RUNWAY EXTENSION FEASIBILITY STUDY

GEOTECHNICAL INTERPRETIVE REPORT

Lord Howe Island Board | 6 August 2018

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Lord Howe Island Airport Runway Extension Feasibility Study

Geotechnical Interpretive Report

Client: Lord Howe Island Board

Co No.: N/A

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1.0 Introduction

1.1 General

AECOM has been engaged by the Lord Howe Island Board (LHIB) to undertake a Feasibility Study to investigate the viability of a runway extension, and subject to LHIB approvals, progress technical studies, develop conceptual engineering plans and undertake community engagement.

Lord Howe Island is among Australia's premier tourist destinations, known nationally and internationally for its natural beauty and biodiversity, as recognised in the United Nations Educational, Scientific and Cultural Organization (UNESCO) World Heritage Listing.

On 20 April 2018, AECOM issued a detailed assessment of extended runway requirements and suitable aircraft. The main recommendation of this assessment was to investigate a 570 m extension of the current runway towards the west.

This report presents a preliminary interpretation of the geotechnical conditions along proposed expansion alignment and includes:

- Desktop study based on existing information to assess likely ground conditions
- Geophysical report by geophysical contractor
- Geological cross sections of the expected geological conditions along the alignment
- Preliminary soil and rock design parameters to inform feasibility design

Additionally, selected historical data was digitised in AGS 3.1 RTA 1.1 format and historical boreholes provided as a GIS shape file. These are provided in a separate digital package.

2.0 Proposed Works

The current runway, built in 1974 and resurfaced in 2015, is oriented in a north-west direction and has an elevation ranging from RL 4.0 to RL 4.5 m local AHD. It includes a 70 m long rock protrusion into the lagoon.

The site is a 570 m proposed extension of the current runway westwards, towards the Lagoon (Figure 2-1). This extension was defined during the detailed assessment of the extended runway requirements and suitable aircraft issued by AECOM on 20 April 2018.

It is understood that two options are being assessed for the runway extension:

- Reclaiming the area using imported fill
- Constructing a deck founded on piles

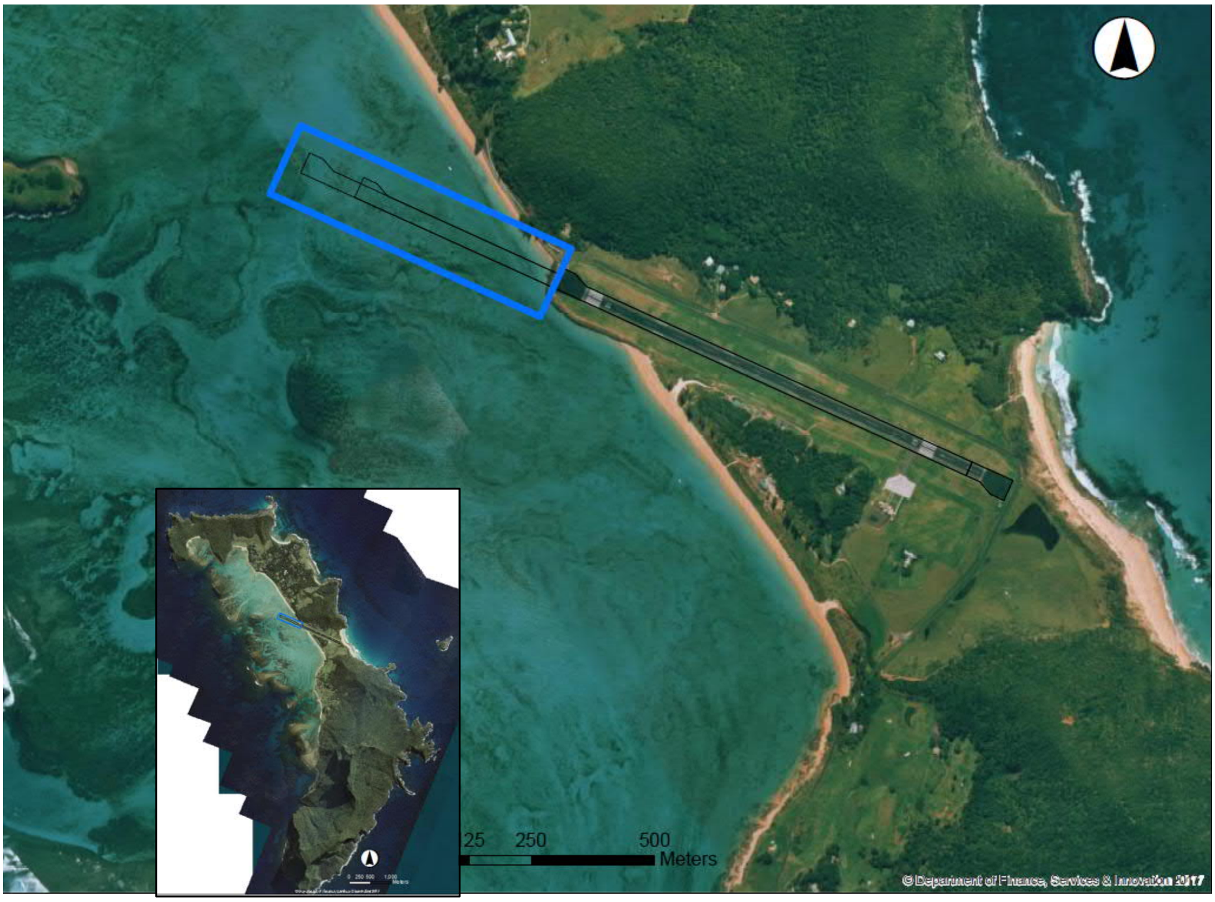

Figure 2-1 Site (outlined in blue) – proposed runway extension (includes 450 m and 570 m options)

3.0 Geological and Geotechnical Data sources

AECOM has referred to the sources of information shown in Table 1. These and other sources are referenced in Section 11.0.

Table 1. Main sources of information

Source Name	Year	Document Reference	Provided by
The physical and geological structure of Lord Howe Island	1889	Etheridge	Publicly available
Lord Howe Island Runway Investigation 1971/72*	1970-1972	Department of Public Works	LHIB
Regional Environmental Study – Land Resources	1984	LHIB	LHIB
Lord Howe Island 1:20,000 Geological Map	1987	Geological Survey of New South Wales	Publicly available
Holocene lagoonal sedimentation at the latitudinal limits of reef growth, Lord Howe Island, Tasman Sea. Marine Geology	2000	Kennedy and Woodroffe	Elsevier
Stratigraphy of the Quaternary eolianite on Lord Howe Island, southwest Pacific Ocean	2003	Brookes et al.	Publicly available
Airport Pavement and Drainage Assessment – Pavement and Geotechnical Investigation Report	2014	GHD	LHIB
Coastline Hazard Definition and Costal Management Study Issue 5	2014	Royal Haskoning DHV	LHIB
Hydrographic Survey Drawing LHI1 001-A and LHI2 001-A	2015	Port Authority of New South Wales	LHIB
Past and present coral distribution at the latitudinal limit of reef development, southwest Pacific Ocean (thesis)	2016	Linklater et al.	Publicly available
Detailed Assessment of Extended Runway Requirements and Suitable Aircraft	2018	AECOM Australia	LHIB
The physical and geological structure of Lord Howe Island	1889	Etheridge	Publicly available
Lord Howe Island Runway Investigation 1971/72*	1970-1972	Department of Public Works	LHIB
Regional Environmental Study – Land Resources	1984	LHIB	LHIB
Lord Howe Island 1:20,000 Geological Map	1987	Geological Survey of New South Wales	Publicly available
Notes 1. *Drawings from this report were referenced as "1970 Drawing"*			

The vertical datum used in this report is the Local Australian Height Datum (Local AHD), which corresponds to the 1954 Lord Howe Island Hydrographic Datum (LHIHD54). This "Local AHD" is not related to the mean sea level and is therefore different to the Australian Height Datum.

Lord Howe Island Hydro Datum (LHITD), also called Manly Hydraulics Laboratory (MHL) tide gauge zero, is understood to be 0.144 metres above the Local Australian Height Datum.

Manly Hydraulics Laboratory have reviewed successive survey data of a triangular cut marker on top of a concrete step on right of the Lord Howe Island wharf, facing inland. This mark is known as 1954 BM and NVM/c/447, LHI-16, PM 1030 and was referenced in a number of reports from 1954 to 2008.

Note that the current tide gauge zero is set 0.07 m above Local AHD and that the Mean Sea Level (MSL) is 1.11 above current tide gauge zero. Therefore, the Mean Sea Level (MSL) is 1.18 m above Local AHD.

4.0 Site description

4.1 Onshore

Lord Howe Island (LHI) is an island in the Tasman Sea, 600 km east of Port Macquarie, New South Wales. The island is about 10 km long by about 0.5 to 2 km wide, with a total surface area of 14.55 km^2. The islands topography is highly variable. The northern extremity comprises several 100 m high hills. The southern third of the island comprises two steep peaks (Mount Gower, 875 m, and Mount Lidgbird, 777 m). The central area of the island is general flat, with the exception of Transit Hill (100m).

Figure 4-1 Lord Howe Island map, Tourism New South Wales

The main beaches in the central area of the island are Neds Beach, Middles Beach and Blinky Beach on the eastern side of the island and Old Settlement Beach, Lagoon Beach (north of the Airport) and Cobbys Beach (south of the airport) in the western area of the island, along the Lagoon.

The airport is located in a 500 m-wide central section of the island, between The Lagoon and Blinky Beach. This area is flat, with an elevation ranging from 3.1 to 4.5 m Local AHD.

4.2 Marine

Lord Howe Island and Ball's Pyramid are surrounded by a shallow shelf, about 20 km wide by 50 km long (Figure 4-2) and with a surface of 500 km^2 around Lord Howe Island and 260 km^2 around Ball's Pyramid. The water depth over the shelf varies from 20 to 120 m; with an average depth of about 50 m. Fossil reefs are present on the shelf, down to water depths of 50 m (Speare et al., 2004). The inner-shelf around Lord Howe Island has an average depth of 25 m and extends about 4 km from the coastline. About 70% of the shelf area is a middle-shelf platform (water depths of 30-50 m), with a terrace step leading to a deeper outer-shelf platform (Linklater, 2016).

The western side of the island is surrounded by a 6 km long Holocene fringing reef, which has an average crest level of 1.0 m Local AHD, about 0.2 m below the mean sea level in the lagoon.

Mleczko et al. 2010 reviewed and compiled all available bathymetry data around LHI. The most useful data in the lagoon was derived from multi-spectral satellite data (Quickbird in 2008 and World View II in 2016), which shows that the floor of the lagoon averages a few meters below mean sea level.

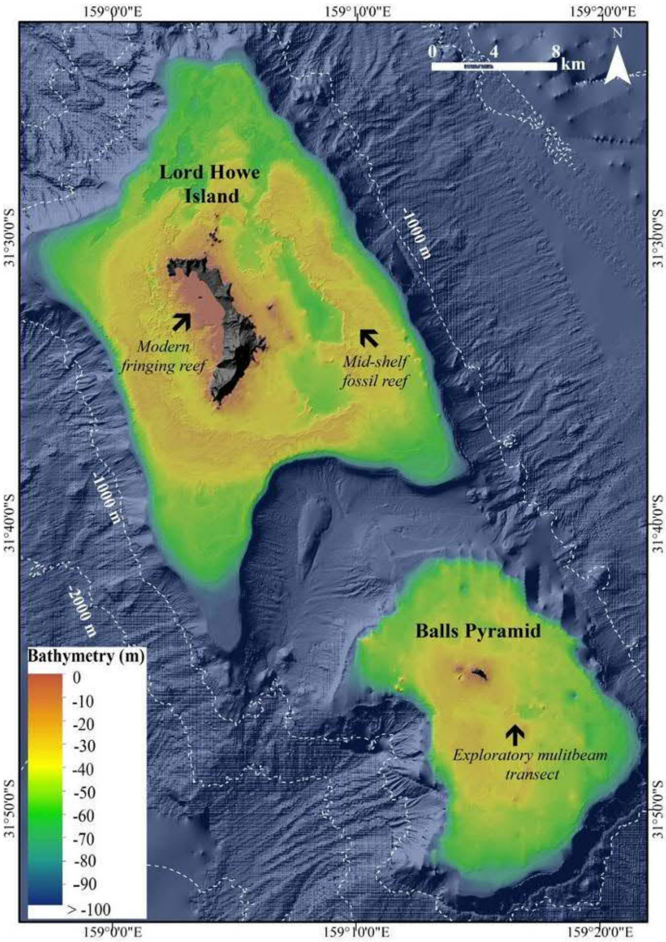

Figure 4-2 Shallow marine shelf (in meters below mean sea level), Mleczko at al. 2010

The Coastal Assessment from 2014 refers to a NSW Maritime survey carried out in 2008 (Figure 4-3) but the raw data was not available.

Additionally, the Port Authority of New South Wales carried out a multibeam swath bathymetry survey over the south of the Lagoon in March 2015 to check for barge accessibility as part of the airport resurfacing works. This data covers about 70% of the site and shown on Figure 4-4.

Over the footprint of the runway extension, the lagoon is very shallow and reasonably flat, with seabed levels typically ranging from 0.3 to 0.9 m below Local AHD, with the exception of the meandering channel at the western extremity of the site which reaches 1.5 m below Local AHD. A deep sediment sink area called Comets Hole, extending to RL -7 m Local AHD is present south of the site.

Lord Howe Island Marine Park extends from the mean high water mark to the three nautical mile limit of NSW waters. The Lord Howe Island Commonwealth Marine Reserve surrounds the NSW Lord Howe Island Marine Park and extends further seaward to 12 nautical miles.

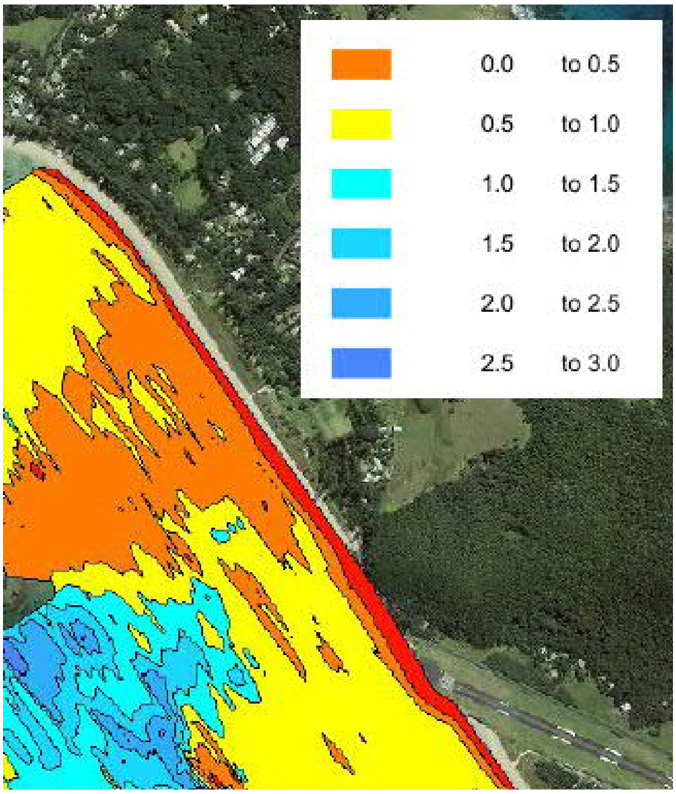

Figure 4-3 Extract from Coastal Assessment 2014 (Local AHD)

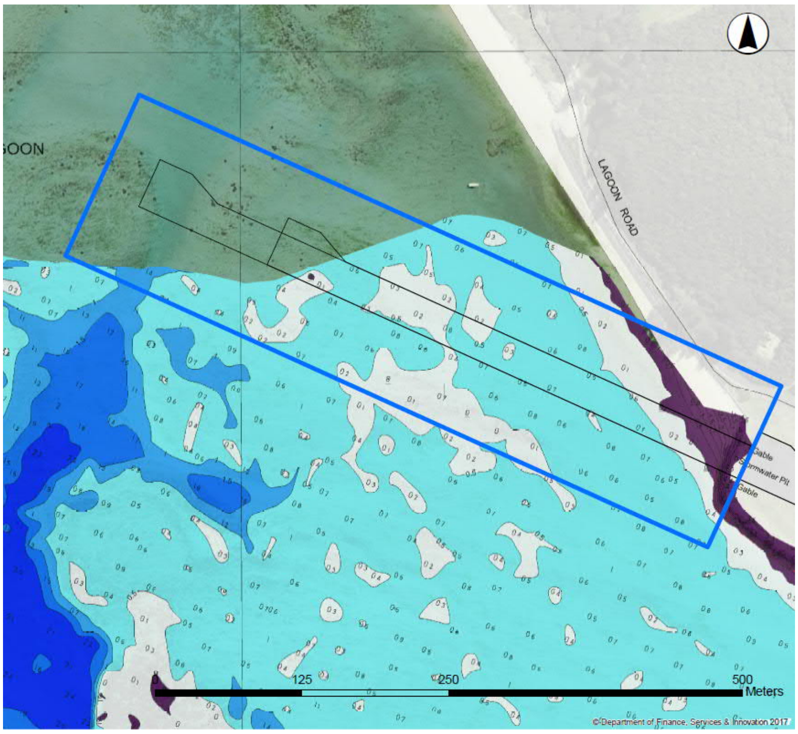

Figure 4-4 Bathymetry data to LHITD (Port Authority of New South Wales) _ georeferenced by AECOM

5.0 Heritage and historical land use

LHI was primarily used as a whaling station from the early 1800s to 1881, with permanent settlement from 1834. Kentia Palm industry started in 1878 and tourism started in the 1900s. The airport was built in 1974.

The Lord Howe Island Group is listed on the NSW Office of Environment and Heritage (OEH) State Heritage Register (SHR 00970). Individual heritage items on Lord Howe Island are managed by the *Lord Howe Island Local Environment Plan 2010* which includes the house “Kentia” (formerly the residence of A Christian) on Lagoon Road, Portion 111.

In relation to indigenous heritage, there has been no evidence to date to suggest that Lord Howe Island was settled by peoples of the Pacific region, including Polynesians, Melanesians or from the Australian mainland. A survey was undertaken in 1996 by archaeologists from the University of Wollongong which found no evidence in analysis of pollens and deposits to indicate for human colonisation prior to the time of the European discovery in 1788. Given this, there has been no previous and limited potential for any indigenous items to be present on the island.

The Lord Howe Island Group (comprising LHI, the Admiralty group and Balls Pyramid) was included in the World Heritage List in 1982.

In 1999, the Lord Howe Island Marine Park was established and comprises a number of sanctuary zones. The Lord Howe Island Lagoon Sanctuary Zone covers the central section of the barrier reef lagoon, from the south of Blackburn Island to Erscotts Passage. The sanctuary zone intersects the eastern portion of the site. The shoreline boundary of the zone is offset from the mean high water mark by 50 metres, to allow for shore based fishing from the beach. Areas within the Lord Howe Island Marine Park not within the Lagoon Sanctuary Zone are designated as Habitat Protection Zones and are also subject to restrictions.

6.0 Regional geology

The Lord Howe Island lies on the western edge of the Lord Howe Island Rise (LHR)/Challenger Plateau. The LHR is a predominantly submerged continental ribbon that is inferred to have detached from eastern Australia about 75 Ma. (Gaina et al. 1998, McDougall et al. 1994).

The geology of the island is described by McDougall et al. (1981) and summarised by Atkinson (1984). The Lord Howe Island 1:20,000 Geological Sheet (1987) shows the current mapped surface repartition of the geological units.

These comprise, by most recent to oldest: aeolian and alluvial deposits, calcarenite, red clays and volcanic bedrock (see Table 2 below).

Table 2 Geological Unit Summary

Unit	Age	Description
Recent Sediments	Less than 6,000 yrs	Aeolian, alluvial, and marine calcareous sands
Current Reef	6,000 yrs	Source of recent sediments
Fossil Reef	Holocene	Drowned, at water depths of 30 to 50 m
Calcarenites • **Neds Beach Formation** • **Searles Point Formation**	240-80 Ka (Pleistocene)	 • dune and beach deposits • dune deposits with clay-rich paleosols
Volcanic Bedrock	6.9-6.4 Ma (Miocene)	Basalt and Breccia

6.1 Volcanic bedrock (6.9-6.4 Ma)

The Lord Howe Island (together with Ball's Pyramid) is interpreted to be the highly eroded remains of volcanic activity which happened when the Australian plate moved over a volcanic hotspot. It is interpreted to have occurred in two separate volcanic episodes, both during the late Miocene Epoch.

In the first episode, about 6.9 Ma, a 30 km diameter shield volcano was formed. The geological unit forming this volcano is the North Ridge Basalt, which is composed of at least 30 lava flows ranging from 1 to 10 m in thickness, with very variable weathering. This unit now forms the north of the island and also most of Transit Hill, in the middle of the island.

Additionally, breccia formed within the throat of the volcano following explosive eruptions. This unit, called Boat Harbour Breccia, is well indurated and comprises angular to sub-angular basaltic inclusions of up to one meter in size and volcanic bombs in fine grained matrix. This unit now forms the lower slopes of Mount Lidgbird.

Both the North Ridge Basalt and the Boat Harbour Breccia are intersected by numerous basaltic dyke swarms; sub vertical and striking South-South-East to South-East.

About 6.4 Ma, the main vent collapsed, creating a 900 m deep caldera which was gradually filled with successive tabular lava flows, ranging from 1 to 30 m in thickness. This unit, called Mount Lidgbird Basalt, is more resistant to erosion than the North Ridge Basalt and forms the largest peaks on the island, Mount Lidgbird and Mount Gower in the south of the Island.

Marine (90%) and sub-aerial (10%) erosion truncated the volcano to form a relatively shallow 20 km wide by 50 km long shelf from which Lord Howe Island and Ball's Pyramid protrude (Figure 6-1) (Dickson, 2004).

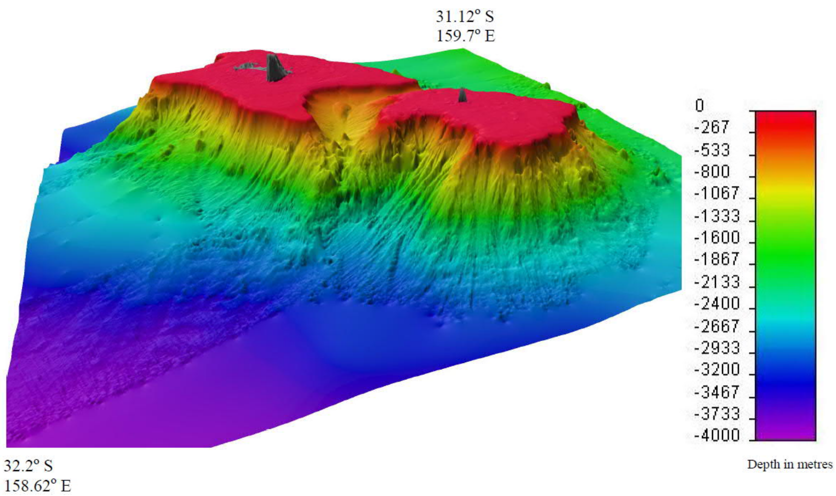

Figure 6-1 3D view of the truncated shield volcano (x6 vertical exaggeration), meters below mean sea level, Mleczko et al. 2010.

The weathering profile for the North Ridge Basalt is highly variable and the thickness of residual soils can be expected to vary. Colluvium on foot slopes is described in Atkinson 1984 as a mix of plastic clays (brown structured clays) with boulders.

Etheridge 1889 mentions a stiff to very stiff red or yellow clay underlying the calcarenite in Wilkinson's Promontory (Stevens Point), Fern Glen (probably near the Clear Place, based on ANPS Placename Report) and Deep Creek (Soldier Creek). This unit is expected to consist of weathered volcanic rock.

Photos of the main different volcanic rock units are presented in Appendix D.

6.1.1 Calcarenites (240-80 Ka)

During the Pleistocene, during episodes of lower sea levels, calcareous shelf sediments were exposed to wave and wind action. As a result, coastal dunes were formed, infilling valleys and climbing the steep basalt slopes. These transverse and climbing dunes cemented and formed a cross bedded calcareous sandstone or “calcarenite” which have been mapped up to 75 m above mean seal level. This unit is described as “coral-sand rock series” by Etheridge 1889. About 80% of the calcarenite has an aeolian origin (“eolianite”), the remaining being of marine origin (beach deposits).

The sediments forming the calcarenite are typically rounded and mostly comprise fragments of coralline algae (“red algae”) with varying but less abundant foraminifera, micromollusks and coral. Volcanic grains are also present south of Cobbys Beach.

This calcarenite was defined and mapped as a single lithostraphic unit called Ned Beach Calcarenite (Standard, 1963), due the predominance of the skeletal carbonate component, the apparent homogeneity of the particles and lack of visible horizons. This geological unit is mapped (1987) on most of the cliffs from Neds Beach to Middle Beach, Signal Point and the cliffs to the south of the Lagoon. It is also exposed between the northern flanks of Transit Hill and Neds Beach.

Above the water table, this material is very prone to weathering, forming karsts, becoming porous and breaking down to a pale calcareous sand.

Brookes et al., 2003, carried out extensive mapping and age dating of the calcarenite. The works suggested that the cycles of carbonate deposition was associated with interglacial (OIS Stage 5e) and interstadial episodes (OIS Stage 5a and 5c) during the mid to late Pleistocene. The Ned Beach Calcarenite was subdivided in two formations, the Searles Point Formation and the Neds Beach Formation, the latter incorporating two members.

The earliest unit, called Searles Point Formation, overlies the basalt. It is composed of dune deposits bounded by paleosols and well-formed protosols. It can be described as a typically yellow to very pale brown aeolinite bounded by clay-rich (“terra rossa”) paleosols. The top of this unit was exposed to subaerial processes (prior to the Last Interglacial period) and shows evidence of dissolution features (karsts or solution pipes) prior to having been capped by paleosols. This unit was deposited in up to 7 discrete phases, some of which were interrupted by pedogenesis. Age dating suggests that this unit was deposited from 240 Ka (Middle Pleistocene, OIS Stage 7). Thin sections suggest typical compositions about 40% of skeletal carbonate, 1% foraminifera, 15% peloidal, 5% volcanic, 30% cement (sparite), 5% matrix and 4% pore space. This unit is exposed in North Bay, Searle Point and next to the Boat ramp.

The Neds Beach Formation overlies the Searles Point Formation and is made both of dune and beach deposits deposited in two major episodes separated by a well-formed protosol. The beach units were deposited between 120-110 Ka (late Pleistocene, OIS Stages 5e) and suggest an open coastal environment. The aeolian dune units were deposited as thick layers in two episodes, the first shortly after the beach deposits, the second later (late Pleistocene, OIS Stage 5a) when the beach and dune deposits were buried. The dune units are typically lighter in colour than the Searles Point Formation, ranging from very pale brown (10YR 8/4) to white. Beach units are darker, ranging from brown-yellow (10YR 6/6) to pale brown (10YR 6/3).

The Neds Beach Formation was itself subdivided in 2 members: the Middle Beach Member (dune unit, white, rich in foraminifera) and the Cobbys Corner Member (brown-yellow due to its high content of volcanic grains).

Brooke et al., 2003 also mention that, based on the thickness of the current exposures, the sediment supply was seaward and several meters below the current shoreline. Several dune units were found to extend at least several meters below present sea level, suggesting that the eolianite was deposited during glacial low-stands, however Brooke et al. note that the shelf limits coastal deposition to periods when seal level was higher than 30 m below current sea levels, so that the shelf was flooded and formed a “carbonate province” and sediment supply. This, together with the age dating, suggests that the eolianite was therefore deposited in interglacial and interstadial periods of high or falling sea level, e.g. 2-10 m less than current.

6.1.2 Fossil and current coral reefs

Reefs have a key impact on the recent geology around Lord Howe Island as they tend to protect the shoreline from erosion and contribute to carbonate production.

A drowned Holocene fossil coral limestone reef was found be present on the shelf around the island, at water depths of 30 to 50 m (Speare 2004). This fossil reef is about 25 times larger in area than the current fringing reef (Linklater 2009, Woodroffe at al. 2010) and formed from 10,000 to 7,000 years ago. This reef was drowned and back-stepped (i.e. relocated further inshore) to its current, relatively limited, extent.

