EXECUTIVE SUMMARY

This study has been progressing, in stages, over approximately two years. It builds on earlier work by GNS Science (GNS) in 2002 and 2003, and uses results of more extensive, detailed investigation and analytical work carried out subsequently by Newmont Waihi Gold (NWG) and their technical consultant PSM.

The August 2002 GNS report formulated a method for estimating the hazard of a sink-hole subsidence reaching the surface from the abandoned underground Martha Mine workings at Waihi. Based on the assessment of risk in the August 2002 GNS report, occupied parts of Waihi located in hazardous areas above the Royal and Empire stopes of the old underground mines, were evacuated. Subsequent sub-surface investigations in the Edward South stope area established that the rock mass is of good quality and the sink-hole subsidence hazard appears very low (GNS 2003).

Since public release of the GNS report in 2002 and the Addendum Report covering investigations and hazard in the Edward South area (GNS 2003), major works in the open pit have included:

- Completion in 2007 of mining at the bottom of the open pit;
- Shifting the Cornish Pumphouse - following slope movements and concerns for the long-term stability of the southern open pit wall, the Cornish pumphouse has been shifted to a safer site closer to Waih;
- Commencement of the stabilising “south wall cut-back” – once the Cornish pumphouse was moved. The south wall cut-back decreases the slope angle of the south wall and is designed to improve its long-term stability. In its later stages, the cut-back excavation also allows the recovery of additional ore from the open pit. To assist with understanding the stability behaviour of the open pit walls, NWG have installed a comprehensive system for the continuous measuring and monitoring of slope deformation, both within and around the perimeter of the open pit.

This report reviews the sink-hole subsidence hazard assessment methodology used in the August 2002 GNS report and applies it to the “Martha” lodes located in the north-east quadrant beyond the perimeter of the open pit. The “Martha” lodes (North Branch, Mary, No. 2 and Martha lodes) were specifically not included in the 2002 subsidence assessment. High, medium and low sink-hole subsidence hazard zones have now been established above these parts of the old underground mine. An evaluation of risk suggests that transient movements, such as vehicle, cycle and pedestrian access are acceptable on roads or tracks established through all the high sink-hole hazard areas. This report also assesses the known creep deformations that have occurred in Waihi since the 2002 GNS reports.

Where the August 2002 GNS report focused on the risk of sink-hole collapses, this report recognises the additional possibility of low hazard, long-term creep movements associated with underground and open pit mining. While it is likely that such creep deformations may occur in parts of Waihi adjacent to the mines, without accurate monitoring information it is not possible to establish if, how much, or over what area the creep movements are actually occurring

Prior to, and while this report has been in progress, ground cracking (a slow creep deformation) has been observed outside the mine area along a lineament in Seddon and Haszard Streets, in part outside the hazard zones outlined by GNS in 2002. These areas of ground cracking are now included in the regular movement monitoring being carried out by NWG.

Slow creep movements are influenced by subsurface rock mass properties and by through-going rock mass defects such as shears and faults, which can weaken with time due to strain softening. As a first approximation, we estimate that the creep movements may possibly extend in the poorer rock mass on the southern and eastern sides of the open pit as far as the angle of draw (~30º from the vertical) from the deepest underground mine workings, and/or as far as the open pit depth from the pit rim. Whichever of these extends the furthest from the mine workings is taken as the probable limit of creep deformation.

Currently it is not possible to determine whether active cracking is due to collapse into stopes, pit wall instability, or a combination of both. It is important for future management of the hazards posed by this movement that its magnitude and trend over time be adequately understood. Complicating interpretation of this movement within the town streets is the fact that chimney caves found during the current Pit 64 cutback appear to lie directly above the stopes rather than aligned along the inferred 30° angle of draw.

