Sub-surface stratigraphy of Stella Passage, Tauranga Harbour

2013

ERI report number 28

Prepared for Port of Tauranga

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Introduction

Port of Tauranga Ltd supported two initiatives designed to develop a greater understanding of the distribution of sediments below Stella Passage (Figure 1), particularly relating to areas that may require future dredging:

(1) As part of INTERCOAST PhD research by Ehsan Jorat, Port of Tauranga provided logistic support for a series of high-resolution Cone Penetration Test (CPT) soundings along a transect on the western margin of Stella Passage in February – March 2012;

(2) Port of Tauranga provided part-funding of a Summer Scholarship student (Amy Christophers) over the 2012/13 summer, particularly to look at pre-existing cores and core descriptions.

In addition, the University of Waikato undertook a series of sub-bottom seismic profile measurements in Stella Passage as part of a Summer Scholarship funded by the University over the 2012/13 summer.

This report summarises the current state of these investigations.

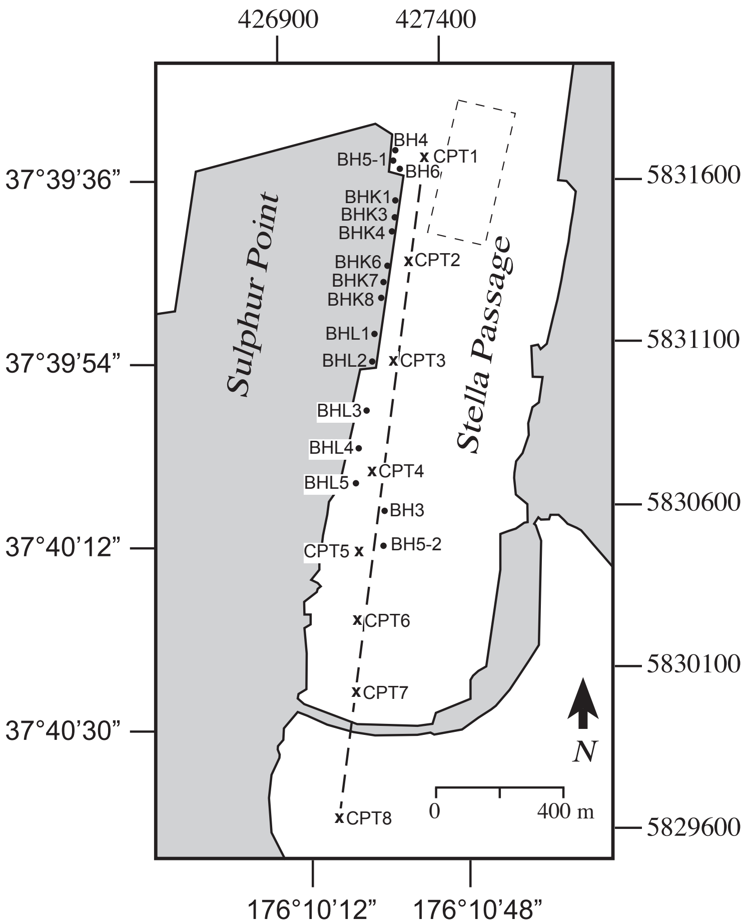


Figure 1: Location map of Stella Passage, Tauranga Harbour, and summary of CPT and borehole locations used to derive the 2D model of sub-surface stratigraphy. Dashed line indicates approximate line of 2D transect. Dashed box indicates approximate extent of 3D model. Co-ordinates on left margin and base are in latitude / longitude; co-ordinates on top and right margin are NZGD2000 Transverse Mercator Projection eastings and northings.

Data Sources

Port of Tauranga provided PDF files summarizing previous borehole and CPT data that exists within the Stella Passage area. These data date back to 1948, but most importantly, recent investigations associated with the development and extension of Sulphur Point Wharf in 1988 and 2011 provided useful data sources.

Three existing cores obtained for the geotechnical investigations of the current northwards extension of Sulphur Point Wharf were also made available from OPUS. These were described by Amy Christophers using standard sedimentological methods in much greater detail than the original drill descriptions given for cores 4, 5 and 6 in OPUS (2011). The new detailed core description summaries are presented in Appendix 1.

In February 2012, a field investigation was undertaken in collaboration between University of Bremen, University of Waikato and Port of Tauranga. This investigation involved taking a series of CPT tests using GOST, an offshore CPT tool that was invented and developed at Bremen University (MARUM – Centre for Marine Environmental Sciences). GOST incorporates a small (5 cm^2) cone, giving high-resolution traces. During 4 weeks of operation, a series of 15 CPT tests were performed in Stella Passage and at the entrance channel. Of these, 8 CPT sites are located along a north-south transect on the western side of Stella Passage (Figure 1); these 8 are used to develop the interpretation presented in this report.

As part of the University of Waikato Summer Scholarship programme, 16 seismic lines were run during the installation and sea trials of a new Sub-Bottom Profiler (SBP). These are located in two groups: a northern group (1 – 8) off Sulphur Point Wharf, and a southern group between the wharf and the Harbour Bridge (Figure 2). The collection of these data occurred during two main trials and did not follow a systematic survey pattern, so the numbering of the survey lines is not consistent. The seismic system used was a Knudsen Pinger SBP with dual 3.5 kHz and 200 kHz transducers. The system is designed to connect into the vessel's navigation and heave compensation hardware, but due to initial technical difficulties this did not always work correctly. However, navigation data were logged independently using HYDRONAV permitting further analysis. Ranges of instrument settings were used to test the functioning of the instrument, particularly to determine suitable configurations for very shallow and shallow water depths. It was discovered that a key control switch was installed backwards during manufacture and this resulted in some poor quality records. However, this mostly affected trials in Maunganui Roads and Cutter Channel, and these data have been discarded.

Borehole descriptions

Summarised borehole descriptions from sites BH 4, BH 5-1 and BH 6 at the northern end of Sulphur Point are given in Appendix 1. From all three it is apparent that at the top of the profile is a sequence of grey sands and silts containing shell material; this shell material disappears suddenly at depths of between 4 and 17 m below the drilling datum. This unconformity represents the boundary between

Holocene sediment mobilised by the marine transgression ending 7200 cal BP and older Pleistocene sequences. Thus all of the material above this boundary represents recent to modern marine sedimentation. These materials are characterized as typically grey sands and silts containing shell fragments.

