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Geotechnical & Environmental

DUNOON DAM SITE

CONCEPT STAGE GEOTECHNICAL INVESTIGATION

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Rous Water
REGIONAL WATER SUPPLY

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1 Introduction

1.1 General

Rous Water is currently undertaking strategic planning to secure the regional water supply. A new dam on Rocky Creek, Dunoon Dam site, could supply additional storage capacity of up to 50,000ML. Dams and Civil Section of NSW Public Works have been engaged to develop concept designs for the proposed dam, and project manage specialist studies, including geotechnical studies, required to develop the project.

In response to our proposal of 14th August 2012, Rous Water also engaged Dams and Civil Section to conduct concept stage geotechnical investigations at the site. The embankment/wall site is located in a steep-sided gorge in rainforest, and access to the site with investigation equipment would create considerable environmental disturbance. Dams and Civil have recently investigated, designed and assisted with construction of Shannon Creek Dam (Grafton) in a similar geological setting and in the same geological units as at Dunoon Dam site. To lessen environmental impact, the surface geology was confirmed and knowledge gained from Shannon Creek Dam has been used to interpret likely foundation conditions for the proposed structure. The main focus of the current investigation was to confirm the presence of the on-site construction materials, and to determine their indicative properties. The investigation also gathered data on potential sources of off-site construction materials.

1.2 Location and Access

Lismore is located in the hinterland of the far north coast of New South Wales. Dunoon is a small village located approximately 15km to the north of Lismore (see **Figure 1**).

The site is located on Rocky Creek at GR 286274 Dunoon 1:25,000 Sheet (9540-1-S), and is approximately 15km downstream of Rocky Creek Dam. The embankment/wall site is covered by rainforest/wet sclerophyll forest, as is the lower storage area for 300m (right bank) and 700m (left bank) upstream of the embankment/wall centreline. Further upstream, the storage area largely comprises grazing land. Much of the storage area is owned by Rous Water.

Access to the left abutment is via Munro Road. The embankment site can only be reached on foot from the top of the ridge system; however, a steep 4WD track provides access to the lower storage area. The right abutment can be reached by foot from The Channon, via forested farms on the right abutment ridge. Similarly, the alluvial terrace on the lower right abutment can be reached by a 4WD track that has been used to lay a Telstra cable; however, a fallen tree currently blocks access.

1.3 Outline of Proposed Dam

A 175 m long, zoned earthfill embankment with a central clay core is one option that is proposed at the site. The proposed 47m high embankment would have a crest level of RL 90m (Australian Height Datum), with the creek bed being at approximate RL 37m. A full supply level of RL 82.25m would create a storage volume of approximately 50,000ML. **Figure 2** shows the general arrangement proposed at the site, and a typical cross section through the embankment.

Stream diversion will be achieved via a diversion tunnel through the right abutment. The tunnel would also act as part of the outlet works of the dam.

A spillway channel would be located in a deep cut on the left abutment.

The site is topographically well suited for construction of an alternative design of a roller compacted concrete (RCC) dam with a central spillway. However, there are no potential sources of concrete aggregate on site, and all materials would have to be transported from district commercial quarries over the local road network. A RCC dam would have similar wall height to an earthfill embankment. A spillway section would be located near the central portion of the dam wall. **Figure 3** shows the

general arrangement of the alternative RCC dam proposed at the site, and a typical cross section through the wall.

1.4 Previous Work

Brunker, Cameron, Tweedale and Reiser (1972) compiled the geology of the Tweed Heads 1:250,000 Geological Series Sheet (SH 56-3).

Reconnaissance stage geological investigations and engineering assessments are reported in Public Works (1994).

1.5 Aims of Investigation

The aims of the investigation at the site were to:

(i) Confirm the initial understanding of the regional geology and the site geology, which were gained during the reconnaissance geological investigation (Public Works, 1994).

(ii) Formulate a geological model for the site, and confirm the geological suitability of the site for the proposed embankment/wall and ancillary structures.

(iii) Make a preliminary estimate of the likely foundation conditions and any foundation treatment which is likely to be required, including the need for grouting.

(iv) Make preliminary estimates of depths of excavation along the proposed core trench/wall foundation, and under the earthfill shells of a proposed embankment.

(v) Make a preliminary estimation of rock mass conditions along the proposed diversion tunnel, or diversion conduit.

(vi) Estimate the likely rock mass conditions along the proposed spillway alignment.

(vii) Establish sources and characteristics of embankment construction materials for the core, outer zone, filters and rip-rap; and potential sources of aggregate for an alternative concrete wall.

(viii) Provide a geological basis for the formulation of the design stage geological investigation.

1.6 Map and Air Photo Cover

Topographic maps covering the area are:

(i) Central Mapping Authority, Tweed Heads 1:250,000 Sheet (SH 56-3).

(ii) Central Mapping Authority, Lismore 1:100,000 Sheet (9540).

(iii) Central Mapping Authority Dunoon 1:25,000 Sheet (9540-I-S).

In addition to the published maps, the Land and Property Management Authority flew LiDAR photogrammetry of the Dunoon site and storage area.

1.7 Work Carried Out

The investigation included reconnaissance geological mapping, excavator test pits, laboratory testing and a survey of potential commercial sources of sand, gravel, and rip-rap. Details of the investigation methods used are given in **Section 2**. The geological interpretations made in this report, and the necessary fieldwork, were carried out by Mr M. J. Neville, a senior engineering

geologist of the Dams and Civil Section. Mr D. Guest, design engineer, assisted during a portion of the fieldwork.

1.8 Terminology

Accepted engineering geological terminology is used in this report. **Appendix A** documents terms relating to soil description and classification, as well as geological terminology relating to weathering, rock strength, discontinuity spacing, block size, and aperture of discontinuity surfaces. Estimated rock strength refers to the rock substance strength, as opposed to the rock mass strength.

Geotechnical data generally fall into the categories of fact, interpretation and opinion, as defined by the Institution of Engineers, Australia (1987) - Guidelines for the Provision of Geotechnical Information in Construction Contracts. Definitions of this characterisation of geotechnical data are provided at the start of **Appendix A**.

2 Summary of Investigations

2.1 General

Fieldwork commenced on 8th October 2012, and continued until 17th October 2012. The investigation included reconnaissance geological mapping, excavator test pits, laboratory testing and a survey of potential commercial sources of sand, gravel, and rip-rap. Details of the investigation methods used are given below.

2.2 Reconnaissance Geological Mapping

Characteristics of the rock mass were recorded in lower abutment cliff outcrops at the embankment/wall site and at the downstream toe of the embankment. Geological unit boundaries were mapped on the abutments and above the borrow areas, particularly the boundary between the basalt and underlying sedimentary rocks. Geological unit boundaries were also checked/confirmed on the access roads within the storage area.

2.3 Test Pits

Test pits in potential borrow areas within the storage area were excavated with a Caterpillar D320D-L hydraulic excavator. Thirty test pits (DTP 1 – DTP 30) were excavated between 9.10.2012 and 13.10.2012. Pits were logged by geological staff. Samples and bulk samples were taken for later laboratory testing.

Hand held GPS grid references and RL's of test pits are given in **Table 1**, and locations of test pits are shown on **Figure 6**. The logs of the test pits and selected test pit photographs are presented in **Appendix B**.

Table 1 Summary Details of Test Pits

Test Pit No.	Easting*	Northing*	RL (m)**
DTP 1	529391	6827778	63
DTP 2	529329	6827693	60
DTP 3	529332	6827833	43
DTP 4	529332	6827885	44
DTP 5	529554	6827953	78
DTP 6	529708	6827961	82
DTP 7	529474	6827964	69
DTP 8	529359	6828019	54
DTP 9	529465	6827871	54
DTP 10	529586	6827869	76
DTP 11	529685	6827879	77
DTP 12	529709	6828011	81
DTP 13	529578	6828045	66
DTP 14	529496	6827999	76
DTP 15	529427	6827996	60
DTP 16	529528	6828259	81
DTP 17	529465	6828214	75
DTP 18	529308	6828156	52
DTP 19	529392	6828185	63
DTP 20	529265	6828221	51
DTP 21	529367	6828246	70
DTP 22	529458	6828280	69
DTP 23	529586	6828348	85
DTP 24	529534	6828367	83
DTP 25	529602	6828233	84
DTP 26	529539	6828175	79
DTP 27	529464	6828121	68
DTP 28	529364	6828093	54
DTP 29	529670	6828224	79
DTP 30	529272	6827756	50

* Map Grid of Australia (MGA) ** Very approximate

2.4 Laboratory Tests

Small samples for index tests were taken from selected test pits, as shown in the test pit logs in **Appendix B**. Representative samples of different soil types were chosen for index testing, including:

(a) As Received Moisture Content

(b) Particle Size Distribution

(c) Atterberg Limits and Classification

(d) Dispersal Index

The Unified Soil Classification (metricated) has been adopted for soil classification. Laboratory tests were performed according to the relevant method in AS1289 (1997) - Methods of Testing Soils for Engineering Purposes. Soil testing was carried out at the Department of Public Works, Geotechnical Centre, at Ultimo.

Summary test results and individual test result sheets for the core material are presented in **Appendix C**.

3 Topography

The site is located at a narrow constriction in the valley of Rocky Creek (see **Figures 2 and 3**; **Photo 1**). The left abutment is located on the side of a narrow, westerly-tending spur that extends from undulating higher ground around Dunoon. The right abutment is located on the tip of a southerly-tending spur that extends from a high hill to the east of The Channon.

The valley is slightly asymmetric in profile. The left abutment is very steep, as shown in **Figures 2 and 3**. The upper abutment area has a slope of approximately 30°, while the middle abutment area takes the form of several cliff sections of approximately 40m total height (average slope 45°). Beneath the cliff an interpreted scree deposit extends to creek bed level at a slope of approximately 8° and steeper. The right abutment is also very steep and contains localised cliff sections. The upper/middle right abutment has an approximate slope of 35°, while the middle/lower abutment, which almost extends to the creek bed, has an approximate slope of 25°.

The topography of the storage area and lower catchment area is shown with overlain geology on **Figure 4**. The lower/middle portions of the valley generally have gently to moderately sloping spurs extending from steeper upper slopes created by basalt caps at the tops of the confining ridges (see **Photos 2, 3, and 4**). Overall, Rocky Creek follows a southwesterly course below Rocky Creek Dam; however, in greater detail the course comprises a number of southerly then westerly oriented sections. At the proposed embankment/wall site, the stream flows in a westerly direction. However, some 250m downstream the flow changes course to a southerly direction. These stream orientations are interpreted to mirror the orientation of the major joint network in the sedimentary rocks.

4 Regional Geology

The regional geology is shown on the Tweed Heads 1:250,000 Geological Series Sheet SH56-3 (Brunker et.al., 1972). Sedimentary strata of the Clarence-Morton Basin are overlain by basalt of Tertiary age. In the Dunoon area, shale, claystone, sandstone and coal of the **Walloon Coal Measures** are overlain by quartz sandstone and conglomerate of the **Kangaroo Creek**

Sandstone. These geological units are Jurassic in age. The **Lismore Basalt**, comprising basalt with agglomerate and bole (thin weathered horizons and soil formed between basalt lava flows), is at the top of the geological sequence and is Tertiary in age. It forms the undulating higher ground in the area. Major streams are lined by alluvial sediments of Quaternary age. In the local area of the dam site, the boundaries on the Tweed Heads 1:250,000 Geological Series Sheet (SH56-3) are incorrect. Limited geological checking and air photo interpretation indicate the outcrop areas of the sedimentary rocks to be more extensive than shown on the geological map, with the Kangaroo Creek Sandstone extending to much higher RL's than indicated in the dam site area, and the lower storage area predominantly comprising Walloon Coal Measures rather than Kangaroo Creek Sandstone. Re-interpreted geological boundaries within the local area are shown on **Figure 4**.

5 Site Geology

5.1 Stratigraphy and Lithology

The embankment/wall site is wholly within sandstone strata of the Kangaroo Creek Sandstone. Exposure in the abutment areas at the site consists of continuous and discontinuous sandstone cliff lines (see **Photo 5**). Most of the creek bed contains large sandstone boulders; however, there are beds of sandstone exposed in the creek bed on the bend some 150m downstream of the embankment/wall centreline (see **Photo 6**).

The sandstone is predominantly coarse grained, but varies from medium to very coarse grained, and is quartzose in composition. Thin bands and lines of quartz pebbles are known to occur occasionally in this geological unit. Typically, quartz grains comprise 80% - 85% with 3% - 4% siltstone, chert and feldspar grains, and the remainder consisting of clay matrix. Some secondary siliceous accretion of grains occurs, and secondary cementation by iron oxides is also common in outcrops. Planar cross-bedding is often also well developed in outcrops.

The Walloon Coal Measures will underlie the Kangaroo Creek Sandstone at some depth in the foundation. The Walloon Coal Measures comprise a sequence of sandstone, and siltstone/claystone/shale, with minor conglomerate, siltstone breccia, and coal seams (see **Photo 7**). These rocks underlie the storage area, upstream of the gorge area of the creek.

Small deposits of Quaternary alluvial sediments mantle the bedrock adjacent to Rocky Creek, particularly on the inside of bends. Approximately 700m upstream of the embankment/wall centreline, a small alluvial terrace forms the left creek bank and a larger alluvial terrace is located on the right (inside) bank of the creek (see **Photo 8**). The left bank terrace comprises silty sand (SM) overlying coarse sand (SP), as indicated in the log of test pit DTP 30 (see **Appendix B**).

5.2 Structure

The sandstone rock exposure does not allow accurate measurement of bedding orientation due to an irregular shape of bed partings; however, the general shape of the surfaces in outcrop at the downstream toe of the embankment indicates that there is a gentle dip towards the west (approximately 10° dip in direction 250°M); however , this dip into the left abutment may be a reflection of valley bulge (see **Section 5.4**). In the proposed core material borrow areas in the lower storage area, bedding orientation of coal seams in the Walloon Coal Measures was variable, with dips of less than 10° in directions varying from ea sterly/southerly/westerly (see **Photo 8**); however, individual coal seams can show considerable variation without reflecting overall structural trends.

The distribution of the Kangaroo Creek Sandstone and the Walloon Coal Measures indicates a probable faulted boundary between the two units, as interpreted on **Figure 4**.

5.3 Defects

5.3.1 General

The two geological units cropping out at the embankment/wall site and in the lower storage area have differing rock mass characteristics. Although there is no surface exposure, the Walloon Coal Measures are also interpreted to occur at some depth in the foundation. Within the Kangaroo Creek Sandstone, defects are relatively widely spaced, while within the Walloon Coal Measures defects have a closer spacing, but may vary from very close to widely spaced. Defects at the site may be grouped into categories, as follows: bedding planes/partings, joints, and shear zones. Igneous dykes were not encountered during the current investigations in the storage area, or site mapping; however, investigations were only undertaken at representative, discrete locations, leaving many gaps in the coverage of the site, especially the embankment/wall site. Therefore, the possible presence of dykes must be suspected.

5.3.2 Bedding Planes and Partings

Bedding planes and partings were a common defect observed in outcrop of the Kangaroo Creek Sandstone. The sandstone is bedded in near horizontal layers with bed partings on the lower and upper surfaces; however, each bed may also contain internal cross-bedding (cross laminations) that was induced by its depositional environment (see **Photo 9**). The bed partings are generally undulating to irregular in shape and semi-rough to rough. The shallowly dipping bed partings are continuous over a relatively wide area; however, beds are often lensoidal in shape. The partings are prominent in outcrop, and are often open at the surface. However, experience from similar geological and topographic settings suggests that partings are likely to tighten quickly with distance into the abutment.

Within the Walloon Coal Measures, partings were observed in test pits; however, their condition could not be accurately determined because of the extremely weathered nature of the rock. Based on experience of these rocks in other areas, partings are generally planar to sub-planar, and smooth to semi-rough. Partings also often have carbonaceous coatings, and have occasional laminations of coal. Thin coal seams were encountered in test pits in the borrow area (see **Appendix B**). Little is known of the continuity of bedding this geological unit; however, they are likely to be less continuous than sandstone beds in the Kangaroo Creek Sandstone. Beds are likely to be lensoidal in shape.

5.3.3 Joints

Joints were readily observed in outcrop downstream of the embankment site, and on the left abutment (see **Photos 6 and 9**). In exposures of Kangaroo Creek Sandstone, joints are laterally continuous for several tens of metres. However, exposures also indicate that joints are generally vertically discontinuous, and may be off-set or terminated at bedding planes. Joint patterns are interpreted to have a major influence on topography, and the direction of stream flow. Within the Walloon Coal Measures, joints could not be observed in the test pits; however, they are interpreted to be less continuous, due to the interbedded nature of the strata.

In outcrop, joints generally have steep dips, and a variety of strike orientations. The most prominent strikes were north-south (070° – 080°M) and east-west (170° – 175°M); although, there was a degree of scatter in strike directions.

Joint spacing in the cliff lines of Kangaroo Creek Sandstone is generally moderately wide to wide, with some very wide. Some very large sandstone boulders in the creek bed indicate that spacings of the order of 3 - 5m occur in parts of the rock mass. In the Walloon Coal Measures, spacings within the fine grained and the interbedded strata, are likely to be close to moderately wide, although narrower spacings are also likely to occur, especially adjacent to shear zones.

In exposures, joints in the Kangaroo Creek Sandstone generally have sub-planar to planar shapes (on the macro scale). They are often open, and are infilled with soil and/or roots at the surface; however, they are likely to tighten quickly with depth.

5.3.4 Shears

Shear zones were not observed in outcrop at the site. However, shear zones comprising crushed rock and clay will define the fault interpreted to occur upstream of the proposed embankment site (see **Figure 4**). Extensive shearing, especially along bedding planes is also likely to be present as a result of valley bulge (see **Section 5.4**).

5.4 Valley Bulge

Valley bulge, or valley rebound, is caused by stress relief initiated through excavation of a valley by erosion. These effects are particularly pronounced in horizontally bedded sedimentary rocks. Fell, MacGregor, and Stapledon (1992) summarise the characteristics of valley bulging. The effects of valley bulge have been recorded at a number of dam sites having a similar geological environment to that at Dunoon dam site, including: Mangrove Creek Dam (McNally 1981, 1995), Warragamba Dam (Gray 1982, Johnson 1960), Yellow Pinch Dam at Merimbula (Public Works, 1990), Loyalty Road Dam at North Rocks (Public Works and Services, 1999), and Shannon Creek Dam (Public Works, 2012).

The effects of valley bulging may include:

(i) Formation of a shallow anticlinal structure within the valley, resulting in slight dips into each valley side. Associated with this folding, there is generally slight movement along bedding partings.

(ii) Formation of an anticlinal shaped zone of shearing in the valley base, with an axis running along the creek bed.

(iii) Increased permeability in the valley base along shears and opened horizontal discontinuities.

(iv) Opening up of apertures of steeply dipping joint faces adjacent to cliff faces.

At Dunoon dam site, valley relief is in the order of 170m and is of a similar order to other dam sites where stress relief effects have been recorded. At this stage, there is no detailed investigation data at the dam site. However, some features consistent with valley bulging may be recognised at the site.

At this stage, several factors suggest likely disruption of strata due to valley bulging, including:

(i) The geological setting.

(ii) The topographic setting.

(iii) Shallow dip of bedding into the right abutment; however, the orientation of bedding on the left abutment could not be accurately determined.

(iv) The open nature of the joint sets parallel to the valley.

Although the evidence is not conclusive due to lack of detailed data, valley bulging must be suspected as occurring, and models of the site effects of this phenomenon should be refined as data becomes available.

5.5 Weathering

As no deep investigation has been carried out at the site, specific data on weathering depths is not available. Generally, the pattern of weathering at a site typically shows shallow depths of weathering in the valley base and deeper depths under the abutments. This pattern was observed at Shannon Creek Dam, in a similar geological setting and the same geological units.

At the embankment/wall site, the abutments in sandstone are likely to have a weathering profile comprising shallow soils generally underlain by a thin layer of extremely weathered sandstone then highly weathered rock in the order of 3 - 5m depth. Moderately weathered sandstone generally

underlies highly weathered sandstone and is likely to extend to depths of up to 25 - 30m. Individual beds of slightly weathered sandstone may occur in an essentially moderately weathered sequence. Fresh rock is generally encountered at the approximate depth of the permanent water table. Under the valley base, a thin zone of slightly weathered to fresh (stained) sandstone should be underlain by fresh sandstone. Any thin beds of siltstone/shale may be differentially weathered compared with the enclosing sandstone.

In the proposed borrow area, in fine-grained rocks of the Walloon Coal Measures, the upper portions of the weathering profile comprises a moderately thick silty clay soil overlying extremely weathered and extremely weathered/highly weathered claystone to the depth of investigation of approximately 5m. Soils may be thicker in some areas due to colluvial accumulation. The transition from soil to extremely weathered claystone is generally gradual. Highly weathered claystone is likely to transition abruptly to slightly weathered claystone; however, the depth of this transition is not known at this stage.

5.6 Groundwater

No obvious springs were observed at the embankment/wall site. In the proposed borrow area, an area of boggy ground between test pits DTP 25 and DTP 29 suggests a area of slight seepage from the side of the spur, possibly flowing from the base of basalt that crops out higher on the spur.

As no boreholes have been drilled, groundwater levels at the embankment/wall site are not known at this stage. Generally, in this geological environment, the groundwater table in the valley base coincides with the water level in the creek. Under the abutments the groundwater table generally rises gradually, at a much shallower gradient than the topography. Under the upper abutment areas the groundwater is likely to be at considerable depth. At Shannon Creek Dam, in a similar geological environment in the same geological units, groundwater was below the base of the 45m deep spillway excavation in the upper left abutment.

5.7 Permeability

The rock substance at the site may be considered as being impermeable. However, the rock mass is interpreted to be permeable, due to leakage along defects. Generally, a rock mass contains an upper zone of variable permeability, where defects are open (and sometimes infilled with clay) due to weathering and stress relief. This upper zone is generally underlain by a basal zone of low permeability. In the basal zone there is often an increased spacing of rock mass defects, and tightness of the defects that are present.

Experience in this type of geological setting, at Shannon Creek Dam and sites in sandstone in the Sydney area, indicates a generally low to moderate rock mass permeability on the abutments, largely due to the wide to very wide spacing of defects; however, leakage may be high/very high along individual open joints and/or bedding planes. The depth to a generally tight rock mass may be in the order of 30 – 40m.

Experience at the same dam sites in the valley base, indicates the rock mass is likely to have a moderate to high permeability. The foundation will be affected by valley bulging, and open joints, shears and some bed partings will have high/very high leakage potential. The depth to a generally tight foundation will depend on the detailed geology, particularly the depth of any weaker claystone/shale beds that will be the loci for shearing; however, the depth to a tight rock mass is likely to be deeper than under the abutments.

5.8 Rock Strength

Based on testing at Shannon Creek Dam, the uniaxial compressive strength of sandstone of the Kangaroo Creek Sandstone is likely to be in the order of 20 – 35MPa (medium strong to strong, average strong), depending on degree of weathering and development of secondary silica cementation. Fine grained rocks are likely to only have marginally lower rock strength when slightly

weathered and less weathered; however, they may be weak and very weak with a greater degree of weathering.

6 Interpreted Embankment/Wall Foundation Conditions

6.1 Core Trench/RCC Wall

The general foundation requirements for a core trench of an embankment and RCC wall are interpreted to be similar. They should be founded on groutable, non-erodible rock. At the site, moderately weathered sandstone is likely to form a suitable foundation. Areas containing bed partings with seams of clay or lesser quality rock, vertical joints with infilled apertures, or areas such as shear zones, may require locally deeper excavation.

On the abutments, soil depths are interpreted to be very shallow, and depths of excavation in the order of 3m are likely to be required to encounter a suitable foundation in moderately weathered sandstone; however, this estimate will need to be verified by later detailed foundation investigation. In the valley base, loose boulders will need to be removed and foundations excavated by an additional metre to remove surface loosened defects and expose a slightly weathered to fresh sandstone rock mass (see **Photo 10**); however, additional local excavation may also be required to remove any weak, valley bulge-induced shear zones. Bouldery scree/talus deposits adjacent to the creek bed, particularly on the left abutment, may be up to 5m thick adjacent to the lower abutment cliffs and will need to be stripped, plus an additional metre to remove surface-loosened defects from the foundation. Scree/talus deposits adjacent to the right side of the creek are interpreted to be shallower. At this stage, an average depth of stripping in the valley base of 3m would be appropriate for estimating.

6.2 Embankment Outer Zone

Ideally, the outer zone for an embankment should be founded on non-erodible rock. Highly weathered sandstone should satisfy this requirement.

On the abutments, stripping depths in the order of 1m is likely to be required to remove soil, bouldery outcrop and sandstone outcrop with moderately narrow and wider joint apertures. In the valley base, stripping of all scree/talus deposits and boulders in the creek bed is required. An average depth of stripping of 2m across the valley base would be appropriate for initial estimating purposes.

6.3 Foundation Treatment

6.3.1 Core Trench/Concrete Wall

Following excavation and clean-up, the abutment foundations are likely to assume a stepped shape, reflecting the horizontally bedded nature of the strata and vertical joints in the rock mass. In some areas, additional foundation excavation may be required to remove occasional horizontal clay seams that may extend into the abutment.

The cliff-like nature of the topography indicates that there will be high foundation steps, especially on the steeper left abutment. Near vertical foundation steps will require slope correction with concrete to a maximum batter of ½H:1V, to allow good clay contact and avoid differential settlements in the core trench of an embankment dam. Slope correction will not be as critical for a roller compacted concrete wall; however, overhangs and negative slopes will require correction.

In the valley base, some dental concrete may be required to fill in depressions in the foundation as preparation for the placement of the first layer of rolled concrete or clay core.

6.3.2 Outer Zone

Following excavation of soil, scree/talus deposits in the valley base and extremely weathered rock, no special foundation treatment is envisaged as necessary for the outer zone foundation of an embankment dam.

6.4 Grouting

Rock mass permeability is interpreted to be variable across the site. Curtain grouting will be required to control and reduce the amount of leakage beneath the embankment/dam wall. On the abutments, occasional high and very high leakages are likely to be associated with open joints, interpreted shear zones and some partings. The geological model of the site proposes that the rock mass permeability in the valley base has been disturbed by valley bulging. Grout takes in this area of the foundation may be high to very high.

A better estimate of grouting requirements can be made after the design stage geological investigation. However, the final depth, hole spacing and extent of the grout curtain can only be determined during construction, as the results of water pressure testing and grouting become available. At this stage, it would be normal to allow for grouting to extend to a depth equivalent to full water height. In the upper abutment areas of shallow water depth, a grout curtain of 10m minimum depth is likely to be required.

In the plane of a grout curtain, most of the joints have a near vertical attitude and bedding planes are near horizontal. Grout holes should be angled into the abutments (with cross-over in the valley base) to obtain intersection with all the vertical joints. A nominal angle of inclination of 30° from the vertical is likely to be appropriate. Grout holes at this orientation would also be likely to intersect sub-horizontal shears that could result from valley bulging. Grouting will be difficult and may require modification of normal patterns and procedures because of the steepness of the abutments, particularly on the left abutment.

The generally widely jointed and horizontally bedded nature of the rock mass, and high rock substance strength, indicates that a grout cap will not be required. Grout pressures in the upper stage of each hole should be kept low to avoid jacking of the foundation along bed partings.

7 Diversion

7.1 Embankment Dam

7.1.1 General

The volume of flow in Rocky Creek and the restricted width of the valley base require a tunnel to divert water during construction. Topographically, a diversion tunnel through the right abutment, of approximately 3m diameter and approximately 300m length, would be the most appropriate for the site. This would also place the eventual outlet works on the opposite side of the valley to the spillway (see **Figure 2**). A coffer dam to approximate RL 50m would be incorporated as part of the upstream toe of the embankment, with water transfer to the tunnel along an intake channel.

7.1.2 Coffer Dam

The proposed coffer dam is interpreted to be, at least predominantly, underlain by sandstone of the Kangaroo Creek Sandstone; however, there is potential for some exposure of interbedded fine and coarse grained rocks of the Walloon Coal Measures on the left abutment. On the lower/middle left abutment, sandstone is interpreted to be overlain by a thick scree/talus deposit, with shallow

scree/talus overlying bedrock on the right abutment. Above approximate RL 45m on both abutments bedrock is interpreted to be close to the surface. In the stream bed area, bedrock is interpreted to form the bed of the creek, with some large boulders sitting on the bedrock surface.

7.1.3 Intake Channel

An intake channel of approximately 70 – 80m length would be required to divert water from the creek to the diversion tunnel. The invert level of the channel would need to be at approximate RL 40m, with the channel walls of increasing height to approximately 15m near the proposed tunnel portal.

The geology of the alignment is uncertain at this stage. The geological model of the site interprets an inferred fault in the area of the intake channel. There is potential for the alignment to be in interbedded claystone, shale and sandstone of the Walloon Coal Measures, or sandstone of the Kangaroo Creek Sandstone, depending on the location/existence of the inferred fault. Bedding is interpreted to have a shallowly dipping attitude; however, a fault may cause some disturbance to the normal bedding attitude.

The rock types exposed will determine allowable batter slopes along the intake channel. Appropriate batters in claystone and shale would be 1H:1V as temporary slopes, or 2H:1V for permanent exposed batters. Claystone and shale are likely to deteriorate on exposure due to fretting, and steeper slopes may require protection. Apart from in the upper highly weathered portions of an excavation, appropriate batters in Kangaroo Creek Sandstone would be 1H:2V as permanent slopes. Batters in sandstone should not change appreciably on exposure.

7.1.4 Intake Tower

The proposed intake tower is likely to be founded adjacent to the upstream tunnel portal; however, the location is not exactly known at this stage. Depending on the chosen location, the intake tower foundation is likely to comprise slightly weathered to fresh sandstone of the Kangaroo Creek Sandstone, or interbedded claystone/shale/sandstone of the Walloon Coal Measures. The interbedded rocks are likely to have medium strong/strong rock substance strength, while sandstone is interpreted to be strong.

7.1.5 Upstream Tunnel Portal

A specific location for a tunnel portal has not been selected at this stage. However, it is anticipated that it may be located in an area slightly upstream of the cofferdam crest on the right abutment. In this area, a portal excavation would be in the order of 15m deep. The area may be underlain by fine grained rocks of the Walloon Coal Measures, or sandstone of the Kangaroo Creek Sandstone, and may be traversed by an inferred fault interpreted to separate these units. The location of the portal will need to be optimised once the site geology is better known. To the northwest, on the steeper slopes, the portal could be located in sandstone; however, the height of batter slopes would increase markedly due to the steep surface slope.

7.1.6 Tunnel Alignment

The majority, or all, of the tunnel alignment will be located in sandstone of the Kangaroo Creek Sandstone, depending on the location of the upstream tunnel portal. Based on exposure at the downstream toe of the proposed embankment, the thickly to very thickly bedded sandstone has a gentle westerly dip of approximately 10°. The majo r joint sets will have a vertical attitude and trend across the tunnel in north-south and east-west directions, and should be predominantly at a moderately wide to wide spacing. Downstream of the embankment centreline, a major north-south gully on the right abutment may represent a fault that would cross the middle portions of the alignment. Rock along the alignment is likely to be moderately weathered to slightly weathered.

Details of tunnel support requirements will be better known after detailed site investigation. Primary support comprising rockbolts, mesh and shotcrete are likely to be required in the tunnel crown. Primary support with sets and concrete/shotcrete lining are likely to be required at both portals, and

may also be required to support the shear zone interpreted to cross the middle portions of the tunnel. Secondary concrete lining is likely to be required, with a steel liner downstream of the grout curtain.

7.1.7 Downstream Tunnel Portal and Valve House

A specific location for a downstream tunnel portal has not been selected at this stage; however, it is likely to be located approximately 50m downstream of the embankment toe. In this area, highly/moderately weathered sandstone of the Kangaroo Creek Sandstone is exposed in a cliff line adjacent to the creek bed. It is likely that the valve house will need to be placed in a recess into the cliff line adjacent to the tunnel portal.

The surface exposures are highly/moderately weathered; however, in a portal face a short distance back from the current cliff face (say several joint sets) is likely to be moderately weathered. The foundation of an adjacent valve house is likely to be on moderately/slightly weathered, strong sandstone.

The lower batters within the valve house portion of the foundation are likely to be vertical, to allow the structure to be keyed into the rock. Some minor temporary support with rockbolts may be required during construction, to stabilise unfavourably oriented joints and for construction safety. Above the valve house, batters at an average slope of 1H:2V are likely to be appropriate, with a minimum of permanent support by rockbolts to stabilise unfavourably oriented joints.

As the valve house will be located adjacent to the creek bed, a separate discharge channel will not be required.

7.2 Roller Compacted Concrete Dam

7.2.1 General

Topographically, a concrete-encased diversion conduit of approximately 2m diameter could be placed in a trench on the left side of the valley base, adjacent to the left abutment cliff line. A rigid foundation is required to avoid any differential settlement along the conduit. A foundation in predominantly moderately weathered rock would satisfy this requirement. In the dam wall area, this conduit would form part of the permanent outlet works. A temporary coffer dam to approximate RL 50m would need to be constructed upstream of the dam wall to allow construction in the valley base.

7.2.2 Coffer Dam

The coffer dam is interpreted to be underlain by sandstone of the Kangaroo Creek Sandstone. On the lower/middle left abutment, sandstone is interpreted to be overlain by a thick scree/talus deposit, with shallow scree/talus overlying bedrock on the right abutment. Above approximate RL 45m on both abutments, bedrock is interpreted to be exposed or close to the surface. In the stream bed area, bedrock is interpreted to form the bed of the creek, with large boulders sitting on the bedrock surface.

7.2.3 Conduit Alignment

Following removal of scree/talus deposits on the left side of the valley base, rock at the base of the left abutment cliff is interpreted to comprise moderately weathered to fresh (stained) sandstone. It is likely that the bedrock surface will be at or just above creek level. The rock mass is likely to be thickly bedded, and have a wide to very wide joint spacing.

7.2.4 Intake Tower

An intake tower is likely to be founded adjacent to the dam wall, at the upstream end of the permanent diversion conduit. The foundation is likely to comprise slightly weathered to fresh sandstone of the Kangaroo Creek Sandstone, with interpreted strong rock substance strength.

7.2.5 Valve House

A valve house will be located at the downstream end of the diversion/outlet conduit, adjacent to the left side of the spillway flip bucket. The foundation for the valve house is likely to be on strong, slightly weathered to fresh sandstone.

8 Spillway

8.1 Left Abutment Spillway

8.1.1 General

For an embankment dam, a spillway would be located in a deep cut through the left abutment, as shown on **Figure 2**. An concrete ogee control structure will be located approximately 30m into the spillway channel. A concrete-lined chute will transfer flow to a pre-excavated plunge pool in the valley base. The depth of the approximately 50m-wide cut will need to be optimised as the spillway excavation is likely to be a source of higher quality fill for embankment construction. The proposed cut is likely to be in the order of 15 – 20m deep, with the left wall several metres higher than the right wall until the cut passes through the crest of the spur.

8.1.2 Spillway Channel Geology

The spillway channel is interpreted to be through thickly to very thickly bedded sandstone of the Kangaroo Creek Sandstone. Some minor thin, lensoidal shaped beds of siltstone/shale are known to occur in this geological unit, and their presence at the site should be suspected. Siltstone/shale beds are likely to have limited continuity, say several tens of metres.

Soil and extremely weathered rock may extend to 2 – 3m depth and be underlain by highly weathered then moderately weathered sandstone. The depth of excavation proposed for the spillway indicates that the majority of the walls and floor of the channel is likely to be in moderately weathered sandstone over the majority of its length, with lesser quality rock at each extremity.

8.1.3 Batter Stability

The following batter angles would be appropriate:

Soil/talus	2H:1V
Extremely/highly weathered sandstone	1H:1V
Moderately weathered and better quality sandstone	¼H:1V

An anchored shotcrete lining rather than the free-standing concrete wall could be used to protect against erosion to the height of water flow.

Large-scale instability of batter slopes is unlikely, given the near horizontal attitude of bedding, and predominantly vertical joints. However, there is potential for isolated small failures to occur. Several potential failure modes may be proposed, including:

i. Planar or wedge sliding on steeply dipping joints, either alone, or initiated by fretting of underlying shale beds.

ii. Toppling of tall, slender rock columns/slivers formed by steeply dipping joints, either alone, or initiated by fretting of underlying shale beds.

iii. Sliding on current bedding planes (cross-bedding laminations).

Any siltstone/shale beds should be protected by an anchored shotcrete lining. Potentially unstable, defect-defined blocks and wedges should be stabilised with permanent rockbolts. In areas of highly broken/jointed face, use of anchor bars, mesh and shotcrete may be a more appropriate form of support than rockbolts. The need for remedial treatment should be assessed by an engineering

geologist during excavation; however, the amount of remedial treatment required is likely to be minor.

8.1.4 Stilling Basin

A stilling basin will be required at the end of the spillway channel to dissipate turbulence of the rapidly flowing spillway discharge. A stilling basin in the bed of Rocky Creek would be excavated in slightly weathered to fresh sandstone of the Kangaroo Creek Sandstone. Rock mass conditions would be similar to those in the spillway channel. The walls and floor of the basin would need to be protected by an anchored shotcrete lining.

The excavation will be below the water table and provision will need to be made for drainage.

8.2 Central Spillway

8.2.1 General

A 30m wide, centrally-placed spillway section is proposed for a roller compacted concrete wall design (see **Figure 3**). Water will be discharged into the creek channel through a flip bucket at the base of the dam wall.

8.2.2 Flip Bucket

As for the dam wall foundation in the creek bed, excavation of 1m depth below surface boulders is likely to expose a suitable foundation, comprising slightly weathered to fresh, thickly bedded sandstone with a wide to very wide joint spacing.

Downstream of the flip bucket, the sandstone should have similar rock mass properties. However, the large gully on the right side of the creek may be the surface expression of a fault with inferior rock mass conditions susceptible to erosion. Investigation will be required to confirm conditions in the landing area of the discharge jet.

9 Excavation Conditions

9.1 General Excavation

Rock rippability is largely controlled by rock strength and the character and spacing of defects, together with other minor modifying factors. The steep topography at the site is likely to have a major influence on rock excavation at the embankment/wall site. A number of rippability rating classifications have been developed which are based on the rock mass characteristics and seismic velocity. No data is available for Dunoon dam site; however, experience can be gained from excavation at Shannon Creek Dam, in the same geological setting and the same geological units.

Due to the steep topography, excavation of the core trench/wall foundation is likely to require the use of hydraulic excavators with rock hammer attachments; however, progress may be slow, especially in very thickly bedded sandstone.

The spillway excavation will require blasting. The aim of excavation should be to leave a smooth wall profile, without excavation-induced fracturing that would create stability problems in the final batter faces. To accurately define the batters, lines of pre-split holes will need to be detonated initially, before later sequence delays of the main production blasts.

For an earthfill embankment, weathered claystone/shale/sandstone in upstream borrow areas may be ripped to provide at least a portion of the required earthfill. Experience at Shannon Creek Dam indicates that ripping in these materials may be possible to 10m and greater depth; however, rock rippability in any proposed borrow areas will need to be determined during design stage geotechnical investigations.

9.2 Detailed Excavation

Detailed excavations are likely to be required for structures such as the diversion/outlet conduit for a RCC dam, and for specific concrete structures such as a control structure in the spillway channel, drains beneath the spillway floor, and the intake tower foundation. Such features would normally be excavated using a hydraulic excavator, or with hand tools for very small excavations.

There are no classification systems currently available that allow a "systematic" assessment of excavatability with hydraulic excavators and/or hand tools. However, several observations may be made from experience gained at other sites in similar geological environments, including Shannon Creek Dam. Excavation in confined spaces in highly weathered and better quality sandstone is likely to be difficult, because of the relatively wide defect spacing in the rock. It is likely that hydraulic excavators with hydraulic hammer attachments will be able to excavate the rock, but progress will be slow because much of the rock in small excavations will need to be removed by breaking through the rock substance, instead of breaking along existing defects.

10 Storage Perimeter Stability and Leakage

10.1 Storage Perimeter Stability

Apart from Kangaroo Creek Sandstone in the gorge section immediately upstream of the embankment/wall site, the storage area is underlain by sedimentary rocks of the Walloon Coal Measures. Basalt of the Lismore Basalt may underlie the very upper limit of the storage area.

Near-horizontally bedded sandstone in the steeply sloping gorge section should be essentially stable, with little possibility of deep-seated slope failures through the rock mass. Further upstream the majority of the storage area has gentle to moderate slopes with little potential for significant slope failure. However, areas of steeper slope should be investigated more closely during later design stage geotechnical investigations, as bedding orientation is likely to influence the stability of slopes.

10.2 Storage Perimeter Leakage

There is no possibility of significant leakage from the storage area into an adjacent drainage basin. There are no extremely permeable beds/horizons present that connect to an adjacent drainage basin, and leakage paths away from the storage area are generally very long.

11 Seismicity

Following the Newcastle earthquake in December 1989, earthquake risk maps were upgraded (Gaul, Michael-Leiba and Rynn, 1990). It is now recognised that relatively small earthquakes may generate high accelerations. In the current Australian Standard (AS1170.4 - 2007), earthquake risk maps are presented in terms of a hazard factor (Z). This factor is identical to the acceleration co-efficient (a) of AS1170.4 – 1993, and is derived by dividing the peak ground velocity, in mm/sec, by 750 (Wilson and Lam, 2009).

Dunoon Dam site is located in a seismically inactive area, that is interpreted as having a hazard factor (Z) of 0.06. The nominal probability of the derived force being exceeded is 10% in a 50 year design life, ie, an average recurrence interval of approximately 500 years.

12 Construction Materials

12.1 Core Material (Zone 1)

12.1.1 General

Approximately 160,000m³ of soil will be required for use as core material in an embankment. Clayey soils in borrow areas in the lower storage area are proposed for use as core material. During the current investigation, thirty test pits (DTP 1 to DTP 30) were excavated to investigate a potential borrow area comprising three spurs on the cleared land upstream of the gorge section of Rocky Creek (see **Figure 5**). The locations of borrow area test pits are shown on **Figure 6**. Logs of test pits are presented in **Appendix B**. Photographs of representative test pit profiles are presented after the relevant test pit logs. Results of laboratory tests on selected samples are presented in **Appendix C**, and summary result sheets are presented at the front of the test results.

