GBGMAPS

Advanced Subsurface Investigations

REPORT

GEOPHYSICAL INVESTIGATION TO DETERMINE ROCK PROFILE

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CONTENTS

1. INTRODUCTION

At the request of City of Stirling (The City), GBGMAPS Pty Ltd (GBGMAPS) carried out a geophysical subsurface investigation over a section of coastal dune system in May and June, 2018 as part of The City's Coastal Management Plan.

During the investigation 44 Seismic Refraction transects and 10 Multi-channel Analysis of Surface Waves (MASW) transects were acquired, processed and analysed. The objective of the investigation was to determine and model the interface between the underlying limestone rock and overlying sand strata. In particular the following was sort:

- The depth to competent limestone bedrock relative to the current mean sea level
- The density and thickness of the overlying sand cover

The results of the investigation will be used by The City to determine sections of the coastal dune system vulnerable to erosion and to enable the optimal alignment and indicative construction of permanent defensive measures along these vulnerable sections.

2. INVESTIGATION SITE

The investigation was carried out over an approximate 3.8km section of north-south trending coastal formation parallel to West Coast Drive between Beach Road, Watermans Bay to the intersection of West Coast Drive and West Coast Highway, Trigg Beach. The extent of the investigation site is shown as a series of aerial images in Appendix A.

Geophysical testing was carried out over a variety of surfaces. With the cross- shore transects occupying grassed areas, sand dunes, beach access paths and dune protection zones with low to moderate dense vegetation. The topography across these areas ranged from low lying flat areas to steeply dipping dune/rock formations. Along-shore transects were acquired along the shared path on the western verge of West Coast Drive, West Coast Drive itself and Trigg Beach carpark. All Transects were acquired with appropriate traffic management. Photographs of the typical surface conditions across the site are shown in Figure 1 overleaf.

Figure 1: Photographs showing the typical site conditions across the Geophysical Investigation to Determine Rock Profile along the coast from Trigg Beach north to Watermans Bay.

3. SUBSURFACE TEST METHODS

During the investigation two geophysical test methods were used so as to provide the required subsurface information within the anticipated geological conditions.

- **Multi-channel Analysis of Surface Waves (MASW)** – collected for the Along-Shore Transects to effectively obtain S-wave velocity models along West Coast Drive and it's adjacent shared pedestrian path.
- **Seismic Refraction** – collected for the Cross-Shore Transects within the narrow coastal dune formation to obtain P-wave velocity models.

Refer to Appendix H for more details on the geophysical methods used during the investigation including theory and application.

3.1 MULTI-CHANNEL ANALYSIS OF SURFACE WAVES (MASW)

MASW utilises seismic surface wave phase and frequency information to calculate shear wave (S-wave) velocities of the subsurface material. S-wave velocity is one of the elastic constants and closely related to Young's Modulus. Under most circumstances it is a direct indicator of the

ground strength (stiffness) and as such the method can be used to provide quantitative results on the compaction of the subsurface material.

MASW profiling was used to calculate variations in the compaction rates of the sand unit, and to map the depth to the sand/bedrock interface.

3.2 SEISMIC REFRACTION

Seismic refraction involves the measurement of travel times of seismic compressional waves (P-waves) that are generated at the surface, propagate through the subsurface and return to the surface after being refracted at the interface between layers of contrasting seismic velocity. The method is particularly suitable for mapping bedrock depth and being related to elastic strength and density, the P-wave velocities calculated from the method can be used as a measure of rock hardness.

Seismic refraction profiling was used along transects where surface conditions including moderate to thick vegetation and undulating surface topography precluded the use of MASW profiling. Note the output and interpretative capabilities of the seismic refraction method is similar to that of MASW with the generation of a P-wave velocity section rather than an S-wave velocity section.

4. DATA ACQUISITION

The geophysical site work was carried out in May and June 2018. Geophysical data acquisition was carried out by a two or three person crew from GBGMAPS consisting of qualified Geophysicists under suitable and approved traffic and pedestrian management.

During the investigation a total of 44 seismic refraction transects and 10 MASW transects were acquired. The extents and locations of the geophysical transects are shown in Drawing 70428-A1 to A6 in Appendix A. The following transects were collected:

NOTE: The data presented in the Drawings includes previously acquired data from similar geophysical investigations during May, 2017 and August, 2016.

Table 1: Acquired MASW Profiles

Line	Method	Start		End		Length
		Easting*	Northing*	Easting*	Northing*	
AST-1	MASW	44011.6	271412.9	43942.6	271710.1	308
AST-2	MASW	44039.5	271424.1	43992.0	271613.1	195
AST-3	MASW	44079.0	271432.7	43986.7	271800.9	380
AST-4	MASW	43914.9	271733.6	43898.1	271805.5	74
AST-5	MASW	43896.5	271811.4	43963.3	272352.2	557
AST-6	MASW	43962.5	272358.4	43939.7	272737.9	388
AST-7	MASW	43919.1	273454.0	43908.0	273760.1	322
AST-8	MASW	43892.5	274036.5	43914.9	274468.6	436
AST-9	MASW	43863.0	274873.0	43866.0	275155.3	285
AST-10	MASW	43881.4	274895.2	43878.2	275162.5	269

Table 2: Acquired Seismic Refraction Profiles

Line	Method	Start		End		Length
		Easting*	Northing*	Easting*	Northing*	
CST-01	Seismic Refraction	43938.6	271411.8	44007.2	271412.0	69
CST-02	Seismic Refraction	43921.6	271479.4	43990.4	271479.4	69
CST-03	Seismic Refraction	43902.4	271561.8	43970.4	271549.9	69
CST-04	Seismic Refraction	43892.9	271624.9	43961.3	271618.3	69
CST-05	Seismic Refraction	43886.6	271653.7	43954.6	271660.5	69
CST-06	Seismic Refraction	44017.5	271666.9	43985.6	271661.2	33
CST-07	Seismic Refraction	43943.1	271704.8	43879.2	271685.6	69
CST-08	Seismic Refraction	43858.8	271770.8	43903.9	271769.9	46
CST-09	Seismic Refraction	43851.3	271791.7	43895.1	271801.8	46
CST-10	Seismic Refraction	43898.3	271844.8	43962.7	271841.0	No Data
CST-11	Seismic Refraction	43820.2	271854.4	43888.5	271859.5	69
CST-12	Seismic Refraction	43811.7	271899.7	43856.1	271900.3	46
CST-13	Seismic Refraction	43894.3	271899.1	43938.9	271899.6	45
CST-14	Seismic Refraction	43898.1	272010.5	43966.7	272006.1	69
CST-15	Seismic Refraction	43911.6	272084.1	43969.5	272073.4	60

Table 2 (cont.): Acquired Seismic Refraction profiles

Line	Method	Start		End		Length
		Easting*	Northing*	Easting*	Northing*	
CST-16	Seismic Refraction	43917.7	272152.0	43957.8	272129.5	46
CST-17	Seismic Refraction	43905.2	272224.8	43937.6	272213.1	36
CST-18	Seismic Refraction	43913.9	272254.2	43945.2	272247.5	34
CST-19	Seismic Refraction	43906.8	272279.5	43952.1	272279.5	46
CST-20	Seismic Refraction	43930.7	272337.2	43961.3	272331.6	32
CST-21	Seismic Refraction	43924.4	272356.3	43958.9	272371.3	40
CST-22	Seismic Refraction	43928.6	272382.2	43955.2	272386.8	28
CST-23	Seismic Refraction	43912.4	272428.7	43949.4	272409.2	42
CST-24	Seismic Refraction	43887.7	272487.1	43925.4	272511.3	46
CST-25	Seismic Refraction	43900.8	272524.7	43921.9	272529.8	24
CST-26	Seismic Refraction	43901.9	272549.9	43917.2	272553.5	18
CST-27	Seismic Refraction	43900.1	272603.5	43912.4	272603.9	14
CST-28	Seismic Refraction	43908.7	272654.4	43921.7	272655.2	14
CST-29	Seismic Refraction	43919.5	272700.4	43930.0	272693.0	14
CST-30	Seismic Refraction	43910.1	273525.5	43942.8	273528.2	34
CST-31	Seismic Refraction	43908.3	273554.6	43948.8	273556.3	42
CST-32	Seismic Refraction	43901.3	273593.9	43944.8	273602.9	46
CST-33	Seismic Refraction	43896.8	273634.6	43941.3	273641.8	46
CST-34	Seismic Refraction	43892.5	273683.2	43931.6	273696.4	44
CST-35	Seismic Refraction	43886.6	273759.2	43906.3	273755.2	22
CST-36	Seismic Refraction	43855.2	274106.9	43893.7	274096.0	42
CST-37	Seismic Refraction	43875.5	274147.8	43910.6	274140.9	38
CST-38	Seismic Refraction	43871.9	274199.1	43913.6	274194.8	44
CST-39	Seismic Refraction	43870.4	274225.1	43913.5	274214.5	46
CST-40	Seismic Refraction	43861.1	274259.6	43913.7	274275.2	57
CST-41	Seismic Refraction	43869.3	274299.6	43913.3	274300.3	46
CST-42	Seismic Refraction	43856.6	274354.6	43914.0	274355.8	No Data
CST-43	Seismic Refraction	43851.0	274384.1	43914.1	274405.1	No Data
CST-44	Seismic Refraction	43843.3	274469.2	43912.4	274470.4	69

* Perth Coastal Grid 1994 (PCG94)

4.1 MULTI-CHANNEL ANALYSIS OF SURFACE WAVES

MASW data was acquired using 24, 4.5Hz vibration sensors (geophones) connected via a seismic cable to a Seismograph. The geophone array was attached to a land streamer consisting of a Kevlar reinforced tape and metal base plates which the geophones were fixed to at 1m centres resulting in a total array length of 23m.

Seismic energy was generated using a vehicle mounted accelerated weight drop impacting a steel plate placed on the ground surface. Zero-time of the impact was recorded using a trigger sensor attached to the hammer and connected to the seismograph via a cable. The seismic response was recorded by the seismograph with a time window of 2s at a 0.5ms sample interval.

MASW data acquisition involved laying out the geophone array in a straight line with its centre at the required sounding location. Seismic data was recorded with a source point located 6m before the first geophone, with multiple source impacts being stacked in order to enhance the seismic signal and suppress noise. Data was recorded during dulls in background noise such as in the absence of vehicles and pedestrians to further reduce the effects of background noise on the data. The geophone array was then towed by a 4WD Vehicle 4-6m along the profile with the process repeated until the end of the profile was reached.

Figure 2: MASW data acquisition along the shared path on the western verge of West Coast Drive.

4.2 SEISMIC REFRACTION

Seismic Refraction data was acquired using 24, 14Hz vibration sensors (geophones) connected via two seismic cables to an Ambrogeo Seismograph. The geophones were placed into the ground surface using spikes at 2-3m intervals resulting in a maximum possible array length of 46-69m. Transect lengths were less than this on the cross-shore transects due to the limited distance between the beach foreshore and shared path.

Seismic energy was generated using a 5.8kg sledge hammer impacting a 12mm steel plate placed on the ground surface. Zero-time of hammer impact was recorded using a trigger sensor attached to the hammer and connected to the seismograph via a cable. The seismic response was recorded by the seismograph with a time window of 150ms at a 62.5µs sample interval.

Seismic refraction data acquisition involved laying out the geophone array in a straight line along the required transects. Seismic data was recorded at a number of source points both internally within the array and at offset points outside the array. At each source point multiple hammer impacts were stacked in order to enhance the refracted wave signal and suppress noise.

Figure 3: Seismic refraction data acquisition along the cross-shore dune transects

4.3 LOCATION AND POSITIONING

Spatial positioning was achieved via RTK GPS acquired simultaneously with the data acquisition providing <50mm accuracy vertically and horizontally.

All positions are given in Perth Coastal Grid 1994 (PCG94), whilst elevations are given in Australian Height Datum (AHD).

5. GEOPHYSICAL DATA PROCESSING

The collected geophysical datasets were processed and analysed with current industry standard software by qualified geophysicists using GBGMAPS standard processing routines.

5.1 MULTI-CHANNEL ANALYSIS OF SURFACE WAVES

The MASW data was processed using SurfSeis version 4 (Kansas Geological Survey, 2014). Overtone images giving the percentage intensity of phase velocity versus frequency were generated for each collected seismic record. The maximum intensity across the useful range of frequencies was picked for each record resulting in a dispersion curve. The dispersion curves were then run through a 10 layer inversion algorithm to produce an S-wave velocity sounding, showing the variation in modelled S-wave velocity with depth.

The generated S-wave velocity soundings were compiled and gridded using Surfer version 13 (Golden Software, 2016) to produce 2D S-wave velocity sections along the transects. The sections show variations in the modelled S-wave velocity as per the colour contour scale laterally along the transects and with elevation.

Geological cross-sections giving the interpreted subsurface layering based on contrasts in the S-wave velocity sections were produced. These were correlated with the assumed/known local subsurface conditions at the site, and with consideration of standard seismic velocity values for various materials.

5.2 SEISMIC REFRACTION

The seismic refraction data was processed using Rayfract version 3.33 (Intelligent Resources Incorporated, 2015). The first arrival travel-times for each seismic record were picked and imported into Rayfract. A smooth minimum-structure 1D initial model was then generated directly from the seismic refraction first break picks using the horizontally averaging Delta-t-V (improved Wiechert-Herglotz) method. The initial model was then refined with true 2D Wavepath Eikonal Traveltime (WET) tomogram with the inversion algorithm run for a number of iterations until adequate convergence between the initial model and inverted data occurred.

The final P-wave velocity sections generated from the Rayfract inversion were compiled and gridded in Surfer version 13. The sections shows variations in the modelled P-wave velocity as per the colour contour scale laterally along the transects and with elevation.

Geological cross-sections giving the interpreted subsurface layering based on contrasts in the P-wave velocity sections were produced. These were correlated with the assumed/known local subsurface conditions at the site, and with consideration of standard seismic velocity values for various materials.

5.3 SEISMIC WAVE PROPAGATION

The seismic wave types measured with the geophysical methods during this investigation are elastic body waves, the velocities of which provide useful information on the subsurface material through which they propagate. In particular the velocity of the following wave types were measured:

- Compressional waves (P-waves) as measured by seismic refraction where particle motion is in the direction of propagation.
- Shear waves (S-waves) as measured by MASW where particle motion is perpendicular to the direction of propagation.

Seismic S-wave and P-wave velocities are governed by the elastic properties of the medium they propagate through including bulk modulus, shear modulus and density as shown in the equations

below. As such calculated seismic velocities provide a useful guide to the subsurface material condition with increasing velocity an indication of increasing material hardness and stiffness.

Seismic P-wave velocity $$V_p = \sqrt{\frac{K+\frac{4}{3}G}{\rho}}$$

Seismic S-wave velocity $$V_s = \sqrt{\frac{G}{\rho}}$$

where;

K = Bulk modulus

G = Shear modulus

ρ = In-situ material density

6. RESULTS AND INTERPRETATION

6.1 PRESENTATION OF RESULTS

The results of the geophyiscal investigation to determine rock profile are provided in Appendices A to G of this report as follows:

Appendix A – Base Maps

- **70428-A01** Base map showing acquired geophysical transects (Northing 271390 to 272050)
- **70428-A02** Base map showing acquired geophysical transects (Northing 272035 to 272695)
- **70428-A03** Base map showing acquired geophysical transects (Northing 272680 to 273340)
- **70428-A04** Base map showing acquired geophysical transects (Northing 273410 to 274070)
- **70428-A05** Base map showing acquired geophysical transects (Northing 274020 to 274680)
- **70428-A06** Base map showing acquired geophysical transects (Northing 274630 to 275290)

Appendix B – Geophysical and Interpreted Cross-Shore Sections (Seismic Refraction)

- **70428-B01** – Cross-shore Transects 1 and 2
- **70428-B02** – Cross-shore Transects 3 and 4
- **70428-B03** – Cross-shore Transects 5 and 6

- **70428-B04** – Cross-shore Transects 7 and 8
- **70428-B05** – Cross-shore Transects 9 and 10
- **70428-B06** – Cross-shore Transects 11 and 12
- **70428-B07** – Cross-shore Transects 13 and 14
- **70428-B08** – Cross-shore Transects 15 and 16
- **70428-B09** – Cross-shore Transects 17 and 18
- **70428-B10** – Cross-shore Transects 19 and 20
- **70428-B11** – Cross-shore Transects 21 and 22
- **70428-B12** – Cross-shore Transects 23 and 24
- **70428-B13** – Cross-shore Transects 25 and 26
- **70428-B14** – Cross-shore Transects 27 and 28
- **70428-B15** – Cross-shore Transects 29 and 30
- **70428-B16** – Cross-shore Transects 31 and 32
- **70428-B17** – Cross-shore Transects 33 and 34
- **70428-B18** – Cross-shore Transects 35 and 36
- **70428-B19** – Cross-shore Transects 37 and 38
- **70428-B20** – Cross-shore Transects 39 and 40
- **70428-B21** – Cross-shore Transects 41 and 42
- **70428-B22** – Cross-shore Transects 43 and 44

Appendix C – Geophysical and Interpreted Along-Shore Sections (MASW)

- **70428-C01** – Along-shore Transect 1
- **70428-C02** – Along-shore Transect 2
- **70428-C03** – Along-shore Transect 3
- **70428-C04** – Along-shore Transect 4
- **70428-C05** – Along-shore Transect 5
- **70428-C06** – Along-shore Transect 5ctn
- **70428-C07** – Along-shore Transect 6
- **70428-C08** – Along-shore Transect 7
- **70428-C09** – Along-shore Transect 8
- **70428-C10** – Along-shore Transect 9
- **70428-C11** – Along-shore Transect 10

Appendix D – Modelled Bedrock Level Classed Post Maps

- **70428-D01** Bedrock Level Classed Post Map (Northing 271390 to 272050)
- **70428-D02** Bedrock Level Classed Post Map (Northing 272035 to 272695)
- **70428-D03** Bedrock Level Classed Post Map (Northing 272680 to 273340)
- **70428-D04** Bedrock Level Classed Post Map (Northing 273410 to 274070)
- **70428-D05** Bedrock Level Classed Post Map (Northing 274020 to 274680)
- **70428-D06** Bedrock Level Classed Post Map (Northing 274630 to 275290)

Appendix E – Modelled Bedrock Level Colour Contours

- **70428-E01** Bedrock Level Colour Contours (Northing 271390 to 272050)
- **70428-E02** Bedrock Level Colour Contours (Northing 272035 to 272695)
- **70428-E03** Bedrock Level Colour Contours (Northing 272680 to 273340)
- **70428-E04** Bedrock Level Colour Contours (Northing 273410 to 274070)
- **70428-E05** Bedrock Level Colour Contours (Northing 274020 to 274680)
- **70428-E06** Bedrock Level Colour Contours (Northing 274630 to 275290)

Appendix F – Modelled Sand Thickness Contours

- **70428-F01** Sand Thickness Contours (Northing 271390 to 272050)
- **70428-F02** Sand Thickness Contours (Northing 272035 to 272695)
- **70428-F03** Sand Thickness Contours (Northing 272680 to 273340)
- **70428-F04** Sand Thickness Contours (Northing 273410 to 274070)
- **70428-F05** Sand Thickness Contours (Northing 274020 to 274680)
- **70428-F06** Sand Thickness Contours (Northing 274630 to 275290)

Appendix G – Modelled Bedrock Level Line Contours

- **70428-G01** Bedrock Level Line Contours (Northing 271390 to 272050)
- **70428-G02** Bedrock Level Line Contours (Northing 272035 to 272695)
- **70428-G03** Bedrock Level Line Contours (Northing 272680 to 273340)
- **70428-G04** Bedrock Level Line Contours (Northing 273410 to 274070)
- **70428-G05** Bedrock Level Line Contours (Northing 274020 to 274680)
- **70428-G06** Bedrock Level Line Contours (Northing 274630 to 275290)

6.2 GEOPHYSICAL AND INTERPRETED CROSS SECTIONS

The results of the geophysical transects are presented in 33 Drawings in Appendix B and C.

At the top of each drawing is the seismic P-wave velocity and seismic S-wave velocity section generated from the Seismic Refraction and MASW data respectively. The images show the variations in the seismic wave velocity as a colour contour plot as per the colour scale from blue, green, yellow, orange, red then brown. The subsurface velocity ranges are from 200m/s to 2400m/s for P-wave velocity and from 150m/s to 600m/s for S-wave velocity.

Below the seismic velocity section is a geological section giving the interpreted layering of the subsurface based on detectable seismic velocity contrasts. The calculated seismic velocity values have been classed into four categories representing different subsurface conditions:

1. **Very low seismic wave velocity** (Vs <275m/s, Vp <500m/s). Regions with very low seismic wave velocity are interpreted as sand of low compaction.

2. **Low seismic wave velocity** (Vs 275-350m/s, Vp 500-800m/s). Regions with low seismic wave velocity are interpreted as moderately compacted sand.

3. **Moderate seismic wave velocity** (Vs 350-400m/s, Vp 800-1000m/s). Regions with moderate seismic wave velocity are interpreted as limestone of low to moderate rock strength. It is postulated that this class represents a weathered limestone and transitional zone to stronger, less weathered limestone below.

4. **Moderate to high seismic wave velocity** (Vs >400m/s, Vp >1000m/s). Regions with moderate to high seismic wave velocity are interpreted as moderate to strong limestone of moderate rock strength. It is postulated that this class represents unweathered or slightly weathered limestone.

A reduced level of 0.0mAHD has been considered to be the Mean Sea Level (MSL) for the purpose of this investigation. It should however be pointed out that since AHD represents an average MSL inferred from metropolitan and regional areas, this relationship may not be accurate for this site. Furthermore the relationship 0.0mAHD = MSL represents an average calculated from a Geoscience Australia survey from 1971 (http://www.ga.gov.au/scientific-topics/positioning-navigation/geodesy/ geodetic-datums/australian-height-datum-ahd). As such the relationship between 0.0mAHD and MSL should be used with caution.

6.3 MODELLED LEVEL TO TOP OF ROCK

The Digital Terrain Model (DTM) of the underlying rock profile within the investigation area presented in Appendicies D, E and G. These have been generated by digitising the interface between the natural sand dune strata and the underlying rock profile as modelled from the 44 cross-shore and 10 along-shore transects. The resulting x = Easting, y = Northing, and z = mAHD

values for the top of rock over the entire investigation area was then gridded using a krigging algorithm in Surfer version 13.

The generated DTM of top of rock has been presented in four ways:

- **Appendix D** – as a classed post map giving the top of rock as five classes from less than -2.5mAHD to greater than 10.0mAHD at 2.5m increments.
- **Appendix E** – as a colour contour map ranging from -6mAHD to 18mAHD with contour intervals at 0.5m increments.
- **Appendix F** – colour contour map showing the modelled sand thickness overlying rock ranging from 0m to greater than 13m with contour intervals at 0.5m increments.
- **Appendix G** – as a line contour map ranging from -6mAHD to 18mAHD with major contours at 1.0m increments and minor contours at 0.2m increments. With a blue and black contour line indicating top of rock at 0mAHD and 4mAHD respectively.

The following limitations should be considered when using the DTM of top of rock:

The level to the top of rock has been calculated using un-calibrated geophysical data. At the time of this report no intrusive testing such as test pits or cone penetrometer tests has been carried out at the site. Self calibration was carried out by comparing the modelled levels at the intersection points of the seismic refraction and MASW transects. It is anticipated that quoted levels may vary by as much as +/- 20% without physical calibration using invasive testing.

The generated contours will give the general trend of the top of rock profile however will not image local variations when the extent of these are less then transect spacing. Spatially small features such as karst sinkholes or pinnacle features may not be imaged. The significance of this limitation in regards to generating the top or rock model is considered minor for this investigation. Although local geological features such as pinnacles may not be represented in the data, the generated surface of the top of rock will show the broad trends in the geology over the site which is suitable for engineering design purposes.

Transition zones including between fresh and weathered rock and between sediment and lithified/partially lithified sediment may be gradational and as such the interface between these layers are not well defined.

The calculated levels to the top of rock will only be valid along the geophysical transects. Values shown on the contour maps not on the transects have been interpolated using the krigging algorithm and as such the accuracy of these levels is indeterminable. The contour surface will give the general trend of the interface however may not image local variations, it is recommended that the cross sections presented in the Drawings of both Appendix B and C be used to obtain accurate top of rock levels.

7. CONCLUSIONS AND RECOMMENDATIONS

A geophysical investigation has been carried out by GBGMAPS along an approximate 3.8km section of north-south trending coastal formation parallel to West Coast Drive between Beach Road, Watermans Bay to the intersection of West Coast Drive and West Coast Highway, Trigg Beach Western Australia.

The investigation forms part of The City of Stirling's broader Remainder of Rocky Coastline: Geophysical Investigation to Determine Rock Profile. The section of coastline investigated has been determined by The City through the CHRMAP as being vulnerable to erosion and posing an imminent threat to coastal infrastructure, in particular to West Coast Drive.

The objective of the geophysical investigation was to provide information on the subsurface material across the investigation site in particular to determine and model the interface between the underlying limestone rock and overlying sand strata. The results of the investigation will be used by The City to determine sections of the coastal dune system vulnerable to erosion and to enable the optimal alignment and indicative construction of permanent defensive measures along these vulnerable sections.