The observed ground cracks being formed by lateral and vertical creep movements are small and are presently causing deformation along roads, footpaths and to some properties near the mine on its southern side. In places these movements have required repair and are outside the underground mine low subsidence hazard zone outlined by GNS in 2002. Should the movements continue as they are, or increase and become more widespread with time, the HDC and others will require accurate survey monitoring information to evaluate and assess what actions they may need to take. Survey monitoring is recommended to determine the actual rate and extent of creep movement as it occurs, information that is needed to assess potential damage to buildings and services.

Within the wider Waihi township there are also small, non-damaging, vertical ground settlements due to ground water lowering for the mine pit excavation. These settlements are being monitored by six monthly levelling surveys.

A key recommendation of this report is the establishment of accurate lateral and vertical monitoring in areas of Waihi near the pit. It will assist with better understanding the ground deformations associated with subsidence of the old underground mine workings and movements outside the mine close to the southern highwall. The monitoring system recommended is to install and survey regularly spaced metal pins along lines extending out from and around the cut-back southern, and the eastern pit rim, and adjacent to the underground mine stopes. Survey monitoring is not recommended beyond the northern and western walls of the open pit where pit wall monitoring by NWG shows there are no significant movements.

We recommend accurate survey monitoring along a series of points, initially established along road kerb lines to allow easy access for regular re-surveying. We recommended including in the new survey lines as many as possible of the points that are used for the six monthly settlement monitoring surveys in Waihi. The accurate surveying is required to determine both vertical and lateral creep movements. A similar ground deformation survey in Taupo has achieved good accuracy by using precise levelling for vertical monitoring in combination with an RTK GPS survey for lateral movement monitoring, along lines of points. It is a model which should provide input data of sufficient accuracy from which evaluate creep movements that may occur in Waihi.

It is recommended that the survey monitoring points are established without delay, so that changes in movement rates which could be associated with on-going works, such as the south wall cut back, or to later filling the recreational lake, are recorded. Once an initial network of points is established and re-surveyed, the deformation monitoring frequency and extent can be reviewed and adjusted to suit the locations and movement rates being observed.

1.0 INTRODUCTION

1.1 Mining Background

The Martha mine at Waihi was one of the great gold mines of the world. Underground mining at Martha Hill began in 1882 and by the time the mine closed in 1952, some 12 million tonnes of ore had been mined to yield 1,082 tonnes of gold-silver bullion. Underground mining extracted ore from four main sub-parallel lodes (the Martha, Welcome, Empire and Royal) together with numerous branch and cross lodes e.g. (the Edward). The lodes are sub-vertical or steeply dipping and are quartz/ore infillings of extensional faults and fractures. Early mining in stopes was by the cut and fill method, but after 1908 this method was largely replaced by shrink stoping. After 1914 the shrink stopes were generally not backfilled, but left open. Although late in the retreat mining phase of the mine life, some stopes were apparently back-filled to remove the crown pillars, without this information being entered onto the mine records. Overall the workings reached a total depth of 575m on sixteen levels with access by seven main shafts, although many other shafts were developed for ventilation and exploration.

Exploration drilling between 1980 and 1984 proved large reserves of lower grade ore which could be mined from an open pit located within the underground mine area. In 1988 mining recommenced and in 1997 the open pit was extended to target deeper reserves. The pit was scheduled to close in 2006, but the south wall cut-back, designed to improve the long-term stability of the south wall, will now keep the open pit mining operations running for about four more years until 2010. At completion the pit will be an oval shape about 640m wide, 950m long and 250m deep. After closure a recreational lake is proposed for the open pit.

1.2 Mining Subsidence Review

The sudden formation of ground collapse craters near Upper Seddon Street in 1999 and the similar, highly publicised Barry Road subsidence in 2001, dramatically alerted people to potential hazards associated with the former deep underground mining at Waihi. The August 2002 GNS Report on the Stage II investigations of the Waihi underground mine workings, focussed on this type of sudden chimney collapse subsidence crater. That report concentrated on the probability of occurrence and the risk to public safety of the formation of a sudden sink-hole subsidence migrating to the surface from the worked out Edward South, Royal and Empire stopes of the old underground mine.

