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Our Ref: PSM1059.TR1
Date: 6 February 2007

The General Manager
Hornsby Shire Council
PO Box 37
HORNSBY NSW 1630

ATTENTION: MR CRAIG CLENDINNING

Dear Sir

RE: HORNSBY QUARRY

We are pleased to submit our report relating to geotechnical and hydrogeological constraints relevant to the land use options within the Hornsby Quarry.

For and on behalf of
PELLS SULLIVAN MEYNINK PTY LTD

P.J.N. PELLS

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Hornsby Shire Council

FORMER CSR QUARRY HORNSBY & ASSOCIATED LANDS

Report PSM1059.TR1 6 February 2007

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1. INTRODUCTION

This report presents the findings of the study of geotechnical and hydrological constraints to development of the Hornsby Quarry. The report has been prepared in accordance with Hornsby Shire Council Contract C13/2006 "Geotechnical Investigation – Former CSR Quarry Hornsby & Associated Lands".

Drawing PSM1059-1 and Photograph 1 below set out the quarry area.

Quarrying operations, like any mining activity, are based on design criteria for slope stability and filling operations that are philosophically quite different from equivalent civil engineering works. Slopes are designed with much lower factors of safety than used for civil engineering works because flatter slope angles are a big cost implication to most open pit operations. In an ideal open pit the slopes would fail as the last truck load of product is removed. In quarrying operations, fills are normally a waste disposal operation. They are normally not placed in thin, controlled layers and compacted to density targets applicable to controlled (structural) fills.

This is essentially the situation at the Hornsby diatreme breccia quarry. The quarry faces were designed with low factors of safety, both at bench scale and overall. Most of the fill areas around the quarry are not controlled fills. The surface drainage system was implemented to allow quarry operations to be undertaken, and not explicitly designed for typical urban stormwater management criteria.

These factors all combine to impose geotechnical constraints on potential development of the quarry site. This report seeks to identify these constraints and how they impact on potential use.

The main text of this report has been kept as short as possible to facilitate rapid assimilation. It summarises key facts and sets out the findings of the study. Details of the factual information, analyses and interpretations are given in the Appendices which should be referenced for full understanding of the logic processes that have lead to the findings.

Photograph 1: Study Area

2. WORK UNDERTAKEN

2.1 Factual Data

The study has involved collecting factual data from a large number of sources including:

- technical publications
- air photos,
- previous studies, and
- field work.

A summary of these data sources is set out in the following subsections.

2.1.1 Topography

Air photos from 1961 and 2006 were used to generate contours of the site at the early stages of quarry operations and as of the present day. In addition, stereo air photos were examined back to the early 1930's when quarry development had just started. In those early days the Hornsby diatreme area was used for fruit farming because the weathered rocks provided high quality soil. The contour plans for 1961 and 2006 are attached as Drawings PSM1059-4 and PSM1059-5.

2.1.2 Geology

Geological information on the Hornsby breccia diatreme was obtained from the following sources:

- published papers from geologists of the Geological Survey of New South Wales, in particular, a study undertaken by Barron and Barron (Reference 1),

- borehole data available from the investigations done by the original quarry operators,

- detailed evaluation of a succession of aerial stereo photos taken from the early days of quarry development through to closure of the quarry,

- a large scale investigation undertaken on behalf of Hornsby Council by Coffey & Partners between 1989 and 1990 into the eastern area and the eastern quarry sidewall, with particular reference to additional development of sports fields in this area, and

- test pits and a deep borehole drilled in the southern face of the quarry as part of this study.

The above geological information has been integrated into the geological models that are discussed in Section 3. Details of the factual information are given in Appendix A.

Plates 1 to 6 show views of the quarry faces as of November 2006.

2.1.3 Geotechnical

The geological information described in Section 2.1.2. has been supplemented by engineering parameters obtained from two major sources:

- extensive testing undertaken on both the eastern fills, residual soils and weathered rocks as part of the Coffey 1989 to 1990 investigation, and

- testing of weathered and fresh breccia undertaken as part of this study.

In addition, PSM has information in its database of the properties of similar breccia materials in other parts of Sydney and other parts of the world. In particular, one of the materials which occurs in the Hornsby breccia is termed muddy breccia and is similar to a material encountered in the Kelian Open Pit Gold Mine in East Kalimantan. Therefore, the database available to PSM from that breccia deposit was of value in determining design parameters for the geotechnical model for this study.

Details of the engineering parameters are given in Appendix B.

2.1.4 Hydrogeology

Information on the hydrogeology of the site, namely the groundwater regime and how this regime reacts to changes in external weather conditions was obtained from monitoring of some 37 piezometers that were installed primarily in the eastern area of the quarry in 1989 by Coffey and Partners. One of these deep piezometers was relocated and exposed by excavation as part of the current study by using a differential GPS system, and the water level was again measured after a period of some 16 years since the last measurement. The current water level is virtually the same as it was measured in 1990.

The groundwater monitoring data available from the 1990 study coupled with observations of groundwater seepage around the sides of the pit and a knowledge of the hydrogeology regime of the surrounding Hawkesbury sandstone has enabled a good understanding to be developed of the groundwater regime around the quarry.

Hydrogeological factual data are given in Appendix C.

2.1.5 Hydrology

Factual information for studying of the surface flows around the quarry and the rate of water level rise in the quarry pit have been obtained from recorded metrological data in the area around the quarry and from the 2006 topographic plan described in Section 2.1.1. above.

The hydrology report is given in Appendix D.

2.1.6 Groundwater Chemistry

During the course of the investigations by PSM a total of four samples were collected by PSM for quality testing. The samples were taken at the locations indicated below:

- HQ1 North west quarry ramp at about RL 74m.

- HQ2 North west quarry batter face at about RL 50m.

- HQ3 South east corner of quarry lake (surface).

- HQ4 North east corner of quarry lake (surface).

Results of testing are included in Appendix C. Also included in Appendix C are results of previous testing results provided to PSM by Council. We understand these samples were collected from the quarry lake over the period August 2004 to October 2005.

Overall, the groundwater collecting at the quarry lake is approaching a potable water standard. Without any further treatment, we would expect the water in the quarry lake to be readily usable for use on gardens, parks and playing fields. Further, with some treatment it may be possible to use this water for potable water or industry use.

2.1.7 Quarry Development

A very important part of the study has been determining how the quarry was developed and in particular how modifications were made to the northern face of the quarry. This has been achieved by a study of successive stereo air photos taken of the quarry over the years. These air photos have also enabled an understanding to be obtained of how fill was placed in the south western and eastern area of the quarry, and from where the fill came.