As part of the investigation scope, Seismic Refraction and Multi-channel Analysis of Surface Waves (MASW) datasets were collected along a series of transects within the investigation area. The datasets were processed and analysed to provide colour cross sections showing variations in the seismic wave velocity of the subsurface material. The seismic velocity sections were demarcated into velocity ranges representing different subsurface conditions to generate geological sections showing the modelled depth to top of rock relative to Mean Sea Level. Data collected in close proximity to previous investigations were merged with the associated previously drawn sections.

The top of rock level as modelled along the collected transects were digitised and gridded in order to generate a Digital Terrain Model (DTM) of the underlying rock profile within the investigation area. The DTM has been presented in a number of drawings as classed post maps, colour contours and line contours with a number of limitations being applicable.

It must be stressed that the results of the investigation including the generated DTM of the underlying rock profile has been generated using an un-calibrated geophysical dataset and as such a reduction in accuracy is expected. In order to improve the accuracy and confidence of the DTM it is recommended that intrusive testing be carried out at a number of locations along the geophysical transects. The results of the intrusive testing can be used to update the generated interpreted geological cross sections with a subsequent increase in accuracy and confidence of the resulting DTM of the underlying rock profile.

The methods used during the investigation are geophysical and as such the results are based on indirect measurements and the processing and interpretation of seismic wave signals. The findings in this report represent the best professional opinions of the authors, based on

experience gained during previous similar investigations and with correlation to known and assumed subsurface ground conditions at the site.

We trust that this report and the attached drawings provide you with the information required. If you require clarification on any points arising from this geophysical investigation, please do not hesitate to contact the undersigned on (08) 6436 1599.

For and on behalf of
GBGMAPS PTY LTD

TAVIS LAVELL

Geophysicist

APPENDIX A.
BASE MAPS

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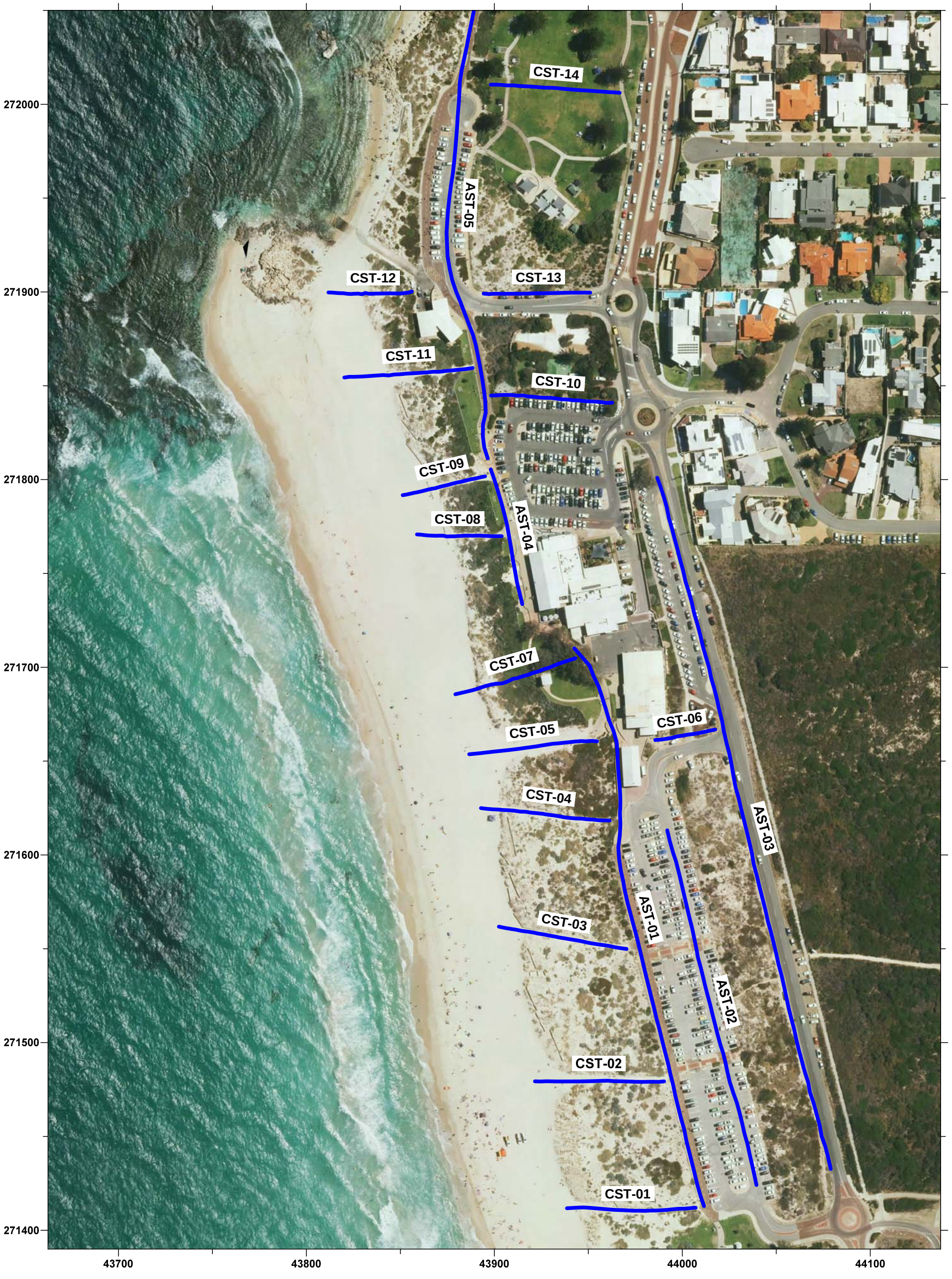
GEOPHYSICAL SUBSURFACE INVESTIGATION TO MAP ROCK PROFILE ALONG COASTLINE

ACQUIRED SEISMIC TRANSECTS (SHEET 1)



N

0 25 50 75 100
Metres

NOTES

Drawing to be used in conjunction with Report 70428.
Aerial image from Landgate January 2018.
Map Projection: Perth Coastal Grid 1994 (PCG94)
Elevation: Australian Height Datum (mAHD).

LEGEND

	Acquired seismic profiles May - June, 2018.
	Acquired seismic profiles 2017.
CST-01	Cross-Shore Transect - with seismic profile number.
AST-01	Along-Shore Transect - with seismic profile number.

Date	28 June 2018	Paper Size	A3
Scale	1:2000	Drawn	AHWS
Drawing	70428-A01	Revision	0

CLIENT **CITY OF STIRLING**

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GEOPHYSICAL SUBSURFACE INVESTIGATION TO MAP ROCK PROFILE ALONG COASTLINE

ACQUIRED SEISMIC TRANSECTS (SHEET 2)

N

0 25 50 75 100
Metres

NOTES

Drawing to be used in conjunction with Report 70428.
Aerial image from Landgate January 2018.
Map Projection: Perth Coastal Grid 1994 (PCG94)
Elevation: Australian Height Datum (mAHD).

LEGEND

	Acquired seismic profiles May - June, 2018.
	Acquired seismic profiles 2017.
CST-01	Cross-Shore Transect - with seismic profile number.
AST-01	Along-Shore Transect - with seismic profile number.

Date	28 June 2018	Paper Size	A3
Scale	1:2000	Drawn	AHWS
Drawing	70428-A02	Revision	0

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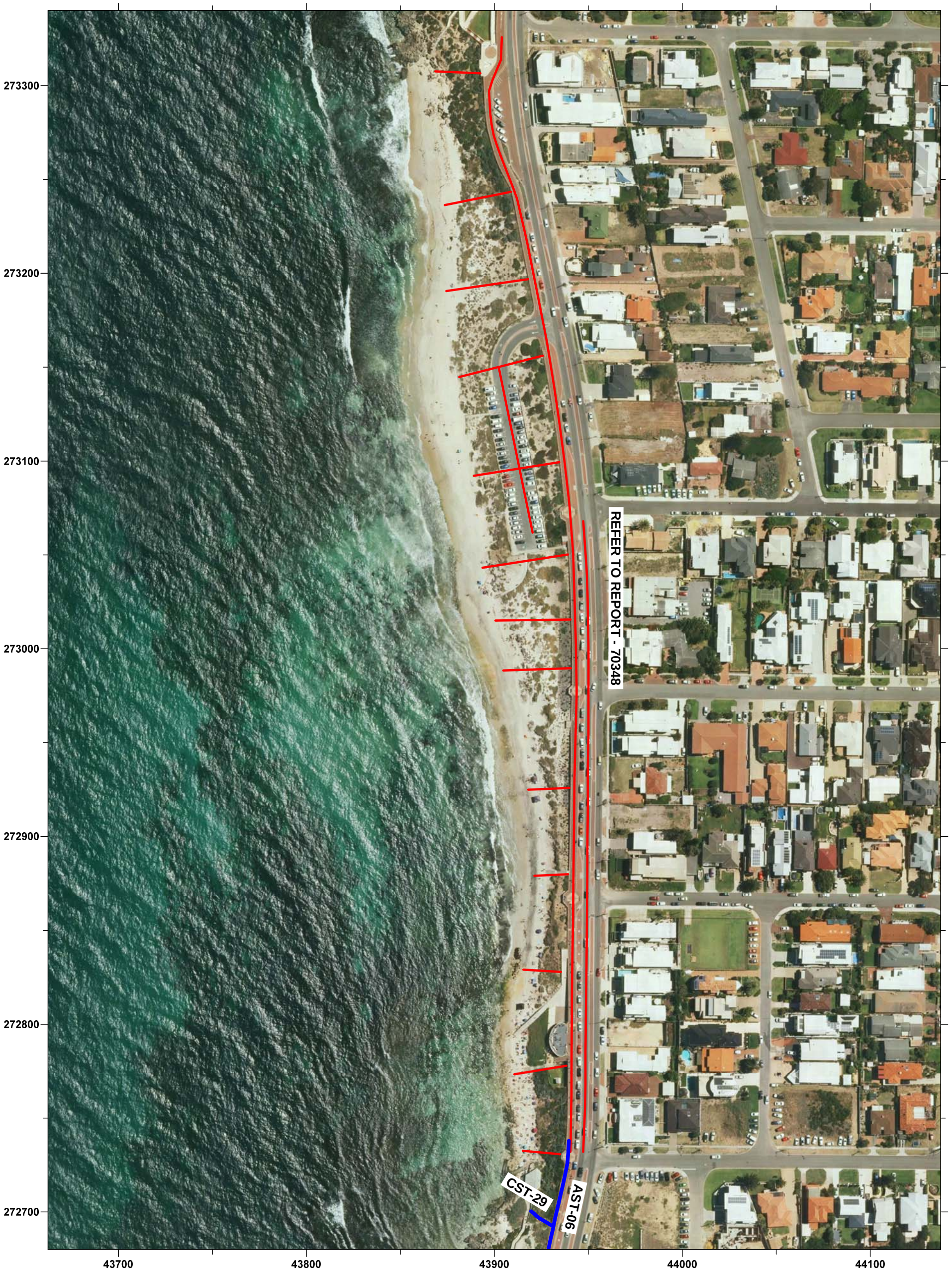
GEOPHYSICAL SUBSURFACE INVESTIGATION TO MAP ROCK PROFILE ALONG COASTLINE

ACQUIRED SEISMIC TRANSECTS (SHEET 3)



N

0 25 50 75 100
Metres

NOTES

Drawing to be used in conjunction with Report 70428.
Aerial image from Landgate January 2018.
Map Projection: Perth Coastal Grid 1994 (PCG94)
Elevation: Australian Height Datum (mAHD).

LEGEND

	Acquired seismic profiles May - June, 2018.
	Acquired seismic profiles 2017.
CST-01	Cross-Shore Transect - with seismic profile number.
AST-01	Along-Shore Transect - with seismic profile number.

Date	28 June 2018	Paper Size	A3
Scale	1:2000	Drawn	AHWS
Drawing	70428-A03	Revision	0

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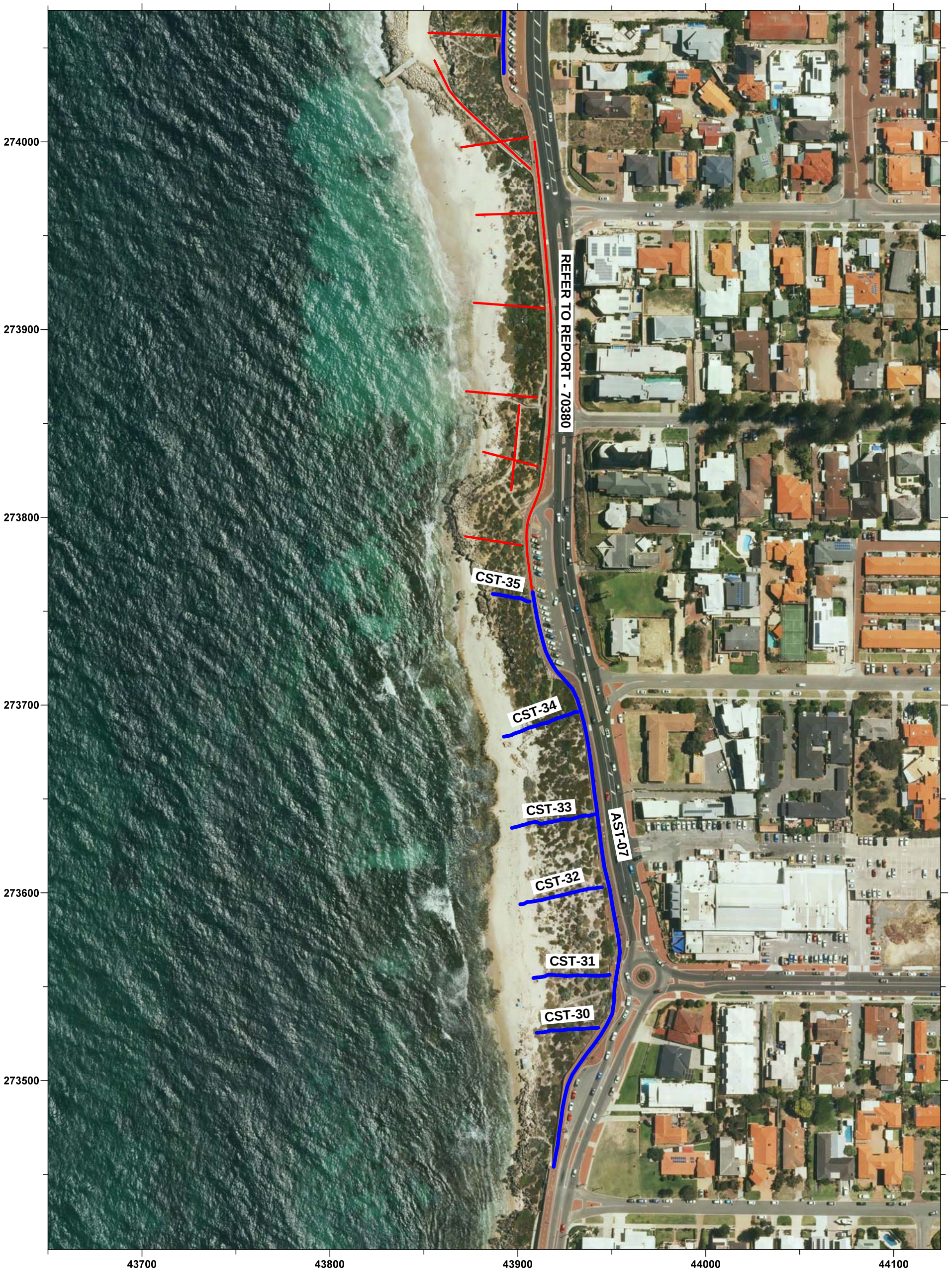
ACQUIRED SEISMIC TRANSECTS (SHEET 4)



N

0 25 50 75 100
Metres

NOTES

Drawing to be used in conjunction with Report 70428.
Aerial image from Landgate January 2018.
Map Projection: Perth Coastal Grid 1994 (PCG94)
Elevation: Australian Height Datum (mAHD).

LEGEND

	Acquired seismic profiles May - June, 2018.
	Acquired seismic profiles 2017.
CST-01	Cross-Shore Transect - with seismic profile number.
AST-01	Along-Shore Transect - with seismic profile number.

Date	28 June 2018	Paper Size	A3
Scale	1:2000	Drawn	AHWS
Drawing	70428-A04	Revision	0

CLIENT: **CITY OF STIRLING**

GEOPHYSICAL SUBSURFACE INVESTIGATION TO DETERMINE ROCK PROFILE ALONG COASTLINE

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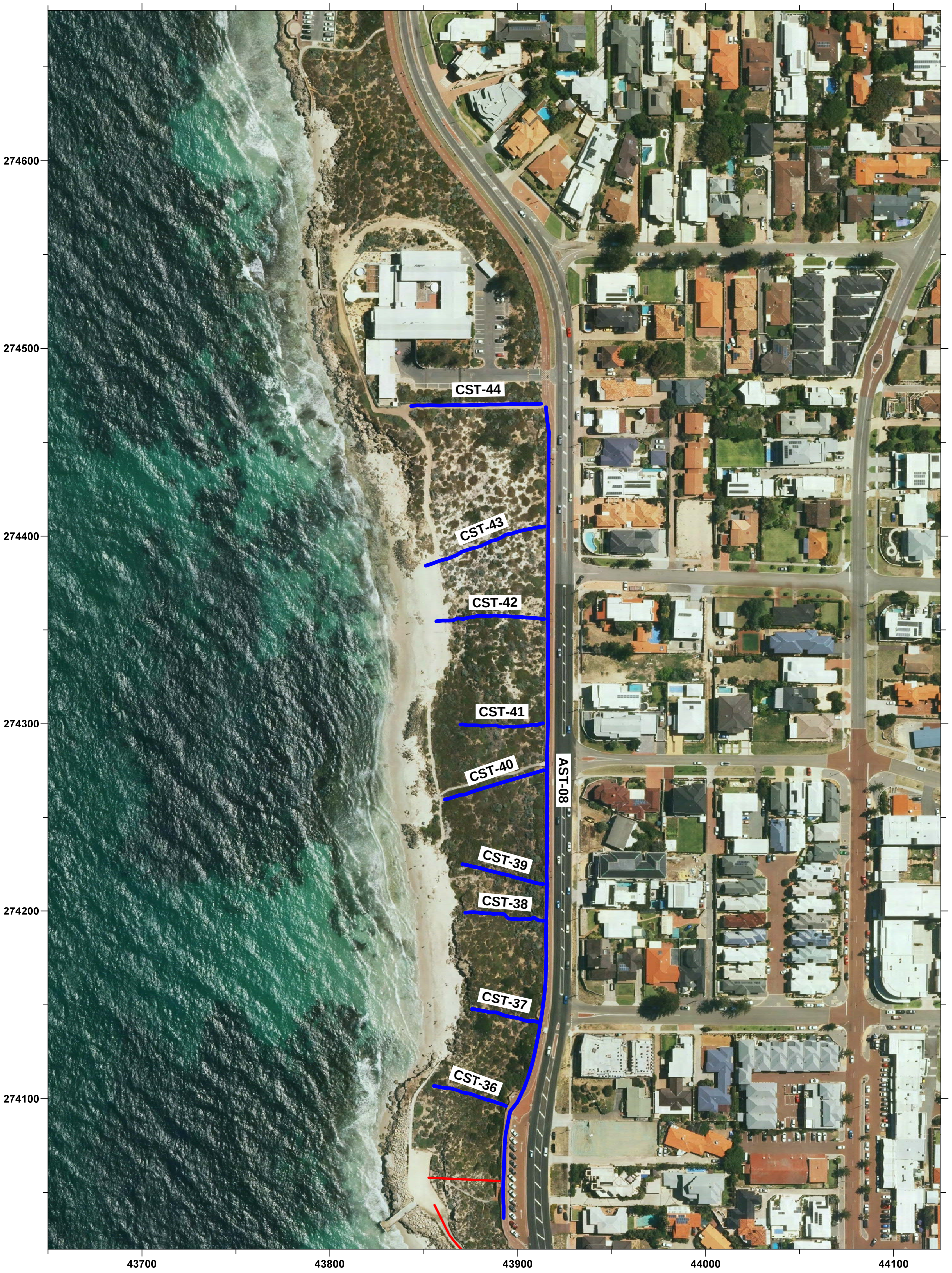
ACQUIRED SEISMIC TRANSECTS (SHEET 5)



N

0 25 50 75 100
Metres

NOTES

Drawing to be used in conjunction with Report 70428.
Aerial image from Landgate January 2018.
Map Projection: Perth Coastal Grid 1994 (PCG94)
Elevation: Australian Height Datum (mAHD).

LEGEND

	Acquired seismic profiles May - June, 2018.
	Acquired seismic profiles 2017.
CST-01	Cross-Shore Transect - with seismic profile number.
AST-01	Along-Shore Transect - with seismic profile number.

Date	28 June 2018	Paper Size	A3
Scale	1:2000	Drawn	AHWS
Drawing	70428-A05	Revision	0

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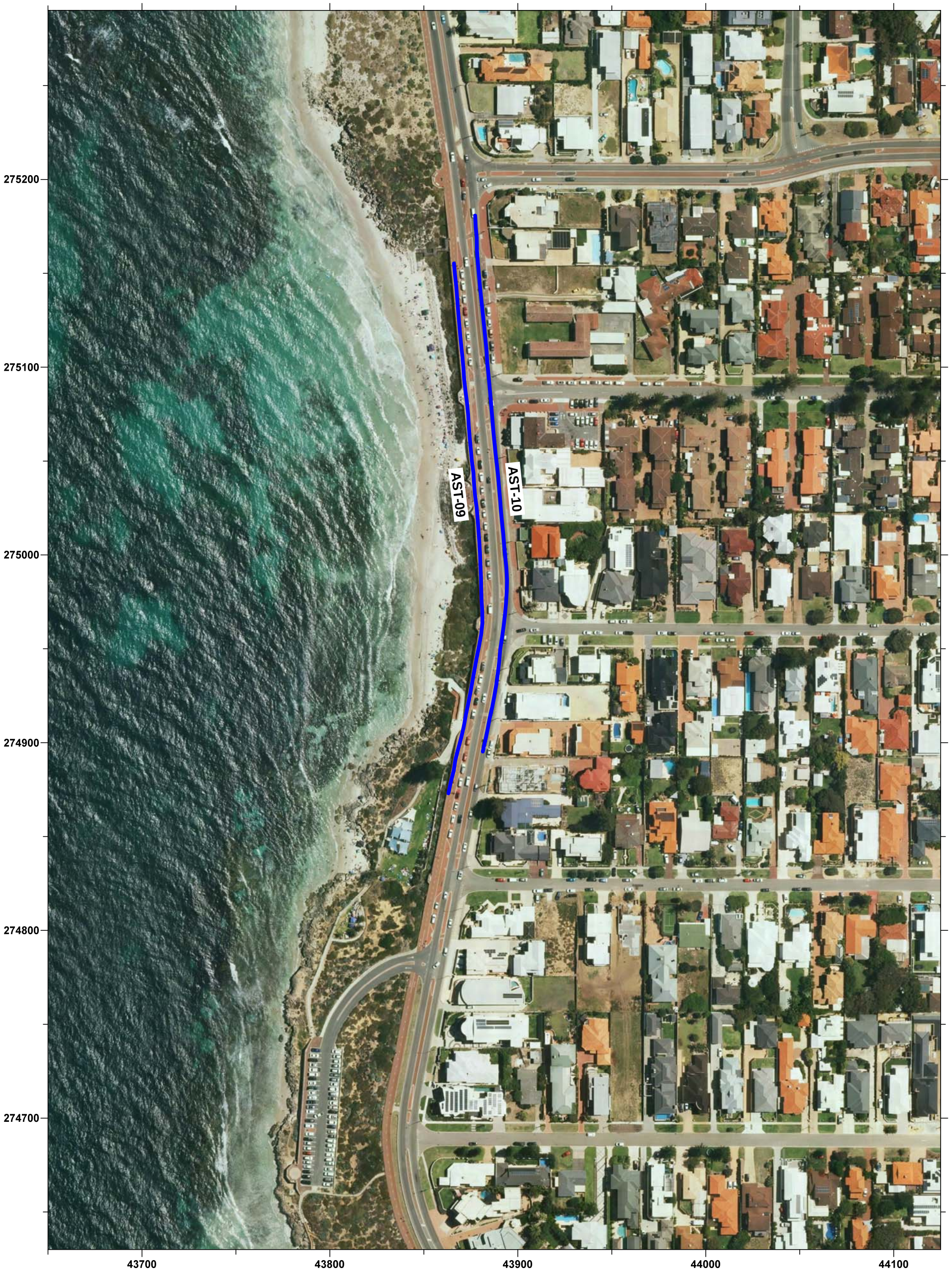
ACQUIRED SEISMIC TRANSECTS (SHEET 6)



N

0 25 50 75 100
Metres

NOTES

Drawing to be used in conjunction with Report 70428.
Aerial image from Landgate January 2018.
Map Projection: Perth Coastal Grid 1994 (PCG94)
Elevation: Australian Height Datum (mAHD).

LEGEND

	Acquired seismic profiles May - June, 2018.
	Acquired seismic profiles 2017.
CST-01	Cross-Shore Transect - with seismic profile number.
AST-01	Along-Shore Transect - with seismic profile number.