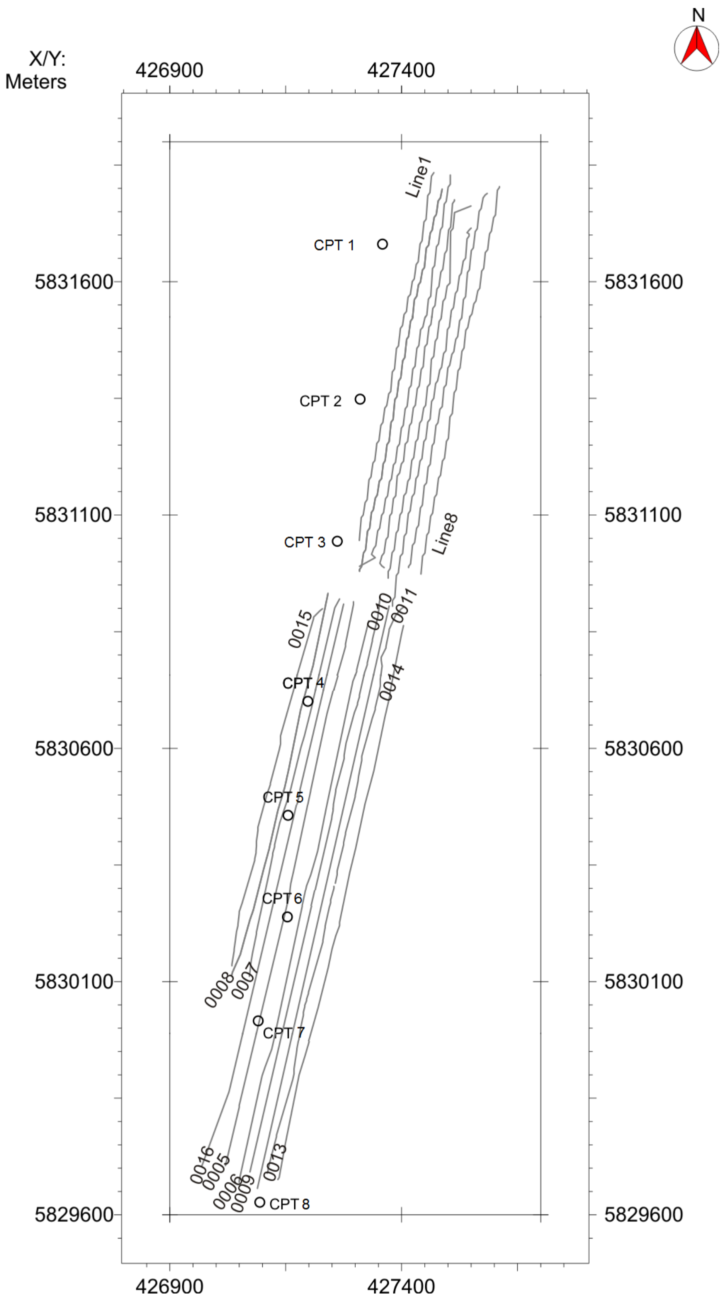


Figure 2: Acquisition tracks for the Knudsen Pinger SBP. Tracks are numbered in the order that they were collected. To simplify boat handling, between Stella Passage and the Harbour Bridge data was acquired by following the nearest unsampled survey line after the vessel had completed a turn. In Stella Passage, lines were sampled consecutively from west to east. NZGD2000 co-ordinates.

Below the Pleistocene-Holocene boundary is a sequence of pumice-bearing materials of various textures from silt to gravel. These are interspersed with paleosols (buried soils) and swamp deposits, indicating terrestrial deposition for the bulk of this sequence. This is considered to correlate with the Matua Sub-group described on land (Briggs *et al*., 1996, 2006); comparison with the on-land stratigraphy suggests that these beds have been derived from primary and reworked pyroclastic materials.

These two primary units and the unconformity separating them are the key components of the stratigraphic sequence seen in the boreholes examined.

Development of a 2D transect

A 2D model was developed along the transect of the GOST CPT soundings in Stella Passage (Figure 3). In order to derive this model, the CPT data along with all nearby existing borehole description data was used (Table 1, Figure 1). Normalised GOST soundings used in this analysis are shown in Appendix 2.

Table 1. CPT and borehole descriptions used for this study

Number	Coordinate		Reference
CPT 1	37° 39' 33.02" S	176° 10' 35.16" E	GOST Feb/March 2012
BH 4	37° 39’ 32.34” S	176° 10’ 30.90” E	OPUS International Consultants, 2011
BH 6	37° 39’ 34.00” S	176° 10’ 31.58” E	OPUS International Consultants, 2011
BH K1	37° 39' 37.33" S	176° 10' 31.16" E	Port of Tauranga, 2000
BH K3	37° 39' 38.93" S	176° 10' 30.85" E	Port of Tauranga, 2000
BH K4	37° 39' 39.89" S	176° 10' 30.56" E	Port of Tauranga, 2000
CPT 2	37° 39' 43.79" S	176° 10' 33.06" E	GOST Feb/March 2012
BH K6	37° 39' 43.74" S	176° 10' 29.95" E	Port of Tauranga, 2000
BH K7	37° 39' 45.35" S	176° 10' 29.65" E	Port of Tauranga, 2000
BH K8	37° 39' 46.95" S	176° 10' 29.35" E	Port of Tauranga, 2000
BH L1	37° 39' 50.62" S	176° 10' 28.42" E	Port of Tauranga, 2000
CPT 3	37° 39' 53.65" S	176° 10' 30.95" E	GOST Feb/March 2012
BH L2	37° 39' 53.53" S	176° 10' 28.07" E	Port of Tauranga, 2000
BH L3	37° 39' 58.37" S	176° 10' 27.23" E	Port of Tauranga, 2000
BH L4	37° 40' 01.90" S	176° 10' 26.84" E	Port of Tauranga, 2000
CPT 4	37° 40' 04.77" S	176° 10' 28.23" E	GOST Feb/March 2012
BH L5	37° 40' 05.72" S	176° 10' 25.90" E	Port of Tauranga, 2000
BH 3	37° 40' 08.40" S	176° 10' 29.40" E	Michels and Healy, 1998
BH 5-2	37° 40' 12.00" S	176° 10' 29.40" E	Michels and Healy, 1998
CPT 5	37° 40' 12.68" S	176° 10' 26.40" E	GOST Feb/March 2012
CPT 6	37° 40' 19.74" S	176° 10' 26.26" E	GOST Feb/March 2012
CPT 7	37° 40' 26.95" S	176° 10' 26.01" E	GOST Feb/March 2012
CPT 8	37° 40' 39.57" S	176° 10' 23.61" E	GOST Feb/March 2012

In Figure 3, the upper blue colours represent modern sedimentation following the Holocene sea level rise; these materials are dominantly silicic sands (quartz and glass) with some pumice and common shell fragments. This unit generally thins towards the south (Town Reach), and the recorded thickness at the northern end is impacted by dredging. Note that the thickness of the units, especially the Holocene sands, may be misrepresented along the transect as the borehole data is largely from along the line of the wharves in an area that was a natural shoal before reclamation.