Based on the presence of large coral clasts in the calcarenite (Brookes et al. 2003), a mineralogy analysis of the fossil reef (Kennedy et al. 2007), and the thickness of the units above the middle-shelf (Linklater 2016), it is likely that an older reef was present around the island from the last and penultimate interglacial stages in the Pleistocene (about 125,000 years ago). Based on the open coastal environment suggested by the Neds Beach Calcarenite Formation, this reef might have been patchy and less developed than the Holocene fossil reef.

Component analysis of the sedimentary matrix within the reef indicates coralline algae dominated sands which are very similar in composition to the modern reef environment (Kennedy 2007).

Speare et al, 2004 described that the reef leads to a sandy seafloor with low profile waves at water depths of 45 m. The outer shelf (water depths of 60-100 m) is mostly a sandy seafloor with rock outcrops, boulders and cobbles. The steep shelf slopes comprised finer “silty” sediments between rock outcrops, and rock walls and overhangs extending to depths of 200 m.

Geophysical and intrusive investigations (submersible rock coring and vibrocoring) were carried out in 2008 and 2013 in the shelf surrounding the Island (Section 4.1.1) and next to Balls Pyramid. These investigations have enabled to map the seafloor. Results are presented in detail by Linklater 2016 (Figure 6-2). The mid-shelf reefs which dominate the fossil reef are drowned coral reefs, and the environment was high energy, with accumulations of soft substrates in basins and channels. Variations in sea levels had a key role on the formation of these features.

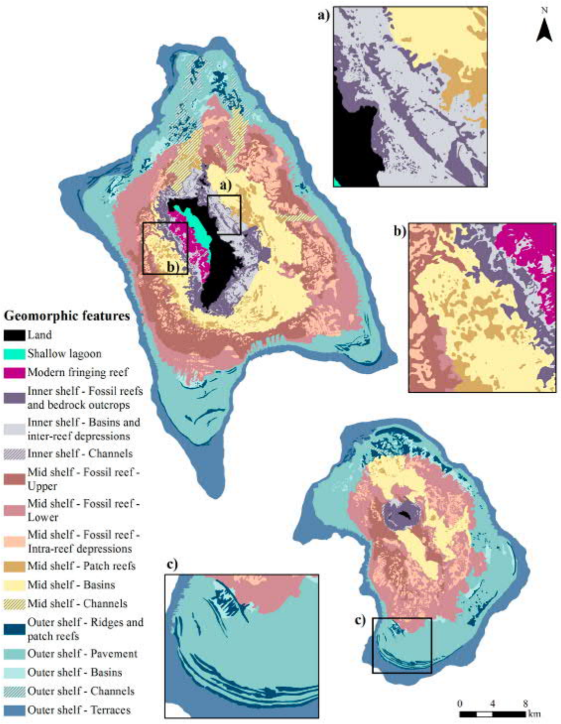

Figure 6. Geomorphic feature interpretation of the Lord Howe Island and Balls Pyramid shelves. Inset locations show: **(a)** linear reefs on the eastern inner shelf of Lord Howe Island; **(b)** patch reefs on the western mid shelf of Lord Howe Island; and **(c)** sub-parallel, linear ridges along the southern outer shelf of Balls Pyramid.

Figure 6-2 Inner Shelf, figure extracted from Linklater 2018

From about 7,000 years ago, the reef back-stepped landwards, and formed the modern fringing reef on top of the calcarenites and the potential Pleistocene reef (Linklater 2016). This modern fringing reef thrived 6,000 years ago (Woodroffe et al., 2005). As a result, calcareous sediment started accumulating on the seafloor, with backfilling in the Lagoon from about 4,600 years ago (potentially due to the reduction in marine energy due to the growth of the reef). By 4,000 years ago, the reef was close to modern levels, sediment infill had an average rate of infilling of 5 mm per year but up to 10 mm per year locally.

Kennedy and Woodroffe (2000) mention that there was a phase of mud sedimentation at this time, with replacement by superficial sands in the late Holocene. The thickness of sediment infill then reached 11 m in the north part of the Lagoon and possibly up to 30 m in the southern part.

From about 2,800 years ago, the sediment backfill had reached a depth which was sufficient to be subject to wave action. At the time, the sea levels were about 1 to 1.5 m higher than present. In the last 6000 years, a drop in sea levels and an increase in westerly wind strength caused an accumulation of sediment from the reef to the shore and the formation of the current beaches.

The modern fringing reef contains a large proportion of calcareous algae mixed with coral, due to a mix of cold and warm currents (Lord Howe Island Board, 1987). The modern reef has continued to grow in recent times (Lord Island Board, 1987). Most of the beaches are made of calcareous sands broken from the reef.

6.1.3 Recent deposits

The soil units are of alluvial/marine, aeolian or residual origin. The units are described by Atkinson 1984 and main units shown on the 1987 geological map (Figure 6-3).

- alluvial/marine calcareous sands: medium to coarse alluvial and marine calcareous sands with coral gravel, sand is uniform, pale yellow, loose. Can be stratified and contain layers of sandy clay and peat representative of low- energy, swamp conditions. Grain mineralogy is similar to the calcarenite (see 6.1.1). Most modern beaches on the island, and disturbed sections of dunes immediately behind the beaches, do not show stratification or soil lenses (and classified as "beach sands"). Stratification is visible in the low-lying flats surrounding the airport.

- aeolian (dune) calcareous sand: fine to medium calcareous sands, uniform, pale yellow. Weakly structured. Loose. Forms current sand dunes. pH 8-8.5
- alluvial clay: either calcareous (e.g. "brown friable alluvial loams and clays") or non-calcareous ("brown structured clays"), suggesting low energy environments and exposed inland of some beaches. Atkinson 1984 separated these deposits in a number of soil landscapes. Depending on the landscape and horizons within each landscape, colours vary from black, brown and red-brown. pH is usually neutral or slightly alkaline. Plasticity is generally high, with all liquid limits available ranging from 66 to 85%.
- undifferentiated alluvium: alluvial fan deposits which varying from plastic clays with gravels and boulders in basaltic catchments to interbedded calcareous sands and clays with occasional gravel in calcarenite catchments. Mapped in the lower west facing slopes of Transit Hill and Mount Lidgbird.
- Residual and colluvial soils derived from calcarenite: "weakly structured sandy soils" is characterised by sand, pale yellow, calcareous, loose, pH 8.5. Can be bioturbated ("bioturbated sandy soils") due to burrowing birds. Occurs in crests and slopes.

The seafloor is expected to be mostly made of coral west of Blackburn Island, with more sand east of Blackburn Island. This sand is expected to be typically medium to coarse grained (Kennedy and Woodroofe 2000).

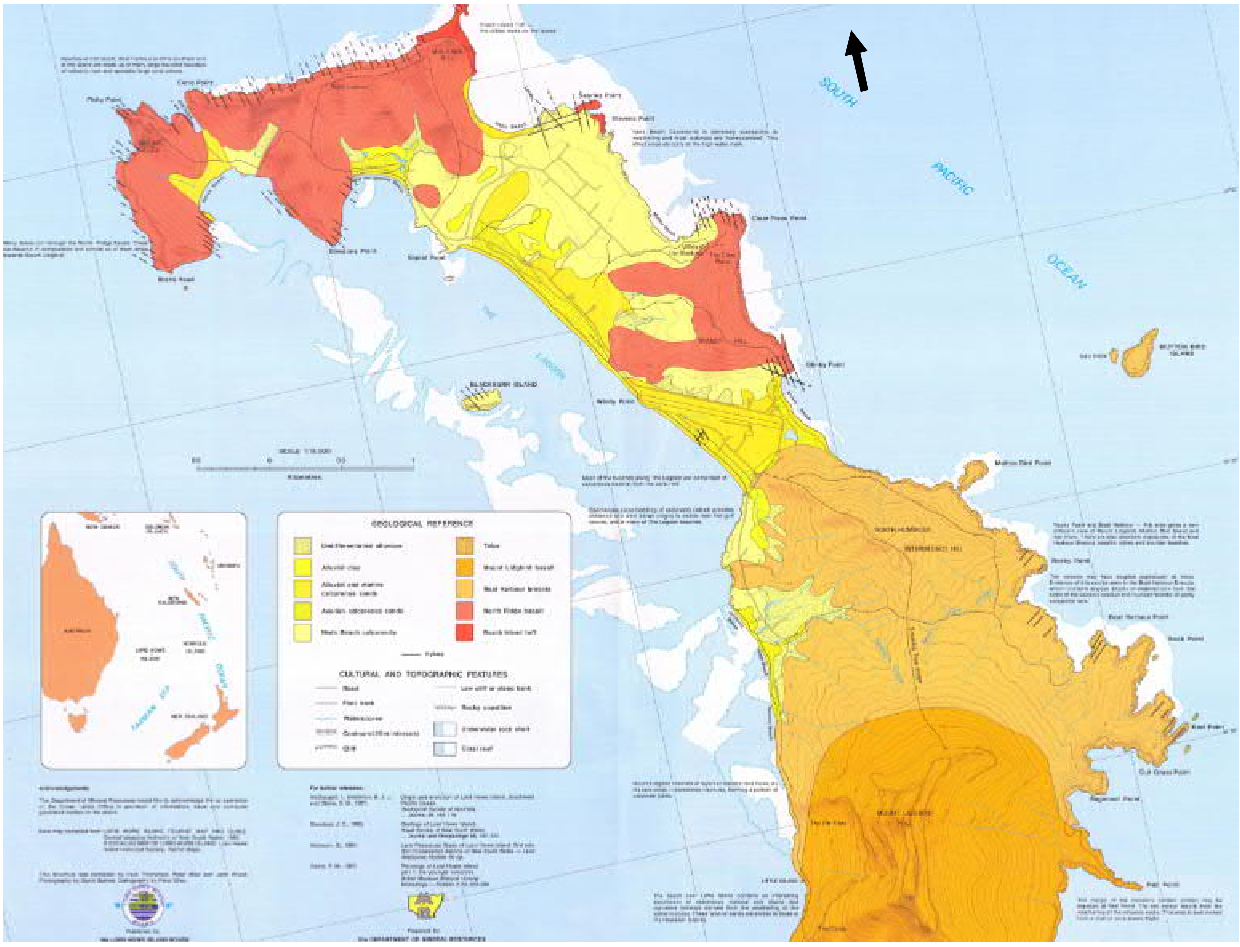

Figure 6-3 - Extract from the Lord Howe Island 1:20,000 Geological Sheet (1987)

7.0 Previous Work

7.1 Lord Howe Island 1:20,000 Geological Sheet

Whilst the geology of the island and its surrounding shelf has been the focus of many studies, limited published geological information is available regarding the geology of the Lagoon.

Reference to the Lord Howe Island 1:20,000 Geological Sheet (Figure 7-1), indicates that the ground conditions across the site appear to comprise aeolian calcareous sands, overlying alluvial and marine calcareous sands. Neds Beach Calcarenite is mapped on the flanks of Transit Hill to the east of the alignment and Cobbys Corner to the south of the lagoon, about 1 km south of the site (see Appendix D, Figure 12-21).

Remnants of an aeolian ridge were found to extend 150 m seaward off the present coast at Signal Point, into the lagoon (Brooke et al., 2003). The orientation of the bedding at Johnsons Beach, south of the site, indicates that the aeolian ridge was a transverse or oblique dune ridge (Brooke et al. 2003).

Calcarenite was also mapped at Blackburn Island west of the site and Atkinson 1984 (referred to as "Rabbit Island"), however, observations from the lagoon suggested that this unit is of volcanic origin as mapped by Etheridge 1889 (Figure 7-2, referred to as "Goat Island"). In addition, North-North-West trending dykes are mapped 250 m south of the alignment and on Blackburn Island. This would suggest that shallow bedrock may be present.

The Boat Harbour Breccia is present about 100 m of the site on the flanks of Transit hill (see Appendix D, Figure 12-14) and could be encountered under the site.

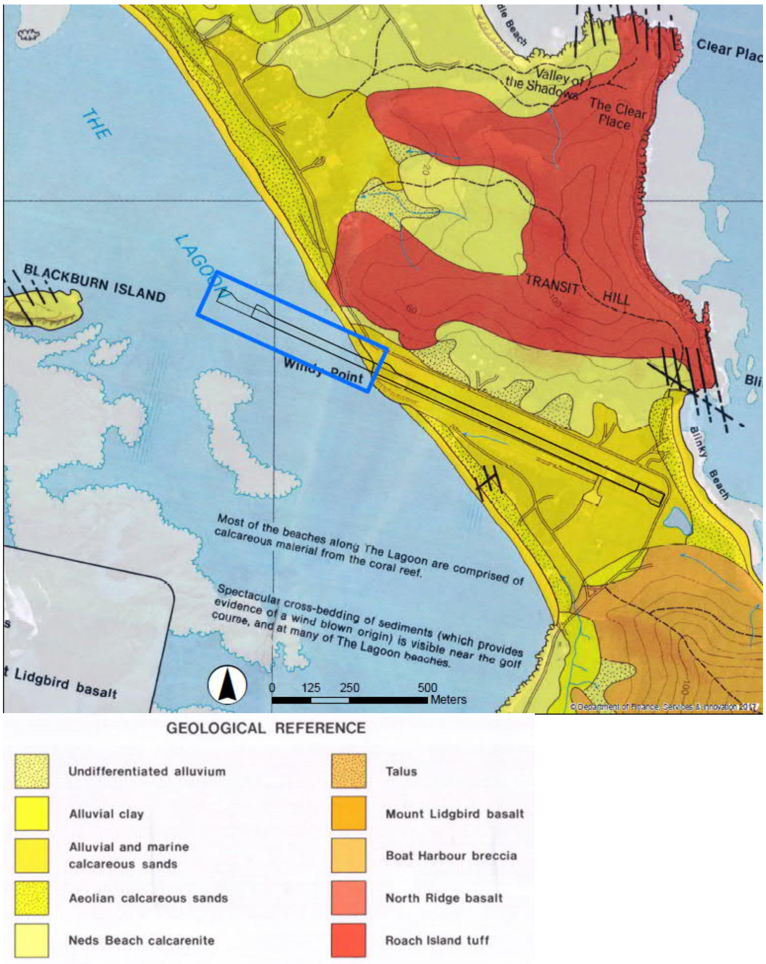

Figure 7-1 – Extract of Lord Howe Island 1:20,000 Geological Sheet – georeferenced by AECOM

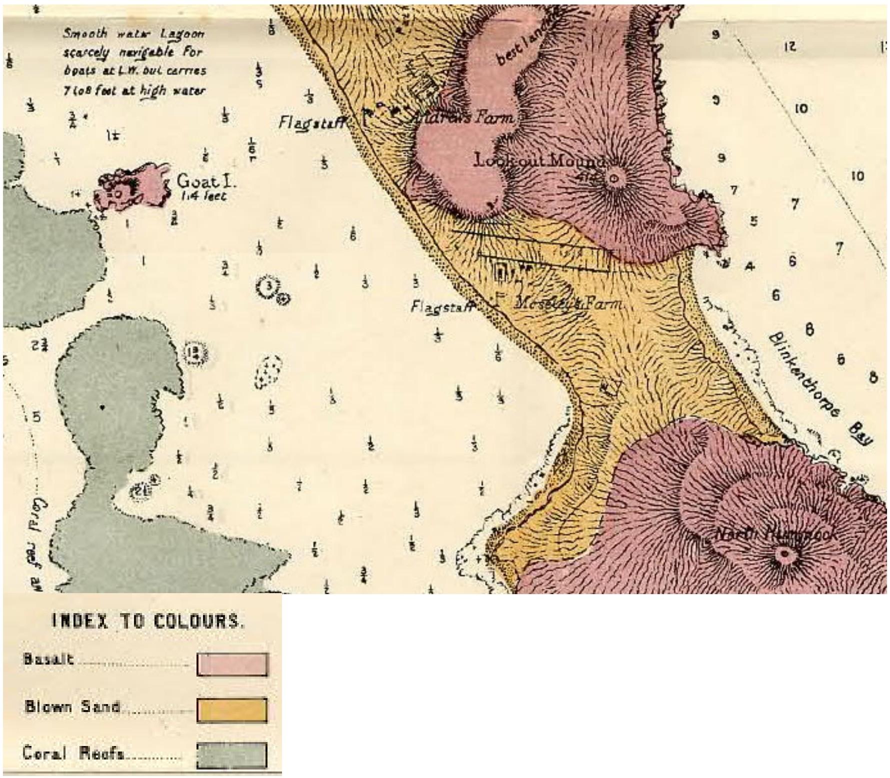

Figure 7-2 Blackburn Island ("Goat Island") - extract from Etheridge 1889

7.2 Kennedy and Woodroffe (2000, 2001)

Kennedy and Woodroffe (2000) drilled a few holes next to the Jetty in the Lagoon, about 1.5 km north of the site. The core close to the jetty north of the Lagoon (LV11) and found 1-2 m of Holocene sediment, several meters of calcarenite dating from 82,000 years ago, 6.5 m of "potential" Pleistocene reef limestone and calcarenite, with volcanic basalt at 10.8 m. Based on these results the depth to Pleistocene was expected to be at least 10 m on the crest of the modern reef.

Kennedy and Woodroffe (2000) also interpreted that in the lagoon, the pre-Holocene surface under the loose Holocene deposits was 5-25 m below the current seafloor. Geological long sections by Kennedy and Woodroffe (2000, 2001) Figure 7-3, Figure 7-4 suggest that the conditions north of the Lagoon within 500 m of the shoreline consists of about 1-2 m of sand, overlying about 5 m of "gravelly mud sediment", also called "mud with Coral Gravel". This overlays the calcarenite, which was only intersected in one borehole (LV11). Next to the shoreline, the underlying basalt and a superficial layer of "mangrove mud" were intersected. Part of the most recent (3,000 years and younger) reef has been reworked as "cemented rounded rubble", which could be due to a fall in sea-level or change if the reef-crest community (Kennedy and Woodroffe 2001).

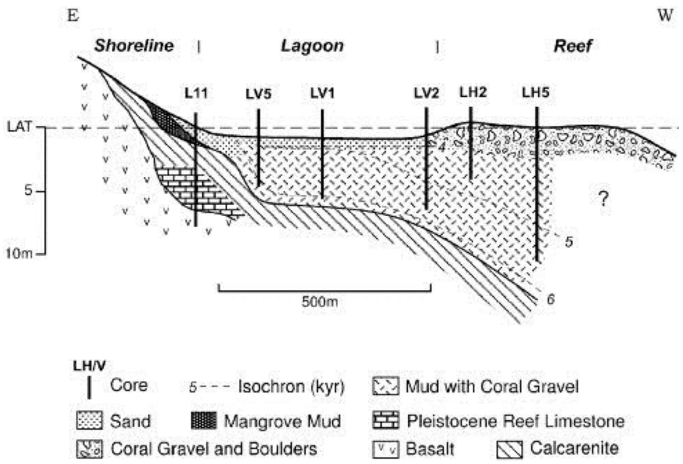

Figure 7-3 Geological section of the Lagoon - Figure extracted from Kennedy and Woodroffe 2000

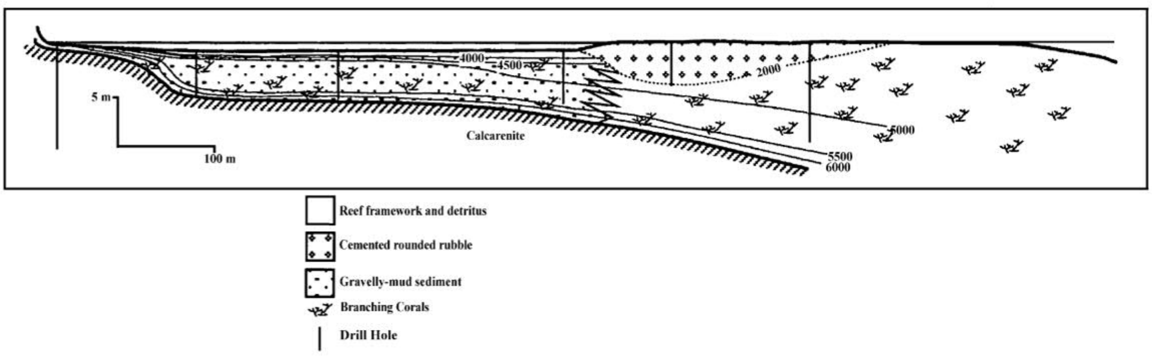

Figure 7-4 Geological section of the Lagoon - Figure extracted from Kennedy and Woodroffe 2001

7.3 Brookes et al. (2003)

As discussed in Section 6.1.1, Brookes et al. (2003) differentiated the Neds Beach Calcarenite into two members (Figure 7-5). At Lovers Bay (south of the site), the Neds Beach Formation overlies the basalt. At Cobbys Beach, the Cobbys Corner Member was found to be 11 m thick. Neds Beach Formation is also mapped on the flanks of Transit Hill above the site. Additionally, Brookes mapped eolianite remnants in the Lagoon, at Signal Point, Lovers Bay and Johnsons Beach. These occurrences correspond to shallower depths in the Lagoon.

This suggests that the calcarenite underlying the Recent Sediments may comprise either Neds Beach Formation or Cobbys Corner Member.

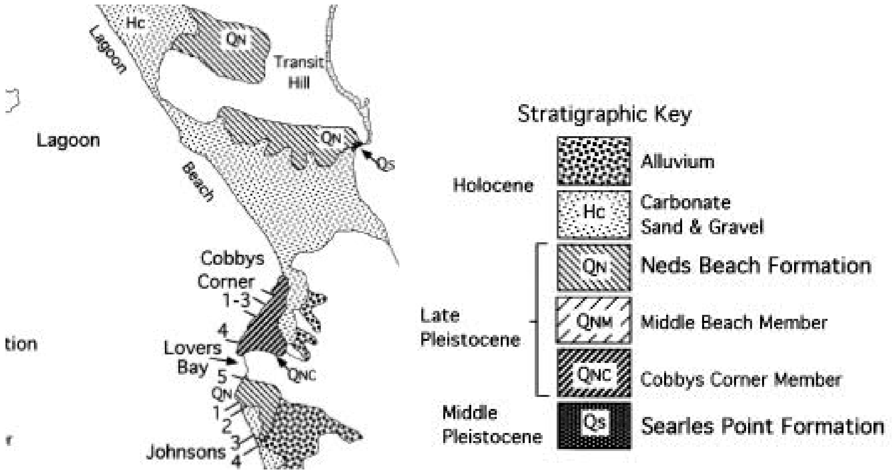

Figure 7-5 Local distribution of the calcarenites – extracted from Brookes at al. 2003

7.4 1970-1971 Airstrip Investigation

An intrusive geotechnical investigation was carried out for the airport between December 1970-February 1971 by A.R.D.E.C for the Department of Public Works with logs and long sections presented in GS00078 (1970 Drawing B3 L60). At the time, the proposed alignment orientation was slightly different to the one eventually built in 1974 and it also extended further in the Lagoon.

As shown on Figure 12-1, the site investigation comprised approximately:

- 55 boreholes (S1 to S40) along the alignment to a maximum depth of 15 m. 8 of these boreholes were drilled in the Lagoon: S17, S18, S19, S20, S21, S30, S31 and S40 to a maximum depth of 11 m below seabed. The original location map (1970 Drawing BL60) shows two S23 locations and it based on the labelling methodology, it was assumed that the northern one was S23A.
- 53 boreholes in proposed borrow areas to a maximum depth of 16 m: Kirribilli Ridge (K1 to K32), Transit Hill (T1 to T13), Intermediate Hill (IHA to IHH), Fenton (F1). IHG, IHI, K8 and K29 are not shown on the maps and have probably not been drilled.

The logs for S6, S52, S53A, and S54 are not available. One of the borehole log scans is illegible. Additionally, three boreholes (BH1, BH2 and BH3) are shown in the Lagoon on the original location map (1972 Drawing BL- 20) in 1971. However, information regarding these bores was not available.

Coordinates were not provided and these locations were georeferenced in ArcGIS by AECOM based on Drawing BL60 to an estimated accuracy of ±10 m (due to the resolution of the original map and the georeferencing process). Boreholes are presented with a “1970_” prefix. Key log information was imported in Bentley gINT in S.I units and the approximate coordinates are in Appendix B.

Despite the 1971 long sections showing Indian Spring Low Water (ISLW) vertical datum, the logs refer to the zero tide gauge and it has therefore been assumed that all levels relate to the 1954 Hydro datum (Local AHD). The difference between ISLW and the “zero tide gauge” was given in the 1972 long sections (1972 Drawing B-L-29) to be 0.19 m (0.62 feet) below ISLW. A report from 1954 and provided by Manly Hydraulics Laboratory mentions that the datum of tide gauge is 0.64 inches below ISLW which is close.

The land boreholes were drilled with either percussion, auger (blank or TC bit), rotary non-core (rock-roller bit) and some land boreholes where followed with NMLC diamond coring: S1, S3, S7 and the IHA series.

Standard penetration tests (SPTs) were carried out in most holes (as number of blows per foot of penetration). Based on the 1972 report, the SPTs were completed using a 140 lb hammer from a height of 30 inches and measured as number of blows per foot of penetration, which is similar to modern SPTs. The energy ratio of these SPTs was assumed to be 60%.

No coring was carried out in the marine boreholes. These were initially drilled with a bailer (within the top loose deposits), then rock rolled to completion. Based on the logs, SPTs were carried out in all marine boreholes except S31 and S18. S18 refers to a “cone penetrometer test”, however based on the 1972 sections (1972 Drawing B-L-29, see 7.5); this test is actually an SPT using a cone tip rather than an open shoe. S31 was drilled continuously with a “continuous cone penetration test”, providing a number of blows and an associated penetration, however the height and mass of the drops is not stated. Based on the ratios of number of blows per foot in this “continuous cone penetration test”, which seem to correlate well with the SPT results (1970 Drawing B-L-29), it was assumed that the set up was similar to that of an SPT but with a cone tip instead of an open shoe.

The intrusive data is interpreted further in Section 4.4 but the key relevant findings at the site suggest:

- up to 1.8 m of very loose coarse coral sand in the Lagoon (S18) and at least 2 m of calcareous sands along the runway
- 10.4 m (proven) of very loose coarse sand with “coral pieces and volcanic ash” in the Lagoon. Undisturbed tube samples penetrated this unit but usually failed to recover any sample, suggesting a predominantly non-cohesive material.
- potentially discontinuous clay lenses (described as “silty clayey Sand” on 1971 long section) beds over the calcarenite at levels of 0 to -3 m Local AHD. Based on S38, this layer could be 5.5 m thick. This layer is 2.6 m thick in S17 and was described as a “brown saturated soft basaltic clay”. Typical SPT blow counts in the clay are 5 to 6, suggesting a firm consistency.
- A top of calcarenite typically at about RL -10 m Local AHD (depth 11 m) in the Lagoon close to the runway and RL 0 to -2 m Local AHD on land. The calcarenite is associated with typical SPT blow counts of N ≈ 40-50.
- At the western end of the runway, the calcareous sand is underlain by sand with volcanic ash to – RL 6 m to -10 m Local AHD

The thick sand layer in the Lagoon under the upper sand was typically described as a: “grey coarse coral sand, high content coral pieces to 2” [60 mm], some shell, lightly bound with saturated volcanic ash (ash slurry), material is banded or honeycomb formation” or as a “lightly clay-bound sandy gravel”. The logs also mention that “when placed in a container, the sand and gravel settled within minutes leaving a slurry of volcanic ash (similar to bentonite) which continues to give up water over a period of [*unreadable*] days. Material continually blew up casing [*unreadable*].” S17 mentions that the inferred volcanic ash content is approx. 40%.

An approximatively 100 m long unidentified rock outcrop is mapped south of the current runway, in the middle of the island (GDA94/MGA 57 coordinates of centre 507478, 6510466), 1970 Drawing C 3L61. This outcrop was not visible during the site visit and is expected to consist either of Boat Harbour Breccia or calcarenite.

7.5 1972 Airstrip Lagoon investigation

Between 1971 and 1972, the proposed airstrip alignment changed slightly (from an original bearing of 273”34’ MN to 270” 34’ MN (“NEW 2nd proposition”) to 276”08’ MN (“NEW 3rd proposition”).

From April to May 1972, additional testing was carried out at 4 different locations in the Lagoon, as shown on Figure 7-6. Location A is a proposed preloading tank position. Locations B, C and D are situated along the new 3rd proposed central line.

Coordinates were not provided and these locations were georeferenced in ArcGIS by AECOM based on 1970 Drawings BL-20 and CL24 to an expected accuracy of ±10 m or better (due to the resolution of the original map). Boreholes were recorded with a "1972_" prefix. Key log information was imported in Bentley gINT in S.I units.