Date	28 June 2018	Paper Size	A3
Scale	1:2000	Drawn	AHWS
Drawing	70428-A06	Revision	0

CLIENT: **CITY OF STIRLING**

GEOPHYSICAL SUBSURFACE INVESTIGATION TO DETERMINE ROCK PROFILE ALONG COASTLINE

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APPENDIX B.
GEOPHYSICAL AND INTERPRETED CROSS-SHORE SECTIONS (SEISMIC REFRACTION)

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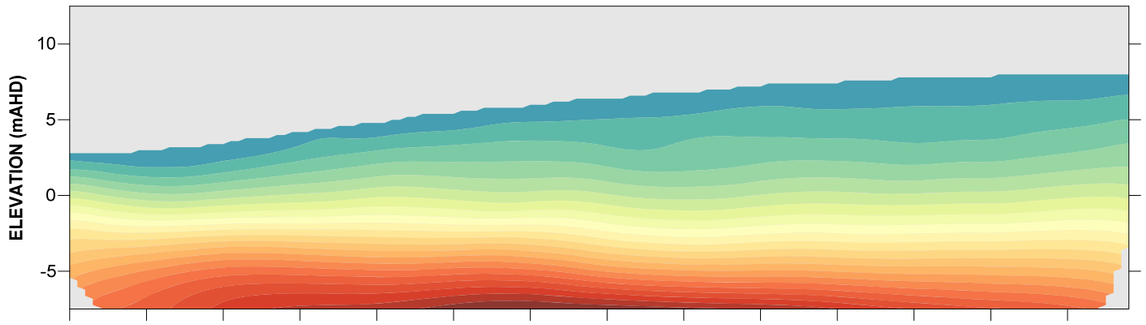
COASTAL MANAGEMENT PLAN - GEOPHYSICAL INVESTIGATION TO DETERMINE ROCK PROFILE

CROSS-SHORE TRANSECT 1 AND 2

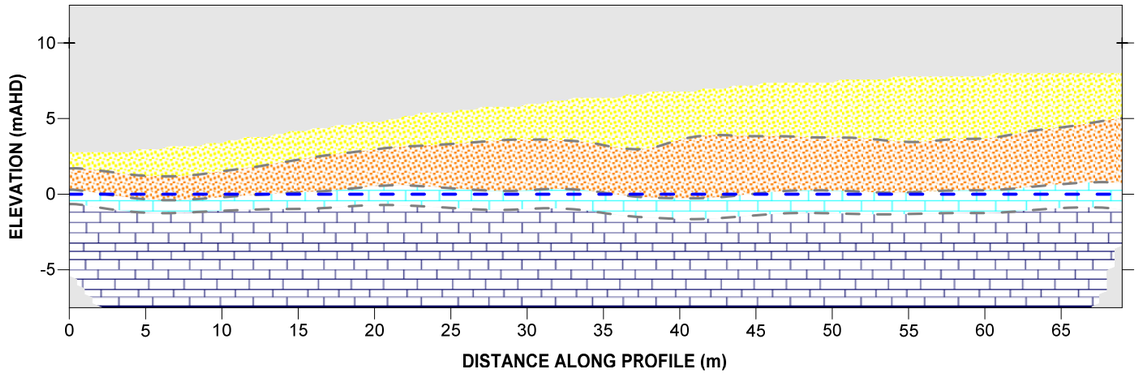
CROSS-SHORE TRANSECT 1
SEISMIC P-WAVE VELOCITY SECTION



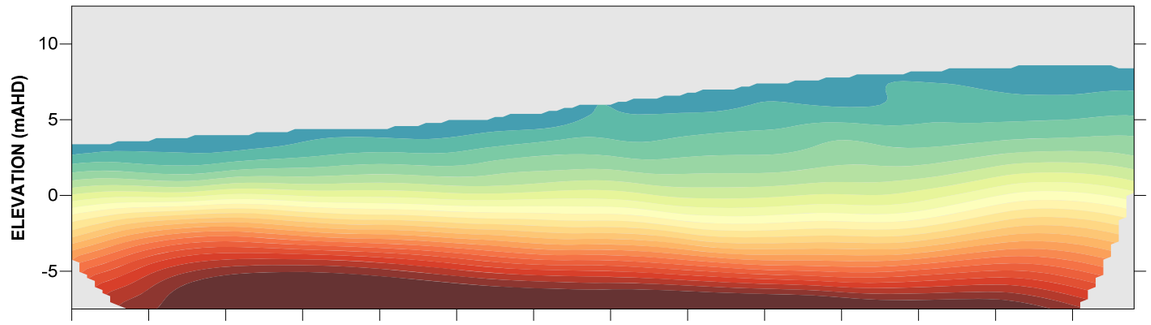
43938.6 E
271411.8 N

44007.2 E
271412.0 N

INTERPRETED SECTION



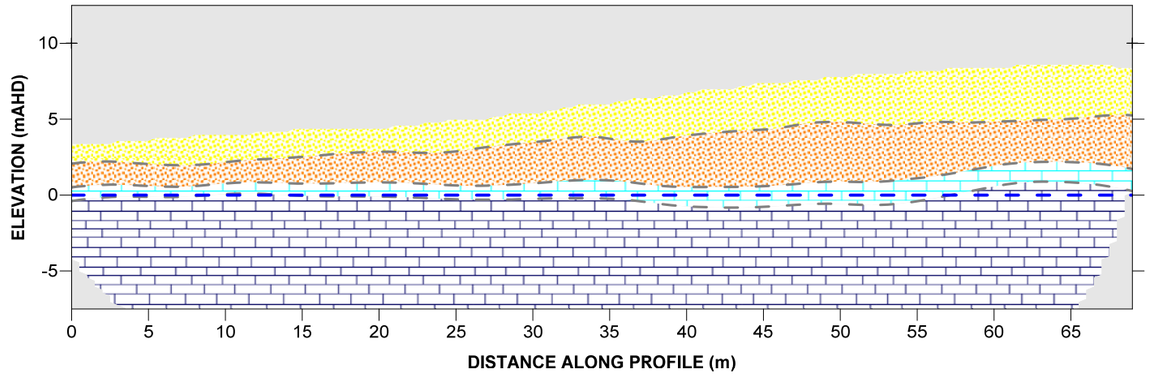
CROSS-SHORE TRANSECT 2
SEISMIC P-WAVE VELOCITY SECTION



43921.6 E
271479.4 N

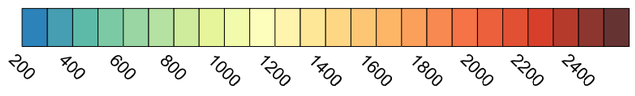
43990.4 E
271479.4 N

INTERPRETED SECTION



LEGEND

- SAND - LOW COMPACTION S-WAVE VELOCITY <500 m/s
- SAND - MODERATE COMPACTION S-WAVE VELOCITY 500-800 m/s
- LIMESTONE - INTERPRETTED LOW TO MODERATE ROCK STRENGTH, S-WAVE VELOCITY 800-1000 m/s.
- LIMESTONE - INTERPRETED MODERATE ROCK STRENGTH, S-WAVE VELOCITY > 1000 m/s.
- MEAN SEA-LEVEL (0mAHD)



NOTES

Map Projection PCG 94.
Refer to Drawing 70428-A01 ACQUIRED SEISMIC TRANSECTS (SHEET 1) for positioning.
Drawing to be used in conjunction with Report 70428.

CLIENT	CITY OF STIRLING	Date	27 June 2018	Paper Size	A3
COASTAL MANAGEMENT PLAN GEOPHYSICAL INVESTIGATION TO DETERMINE BEDROCK PROFILE		Scale	1:400	Drawn	PEC
		Drawing	70428-B01	Revision	0

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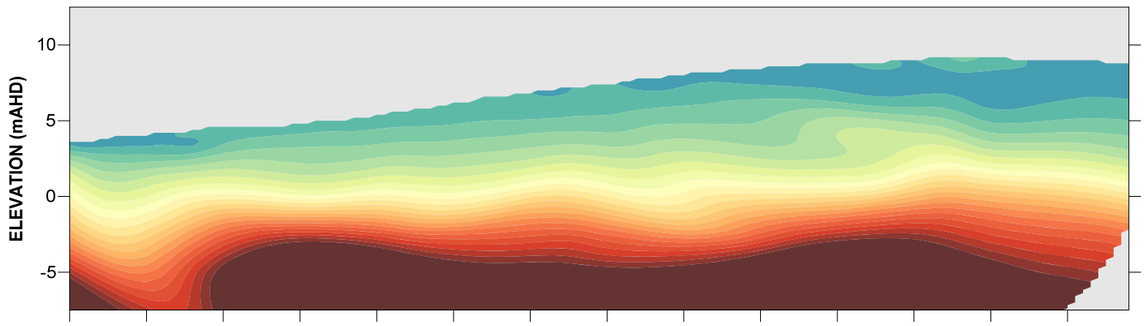
COASTAL MANAGEMENT PLAN - GEOPHYSICAL INVESTIGATION TO DETERMINE ROCK PROFILE

CROSS-SHORE TRANSECT 3 AND 4

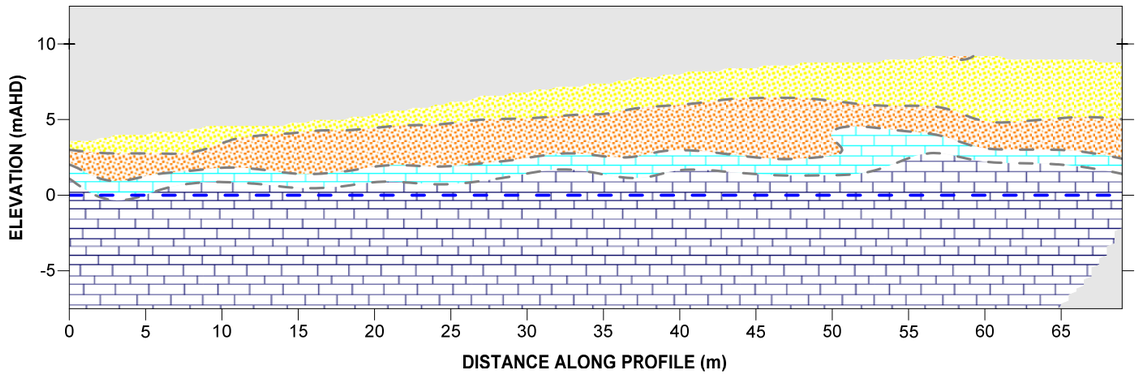
CROSS-SHORE TRANSECT 3
SEISMIC P-WAVE VELOCITY SECTION



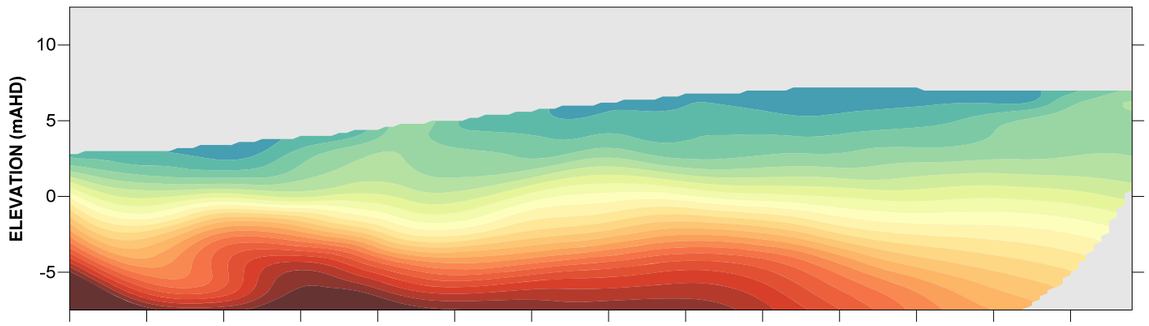
43902.4 E
271561.8 N

43970.4 E
271549.9 N

INTERPRETED SECTION



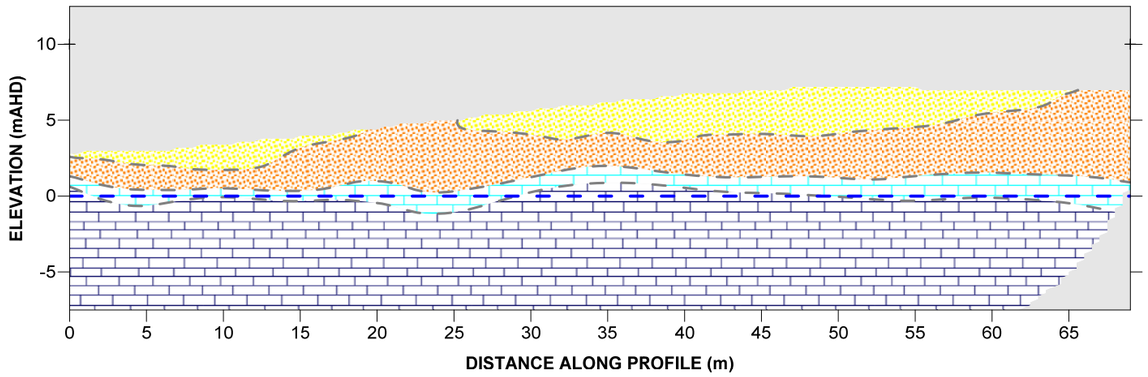
CROSS-SHORE TRANSECT 4
SEISMIC P-WAVE VELOCITY SECTION



43892.9 E
271624.9 N

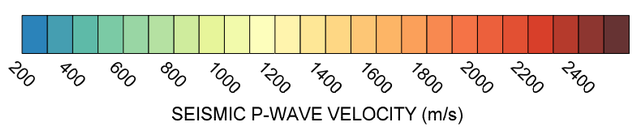
43961.3 E
271618.3 N

INTERPRETED SECTION



LEGEND

- SAND - LOW COMPACTION
  S-WAVE VELOCITY <500 m/s
- SAND - MODERATE COMPACTION
  S-WAVE VELOCITY 500-800 m/s
- LIMESTONE - INTERPRETTED LOW TO MODERATE
  ROCK STRENGTH, S-WAVE VELOCITY 800-1000 m/s.
- LIMESTONE - INTERPRETED MODERATE ROCK
  STRENGTH, S-WAVE VELOCITY > 1000 m/s.
- MEAN SEA-LEVEL (0mAHD)



NOTES

Map Projection PCG 94.
Refer to Drawing 70428-A01 ACQUIRED SEISMIC TRANSECTS (SHEET 1) for positioning.
Drawing to be used in conjunction with Report 70428.

CLIENT	CITY OF STIRLING	Date	27 June 2018	Paper Size	A3
COASTAL MANAGEMENT PLAN GEOPHYSICAL INVESTIGATION TO DETERMINE BEDROCK PROFILE		Scale	1:400	Drawn	PEC
		Drawing	70428-B02	Revision	0

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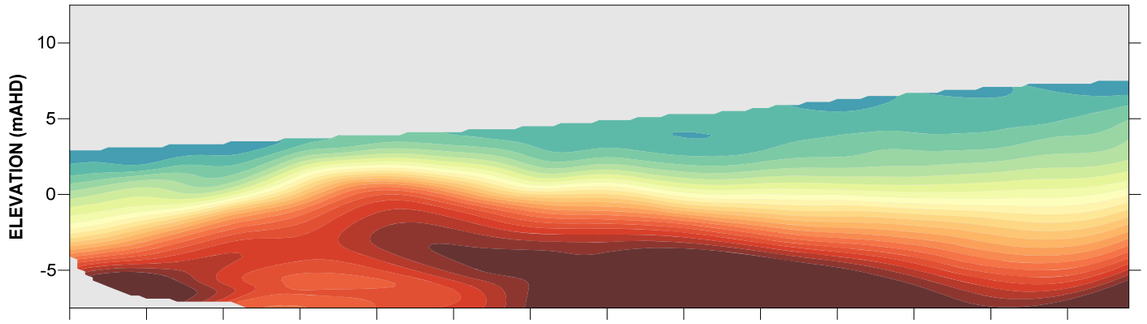
COASTAL MANAGEMENT PLAN - GEOPHYSICAL INVESTIGATION TO DETERMINE ROCK PROFILE

CROSS-SHORE TRANSECT 5 AND 6

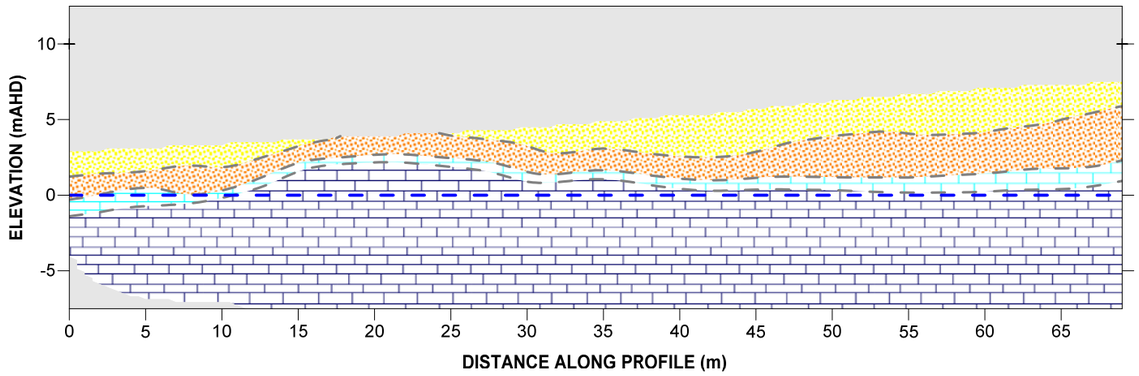
CROSS-SHORE TRANSECT 5
SEISMIC P-WAVE VELOCITY SECTION



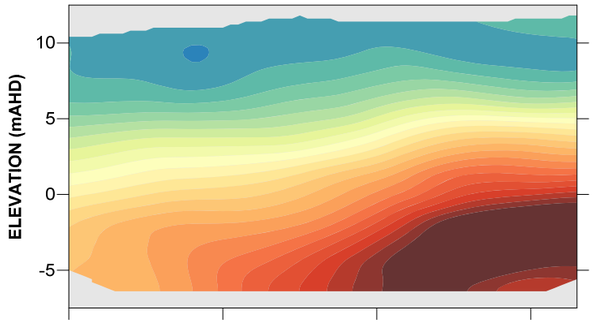
43886.6 E
271653.7 N

43954.6 E
271660.5 N

INTERPRETED SECTION



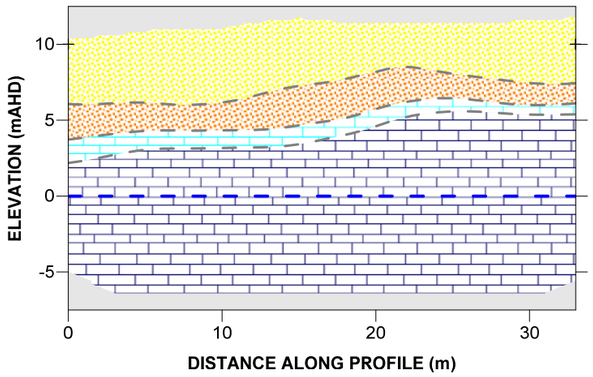
CROSS-SHORE TRANSECT 6
SEISMIC P-WAVE VELOCITY SECTION



43985.6 E
271661.2 N

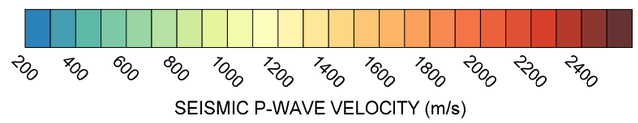
44017.5 E
271666.9 N

INTERPRETED SECTION



LEGEND

- SAND - LOW COMPACTION S-WAVE VELOCITY <500 m/s
- SAND - MODERATE COMPACTION S-WAVE VELOCITY 500-800 m/s
- LIMESTONE - INTERPRETTED LOW TO MODERATE ROCK STRENGTH, S-WAVE VELOCITY 800-1000 m/s.
- LIMESTONE - INTERPRETED MODERATE ROCK STRENGTH, S-WAVE VELOCITY > 1000 m/s.
- MEAN SEA-LEVEL (0mAHD)



NOTES

Map Projection PCG 94.
Refer to Drawing 70428-A01 ACQUIRED SEISMIC TRANSECTS (SHEET 1) for positioning.
Drawing to be used in conjunction with Report 70428.

CLIENT	CITY OF STIRLING	Date	27 June 2018	Paper Size	A3
	COASTAL MANAGEMENT PLAN GEOPHYSICAL INVESTIGATION TO DETERMINE BEDROCK PROFILE	Scale	1:400	Drawn	PEC
		Drawing	70428-B03	Revision	0

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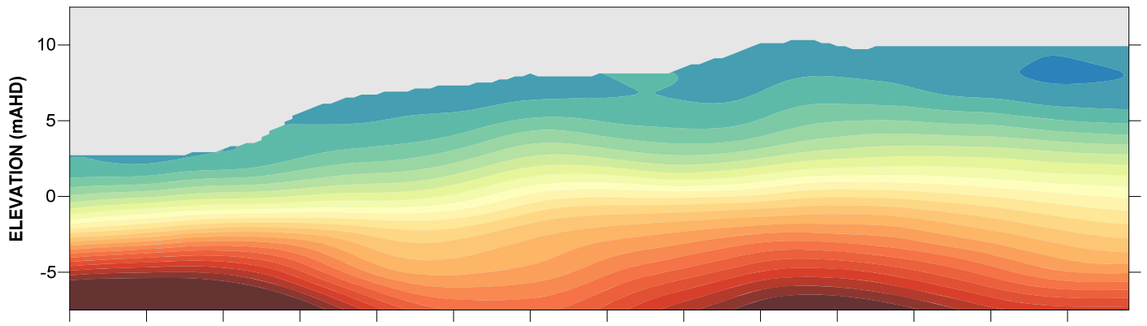
CROSS-SHORE TRANSECT 7 AND 8

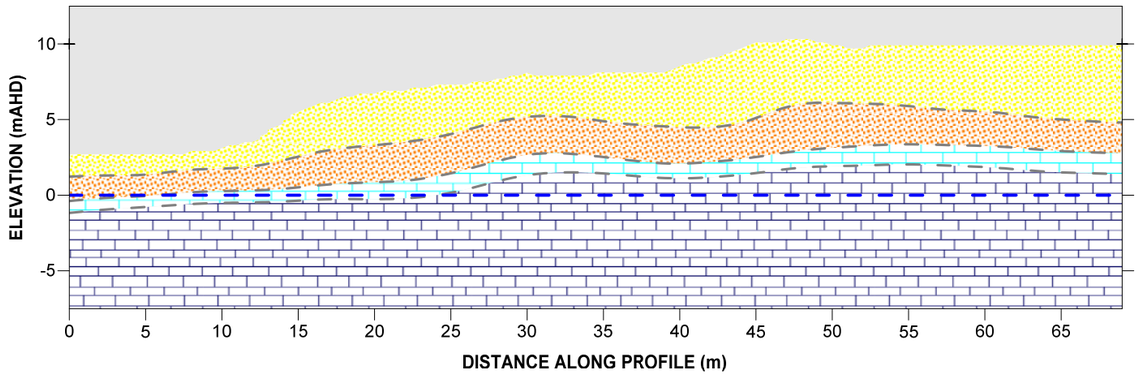
CROSS-SHORE TRANSECT 7
SEISMIC P-WAVE VELOCITY SECTION



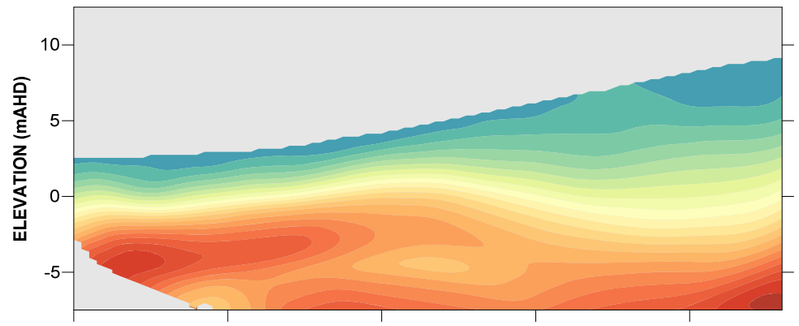
43879.2 E
271685.6 N

43943.1 E
271704.8 N

INTERPRETED SECTION



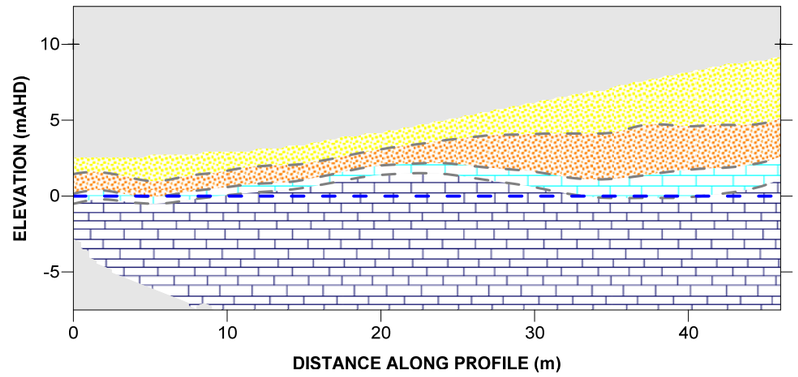
CROSS-SHORE TRANSECT 8
SEISMIC P-WAVE VELOCITY SECTION



43858.8 E
271770.8 N

43903.9 E
271769.9 N

INTERPRETED SECTION



LEGEND

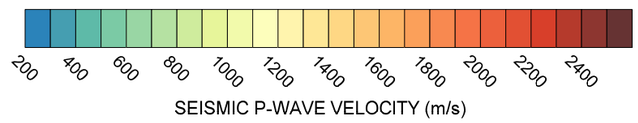
SAND - LOW COMPACTION
S-WAVE VELOCITY <500 m/s

SAND - MODERATE COMPACTION
S-WAVE VELOCITY 500-800 m/s

LIMESTONE - INTERPRETTED LOW TO MODERATE ROCK STRENGTH, S-WAVE VELOCITY 800-1000 m/s.

