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TOP TIPPERARY TAILINGS STORAGE FACILITY

Active Fault Hazard Assessment

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REPORT

Report Number 1078301051.002-R100E

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Executive Summary

This report describes the results of an evaluation of the likelihood of the Macraes Fault rupturing and affecting the proposed Top Tipperary tailings storage facility (TTTSF) at the Macraes Gold Project, East Otago. The Macraes Fault that underlies the proposed impoundment and embankment was assumed to be a potential earthquake source in a 2005 seismic hazard study completed for OceanaGold by GNS Science.

The location of the Macraes Fault in this study has been identified from interpretations of surface lineaments, drillhole logs, exposures in the Innes Mills and Frasers pits, aerial electromagnetic survey, and mapping of bedrock schistocity orientation. The fault crosses the northern side of the proposed TTTSF impoundment, including the main embankment and western saddle embankment footprints.

West of the proposed impoundment, the Macraes Fault forms a subdued, linear step in the topography with the ground rising as much as 80 m above the adjacent North Branch Waikouaiti River valley. The higher ground on the north side of the fault represents the catchment divide between Deepdell Creek and North Branch Waikouaiti River.

At the main embankment site there is no surface expression of the Macraes Fault. In the embankment footprint the schist /cover soil contact slopes gently (<2° slope) to the south and there are no significant scarps, steps or warps in the surface. The western embankment footprint slopes more steeply to the south in the vicinity of the Macraes Fault (<5° slope), although there are no significant scarps, steps or warps.

West of the impoundment, the slope across the Macraes Fault steepens (about 10° slope angle). Trenches across the fault approximately 400 m west of the impoundment exposed a 400 m wide drag fold and numerous faults and foliation shears within the Mesozoic Era bedrock schist. Trench excavations did not expose any offset or disturbance of the surficial soils. The age of the surficial soils is unknown, however a nearly continuous 0.6 to 1.0 m thick loess layer inferred to be at least 11,500 years old is undisturbed across an exposed fault, and appears unaffected by tilting or other tectonic deformation. Schist immediately beneath the soil cover has been dated at about 25,000 years old using cosmogenic nuclide techniques and this is consistent with the soil age and is assumed to be an approximate maximum age of the surficial materials.

A trench excavated along the main embankment footprint crosses the Macraes Fault. This trench exposes faults interpreted to be part of the Macraes Fault across a zone about 550 m wide. No offset of the rock/soil contact was identified.

The surface expression of the Macraes Fault is very subdued compared to other structures that have reported tectonic activity during the Holocene (last 10,000 years). We conclude that the Macraes Fault has not ruptured to the ground surface during the last 11,500 years. Furthermore, no evidence of any late Quaternary deformation of the Macraes Fault has been found. We conclude that the Macraes Fault has not had surface fault rupture or other near-surface deformation for at least the last 11,500 years, and the annual exceedence probability of rupture of the Macraes Fault is significantly lower than 1/10,000 (0.0001). However, given its location and orientation with respect to other faults that are thought to be active faults, the Macraes Fault remains a potential source structure for earthquake generation, though with a low likelihood as described above.

If the Macraes Fault and Billy's Ridge were to rupture co-seismically, the estimated total maximum offset, based on empirical relationships would be 1.92 m, which could equate to 1.4 m vertically and 1.4 m horizontally. It is possible that the deformation would occur on more than one fault structure within the mapped zone of deformation, though the predicted total deformation would be distributed among multiple structures.

1.0 INTRODUCTION

1.1 Background

OceanaGold (New Zealand) Limited (OceanaGold) requires an additional tailings storage facility (TSF) at the Macraes mine site in East Otago, New Zealand (Figure 1, Photograph 1). The purpose of the TSF is to impound mine tailings through to the projected life of the mine. A recent study by Golder Associates (NZ) Limited (Golder, 2010) of tailings storage options identified a new site (the "Top Tipperary" site - TTTSF) as having a suitable geometry to store the anticipated volume of tailings. The proposed TTTSF comprises an embankment approximately 2.9 km long across the upper catchment of Tipperary Creek and a 1.3 km long embankment along the catchment divide between Tipperary Creek and Waikouaiti River on the western side of the impoundment (Figure 2). The maximum height of the proposed embankment is about 70 m, although most of the embankment will be less than 40 m high.

The Macraes Fault has been identified as an earthquake source by Litchfield et al (2005). The fault strikes approximately east-west (Macraes Grid) through the proposed TTTSF embankment and impoundment area (Figure 2). The Macraes Fault offsets the Hyde-Macraes Shear Zone, the main ore body mined by OceanaGold. The presence of the Macraes Fault within the impoundment area and beneath the proposed embankment is of geotechnical significance to the TTTSF feasibility and design. If the Macraes Fault is an active fault, as suggested by Litchfield et al (2005), then future surface fault rupture could result in metre-scale differential displacements along the fault trace or traces and large, near-field earthquake ground shaking in association with these fault movements. Confirmation of potential surface fault rupture could have a significant effect on the type of dam design and construction, requiring either the abandonment of the proposed site or incorporation of design elements such as additional or thickened filters and drainage elements to accommodate fault movement.

In dam design it is common that earthquake design criteria are determined such that the dam must be able to cope with a design earthquake event without uncontrolled release of the reservoir. Where a foundation fault is present, design criteria are determined that relate to the likelihood of fault displacement and the expected consequences of failure of the structure. These criteria identify an annual exceedence probability against which the average return period for a foundation fault can be evaluated. Typically, the design annual exceedence probability might be in the range 1/1,000 to 1/10,000 depending on the potential impact category of the structure. If the annual exceedence probability of foundation fault rupture is greater than the design criteria, then the dam must incorporate design features that will allow the dam to accommodate the predicted fault deformation without catastrophic loss of the reservoir.

At the time of writing this report[1], the design criteria for the TTTSF with respect to foundation fault displacement had not been specified. It is anticipated that the foundation fault design criteria and an evaluation of the findings of this study relative to the criteria will be reported in the preliminary dam design report.

1.2 Peer Review

The author of this report (Tim McMorran, Principal Engineering Geologist, Golder Associates (NZ) Limited) has experience in evaluation of tectonically active structures with respect to dams. The report has been technically reviewed by Dr Alan Hull, international Seismic Hazard Practice Leader for Golder Associates.

This report has been externally reviewed by Don Macfarlane, Senior Principal Engineering Geologist at URS New Zealand Limited, who has extensive experience in active faults that affect dams.

Independent peer review has also been undertaken by David Barrell and Russ Van Dissen from GNS Science, who both have extensive experience in paleoseismicity, seismic hazard assessment for dams, and regional geology and geomorphology.

[1] This report is provided subject to the limitations in Appendix C.

During the course of the study the site was visited by Don Macfarlane, David Barrell and Russ Van Dissen to gain an understanding of the proposed TTTSF and the findings of the study. Discussions on regional geology and evidence for Quaternary fault movement in east Otago have been had between the author and Prof Richard Norris at Otago University.

1.3 Scope of Work

Golder was contracted by OceanaGold to evaluate the activity of Macraes Fault (letter proposal to OceanaGold dated 15 April, 2010). This report summarises the work undertaken, the principal data collected and analysed and our investigation results and conclusions.

All orientations presented in this report are with respect to "Macraes Grid", where "Macraes North" is equivalent to true northwest.

1.4 GNS Seismic Hazard Study

In 2005, the Institute of Geological and Nuclear Sciences (now GNS Science) completed a site-specific probabilistic seismic hazard analysis (PSHA) for the Macraes Gold Project (Litchfield et al, 2005). The objectives of the PSHA were to:

- Compile an earthquake source catalogue based on existing data held by GNS Science;
- Identify the major earthquake sources contributing to the seismic hazard;
- Compute probabilistic ground motions for the Macraes mine site for return periods of up to 10,000 years; and
- Provide suitable earthquake acceleration time histories for engineering evaluations of the TSF.

The GNS Science catalogue of potential earthquake sources includes two major fault structures that are relevant to the current study— the Taieri Ridge Fault and the Billy's Ridge Fault (with possible extension along the Macraes Fault) (Figure 1, Photograph 2). The trace of the Taieri Ridge Fault is located approximately 6 km north of the proposed TTTSF. Research by Norris and Nicholls (2004) reported Late Quaternary (last 125,000 years) surface deformation on this fault. The Taieri Ridge Fault has a mapped length of 35 km and trends east-west. Natural exposures indicate that the Taieri Ridge Fault is a north-dipping reverse fault that vertically offsets the Late Cretaceous erosion surface ("peneplain") by 150 m (Norris and Nicholls, 2004). Several basement fault exposures are noted by Norris and Nicholls (2004) including moderately and steeply dipping faults to the east and west.