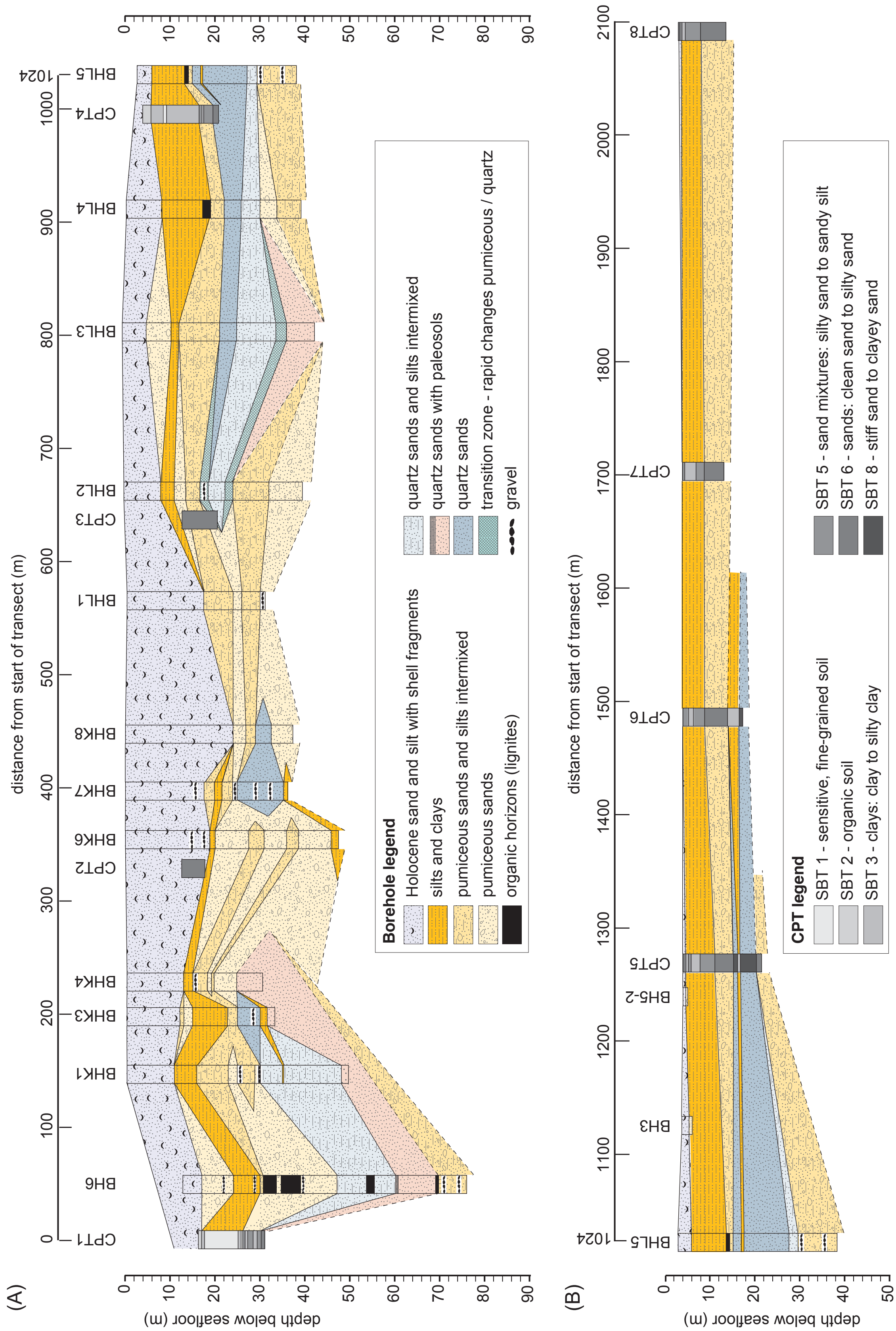


Figure 3: 2D transect along Stella Passage summarising the main units in the CPT and borehole profiles. (A) extends from CPT1 in the north to BHL5; (B) joins with this and extends the profile to CPT8 in the south. SBT = Soil Behaviour Type derived from CPT testing.

Beneath the Holocene sediments is a predominantly pumiceous sediment sequence (considered to correlate with the Matua Subgroup on land). This is a complex unit (and undoubtedly even more complex than is shown here), and includes intermixed pumiceous sands and silts, interspersed with gravels (generally discrete zones) and ignimbrites (often just gravels, but sometimes indurated). The unit as a whole consists of primary and reworked silicic pyroclastic materials. It represents terrestrial deposition, most likely dominantly in the form of an alluvial fan system. The environment would have been one of rapidly migrating braided river channels depositing sediment derived from further upstream. Rapidly migrating channels form a complex mosaic of coarse channel deposits, finer overbank deposits, and small swamps and lakes with peat formation (now lignite). Numerous paleosols are recorded in this unit, indicating significant periods of terrestrial weathering and erosion between sedimentation events. The main river channel appears to have been near the location of BH K8, and it was a wide channel (approximately 300 m across), suggesting that it probably was a braided river with multiple shallow channel locations.

Intruding into this Matua Subgroup sequence is a zone of further marine sedimentation marked by quartz-dominated sand deposits (blue and red colours on Figure 3). This represents a high sea-level Pleistocene interglacial period. These are only partially preserved, but the lower portions of this unit (red colours) show colours, textures, and minor paleosols suggesting onshore deposition in dunes, to be later over run by shallow marine sediments (blue colours) as the sea level continued to rise. We suggest that this is possibly representing Marine Oxygen Isotope Stage (MOIS) 11 of approximately 427,000 years ago, as this is supposedly the MOIS most similar to present-day conditions.

An ignimbrite is recognized within the upper parts of the Matua Subgroup materials. This is likely to be the Te Ranga Ignimbrite with an age of 0.27 Ma (Briggs *et al*. 2005) by comparison with a local outcrop of this ignimbrite near the harbour bridge approaches and along the margins of Town Reach. Alternatively, the Te Puna Ignimbrite, found extensively further north in the Tauranga Harbour area, could also be here, but is older and hence probably deeper in the sequence. Erosion of this ignimbrite in a terrestrial environment during lower sea level (or prior to down-faulting) has resulted in a series of ridges and valleys representing a fluvial landscape.

The resulting landscape is covered with a silty layer that extends and thickens both northwards and southwards away from the main channel area. In BH 6 this unit is silty and laminated, and is inferred to have formed in a low energy lacustrine (lake) environment. The unit extends southwards as a reasonably uniform layer, based on CPT and seismic data. By analogy with on-land sites, we interpret this as a reworked tephra sequence (Pahoia Tephras and possibly Hamilton Ashes of Briggs *et al.* (1996)) that has accumulated as lake, on-land, or overbank stream deposits following erosion and reworking. Note that lacustrine (diatomaceous) and estuarine laminated silts are found in the Matua Subgroup sediments elsewhere.

All of this is consistent with a major phase of alluvial fan development with a large sediment source associated with volcanic activity in the river source area, and likely subsidence of the basin. Marine deposition of largely estuarine materials followed the Holocene marine transgression and development of enclosing barrier islands / tombolo, producing the uppermost unit.

Correlation of CPT, borehole, and seismic data

CPT 1 was taken close to the site of BH 6. Comparison of the two (Figure 4) shows clearly the upper zone of Holocene marine sediments represented by a relatively high tip resistance and low induced pore water pressure extending to a depth of 1.5 m at CPT 1 site.

Below the Holocene sediments, the pumiceous sands and silts return a very low tip resistance and high induced pore water pressure. These materials are classed as soft, sensitive soil by Soil Behaviour Type (SBT), and typically would indicate fine materials with low permeability. From the core description the materials are much coarser than the SBT would suggest, with the tip resistance probably being low due to the dominance of pumice.

At approximately 7.5 m depth in the CPT trace, a sharp drop in the induced pore water pressure is noted; this corresponds with the change from pumiceous sand / silt intermixes to dominantly pumiceous silt in BH6. The pore water pressure drop suggests a zone of freer drainage along this contact. The pumiceous silts observed in BH6 are again characterised as soft sensitive soils or clays by SBT, with high induced pore water pressure and low tip resistance; one spike in tip resistance representing a sandy layer is not recognised in the CPT1 sequence.

Near the base of the CPT trace the tip resistance rises sharply across an approximately 0.5 m thick zone in which the pore water pressures drop to hydrostatic, suggesting ready drainage of this layer. Comparison with BH 6 suggests that this is an ignimbrite layer that is encountered at a similar depth and is described as a 0.5 m thick, coarse, pumiceous sand and gravel layer.

Correlation of depths is difficult as it is not clear how much material has been removed from the top of the profile in the dredged part of the channel (CPT1 site), but the comparison in Figure 4 represents our best estimate of how these relate, and the ignimbrite position fits well between the CPT and borehole data. Below the ignimbrite layer the tip resistance tends to increase and the materials are better drained than higher in the profile – these are generally sands, gravels, and organic (lignite) layers in the boreholes and exposed sites.

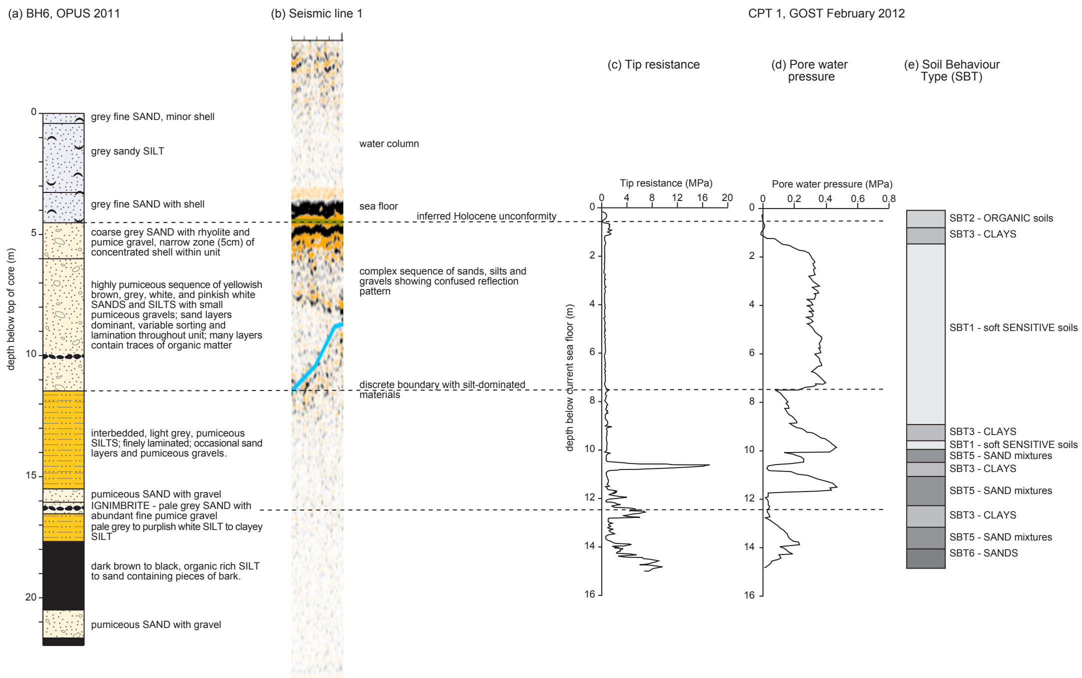


Figure 4: Comparison of description of Borehole 6 and measured tip resistance and pore water pressure for CPT1. Seismic trace of line 1 is superimposed.