Time	Development
Prior to mid 1950's	Only a small excavation in the valley floor nestled up against the steep, natural slopes at the western side of today's pit. High wall at western and northern side of void.
Mid 1960's	Quarrying works begin to increase in this period with the pit doubling in size since 1956. A crusher plant operation has been established at the end of Quarry road. Some clearing works underway on the natural slopes to the north. No works in eastern area (Old Mans valley)
Early to Mid 1970's	Existing access roads at the south side of the quarry appear to be established in this period. Excavations extend into the slopes to the north of the site with haul road ramps established up the slopes at the north eastern side of the quarry. The area of the sound barrier appears to have been flattened. By 1972 some clearing and possible dumping of fill has occurred in the approximate area now occupied by the playing fields. Workshop is established at western side by at least 1972.
Late 1970's	South western fill area is cleared of old buildings with some fill placed in zone. Fill dumping in eastern areas has ceased at this time. Works at the northern slopes appears to have ceased. Pit is deepened and extended to the east, approaching the final eastern advance achieved.
Mid 1980's	Quarry void is deepened significantly as the northern extent of steep excavation is pushed north. In 1986 the playing field area is reactivated with an embankment formed and new fill placed. Dumping of fill in the south western area appears to have ceased.
Late 1980's	Placement of fill in the area behind the embankment constructed in the eastern part of the site has ceased. Work commences to clear, and possibly dump fill in the eastern area immediately north of the playing field area. The northern batters above about RL88m are being cut back.
Mid 1990's	Northern batter appears to have been cut back to its final geometry. Concrete drain established at northern side. Excavation and minor filling works in area north of playing fields completed by 1997.
Late 1990's	Quarry operations ceased.
Sept 2003	Lake Level at about RL17m (Sept 2003 Parsons Study)
Nov 2006	Lake Level at about RL28.5m

3. INTERPRETATION

3.1 Formation of the Breccia Deposit

In Section 2.1.1. reference has already been made to the topographic plans developed from the 1961 and 2006 air photos. These plans were used as the basis for entering geological data obtained from the sources described in Section 2.1.2. The resulting interpreted geological plan is set out in Drawing PSM1059-2.

At this point it is worth describing the main characteristics of the Hornsby diatreme. This geological deposit comprises material ejected from deep in the earth's crust in a succession of explosive events which forced this material up through fractures and vents in the overlying rocks. This violent injection of material from deep beneath the earth's crust occurred in trumpet-like or column-like features with the material being blown up through the overlying Triassic sandstone and shales, and at the same time encapsulating pieces of sandstone and shale.

Unlike other diatreme deposits in the Sydney area the Hornsby diatreme is made up of several of these trumpet or column intrusions from deep in the earth's crust. At present the interpretation is that there are at least two or three of these trumpet structures which mesh with each other to form the total Hornsby diatreme deposit. One of these trumpet structures is in the eastern area of the quarry and is illustrated in Figures 1 and 2. These figures are in effect a cartoon superimposed on the photograph of the eastern side of the quarry which illustrates how the structure visible in the eastern face relates to this violent intrusion of material from deep in the earth's crust.

A full technical description of the geology of the Hornsby quarry is given in the main geological appendix in the report (Appendix A).

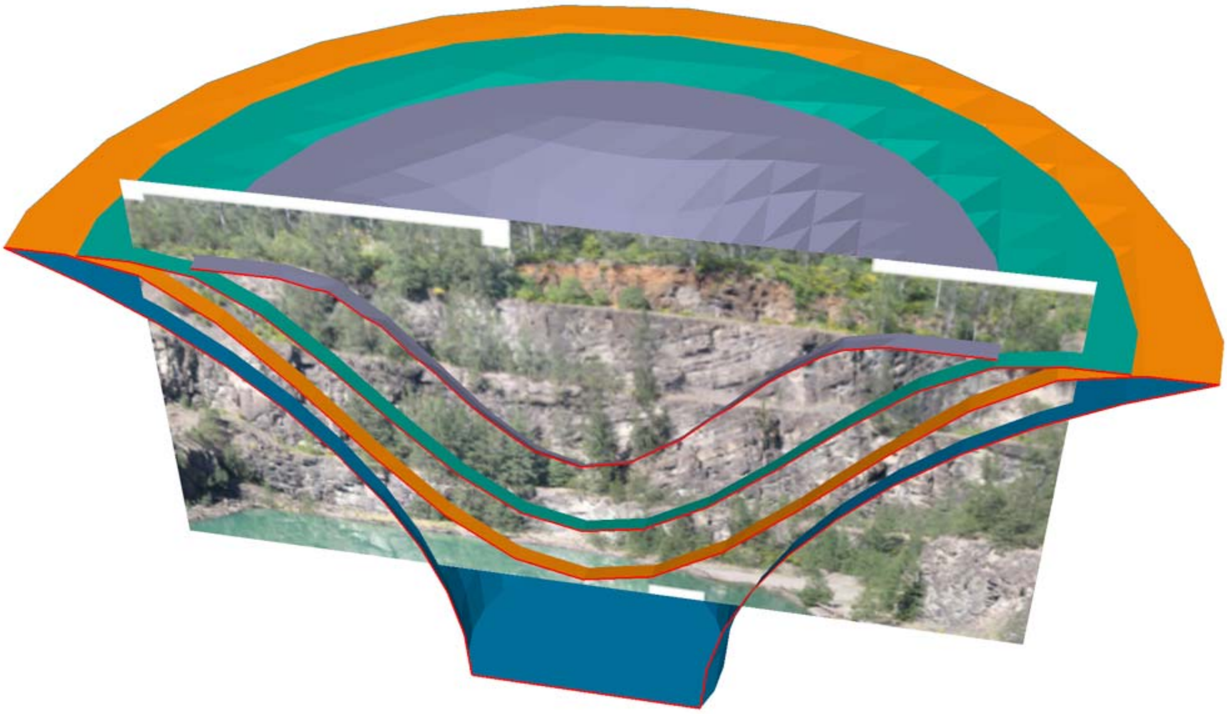

Figure 1: Face view illustration of eastern face in relation to “trumpet” shape of eastern diatreme body

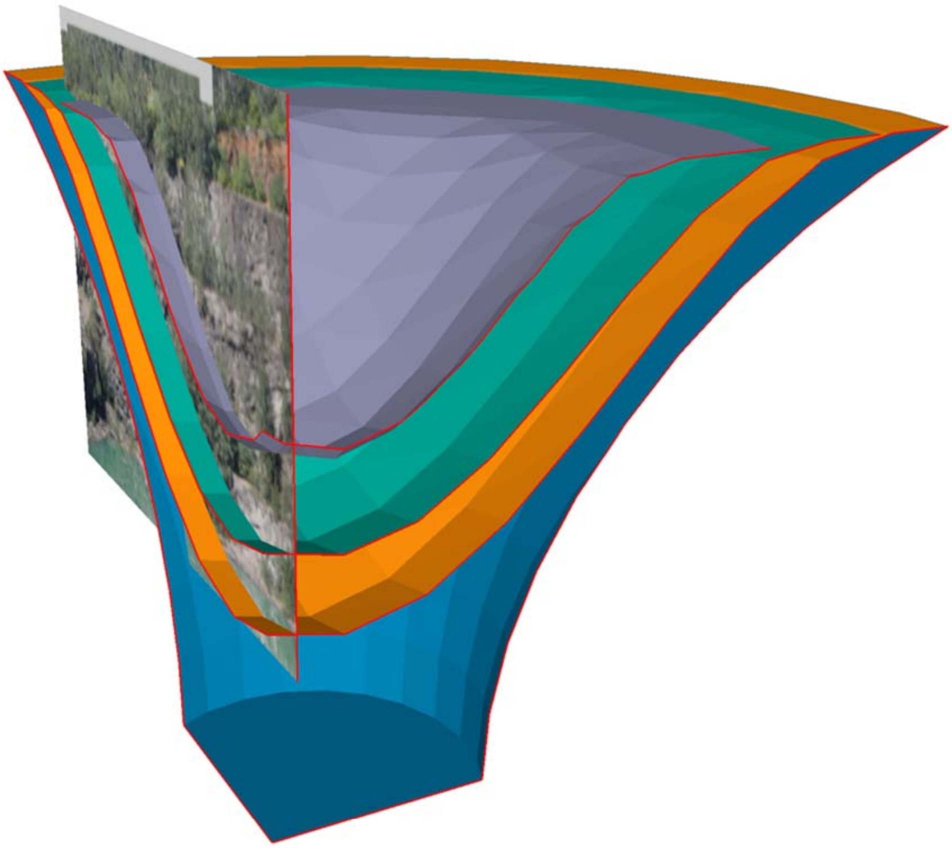

Figure 2: Side view showing how bedding dips into the face

3.2 Division of the Quarry Land into Areas of Similar Character

The findings of the study have been expressed by dividing the quarry area into five major parts as shown on Drawing PSM1059-3, and reproduced below as Figure 3.

