APPENDIX A

GEOLOGY – FACTUAL AND INTERPRETATION

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A1. INTRODUCTION

This Appendix discusses the geology of the Hornsby diatreme and presents the results of a structural stability assessment. This work was undertaken as part of a larger geotechnical study of the Hornsby Quarry on behalf of Hornsby Shire Council with the overall objective to assess potential land use.

Specific objectives of the geological discussion include:

- outlining the regional setting of the diatreme, and
- providing an understanding of the formation of the diatreme.

This information is important to understanding the complexity of the diatreme geology and provides the foundation for the structural stability assessment which is presented as Part of this Appendix.

A2. BACKGROUND INFORMATION

A2.1. Background, Methodology and Study Approach

This investigation has provided an opportunity to study what is known as a relatively complex geological setting for the Sydney Region. The approach undertaken to investigate the geological and geotechnical setting of Hornsby Quarry was in four main stages:

1. Desktop study.
2. Initial site walkover.
3. Detailed site investigation.
4. Collation and analysis of relevant information.

A2.1.1. Desktop Study

A desktop study was initially completed that involved collating and examining the material listed in Section 2.2 below.

A2.1.2. Initial Site Walkover

Following on from the desktop study, an initial site visit was undertaken by Principals, an Associate, a Senior Engineering Geologist and an Engineer from PSM with the intention of developing an investigation programme. Visual assessment of the conditions of the pit walls were also made at this time. These assessments are included in Attachment A1.

All pit walls were visually assessed to be in poor condition as a result of previous mining/quarrying activities. It was also noted that the geology of the four pit walls was complex, with numerous minor geological features and some major geological features that were likely to be the principal controls on potential large scale pit instability.

A2.1.3. Detailed Site Investigation Stage

Following on from the initial site walkover and in consideration of the desktop study, a site investigation program was developed whereby the major geological features in the pit would be mapped, rock types described and fill material surrounding the pit classified from a series of excavated test pits.

A2.1.4. Drilling, Collation and Analysis of Relevant Information

After an initial evaluation of this data it was concluded that there was insufficient information on the geological and hydrogeological condition in the south western corner of the site. An inclined borehole was subsequently drilled with the aim of providing additional structural information on the rock units as well as defining the nature of the contact between the diatreme and surrounding Hawkesbury Sandstone. A vibrating wire piezometer was installed in this borehole to provide information on the hydrogeological conditions in this area of the pit.

From these studies and site investigations a geological map of the quarry has been developed along with numerous cross-sections through the quarry and surrounding land. Following on from this geological information stability analyses were undertaken to provide an understanding on the stability conditions in the quarry faces. The results of kinematic stability assessments are included as Section 6 of this Appendix whereas the limit equilibrium analyses are included as Appendix E.

A2.2. <u>Existing Data</u>

Existing geological and geotechnical data on Hornsby Quarry has been gathered from the following sources. The type of information from each source is also described.

1. Diatremes of the Sydney Basin by EA Crawford, C Herbert, G Taylor, R Helby, R Morgan and J Ferguson, A Guide to the Sydney Basin, by H Herbert and R Helby, Geological Survey of NSW, Bulletin 26, 1980, pages 294-323 (Reference 1):

   - provides a conceptual model for the development of diatremes in the Sydney Basin, and

   - provides some photos of the quarry from c1980.

2. Herbert, C, 1983, Geology of the Sydney 1:100,000 Sheet, pages 93-103 and Map (Reference 2):

   - provides similar information to that found in Reference 1, with

   - the sandstone-diatreme contact marked at a small scale of 1:100,000.

3. Branagan and Packham, 2000, Field Geology of New South Wales, pages 109-111 (Reference 3):

   - provides information about the diatreme – sandstone contact, (this contact is more refined than that presented in Reference 2), and

   - describes nearby geological features that may be related to the formation of the diatreme.

4. Barron L, Barron J, 2001, Photographs, Geology and Petrology of Hornsby Diatreme, Geological Survey Report GS2001/226 (Reference 4):

   - this report was commissioned by Geological Survey of New South Wales to provide a record of geological conditions found at the quarry site at the end of quarrying operations, in case the quarry was to be used for land fill in the near future,

   - it provides many detailed photographs and descriptions of rock types and structures encountered, and

   - it provides a diatreme formation model that is conceptually different to the commonly understood mechanism provided in Reference 1.

5. Two geotechnical investigation reports by Coffey and Partners (for Hornsby Shire Council) (References 5 and 6):

   - reports focus on stability of the eastern fill area and includes numerous borehole and test pit logs, and laboratory data, along with remedial design recommendations.

6. Parsons Brinckerhoff Report dated 2004 – Volume 1, Technical Investigations for Hornsby Quarry and Environs Land Capability Study and Master Plan (References 7 and 8):

   - provides general information on the geological and geotechnical conditions found on site, and

   - provides results of their series of field investigations (test pits and water quality data).

7. A statement by Dr Charles Gerrard in 2002 relating to geotechnical aspects of the quarry (Reference 9).

8. Aerial photos from Hornsby Shire Council:

   - stereo plots of aerial photos from 1930, 1956, 1965, 1972, 1975, 1978, 1985, 1986, 1989, 1992, 1995, 1997 and 2005 were studied to identify the changes over time that have occurred at the quarry.

A2.3. Data from this Investigation

Data collected from this investigation has come from the following sources. The locations of investigations are shown on Figure A1.

1. Inspection of nearby outcrops mentioned in Reference 3.

2. Geological mapping of major geological features seen in the pit.

3. Geomorphological mapping from both aerial photo interpretation and site inspections.

4. Excavation of test pits to verify previous investigations by Coffey (References 5 and 6) and Parsons Brinckerhoff (References 7 and 8) as well as to provide additional information regarding the extent and nature of fill in areas not previously investigated. The logs and photographs of these test pits are included as Attachment A2.

5. Collection of water samples to ascertain current water quality and to compare with samples collected and reported by Parsons Brinckerhoff (References 7 and 8).

6. Limited geomechanical material testing was undertaken to provide quantitive data on:

    - strength testing of muddy breccia rock,

    - soil properties testing of fill material.

    The results of this testing are included in Appendix B.

7. Re-establishment of piezometer BH18 drilled by Coffey and Partners (1990).

Following a general assessment of the above data and considering previous data, a decision to drill a hole in the south west area of the pit was made.

The borehole BH HQ1 was located to provide structural data behind the existing southern face in an area where insufficient data was available from previous sub-surface work and from mapping. The borehole logs, photographs and explanation sheets are included as Attachment A3.

A vibrating wire piezometer was installed in this hole to provide detailed information on groundwater in this area of the quarry.

To provide detailed structural data, borehole image processing was also undertaken by RAAX Australia. The RAAX Report is included as Attachment A4.

A3. GEOLOGICAL AND GEOMORPHOLOGICAL SETTING

A3.1. Physical and Geomorphological Setting

The Site Plan Drawing PSM1059-1 of the main Report, shows the following current geomorphological features. These features have been located based on aerial photo interpretation.

- roads,
- embankments and slopes,
- historical locations, and
- major buildings.

The site is centred around Old Mans Valley, which is the main source of drainage through the site. The natural valley walls slope up to about 35° and are steeper in sandstone than volcanic breccia. Quarry development over time has meant that Old Mans Creek has been rediverted through a drainage channel midway along the north wall. The current drainage pattern is shown on Drawing PSM1059-4 of the main Report.

The geomorphology of Hornsby Quarry has evolved over time, from its original land use as an orchard to the recent large scale quarrying practices. A summary of the changes in the land is presented in Table A1.

TABLE A1
QUARRY DEVELOPMENT TIMELINE

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 excavation.
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

TIME	DEVELOPMENT
	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 (Reference 7).
Nov 2006	Lake Level at about RL28.5m.

A3.2. Regional Geological Setting

Hornsby Quarry is located within what is known as the Hornsby Diatreme. Surrounding the diatreme is Hawkesbury Sandstone. Ashfield Shale outcrops to the east and northeast of the quarry (see Figure A2).

Diatremes are common in the Sydney Region, with at least 10 identified by Rickwood in the Hornsby Area (Reference 10) and another has recently been discovered nearby at Hornsby train station by recent drilling (Greg Kotze, GHD, personnel communication).

Branagan and Packham (Reference 3) have identified some major faulting at Norman Avenue and Vale Roads as well as Brushwood Place. These faults have a similar southwest-northeast trend to the line of diatremes on Figure A2. This is suggestive of a structural control on diatreme emplacement.

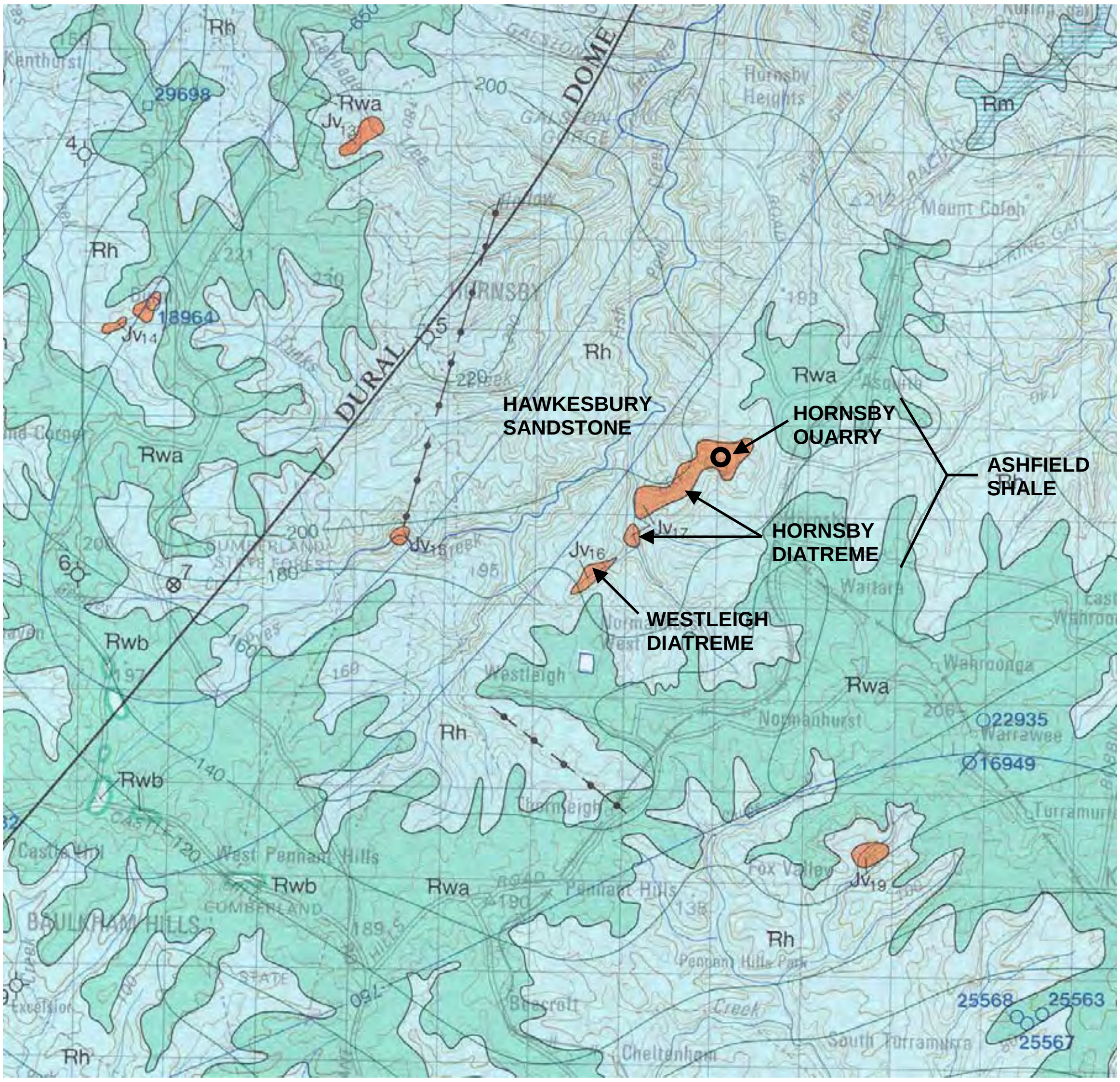


Figure A2: Extract from Sydney 1:100,000 Geological Map

A3.3. Formation of Hornsby Diatreme

Diatremes are formed by gaseous explosions forcefully intruding through the surrounding country rock mass and depositing a pipe of tunnel shaped mass of volcanic breccia.

The Hornsby Diatreme is considered by many to represent more than one explosive event, as alluded to by its 'dumbbell' shape. However, the relationship and number of intrusions is open to speculation. Two distinctly different mechanisms for the Hornsby Diatreme have been postulated:

1. Layers of breccia were initially deposited horizontally and subsequently slumped to form a bowl shape (as described in References 1 and 2).

2. Breccia laid insitu on steep slopes with little or no subsequent deformation (described in Reference 4).

The eastern wall of the Hornsby Diatreme (see Photo A1) shows a classical example of basinal layering within a diatreme and for this geological reason, the quarry is on the Register of the National Estate as being "worthy of preservation". This basinal layering was previously assumed to have formed by the volcanic breccia subsiding back into the pipe (mechanism 1 above). However, detailed observations by Barron and Barron (Reference 4) indicate that this basinal layering may have formed insitu and there has been very little post depositional deformation of the diatreme (mechanism 2 above).

Photo A1: Basinal layering on the East Wall of Hornsby Quarry

Barron & Barron's model for the creation of Hornsby Diatreme is as follows:

1. Large blast or explosion excavates an open cavity or pipe east of the existing quarry (just behind existing eastern wall).

2. Repeated small explosions generate basal surge flows of volcanic breccia material (similar to ash deposits) and which forms a broad shallow inverted cone.

3. The explosive stages give way to a dormant stage whereby a deep crater lake progressively fills with sediment that lithifies over geological time (turns from sediments to rock).

4. A second major explosion located within and below the quarry pit created a second pipe and which also formed following stages 1 to 3 above.

5. More explosions may have created additional pipes to the southwest as the volcanic breccia has been identified in a reserve off Quarter Sessions Road, Westleigh.

Basal surge flows produce instanteous lithification of the sediments and because the surge flow is a thixotropic (has both fluid and solid properties) muddy ash, it is able to deposit itself as thin to thick layers on steep to vertical (even overturned) surfaces. Bedding orientations are expected to follow a bowl pattern. In addition, at many places within the quarry, pieces of wood have been converted to charcoal insitu and immediately after deposition. These pieces of wood are assumed to be remnants of trees destroyed by the basal surges.

If the basinal layering within the diatreme had been formed by post depositional slumping, there should be evidence such as differential subsidence, minor faulting and more randomly orientated bedding planes. Major defects such as bedding plane shears and faults should be more prevalent than observed. These features generally do not occur in Hornsby Quarry and where they do occur, they are small and represent localised features only.

It is important to understand that the evidence seen in the quarry supports the Barron and Barron model. In turn this model implies that there has been very little post depositional deformation in the quarry and hence, large, deep seated shear planes, as postulated in Mechanism 1, do not occur in this diatreme formation model.

A conceptual model of the formation of the diatreme bedding is shown in Figure A3.