The Billy's Ridge Fault and Macraes Fault are two named faults that are continuous along strike (Figure 2). The faults have a total combined length of 38 km, and are approximately parallel to the Taieri Ridge Fault about 5 km to the west. The Billy's Ridge Fault has a similar geomorphic expression to the Taieri Ridge Fault — i.e. an approximately linear, asymmetric, northwest-facing ridge about 150 m high. Litchfield et al (2005) infer that Billy's Ridge Fault is a potential earthquake source because it is similar in orientation and geomorphic expression to the Taieri Ridge Fault, which they consider to be an active seismic source in their site-specific PSHA. However, surface ruptures of late Quaternary age have not been documented for either the Billy's Ridge Fault or Macraes Fault. The Billy's Ridge Fault extends to within about 10 km southwest from the proposed TTTSF.

Litchfield et al (2005) infer that Macraes Fault is a potential earthquake source because it:

a) offsets the peneplain and the Hyde-Macraes shear zone, and

b) is a structural continuation of Billy's Ridge fault that they consider to be active seismic source for their PSHA.

The trace of Macraes Fault as illustrated by Forsyth (2001), Litchfield et al (2005), and the GNS Science NZ active faults database (http://www.gns.cri.nz/af) crosses the proposed TTTSF impoundment footprint approximately 500 m from the left (northern) abutment of the dam. Specific investigation of the location and activity of Macraes Fault, including geomorphic mapping or subsurface investigations, was beyond the scope of the Litchfield et al (2005) study.

The probabilistic seismic hazard model developed by Litchfield et al (2005) includes active fault characterization parameters of mean, maximum and minimum estimates for fault length and depth, fault dip and slip rate. From these estimates, earthquake magnitude and recurrence intervals are calculated. These values are presented in Table 1. The Litchfield et al (2005) probabilistic model includes likelihood of rupture weighting factors for the three possible fault length options for Billy's Ridge Fault (i.e. (i) excluding Macraes Fault, or including (ii) part or all (iii) of Macraes Fault). Utilising these 'best inference' fault characteristic parameters, Litchfield et al. (2005) calculated the average recurrence interval for a surface rupturing earthquake on the Billy's Ridge Fault plus the full length of the Macraes Fault as 6,375 years. However, there is a very large uncertainty as encapsulated by the range between minimum (3365 years) and maximum (25,798 years) values.

Table 1: Potential earthquake source parameters (Litchfield et al, 2005).

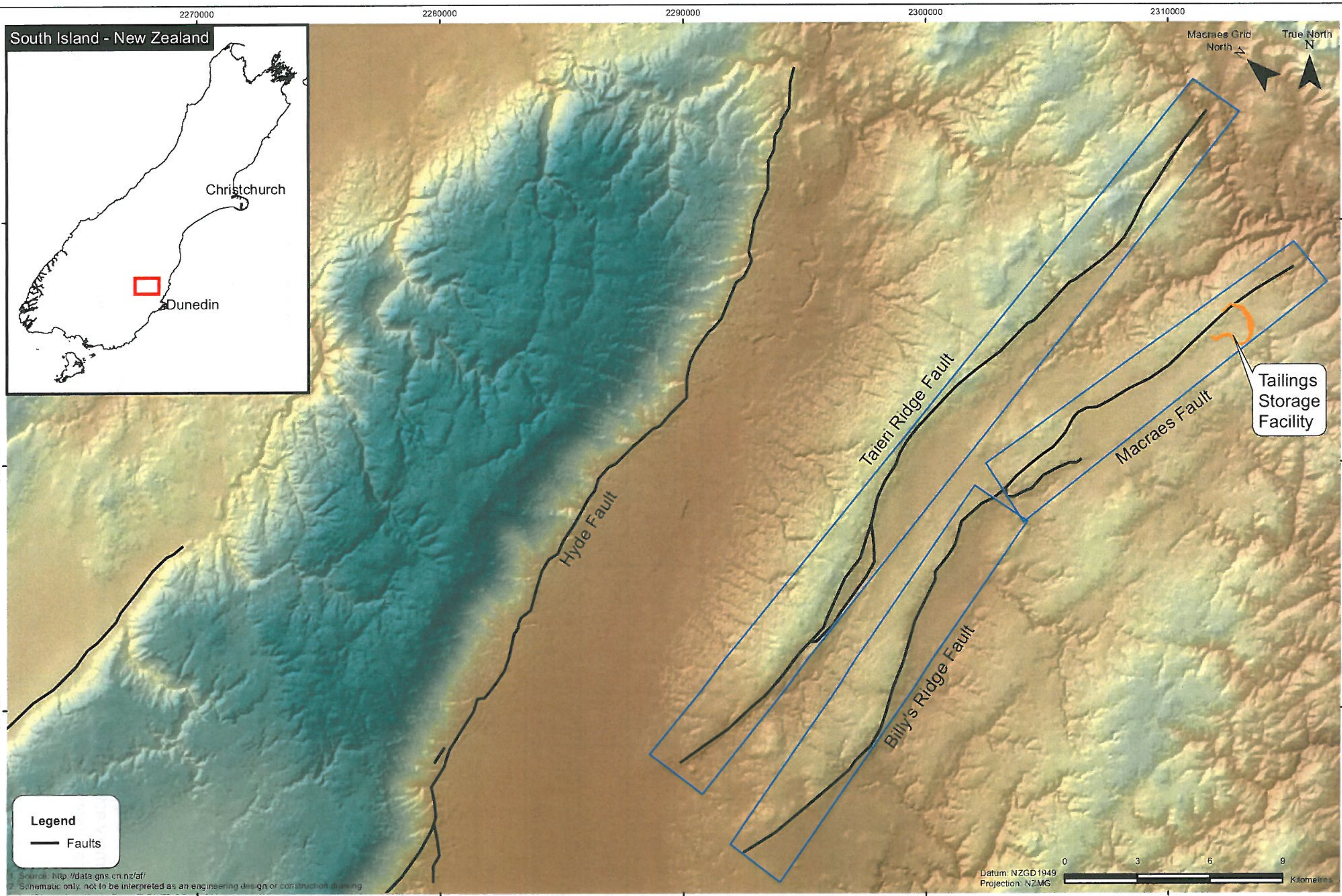
Parameter	**Potential Earthquake Source [presented as mean (min – max)]**			
Fault Name	Taieri Ridge Fault	Billy's Ridge Fault (with or without Macraes Fault)[1]		
		(Option i)	(Option ii)	(Option iii)
Length (km)	35 (28 – 42)	22.4 (no range)	31 (no range)	38 (no range)
Dip (degrees°)	45 (30 – 60)	45 (30 – 60)	45 (30 – 60)	45 (30 – 60)
Dip direction (Macraes grid)	Northwest	North	North	North
Seismogenic thickness (km)	15 (13 – 17)	15 (13 – 17)	15 (13 – 17)	15 (13 – 17)
Slip rate (mm/year)	0.25 (0.05 – 0.31)	0.25 (0.05 – 0.31)	0.25 (0.05 – 0.31)	0.25 (0.05 – 0.31)
Magnitude (M_w)	7.06 (6.85 – 7.25)	6.86 (6.72 – 7.03)	7.00 (6.86 – 7.19	7.09 (6.94 – 7.26)
Recurrence interval (years)	5901 (3046 – 22,371)	4736 (2506 – 19,723)	5572 (3040 – 25,052)	6375 3365 – 25,798)
	Displacement assessment (m) (after Wells and Coppersmith, 1994) Mean value, 84th percentile value given in brackets			
Average displacement (m)[2]	0.89 (1.32)	0.83 (1.24)	0.87 (1.30)	0.90 (1.34)
Maximum displacement (m)[3]	1.23 (1.89)	1.14 (1.75)	1.20 (1.85)	1.25 (1.92)

[1] The weighting factors of these three fault length options, based on judgement of the authors are 0.5 for the Billy's Ridge Fault alone, 0.3 for Billy's Ridge Fault and Macraes Fault west of the Hyde-Macraes Shear Zone and 0.2 for Billy's Ridge Fault and all of the Macraes Fault. Only "Option 3" affects the proposed TSF as a potential foundation fault hazard.

[2] log(average displacement) = -0.60 + 0.31 * log (surface rupture length); standard deviation = 0.43.

[3] log(maximum displacement) = -0.44 + 0.42 * log (surface rupture length); standard deviation = 0.44.

Despite the earthquake source parameters described in Litchfield et al (2005), no evidence of late Quaternary activity of the Macraes Fault has been presented, and evidence that the nearby Taieri Ridge Fault has been active during the late Quaternary is the basis for inferring that the Macraes Fault may also be active.