Including the appropriate section of seismic line 1 (Figure 4b) shows two recognisable reflectors in the seismic sequence: one corresponds to the base of the Holocene sequence (green line in Figure 4b), and the second (blue line in Figure 4b) corresponds to the discontinuity at the top of the pumiceous silts, which is also marked by the dramatic drop in induced pore water pressure at this depth (Figure 4d).

Inserting these two seismic lines on the 2D transect allows an interpretation of the stratigraphy beneath the present dredged sea floor to be developed (Figure 5). In order to draw this model the depths of some of the cores were altered to line the stratigraphy up with the seismic reflectors. This accounts for the offset of the core and CPT data from the seismic line. Some of the units have also been simplified to make this model.

Within the dredged channel it can be seen that a thin layer of Holocene marine sediments lies over a relatively flat surface representing the level of dredging. The Holocene sands appear to be forming sand waves that may migrate across the dredged surface. Most of the sediment immediately below the Holocene sands in the dredged channel is pumiceous sand and silt intermixes, but in one area the silts occur along this surface; this likely corresponds to where fine, white material was liberated during previous dredging operations.

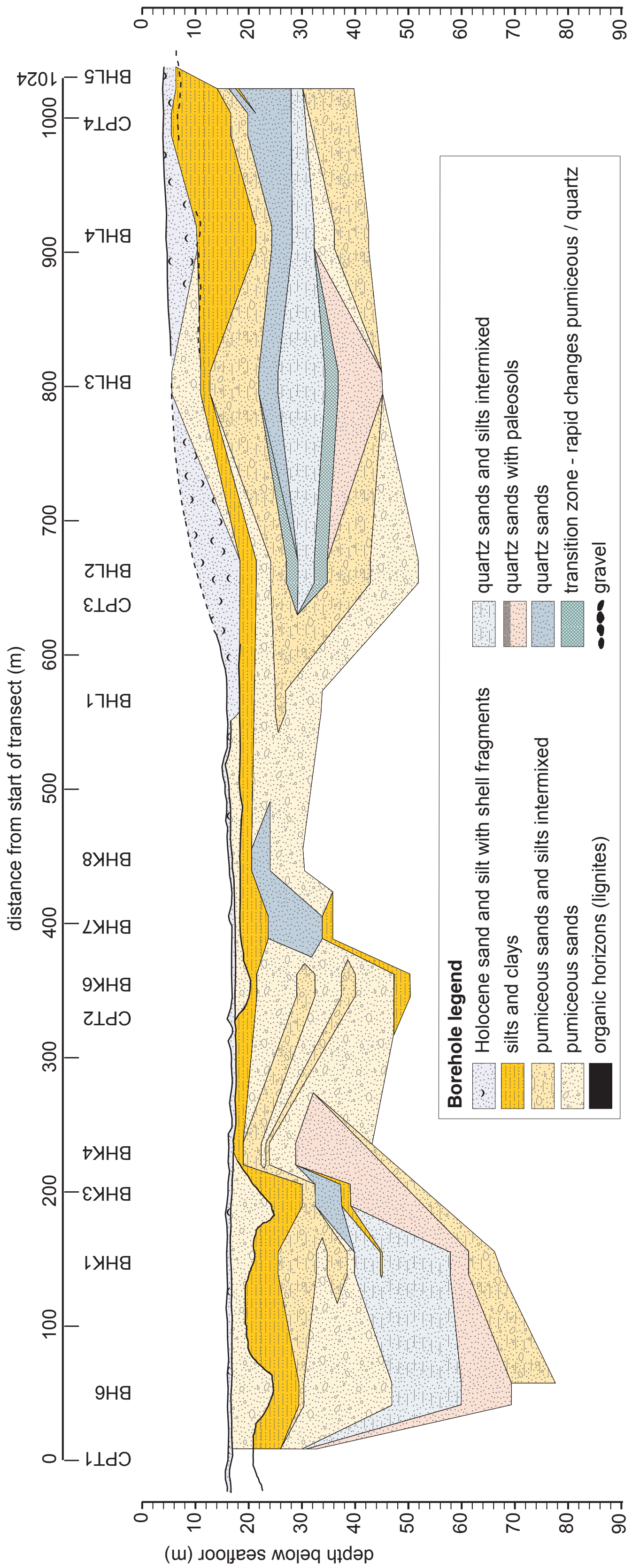


Figure 5: Estimated sequence along transect in Figure 3 following dredging of the current shipping channel. Seismic line 1 has been used to derive the unconformity representing the Holocene transgression, and the upper surface of the orange silt / clay layer. The levels of the boreholes have been adjusted to fit with these reflectors in the seismic sequence.

Beneath the undredged part of Stella Passage the silts are at some depth initially, where there appears to be a thickened wedge of Holocene sediments at the base of the dredged cut slope. However, at approximately 1000 m from the start of the transect the silt materials again appear to be near the sea floor. Poor seismic results in this area meant that these inferences are speculative, but are supported by small sections of good reflection that were observed, and by observations of white silts on the barge anchor in this area during the GOST deployment. CPT data suggests that the silts are near the surface further south into Town Reach.

Development of a 3D model

Using the 2D model as a base concept, a 3D model was attempted to extend this interpretation across Stella Passage by correlating the 2D model with the seismic sub-bottom profiles. The recorded seismic lines were processed and interpreted by Geo-Engineering GmbH in Germany. The final processed seismic lines with inferred reflectors are presented in Appendix 3. Geo-Engineering GmbH also used these to develop the 3D model shown in Figure 6. Note, as discussed above, the primary purpose for collecting the data was to test the installation of new equipment, which was found to have some minor technical faults. Hence, the settings used and locations of seismic lines were not optimal for interpretation of the sub-surface stratigraphy. Thus, at this stage the analysis undertaken is more a proof of method rather than a definitive analysis.

Only one reflector was consistent enough to give adequate data to model – mainly because much of the Holocene has already been dredged in the area of concern, and so resolving the Holocene unconformity very near the present seabed was difficult. To the south, the reflectors were inconsistent, and more work needs to be done to get consistent results here.

The reflector mapped in this seismic analysis is assumed to represent the top of a silty layer, which will have contrasting seismic properties from the coarser pumiceous sands and silts. The reflector surface in the 3D model shows considerable relief. On land, the ignimbrite and overlying Pahoia Tephras display this degree of relief (e.g. Omokoroa sequence in Figure 7).

The depth data for the seismic profiles is inferred from an assumed speed of sound within the water column and the sediment. The Knudsen Pinger uses a 200 kHz transducer to locate the seabed, and a 3.5 kHz transducer for the sub-surface stratigraphy, so separate sound velocities are used to determine depth for each transducer. For this analysis, only the 3.5 kHZ channel was processed by Geo-Engineering GmbH, and a standard velocity for sandy sediment was assumed. Therefore, there is some uncertainty about the true depths of the seismic reflectors, and the seismic profiles were adjusted to correspond with the CPT profiles.