LIMESTONE - INTERPRETED MODERATE ROCK STRENGTH, S-WAVE VELOCITY > 1000 m/s.

MEAN SEA-LEVEL (0mAHD)



NOTES

Map Projection PCG 94.
Refer to Drawing 70428-A01 ACQUIRED SEISMIC TRANSECTS (SHEET 1) for positioning.
Drawing to be used in conjunction with Report 70428.

CLIENT	CITY OF STIRLING	Date	27 June 2018	Paper Size	A3
COASTAL MANAGEMENT PLAN GEOPHYSICAL INVESTIGATION TO DETERMINE BEDROCK PROFILE		Scale	1:400	Drawn	PEC
		Drawing	70428-B04	Revision	0

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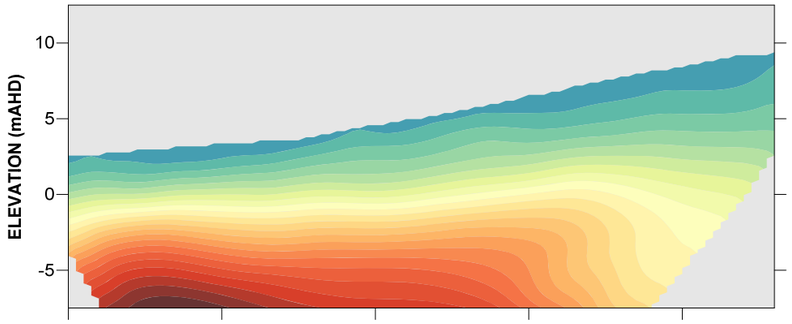
COASTAL MANAGEMENT PLAN - GEOPHYSICAL INVESTIGATION TO DETERMINE ROCK PROFILE

CROSS-SHORE TRANSECT 9 AND 10

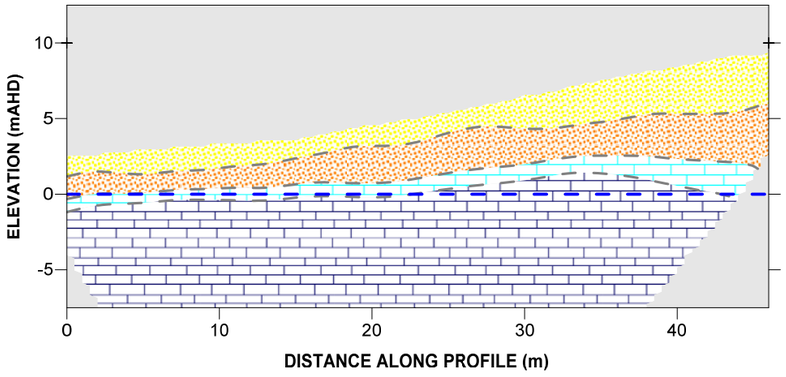
CROSS-SHORE TRANSECT 9
SEISMIC P-WAVE VELOCITY SECTION



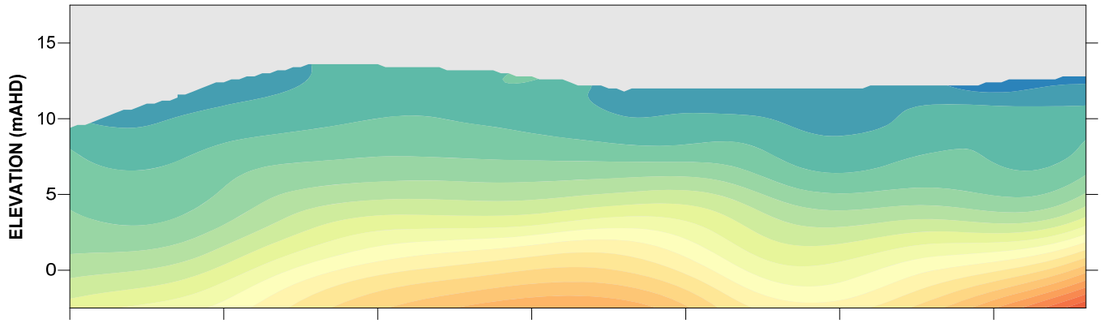
43851.3 E
271791.7 N

43895.1 E
271801.8 N

INTERPRETED SECTION



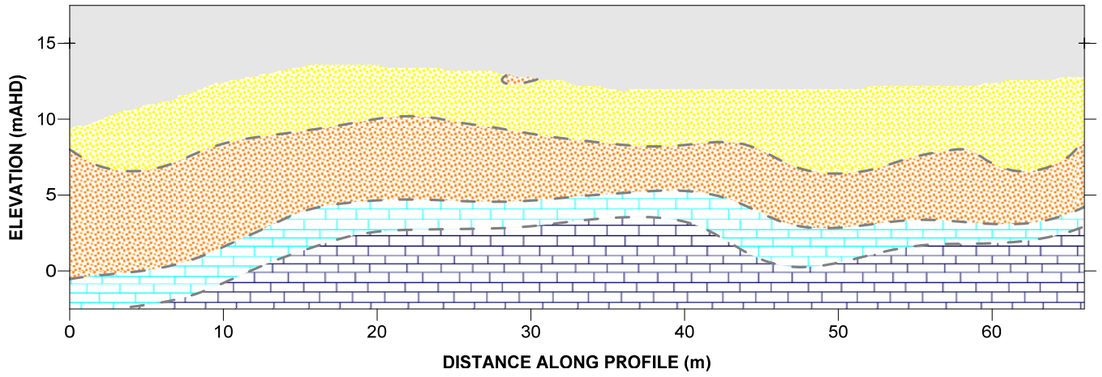
CROSS-SHORE TRANSECT 10
SEISMIC P-WAVE VELOCITY SECTION



43898.3 E
271844.8 N

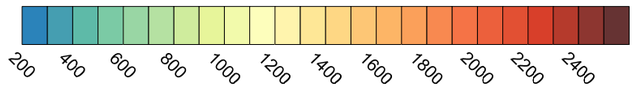
43962.7 E
271841.0 N

INTERPRETED SECTION



LEGEND

- SAND - LOW COMPACTION S-WAVE VELOCITY <500 m/s
- SAND - MODERATE COMPACTION S-WAVE VELOCITY 500-800 m/s
- LIMESTONE - INTERPRETTED LOW TO MODERATE ROCK STRENGTH, S-WAVE VELOCITY 800-1000 m/s.
- LIMESTONE - INTERPRETED MODERATE ROCK STRENGTH, S-WAVE VELOCITY > 1000 m/s.
- MEAN SEA-LEVEL (0mAHD)



NOTES

Map Projection PCG 94.
Refer to Drawing 70428-A01 ACQUIRED SEISMIC TRANSECTS (SHEET 1) for positioning.
Drawing to be used in conjunction with Report 70428.

CLIENT	CITY OF STIRLING	Date	4 July 2018	Paper Size	A3
COASTAL MANAGEMENT PLAN GEOPHYSICAL INVESTIGATION TO DETERMINE BEDROCK PROFILE		Scale	1:400	Drawn	PEC
		Drawing	70428-B05	Revision	1

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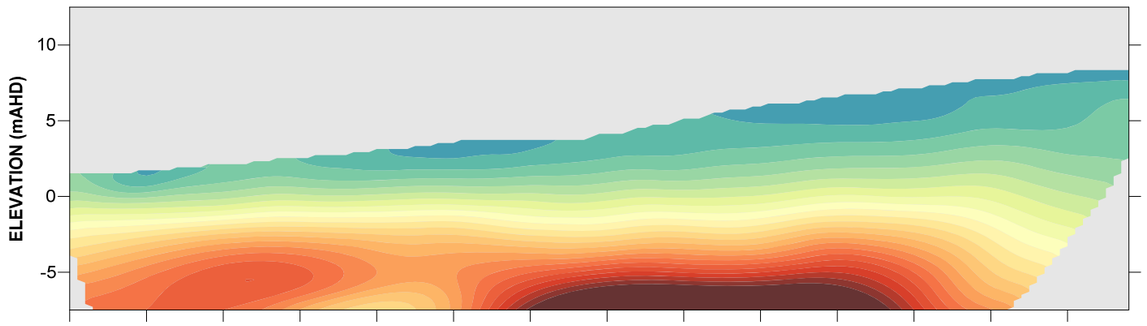
COASTAL MANAGEMENT PLAN - GEOPHYSICAL INVESTIGATION TO DETERMINE ROCK PROFILE

CROSS-SHORE TRANSECT 11 AND 12

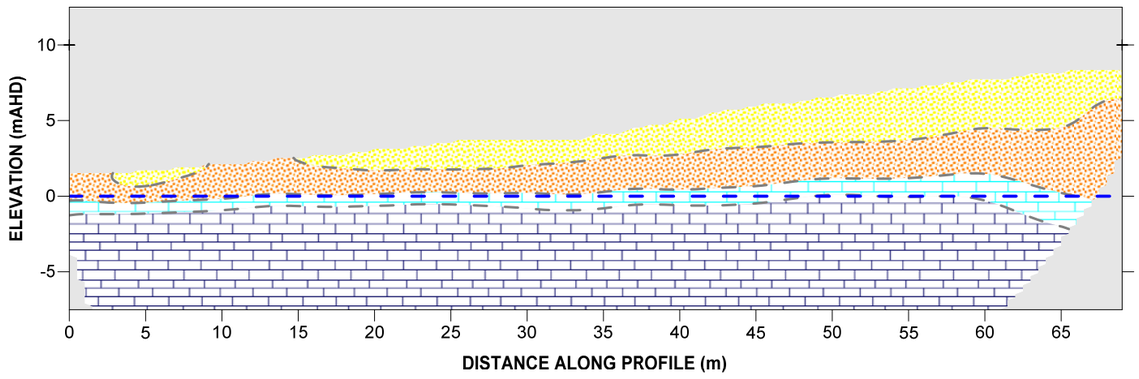
CROSS-SHORE TRANSECT 11
SEISMIC P-WAVE VELOCITY SECTION



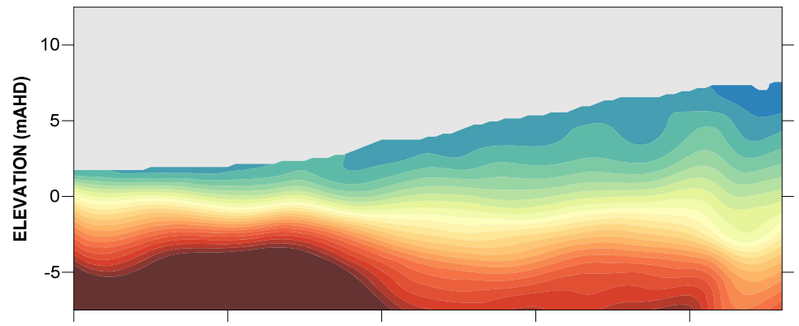
43820.2 E
271854.4 N

43888.5 E
271859.5 N

INTERPRETED SECTION



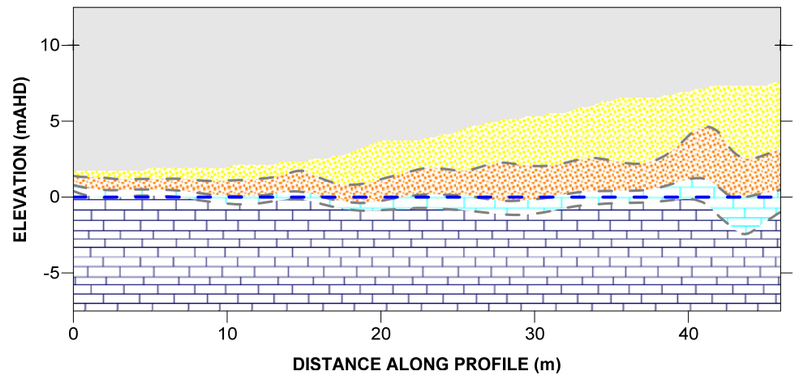
CROSS-SHORE TRANSECT 12
SEISMIC P-WAVE VELOCITY SECTION



43811.7 E
271899.7 N

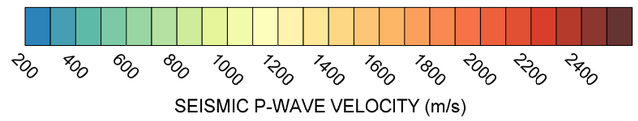
43856.1 E
271900.3 N

INTERPRETED SECTION



LEGEND

- SAND - LOW COMPACTION S-WAVE VELOCITY <500 m/s
- SAND - MODERATE COMPACTION S-WAVE VELOCITY 500-800 m/s
- LIMESTONE - INTERPRETTED LOW TO MODERATE ROCK STRENGTH, S-WAVE VELOCITY 800-1000 m/s.
- LIMESTONE - INTERPRETED MODERATE ROCK STRENGTH, S-WAVE VELOCITY > 1000 m/s.
- MEAN SEA-LEVEL (0mAHD)



NOTES

Map Projection PCG 94.
Refer to Drawing 70428-A01 ACQUIRED SEISMIC TRANSECTS (SHEET 1) for positioning.
Drawing to be used in conjunction with Report 70428.

CLIENT	CITY OF STIRLING	Date	27 June 2018	Paper Size	A3
	COASTAL MANAGEMENT PLAN GEOPHYSICAL INVESTIGATION TO DETERMINE BEDROCK PROFILE	Scale	1:400	Drawn	PEC
		Drawing	70428-B06	Revision	0

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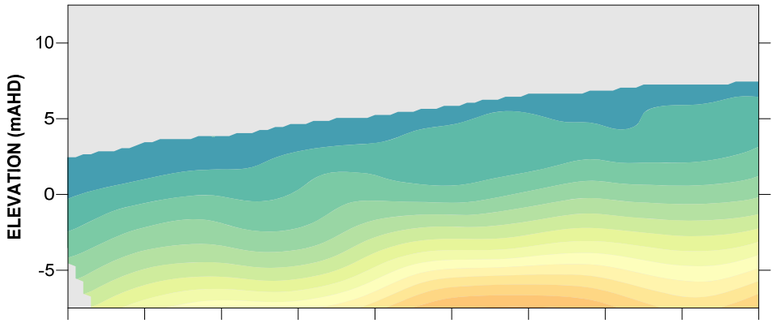
CROSS-SHORE TRANSECT 13 AND 14

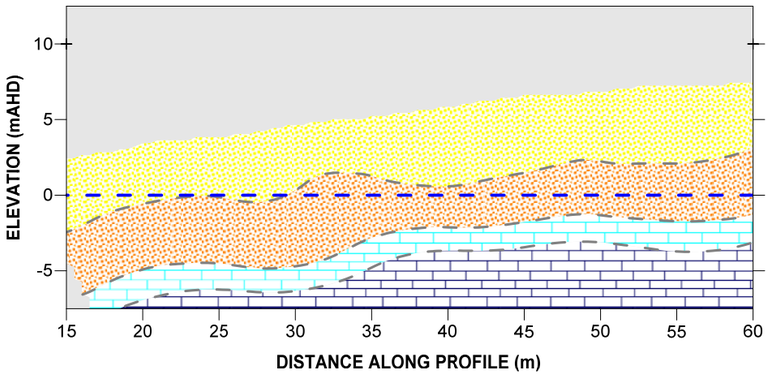
CROSS-SHORE TRANSECT 13
SEISMIC P-WAVE VELOCITY SECTION



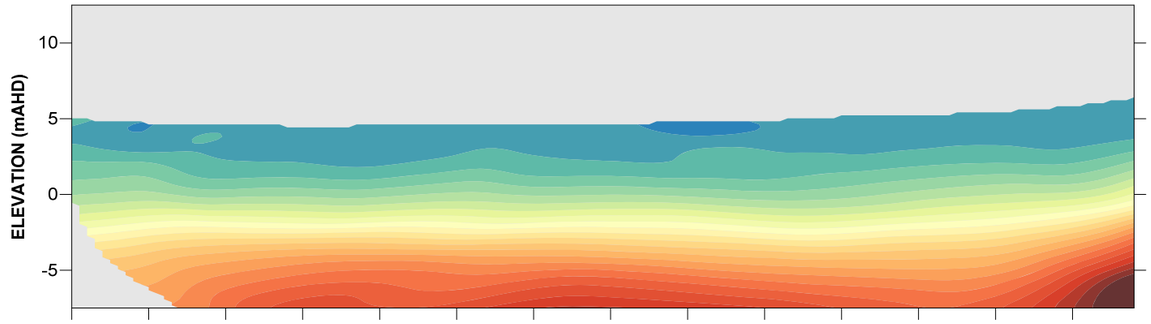
43894.3 E
271899.1 N

43938.9 E
271899.6 N

INTERPRETED SECTION



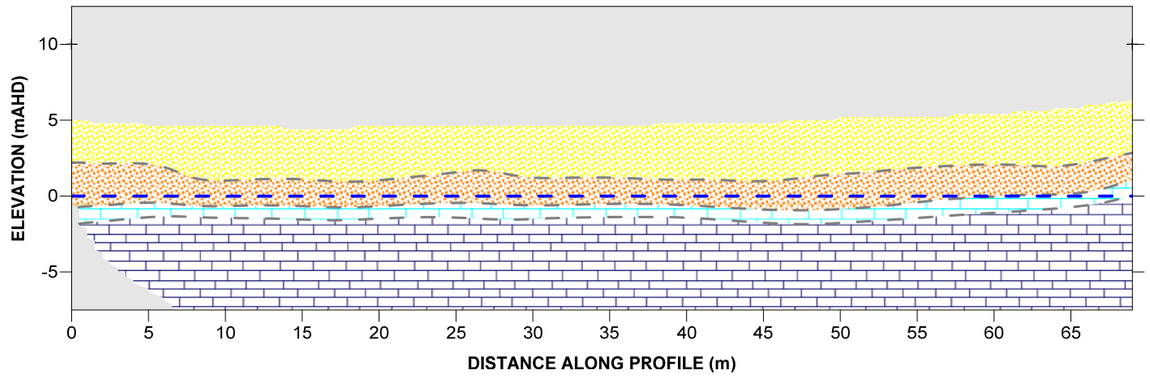
CROSS-SHORE TRANSECT 14
SEISMIC P-WAVE VELOCITY SECTION



43898.1 E
272010.5 N

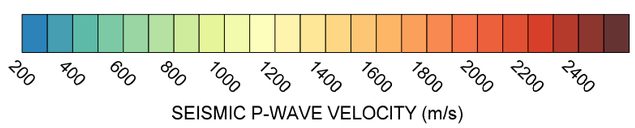
43966.7 E
272006.1 N

INTERPRETED SECTION



LEGEND

- SAND - LOW COMPACTION S-WAVE VELOCITY <500 m/s
- SAND - MODERATE COMPACTION S-WAVE VELOCITY 500-800 m/s
- LIMESTONE - INTERPRETTED LOW TO MODERATE ROCK STRENGTH, S-WAVE VELOCITY 800-1000 m/s.
- LIMESTONE - INTERPRETED MODERATE ROCK STRENGTH, S-WAVE VELOCITY > 1000 m/s.
- MEAN SEA-LEVEL (0mAHD)



NOTES

Map Projection PCG 94.
Refer to Drawing 70428-A01 ACQUIRED SEISMIC TRANSECTS (SHEET 1) for positioning.
Drawing to be used in conjunction with Report 70428.

CLIENT	CITY OF STIRLING	Date	27 June 2018	Paper Size	A3
COASTAL MANAGEMENT PLAN GEOPHYSICAL INVESTIGATION TO DETERMINE BEDROCK PROFILE		Scale	1:400	Drawn	PEC
		Drawing	70428-B07	Revision	0

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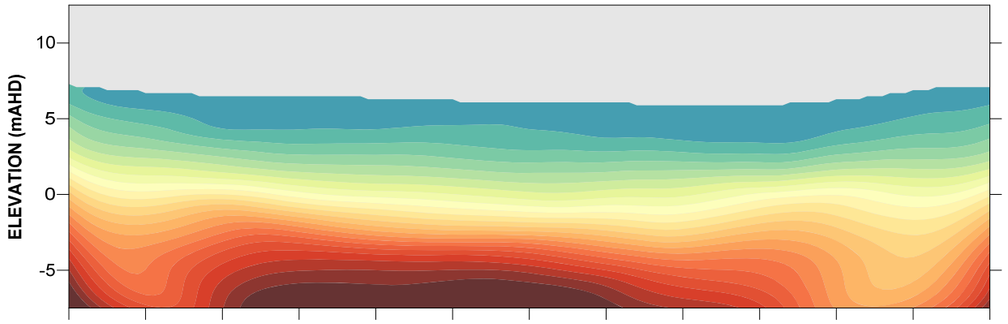
CROSS-SHORE TRANSECT 15 AND 16

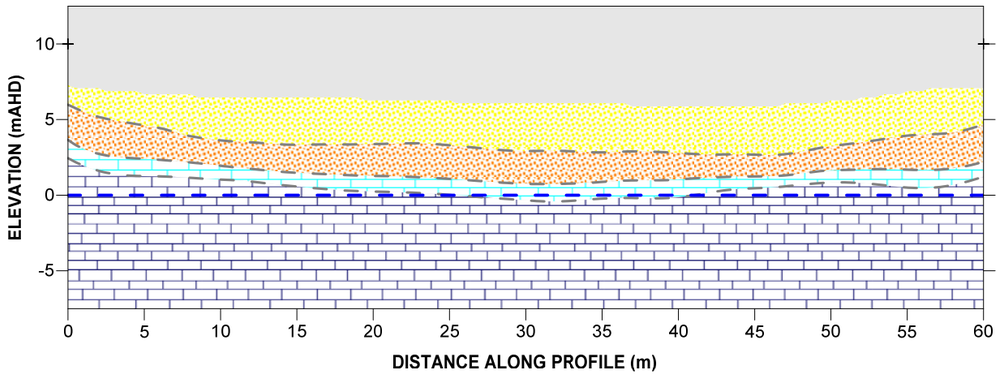
CROSS-SHORE TRANSECT 15
SEISMIC P-WAVE VELOCITY SECTION



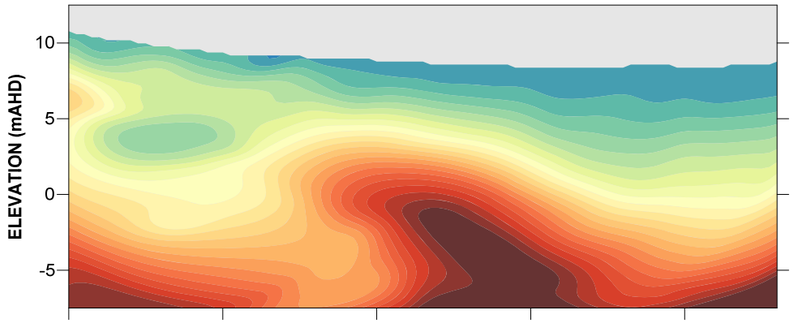
43911.6 E
272084.1 N

43969.5 E
272073.4 N

INTERPRETED SECTION



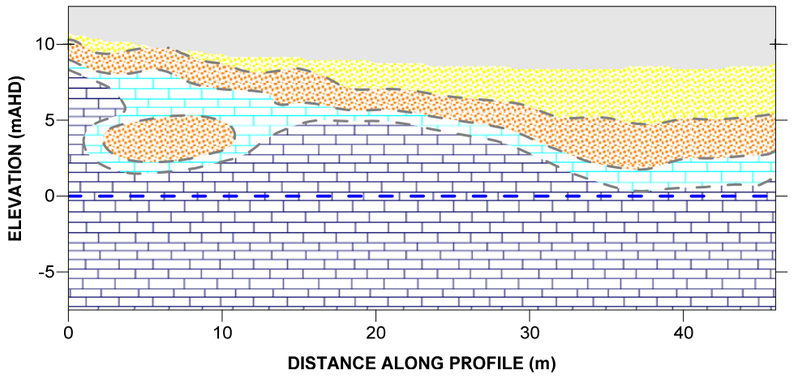
CROSS-SHORE TRANSECT 16
SEISMIC P-WAVE VELOCITY SECTION



43917.7 E
272152.0 N

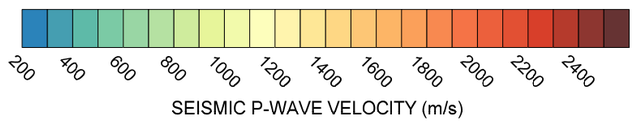
43957.8 E
272129.5 N

INTERPRETED SECTION



LEGEND

- SAND - LOW COMPACTION, S-WAVE VELOCITY <500 m/s
- SAND - MODERATE COMPACTION, S-WAVE VELOCITY 500-800 m/s
- LIMESTONE - INTERPRETTED LOW TO MODERATE ROCK STRENGTH, S-WAVE VELOCITY 800-1000 m/s.
- LIMESTONE - INTERPRETED MODERATE ROCK STRENGTH, S-WAVE VELOCITY > 1000 m/s.
- MEAN SEA-LEVEL (0mAHD)



NOTES

Map Projection PCG 94.
Refer to Drawing 70428-A02 ACQUIRED SEISMIC TRANSECTS (SHEET 2) for positioning.
Drawing to be used in conjunction with Report 70428.