12.1.2 Soil Types

The three spurs in the proposed borrow area are underlain by the Walloon Coal Measures, comprising predominantly claystone with shale, minor sandstone and traces/thin seams of coal. Very thin coal seams and coal laminae were encountered in nineteen of the thirty test pits.

On the majority of the three spurs that comprise the borrow area, shallow residual soils mantle most of the surface. They generally have the following typical shallow soil profile, including underlying extremely weathered claystone:

0 – 0.25m	CLAYEY SILT (TOPSOIL); ML, minor sand, brown-grey, organic, trace grass roots, dry, firm. Some areas have silty sand topsoil with minor/trace clay (SM).
0.25 – 1.0m	SILTY CLAY; CH, trace sand, grey-brown, brown and minor red-brown mottled, moist, stiff.
1.0 – 5.0m	CLAYSTONE & COAL; EW, with silty clay, behaves as CH, several thin to medium lensoidal coal seams (maximum seam thickness approximately 0.2m), minor fine grained sandstone. At approx. 3m - becomes HW/EW.

Thicker accumulations of colluvial soils are present on the southern-most spur (DTP 1 – DTP 4), the western extremity of the northern-most spur (DTP18, DTP 20 and DTP 28), and other bench-like shelves below steeper slopes (DTP 6, DTP 16 and DTP 29). These soils were underlain by extremely weathered claystone, or were thicker than the depth of investigation, and had the following typical soil profiles:

0 – 0.4m	CLAYEY SILT (TOPSOIL); ML, minor sand, grey-brown with trace brown, organic, trace grass roots, dry, firm.
0.4 – 4.0m	SILTY CLAY; CH, grey and red-brown mottled, moist, stiff.
4.0 - 5.4m	CLAYSTONE; EW, with COAL laminae/thin seams, behaves as CH. Becomes HW near the base of the pit.

Two additional soil types were encountered; however, these did not have a wide distribution. Test pit DTP 24 was excavated in silty clay soil with basalt boulders. This was interpreted as the toe area of a small, ancient landslide from further up the slope. Test pit DTP 30 is in alluvial silty sand and sand on a narrow terrace adjacent to the creek bed.

12.1.3 Soil Properties

Laboratory test results and summary results are presented in **Appendix C**.

The engineering properties of topsoil have not been determined in the laboratory. Field identification indicates that the topsoil comprises sandy silt with clay (ML) and some silty sand with trace to minor clay (SM), containing traces of gravel. Sand is generally of medium grainsize. This uppermost horizon of the soil profile would not be suitable for use as core material.

Residual soil and colluvial soil profiles generally comprise silty clay with traces to minor sand. These soils generally classified as CH; however, the plasticity of several samples plotted close to the 'A-Line' and these samples were given a dual CH-MH classification. They would be suitable for use as core material.

Extremely weathered claystone and claystone/siltstone/sandstone, including silty clay soil, formed a thick horizon between the overlying soil and the base of the test pits. The rock readily broke down in the hand to silty clay/clayey sand with variable sand content. These soils classified as CH, CI, MH and SM (one sample). They would be suitable for use as core material; however, minor coal seams are present in the rock profiles and these would need to be well mixed.

12.1.4 Indicated Resources

Within the proposed borrow area, the depths of useable soil have been interpreted from test pit logs (see **Appendix B**). Extremely weathered claystone underlying the soil profile breaks down easily to silty clay (CH) with very little working, and has been included in resource calculations. Soil depths (including the extremely weathered claystone) often extended beneath the depth of investigation, and the conservative depths to the bases of the test pits were used in calculations.

Volumes of potential core material in each borrow area were estimated by calculating an approximate surface area of each spur, and then multiplying by an interpreted average depth of useable soil of 4.0m for each spur within the borrow area. A combined resource of 600,000m^3 is available in the three spurs that comprise the borrow area. The interpretation of average soil thickness is based on relatively wide pit spacings. The margins of the borrow areas are also very interpretative. A closer pit spacing is required to accurately delineate soil thickness and borrow area boundaries. Therefore, estimates of soil volumes should be regarded as indicated resources rather than reserves.

The clayey silt/silty sand (ML/SM), organic topsoil would not be suitable for use as core material, and should be considered as overburden. An average thickness of 0.3m (range 0.2 – 0.5m) over the borrow area gives a total overburden volume in the order of 50,000m^3; however, concentration of the core material extraction area would reduce overburden volumes considerably.

12.2 Fine Filter Material (Zone 2A)

In the order of 25,000m³ of sand is required for use as fine filter in chimney and blanket filters in the embankment. Sand will need to be purchased from local commercial suppliers. Potential sources would include fines from local aggregate quarries (see **Section 12.3 and 12.4**), or natural sources. Holcim (Australia) Pty Ltd obtain sand from a deposit at New Italy (near Evans Head) and from Ross Lane at Lennox Head. Boral Pty Ltd dredge river sand at Woodburn. Holmes Extractive Resources (Clovass Quarry) win sand from a deposit adjacent to Six Mile Swamp Creek, near Wyan Wyan.

12.3 Coarse Filter Material (Zone 2B) and Concrete Aggregate

12.3.1 General

In the order of 15,000m³ of graded gravel/aggregate is required for use as coarse filter in the blanket filter. In the case of a roller compacted concrete dam, 115,000m³ of concrete is required for construction of the dam wall. These materials will need to be purchased from local commercial suppliers, including:

- Corndale Quarry
- Holcim Teven Quarry
- Boral Teven Quarry

- Blakebrook Quarry
- Clovass Quarry, and
- Piora Quarry.

12.3.2 Boral Teven Quarry

Location and Access

The quarry is located near Teven, at GR 488115 Lismore 1:25,000 sheet (9540-2-N), and is approximately 4km northwest of Ballina (see **Figure 7**). It is readily subdivided into two geologically distinct sub-areas: the basalt quarry in the east (see **Photo 11**), and an argillite quarry in the west (see **Photo 12**). The quarry is owned and operated by Boral Resources (Country) Pty. Limited.

Access from the Pacific Highway south of Ballina is along the main Teven-Ballina road, which follows the eastern bank of Macguires Creek, followed by North Teven Road. Alternative access from the Pacific Highway further north of Ballina is provided by the main Teven-Tintenbar road, followed by North Teven Road.

Geology

The Tweed Heads 1:250,000 Geological Series Sheet SH56-3 (Brunker et. al., 1972) indicates that the quarry is located within basalt of the **Lismore Basalt**, and the underlying metamorphosed sedimentary rocks of the **Neranleigh-Fernvale Beds**. The Lismore Basalt generally comprises basalt with minor agglomerate and bole (thin weathered horizons and soil formed between basalt lava flows), and is Tertiary in age. The Neranleigh-Fernvale Beds comprise greywacke, slate, phyllite and quartzite and are of Silurian (in part) age.

Quarry Products

The quarry produces a range of products, including aggregate up to gabion size, crusher fines, quarry run rock and general fill comprising weathered rock/clay (overburden). The quarry has reserves to satisfy current production volumes for the medium term.

12.3.3 Holcim Teven Quarry

Location and Access

The quarry is located at GR 476097 Lismore 1:25,000 sheet (9540-2-N), on the western side of the Pacific Highway, at Teven (see **Photo 13**). It is approximately 4km northwest of Ballina (see **Figure 7**). The quarry is owned Holcim Australia Pty Ltd.

Access from the Pacific Highway is initially along the main Ballina-Teven road, followed by Stokers Lane towards the west, and a short quarry access road.

Geology

The Tweed Heads 1:250,000 Geological Series Sheet SH56-3 (Brunker et al., 1972) indicates that the quarry is located within metamorphosed sedimentary rocks of the **Neranleigh-Fernvale Group**. This rock unit consists of metamorphosed greywacke, slate, phyllite and quartzite of Silurian (in part) age.

The quarry has been developed in the following materials:

- Meta-argillite;
- minor meta-greywacke;
- minor very siliceous meta-argillite/chert.

Quarry Products

Holcim's Teven Quarry is a large, hard rock quarry, producing crushed rock for road construction and concrete aggregates. The quarry produces a range of aggregate sizes up to 40mm, plus crusher dust for fines, and run of quarry rock.

Reserves in the quarry indicate a 20 year life at the current production rate.

12.3.4 Corndale Quarry

Location and Access

Corndale Quarry is a medium size hard rock quarry, producing rock for road construction and other use (see **Photo 14**). The quarry only has portable crushing facilities. The quarry is located at GR 364224 Dunoon 1:25,000 sheet (9540-1-S), off the James Gibson Road, in the area between the townships of Bexhill, Corndale and Clunes. It is the closest quarry to the dam site (see **Figure 7**). The quarry is owned and operated by Smith Plant (Lismore) Pty Ltd.

Geology

The Tweed Heads 1:250,000 Geological Series Sheet SH56-3 (Brunker et. al., 1972) indicates that the quarry is located within the **Lismore Basalt**. This rock unit comprises basalt with minor agglomerate and bole (thin weathered horizons and soil formed between basalt lava flows), and is Tertiary in age.

Quarry Products

Currently, the quarry has limited crushing capacity and the main products are gabion size aggregate, run of quarry rock (small rip rap) and road base; however, crushing capacity may change in the future.

Currently, the quarry has reserves of 900,000m^3 over 15 years, or until the resource is expired.

12.3.5 Blakebrook Quarry

Location and Access

Blakebrook Quarry is a large, hard rock quarry, producing crushed basalt for road construction and concrete aggregates, primarily for Lismore Council's requirements (see **Photos 15 and 16**). The quarry is located approximately 5km northwest of Lismore, at GR 151077 Casino 1:25,000 sheet (9540-3-N), near Blakebrook (see **Figure 7**). The quarry is operated as Northern Rivers and Asphalt, a commercial arm of Lismore City Council.

Access from Lismore is provided by the Lismore - Nimbin road, followed by a sealed quarry access road.

Geology

The Tweed Heads 1:250,000 Geological Series Sheet SH56-3 (Brunker et. al., 1972) indicates that the quarry is located within basalt of the **Lismore Basalt**. This rock unit comprises basalt with minor agglomerate and bole (thin weathered horizons and soil formed between basalt lava flows), and is Tertiary in age. Several basalt flows can be identified in the quarry faces.

Quarry Products

The quarry produces a full range of products, including aggregate up to gabion size, crusher fines, quarry run rock and general fill comprising weathered rock/clay (overburden). The quarry has reserves for 25 plus years at maximum production, or 75 years plus at the average production rate.

12.3.6 Clovass Quarry

Location and Access

Clovass Quarry is a medium size, hard rock quarry, producing crushed basalt for road construction and concrete aggregates (see **Photo 17 and 18**). The quarry is located at GR 244181 Casino 1:25,000 (9540-3-N) sheet, on the northern side of the Bruxner Highway, at Clovass, approximately 10km east of Casino and 15km west-southwest of Lismore (see **Figure 7**). The quarry is owned and operated by R.K. and B.P. Holmes.

Access northwards from the Bruxner Highway is provided by Clovass Road, and a short quarry access road.

Geology

The Tweed Heads 1:250,000 Geological Series Sheet SH56-3 (Brunker et. al., 1972) indicates that the quarry is located within basalt of the **Lismore Basalt**. This rock unit comprises basalt with minor agglomerate and bole (thin weathered horizons and soil formed between basalt lava flows), and is Tertiary in age.

Quarry Products

The quarry uses portable crushing plant to produce a range of products, including aggregate up to gabion size, crusher fines, and quarry run rock. Quarry reserves are in the order of 800,000m^3.

12.3.7 Piora Quarry

Location and Access

Piora Quarry is a currently operating to supply quarry products to Casino Council (see **Photo 19**). The quarry is located approximately 11km west of Casino, at GR 938079 Mummulgum 1:25,000 sheet (9440-2-N), on the northern side of the Bruxner Highway, several km east of Piora, (see **Figure 7**).

Access from the Bruxner Highway is along a short, quarry access road.

Geology

The Warwick 1:250,000 Geological Series Sheet (SH56-2) indicates that the quarry is located within basalt of the **Lamington Volcanics**. This rock unit consists of basalt, rhyolite, trachyte, tuff, agglomerate and conglomerate, and is Tertiary in age. The quarry has been developed with two, 6-7m high faces within the following material:

- vesicular basalt, with well developed columnar to blocky jointing;
- massive basalt, with well developed columnar to blocky jointing.

Quarry Products

When contacted by phone, the quarry operator indicated that quarry production would not suit the requirements for the proposed dam; however, formerly the quarry produced a range of crushed basalt products for road construction and concrete aggregate. The quarry should be considered as a resource, as future production may suit the requirements for at least some of the materials required for dam construction. Reserves are not known.

12.4 Earthfill (Zone 3)

12.4.1 General

Approximately 560,000m³ of earthfill is required for construction of the outer shells of the embankment. Potential sources of earthfill are:

- Weathered claystone from beneath the upstream core borrow area (see **Section 12.1**).
- Sandstone from the spillway excavation.
- Sandstone from the diversion tunnel excavation.
- Sandstone that will be excavated from the embankment area during foundation stripping.

12.4.2 Borrow Area Geology

It is assumed that soil and extremely weathered rock would have been excavated, or partially excavated for use as core (Zone 1) material. The borrow area comprises claystone, siltstone shale and sandstone of the Walloon Coal Measures, with trace to minor coal. Test pits indicate that extremely weathered/highly weathered rock extends to 5m plus in depth; however, at this stage the deeper weathering profile in the rock mass is unknown. Based on experience with fine-grained sedimentary rock at other sites, the extremely/highly weathered rock will be underlain by a thin zone of moderately weathered rock, then slightly weathered rock to the depth of the permanent water table (near creek bed level). The weathering profile will need to be established by diamond drilling during later geotechnical investigation.

12.4.3 Spillway, Diversion and Embankment Excavations

The excavation for the spillway is likely to be prominently within moderately weathered sandstone of the Kangaroo Creek Sandstone. The diversion tunnel through the lower right abutment is likely to encounter predominantly slightly weathered to fresh (stained) sandstone of the Kangaroo Creek Sandstone, with moderately weathered sandstone adjacent to the portal areas. The majority of site stripping for the embankment foundation is likely to comprise highly weathered to moderately weathered sandstone of the Kangaroo Creek Sandstone.

12.4.4 Earthfill Properties

The properties of claystone/siltstone/sandstone earthfill won from the upstream borrow areas will depend on the weathering profile in the borrow area, in particular the depth to more competent moderately weathered rock. Based on test results from Shannon Creek Dam, this type of material broke down to silty clay with minor gravel (rock chips) content, and classified as MH and CH. It is likely that less weathered rock would have greater gravel content and lower plasticity. Material parameters adopted for Shannon Creek Dam were: compaction MDD 1.46 – 1.57 tonnes/m³ at OMC 23.5 - 29%; effective stress C' = 6kPa, $Ø'$ = 29º; total stress C_u = 50kPa, $Ø_u$ = 7º (Commerce, 2003).

Sandstone of the Kangaroo Creek Sandstone breaks down to its constituent particles on excavation, loading and placement. Based on test results from Shannon Creek Dam, this type of material broke down to clayey sand with minor small boulders and gravel. Material parameters adopted for Shannon Creek Dam were: compaction MDD 1.82 tonnes/m³ at OMC 14%; effective stress C' = 5kPa, $Ø'$ = 37º; total stress C_u = 25kPa, $Ø_u$ = 20º (Commerce, 2003).

12.4.5 Earthfill Resources

Fill comprising sandstone of the Kangaroo Creek Sandstone has superior compaction and strength characteristics to fill derived from claystone of the Walloon Coal Measures. Approximate computer modelling indicates that in the order of 350,000m^3 of sandstone fill (clayey sand with minor boulders) will be excavated from a 50m-wide spillway channel. Excavation of the diversion tunnel and embankment foundation stripping will also generate small volumes of additional sandstone fill; however, properties of these materials will be slightly inferior due to the highly weathered nature of the foundation stripping and heavy fragmentation of the rock during tunnel excavation.

In the order of 210,000m^3 of claystone-derived fill will be required from the upstream borrow areas. The three spurs in the proposed borrow area have a combined surface area in excess of 160,000m^2. These areas are also proposed for the extraction of core material from soil and extremely weathered claystone in the upper 4 – 5m. Highly weathered and better quality claystone won from beneath the core material would optimise the compaction and strength characteristics of the earthfill. Concentration of excavation in one of the three spurs would also produce less weathered rock, and optimise compaction and strength characteristics of the earthfill. There are more than adequate resources of earthfill in the nominated borrow area spurs; however, the rock mass conditions will require later detailed investigation to determine rock type, weathering and excavation conditions for construction planning.

12.5 Rip-Rap

Approximately 18,000m^3 of rip-rap will be required on the upstream face of the embankment for protection against erosion by wave action. Rip-rap will need to be graded from approximately 0.2m to 0.5m in size. Suitable rock will not be found in the storage/catchment area. Operating local quarries, discussed in **Section 12.3** for the production of coarse filter (Zone 2B) and concrete aggregate, would also be able to supply basalt, or argillite, that would be suitable for use as rip rap.

13 Future Geotechnical Investigation

If Dunoon Dam site is confirmed as the most favoured alternative for the augmentation of the Rous Water supply, extensive further geotechnical investigation will be required. The investigation may need to be in two phases: an initial phase to confirm the geological model for the design concepts and a second major phase to provide geotechnical data for detailed design and answered geotechnical questions arising from the first phase. Depending on the type of dam selected, specific areas requiring investigation would include:

- Close geological mapping is required in the gorge area to define and describe the outcrops and form the basis for more detailed site investigation.
- The geological sequence in the valley base, particularly to investigate if fine-grained rocks of the Walloon Coal Measures occur within the foundation of the proposed embankment/wall.
- The geological sequence, foundation conditions and rock mass leakage potential for the embankment core trench, or alternative RCC wall foundation.
- Any effects of valley bulge in the valley base.
- The proposed left abutment spillway alignment for an embankment dam, including the crest area, the alignment and the stilling basin.
- The spillway flip-bucket foundation for a RCC dam wall and any downstream stilling basin.
- The diversion tunnel alignment through the right abutment for an earthfill embankment, including the upstream and downstream portals (incorporating the intake tower and valve house), the tunnel alignment and the intake channel alignment. The presence/location and characteristics of the inferred fault in the vicinity of the upstream portal need to be established. Similarly, the fault interpreted to cross the middle portion of the tunnel alignment needs to be verified, located and investigated.
- The diversion alignment along the left valley base for a RCC dam, including an intake tower attached to the dam wall, a valve house at the toe of the dam wall, and intake and exit alignments.

- The geology of the upstream borrow area, including rock types and weathering need to be determined, including the excavation characteristics (rippability) of the rock mass.
- Upstream borrow area sources of core material and earthfill need to be proven and optimised for an earthfill embankment. Soil properties of the core (Zone 1) material and earthfill (Zone 3) need to be determined, including the properties of fill from the spillway excavation.
- Off site materials, including fine filter (Zone 2A), coarse filter (Zone 2B) and rip rap (Zone 4) for an embankment dam, and concrete aggregate for a RCC dam need investigation to establish resources and material characteristics. Samples of materials need to be tested for grading and durability.
- Storage area geology requires mapping in closer detail to allow more detailed assessment of storage rim stability.
- Seismicity needs to be reviewed to determine appropriate Peak Ground Acceleration recurrence of the proposed dam site.

The steep topography and cliff lines will pose challenges to site investigation, and will require construction of multiple access tracks. Separate access to the creek bed area of the site and to each abutment are likely to be required. Access to individual investigation sites on the abutments is likely to require a track network along the abutment benches. Diamond drilling will be required to determine rock mass quality/conditions (including leakage potential), excavation conditions, and batter stability for all elements of the proposed dam, including earthfill resources for an embankment dam.

Use of the seismic refraction method, to assess general rock mass properties, may be possible in the borrow areas and parallel to the creek bed at the embankment/wall site; however, shooting seismic lines across the valley will not be possible because of the steep topography.

14 Conclusions

1. The geological setting of the proposed dam is generally understood, and has allowed the formulation of a preliminary geological model at the site. However, further work is required to refine the model, and to gain an appreciation of the variations in rock mass conditions across the site.

2. There are no major reasons which would preclude construction of a zoned earthfill embankment or RCC wall at the site.

3. Moderately weathered and better quality sandstone is likely to form a suitable foundation for the core trench of an embankment dam, or foundation of a RCC wall.

4. Highly weathered and better quality sandstone is likely to form a suitable foundation for the outer zone of an embankment dam.

5. A grout curtain will be required to reduce seepage beneath the embankment; however, the steepness of the site will pose challenges during grout curtain construction, particularly on the left abutment.

6. Sufficient supplies of core material (Zone 1), and earthfill (Zone 3) for an embankment dam are likely to be available from the storage area. Filter materials (Zones 2A and 2B) and rip-rap (Zone 4) are available from commercial suppliers in the area. Similarly, concrete aggregate for a RCC dam is also available from commercial quarries.

7. Comprehensive further geotechnical investigation is required for the embankment/RCC wall and all appurtenant structures, to refine the geological model, and to prove the reserves and properties of construction materials.

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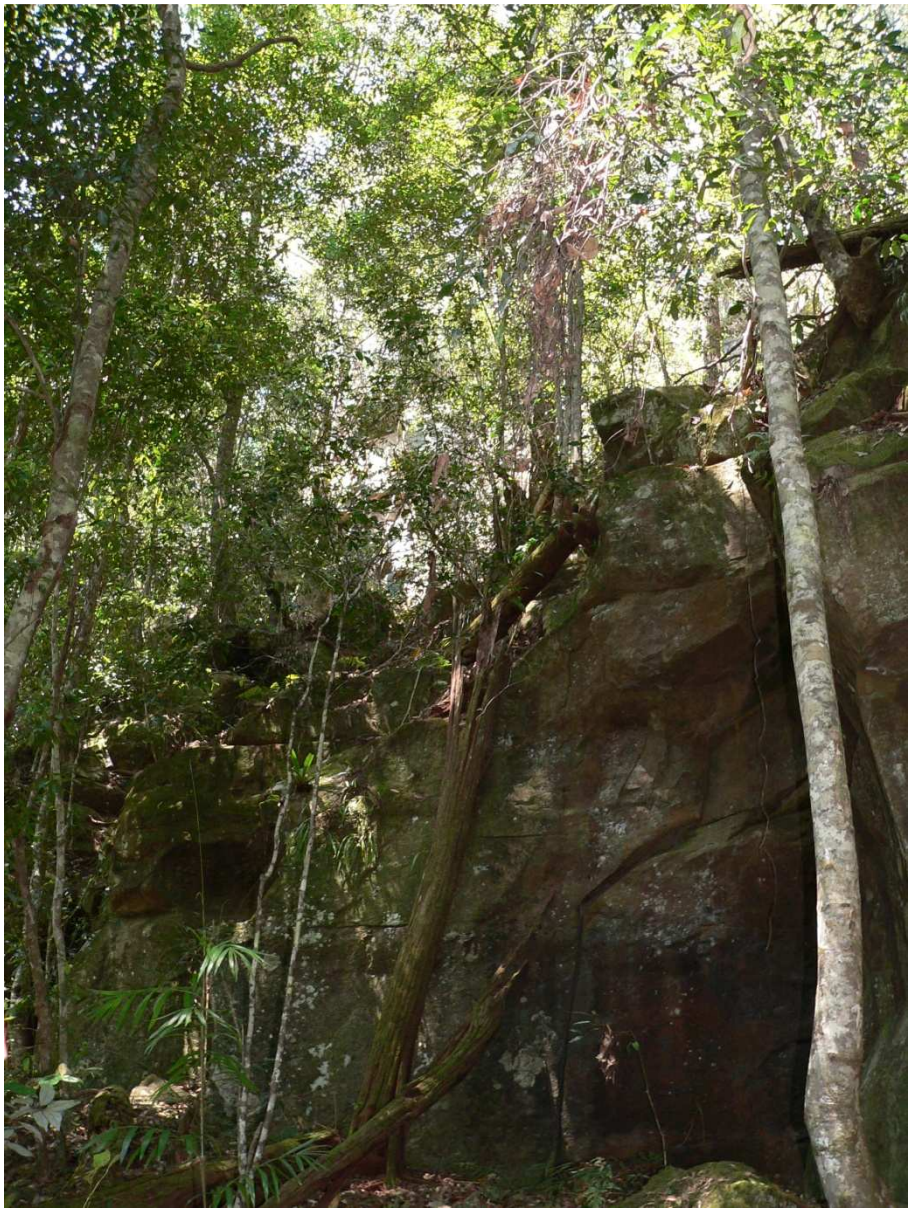
PHOTOS

PHOTO 1 View looking up valley from downstream of the embankment toe, showing the steep right abutment. Note the sandstone exposure in the creek bed in the foreground.

PHOTO 2 Upstream view across the right bank alluvial terrace towards a gently sloping spur in the borrow area. Note the steeper slope in the upper wooded slope in basalt.

PHOTO 3 Close view of the middle borrow area spur showing steeper wooded slope in basalt.

PHOTO 4 Close view of the northern borrow area spur showing steeper wooded slope in basalt.



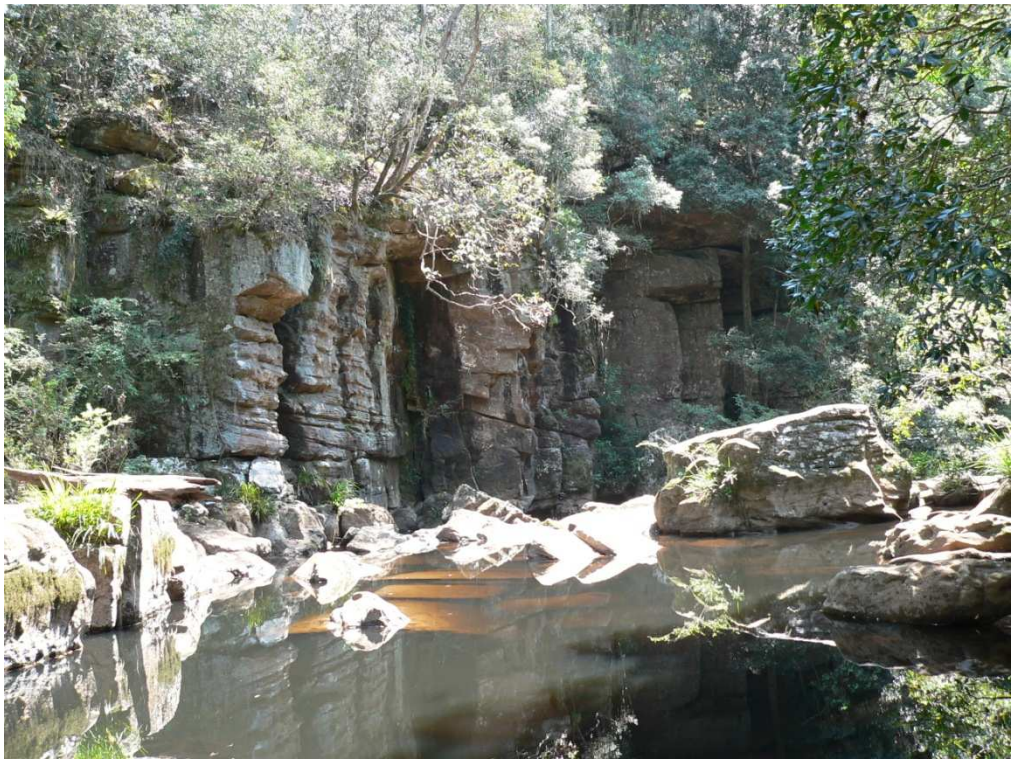


PHOTO 6 (Above) View of sandstone cliffs downstream of the embankment toe, in the vicinity of the downstream diversion tunnel portal. Note the very large boulders in the stream channel.

PHOTO 5 (Left) View of continuous cliff on the lower left abutment in thickly and very thickly bedded, widely jointed sandstone.

PHOTO 7 Test pit DTP 1, showing interbedded claystone, siltstone/shale and black coal of the Walloon Coal Measures. Beds dip at approximately 10° in direction 150°M.

PHOTO 8 View of the alluvial terrace on the right creek bank, located immediately upstream of the dam site gorge.

PHOTO 9 Close view of cross laminated bed in cliff face, downstream of the embankment toe, in the vicinity of the downstream diversion tunnel portal. The upper and lower surfaces of the bed are highlighted, with internal cross laminations at ~15°.

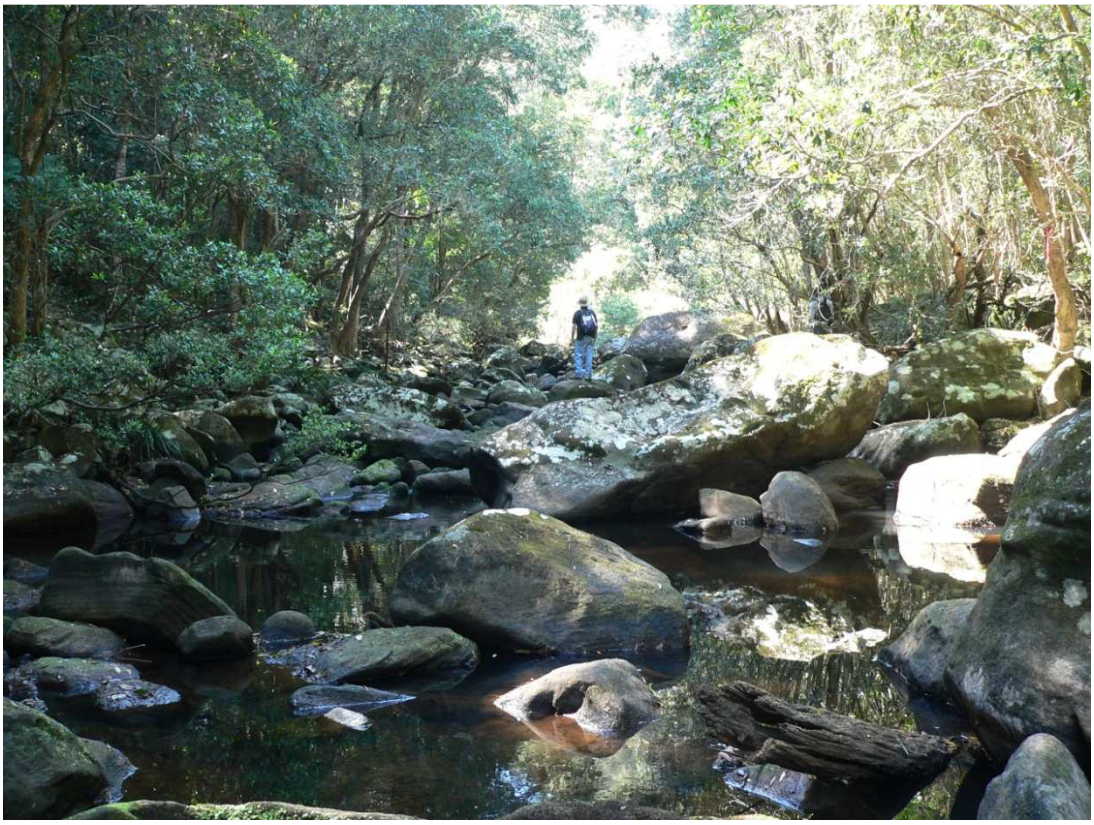


PHOTO 10 Sandstone boulders in the bed of Rocky Creek, looking downstream of the proposed embankment centreline.

PHOTO 11 General view of faces in the basalt portion of Boral's Teven Quarry.

PHOTO 12 General view of faces, crushed rock and run of quarry rock piles in the argillite portion of Boral's Teven Quarry.

PHOTO 13 View of the main faces in Holcim's Teven Quarry, in metamorphosed argillite of the Neranleigh-Fernvale Group.

PHOTO 14 General view of Corndale Quarry, in basalt of the Lismore Basalt.

PHOTO 15 General view of portion of Blakebrook Quarry, in basalt of the Lismore Basalt. Two basalt flows are exposed in the face, and piles of crushed rock in the foreground.

PHOTO 16 View of portion of the main working face in Blakebrook Quarry, in basalt of the Lismore Basalt. Note the light coloured inter-flow soil deposit (bole) near the top of the face.

PHOTO 17 General view of Clovass Quarry, in basalt of the Lismore Basalt.

PHOTO 18 View of portion of the face Clovass Quarry, in basalt of the Lismore Basalt. The basalt is highly jointed and fractured.

PHOTO 19 View of the northern face Clovass Quarry (1996), in basalt of the Lamington Volcanics.

FIGURES

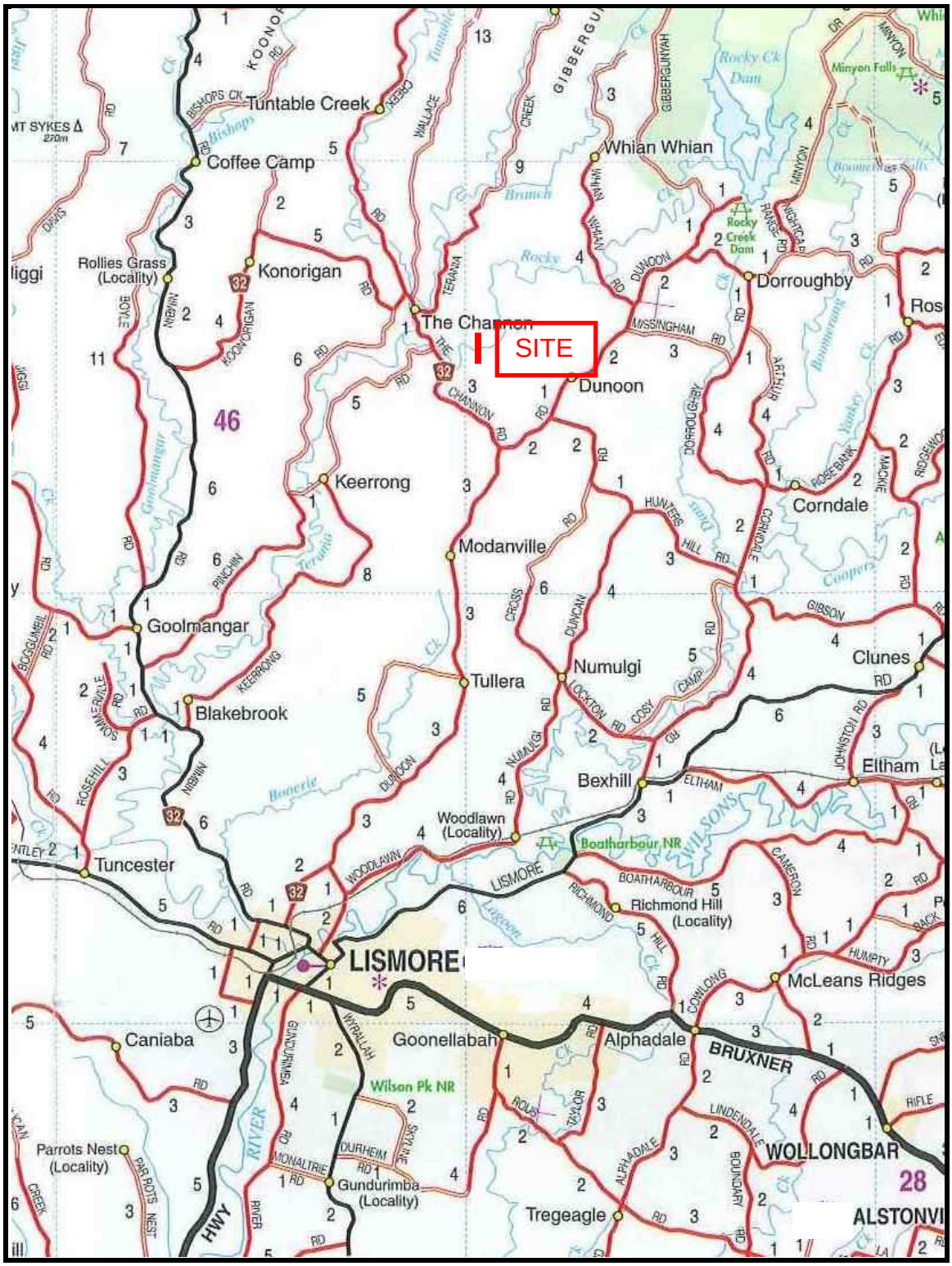
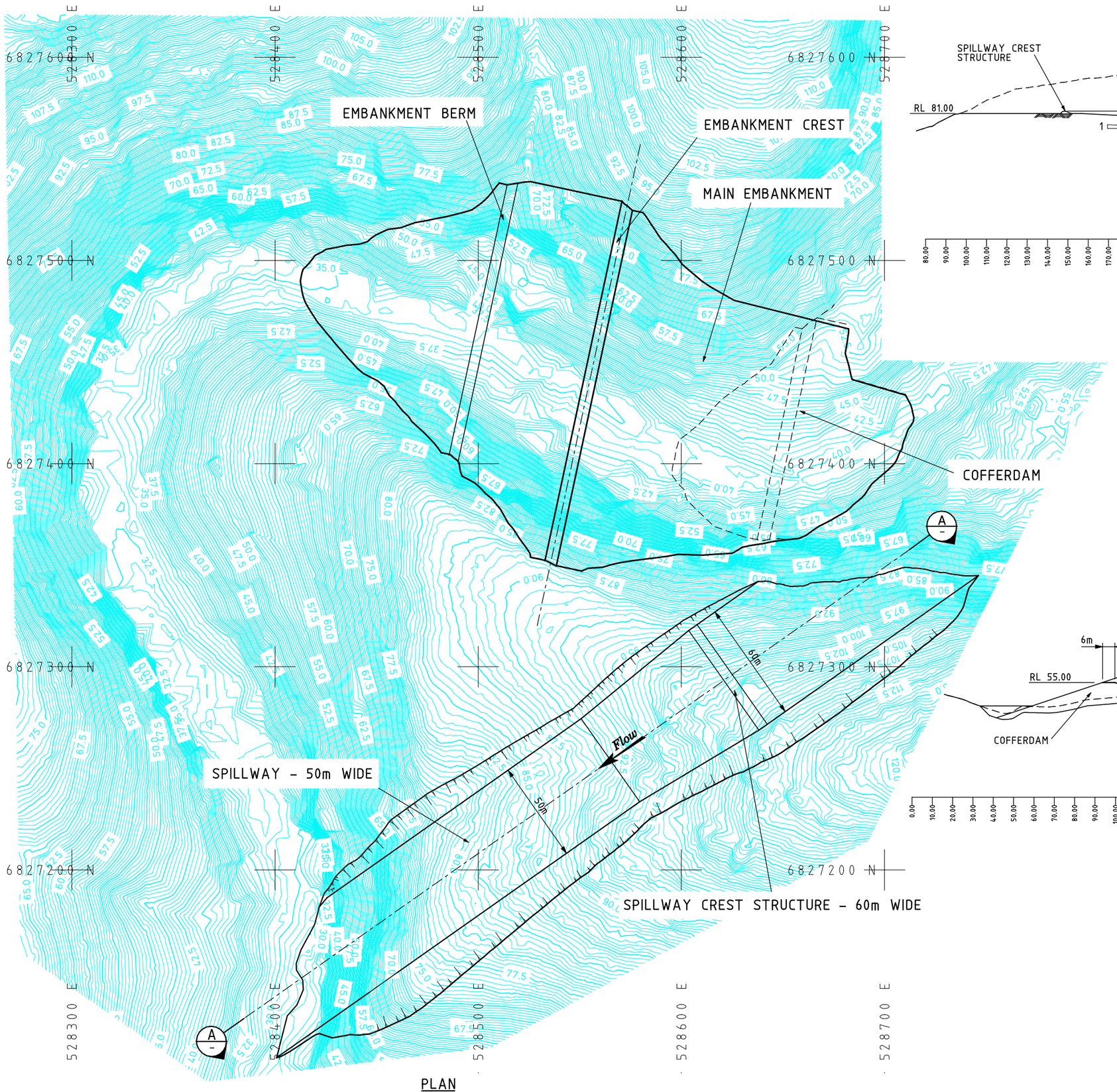
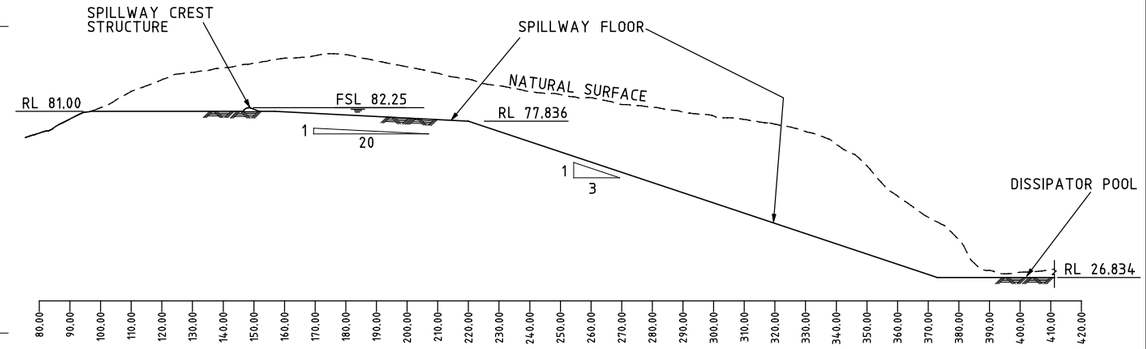