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TITLE POTENTIAL EARTHQUAKE SOURCE STRUCTURES NEAR TO TOP TIPPERARY TSF

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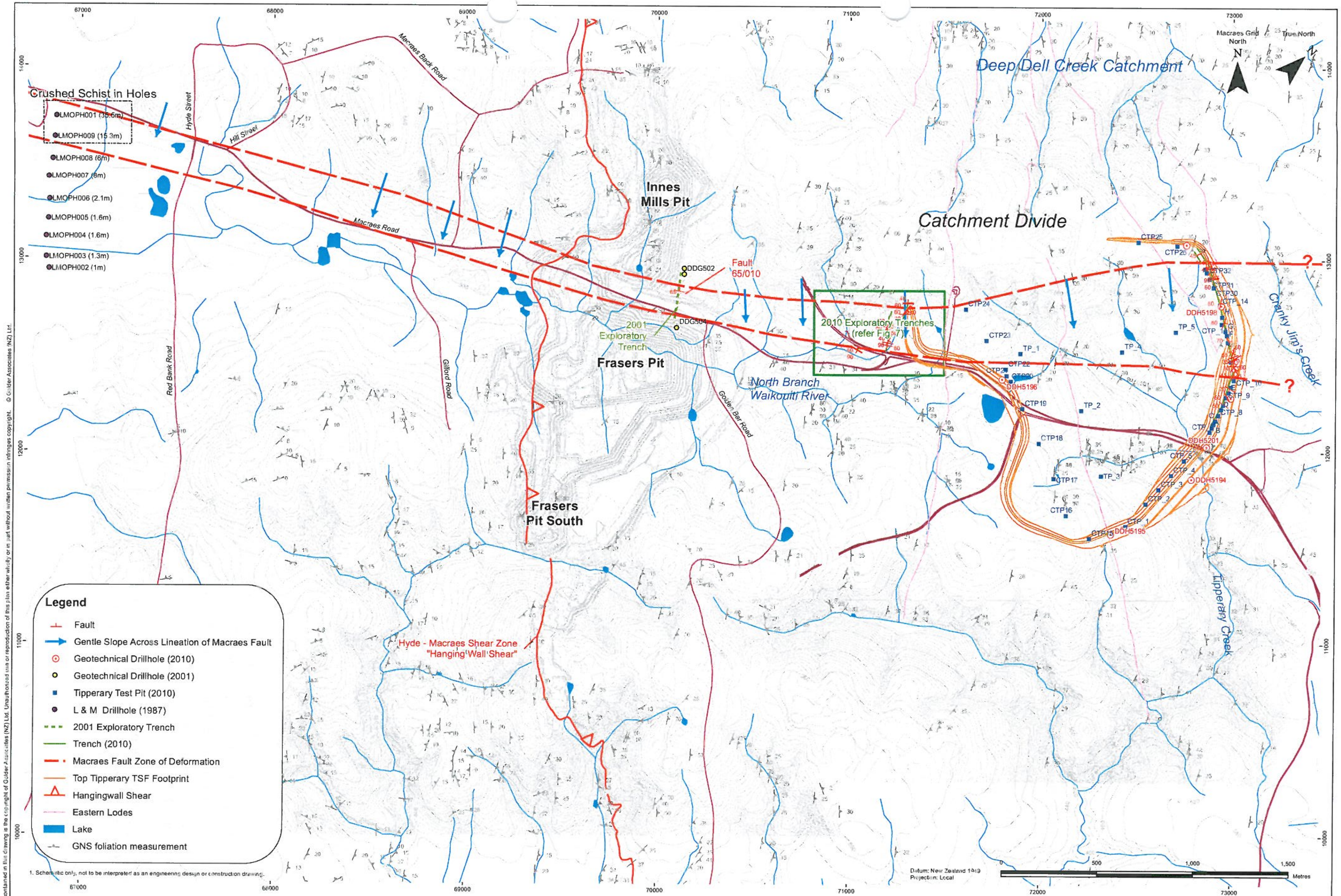

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PLAN SHOWING SITE LAYOUT AND KEY GEOLOGICAL FEATURES

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1.5 Investigation Methods

The investigations described in this report were developed to characterise the location and width of the Macraes Fault, and to attempt to identify any evidence in cover soils that could indicate late Quaternary deformation or surface rupture of the fault. The investigations included compilation of geological data held by OceanaGold (a large volume of geological data has been accumulated by the exploration and operations departments) and readily available sources in the open literature (e.g. Craw & Chappell 1999; Forsyth, 2001; Norris & Nicolls, 2004). Detailed geological and geomorphic mapping was undertaken specifically for this investigation in the area of the proposed TSF and along the inferred trace of the Macraes Fault. Aerial photographs of different ages held by OceanaGold and available digital terrain models were reviewed to support the field investigations.

Stereopairs of aerial photographs were supplied by OceanaGold for this assessment:

- T08 Run 1: 0215, 0216, 0217 (Terralink International, flown 2005)
- T09 Run 2: 0227, 0228, 0229, 0230 (Terralink International, flown 2005)

A programme of geotechnical test pits and drill holes was completed as part of the investigation to support design of the TTTSF (Figure 2). Test pit and borehole logs were reviewed for any information relevant to the location or characteristics (e.g. shear zone orientation) of the Macraes Fault. The extent of investigations and the main geologic features are summarised in Figure 2. The findings of the geotechnical investigations are presented in a separate report (Golder, 2011).

2.0 REGIONAL GEOLOGICAL SETTING

The eastern area of Otago is underlain principally by Mesozoic-age schist of the Torlesse Terrane (Forsyth, 2001). Weathering and erosion over a long period formed the distinctive low relief surface of the Otago peneplain. Deposition of alluvium rich in quartz gravel occurred in the vicinity of Macraes Flat during the Eocene Epoch (56 to 34 million years ago) (Hogburn Formation). Miocene-age volcanic rocks were also widespread through this part of Otago. Several radiometric ages have been obtained from these volcanic rocks near Macraes Flat, including Stag Hill 6 km west of Frasers Pit, and Brothers Peaks on Taieri Ridge, and consistently returned ages of 15 million years (Coombs et al 2008). This indicates that 15 million years ago, schist in the Macraes area was still covered by sedimentary rocks, over which volcanic lavas were being erupted. Post-Miocene tectonic uplift, faulting and folding, and coeval erosion removed much of the formations deposited in the Tertiary Era, along with an unknown thickness of Mesozoic Era schist. The resulting, present-day landscape in the Macraes area comprises widespread outcrop of schist with thin, patchy accumulations of Quaternary-age (i.e. less than 2.5 million years) deposits including windblown loess silt, alluvial sediments and colluvial debris on slopes.

Prominent in the Otago landscape are wide areas of gently undulating topography that represent a Late Cretaceous age erosion surface or "peneplain". Linear ranges or ridges, such as the Rock and Pillar Range or Taieri Ridge are interpreted to have been elevated by fault or fold movements that have offset or buckled the peneplain. Some of these faults and folds show some evidence of late Quaternary tectonic deformation (Norris and Nicolls, 2004).

The general landscape in the vicinity of the Macraes Gold Project is dominated by gently undulating peneplain surfaces (generally 500 to 580 m elevation). The North Branch of the Waikouaiti River flows to the west along a wide, shallow valley across the lineament of the Macraes Fault before turning south into a 150 m deep incised gorge. Tributaries of Deepdell Creek and Tipperary Creek have steep sided channels, incised tens of metres into the schist.

Of particular significance to this investigation are thin deposits of alluvial sediments beneath the floor of the Macraes Flat depression. These were described in the vicinity of what is now Frasers Pit by Craw and Chappell (1999) who documented approximately 5.5 m of gravel, sand and silt overlying schist. Organic materials within these sediments were radiocarbon dated, indicating an age of approximately 33,000 calendar years before present (BP) for the lowermost sediments, while a sample about two-thirds of the way up the deposit returned an age of about 15,000 calendar years (original radiocarbon ages converted using INTCAL09 calibration programme; Stuiver et al 2005). Although alternative interpretations of the significance of these ages were discussed in detail by Craw and Chappell (1999), the preference in this report is to adopt the simplest interpretation that both ages are reliable, and indicate that these alluvial sediments were deposited from a little more than 33,000 years ago, until somewhat more recently than 15,000 years ago. Craw and Chappell (1999) also show that the alluvial sediments overlie the Macraes Fault west of Macraes Flat. No offset of the sediments is shown and no known fault scarp crosses the alluvial sediments.