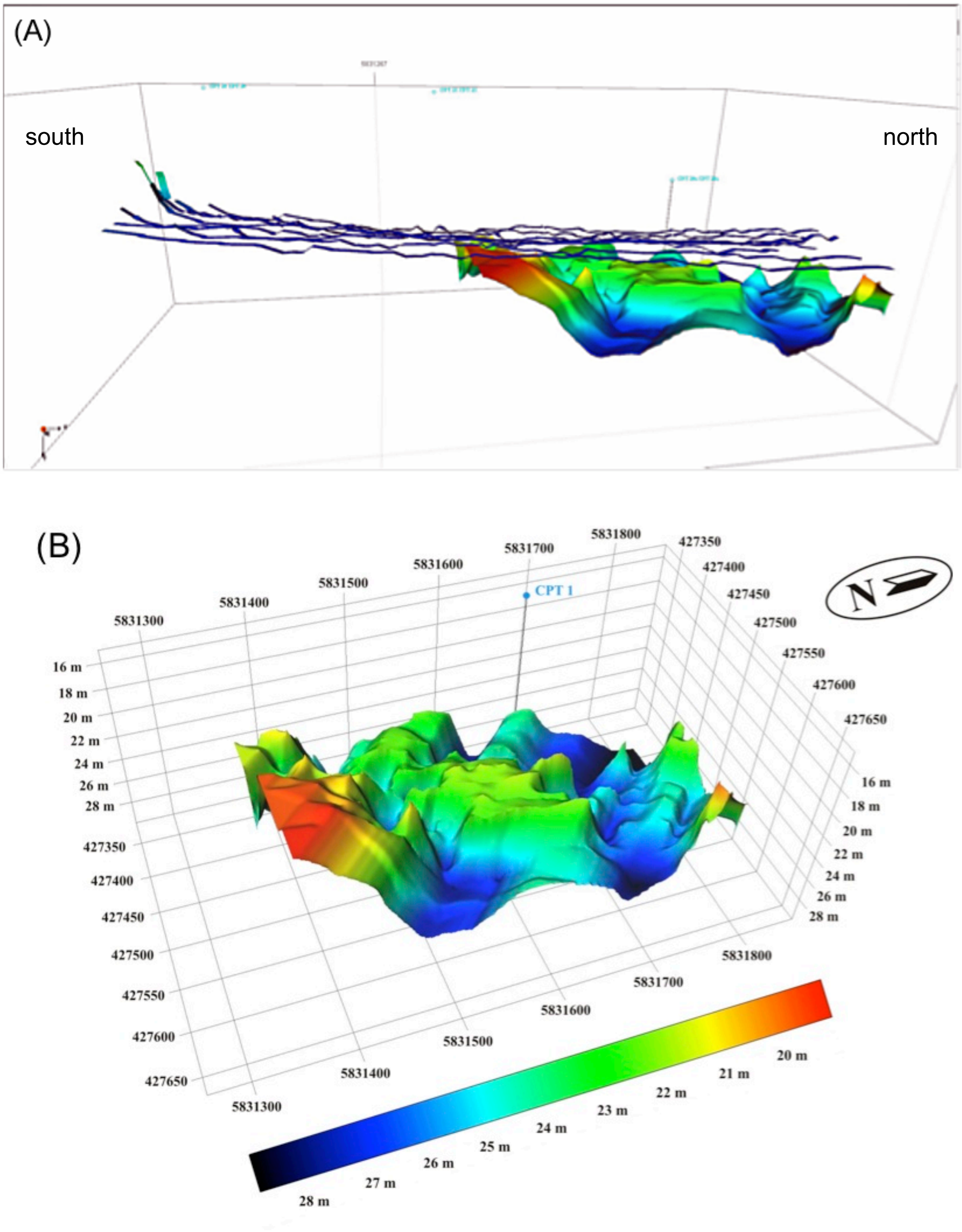


Figure 6: 3D model for the upper surface of unit 3, which is inferred to be a silt layer. (A) shows the location of unit 3 relative to the seabed recorded in the seismic profiles. (B) is an oblique view from the southeast, with the location of CPT1 marked. NZGD2000 co-ordinates.

Figure 7: A cliff exposure of the Te Puna Ignimbrite and Pahoia Tephra units at Omokoroa, which is similar to the sequence in Stella Passage. The total width of the image is approximately 50 m, and the relief on the ignimbrite surface (solid and dashed line) is approximately 5 m. This scale of topographic variation is consistent with the 3D model reflector surface. Photo Hadley Craig.

Interpretation of model

From the 3D model (Figure 6) we can see two distinct valleys on the top of the silty material that provides the reflector, probably representing the main threads of the river system at or around the time of alluvial fan development. Note that the model has not been smoothed, and so there are some spurious peaks. Additional seismic data are needed to refine it.

Most notable is that these valleys run transverse to the present orientation of Stella Passage, suggesting a fluvial system that ran approximately parallel to the present-day coastline of the Bay of Plenty and probably continued beneath what is now Mt Maunganui tombolo. This interpretation is consistent with that of Davis and Healy (1993), based on borehole data, a seismic survey and surficial sediment from Stella Passage before the 1992 capital dredging (Figure 8).

