.
3. Avoidance through cessation of mining/sterilisation.
4. Monitoring.
5. Modelling.
6. Void stand-off distances.
7. Stability pillars.

8.1.1 Mining Method

The mining methods to be used are those that require stope voids to be backfilled after the extraction of the ore, which is a requirement of the Land Use Consent Conditions. In areas that are considered virgin, Modified Avoca will be the primary method, but there may be areas utilising Overhand Cut and Fill, and possibly localised areas where transverse stoping methods may be used. The mining of these areas will proceed in a bottom up sequence either from the bottom of the orebody, or from a crown pillar.

A proportion of the resource is considered as remnants and either contained in mineralised envelopes immediately adjacent to unfilled historical stopes or as mineralised waste that was placed in historical stopes. In the case of being adjacent to open historical stopes these “skins” may be slashed into the existing void from a proximal development drive using a side-drilling method, or the historical void may be filled with a consolidated fill to stabilise it before the skin is extracted either by the side ring or Avoca method. The Stopes will be backfilled following the extraction of the ore. Mining of these areas will proceed from the bottom up either from the bottom of the orebody or from a crown.

Where the mineralised fill material is to be extracted, mining will proceed from the top down, with the rockmass above the panel investigated, and if required, supported prior to extraction to prevent any possible caving or void propagation. The height and length of each panel will be determined by the methods outlined in Section 7 and restricted to ensure that their wall stability is not compromised. This method will be employed unless another method of extraction can be developed and proven by way of risk assessment that the material can be extracted without causing caving or void propagation that may impact on other underground workings and on the surface.

All methods involve sequential filling of voids as the mining front progresses. The mining methods do not leave voids and therefore any significant collapse of newly created voids leading to surface instability is not considered to be conceivable. Mining spans will be limited to reduce the likelihood of instability during extraction and will be promptly backfilled.

Stability pillars will be left as required to ensure the stability of stopes is maintained prior to backfilling. These are normally a section of intact rock which is not extracted to isolate mining blocks which may have some stability concerns such as a potential structural failure of a hanging wall. Pillars will also be left through sub-economic sections of the ore-body. Cemented rock-fill may also be utilised to create stability pillars. Exact pillar specifications are assessed on a case-by-case basis depending on the position and requirements.

Development drive dimensions will be generally less than 6 m wide x 6 m high.

There is extensive site-experience with the mining methods to be used and the ground conditions expected to be encountered.

8.1.2 Backfilling Voids

All stoping voids created by modern mining will be promptly backfilled following the extraction of the ore. This fill may be run of mine waste or consolidated fill.

Selected historical voids will be backfilled as required to maintain local and regional stability. Fill may be either run of mine waste rock or consolidated fill depending on the stabilisation requirements. For example if the company is seeking to extract ore from the margins of an historical void consolidated fill may be required to achieve sufficient strength.

In all cases backfilling of voids is expected to largely remove any instability which would be confirmed by monitoring, see 8.1.4.

8.1.3 Avoidance through the Cessation of Mining

In some areas rock mass conditions or the stability of the voids will mean further extraction would carry unacceptable stability risks. This will be determined during the team based risk assessment process. Such areas will be removed from the planning / design process and any associated ore considered sterilised. This is standard mining practice and it is accepted that not all of the ore-body can be recovered. Mine plans are updated to reflect the design changes.

8.1.4 Monitoring

Voids and the surrounding rock mass will be monitored by a combination of methods depending on access for installation and results retrieval and may include:

- Probe drilling with C-ALs surveys;
- Installation of instrumentation e.g extensometers, slough meters, SMART cables and tell-tale clock-its, as well as other instrumentation as appropriate;
- Micro-seismics – the Waihi operations operates a two-hub micro-seismic system installed with geophones giving broad coverage of the working areas. The overall level of seismic activity has been consistently very low. Results are reported monthly to the Hauraki District Council and any increase in the number of events is noted. Any event greater than ML-0.5 are designated “reportable events” under the terms of the licence conditions;
- Observational monitoring for all active mining areas. Non-active areas will be placed on inspection schedules for formal inspections, either monthly, six-monthly or annually depending on location, usage and proximity to other mining areas.