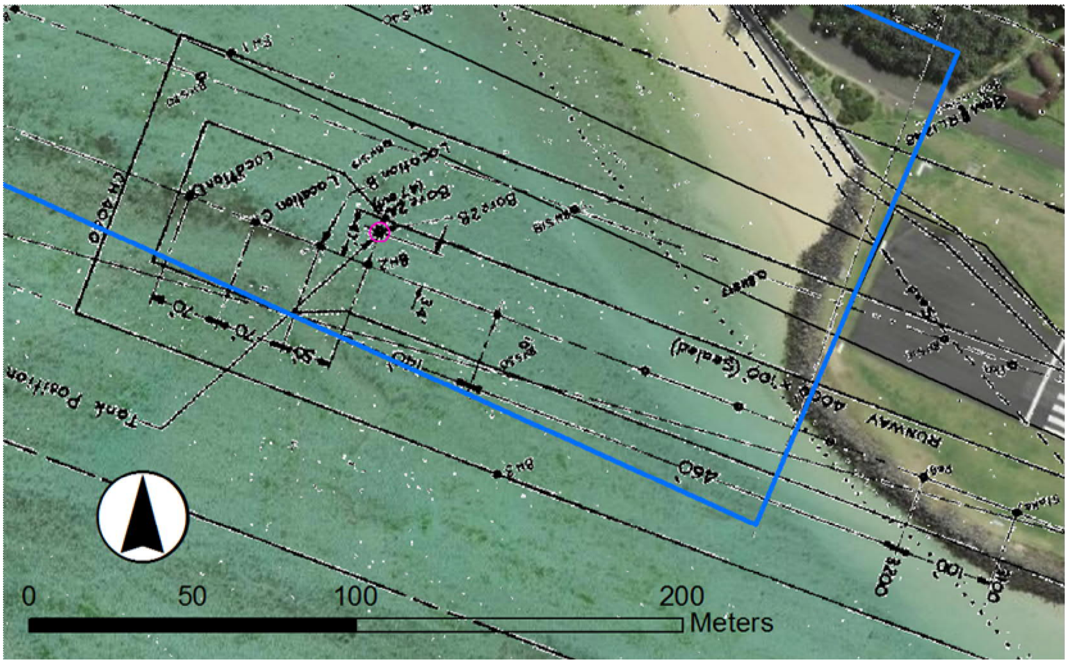

Figure 7-6 Map of 1972 Locations A, B, C and D and tank. Georeferenced by AECOM

Individual exploratory holes at each of these locations were drilled within 0.4 to 0.8 m of each other and are summarised in Table 3 and georeferenced in Appendix A and Appendix B.

Table 3. 1972 Site Investigation

Location	Augered Borehole	"Cone Penetration Test" (Continuous SPT)	"Dutch Cone" (Mechanical CPT)	Continuous Sampler Penetrometer Test
Location A		2 (2A, 2B)		
Location B	3 (B2, B5, B7)	1 (B1)	1 (B3)	1 (B6)
Location C	1 (C3)		1 (C1)	2 (C2, C4)
Location D	2 (D1, D3)	1 (D2)	1 (D2)	

Limited NMLC coring was carried out in the calcarenite (logged as calcareous sandstone) in 1972_C2 and 1972_C3.

The continuous sampling used an undersize cutting shoe driven with an SPT Hammer and the number of blows per feet was recorded.

The Dutch Cone is a mechanical Cone Penetrometer Test which records the end cone resistance but not the friction. The diameter of the cone was 2.5 cm, which is smaller than the diameter for typical modern tips (3.6 cm for 10 cm^2 and 4.4 for 15 cm^2).

A few density tests were carried out in 1972_B2 and 1972_B5.

The preloading tank was 5.89 m (19"4') in diameter by 0.71 m high (28'). Seven boreholes (labelled TK) where drilled at the tank position to install monitoring instrumentation. Maihak strain gauges were placed in TK1, TK2, TK3 (2 gauges) and TK4. 2 piezometers were installed in TK5. A cone point settlement gauge installed in TK6 and TK7. The data collected from this instrumentation is unavailable, and it is unknown if the instrumentation was left down the holes. Based on information provided by the Board, the tank was decommissioned in the early 80s.

The 1972 report included updated long sections of 1970 data showing standard penetration tests for the marine boreholes and revised units (1970 Drawing B-L-29).

The unit logged as "coral sand with volcanic ash" in 1970 was typically renamed on the 1972 sections as "calcareous ooze with coral and silty sand". The only reference to ash is in 1972_B7. Testing of the mineralogy of the sediments (e.g. XRD) would be required to confirm if the finer component of these sediments is volcanic ash.

Also, the calcarenite in the 1970 site investigation was relogged as "silty sands" on the marine boreholes presented on the 1972 section. Indeed, the 1972 investigation generally went deeper in the Lagoon that the 1972 investigation and most holes suggest that what logged as calcarenite in 1970 might actually be a dense to medium dense silty sand layer and be more than 3 m above the top of the 'calcareous sandstone' (calcarenite) which was cored in C2 and D3. A layer of sandy silty clay and a layer of calcareous sand with weathered calcarenite are described between the dense silty sand layer and the top of the calcarenite.

7.6 2014 Geotechnical investigation

The 2014 investigation carried out as part of the airport pavement and drainage assessment comprised 7 test pits at the seal edge (PP01 to PP07), 5 test pits adjacent to the runway (TP01 to TP05), 12 Dynamic Cone Penetrometer tests (DCPs) and 8 pavement DCPs. Laboratory testing comprised: 5 maximum dry density (modified) test, 5 California Bearing Ratios, 8 Particle size distribution, 4 Atterberg limits and 4 constant head permeability tests.

The depth of the investigation was limited to 1 m for pavement test pits and 2.6 m for the test pits. Calcarenite was not encountered and with the exception of TP05, which was excavated in aeolian sand, only the bottom of these test pits encountered natural aeolian sands. This limits the relevance of this investigation for the proposed runway expansion site.

Figure 7-7 TP05 Photos - extract from GHD 2014

The pavement boreholes under the current runway and test pits in the drainage area identified:

- TOPSOIL: 0.03 to 0.15 m thick, sand and silty sand
- FILL: 0.5 to 1.5 m of dense to very dense SAND with gravel with fines, very weakly to weakly cemented, of crushed calcarenite (basecourse). Liquid limit of 20% and linear shrinkage of 1%. Four PSDs suggested about 65% of sand, 25% gravel and 10% of fines. Occasional cobbles (up to 0.25 m in size) were encountered at two locations.
- Remnant topsoil: potential 0.1-0.2 m of clayey sand and sandy clay
- Proven to 2.6 m: fine to medium grained poorly graded sand with traces of coral and shells.

The report includes a long section along the runway which includes selected data from the 1970 investigation (Section 7.4); however S16 seems to have been plotted at an incorrect level.

The report includes soil landscape mapping (Figure 7-8) using the soil landscapes defined by Atkinson et al. 1984 (Section 6.1.3). This suggest that the top sediments under the runway are stratified marine and alluvial sands, with weakly structured sandy soils over Ned's Beach Calcarenite and brown structured clays above the North Ridge Basalt in Transit Hill. Brown structured clays are described as high plasticity, brown, strongly structured clays, with potential colluvial boulders and cobbles in foot slopes.

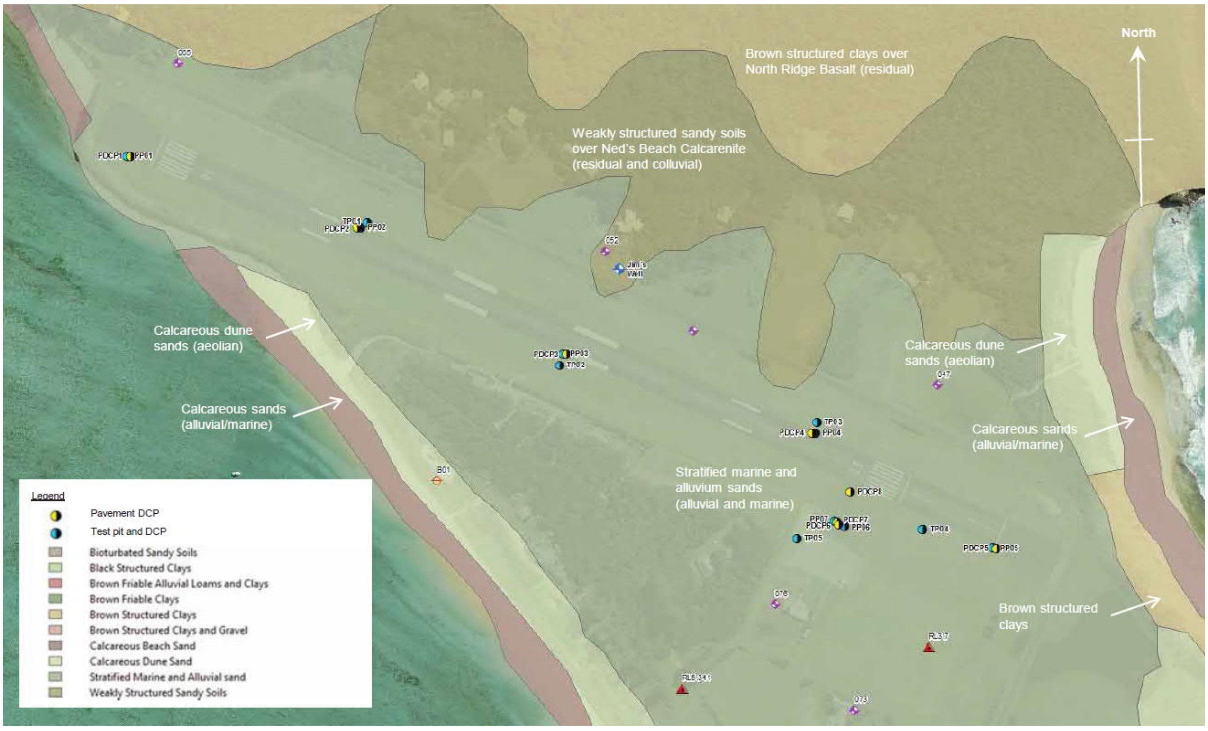

Figure 7-8Soil landscape and geology - extract from GHD 2014

7.7 Coastal Study (2014)

A coastal study was carried out by Royal Haskoning in 2014. Key findings in terms of sediment mobility are summarised below:

- the sediment is naturally mobile in the wider Lagoon
- most of the length of the beaches on the Lagoon side of LHI are prograding, with sediment transported from the Lagoon to the beach over the last 50 years. As discussed in Section 4.2, a similar process formed the current beaches over the previous thousands of years.
- the only two areas receding are the 600 m long section of the beach north of the runway and the 100 m long section south of the runway. This is expected to be due to higher wave energy and structure effects, and less supply of sediment due to the sink areas further south (e.g. Comets Hole). These are expected to capture some of the sediment supply from the reef, effectively creating a barrier to sediment transport.
- potential sediment smothering reef area at northern end of Lagoon Beach (north of runway) and Cobbys Beach (south of runway) between 2001 and 2011
- the erosion at Windy Point pre-dates the construction of the rock apron for the airport

A number of shallow beach and lagoon sediment samples were tested by Kennedy (1999) and Royal Haskoning (2014) around the island. Key findings on the alluvial and marine calcareous sands in the Lagoon are summarised below:

- 99% of the beach and lagoon sediments are skeletal carbonates (the rest being volcanic grains and accessory minerals)

- Beach sediments were almost all fine to coarse, rounded to angular sand, with limited fines (note that the report places the boundary between fines and sands at 62 microns instead of the 75 microns from the Australian Standards).
- Lagoon sediments were close to entirely sand sized (except W3 and W4), with very minor amounts of foraminifera, echinoderms, sponges and crustaceans.
- In the southern Lagoon Beach, the samples with significant gravel fraction were all taken within 1 to 3 m from the water level. Gravel was angular. The coarse sand particles are dominated by corals and molluscs.
- Coarser sediments were present near the waterline, but similar sizes were found in the Lagoon and on the beach

In more detail, testing on the 2012 samples closest to site (SR1, SR2, L1, L2, L3, L4, W3, W4, W5, W13 and W15, see Figure 7-9) shows:

- >85% particles from 62 microns to 2 mm, except W3 and W4 which show 73-74%. The rest is gravel size.
- sub angular to rounded mollusc / coral and coralline algae to 15 mm
- well sorted beach deposits

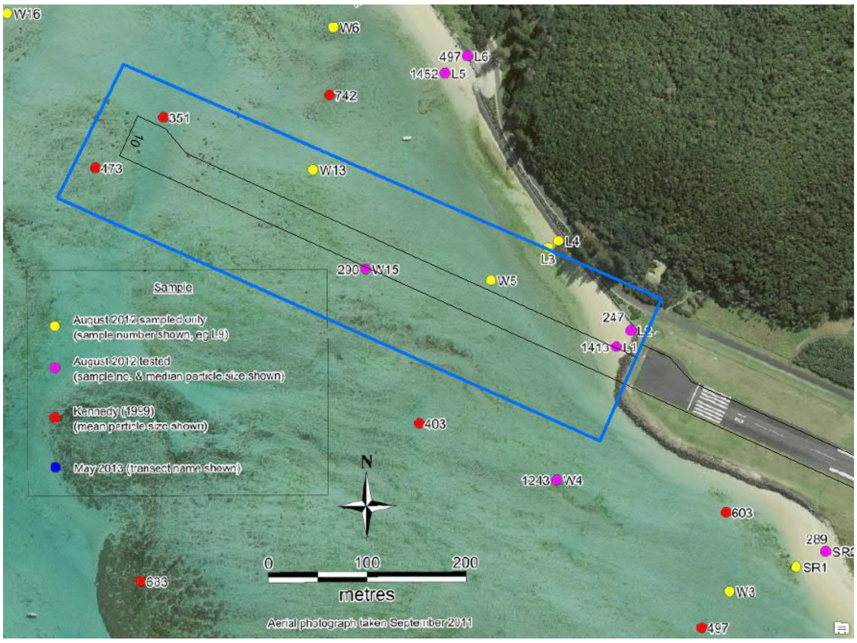

Figure 7-9 Sediment Samples – extracted from Coastal Study 2014 (sizes in microns) – Georeferenced by AECOM

8.0 Geophysical Survey (2018)

A geophysical survey was carried out by Marine Earth Sciences, in the presence of AECOM, on 29-30 May 2018. The works comprised:

- Marine seismic reflection (sub-bottom profiling) lines within a 600 by 150 m zone (boomer)
- Marine refraction lines within a 600 by 150 m zone (airgun)
- A 70 m long land refraction line on the beach next to Seabee revetment (hammer and plate)

The results of this survey are documented in the report in Appendix E and are summarised below.

8.1 Sub-Bottom Profiling

Interpretation of the SBP records has identified one continuous reflector across the site which coincides with the seafloor. Due to the nature of the seafloor material related to the coral structures and coral detritus materials over the site, very limited penetration is due to backscatter effect. No observable reflectors were mapped at the site with this technique.

8.2 Seismic Refraction

The seismic refraction surveys have successfully mapped subsurface conditions up 45m below the seabed. Some seismic lines have intersected historic geotechnical boreholes which identified variably thick coral sands and calcarenite at depth. The comparison of seismic velocity with geological materials at these locations indicate that coral sands correlate with a seismic velocity ranging from 1500m/s to 1850m/s and calcarenites having seismic velocities greater than 1850m/s.

The top of calcarenite is irregular in profile, and appears to increase in depth towards the north east (into the lagoon) with an area of very loose sand extending to RL-20 Local AHD at the north eastern end of the seismic line.

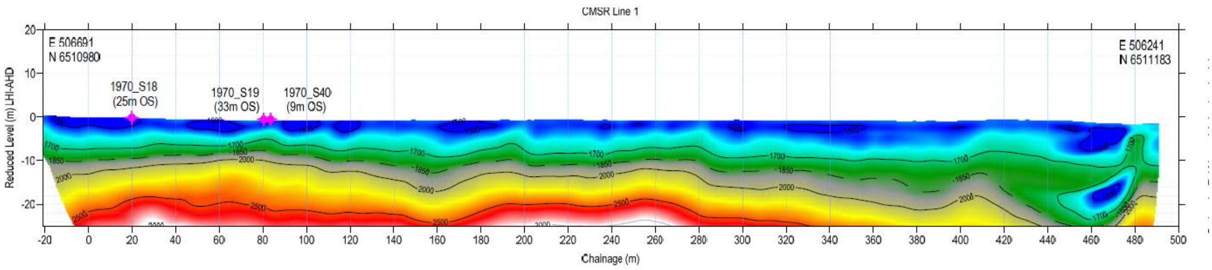

Figure 10 Seismic Refraction Survey - Line 1 (along Runway)

At depth (generally below RL -20m Local AHD) seismic velocities increase to >3000m/sec, which is inferred to be volcanic bedrock. The top of volcanic bedrock also seems to be irregular in profile with an increase in depth towards the north east (into the lagoon).

9.0 Preliminary geological model

We have used the information presented above to develop the preliminary geological model in Table 4. The depths and thicknesses are solely based on the intrusive investigations in the lagoon. Depths are below seabed.

Table 4 – Interpreted geological model

Geotechnical Unit	Abbreviation	Simplified Description	Typical RL Local AHD	Depth to Top of Unit (m)	Unit thickness (m)
Upper Sands	UP SANDS	Carbonate sands trace gravel	0 to -2	0.0	1.9
Lower Sands	LO SANDS	Carbonate silty gravelly sands	-2 to -9	0.0 to 2.0	7.3 - 10.4
Interbedded Sands and Clays	INT S-C	Interbedded Sands and Clays	-9 to -12	7.9 to 9.5	2.8 - 4.9
Calcarenite	CAL	Undifferentiated	-12 to -15	11.0 to 13.8	
	CAL-W	Weathered	-12 to -14		1.8 to 3.1
	CAL-F	Sound	-14 to -15 (proven)		0.7 (proven)
Volcanic Bedrock	VOLC	Basalt, Breccia and Tuff	Not encountered	Not encountered	Not encountered

The unit depths, thicknesses and material properties presented in Table 4 should not be assumed to represent the extremes that may be encountered across the site. Actual unit boundaries and material properties can be highly variable.

The interpreted lateral distribution of the units based on the data presented the geological long and cross sections in Appendix C.

The geology units were interpreted based on the geological descriptions. Generally, SILT was used for ooze, with GRAVEL used for coral. A stratum described in the original SI as “calcareous ooze with coral” would generally be presented as a gravelly silt on the long sections in Appendix C, due to the interpretation that the coral would have an impact on the engineering behaviour of the ooze and that most pieces would consist of fine gravel. If “little” coral or sand was described on the original logs, the coral or sand was considered not to impact on the engineering behaviour of the soil. “Coral sand, high content coral pieces - some shell - material lightly bound with volcanic ash slurry” would be typically described as a silty gravelly sand. However, proportions were not provided in the 1970 and 1972 investigation and due care is required when referring to these legends.

The soil consistencies and densities on the original logs do not follow current standards. They vary between terms for cohesive and non-cohesive terms often independently of the geological descriptions and these consistencies and densities were copied on the long sections for correlation between the units only.

The blow counts reported for 1972_B6, 1972_C2 and 1972_C4 were not carried out using an SPT shoe but with an undersize cutting shoe – values are presented as CS values on the geological sections. The blow counts reported for 1972_D3 were carried out by driving a casing with a SPT hammer and were not continuous – these values are not shown on the geological sections.

The blow counts reported for 1970_S31, 1972_B1, 1972_D1 and 1972_D2 are expected to have been carried out with a closed SPT shoe – values are presented as Nc on the geological sections.

Rock roller yields much less information and certainty on the stratigraphy than continuous sampling and during the interpretation, more reliability was placed on the boreholes with continuous sampling: 1972_B6, 1972_C2, 1972_C4.

9.1 Upper sands

9.1.1 Description

Based on the historical information, and logging of the sands at the beach, these sediments are typically carbonate sands, fine to coarse, well graded, sub angular to rounded, platy, predominantly pale with yellow-brown to white, black and red-brown, predominantly of coral and shells; trace fine to medium gravel, gravel is typically fine, platy, white, of coral and shells. The gravel proportion can occasionally reach 25%.

A strong sustained reaction on a sample tested by AECOM with a 10% solution of hydrochloric acid confirmed that these sands are carbonate. This sample seemed very similar to the sand forming the calcarenite dune deposits in Lover’s Bay south of the site.

9.1.2 Distribution

This typically one meter thick unit is encountered in most marine boreholes across the site. It is expected to be present within one to two meters from the seabed, as shown on the geological sections in Appendix C.

9.1.3 Geotechnical properties

The density of this unit is very loose to loose, with SPTs in this unit typically less than 4 (Figure 9-1, Table 5). The high values of N=13 in 1972_2A and N=14 (1972_2B) are likely to be due to coral gravel rather than due to an increase in density.

9.2 Lower sands

9.2.1 Description

This unit is described as coral sand with volcanic ash in the 1970 investigation and “calcareous ooze with coral and silty sand” in the 1972 investigation (except for 1972_B7 which used: “volcanic ash slurry with coral”). This unit was described as gravelly mud in the Woodroffe investigation.

As shown on the geological sections, this unit varies greatly in composition, from a silty gravelly carbonate sand to a silt or gravelly silt. It comprises occasional beds of coral gravel, usually about 200mm thick but exceeding 1 m in bores 1972_D2, 1972_TK1 and 1972_C3.

For the purpose of this model, this unit is interpreted to consist of a silty gravelly carbonate sand, fine, grey-brown to brown; gravel is fine, of coral, with occasional beds of coarse coral gravel.

9.2.2 Distribution

This unit is encountered in all boreholes in the Lagoon as a unit of 7 to 10 m thickness and seems to thicken towards the west (1970_S20 and S21).

9.2.3 Geotechnical properties

This unit is very loose to loose, with SPTs in this unit typically less than N=2 (Figure 9-1, Table 5) and occasionally N=6 due to coral gravel. There is no clear increase in density with depth on either on the blow count plots (Figure 9-2 and Figure 9-3).

Field bulk and dry unit weight tests were carried out on five undisturbed samples within this unit in 1972_B2 and 1972_B5. The average bulk unit weight of 16 kN/m^3 (15 to 18 kN/m^3 range) and dry unit weight of 9 kN/m^3 (7 to 13 kN/m^3 range).

9.3 Interbedded sands and clays

9.3.1 Description

This layer consists of alternating beds of silty sands and silty sandy clays.

The thickness of the clay and sand beds vary from 0.3-0.4 m to 2.6-2.8 m. Typically, the top of the unit is characterised by a silty sand, which overlays a clay bed. However the units alternate in 1972_C2 and 1972_D3.

This top silty sand layer was described as calcarenite in the 1970 but revisited in 1972, which went deeper. It also corresponds with the top of the sound calcarenite in 1970_S16. This origin of this unit is unclear. There is a possibility that this unit is weathered calcarenite as logged in 1970, however, based on the typically dark brown colour of this unit, this could also be of alluvial origin. In S17, the clay was described as “basaltic clay”, suggesting material sourced from volcanic bedrock, or dykes.

9.3.2 Distribution

This layer is typically 3 m thick. The top of this unit is relatively uniform at about RL -9 to RL -10 m Local AHD but was not encountered in 1970_S20, 21 and 40, suggesting this unit could be absent or deeper below most of the site.

9.3.3 Geotechnical properties

This unit is denser/stiffer than the units above with SPTs in this unit ranging from 4 to 16 (Figure 9-1, Table 5), suggesting loose to medium dense and firm to stiff deposits. The continuous sampler blow counts suggest that there is a decrease in strength with depth; this is expected to be due to the predominance of the clay below the denser silty sand layer at the top in these boreholes (Figure 9-3).

9.4 Calcarenite

9.4.1 Description

The calcarenite was only cored in the Lagoon in 1972_C2 and 1972_D3 and was described as brown, suggesting potential presence of volcanic material more similar to the Cobbys Corner Member than the Neds Beach Calcarenite.

It is expected to be bedded, with bedding generally dipping gently towards the west.

The top of the calcarenite was typically described as silty sand and weathered in the 1972 investigation. The thickness of this weathering seems to vary between 2 and 3 m.

A small thickness of “hard” calcarenite was described below weathered calcarenite as “sandstone”. Sandstone was also described in some land holes such as 1972_ S9 and S1, however it is inferred that this is the same unit.

9.4.2 Distribution

The top of the calcarenite may be highly variable, especially if exposed to subaerial processes.

The elevation of calcarenite seems to drop westwards from 1970_S28 to a plateau at RL -9.5 m Local AHD in 1970_S15 and S16, then drop to RL -14 m AHD in 1972_B1, C2 and D3. The holes further north-west from 1972_D3 were not drilled deep enough to encounter the top of the calcarenite.

9.4.2.1 Geotechnical properties

No strength testing is available on the calcarenite. Exposed outcrops showed strengths varying from high to very low. Although the probability of high SPTs and refusal increases with depth, available SPTs in this unit close to the lagoon (K series, S8, S11, S12, S16, S26, S28, S35, S36, S38) suggest that the strength properties vary with depth without necessarily increasing (Figure 9-4).

Table 5 Summary of SPT Blow counts per Unit (Marine boreholes only)

Values	UP SANDS	LO SANDS	INT S-C	CAL-W
Count of SPT N values	10	30	3	43
Max of SPT N	14	6	16	16
Min of SPT N	1	1	4	1
Average of SPT N	5	2	9	3

Table 6 Summary of Nc Blow counts per Unit (Marine boreholes only)

Values	UP SANDS	LO SANDS	INT S-C	CAL-W
Count of Nc values	3	53	16	16
Max of Nc	22	10	25	50
Min of Nc	1	1	1	10
Average of Nc	9	2	14	17

Table 7 Summary of CS Blow counts per Unit (Marine boreholes only)

Values	UP SANDS	LO SANDS	INT S-C	CAL-W
Count of CS values	10	73	16	2
Max of CS	9	29	31	17
Min of CS	1	1	12	12
Average of CS	4	6	19	15

9.5 Volcanic Bedrock

This unit forms the bedrock and can therefore be expected at depth; however the top of rock could be sloping steeply to the depth of the shelf.

The basalt, when fresh, is a high strength to very high strength rock.

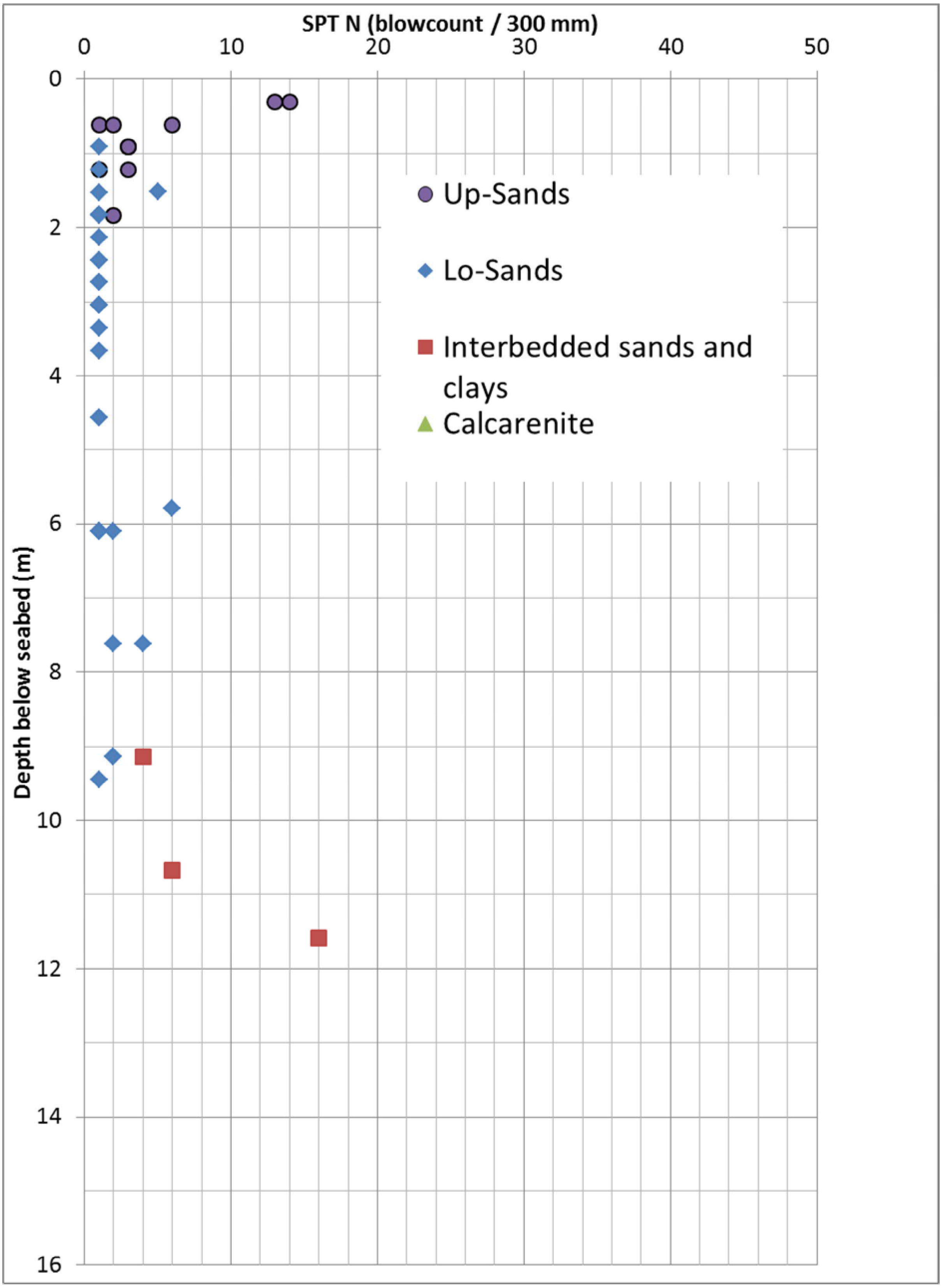

Figure 9-1 SPT Blow counts (marine boreholes only) – values were entered as 1 if less than 1 and 50 if more than 50.