3.0 REVIEW OF THE MACRAES FAULT

3.1 Topographic Expression

Billy's Ridge is a prominent east-west trending ridge uplifted to the west of a late Cenozoic fault/fold, whose existence is demonstrated by remnants of Eocene to Miocene rocks preserved on the schist on the eastern, lower side (Forsyth 2001). The extent and variation in the height of the topographic step across the fault is shown in four topographic cross sections in Figure 3. The vertical offset at Billy's Ridge to the west is between about 150 m and 200 m and decreases to a negligible offset at the catchment divide between Nenthorn Stream and North Branch Waikouaiti River, approximately 7 km west of the TTTSF (Figure 3). At this location the Billy's Ridge Fault ends. To the northeast, a topographic step commences and rises from about 30 m high near Macraes Flat to as much as 80 m adjacent to Frasers Pit. This topographic step has long been interpreted as an offset of the peneplain by late Cenozoic movement of the Macraes Fault. The pre-mining topographic relief across the fault decreases to the east of Frasers Pit, and the topographic expression also changes from a relatively sharp step in the vicinity of the open pits to a gentle slope at the site of the proposed impoundment (Photographs 3 & 4). Figure 4 presents three topographic cross sections normal to the strike of the Macraes Fault and across the proposed TTTSF impoundment area.

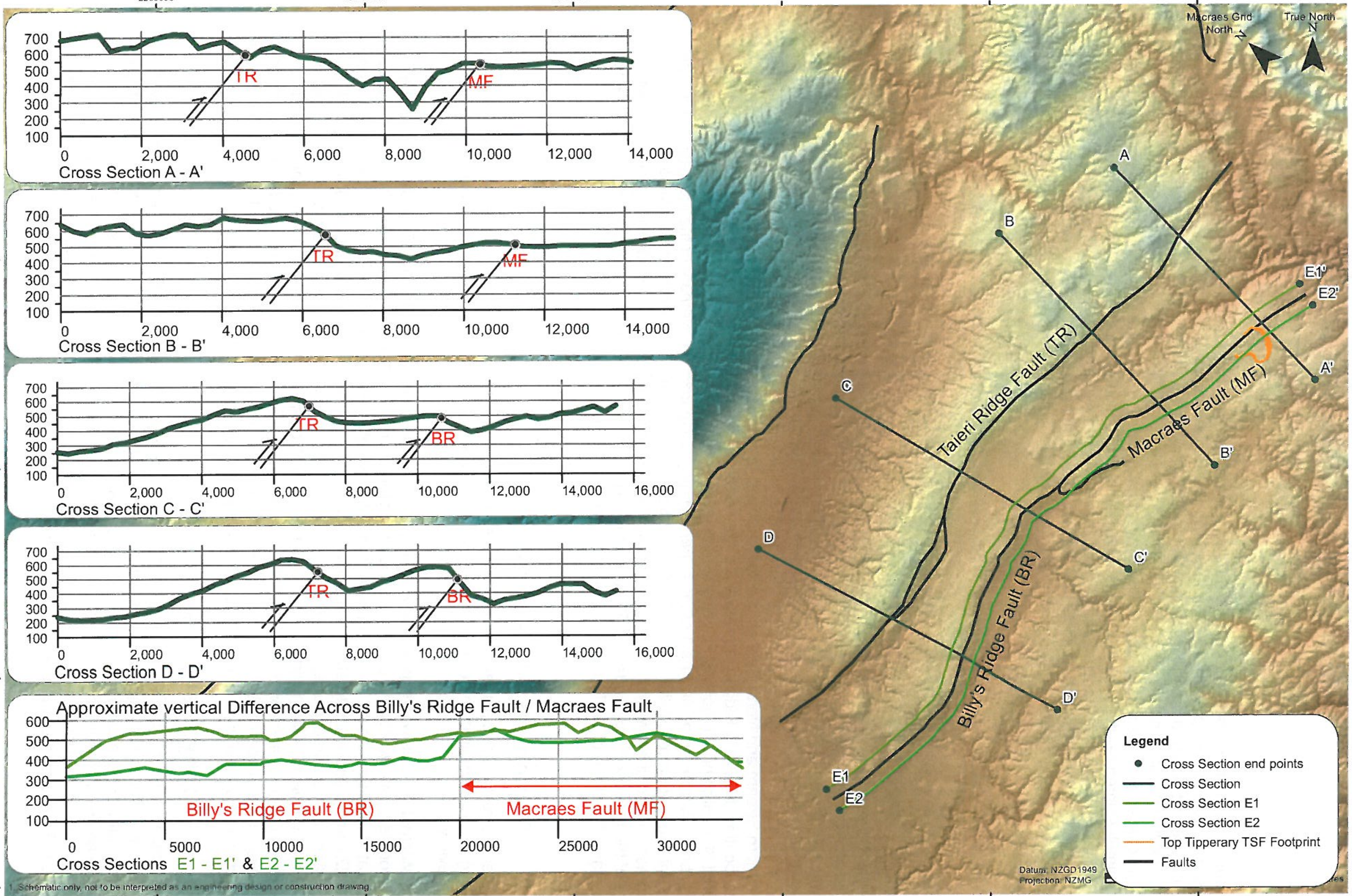
3.2 Geological Characteristics

Golder has reviewed observations from surface outcrop, exploratory trenches and OceanaGold exploratory drilling results to develop a detailed description of the Macraes Fault. This section describes the results of our review.

The Macraes Fault is well expressed by changes in foliation orientation within the Mesozoic schist. The foliation defines a monocline or drag fold as illustrated in cross section in Figure 5. The monocline is also illustrated in Figure 2 as a zone of drag folding of the hanging wall shear of the Hyde-Macraes Shear Zone (HMSZ) on the approximate alignment of the open pits. The zone of foliation folding associated with the Macraes Fault is approximately 400 m wide (normal to the fault), and the HMSZ is offset by about 250 m vertically. Within the 400 m wide zone, foliation is rotated to dip 60° to 80° south east in contrast to the regional foliation orientation that dips 20° to the east. A detailed assessment of the Macraes Fault drag fold has been made as part of the trenching investigation (see below). The assessment confirms that foliation is folded across a zone up to about 550 m wide in the vicinity of the TTTSF (Figure 2).

3.3 Geophysical Constraints

The location of the Macraes Fault shear zone can be interpreted from an airborne EM survey provided to Golder by OceanaGold (Figure 6). The aeromagnetic survey indicates a corridor of low conductivity material in the vicinity of the mapped location of the Macraes Fault (as well as other recognised faults). We interpret the low conductivity corridor to indicate the location of the Macraes Fault within the TTTSF impoundment area (Figure 6). The low conductivity zone is consistent with the location, orientation and width data of the Macraes Fault based on surface and subsurface geology.



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TITLE REGIONAL TOPOGRAPHIC CROSS SECTIONS SHOWING FAULT OFFSET

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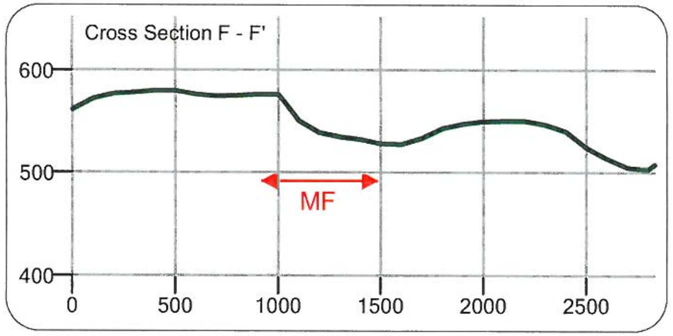
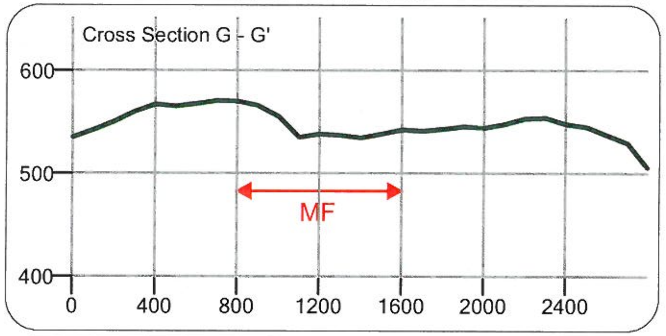
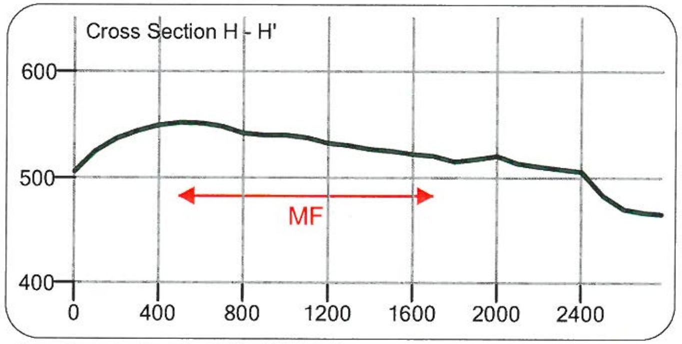