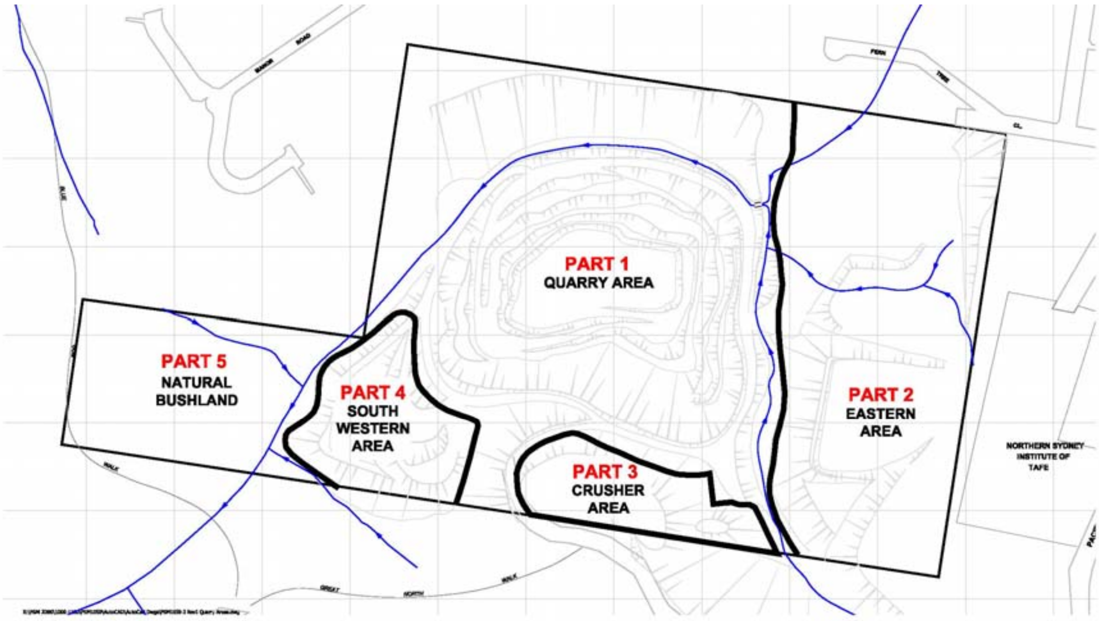

Figure 3: Quarry Areas

These parts are:

Part 1

This comprises the quarry itself and the excavated sidewalls to the quarry. This area includes the northern batter slope extending to, and beyond, the northern boundary.

Part 2

This is termed the eastern area and comprises the part to the east of a drainage system (Old Mans Valley) that runs south to north and is then diverted around the quarry on the quarry bench at about RL 90m.

Part 3

This comprises the area originally occupied by the quarry crusher plant, and filling to the east of the crusher.

Part 4

Is the area of fill placed by the quarry operators in the valley to the south west of the main quarry.

Part 5

The area of natural bushland in the western part of the site, an area that is understood to remain undisturbed for environmental/heritage reasons.

The boundaries of the parts described above are also indicated on cross sections presented in Drawings PSM1059-6 to 17.

A finding of this study is that the risks associated with the existing quarry walls are such that most of the quarry itself (Part 1) should be quarantined from the public unless the walls are stabilised by backfilling the quarry with natural material brought in from elsewhere.

The remaining three Parts, namely the eastern area, the crusher area and the south west fill area could be used in a number of ways as is discussed in Section 4.

The location of the boundaries of Part 1 (quarry void) in relation to Parts 2, 3 and 4 have been made to ensure a factor of safety greater than 1.5 is applicable to the ground below these areas, regardless of remedial works undertaken at the quarry. In particular, the boundary at the northern sides of the crusher plant area and the south western fill area have been denoted at the boundary between the breccia and the Hawkesbury sandstone.

The total areas associated with each Part of the site are:

Part 1	17.6 Hectares (Quarry Area to RL 90m – 11.5 Hectares)
Part 2	11.2 Hectares
Part 3	2.1 Hectares
Part 4	2.8 Hectares
Part 5	4.6 Hectares

3.3 Geotechnical Sections

Geotechnical sections have been developed through the western, northern, eastern and southern walls of the quarry and south western fill area as shown on Drawings PSM1059-6 to 17. The sections, in combination with a kinematic assessment of the structural defects in the rock have been used to assess the stability of the existing faces of the quarry as detailed in Appendix E. They have also been used to assess the stability of fill materials in the eastern part of the quarry (the existing playing field and fills placed during excavation of the northern face of the quarry), around the crusher plant and in the south western part of the site.

The findings of the stability analyses can be summarised as follows:

Quarry Faces

- There is a high risk of small scale instability, at bench scale, around all four faces of the quarry. This instability makes it dangerous for the public to be close to or to walk along the benches within the existing quarry excavation.

  Furthermore, the amount of work that would be required to render these excavated benches safe would be very substantial. It would include a major exercise of rockbolting and include extensive use of shotcrete.

  Alternatively the pit could be backfilled and/or cut back as discussed in Section 4.

- There is no meaningful risk of deep seated sliding of the northern face of the quarry affecting existing buildings and infrastructure to the north of the quarry. However, there is moderate risk of slips that could impact on the north face within the footprint of Part 1 and potentially up to 10m into the lands immediately north of the boundary. The extent of this area beyond the boundary is between about 323000E and 323300E which is approximately the base of the creek just north of the Part 1 boundary.

- There is a moderate risk of moderately deep seated sliding in the south face of the quarry and this places a limit on the extent of possible development within the crusher area. The factor of safety of the south face could be increased to the requisite level by very large scale cablebolting of the southern face of the quarry or massive earthworks to cut back that quarry face. The alternative would be to fill the quarry as is discussed in Section 4.

- Without substantial stabilisation works to the south face the existing haul/access road at the top of this face should not become a public roadway. It may still be used as access to the historical sites.

- There is a moderate to high risk of moderately deep seated sliding in the south western faces of the quarry. This places a limit on the extent of possible development in, and access to the south western area.

- There is only a low risk of deep seated instability in both the western and eastern faces of the quarry because of the advantageous orientation of the bedding features in the breccia.

Drawing PSM1059-18 shows the areas of risk associated with pit wall instability.