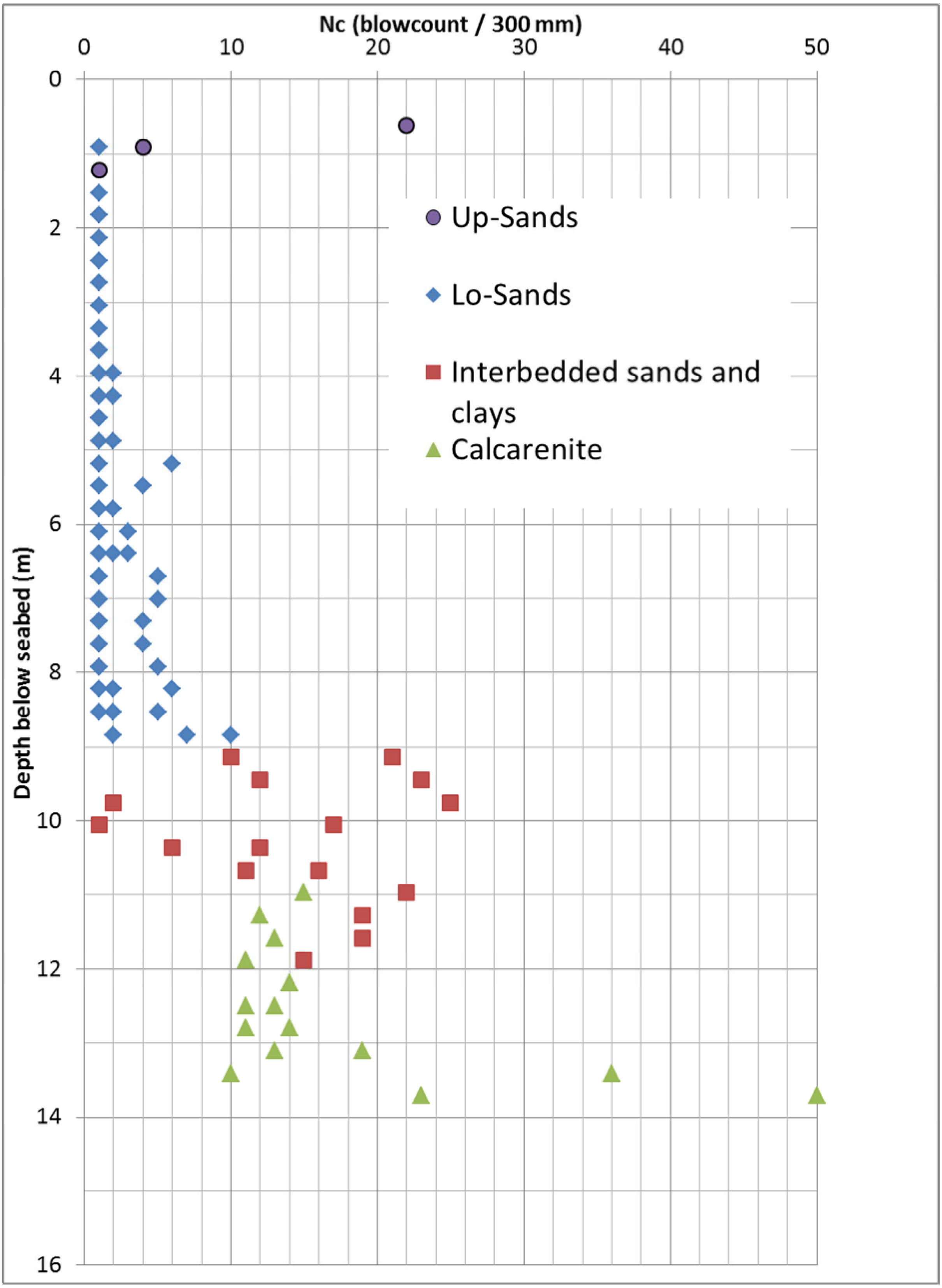

Figure 9-2 Nc Blow counts (marine boreholes only) – values were entered as 1 if less than 1 and 50 if more than 50.

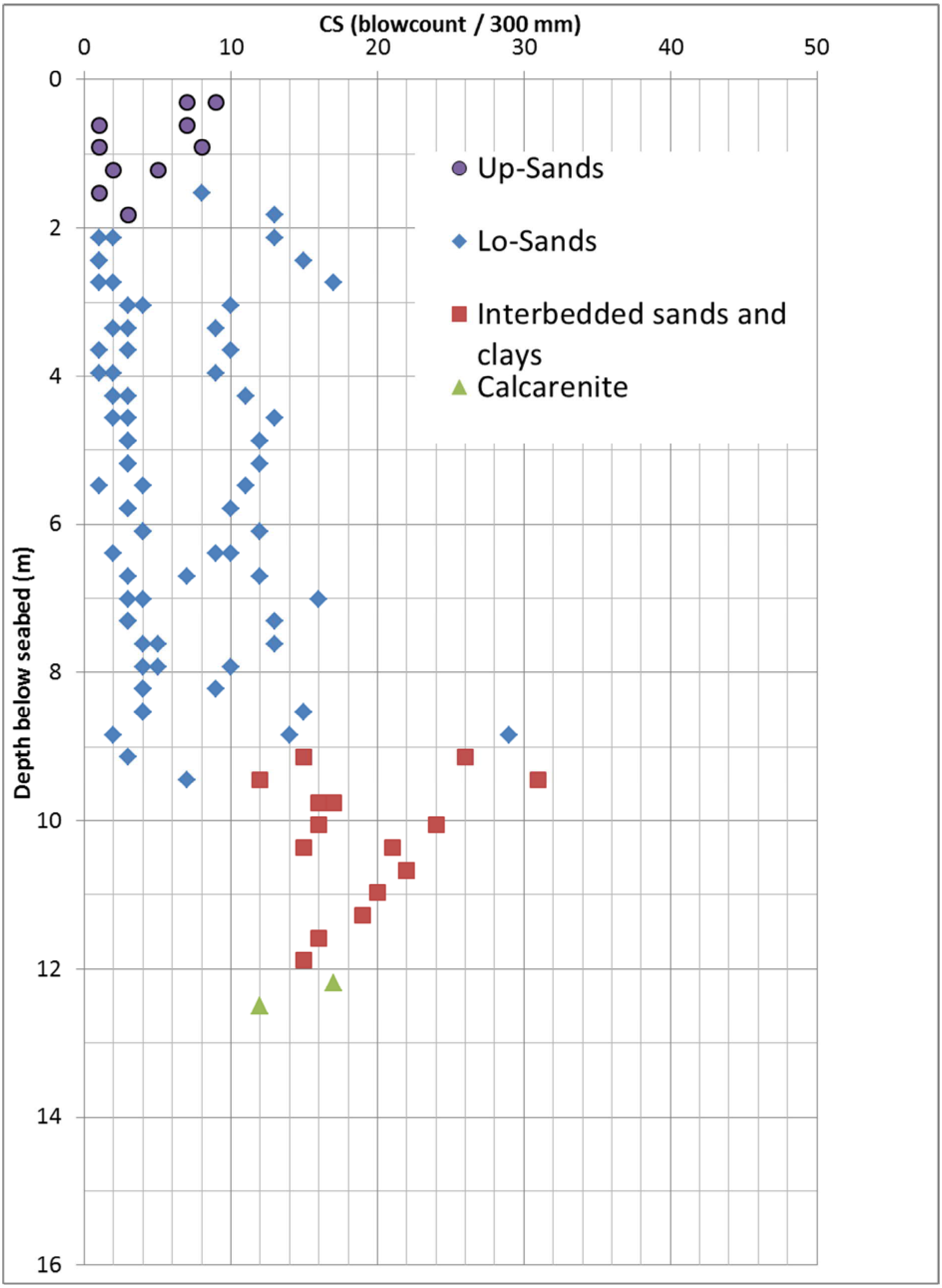

Figure 9-3 CS Blow counts (marine boreholes only) – values were entered as 1 if less than 1 and 50 if more than 50.

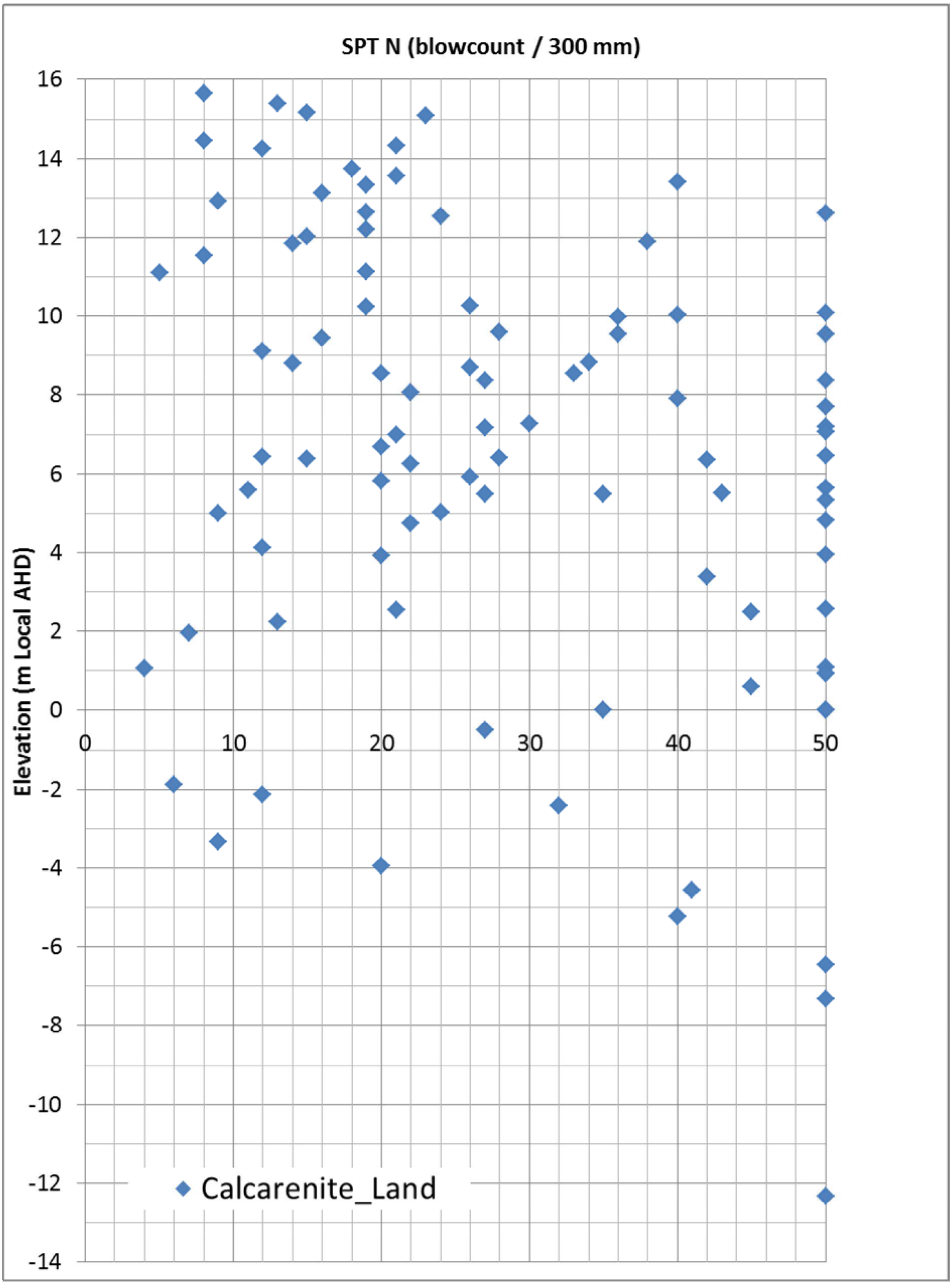

Figure 9-4 SPT N Blow counts in Calcarenite. Values were entered as 1 if less than 1 and 50 if more than 50.

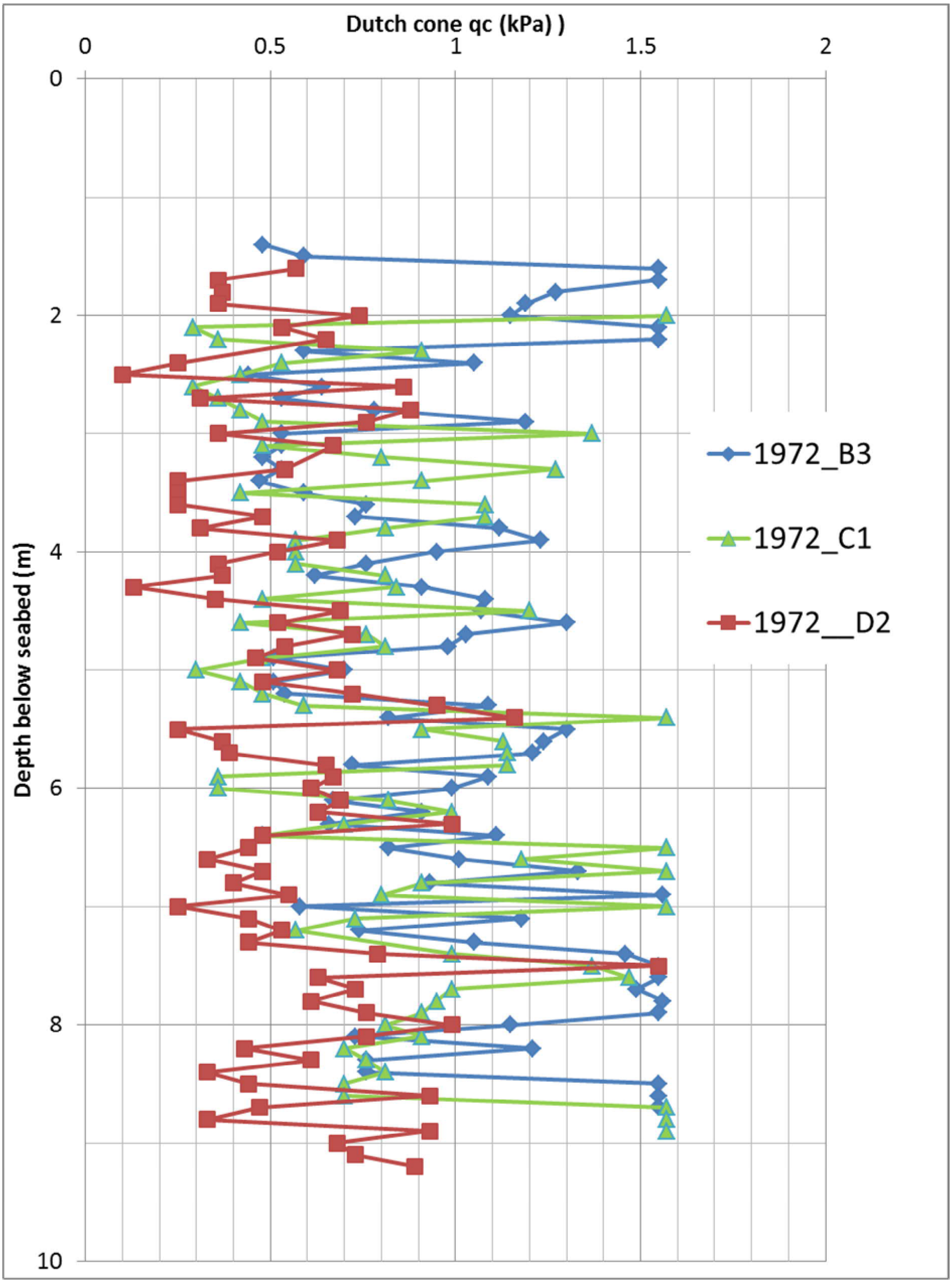

Figure 9-5 Non-normalised cone end resistance

Table 8 – Preliminary Geotechnical Parameters

Geotechnical Unit	Density/Consistency	Bulk Unit Weight	Effective Cohesion (kPa)	Effective angle of internal shearing resistance (deg)
(kN/m3)	Effective Cohesion (kPa)	Effective angle of internal shearing resistance (deg)		
Upper Sands	Loose	16	0	25
Lower Sands	Very loose / very soft	16	0	25
Interbedded Sands and Clays	Loose to medium dense	16	0	30
Calcarenite	Weathered	18	10	32
	Sound	20	50	35
Volcanic Bedrock				

10.0 Discussion and recommendations

10.1 Digital data package

The data package includes:

- 1970 and 1972 boreholes in ArcMap GIS files
- 1970 and 1972 boreholes coordinates in GDA94 / MGA Zone 57
- an AGS export of selected data which was collated in gINT.

In the gINT database the silt legend was typically used for material logged as Ooze, and the gravel legend for coral fragments. The continuous cone penetration tests were entered as conventional SPTs. The Dutch cone data was entered as cone end resistance in kPa.

10.2 Geotechnical considerations and risks

10.2.1 Soils Overlying Calcarenite

The overlying soils are low strength, compressible, and may be susceptible to liquefaction under seismic loading. The depth of soil increases into the lagoon, with material with a seismic velocity of less than 1850m/s extending to below RL -25 local AHD at the north western end of the proposed runway extension.

Placing fill to on these soils will result in settlement, increasing the volume of material required. The design of the fill embankment would also need to incorporate measures to accommodate the low bearing capacity of the soils, such as toe berms and flat batters. These measures would also increase the volume of fill material required.

The potential for liquefaction of clean sands may be assessed using a Peak Ground Acceleration (Z) of 0.06 for Lord Howe Island as per Table 3.2 of Australian Standard 1170.4 – 2007.

For the piled option the contribution of the overlying soils to the pile capacity will be very small and would be ignored.

10.2.2 Calcarenite

Reference to the Seismic Refraction results indicate that the inferred top of calcarenite can vary in level by up to 5m over short distances. Given the calcarenite is weathered; these variations may be the result of karst type weathering.

The potential for voids and weathered zones in the calcarenite precludes using driven piles driven to refusal in calcarenite as a foundation option. Pile embedment will need to be proved by detailed drilling.

The strength and stiffness of the calcarenite will also need to be proved if this material it is to be considered as the bearing strata for a piled deck option.

10.2.3 Volcanic Bedrock

The volcanic bedrock may comprise high strength basalt that may be difficult to drill.

10.2.4 Constructability

Major constructability challenges affect both the reclaimed land and deck-on-pile options. These include:

- Mobilising equipment to site
- material supply (especially borrow material for the reclaimed land option)
- site access
- environmental impacts

10.3 Further geotechnical investigations

This desktop study has been based on a limited number of boreholes from within and surrounding the site. Intrusive drilling will be required to inform future design stages. The investigation programme should:

- include the western section of the alignment to cover the existing gap in information
- correlate with the 1972 investigation
- Collect samples of the overlying soils for laboratory characterisation testing (PSD, Atterberg limits, and
- core the calcarenite (with acceptable core recovery) to carry out rock strength testing (UCS and Point Load Testing)
- prove the depth to top of the volcanic rock

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12.0 Important information about this geotechnical report

Client details, scope and reliance

AECOM has prepared this report for the sole use of the Client and for a specific purpose, each as expressly stated in the report. No other party should rely on this report without the prior written consent of AECOM. AECOM undertakes no duty, nor accepts any responsibility, to any third party who may rely upon or use this report. This report has been prepared based on the Client's description of its requirements and AECOM's experience, having regarding assumptions that AECOM can reasonably be expected to make in accordance with sound professional principles. AECOM's findings represent its reasonable judgment within the time and budget context of its commission and utilising the information available to it at the time.

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AECOM may have relied on information provided by the Client and third parties (Information Providers) to produce this report and arrive at its conclusions. AECOM has not verified information provided by the Information Providers (unless specifically agreed as part of AECOM's scope of work) and we assume no responsibility and make no representations with respect to the adequacy, accuracy or completeness of such information. AECOM assumes no responsibility for inaccuracies in reporting by the Information Providers including, without limitation, by the Client's employees or representatives or for inaccuracies in any other data source whether provided in writing or orally used in preparing or presenting the report.

Variability in conditions and limitations of data

Subsurface conditions are formed through a variety of natural processes and can be altered by human activities. The behaviour of the ground, groundwater and contaminants are complex and conditions can vary across a particular site. As a result, subsurface conditions cannot be exhaustively defined by investigations at discrete locations. Therefore, it is unlikely that the results and assessments expressed in this report will represent conditions at any location removed from the specific points of sampling. The precision with which conditions can be inferred depends largely on the uniformity of subsurface conditions and on the frequency and method of sampling as constrained by factors such as project budget and time limitations and physical constraints.

Furthermore, subsurface conditions can change over time, which should be considered when interpreting or using the data within this report.

Verification of opinions and recommendations

The opinions and recommendations in this report apply to the proposed development and the site existing at the time of our investigation and cannot necessarily apply to changes in the proposed development or site changes of which AECOM is not aware and has not had the opportunity to evaluate. Our recommendations should be considered to be preliminary and subject to verification during project implementation. If conditions encountered at the site are subsequently found to differ significantly from those anticipated, AECOM must be notified and be provided with an opportunity to review the recommendations.

Appendix A Site Plans

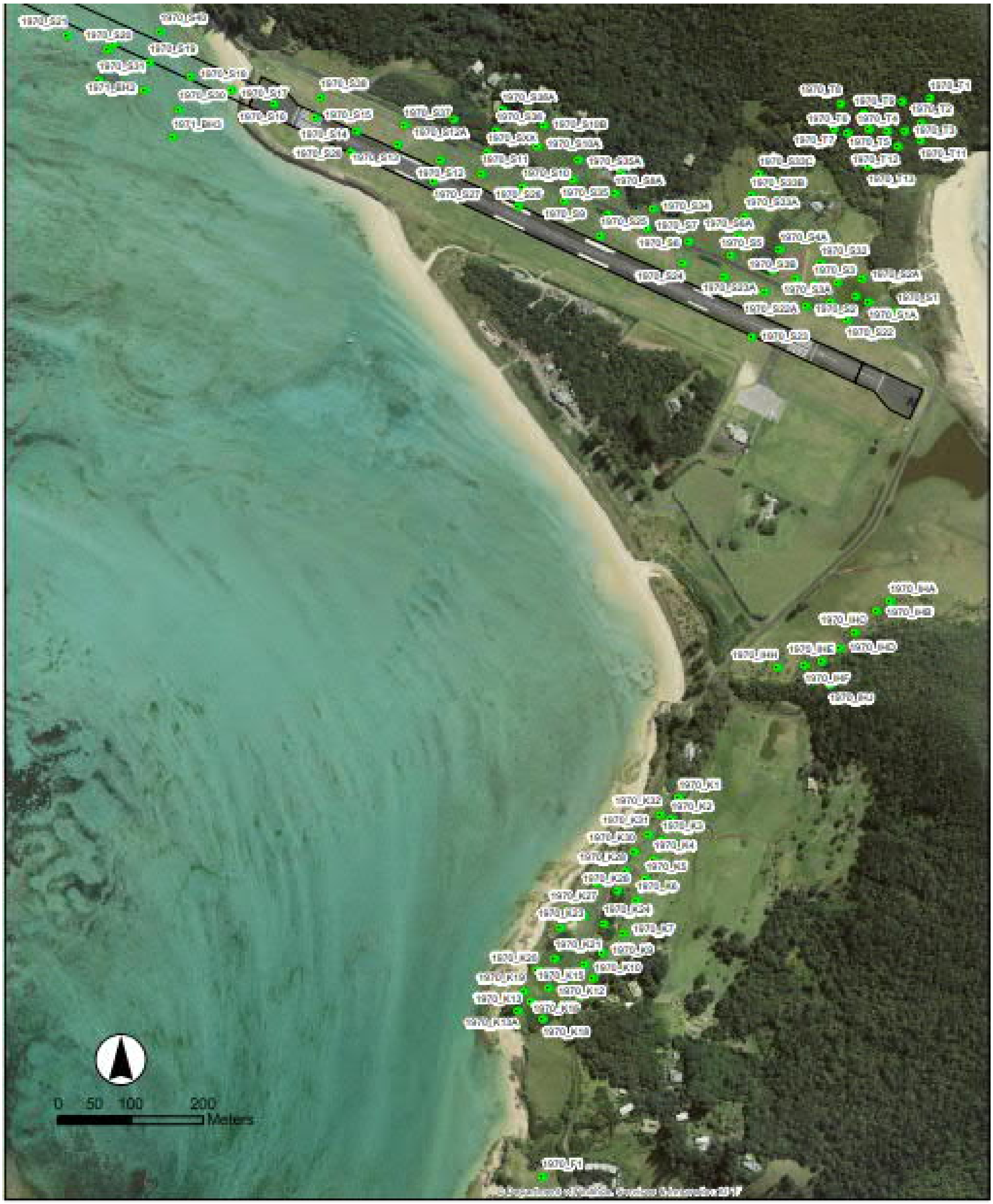


Figure 12-1 1970 Site Investigation (georeferenced by AECOM)