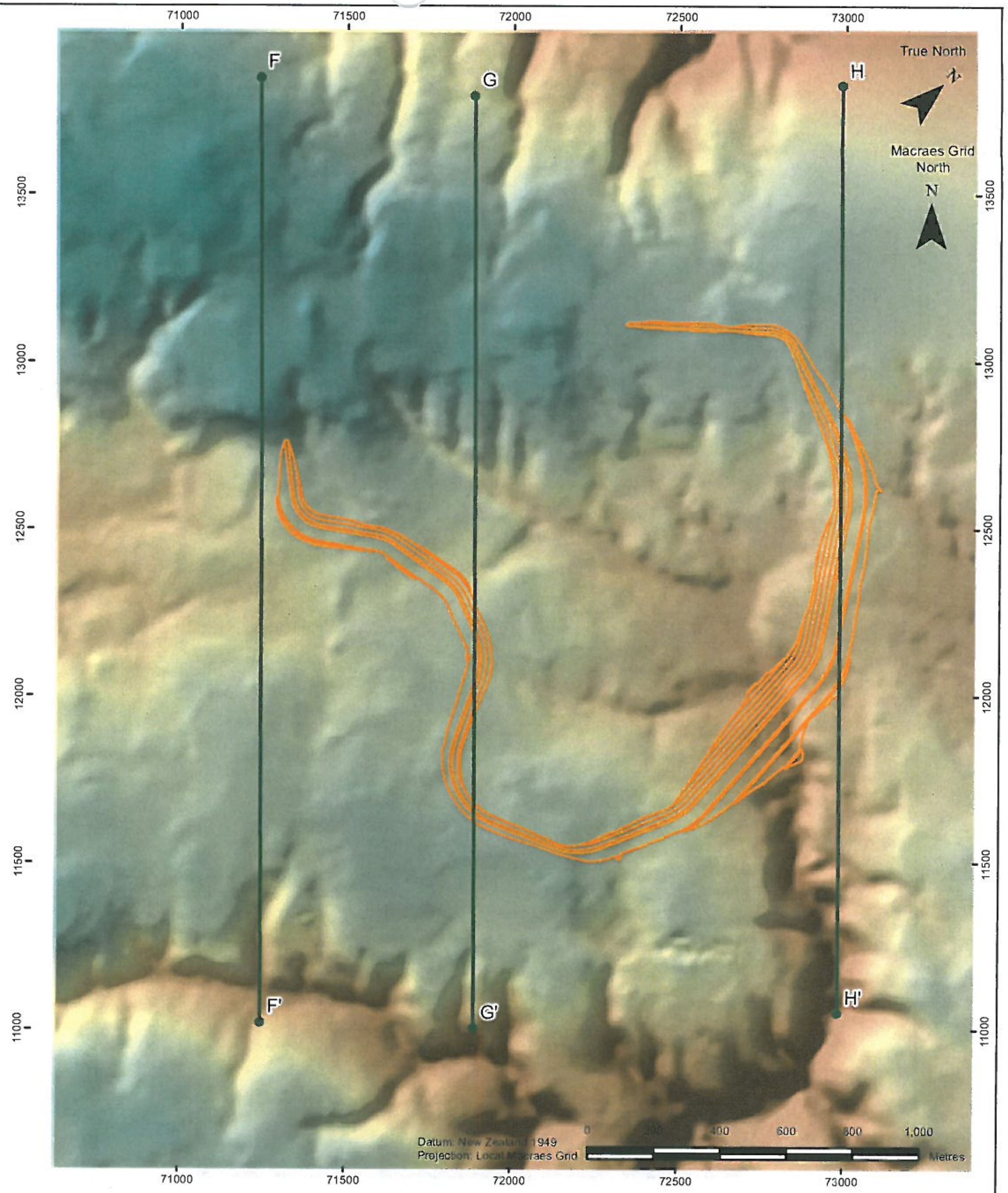




Legend

- Cross Section End Points
- Cross Section
- Top Tipperary TSF Footprint

1. Source: http://data.gns.cri.nz/af/
2. Schematic only, not to be interpreted as an engineering design or construction drawing.



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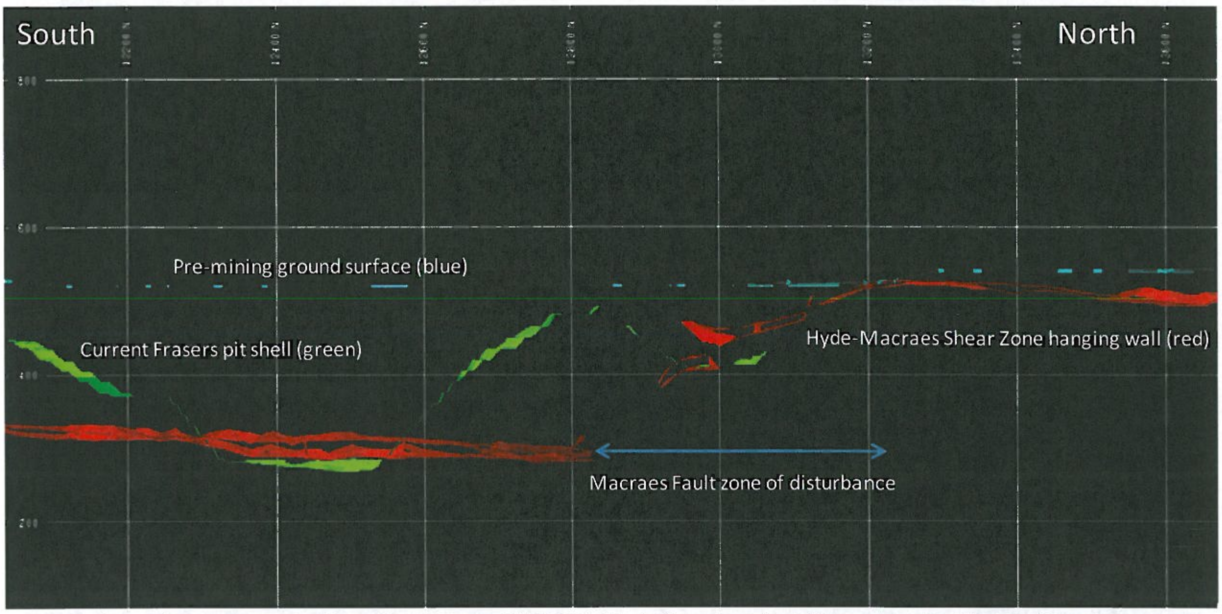
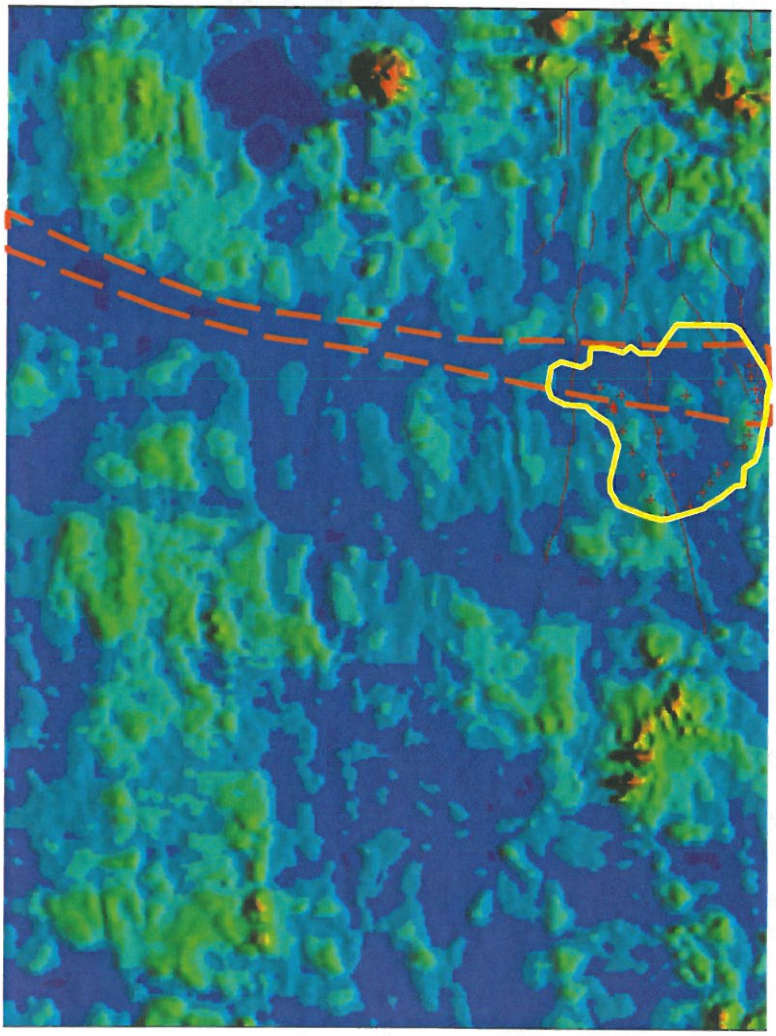


North trending cross section through HMSZ on grid E69800. The indicated vertical offset across the HMSZ is about 250 m over a zone about 400 m wide. This corresponds well with observations of deformation of foliation in surface observations.