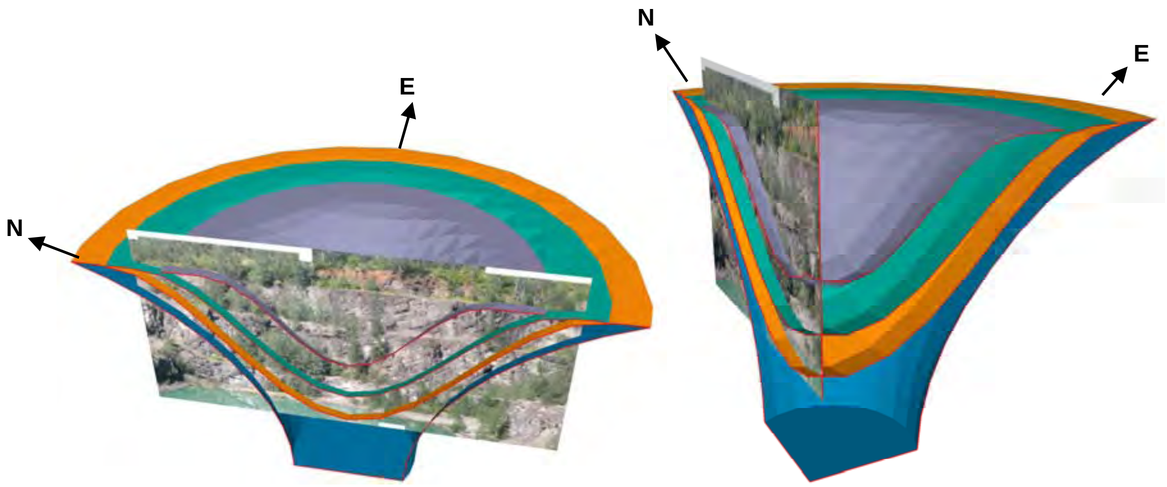


Figure A3: Conceptual Model of Hornsby Diatreme

A4. SITE GEOLOGY

A geological map of Hornsby Quarry has been formulated and is produced in Figure A4 with the pit geology shown in greater detail in Figure A5. These figures show only major geological features. Various units and features of the geological map are described below.

The Hornsby Quarry provides a unique opportunity to study four sections of overprinting diatreme events, with each wall showing a different section through the resulting diatreme. The geology as seen on the four walls is structurally complex and the relationship between various features is often difficult to understand.

A4.1. Volcanic Breccia

The Hornsby Diatreme is principally composed of what is commonly referred to as volcanic breccia. At the quarry, the volcanic breccia is generally composed of a mix of grey to green-grey angular to subrounded fragments of volcanic rock, fragments of mantle material (rocks from deep in the earth's crust), occasional clasts of sandstone, shale and rare clasts of wood that has altered to charcoal.

The volcanic breccia is of high to very high strength when slightly weathered to fresh and in places, in particular the eastern wall, is interlayered with fine grained and medium to coarse grained beds.

A4.2. Muddy Breccia

Muddy breccia is a localised term used to describe volcanic breccia with a distinctly fine-grained matrix. Beds of muddy breccia are generally 20mm to 2m in thickness. Major muddy breccia units have been mapped and marked on Figures A4 and A5 as well as the cross sections on Drawings PSM1059-6 to 16 of the main Report.

Muddy breccia is of low to medium strength and when exposed in the pit, contains numerous microfractures, interpreted to be shrink-swell fractures.

Most contacts between volcanic breccia and muddy breccia have a fractured appearance (see Photo A2) although some contacts are gradational. These contacts are discussed in more detail in Section A4.6.

The muddy breccia as seen in Hornsby Quarry has similar geotechnical characteristics as a muddy breccia unit that PSM has considerable experience with in Kelian Mine, Kalimantan, Indonesia.

The Kelian muddy breccia is thought to have originated from reworked carbonaceous sediments and consists of angular clasts of country rock in a black 'mud' matrix.

It is interpreted that the Hornsby muddy breccia has originated from reworking of either massive shale units from within the Hawkesbury Sandstone, or from the overlying Ashfield Shale.

Photo A2: Contact between Muddy Breccia (lower right)
and Volcanic Breccia (upper left)

A4.3. Hawkesbury Sandstone

The Hornsby Diatreme is surrounded by Hawkesbury Sandstone (see Figure A4). The Hawkesbury Sandstone is a more resistant unit than the volcanic breccia and therefore tends to form escarpments to the north, east and south.

Visible outcrops of sandstone along Quarry Road and the eastern fill access track show the sandstone is essentially no different from elsewhere in Sydney, although sandstone at the contact zone (refer to Section 4.5 below) has a more brecciated, yet healed or recrystallised matrix, as was seen in BH HQ1.

Sandstone is generally of high strength when slightly weathered or fresh and may even be stronger near the contact where heat from the eruption has thermally metamorphosed the sandstone.

A4.4. Effect of Weathering

The effect of weathering is to alter and generally weaken the rock mass. Figures A4 and A5 and the cross sections, Drawings PSM1059-6 to 19, show the units divided into three main weathering categories, namely, residual and extremely weathered (RES/EW), highly to moderately weathered (HW/MW) and slightly weathered to fresh (SW/FR). The geotechnical properties within the three groups are similar (refer to Appendix B for collated results). Standard weathering terminology has been used and is described in Table A2.

TABLE A2
WEATHERING TERMINOLOGY

	TERM	DESCRIPTION
FR	Fresh	Rock substance unaffected by weathering.
SW	Slightly Weathered	Rock substance affected by weathering to the extent that partial staining or partial discolouration of the rock substance usually by limonite has taken place. The colour and texture of the fresh rock is recognisable; strength properties are essentially those of the fresh rock substance.
MW	Moderately Weathered	Rock substance affected by weathering to the extent staining extends throughout whole of the rock substance and the original colour of the fresh rock is no longer recognisable.
HW	Highly Weathered	Rock substance affected by weathering to the extent that limonite staining or bleaching affects the whole of the rock substance and signs of chemical or physical decomposition of individual minerals are usually evident. Porosity and strength may be increased or decreased when compared to the fresh rock substance, usually as a result of the leaching or deposition of iron. The colour and strength of the original fresh rock substance is no longer recognisable.
EW	Extremely Weathered	Rock substance affected by weathering to the extent that the rock exhibits soil properties, i.e. it can be remoulded and can be classified according to the Unified Soil Classification System, but the texture of the original rock is still evident.
RES	Residual	Soil developed on extremely weathered rock. The rock mass structure and substance fabric is no longer evident, there is a large change in volume but the material has not been significantly transported.

Weathering of the diatreme is deeper than the surrounding sandstone and this is reflected in the fact that Old Mans Creek has preferentially eroded along the diatreme. The depth of weathering of the volcanic breccia is detailed in Table A3.

TABLE A3
DEPTH OF WEATHERING OF VOLCANIC BRECCIA

WALL	DEGREE OF WEATHERING	ZONE OF WEATHERING RL (m AHD)
NORTH	RES/EW HW/MW SW/FR	95m – 100m – 140m 85m – 95m <8m – 95m
EAST	RES/EW HW/MW SW/FR	95m – 125m 90m – 110m <8m – 90m
SOUTH	RES/EW HW/MW SW/FR	~7m – 8m (from BH HQ1) 90m – 130m 8 – 80m
WEST	RES/EW HW/MW SW/FR	~110m ~80 – 110m <8 – 80m

A4.5. Diatreme – Sandstone Contact

The nature and location of the contact between the diatreme and surrounding sandstone is important to define because this defect in the rock mass may be the most critical from a stability viewpoint.

The location of the contact between the intruding diatreme and the sandstone that surrounds the quarry is shown in Figure A4. This contact has been collated from the following sources:

- Sydney 1,000,000 Geological Map (Reference 2).
- Field Geology of New South Wales (Reference 3).
- Coffey & Partners Geotechnical Report (Reference 5 and 6).
- Results of drilling and test pit excavations from this investigation.

The contact drawn by Branagan and Packham (Reference 3) is more accurate than the contact drawn on the Sydney 1,100,000 Geological Map. Coffey and Partners refined the contact to the east and this investigation confirms the contact location to the south.

A4.5.1.Contact South of the Pit

Coffey and Partners borehole BH 103, located in the south east corner of the pit and BH HQ1, located in the south west corner, from this investigation have both intersected the contact. BH 103 found an approximately 70m "transitional zone" between volcanic breccia and sandstone, where this transitional zone had zones of volcanic breccia, siltstone and interbedded sandstone and volcanic breccia. This "transitional zone" is interpreted to be interfingering of the contact. BH HQ1 also found interfingering of the contact. In both holes, the interfinger contacts were found to be fractured to highly fractured with no evidence of shearing observed.

BH HQ1 also showed a 13m long (true thickness of about 6m to 7m) zone at the lower contact where sandstone has undergone a process of thermal or contact metamorphism. This process has effectively 'cooked' the sandstone, turning sandstone grains into crystals of mainly quartz. This has in fact made the sandstone in this zone of higher relative strength than typical Hawkesbury Sandstone. It is not clear from the log of BH 103 whether or not this effect was seen in this borehole.

Surrounding the volcanic breccia interfingers in BH HQ1, the sandstone was actually sandstone breccia. These units had angular to rounded 10mm to 50mm sized clasts of sandstone in a fine sand and silt recrystallised matrix. As with the lower contact zone, this sandstone breccia has undergone thermal metamorphism, which in turn has also made the sandstone in these zones of higher relative strength than typical Hawkesbury Sandstone.

A4.5.2. Contact Near the West Wall

The west wall of the quarry does not intersect the contact. Branagan and Packham (Reference 3) show the contact to be west of Old Man's Creek. This investigation has not seen any borehole logs through the contact near this pit wall. The nature of the contact and its interfingering, as seen in the southern wall, is also expected at this location.

A4.5.3. Contact Near the North Wall

This investigation has not uncovered any borehole logs in the area of the north wall that intersect the contact. However, the contact shown in Branagan and Packham (Reference 3) appears to follow changes in surface topography. A walkover of the north wall during the site visits for this investigation confirm their observations. The nature of the contact is interpreted to be similar to that found in the south wall and this is reflected in Cross Sections 4 and 5 that have been drawn through the north wall (Drawings PSM1059-9 and 10 of the main Report).

A4.5.4. Contact Near the East Wall

Coffey's Report (Reference 6) delineates the location of the contact through a series of shallow boreholes and testpits through the overlying fill material (refer to Figure A1 for the location of these investigation locations). The nature of that contact is interpreted to be the same as the south wall and is shown in Cross Sections 1 to 3 (Drawings PSM1059-6 to 8 of the main Report).

A4.6. Major Geological Structures

The investigating program included a walkover of most of the accessible benches identifying major geological structures that are expected to control large scale pit wall stability. It should be noted that there are numerous features that are considered to be minor in nature, namely small non-persistent joints, veins, some bedding planes and blast damage features. These features generally only control bench scale instability.

A4.6.1. Muddy Breccia – Volcanic Breccia Contacts (CN)

The surface expression of major muddy breccia units is shown in Figure A5. These units are very persistent, being longer than 300m on the north and west walls of the pit. The contact zone is generally planar, rough about 100mm to 400mm in thickness and is composed of significantly more fractured material than the surrounding units. There is no evidence of shearing or soil material as infill on any of the contacts. Contacts on the north and west walls generally dip about 45° to 70° towards the south east, whereas on the south wall, contacts dip at about 50° to 60° towards the north east. Photo A3 shows two examples of the contact between muddy breccia and volcanic breccia.

Photo A3: Examples of Contacts between Muddy Breccia and Volcanic Breccia.
Refer also to Photo A2 in Section A4.2.

A4.6.2. Sheared Zones

A sheared zone is a zone along which movement may have taken place, but displacement is not recognisable. The evidence for movement may be slickenside striations or polished surfaces and/or clay gouge. Crushed zones are zones containing disorientated, usually angular rock fragments in a soil matrix. Both sheared zones and crushed zones are similar in nature and therefore have been referred to as sheared zones in this Appendix.

Sheared zones in Hornsby Quarry were mainly identified on the north wall. They typically have subhorizontal to moderate dips (0° to 40°) and are discrete, that is, they do not occur in sets or swarms. Sheared zones are infilled with 100mm to 300mm of soil like material, are traceable between benches and often have vegetation growing along their trace. A sheared zone on the north wall has been supported with rockbolts. Two examples of sheared zones are shown in Photo A4.

Photo A4: Two examples of sheared zones in Hornsby Quarry

A4.6.3. Joint Swarms

A joint swarm is a zone where numerous joints of a similar orientation occur in close proximity. Two major joint swarms were identified, one on the west wall, and one on the south wall. Both swarms have persistent joints, with traces as long as 50m, are subvertical (dips of 80° to 90°) and trend from the south west to the north east, on a similar orientation to the muddy breccia zones in the north and west walls. A photo of the joint swarm in the south wall is shown in Photo A5.

Photo A5: Joint Swarm in South Wall

A4.6.4. Bedding Planes

A bedding plane or parting is a continuous plane of mineral grains or crystals that were laid parallel to the deposition surface. As mentioned in Section 3.3 above, in the diatreme creation model proposed by Barron and Barron (Reference 4), bedding partings either form with a steep dip (explosive stages) or a shallow dip (dormant stage).

Bedding partings formed during the explosive stage represent separate explosive events or basal surge flows. They often separate different rock types, for example finer grained volcanic breccia and coarse grained volcanic breccia. On the east wall, these bedding partings are typically 200mm to 1,000mm apart. For example, the muddy breccia shown in the south east corner of the pit (Figure A5) is one bedding parting related to a muddy breccia unit about 1m in thickness (Photo A6). Horizontal to shallow bedding partings formed during the dormant stage and represent sediments settling in a lake. These bedding partings are also persistent and separate 2m to 3m thick beds. They have mainly been mined out as they only occur in the centre of the diatreme, although they are exposed on the lower north wall (Photo A7).

Some of the bedding partings in Hornsby Quarry are grouped in with the major structures in the stability assessment because of their unfavourable orientation and size. Major failures on steeply dipping bedding planes have occurred on the south wall during mining and shallow dipping bedding partings, because of their persistence, may provide a release plane to a sheared zone or other major defect that is not exposed or daylights into the pit.

Photo A6: Steeply Dipping Bedding on the South Wall

Photo A7: Subhorizontal Bedding on the Lower North Wall

A4.7. Fill Material

Fill material is found in four zones within the study area:

(1) Eastern fill area
(2) Crusher plant area
(3) South western fill area
(4) Upper north slope.

Both Coffey and Partners (Reference 5 and 6) and Parsons Brinckerhoff (Reference 7) have described fill from these areas. This investigation also excavated 16 testpits from zones 1 to 3 above. Zone 4 was not accessible to earthmoving machinery.

A comparison of contours from a 2m interval contour map generated from 1961 aerial photos (pre major quarry development; Drawing PSM1059-5) and the current topography (2005, 2m contours; Drawing PSM1059-4) has enabled an assessment of the thickness of fill around the quarry area. Isopachs of the thickness of fill have been drawn as Drawing PSM1059-20 in the main Report and they are also shown on Figure A4.

Test pit logs and photographs are reproduced in Attachment A2. Soil Test Certificates from laboratory tests are included in Appendix B and the fill material at each location is described below.

A4.7.1. Eastern Fill Zone

Coffey and Partners (Reference 6) completed a series of test pits and boreholes to delineate the quality of fill in this zone. Testpits from this investigation and previously by Parsons Brinckerhoff have confirmed the Coffey and Partners findings.

Section G3 of Appendix G discusses the fill material properties found in the eastern zone, but in summary, fill material does not appear to have been properly engineered or compacted with any control. Therefore, in this zone the fill should be considered to be non-engineered fill.

A4.7.2. Crusher Plant Fill Zone

Three test pits from this investigation were excavated in the vicinity of the crusher plant. The upper approximately 1.2m is engineered fill of well graded, medium dense silty sandy gravel. Below this engineered fill is non-engineered clayey sandy gravel and gravely sand with numerous boulders up to 1.0m.

Fill material from this area is discussed in more detail in Section H3 to H5 of Appendix H.

A4.7.3. South Western Fill Zone

A total of four test pits were dug in fill material from this zone. Fill in this zone may be divided into two areas, namely, the main body and the lower fill area. The main body of fill is composed of sandy gravels with some cobbles and boulders up to 1.0m. The lower fill area contained clayey gravely sands, also with some large boulders and also including a range of man-made objects such as car seats, air conditioning units and so on. Both of these areas of fill material should be considered non-engineered. Further discussion on the fill material found in the south western zone may be found in Section I2 to I4 of Appendix I.

A4.7.4. Fill on the Northern Slope

Access limitations prevented an excavator from accessing this slope but from the changes between the 1961 contour plan and 2005 contour plan, zones of fill have been delineated.

At the northern extreme of the study area, an approximately 5m high sound barrier was constructed. It is assumed that non-engineered fill has been used here as well. Three other zones of fill on the north wall may represent material dumps from when the north slope was excavated/cut back to its current profile (refer to Figure A4 or Drawing PSM1059-20 of the main Report).