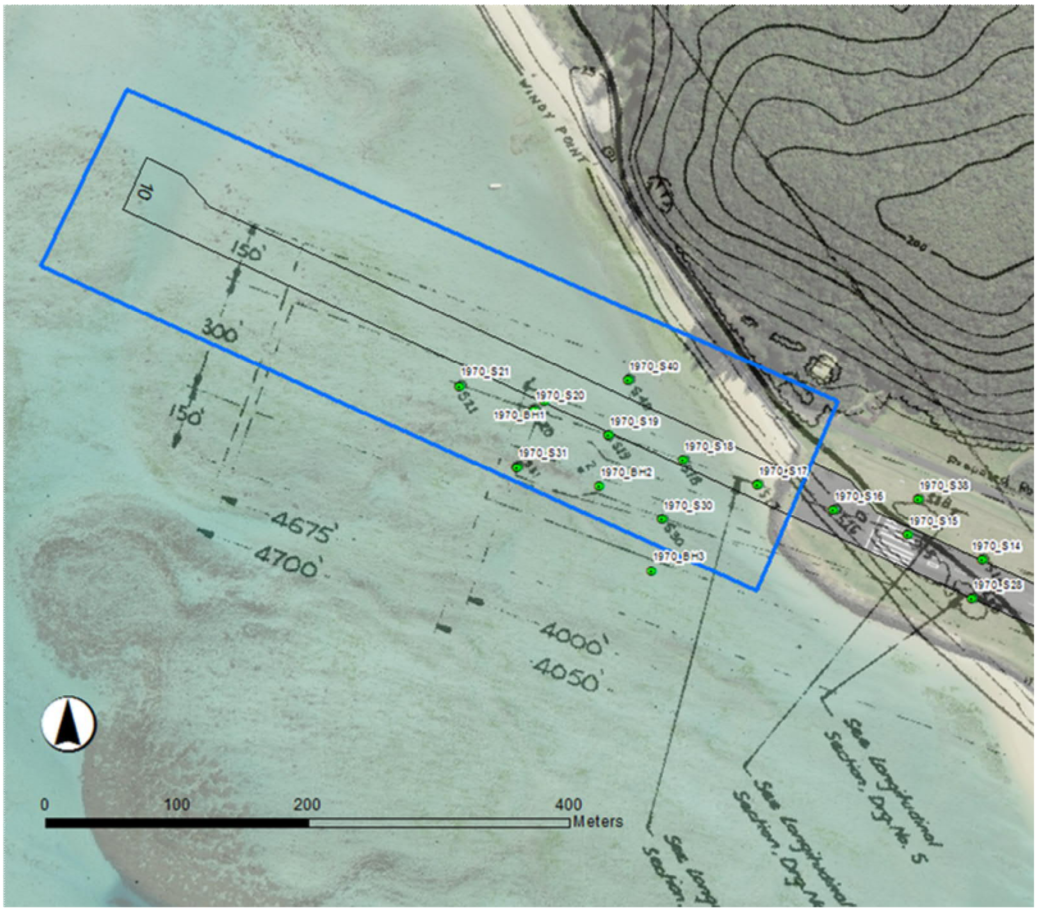


Figure 12-2 1970 SI – Detail of Georeferencing in the Lagoon

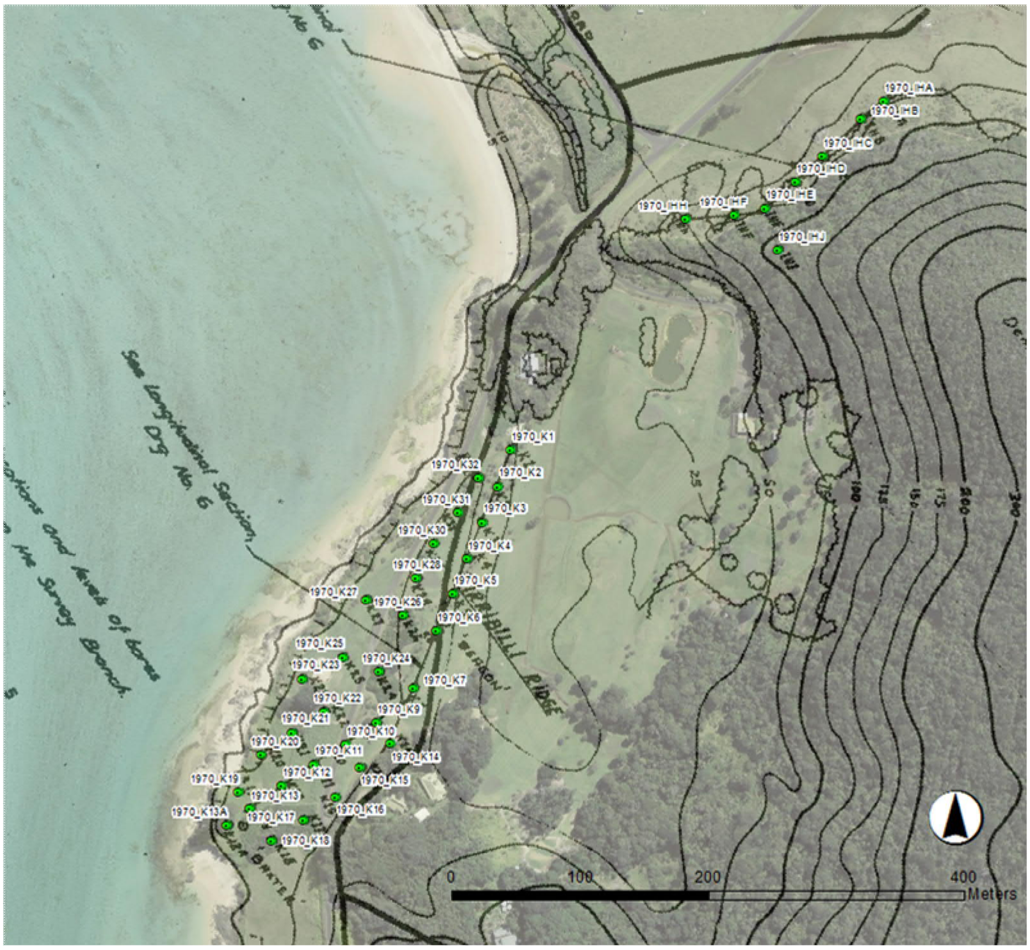


Figure 12-3 1970 SI - Detail of Georeferencing Land South

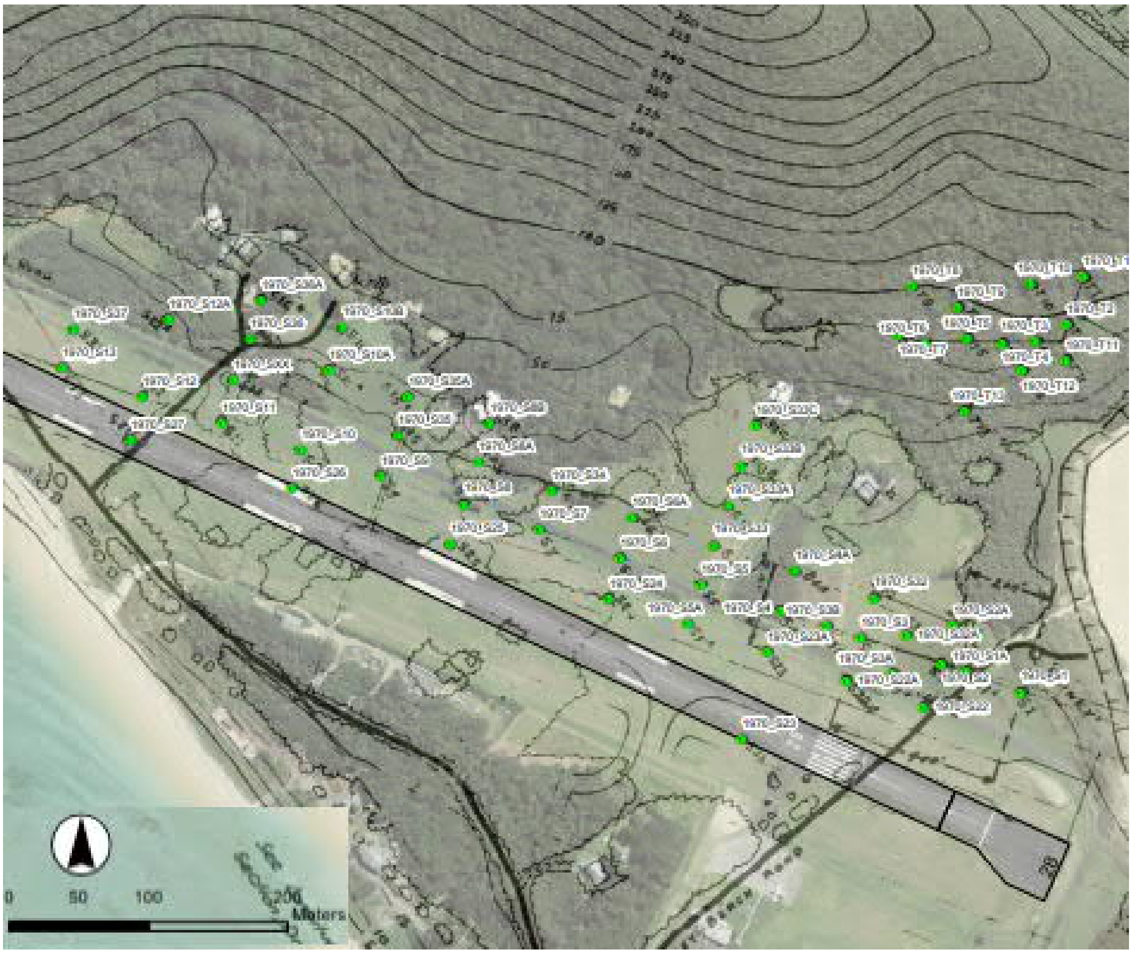


Figure 12-4 1970 SI - Detail of Georeferencing Land North

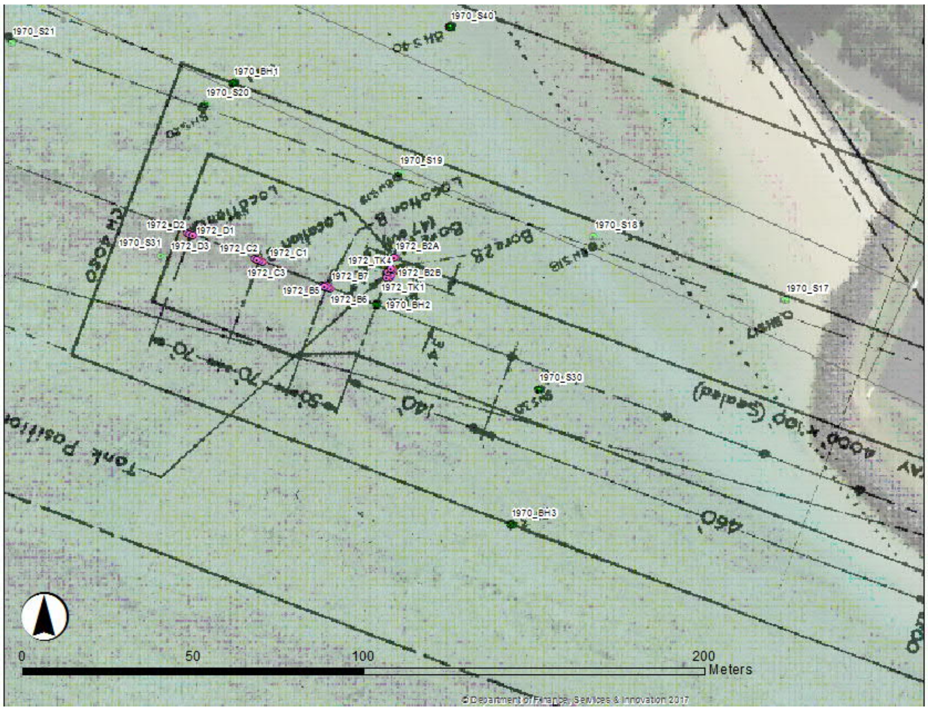


Figure 12-5 1972 SI – Detail of Georeferencing in the Lagoon (note difference of 1970 SI which was georeferenced with Drawing BL-29)

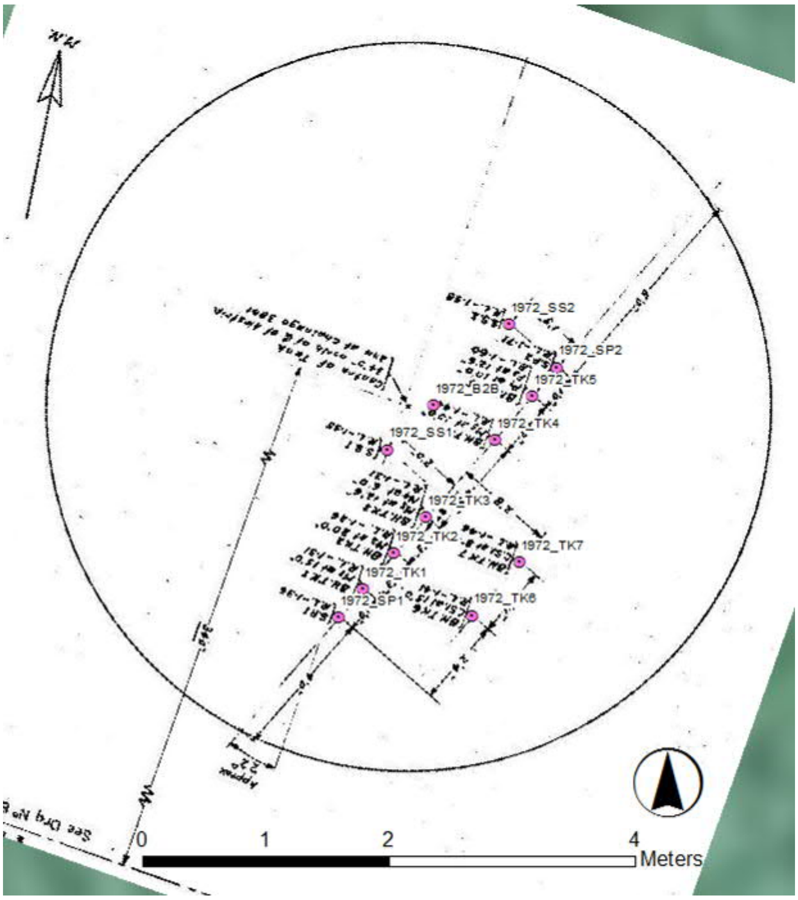


Figure 12-6 1972_SI Georeferencing of TK holes

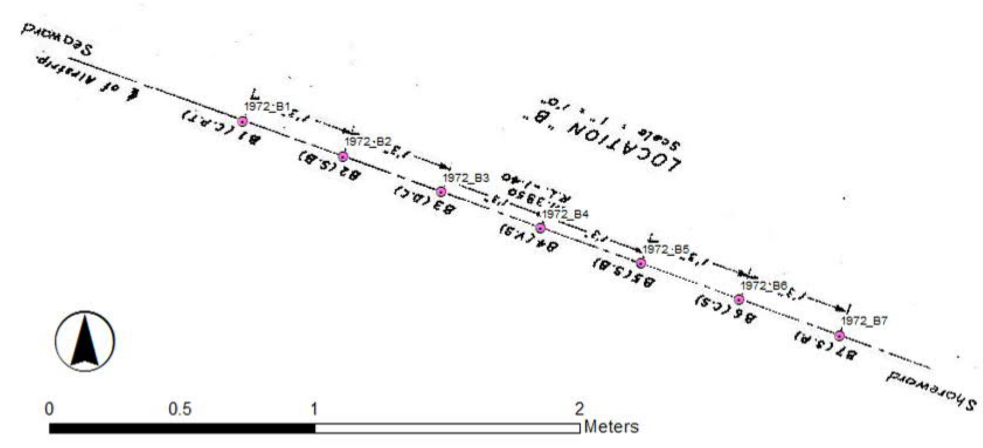


Figure 12-7 1972_SI Georeferencing of Location B holes

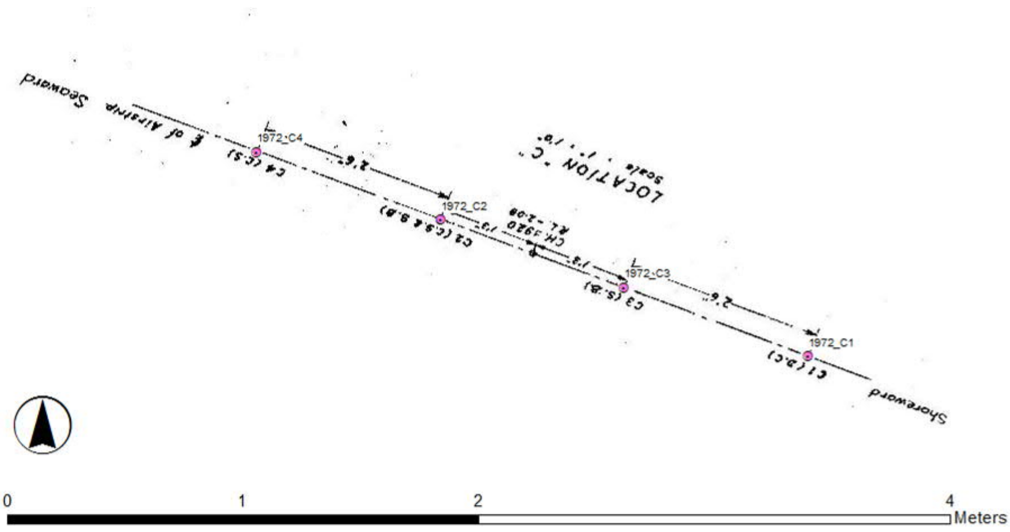


Figure 12-8 1972_SI Georeferencing of Location C holes

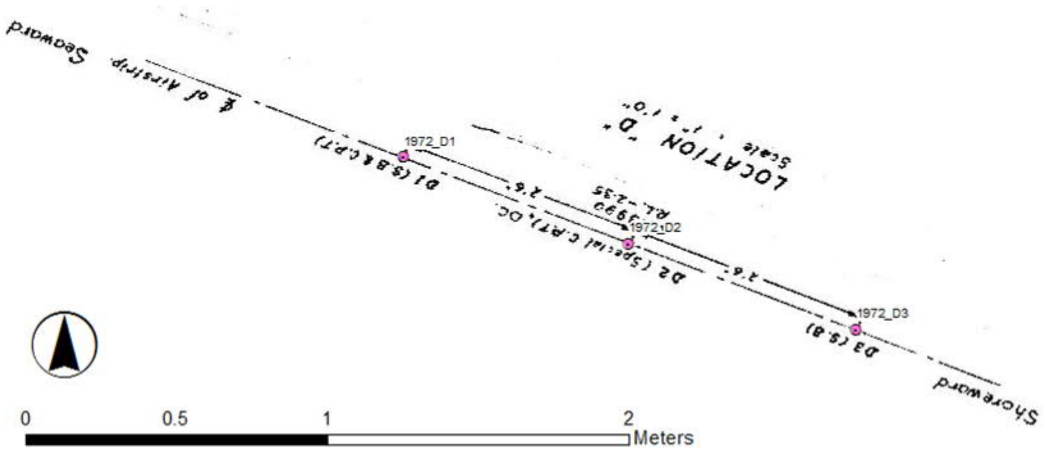


Figure 12-9 1972_SI Georeferencing of Location D holes

Appendix B Historical Boreholes

The following boreholes are available close to the site. The 1970 and 1972 were georeferenced to an expected horizontal accuracy of about 10 m. The elevations are the original ones – it was assumed that the vertical datum was the 1954 hydrographic datum (same as the Local AHD).

Borehole	Eastings (MGA 57)	Northings (MGA 57)	Elevation (m Local AHD)	Termination Depth (m)	Hole Type	Location
1970_F1	507148.2	6509447.3	18.29	12.65	NonCore	Pavement and Fill Borrow Area, Fenton
1970_IHA	507627.8	6510241.2	18.52	15.37	Cored	Rock Borrow Area, Intermediate Hill
1970_IHB	507609.6	6510227.3	18.50	15.65	Cored	Rock Borrow Area, Intermediate Hill
1970_IHC	507579.8	6510198.2	18.67	15.32	Cored	Rock Borrow Area, Intermediate Hill
1970_IHD	507558.6	6510178.3	17.73	10.85	Cored	Rock Borrow Area, Intermediate Hill
1970_IHE	507534.5	6510157.8	18.76	15.24	Cored	Rock Borrow Area, Intermediate Hill
1970_IHF	507510.7	6510152.5	18.69	15.47	Cored	Rock Borrow Area, Intermediate Hill
1970_IHH	507473.0	6510149.2	18.65	15.06	Cored	Rock Borrow Area, Intermediate Hill
1970_IHJ	507544.4	6510125.7	31.94	13.77	Cored	Rock Borrow Area, Intermediate Hill
1970_K1	507336.5	6509969.8	14.94	10.67	NonCore	Pavement and Fill Borrow Area, Kirribilli Ridge
1970_K10	507206.9	6509740.2	13.08	9.60	NonCore	Pavement and Fill Borrow Area, Kirribilli Ridge
1970_K11	507182.7	6509724.5	11.68	9.60	NonCore	Pavement and Fill Borrow Area, Kirribilli Ridge
1970_K12	507157.0	6509707.8	9.47	9.14	NonCore	Pavement and Fill Borrow Area, Kirribilli Ridge
1970_K13	507132.3	6509690.2	10.23	9.47	NonCore	Pavement and Fill Borrow Area, Kirribilli Ridge
1970_K13A	507114.6	6509677.5	9.40	7.62	NonCore	Pavement and Fill Borrow Area, Kirribilli Ridge
1970_K14	507241.8	6509740.8	16.18	10.82	NonCore	Pavement and Fill Borrow Area, Kirribilli Ridge
1970_K15	507218.5	6509722.1	15.65	10.97	NonCore	Pavement and Fill Borrow Area, Kirribilli Ridge
1970_K16	507199.1	6509699.0	15.03	10.36	NonCore	Pavement and Fill Borrow Area, Kirribilli Ridge
1970_K17	507174.6	6509681.1	12.17	5.79	NonCore	Pavement and Fill Borrow Area, Kirribilli Ridge
1970_K18	507149.1	6509665.6	8.53	3.51	NonCore	Pavement and Fill Borrow Area, Kirribilli Ridge
1970_K19	507123.7	6509703.1	8.67	8.08	NonCore	Pavement and Fill Borrow Area, Kirribilli Ridge
1970_K2	507325.9	6509941.2	15.69	11.13	NonCore	Pavement and Fill Borrow Area, Kirribilli Ridge
1970_K20	507141.5	6509732.0	8.04	6.55	NonCore	Pavement and Fill Borrow Area, Kirribilli Ridge
1970_K21	507165.3	6509749.5	10.12	8.08	NonCore	Pavement and Fill Borrow Area, Kirribilli Ridge
1970_K22	507190.5	6509765.6	10.43	8.23	NonCore	Pavement and Fill Borrow Area, Kirribilli Ridge
1970_K23	507173.3	6509791.5	9.7	11.28	NonCore	Pavement and Fill Borrow Area, Kirribilli Ridge
1970_K24	507233.2	6509797.1	14.42	11.28	NonCore	Pavement and Fill Borrow Area, Kirribilli Ridge
1970_K25	507204.9	6509808.4	12.63	10.97	NonCore	Pavement and Fill Borrow Area, Kirribilli Ridge
1970_K26	507252.0	6509841.2	15.63	12.19	NonCore	Pavement and Fill Borrow Area, Kirribilli Ridge
1970_K27	507223.1	6509853.4	11.51	12.19	NonCore	Pavement and Fill Borrow Area, Kirribilli Ridge

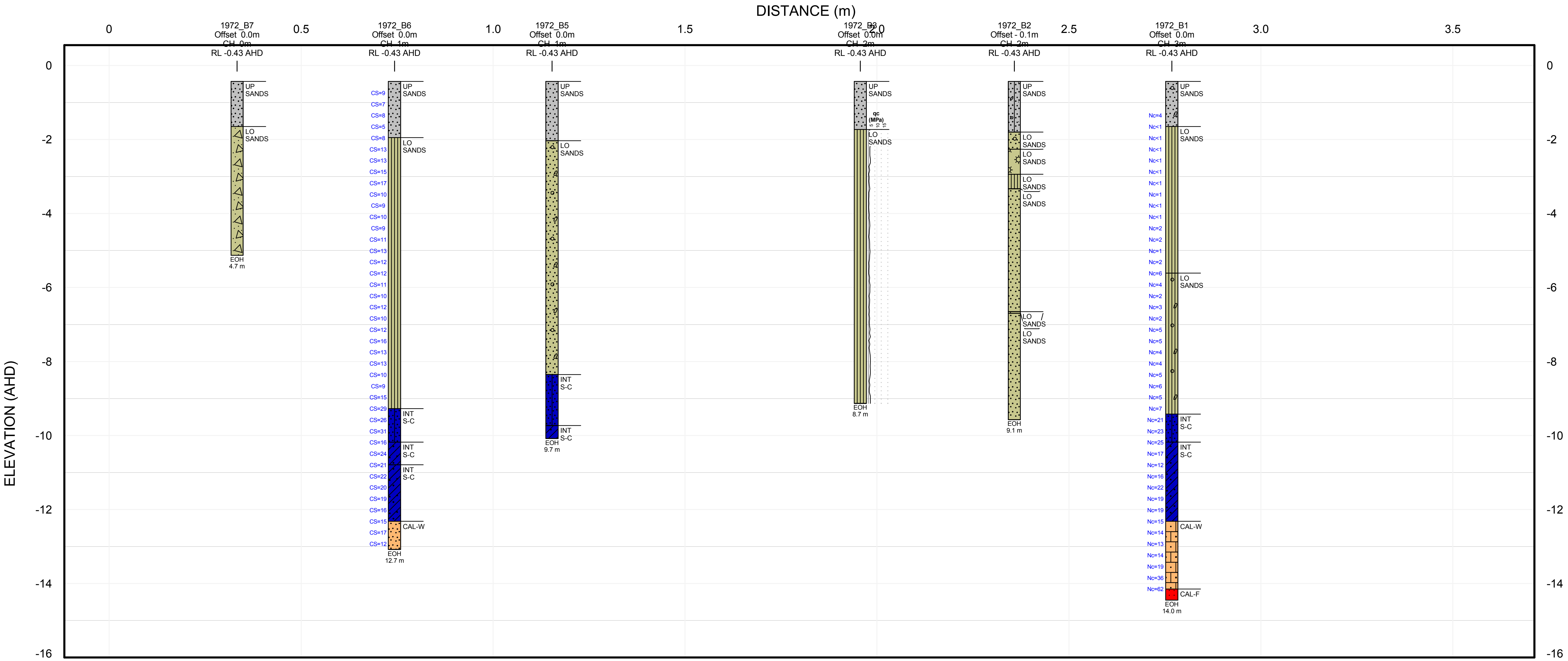
Borehole	Eastings (MGA 57)	Northings (MGA 57)	Elevation (m Local AHD)	Termination Depth (m)	Hole Type	Location
1970_K28	507262.7	6509869.5	15.87	12.19	NonCore	Pavement and Fill Borrow Area, Kirribilli Ridge
1970_K3	507313.6	6509913.3	16.32	11.28	NonCore	Pavement and Fill Borrow Area, Kirribilli Ridge
1970_K30	507275.8	6509896.5	15.18	10.97	NonCore	Pavement and Fill Borrow Area, Kirribilli Ridge
1970_K31	507294.7	6509921.1	15.07	10.97	NonCore	Pavement and Fill Borrow Area, Kirribilli Ridge
1970_K32	507311.4	6509947.7	14.51	10.97	NonCore	Pavement and Fill Borrow Area, Kirribilli Ridge
1970_K4	507302.1	6509885.0	17.5	12.04	NonCore	Pavement and Fill Borrow Area, Kirribilli Ridge
1970_K5	507291.1	6509857.8	17.95	12.04	NonCore	Pavement and Fill Borrow Area, Kirribilli Ridge
1970_K6	507278.4	6509828.9	17.98	11.43	NonCore	Pavement and Fill Borrow Area, Kirribilli Ridge
1970_K7	507260.5	6509784.6	16.37	10.36	NonCore	Pavement and Fill Borrow Area, Kirribilli Ridge
1970_K9	507231.3	6509757.2	14.46	9.27	NonCore	Pavement and Fill Borrow Area, Kirribilli Ridge
1970_S1	507637.9	6510640.4	4.79	7.62	Cored	Airport runway
1970_S10	507121.4	6510812.3	3.38	5.64	NonCore	Airport runway
1970_S10A	507141.5	6510869.1	8.29	6.10	NonCore	Airport runway
1970_S10B	507150.8	6510898.7	12.5	3.96	NonCore	Airport runway
1970_S11	507064.6	6510831.8	3.38	7.32	NonCore	Airport runway
1970_S12	507007.4	6510850.1	3.60	8.38	NonCore	Airport runway
1970_S12A	507026.2	6510905.1	6.28	6.10	NonCore	Airport runway
1970_S13	506949.7	6510869.8	4.30	8.08	NonCore	Western end airport runway
1970_S14	506892.0	6510889.1	4.27	6.55	NonCore	Western end airport runway
1970_S15	506835.3	6510907.8	4.69	14.78	NonCore	Western end airport runway
1970_S16	506778.0	6510926.6	1.83	15.24	NonCore	Western end airport runway
1970_S17	506719.7	6510946.2	-0.43	12.19	NonCore	Beach, Western end airport runway
1970_S18	506663.4	6510964.9	-0.95	9.91	NonCore	The Lagoon
1970_S19	506606.4	6510983.6	-0.88	6.25	NonCore	The Lagoon
1970_S1A	507598.6	6510654.4	3.17	10.97	NonCore	Airport runway
1970_S2	507580.9	6510660.6	2.68	9.14	NonCore	Airport runway
1970_S20	506549.5	6511003.4	-1.1	10.97	NonCore	The Lagoon
1970_S21	506492.7	6511021.4	-0.95	9.60	NonCore	The Lagoon
1970_S22	507568.4	6510629.3	2.71	6.71	NonCore	Airport runway
1970_S22A	507512.6	6510648.8	3.29	10.97	NonCore	Airport runway
1970_S23	507437.8	6510606.9	3.84	6.71	NonCore	Airport runway
1970_S23A	507455.7	6510668.3	3.90	7.01	NonCore	Airport runway
1970_S24	507342.6	6510706.6	4.02	8.69	NonCore	Airport runway
1970_S25	507228.7	6510744.9	3.60	10.49	NonCore	Airport runway
1970_S26	507115.0	6510784.7	3.60	10.52	NonCore	Airport runway
1970_S27	506998.9	6510819.4	4.08	9.68	NonCore	Airport runway