Fill Areas

- The existing fill areas to the east of the quarry excavation have computed factors of safety, under design groundwater levels, that are less than would be normally accepted for permanent fill features. This means that development of this eastern area would require some modifications to the existing fill slopes and/or the installation of additional subsurface drainage measures. This area is discussed in detail in Appendix G.

- The fill batters listed below have computed factors of safety under current groundwater levels that are less than would be normally acceptable for permanent fill structures (see Appendix E). Under an assumed groundwater regime of near saturated fill, the batters would become unstable.

    - Fill batters to the north and east of the original crusher plant.

    - Fill batters of the south western-area.

    - The sound barrier along part of the crest of the northern slope above the quarry.

- Possible zone of infill of an "old" creek in its northern slope above the quarry.

- Fill associated with an old haul road along the upper parts of the north eastern slopes above the quarry.

This all means these areas would require some modifications to fill batters and drainage works to ensure high water levels do not develop in the fills.

In the case of fills along the northern and north eastern slopes above the quarry, it may be simpler to remove the fill.

3.4 Hydrology

The purposes of the hydrology study, given in Appendix D, were to determine the likely rate of filling of the quarry under the present surface drainage conditions and to make a recommendation for dealing with the water that is accumulating within the quarry.

Three operating water levels for the Hornsby Quarry Lake have been considered, the current level about RL 28.5 m, RL 70 and the natural overflow level RL 88m.

The conclusions from the hydrology study are primarily as follows:

- With the existing drainage it is estimated RL 70 will be reached in around 23 years and the natural overflow level RL 88 in about 43 years. If the bypass channel were diverted into the pit these levels would be reached in around 11 and 19 years respectively.

- To maintain the current or an intermediate level, pumping will be required. The RL 28.5 and RL 70 levels would be maintained by pumping out estimated mean discharge rates (existing catchment only) of 2.5 L/s to maintain RL 28.5 and 2.1 L/s to maintain RL 70.

- For a nominal lake level of 28.5m with corresponding surface area of 18,000m^2 under ARI 100 conditions, the lake level rise can be maintained at $\leq$2m with 25 L/s pump capacity. For <4m rise at ARI 100 the pump capacity required reduces to 8 L/s.

- For a nominal lake level of RL 70m with corresponding surface are of 60,000m^2 under ARI 100 conditions the lake level rise can be maintained at <1m with 10 L/s pump capacity.

4. FINDINGS

4.1 Land Use Summary

Options for land use, most particularly in the eastern area, are essentially unlimited by major geotechnical constraints but rather questions of economics, amenity and community desire. A list of potential uses is made below, but is by no means considered exhaustive.

- Botanic Gardens – such as the Butchart Gardens, Vancouver Island
- Playing Fields – netball, cricket, football
- Parkland/Walking Tracks
- Swimming Pool
- Park and Ride
- TAFE/University
- School(s)
- Light Industrial Park
- High Tech Park (e.g. North Ryde)
- Restaurant/Café precinct
- Low, medium and high density residential housing
- Multi-story Commercial
- Museum
- Caravan Park
- Agriculture on Volcanic Soils – vineyard, orchard, market garden
- Theatre/Open Air Theatre.

Each option will have particular requirements in terms of land area and infrastructure such as power supply, water supply, storm water and sewer and access paths/roads. Each of these aspects would need to be considered in detailed studies that are beyond the scope of this report.

4.2 Slope Instability

PSM have chosen to present the results of stability assessments based on factors of safety (FOS) for potential failure paths/mechanisms. A target FOS of 1.5 has been adopted as the minimum value for slopes to be judged as suitable for general public access. This is based on internationally accepted practice[1].

PSM consider this approach to be appropriate for the purposes of this study, i.e. a preliminary assessment of costs to allow Council to assess the options for land use. If Council wish to think in terms of probability of failure then it should be noted that a FOS = 1.5 is generally taken as equivalent to be a probability of failure of 1 in 1,000.

An assessment of the probabilities of failure would allow a risk-benefit analysis to be undertaken. However, we feel the assessment of the site in these terms would not have facilitated a simple and clear discussion of the issues with Council. Indeed, the number of assumptions that may be required for this approach may well mask the true accuracy of the assessment and provide Council with a misleading level of confidence in the

[1] Walker and Fell. Soil Slope Instability and Stabilisation, Balkema 1987.

stability assessment. In this regard we refer you to the following quote from a paper by Baynes[2].

> *"This resulted in assessed probabilities which, whilst being defensible, nevertheless were approximations. Indeed it was stated in the report that different approaches could generate probabilities that might differ from the reported figures by several orders of magnitude, and yet still be based on reasonable considerations. Nevertheless, once the probabilities had been reported they were seized upon and given far greater credibility than was considered justified. This resulted in attention being focused on the values of the assessed probabilities relative to possible acceptance criteria, whilst ignoring the attendant imprecision of the figures and the fact that acceptance criteria had not been established."*

4.3 Part 1 – Quarry Area

The findings of the study are that the prime risks associated with the quarry sidewalls in terms of the public are from small scale instability rather than total failure of the quarry faces. This means that there is a high risk of rockfalls ranging from a few cubic metres up to many hundreds of tonnes which could come down either during wet periods or unannounced (without the benefit of monitoring – see Section 4.8) simply due to gradual degradation of the rock itself.

The calculations undertaken by PSM indicate that there is a risk of moderately deep seated failure within the north face of the quarry. These calculations show that if a failure did occur in the northern face of the quarry, it would not extend any where near the existing residential developments and roads to the north of the quarry. However, the zone of potential instability may extend up to about 10m beyond the northern boundary between about 323000E and 323300E. This area approximately equates to the base of the creek aligned east to west at the northern side of the property boundary.

Calculations also show a similar risk of moderately deep seated failures along the southern and south western quarry faces. These failures would extend back to the existing access road along the southern side of the quarry.

4.3.1 Remedial Options

There are considered to be three options available to remove the risk posed by the quarry walls, namely;

- backfilling the quarry,
- a combination of backfilling the quarry and cutting back (flattening) the upper quarry walls, and
- supporting the walls with a combination of drainage holes, rock bolts, shotcrete, mesh, and scaling.

It is expected the latter option would only provide for public access to the quarry area. Yet the costs to undertake such works would be significant and require a detailed design of support works. The order of magnitude of costs of these works is about $10 Million.

[2] Cruden and Fell (1997) Landslide Risk Assessment.

Further, as discussed in Section 3.4, to provide public access the lake level would be required to be kept low, i.e. at RL30m or lower.

<u>Backfilling</u>

The major development option for the quarry would be to fill it with natural material brought either from outside the quarry area or sourced from cutting back, or flattening the excavated quarry faces. It would also be possible to place some of the existing fills located in the eastern or southern areas into the quarry but these would not fill the quarry so as to provide stability to the quarry walls.

A number of points should be noted regarding backfilling. The discussions herein are based on uncompacted or dumped fill being placed into the quarry rather than a compacted, engineered fill. Firstly this is a significantly cheaper form of operation. Secondly the increase in costs to provide a well compacted, *engineered* fill compared to a dumped fill are significant. This must be carefully considered in the light of experiences of projects such as Penrith Lakes and the Enfield Brick pit where approval of apparently well engineered fills for residential uses is very difficult and are thought to be unfeasible due to insurance issues.