A5. STRUCTURAL DOMAINS AND PIT SECTORS

A structural domain is a zone that contains similar geological conditions, namely rock types, defect type and orientation. Following the collation of geological data described in Section 4 above, the pit and the immediate slopes have been divided into four structural domains, as shown on Figure A6.

(1) Western Domain
(2) North Eastern Domain
(3) Eastern Domain
(4) Southern Domain

Each domain has been further subdivided into pit sectors, whereby a specific pit sector has a different pit wall orientation. The relationship between the geological structures in a domain and the orientation and angle of the pit wall generally dictates the type of structural failure that is possible at that location.

Table A4 lists the domains and pit sectors and other relevant information such as typical batter and inter ramp heights and angles. This information has been used to assess the kinematic failure mechanisms in each pit sector and which is discussed in further detail in Section A6.

TABLE A4
STRUCTURAL DOMAINS AND PIT SECTORS

DOMAIN	PIT SECTOR	DIP DIRECTION OF PIT WALL (°)	BENCH HEIGHT (m)	TYPICAL BENCH SLOPE ANGLE (°)	INTERRAMP HEIGHT (2 OR 3 BENCHES) (m)	INTERRAMP SLOPE ANGLE (°)
Western	W1	095	20-26	60-70	46	50
	W2	140	16-22	55	40	37
	W3	170	10-16	50	40	40
	W4	N/A[1]	N/A	N/A	N/A	N/A
North Eastern	NE1	175	16	55	32	30
	NE2	200	20-24	36-50	42	45
Eastern	E1	275	12-26	60-75	70	48
	E2	N/A	N/A[1]	N/A	N/A	N/A
Southern	S1	030	20-50	55	80	55
	S2	350	14-26	70	72	66
	S3	020	14-26	70	54	60
	S4	N/A	N/A[1]	N/A	N/A	N/A

[1] Pit sectors W4, E2 and S4 are zones of fill material.

A6. KINEMATIC FAILURE ASSESSMENT

The assessment of potential structural failure mechanisms that could occur on any of the pit walls is based on the mapped major geological structures. As stated previously, numerous bench scale failures have occurred or are likely to occur given the current condition of the bench slopes. The kinematic failure assessment in this Section of the Appendix, therefore, only deals with potential large scale failures that could affect two to three batters (interramp scale) or the entire slope.

A6.1. Objective and Approach

The objective of a kinematic failure assessment is to assess what potential or critical failure mechanism for each pit sector might be.

The first stage was to plot all relevant major structural defects in a given domain onto a stereoplot and for each pit sector, the wall orientation and slope angle was marked on the relevant stereoplot.

The second stage was to perform the Markland Test, as described in Hoek and Bray (Reference 11). This test is a simple test to assess what failure mechanism, such as planar sliding or wedge block failure is kinematically possible. For each pit sector, the Markland Test was performed for:

- planar sliding, and
- wedge block sliding.

A toppling assessment was not performed as toppling in the pit is considered to be a bench scale problem, caused by a combination of unfavourably orientated joints and blast damage to the pit walls.

The third stage involved a mechanical assessment of potential failure mechanisms highlighted in the kinematic assessment. This was achieved using ROCSCIENCE programs; Rocplane 2.0 for planar sliding and Swedge 4.0 for wedge block failures.

The results of the kinematic and mechanical assessments for each pit sector are discussed below. Stereoplots are reproduced in each section. This information has also been summarised into Drawing PSM1059-2 of the main Report.

A6.2. Western Domain

The kinematic assessment for pit sectors W1 to W3 are reproduced in Figures A7 to A9. These figures also show the geological map of the sector and provide a simple visual block model of the failure mechanism. Table A5 collates this information and provides a comment regarding the visual and mechanical assessment. Definitions of the defect types may be found in the borehole explanation sheet in Attachment A2.

TABLE A5
WESTERN DOMAIN KINEMATIC AND MECHANICAL ASSESSMENT

SECTOR	FAILURE MECHANISMS	CRITICAL DEFECTS IN KINEMATIC WINDOW	VISUAL AND MECHANICAL ASSESSMENT	COMMENT
W1	Planar Sliding	CN	Failure not likely	Defect lies just outside the kinematic window and is at an angle greater than 30° to the face.
		SZ	Failure not likely	Sheared zone is discrete zone that does not occur in this pit sector. No evidence in the field of any other similarly orientated shears in this pit sector.
	Wedge Block	CN-SZ	Failure not likely	Sheared zone is discrete zone that does not occur in this pit sector. No evidence in the field of any other similarly orientated shears in this pit sector.
		CN-SZ	Failure not likely	Sheared zone is discrete zone that does not occur in this pit sector. No evidence in the field of any other similarly orientated shears in this pit sector.
		SZ-SZ	Failure not likely	Sheared zone is discrete zone that does not occur in this pit sector. No evidence in the field of any other similarly orientated shears in this pit sector. Both shears are discrete structures.
W2	Planar	CN	Possibility of large scale failure	Contact is unfavourably orientated and lies above and below the haul road.
		SZ	Failure not likely	Sheared zone is a discrete zone that does not occur in this pit sector.
	Wedge	CN-SZ	Failure not likely	Sheared zone is a discrete zone that does not occur in this pit sector.
		CN-SZ	Failure not likely	Sheared zone is a discrete zone that does not occur in this pit sector.
		SZ-SZ	Failure not likely	Sheared zones are discrete zones that do not occur in this pit sector.
	Circular	Weathered Breccia	Possibility of failure	Steep slope of ~30° coupled with weathered breccia materials could result in a circular failure similar to one that has occurred in W3 during mining activities.
W3	Planar	SZ	Possibility of large scale failure	Discrete sheared zone occurs in this pit sector. Rockbolts already support this sheared zone on the upper bench immediately below the access road.

SECTOR	FAILURE MECHANISMS	CRITICAL DEFECTS IN KINEMATIC WINDOW	VISUAL AND MECHANICAL ASSESSMENT	COMMENT
	Wedge	SZ-CN	Possibility of large scale failure	Discrete sheared zone occurs in this pit sector. Rockbolts already support this sheared zone on the upper bench immediately below the access road. Contact acts as a side release plane or tension crack, thereby facilitating planar sliding on the sheared zone.
		CZ-JN	Failure not likely	Swedge indicates a factor of safety of ~1.6, therefore planar sliding along sheared zone is more likely to occur.
		SZ-SZ	Failure not likely	Swedge indicates a factor of safety of ~1.3, therefore planar sliding along sheared zone is more likely to occur.
	Circular	Weathered Breccia	Possibility of failure	Failure has occurred during mining activities.
W4	Circular	Fill material	Possibility of large scale failure	Fill has not been placed in an engineered manner and therefore its properties will be highly variable.

Where a potential failure is possible, a limit state equilibrium stability analysis has been undertaken. The results of these analyses are included as Appendix E.

A6.3. North Eastern Domain

The kinematic assessment for pit sectors NE1 and NE2 are reproduced in Figures A10 to A11. These figures also show the geological map of the sector and provide a simple visual block model of sliding. Table A6 collates this information and provides a comment regarding the visual and mechanical assessment.

TABLE A6
NORTH EASTERN DOMAIN KINEMATIC, VISUAL AND MECHANICAL ASSESSMENT

SECTOR	FAILURE MECHANISMS	CRITICAL DEFECTS IN KINEMATIC WINDOW	VISUAL AND MECHANICAL ASSESSMENT	COMMENT
NE1	Planar	None indicated	Large scale failure not likely	Bedding is either too steep or too shallow for failure to occur.
	Wedge Block	SZ-BD	Large scale failure not likely	Discrete shear that dips from 0° to 30°, therefore wedge geometry not realistic.
NE2	Planar	None indicated	Large scale failure not likely to occur	
	Wedge	None indicated	Large scale failure not likely to occur	

No large scale failure mechanisms have been identified as being kinematically feasible in this domain. However, a potential failure mechanism exists whereby failure occurs through the rock mass, using a steep bedding parting as a tension crack. A limit state equilibrium stability analysis for this mechanism has been undertaken and is included in Appendix E.

A6.4. Eastern Domain

The kinematic assessment for pit sector E1 is reproduced in Figure A12. This figure also show the geological map of the sector and provide a simple visual block model of sliding. Table A7 collates this information and provides a comment regarding the visual and mechanical assessment.

TABLE A7
EASTERN DOMAIN KINEMATIC, VISUAL AND MECHANICAL ASSESSMENT

SECTOR	FAILURE MECHANISMS	CRITICAL DEFECTS IN KINEMATIC WINDOW	VISUAL AND MECHANICAL ASSESSMENT	COMMENT
E1	Planar	None	No large scale failure likely.	
	Wedge	None	No large scale failure likely	
E2	Circular	Fill material	Possibility of failure	Fill has not been placed in an engineered or controlled manner and therefore its properties will be highly variable.

No kinematic large scale failure mechanisms have been identified in Sector E1. However, there is a potential for circular failures to occur in Sector E2 located in the fill material. Limit state equilibrium stability analyses of the potential circular failure in the fill material in this sector are discussed in Appendices E and G.

A6.5. Southern Domain

The kinematic assessment for pit sectors S1 to S3 are reproduced in Figures A13 to A15. These figures also show the geological map of the sector and provide a simple visual block model of sliding. Table A8 collates this information and provides a comment regarding the visual and mechanical assessment.

TABLE A8
SOUTHERN DOMAIN KINEMATIC, VISUAL AND MECHANICAL ASSESSMENT

SECTOR	FAILURE MECHANISMS	CRITICAL DEFECTS IN KINEMATIC WINDOW	VISUAL AND MECHANICAL ASSESSMENT	COMMENT
S1	Planar	BD	Possibility of large scale instability	Failure along bedding parting has already occurred during mining. Refer to Photo A6.
		CN	Failure not likely	Contact is a discrete structure that does not occur in this pit sector.
	Wedge	BD-JNS	Possibility of large scale instability	Joint swarm may act as a side release plane to planar sliding along the bedding plane.
S2	Planar	BD	Failure not likely	Bedding is at angle greater than 30° to the pit wall, therefore failure is not likely.
		CN	Failure not likely	Contact is a discrete structure that does not occur in this pit sector.
	Wedge	BD-JN	Possibility of small failures	Joint swarms acts as a side release plane that may facilitate planar sliding along bedding. Wedge geometry indicates failure will be small only, therefore this is expected to be bench size instability only.
		BD-CN	Failure not likely	Contact is a discrete structure that does not occur in this pit sector.
		JN-CN	Failure not likely	Contact is a discrete structure that does not occur in this pit sector.
S3	Planar	BD	Possibility of large scale instability	Failure along bedding partings in this sector have already occurred during mining.
		CN	Failure not likely	Contact is discrete and occurs in this domain, however it is located at the boundary of S3 and W1 where the wall geometry is slightly different such that planar sliding is unlikely at this location.

SECTOR	FAILURE MECHANISMS	CRITICAL DEFECTS IN KINEMATIC WINDOW	VISUAL AND MECHANICAL ASSESSMENT	COMMENT
	Wedge	BD-CN	Failure not likely	Unrealistic wedge geometry found.
		BD-JN	Possibility of small failures	Joint swarms acts as a side release plane that may facilitate planar sliding along bedding. Wedge geometry indicates failure will be small only, therefore this is expected to be bench size instability only.
		CN-JN	Possibility of large scale instability	Potential wedge formed with factor of safety <1.0. However, large scale failures have not occurred in this sector, indicating that the potential wedge is not formed in reality. A reason for this may be because the joints are not as persistent adjacent to the contact.
S4	Circular	Fill material	Possibility of failure	Fill has not been placed in an engineered or controlled manner and therefore its properties will be highly variable.

There is the possibility of large scale failures occurring, principally as a result of sliding on bedding planes. Large scale failures have already occurred during mining. Where large scale instability mechanism has been assessed, a limit state equilibrium stability analysis has been undertaken. The results of these analyses are in Appendices E and H.

A6.6. Kinematic Assessment Summary

This assessment was performed to consider what type of large scale instability is structurally feasible. Possible large scale failure mechanisms in each domain are discussed below. Drawing PSM1059-2 summarises the findings of the assessment.

A6.6.1. Western Domain

Large scale instability is not likely to occur in Pit Sector W1. In W2 there is a possibility of planar sliding along contacts between muddy breccia and volcanic breccia. In W3 there is the possibility of large scale failure along an existing sheared zone. Rockbolts already support a section of this sheared zone on the bench above the haul road. Failure of this sheared zone could occur by planar sliding and with muddy breccia-volcanic breccia contacts acting as a side release plane.

Circular features in RES-HW breccia and in fill material is also possible in pit sectors W2, W3 and W4.

A6.6.2. North Eastern Domain

No large scale instability mechanisms are kinematically feasible. However, block sliding that utilises a steep bedding parting as a tension crack could occur.

A6.6.3. Eastern Domain

No large scale instability mechanisms are kinematically feasible. However, the possibility of circular failure occurring in fill materials.

A6.6.4. Southern Domain

Large scale instability is possible in pit sector S1 along bedding partings with a large scale failure understood to have occurred during mining. Subvertical joints may also act as side release planes to facilitate planar sliding. In S2 only bench scale stability occurring along unfavourably orientated bedding planes. Large scale failures in this zone have already occurring during mining.

A7. REFERENCES

1. Crawford, E et al, 1980, Diatremes of the Sydney Basin, in A Guide to the Sydney Basin by C Herbert and R Helby, Geological Survey of NSW, Bulletin 26.

2. Herbert, C, 1983, Geology of the Sydney 1:100,000 Sheet.

3. Branagan and Packham, 2000, Field Geology of New South Wales.

4. Barron, L and Barron, J, 2001, Photographs, Geology and Petrology of Hornsby Diatreme, Geological Survey Report GS2001/226.

5. Coffey and Partners, May 1990, Rock Mechanics Study, Hornsby Quarry, Old Mans Valley, Report No. S8463/4-AD.

6. Coffey and Partners, July 1990, Old Mans Valley Geotechnical Investigations, Report No. S8463/3-AG.

7. Parsons Brinckerhoff, 2004, Volume 1, Technical Investigations for Hornsby Quarry and Environs Land Capability Study and Master Plan.