Borehole	Eastings (MGA 57)	Northings (MGA 57)	Elevation (m Local AHD)	Termination Depth (m)	Hole Type	Location
1970_S28	506884.2	6510859.1	4.27	9.30	NonCore	Western end airport runway
1970_S2A	507589.6	6510687.1	2.93	10.67	NonCore	Airport runway
1970_S3	507523.2	6510679.2	3.09	12.73	Cored	Airport runway
1970_S30	506647.4	6510920.2	-1.00	10.36	NonCore	The Lagoon
1970_S31	506536.5	6510959.4	-0.61	9.91	NonCore	The Lagoon
1970_S32	507532.4	6510707.0	2.99	9.27	NonCore	Airport runway
1970_S32A	507555.9	6510681.2	2.59	5.33	NonCore	Airport runway
1970_S33	507417.7	6510744.5	8.29	11.89	NonCore	Airport runway
1970_S33A	507427.9	6510772.2	8.93	6.10	NonCore	Airport runway
1970_S33B	507437.0	6510800.9	10.97	6.10	NonCore	Airport runway
1970_S33C	507447.7	6510829.6	13.11	6.10	NonCore	Airport runway
1970_S34	507301.3	6510783.2	5.24	7.32	NonCore	Airport runway
1970_S35	507190.7	6510822.5	5.06	6.86	NonCore	Airport runway
1970_S35A	507198.3	6510850.3	8.23	2.74	NonCore	Airport runway
1970_S36	507084.7	6510890.4	5.49	4.98	NonCore	Airport runway
1970_S36A	507092.7	6510918.6	7.53	6.10	NonCore	Airport runway
1970_S37	506957.8	6510897.5	3.78	8.23	NonCore	Western end airport runway
1970_S38	506842.5	6510935.0	4.11	11.73	NonCore	Western end airport runway
1970_S3A	507545.9	6510653.7	3.29	7.85	NonCore	Airport runway
1970_S3B	507498.14	6510687.342	3.32	10.97	NonCore	Airport runway
1970_S40	506621.3	6511026	-0.82	10.52	NonCore	The Lagoon
1970_S4A	507475.82	6510726.005	3.6	4.80	NonCore	Airport runway
1970_S5	507408.54	6510717.178	4.69	10.36	NonCore	Airport runway
1970_S5A	507399.07	6510688.756	3.69	10.97	NonCore	Airport runway
1970_S6A	507359.07	6510764.592	4.97	7.09	NonCore	Airport runway
1970_S7	507292.42	6510755.672	4.11	6.71	Cored	Airport runway
1970_S8	507238.1	6510773.9	n/a	7.47	NonCore	Airport runway
1970_S8A	507248.36	6510803.542	6.31	1.83	NonCore	Airport runway
1970_S8B	507256.75	6510830.78	10.88	1.93	NonCore	Airport runway
1970_S9	507178.7	6510793.6	4.02	4.88	NonCore	Airport runway
1970_T1	507682.92	6510934.679	30.18	4.57	NonCore	Pavement and Fill Borrow Area Transit Hill
1970_T10	507644.82	6510929.599	30.57	7.32	NonCore	Pavement and Fill Borrow Area Transit Hill
1970_T11	507670.22	6510875.624	18.96	7.32	NonCore	Pavement and Fill Borrow Area Transit Hill
1970_T12	507638.89	6510868.215	18.62	7.32	NonCore	Pavement and Fill Borrow Area Transit Hill
1970_T13	507597.62	6510840.064	14.51	7.32	NonCore	Pavement and Fill Borrow Area Transit Hill
1970_T2	507670.85	6510901.024	25.69	7.32	NonCore	Pavement and Fill Borrow Area Transit Hill

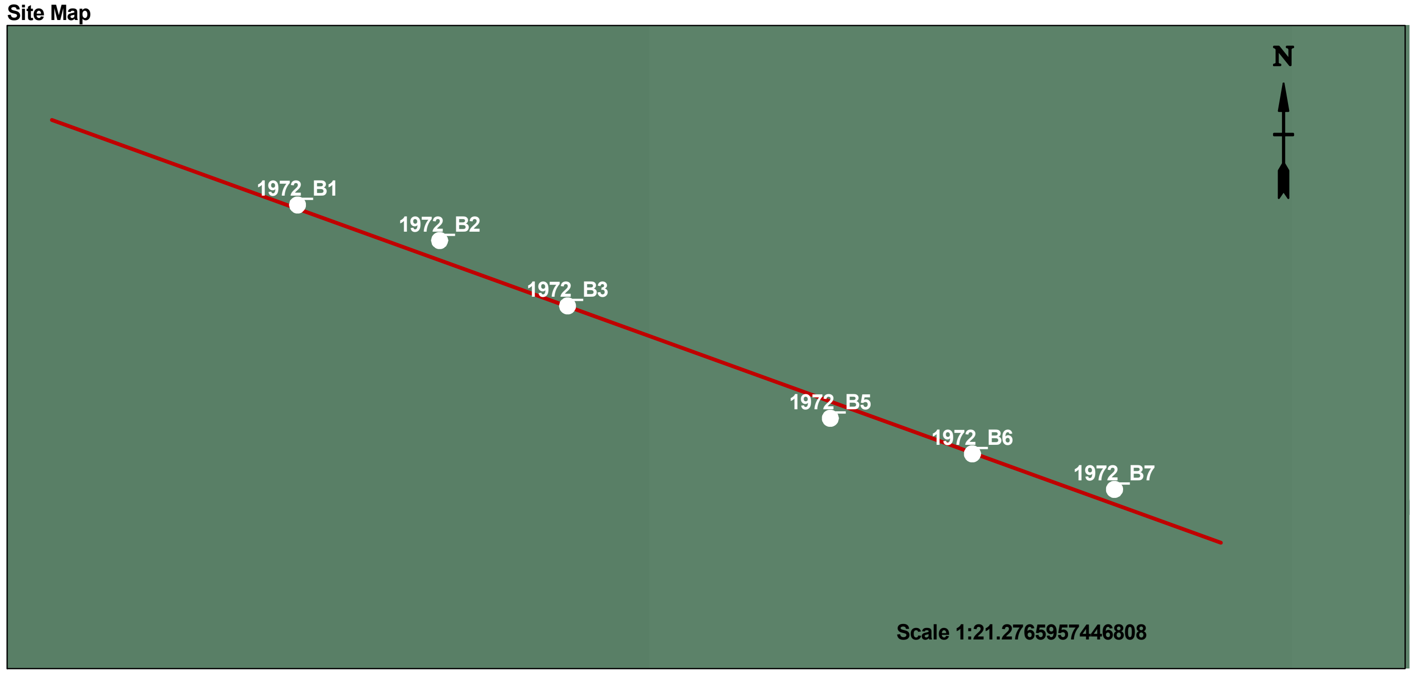
Borehole	Eastings (MGA 57)	Northings (MGA 57)	Elevation (m Local AHD)	Termination Depth (m)	Hole Type	Location
1970_T3	507648.42	6510889.594	23.87	4.57	NonCore	Pavement and Fill Borrow Area Transit Hill
1970_T4	507624.29	6510888.324	23.29	7.32	NonCore	Pavement and Fill Borrow Area Transit Hill
1970_T5	507599.1	6510891.287	24.38	7.32	NonCore	Pavement and Fill Borrow Area Transit Hill
1970_T6	507569.47	6510887.9	24.11	7.32	NonCore	Pavement and Fill Borrow Area Transit Hill
1970_T7	507550.84	6510893.615	23.35	7.32	NonCore	Pavement and Fill Borrow Area Transit Hill
1970_T8	507559.94	6510927.905	31.42	7.32	NonCore	Pavement and Fill Borrow Area Transit Hill
1970_T9	507592.33	6510913.089	29.99	7.32	NonCore	Pavement and Fill Borrow Area Transit Hill
1972_2A	506604.97	6510958.648	-0.43	2.44	NonCore	The Lagoon
1972_2B	506603.39	6510954.679	-0.43	3.35	NonCore	The Lagoon
1972_B1	506583.9	6510950.5	-0.43	14.02	NonCore	The Lagoon
1972_B2	506584.3	6510950.4	-0.43	9.14	NonCore	The Lagoon
1972_B3	506584.66	6510950.216	-0.43	8.70	CPT	The Lagoon
1972_B5	506585.4	6510949.9	-0.43	9.65	NonCore	The Lagoon
1972_B6	506585.8	6510949.8	-0.43	12.65	NonCore	The Lagoon
1972_B7	506586.2	6510949.7	-0.43	4.70	NonCore	The Lagoon
1972_C1	506566.31	6510957.328	-0.63	8.90	CPT	The Lagoon
1972_C2	506564.8	6510957.9	-0.63	14.22	Cored	The Lagoon
1972_C3	506565.5	6510957.6	-0.63	12.57	NonCore	The Lagoon
1972_C4	506564	6510958.2	-0.63	9.86	NonCore	The Lagoon
1972_D1	506544.3	6510965.9	-0.72	14.02	NonCore	The Lagoon
1972_D2	506545.08	6510965.586	-0.72	9.20	CPT	The Lagoon
1972_D3	506545.8	6510965.3	-0.72	14.38	Cored	The Lagoon
1972_TK1	506602.81	6510953.19	-0.4	4.57	NonCore	Preloading Tank, the Lagoon
1972_TK2	506603.07	6510953.481	-0.38	6.10	NonCore	Preloading Tank, the Lagoon
1972_TK3	506603.33	6510953.772	-0.4	3.81	NonCore	Preloading Tank, the Lagoon
1972_TK4	506603.89	6510954.4	-0.44	3.05	NonCore	Preloading Tank, the Lagoon
1972_TK5	506604.19	6510954.751	-0.49	3.81	NonCore	Preloading Tank, the Lagoon
1972_TK6	506603.7	6510952.972	-0.43	4.57	NonCore	Preloading Tank, the Lagoon
1972_TK7	506604.09	6510953.408	-0.45	2.44	NonCore	Preloading Tank, the Lagoon
2014_PP01	506778	6510905	4.2	0.80	TestPit	Adjacent to airport runway
2014_PP02	507001	6510837	4.1	0.90	TestPit	Adjacent to airport runway
2014_PP03	507195	6510716	4.1	0.90	TestPit	Adjacent to airport runway
2014_PP04	507436	6510640	4.4	1.00	TestPit	Airport runway
2014_PP05	507606	6510530	4.7	0.90	TestPit	Western end airport runway
2014_PP06	507464	6510551	4.0	0.90	TestPit	Airport runway
2014_PP07	507455	6510556	4.0	0.30	TestPit	Airport runway

Borehole	Eastings (MGA 57)	Northings (MGA 57)	Elevation (m Local AHD)	Termination Depth (m)	Hole Type	Location
2014_TP01	507008	6510841	4.2	2.30	TestPit	Adjacent to airport runway
2014_TP02	507192	6510705	4.0	2.30	TestPit	Adjacent to airport runway
2014_TP03	507438	6510650	4.3	2.60	TestPit	Western end airport runway
2014_TP04	507539	6510548	4.4	2.40	TestPit	Western end airport runway
2014_TP05	507419	6510539	4.2	2.00	TestPit	Taxiway

Appendix C Long Sections



Site Map

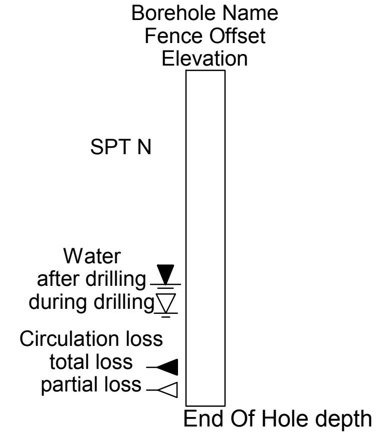


LEGEND

- SAND
- SILTY GRAVELLY SAND
- CALCARENITE
- GRAVELLY SAND
- SILT
- GRAVELLY SILT
- SILTY SAND
- SANDY CLAY
- SANDSTONE
- SANDY SILT
- CLAYEY SAND
- CLAY

MATERIAL CLASSIFICATION

- Neds Beach Calcarenite
- Weathered Neds Beach Calcarenite
- Interbedded Sands and Clays
- Lower silty carbonate sands
- Upper carbonate sands



Notes:
1. For detailed descriptions of the geological material at specific investigation locations, refer to the respective logs and explanatory notes.
2. Any geological boundaries are inferred.

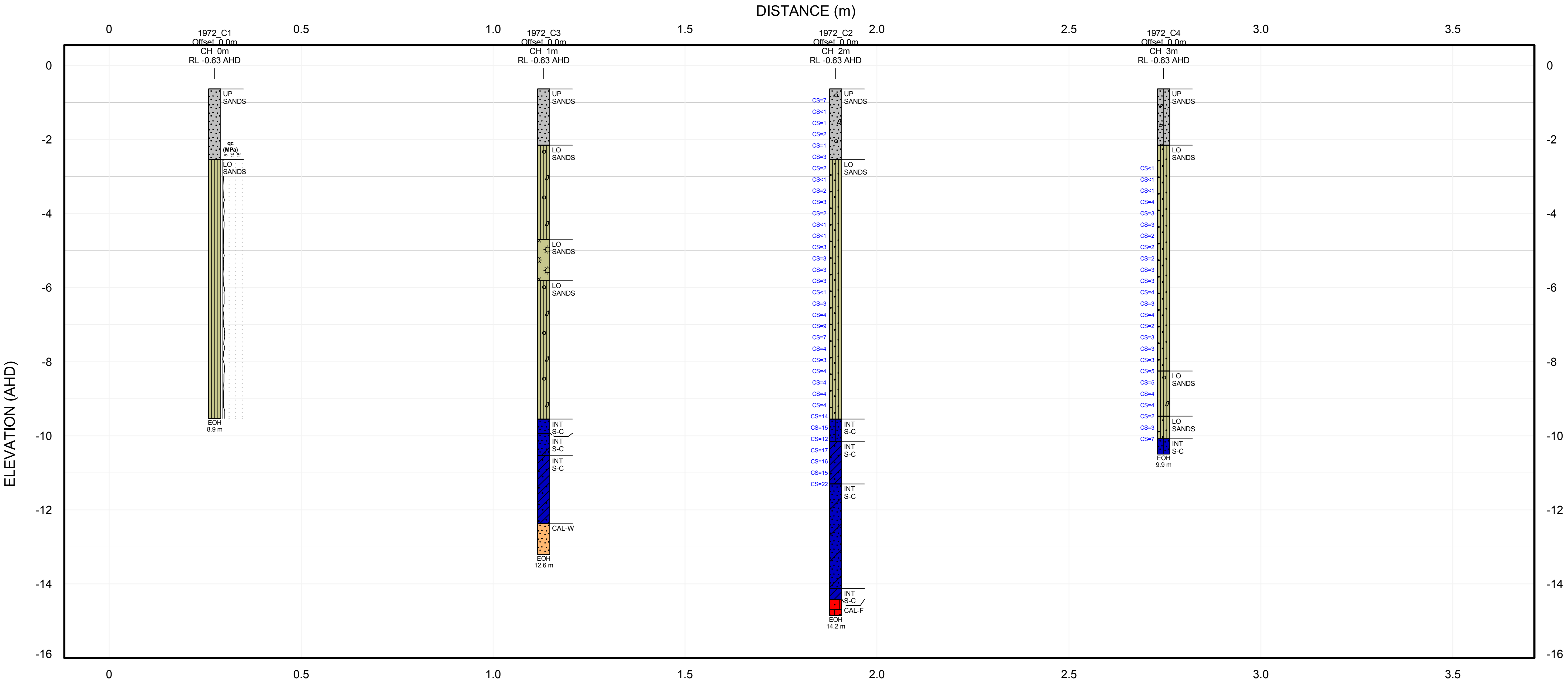
AECOM

Vert Scale: *1:110*
Horiz Scale: *1:11*

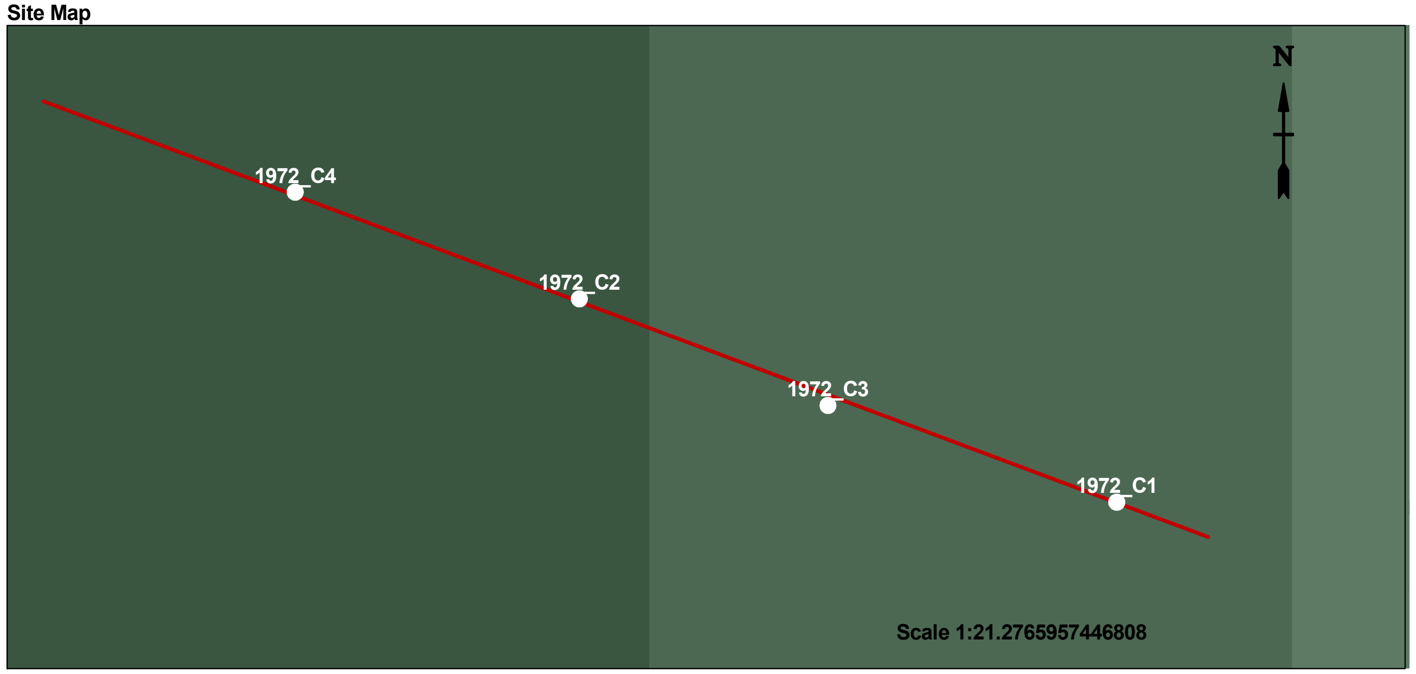
LOCATION B GEOLOGICAL CROSS SECTION

CLIENT: Lord Howe Island Board
PROJECT NAME: LHIB RWY Extension Study
PROJECT No: 60559990

2017_AECOM_STRATIGRAPHY_MAP_REV5 LORD HOWE DIGITAL.GPJ AECOM_5-00AA.GLB 22.6.2018



Site Map

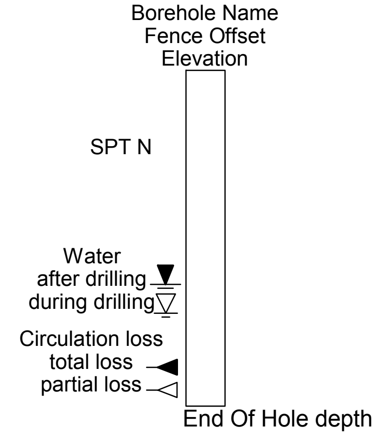


LEGEND

- SAND
- SILTY GRAVELLY SAND
- CALCARENITE
- GRAVELLY SAND
- SILT
- GRAVELLY SILT
- SILTY SAND
- SANDY CLAY
- SANDSTONE
- SANDY SILT
- CLAYEY SAND
- CLAY

MATERIAL CLASSIFICATION

- Neds Beach Calcarenite
- Weathered Neds Beach Calcarenite
- Interbedded Sands and Clays
- Lower silty carbonate sands
- Upper carbonate sands



Notes:
1. For detailed descriptions of the geological material at specific investigation locations, refer to the respective logs and explanatory notes.
2. Any geological boundaries are inferred.

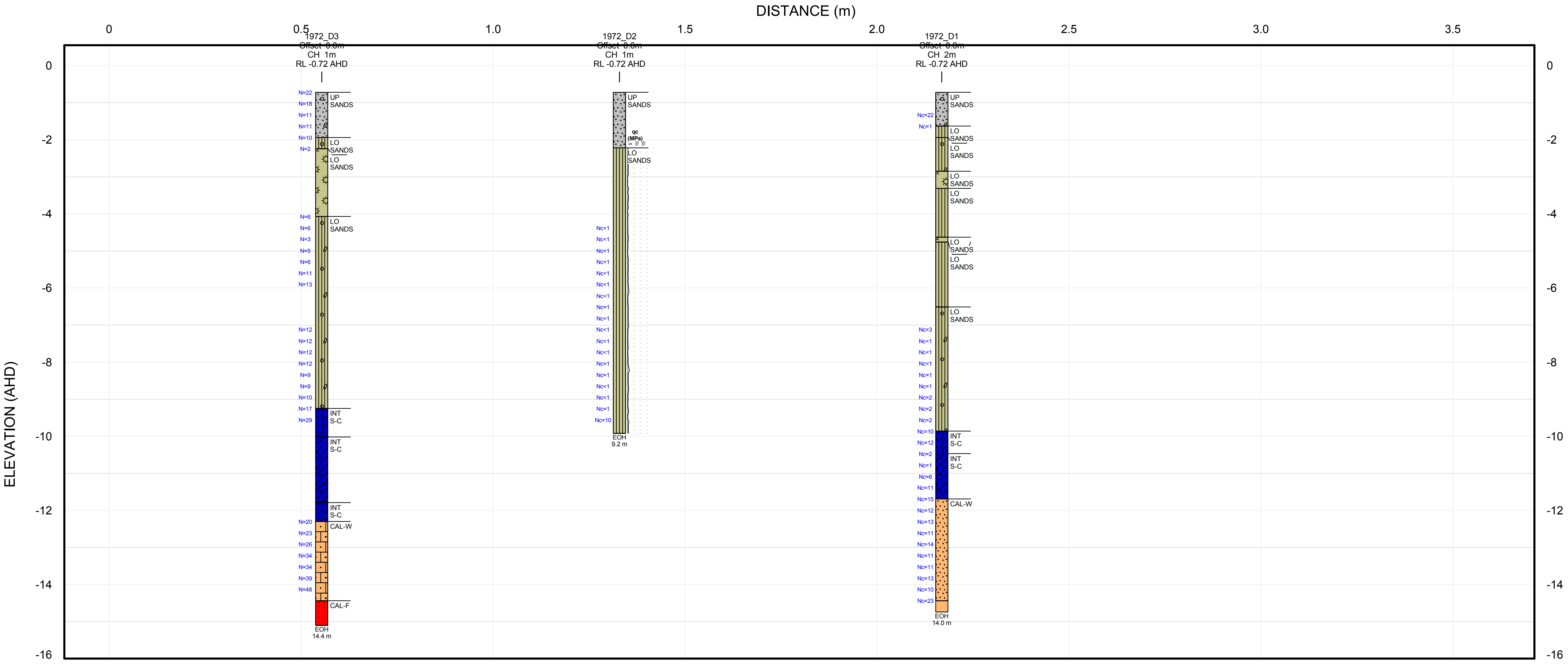
AECOM

Vert Scale: *1:110*
Horiz Scale: *1:11*

LOCATION C GEOLOGICAL CROSS SECTION

CLIENT: Lord Howe Island Board
PROJECT NAME: LHIB RWY Extension Study
PROJECT No: 60559990

2017_AECOM_STRATIGRAPHY_MAP_REV5 LORD HOWE DIGITAL.GPJ AECOM_5-00AA.GLB 22.6.2018



Site Map

LEGEND

- SAND
- SILTY GRAVELLY SAND
- CALCARENITE
- GRAVELLY SAND
- SILT
- GRAVELLY SILT
- SILTY SAND
- SANDY CLAY
- SANDSTONE
- SANDY SILT
- CLAYEY SAND
- CLAY

MATERIAL CLASSIFICATION

- Neds Beach Calcarenite
- Weathered Neds Beach Calcarenite
- Interbedded Sands and Clays
- Lower silty carbonate sands
- Upper carbonate sands

Borehole Name
Fence Offset
Elevation

SPT N

Water
after drilling
during drilling

Circulation loss
total loss
partial loss

End Of Hole depth

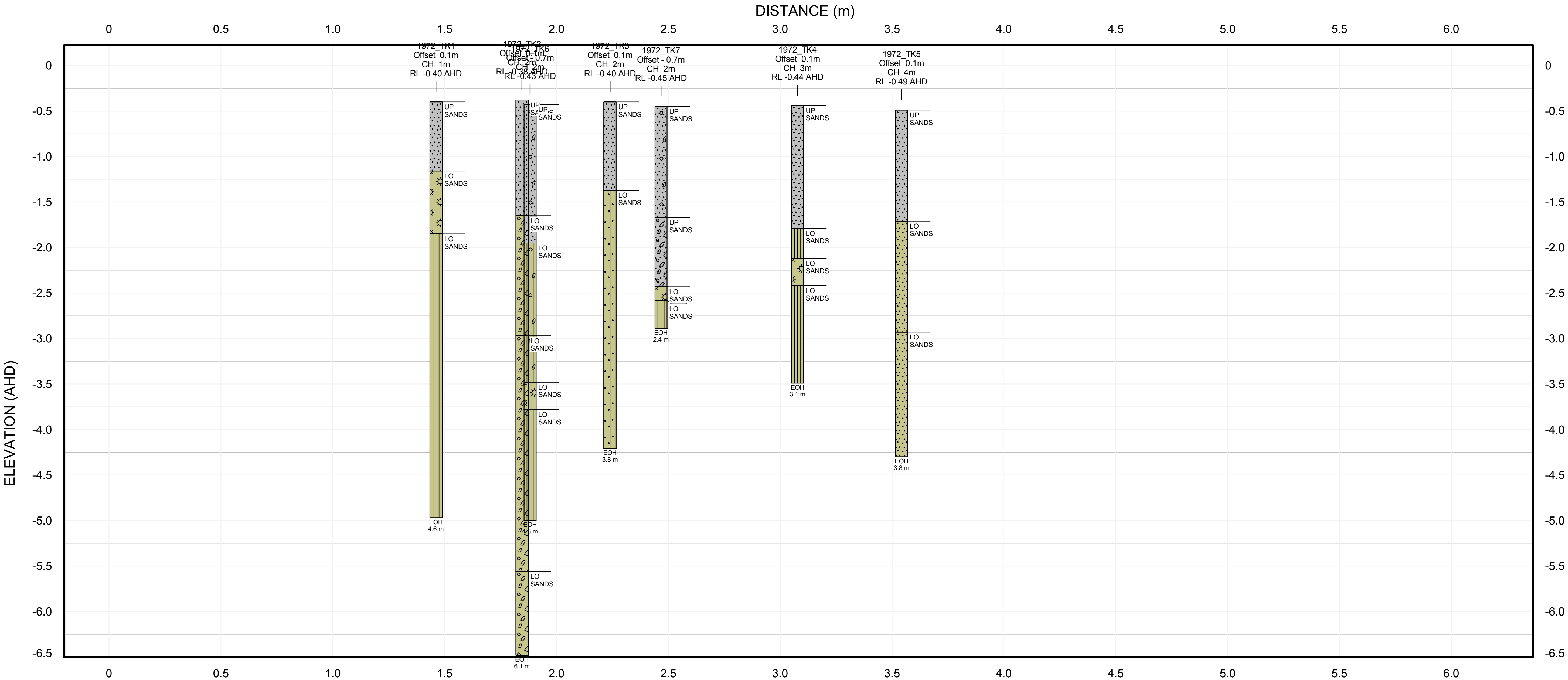
Notes:
1. For detailed descriptions of the geological material at specific investigation locations, refer to the respective logs and explanatory notes.
2. Any geological boundaries are inferred.