Lastly, we understand that the landfill market today is such that those wanting fill are required to purchase it, or at least pay for transport costs to have it delivered. While market realities may well change in the future, the estimate of costs provided herein to fill the quarry from external fill sources is based on the cost to transport materials to site.

With regard to backfilling the quarry from material sourced outside of the quarry, a conceptual layout is shown on Drawing PSM1059-19 and comprises:

- Quarry void filled to between RL 88m and RL 90m with a drainage line running from east to west. Total fill required is about 3.3 Million cubic meters.
- A triangular buttress against the southern quarry slopes above RL 90m. A total volume of about 0.3 Million cubic metres would be required.
- A wide buttress against the northern slopes to just below the current ridgeline. A total volume of about 0.6 Million cubic metres would be required.

Figure 4 shows a cross section through these works.

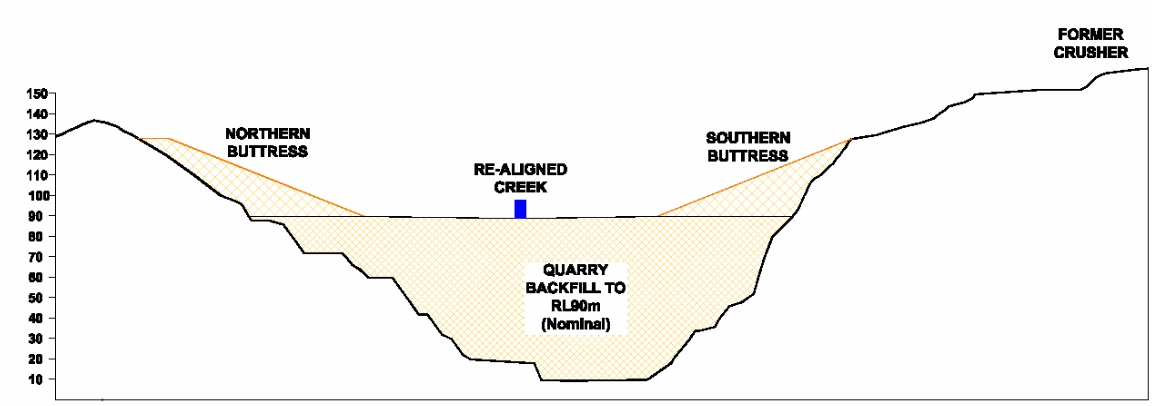

Figure 4: Backfilled Quarry

For the works described above, it is estimated a total of about 850,000 truck movements (6 wheel double bogeys) would be required to provide this volume of fill material. Costs to complete the conceptual design above are high, in the order of $60 million.

It is worth noting, the volume of fill in the south western and eastern areas are estimated to be 0.3 million cubic meters and 0.37 million cubic meters respectively. The costs to move these fills into the quarry are estimated at $1.85 million and $1.5 million respectively.

Other filling options may be considered such as (i) the works described above but without the southern wall buttress or (ii) only supporting the northern batter with a buttress. The latter option may be achieved by extending the northern batter indicated in Figure 4 to the quarry floor. The two, reduced filling options above would cost about $55 million and about $38 million to $43 million respectively.

Any limitation to the extent of fill placed to support the quarry walls will impose constraints on the quarry and surrounding land use. These options are discussed in Appendix E.

<u>Backfilling combined with wall cutback</u>

Council may consider sourcing the materials for backfilling of the quarry from within the quarry area by cutting back, or flattening of the existing quarry faces. This approach would also improve stability of the quarry walls.

A balance may be achieved between fill placed in the quarry void and material won through flattening the batters around the quarry excavation. The concept is shown in Drawing PSM1059-22. Preliminary calculations show the following:

- Place dumped fill in the quarry to about RL 56m – all fill materials sourced from flattening of the existing quarry walls – requires about 1.1 million cubic meters of material.

- Cut back the northern slope above RL56m to about 1.85 to 1.9(H):1(V).

- Cut back the southern wall to about 40 degrees to the horizontal – no impact on the Part 3 and Part 4 boundaries.

- Flattening of batters at the eastern side are not considered necessary. Stabilisation works to the eastern and western faces may be able to be limited to minor cut backs to simply provide an improved level of stability.

- Provision of slope drainage measures – horizontal drains nominally 30m long.

- Development of a lake in the quarry void would reduce the impact of cut back works, particularly for the south western and northern slopes of the quarry. For the cut back works described, we recommend a lake of no more than 10m depth be allowed to develop.

- Excavation and placement costs (dumped fill) estimated to be $6.6 million.

Depending on final geometry and pumping regime, it may be possible for the quarry to be accessed by the public, or a walking path established from east to west.

Northern Walkway

An option for allowing some public access to the existing quarry area would involve creation of a walkway around the north face of the quarry on the quarry bench at RL 90m. This option is presented in detail in Appendix F and is estimated to cost about $680,000. The walkway would provide spectacular views of the quarry. The extent of stabilisation works necessary for implementation of this option depends on Council's view of feasibility issues, as set out in Appendix F.

Lake Level

If the quarry is not filled and therefore remains a lake as it is today, then the level would gradually rise as discussed in Section 3.4. It would take between 19 and 43 years to fill the quarry to RL 88m and thereafter water would flow in the stream down to the south west (see Drawing PSM1059-3). The alternative would be to constrain the rise of the quarry water level by continual pumping as was undertaken during quarrying operations.

The calculations undertaken as part of the hydrology studies indicate that a possible appropriate level for controlling the water level would be about its current level (≈RL 30m, or lower) and would involve permanent pumping at the rate of 2.5 litres per second, with a peak capacity of 8L/s required for a 100ARI storm event. The peak pump capacity is required to limit lake level rise to less than 4m. Details of pump type, size and costs are presented in Appendix E (Section E7.5).

The stability calculations undertaken by PSM have considered different levels of water in the quarry. As the water level in the quarry rises the presence of the water provides some stabilising influence but at the same time the groundwater within the fresh breccia would rise because of the higher water level in the quarry. This combination results in an overall decrease in the factor of safety of the slopes as the water level in the quarry rises.

Therefore, it is PSM's recommendation that if the quarry is not backfilled, the water level should be controlled at about RL 30m, or lower, so that the risk of significant scale instability of the northern and southern faces is limited to values that would not impinge on development within the southern area (see Section 4.5 below), or could lead to failures of the northern slope that would cause disquiet for people who have developed around the quarry, even though such failures would not impact on their safety or on the safety on existing residences to the north of the quarry.

4.4 Part 2 – Eastern Area

As shown on Drawing PSM1059-3 the eastern area is a large area of land (some 11 hectare) that is available and suitable for development in any one of a number of ways. The area does contain three zones of filling placed during the quarrying operations, or by Hornsby Council. One of these zones of filling is understood to have been occupied by playing fields, the others zones were placed by both Council (south of the playing fields), and the quarry operator (north of the playing fields) between 1986 and about 1993.

The geotechnical constraints impacting on the eastern area are set out in detail in Appendix G and are summarised below.

The work that would be needed to be undertaken to develop the eastern area would depend entirely on the nature of the development. This area could be used for buildings, factories, industrial areas, high tech offices, or playing fields, or simply a botanical garden. Depending upon the type of development the amount of work that had to be done on the existing fill areas would be different.