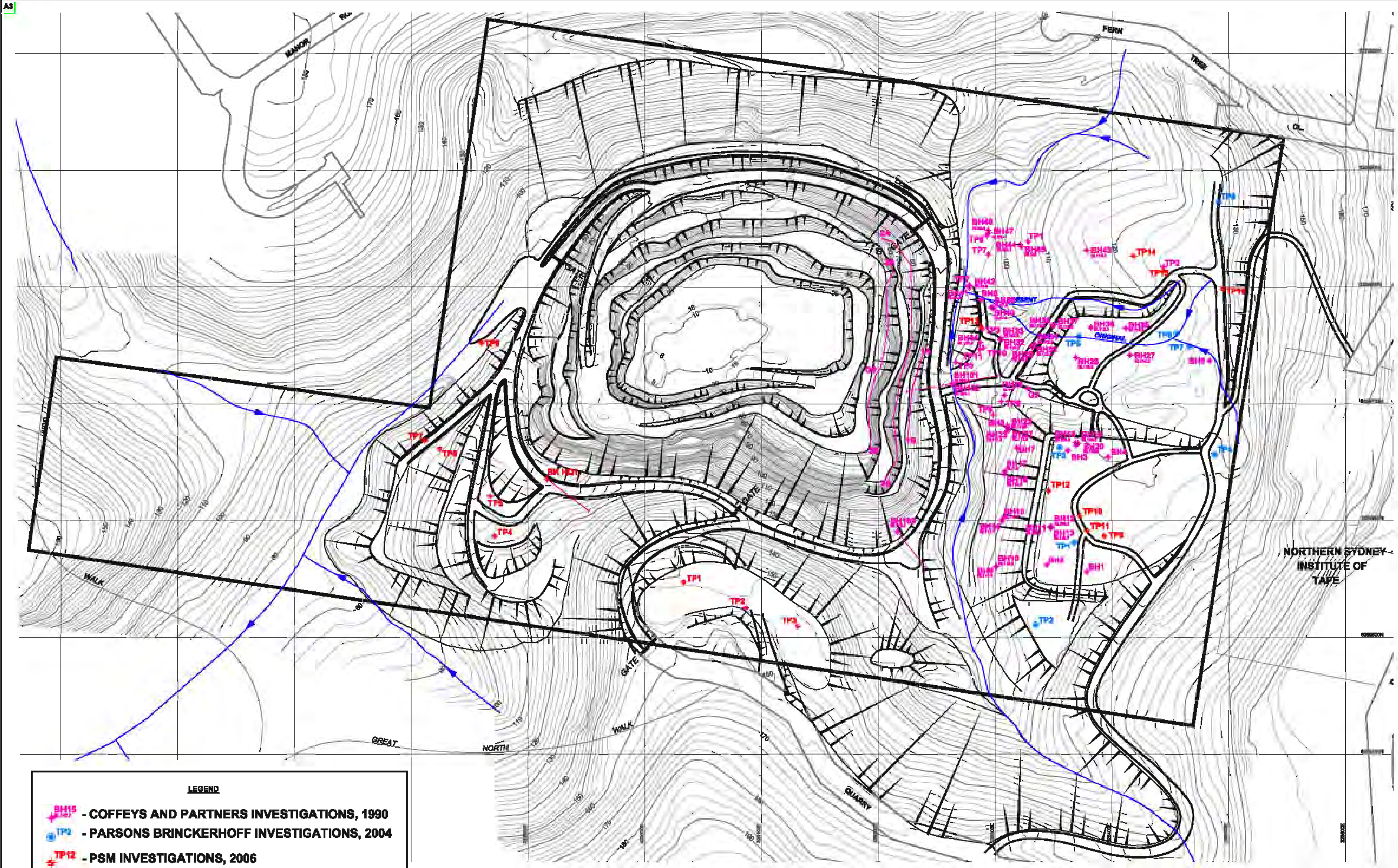
8. Parsons Brinckerhoff, 2004, Master Plan Report for Hornsby Quarry and Environs Land Capability Study and Master Plan.

9. Gerrard, C, 2002, Witness Statement Relating to Geotechnical Aspects of the Quarry.

10. Rickwood, P G, 1985, Igneous Intrusives in the Greater Sydney Region, in Engineering Geology of the Sydney Region, edited by P J N Pells.

11. Hoek, E and Bray, J, 1981, Rock Slope Engineering, Revised 3rd Edition.

A3



LEGEND

- BH15 - COFFEYS AND PARTNERS INVESTIGATIONS, 1990
- TP2 - PARSONS BRINCKERHOFF INVESTIGATIONS, 2004
- TP12 - PSM INVESTIGATIONS, 2006

NOTE:

- SUBSURFACE GEOLOGICAL INTERPRETATION INDICATIVE ONLY.
- LOCATION OF DIATREME - SANDSTONE CONTACT FROM BRANAGAN AND PACKHAM, 2000, AND CHARACTERISTICS OF CONTACT BASED ON INTERPRETATION OF BH HQ1 (THIS INVESTIGATION) AND BH103 (COFFEY'S 1990).
- ONLY MAJOR GEOLOGICAL STRUCTURES MAPPED IN THE PIT BY PSM (THIS STUDY). ORIENTATION ON THE EAST WALL ARE FROM COFFEY'S DATA.

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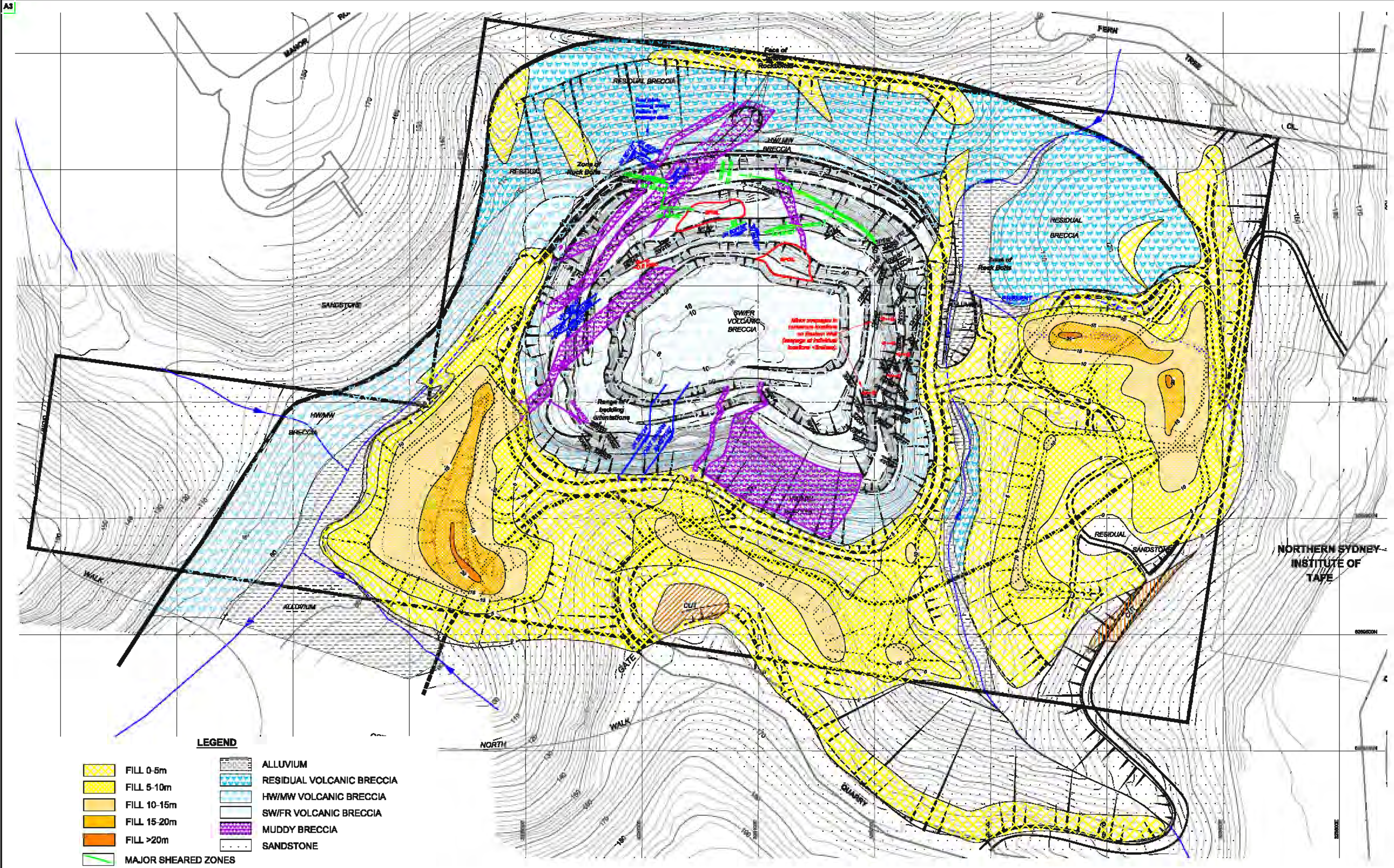
LOCATION OF BOREHOLES AND TEST PITS

PSM1059	Figure A1



LEGEND

FILL 0-5m		ALLUVIUM	
FILL 5-10m		RESIDUAL VOLCANIC BRECCIA	
FILL 10-15m		HW/MW VOLCANIC BRECCIA	
FILL 15-20m		SW/FR VOLCANIC BRECCIA	
FILL >20m		MUDDY BRECCIA	
		SANDSTONE	

MAJOR SHEARED ZONES

CONTACT BETWEEN DIATREME AND HAWKESBURY SANDSTONE

REFER TO BOREHOLE EXPLANATION SHEET IN ATTACHMENT A2 FOR DEFINITION OF ABBREVIATIONS

NOTE:
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0 30 60 120m
1 : 3000@A3

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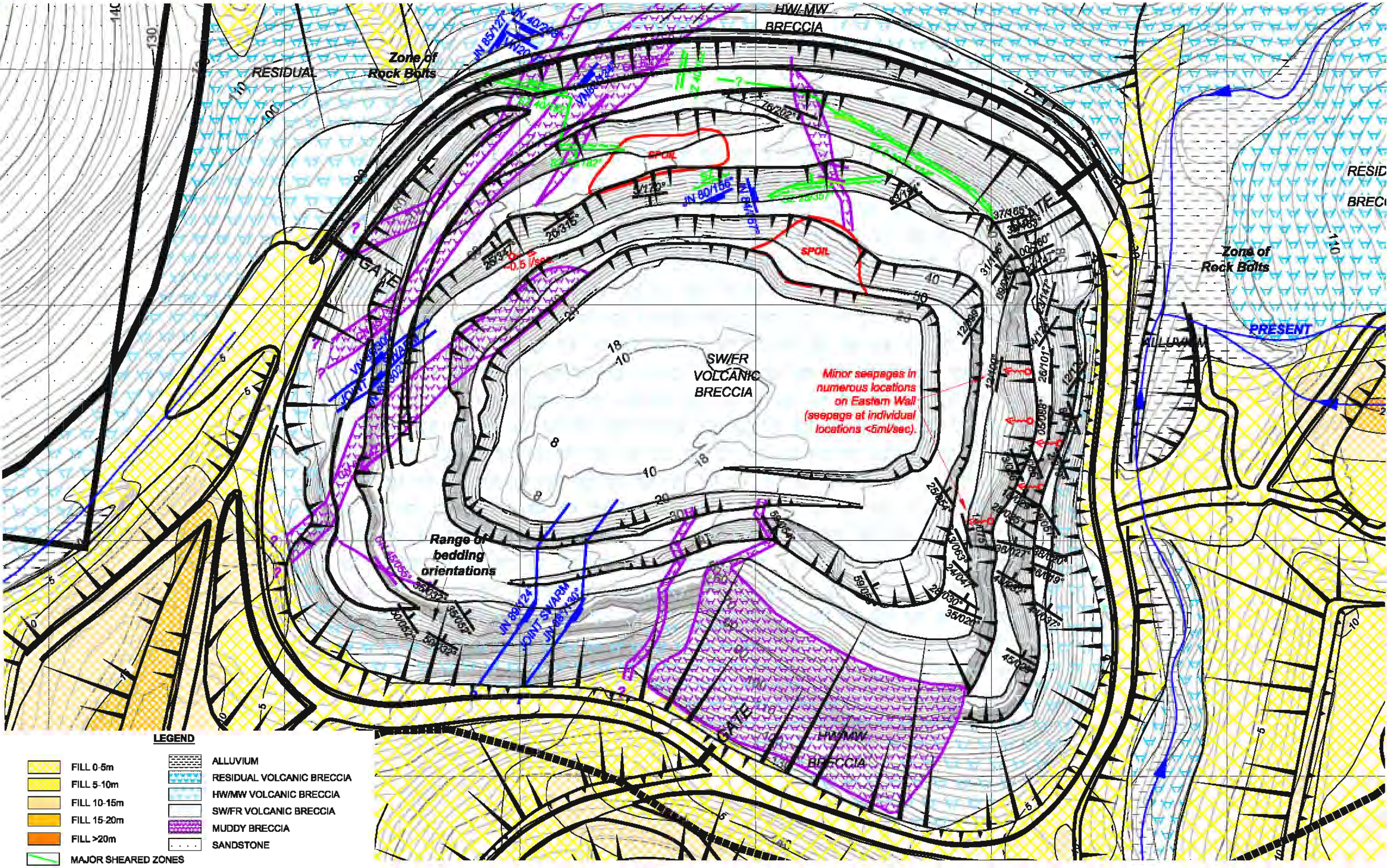
GEOLOGICAL PLAN OF HORNSBY QUARRY

PSM1059 | Figure A4

A3



LEGEND

FILL 0-5m	ALLUVIUM
FILL 5-10m	RESIDUAL VOLCANIC BRECCIA
FILL 10-15m	HW/MW VOLCANIC BRECCIA
FILL 15-20m	SW/FR VOLCANIC BRECCIA
FILL >20m	MUDDY BRECCIA
	SANDSTONE

MAJOR SHEARED ZONES

CONTACT BETWEEN DIATREME AND HAWKESBURY SANDSTONE

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- ONLY MAJOR GEOLOGICAL STRUCTURES MAPPED IN THE PIT BY PSM (THIS STUDY). ORIENTATION ON THE EAST WALL ARE FROM COFFEY'S DATA.

0 15 30 60m
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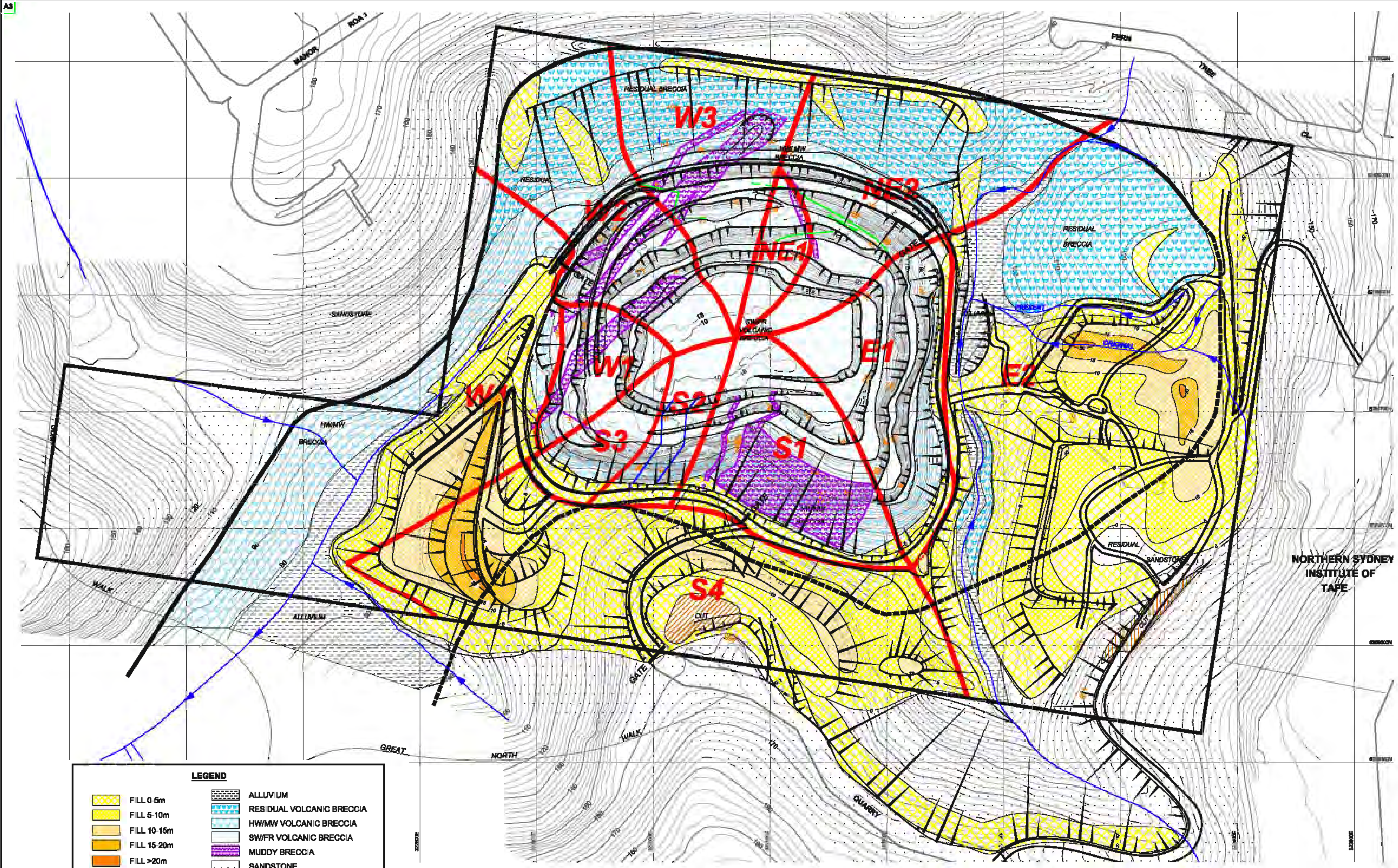
GEOLOGICAL PLAN OF HORNSBY QUARRY