FIGURE 1 Locality Map

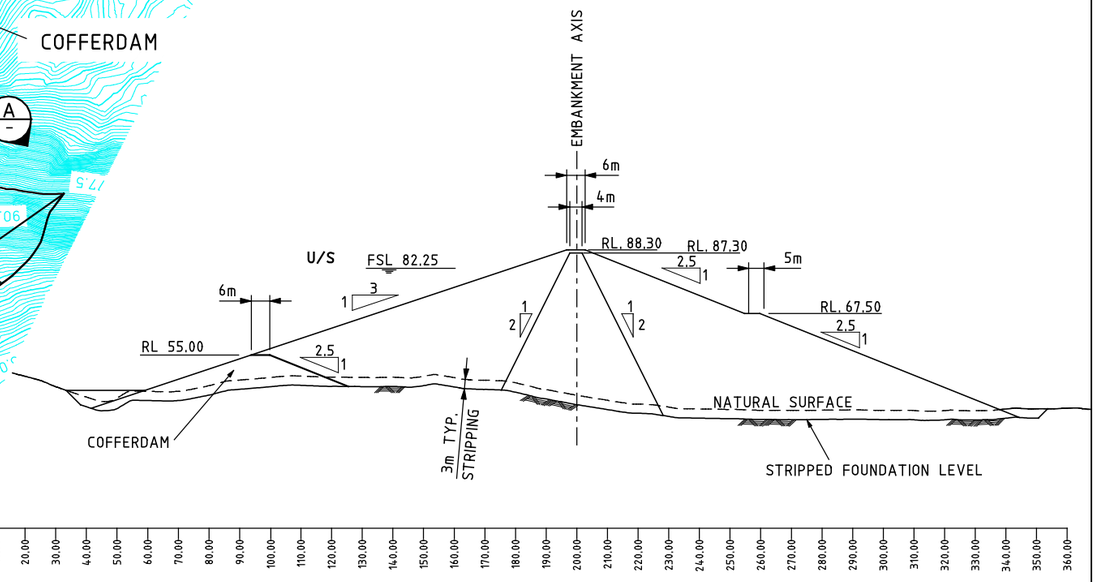


PLAN
SCALE A



SECTION A
SCALE A

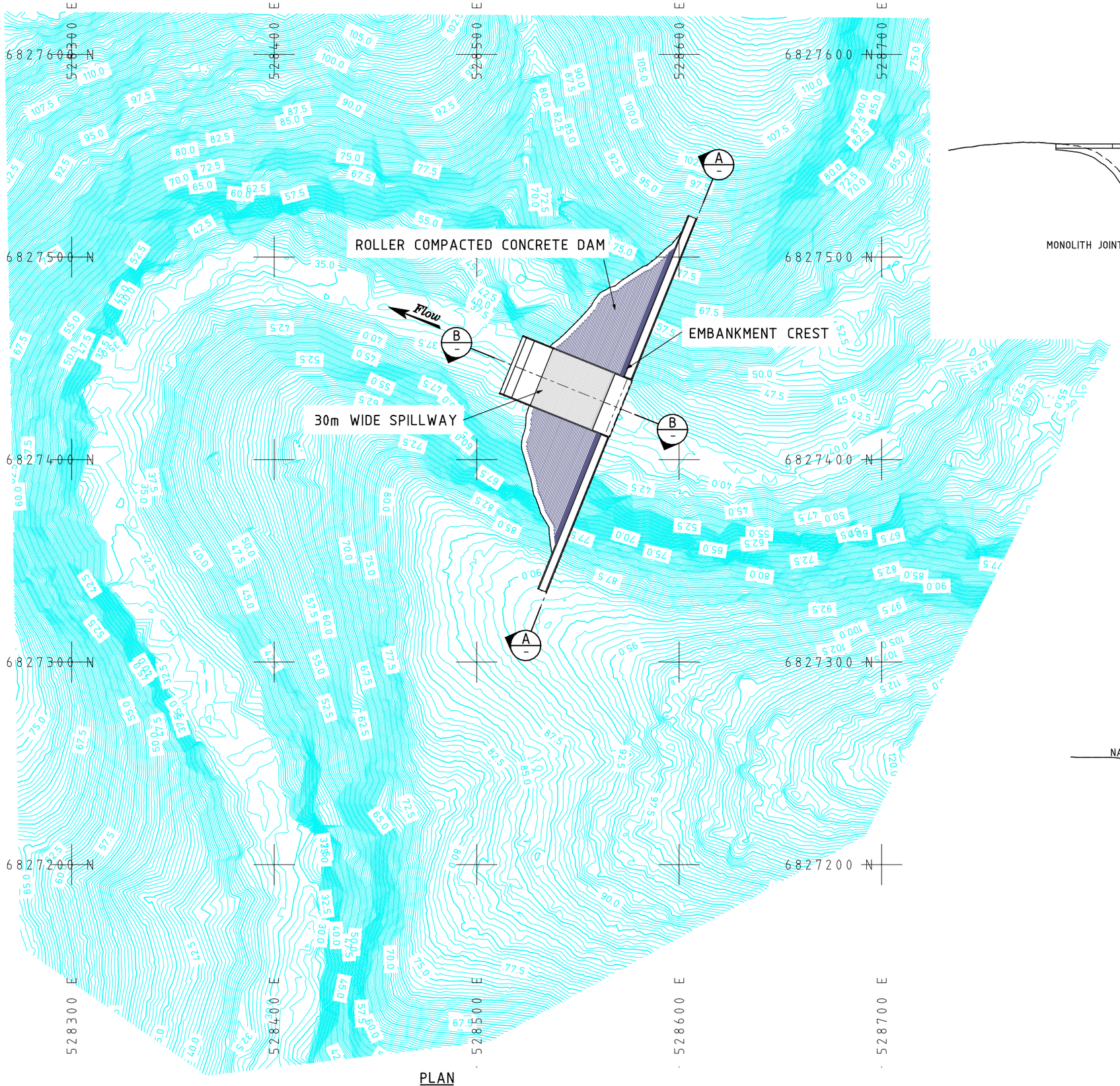
SPILLWAY LONGITUDINAL SECTION



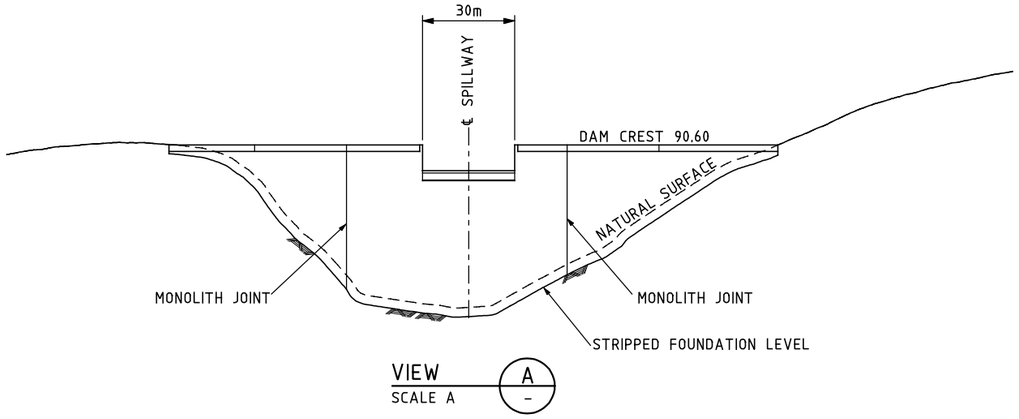
TYPICAL EMBANKMENT SECTION
SCALE A

SCALE A 0 40 80 120 160 200 m
40 20

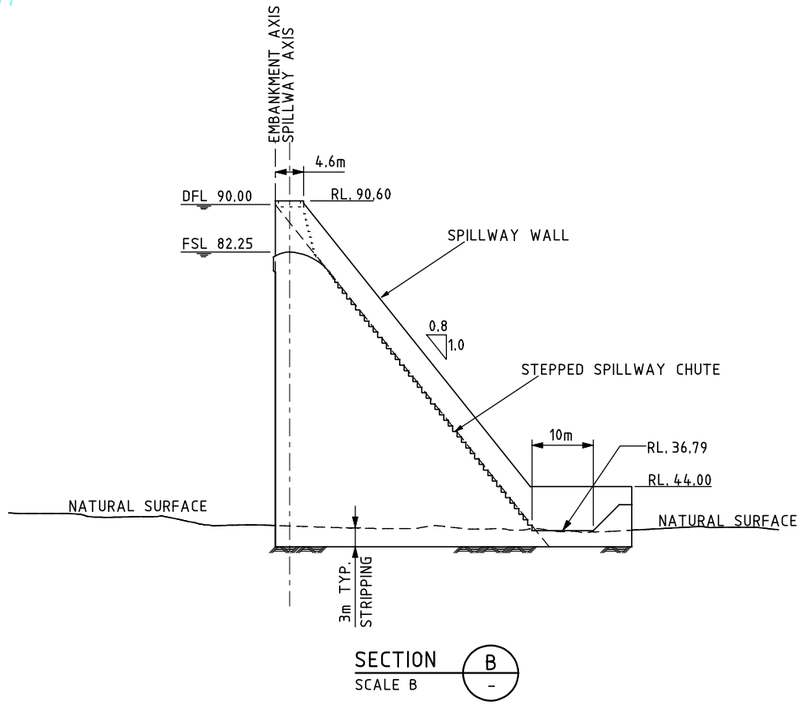
FIGURE 2 – GENERAL ARRANGEMENT OF EARTHFILL EMBANKMENT



PLAN
SCALE A



VIEW A
SCALE A



SECTION B
SCALE B

SCALE A 0 40 80 120 160 200 m
40 20

SCALE B 0 20 40 60 80 100 m
20 10

FIGURE 3 – GENERAL ARRANGEMENT OF ROLLER COMPACTED CONCRETE DAM

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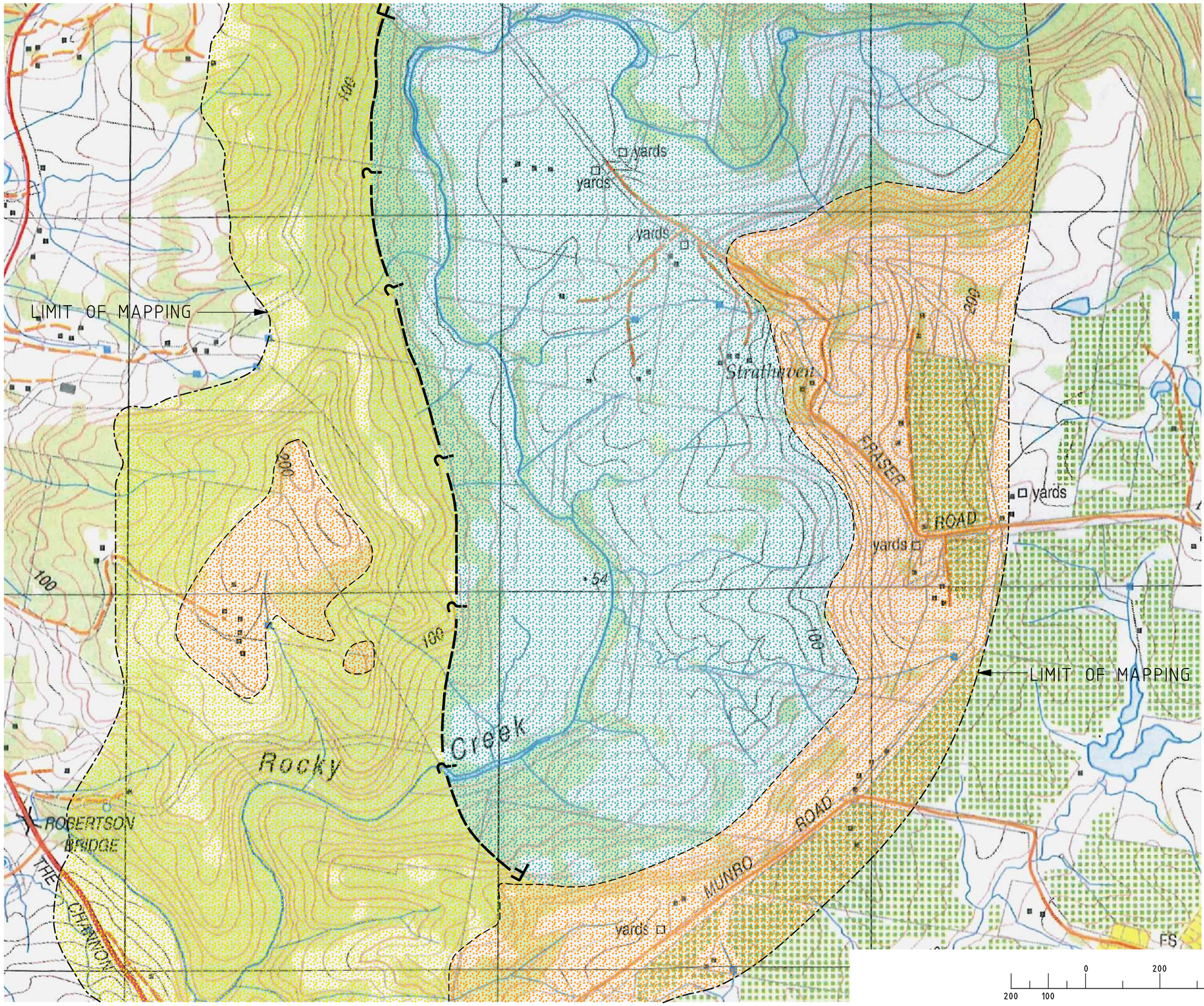


LEGEND

- LISMORE BASALT
- KANGAROO CREEK SANDSTONE
- WALLOON COAL MEASURES
- GEOLOGICAL BOUNDARY (POSITION APPROXIMATE)
- FAULT, INTERPRETED (POSITION APPROXIMATE)

0 200 400 600 800 1000 m

200 100

FIGURE 4 –
REGINAL GEOLOGY MAP

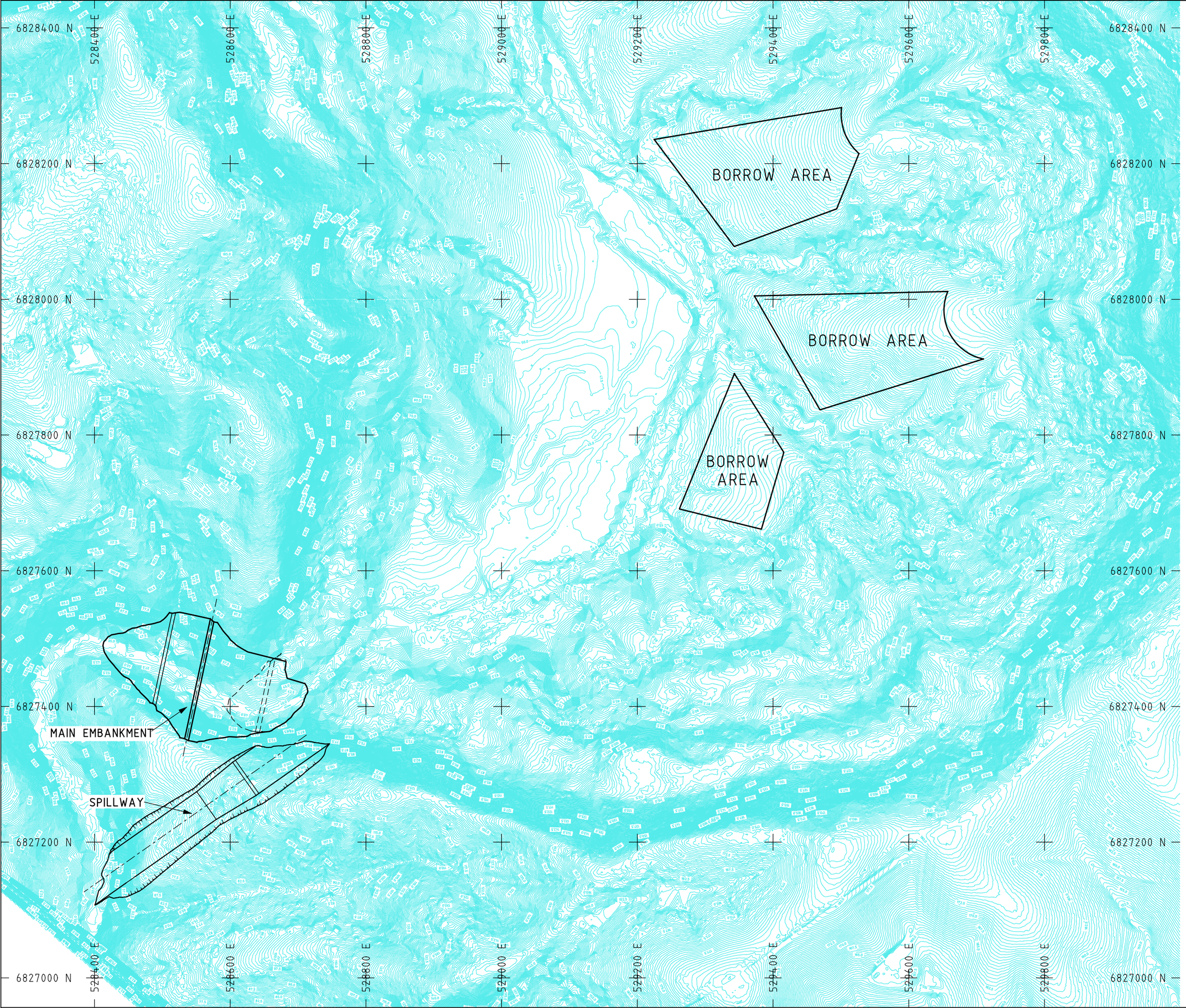
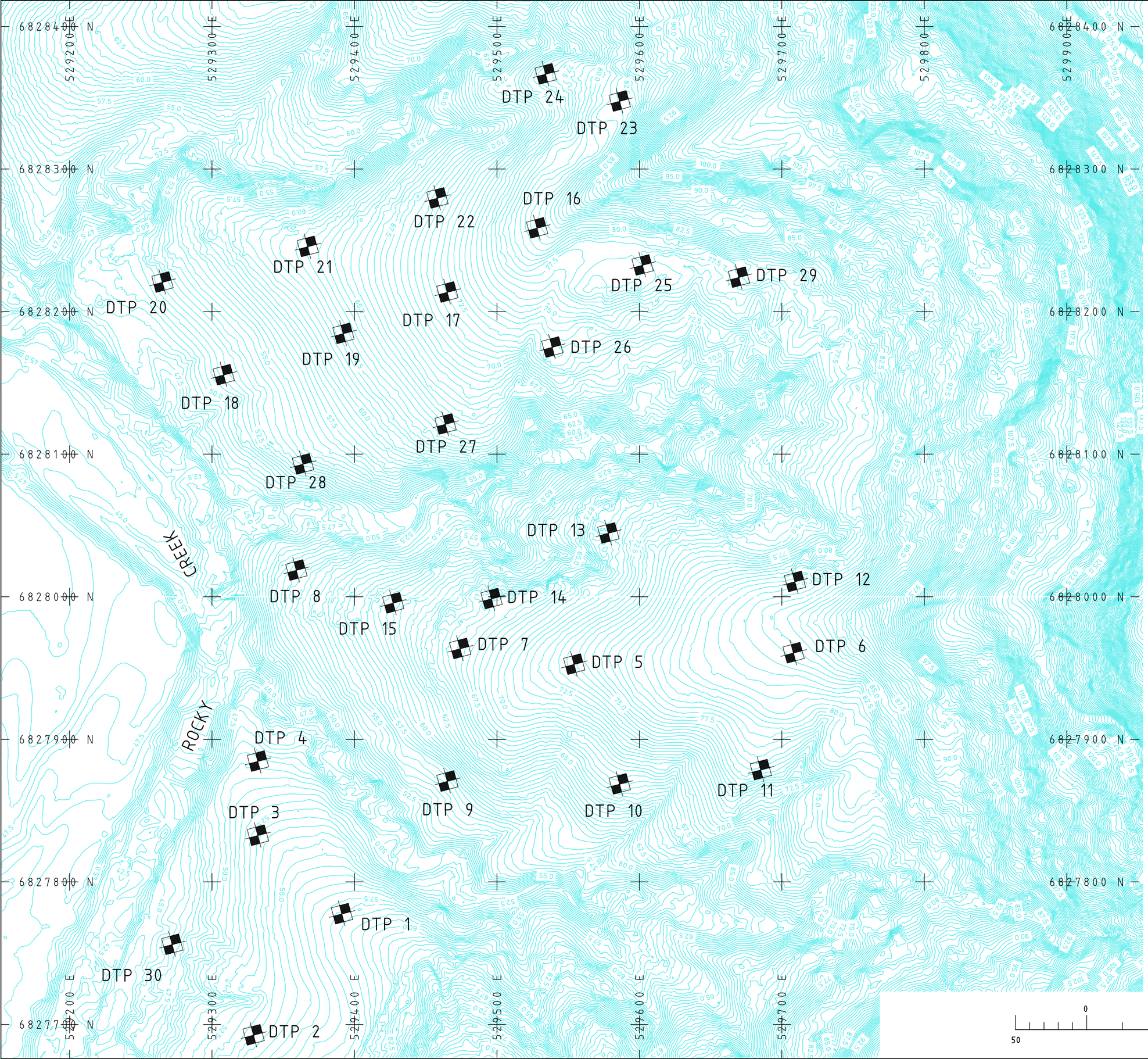


FIGURE 5 –
LOCATION OF
SOIL BORROW AREAS



LEGEND

DTP 6 — LOCATION OF TEST PIT

NOTE: BORROW AREA LOCATIONS SHOWN ON FIGURE 5.

FIGURE 6 –
LOCATIONS OF BORROW AREA
TEST PITS

0 50 100 150 200 250 m

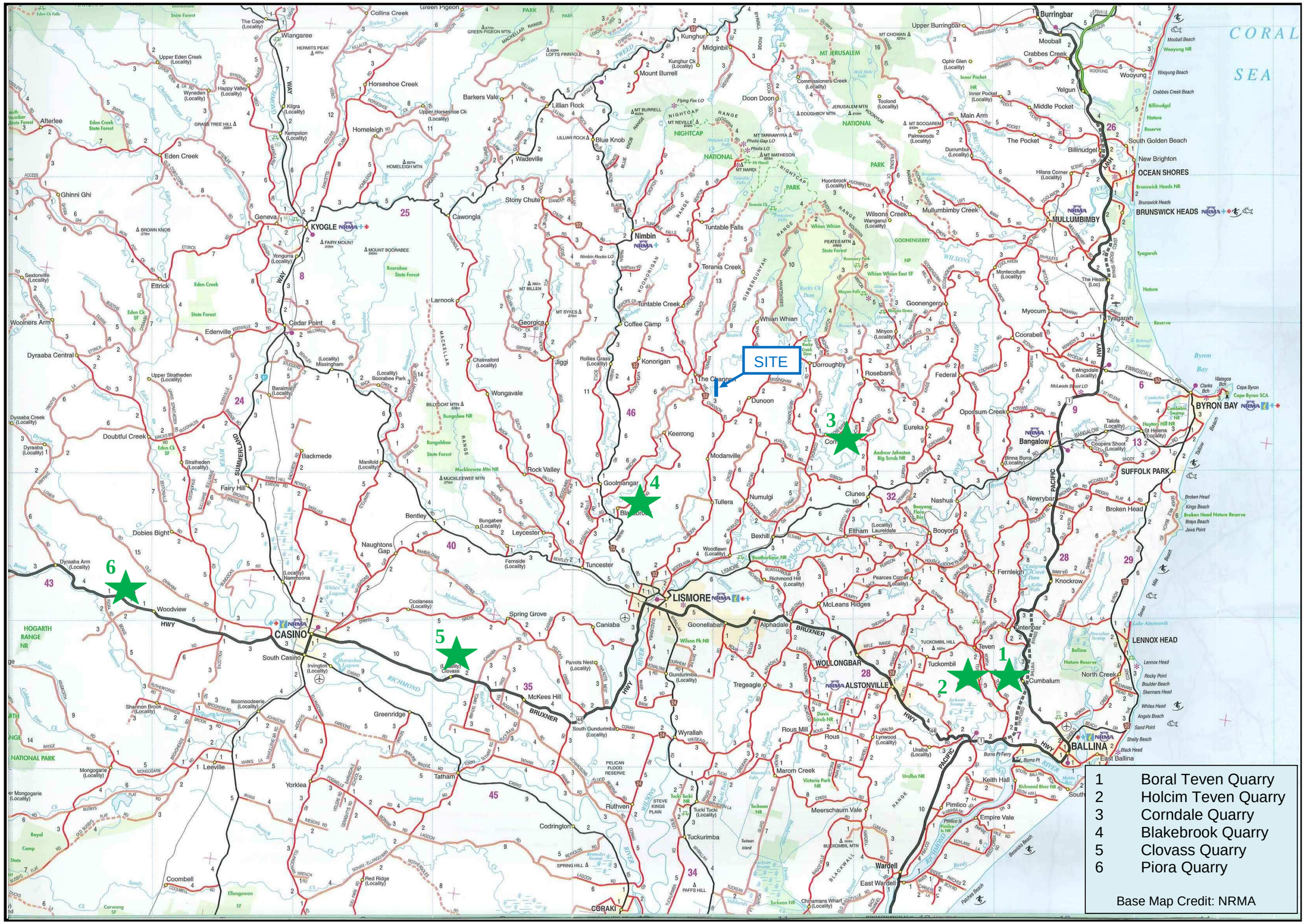


FIGURE 7 Locations of Commercial Quarries

Appendix A Definitions of Terms

CHARACTERISATION OF GEOTECHNICAL DATA

Geotechnical data generally fall into the categories of fact, interpretation and opinion, as defined by the Institution of Engineers, Australia, 1987 - Guidelines for the Provision of Geotechnical Information in Construction Contracts.

Facts are defined as the materials, statistics and properties which may be seen, measured or identified by means of accepted and preferably standardised criteria, classifications and tests. Examples of facts include: exploration locations, outcrop locations, samples and drill core, lithological names/descriptions of soils and rocks, measured water levels, laboratory test results and seismic time/distance plots.

Interpretative data is defined as information derived from competently made interpretation of facts using accepted and proven techniques, or reasonable judgement exercised in the knowledge of geological conditions or processes evident at the site. Examples of interpretative data are: borehole and test pit logs, inferred stratigraphy and correlations between boreholes or test pits, material and rock mass properties used in analysis (e.g. permeability), and seismic interpretation (yielding velocity and layer depths).

Opinion is derived from consideration of relevant available facts, interpretations and analysis and/or the exercise of judgement. Examples of opinions based on geotechnical/geological interpretations include bearing capacity and foundation suitability, need for foundation treatment, settlements, potential for grouting, excavation stability, ease of excavation, and suitability of construction materials.

SOIL DESCRIPTION

The methods of description and classification of soils are based on Australian Standard 1726, the SAA Site Investigation Code. The description of a soil is based on particle size distribution and plasticity as shown in the "GUIDE TO THE DESCRIPTION, IDENTIFICATION AND CLASSIFICATION OF SOILS".

SOIL CLASSIFICATION

The basic soil types and their subdivisions are defined by their particle sizes:

MAJOR SOIL CATEGORIES

Soil Classification	Particle Size
Boulders	Greater than 200mm
Cobbles	63 - 200mm
Gravel	2.36 - 63mm
Sand	0.075 - 2.36mm
Silt	0.002 - 0.075mm
Clay	Less than 0.002mm

MINOR SOIL CONSTITUENTS

As most natural soils are combinations of various constituents, the primary soil is further described and modified by its minor components:

Coarse grained soils			**Fine grained soils**		
% Fines		**Modifier**	**% Coarse**		**Modifier**
	≤ 5	Omit, or use 'trace'		≤ 15	Omit, or use 'trace'
> 5	≤ 12	Describe as 'with clay/silt', as applicable	> 15	≤ 30	Describe as 'with sand/gravel', as applicable
> 12		Prefix soil as 'silty/clayey', as applicable	> 30		Prefix soil as 'sand/gravelly', as applicable

COHESIVE SOILS

Clay and silt may be described according to their plasticity:

Descriptive Term	**Range of liquid limit (percent)**
Of low plasticity	≤ 35
Of medium plasticity	> 35 ≤ 50
Of high plasticity	> 50

MOISTURE CONDITION

Term	Description
Dry (D)	Cohesive soils; hard and friable or powdery, well dry of plastic limit. Granular soils; cohesionless and free-running.
Moist (M)	Soil feels cool, darkened in colour. Cohesive soils can be moulded. Granular soils tend to cohere.
Wet (W)	Soil feels cool, darkened in colour. Cohesive soils usually weakened and free water forms on hands when handling. Granular soils tend to cohere.

CONSISTENCY - NON-COHESIVE SOILS

Term	Density index %		SPT "N" value
Very loose		≤ 15	< 5
Loose	> 15	≤ 35	5 - 10
Medium dense	> 35	≤ 65	10 - 30
Dense	> 65	≤ 85	30 - 50
Very dense	> 85		> 50

CONSISTENCY - COHESIVE SOILS

Term	Undrained shear strength (kPa)		Field guide to consistency	SPT "N" value
Very soft		≤ 12	Exudes between the fingers when squeezed in hand.	< 2
Soft	> 12	≤ 25	Can be moulded by light finger pressure.	2 - 4
Firm	> 25	≤ 50	Can be moulded by strong finger pressure.	4 - 8
Stiff	> 50	≤ 100	Cannot be moulded by fingers; can be indented by thumb	8 - 16
Very stiff	> 100	≤ 200	Can be indented by thumb nail.	16 - 32
Hard	> 200		Can be indented with difficulty by thumb nail.	> 32

GRAPHICAL SYMBOLS USED FOR GEOTECHNICAL BOREHOLE AND TEST PIT LOGS

SOIL - COARSE GRAINED


GW


GP


GM


GC

SW


SP


SM


SC

SOIL - FINE GRAINED


CH


CI

CL


MH


ML


OH


OL


Pt

ROCK


Sedimentary rock


Igneous rock


Metamorphic rock

FILL MATERIAL


Fill

GROUNDWATER


Level


Inflow

NGE No Groundwater Encountered

SOIL HORIZON BOUNDARIES

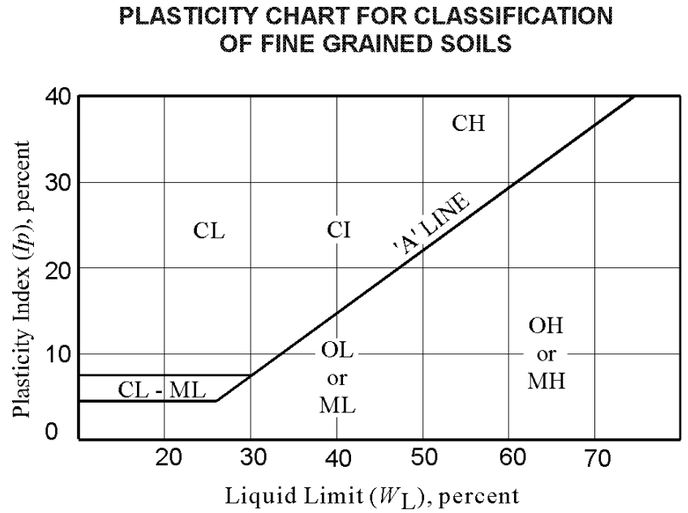
Boundary measured or determined from drilling conditions

Diffuse or uncertain boundary

GUIDE TO THE DESCRIPTION IDENTIFICATION AND CLASSIFICATION OF SOILS

Major Divisions		Particle Size (mm)	Group Symbol	Typical Names	Field Identification Sand and Gravels	Laboratory Classification				
							% < 0.06mm (see note 2)	Plasticity of Fine Fraction	$C_u = \frac{D_{50}}{D_{10}}$	$C_c = \frac{(D_{30})^2}{D_{10}D_{60}}$	Notes
COARSE GRAINED SOILS (more than half of material less than 63 mm is larger than 0.075 mm)	**BOULDERS**	200				Use the gradation curve of material passing 63mm for classification of fractions according to the criteria given in "Major Divisions"	—	—	—	—	
	COBBLES	63					—	—	—	—	
	GRAVELS (more than half of coarse fraction is larger than 2.36mm)	coarse 20	GW	Well-graded gravels, gravel-sand mixtures, little or no fines	Wide range in grain size and substantial amounts of all intermediate sizes, not enough fines to bind coarse grains, no dry strength		0-5	—	> 4	between 1 and 3	1. Identify lines by the method given for fine grained soils.
			GP	Poorly graded gravels and gravel-sand mixtures, little or no fines, uniform gravels	Predominantly one size or range of sizes with some intermediate sizes missing, not enough fines to bind coarse grains, no dry strength		0-5	—	Fails to comply with above	—	
		medium 6	GM	Silty gravels, gravel-sand-silt mixtures	'Dirty' materials with excess of non-plastic fines, zero to medium dry strength		12-50	Below 'A' line or $I_p < 4$	—	—	2. Borderline classifications occur when the percentage of fines (fraction smaller than 0.06mm size) is greater than 5% and less than 12%.
		fine 2.36	GC	Clayey gravels, gravel-sand-clay mixtures	'Dirty' materials with excess of plastic fines, medium to high dry strength		12-50	Above 'A' line or $I_p > 7$	—	—	Borderline classifications require the use of dual symbols e.g. SP-SM, GW-GC
	SANDS (more than half of coarse fraction is smaller than 2.36mm)	coarse 0.6	SW	Well graded sands, gravelly sands, little or no fines	Wide range in grain size and substantial amounts of all intermediate sizes, not enough fines to bind coarse grains, no dry strength		0-5	—	> 6	between 1 and 3	3. I_p = Plasticity Index
			SP	Poorly graded sands and gravelly sands; little or no fines	Predominantly one size or range of sizes with some intermediate sizes missing, not enough fines to bind coarse grains, no dry strength		0-5	—	Fails to comply with above	Fails to comply with above	
		medium 0.2	SM	Silty sands, sand-silt mixtures	'Dirty' materials with excess of non-plastic fines, zero to medium dry strength		12-50	Below ‘A’ line or $I_p < 4$	—	—	
		fine 0.075	SC	Clayey sands, sand-clay mixtures	'Dirty' materials with excess of plastic fines, medium to high dry strength		12-50	Above ‘A’ line or $I_p > 7$	—	—	

GUIDE TO THE DESCRIPTION, IDENTIFICATION AND CLASSIFICATION OF SOILS (CONT.)

Major Divisions		Particle Size (mm)	Group Symbol	Typical Names	Field Identification			Laboratory Classification			Notes
					Dry* Strength	Dilatancy†	Toughness ‡			Plasticity of Fine Fraction	
FINE GRAINED SOILS (more than half of material less than 63 mm is smaller than 0.075 mm)	**SILTS & CLAYS** (liquid limit < 50%)	<0.075	ML	Inorganic silts and very fine sands, rock flour, silty or clayey fine sands or clayey silts with slight plasticity	None to low	Quick to slow	None	Use the gradation curve of material passing 63mm for classification of fractions according to the criteria given in "Major Divisions"	More than 50% passing 0.06 mm	Below 'A' line	
			CL, CI	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays	Medium to high	None to very slow	Medium			Above 'A' line	
			OL ⌖	Organic silts and organic silty clays of low plasticity	Low to medium	Slow	Low			Below 'A' line	
	SILTS & CLAYS (liquid limit > 50%)		MH	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, clastic silts	Low to medium	Slow to none	Low to medium			Below 'A' line	
			CH	Inorganic clays of high plasticity, fat clays	High to very high	None	High			Above 'A' line	
			OH ⌖	Organic clays of medium to high plasticity, organic silts	Medium to high	None to very slow	Low to medium			Below 'A' line	
	HIGHLY ORGANIC SOILS		Pt ⌖	Peat and other highly organic soils	Identified by colour, odour, spongy feel and generally by fibrous texture					—	⌖ Effervesces with H_2O_2

PLASTICITY CHART FOR CLASSIFICATION OF FINE GRAINED SOILS

FIELD IDENTIFICATION PROCEDURE FOR FINE GRAINED SOILS OR FRACTIONS

THESE PROCEDURES ARE TO BE PERFORMED ON THE MINUS 0.2MM SIZE PARTICLES. FOR FIELD CLASSIFICATION PURPOSES, SCREENING IS NOT INTENDED, SIMPLY REMOVE BY HAND THE COARSE PARTICLES THAT INTERFERE WITH THE TESTS.

*** Dry strength (Crushing characteristics)**

After removing particles larger than 0.2mm size, mould a pat of soil to the consistency of putty, adding water if necessary. Allow the pat to dry completely by oven, sun or air drying, and then test its strength by breaking and crumbling between the fingers. This strength is a measure of the character and quantity of the colloidal fraction contained in the soil. The dry strength increases with increasing plasticity. High dry strength is characteristic for clays of the CH group.

A typical inorganic silt possesses only very slight dry strength.

Silty fine sands and silts have about the same slight dry strength, but can be distinguished by the feel when powdering the dried specimen. Fine sand feels gritty whereas a typical silt has the smooth feel of flour.

† Dilatancy (Reaction to shaking)

After removing particles larger than 0.2mm size, prepare a pat of moist soil with a volume of 10 cm³. Add enough water if necessary to make the soil soft but not sticky.

Place the pat in the open palm of one hand and shake horizontally, striking vigorously against the other hand several times. A positive reaction consists of the appearance of water on the surface of the pat which changes to a livery consistency and becomes glossy. When the sample is squeezed between the fingers, the water and gloss disappear from the surface, the pat stiffens, and finally it cracks or crumbles.

The rapidity of appearance of water during shaking and of its disappearance during squeezing assist in identifying the character of the fines in a soil.

Very fine clean sands give the quickest and most distinct reaction whereas a plastic clay has no reaction. Inorganic silts, such as a typical rock flour, shows a moderately quick reaction.

‡ Toughness (Consistency near plastic limit)

After removing particles larger than 0.2mm size, a specimen of soil about 10cm³ in size is moulded to the consistency of putty. If too dry, water must be added and if sticky, the specimen should be spread out in a thin layer and allowed to lose some moisture by evaporation. The specimen is then rolled out by hand on a smooth surface or between the palms into a thread about 3mm in diameter. The thread is then folded and re-rolled repeatedly. During this manipulation the moisture content is gradually reduced and the specimen stiffens, finally loses its plasticity, and crumbles when the plastic limit is reached.

After the thread crumbles, the pieces should be lumped together with a slight kneading action continued until the lump crumbles. The tougher the thread near the plastic limit and the stiffer the lump when it finally crumbles, the more potent is the colloidal clay fraction in the soil.

Weakness of the thread at the plastic limit and quick loss of coherence of the lump below the plastic limit indicate either inorganic clay of low plasticity, or materials such as kaolin-type clays and organic clays which occur below the A-line. Highly organic clays have a very weak and spongy feel at the plastic limit.

EXPLANATION OF LOGGING TERMS FOR ENGINEERING GEOLOGY BOREHOLE LOGGING

ROCK SUBSTANCE WEATHERING CLASSIFICATION

RS	Residual soil
EW	Extremely weathered
HW	Highly weathered
MW	Moderately weathered
SW	Slightly weathered
F(s)	Fresh (stained defects)
F	Fresh

ESTIMATED STRENGTH CLASSIFICATION

EW	Extremely weak
VW	Very weak
W	Weak
MS	Medium strong
S	Strong
VS	Very strong
ES	Extremely strong

DEFECTS

Defects include all joints, bedding planes, fracture zones, seams, veins and cleavage partings.

RQD

Rock quality designation:

$$RQD = \frac{\text{length of core in pieces 100mm or longer}}{\text{length of run}} \times 100\%$$

WATER

Water table, with date

Water inflow

Partial drilling water loss

Complete drilling water loss

Angles of joint inclination (and other geological features and drill holes) are angles between the feature and a horizontal plane. In core, angles of joints (and other geological structures) are angles between the structure and the plane normal to the axis of the core. In vertical holes these angles are then the true inclination (dip) of the structure.

DEFINITIONS OF ENGINEERING GEOLOGICAL TERMS

This classification system provides a standard terminology for the engineering description of rock.

DEGREE OF WEATHERING [1]

TERM	SYMBOL	DEFINITION
Residual Soil	RS	Rock is converted to soil. The mass structure and material fabric are destroyed. There is a large change in volume, but the soil has not been significantly transported.
Extremely Weathered	EW	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 Classification System, but the texture of the original rock is still evident.
Highly Weathered	HW	Rock substance affected by weathering to the extent that limonite staining or bleaching affects the whole of the rock substance, and other signs of chemical or physical decomposition are evident. Porosity and strength may be increased or decreased compared to the fresh rock, usually as a result of iron bleaching or deposition. The colour and strength of the original substance is no longer recognisable.
Moderately Weathered	MW	Rock substance affected by weathering to the extent that staining extends throughout the whole of the rock substance, and the original colour of the fresh rock is no longer recognisable.
Slightly Weathered	SW	Rock substance affected by weathering to the extent that partial staining or discolouration of the rock substance, usually by limonite has taken place. The colour and texture of the fresh rock is recognisable.
Fresh (stained)	F_S	Rock substance unaffected by weathering. Weathering is limited to the surface of major discontinuities, for example an iron-stained joint.
Fresh	F	Rock substance unaffected by weathering.

ROCK STRENGTH [2]

Rock strength is defined by the Point Load Strength Index (Is (50)), and refers to the strength of the rock substance in the direction normal to the bedding.

TERM	Is (50)	FIELD GUIDE	APPROX. qu MPa *
Extremely Weak (EW)		Easily remoulded by hand to a material with soil properties.	
	0.03		0.7
Very weak (VW)		May be crumbled in the hand. Sandstone is "sugary" and friable.	
	0.1		2.4
Weak (W)		A piece of core 150mm long x 50mm dia. may be broken by hand and easily scored with a knife. Sharp edges of core may be friable and break during handling.	
	0.3		7
Medium Strong (MS)		A piece of core 150mm long x 50mm dia. may be broken by hand with considerable difficulty. Readily scored with a knife.	
	1		24
Strong (S)		A piece of core 150mm long x 50mm dia. cannot be broken by unaided hands, may be slightly scratched or scored with knife.	
	3		70
Very Strong (VS)		A piece of core 150mm long x 50mm dia. may be broken readily with hand held hammer. Cannot be scratched with pen knife.	
	10		240
Extremely Strong (ES)		A piece of core 150mm long x 50mm dia. is difficult to break with hand held hammer. Rings when struck with hammer.	

* The approximate unconfined compressive strength (qu) shown in the table is based on an assumed ratio to the point load index of 24:1. This ratio may vary widely and should be calibrated on site.