8.1.5 Modelling

Modelling of stope stabilities will include the Potvin / Mathews Stope Stability Method to manage temporary openings (i.e. stopes being mined that will be filled). This is an industry standard and has proven to be a good predictor of stope behaviour over many years of production and several different ore-bodies at the Waihi Underground Operations. Additional computer-based numerical modelling to assess stress redistributions and rock strengths around historic workings may also be carried out. It is not possible to give an exact span limit as stable spans are dependent on several variables but good mining practices dictate stable stope spans with minimal dilution and this should ensure instability is minimised.

8.1.6 Void Stand-off

As discussed above, the Stability Assessment is an iterative assessment process between all the stakeholder departments whereby stand-off distances are assessed and agreed. Stand-off distances will be based on the planned mining activity, the local rock mass conditions, the type of historical void, the known spatial accuracy of the historical void, and information on the contents of the historical void (empty, filled, or unknown).

Subject to further monitoring and assessment a stand-off distance of 40m from the proposed stoping to the Martha open pit will be maintained. Entech[1] suggest this stand-off distance will ensure there is sufficient natural rock pillars remain in place to maintain regional stability.

No stoping shall occur within 20 m of the mapped extent of the Milking Cow Zone. This three-dimensional zone is held within the consent holder's geological model and shown schematically as Appendix 5 in the HDC LUC.

For mining areas within the Slevin Underground Project Area (SUPA), the relevant land use consent conditions require the following stand off distances to historical voids.

Planned Mining	Historical Mining	Proposed Stand Off Distances
Development Drives	Development, rises and access drives	Historical development shall not be intentionally intersected
Development Drives	Unfilled portions of Stopes	Development drives shall have a minimum standoff distance of 10 m to unfilled portions of historical stopes.
AVOCA Stopes	Unfilled portions of Stopes	Stoping shall not occur within 25m of unfilled portions of historical stopes
AVOCA Stopes	Crown pillars	Standoff distance shall be increased to 30m, unless mitigation measures can be put in place. Mitigation measures include monitoring with laser scanning devices such as CAL-S, or filling of the unfilled void. via one or more boreholes from a location outside the standoff zone.

1. Entech, Martha Underground Scoping Study (2018)

8.1.7 Probe Drilling

Once mining development activities are within the vicinity of historical workings (typically at a stand-off distance as defined by the Stability Assessment Process) targeted probe drilling will be undertaken. The purpose of the drilling will be to confirm the position of the workings and to obtain information as to the nature of the workings.

The process to be followed is described in the Probe Management Process and is summarised below:

1. Development drive reaches a stand-off distance or part of the mine design that requires probes to be undertaken.
2. Probe drilling from mine development drives.
3. All probe holes will be entered into a database noting the dip / azimuth and distance the void was intercepted.
4. As historical workings are intersected by the probe holes, the 3D model will be updated as needed to reflect actual void locations.
5. Stope and tunnel (development) voids may be further assessed using C-ALS instrumentation. Models of the historical workings will be updated if there is variance from historic records.
6. Once the data has been assessed, a review is held and instructions on the next course of action are issued. This course of action could include more probe drilling, continue development, or redesign future development.

The frequency and density of probe drilling and probe hole designs will be based on previous knowledge of the location and nature of the void and will be part of the risk assessment process.

8.1.8 Cavity Auto-scanning laser System (C-ALS)

The C-ALS scanning systems is a tool utilised by the Survey department and consists of a cylindrical scanning head which is attached to rods that are used to insert the scanner into a void through a drill hole. The scanner can be inserted into a void from a distance of up to 200m, but a distance of around 35m is more typical due to the logistics associated with longer drill holes. It produces a three dimensional image of the void, and also contains a low resolution camera that is used to gain information on the void.