PSM1059	Figure A5



NOTE:
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0 30 60 120m
1 : 3000@A3

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PIT SECTORS

PSM1059	Figure A6

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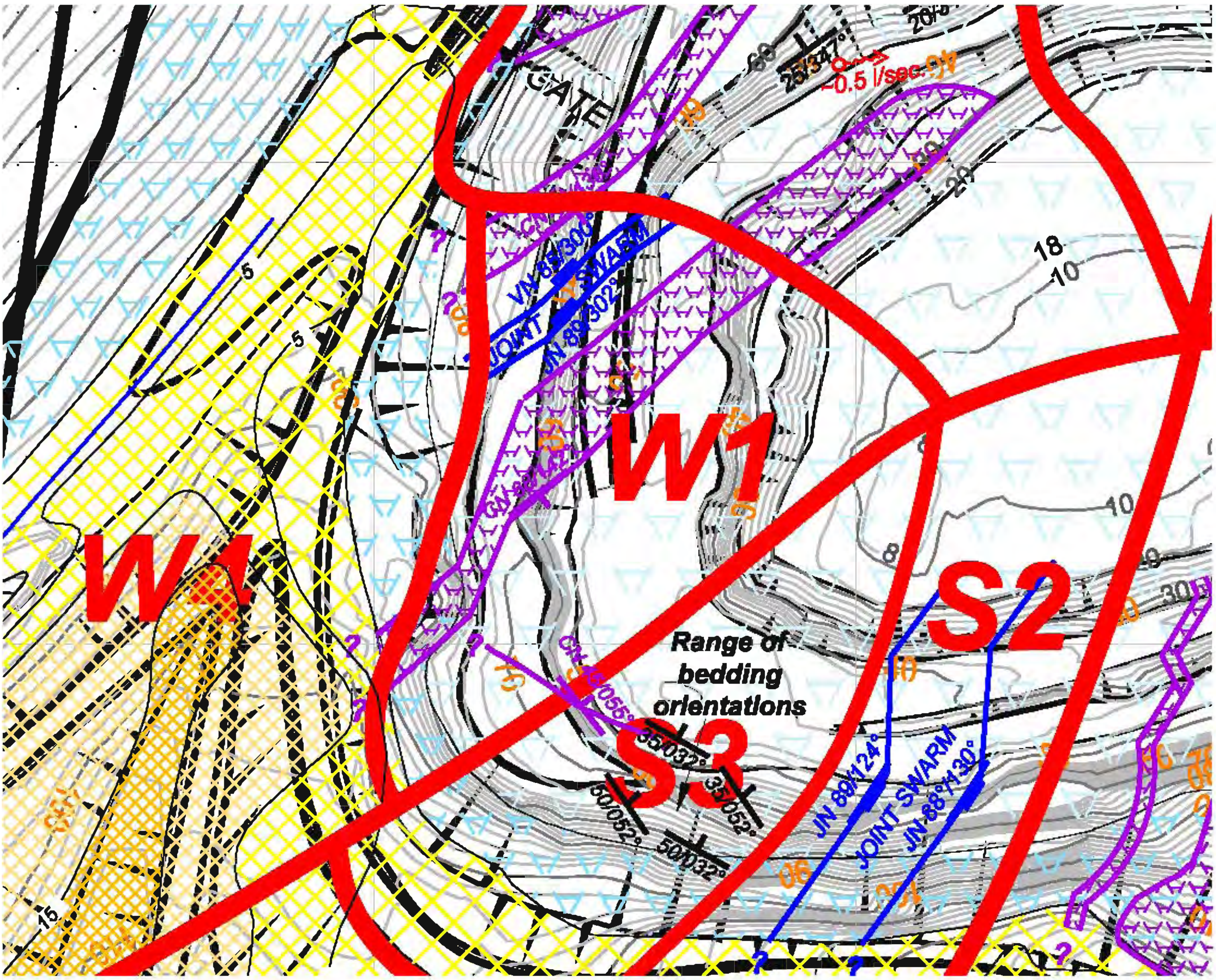
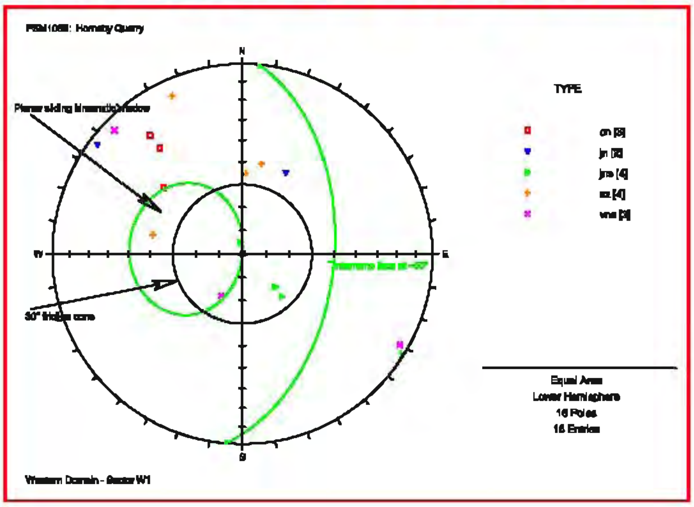
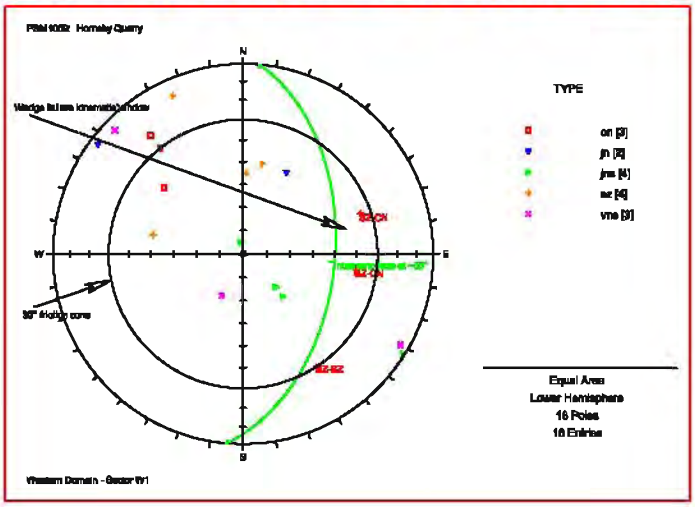
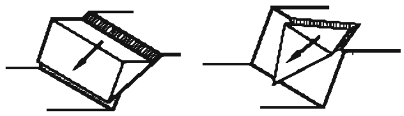






SECTOR W1

- PLANAR SLIDING AND WEDGE FAILURE ON MUDDY BRECCIA CONTACT AND SHEARED ZONES, KINEMATICALLY FEASIBLE



LEGEND

- FILL 0-5m
- FILL 5-10m
- FILL 10-15m
- FILL 15-20m
- FILL >20m
- ALLUVIUM
- RESIDUAL VOLCANIC BRECCIA
- HW/MW VOLCANIC BRECCIA
- SW/FR VOLCANIC BRECCIA
- MUDDY BRECCIA
- SANDSTONE
- MAJOR SHEARED ZONES
- CONTACT BETWEEN DIATREME AND HAWKESBURY SANDSTONE

REFER TO BOREHOLE EXPLANATION SHEET IN ATTACHMENT A2 FOR EXPLANTION OF ABBREVIATIONS

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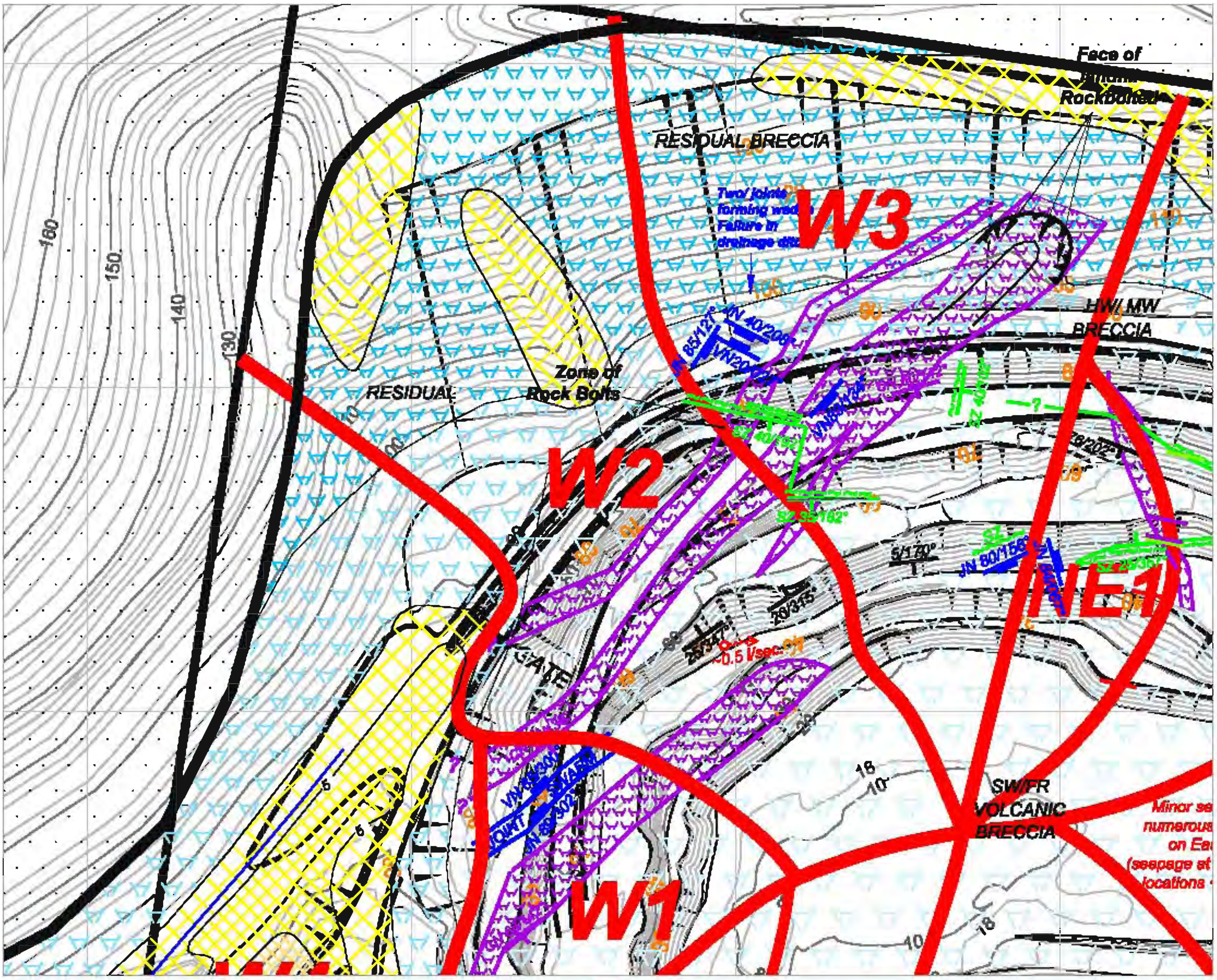
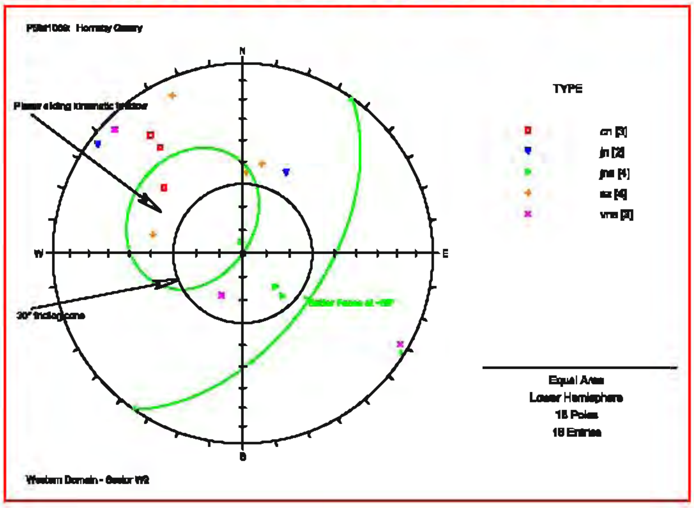
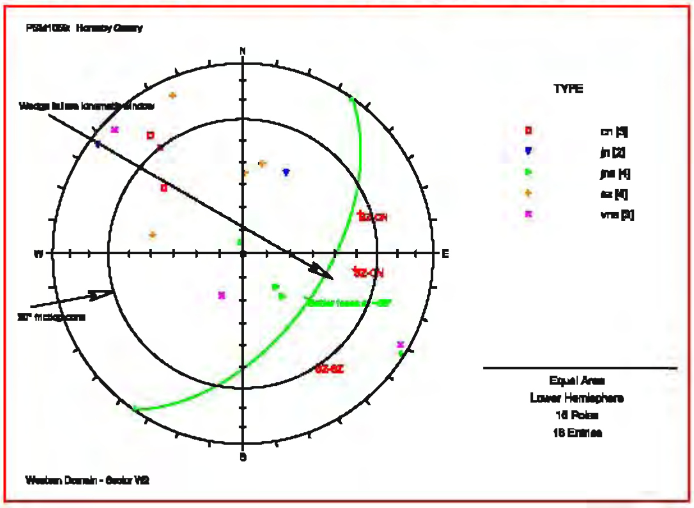
PIT SECTOR W1

PSM1059	Figure A7

NOT TO SCALE

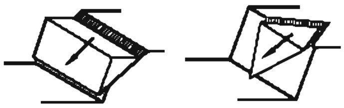






SECTOR W2
ABOVE PIT ACCESS ROAD
- CIRCULAR FAILURE IN RESIDUAL TO HIGHLY WEATHERED MATERIAL FEASIBLE

SECTOR W2
BELOW PIT ACCESS ROAD
- PLANAR SLIDING AND WEDGE FAILURE ON MUDDY BRECCIA CONTACTS AND SHEARED ZONES, KINEMATICALLY FEASIBLE



LEGEND

- FILL 0-5m
- FILL 5-10m
- FILL 10-15m
- FILL 15-20m
- FILL >20m
- MAJOR SHEARED ZONES
- CONTACT BETWEEN DIATREME AND HAWKESBURY SANDSTONE
- ALLUVIUM
- RESIDUAL VOLCANIC BRECCIA
- HW/MW VOLCANIC BRECCIA
- SW/FR VOLCANIC BRECCIA
- MUDDY BRECCIA
- SANDSTONE