CLIENT	CITY OF STIRLING	Date	27 June 2018	Paper Size	A3
COASTAL MANAGEMENT PLAN GEOPHYSICAL INVESTIGATION TO DETERMINE BEDROCK PROFILE		Scale	1:400	Drawn	PEC
		Drawing	70428-B08	Revision	0

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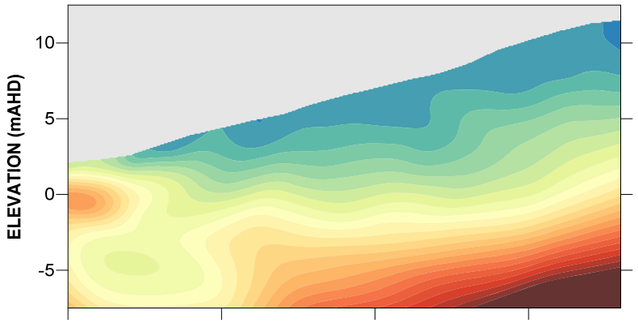
CROSS-SHORE TRANSECT 17 AND 18

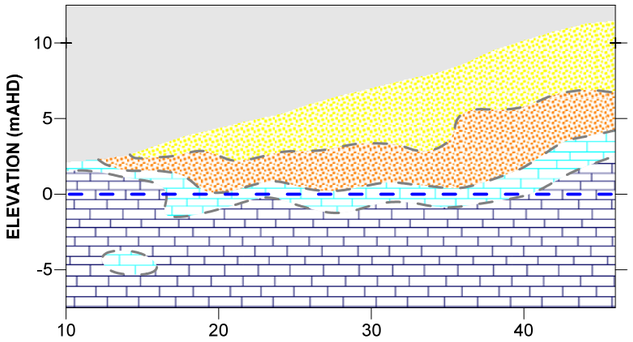
CROSS-SHORE TRANSECT 17
SEISMIC P-WAVE VELOCITY SECTION



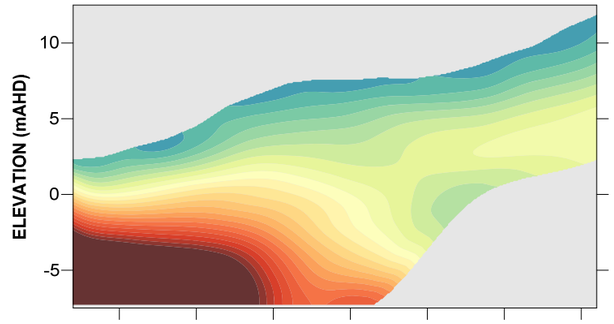
43905.2 E
272224.8 N

INTERPRETED SECTION

43937.6 E
272213.1 N



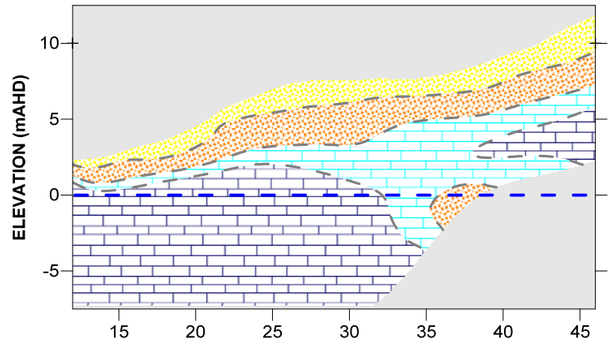
CROSS-SHORE TRANSECT 18
SEISMIC P-WAVE VELOCITY SECTION



43913.9 E
272254.2 N

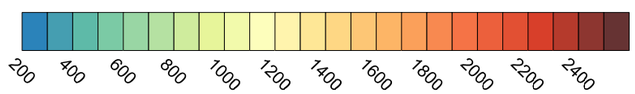
INTERPRETED SECTION

43945.2 E
272247.5 N



LEGEND

- SAND - LOW COMPACTION, S-WAVE VELOCITY <500 m/s
- SAND - MODERATE COMPACTION, S-WAVE VELOCITY 500-800 m/s
- LIMESTONE - INTERPRETTED LOW TO MODERATE ROCK STRENGTH, S-WAVE VELOCITY 800-1000 m/s.
- LIMESTONE - INTERPRETED MODERATE ROCK STRENGTH, S-WAVE VELOCITY > 1000 m/s.
- MEAN SEA-LEVEL (0mAHD)



SEISMIC P-WAVE VELOCITY (m/s)

NOTES

Map Projection PCG 94.
Refer to Drawing 70428-A02 ACQUIRED SEISMIC TRANSECTS (SHEET 2) for positioning.
Drawing to be used in conjunction with Report 70428.

CLIENT	CITY OF STIRLING	Date	27 June 2018	Paper Size	A3
COASTAL MANAGEMENT PLAN GEOPHYSICAL INVESTIGATION TO DETERMINE BEDROCK PROFILE		Scale	1:400	Drawn	PEC
		Drawing	70428-B09	Revision	0

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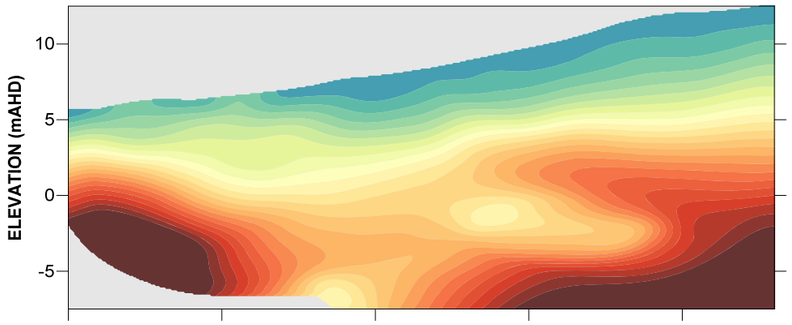
CROSS-SHORE TRANSECT 19 AND 20

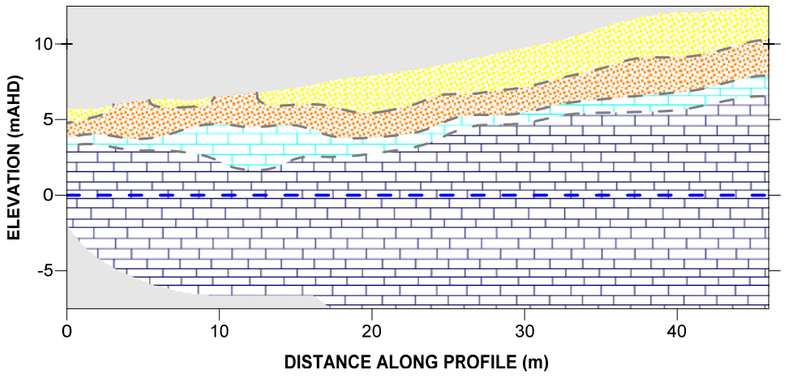
CROSS-SHORE TRANSECT 19
SEISMIC P-WAVE VELOCITY SECTION



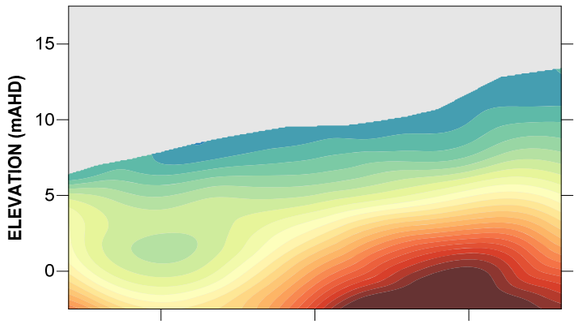
43906.8 E
272279.5 N

INTERPRETED SECTION

43952.1 E
272279.5 N



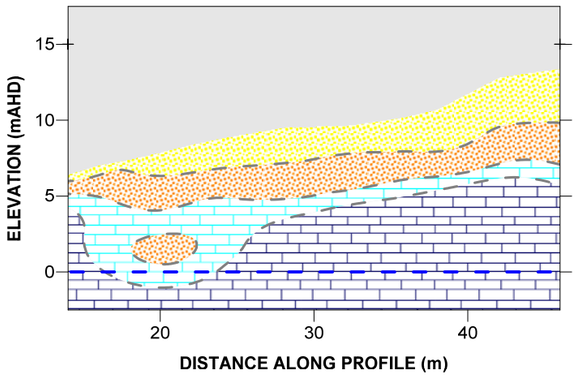
CROSS-SHORE TRANSECT 20
SEISMIC P-WAVE VELOCITY SECTION



43930.7 E
272337.2 N

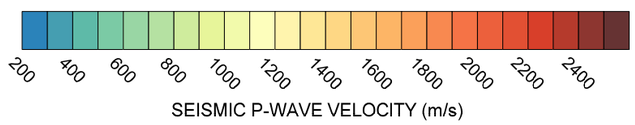
INTERPRETED SECTION

43961.3 E
272331.6 N



LEGEND

- SAND - LOW COMPACTION, S-WAVE VELOCITY <500 m/s
- SAND - MODERATE COMPACTION, S-WAVE VELOCITY 500-800 m/s
- LIMESTONE - INTERPRETTED LOW TO MODERATE ROCK STRENGTH, S-WAVE VELOCITY 800-1000 m/s.
- LIMESTONE - INTERPRETED MODERATE ROCK STRENGTH, S-WAVE VELOCITY > 1000 m/s.
- MEAN SEA-LEVEL (0mAHD)



NOTES

Map Projection PCG 94.
Refer to Drawing 70428-A02 ACQUIRED SEISMIC TRANSECTS (SHEET 2) for positioning.
Drawing to be used in conjunction with Report 70428.

CLIENT	CITY OF STIRLING	Date	27 June 2018	Paper Size	A3
	COASTAL MANAGEMENT PLAN GEOPHYSICAL INVESTIGATION TO DETERMINE BEDROCK PROFILE	Scale	1:400	Drawn	PEC
		Drawing	70428-B10	Revision	0

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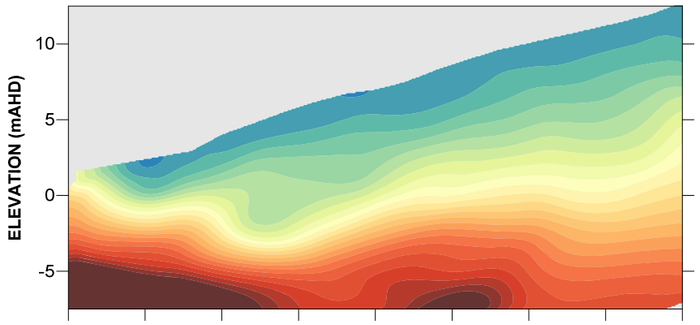
CROSS-SHORE TRANSECT 21 AND 22

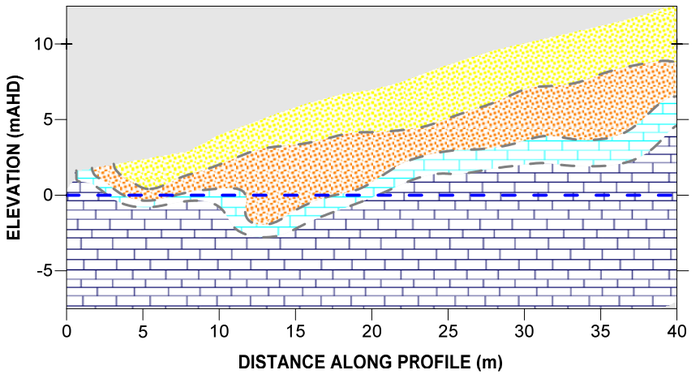
CROSS-SHORE TRANSECT 21
SEISMIC P-WAVE VELOCITY SECTION



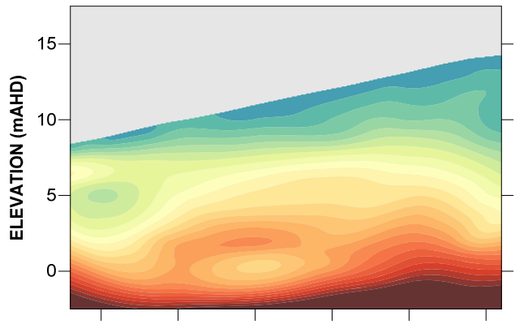
43924.4 E
272356.3 N

INTERPRETED SECTION

43958.9 E
272371.3 N



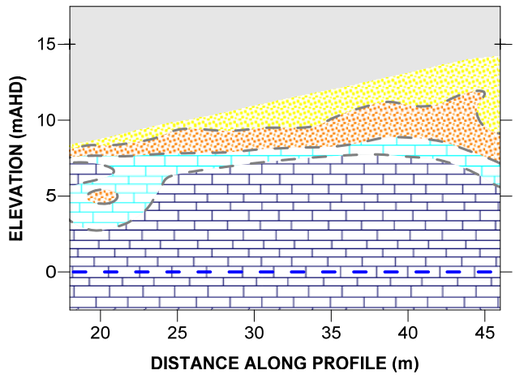
CROSS-SHORE TRANSECT 22
SEISMIC P-WAVE VELOCITY SECTION



43928.6 E
272382.2 N

INTERPRETED SECTION

43955.2 E
272386.8 N



LEGEND

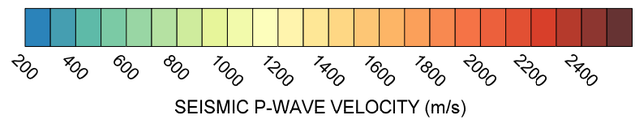
SAND - LOW COMPACTION
S-WAVE VELOCITY <500 m/s

SAND - MODERATE COMPACTION
S-WAVE VELOCITY 500-800 m/s

LIMESTONE - INTERPRETTED LOW TO MODERATE ROCK STRENGTH, S-WAVE VELOCITY 800-1000 m/s.

LIMESTONE - INTERPRETED MODERATE ROCK STRENGTH, S-WAVE VELOCITY > 1000 m/s.

MEAN SEA-LEVEL (0mAHD)



SEISMIC P-WAVE VELOCITY (m/s)

NOTES

Map Projection PCG 94.
Refer to Drawing 70428-A02 ACQUIRED SEISMIC TRANSECTS (SHEET 2) for positioning.
Drawing to be used in conjunction with Report 70428.

CLIENT	CITY OF STIRLING	Date	27 June 2018	Paper Size	A3
	COASTAL MANAGEMENT PLAN GEOPHYSICAL INVESTIGATION TO DETERMINE BEDROCK PROFILE	Scale	1:400	Drawn	PEC
		Drawing	70428-B11	Revision	0

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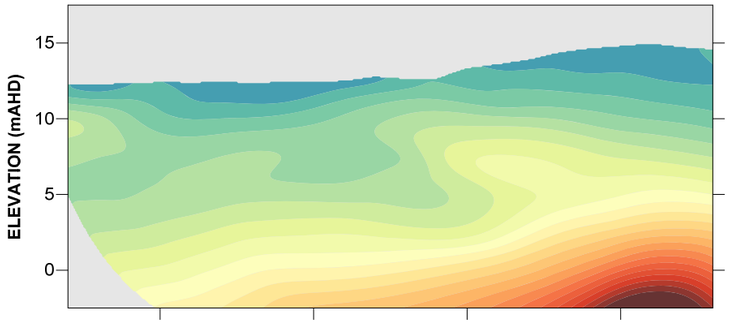
CROSS-SHORE TRANSECT 23 AND 24

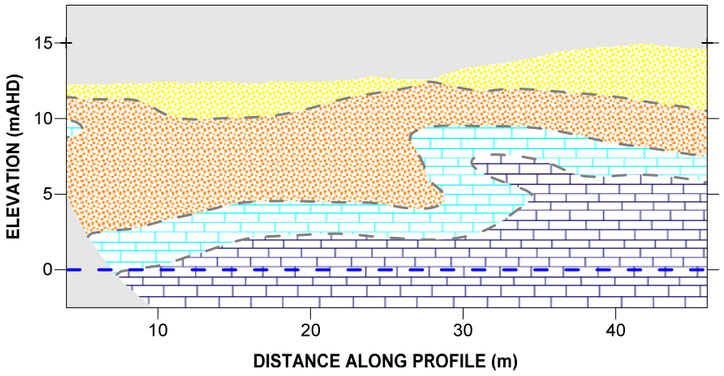
CROSS-SHORE TRANSECT 23
SEISMIC P-WAVE VELOCITY SECTION



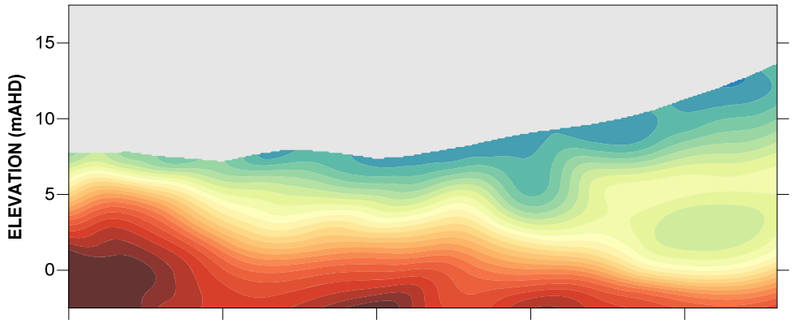
43912.4 E
272428.7 N

INTERPRETED SECTION

43949.4 E
272409.2 N



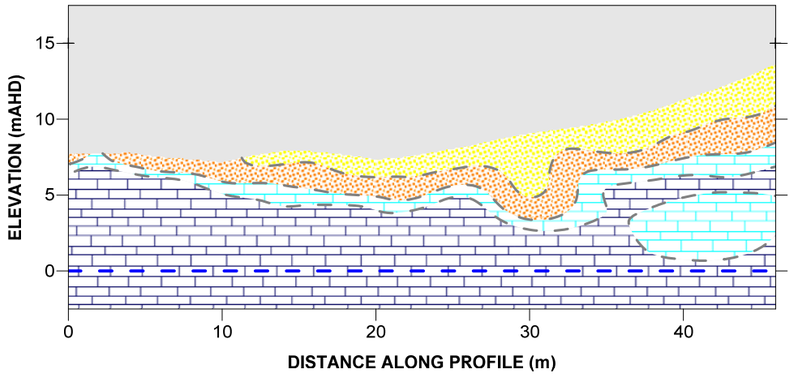
CROSS-SHORE TRANSECT 24
SEISMIC P-WAVE VELOCITY SECTION



43887.7 E
272487.1 N

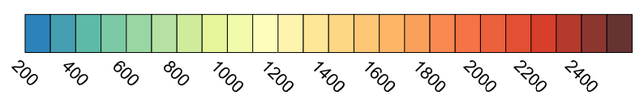
INTERPRETED SECTION

43925.4 E
272511.3 N



LEGEND

- SAND - LOW COMPACTION, S-WAVE VELOCITY <500 m/s
- SAND - MODERATE COMPACTION, S-WAVE VELOCITY 500-800 m/s
- LIMESTONE - INTERPRETTED LOW TO MODERATE ROCK STRENGTH, S-WAVE VELOCITY 800-1000 m/s.
- LIMESTONE - INTERPRETED MODERATE ROCK STRENGTH, S-WAVE VELOCITY > 1000 m/s.
- MEAN SEA-LEVEL (0mAHD)



NOTES

Map Projection PCG 94.
Refer to Drawing 70428-A02 ACQUIRED SEISMIC TRANSECTS (SHEET 2) for positioning.
Drawing to be used in conjunction with Report 70428.

CLIENT	CITY OF STIRLING	Date	27 June 2018	Paper Size	A3
	COASTAL MANAGEMENT PLAN GEOPHYSICAL INVESTIGATION TO DETERMINE BEDROCK PROFILE	Scale	1:400	Drawn	PEC
		Drawing	70428-B12	Revision	0

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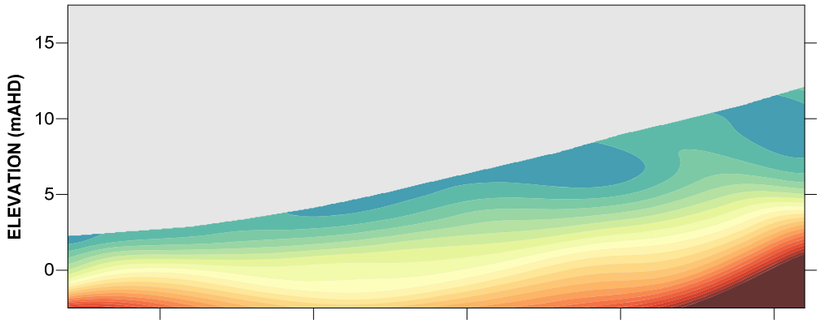
COASTAL MANAGEMENT PLAN - GEOPHYSICAL INVESTIGATION TO DETERMINE ROCK PROFILE

CROSS-SHORE TRANSECT 25 AND 26

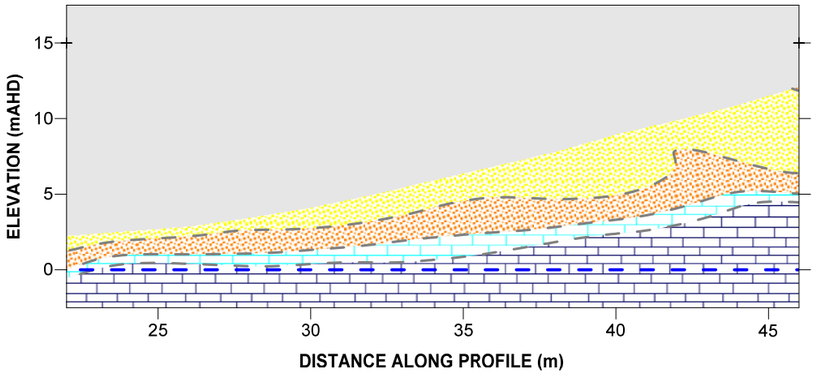
CROSS-SHORE TRANSECT 25
SEISMIC P-WAVE VELOCITY SECTION



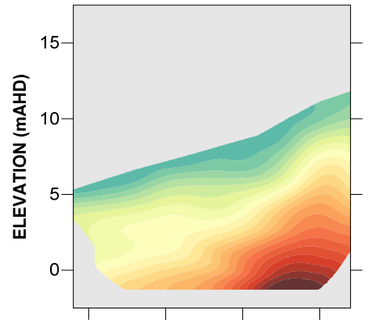
43900.8 E
272524.7 N

43921.9 E
272529.8 N

INTERPRETED SECTION



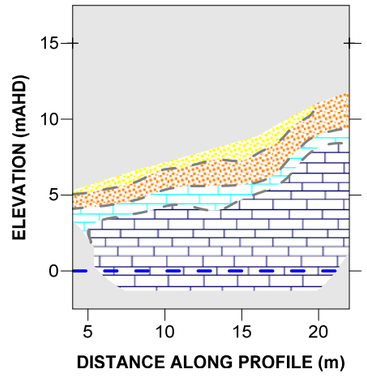
CROSS-SHORE TRANSECT 26
SEISMIC P-WAVE VELOCITY SECTION



INTERPRETED SECTION

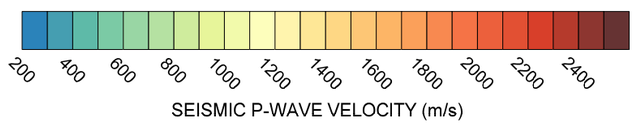
43901.9 E
272549.9 N

43917.2 E
272553.5 N



LEGEND

- SAND - LOW COMPACTION, S-WAVE VELOCITY <500 m/s
- SAND - MODERATE COMPACTION, S-WAVE VELOCITY 500-800 m/s
- LIMESTONE - INTERPRETTED LOW TO MODERATE ROCK STRENGTH, S-WAVE VELOCITY 800-1000 m/s.
- LIMESTONE - INTERPRETED MODERATE ROCK STRENGTH, S-WAVE VELOCITY > 1000 m/s.
- MEAN SEA-LEVEL (0mAHD)



NOTES

Map Projection PCG 94.
Refer to Drawing 70428-A02 ACQUIRED SEISMIC TRANSECTS (SHEET 2) for positioning.
Drawing to be used in conjunction with Report 70428.