Therefore, for example, if the area were used as a botanic garden, little or no work would be necessary other than landscaping. Alternatively, if the playing field area were to be extended there would be the need for certain drainage measures as detailed by Coffey's in their 1989/1990 study, but otherwise there would be no need for large scale earthworks. However, if the area were to be used for building development with new roads and associated infrastructure it would be necessary to undertake appropriate investigations focused on the particular buildings and particular infrastructure. It is certain that such buildings would have to be on piles in the areas of existing fill and it is also certain that additional drainage measures would have to be implemented and some modifications made to the western batter of the existing playing field area.

It is not possible as part of this study to detail all the possible works that would have to be done for all the possible developments of this area. The point is that this is a large area of land that would be available for commercial development if the Council so chooses.

4.5 <u>Part 3 – Crusher Area</u>

4.5.1 Stability

Details of this area are set out in Appendix H, and summarised below.

The crusher area is defined on its southern boundary by the quarry property boundary and on its northern and western sides by a set back limit established from considering the risk of instability in the southern quarry face, and in fills originally placed along the western side of the crusher area as part of the access road construction. Because this access road on the western side of the crusher was not built to civil engineering standards, PSM cannot presume that the fill batters that support this road comply with normal civil engineering safety requirements.

The set back limits chosen to define the southern area (see Drawing PSM1059-3) are such that the available area is essentially unaffected by the risk of quarry slope instability.

The area is underlain by about 2.5m of fill at the crusher itself increasing up to about 12m to 15m in the northern and eastern parts of the area. Stability of the lower fill slopes down to the existing access road between the crusher and the quarry is marginal under current groundwater conditions and less than acceptable if the fills are able to become saturated.

Depending on the scope of the development, surface and/or subsurface drainage works are likely to be required as part of a development to ensure stability of the fill batters.

4.5.2 Foundations

Hawkesbury sandstone is present underlying the fills, and would therefore provide suitable founding materials for any building development which Council wishes to consider.

4.5.3 Remediation

Developments in this area would require the lower parts of the fill batters to be either flattened to about 2.5(H):1(V) or stabilised with soil nails or by construction of new retaining or block walls. Indeed, the size of the developable land could be maximised through construction of retaining walls or stabilised fill slopes.

A conceptual system has been provided in this report and comprises a tiered, reinforced earth wall with a gabion basket facade. This style of structure is thought most likely to provide a cost effective means of maximising the useable area in Part 3. Figure 5 below shows a possible wall arrangement.

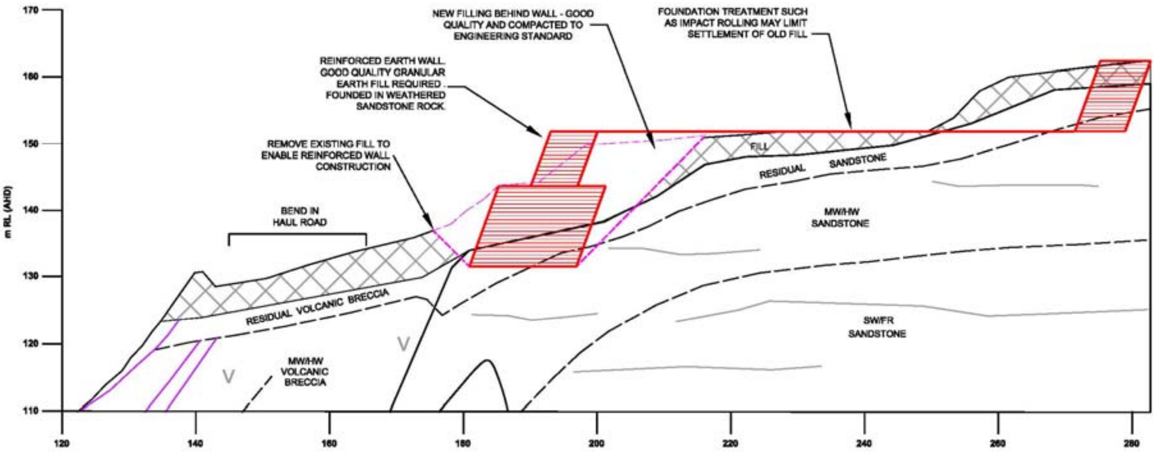

Figure 5: Reinforced Earth Wall Conceptual Layout

The layout shown is likely to provide a useable area of up to 1.8 to 2.0 Hectares. Works to design and construct a reinforced earth wall such as this are estimated to cost about $3 million. More detail is provided in Appendix H, Section H7.

4.6 <u>Part 4 – South Western Area</u>

The south western area, detailed in Appendix I, comprises an area of substantial filling where waste material was dumped during the quarrying operations. This is an area of land which could be developed but upon which there are significant constraints generated by the existing fill.

At present the extent of this area has been set as not to impact on the drainage valley to the west of the area.

The existing fill cannot be considered to be engineered fill as it was not placed in a controlled manner. A development of this area which comprised, for example playing fields, could be undertaken by altering the contours of the existing fill without major excavation and recompaction. However, any other form of development involving buildings or facilities which are sensitive to long term settlements would encounter significant constraints. Buildings could be placed in this area but would have to be supported by piles down through the existing fill. Consideration would also have to be given to the risk of differential settlement between the piled buildings and the surrounding fill and this would place constraints on the design of services to the buildings. The depth of fill is typically between about 10m and 18m.

This area could also readily be developed as a public facility for picnics or for similar activities not involving the construction of important buildings or settlement sensitive facilities. Any such development would basically require moving of the existing fill to create the requisite contours, and associated control of drainage.

Finally, unless the quarry is backfilled access to this area would best be provided from the south west, i.e. from Rosemead Road.

4.7 Access Road Options

Drawing PSM1059-21 summaries access road options to the four major parts of the site, based on existing or old quarry roads and tracks. Obviously completely new roads could be built by acquiring private property, or through public land, but these would be major undertakings in respect of planning and finance, and are outside the scope of this study. In this regard it should be noted that there is no access from the end of Manor Road or Ferm Tree Close because of existing houses.

4.7.1 Part 1 – Quarry Area

In its present state the quarry area should be quarantined from general public access. However, as discussed in Appendix F, even without major stabilisation works (including the option of backfilling) a walkway could be created around the north side using the existing perimeter access road on the RL 90 bench. This would not involve vehicle access except for Council maintenance workers.

The key access to the quarry area in respect to implementation of major stabilisation works, including possible backfilling, is the main haul road (see Drawing PSM1059-21). For construction purposes this road is in an adequate state down to about RL 40m. Below this level the road is quite narrow in places and would require partial reconstruction. It is not known what state the road below the present pit water level is in. The floor of the pit is at about RL 8m.

4.7.2 Part 2 – Eastern Area

As shown on Drawing PSM1059-21 there is presently access to the Eastern Area from Quarry Road, in the south, and from the TAFE access road in the north west. Portions of these roads are shown in Photographs 2 and 3.

Both roads are located in Hawkesbury Sandstone terrain, with weathered sandstone at or close to subgrade level.

The initial part of the access road from Quarry Road is moderately steep but the remainder is at gentle grades. A permanent bitumen road could be constructed along the present alignment, probably with a new culvert at the creek crossing and with a properly designed surface drainage system.

The upper part of access road from near the TAFE entrance is steep (about 15%). Therefore construction of a permanent bitumen road at this location would involve changes to the existing alignment.