AECOM

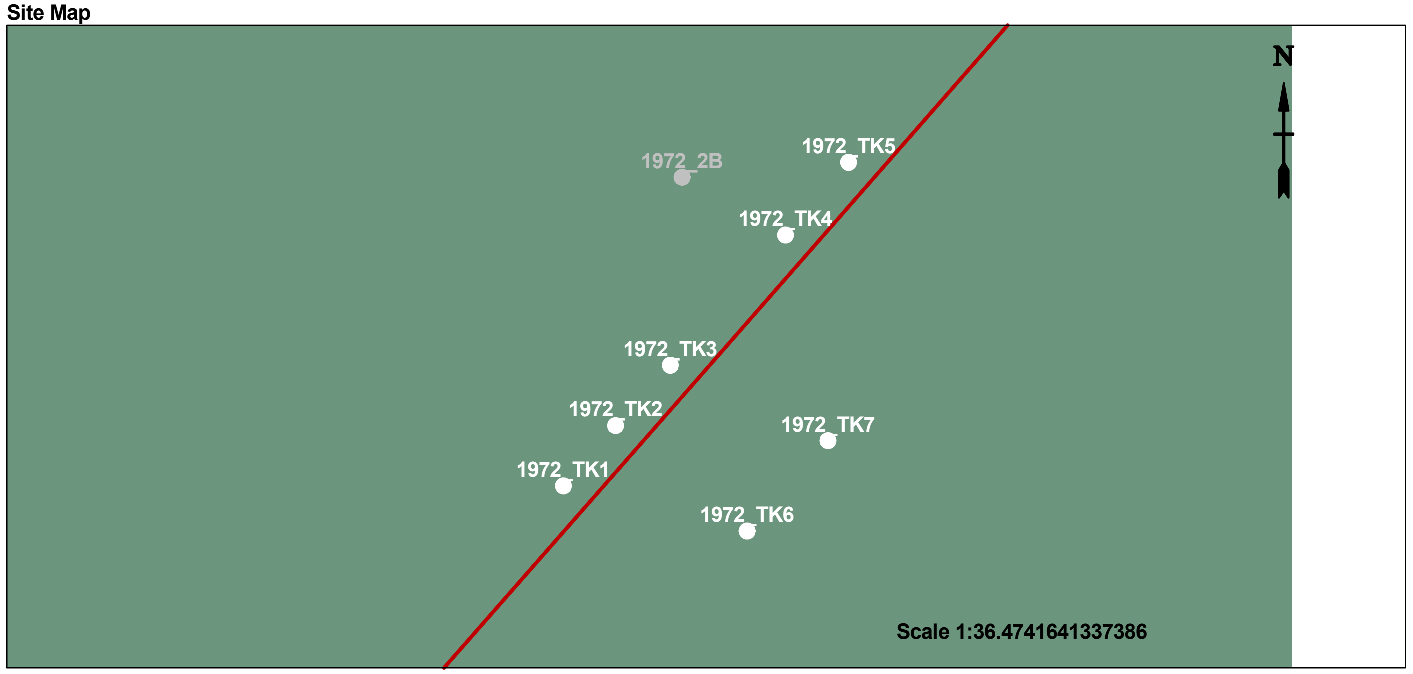
Vert Scale: *1:110*
Horiz Scale: *1:11*

LOCATION D GEOLOGICAL CROSS SECTION

CLIENT: Lord Howe Island Board
PROJECT NAME: LHIB RWY Extension Study
PROJECT No: 60559990



Site Map

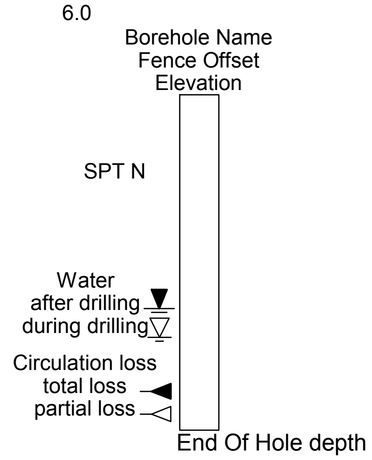


LEGEND

- SAND
- CORAL
- SILT
- SILTY GRAVEL
- SANDY SILT
- GRAVELLY SAND
- GRAVELLY SILT
- SANDY GRAVEL

MATERIAL CLASSIFICATION

- Lower silty carbonate sands
- Upper carbonate sands



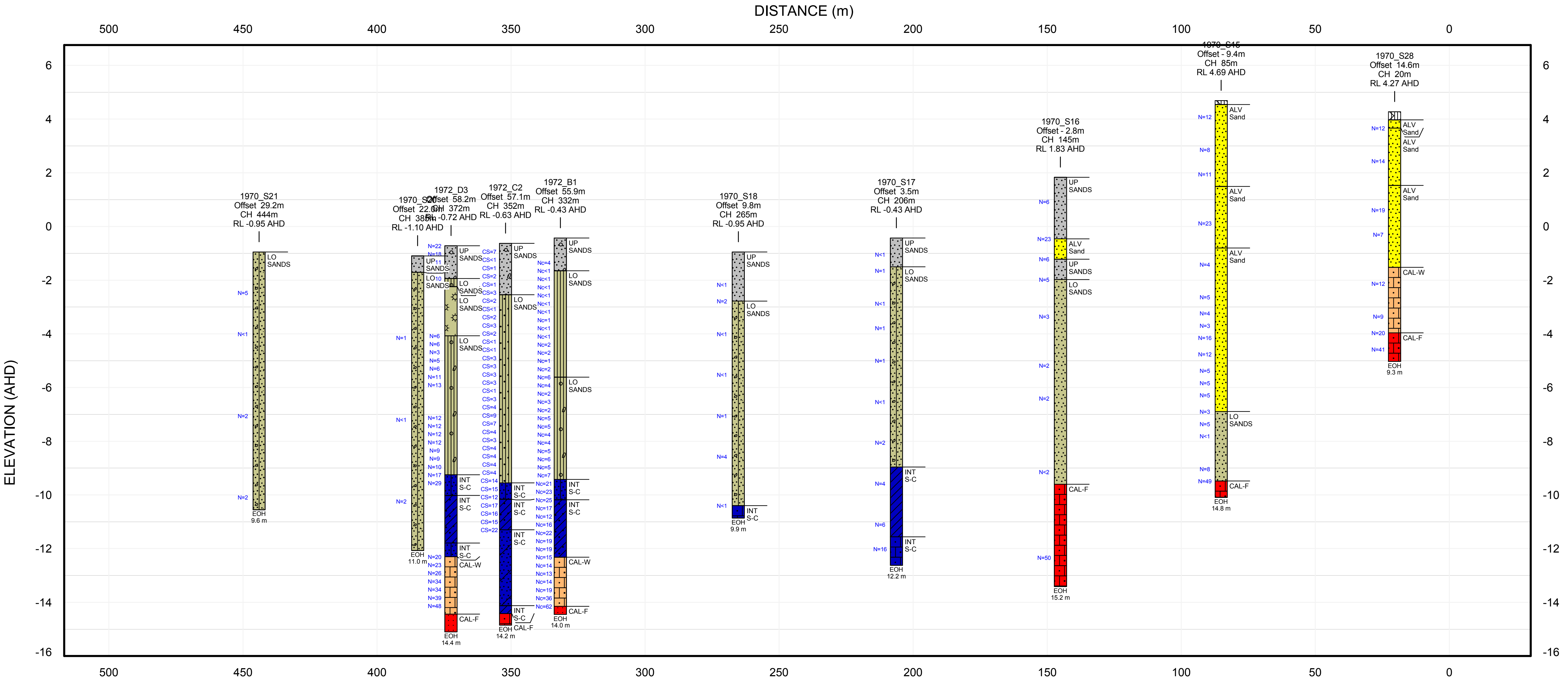
Notes:
1. For detailed descriptions of the geological material at specific investigation locations, refer to the respective logs and explanatory notes.
2. Any geological boundaries are inferred.

AECOM

Vert Scale: *1:45*
Horiz Scale: *1:18*

PRELOADING TANK GEOLOGICAL CROSS SECTION

CLIENT: Lord Howe Island Board
PROJECT NAME: LHIB RWY Extension Study
PROJECT No: 60559990



Site Map

LEGEND

- TOPSOIL
- SAND
- CALCARENITE
- SILTY GRAVELLY SAND
- CLAY
- GRAVELLY SAND
- SILT
- GRAVELLY SILT
- SILTY SAND
- SANDY CLAY
- SANDSTONE
- SANDY SILT

MATERIAL CLASSIFICATION

- Alluvial and marine calcareous sands
- Neds Beach Calcarenite
- Weathered Neds Beach Calcarenite
- Interbedded Sands and Clays
- Lower silty carbonate sands
- Upper carbonate sands

Borehole Name
Fence Offset
Elevation

SPT N

Water
after drilling
during drilling

Circulation loss
total loss
partial loss

End Of Hole depth

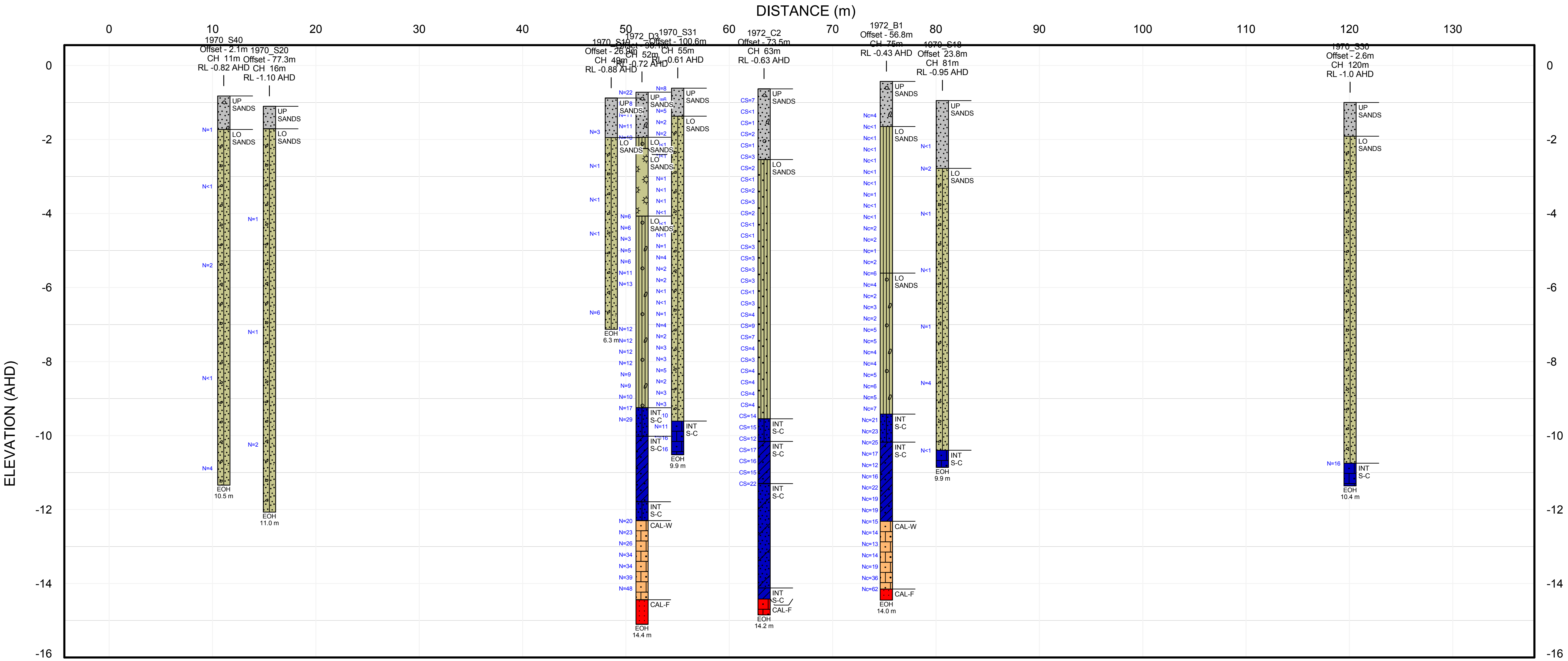
Notes:
1. For detailed descriptions of the geological material at specific investigation locations, refer to the respective logs and explanatory notes.
2. Any geological boundaries are inferred.

AECOM

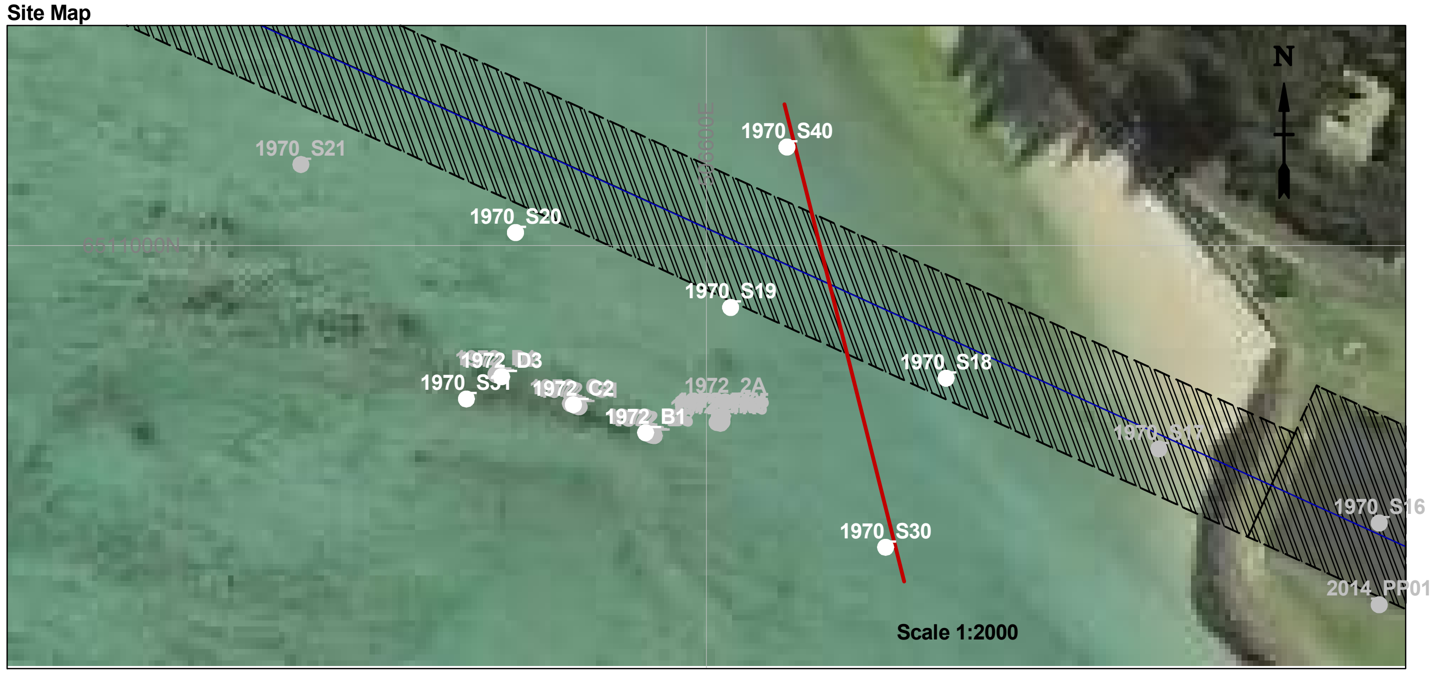
Vert Scale: *1:152*
Horiz Scale: *1:1520*

THE LAGOON GEOLOGICAL LONG SECTION

CLIENT: Lord Howe Island Board
PROJECT NAME: LHIB RWY Extension Study
PROJECT No: 60559990



Site Map



LEGEND

- SAND
- SILTY GRAVELLY SAND
- CALCARENITE
- GRAVELLY SAND
- SILT
- GRAVELLY SILT
- SILTY SAND
- SANDY CLAY
- SANDSTONE
- SANDY SILT
- CLAYEY SAND
- CLAY

MATERIAL CLASSIFICATION

- Neds Beach Calcarenite
- Weathered Neds Beach Calcarenite
- Interbedded Sands and Clays
- Lower silty carbonate sands
- Upper carbonate sands

Borehole Name
Fence Offset
Elevation

SPT N

Water
after drilling
during drilling

Circulation loss
total loss
partial loss

End Of Hole depth

Notes:
1. For detailed descriptions of the geological material at specific investigation locations, refer to the respective logs and explanatory notes.
2. Any geological boundaries are inferred.

AECOM	Vert Scale: 1:110 Horiz Scale: 1:395	*NORTH TO SOUTH GEOLOGICAL LONG SECTION*	**CLIENT:** Lord Howe Island Board **PROJECT NAME:** LHIB RWY Extension Study **PROJECT No:** 60559990

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Appendix D Site Photos

Photos taken by AECOM between 26 May and 3 June 2018.

Figure 12-10 Sub vertical dykes intersecting North Ridge Basalt (West of Malabar Hill)

Figure 12-11 Weathered North Ridge Basal (Mount Eliza)

Figure 12-12 Lidgbird basalt at Goat House

Figure 12-13 Boat Harbour Breccia at Rocky Point

Figure 12-14 Boat Harbour Breccia at Lagoon Road, 90 m north from the site

Figure 12-15 Blackburn Island (western extremity, looking south-east) – sub vertical dykes

Figure 12-16 Cross-bedded calcarenite outcrop, Signal Point

Figure 12-17 Laminated Calcarenite, King's Beach (1.8 km south from site)

Figure 12-18 Dune calcarenite (eolianite) overlying beach calcarenite, Ned's Beach

Figure 12-19 Calcarenite outcrop, Middle Beach (Looking South)

Figure 12-20 Dissolution features (karst) in calcarenite (Cobbys Corner Member), Johnson's Beach

Figure 12-21 Boat Harbour Breccia outcrop, Johnson's Beach, looking South (1.4 km south from site)

Figure 12-22 Calcarenite, 1 km south of site, looking north. West maximum dip direction

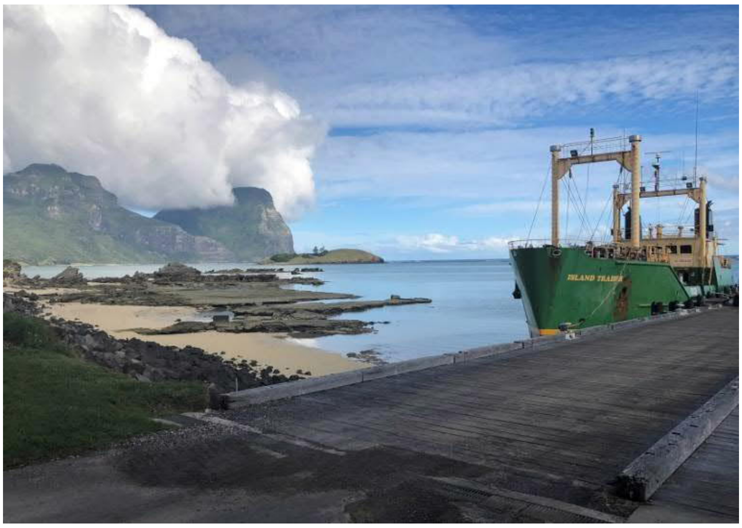

Figure 12-23 Submerged calcarenite, Jetty

Figure 12-24 Marine Seismic Reflection

Figure 12-25 Sand and sporadic coral in the Lagoon

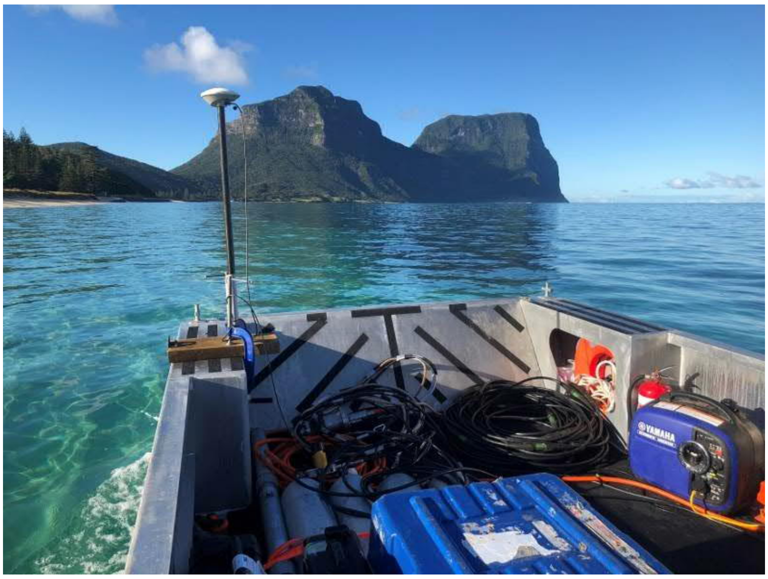

Figure 12-26 Marine Seismic Refraction Set up

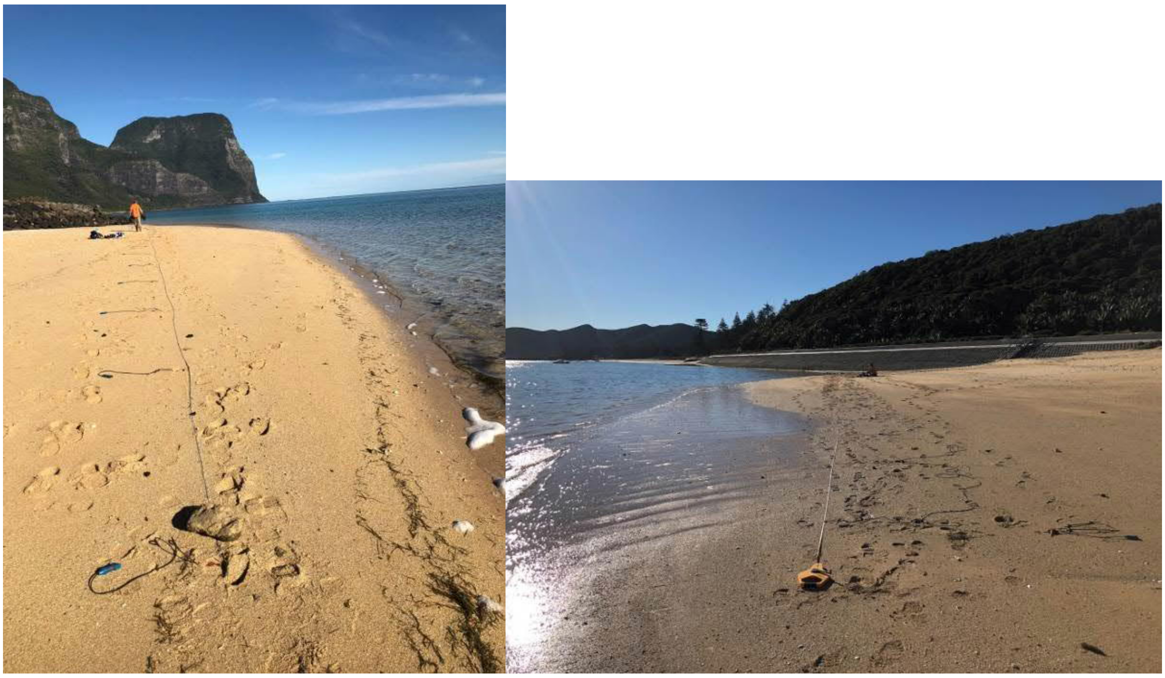

Figure 12-27 Land Seismic Refraction Line (left, looking south – right, looking north)

Appendix E Marine & Earth Sciences Geophysical Survey Report

AECOM PTY LTD

LORD HOWE ISLAND AIRPORT EXTENSION FEASIBILITY STUDY –

GEOPHYSICAL SURVEYS

Lord Howe Island, NSW

9 July 2018

MES_638_LordHoweIs_ab.doc

Lord Howe Island Airport Extension Feasibility Study – Geophysical Surveys
9/07/2018

AECOM Pty Ltd
Level 21, 420 George Street
Sydney NSW 2000

Attention: Mr Sven Thorin

Dear Sven

RE: LORD HOWE ISLAND AIRPORT EXTENSION FEASIBILITY STUDY – GEOPHYSICAL SURVEYS

Please find our report on the geophysical surveys for the above project. Should you require any further information please contact the undersigned.

For and on behalf of

MARINE & EARTH SCIENCES PTY LTD

David King

Principal Geophysicist

Distribution: Original held by Marine & Earth Sciences Pty Ltd

AECOM Pty Ltd Electronic Copy

marine&earthsciences
geophysical consultants and contractors

ACN 111 435 717

+61 409 844 605

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1. INTRODUCTION

Marine & Earth Sciences Pty Ltd (MES) was commissioned by AECOM Pty Ltd to undertake geophysical surveys as part of Geotechnical Investigations for the Lord Howe Island Airport Runway Extension Feasibility Study.

The aim of the survey is to map subsurface conditions along a 600m long x 150m wide corridor extending from the existing runway into the lagoon. The area of investigation is shown on the Location Plan in Figure 1. The information gathered as part of the geophysical surveys will be used to assess foundation conditions and allow a concept feasibility design to be developed. The scope of works is summarised below:

- Sub-Bottom Profiling on a series of lines over the corridor to map sub-bottom reflectors.
- Continuous Marine Seismic Refraction along the centreline of the corridor to map the sub-surface seismic velocities.
- Land Based Seismic Refraction Line along the shoreline at the end of the existing runway to map the sub-surface seismic velocities.

During the sub-bottom profiler survey data acquisition, it was apparent that this technique was not achieving adequate penetration below seabed and detectability of the calcarenite layer was not possible. It was decided to complete more continuous marine seismic refraction survey lines where possible to achieve better coverage and to meet the projects objectives.

The surveys were carried out from the 28th June to the 1st of June 2018 by MES field geophysicist. All operations were carried out as per our SMWS and JSEA plans with no accidents or incidents occurring.

2. FIELD TECHNIQUES AND EQUIPMENT SPECIFICATIONS

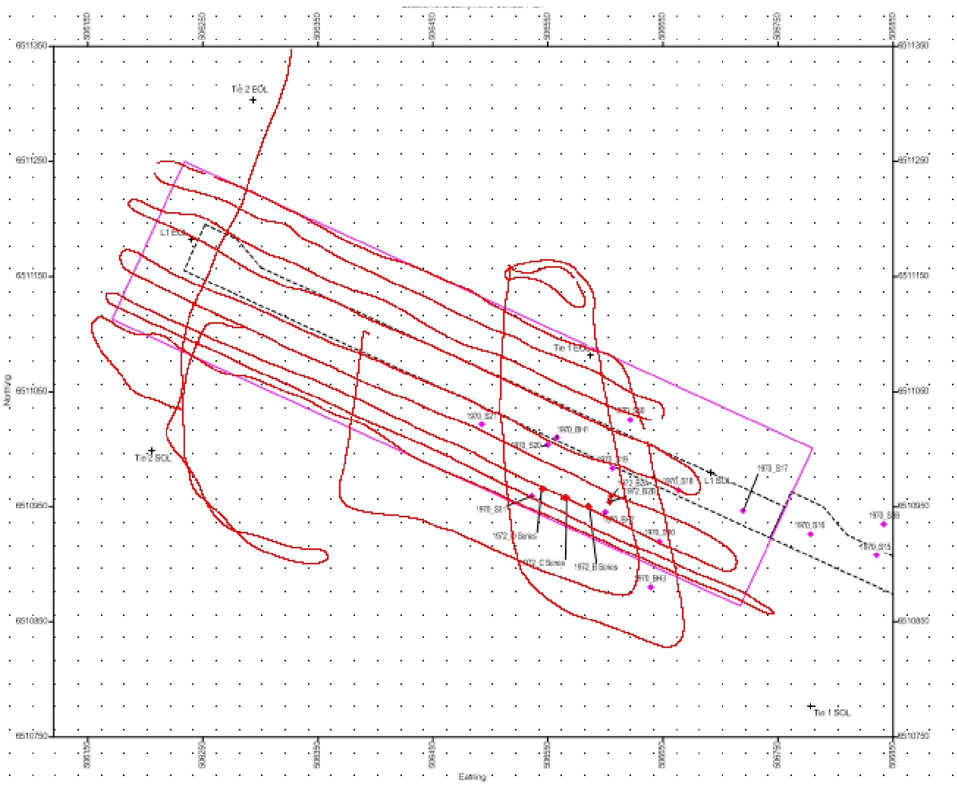
2.1 Sub-Bottom Profiling (Seismic Reflection)

An Innomar SES-2000 Sub-Bottom Profiling system was used to acquire sub-bottom profiling data for mapping geological layers across the site and was operated in dual frequency mode with high frequency (12kHz) data captured to map shallow reflectors and the low frequency (4kHz) component used to map deeper levels with a pulse rate of 10Hz. The seismic acquisition system was interfaced to the GPS system with position, heading, speed and ping number appended in the seg-y seismic file.