REFER TO BOREHOLE EXPLANATION SHEET IN ATTACHMENT A2 FOR EXPLANTION OF ABBREVIATIONS

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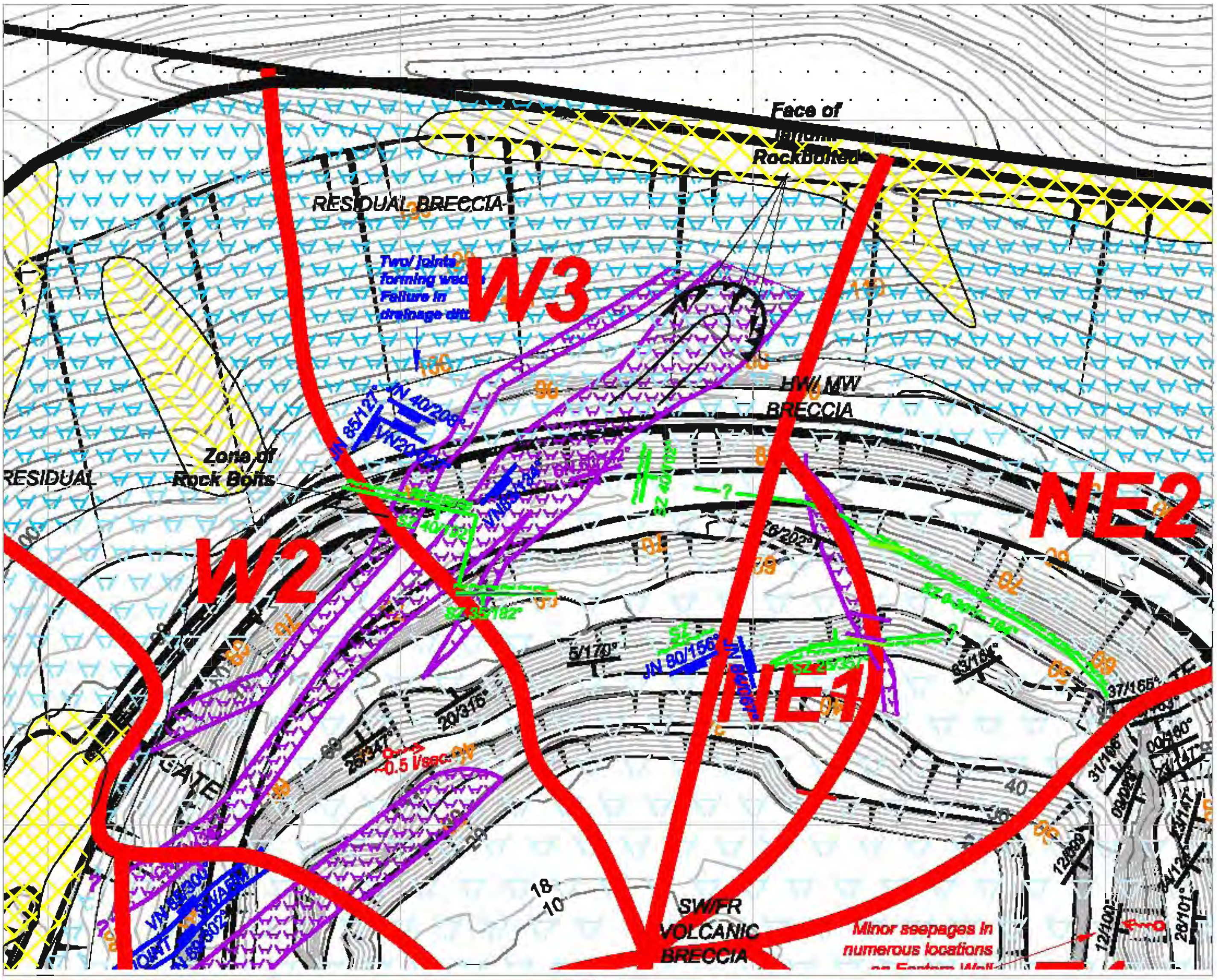
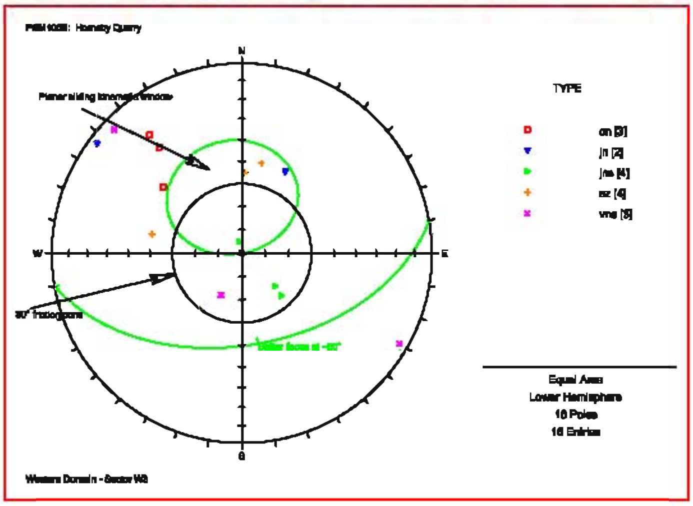
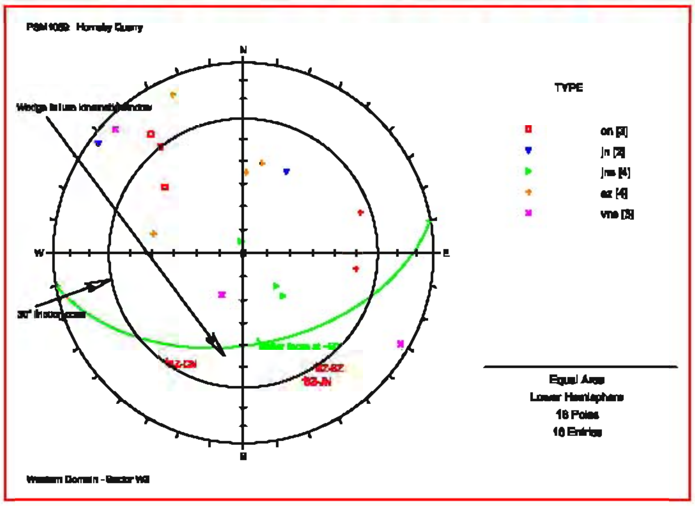
PIT SECTOR W2

PSM1059	Figure A8

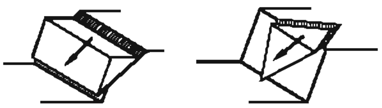
NOT TO SCALE







SECTOR W3 BELOW PIT ACCESS ROAD	SECTOR W3 ABOVE PIT ACCESS ROAD
- PLANAR SLIDING AND WEDGE FAILURE ON MUDDY BRECCIA CONTACTS AND SHEARED ZONES, KINEMATICALLY FEASIBLE	- CIRCULAR FAILURE IN RESIDUAL TO HIGHLY WEATHERED MATERIAL FEASIBLE



LEGEND

- FILL 0-5m
- FILL 5-10m
- FILL 10-15m
- FILL 15-20m
- FILL >20m
- MAJOR SHEARED ZONES
- CONTACT BETWEEN DIATREME AND HAWKESBURY SANDSTONE
- ALLUVIUM
- RESIDUAL VOLCANIC BRECCIA
- HW/MW VOLCANIC BRECCIA
- SW/FR VOLCANIC BRECCIA
- MUDDY BRECCIA
- SANDSTONE

REFER TO BOREHOLE EXPLANATION SHEET IN ATTACHMENT A2 FOR EXPLANTION OF ABBREVIATIONS

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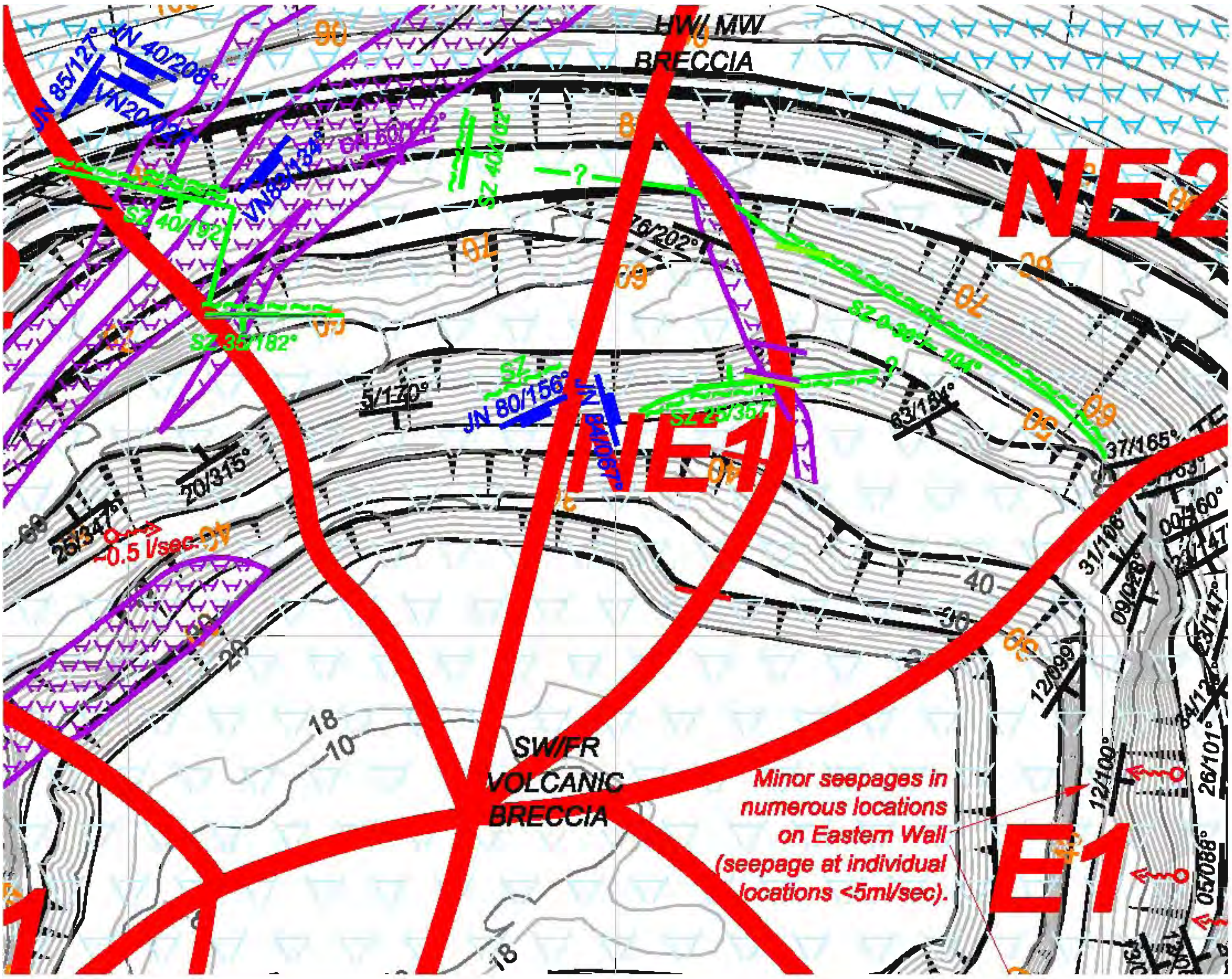
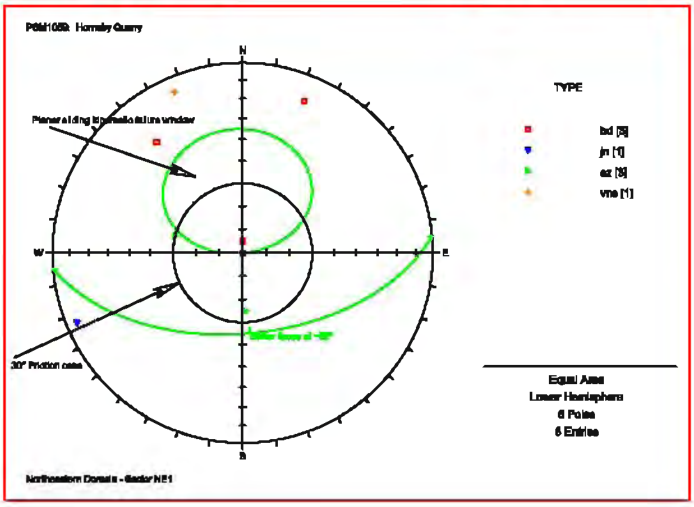
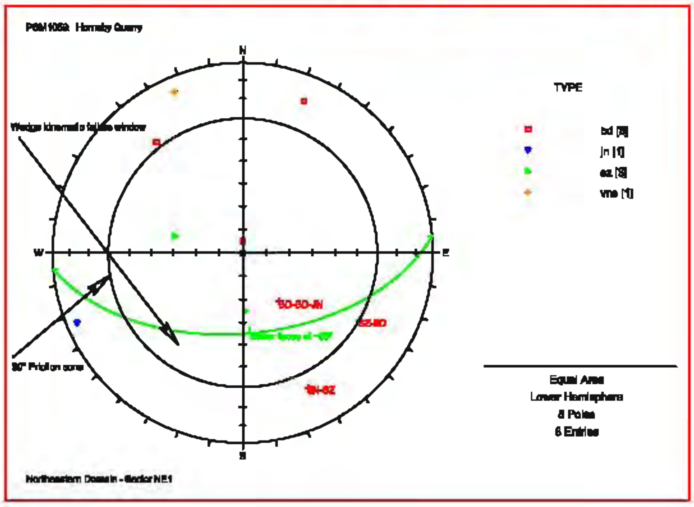
PIT SECTOR W3

PSM1059	Figure A9

NOT TO SCALE

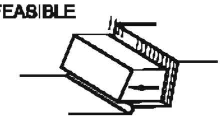






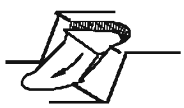
SECTOR NE1 AND NE 2
BELOW PIT ACCESS ROAD

- NO KINEMATIC SIMPLE FAILURE MECHANISM FEASIBLE,
- COMPLETE FAILURE VIA BLOCK SLIDING KINEMATICALLY FEASIBLE



SECTORS NE1 AND NE2
ABOVE PIT ACCESS ROAD

- CIRCULAR FAILURE IN FILL MATERIAL AND RESIDUAL TO HIGHLY WEATHERED MATERIAL FEASIBLE.



LEGEND

- FILL 0-5m
- FILL 5-10m
- FILL 10-15m
- FILL 15-20m
- FILL >20m
- ALLUVIUM
- RESIDUAL VOLCANIC BRECCIA
- HW/MW VOLCANIC BRECCIA
- SW/FR VOLCANIC BRECCIA
- MUDDY BRECCIA
- SANDSTONE
- MAJOR SHEARED ZONES
- CONTACT BETWEEN DIATREME AND HAWKESBURY SANDSTONE

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PIT SECTOR NE1

PSM1059	Figure A10

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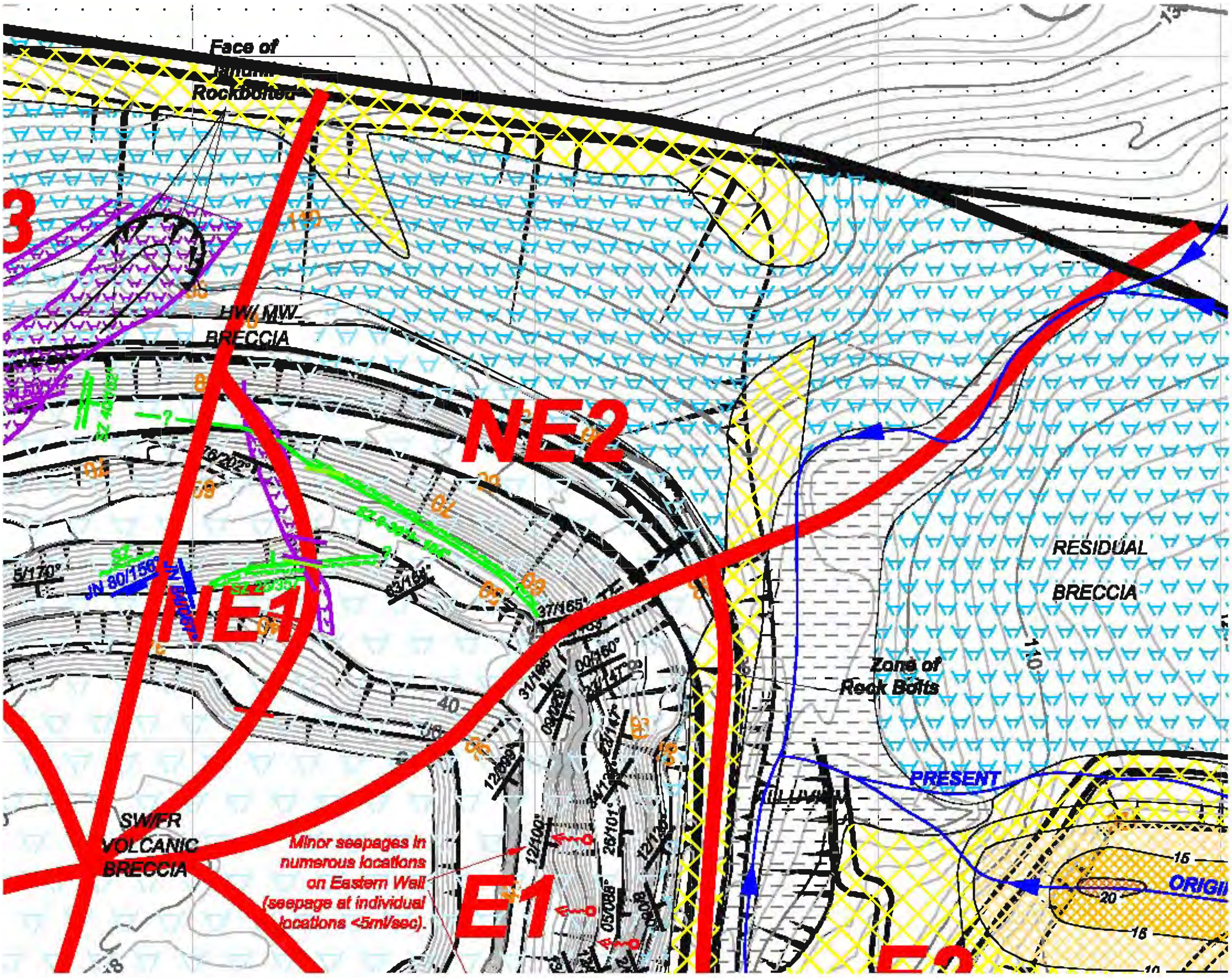