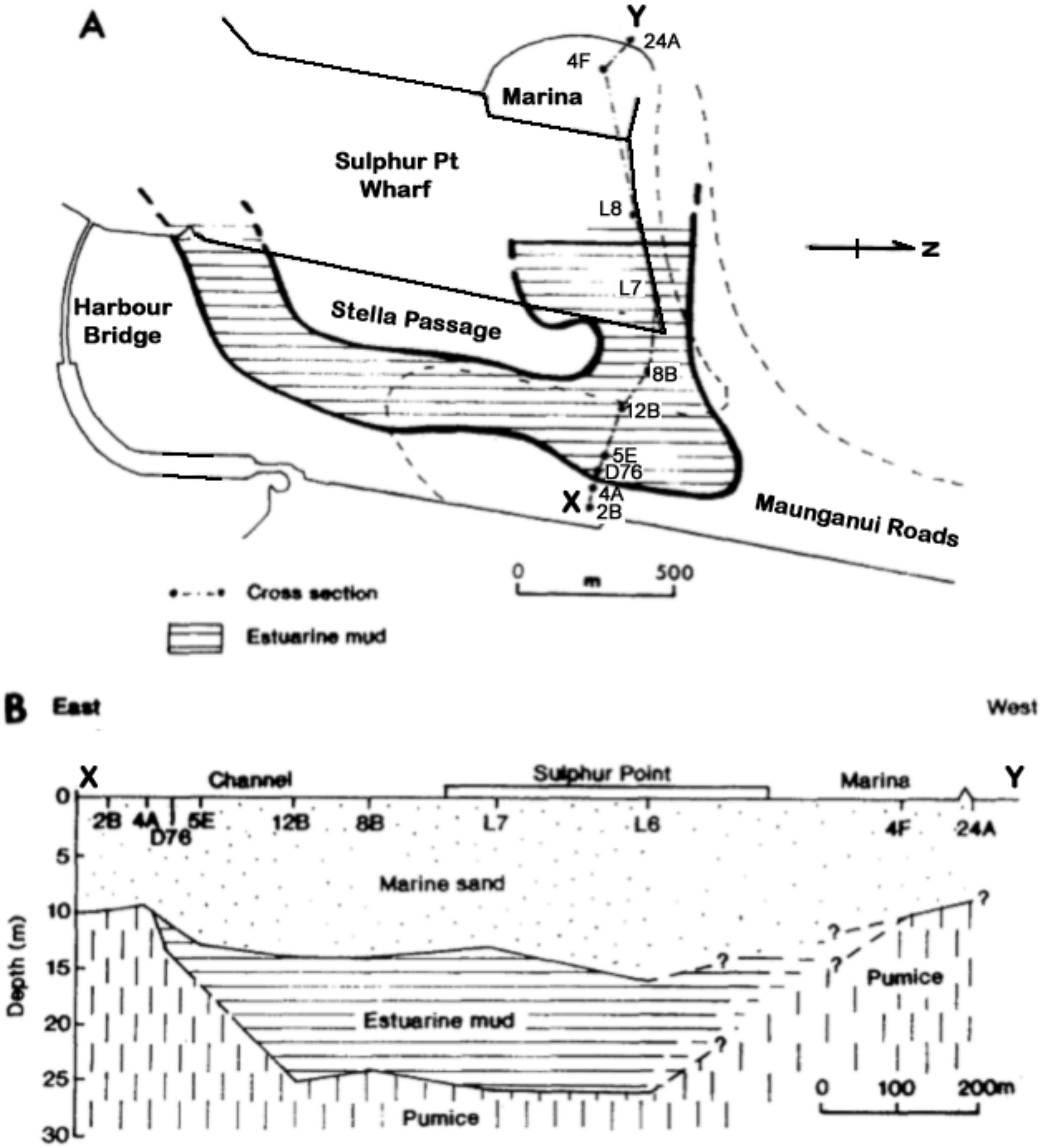


Figure 8: Interpretation of the sub-surface stratigraphy of Stella Passage from Davis and Healy (1993), which was based on incomplete borehole data. (A) Map of Stella Passage showing the position of the paleo-valey or channel infilled with "Estuarine mud" of Davis and Healy (1993). Much of the upper marine sand unit in (B) has been removed by dredging and is the Holocene marine sand upper unit in the 2D Model (Figures 3 and 5). The "Estuarine mud" unit corresponds to the silts and clays within the Pleistocene (Matua Subgroup), and the "Pumice" unit corresponds to the pumiceous sands and silts of the Matua Subgroup.

The valleys identified are each approximately 50–60 m wide, with depths of 4–6 m. This scale of topographic relief is similar to that seen on the Te Puna Ignimbrite surface and the overlying Pahoia Tephras exposed on the Omokoroa Peninsula (Figure 7). It is assumed that a similar scale exists for the Te Ranga Ignimbrite near the Harbour Bridge approaches. The observed channels are consistent with the presence of a prehistoric Wairoa River (Figure 9) as proposed by Davis and Healy (1993).

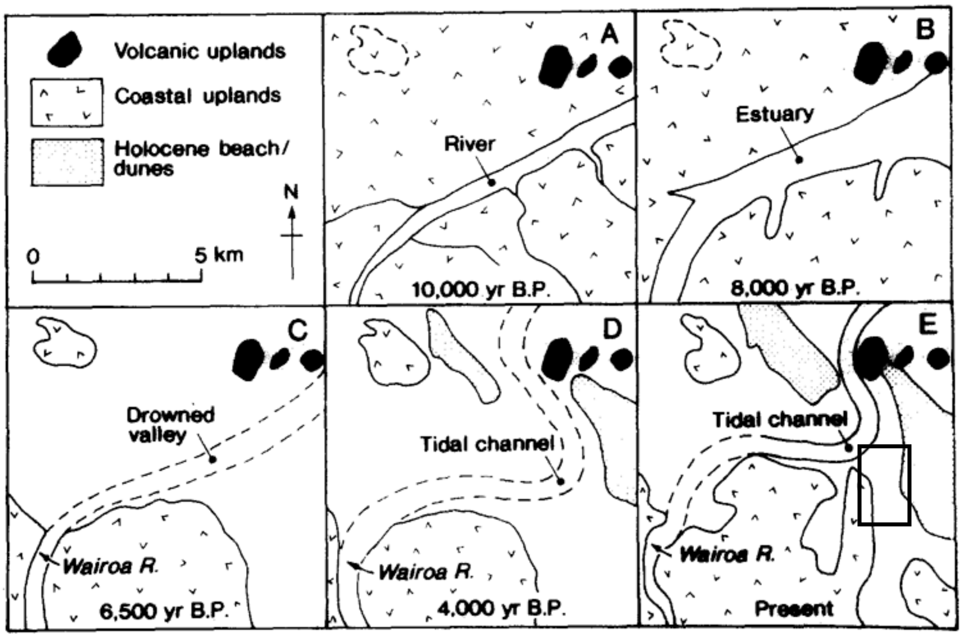


Figure 9: Paleo-interpretation of the evolution of the Tauranga Harbour during the Holocene from Davis and Healy (1993). This interpretation identifies a river system crossing Stella Passage and the realignment of the drainage systems as sea level rose and the Mt Maunganui tombolo and Matakana Island barrier were established. Box on panel E represents approximate area of map and section shown in Figure 8. The suggested ages on this figure are in 14C yr BP.

Above high points in the reflector profile the expected profile starts with about 2 m of grey, shelly, silty - sandy Holocene sediments at the sea floor, corresponding to the modern marine transgression in Figure 8. The thickness of this upper layer decreases towards the south. Underlying the Holocene sediments above the high points in the reflector trace is approximately 1 – 2.5 m of Matua Subgroup – most likely sandy, silty, pale coloured, highly variable materials. Above the paleo-channels in the reflector surface, we would initially expect a similar thickness of approximately 2 m of Holocene sediments. Below these however, is likely as much as 10 m, more commonly 6 m, of Matua Subgroup.

Implications

The deepest reflector recognised in the seismic lines likely represents a complex sequence of weak, sandy and silty materials, correlated with the Pahoia Tephra sequence on land. This contains *in situ* and reworked pyroclastic materials of various sizes from fine silt to small gravels. Overall the geomechanical properties of the unit are dominated by silt-like behaviour, with low tip resistance, and high induced pore water pressures, suggesting low permeability (poor draining). The silts are typically pale coloured, and actually comprise a large quantity of clay. This is likely the material that will cause discolouration of the water column during dredging as it will disperse readily and be slow to settle. Unfortunately, prediction of the exact location of silt layers themselves is difficult as the units are discontinuous, and often occur in lenses.

Where this layer thickens on paleo-valleys is likely to cause problems in (1) finding a stable base, (2) turbidity issues for dredging, and (3) possible batter stability concerns on dredged margins (sensitive soil layers within sequence). It is also likely to contain halloysite as a key clay mineral – this potentially has some value as a resource as halloysite is currently being extensively researched as a nano-material for various uses.

Acknowledgements

The authors acknowledge funding by Deutsche Forschungsgemeinschaft (DFG) via the Integrated Coastal Zone and Shelf Sea Research Training Group (INTERCOAST) and the MARUM Center for Marine Environmental Science, University of Bremen. GOST development and engineering credit is given to Dipl.-Ing.(FH) Wolfgang Schunn as the main technical developer of the tool. We would like to especially thank Sebastian Feldman from Geo-Engineering GmbH (Am Fallturm 5, 28359 Bremen, Germany) for his help on sub-bottom profile data processing, and Dirk Immenga from the University of Waikato for running the sub-bottom profile unit.

References

Briggs R.M., Hall G.J., Harmsworth G.R., Hollis A.G., Houghton B.F., Hughes G.R., Morgan M.D., Whitbread-Edwards AR, 1996 "Geology of the Tauranga area", sheet U14 1:50 000, Occasional Report 22, Department of Earth Sciences, University of Waikato, Hamilton, New Zealand, 1996.

Briggs, R.M., Houghton, B.F., McWilliams, M., Wilson, C.J.N., 2005. $^{40}Ar/^{39}Ar$ ages of silicic volcanic rocks in the Tauranga- Kaimai area, New Zealand: Dating the transition between volcanism in the Coromandel Arc and the Taupo Volcanic Zone. *New Zealand Journal of Geology and Geophysics,* 48(3), 459-469.