STRATIFICATION SPACING [2]

TERM	SEPARATION OF STRATIFICATION PLANES
Thinly laminated	< 6mm
Laminated	6mm - 20mm
Very thinly bedded	20mm - 60mm
Thinly bedded	60mm - 200mm
Medium bedded	200mm - 600mm
Thickly bedded	600mm - 2m
Very thickly bedded	> 2m

DISCONTINUITY SPACING [3]

TERM	SPACING
Very widely spaced	> 2m
Widely spaced	600mm - 2m
Moderately widely spaced	200mm 600mm
Closely spaced	60mm - 200mm
Very closely spaced	20mm - 60mm
Extremely closely spaced	< 20mm

APERTURE OF DISCONTINUITY SURFACES [4]

The degree to which a discontinuity is open, or to which the faces of the discontinuity have been separated and the space subsequently infilled (such as in a vein, fault or joint).

TERM	APERTURE THICKNESS (Discontinuities, veins, faults, joints)
Wide	> 200mm
Moderately wide	60mm - 200mm
Moderately narrow	20mm - 60mm
Narrow	6mm - 20mm
Very narrow	2mm - 6mm
Extremely narrow	> 0 - 2 mm
Tight	Zero

BLOCK SHAPE AND SIZE [4]

The following descriptive terms define shape:

Blocky	- approximately equidimensional.
Tabular	- one dimension considerably shorter than the other two.
Columnar	- one dimension considerably larger than the other two.

Block sizes are defined by the following descriptive terms:

TERM	BLOCK SIZE	EQUIVALENT DISCONTINUITY SPACINGS IN BLOCKY ROCK
Very large	$> 8m^3$	Extremely wide
Large	$> 0.2m^3$ - $8m^3$	Very wide
Medium	$> 0.008m^3$ - $0.2m^3$	Wide
Small	$> 0.0002m^3$ - $0.008m^3$	Moderately wide
Very small	$\leq 0.0002m^3$	Less than moderately wide

REFERENCES

1. Modifications of:
   (a) McMahon, B.K., Douglas, D.J., & Burgess, P.J., 1975. Engineering classification of sedimentary rocks in the Sydney area. Australian Geomechanics Journal, G5 (1), 51-53.
   (b) Geological Society Engineering Group Working Party, 1977. The description of rock masses for engineering purposes. Quarterly Jour. Engg. Geology, 10 (4), 355-388.

2. McMahon, B.K., Douglas , D.J., & Burgess, P. J., 1975. Engineering classification of sedimentary rocks in the Sydney area. Australian Geomechanics Journal, G5 (1), 51 -53.

3. ISRM Commission on Standardisation of Laboratory and Field Tests, 1978. Suggested methods for the quantitative description of discontinuities in rock masses. J1. Rock Mechanics Min. Sci. and Geomech. Abstra., 15, 319-368.

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Appendix B Test Pit Logs

NSW GOVERNMENT Public Works	DAMS & CIVIL	TEST PIT	DTP 1
DUNOON DAM SITE		**DATE**	9.10.2012
LOCATION	**E** 0529391 **N** 6827778	**RL (m)**	63
CONTRACTOR J & M Bashforth	**OPERATOR** L McLeod	**EQUIPMENT**	Caterpillar 320D L

From	To	Sample	Class	Description
0	0.25m		ML (Vis)	CLAYEY SILT (TOPSOIL); minor sand, brown-grey, organic, trace grass roots, dry, firm.
0.25m	0.5m		ML (Vis)	CLAYEY SILT; trace to minor sand, grey-brown, trace grass roots, dry, firm. TRANSITIONAL BOUNDARY
0.5m	2.9m	1.1 – 1.7	MH (Lab)	CLAYEY SILT/SILTY CLAY; trace fine pebbles (rock fragments), red-brown and grey mottled, moist, stiff. Higher % of grey with depth.
2.9m	4.3m		MH/ CH & Rock (Vis)	CLAYEY SILT/SILTY CLAY; as above, with sandstone/claystone fragments, with yellow-brown and white colours. Very moist at 3.1m. Small sandstone boulder, HW/MW, at ~3.6m. Very moist at 4.0m.
4.3m	5.4m		Rock	CLAYSTONE; EW, with COAL laminae/thin seams, behaves as CH. Becomes HW near the base of the pit. Coal ~10° dip in direction ~150°M.

END OF PIT AT 5.4m – LIMIT OF REACH OF EXCAVATOR

LOGGED: M. J. Neville

Test pit DTP 1

NSW GOVERNMENT Public Works	DAMS & CIVIL	TEST PIT	DTP 2
DUNOON DAM SITE		**DATE**	9.10.2012
LOCATION	**E** 0529329 **N** 6827693	**RL (m)**	60
CONTRACTOR J & M Bashforth	**OPERATOR** L McLeod	**EQUIPMENT**	Caterpillar 320D L

From	To	Sample	Class	Description
0	0.45m		ML (Vis)	CLAYEY SANDY SILT (TOPSOIL); grey-brown, organic, trace grass roots, dry, firm.
0.45m	0.9m	0.45 – 0.9	SC (Vis)	SANDY CLAY/CLAYEY SAND; fine grained sand, brown, red-brown and grey mottled, just moist, firm to stiff.
0.9m	3.0m	1.0 – 1.5	CH (Vis)	SILTY CLAY; trace sand, grey with brown mottles, trace red-brown, moist, stiff.
3.0m	3.8m		MH (Vis)	CLAYEY SILT; trace HW/MW sandstone pebbles, light grey with brown, orange-brown and red-brown mottles/nodules, moist, firm.
3.8m	5.1m		Rock	SANDSTONE; EW, fine grained, silty, brown with grey, breaks down to MH. Some claystone laminae/beds with traces of coal.

END OF PIT AT 5.1m – NEAR LIMIT OF REACH

LOGGED: M. J. Neville

Test pit DTP 2

NSW GOVERNMENT Public Works	DAMS & CIVIL	TEST PIT	DTP 3

DUNOON DAM SITE			**DATE**	9.10.2012
LOCATION	**E** 0529332	**N** 6827833	**RL (m)**	43
CONTRACTOR J & M Bashforth		**OPERATOR** L McLeod	**EQUIPMENT**	Caterpillar 320D L

From	To	Sample	Class	Description
0	0.5m		ML (Vis)	SANDY SILT (TOPSOIL); trace clay, dark grey-brown, organic, trace fine tree roots and grass roots, dry becoming moist, firm.
0.5m	1.5m		CH (Vis)	SANDY SILTY CLAY; trace cobble-size sandstone (ext. coarse, EW, sugary), brown, grey with red-brown and orange-brown mottles, moist, stiff.
1.5m	2.3m		CH (Vis)	SANDY SILTY CLAY; as above, with higher proportion of sandstone fragments.
2.3m	3.3m		Rock	CLAYSTONE; EW, with traces of COAL.
3.3m	3.45m		Rock	COAL; HW
3.45m	3.5m		Rock	CLAYSTONE; EW/HW, lens.
3.5m	3.9m		Rock	COAL; MW.
3.9m	4.5m		Rock	CLAYSTONE; MW.

END OF PIT AT 4.5m

LOGGED: M. J. Neville

Test pit DTP 3

NSW GOVERNMENT Public Works	DAMS & CIVIL	TEST PIT	DTP 4

DUNOON DAM SITE			**DATE**	9.10.2012
LOCATION	**E** 0529332	**N** 6827885	**RL (m)**	44
CONTRACTOR J & M Bashforth		**OPERATOR** L McLeod	**EQUIPMENT**	Caterpillar 320D L

From	To	Sample	Class	Description
0	0.5m		ML (Vis)	SILT; trace sand, dark grey-brown, possibly alluvial, trace grass roots and fine tree roots, dry, firm.
0.5m	1.3m		MH (Vis)	CLAYEY SILT; trace small sandstone boulders, grey-brown and red-brown mottled, moist, firm.
1.3m	2.5m		CH (Vis)	SILTY CLAY; light grey with trace orange-brown, moist, stiff.
2.5m	3.8m		Rock	CLAYSTONE; EW, then HW/EW with interbedded sandstone, trace coal. HW sandstone at base.

END OF PIT AT 3.8m – EXCAVATOR REFUSAL ON SANDSTONE BEDDING PLANE

LOGGED: M. J. Neville

Test pit DTP 4

NSW GOVERNMENT Public Works	DAMS & CIVIL	TEST PIT	DTP 5

DUNOON DAM SITE			**DATE**	9.10.2012
LOCATION	**E** 0529554	**N** 6827953	**RL (m)**	78
CONTRACTOR J & M Bashforth		**OPERATOR** L McLeod	**EQUIPMENT**	Caterpillar 320D L

From	To	Sample	Class	Description
0	0.3m		SM (Vis)	SANDY SILT (TOPSOIL); trace clay, grey-brown, organic, trace ash, trace grass roots, dry, firm.
0.3m	0.75m	0.3 – 0.75	CH/ MH (Lab)	SILTY CLAY; trace (one) pebble, grey-brown and orange-brown, clay peds, trace grass roots, just moist, stiff.
0.75m	1.75m	0.75 – 1.75	CH (Lab)	SILTY CLAY; trace fine rock fragments, brown, grey, red-brown and grey-brown mottles, moist, stiff/very stiff.
1.75m	4.1m		CH & Rock (Vis)	SILTY CLAY; as above, with minor EW CLAYSTONE.
4.1m	5.3m		Rock	CLAYSTONE, minor SANDSTONE, trace COAL; EW, grey, grey-brown, and trace black, thinly bedded/laminated.

END OF PIT AT 5.3m – LIMIT OF REACH OF EXCAVATOR

LOGGED: M. J. Neville

Test pit DTP 5

NSW GOVERNMENT Public Works	DAMS & CIVIL	TEST PIT	DTP 6

DUNOON DAM SITE			**DATE**	9.10.2012
LOCATION	**E** 0529708	**N** 6827961	**RL (m)**	82
CONTRACTOR J & M Bashforth		**OPERATOR** L McLeod	**EQUIPMENT**	Caterpillar 320D L

From	To	Sample	Class	Description
0	0.2m		SM (Vis)	SILTY SAND (Topsoil); minor clay, mid grey to brown-grey, organic, trace grass roots, dry, medium dense.
0.2m	0.5m		SM (Vis)	SILTY SAND; grey-brown with yellow-brown mottles, trace grass roots, moist, medium dense.
0.5m	1.0m		CH (Vis)	SILTY CLAY; trace sand, grey-brown, brown and minor red-brown mottled, moist, stiff.
1.0m	2.4m		CH (Vis)	SILTY CLAY; trace sand, grey and red-brown mottled, trace orange-brown, moist, stiff.
2.4m	5.0m		Rock	SANDSTONE; EW, fine grainsize, with claystone and coal.

END OF PIT AT 5.0m – LIMIT OF REACH OF EXCAVATOR

LOGGED: M. J. Neville

NSW GOVERNMENT Public Works	DAMS & CIVIL	TEST PIT	DTP 7

DUNOON DAM SITE				**DATE**	10.10.12
LOCATION	**E** 0529474		**N** 6827964	**RL (m)**	69
CONTRACTOR J & M Bashforth		**OPERATOR** L McLeod		**EQUIPMENT** Caterpillar 320D L	

From	To	Sample	Class	Description
0	0.2m		ML (Vis)	SANDY SILT/SILTY SAND (TOPSOIL); grey-brown, organic, trace grass roots and fine tree roots, dry, firm.
0.2m	0.5m		SM (Vis)	SILTY SAND; grey-brown, organic, trace fine roots, dry, firm/medium dense.
0.5m	0.9m		CH (Vis)	SILTY CLAY; trace sand, grey-brown and red-brown mottled with some grey near the base, moist, stiff.
0.9m	4.2m	0.9 – 1.7	CH & Rock (Lab)	CLAYSTONE; EW, thin seams/laminae of COAL, behaves as CH, grey with minor red-brown mottles, moist, stiff. 2.3 – 4.2 interbedded coal and claystone, EW. Becomes HW at ~3.5m.

PIT TERMINATED AT 4.2m – IN HW CLAYSTONE WITH COAL LAMINAE

LOGGED: M. J. Neville

NSW GOVERNMENT Public Works	DAMS & CIVIL	TEST PIT	DTP 8

DUNOON DAM SITE				**DATE**	10.10.2012
LOCATION	**E** 0529359		**N** 6828019	**RL (m)**	54
CONTRACTOR J & M Bashforth		**OPERATOR** L McLeod		**EQUIPMENT** Caterpillar 320D L	

From	To	Sample	Class	Description
0	0.2m		ML (Vis)	SANDY SILT (TOPSOIL); dark grey-brown, to grey-brown, organic, trace ash, trace grass roots and fine tree roots, dry, firm.
0.2m	0.5m		MI (Vis)	CLAYEY SILT; trace sand, grey-brown, trace fine roots, trace ash, dry,firm.
0.5m	1.1m		CH (Vis)	SILTY CLAY; trace sand, grey with orange-brown mottles, moist, stiff.
1.1m	4.1m	2.5 - 2.7	SM & Rock (Lab)	CLAYSTONE; EW, with silty clay, behaves as SM, grey, red-brown, and orange-brown mottled, moist, stiff. With EW sandstone at depth, possibly SM/MI.

END OF PIT AT 4.1m – NEAR REFUSAL ON HW SANDSTONE

LOGGED: M. J. Neville

Test pit DTP 8

NSW GOVERNMENT Public Works	DAMS & CIVIL	TEST PIT	DTP 9

DUNOON DAM SITE				**DATE**	10.10.2012
LOCATION	**E** 0529465		**N** 6827871	**RL (m)**	54
CONTRACTOR J & M Bashforth		**OPERATOR** L McLeod		**EQUIPMENT** Caterpillar 320D L	

From	To	Sample	Class	Description
0	0.2m		ML/MI (Vis)	CLAYEY SILT (TOPSOIL); dark grey-brown, organic, trace grass roots, ped development, dry, firm.
0.2m	0.8m		CH/CI (Vis)	SILTY CLAY; grey-brown and yellow-brown mottled, trace grass roots decreasing with depth, well developed peds, just moist, stiff.
0.8m	1.2m		CH (Vis)	SILTY CLAY; grey with brown mottles, minor red-brown, moist, stiff.
1.2m	3.5m	1.2 – 1.8	CH & Rock (Lab)	CLAYSTONE; EW, with silty clay, behaves as CH, minor thin coal seams (discontinuous), grey with brown mottles, minor black, moist stiff.
3.5m	3.8m		Rock	SANDSTONE; EW/HW, medium to coarse grainsize, brown with minor grey.

END OF PIT AT 3.8M – REFUSAL ON BEDDING SURFACE OF HW SANDSTONE

LOGGED: M. J. Neville

NSW GOVERNMENT Public Works	DAMS & CIVIL	TEST PIT	DTP 10

DUNOON DAM SITE			**DATE**	10.10.2012
LOCATION	**E** 0529586	**N** 6827869	**RL (m)**	76
CONTRACTOR J & M Bashforth		**OPERATOR** L McLeod	**EQUIPMENT**	Caterpillar 320D L

From	To	Sample	Class	Description
0	0.25m		ML (Vis)	CLAYEY SILT (TOPSOIL); trace to minor sand, dark grey-brown becoming grey-brown with depth, organic, trace grass roots, moist, firm.
0.25m	0.9m		CH (Vis)	SILTY CLAY; grey with traces of orange-brown, trace fine roots in upper half, moist, firm to stiff.
0.9m	4.5m		CH & Rock (Vis)	CLAYSTONE & COAL; EW, with silty clay, behaves as CH, several thin to medium lensoidal coal seams (basal seam 0.2m thick), minor fine grained sandstone. Approx. 3m - becomes HW/EW

END OF PIT AT 4.5m IN HW/EW CLAYSTONE WITH MINOR COAL

LOGGED: M. J. Neville

Test pit DTP 10

NSW GOVERNMENT Public Works	DAMS & CIVIL	TEST PIT	DTP 11
DUNOON DAM SITE		**DATE**	10.10.2012
LOCATION	**E** 0529685 **N** 6827879	**RL (m)**	77
CONTRACTOR J & M Bashforth	**OPERATOR** L McLeod	**EQUIPMENT**	Caterpillar 320D L

From	To	Sample	Class	Description
0	0.25m		ML (Vis)	CLAYE SILT (Topsoil); trace sand, grey-brown, organic, trace grass roots, trace ash, dry, firm.
0.25	1.0m		CI (Vis)	SILTY CLAY/CLAYEY SILT; grey, brown, grey-brown, orange-brown & red-brown mottled, moist, stiff.
1.0	5.1m		CH/ MH & Rock (Vis)	CLAYSTONE; EW & CLAYEY SILT; behaves as a clayey silt, grey, brown, red-brown & grey-brown mottled, moist, stiff. HW/EW from ~2m then consistent to base.

END OF PIT AT 5.1m IN HW/EW CLAYSTONE/SILTSTONE; NEAR LIMIT OF REACH OF EXCAVATOR

LOGGED: M. J. Neville

NSW GOVERNMENT Public Works	DAMS & CIVIL	TEST PIT	DTP 12

DUNOON DAM SITE			**DATE**	10.10.2012
LOCATION	**E** 0529709	**N** 6828011	**RL (m)**	81
CONTRACTOR J & M Bashforth		**OPERATOR** L McLeod	**EQUIPMENT**	Caterpillar 320D L

From	To	Sample	Class	Description
0	0.25m		ML (Vis)	CLAYEY SILT (TOPSOIL); trace sand, grey-brown, organic, trace fine roots, dry, firm.
0.25	0.6m		MI (Vis)	CLAYEY SILT; grey-brown with traces red-brown mottles, trace roots, moist, firm, some ped development.
0.6	3.2m	3.1 – 3.2	MH & Rock (Lab)	CLAYSTONE & COAL; EW, with silty clay, behaves as CI. Each clay seam is thin and lensoidal with thin to medium beds of claystone in between. Seven coal seams; local dip ~20° in direction ~020°M

END OF PIT AT 3.2m IN EW CLAYSTONE

LOGGED: M. J. Neville

Test pit DTP 12

NSW GOVERNMENT Public Works	DAMS & CIVIL	TEST PIT	DTP 13
DUNOON DAM SITE		**DATE**	10.10.2012
LOCATION	**E** 0529578 **N** 6828045	**RL (m)**	66
CONTRACTOR J & M Bashforth	**OPERATOR** L McLeod	**EQUIPMENT**	Caterpillar 320D L

From	To	Sample	Class	Description
0	0.25m		ML (Vis)	CLAYEY SILT (TOPSOIL); minor medium-grained sand, grey-brown, organic, trace fine roots, moist, firm.
0.25	0.75m		CH (Vis)	SILTY CLAY; grey-brown & yellow-brown, trace fine roots, moist, stiff, ped development.
0.75	1.2m		Rock	COAL; HW/MW, minor claystone, black, minor grey.
1.2	2.8m		CH & Rock (Vis)	CLAYSTONE; EW, with silty clay, grey with traces of brown, behaves as a silty clay (CH), moist, stiff; minor sandstone, EW, thinly/very thinly bedded.
2.8	3.8m		Rock	SANDSTONE; EW, brown with grey, breaks down to silty clay/clayey silt with minor sand, MI/CI.

END OF PIT AT 3.8m IN HW/EW SANDSTONE

LOGGED: M. J. Neville

Test pit DTP 13

NSW GOVERNMENT Public Works	DAMS & CIVIL	TEST PIT	DTP 14

DUNOON DAM SITE			**DATE**	11.10.2012
LOCATION	**E** 0529496	**N** 6827999	**RL (m)**	76
CONTRACTOR J & M Bashforth		**OPERATOR** L McLeod	**EQUIPMENT**	Caterpillar 320D L

From	To	Sample	Class	Description
0	0.3m		ML (Vis)	CLAYEY SILT (TOPSOIL); minor sand, grey-brown, organic, trace roots, dry, firm.
0.3	0.9m		CH (Vis)	SILTY CLAY; trace sand, grey-brown & orange-brown mottled, moist, firm to stiff.
0.9	1.5m		Rock	CLAYSTONE; EW with COAL LAMINATIONS, dark grey and black.
1.5	3.4m		CH & Rock (Vis)	CLAYSTONE; EW, with SILTY CLAY, light grey with brown & traces of red-brown, moist, firm to stiff. Becomes HW/EW at ~2.2m.
3.4	4.3m		Rock	SANDSTONE; HW/EW, lithic, medium to coarse grained, grey-brown, breaks down to clayey silt.

END OF PIT AT 4.3m IN HW SANDSTONE (WEAK).

LOGGED: M. J. Neville

Test pit DTP 14

NSW GOVERNMENT Public Works	DAMS & CIVIL	TEST PIT	DTP 15

DUNOON DAM SITE			**DATE**	11.10.2012
LOCATION	**E** 0529427	**N** 6827996	**RL (m)**	60
CONTRACTOR J & M Bashforth		**OPERATOR** L McLeod	**EQUIPMENT**	Caterpillar 320D L

From	To	Sample	Class	Description
0	0.15m		ML (Vis)	CLAYEY SILT (TOPSOIL); trace sand, grey-brown, organic, trace grass and plant roots, dry, firm, cracked into peds.
0.15	0.75m		MH (Vis)	CLAYEY SILT; trace sand, grey-brown with minor orange-brown, just moist, stiff, ped development.
0.75	4.4m		CH & Rock (Vis)	CLAYSTONE; EW, with thin coal seams and laminations, acts as a silty clay with minor sand, light grey with red-brown, and black horizons, dip ~5° in direction ~010° – 020°M. ~2.4m becomes HW/EW 2.8 – 3.4m COAL, HW/MW 3.4 – 4.4m CLAYSTONE; HW/EW, light grey, some fine grained sandstone laminations.

END OF PIT AT 4.4m IN HW CLAYSTONE.

LOGGED: M. J. Neville

Test pit DTP 15

NSW GOVERNMENT Public Works	DAMS & CIVIL	TEST PIT	DTP 16
DUNOON DAM SITE		**DATE**	11.10.2012
LOCATION	**E** 0529528 **N** 6828259	**RL (m)**	81
CONTRACTOR J & M Bashforth	**OPERATOR** L McLeod	**EQUIPMENT** Caterpillar 320D L	

From	To	Sample	Class	Description
0	0.4m		ML (Vis)	CLAYEY SILT (TOPSOIL); minor sand, grey-brown with trace brown, organic, trace grass roots, dry, firm.
0.4	~4.0	1.2 – 2.2	CH (Lab)	SILTY CLAY; grey & red-brown mottled, moist, stiff.
~4.0	5.4		CI & Rock (Vis)	SILTY CLAY; as above, possibly fine-grained rock, slightly higher silt content with depth, tending towards CI.

END OF PIT AT 5.4m; LIMIT OF REACH OF EXCAVATOR

LOGGED: M. J. Neville

Test pit DTP 16

NSW GOVERNMENT Public Works	DAMS & CIVIL	TEST PIT	DTP 17

DUNOON DAM SITE			**DATE**	11.10.2012
LOCATION	**E** 0529465	**N** 6828214	**RL (m)**	75
CONTRACTOR J & M Bashforth		**OPERATOR** L McLeod	**EQUIPMENT**	Caterpillar 320D L

From	To	Sample	Class	Description
0	0.2m		ML (Vis)	CLAYEY SILT (TOPSOIL); grey-brown and brown mottled, organic, trace grass plant roots, dry, firm.
0.2	0.7m		CH (Vis)	SILTY CLAY; mid grey with brown mottles, trace grass roots, just moist, stiff.
0.7	5.0m		CH & Rock (Vis)	CLAYSTONE; EW, with thin coal seams/laminae and silty clay, behaves as CH, grey with brown and red-brown mottles plus black seams. 2.1m HW/EW, mainly claystone with coal laminae and seams.

END OF PIT AT 5.0m; NEAR LIMIT OF REACH OF EXCAVATOR IN EW CLAYSTONE WITH COAL

LOGGED: M. J. Neville

Test pit DTP 17

NSW GOVERNMENT Public Works	DAMS & CIVIL	TEST PIT	DTP 18
DUNOON DAM SITE		**DATE**	12.10.2012
LOCATION	**E** 0529308 **N** 6828156	**RL (m)**	52
CONTRACTOR J & M Bashforth	**OPERATOR** L McLeod	**EQUIPMENT**	Caterpillar 320D L

From	To	Sample	Class	Description
0	0.3m		SM (Vis)	SILTY SAND (TOPSOIL); fine to medium grainsize, trace clay increasing to minor clay with depth, grey-brown, organic, trace grass roots, dry, medium dense.
0.3	0.6m		CH (Vis)	CLAYEY SILT/SILTY CLAY; trace fine to medium grained sand, grey-brown with traces of red-brown, trace grass roots, moist, stiff.
0.6	4.7m	1.0 – 2.0	CH (Vis)	SILTY CLAY; dark grey & red-brown mottled, moist, stiff/very stiff. Dark grey with some chocolate-brown mottles from 4.0m.
4.7	5.1m		CH & Rock (Vis)	EW/HW rock with SILTY CLAY, trace sand, behaves as CH, grey with white and brown, moist, stiff.
5.1	5.4m		Rock	SANDSTONE; HW/EW, medium to coarse grainsize, brown.

END OF PIT AT 5.4m IN HW SANDSTONE; REFUSAL – LIMIT OF REACH OF EXCAVATOR

LOGGED: M. J. Neville

Test pit DTP 18

NSW GOVERNMENT Public Works	DAMS & CIVIL	TEST PIT	DTP 19

DUNOON DAM SITE			**DATE**	11.10.2012
LOCATION	**E** 0529392	**N** 6828185	**RL (m)**	63
CONTRACTOR J & M Bashforth		**OPERATOR** L McLeod	**EQUIPMENT**	Caterpillar 320D L

From	To	Sample	Class	Description
0	0.4m		ML (Vis)	CLAYEY SILT (TOPSOIL); trace sand, grey-brown and brown, organic, trace grass roots, dry, firm.
0.4	1.0m	0.5 – 1.0	CH (Lab)	SILTY CLAY; grey, grey-brown, brown & trace red-brown, moist, stiff.
1.0	1.7m	1.0 – 1.7	CH & Rock (Lab)	SILTY CLAY & CLAYSTONE; EW, trace coal, light grey with minor red-brown mottles, moist, stiff.
1.7	4.1m		CH & Rock (Vis)	CLAYSTONE WITH COAL SEAMS/LAMINAE; EW, light grey with brown & red-brown. Some EW/HW at 1.9m, behaves as CH. Dip ~5° in direction ~050°M. HW from ~2.9m, claystone & siltstone with minor fine sandstone.

END OF PIT AT 4.1m IN HW CLAYSTONE

LOGGED: M. J. Neville

Test pit DTP 19

NSW GOVERNMENT Public Works	DAMS & CIVIL	TEST PIT	DTP 20

DUNOON DAM SITE			**DATE**	12.10.2012
LOCATION	**E** 0529265	**N** 6828221	**RL (m)**	51
CONTRACTOR J & M Bashforth	**OPERATOR** L McLeod		**EQUIPMENT** Caterpillar 320D L	

From	To	Sample	Class	Description
0	0.3m		SM (Vis)	SILTY SAND (TOPSOIL); minor clay near base, grey-brown, organic, trace grass roots, dry, medium dense.
0.3	0.65m	0.3 – 0.65	CH (Lab)	CLAYEY SILT; trace sand, grey-brown with brown & traces red-brown, trace grass roots, moist, stiff.
0.65	3.2m	1.0 – 2.0	CH/ MH (Lab)	SILTY CLAY; red-brown with dark grey, grey of greater proportion with depth, moist, stiff/very stiff. Trace rock fragments (pebbles) at ~1.8m. Gradual change to dark grey with brown and yellow-brown at ~2.5m.
3.2	4.2m		CH (Vis)	SILTY CLAY; with EW CLAYSTONE, behaves as CH, grey, brown with yellow-brown & white/cream, moist, stiff.
4.2	4.6m		MH (Vis)	CLAYEY SANDY SILT; with pebbles of EW/MW sandstone & one small HW/MW sandstone boulder, brown with grey & white, very moist, firm, trace of water at 4.2m.
4.6	4.8m		Rock	SANDSTONE; HW/EW, coarse grainsize, brown with grey.

PIT TERMINATED AT 4.8m IN HW/EW SANDSTONE

LOGGED: M. J. Neville

NSW GOVERNMENT Public Works	DAMS & CIVIL	TEST PIT	DTP 21

DUNOON DAM SITE			**DATE**	12.10.2012
LOCATION	**E** 0529367	**N** 6828246	**RL (m)**	70
CONTRACTOR J & M Bashforth		**OPERATOR** L McLeod	**EQUIPMENT**	Caterpillar 320D L

From	To	Sample	Class	Description
0	0.35m		ML/MI (Vis)	CLAYE SILT (TOPSOIL); grey with some brown mottles, organic, trace grass roots, just moist, firm to stiff.
0.35	1.1m		CH (Vis)	SILTY CLAY; grey with brown & minor red-brown mottles, moist, stiff. GRADATIONAL LOWER BOUNDARY
1.1	3.9m	1.1 – 1.6	CH & Rock (Lab)	CLAYSTONE; EW with SILTY CLAY/CLAYEY SILT; behaves as CH, grey with traces of red-brown & black, moist, stiff. 1.7 – 2.0m thin coal seams, the CLAYSTONE, EW/HW, becoming HW/MW by the base of the pit. Coal dip ~2° – 3° in direction ~150°M

END OF PIT AT 3.9m IN HW/MW CLAYSYONE – DIFFICULT TO EXCAVATE

LOGGED: M. J. Neville

Test pit DTP 21

NSW GOVERNMENT Public Works	DAMS & CIVIL	TEST PIT	DTP 22

DUNOON DAM SITE			**DATE**	12.10.2012
LOCATION	**E** 0529458	**N** 6828280	**RL (m)**	69
CONTRACTOR J & M Bashforth		**OPERATOR** L McLeod	**EQUIPMENT**	Caterpillar 320D L

From	To	Sample	Class	Description
0	0.35m		ML (Vis)	CLAYEY SILT (TOPSOIL); minor sand, grey-brown, organic, trace grass roots, dry, firm.
0.35	0.9m		CH (Vis)	SILTY CLAY; grey-brown & brown, trace grass roots in upper half, moist, stiff.
0.9	2.1m		CH & Rock (Vis)	CLAYSTONE; EW & SILTY CLAY, trace coal, grey & minor brown, minor red-brown & black, behaves as CH, moist, stiff.
2.1	5.1m		Rock	SILTSTONE; EW/HW, grey & brown, becomes grey with some brown, moist, stiff.

END OF PIT AT 5.1m IN HW SILTSTONE – NEAR LIMIT OF REACH OF EXCAVATOR

LOGGED: M. J. Neville

Test pit DTP 22

NSW GOVERNMENT Public Works	DAMS & CIVIL	TEST PIT	DTP 23

DUNOON DAM SITE			**DATE**	12.10.2102
LOCATION	**E** 0529586	**N** 6828348	**RL (m)**	85
CONTRACTOR J & M Bashforth		**OPERATOR** L McLeod	**EQUIPMENT**	Caterpillar 320D L

From	To	Sample	Class	Description
0	0.3m		ML (Vis)	SANDY CLAYEY SILT (TOPSOIL); grey-brown, organic, trace ash, trace grass roots, dry to just moist, firm.
0.3	0.75m		MI (Vis)	SILTY CLAY/CLAYEY SILT; grey-brown & brown, trace fine roots in upper half, moist, stiff.
0.75	4.1m	0.75 – 1.9	CH & Rock (Lab)	CLAYSTONE; EW, & SILTY CLAY, behaves as CH, grey/dark grey with brown & minor red-brown mottles, moist, stiff. ~2.3m becomes EW/HW, interbedded claystone, siltstone and minor fine sandstone, trace ash.

PIT TERMINATED AT 4.1m IN HW/EW SILTSTONE.

LOGGED: M. J. Neville

NSW GOVERNMENT Public Works	DAMS & CIVIL	TEST PIT	DTP 24
DUNOON DAM SITE		**DATE**	12.10.2012
LOCATION	**E** 0529534 **N** 6828367	**RL (m)**	83
CONTRACTOR J & M Bashforth	**OPERATOR** L McLeod	**EQUIPMENT**	Caterpillar 320D L

From	To	Sample	Class	Description
0	0.3m		ML (Vis)	CLAYEY SILT (TOPSOIL); minor sand, trace pebbles (basalt), dark grey-brown, organic, trace ash, trace grass roots, dry to just moist, firm.
0.3	1.2m	0.4 – 1.2	CH (Vis)	SILTY CLAY; minor grit & sand, trace pebbles, cobbles & small boulders (basalt), dark grey-brown with traces of red-brown (rock fragments), pod of light grey clay (possibly sedimentary inclusion, CW), moist, stiff.
1.2	2.4m	1.2 – 1.7	CH (Vis)	SILTY CLAY; trace cobbles (basalt), grey-brown with some brown mottling, moist, stiff. VARIABLE BOUNDARY.
2.4	4.3m		CH (Vis)	SILTY CLAY; trace sand/grit, trace boulders, trace CW boulders (as above), grey, grey-brown with traces of orange-brown, moist, stiff. Many cobbles & small basalt boulders from ~3.8m.

END OF PIT AT 3.8m – NEAR LIMIT OF REACH OF EXCAVATOR (DIGGING DOWNHILL) – DIFFICULT IN BASALT COBBLES & BOULDERS

LOGGED: M. J. Neville

NSW GOVERNMENT Public Works	DAMS & CIVIL	TEST PIT	DTP 25

DUNOON DAM SITE				**DATE**	13.10.2012
LOCATION	**E** 0529602		**N** 6828233	**RL (m)**	84
CONTRACTOR J & M Bashforth		**OPERATOR** L McLeod		**EQUIPMENT** Caterpillar 320D L	

From	To	Sample	Class	Description
0	0.2m		ML (Vis)	CLAYEY SILT (TOPSOIL); trace to minor sand, grey-brown, organic, trace grass roots, dry, firm.
0.2	0.6m		MI (Vis)	CLAYEY SILT; minor sand, grey-brown with minor yellow-brown, trace grass roots at top, moist, stiff.
0.6	~3.0m	0.6 – 1.2	CI & Rock (Lab)	SANDSTONE; EW, with SANDY SILTY CLAY/CLAYEY SAND, behaves as CI, grey & orange-brown mottled, moist, stiff. Minor seepage at ~2.5m (single point source).
~3.0	5.3m		CH & Rock (Vis)	CLAYSTONE; EW, & SILTY CLAY, behaves as CH, grey with brown mottles, moist, stiff. Some interbedded fine grained sandstone, EW.

END OF PIT AT 5.3m – LIMIT OF REACH OF EXCAVATOR – Minor grit at base, rock fragments.

LOGGED: M. J. Neville

Test pit DTP 25

NSW GOVERNMENT Public Works	DAMS & CIVIL	TEST PIT	DTP 26

DUNOON DAM SITE				**DATE**	13.10.2012
LOCATION	**E** 0529539		**N** 6828175	**RL (m)**	79
CONTRACTOR J & M Bashforth		**OPERATOR** L McLeod		**EQUIPMENT** Caterpillar 320D L	

From	To	Sample	Class	Description
0	0.2m		SM (Vis)	SANDY SILT/SILTY SAND (TOPSOIL); grey-brown, organic, trace grass roots, dry, firm.
0.2	0.65m		CH (Vis)	SILTY CLAY; grey-brown, yellow-brown, with traces of grey & red-brown, moist, stiff.
0.65	3.7m	0.7 – 1.8	CH & Rock (Vis)	CLAYSTONE/SILTY CLAY; EW, behaves as CH, grey with brown & red-brown mottles, moist, stiff. 2.4 – 2.7m Coal laminae dip ~2° in direction ~200°M
3.7	5.5m		MH & Rock (Vis)	CLAYSTONE; EW/HW, with silty clay, behaves as MH, grey with brown, moist, stiff. ~4.3m Coal seam, ~0.1m.

END OF PIT AT 5.5m – LIMIT OF REACH OF EXCAVATOR IN EW CLAYSTONE/ SILTY CLAY, MH.

LOGGED: M. J. Neville

Test pit DTP 26

NSW GOVERNMENT Public Works	DAMS & CIVIL	TEST PIT	DTP 27

DUNOON DAM SITE			**DATE**	13.10.2012
LOCATION	**E** 0529464	**N** 6828121	**RL (m)**	68
CONTRACTOR J & M Bashforth		**OPERATOR** L McLeod	**EQUIPMENT**	Caterpillar 320D L

From	To	Sample	Class	Description
0	0.4m		ML (Vis)	CLAYEY SILT (TOPSOIL); trace sand, grey-brown, organic, trace grass roots, dry, firm.
0.4	0.9m		CH (Vis)	SILTY CLAY; grey-brown & brown with trace red-brown, trace grass roots in upper half, moist, stiff.
0.9	2.4m		CH & Rock (Vis)	SILTY CLAY/CLAYSTONE; EW, behaves as CH, grey with grey-brown, brown & red-brown mottles, moist, stiff. Minor coal seams at 1.5m, black, dip ~2° – 3° in direction ~270°M.
2.4	4.7m		MH & Rock (Vis)	CLAYSTONE; EW/HW, with silty clay, behaves as MH, grey with brown, moist, stiff. Minor coal seams. Predominantly HW from 3.3m, some white coatings on some partings – talc-like.

PIT TERMINATED AT 4.7m IN HW CLAYSTONE

LOGGED: M. J. Neville

Test pit DTP 27

NSW GOVERNMENT Public Works	DAMS & CIVIL	TEST PIT	DTP 28

DUNOON DAM SITE				**DATE**	13.10.2012
LOCATION	**E** 0529364		**N** 6828093	**RL (m)**	54
CONTRACTOR J & M Bashforth		**OPERATOR** L McLeod		**EQUIPMENT** Caterpillar 320D L	

From	To	Sample	Class	Description
0	0.4m		ML (Vis)	SANDY CLAYEY SILT (TOPSOIL); medium grained sand, trace ash, grey-brown, organic, trace grass roots, dry/just moist, firm.
0.4	1.0	0.4 – 1.0	CH (Vis)	SILTY CLAY; trace fine sand, grey-brown & red-brown mottled, trace ash, moist, stiff.
1.0	2.3m	1.0 – 1.5	CH (Vis)	SILTY CLAY; grey & red-brown mottled, trace ash, moist, stiff/very stiff.
2.3	3.4m		MH & Rock (Vis)	SILTSTONE, CLAYSTONE & SANDSTONE; EW, behaves as MH, brown & grey, moist, firm to stiff.

END OF PIT AT 3.4m IN HW SILTSTONE.

LOGGED: M. J. Neville

Test pit DTP 28

NSW GOVERNMENT Public Works	DAMS & CIVIL	TEST PIT	DTP 29

DUNOON DAM SITE			**DATE**	13.10.2012
LOCATION	**E** 0529670	**N** 6828224	**RL (m)**	79
CONTRACTOR J & M Bashforth		**OPERATOR** L McLeod	**EQUIPMENT**	Caterpillar 320D L

From	To	Sample	Class	Description
0	0.2m		ML (Vis)	SANDY CLAYEY SILT (TOPSOIL); trace ash, grey-brown, organic, trace grass roots, dry/just moist, firm.
0.2	4.9m	0.7 – 1.6	CH (Vis)	SANDY SILTY CLAY; trace pebbles (ironstone), trace ash, grey & brown mottled, possibly increasing clay content with depth, moist, stiff. 2.9 – 3.5m trace pebbles/cobbles.

END OF PIT AT 4.9m – LIMIT OF REACH OF EXCAVATOR

LOGGED: M. J. Neville

Test pit DTP 29

NSW GOVERNMENT Public Works	DAMS & CIVIL	TEST PIT	DTP 30

DUNOON DAM SITE			**DATE**	13.10.2012
LOCATION	**E** 0529272	**N** 6827756	**RL (m)**	50
CONTRACTOR J & M Bashforth		**OPERATOR** L McLeod	**EQUIPMENT**	Caterpillar 320D L

From	To	Sample	Class	Description
0	0.2m		ML (Vis)	SANDY/CLAYEY SILT; dark grey-brown, organic, trace grass roots, trace ash, dry, firm.
0.2	3.8m		SM (Vis)	SILTY SAND; trace to minor clay (variable), trace ash, chocolate brown, just moist, medium dense.
3.8	4.8m		SP (Vis)	SAND; minor silt, coarse grainsize, light grey-brown, moist, wet at base, loose. Water table at 4.75m.

END OF PIT AT 4.8m IN WATER TABLE.

LOGGED: M. J. Neville

Appendix C Laboratory Test Results

Geotechnical Centre
Unit W4K, 42 Wattle St, ULTIMO, NSW 2007
Telephone 02- 9552 4864 Facsimile 02-9552 3615

NSW GOVERNMENT | Public Works NSW Water Solutions

CLIENT:	DAMS & CIVIL TECHNOLOGIES	BATCH No:	12031
	SOIL SUMMARY SHEET		
PROJECT:	DUNOON DAM SITE	COMPILED BY:	ZG
LOCATION:	LOWER STORAGE AREA	DATE:	8/11/2012

General Information Note: All test methods are as indicated on accompanying test reports.