CLIENT	CITY OF STIRLING	Date	27 June 2018	Paper Size	A3
	COASTAL MANAGEMENT PLAN GEOPHYSICAL INVESTIGATION TO DETERMINE BEDROCK PROFILE	Scale	1:400	Drawn	PEC
		Drawing	70428-B13	Revision	0

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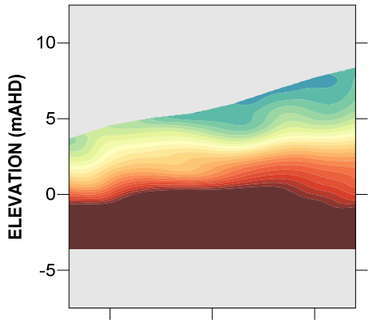
CROSS-SHORE TRANSECT 27 AND 28

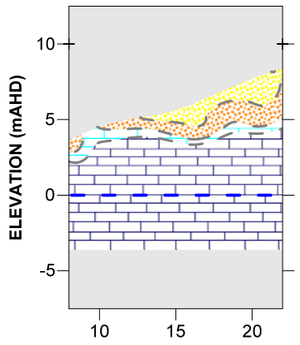
CROSS-SHORE TRANSECT 27
SEISMIC P-WAVE VELOCITY SECTION



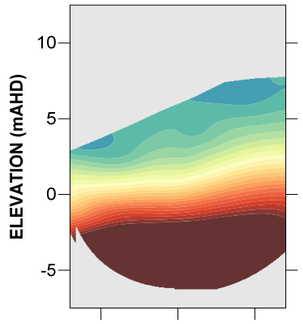
INTERPRETED SECTION

43900.1 E
272603.5 N

43912.4 E
272603.9 N



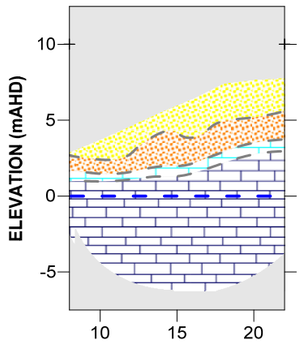
CROSS-SHORE TRANSECT 28
SEISMIC P-WAVE VELOCITY SECTION



INTERPRETED SECTION

43908.7 E
272654.4 N

43921.7 E
272655.2 N



LEGEND

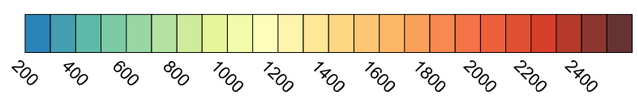
SAND - LOW COMPACTION
S-WAVE VELOCITY <500 m/s

SAND - MODERATE COMPACTION
S-WAVE VELOCITY 500-800 m/s

LIMESTONE - INTERPRETTED LOW TO MODERATE ROCK STRENGTH, S-WAVE VELOCITY 800-1000 m/s.

LIMESTONE - INTERPRETED MODERATE ROCK STRENGTH, S-WAVE VELOCITY > 1000 m/s.

MEAN SEA-LEVEL (0mAHD)



NOTES

Map Projection PCG 94.
Refer to Drawing 70428-A02 ACQUIRED SEISMIC TRANSECTS (SHEET 2) for positioning.
Drawing to be used in conjunction with Report 70428.

CLIENT	CITY OF STIRLING	Date	27 June 2018	Paper Size	A3
COASTAL MANAGEMENT PLAN GEOPHYSICAL INVESTIGATION TO DETERMINE BEDROCK PROFILE		Scale	1:400	Drawn	PEC
		Drawing	70428-B14	Revision	0

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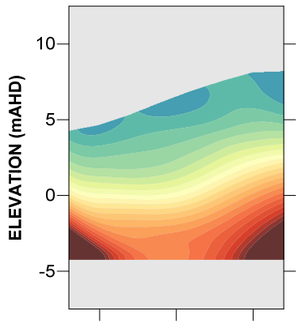
CROSS-SHORE TRANSECT 29 AND 30

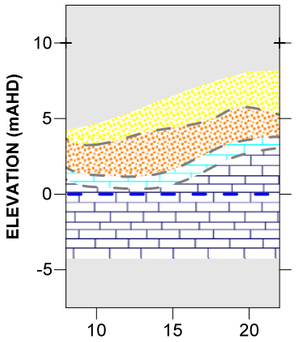
CROSS-SHORE TRANSECT 29
SEISMIC P-WAVE VELOCITY SECTION



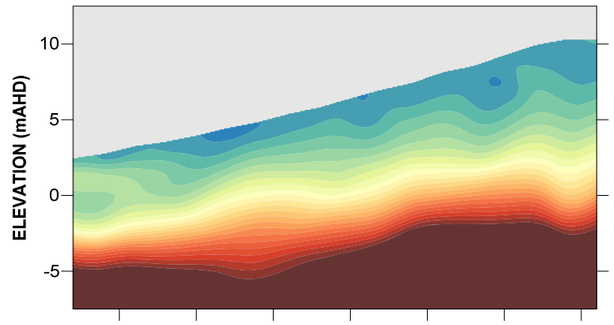
INTERPRETED SECTION

43919.5 E
272700.4 N

43930.0 E
272693.0 N



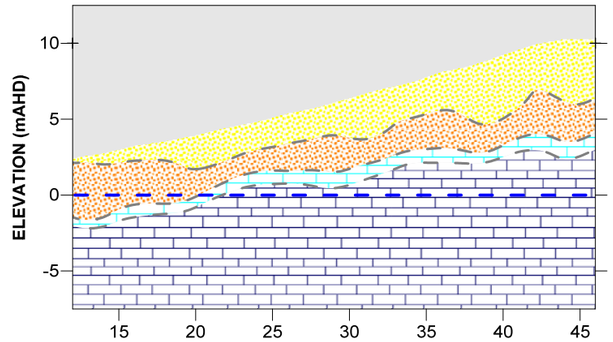
CROSS-SHORE TRANSECT 30
SEISMIC P-WAVE VELOCITY SECTION



43910.1 E
273525.5 N

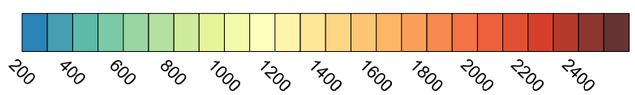
INTERPRETED SECTION

43942.8 E
273528.2 N



LEGEND

- SAND - LOW COMPACTION S-WAVE VELOCITY <500 m/s
- SAND - MODERATE COMPACTION S-WAVE VELOCITY 500-800 m/s
- LIMESTONE - INTERPRETTED LOW TO MODERATE ROCK STRENGTH, S-WAVE VELOCITY 800-1000 m/s.
- LIMESTONE - INTERPRETED MODERATE ROCK STRENGTH, S-WAVE VELOCITY > 1000 m/s.
- MEAN SEA-LEVEL (0mAHD)



SEISMIC P-WAVE VELOCITY (m/s)

NOTES

Map Projection PCG 94.
Refer to Drawings 70428-A03 and A04 ACQUIRED SEISMIC TRANSECTS (SHEETS 3 and 4) for positioning.
Drawing to be used in conjunction with Report 70428.

CLIENT	CITY OF STIRLING	Date	27 June 2018	Paper Size	A3
COASTAL MANAGEMENT PLAN GEOPHYSICAL INVESTIGATION TO DETERMINE BEDROCK PROFILE		Scale	1:400	Drawn	PEC
		Drawing	70428-B15	Revision	0

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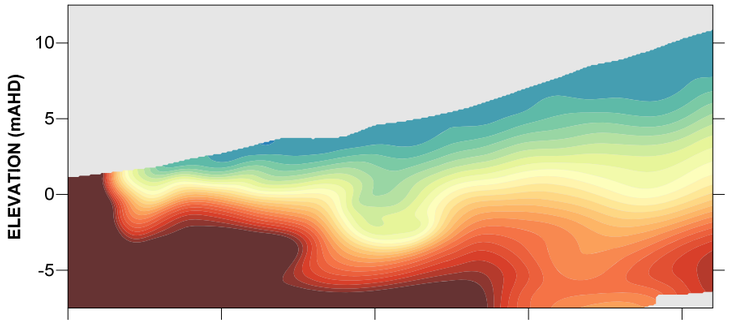
COASTAL MANAGEMENT PLAN - GEOPHYSICAL INVESTIGATION TO DETERMINE ROCK PROFILE

CROSS-SHORE TRANSECT 31 AND 32

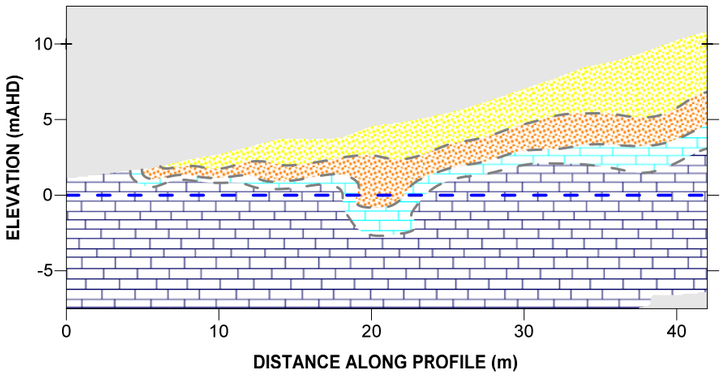
CROSS-SHORE TRANSECT 31
SEISMIC P-WAVE VELOCITY SECTION



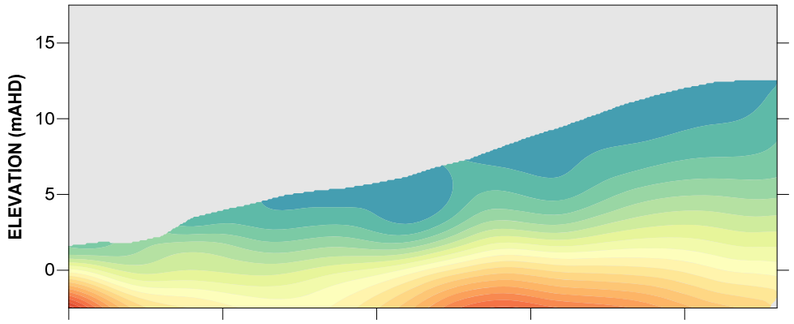
43908.3 E
273554.6 N

43948.8 E
273556.3 N

INTERPRETED SECTION



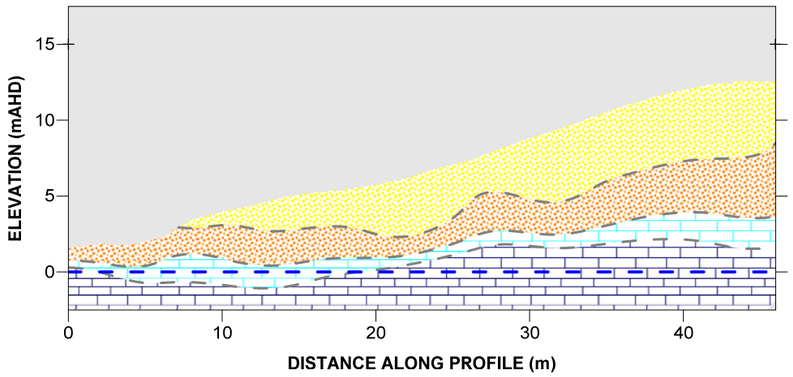
CROSS-SHORE TRANSECT 32
SEISMIC P-WAVE VELOCITY SECTION



43901.3 E
273593.9 N

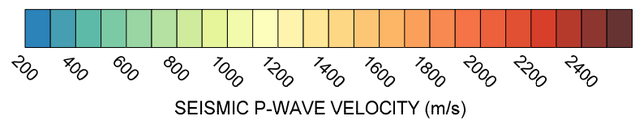
43944.8 E
273602.9 N

INTERPRETED SECTION



LEGEND

- SAND - LOW COMPACTION S-WAVE VELOCITY <500 m/s
- SAND - MODERATE COMPACTION S-WAVE VELOCITY 500-800 m/s
- LIMESTONE - INTERPRETTED LOW TO MODERATE ROCK STRENGTH, S-WAVE VELOCITY 800-1000 m/s.
- LIMESTONE - INTERPRETED MODERATE ROCK STRENGTH, S-WAVE VELOCITY > 1000 m/s.
- MEAN SEA-LEVEL (0mAHD)



NOTES

Map Projection PCG 94.
Refer to Drawing 70428-A04 ACQUIRED SEISMIC TRANSECTS (SHEET 4) for positioning.
Drawing to be used in conjunction with Report 70428.

CLIENT	CITY OF STIRLING	Date	27 June 2018	Paper Size	A3
COASTAL MANAGEMENT PLAN GEOPHYSICAL INVESTIGATION TO DETERMINE BEDROCK PROFILE		Scale	1:400	Drawn	PEC
		Drawing	70428-B16	Revision	0

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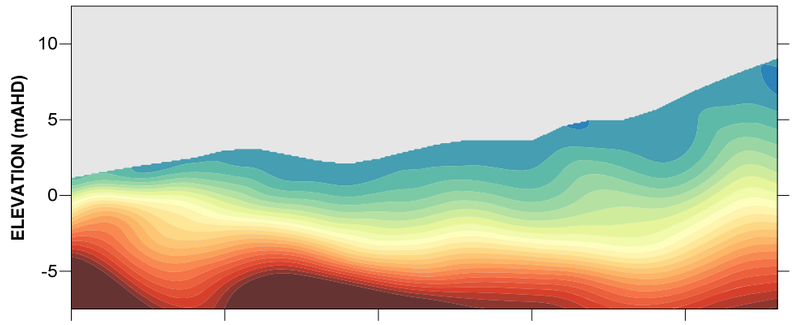
CROSS-SHORE TRANSECT 33 AND 34

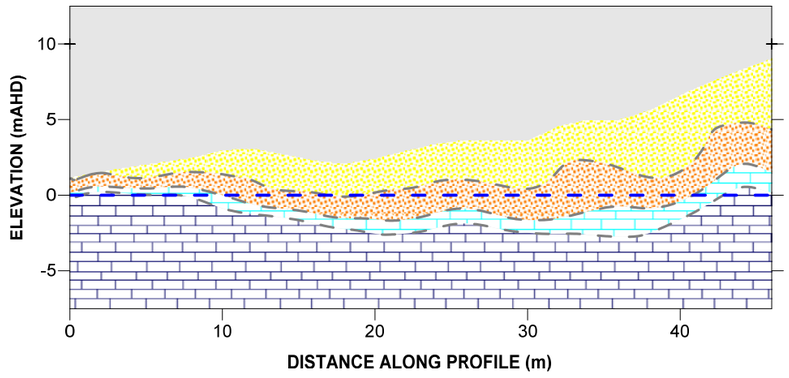
CROSS-SHORE TRANSECT 33
SEISMIC P-WAVE VELOCITY SECTION



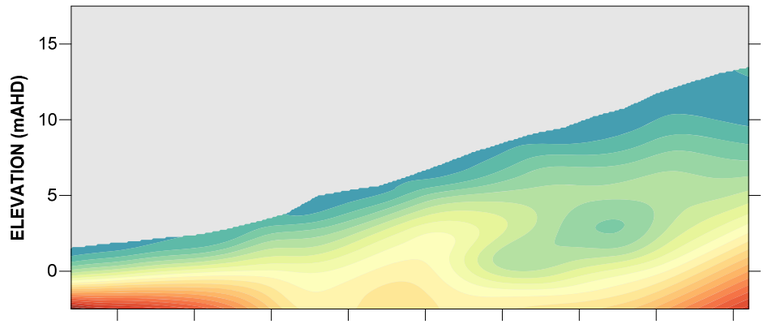
43896.8 E
273634.6 N

INTERPRETED SECTION

43941.3 E
273641.8 N



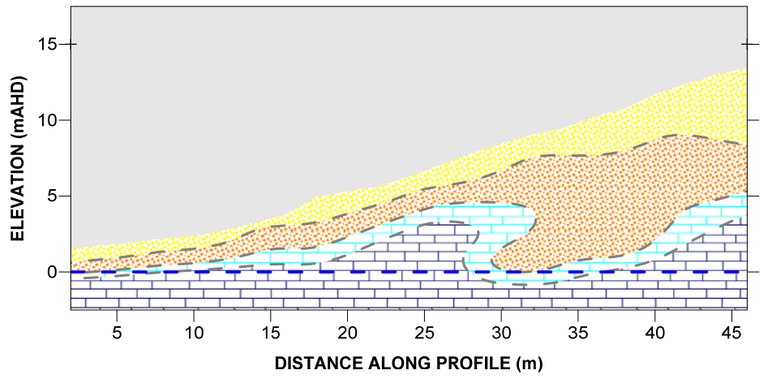
CROSS-SHORE TRANSECT 34
SEISMIC P-WAVE VELOCITY SECTION



43892.5 E
273683.2 N

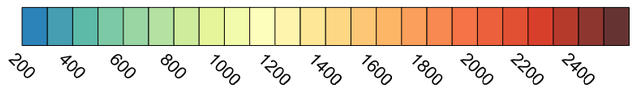
INTERPRETED SECTION

43931.6 E
273696.4 N



LEGEND

- SAND - LOW COMPACTION S-WAVE VELOCITY <500 m/s
- SAND - MODERATE COMPACTION S-WAVE VELOCITY 500-800 m/s
- LIMESTONE - INTERPRETTED LOW TO MODERATE ROCK STRENGTH, S-WAVE VELOCITY 800-1000 m/s.
- LIMESTONE - INTERPRETED MODERATE ROCK STRENGTH, S-WAVE VELOCITY > 1000 m/s.
- MEAN SEA-LEVEL (0mAHD)



NOTES

Map Projection PCG 94.
Refer to Drawing 70428-A04 ACQUIRED SEISMIC TRANSECTS (SHEET 4) for positioning.
Drawing to be used in conjunction with Report 70428.

CLIENT	CITY OF STIRLING	Date	27 June 2018	Paper Size	A3
	COASTAL MANAGEMENT PLAN GEOPHYSICAL INVESTIGATION TO DETERMINE BEDROCK PROFILE	Scale	1:400	Drawn	PEC
		Drawing	70428-B17	Revision	0

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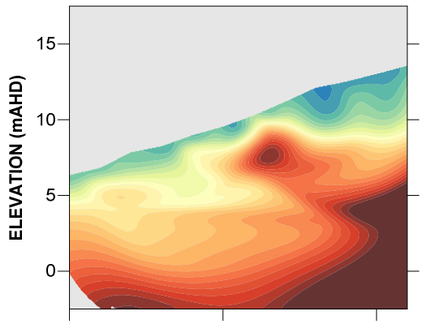
CROSS-SHORE TRANSECT 35 AND 36

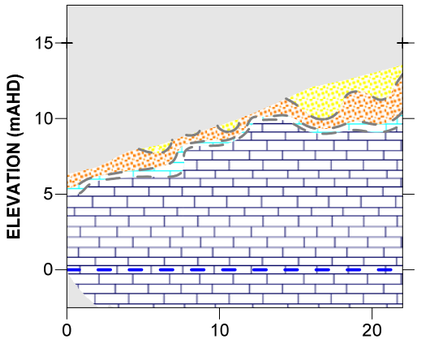
CROSS-SHORE TRANSECT 35
SEISMIC P-WAVE VELOCITY SECTION



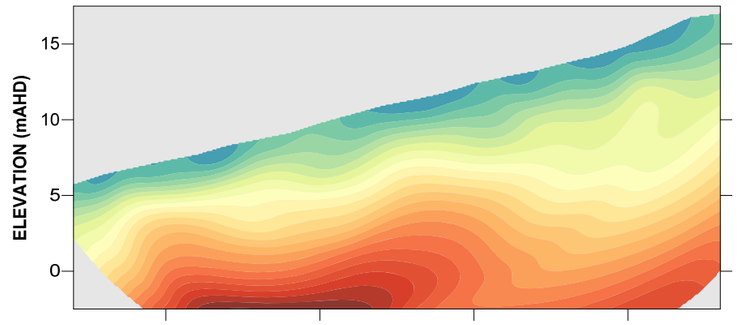
43886.6 E
273759.2 N

INTERPRETED SECTION

43906.3 E
273755.2 N



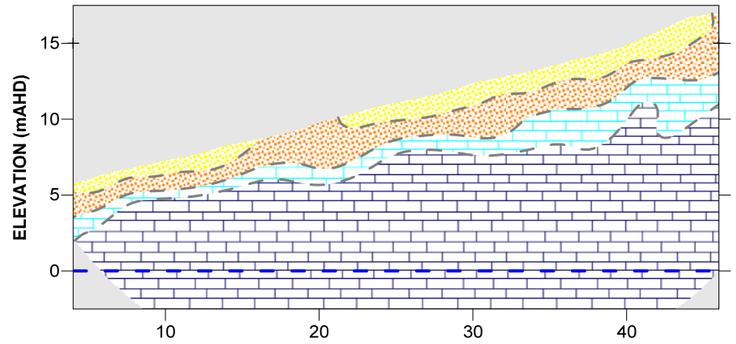
CROSS-SHORE TRANSECT 36
SEISMIC P-WAVE VELOCITY SECTION



43855.2 E
274106.9 N

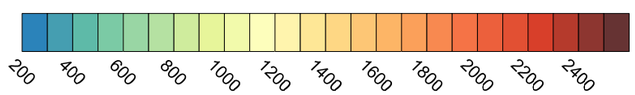
INTERPRETED SECTION

43893.7 E
274096.0 N



LEGEND

- SAND - LOW COMPACTION S-WAVE VELOCITY <500 m/s
- SAND - MODERATE COMPACTION S-WAVE VELOCITY 500-800 m/s
- LIMESTONE - INTERPRETTED LOW TO MODERATE ROCK STRENGTH, S-WAVE VELOCITY 800-1000 m/s.
- LIMESTONE - INTERPRETED MODERATE ROCK STRENGTH, S-WAVE VELOCITY > 1000 m/s.
- MEAN SEA-LEVEL (0mAHD)



SEISMIC P-WAVE VELOCITY (m/s)

NOTES

Map Projection PCG 94.
Refer to Drawing 70428-A04 and A05 ACQUIRED SEISMIC TRANSECTS (SHEETS 4 and 5) for positioning.
Drawing to be used in conjunction with Report 70428.

CLIENT	CITY OF STIRLING	Date	27 June 2018	Paper Size	A3
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		Drawing	70428-B18	Revision	0

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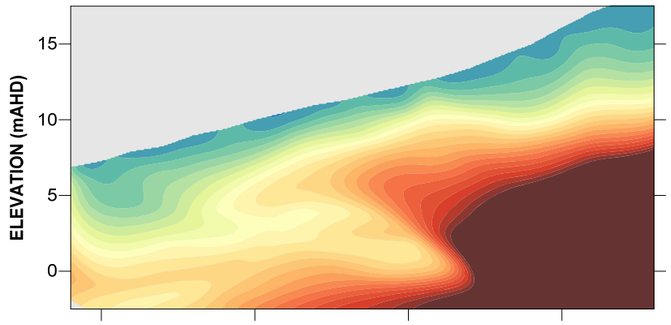
COASTAL MANAGEMENT PLAN - GEOPHYSICAL INVESTIGATION TO DETERMINE ROCK PROFILE

CROSS-SHORE TRANSECT 37 AND 38

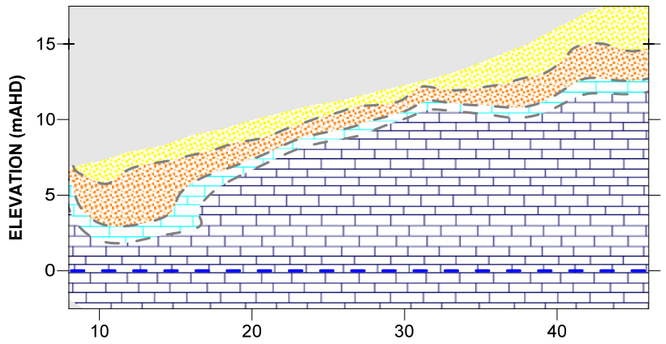
CROSS-SHORE TRANSECT 37
SEISMIC P-WAVE VELOCITY SECTION



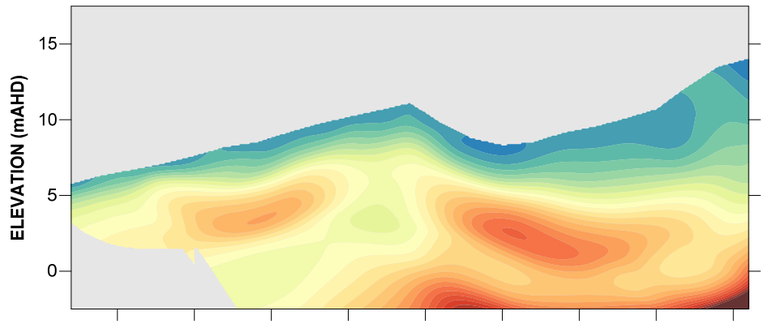
43875.5 E
274147.8 N

INTERPRETED SECTION

43910.6 E
274140.9 N



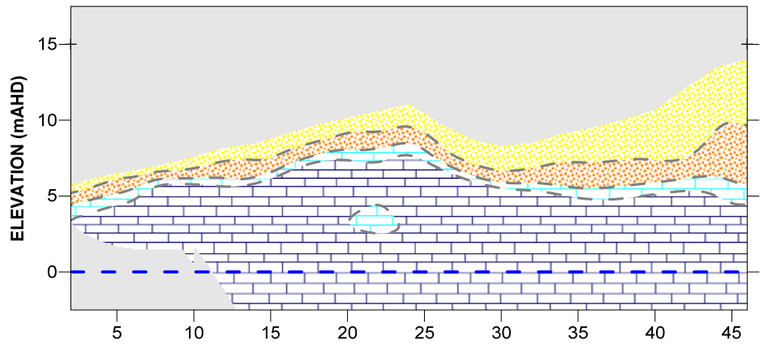
CROSS-SHORE TRANSECT 38
SEISMIC P-WAVE VELOCITY SECTION



43871.9 E
274199.1 N

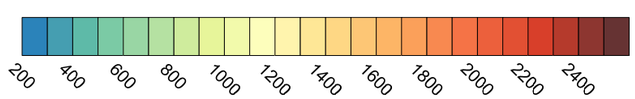
INTERPRETED SECTION

43913.6 E
274194.8 N



LEGEND

- SAND - LOW COMPACTION S-WAVE VELOCITY <500 m/s
- SAND - MODERATE COMPACTION S-WAVE VELOCITY 500-800 m/s
- LIMESTONE - INTERPRETTED LOW TO MODERATE ROCK STRENGTH, S-WAVE VELOCITY 800-1000 m/s.
- LIMESTONE - INTERPRETED MODERATE ROCK STRENGTH, S-WAVE VELOCITY > 1000 m/s.
- MEAN SEA-LEVEL (0mAHD)



NOTES

Map Projection PCG 94.
Refer to Drawing 70428-A05 ACQUIRED SEISMIC TRANSECTS (SHEET 5) for positioning.
Drawing to be used in conjunction with Report 70428.