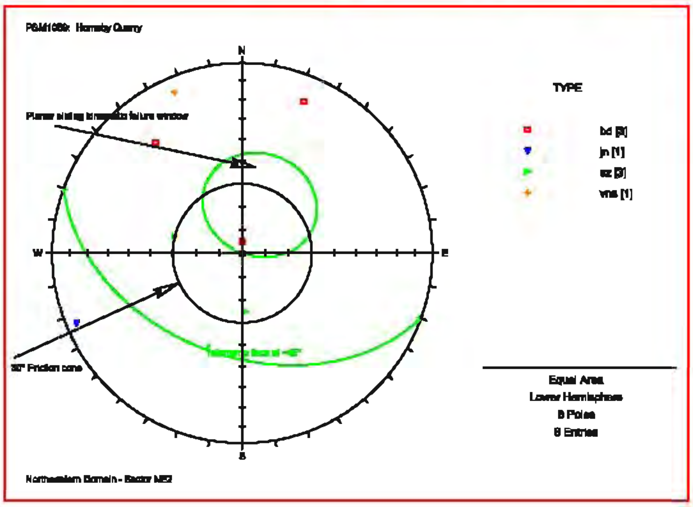

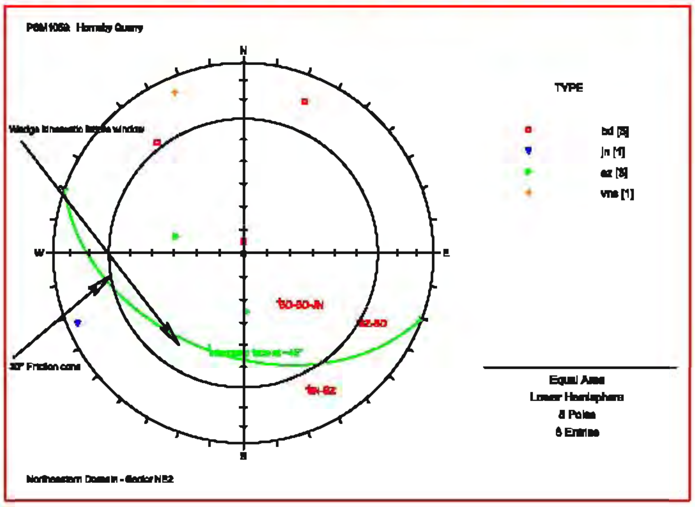

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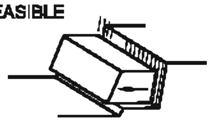
SECTOR NE1 AND NE 2

BELOW PIT ACCESS ROAD

- NO KINEMATIC SIMPLE FAILURE MECHANISM FEASIBLE,
- COMPLETE FAILURE VIA BLOCK SLIDING KINEMATICALLY FEASIBLE



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SECTORS NE1 AND NE2

ABOVE PIT ACCESS ROAD

- CIRCULAR FAILURE IN FILL MATERIAL AND RESIDUAL TO HIGHLY WEATHERED MATERIAL FEASIBLE.

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LEGEND

- FILL 0-5m
- FILL 5-10m
- FILL 10-15m
- FILL 15-20m
- FILL >20m
- MAJOR SHEARED ZONES
- CONTACT BETWEEN DIATREME AND HAWKESBURY SANDSTONE
- ALLUVIUM
- RESIDUAL VOLCANIC BRECCIA
- HW/MW VOLCANIC BRECCIA
- SW/FR VOLCANIC BRECCIA
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PIT SECTOR NE2

PSM1059	Figure A11

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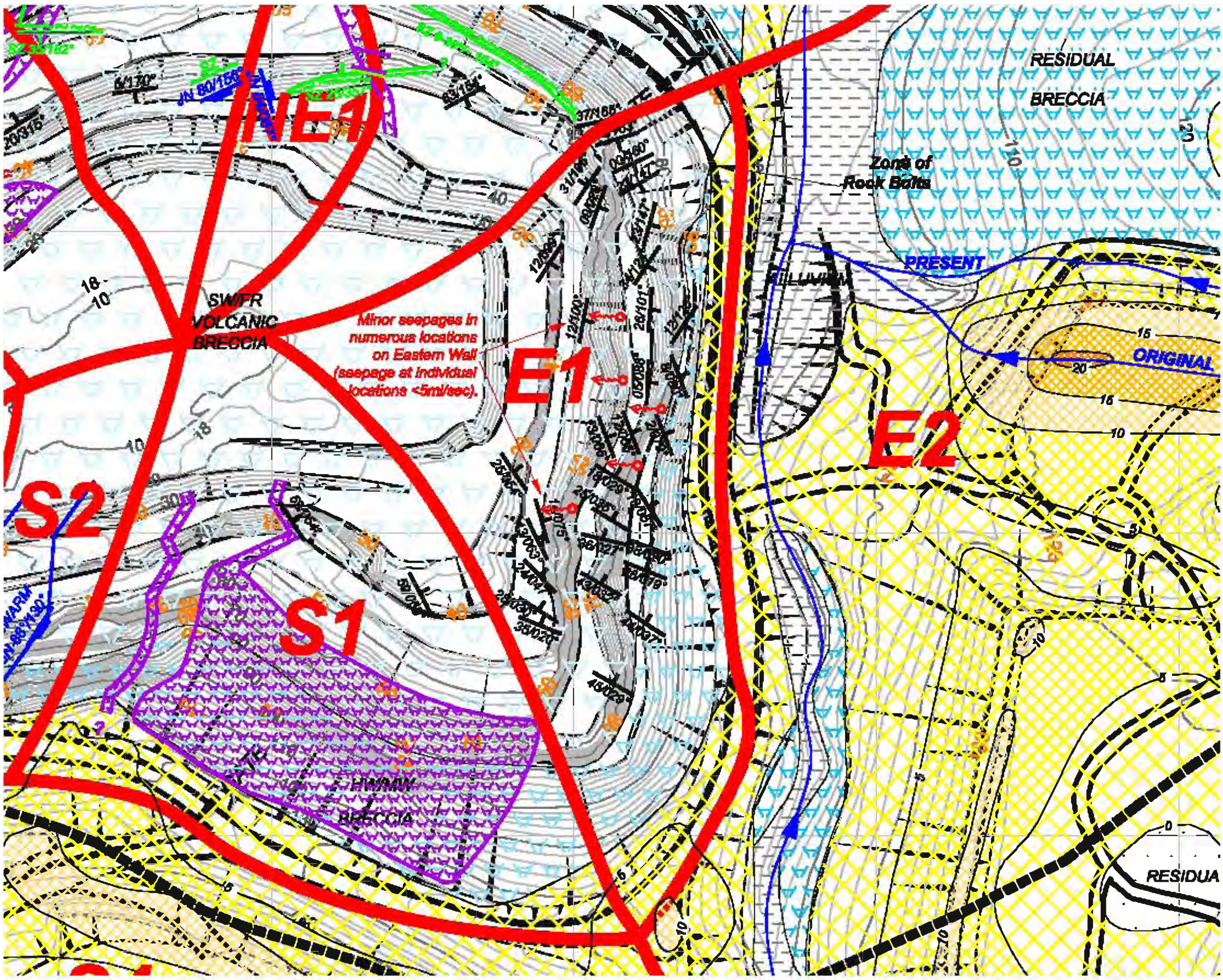

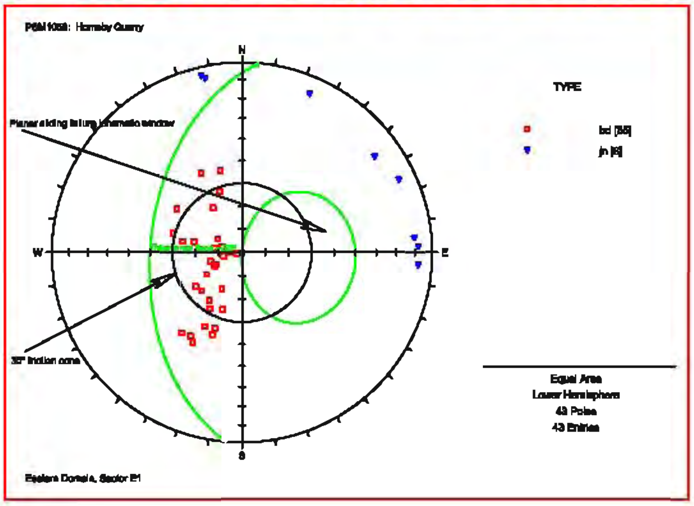

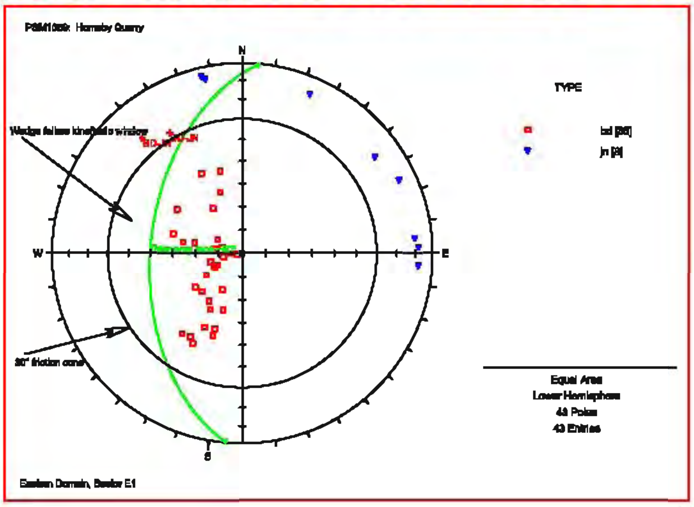

SECTOR E1
- NO KINEMATIC FAILURE MECHANISM FEASIBLE

LEGEND

- FILL 0-5m
- FILL 5-10m
- FILL 10-15m
- FILL 15-20m
- FILL >20m
- MAJOR SHEARED ZONES
- CONTACT BETWEEN DIATREME AND HAWKESBURY SANDSTONE
- ALLUVIUM
- RESIDUAL VOLCANIC BRECCIA
- HW/MW VOLCANIC BRECCIA
- SW/FR VOLCANIC BRECCIA
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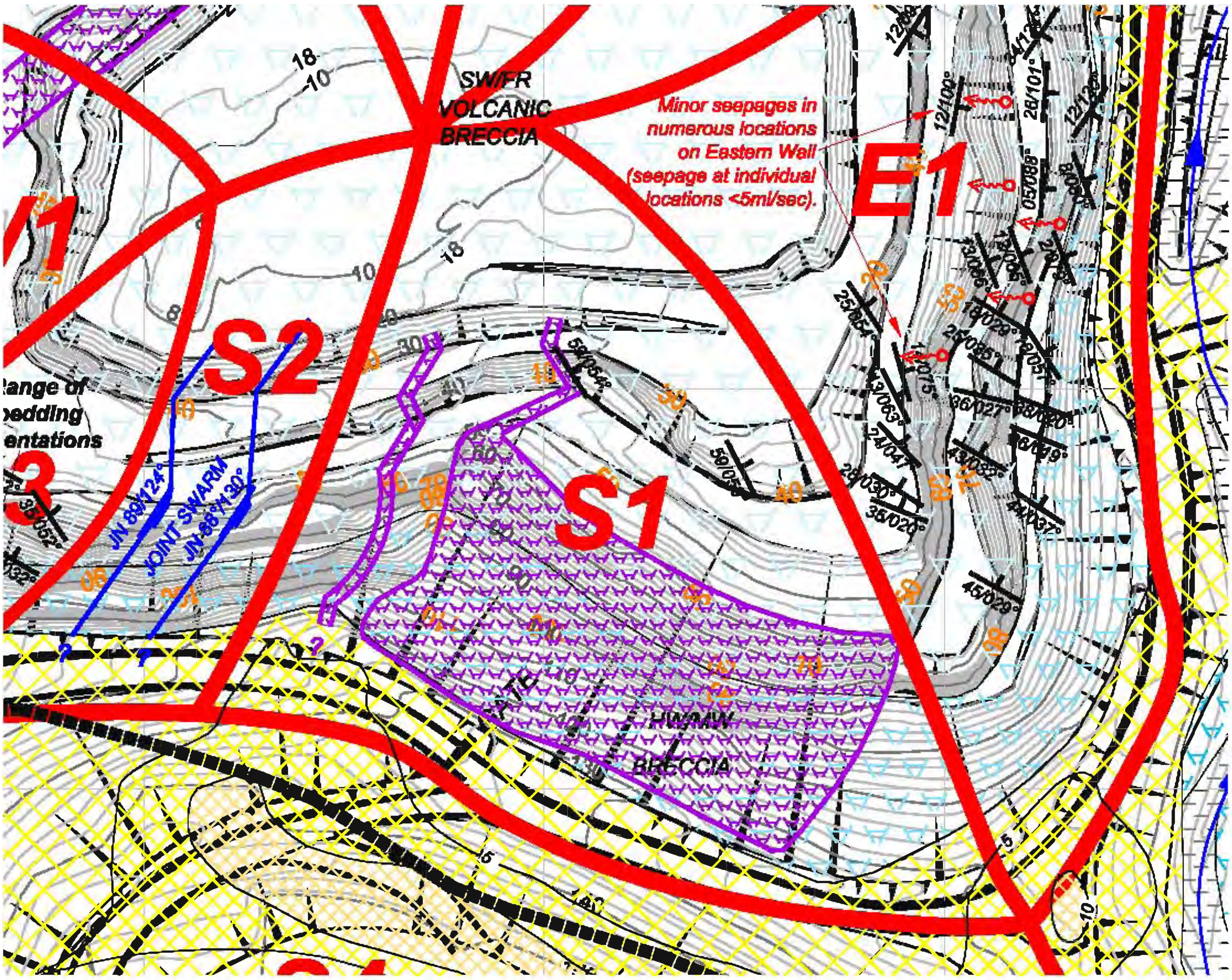
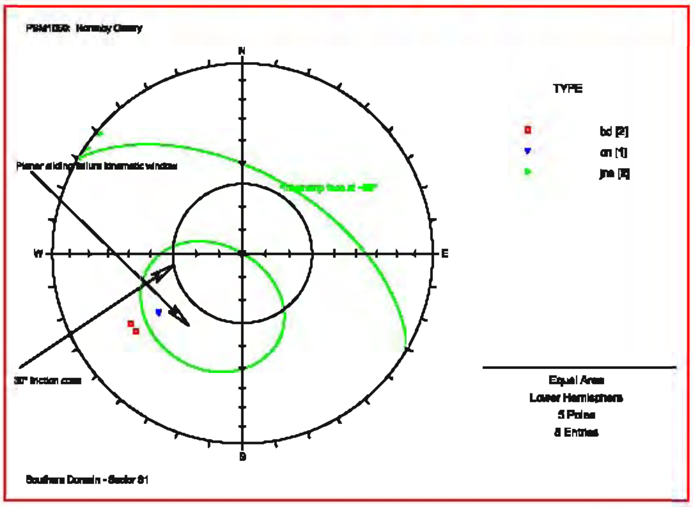
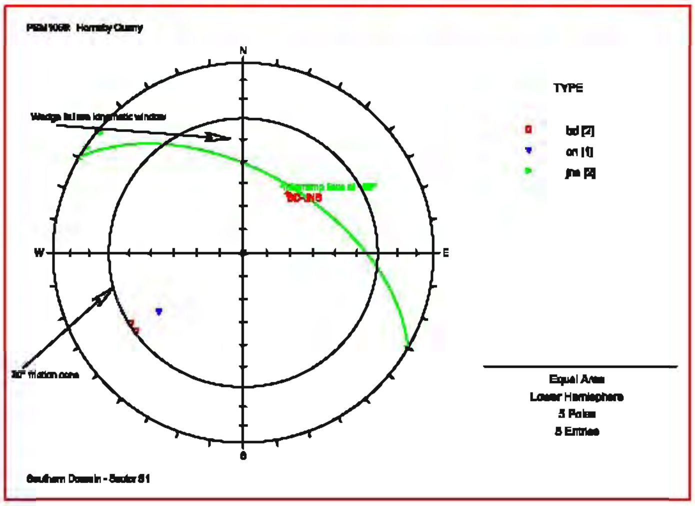
PIT SECTOR E1