Sample No.	3325	3328	3329	3330	3331	3332	3333	3334
Bore/Reference	DTP 1	DTP 5	DTP 5	DTP 7	DTP 8	DTP 9	DTP 12	DTP 16
Depth (m)	1.1 - 1.7	0.3 - 0.75	0.75 - 1.75	0.9 - 1.7	2.5 - 2.7	1.2 - 1.8	3.1 - 3.2	1.2 - 2.2
Sample Type	D	D	D	D	D	D	D	D
Soil Colour & Description (v) indicates visual classification	Yellow Brown Red Brown and Grey Mottled Silty Clay with Sand	Grey Brown and Orange Brown Silty Clay trace of Sand	Brown Grey Red Brown and Grey Brown Silty Clay trace of Sand	Grey with Minor Red Brown Mottles Silty Clay trace of Sand	Brown Grey Red Brown and Orange Brown Clayey Silty Sand	Grey with Brown Mottles and trace of Black Silty Clay trace of Sand	Brown and Grey with Black Silty Clay trace of Sand	Grey and Red Brown Mottled Silty Clay trace of Sand
Classification	MH	CH-MH	CH	CH	SM	CH	MH	CH

Moisture Content & Density

Field Moisture Content (%)	31.5	27.9	28.8	31.7	28.6	36.1	24.4	31.5
Field Wet Density (t/m³)								
Field Dry Density (t/m³)								
Soil Particle Density (t/m³)								

Particle Size Distribution

Cobble Size (%)	0	0	0	0	0	0	0	0
Gravel Size (%)	1	0	0	0	0	0	1	0
Sand Size (%)	22	7	8	5	51	3	5	12
Silt Size (%)	16	37	26	31	30	24	43	23
Clay Size (%)	61	56	66	64	19	73	51	65
Effective Size (mm)								
Uniformity Coefficient								
Curvature Coefficient								

Plasticity

Liquid Limit (%)	81	76	92	85	49	93	61	95
Plastic Limit (%)	45	35	37	34	31	37	33	36
Plasticity Index (%)	36	41	55	51	18	56	28	59
Linear Shrinkage (%)								

Dispersion

Dispersal Index	N.D.	4.5	3.6	3.4	2.2	3.7	3.2	N.D.
Percent Dispersion (%)								
Emerson Class No.								

Compaction

Compaction Type								
Optimum Moisture Content (%)								
Maximum Dry Density (t/m³)								

California Bearing Ratio

Placement Moisture Content (%)								
Placement Dry Density (t/m³)								
Swell under 4.5kg Surcharge (%)								
C.B.R. at 2.5% Penetration (%)								
C.B.R. at 5.0% Penetration (%)								

Geotechnical Centre
Unit W4K, 42 Wattle St, ULTIMO, NSW 2007
Telephone 02- 9552 4864 Facsimile 02-9552 3615

NSW GOVERNMENT | Public Works NSW Water Solutions

CLIENT:	DAMS & CIVIL TECHNOLOGIES	BATCH No:	12031
	SOIL SUMMARY SHEET		
PROJECT:	DUNOON DAM SITE	COMPILED BY:	ZG
LOCATION:	LOWER STORAGE AREA	DATE:	8/11/2012

General Information Note: All test methods are as indicated on accompanying test reports.

Sample No.	**3336**	**3337**	**3338**	**3339**	**3340**	**3341**	**3344**	
Bore/Reference	DTP 19	DTP 19	DTP 20	DTP 20	DTP 21	DTP 23	DTP 25	
Depth (m)	0.50 - 1.0	1.0 - 1.7	0.30 - 0.65	1.0 - 2.0	1.1 - 1.6	0.75 - 1.90	0.6 - 1.2	
Sample Type	D	D	D	D	D	D	D	
Soil Colour & Description (v) indicates visual classification	Grey Grey Brown and a trace Red Brown Silty Clay trace of Sand	Light Grey with Minor Red Brown Mottles Silty Clay trace of Sand	Grey Brown with Brown and trace of Red Brown Silty Clay with Sand and trace of Gravel	Red Brown with Dark Grey Silty Clay with Sand and trace of Gravel	Grey with traces of Red Brown and Black Silty Clay	Grey/Dark Grey with Brown and Red Brown Mottles Silty Clay trace of Sand and Gravel	Grey and Orange Brown Mottled Sandy Silty Clay trace of Gravel	
Classification	CH	CH	CH	CH-MH	CH	CH	CI	

Moisture Content & Density

Field Moisture Content (%)	33.8	32.5	18.0	32.2	27.7	23.6	22.6	
Field Wet Density (t/m³)								
Field Dry Density (t/m³)								

Particle Size Distribution

Cobble Size (%)	0	0	0	0	0	0	0	
Gravel Size (%)	0	0	6	3	0	3	3	
Sand Size (%)	3	4	26	20	1	7	38	
Silt Size (%)	20	22	23	20	23	42	23	
Clay Size (%)	77	74	45	57	76	48	36	
Effective Size (mm)								
Uniformity Coefficient								
Curvature Coefficient								

Plasticity

Liquid Limit (%)	106	100	54	81	81	65	48	
Plastic Limit (%)	39	38	26	36	34	31	24	
Plasticity Index (%)	67	62	28	45	47	34	24	
Linear Shrinkage (%)								

Dispersion

Dispersal Index	4.0	N.D.	6.0	N.D.	5.4	4.0	2.6	
Percent Dispersion (%)								
Emerson Class No.								

Compaction

Compaction Type								
Optimum Moisture Content (%)								
Maximum Dry Density (t/m³)								

California Bearing Ratio

Placement Moisture Content (%)								
Placement Dry Density (t/m³)								
Swell under 4.5kg Surcharge (%)								
C.B.R. at 2.5% Penetration (%)								
C.B.R. at 5.0% Penetration (%)								

Geotechnical Centre

Unit W4K, 42 Wattle Street, ULTIMO NSW 2007
Telephone 02 9552 4864 Facsimile 02 9552 3615
NATA Accreditation Number: 13380

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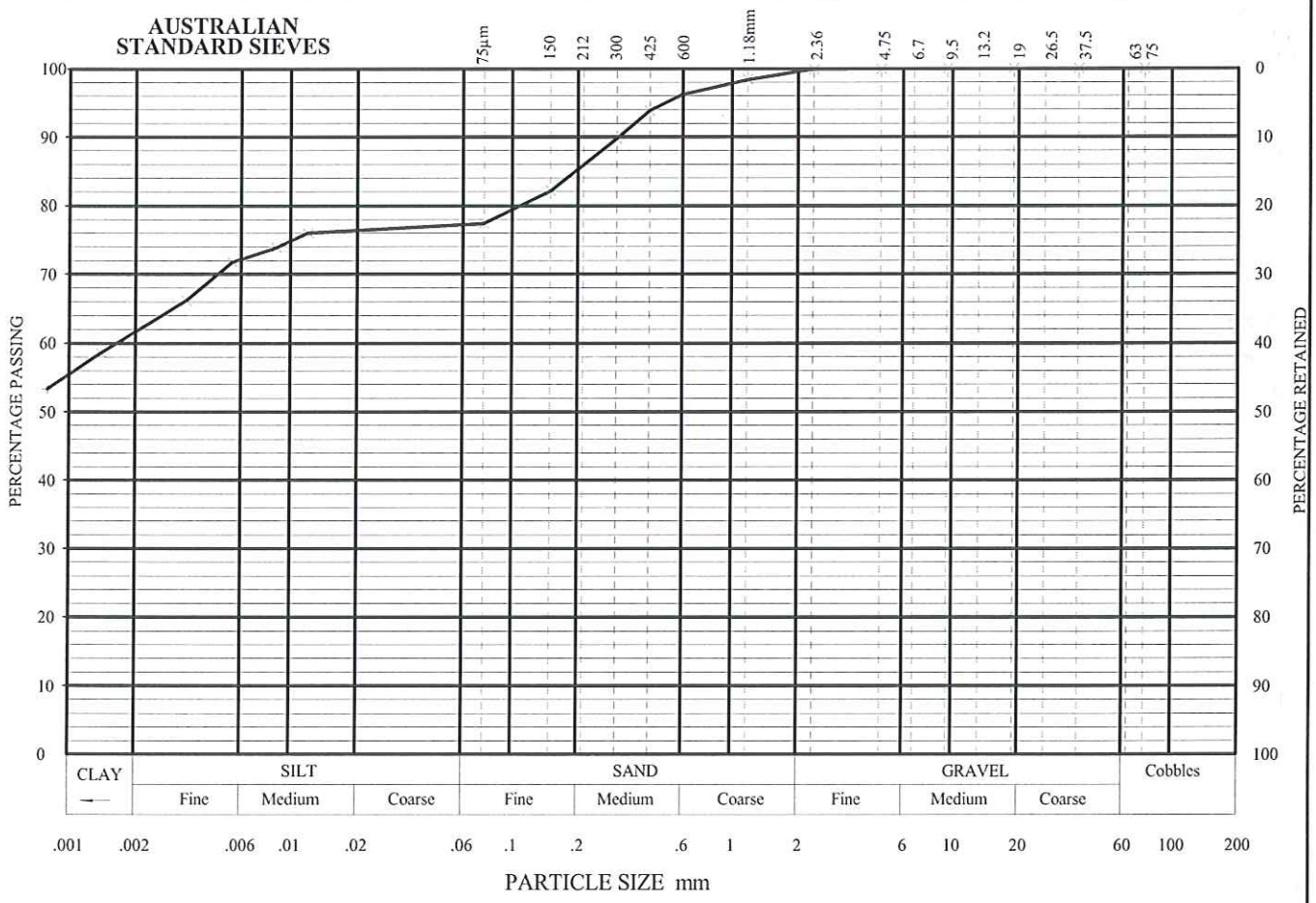
CLIENT: DAMS & CIVIL TECHNOLOGIES | REPORT No: 12031/3325/R1119

PARTICLE SIZE DISTRIBUTION

PROJECT: DUNOON DAM SITE | SAMPLE No: 3325

LOCATION: LOWER STORAGE AREA | HOLE No: DTP 1 | DEPTH (m): 1.1



SIZE DISTRIBUTION	
COBBLES	0 %
GRAVEL	1 %
SAND	22 %
SILT	16 %
CLAY	61 %
EFFECTIVE SIZE D10:	-
UNIFORMITY COEFFICIENT D60/D10(Cu):	-
CURVATURE COEFFICIENT $D30^2$ /(D60 x D10) (Cc):	-

Soil Particle Density: 2.65 t/m³ (estimated for analysis)

Method of dispersion: End-over-end shaking

Hydrometer: ASTM 152H

Dispersion chemical: Sodium hexametaphosphate + Anhydrous sodium carbonate

Notes on Test: Tested as received

Loss in pre-treatment: 0 %

Test Methods:
DPWS GM 9: Determination of the Particle Size Distribution of a Soil

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Tested By: MA Date Tested: 26/10/2012

APPROVED SIGNATORY M. Ashover

Mark Ashover 08/11/2012

PARTICLE SIZE DISTRIBUTION R1119 (ISSUE 4, 2005)

Geotechnical Centre

Unit W4K, 42 Wattle Street, ULTIMO NSW 2007
Telephone 02 9552 4864 Facsimile 02 9552 3615
NATA Accreditation Number: 13380

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CLIENT: DAMS & CIVIL TECHNOLOGIES | REPORT No: 12031/3325/R1115

SOIL INDEX PROPERTIES

PROJECT: DUNOON DAM SITE | SAMPLE No: 3325

LOCATION: LOWER STORAGE AREA | HOLE No: DTP 1 | DEPTH (m): 1.1

SOIL INDEX PROPERTIES		RESULT		TEST METHOD
Moisture Content (as received)	:	31.5	%	AS 1289.2.1.1
Liquid Limit	:	81	%	AS 1289.3.1.1
Plastic Limit	:	45	%	AS 1289.3.2.1
Plasticity Index	:	36	%	AS 1289.3.3.1
Linear Shrinkage	:	-		AS 1289.3.4.1
Soil Particle Density	:	-		GM 8
Classification	:	MH		AS 1726

Sample History: ☐ Natural State ☒ Air Dried ☐ Oven Dried

Method of Preparation: ☐ Wet Sieved ☒ Dry Sieved

Linear Shrinkage Sample: ☐ Curling ☐ Crumbling ☐ No Deformation

Notes on test: Sample tested as received from client.

ATTERBERG LIMITS R1115 (ISSUE 4, 2005)

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Tested By: ZG Date Tested: 01/11/2012

APPROVED SIGNATORY M. Ashover

Mark Ashover 08/11/2012

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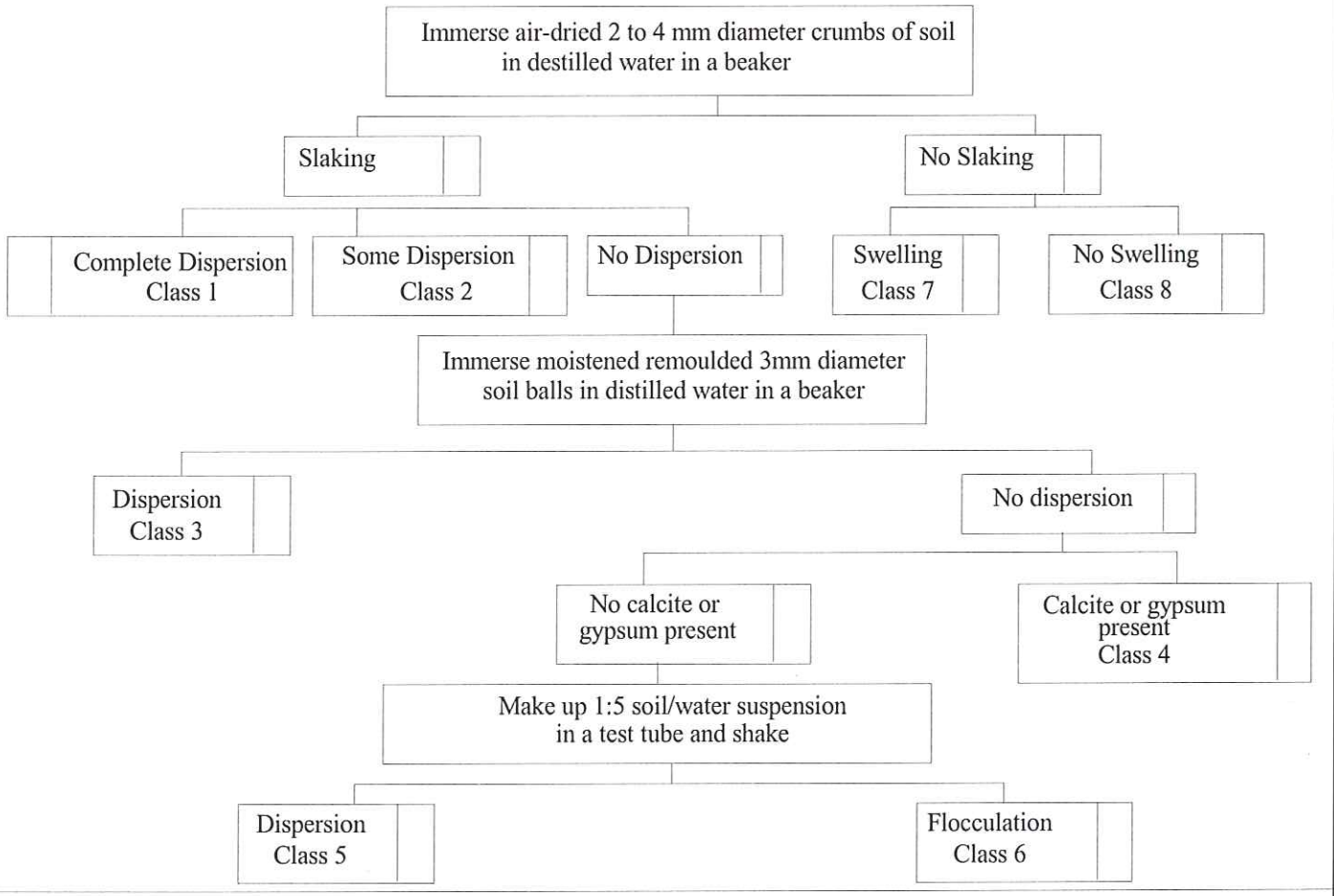
CLIENT: DAMS & CIVIL TECHNOLOGIES	REPORT No: 12031/3325/R1118

DISPERSION TESTS

PROJECT: DUNOON DAM SITE		SAMPLE No: 3325
LOCATION: LOWER STORAGE AREA	HOLE No: DTP 1	DEPTH (m): 1.1

Determination of the Emerson Class Number of a soil



Emerson Class Number	(AS 1289.3.8.1)	No Test
Percent Dispersion	(AS 1289.3.8.2)**	No Test
Dispersal Index	(DPWS GM 15)	N.D.

Sample Description: Yellow Brown, Red Brown and Grey Mottled Silty Clay with Sand

Type and temperature of water: Distilled, 21.3 ° C

Notes on test: Sample tested as received from client.

** 0.05mm size interpolated from hydrometer readings taken after 21min, 1hour and 2 hours.

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Tested By: ZG/MA Date Tested: 30/10/2012

APPROVED SIGNATORY M. Ashover

Mark Ashover 08/11/2012

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NATA Accreditation Number: 13380

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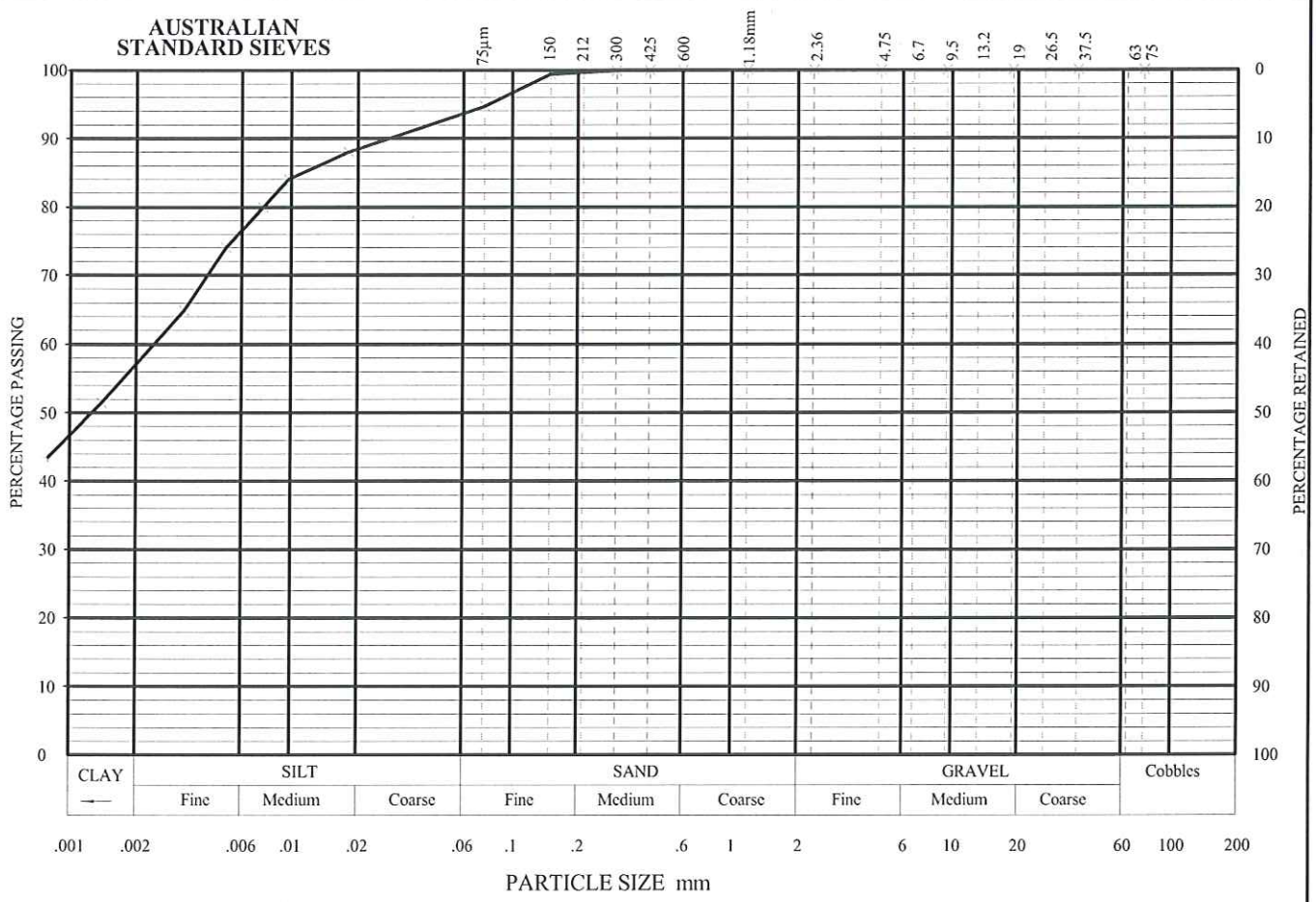
CLIENT: DAMS & CIVIL TECHNOLOGIES | REPORT No: 12031/3328/R1119

PARTICLE SIZE DISTRIBUTION

PROJECT: DUNOON DAM SITE | SAMPLE No: 3328

LOCATION: LOWER STORAGE AREA | HOLE No: DTP 5 | DEPTH (m): 0.30



SIZE DISTRIBUTION	
COBBLES	0 %
GRAVEL	0 %
SAND	7 %
SILT	37 %
CLAY	56 %
EFFECTIVE SIZE D10:	-
UNIFORMITY COEFFICIENT D60/D10(Cu):	-
CURVATURE COEFFICIENT $D30^2$ /(D60 x D10) (Cc):	-

Soil Particle Density: 2.65 t/m³ (estimated for analysis)

Method of dispersion: End-over-end shaking

Hydrometer: ASTM 152H

Dispersion chemical: Sodium hexametaphosphate + Anhydrous sodium carbonate

Notes on Test: Tested as received

Loss in pre-treatment: 0 %

Test Methods:
DPWS GM 9: Determination of the Particle Size Distribution of a Soil

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Tested By: ZG Date Tested: 26/10/2012

APPROVED SIGNATORY M. Ashover

Mark Ashover 08/11/2012

PARTICLE SIZE DISTRIBUTION R1119 (ISSUE 4, 2005)

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CLIENT: DAMS & CIVIL TECHNOLOGIES | REPORT No: 12031/3328/R1115

SOIL INDEX PROPERTIES

PROJECT: DUNOON DAM SITE | SAMPLE No: 3328

LOCATION: LOWER STORAGE AREA | HOLE No: DTP 5 | DEPTH (m): 0.30

SOIL INDEX PROPERTIES	RESULT		TEST METHOD
Moisture Content (as received)	:	27.9 %	AS 1289.2.1.1
Liquid Limit	:	76 %	AS 1289.3.1.1
Plastic Limit	:	35 %	AS 1289.3.2.1
Plasticity Index	:	41 %	AS 1289.3.3.1
Linear Shrinkage	:	-	AS 1289.3.4.1
Soil Particle Density	:	-	GM 8
Classification	:	CH-MH	AS 1726

Sample History: ☐ Natural State ☒ Air Dried ☐ Oven Dried

Method of Preparation: ☐ Wet Sieved ☒ Dry Sieved

Linear Shrinkage Sample: ☐ Curling ☐ Crumbling ☐ No Deformation

Notes on test: Sample tested as received from client.

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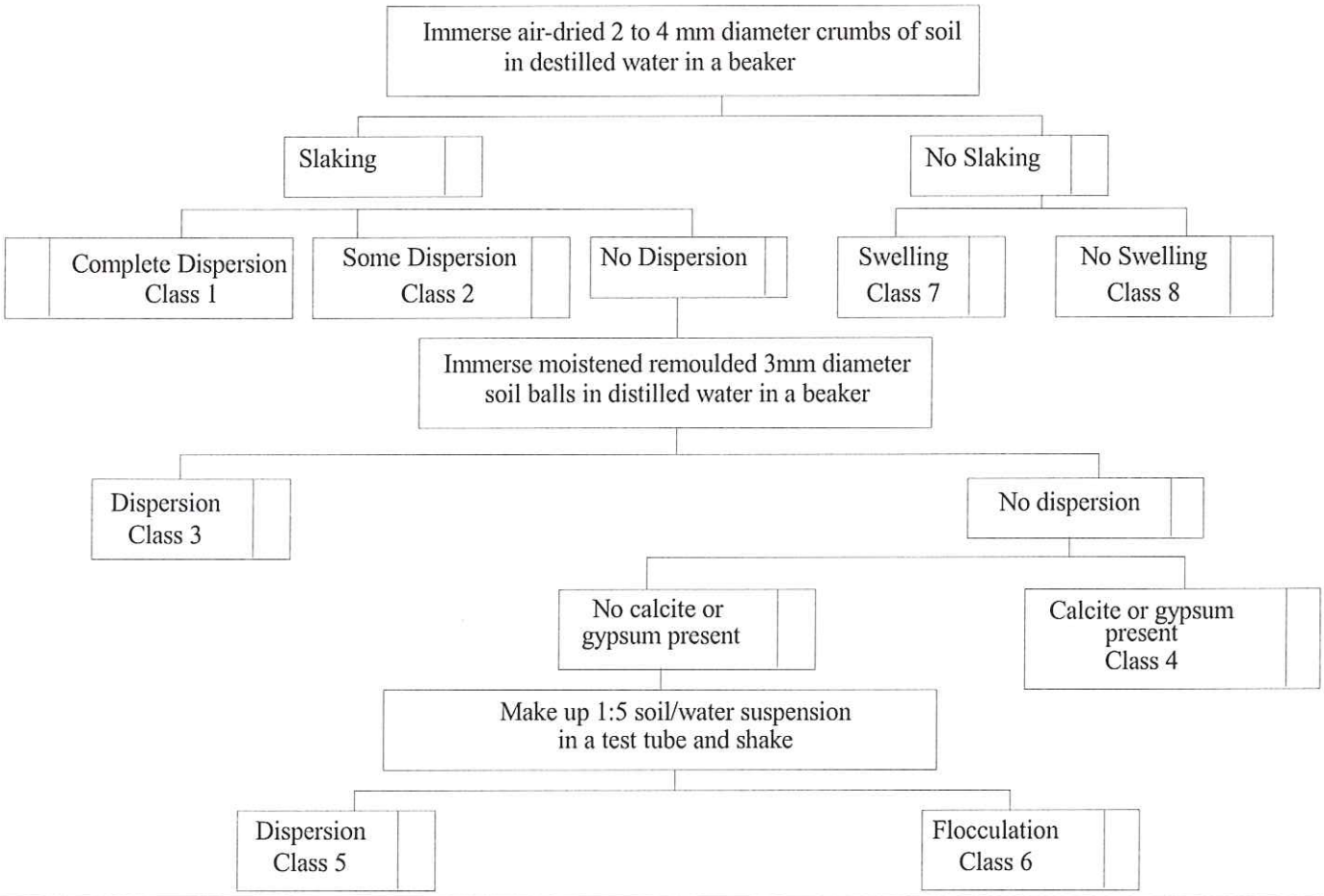
CLIENT: DAMS & CIVIL TECHNOLOGIES	REPORT No: 12031/3328/R1118

DISPERSION TESTS

PROJECT: DUNOON DAM SITE		SAMPLE No: 3328
LOCATION: LOWER STORAGE AREA	HOLE No: DTP 5	DEPTH (m): 0.30

Determination of the Emerson Class Number of a soil



Emerson Class Number	(AS 1289.3.8.1)	No Test
Percent Dispersion	(AS 1289.3.8.2)**	No Test
Dispersal Index	(DPWS GM 15)	4.5

Sample Description: Grey Brown and Orange Brown Silty Clay trace of Sand

Type and temperature of water: Distilled, 21.3 ° C

Notes on test: Sample tested as received from client.

** 0.05mm size interpolated from hydrometer readings taken after 21min, 1hour and 2 hours.

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Tested By: ZG/MA Date Tested: 30/10/2012

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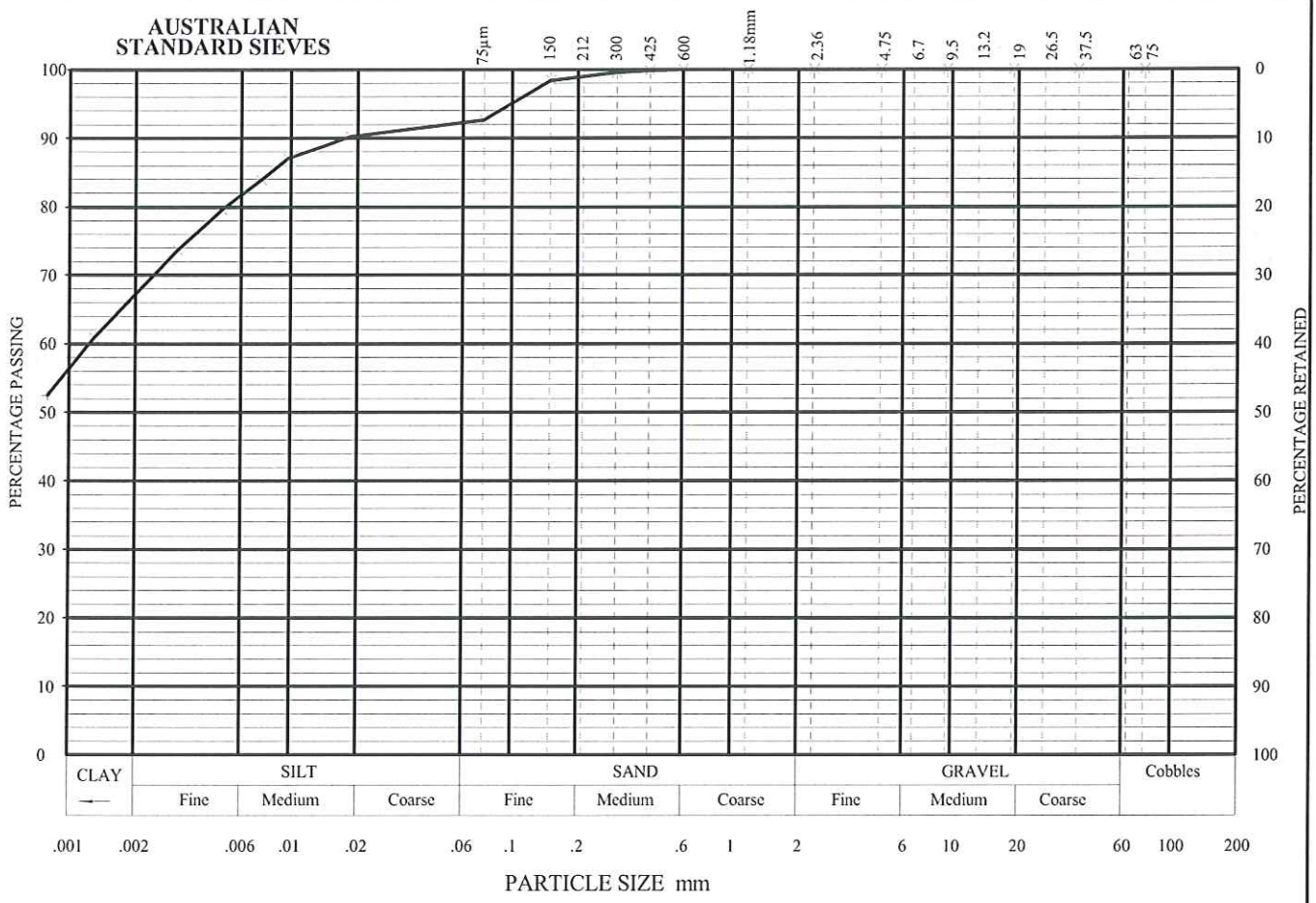
CLIENT: DAMS & CIVIL TECHNOLOGIES | REPORT No: 12031/3329/R1119

PARTICLE SIZE DISTRIBUTION

PROJECT: DUNOON DAM SITE | SAMPLE No: 3329

LOCATION: LOWER STORAGE AREA | HOLE No: DTP 5 | DEPTH (m): 0.75



SIZE DISTRIBUTION	
COBBLES	0 %
GRAVEL	0 %
SAND	8 %
SILT	26 %
CLAY	66 %
EFFECTIVE SIZE D10:	-
UNIFORMITY COEFFICIENT D60/D10(Cu):	-
CURVATURE COEFFICIENT $D30^2$ /(D60 x D10) (Cc):	-

Soil Particle Density: 2.65 t/m³ (estimated for analysis)

Method of dispersion: End-over-end shaking

Hydrometer: ASTM 152H

Dispersion chemical: Sodium hexametaphosphate + Anhydrous sodium carbonate

Notes on Test: Tested as received

Loss in pre-treatment: 0 %

Test Methods:
DPWS GM 9: Determination of the Particle Size Distribution of a Soil

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Tested By: MA Date Tested: 26/10/2012

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CLIENT: DAMS & CIVIL TECHNOLOGIES | REPORT No: 12031/3329/R1115

SOIL INDEX PROPERTIES

PROJECT: DUNOON DAM SITE | SAMPLE No: 3329

LOCATION: LOWER STORAGE AREA | HOLE No: DTP 5 | DEPTH (m): 0.75

SOIL INDEX PROPERTIES		RESULT		TEST METHOD
Moisture Content (as received)	:	28.8	%	AS 1289.2.1.1
Liquid Limit	:	92	%	AS 1289.3.1.1
Plastic Limit	:	37	%	AS 1289.3.2.1
Plasticity Index	:	55	%	AS 1289.3.3.1
Linear Shrinkage	:	-		AS 1289.3.4.1
Soil Particle Density	:	-		GM 8
Classification	:	CH		AS 1726

Sample History: ☐ Natural State ☒ Air Dried ☐ Oven Dried

Method of Preparation: ☐ Wet Sieved ☒ Dry Sieved

Linear Shrinkage Sample: ☐ Curling ☐ Crumbling ☐ No Deformation

Notes on test: Sample tested as received from client.

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Tested By: ZG Date Tested: 01/11/2012

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Mark Ashover 08/11/2012

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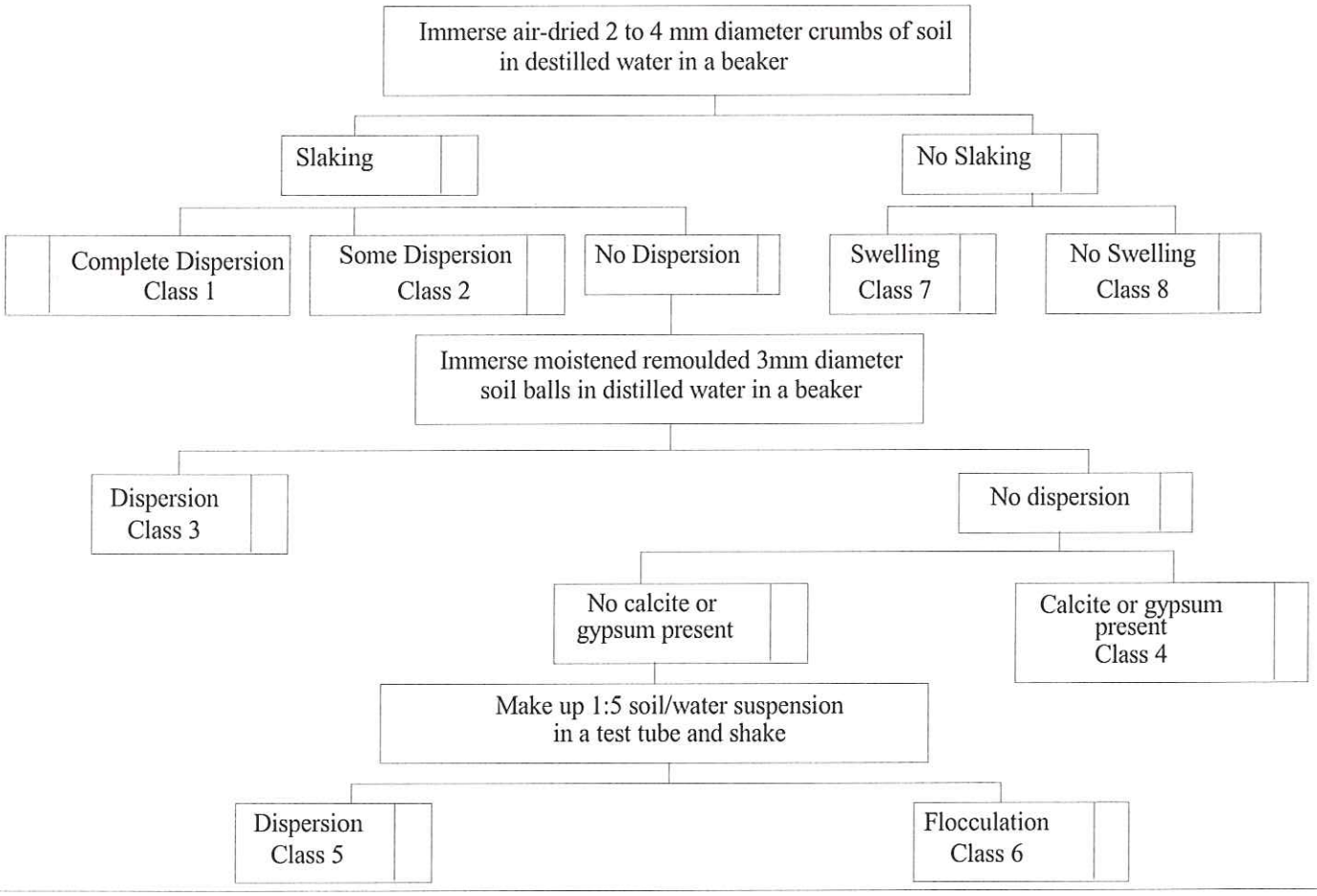
CLIENT: DAMS & CIVIL TECHNOLOGIES		REPORT No: 12031/3329/R1118
DISPERSION TESTS		
PROJECT: DUNOON DAM SITE		SAMPLE No: 3329
LOCATION: LOWER STORAGE AREA	HOLE No: DTP 5	DEPTH (m): 0.75

Determination of the Emerson Class Number of a soil



Emerson Class Number	(AS 1289.3.8.1)	No Test
Percent Dispersion	(AS 1289.3.8.2)**	No Test
Dispersal Index	(DPWS GM 15)	3.6

Sample Description: Brown, Grey, Red Brown and Grey Brown Silty Clay trace of Sand
Type and temperature of water: Distilled, 21.5 ° C

Notes on test: Sample tested as received from client.
** 0.05mm size interpolated from hydrometer readings taken after 21min, 1hour and 2 hours.

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Tested By: ZG/MA Date Tested: 30/10/2012

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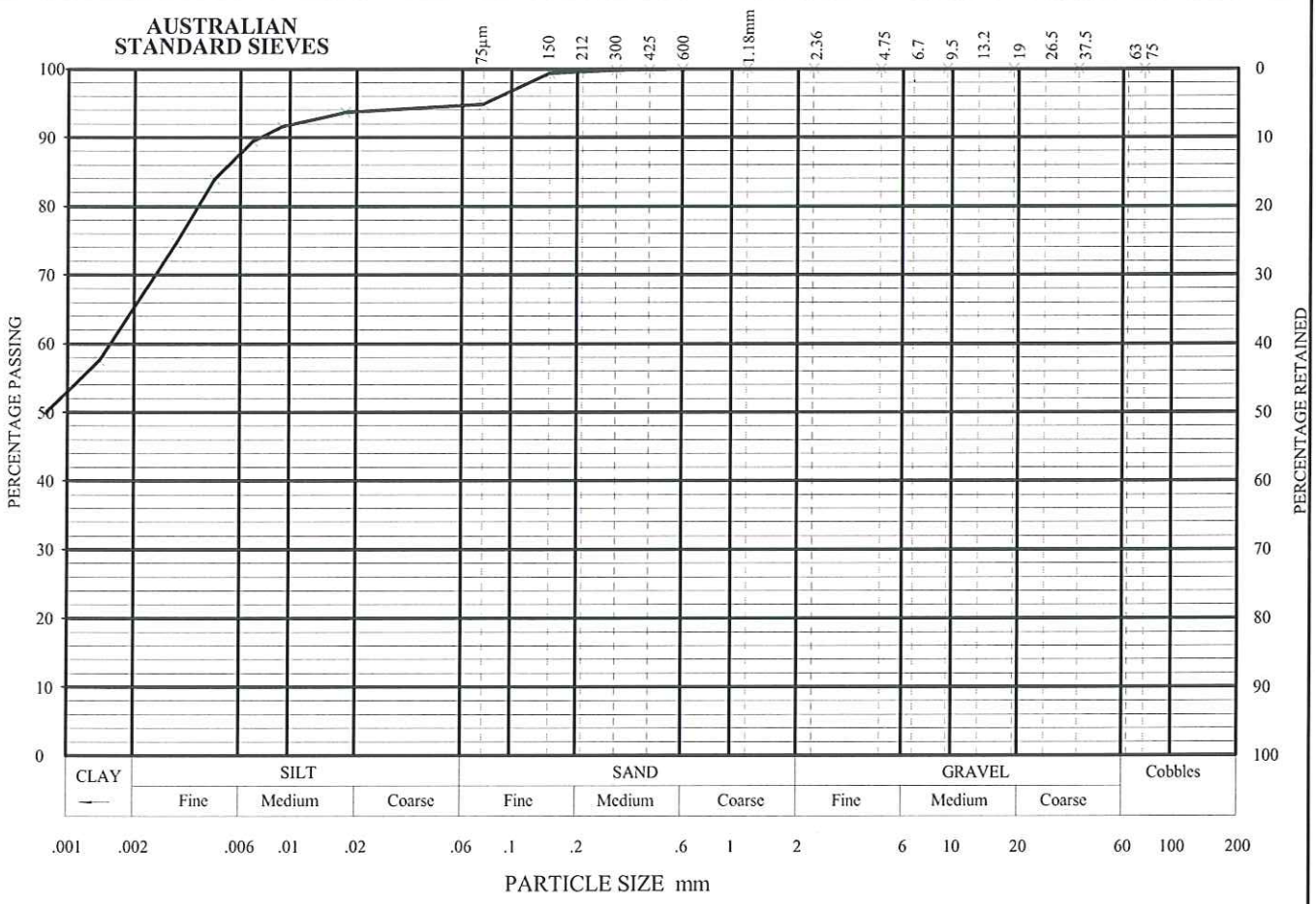
CLIENT: DAMS & CIVIL TECHNOLOGIES | REPORT No: 12031/3330/R1119

PARTICLE SIZE DISTRIBUTION

PROJECT: DUNOON DAM SITE | SAMPLE No: 3330

LOCATION: LOWER STORAGE AREA | HOLE No: DTP 7 | DEPTH (m): 0.9



SIZE DISTRIBUTION	
COBBLES	0 %
GRAVEL	0 %
SAND	5 %
SILT	31 %
CLAY	64 %
EFFECTIVE SIZE D10:	-
UNIFORMITY COEFFICIENT D60/D10(Cu):	-
CURVATURE COEFFICIENT $D30^2$ /(D60 x D10) (Cc):	-

Soil Particle Density: 2.65 t/m³ (estimated for analysis)

Method of dispersion: End-over-end shaking

Hydrometer: ASTM 152H

Dispersion chemical: Sodium hexametaphosphate + Anhydrous sodium carbonate

Notes on Test: Tested as received

Loss in pre-treatment: 0 %

Test Methods:
DPWS GM 9: Determination of the Particle Size Distribution of a Soil

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Tested By: ZG Date Tested: 26/10/2012

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Mark Ashover 08/11/2012

PARTICLE SIZE DISTRIBUTION R1119 (ISSUE 4, 2005)

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CLIENT: DAMS & CIVIL TECHNOLOGIES	REPORT No: 12031/3330/R1115

SOIL INDEX PROPERTIES

PROJECT: DUNOON DAM SITE	SAMPLE No: 3330

LOCATION: LOWER STORAGE AREA	HOLE No: DTP 7	DEPTH (m): 0.9

SOIL INDEX PROPERTIES		RESULT	TEST METHOD
Moisture Content (as received)	:	31.7 %	AS 1289.2.1.1
Liquid Limit	:	85 %	AS 1289.3.1.1
Plastic Limit	:	34 %	AS 1289.3.2.1
Plasticity Index	:	51 %	AS 1289.3.3.1
Linear Shrinkage	:	-	AS 1289.3.4.1
Soil Particle Density	:	-	GM 8
Classification	:	CH	AS 1726

Sample History: ☐ Natural State ☒ Air Dried ☐ Oven Dried

Method of Preparation: ☐ Wet Sieved ☒ Dry Sieved

Linear Shrinkage Sample: ☐ Curling ☐ Crumbling ☐ No Deformation

Notes on test: Sample tested as received from client.