8.1.9 Visual Monitoring

All active working areas are regularly inspected by senior mining personnel i.e. Mine Foremen, Shift-Supervisors and Geotechnical Engineers. Additionally all mine personnel are trained, and required to, carry out work place inspections prior to commencing work in any area. There are numerous visual indicators of unusual rock mass responses which may be pre-cursors to developing stability issues. Some indicators include:

- fresh surface cracking;
- cracks in shotcrete or fibrecrete;
- bagging of scats in the mesh;
- ravelling on walls;
- loading of bolts / deformation of ground support;
- “pig-tailing” cable-bolt end strands;
- ground noise;
- small rock falls or scats falling; and
- any changes to the work place since the previous inspection.

The underground workforce is experienced and trained to look for any visual indicators and are required to report any unusual occurrences or concerns immediately.

8.1.10 Pit Wall Monitoring

The open pit, although currently not operating has a network of prism stations on the pit slope walls and surrounds and are auto-scanned by a high precision theodolite at approximate 4-hourly intervals. Results are checked and plotted daily. In addition a radar scanner monitors sections of the pit walls as required. Any movements outside of set threshold limits automatically triggers alerts to the open pit geotechnical engineer and pit supervisor. These notifications will be given to relevant underground personnel once mining in the Martha Project Area commences.

8.1.11 Displacement Instrumentation

Use of instrumentation such as multi-point borehole extensometers (MPBX), vibrating wire stress meters, slough meters or tell-tale “clock-its” are installed as required in areas requiring a higher level of monitoring. These instruments provide early indications of ground movements and are routinely used in the underground operations.

8.1.12 Additional Monitoring

Monitoring of proposed (modern) stoping voids will be undertaken via regular Cavity Monitoring Survey (CMS) of stopes once they are emptied, as is the current practice at the Correnso Underground Mine. This allows the capture of detailed and accurate 3D void models. It will also enable the mine to measure performance of stopes against designs, which are fed back into the design loop for improvement where required. Active stopes will also be visually inspected by mine employees on typically a shift by shift basis as part of routine activities.

9 PREVENTATIVE AND MITIGATION ACTIONS FOR PROTECTING THE UPPER AQUIFER

To ensure that there are no surface effects caused by the draining of the strata above the andesite layer that overlies several areas of the mining operations, the following measures have been implemented. These include:

- No stoping will occur in the Rex Orebody above a depth of 40m below the andesite contact;
- All surface drill holes into the Rex Orebody area will be fully grouted.. If this is not possible due to a void or porous veining etc, van ruth plugs will be installed in the hole to isolate these areas and the remainder of the hole is to be grouted. This information is to be stored in Drill Hub for future reference;
- All surface drill holes that are intersected by underground workings that are producing water will be plugged (usually by grouting) within 36hrs of being intersected; and
- All diamond drill holes will be clearly marked on plans used by underground workers to alert them of their presence.

10 SUMMARY

Mining in the Martha underground project area is planned to extract remnant ore adjacent to historical voids as well as more recently identified ore-zones. Void management utilising the management, monitoring and mitigation controls detailed in this plan will ensure the stability of the historical voids.

The management processes utilising all the controls within the VMP are to be implemented whenever mining activity is within the identified potential zone of influence of any historic voids.

Monitoring of the voids utilising C-ALS instrumentation will improve the knowledge of the nature of the voids and allow for on-going assessments and checks and model validation. Additional monitoring, both near-field and more distal will ensure all developing stability-related issues are identified at an early stage, allowing prompt management and mitigation.

If modern mining activity has the effect of destabilising any historical voids to the extent that the void becomes a risk to surface stability, then the historical void will be stabilised. This will be achieved by backfilling the historical void in question. In effect, the company commits to the on-going stability or stabilisation of the historical voids in relation to the impact of its operations.

11 REFERENCE DOCUMENTS

Document Name	Document ID
Development Design Guide	WAI-415-GUI-003
Probe Hole Management Guide	WAI-415-GUI-002
Probe Hole Management Form	WAI-415-FOR-001
Stability Assessment Process	WAI-415-GUI-003