CLIENT	CITY OF STIRLING	Date	27 June 2018	Paper Size	A3
COASTAL MANAGEMENT PLAN GEOPHYSICAL INVESTIGATION TO DETERMINE BEDROCK PROFILE		Scale	1:400	Drawn	PEC
		Drawing	70428-B19	Revision	0

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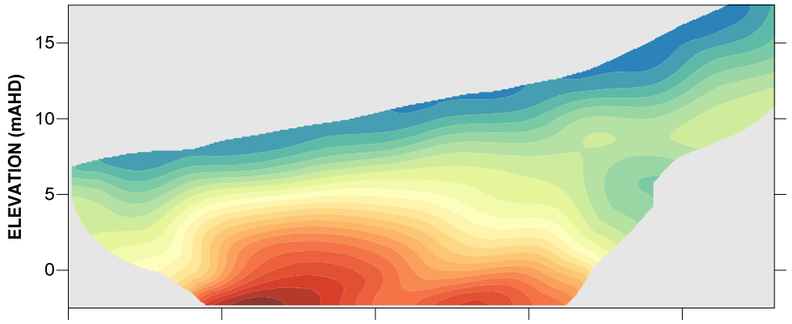
COASTAL MANAGEMENT PLAN - GEOPHYSICAL INVESTIGATION TO DETERMINE ROCK PROFILE

CROSS-SHORE TRANSECT 39 AND 40

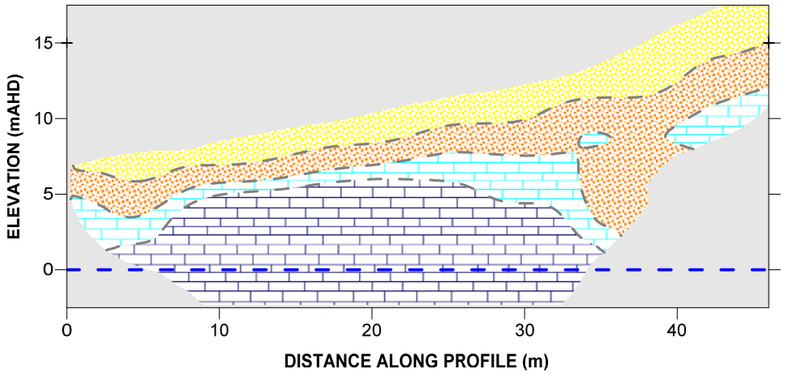
CROSS-SHORE TRANSECT 39
SEISMIC P-WAVE VELOCITY SECTION



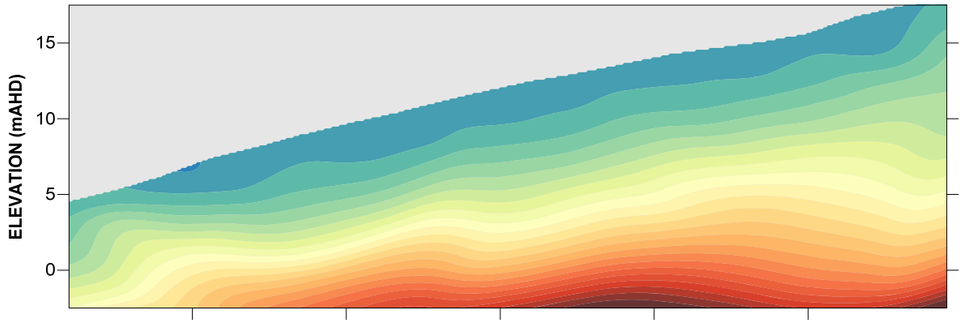
43870.4 E
274225.1 N

43913.5 E
274214.5 N

INTERPRETED SECTION



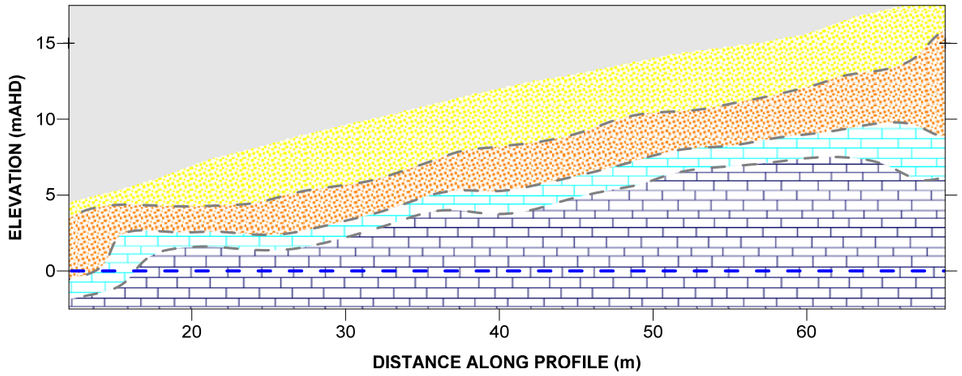
CROSS-SHORE TRANSECT 40
SEISMIC P-WAVE VELOCITY SECTION



43861.1 E
274259.6 N

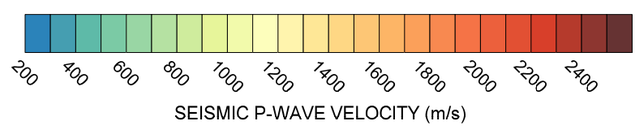
43913.7 E
274275.2 N

INTERPRETED SECTION



LEGEND

- SAND - LOW COMPACTION S-WAVE VELOCITY <500 m/s
- SAND - MODERATE COMPACTION S-WAVE VELOCITY 500-800 m/s
- LIMESTONE - INTERPRETTED LOW TO MODERATE ROCK STRENGTH, S-WAVE VELOCITY 800-1000 m/s.
- LIMESTONE - INTERPRETED MODERATE ROCK STRENGTH, S-WAVE VELOCITY > 1000 m/s.
- MEAN SEA-LEVEL (0mAHD)



NOTES

Map Projection PCG 94.
Refer to Drawing 70428-A05 ACQUIRED SEISMIC TRANSECTS (SHEET 5) for positioning.
Drawing to be used in conjunction with Report 70428.

CLIENT	CITY OF STIRLING	Date	27 June 2018	Paper Size	A3
		Scale	1:400	Drawn	PEC
	COASTAL MANAGEMENT PLAN GEOPHYSICAL INVESTIGATION TO DETERMINE BEDROCK PROFILE	Drawing	70428-B20	Revision	0

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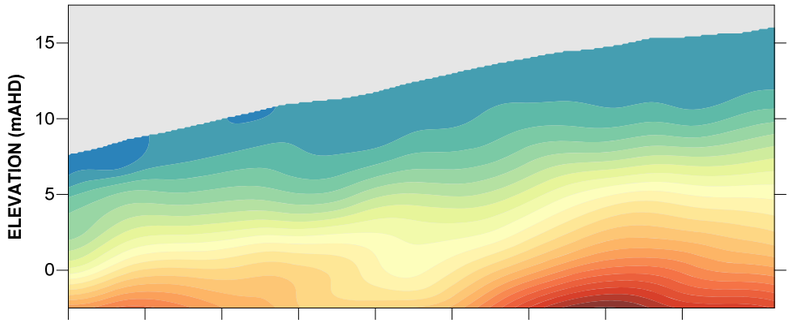
COASTAL MANAGEMENT PLAN - GEOPHYSICAL INVESTIGATION TO DETERMINE ROCK PROFILE

CROSS-SHORE TRANSECT 41 AND 42

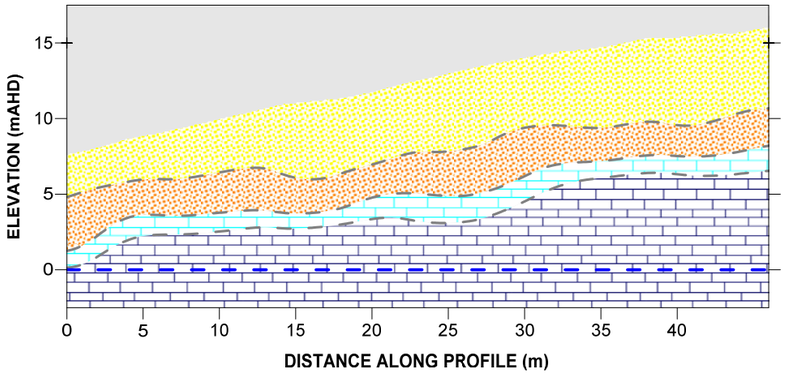
CROSS-SHORE TRANSECT 41
SEISMIC P-WAVE VELOCITY SECTION



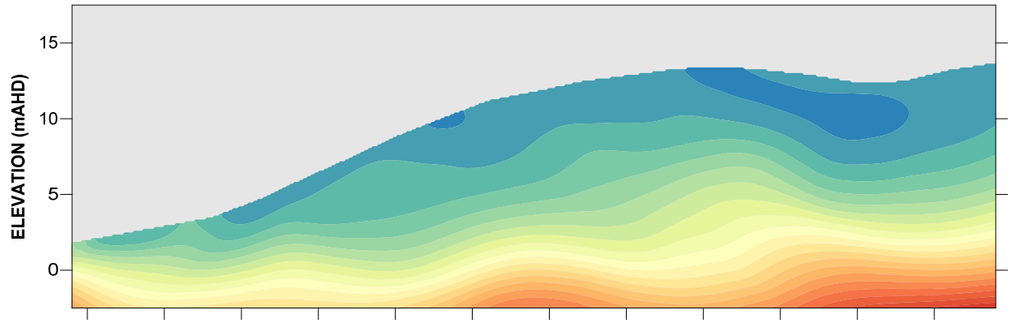
43869.3 E
274299.6 N

43913.3 E
274300.3 N

INTERPRETED SECTION



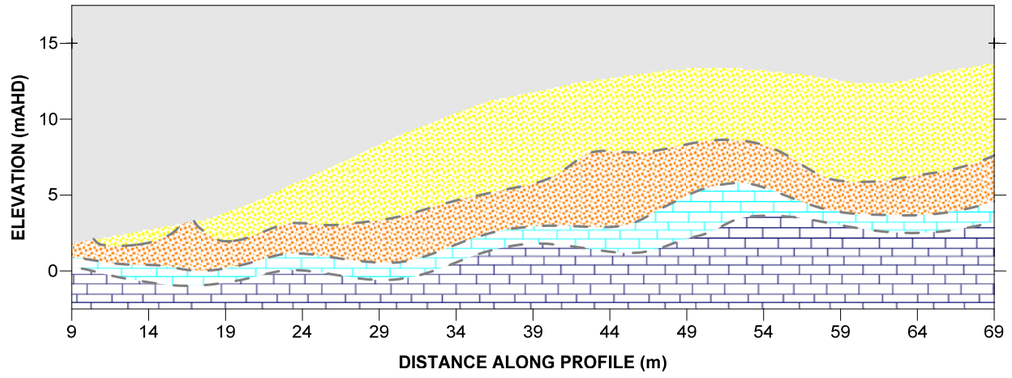
CROSS-SHORE TRANSECT 42
SEISMIC P-WAVE VELOCITY SECTION



43856.6 E
274354.6 N

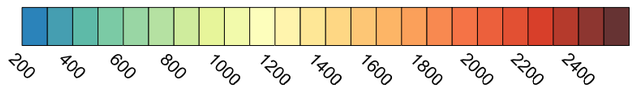
43914.0 E
274355.8 N

INTERPRETED SECTION



LEGEND

- SAND - LOW COMPACTION S-WAVE VELOCITY <500 m/s
- SAND - MODERATE COMPACTION S-WAVE VELOCITY 500-800 m/s
- LIMESTONE - INTERPRETTED LOW TO MODERATE ROCK STRENGTH, S-WAVE VELOCITY 800-1000 m/s.
- LIMESTONE - INTERPRETED MODERATE ROCK STRENGTH, S-WAVE VELOCITY > 1000 m/s.
- MEAN SEA-LEVEL (0mAHD)



NOTES

Map Projection PCG 94.
Refer to Drawing 70428-A05 ACQUIRED SEISMIC TRANSECTS (SHEET 5) for positioning.
Drawing to be used in conjunction with Report 70428.

CLIENT	CITY OF STIRLING	Date	4 July 2018	Paper Size	A3
	COASTAL MANAGEMENT PLAN GEOPHYSICAL INVESTIGATION TO DETERMINE BEDROCK PROFILE	Scale	1:400	Drawn	PEC
		Drawing	70428-B21	Revision	1

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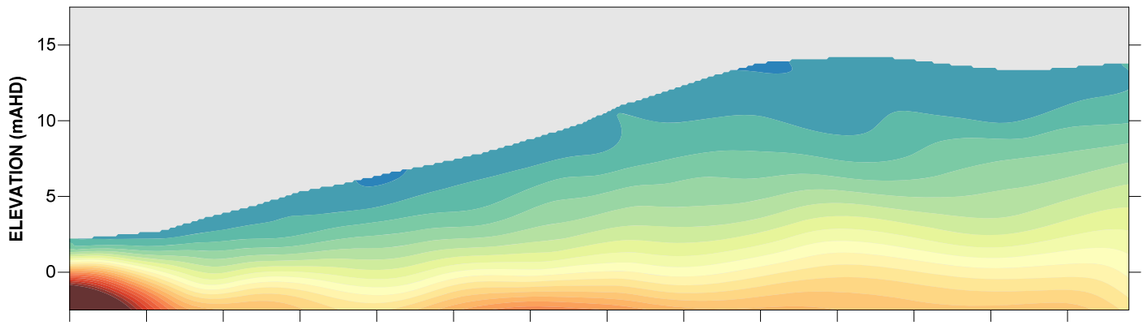
COASTAL MANAGEMENT PLAN - GEOPHYSICAL INVESTIGATION TO DETERMINE ROCK PROFILE

CROSS-SHORE TRANSECT 43 AND 44

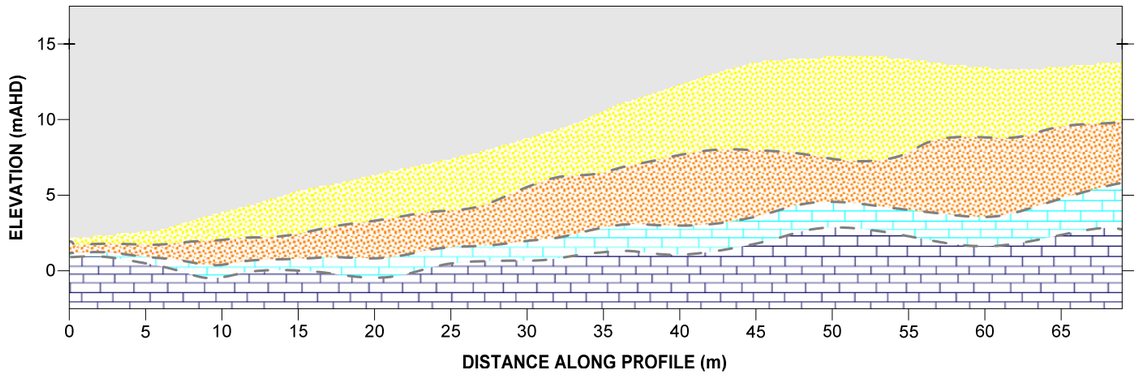
CROSS-SHORE TRANSECT 43
SEISMIC P-WAVE VELOCITY SECTION



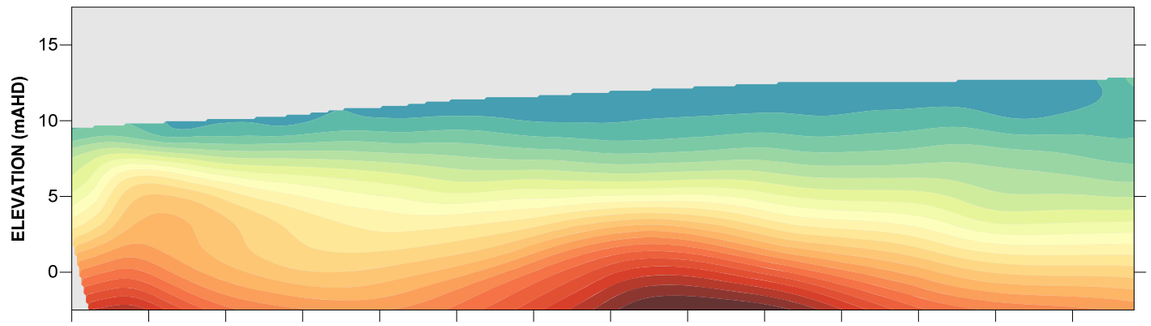
43851.0 E
274384.1 N

43914.1 E
274405.1 N

INTERPRETED SECTION



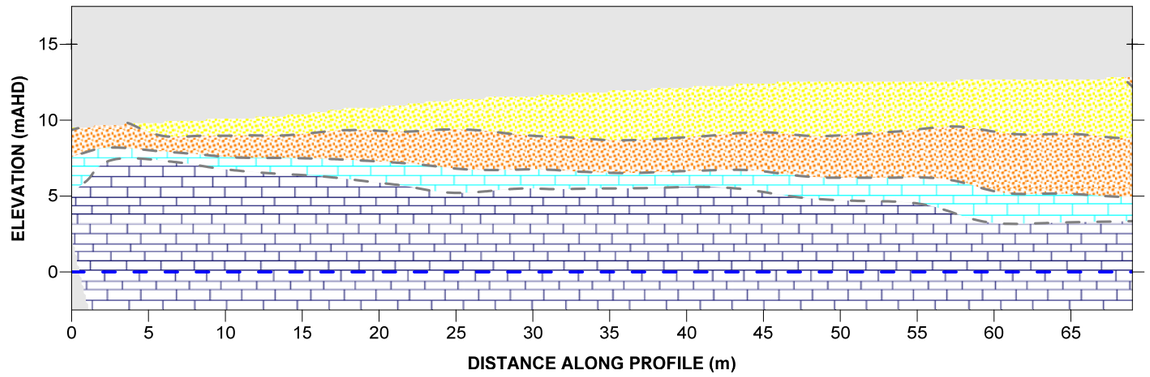
CROSS-SHORE TRANSECT 44
SEISMIC P-WAVE VELOCITY SECTION



43843.3 E
274469.2 N

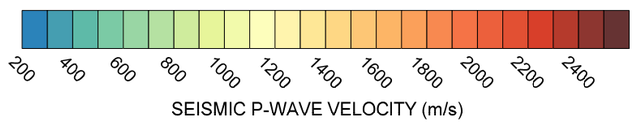
43912.4 E
274470.4 N

INTERPRETED SECTION



LEGEND

- SAND - LOW COMPACTION S-WAVE VELOCITY <500 m/s
- SAND - MODERATE COMPACTION S-WAVE VELOCITY 500-800 m/s
- LIMESTONE - INTERPRETTED LOW TO MODERATE ROCK STRENGTH, S-WAVE VELOCITY 800-1000 m/s.
- LIMESTONE - INTERPRETED MODERATE ROCK STRENGTH, S-WAVE VELOCITY > 1000 m/s.
- MEAN SEA-LEVEL (0mAHD)



NOTES

Map Projection PCG 94.
Refer to Drawing 70428-A05 ACQUIRED SEISMIC TRANSECTS (SHEET 5) for positioning.
Drawing to be used in conjunction with Report 70428.

CLIENT	CITY OF STIRLING	Date	4 July 2018	Paper Size	A3
	COASTAL MANAGEMENT PLAN GEOPHYSICAL INVESTIGATION TO DETERMINE BEDROCK PROFILE	Scale	1:400	Drawn	PEC
		Drawing	70428-B22	Revision	1

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APPENDIX C.
GEOPHYSICAL AND INTERPRETED ALONG-SHORE SECTIONS (MASW)

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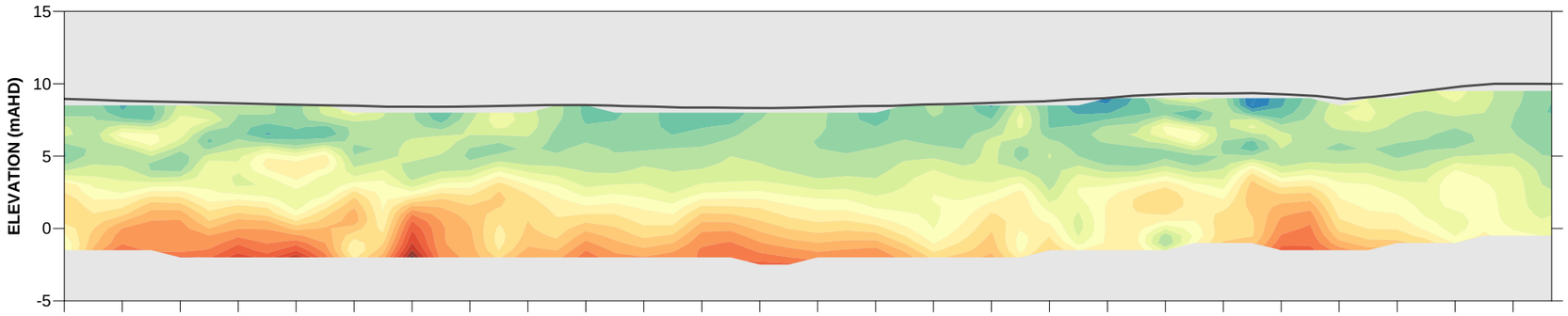
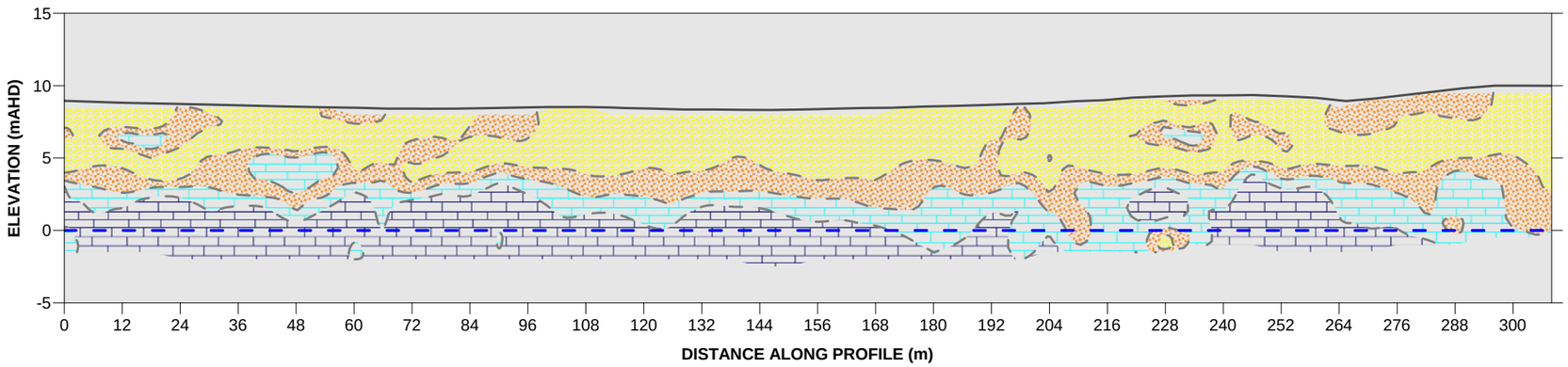
COASTAL MANAGEMENT PLAN - GEOPHYSICAL INVESTIGATION TO DETERMINE ROCK PROFILE

ALONG-SHORE TRANSECT 1

ALONG-SHORE TRANSECT 1
SEISMIC S-WAVE VELOCITY SECTION

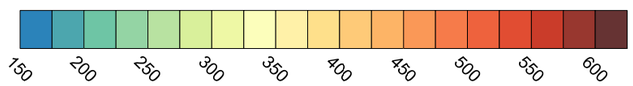


ALONG-SHORE TRANSECT 1
INTERPRETED SECTION



LEGEND

- SAND - LOW COMPACTION S-WAVE VELOCITY < 275 m/s
- SAND - MODERATE COMPACTION S-WAVE VELOCITY 275-350 m/s
- LIMESTONE - INTERPRETTED LOW TO MODERATE ROCK STRENGTH, S-WAVE VELOCITY 350-400 m/s.
- LIMESTONE - INTERPRETED MODERATE ROCK STRENGTH, S-WAVE VELOCITY > 400 m/s.
- MEAN SEA-LEVEL (0mAHD)



NOTES

Map Projection PCG 94.
Refer to Drawing 70428-A01 ACQUIRED SEISMIC TRANSECTS (SHEET 1) for positioning.
Drawing to be used in conjunction with Report 70428.