PSM1059	Figure A12

NOT TO SCALE

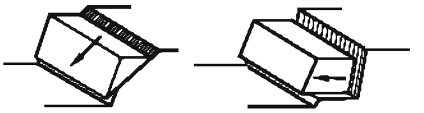






SECTOR S1

-PLANAR SLIDE FAILURE ON BEDDING PARTINGS AND COMPLEX FAILURE VIA BLOCK SLIDING KINEMATICALLY FEASIBLE



LEGEND

- FILL 0-5m
- FILL 5-10m
- FILL 10-15m
- FILL 15-20m
- FILL >20m
- MAJOR SHEARED ZONES
- CONTACT BETWEEN DIATREME AND HAWKESBURY SANDSTONE
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- RESIDUAL VOLCANIC BRECCIA
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- SW/FR VOLCANIC BRECCIA
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PIT SECTOR S1

PSM1059	Figure A13

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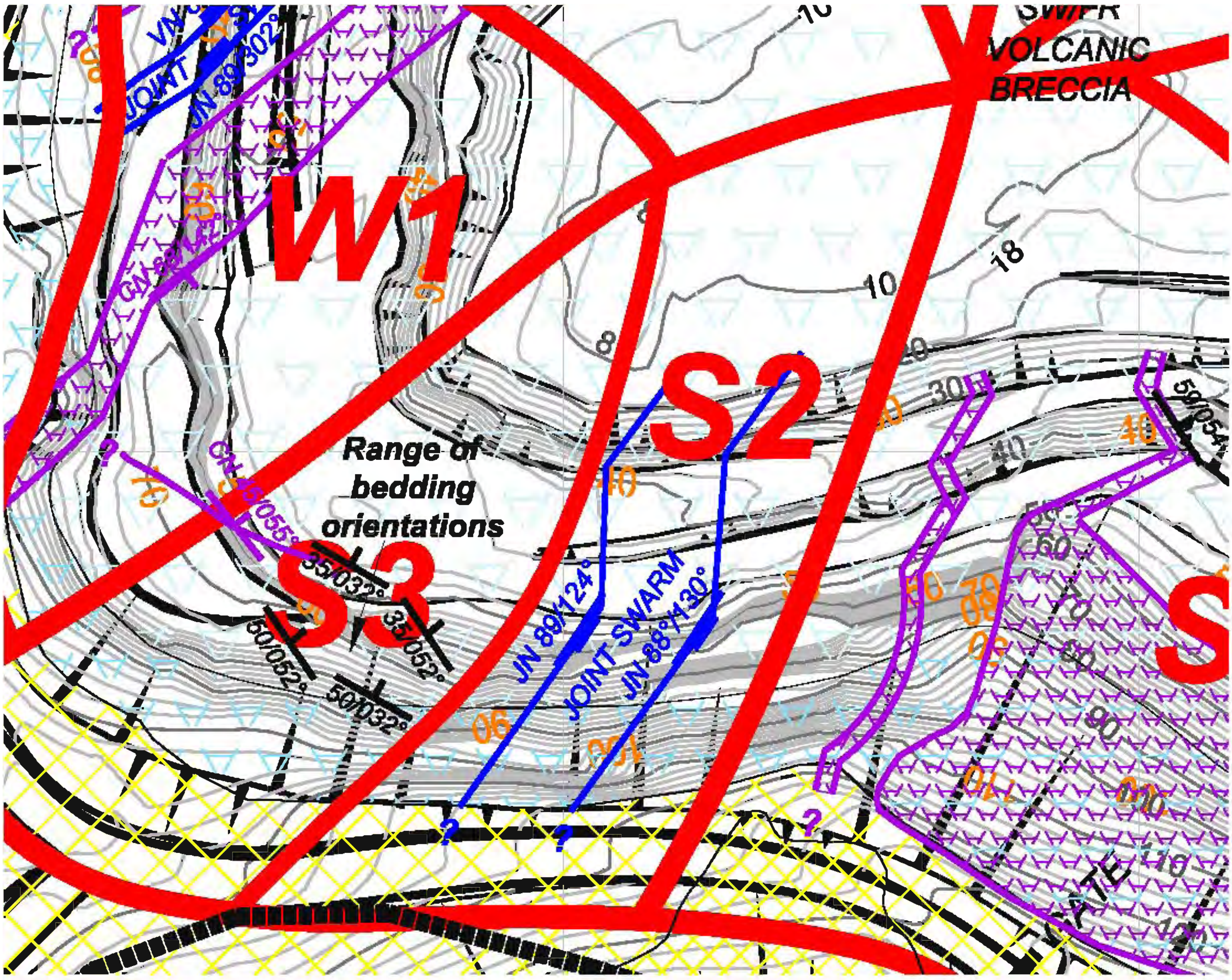

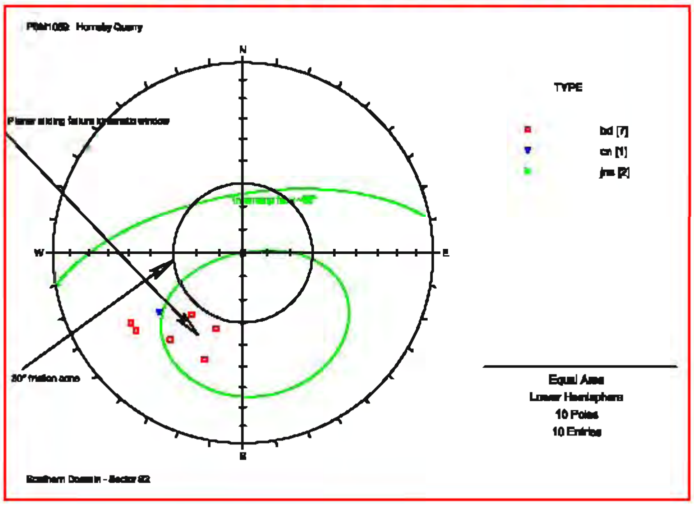

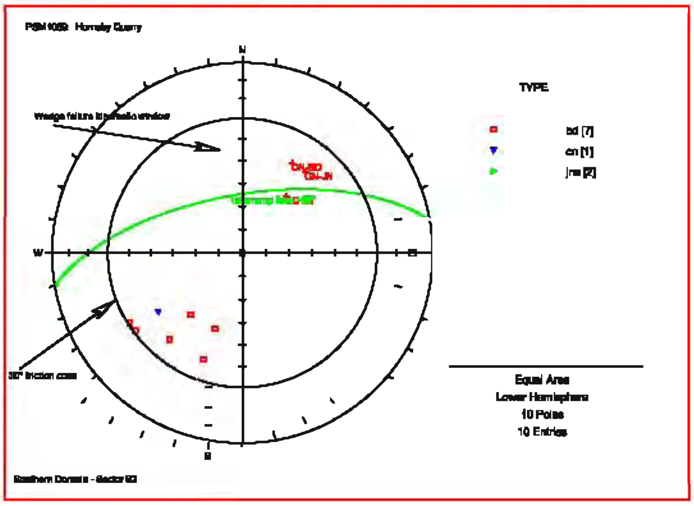

SECTOR S2

- WEDGE FAILURE BETWEEN BEDDING AND JOINTS KINEMATICALLY FEASIBLE

LEGEND

- FILL 0-5m
- FILL 5-10m
- FILL 10-15m
- FILL 15-20m
- FILL >20m
- MAJOR SHEARED ZONES
- CONTACT BETWEEN DIATREME AND HAWKESBURY SANDSTONE
- ALLUVIUM
- RESIDUAL VOLCANIC BRECCIA
- HW/MW VOLCANIC BRECCIA
- SW/FR VOLCANIC BRECCIA
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PIT SECTOR S2

PSM1059	Figure A14

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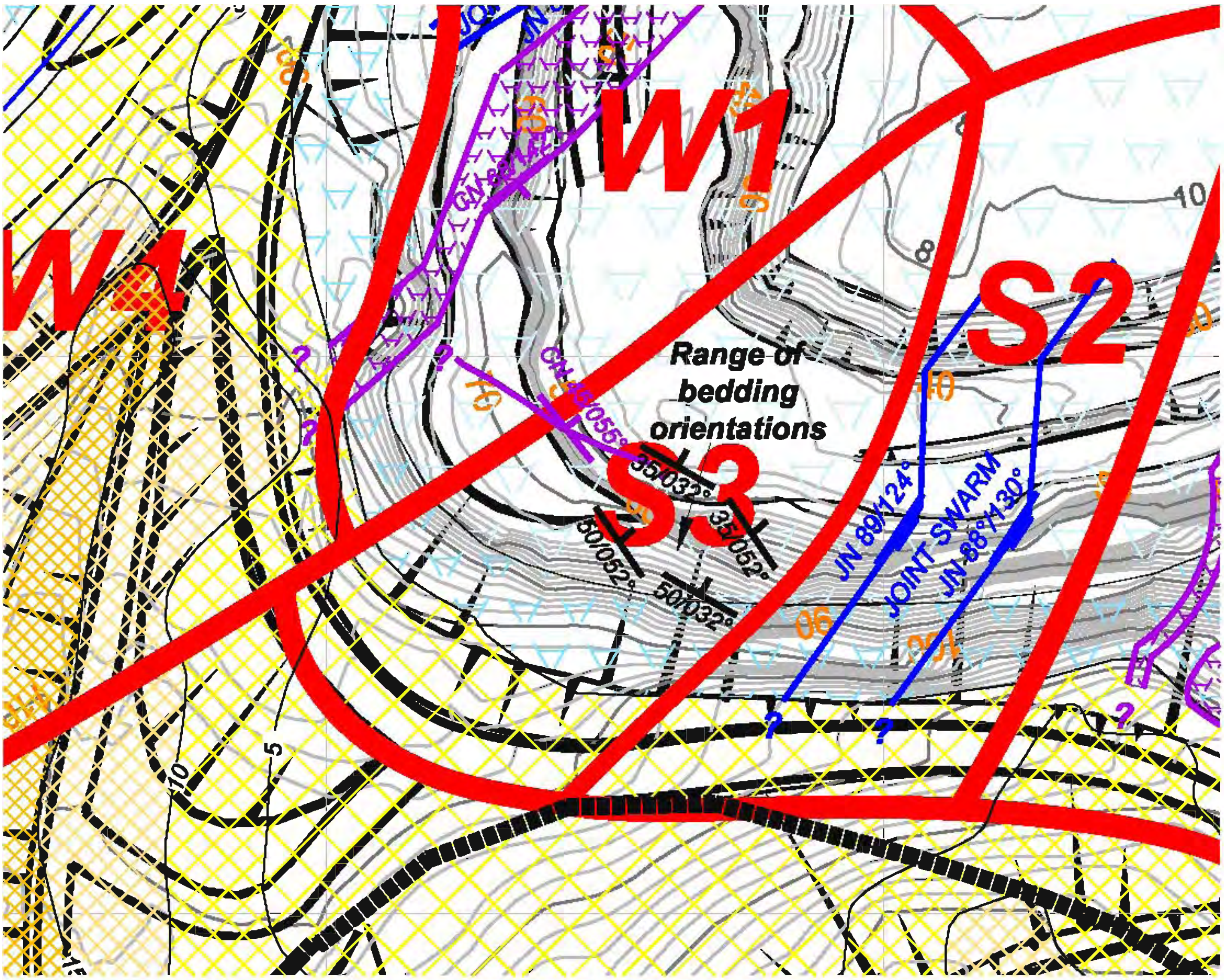
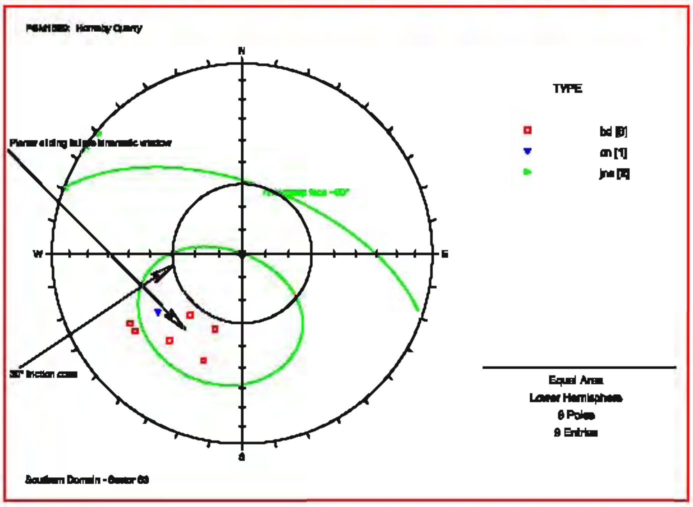
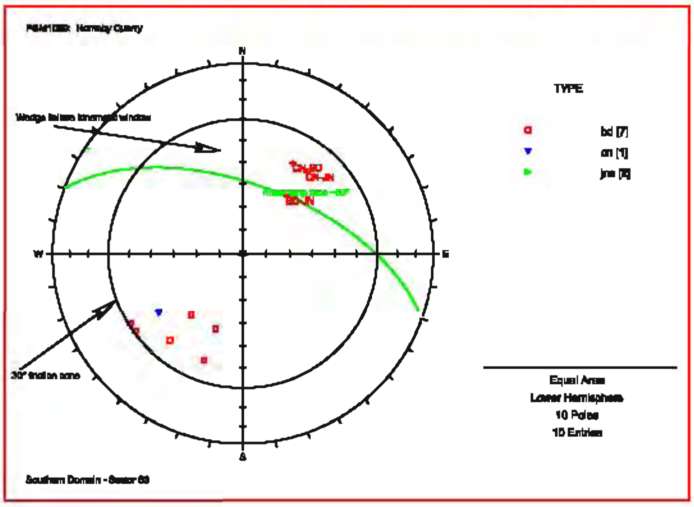
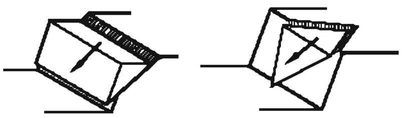






SECTOR S3

- PLANAR FAILURE ON BEDDING AND WEDGE FAILURE BETWEEN AND BEDDING AND JOINTS KINEMATICALLY FEASIBLE



LEGEND

- FILL 0-5m
- FILL 5-10m
- FILL 10-15m
- FILL 15-20m
- FILL >20m
- ALLUVIUM
- RESIDUAL VOLCANIC BRECCIA
- HW/MW VOLCANIC BRECCIA
- SW/FR VOLCANIC BRECCIA
- MUDDY BRECCIA
- SANDSTONE
- MAJOR SHEARED ZONES
- CONTACT BETWEEN DIATREME AND HAWKESBURY SANDSTONE

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PIT SECTOR S3

PSM1059	Figure A15