ATTERBERG LIMITS R1115 (ISSUE 4, 2005)

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Tested By: ZG Date Tested: 01/11/2012

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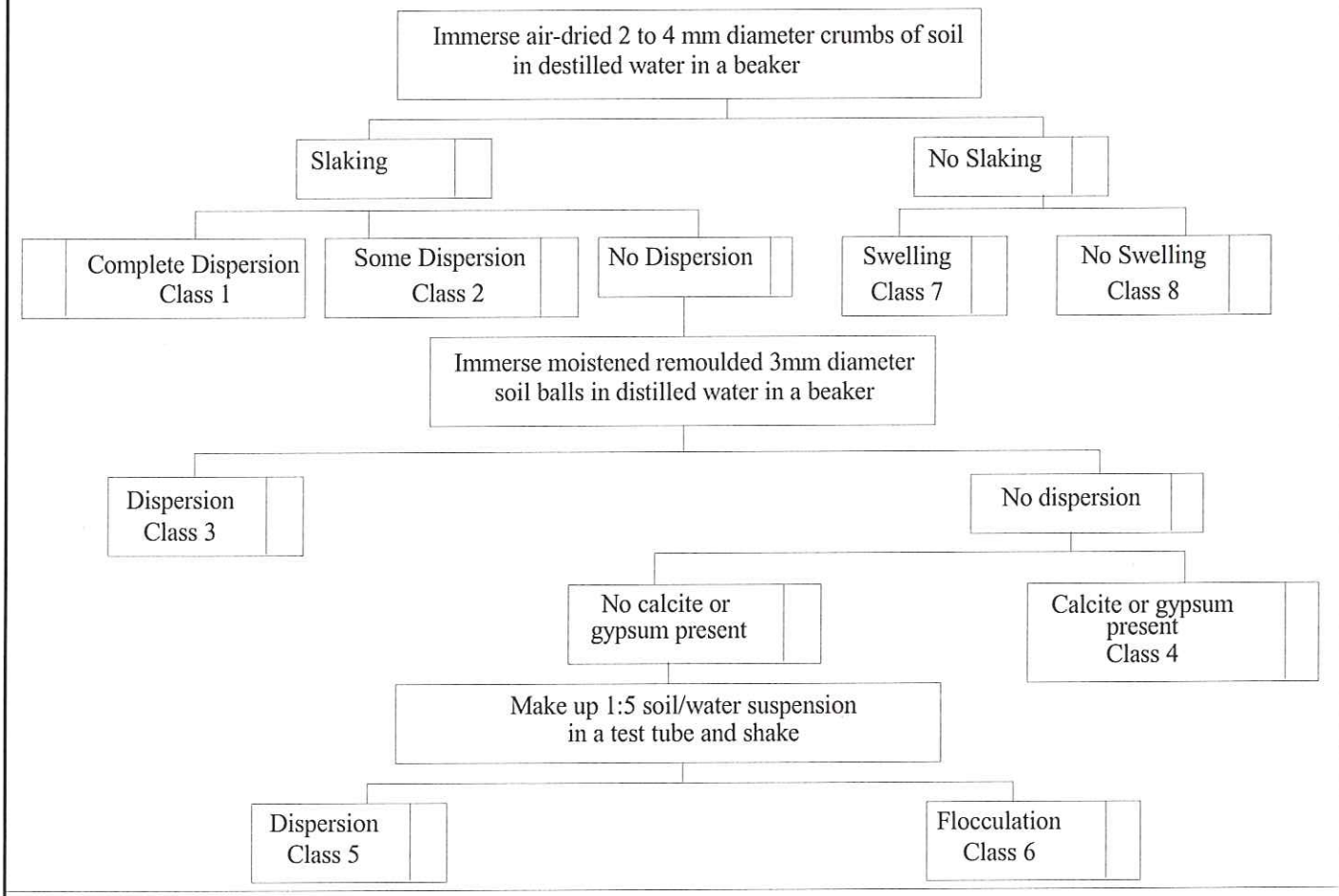
CLIENT: DAMS & CIVIL TECHNOLOGIES	REPORT No: 12031/3330/R1118

DISPERSION TESTS

PROJECT: DUNOON DAM SITE		SAMPLE No: 3330
LOCATION: LOWER STORAGE AREA	HOLE No: DTP 7	DEPTH (m): 0.9

Determination of the Emerson Class Number of a soil



Emerson Class Number	(AS 1289.3.8.1)	No Test
Percent Dispersion	(AS 1289.3.8.2)**	No Test
Dispersal Index	(DPWS GM 15)	3.4

Sample Description: Grey with Minor Red Brown Mottles Silty Clay trace of Sand

Type and temperature of water: Distilled, 21.6 ° C

Notes on test: Sample tested as received from client.

** 0.05mm size interpolated from hydrometer readings taken after 21min, 1hour and 2 hours.

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Tested By: ZG/MA Date Tested: 30/10/2012

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Mark Ashover 08/11/2012

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NATA Accreditation Number: 13380

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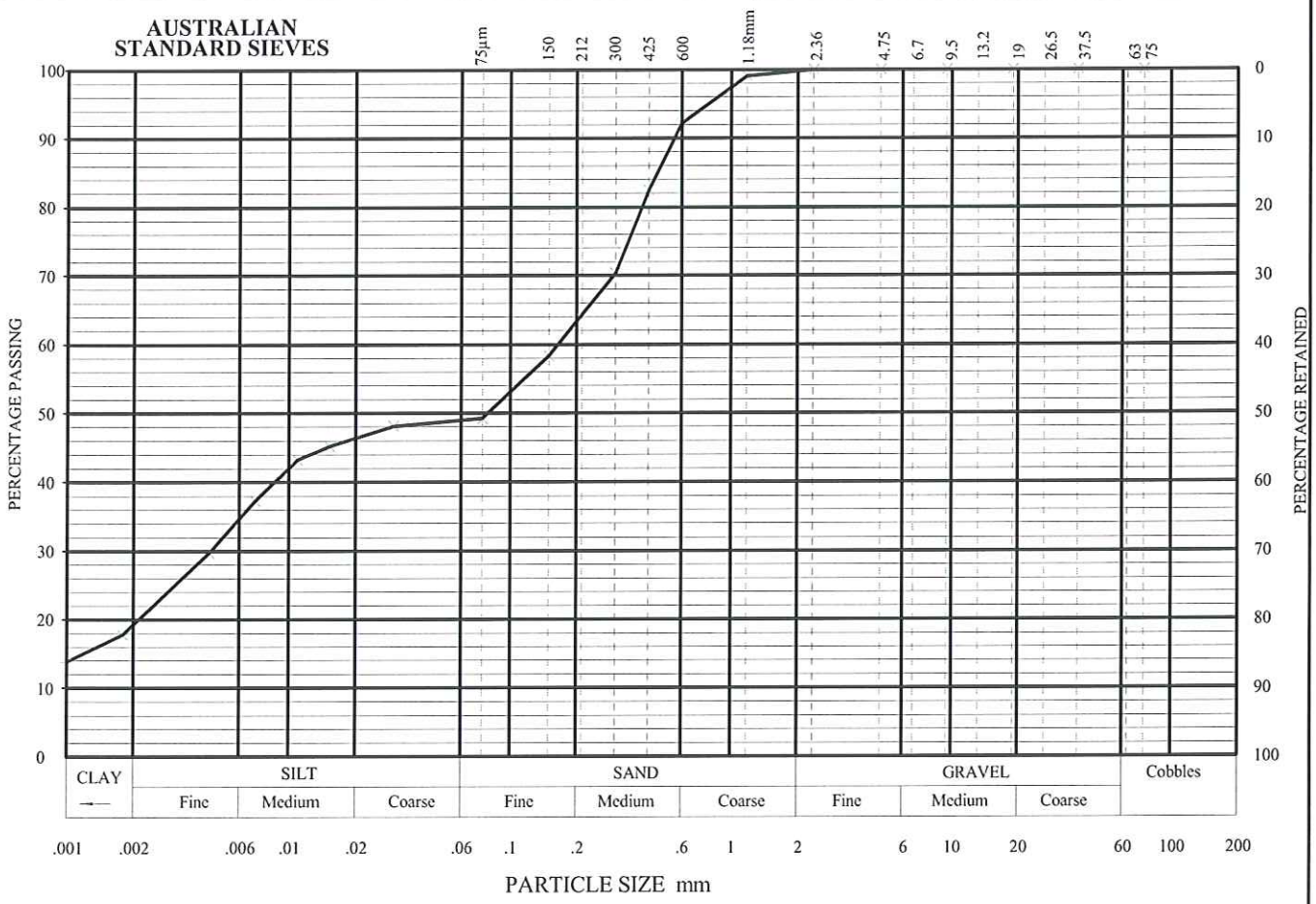
CLIENT: DAMS & CIVIL TECHNOLOGIES | REPORT No: 12031/3331/R1119

PARTICLE SIZE DISTRIBUTION

PROJECT: DUNOON DAM SITE | SAMPLE No: 3331

LOCATION: LOWER STORAGE AREA | HOLE No: DTP 8 | DEPTH (m): 2.5



SIZE DISTRIBUTION	
COBBLES	0 %
GRAVEL	0 %
SAND	51 %
SILT	30 %
CLAY	19 %
EFFECTIVE SIZE D10:	-
UNIFORMITY COEFFICIENT D60/D10(Cu):	-
CURVATURE COEFFICIENT $D30^2$ /(D60 x D10) (Cc):	-

Soil Particle Density: 2.65 t/m³ (estimated for analysis)

Method of dispersion: End-over-end shaking

Hydrometer: ASTM 152H

Dispersion chemical: Sodium hexametaphosphate + Anhydrous sodium carbonate

Notes on Test: Tested as received

Loss in pre-treatment: 0 %

Test Methods:
DPWS GM 9: Determination of the Particle Size Distribution of a Soil

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Tested By: ZG Date Tested: 26/10/2012

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CLIENT: DAMS & CIVIL TECHNOLOGIES	REPORT No: 12031/3331/R1115

SOIL INDEX PROPERTIES

PROJECT: DUNOON DAM SITE	SAMPLE No: 3331
LOCATION: LOWER STORAGE AREA	HOLE No: DTP 8 / DEPTH (m): 2.5

SOIL INDEX PROPERTIES		RESULT		TEST METHOD
Moisture Content (as received)	:	28.6	%	AS 1289.2.1.1
Liquid Limit	:	49	%	AS 1289.3.1.1
Plastic Limit	:	31	%	AS 1289.3.2.1
Plasticity Index	:	18	%	AS 1289.3.3.1
Linear Shrinkage	:	-		AS 1289.3.4.1
Soil Particle Density	:	-		GM 8
Classification	:	SM		AS 1726

Sample History: ☐ Natural State ☒ Air Dried ☐ Oven Dried

Method of Preparation: ☐ Wet Sieved ☒ Dry Sieved

Linear Shrinkage Sample: ☐ Curling ☐ Crumbling ☐ No Deformation

Notes on test: Sample tested as received from client.

ATTERBERG LIMITS R1115 (ISSUE 4, 2005)

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Tested By: ZG Date Tested: 01/11/2012

APPROVED SIGNATORY M. Ashover

Mark Ashover 08/11/2012

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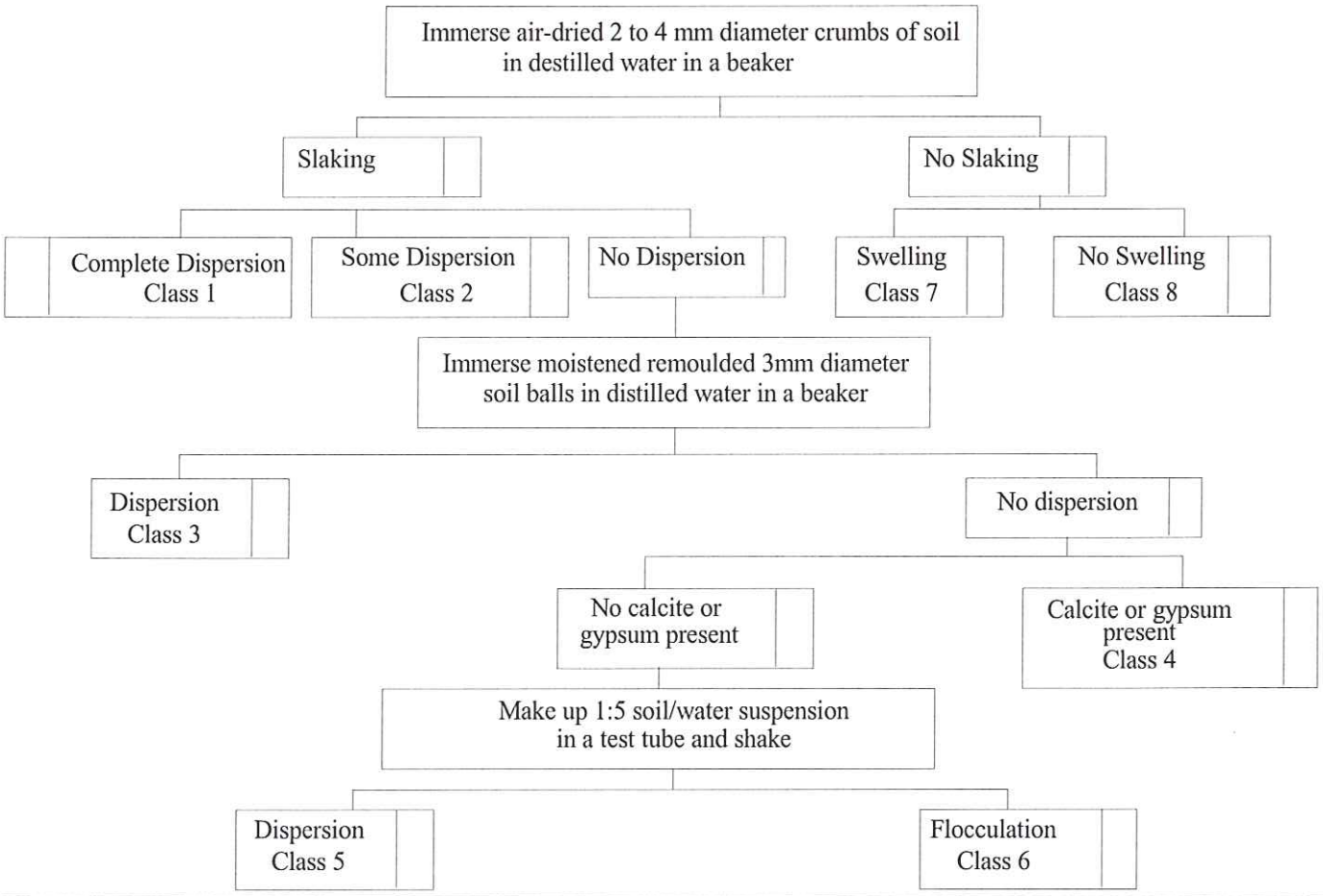
CLIENT: DAMS & CIVIL TECHNOLOGIES		REPORT No: 12031/3331/R1118
DISPERSION TESTS		
PROJECT: DUNOON DAM SITE		SAMPLE No: 3331
LOCATION: LOWER STORAGE AREA	HOLE No: DTP 8	DEPTH (m): 2.5

Determination of the Emerson Class Number of a soil



Emerson Class Number	(AS 1289.3.8.1)	No Test
Percent Dispersion	(AS 1289.3.8.2)**	No Test
Dispersal Index	(DPWS GM 15)	2.2

Sample Description: Brown, Grey, Red Brown and Orange Brown Clayey Silty Sand
Type and temperature of water: Distilled, 21.6 ° C

Notes on test: Sample tested as received from client.
** 0.05mm size interpolated from hydrometer readings taken after 21min, 1hour and 2 hours.

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Tested By: ZG/MA Date Tested: 30/10/2012

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Mark Ashover 08/11/2012

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NATA Accreditation Number: 13380

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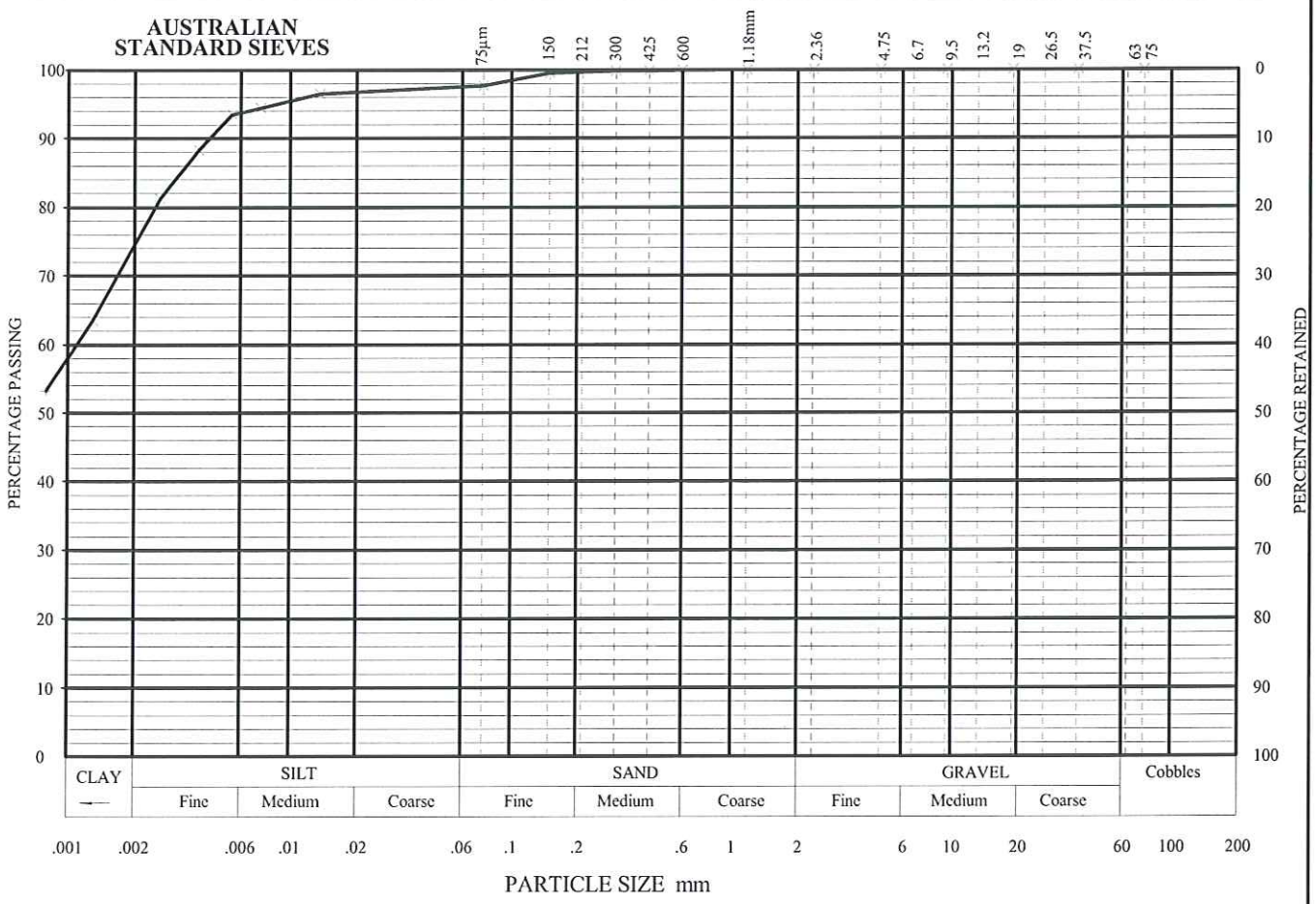
CLIENT: DAMS & CIVIL TECHNOLOGIES | REPORT No: 12031/3332/R1119

PARTICLE SIZE DISTRIBUTION

PROJECT: DUNOON DAM SITE | SAMPLE No: 3332

LOCATION: LOWER STORAGE AREA | HOLE No: DTP 9 | DEPTH (m): 1.2



SIZE DISTRIBUTION	
COBBLES	0 %
GRAVEL	0 %
SAND	3 %
SILT	24 %
CLAY	73 %
EFFECTIVE SIZE D10:	-
UNIFORMITY COEFFICIENT D60/D10(Cu):	-
CURVATURE COEFFICIENT $D30^2$ /(D60 x D10) (Cc):	-

Soil Particle Density: 2.65 t/m³ (estimated for analysis)

Method of dispersion: End-over-end shaking

Hydrometer: ASTM 152H

Dispersion chemical: Sodium hexametaphosphate + Anhydrous sodium carbonate

Notes on Test: Tested as received

Loss in pre-treatment: 0 %

Test Methods:
DPWS GM 9: Determination of the Particle Size Distribution of a Soil

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Tested By: ZG Date Tested: 26/10/2012

APPROVED SIGNATORY M. Ashover

Mark Ashover 08/11/2012

Geotechnical Centre

Unit W4K, 42 Wattle Street, ULTIMO NSW 2007
Telephone 02 9552 4864 Facsimile 02 9552 3615
NATA Accreditation Number: 13380

NSW GOVERNMENT | Public Works NSW Water Solutions

CLIENT: DAMS & CIVIL TECHNOLOGIES | REPORT No: 12031/3332/R1115

SOIL INDEX PROPERTIES

PROJECT: DUNOON DAM SITE | SAMPLE No: 3332

LOCATION: LOWER STORAGE AREA | HOLE No: DTP 9 | DEPTH (m): 1.2

SOIL INDEX PROPERTIES	RESULT		TEST METHOD
Moisture Content (as received)	:	36.1 %	AS 1289.2.1.1
Liquid Limit	:	93 %	AS 1289.3.1.1
Plastic Limit	:	37 %	AS 1289.3.2.1
Plasticity Index	:	56 %	AS 1289.3.3.1
Linear Shrinkage	:	-	AS 1289.3.4.1
Soil Particle Density	:	-	GM 8
Classification	:	CH	AS 1726

Sample History: ☐ Natural State ☒ Air Dried ☐ Oven Dried

Method of Preparation: ☐ Wet Sieved ☒ Dry Sieved

Linear Shrinkage Sample: ☐ Curling ☐ Crumbling ☐ No Deformation

Notes on test: Sample tested as received from client.

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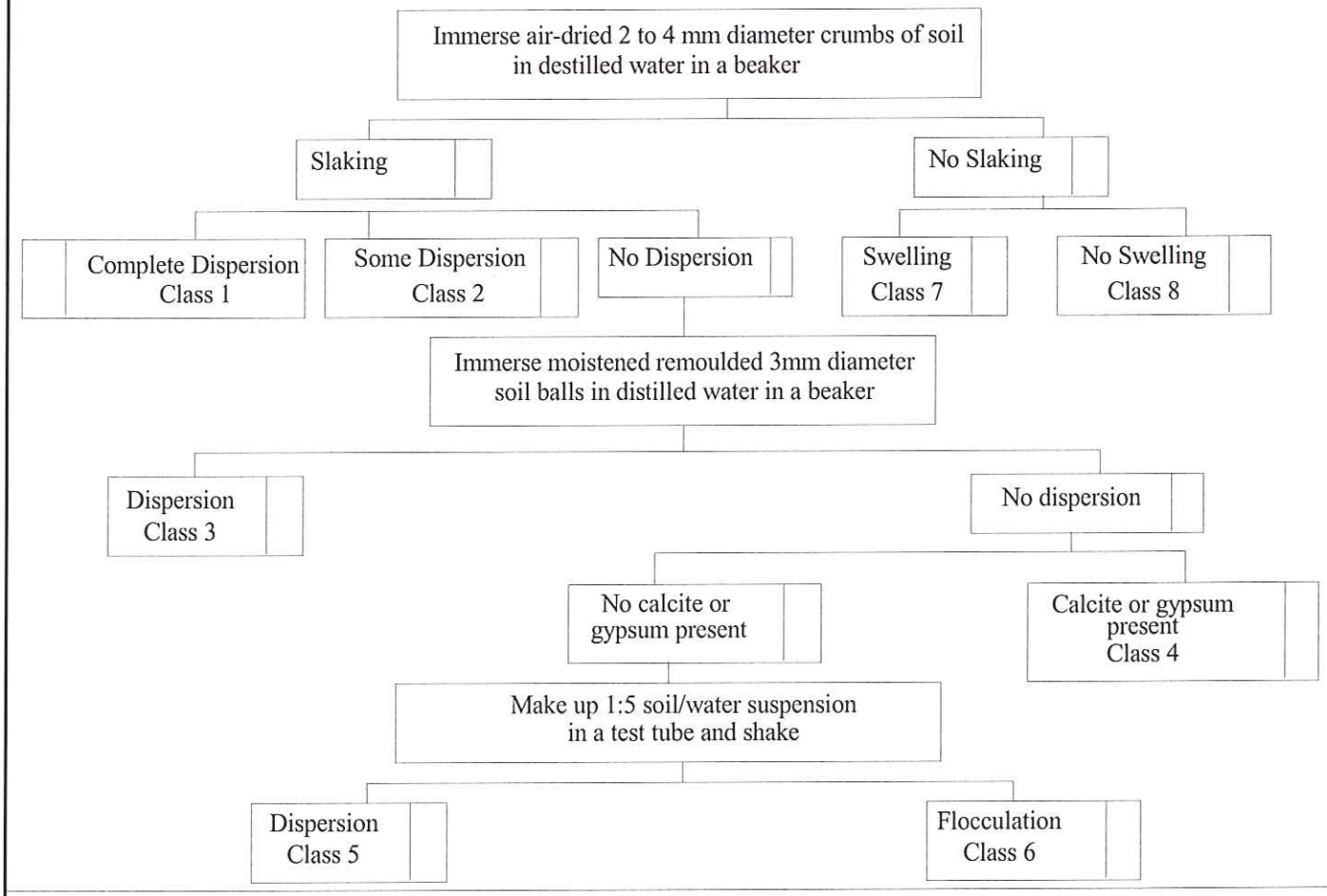
CLIENT: DAMS & CIVIL TECHNOLOGIES		REPORT No: 12031/3332/R1118
DISPERSION TESTS		
PROJECT: DUNOON DAM SITE		SAMPLE No: 3332
LOCATION: LOWER STORAGE AREA	HOLE No: DTP 9	DEPTH (m): 1.2

Determination of the Emerson Class Number of a soil



Emerson Class Number	(AS 1289.3.8.1)	No Test
Percent Dispersion	(AS 1289.3.8.2)**	No Test
Dispersal Index	(DPWS GM 15)	3.7

Sample Description: Grey with Brown Mottles and trace of Black Silty Clay trace of Sand

Type and temperature of water: Distilled, 21.8 ° C

Notes on test: Sample tested as received from client.

** 0.05mm size interpolated from hydrometer readings taken after 21min, 1hour and 2 hours.

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Tested By: ZG/MA Date Tested: 30/10/2012

APPROVED SIGNATORY M. Ashover

Mark Ashover 08/11/2012

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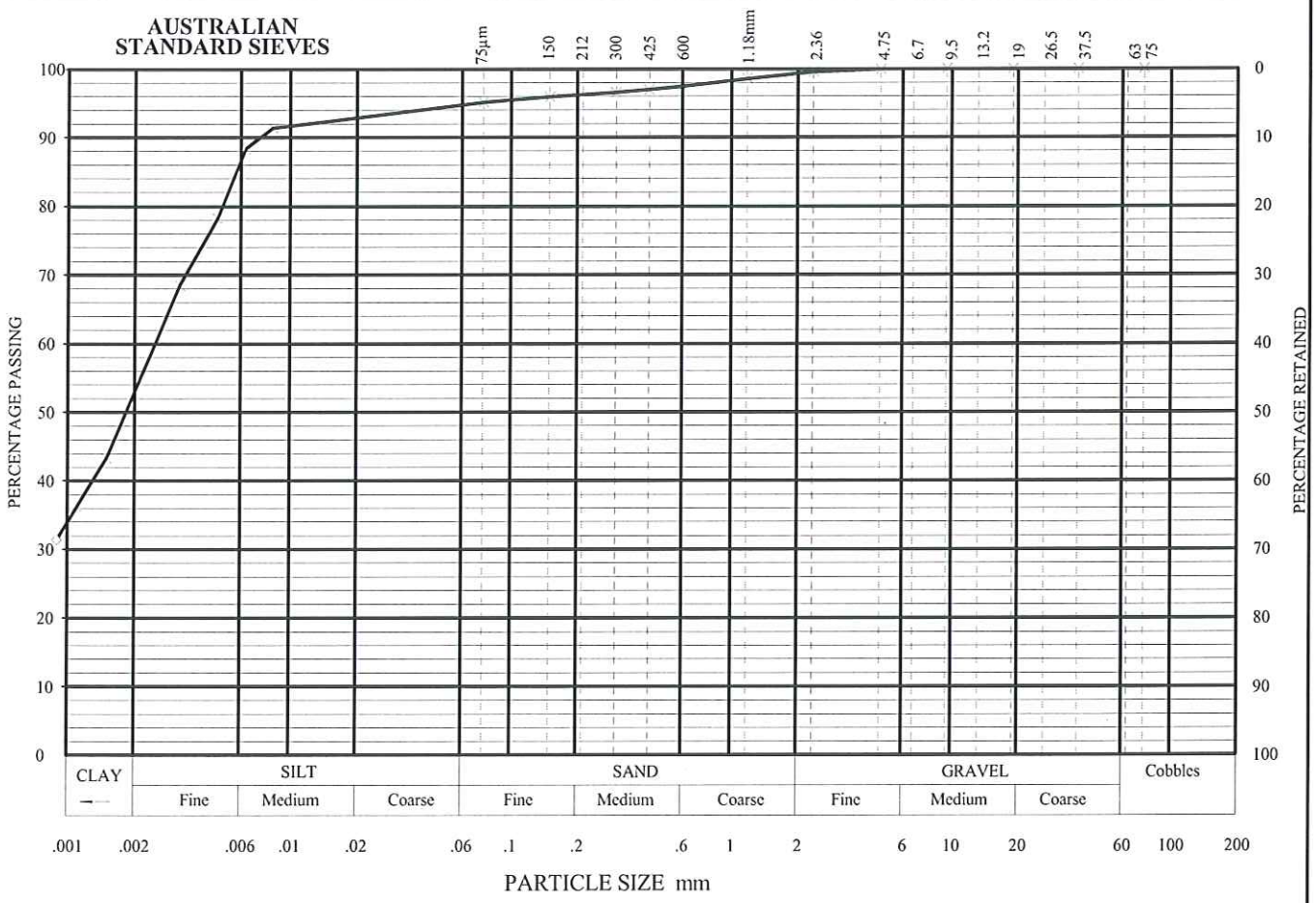
CLIENT: DAMS & CIVIL TECHNOLOGIES | REPORT No: 12031/3333/R1119

PARTICLE SIZE DISTRIBUTION

PROJECT: DUNOON DAM SITE | SAMPLE No: 3333

LOCATION: LOWER STORAGE AREA | HOLE No: DTP 12 | DEPTH (m): 3.1



SIZE DISTRIBUTION	
COBBLES	0 %
GRAVEL	1 %
SAND	5 %
SILT	43 %
CLAY	51 %
EFFECTIVE SIZE D10:	-
UNIFORMITY COEFFICIENT D60/D10(Cu):	-
CURVATURE COEFFICIENT D30² /(D60 x D10) (Cc):	-

Soil Particle Density: 2.65 t/m³ (estimated for analysis)

Method of dispersion: End-over-end shaking

Hydrometer: ASTM 152H

Dispersion chemical: Sodium hexametaphosphate + Anhydrous sodium carbonate

Notes on Test: Tested as received

Loss in pre-treatment: 0 %

Test Methods:
DPWS GM 9: Determination of the Particle Size Distribution of a Soil

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Tested By: MA Date Tested: 26/10/2012

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Mark Ashover 08/11/2012

PARTICLE SIZE DISTRIBUTION R1119 (ISSUE 4, 2005)

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CLIENT: DAMS & CIVIL TECHNOLOGIES	REPORT No: 12031/3333/R1115

SOIL INDEX PROPERTIES

PROJECT: DUNOON DAM SITE	SAMPLE No: 3333
LOCATION: LOWER STORAGE AREA	HOLE No: DTP 12 / DEPTH (m): 3.1

SOIL INDEX PROPERTIES		RESULT		TEST METHOD
Moisture Content (as received)	:	24.4	%	AS 1289.2.1.1
Liquid Limit	:	61	%	AS 1289.3.1.1
Plastic Limit	:	33	%	AS 1289.3.2.1
Plasticity Index	:	28	%	AS 1289.3.3.1
Linear Shrinkage	:	-		AS 1289.3.4.1
Soil Particle Density	:	-		GM 8
Classification	:	MH		AS 1726

Sample History: ☐ Natural State ☒ Air Dried ☐ Oven Dried

Method of Preparation: ☐ Wet Sieved ☒ Dry Sieved

Linear Shrinkage Sample: ☐ Curling ☐ Crumbling ☐ No Deformation

Notes on test: Sample tested as received from client.

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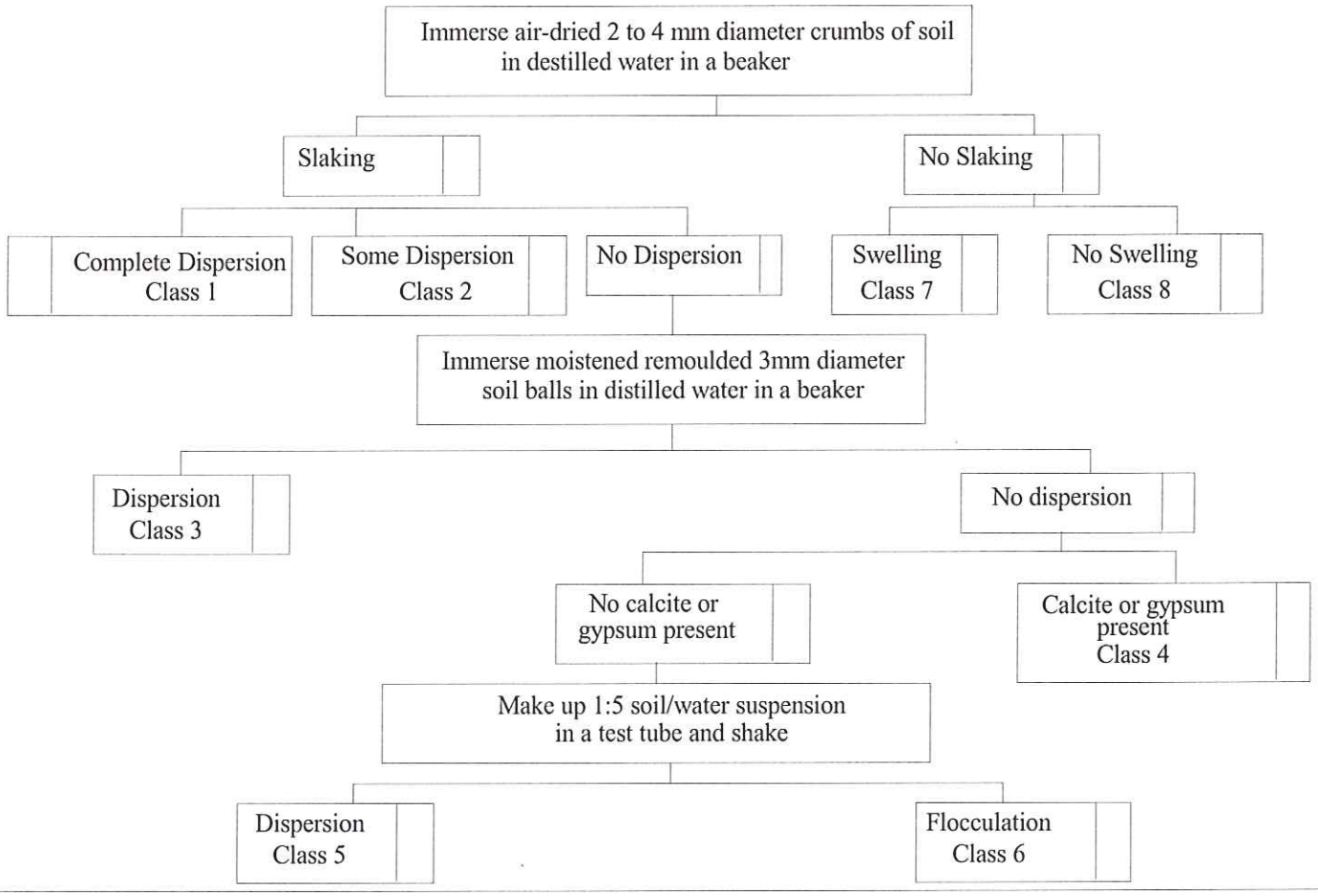
CLIENT: DAMS & CIVIL TECHNOLOGIES		REPORT No: 12031/3333/R1118
DISPERSION TESTS		
PROJECT: DUNOON DAM SITE		SAMPLE No: 3333
LOCATION: LOWER STORAGE AREA	HOLE No: DTP 12	DEPTH (m): 3.1

Determination of the Emerson Class Number of a soil



Emerson Class Number	(AS 1289.3.8.1)	No Test
Percent Dispersion	(AS 1289.3.8.2)**	No Test
Dispersal Index	(DPWS GM 15)	3.2

Sample Description: Brown and Grey with Black Silty Clay trace of Sand
Type and temperature of water: Distilled, 21.8 ° C

Notes on test: Sample tested as received from client.
** 0.05mm size interpolated from hydrometer readings taken after 21min, 1hour and 2 hours.