Figure 5: Structural cross section across Macraes Fault, supplied to Golder by OceanaGold.



Aerial EM survey showing the inferred location of Macraes Fault (orange dashed zone) relative to the proposed TTTSF site (yellow area). The inferred fault zone corresponds with the approximate location determined from mapping foliation orientations in the schist .

Figure 6: Results of aerial electromagnetic survey, supplied to Golder by OceanaGold.

3.4 Location and Width of the Macraes Fault Zone

A series of exploratory drill holes were advanced across Macraes Flat using an auger in soils and a tricone in the deeper part of the holes (Farmer (1989) - Figure 2). The drill holes encountered schist at up to 5.5 m depth overlain by "clay" and "clay-bound grit" (drill holes LMOPH002 to 008). Two holes drilled within about 200 m of Macraes Road were advanced to 15 m and 35 m depth using a tricone. Farmer (1989) describes the materials as "pug, clay, schist fragments and quartz" and interprets this material as alluvium. Because these holes were located across the lineament that marks the trace of the Macraes Fault, we infer that the "pug, clay, schist fragments and quartz" that they encountered are fault-sheared schist associated with the Macraes Fault rather than alluvium.

Photograph 1 shows a separation between Frasers Pit and Innes Mills Pit, along which the Macraes Road passes. The adjacent slopes in Frasers Pit and Innes Mills Pit were subject to poor ground conditions relating to weak sheared rock associated with the Macraes Fault Zone. The width of this zone of faulted ground was approximately 400 m. An exploratory trench excavated by OceanaGold across the Macraes

Fault in 2001 (location shown in Figure 2) defined a 400 m wide zone of deformation including a north dipping (65/010) fault near to the northern margin of the fault zone.

East of the HMSZ no natural exposures of large crush zones associated with the Macraes Fault Zone have been reported. The width of the zone of foliation rotated with respect to the regional foliation orientation and observations from test pit and trench exposures suggests that folding associated with the Macraes Fault affects a zone of schist that widens from about 400 m in the vicinity of Frasers Pit to about 550 m wide in the vicinity of the main embankment (Figure 2).

4.0 INVESTIGATION OF THE MACRAES FAULT ZONE NEAR TOP TIPPERARY TAILINGS STORAGE FACILITY

4.1 Trench Investigations

Five overlapping exploratory trenches (Trenches 100, 200, 300, 400 and 500) were excavated in July 2010 across the expected position of the Macraes Fault as part of the current study. The purpose of the trenches was to investigate the bedrock structure, describe the cover soils, and evaluate any evidence for displacement of the rock/soil interface, tilting or folding of the cover soils. The location of these exploratory trenches is approximately 400 m west of the impoundment, at the nearest well-defined topographic step along the Macraes Fault - a gentle step of approximately 50 m in the relatively flat topography (Figure 2). The intent was to try and produce a composite exposure of the bedrock profile spanning the expected location of the Macraes Fault Zone. It was not possible to excavate a single, continuous trench across the fault zone because at different locations the trench encountered the Macraes-Dunback Road, an old earth cable trench, thick cover soils and high groundwater levels. However, the resulting layout of trenches gives reasonable overlapping coverage of the whole basement fault zone. The trench layout plan and summary of the structural data collected from Trenches 100 to 500 is presented in Figure 7.

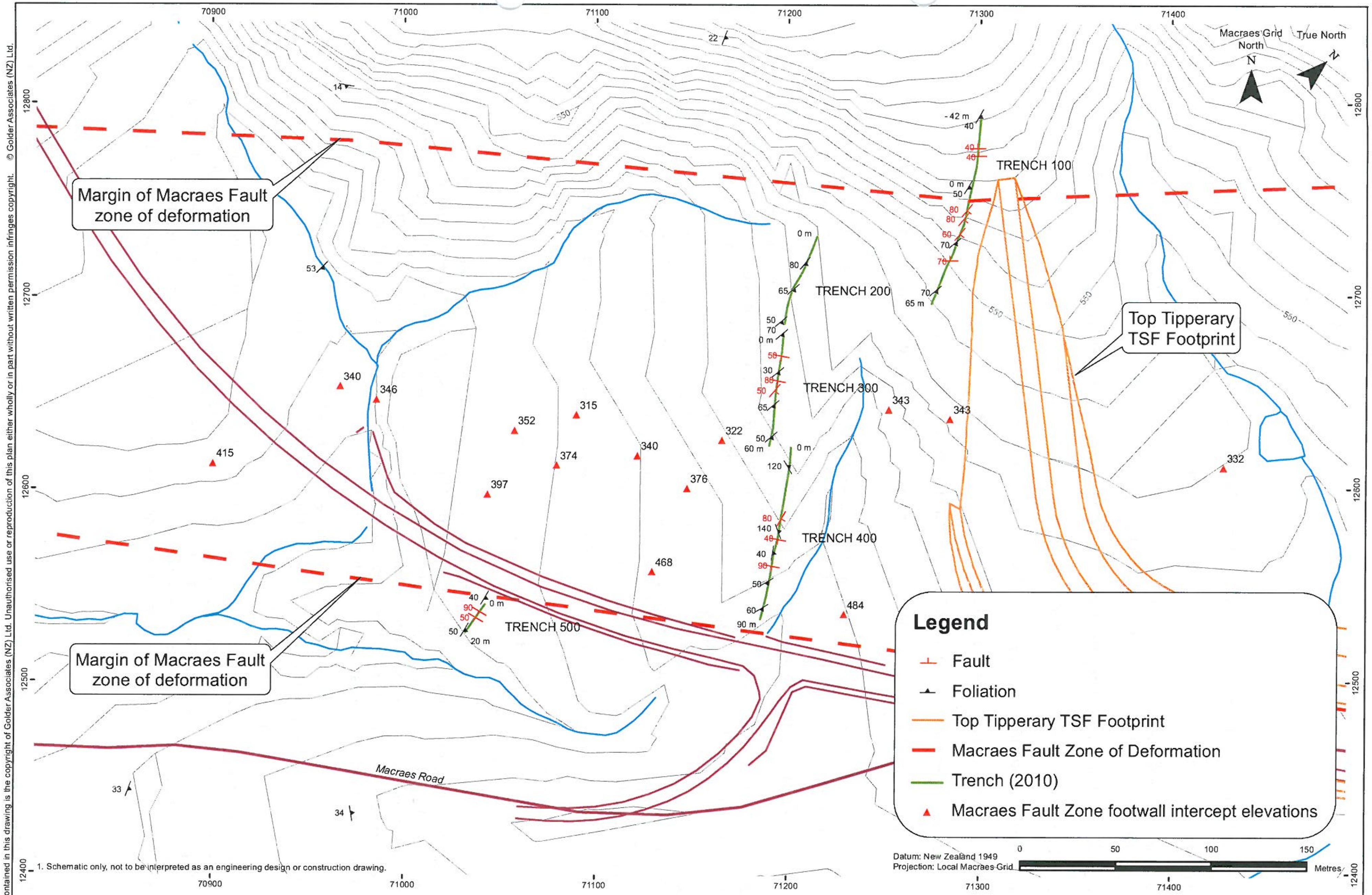
An additional trench (Trench 700) was excavated in November 2010 across the Macraes Fault along the main embankment footprint. At this location there is no defined step across the fault and the objective was to identify the location and width of the fault and identify any offsets in the rock surface. Trench 700 gave continuous exposure for a length of nearly 1000 m across the fault. Logs of all trenches and selected photographs (Photographs 5 to 12) are presented in Appendix B.

4.1.1 Basement schist

Basement rock in the vicinity of the Macraes Gold Project comprises Torlesse Terrane schist of textural zone III (Forsyth, 2001). Unweathered, the schist is grey, moderately strong or strong, well foliated and fine-grained (pelitic) to coarse-grained (psammitic). Where moderately or highly weathered the schist becomes very weak or weak and brown or light grey in colour.

4.1.2 Basement faults

A north-dipping fault was exposed in Trench 100 approximately 10 m below the ridge crest, and striking generally parallel to the regional trend of the Macraes Fault. This fault comprised a zone about 5 m wide of sheared and broken schist with a 100 mm thick, dark-grey clay gouge dipping 40° to the north along the upslope margin. The fault location is close to the northern margin of fault deformation within the zone of foliation rotation. The clay-gouge zone was the only north dipping fault exposed in the trenches excavated for this investigation. The orientation of this fault is consistent with the predicted orientation of the Macraes Fault and is the widest fault found in Trenches 100 to 500. As such, it is judged to be a likely location for a surface rupturing earthquake to disrupt the surficial materials, had such an event occurred in the recent geological past. A similarly oriented fault was exposed in an exploration trench undertaken by OceanaGold in 2001 approximately 1200 m east of Trench 100 (Figure 2). No disturbance of surficial soils in that trench was noted on the logs prepared by the OceanaGold geologist in 2001.