Although it was recognised in the August 2002 GNS report that slow creep movement of the ground surface is common where underground mining, or the removal of underground fluids such as oil, water or geothermal steam has taken place, this type of subsidence appeared to be of minor significance and risk compared to the sudden collapse craters. Since 2002, the observation of surface creep deformation in the pavements and road surface of Seddon and Haszard Streets (Photos 1 to 7) has raised concern about the causes and potential risks of these ground movements.

Report Objectives. GNS Science (GNS) and URS Corp NZ Ltd. are presently engaged by Hauraki District Council (HDC) to review the 2002 GNS report, and if appropriate to extend the sink hole risk assessment methodology to the Martha Lodes, and to report on the ground cracking now being observed outside the sink-hole subsidence hazard zones outlined in 2002.

Photos 1&2 Cracking in Haszard Street with an unusual north (pit wall) side up and small right lateral component, suggestive of large "block" movement on a through-going rock mass defect.

Photos 3&4 Cracking in Seddon Street appears to be extensional but also has a small right lateral component of movement in the pavement above.

As well as the potential sudden collapse craters, there was recognition in the August 2002 GNS report of the small, relatively predictable surface settlements of up to 260mm due to lowering of the groundwater table affecting the subsurface geology. However, there was a lack of recognition of the possible extent of gradual vertical, lateral and rotational adjustments of the ground due to the earlier deep underground mining, later combined with possible influences from the excavation of the open pit. Gradual ground movements began and were recorded during the era of underground mining, most notably about the “milking cow” subsidence zone on the main Martha lode, but also in the mine shafts and other parts of the underground workings. Early geologists noted that such movements could be concentrated on through-going rock mass defects, such as faults. It is noted that much of the ore mineralisation occurred along faults and shears that were sometimes cut by later non-mineralised faults. In places the creep movements of the deep underground mine era are likely to have been influenced to some degree more recently by the excavation of the large open pit, more apparent in the poorer rock mass of the south wall area of the pit than the better rock mass of the north wall.

The accurate ground surface monitoring recommended below is intended to assist with the assessment and interpretation of the causes, and in determining the extent of the slow creep ground movements that are occurring in Waihi near the mine areas.

1.3 Previous Reporting

Following the ground collapse which formed the 1999 subsidence crater in reserve land near Seddon Street, the HDC assembled the Waihi Underground Mines Technical Working Party (TWP) and assigned it the task of investigating the abandoned mine workings, the likely cause of the collapse events, the implications for Waihi and the possible management of affected areas. In September 2001 GNS was contracted by HDC to compile a GIS dataset of the underground mine workings at Waihi using all available data. Reasonably good records from various sources were used by GNS to build a three dimensional digital model of the mine (GNS Feb. 2002).

The subsidence crater collapse in a developed urban part of Waihi at Barry Road in 2001, heightened the concern regarding the threat to public safety and other issues posed by further similar collapses. The TWP commissioned GNS to assess the causes of the subsidence crater collapses for Edward South, Royal and Empire lodes, determine where further such collapses might occur in the future on these lodes, particularly outside the mine boundary, and to investigate what could be done to mitigate their affects (August 2002 GNS report). The “Martha” stopes were specifically excluded from the August 2002 GNS study, but are included in this study.

Newmont Waihi Gold (NWG) have built up an extensive dataset of the old underground mine workings combined with later drilling investigations, geological records and a large quantity of their “in house” open pit information. This valuable dataset has been utilised and extended by Technical Consultants employed by NWG. In particular there have been comprehensive studies such as the 2002-2003 Geotechnical Investigations (PSM125.R28), Pit Closure Studies (PSM125.R34) and the Pump house Relocation: Geotechnical Risk Assessment of Site 4A (PSM125.L88).