Briggs, R.M.; Lowe, D.J.; Esler, W.R.; Smith, R.T.; Henry, M.A.C.; Wehrmann, H.; Manning, D.A. 2006. Geology of the Maketu area, Bay of Plenty, North Island, New Zealand - Sheet V14 1:50 000. Department of Earth Sciences, University of Waikato, Occasional Report 26. 44 pp + map. [Published in collaboration with Bay of Plenty Regional Council, Whakatane

Davis, R.A. and Healy, T.R., 1993, Holocene coastal depositional sequences on a tectonically active setting: southeastern Tauranga Harbour, New Zealand: Sedimentary Geology, v. 84, p. 57-69.

Michels K., Healy T., 1998. Investigation of sediments to be dredged in the lower Town Reach-Upper Stella Passage and disposed of at an inner shelf dump ground. A Report to Port of Tauranga Ltd., April, 1998.

OPUS International Consultants Ltd., 2011. Sulphur Point Northern Wharf Extension – Port of Tauranga. Geotechnical Factual Report. Geotechnical Report G2899.

Port of Tauranga, 2000. Site Investigations. Boreholes and Penetrometer Data.

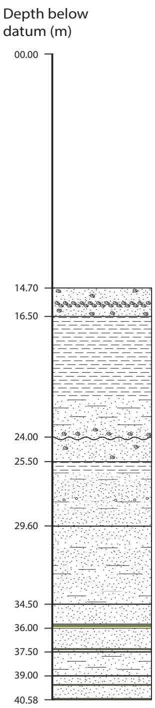
Appendix 1 – Summarised core descriptions

Amy Christophers
23/06/2013

Borehole 4 Summary

Project: Sulphur Point Wharf
Borehole: 4
Box: 1-6
Depth below datum (m): 14.70-40.585

Co-ordinates: 374335.0 E, 811295.5 N
Grid: BOP2000



Fine-medium Grey SAND, shell material increasing down, poorly sorted. High shell content (6 cm thick).

Olive Grey SILT, well sorted, minor sand with shell material at base.

Light Grey fine-medium pumiceous SAND, trace shell material, moderately sorted.

Yellowish Olive Grey SAND, silt at top decreasing down with increasing coarse sand, poorly sorted, minor fine gravel, inversely graded towards base into a fine, well sorted SAND.

Light Olive Grey fine-medium SAND, moderately sorted, trace organic matter, three series of fining.

Olive/Red medium-coarse SAND, moderately sorted, organic matter. PALEOSOL (35.95-35.98, 37.30-37.40) and a possible TEPHRA (35.98-36.00).

Grey Silty SAND, well sorted, fining down.

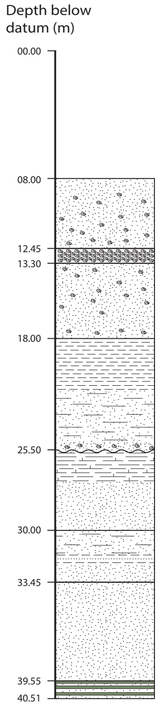
Olive Grey fine-medium SAND, well sorted, trace silt, high organic matter, two particially developed PALEOSOLS (39.59-39.61, 40.56-40.58), area of fine sand with orange surface (39.45-39.55).

Amy Christophers
23/06/2013

Borehole 5 Summary

Project: Sulphur Point Wharf
Borehole: 5
Box: 1-8
Depth below datum (m): 08.00-40.51

Co-ordinates: 374336.9 E, 811269.8 N
Grid: BOP2000



Fine-medium Grey SAND, containing shell material increasing down (variations in abundance), poorly sorted.

Shell bed.

Fine-medium Grey SAND, containing shell material decreasing down into a moderately sorted, fine-medium Grey SAND.

Olive Grey SILT, well sorted, sand content increasing down with shell material at base.

Yellowish Olive Clayey SILT, well sorted, grading down into poorly sorted, fine-coarse SAND.

Light Grey, highly pumiceous silty SAND, contains coarse pumice pieces, and some fine laminations, and trace organic matter, texture coarser at base.

Olive/Red medium-coarse SAND, moderately sorted, fines at base and well sorted, areas of increased fine sand/silt and highly compacted, minor organic matter.

Olive Brown Silty SAND, high organic matter, three developed PALEOSOLS (fine sand at base with orange surface).

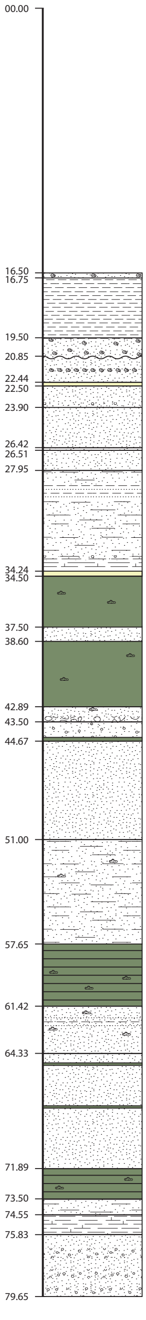
Amy Christophers
23/06/2013

Borehole 6 Summary

Project: Sulphur Point Wharf
Borehole: 6
Box: 1-17
Depth below datum (m): 16.50-79.65

Co-ordinates: 374351.9 E, 811244.4 N
Grid: BOP2000

Depth below datum (m)



Grey fine SAND, moderately sorted, minor shell material at base.

Grey Sandy SILT, normally graded, well sorted.

Grey fine SAND, moderately sorted, shell material, increased at base.

Coarse Grey SAND, rhyolite and pumics. High shell content (5 cm thick).

Possible TEPHRA, coarse pumiceous.

Pale Yellow fine-coarse SAND, poorly sorted, minor silt, grades into Light Grey SAND at base with pumice clasts

Grey SAND, fine-coarse, poorly sorted, contains pumice clasts, two series of fining (Layer of fine sand).

Highly pumiceous Light Grey Sandy SILT. Clayey SILT, SILT, Silty SAND laminations. Silty SAND with pumice clasts and well sorted Clayey SILT at the base.

Possible TEPHRA, Light Grey Silty CLAY, well sorted.

PALEOSOL, sandy, contains fragments of bark, grades down into sand.

Grey medium SAND, well sorted, grades into paleosol (minor organic matter/paleosol development).

PALEOSOL, sandy, contains fragments of bark, grades down into sand.

Light Grey medium SAND, well sorted, piece of bark at top

Olivish Grey fine-coarse SAND, poorly sorted, fining up with pumice clasts, slight development of PALEOSOL at base.

Olivish Grey fine-medium SAND, well sorted, high organic matter (area with orange surface).

Light Grey Silty SAND, well sorted, high organic matter contains bark (Yellow surface staining).

PALEOSOL: Organic matter laminations, interbedded with fine SAND/Silty SAND high organic matter. Lignites. (Yellow and orange surface discolouration).

Light Grey Silty SAND, well sorted, normally graded, with high organic matter contains bark, series of four normally graded laminations, 1 cm thick, medium SAND at base.

Dark Olivish Brown medium SAND, high organic matter, well sorted, fines down into silty SAND. Contains two Sandy PALEOSOLS (64.98-65.07, 67.80-67.86).

PALEOSOL: Organic matter laminations, interbedded with fine SAND/Silty SAND high organic matter. Lignites. (Yellow and orange surface discolouration).

Light Grey pumiceous Silty SAND, well sorted (Yellow and orange surface discolouration).

Grey Clayey SILT, well sorted, normally graded, into Silty SAND (Yellow and orange surface discolouration).