In addition to capturing sub-bottom data this system was used to measure water depths over the site and allow these to be reduced seafloor level to project datum. Tide data from the Lord Howe Island Tide Gauge operated and maintained by Manly Hydraulics Laboratory was used for the reduction and allowed the existing bathymetric contour dataset to be extended over the north western corner of the area where coverage was missing from the 2015 survey by Port Authority of New South Wales.

The vessel trackplots for the sub-bottom profiling survey are shown in Figure A below.

Figure A – Sub-Bottom Profiling Trackplots



2.2 Continuous Marine Seismic Refraction (CMSR)

The CMSR technique is a bottom towed velocity profiler, designed to measure the compressional p-wave velocity of sub-bottom materials and their distribution. Correlation of compressional p-wave velocities and materials in situ strength can provide very useful information for engineering projects such as dredging and foundation design. This approach has proven successful in targeting geotechnical boreholes more effectively over areas where shallow high velocity / high strength material has been identified which can significantly impact dredging operations.

CMSR data was acquired with a Geometrics Geode 24 channel digital enhancement seismograph. Acquisition parameters for the geode were configured with a sampling interval of 0.00625 milliseconds and a record length of 120ms. Seismic data was time stamped with the navigation log file and backed up on a daily basis on digital medium for post processing. The seismic refraction survey used a 12-channel hydrophone array with sensor intervals of 5m. Seismic energy was provided by a 2800LX Bolt airgun fitted with a 5-cubic inch chamber. The airgun unit and hydrophone array were towed on the sea floor along the pre-selected alignments with the aid of the on-board DGPS navigation system. The seismic refraction lines were run with a source to receiver offset of 2m on all lines with an additional longer offset of 47m applied for CMSR Line 1 to achieve deeper levels of investigation. A gun phone was fitted to the airgun to provide the recording seismograph with an accurate time zero for each shot. Prestart equipment checks were undertaken to ensure accurate time breaks from airgun initiation as well as quality control checks on hydrophone response from the airgun to ensure first arrivals on the seismic records are clear and reliable for post processing. On start up the digital seismograph performs internal tests and calibrations of A-D converters.

Significant extents of coral growth along the centreline of the runway extension was observed during the sub-bottom profiling survey and the position of the proposed CMSR line was moved approximately 25m to the north on an alignment where limited coral was observed to avoid any environmental impacts at the site. Two additional lines were positioned where coral was sparse, and these were located orthogonal to CMSR Line 1 within the nearshore area and the end of the proposed runway extinction.

2.3 Offshore Positioning and Levelling

The survey extents were provided by the Client based on MGA/GDA 94 Zone 57 South coordinates. This data was imported into the Chesapeake survey software package which was interfaced to a Hemisphere R131 differential GPS using wide area differential corrections transmitted from the AMSA network. Accuracy of horizontal positioning is +/- 0.5 metres. The Chesapeake survey software package, which when interfaced with the positioning system and sensors, provides pre-navigation survey design, on line navigation control, data logging of full raw data set and on-screen real-time quality control information. The differential GPS signal was interfaced via serial cables with the seismic data acquisition system along with time stamps in accordance with accepted practice and quality procedures. Seafloor levels were provided by the Client in electronic format and were based on Lord Howe Island Hydro Datum (LHI-HD). An offset of 0.144m was applied to these to convert to Lord Howe Island AHD (LHI-AHD) which is the nominated project datum and identical to the 1954 hydrographic datum.

2.4 Land Based Seismic Refraction

Seismic refraction data was acquired with a Geometrics Geode 24 channel digital enhancement seismograph. Acquisition parameters for the geode were set at a sampling interval of 0.00625 milliseconds with a record length of 128 mS. Seismic data was backed up daily and stored on digital medium for post processing. A geophone interval of 3m was used for all seismic lines completed. Geospace GS11D, 7.55Hz geophones were rigidly coupled with the ground with 75mm tapered spikes on the geophone base that were pressed firmly into the soil. For the 24-channel seismic spread, a 9m shot spacing was used with a minimum of two offsets. Seismic energy was provided by striking a sledge hammer on an aluminium plate successively until a clear first break arrival was observable on the seismic record.

3. PROCESSING AND INTERPRETATION PROCEDURES

3.1 Sub-Bottom Profiling (Seismic Reflection)

The interpretation process involved replaying the digital seismic data using Chesapeake software, and applying layback corrections, band pass filters and time variable gains to the seismic data to optimise the detection of reflectors from subsurface layers.

Interpretation of the SBP records has been attempted to map sub-surface reflectors related to geology and this involved replaying the records to identify and digitise coherent laterally continuous reflectors. However very limited penetration over the site with this system has been achieved. This is expected to be related to the hard coral structures and coral detritus materials at the surface limiting penetration due to seismic signal backscatter effect. No observable reflectors have been mapped at the site with this technique.

3.2 Continuous Marine Seismic Refraction (CMSR)

The digital seismic data has been archived in Marine & Earth Sciences seismic database. The digital seismic records were examined on computer, and the first arrival times were determined using Rayfract, an engineering seismic refraction software package. Generally, the seismic data was considered of good quality and adequate for interpretation. Shot points, receivers and associated first breaks were assigned an X, Y position based on the layback of the source and receivers from the vessel DGPS antenna. These locations were converted to seismic chainage using the GPS position of the designated start location of each seismic line.

The seismic refraction data along each line was merged to construct a combined travel time plot using the elevations as determined by the bathymetric data provided to MES. This merged travel time plot was imported to Rayfract software and processed with the Wavepath Eikonal Travel-time (WET) tomography algorithm. This technique has the ability to resolve strong lateral and vertical velocity gradients with relatively complex topography and efficiently handle large seismic refraction data sets. As with all seismic methods, seismic refraction has inherent limitations and problems in effectively accurately representing subsurface conditions in all geological environments.

The interpreted seismic refraction sections are presented on Figure 1 as 2D seismic velocity contour images beneath the line of traverse.

3.3 Land Based Seismic Refraction

The digital seismic data has been archived in Marine & Earth Sciences seismic database. The digital seismic records were examined on computer, and the first arrival times were determined using Fbpick software. These measured first arrival travel times were analysed using the interpretation program REFRACT 2006 based on the intercept time and reciprocal method and refined with Rayfract software based on the Wavepath Eikonal Travel-time tomography (WET) algorithm. This technique has the ability to resolve strong lateral and vertical velocity gradients with relatively complex topography. In general, the seismic data was of good quality and adequate for interpretation. As with all seismic methods, seismic refraction has inherent limitations and problems in effectively accurately representing subsurface conditions in all geological environments.

4. RESULTS

4.1 Sub-Bottom Profiling

Interpretation of the SBP records has identified one continuous reflector across the site which coincides with the seafloor. Due to the nature of the seafloor material related to the coral structures and coral detritus materials over the site, very limited penetration is due to backscatter effect. No observable reflectors have been mapped at the site with this technique.

4.2 Seismic Refraction

The scope of the CMSR survey was increased from 1 line to 3 to achieve better coverage and better depths of investigation because of the limitations with the SBP system at this site. The seismic refraction interpretation along these lines has identified seismic velocities ranging from 1500m/s to greater than 4000m/s and correlate with a wide range of materials from saturated loose to very dense sands, to fresh, high strength rock.

The summary of the CMSR results are provided in Table 1 below:

Table 1 – Summary of CMSR and land Based Seismic Refraction Lines

Line Name	Velocity Range (m/s)	Interpretative Comments
CMSR Line 1	1500->4000	The seismic velocity profile along this line is generally gradational from the surface (1500m/s) to the 1800-1900m/s contour interval and at this level the seismic velocity gradient increases, and a significant density contrast or lithological change is expected. The seismic velocities increase to greater than 4000m/s with a sharper gradient observed at around the 2800-2900m/s interval. Below the 2800-2900m/s contour interval the seismic velocity profile is more laterally variable and is expected to be related to the basement bedrock. Between CH430 to 480m a deeper low velocity channel feature is observed underlying a velocity inversion.
CMSR Tie Line 1	1500 - 2200	The seismic velocity profile along this line is generally gradational from the surface (1500m/s) to the 1800-1900m/s contour interval and at this level the seismic velocity gradient increases, and a significant density contrast or lithological change is expected. The 1800-1900m/s contour interval is shallowing from CH240m to the end of the line.
CMSR Tie Line 2	1500 - 1650	The interpreted seismic velocities along this line are low and laterally continuous indicating no major density boundaries.
SR1	1200 - 2250	The seismic velocity profile along this line is generally gradational from the surface (1500m/s) to the 1800-1900m/s contour interval and at this level the seismic velocity gradient increases, and a significant density contrast or lithological change is expected. The 1800-1900m/s contour interval is shallowing toward the start of the line. The are velocity inversions observed on this line within the near surface which are likely related to buried rock revetment material.

5. DISCUSSION

The sub-bottom profiling surveys undertaken at the Lord Howe Island site have not been effective in mapping the sub-surface as very limited penetration has been achieved. It is expected that the coral and coral detritus have effectively backscattered the seismic pulse and produced no reflections from deeper density/velocity boundaries.

Digitisation of the seafloor using the sub-bottom profiling data has allowed the bathymetry model to be extended to the north west corner of the site where data was missing at this location. The reduced data from this exercise closely agree with the existing bathymetry dataset.

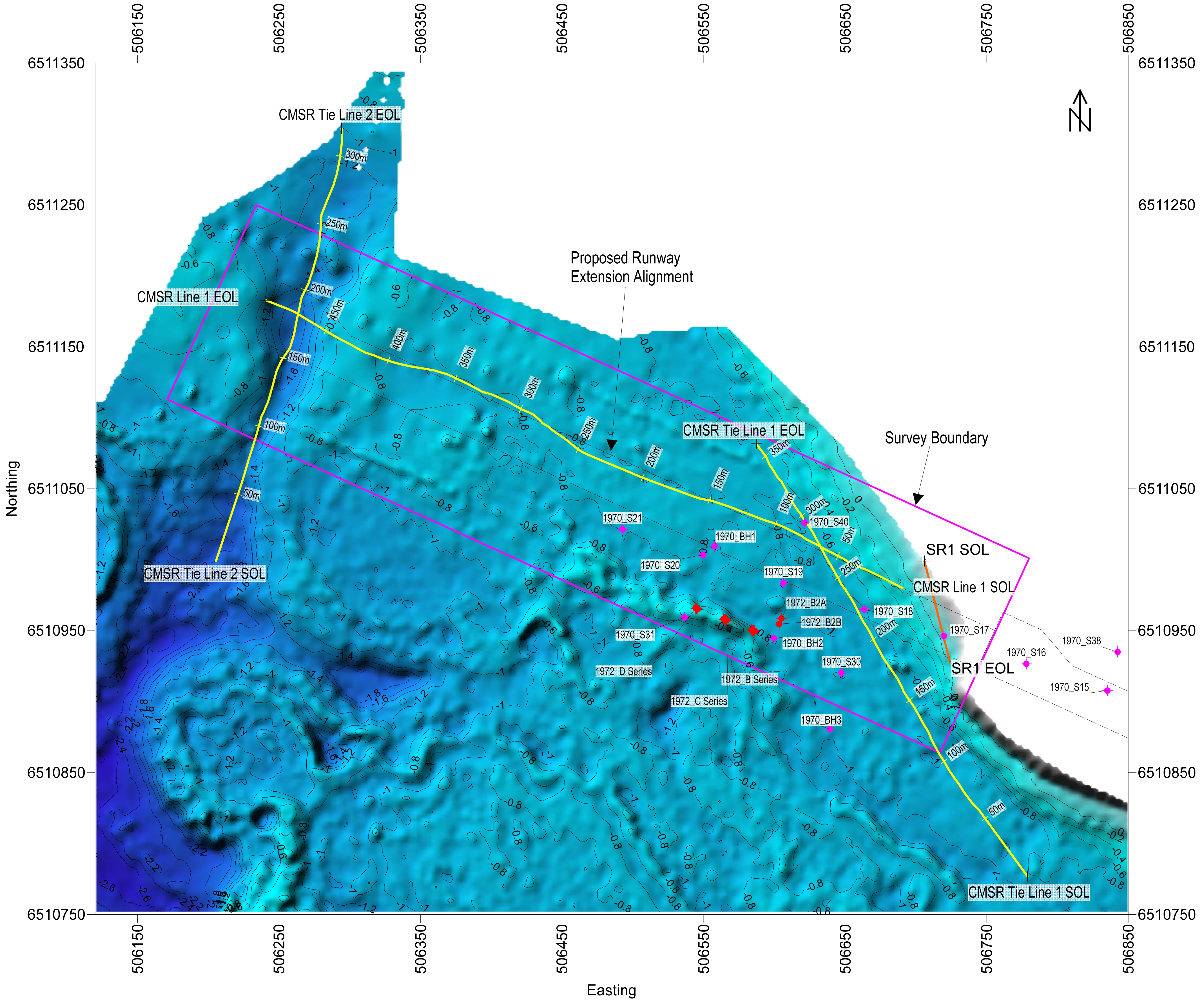
The seismic refraction surveys have successfully mapped subsurface conditions up 45m below the seabed and have allowed a good appreciation of conditions along the alignment. Some seismic lines have intersected historic geotechnical boreholes which identified variably thick coral sands and calcarenite at depth. The comparison of seismic velocity with geological materials at these locations indicate that coral sands correlate with a seismic velocity ranging from 1500m/s to 1850m/s and calcarenites having seismic velocities greater than 1850m/s.

For and on behalf of

MARINE & EARTH SCIENCES PTY LTD

David King

Principal Geophysicist



Legend

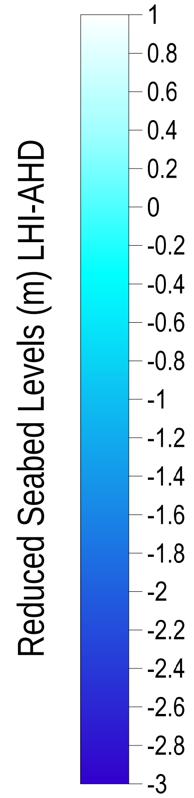
Geotechnical Borehole Location

Land Based Seismic Refraction Line

CMSR Line

SOL Start of Line

EOL End of Line



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LORD HOWE ISLAND AIRPORT EXTENSION FEASIBILITY STUDY
GEOPHYSICAL SURVEYS

LOCATION PLAN AND BATHYMETRIC CONTOUR PLAN

GEODETIC INFORMATION
Horizontal Datum: WGS84 UTM Zone 57S
Vertical Datum: Lord Howe Island - AHD (m)
SCALE
1:30,000

Note:
Plans and sections should be read in conjunction with the accompanying report.

Survey Date: MAY 18

Project Ref: MES 638

Issue No.	Date:	Description	Surv.	Interp.	Drawn	Appr.
1	17/06/2018	LP ISS				
2	09/07/2018	LP				

Client Drawing No.

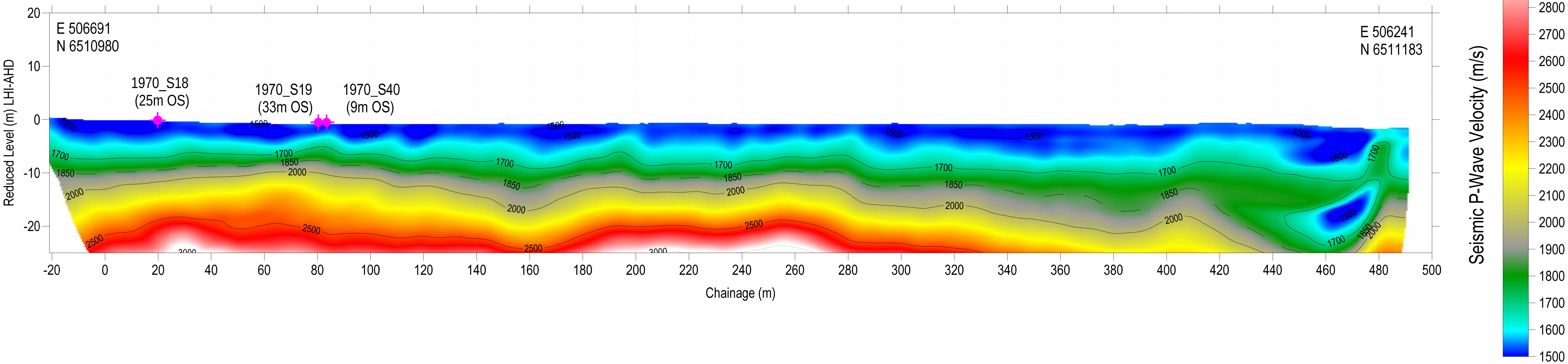
Figure No. 1

Sheet No.

Legend

Geotechnical borehole location

CMSR Line 1



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LORD HOWE ISLAND AIRPORT EXTENSION FEASIBILITY STUDY
GEOPHYSICAL SURVEYS

CMSR LINE 1
INTERPRETED SEISMIC REFRACTION SECTION

GEODETIC INFORMATION
Horizontal Datum: WGS84 UTM Zone 57S
Vertical Datum: Lord Howe Island - AHD (m)
SCALE
H 1:15,000
V 1:7,500

Note:
Plans and sections should be read in conjunction with the accompanying report.

Survey Date: MAY 18

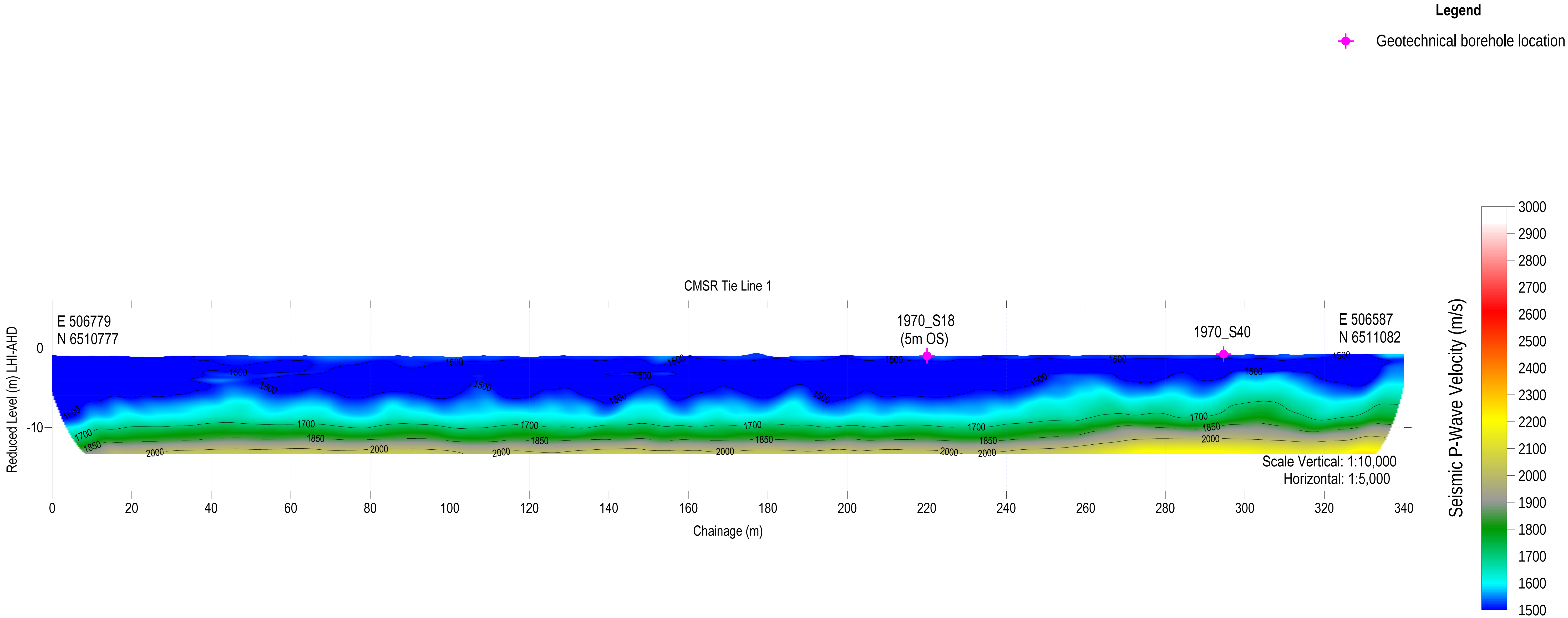
Project Ref: MES 638

Issue No.	Date:	Description	Surv.	Interp.	Drawn	Appr.
1	17/06/2018	LP ISS				
2	09/07/2018	ISS				

Client Drawing No.

Figure No. 2

Sheet No.



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LORD HOWE ISLAND AIRPORT EXTENSION FEASIBILITY STUDY
GEOPHYSICAL SURVEYS

CMSR TIE LINE 1
INTERPRETED SEISMIC REFRACTION SECTION

GEODETIC INFORMATION
Horizontal Datum: WGS84 UTM Zone 57S
Vertical Datum: Lord Howe Island - AHD (m)
SCALE
H 1:10,000
V 1:5,000

Note:
Plans and sections should be read in conjunction with the accompanying report.

Survey Date: MAY 18

Project Ref: MES 638

Issue No.	Date:	Description	Surv.	Interp.	Drawn	Appr.
1	17/06/2018	LP ISS				
2	09/07/2018	ISS				

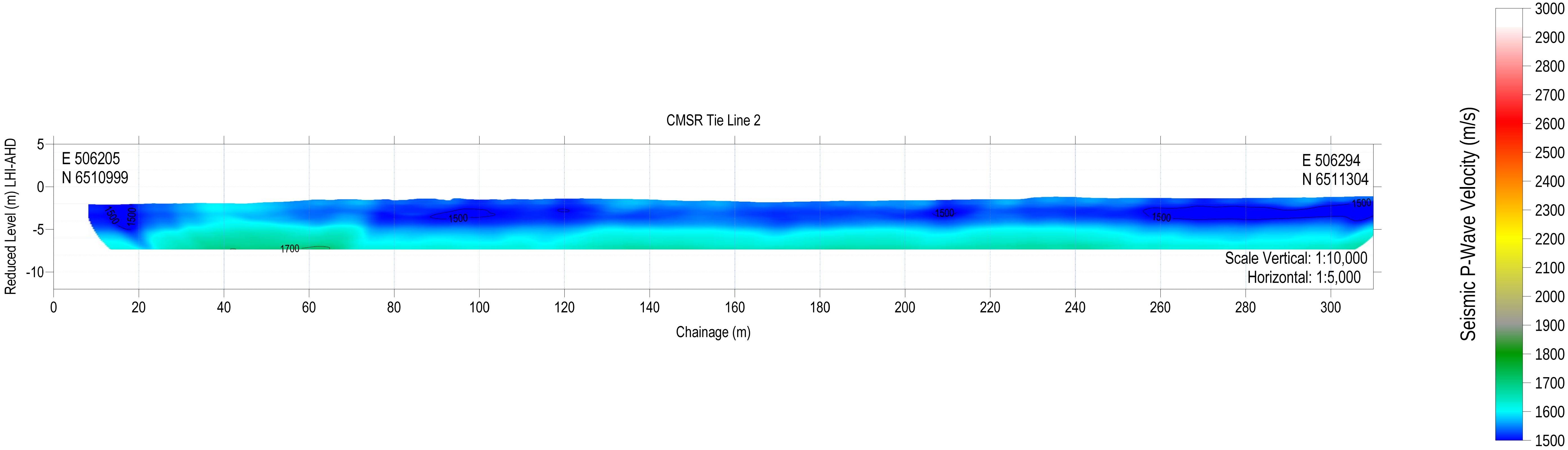
Client Drawing No.

Figure No. 3

Sheet No.

Legend

Geotechnical borehole location



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LORD HOWE ISLAND AIRPORT EXTENSION FEASIBILITY STUDY
GEOPHYSICAL SURVEYS

CMSR TIE LINE 2
INTERPRETED SEISMIC REFRACTION SECTION

GEODETIC INFORMATION
Horizontal Datum: WGS84 UTM Zone 57S
Vertical Datum: Lord Howe Island - AHD (m)
SCALE
H 1:10,000
V 1:5,000

Note:
Plans and sections should be read in conjunction with the accompanying report.

Survey Date: MAY 18

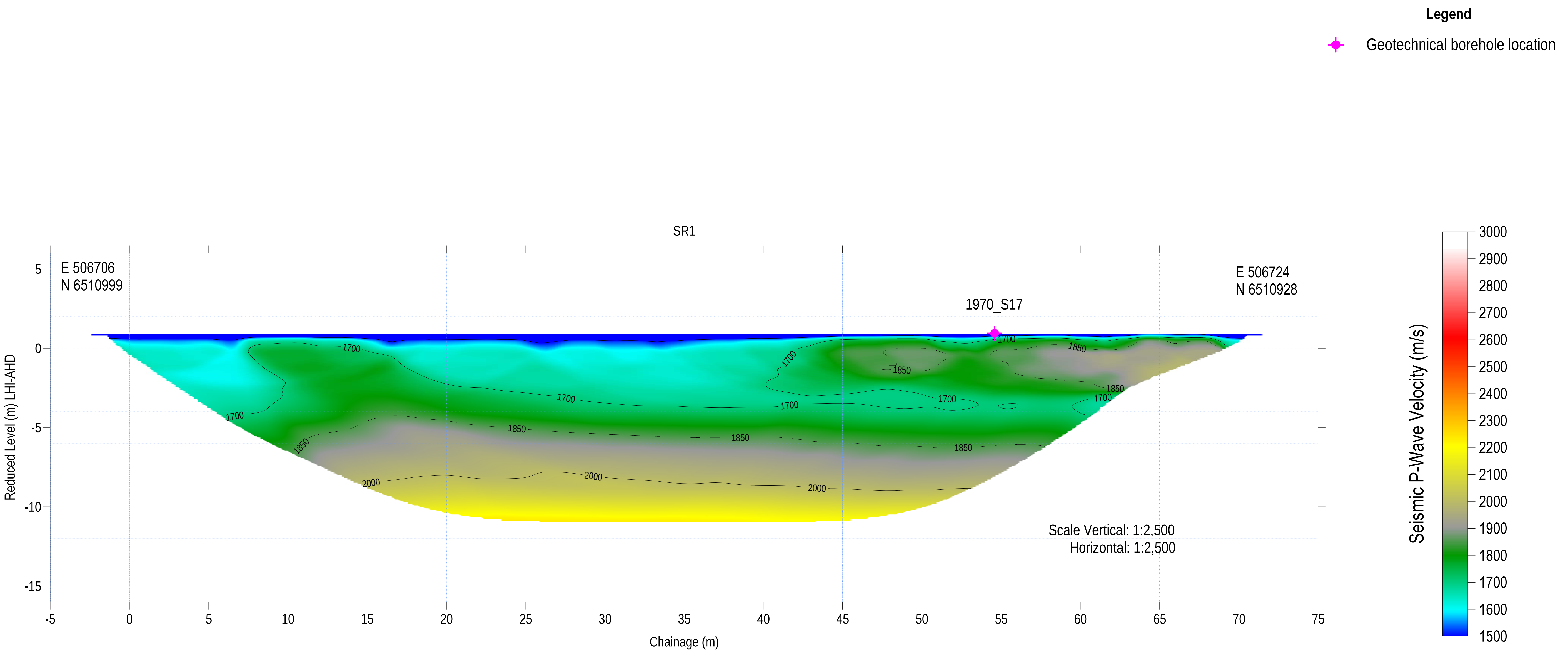
Project Ref: MES 638

Issue No.	Date:	Description	Surv.	Interp.	Drawn	Appr.
1	17/06/2018	LP ISS				
2	09/07/2018	ISS				

Client Drawing No.

Figure No. 4

Sheet No.



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LORD HOWE ISLAND AIRPORT EXTENSION FEASIBILITY STUDY
GEOPHYSICAL SURVEYS

SR LINE 1
INTERPRETED SEISMIC REFRACTION SECTION

GEODETIC INFORMATION
Horizontal Datum: WGS84 UTM Zone 57S
Vertical Datum: Lord Howe Island - AHD (m)
SCALE
H 1:2,500
V 1:2,500

Note:
Plans and sections should be read in conjunction with the accompanying report.

Survey Date: MAY 18

Project Ref: MES 638

Issue No.	Date:	Description	Surv.	Interp.	Drawn	Appr.
1	17/06/2018	LP ISS				
2	09/07/2018	ISS				

Client Drawing No.

Figure No. 5

Sheet No.

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