Photograph 2: Existing Access Road from Quarry Road

Photograph 3: Existing Access Road from TAFE

4.7.3 Part 3 – Crusher Area

Access to the crusher area is directly from Quarry Road. The present road around the western side of the crusher (see Drawing PSM1059-21) is moderately steep and appears to have been constructed by cross-slope cutting and filling. There is no information on the design and construction of the downslope fills and PSM's assessment is that these may not conform to normal civil engineering standards. The assumption is made that these fills may require remedial work If this portion of the road were to be turned into a permanent public road.

4.7.4 Part 4 – South Western Area

It would be possible, but expensive, to build a road down to the south western area from the end of Quarry Road. However, such a road would have to be substantially outside the boundary of the study area (i.e. outside the quarry land) and is beyond the scope of this study.

From the viewpoints of topography and geotechnical constraints, it would be relatively easy to design and construct a new road from the end of Rosemead Road, into the south western area.

4.8 Monitoring

When considering monitoring of rock slopes, consideration must be given to the reality that while the actual failure of material may appear to have occurred rapidly, the precursors to failure are evident for long periods leading up to the actual event ranging from weeks, months and even years.

Precursors such as cracking behind the crest of the slope, increased frequency of small rockfalls of single or several blocks, deformation of the rock face, rising groundwater levels and opening of joints can readily be looked for, and recorded where present, by a suitable monitoring programme. The results of the monitoring can then be used to effectively manage the quarry faces. In light of this, and given that the site is currently not being actively developed, we suggest that Council consider establishing a monitoring programme comprising the items listed below.

- Establish a series of survey points – an initial regime of say 14 survey stations/markers located around the quarry rim. Indicative locations are shown in Figure 6.
- Water information comprising rainfall data, lake level and piezometer level.
- Regular observation of the condition of the quarry faces.

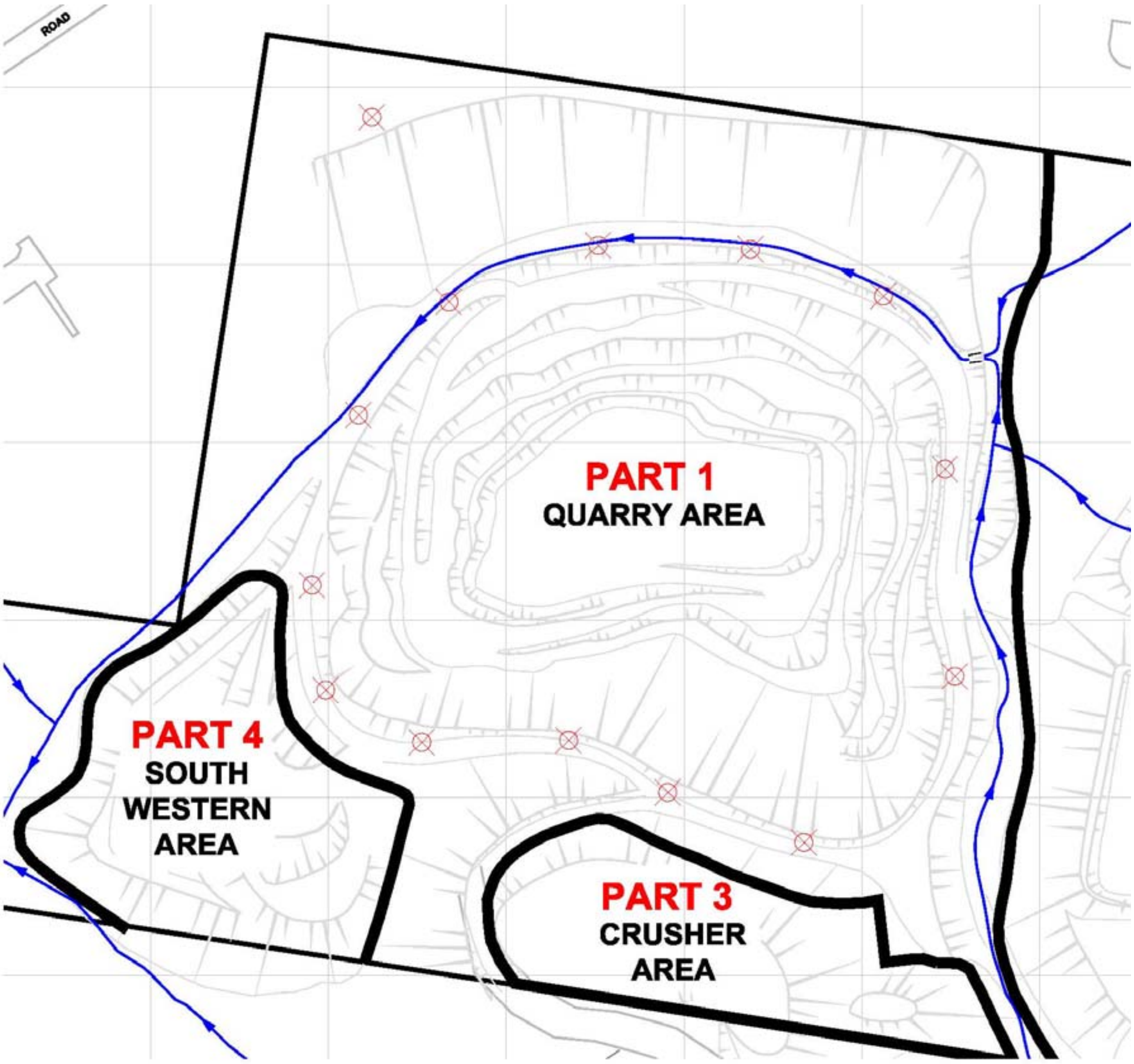

Figure 6: Initial survey monitoring point locations

In order to establish a data set against which future readings can be measured, we suggest the points be surveyed once a week for a month then monthly for a year after which the frequency regime should be reviewed.

Suggested frequencies of the initial measurements and inspections are set out in Appendix E. Indicative costs for establishment and ongoing monitoring are summarised in Section 5.

4.9 Viewing Platform

Council may consider providing areas from which the public can view the quarry void if it is left unfilled.

Based primarily on the results of stability assessments, but also considering features of the quarry that may provide interesting views, the following points are made.