1. Schematic only, not to be interpreted as an engineering design or construction drawing.

Golder Associates

TITLE TRENCH LOCATIONS ACROSS MACRAES FAULT TRENCHES 100-500

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Additional faults identified within Trenches 100 to 500 include:

- 600 mm wide zone of sheared rock and clay gouge, oriented 50/180, observed at 10 m in Trench 300.
- 20 mm wide clay shear, oriented 90/000 was observed in Trench 100 at 40 m. This fault had no apparent effect on the adjacent schist foliation orientation.
- 50 to 300 mm wide dark grey clay gouge oriented 80/190, located at 25 m in Trench 300
- 20 mm wide shear, oriented 80/300 at 40 m in Trench 400.
- 300 mm wide fault, oriented 80/190 located at 66 m in Trench 400.
- 100 mm wide fault, oriented 90/210, at 8 m in Trench 500
- 50 mm wide shear, oriented 50/210, located in Trench 500 at 15 m
- Foliation parallel faults (typically <0.5 m wide) spaced approximately 5 m to 50 m throughout the trenches

None of these additional faults were observed to disrupt the surficial soil materials, indicating that none of the faults exposed in Trenches 100 to 500 have ruptured since the surfical soils were deposited.

Trench 700 exposed two significant zones of shearing within a 550 m wide zone of schist deformation. The northern boundary of the zone is at approximately 13000 mN. Five parallel faults that strike east-west and dip to the north are exposed over a distance of about 70 m (measured along the trench). At least 7 foliation parallel faults were encountered between about 12400 mN and 12500 mN, marking the southern margin of the zone of faulting. An abrupt change in foliation orientation occurs at this location, from a dip direction of about 140° north of 12400 mN to about 100°-110° south of 12400 mN. Less faulting was observed between the two distinct zones of faulting described above. This includes several additional foliation parallel faults, as well as occasional faults that cut across foliation, distributed across about 350 m. Figure 8 presents a summary of the main geological features observed in Trench 700.

None of the faults exposed in Trench 700 were observed to offset the schist/cover soil contact.

4.1.3 Cover deposits

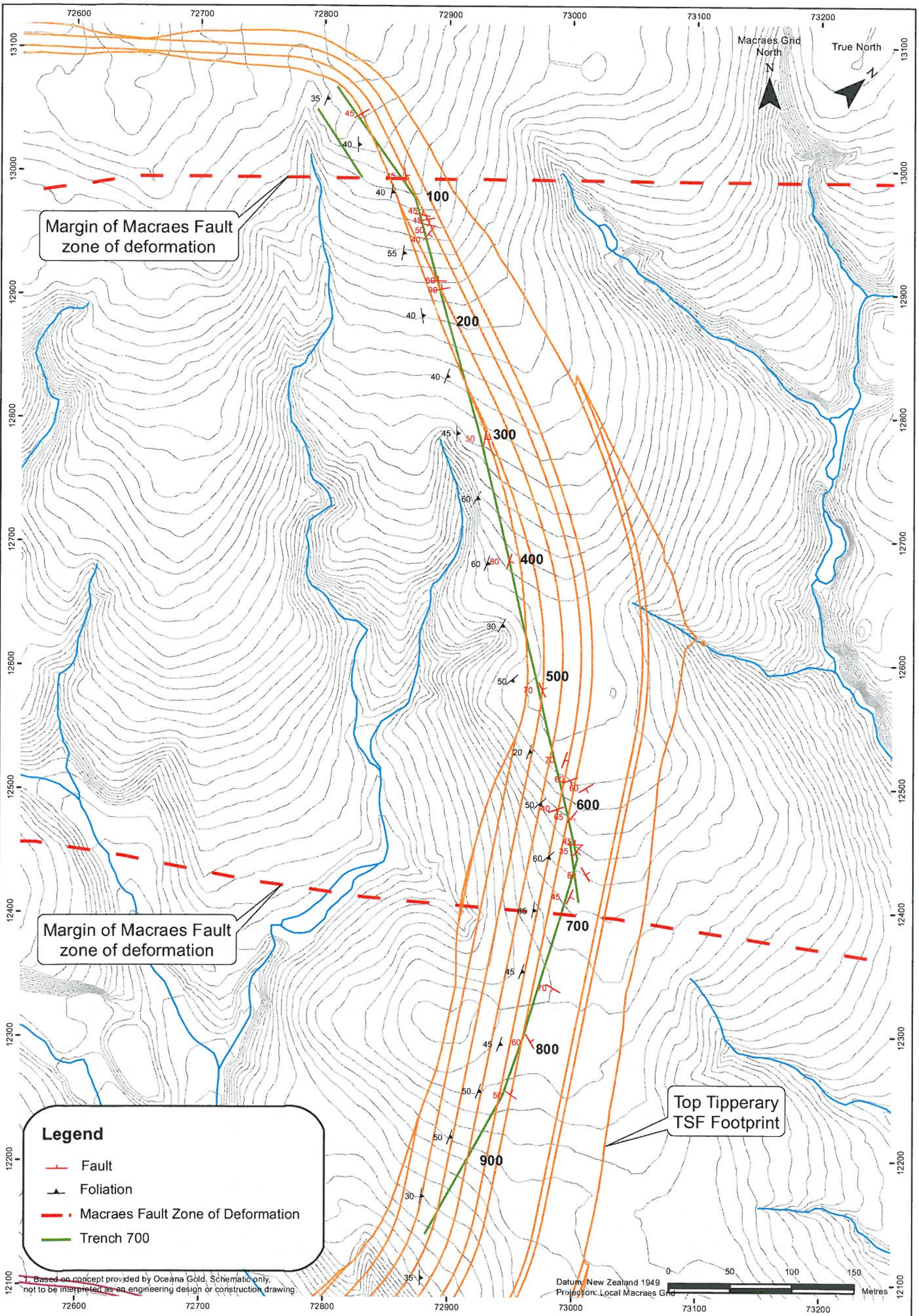
Cover deposits were described from the trenches completed as part of this investigation (refer to the trench logs presented in Appendix B).

At most locations, the trenches encountered light yellow-grey, moist, unweathered, sandy silt (loess) up to about one metre thick, and typically about 600 mm thick. The loess generally directly overlies variably weathered schist, or a thin layer (up to about 200 mm) of weathered schist gravel clasts (up to about 20 mm) in a silty sand matrix. The loess did not appear to be significantly weathered. The upper ~200 mm of the loess comprised a dark brown silt loam (topsoil). The exploratory trenches exposed loess or silt loam in a continuous layer overlying schist or colluvium.

The thickness of cover soils in Trench 700 was generally less that in Trenches 100 to 500. The total soil thickness was typically less than 500 mm including about 200 mm of topsoil.

4.1.3.1 Colluvium

In the steeper areas through which Trench 100 was excavated, granular soils up to about 1 m in thickness were encountered. The soils comprised interbedded gravelly sand and thin layers of sandy silt. The gravels comprised slightly or moderately weathered schist fragments up to about 20 mm in maximum dimension. Bedding, where apparent, was approximately slope parallel. These materials are interpreted to be colluvium derived from the erosion of the schist outcrops and loess from the slopes immediately above the trench site.



Golder Associates

TITLE **GEOLOGICAL SUMMARY OF TRENCH 700**

DECEMBER 2010

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A gravel layer was encountered in Trench 200 that comprised horizontally-bedded, sandy, medium or coarse gravel, containing subangular schist clasts typically between 20 and 60 mm in maximum dimension. Many of the schist clasts appeared to dip out of the eastern trench wall, but consistent clast imbrication was not evident. This depositional flow direction is consistent with the location near the head of a small west-draining tributary of the North Branch Waikouaiti River. At the northern end of the trench, the gravel-schist contact could not be observed as it was below groundwater level, but schist was excavated from the base of the excavation along this trench. The gravels are overlain by up to 1 m of loess that is in turn overlain by up to 0.8 m of gravelly, silty sand with 0.2 to 0.3 m thick topsoil developed on it. The upper gravelly silty sand is interpreted to be a colluvium deposit.

Colluvial soils were rarely observed in Trench 700 and were only locally present where the trench passed close to the heads of gullies.

4.2 Interpretation and Assessment

4.2.1 Age of the cover soils

No specific dating of the soils has been undertaken as part of this investigation. However, information on the landscape age can be inferred from other studies as discussed below.