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Tested By: ZG/MA Date Tested: 30/10/2012

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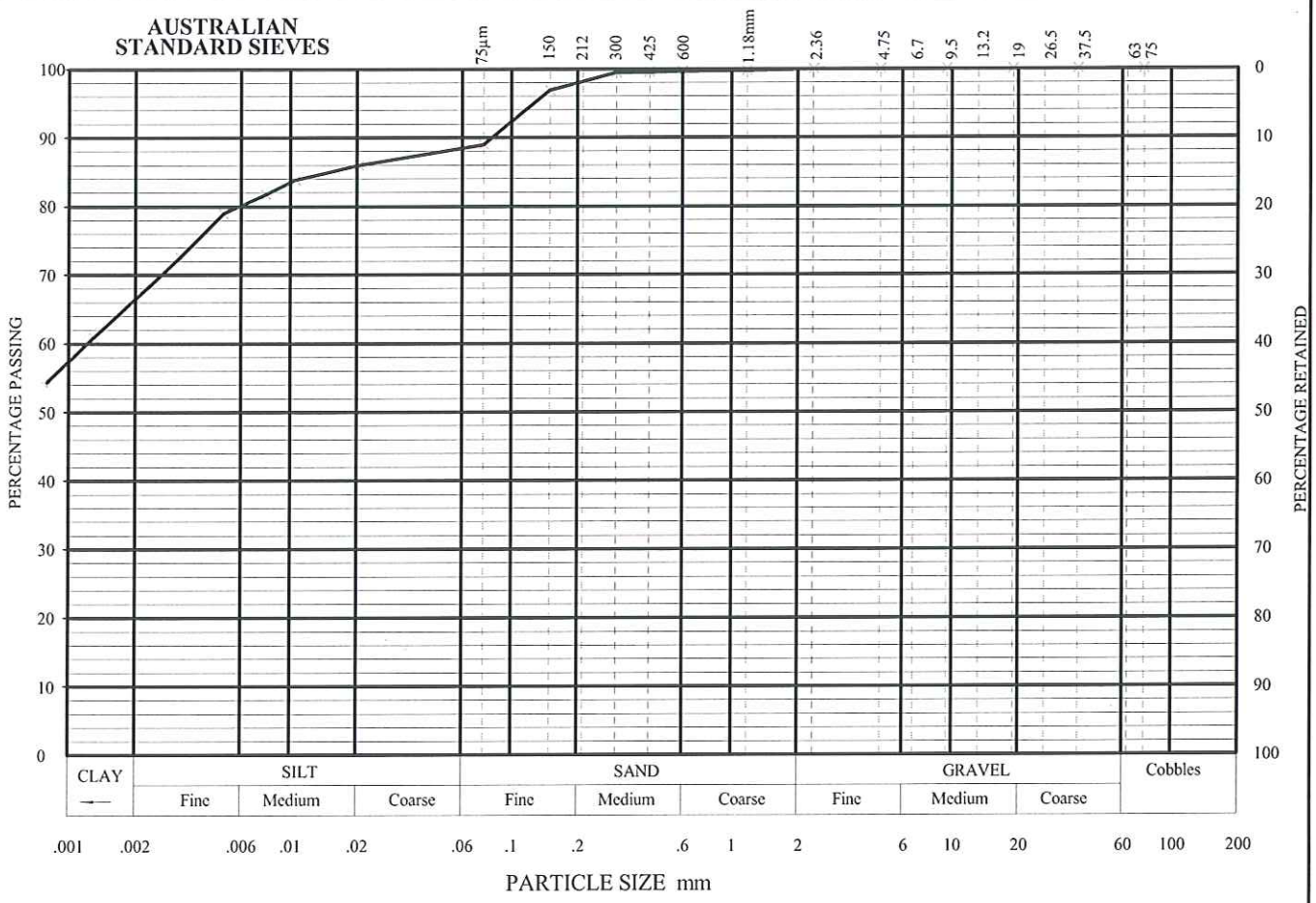
CLIENT: DAMS & CIVIL TECHNOLOGIES | REPORT No: 12031/3334/R1119

PARTICLE SIZE DISTRIBUTION

PROJECT: DUNOON DAM SITE | SAMPLE No: 3334

LOCATION: LOWER STORAGE AREA | HOLE No: DTP 16 | DEPTH (m): 1.2



SIZE DISTRIBUTION	
COBBLES	0 %
GRAVEL	0 %
SAND	12 %
SILT	23 %
CLAY	65 %
EFFECTIVE SIZE D10:	-
UNIFORMITY COEFFICIENT D60/D10(Cu):	-
CURVATURE COEFFICIENT $D30^2$ /(D60 x D10) (Cc):	-

Soil Particle Density: 2.65 t/m³ (estimated for analysis)

Method of dispersion: End-over-end shaking

Hydrometer: ASTM 152H

Dispersion chemical: Sodium hexametaphosphate + Anhydrous sodium carbonate

Notes on Test: Tested as received

Loss in pre-treatment: 0 %

Test Methods:
DPWS GM 9: Determination of the Particle Size Distribution of a Soil

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Tested By: MA Date Tested: 26/10/2012

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PARTICLE SIZE DISTRIBUTION R1119 (ISSUE 4, 2005)

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CLIENT: DAMS & CIVIL TECHNOLOGIES | REPORT No: 12031/3334/R1115

SOIL INDEX PROPERTIES

PROJECT: DUNOON DAM SITE | SAMPLE No: 3334

LOCATION: LOWER STORAGE AREA | HOLE No: DTP 16 | DEPTH (m): 1.2

SOIL INDEX PROPERTIES	RESULT		TEST METHOD
Moisture Content (as received)	:	31.5 %	AS 1289.2.1.1
Liquid Limit	:	95 %	AS 1289.3.1.1
Plastic Limit	:	36 %	AS 1289.3.2.1
Plasticity Index	:	59 %	AS 1289.3.3.1
Linear Shrinkage	:	-	AS 1289.3.4.1
Soil Particle Density	:	-	GM 8
Classification	:	CH	AS 1726

Sample History: ☐ Natural State ☒ Air Dried ☐ Oven Dried

Method of Preparation: ☐ Wet Sieved ☒ Dry Sieved

Linear Shrinkage Sample: ☐ Curling ☐ Crumbling ☐ No Deformation

Notes on test: Sample tested as received from client.

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Tested By: ZG Date Tested: 01/11/2012

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Mark Ashover 08/11/2012

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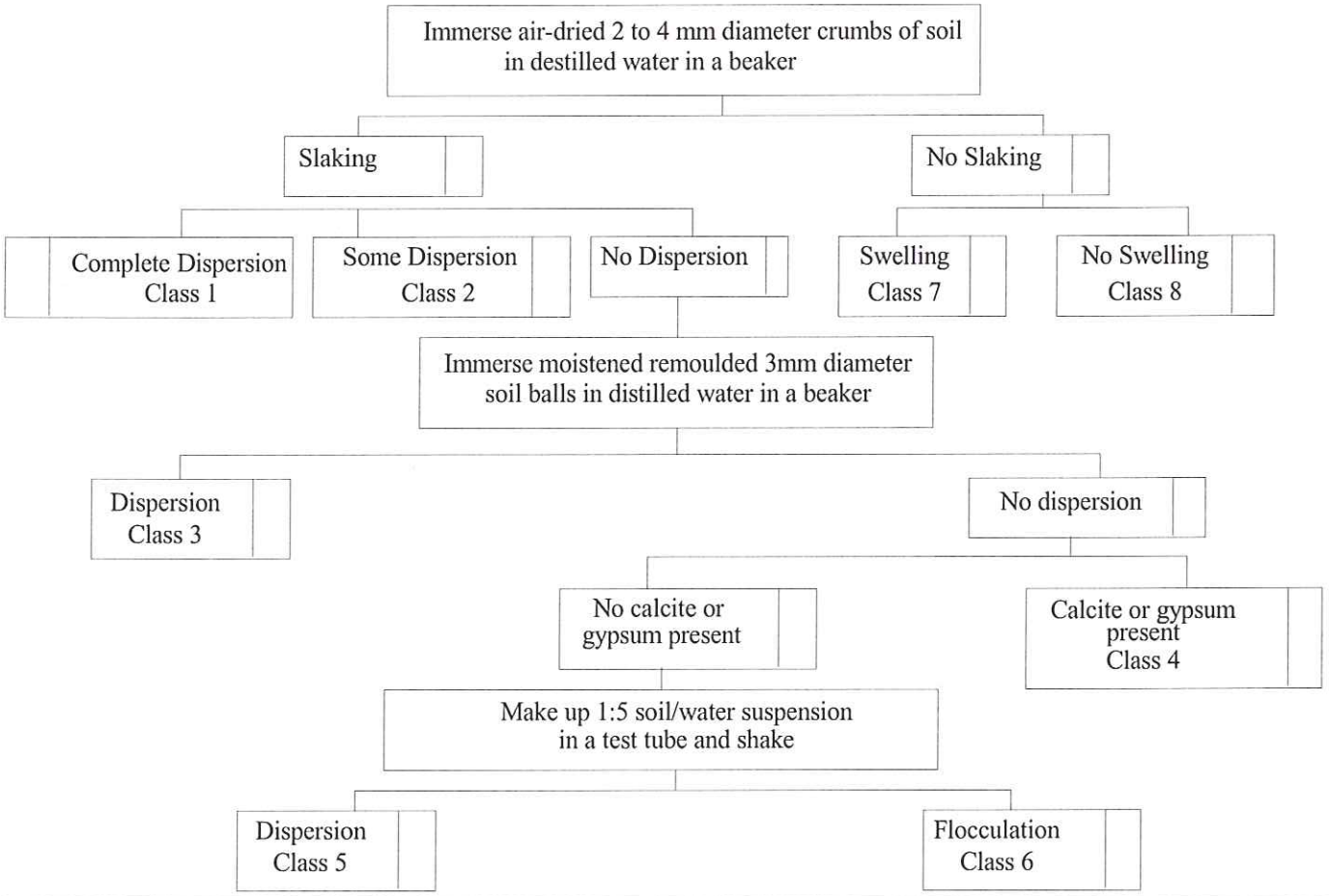
CLIENT: DAMS & CIVIL TECHNOLOGIES		REPORT No: 12031/3334/R1118
DISPERSION TESTS		
PROJECT: DUNOON DAM SITE		SAMPLE No: 3334
LOCATION: LOWER STORAGE AREA	HOLE No: DTP 16	DEPTH (m): 1.2

Determination of the Emerson Class Number of a soil



Emerson Class Number	(AS 1289.3.8.1)	No Test
Percent Dispersion	(AS 1289.3.8.2)**	No Test
Dispersal Index	(DPWS GM 15)	N.D.

Sample Description: Grey and Red Brown Mottled Silty Clay trace of Sand

Type and temperature of water: Distilled, 21.8 ° C

Notes on test: Sample tested as received from client.

** 0.05mm size interpolated from hydrometer readings taken after 21min, 1hour and 2 hours.

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Tested By: ZG/MA Date Tested: 30/10/2012

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Mark Ashover 08/11/2012

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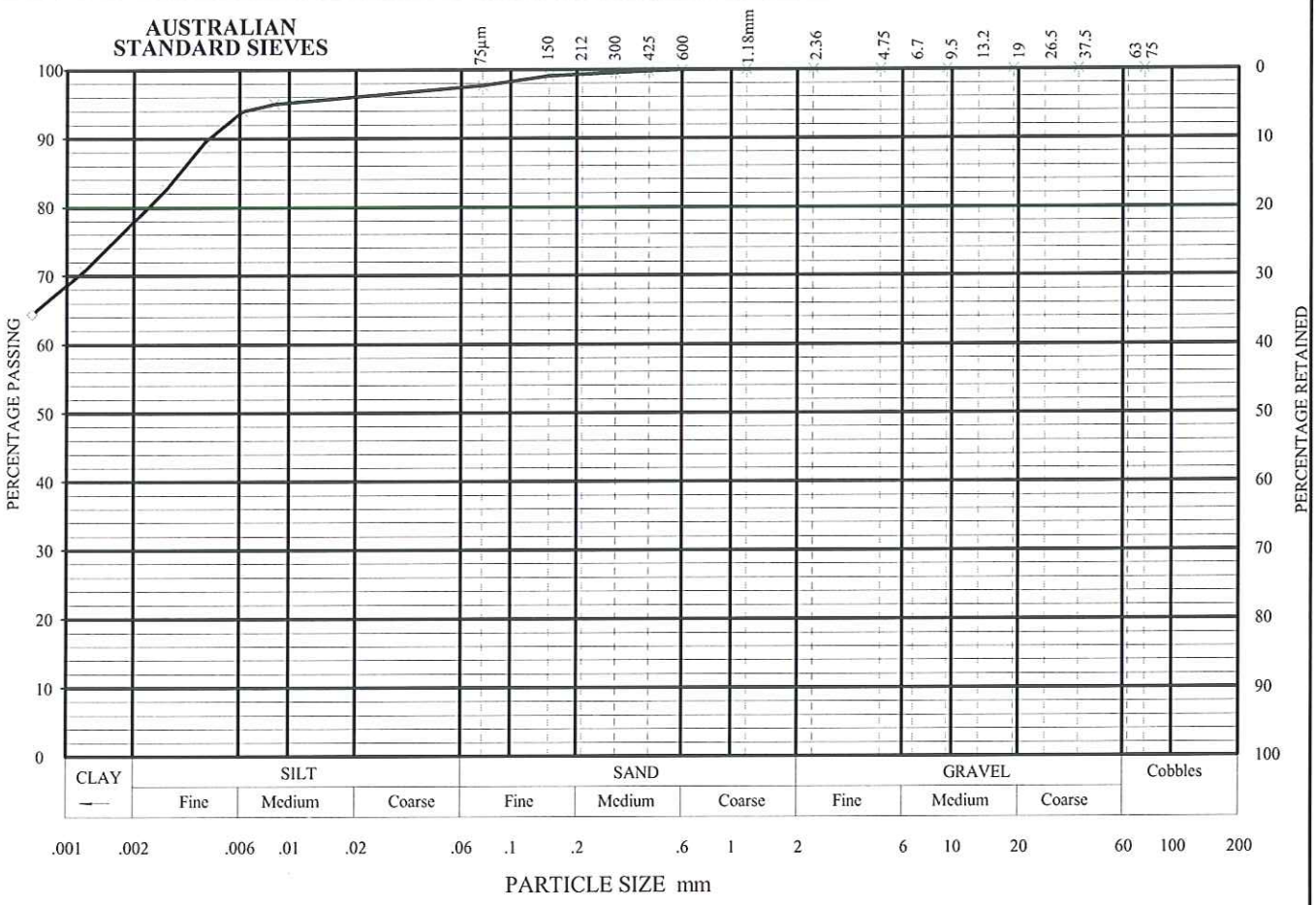
CLIENT: DAMS & CIVIL TECHNOLOGIES | REPORT No: 12031/3336/R1119

PARTICLE SIZE DISTRIBUTION

PROJECT: DUNOON DAM SITE | SAMPLE No: 3336

LOCATION: LOWER STORAGE AREA | HOLE No: DTP 19 | DEPTH (m): 0.5



SIZE DISTRIBUTION	
COBBLES	0 %
GRAVEL	0 %
SAND	3 %
SILT	20 %
CLAY	77 %
EFFECTIVE SIZE D10:	-
UNIFORMITY COEFFICIENT D60/D10(Cu):	-
CURVATURE COEFFICIENT $D30^2$ /(D60 x D10) (Cc):	-

Soil Particle Density: 2.65 t/m³ (estimated for analysis)

Method of dispersion: End-over-end shaking

Hydrometer: ASTM 152H

Dispersion chemical: Sodium hexametaphosphate + Anhydrous sodium carbonate

Notes on Test: Tested as received

Loss in pre-treatment: 0 %

Test Methods:
DPWS GM 9: Determination of the Particle Size Distribution of a Soil

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Tested By: MA/ZG Date Tested: 30/10/2012

APPROVED SIGNATORY

Mark Ashover 08/11/2012

PARTICLE SIZE DISTRIBUTION R1119 (ISSUE 4, 2005)

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CLIENT: DAMS & CIVIL TECHNOLOGIES		REPORT No: 12031/3336/R1115
SOIL INDEX PROPERTIES		
PROJECT: DUNOON DAM SITE		SAMPLE No: 3336
LOCATION: LOWER STORAGE AREA	HOLE No: DTP 19	DEPTH (m): 0.5

SOIL INDEX PROPERTIES		RESULT	TEST METHOD
Moisture Content (as received)	:	33.8 %	AS 1289.2.1.1
Liquid Limit	:	106 %	AS 1289.3.1.1
Plastic Limit	:	39 %	AS 1289.3.2.1
Plasticity Index	:	67 %	AS 1289.3.3.1
Linear Shrinkage	:	-	AS 1289.3.4.1
Soil Particle Density	:	-	GM 8
Classification	:	CH	AS 1726

Sample History: ☐ Natural State ☒ Air Dried ☐ Oven Dried

Method of Preparation: ☐ Wet Sieved ☒ Dry Sieved

Linear Shrinkage Sample: ☐ Curling ☐ Crumbling ☐ No Deformation

Notes on test: Sample tested as received from client.

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Tested By: ZG Date Tested: 05/11/2012

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Mark Ashover 08/11/2012

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NATA Accreditation Number: 13380

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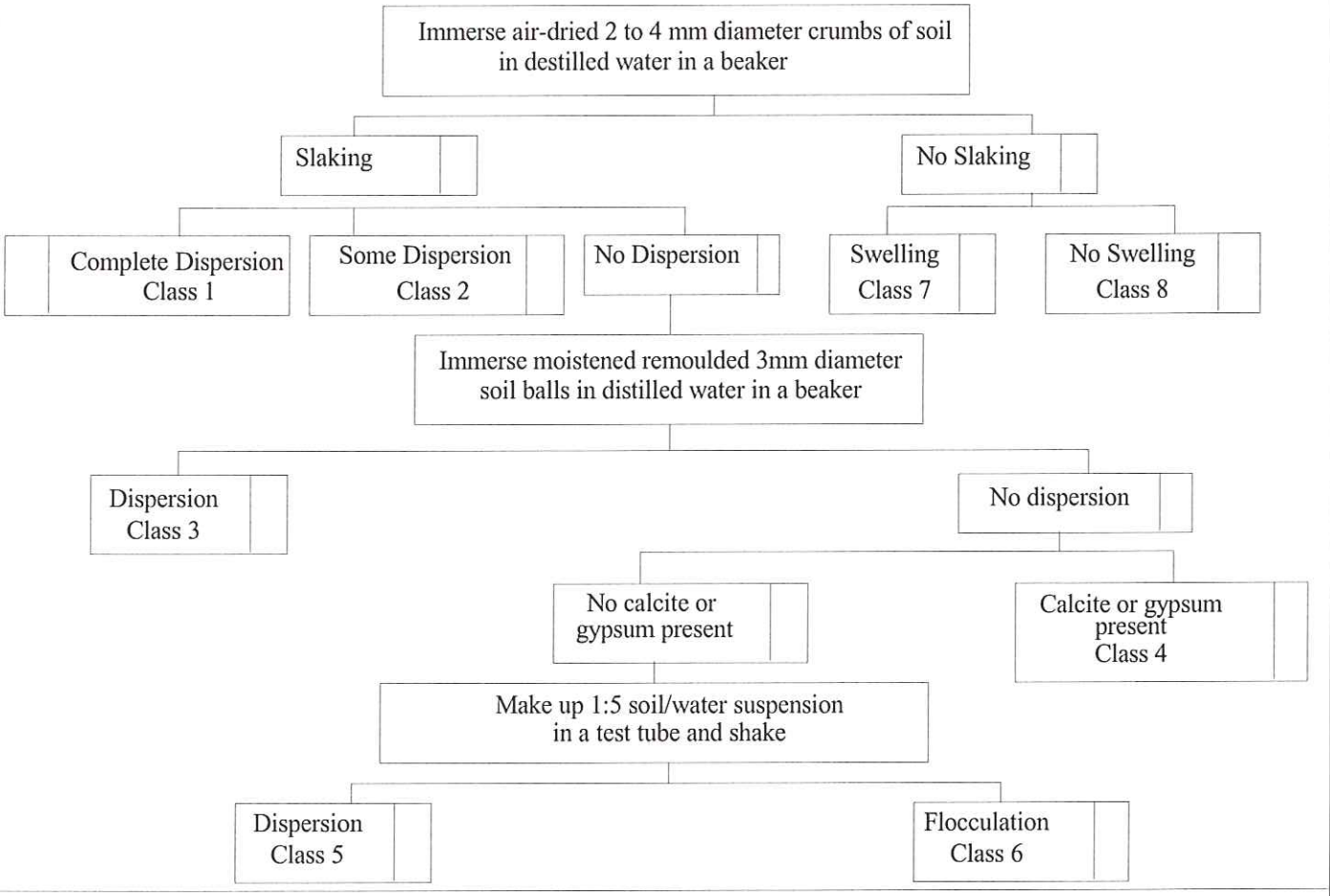
CLIENT: DAMS & CIVIL TECHNOLOGIES	REPORT No: 12031/3336/R1118

DISPERSION TESTS

PROJECT: DUNOON DAM SITE		SAMPLE No: 3336
LOCATION: LOWER STORAGE AREA	HOLE No: DTP 19	DEPTH (m): 0.5

Determination of the Emerson Class Number of a soil



Emerson Class Number	(AS 1289.3.8.1)	No Test
Percent Dispersion	(AS 1289.3.8.2)**	No Test
Dispersal Index	(DPWS GM 15)	4.0

Sample Description: Grey, Grey Brown and a trace of Red Brown Silty Clay trace of Sand

Type and temperature of water: Distilled, 20.9 ° C

Notes on test: Sample tested as received from client.

** 0.05mm size interpolated from hydrometer readings taken after 21min, 1hour and 2 hours.

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Tested By: ZG/MA Date Tested: 07/11/2012

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Mark Ashover 08/11/2012

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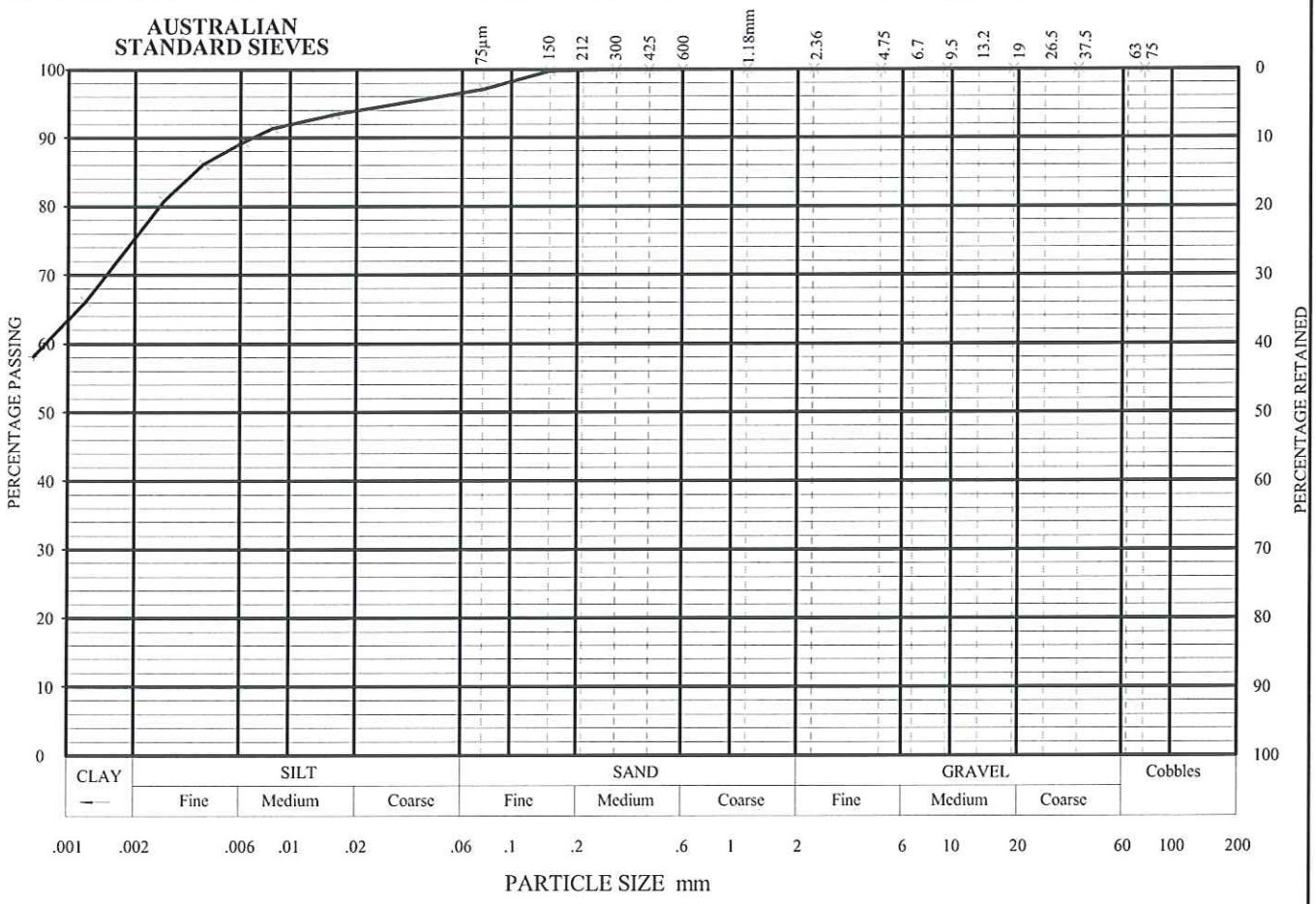
CLIENT: DAMS & CIVIL TECHNOLOGIES | REPORT No: 12031/3337/R1119

PARTICLE SIZE DISTRIBUTION

PROJECT: DUNOON DAM SITE | SAMPLE No: 3337

LOCATION: LOWER STORAGE AREA | HOLE No: DTP 19 | DEPTH (m): 1.0



SIZE DISTRIBUTION	
COBBLES	0 %
GRAVEL	0 %
SAND	4 %
SILT	22 %
CLAY	74 %
EFFECTIVE SIZE D10:	-
UNIFORMITY COEFFICIENT D60/D10(Cu):	-
CURVATURE COEFFICIENT $D30^2$ /(D60 x D10) (Cc):	-

Soil Particle Density: 2.65 t/m³ (estimated for analysis)

Method of dispersion: End-over-end shaking

Hydrometer: ASTM 152H

Dispersion chemical: Sodium hexametaphosphate + Anhydrous sodium carbonate

Notes on Test: Tested as received

Loss in pre-treatment: 0 %

Test Methods:
DPWS GM 9: Determination of the Particle Size Distribution of a Soil

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Tested By: MA/ZG Date Tested: 30/10/2012

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PARTICLE SIZE DISTRIBUTION R1119 (ISSUE 4, 2005)

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CLIENT: DAMS & CIVIL TECHNOLOGIES | REPORT No: 12031/3337/R1115

SOIL INDEX PROPERTIES

PROJECT: DUNOON DAM SITE | SAMPLE No: 3337

LOCATION: LOWER STORAGE AREA | HOLE No: DTP 19 | DEPTH (m): 1.0

SOIL INDEX PROPERTIES		RESULT		TEST METHOD
Moisture Content (as received)	:	32.5	%	AS 1289.2.1.1
Liquid Limit	:	100	%	AS 1289.3.1.1
Plastic Limit	:	38	%	AS 1289.3.2.1
Plasticity Index	:	62	%	AS 1289.3.3.1
Linear Shrinkage	:	-		AS 1289.3.4.1
Soil Particle Density	:	-		GM 8
Classification	:	CH		AS 1726

Sample History: ☐ Natural State ☒ Air Dried ☐ Oven Dried

Method of Preparation: ☐ Wet Sieved ☒ Dry Sieved

Linear Shrinkage Sample: ☐ Curling ☐ Crumbling ☐ No Deformation

Notes on test: Sample tested as received from client.

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Tested By: ZG Date Tested: 05/11/2012

APPROVED SIGNATORY M. Ashover

Mark Ashover 08/11/2012

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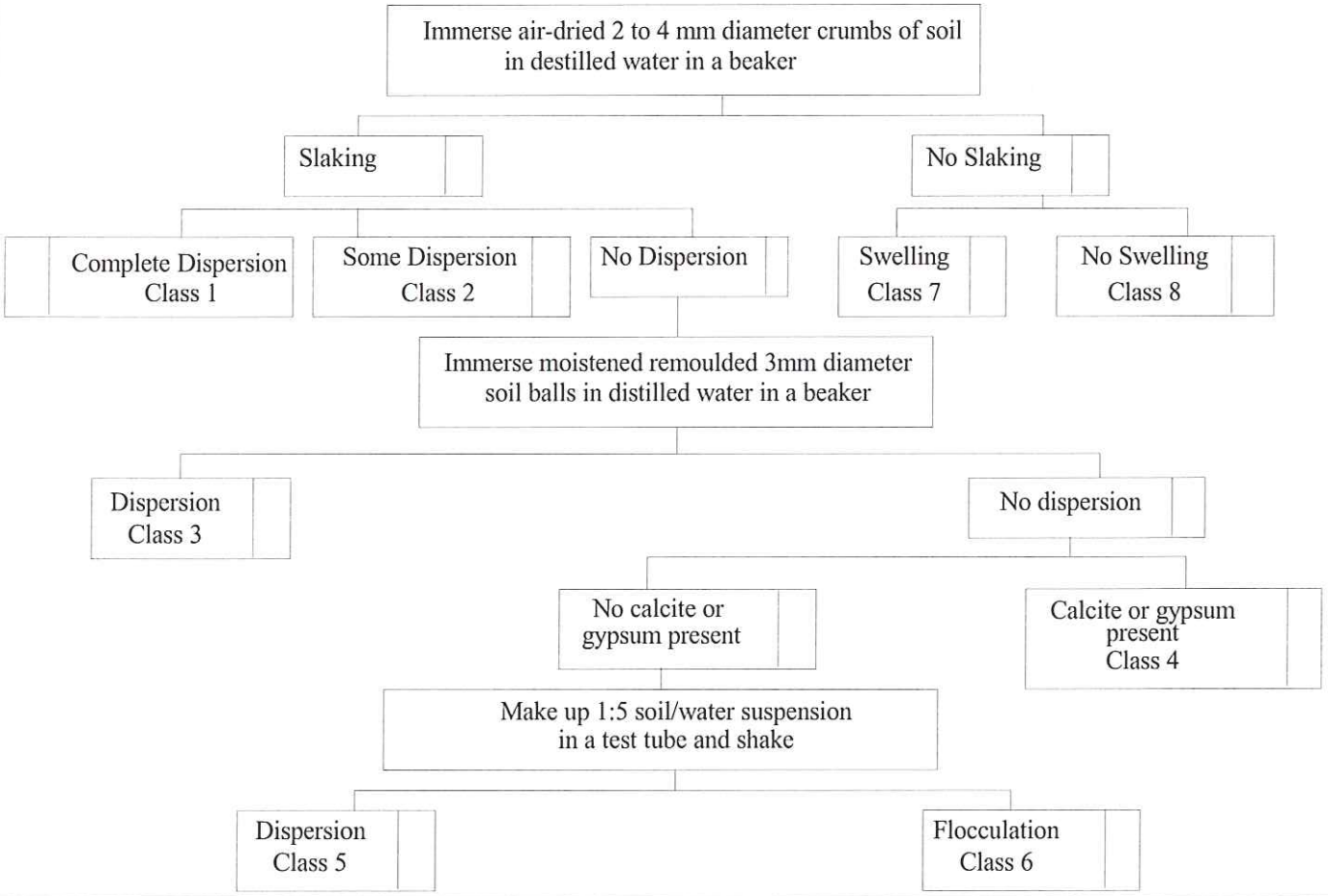
CLIENT: DAMS & CIVIL TECHNOLOGIES		REPORT No: 12031/3337/R1118
DISPERSION TESTS		
PROJECT: DUNOON DAM SITE		SAMPLE No: 3337
LOCATION: LOWER STORAGE AREA	HOLE No: DTP 19	DEPTH (m): 1.0

Determination of the Emerson Class Number of a soil



Emerson Class Number	(AS 1289.3.8.1)	No Test
Percent Dispersion	(AS 1289.3.8.2)**	No Test
Dispersal Index	(DPWS GM 15)	N.D.

Sample Description: Light Grey with minor Red Brown Mottles Silty Clay trace of Sand

Type and temperature of water: Distilled, 20.8 ° C

Notes on test: Sample tested as received from client.

** 0.05mm size interpolated from hydrometer readings taken after 21min, 1hour and 2 hours.

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Tested By: ZG/MA Date Tested: 07/11/2012

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NATA Accreditation Number: 13380

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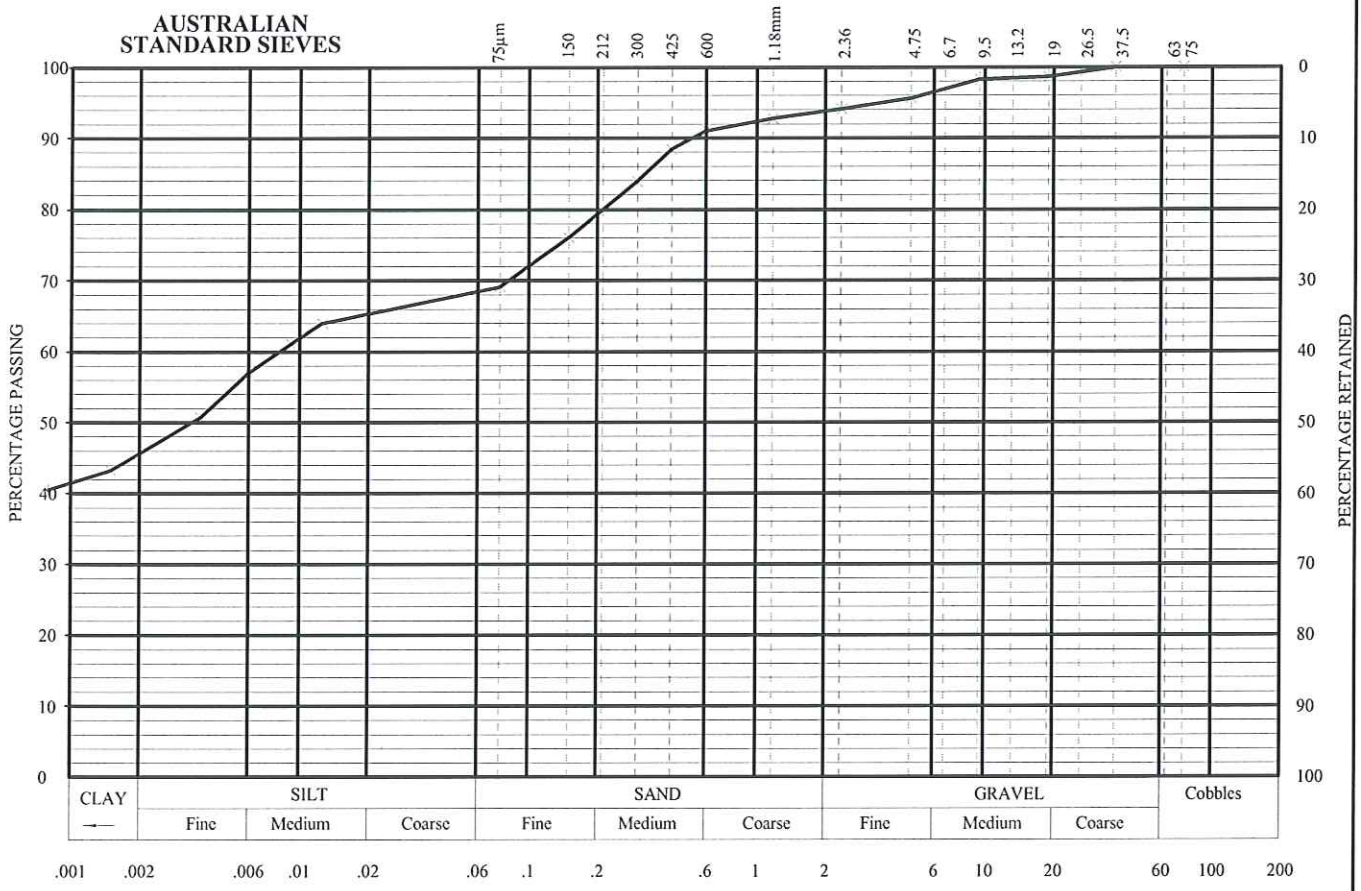
CLIENT: DAMS & CIVIL TECHNOLOGIES | REPORT No: 12031/3338/R1119

PARTICLE SIZE DISTRIBUTION

PROJECT: DUNOON DAM SITE | SAMPLE No: 3338

LOCATION: LOWER STORAGE AREA | HOLE No: DTP 20 | DEPTH (m): 0.30



SIZE DISTRIBUTION	
COBBLES	0 %
GRAVEL	6 %
SAND	26 %
SILT	23 %
CLAY	45 %
EFFECTIVE SIZE D10:	-
UNIFORMITY COEFFICIENT D60/D10(Cu):	-
CURVATURE COEFFICIENT $D30^2$ /(D60 x D10) (Cc):	-

Soil Particle Density: 2.65 t/m³ (estimated for analysis)

Method of dispersion: End-over-end shaking

Hydrometer: ASTM 152H

Dispersion chemical: Sodium hexametaphosphate + Anhydrous sodium carbonate

Notes on Test: Tested as received

Loss in pre-treatment: 0 %

Test Methods:
DPWS GM 9: Determination of the Particle Size Distribution of a Soil

Tested By: MA/ZG Date Tested: 30/10/2012

APPROVED SIGNATORY M. Ashover

Mark Ashover 08/11/2012

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NSW GOVERNMENT | Public Works
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CLIENT: DAMS & CIVIL TECHNOLOGIES | REPORT No: 12031/3338/R1115

SOIL INDEX PROPERTIES

PROJECT: DUNOON DAM SITE | SAMPLE No: 3338

LOCATION: LOWER STORAGE AREA | HOLE No: DTP 20 | DEPTH (m): 0.30

SOIL INDEX PROPERTIES		RESULT		TEST METHOD
Moisture Content (as received)	:	18.0	%	AS 1289.2.1.1
Liquid Limit	:	54	%	AS 1289.3.1.1
Plastic Limit	:	26	%	AS 1289.3.2.1
Plasticity Index	:	28	%	AS 1289.3.3.1
Linear Shrinkage	:	-		AS 1289.3.4.1
Soil Particle Density	:	-		GM 8
Classification	:	CH		AS 1726

Sample History: ☐ Natural State ☒ Air Dried ☐ Oven Dried

Method of Preparation: ☐ Wet Sieved ☒ Dry Sieved

Linear Shrinkage Sample: ☐ Curling ☐ Crumbling ☐ No Deformation

Notes on test: Sample tested as received from client.

ATTERBERG LIMITS R1115 (ISSUE 4, 2005)

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Tested By: ZG Date Tested: 05/11/2012

APPROVED SIGNATORY M. Ashover

Mark Ashover 08/11/2012

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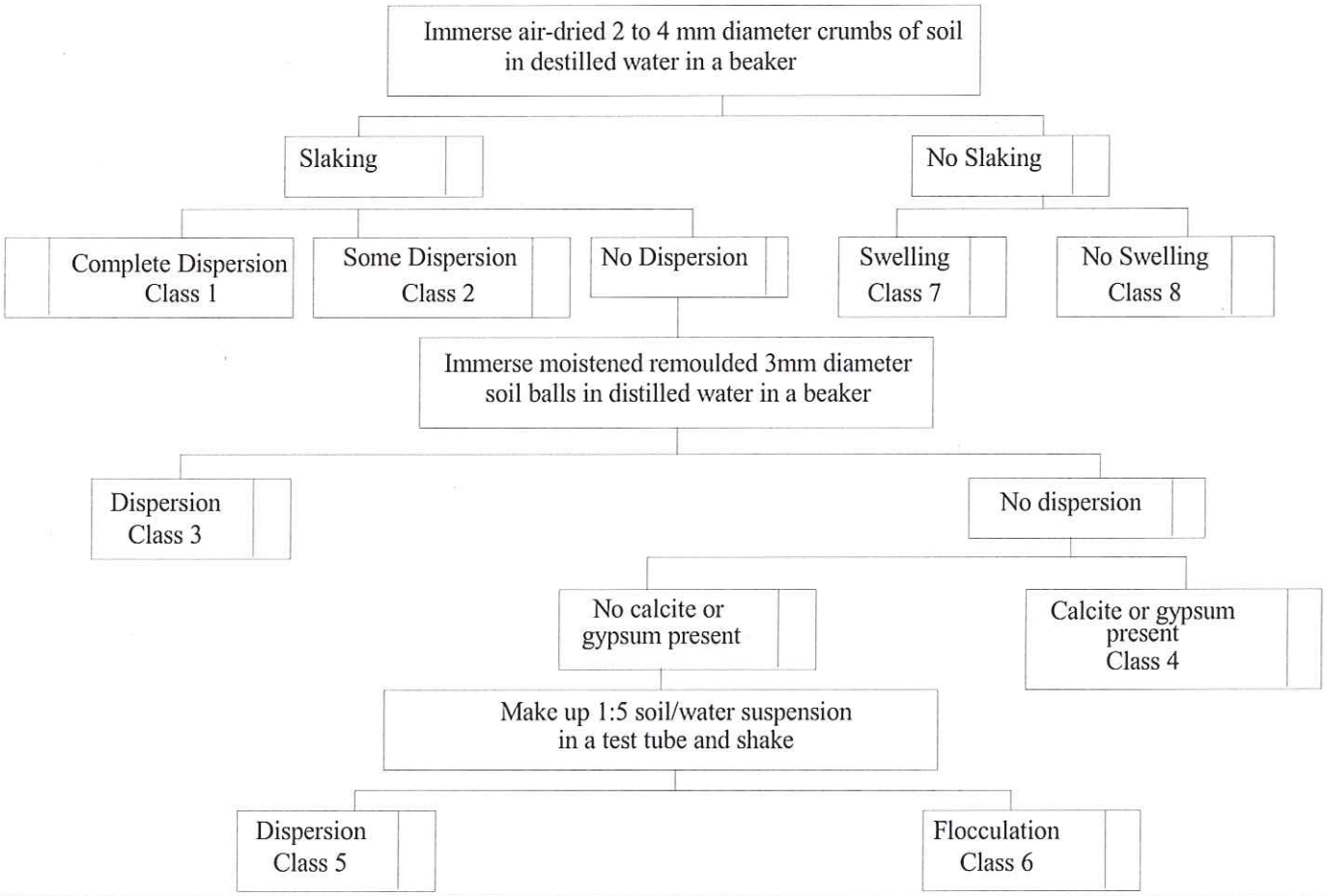
CLIENT: DAMS & CIVIL TECHNOLOGIES		REPORT No: 12031/3338/R1118
DISPERSION TESTS		
PROJECT: DUNOON DAM SITE		SAMPLE No: 3338
LOCATION: LOWER STORAGE AREA	HOLE No: DTP 20	DEPTH (m): 0.30

Determination of the Emerson Class Number of a soil



Emerson Class Number	(AS 1289.3.8.1)	No Test
Percent Dispersion	(AS 1289.3.8.2)**	No Test
Dispersal Index	(DPWS GM 15)	6.0

Sample Description: Grey Brown with Brown and traces of Red Brown Silty Clay with Sand and trace of Gravel
Type and temperature of water: Distilled, 20.8 ° C

Notes on test: Sample tested as received from client.
** 0.05mm size interpolated from hydrometer readings taken after 21min, 1hour and 2 hours.