1. The most suitable areas for viewing the quarry are shown in Figure 7.

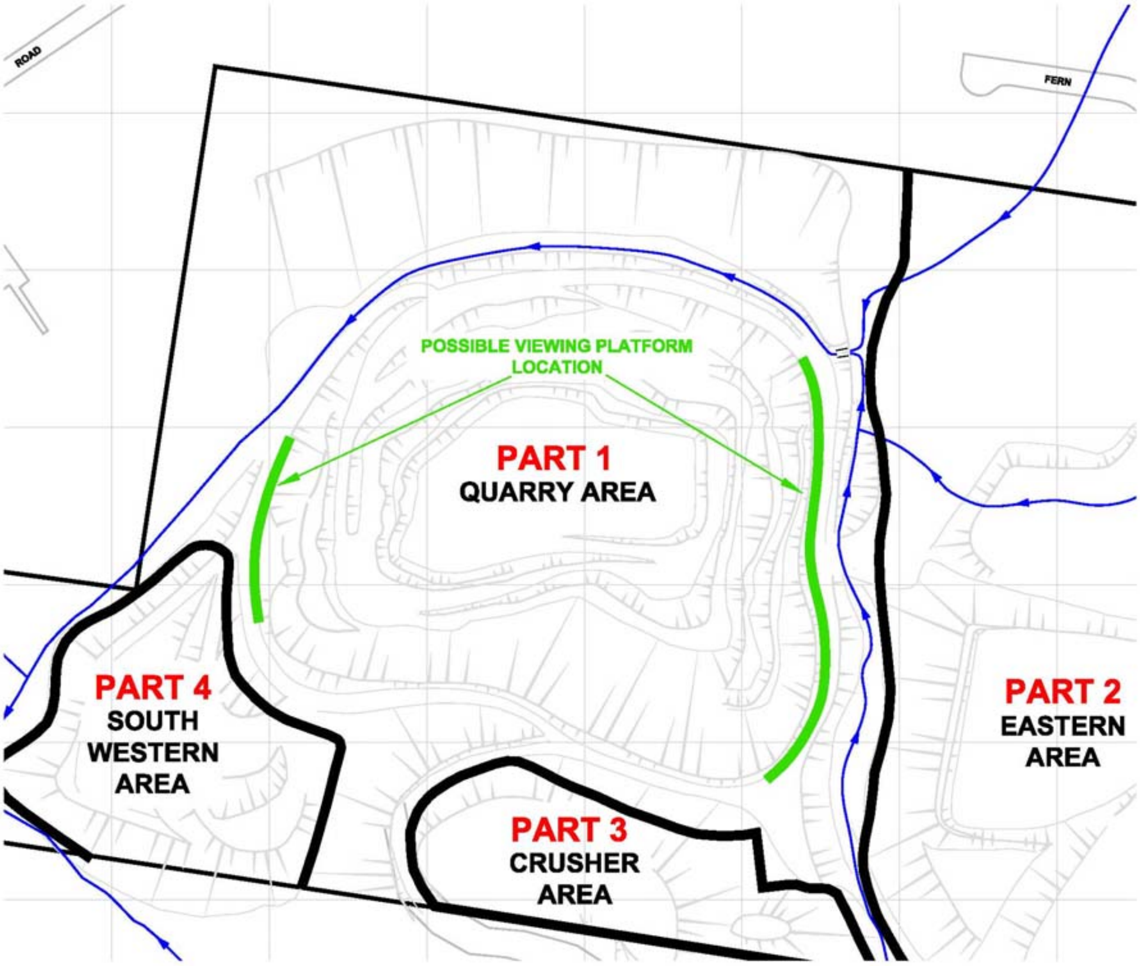

Figure 7: Possible viewing platform locations.

2. Possible viewing locations comprise:

    a. Along the eastern rim of the quarry – provides for easy access from Part 2 of the site.

    b. Along the western rim of the quarry providing a view of the diatreme exposed in the eastern face. Access may best be achieved from the south west, or possibly from walking tracks in the bush to west of the quarry.

The final selection of viewing location(s) will require a detailed study of the quarry faces immediately below the site selected to ensure:

i. No localised instability issues are present due to factors such as blasting.

ii. At the western rim, no bench scale wedge on sliding type failures can occur.

iii. Erosion of the rock face below the location will not cause any instability.

Works to ensure the locations are suitable may include scaling of rock faces to remove existing or potentially loose blocks and possible stabilisation works using shotcrete, mesh and/or rockbolts to support the face immediately below the viewing location.

Obviously costs are location dependent but we would suggest Council allow budgets of:

Eastern Area	$100,000
Western Area	$50,000 (excluding access)

5. SUMMARY OF COST ESTIMATES

Quarry Remedial Works

1. Do Nothing to Quarry

a.	Maintain lake at RL30m – purchase & install pump and establish 3 phase electricity supply	$220,000
b.	Annual pumping costs	$2000 p.a.
c.	Access to quarry floor For infrequent access/use	$200,000
	TOTAL (50 years)	≈$0.5 million

2. Backfill Works

New Fill Purchased for use as a dump quarry backfill

a.	Stabilise entire quarry - remove all instability issues	>$60 million
b.	Stabilise quarry and north batter	>$55 million
c.	Stabilise north batter only	$38 to 43 million
d.	Move fill from Parts 2 and 4 into quarry	$1.85 and 1.5 million respectively
e.	Access to quarry floor For backfilling operations	$320,000

3. Mechanical Stabilisation

a.	All quarry faces	$6.5 million
b.	Design, Inspection and Certification	$0.3 million
c.	Drainage works	$0.75 million
d.	Contingency (set at 30%)	$2.3 million approximately
	TOTAL	$10 million

4. Cut Back Existing Batters and Backfill Quarry

New dumped fill sourced from battering back of existing batters. Fill placed in void to about RL56m in a balanced cut/fill operation.

a.	Fills, residual and highly weathered rock	$1 million
b.	SW/FR breccia – pre spilt with drill and blast	$4.5 million

c.	Access to quarry floor For backfilling operations	$320,000
d.	Drainage works	$0.5 million
e.	Maintain lake at about 10m depth – purchase & install pump and establish 3 phase electricity supply	$220,000
f.	Annual pumping costs	$2000 p.a.
	TOTAL	say $6.6 million

5. Monitoring

We would recommend these costs be included with any of the options above from Don nothing to supporting the quarry. Total ongoing costs will depend on the option selected and results found.

Establishment

a.	Establish Survey	$10,000
b.	Establish Rainfall	$5000
c.	Establish Lake Level Pole	$2,000
	Total	$17,000

Ongoing Measurements (initial 12 month period)

d.	Ongoing Survey	$10,000
e.	Ongoing Rainfall	$1,000
f.	Ongoing Lake Level	$1,000
g.	Ongoing Face Inspections	$10,000
h.	Ongoing Piezometer	$2,000
	Total	$24,000
	OVERALL TOTAL COSTS	$41,000

Walking Track At North Face

1.	Support Batter below Track		
a.	Compacted Backfill		$300,000
OR			
b.	Rock bolts and shotcrete		$180,000
2.	Stabilise Slopes above track		
a.	Shotcrete and dowels		$60,000
b.	Fill Removal		$300,000
c.	Stormwater Control		$110,000
d.	Outlet pipe erosion control		$15,000
		TOTAL	$485,000
		Say	$500,000
	OVERALL TOTAL	Say	$680,000

Develop Eastern Area (Part 2)

Costs dependant on land use(s) selected.

Develop Crusher Area (Part 3)

1.	Costs are dependant on the land use(s) selected	
2.	Reinforced earth (RE) wall to maximise useable land	$3.15 million
3.	Stabilise existing fills (in-situ)	
a.	Flatten batters	$200,000
b.	Soil nails	$2 million
c.	Series of gabion walls	$750,000
d.	Drainage measures for b. and c. above	$150,000

Develop South West Fill Area (Part 4)

1.	Costs are dependant on the land use(s) selected	
2.	Stabilise existing fills (in-situ)	
a.	Flatten batters	$100-150,000
b.	Drainage measures	$150,000

Viewing Platform

1.	Eastern Area	$100,000
2.	Western Area (excluding access)	$50,000

For and on behalf of
PELLS SULLIVAN MEYNINK PTY LTD

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