The Otago Peneplain surface was covered by widespread deposition of marine and non-marine sediments in mid-Tertiary time. The schist was subsequently exposed by erosion that is inferred to have occurred throughout Pliocene and Quaternary times (last 5 million years). No Tertiary-age sediments, however, have been identified in the vicinity of the Macraes Gold Project area, and it is not known whether the area was covered with Tertiary sediments that have been subsequently removed. However, it is likely that this area was part of the regional low relief peneplain at that time, covered with sediments and volcanic rocks. Litchfield et al (2005) estimated the age of exposure of the peneplain on Taieri Ridge to be about 1.5 million years ago.

Kim and Englert (2004) measured a depth profile of nuclides of beryllium and aluminium (^{10}Be and ^{26}Al), produced by penetration of cosmogenic radiation into the basement rock in the Macraes area. Their study included samples from deep in the opencast mine pits at Frasers and Round Hill. The variations in nuclide concentrations are a measure of the thickness of rock over the sample, and can be used to estimate erosion rates (or more correctly exhumation rates). Their studies indicate a long-term rate of erosion of the basement schist of about 12 m per million years. This in turn can be used to examine two alternative explanations concerning evolution of the Macraes Fault:

i) The Macraes Fault is a late-Cenozoic fault that is potentially active, and the current topography is the result of fault offset and subsequent erosion of the northern, upthrown side. This requires that about 200 m of schist has been eroded off the upthrown side (the vertical offset at depth is about 250 m (Figure 5), while the current topography illustrates an offset of as much as 80 m: a difference of about 200 m). At an exhumation rate of 12 m per million years, this would require 17 million years. However, Coombs et al (2008) have shown that the regionally widespread volcanics that capped the schist and sedimentary rocks are only 15 million years old.

ii) The Macraes Fault is an older structure that has not offset the peneplain, and the current topography is the result of as much as 80 m of erosion of the southern, downthrown side, sufficient to create the topographic escarpment aligned with the Macraes Fault. Erosion may have occurred preferentially on the downthrown side due to the weaker nature of the rock within this zone. At an exhumation rate of 12 m per million years, this would require between 4 and 7 million years.

All of this evidence suggests that the lesser amount of erosion, and by implication the Macraes Fault being an old feature, provides a more satisfactory explanation. However, given the numerous uncertainties that surround these lines of evidence, not least the assumptions that underpin cosmogenic nuclide interpretation (Kim and Englert 2004), it is important to place constraints on the alternative option that the Macraes Fault, as an extension of the Billy's Ridge Fault, is nonetheless a potential surface rupture source.

Loess is widespread across the eastern South Island and the relatively silty, unweathered character of the loess in the trenches at Macraes is typical of loess deposited during the last glacial period. Regional studies indicate deposition of this loess sheet was tailing off by 13,000 years ago, and had ended by about 11,500 calendar years ago (Alloway et al. 2007). This is compatible with the absence of loess on the alluvial sediments at Frasers Pit (Section 2) the uppermost of which were still undergoing deposition at about 15,000 calendar years ago. For the purposes of discussion a minimum age of 11,500 calendar years is adopted for the loess exposed in the TTTSF investigation area.

Cosmogenic nuclides of beryllium and aluminium (^{10}Be and ^{26}Al), have been used to date the schist surface exposure age (Kim and Englert, 2004). The average age of schist exposure at Macraes Flat has been estimated to be 25,000 ± 3,300 years. However, this estimate depends on many assumptions, and the question arises as to whether it is generally representative of the investigation area, as Craw and Chappell (1999) have demonstrated that detritus from erosion of schist on the Macraes Fault lineament was being deposited as alluvium through to at least 15,000 years ago. The loess is regarded as a safer age marker horizon in the investigation area.

4.2.2 Evidence for deformation of soil and sedimentary units

No faults, folds or anomalous bedding orientations were observed in the surficial soils and sediment that indicate fault displacement or tectonic deformation since their deposition.

4.2.3 Comparison to faults with known history of repeated fault movements

It is useful to compare the physical appearance of the Macraes Fault to the Ostler Fault, an active fault that has experienced repeated fault ruptures during the late Quaternary. The Ostler Fault is located in the Mackenzie Basin, about 120 km northwest of the Macraes Gold Project. Repeated fault ruptures with an average recurrence interval of about 3000 years have been documented for the Ostler Fault (Amos et al 2010). The Ostler Fault has well documented fault scarps cutting cover soils and tilting young alluvial soils.

Though the geology differs between Macraes Flat and the Mackenzie Basin, where the Ostler Fault cuts glacial gravels of Quaternary age, the geomorphic features associated with repeated late Quaternary fault rupture would be expected to be present along the Macraes Fault, if it had also experienced a similar level of activity.

5.0 FOUNDATION FAULT HAZARD EVALUATION

This assessment suggests that the estimated likelihood of surface rupture of the Macraes Fault is significantly lower than assumed in the GNS seismic hazard assessment (GNS, 2005). The average recurrence interval for the 38-km long rupture of the Billy's Ridge Fault/Macraes Fault assumed by GNS (2005) is 6375 years, or an annual exceedence probability (AEP) for surface rupture earthquake of 1/6375 (0.000157). The observations in the current study suggest that the Macraes Fault has not ruptured during the last 11,500 years and has possibly not ruptured in the late Quaternary (125,000 years). Accordingly, the annual likelihood of rupture of the fault is judged to be significantly less than 1/10,000.

If dam design needs to take into account fault rupture, the maximum ground offset during rupture of the Macraes Fault can be estimated based on empirical data presented by Wells and Coppersmith (1994). The predicted maximum offset during a 38 km long rupture is 1.25 m, with an 84th percentile estimate of 1.92 m (refer to Table 1). The Macraes Fault is considered to be a reverse fault, so the majority of this deformation is expected to be dip slip. However, it is possible that some strike slip deformation could occur during rupture as the vector of plate boundary deformation is oriented approximately 45° to the Macraes Fault. A conservative assessment of likely movement during fault rupture is thus 1.4 m horizontally (with a right lateral sense) and 1.4 m vertically (north side up), with all motion concentrated on one structure. It is also possible that this fault deformation could be distributed among multiple faults within the wider fault zone.

6.0 SHAKING HAZARD

The PSHA completed by GNS uses a methodology that is widely accepted for engineering studies. The seismic hazard assessment was based on the best geological data available at the time, and assumed Holocene movement and large earthquakes along the Billy's Ridge and Macraes Fault. Any modification to increase the recurrence interval or remove the Macraes and Billy's Ridge Fault from the PSHA is expected to reduce the earthquake ground shaking hazard at the TTTSF site.

7.0 CONCLUSIONS

1) The trace of the Macraes Fault is mapped to cross the impoundment and embankment of the proposed TTTSF. It trends east-west and crosses both the main embankment and western embankment near the northern edge of the impoundment footprint.

2) The Macraes Fault is a zone of rotation and increased dip of the regional schist foliation about 400 m wide at the western embankment, widening to about 550 m wide at the main embankment footprint. This zone comprises a drag fold, locally increased weathering, reduced rock strength and multiple shears and faults. The maximum vertical offset across the zone of deformation is about 250 m.

3) The surface expression of the Macraes Fault changes in the vicinity of the proposed TTTSF impoundment area. To the west, the topographic elevation difference across the Macraes Fault is as much as 80 m, and it is a subdued step in the landscape. This step decreases in elevation and width to the east to form a gentle, southeast-facing slope with no significant steps. The ridge that underlies the proposed main embankment represents the catchment divide between Tipperary Creek and Cranky Jims Creek. This ridge has no significant steps, warps or slope changes along the line of the Macraes Fault that indicate Quaternary or earlier tectonic deformation. This lack of offset suggests that much of the topographic offset across the Macraes Fault lineament could have formed due to differential erosion along the fault zone rather than ongoing fault displacement.

4) Trenches excavated across the Macraes Fault indicate a widespread soil profile of less than about 1 m thick, overlying weathered schist. The trench exposures showed no evidence for fault offset, warping or tilting at the soil/schist contact, or within the soil. The soil profile includes, in most places, a layer of loess up to about 1 m thick, which is interpreted to be at least 11,500 years old, though it has not been dated locally to confirm this age.

5) Because the loess layer is undeformed across the fault and is interpreted to be at least 11,500 years old, the likelihood of rupture of the Macraes Fault during the life of the TTTSF is considered very low. Accordingly, for this study the Macraes Fault is interpreted to have a recurrence interval in excess of 11,500 years, equivalent to an annual exceedence probability of less than 1/10,000.

6) If the Macraes Fault and Billy's Ridge were to rupture co-seismically, the estimated total maximum offset would be 1.92 m, which could equate to 1.4 m vertically and 1.4 m horizontally. It is possible that the deformation may be diffused across more than one fault structure within the mapped zone of deformation.

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APPENDIX A

Photographs