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Tested By: ZG/MA Date Tested: 07/11/2012

APPROVED SIGNATORY M. Ashover

Mark Ashover 08/11/2012

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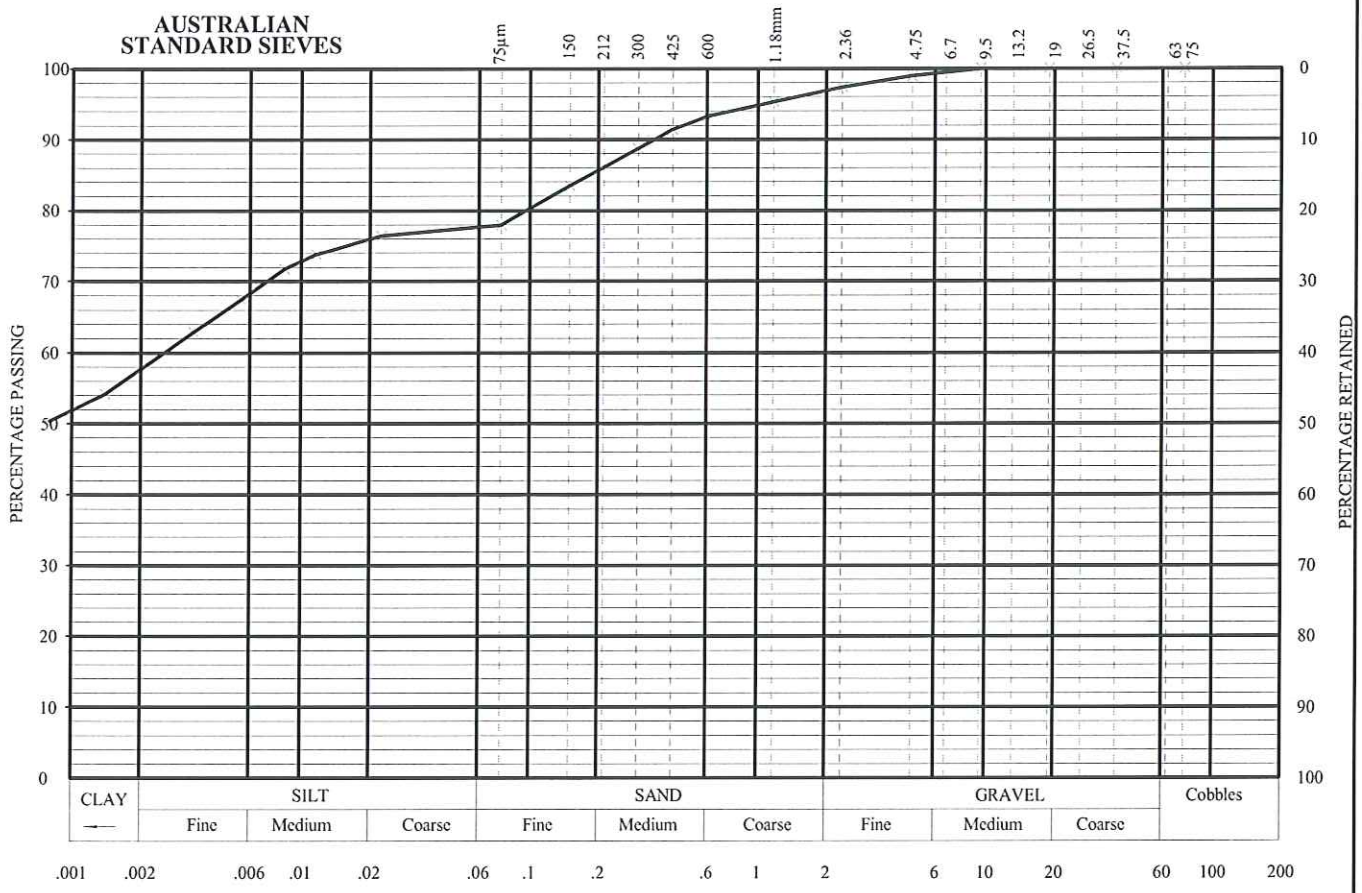
CLIENT: DAMS & CIVIL TECHNOLOGIES | REPORT No: 12031/3339/R1119

PARTICLE SIZE DISTRIBUTION

PROJECT: DUNOON DAM SITE | SAMPLE No: 3339

LOCATION: LOWER STORAGE AREA | HOLE No: DTP 20 | DEPTH (m): 1.0



SIZE DISTRIBUTION

COBBLES	0 %
GRAVEL	3 %
SAND	20 %
SILT	20 %
CLAY	57 %
EFFECTIVE SIZE D10:	-
UNIFORMITY COEFFICIENT D60/D10(Cu):	-
CURVATURE COEFFICIENT $D30^2$ /(D60 x D10) (Cc):	-

Soil Particle Density: 2.65 t/m³ (estimated for analysis)

Method of dispersion: End-over-end shaking

Hydrometer: ASTM 152H

Dispersion chemical: Sodium hexametaphosphate + Anhydrous sodium carbonate

Notes on Test: Tested as received

Loss in pre-treatment: 0 %

Test Methods:
DPWS GM 9: Determination of the Particle Size Distribution of a Soil

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Tested By: MA/ZG Date Tested: 30/10/2012

APPROVED SIGNATORY M. Ashover

Mark Ashover 08/11/2012

PARTICLE SIZE DISTRIBUTION R1119 (ISSUE 4, 2005)

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CLIENT: DAMS & CIVIL TECHNOLOGIES	REPORT No: 12031/3339/R1115

SOIL INDEX PROPERTIES

PROJECT: DUNOON DAM SITE	SAMPLE No: 3339

LOCATION: LOWER STORAGE AREA	HOLE No: DTP 20	DEPTH (m): 1.0

SOIL INDEX PROPERTIES		RESULT		TEST METHOD
Moisture Content (as received)	:	32.2	%	AS 1289.2.1.1
Liquid Limit	:	81	%	AS 1289.3.1.1
Plastic Limit	:	36	%	AS 1289.3.2.1
Plasticity Index	:	45	%	AS 1289.3.3.1
Linear Shrinkage	:	-		AS 1289.3.4.1
Soil Particle Density	:	-		GM 8
Classification	:	CH-MH		AS 1726

Sample History: ☐ Natural State ☒ Air Dried ☐ Oven Dried

Method of Preparation: ☐ Wet Sieved ☒ Dry Sieved

Linear Shrinkage Sample: ☐ Curling ☐ Crumbling ☐ No Deformation

Notes on test: Sample tested as received from client.

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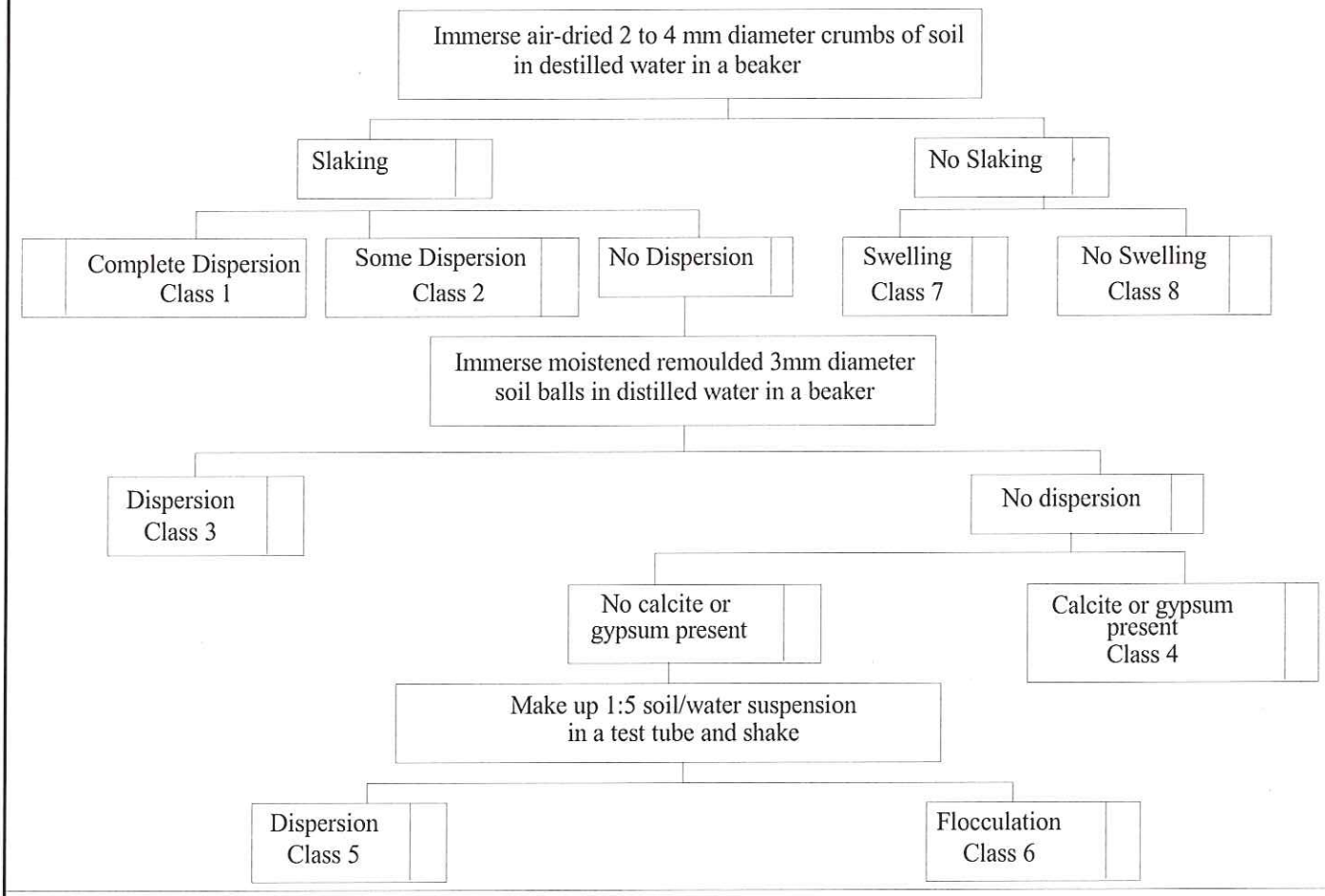
CLIENT: DAMS & CIVIL TECHNOLOGIES	REPORT No: 12031/3339/R1118

DISPERSION TESTS

PROJECT: DUNOON DAM SITE		SAMPLE No: 3339
LOCATION: LOWER STORAGE AREA	HOLE No: DTP 20	DEPTH (m): 1.0

Determination of the Emerson Class Number of a soil



Emerson Class Number	(AS 1289.3.8.1)	No Test
Percent Dispersion	(AS 1289.3.8.2)**	No Test
Dispersal Index	(DPWS GM 15)	N.D.

Sample Description: Red Brown with Dark Grey Silty Clay with Sand and trace of Gravel

Type and temperature of water: Distilled, 20.8 ° C

Notes on test: Sample tested as received from client.

** 0.05mm size interpolated from hydrometer readings taken after 21min, 1hour and 2 hours.

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Tested By: ZG/MA Date Tested: 07/11/2012

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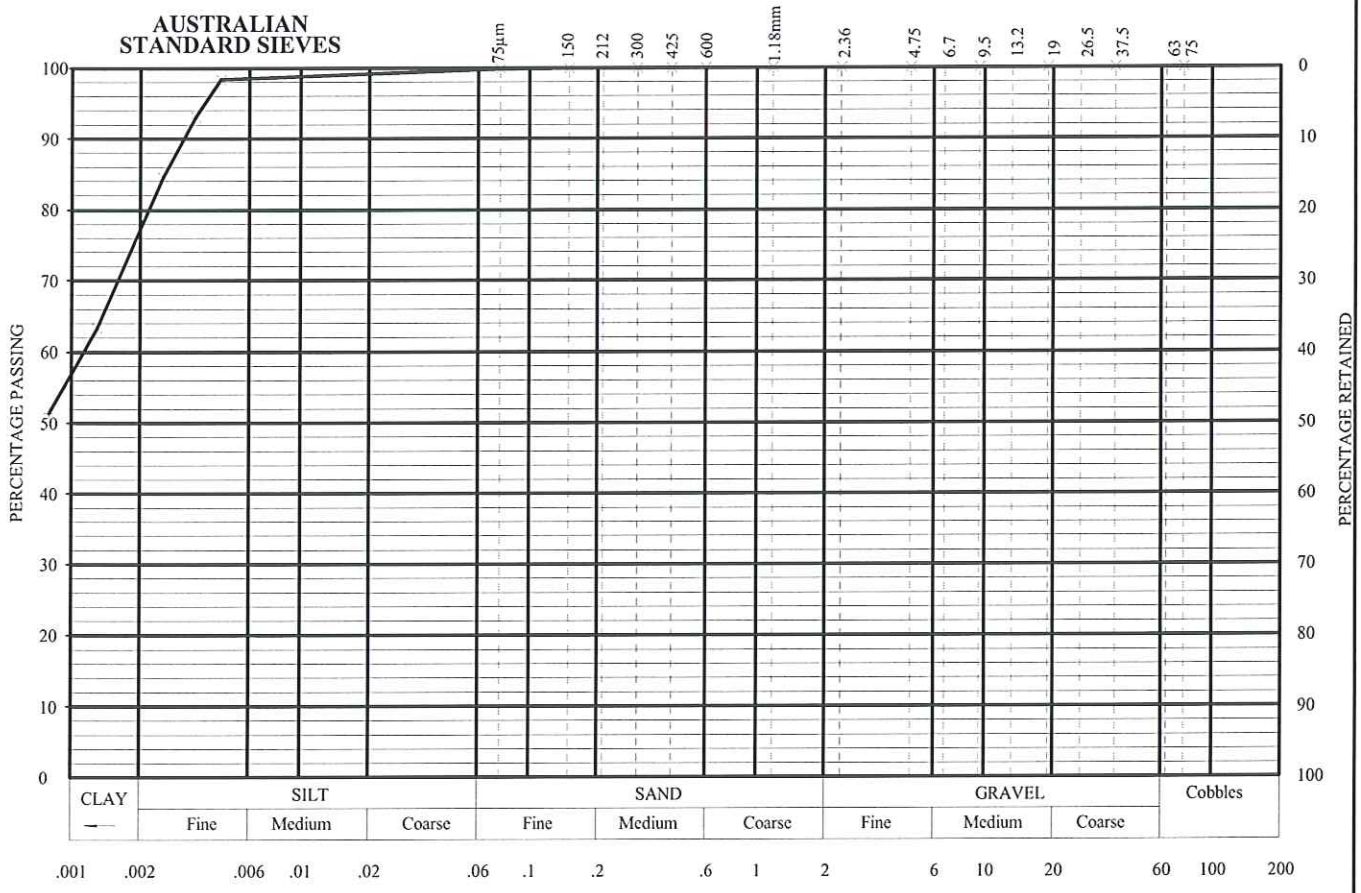
CLIENT: DAMS & CIVIL TECHNOLOGIES | REPORT No: 12031/3340/R1119

PARTICLE SIZE DISTRIBUTION

PROJECT: DUNOON DAM SITE | SAMPLE No: 3340

LOCATION: LOWER STORAGE AREA | HOLE No: DTP 21 | DEPTH (m): 1.1



SIZE DISTRIBUTION	
COBBLES	0 %
GRAVEL	0 %
SAND	1 %
SILT	23 %
CLAY	76 %
EFFECTIVE SIZE D10:	-
UNIFORMITY COEFFICIENT D60/D10(Cu):	-
CURVATURE COEFFICIENT $D30^2$ /(D60 x D10) (Cc):	-

Soil Particle Density: 2.65 t/m³ (estimated for analysis)

Method of dispersion: End-over-end shaking

Hydrometer: ASTM 152H

Dispersion chemical: Sodium hexametaphosphate + Anhydrous sodium carbonate

Notes on Test: Tested as received

Loss in pre-treatment: 0 %

Test Methods:
DPWS GM 9: Determination of the Particle Size Distribution of a Soil

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Tested By: MA/ZG Date Tested: 30/10/2012

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PARTICLE SIZE DISTRIBUTION R1119 (ISSUE 4, 2005)

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CLIENT: DAMS & CIVIL TECHNOLOGIES | REPORT No: 12031/3340/R1115

SOIL INDEX PROPERTIES

PROJECT: DUNOON DAM SITE | SAMPLE No: 3340

LOCATION: LOWER STORAGE AREA | HOLE No: DTP 21 | DEPTH (m): 1.1

SOIL INDEX PROPERTIES		RESULT		TEST METHOD
Moisture Content (as received)	:	27.7	%	AS 1289.2.1.1
Liquid Limit	:	81	%	AS 1289.3.1.1
Plastic Limit	:	34	%	AS 1289.3.2.1
Plasticity Index	:	47	%	AS 1289.3.3.1
Linear Shrinkage	:	-		AS 1289.3.4.1
Soil Particle Density	:	-		GM 8
Classification	:	CH		AS 1726

Sample History: ☐ Natural State ☒ Air Dried ☐ Oven Dried

Method of Preparation: ☐ Wet Sieved ☒ Dry Sieved

Linear Shrinkage Sample: ☐ Curling ☐ Crumbling ☐ No Deformation

Notes on test: Sample tested as received from client.

ATTERBERG LIMITS R1115 (ISSUE 4, 2005)

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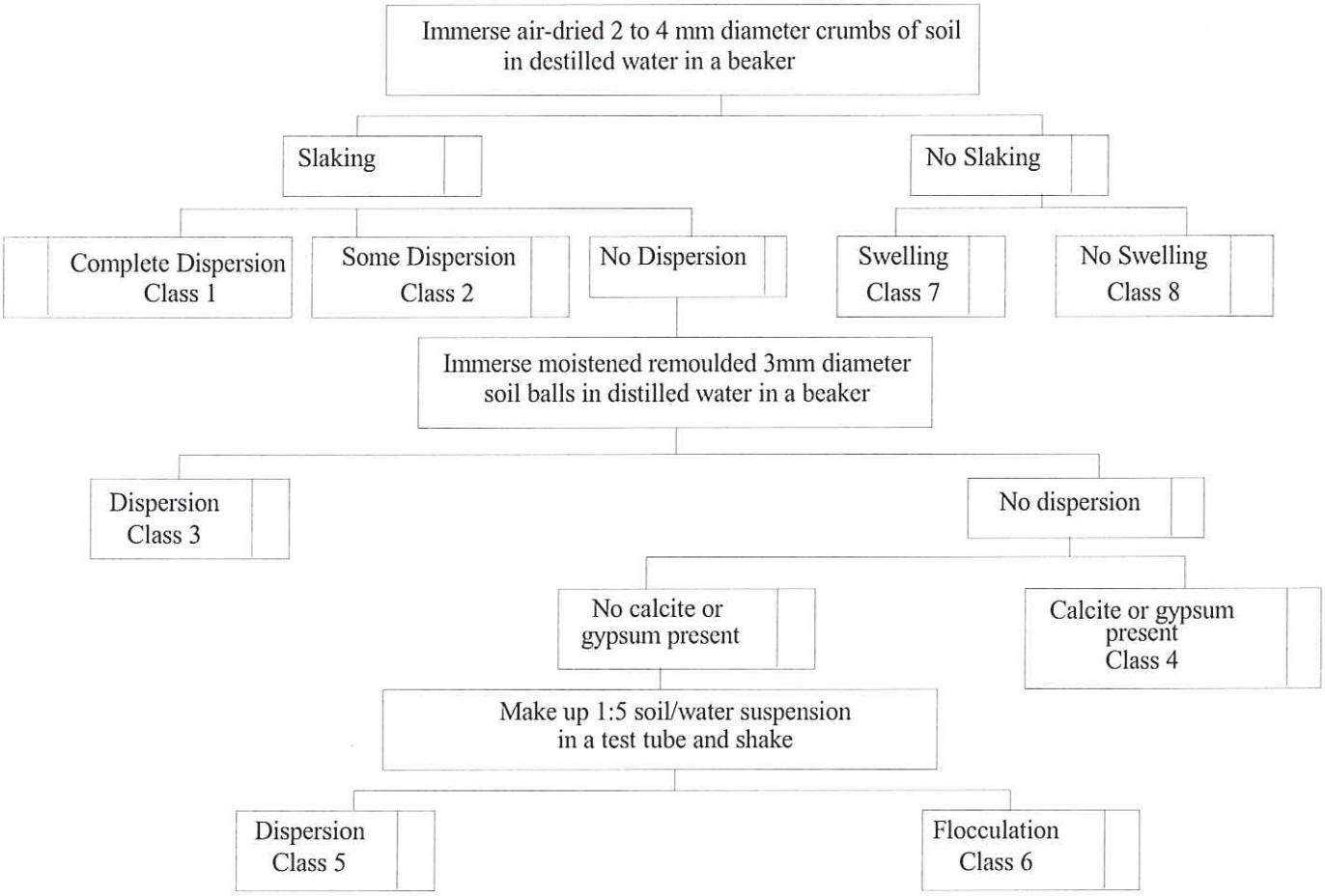
CLIENT: DAMS & CIVIL TECHNOLOGIES | REPORT No: 12031/3340/R1118

DISPERSION TESTS

PROJECT: DUNOON DAM SITE | SAMPLE No: 3340

LOCATION: LOWER STORAGE AREA | HOLE No: DTP 21 | DEPTH (m): 1.1

Determination of the Emerson Class Number of a soil



Emerson Class Number	(AS 1289.3.8.1)	No Test
Percent Dispersion	(AS 1289.3.8.2)**	No Test
Dispersal Index	(DPWS GM 15)	5.4

Sample Description: Grey with traces of Red Brown and Black Silty Clay

Type and temperature of water: Distilled, 21.2 ° C

Notes on test: Sample tested as received from client.

** 0.05mm size interpolated from hydrometer readings taken after 21min, 1hour and 2 hours.

DISPERSIVE SOILS R1118 (ISSUE 4, 2005)

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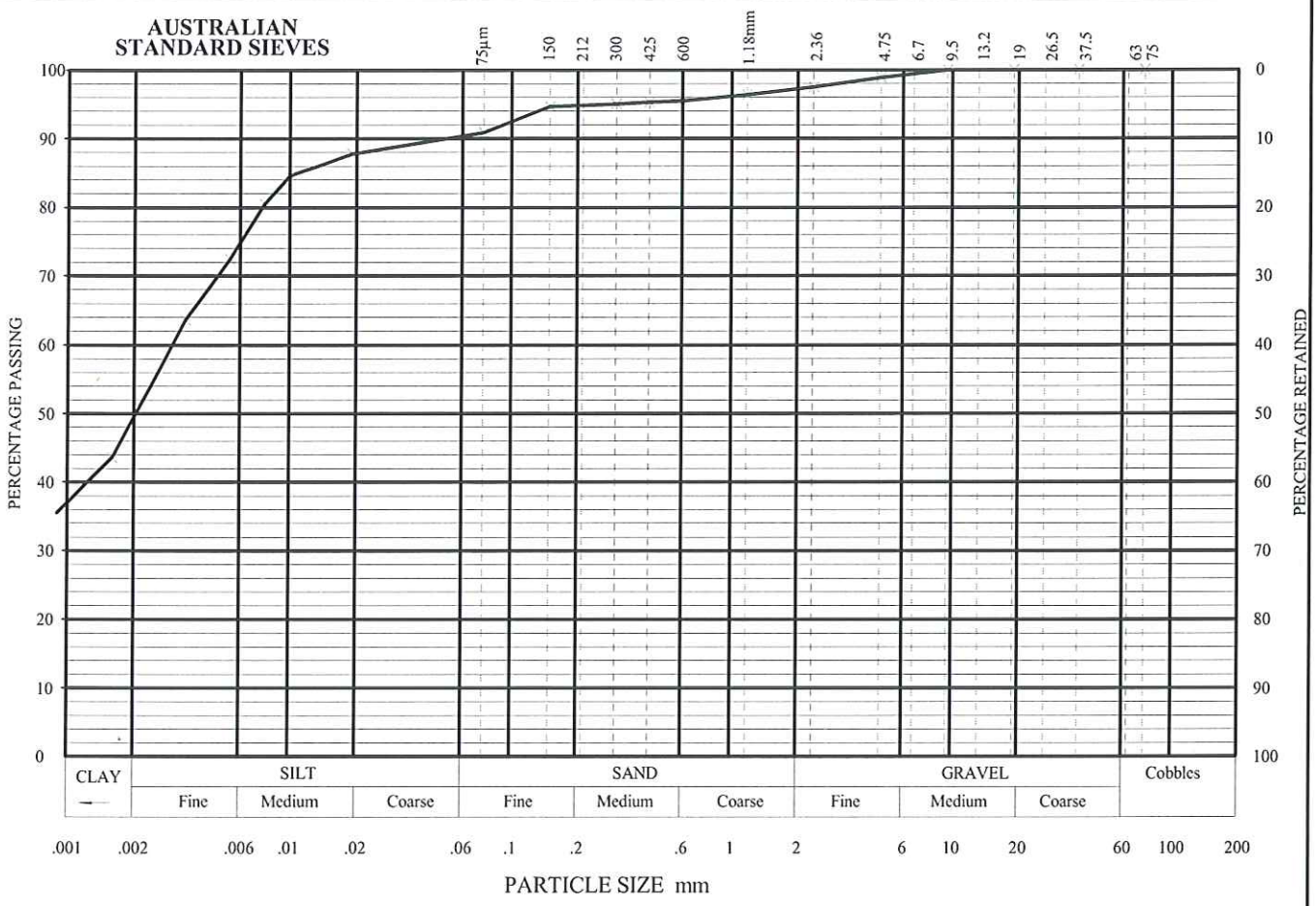
CLIENT: DAMS & CIVIL TECHNOLOGIES | REPORT No: 12031/3341/R1119

PARTICLE SIZE DISTRIBUTION

PROJECT: DUNOON DAM SITE | SAMPLE No: 3341

LOCATION: LOWER STORAGE AREA | HOLE No: DTP 23 | DEPTH (m): 0.75



SIZE DISTRIBUTION	
COBBLES	0 %
GRAVEL	3 %
SAND	7 %
SILT	42 %
CLAY	48 %
EFFECTIVE SIZE D10:	-
UNIFORMITY COEFFICIENT D60/D10(Cu):	-
CURVATURE COEFFICIENT $D30^2$ /(D60 x D10) (Cc):	-

Soil Particle Density: 2.65 t/m³ (estimated for analysis)

Method of dispersion: End-over-end shaking

Hydrometer: ASTM 152H

Dispersion chemical: Sodium hexametaphosphate + Anhydrous sodium carbonate

Notes on Test: Tested as received

Loss in pre-treatment: 0 %

Test Methods:
DPWS GM 9: Determination of the Particle Size Distribution of a Soil

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Tested By: MA/ZG Date Tested: 30/10/2012

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PARTICLE SIZE DISTRIBUTION R1119 (ISSUE 4, 2005)

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CLIENT: DAMS & CIVIL TECHNOLOGIES | REPORT No: 12031/3341/R1115

SOIL INDEX PROPERTIES

PROJECT: DUNOON DAM SITE | SAMPLE No: 3341

LOCATION: LOWER STORAGE AREA | HOLE No: DTP 23 | DEPTH (m): 0.75

SOIL INDEX PROPERTIES		RESULT		TEST METHOD
Moisture Content (as received)	:	23.6	%	AS 1289.2.1.1
Liquid Limit	:	65	%	AS 1289.3.1.1
Plastic Limit	:	31	%	AS 1289.3.2.1
Plasticity Index	:	34	%	AS 1289.3.3.1
Linear Shrinkage	:	-		AS 1289.3.4.1
Soil Particle Density	:	-		GM 8
Classification	:	CH		AS 1726

Sample History: ☐ Natural State ☒ Air Dried ☐ Oven Dried

Method of Preparation: ☐ Wet Sieved ☒ Dry Sieved

Linear Shrinkage Sample: ☐ Curling ☐ Crumbling ☐ No Deformation

Notes on test: Sample tested as received from client.

ATTERBERG LIMITS R1115 (ISSUE 4, 2005)

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Tested By: ZG Date Tested: 07/11/2012

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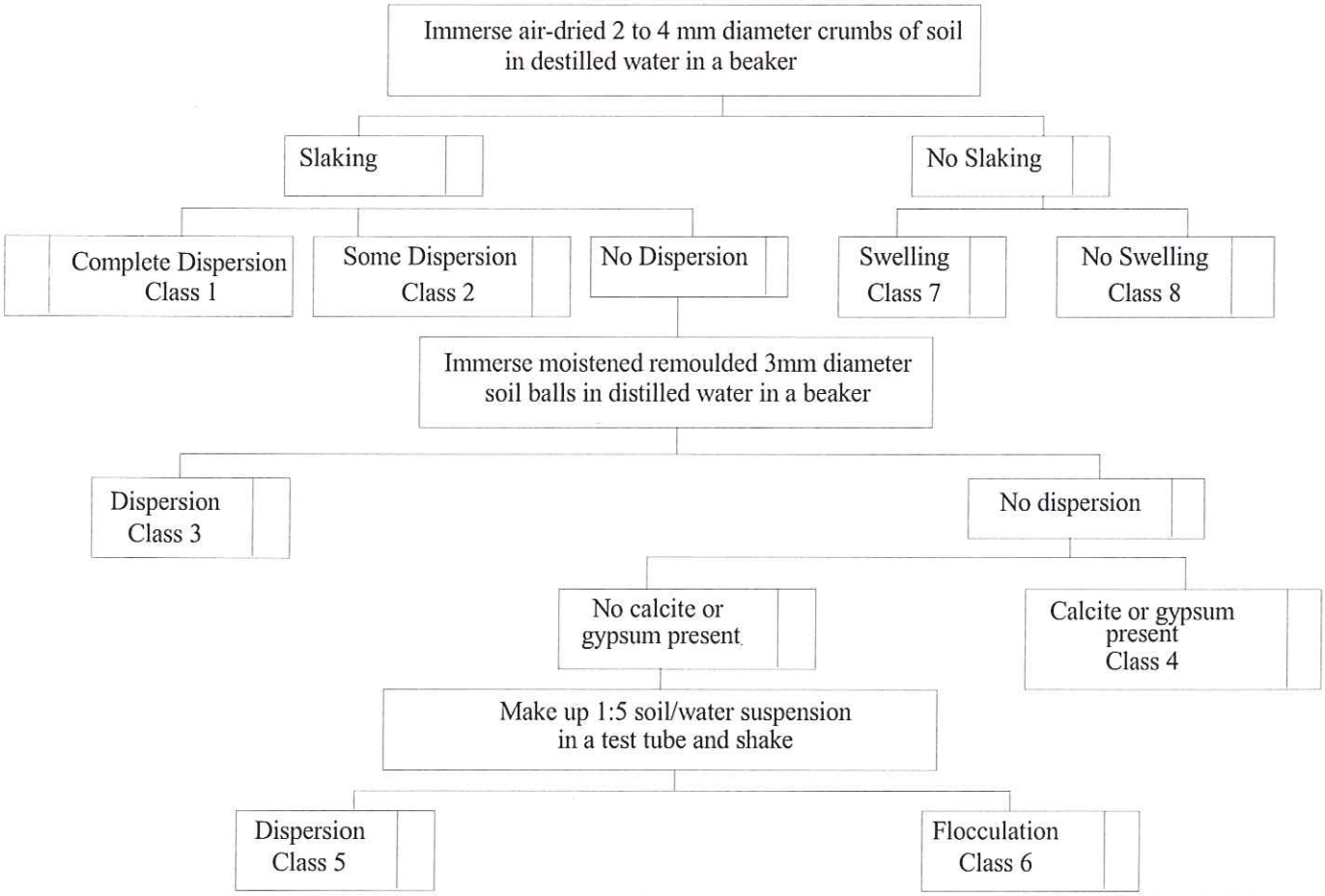
CLIENT: DAMS & CIVIL TECHNOLOGIES		REPORT No: 12031/3341/R1118
DISPERSION TESTS		
PROJECT: DUNOON DAM SITE		SAMPLE No: 3341
LOCATION: LOWER STORAGE AREA	HOLE No: DTP 23	DEPTH (m): 0.75

Determination of the Emerson Class Number of a soil



Emerson Class Number	(AS 1289.3.8.1)	No Test
Percent Dispersion	(AS 1289.3.8.2)**	No Test
Dispersal Index	(DPWS GM 15)	4.0

Sample Description: Grey/Dark Grey with Brown and Red Brown Mottles Silty Clay trace of Sand and Gravel

Type and temperature of water: Distilled, 21.4 ° C

Notes on test: Sample tested as received from client.

** 0.05mm size interpolated from hydrometer readings taken after 21min, 1hour and 2 hours.

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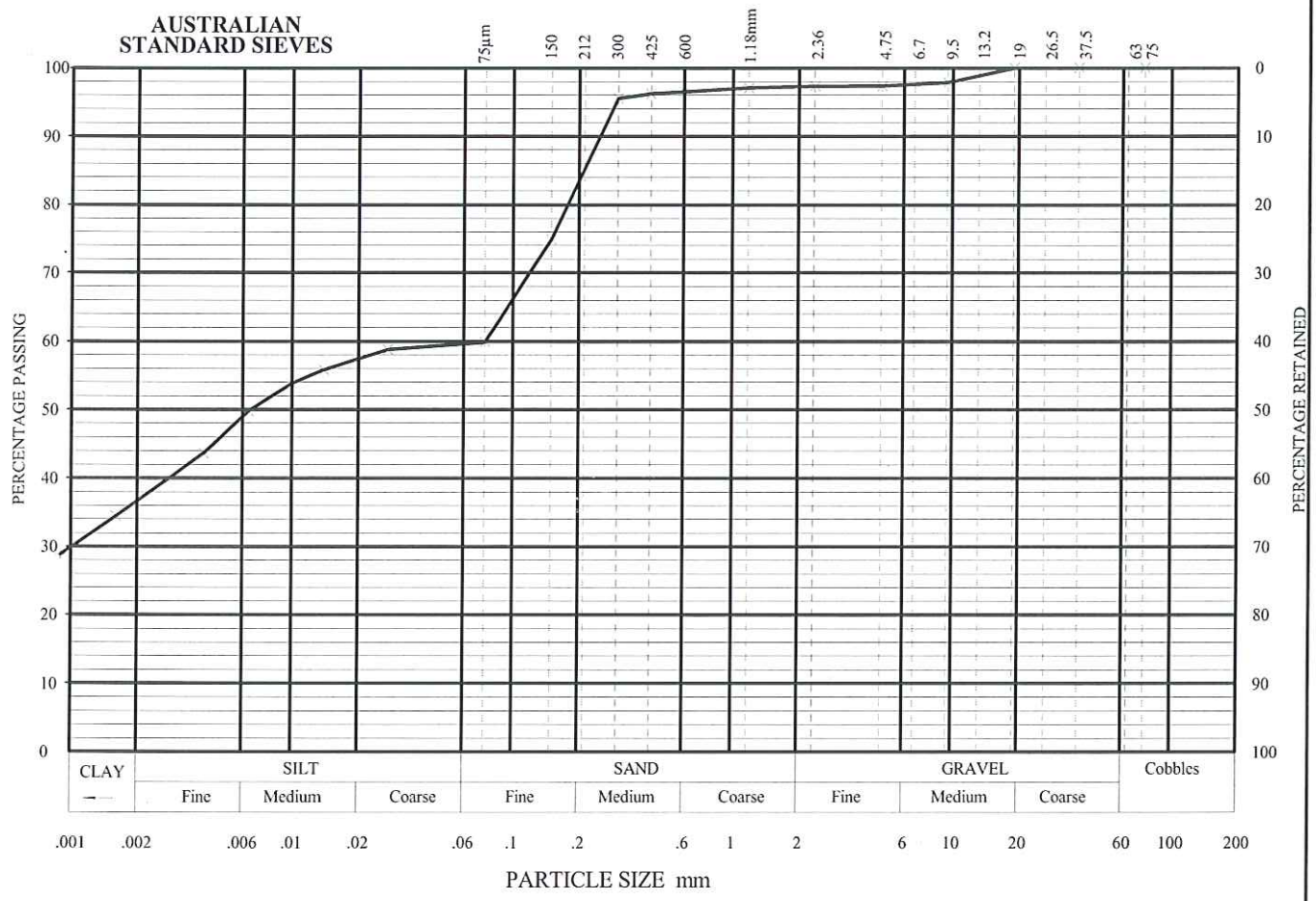
CLIENT: DAMS & CIVIL TECHNOLOGIES | REPORT No: 12031/3344/R1119

PARTICLE SIZE DISTRIBUTION

PROJECT: DUNOON DAM SITE | SAMPLE No: 3344

LOCATION: LOWER STORAGE AREA | HOLE No: DTP 25 | DEPTH (m): 0.6



SIZE DISTRIBUTION	
COBBLES	0 %
GRAVEL	3 %
SAND	38 %
SILT	23 %
CLAY	36 %
EFFECTIVE SIZE D10:	-
UNIFORMITY COEFFICIENT D60/D10(Cu):	-
CURVATURE COEFFICIENT $D30^2$ /(D60 x D10) (Cc):	-

Soil Particle Density: 2.65 t/m³ (estimated for analysis)

Method of dispersion: End-over-end shaking

Hydrometer: ASTM 152H

Dispersion chemical: Sodium hexametaphosphate + Anhydrous sodium carbonate

Notes on Test: Tested as received

Loss in pre-treatment: 0 %

Test Methods:
DPWS GM 9: Determination of the Particle Size Distribution of a Soil

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Tested By: MA/ZG Date Tested: 30/10/2012

APPROVED SIGNATORY

Mark Ashover 19/11/2012

PARTICLE SIZE DISTRIBUTION R1119 (ISSUE 4, 2005)

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CLIENT: DAMS & CIVIL TECHNOLOGIES	REPORT No: 12031/3344/R1115

SOIL INDEX PROPERTIES

PROJECT: DUNOON DAM SITE	SAMPLE No: 3344
LOCATION: LOWER STORAGE AREA	HOLE No: DTP 25 / DEPTH (m): 0.6

SOIL INDEX PROPERTIES		RESULT		TEST METHOD
Moisture Content (as received)	:	22.6	%	AS 1289.2.1.1
Liquid Limit	:	48	%	AS 1289.3.1.1
Plastic Limit	:	24	%	AS 1289.3.2.1
Plasticity Index	:	24	%	AS 1289.3.3.1
Linear Shrinkage	:	-		AS 1289.3.4.1
Soil Particle Density	:	-		GM 8
Classification	:	CI		AS 1726

Sample History: ☐ Natural State ☒ Air Dried ☐ Oven Dried

Method of Preparation: ☐ Wet Sieved ☒ Dry Sieved

Linear Shrinkage Sample: ☐ Curling ☐ Crumbling ☐ No Deformation

Notes on test: Sample tested as received from client.

ATTERBERG LIMITS R1115 (ISSUE 4, 2005)

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Tested By: ZG Date Tested: 07/11/2012

APPROVED SIGNATORY M. Ashover

Mark Ashover 13/11/2012

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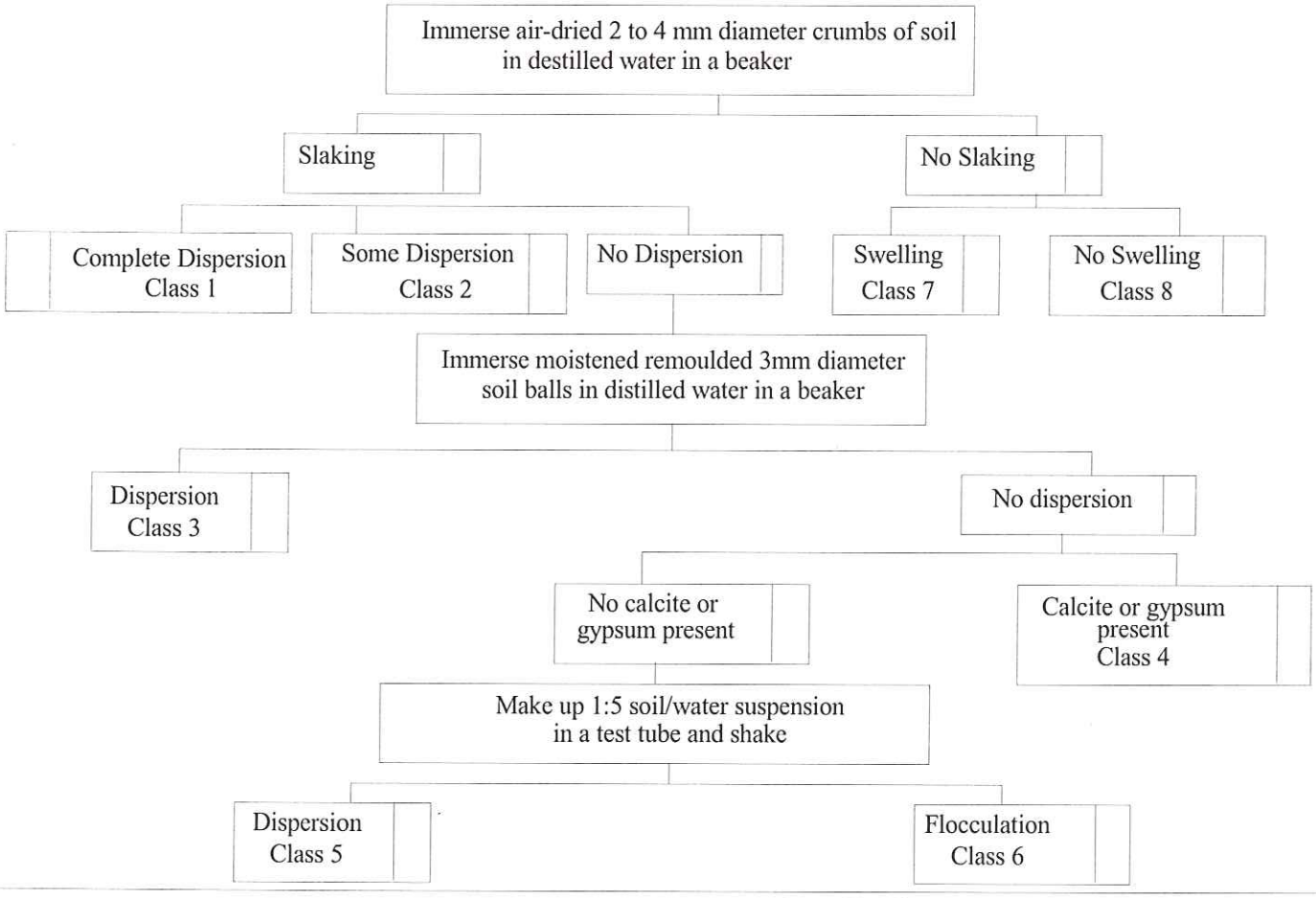
CLIENT: DAMS & CIVIL TECHNOLOGIES		REPORT No: 12031/3344/R1118
DISPERSION TESTS		
PROJECT: DUNOON DAM SITE		SAMPLE No: 3344
LOCATION: LOWER STORAGE AREA	HOLE No: DTP 25	DEPTH (m): 0.6

Determination of the Emerson Class Number of a soil



Emerson Class Number	(AS 1289.3.8.1)	No Test
Percent Dispersion	(AS 1289.3.8.2)**	No Test
Dispersal Index	(DPWS GM 15)	2.6

Sample Description: Grey and Orange Brown Mottled Sandy Silty Clay trace of Gravel

Type and temperature of water: Distilled, 21.5 ° C

Notes on test: Sample tested as received from client.

** 0.05mm size interpolated from hydrometer readings taken after 21min, 1hour and 2 hours.

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Tested By: ZG/MA Date Tested: 07/11/2012

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