Series of three normally graded events from Grey fine SAND to Yellowish Grey coarse poorly sorted SAND and GRAVEL with pumice clasts

Appendix 2 – GOST soundings

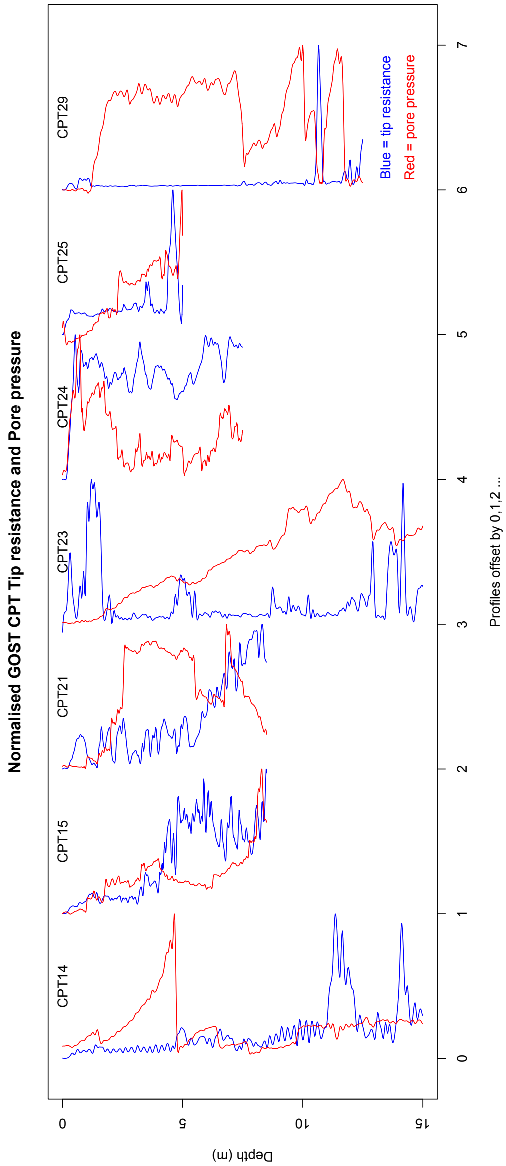
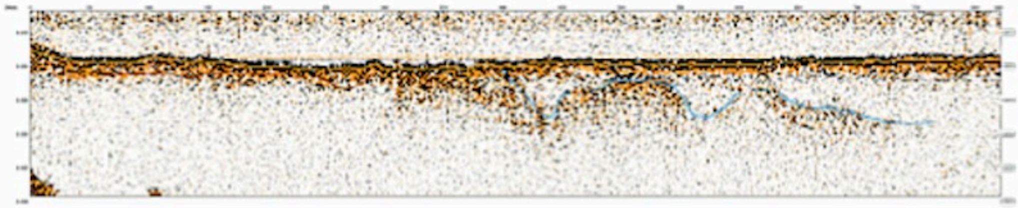


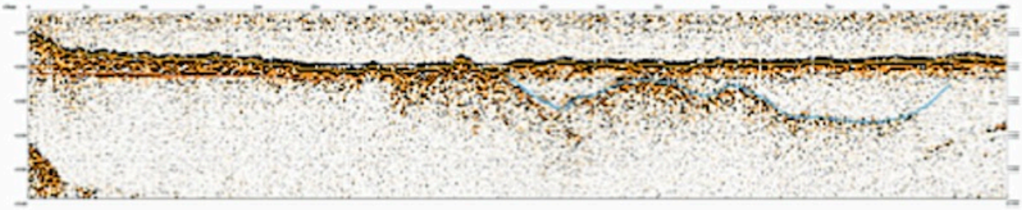
Figure A2.1. Summary of the GOST CPT tip resistance (blue) and pore water pressure (red) data obtained for Stella Passage. The data have been normalized to the maximum values for each of tip resistance and pore water pressure to highlight similar patterns (so all data vary between 0 and 1). For display purposes, each CPT data set is offset by one unit.

Appendix 3 – Seismic lines

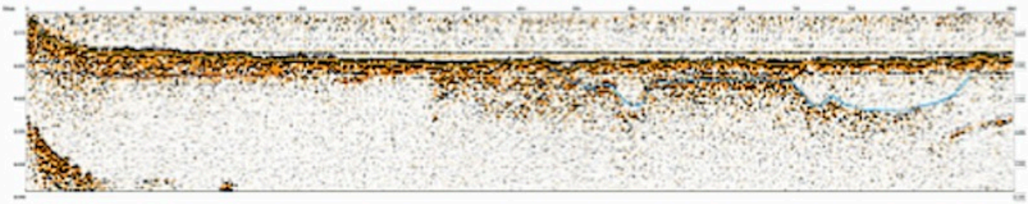
The following seismic profiles correspond to the Stella Passage lines 1-8 in Figure 2.



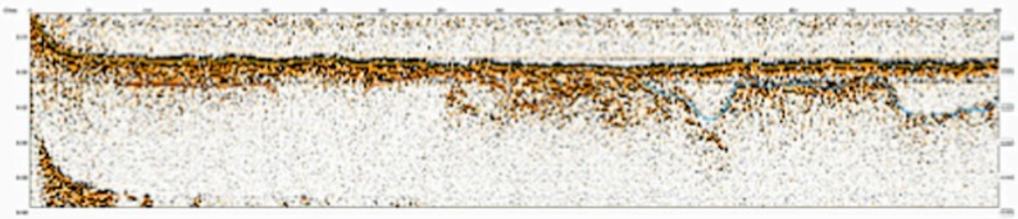
LINE 1



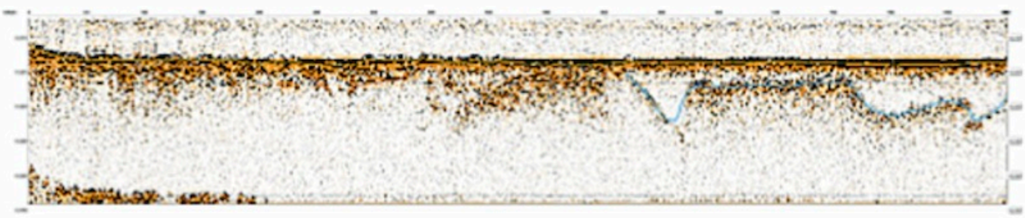
LINE 2



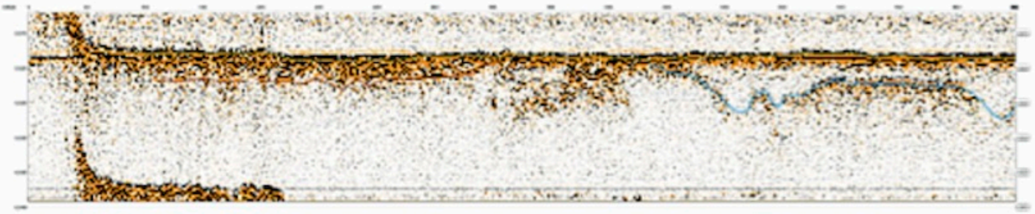
LINE 3



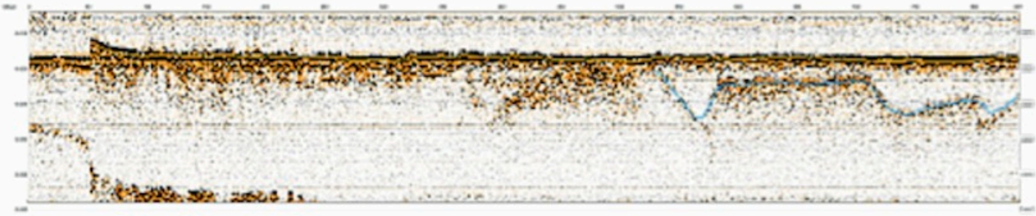
LINE 4



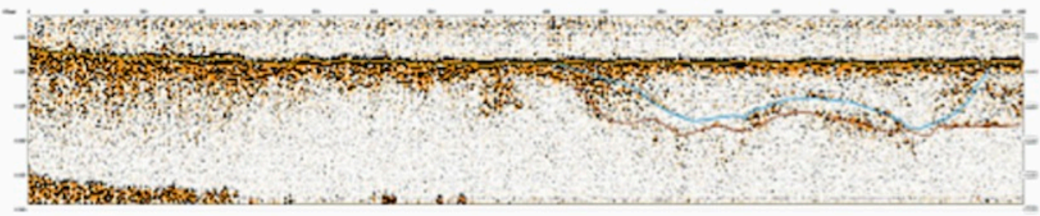
LINE 5



LINE 6



LINE 7



LINE 8