CLIENT	CITY OF STIRLING	Date	27 June 2018	Paper Size	A3
COASTAL MANAGEMENT PLAN GEOPHYSICAL INVESTIGATION TO DETERMINE BEDROCK PROFILE		Scale	1:400 Ver, 1:1200 Hor	Drawn	TAL
		Drawing	70428-C01	Revision	0

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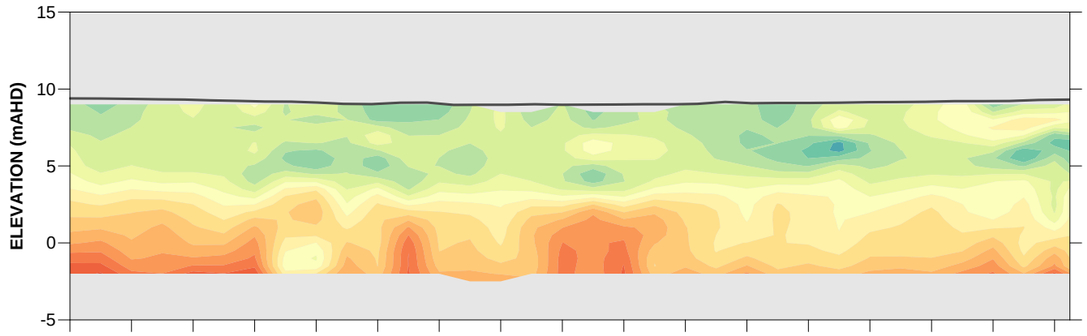
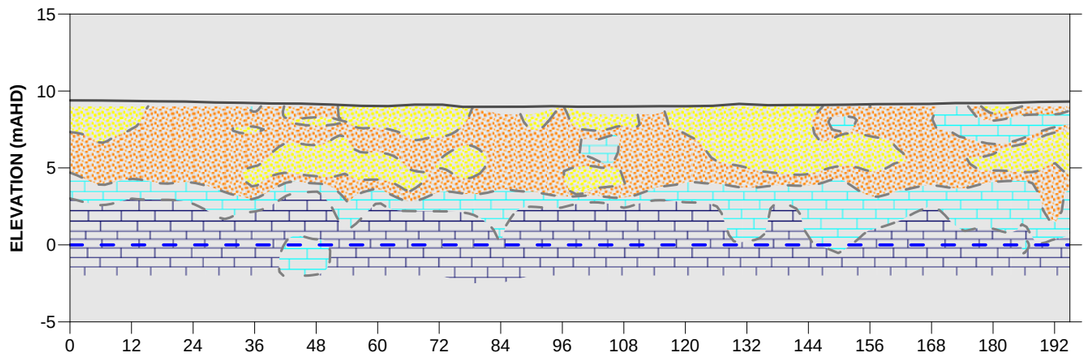
COASTAL MANAGEMENT PLAN - GEOPHYSICAL INVESTIGATION TO DETERMINE ROCK PROFILE

ALONG-SHORE TRANSECT 2

ALONG-SHORE TRANSECT 2
SEISMIC S-WAVE VELOCITY SECTION

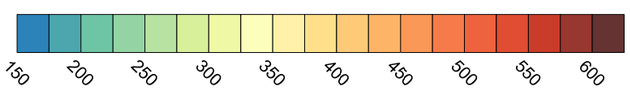


ALONG-SHORE TRANSECT 2
INTERPRETED SECTION



LEGEND

- SAND - LOW COMPACTION S-WAVE VELOCITY < 275 m/s
- SAND - MODERATE COMPACTION S-WAVE VELOCITY 275-350 m/s
- LIMESTONE - INTERPRETTED LOW TO MODERATE ROCK STRENGTH, S-WAVE VELOCITY 350-400 m/s.
- LIMESTONE - INTERPRETED MODERATE ROCK STRENGTH, S-WAVE VELOCITY > 400 m/s.
- MEAN SEA-LEVEL (0mAHD)



NOTES
Map Projection PCG 94.
Refer to Drawing 70428-A01 ACQUIRED SEISMIC TRANSECTS (SHEET 1) for positioning.
Drawing to be used in conjunction with Report 70428.

CLIENT	CITY OF STIRLING	Date	27 June 2018	Paper Size	A3
COASTAL MANAGEMENT PLAN GEOPHYSICAL INVESTIGATION TO DETERMINE BEDROCK PROFILE		Scale	1:400 Ver, 1:1200 Hor	Drawn	TAL
		Drawing	70428-C02	Revision	0

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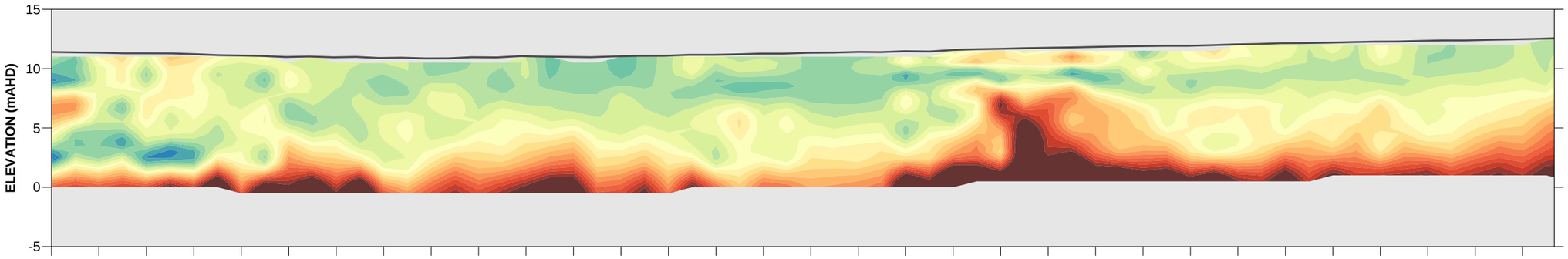
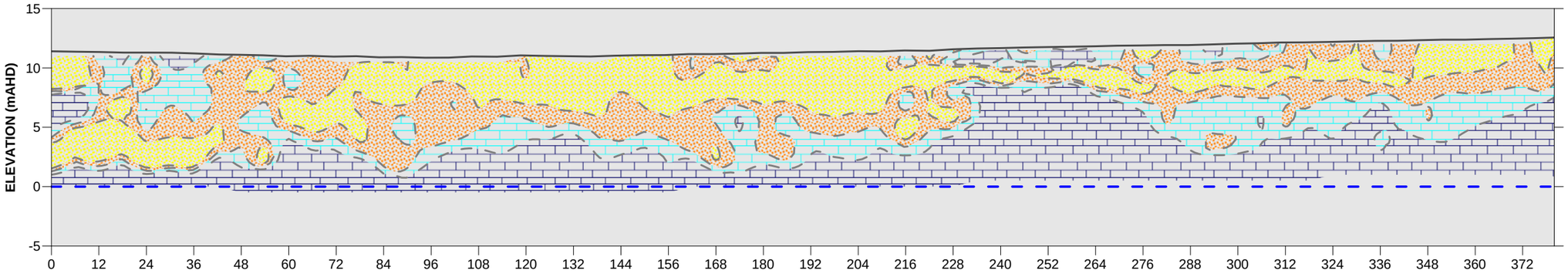
COASTAL MANAGEMENT PLAN - GEOPHYSICAL INVESTIGATION TO DETERMINE ROCK PROFILE

ALONG-SHORE TRANSECT 3

ALONG-SHORE TRANSECT 3
SEISMIC S-WAVE VELOCITY SECTION

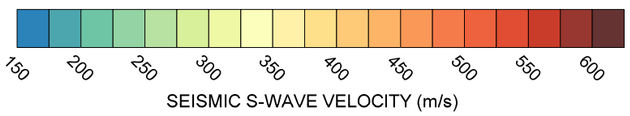


ALONG-SHORE TRANSECT 3
INTERPRETED SECTION



LEGEND

- SAND - LOW COMPACTION, S-WAVE VELOCITY < 275 m/s
- SAND - MODERATE COMPACTION, S-WAVE VELOCITY 275-350 m/s
- LIMESTONE - INTERPRETTED LOW TO MODERATE ROCK STRENGTH, S-WAVE VELOCITY 350-400 m/s.
- LIMESTONE - INTERPRETED MODERATE ROCK STRENGTH, S-WAVE VELOCITY > 400 m/s.
- MEAN SEA-LEVEL (0mAHD)



NOTES

Map Projection PCG 94.
Refer to Drawing 70428-A01 ACQUIRED SEISMIC TRANSECTS (SHEET 1) for positioning.
Drawing to be used in conjunction with Report 70428.

CLIENT	CITY OF STIRLING	Date	27 June 2018	Paper Size	A3
COASTAL MANAGEMENT PLAN GEOPHYSICAL INVESTIGATION TO DETERMINE BEDROCK PROFILE		Scale	1:400 Ver, 1:1200 Hor	Drawn	TAL
		Drawing	70428-C03	Revision	0

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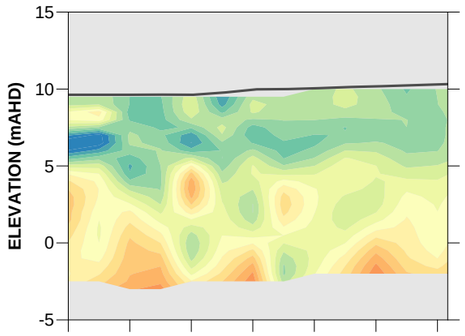
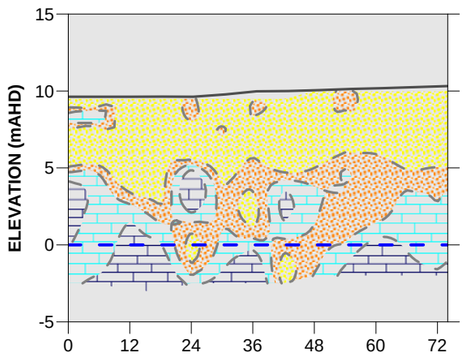
COASTAL MANAGEMENT PLAN - GEOPHYSICAL INVESTIGATION TO DETERMINE ROCK PROFILE

ALONG-SHORE TRANSECT 4

ALONG-SHORE TRANSECT 4
SEISMIC S-WAVE VELOCITY SECTION



ALONG-SHORE TRANSECT 4
INTERPRETED SECTION

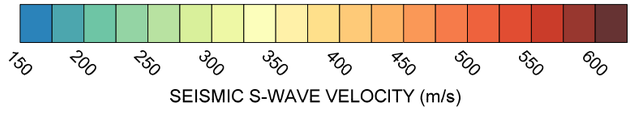


43914.9E
271733.6N

43898.1E
271805.5N

LEGEND

- SAND - LOW COMPACTION S-WAVE VELOCITY < 275 m/s
- SAND - MODERATE COMPACTION S-WAVE VELOCITY 275-350 m/s
- LIMESTONE - INTERPRETTED LOW TO MODERATE ROCK STRENGTH, S-WAVE VELOCITY 350-400 m/s.
- LIMESTONE - INTERPRETED MODERATE ROCK STRENGTH, S-WAVE VELOCITY > 400 m/s.
- MEAN SEA-LEVEL (0mAHD)



NOTES

Map Projection PCG 94.
Refer to Drawing 70428-A01 ACQUIRED SEISMIC TRANSECTS (SHEET 1) for positioning.
Drawing to be used in conjunction with Report 70428.

CLIENT	CITY OF STIRLING	Date	27 June 2018	Paper Size	A3
COASTAL MANAGEMENT PLAN GEOPHYSICAL INVESTIGATION TO DETERMINE BEDROCK PROFILE		Scale	1:400 Ver, 1:1200 Hor	Drawn	TAL
		Drawing	70428-C04	Revision	0

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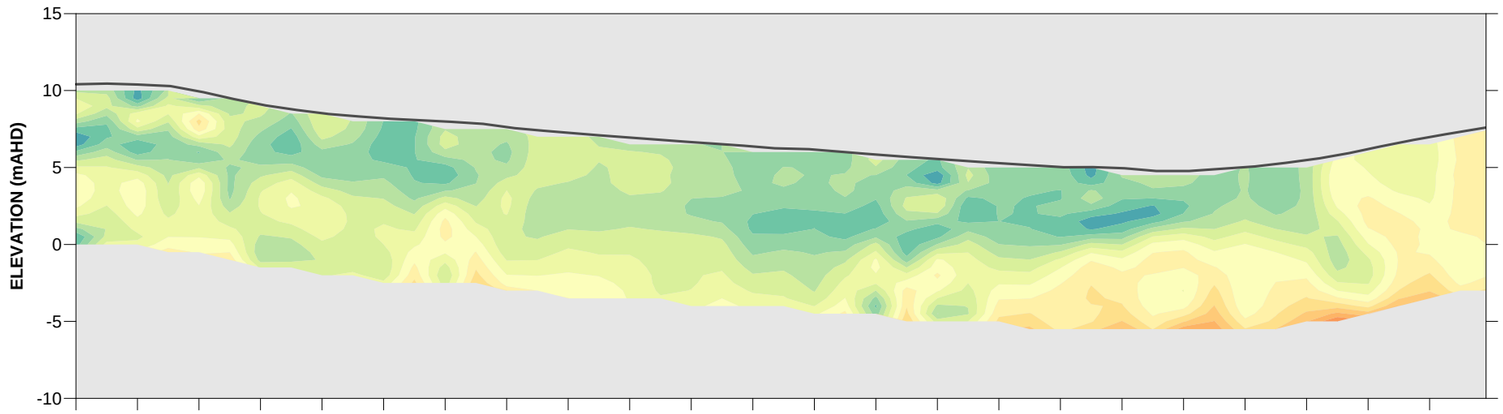
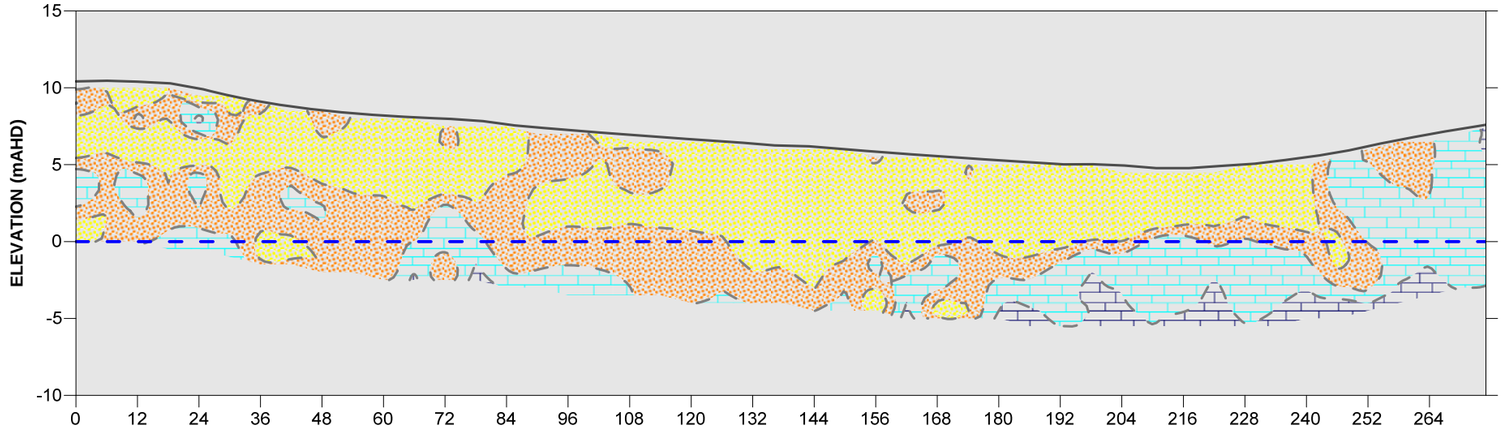
COASTAL MANAGEMENT PLAN - GEOPHYSICAL INVESTIGATION TO DETERMINE ROCK PROFILE

ALONG-SHORE TRANSECT 5

ALONG-SHORE TRANSECT 5
SEISMIC S-WAVE VELOCITY SECTION

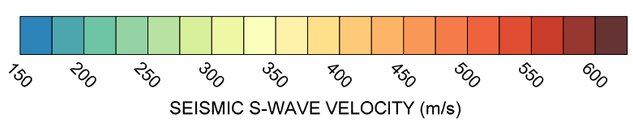


ALONG-SHORE TRANSECT 5
INTERPRETED SECTION



LEGEND

- SAND - LOW COMPACTION S-WAVE VELOCITY < 275 m/s
- SAND - MODERATE COMPACTION S-WAVE VELOCITY 275-350 m/s
- LIMESTONE - INTERPRETTED LOW TO MODERATE ROCK STRENGTH, S-WAVE VELOCITY 350-400 m/s.
- LIMESTONE - INTERPRETED MODERATE ROCK STRENGTH, S-WAVE VELOCITY > 400 m/s.
- MEAN SEA-LEVEL (0mAHD)



NOTES

Map Projection PCG 94.
Refer to Drawing 70428-A01 ACQUIRED SEISMIC TRANSECTS (SHEET 1) for positioning.
Drawing to be used in conjunction with Report 70428.

CLIENT	CITY OF STIRLING	Date	27 June 2018	Paper Size	A3
COASTAL MANAGEMENT PLAN GEOPHYSICAL INVESTIGATION TO DETERMINE BEDROCK PROFILE		Scale	1:400 Ver, 1:1200 Hor	Drawn	TAL
		Drawing	70428-C05	Revision	0

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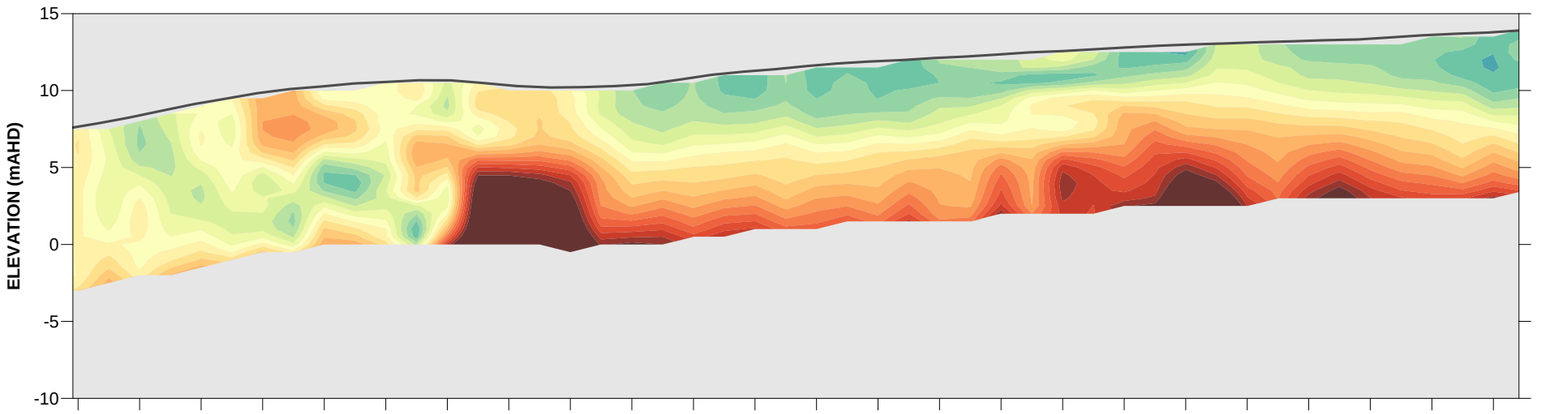
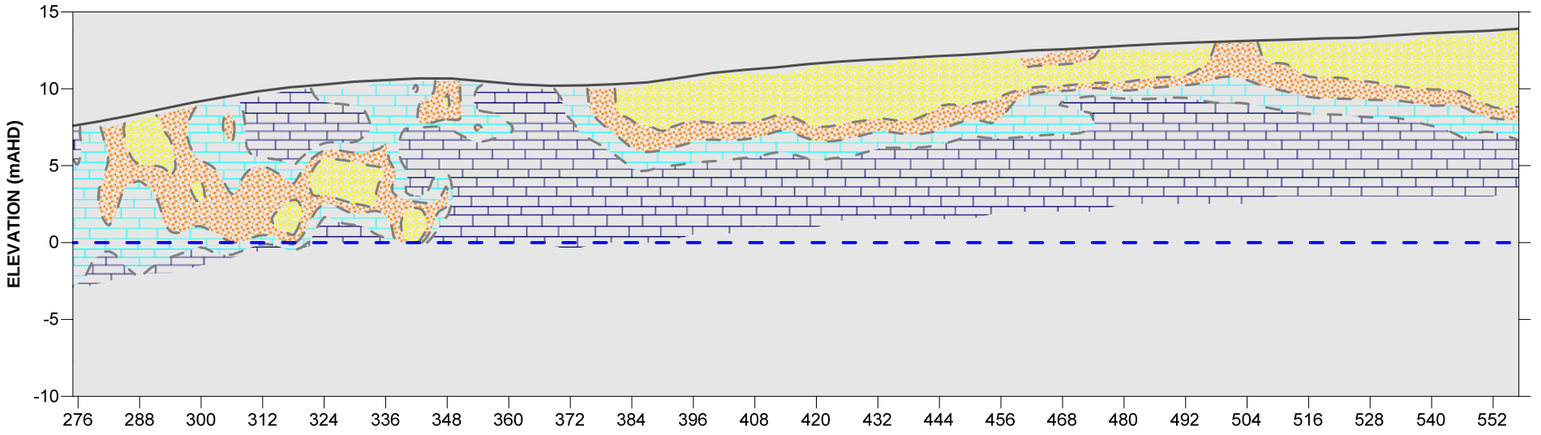
ALONG-SHORE TRANSECT 5 ctn.

ALONG-SHORE TRANSECT 5 ctn.
SEISMIC S-WAVE VELOCITY SECTION

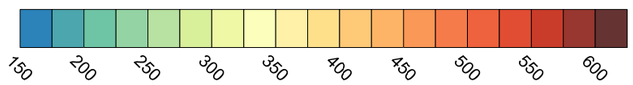


ALONG-SHORE TRANSECT 5 ctn.
INTERPRETED SECTION



LEGEND

- SAND - LOW COMPACTION, S-WAVE VELOCITY < 275 m/s
- SAND - MODERATE COMPACTION, S-WAVE VELOCITY 275-350 m/s
- LIMESTONE - INTERPRETTED LOW TO MODERATE ROCK STRENGTH, S-WAVE VELOCITY 350-400 m/s.
- LIMESTONE - INTERPRETED MODERATE ROCK STRENGTH, S-WAVE VELOCITY > 400 m/s.
- MEAN SEA-LEVEL (0mAHD)



NOTES

Map Projection PCG 94.
Refer to Drawing 70428-A02 ACQUIRED SEISMIC TRANSECTS (SHEET 2) for positioning.
Drawing to be used in conjunction with Report 70428.

CLIENT	CITY OF STIRLING	Date	27 June 2018	Paper Size	A3
COASTAL MANAGEMENT PLAN GEOPHYSICAL INVESTIGATION TO DETERMINE BEDROCK PROFILE		Scale	1:400 Ver, 1:1200 Hor	Drawn	TAL
		Drawing	70428-C06	Revision	0

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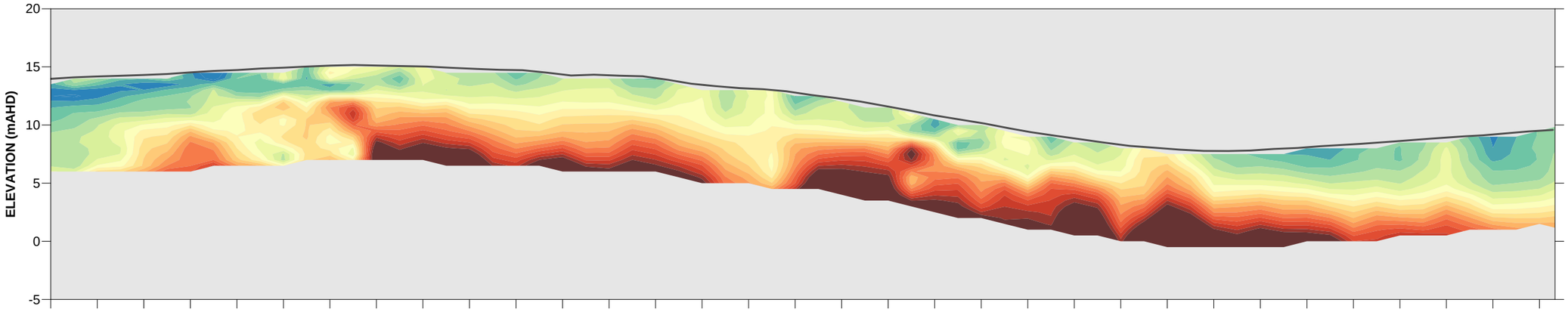
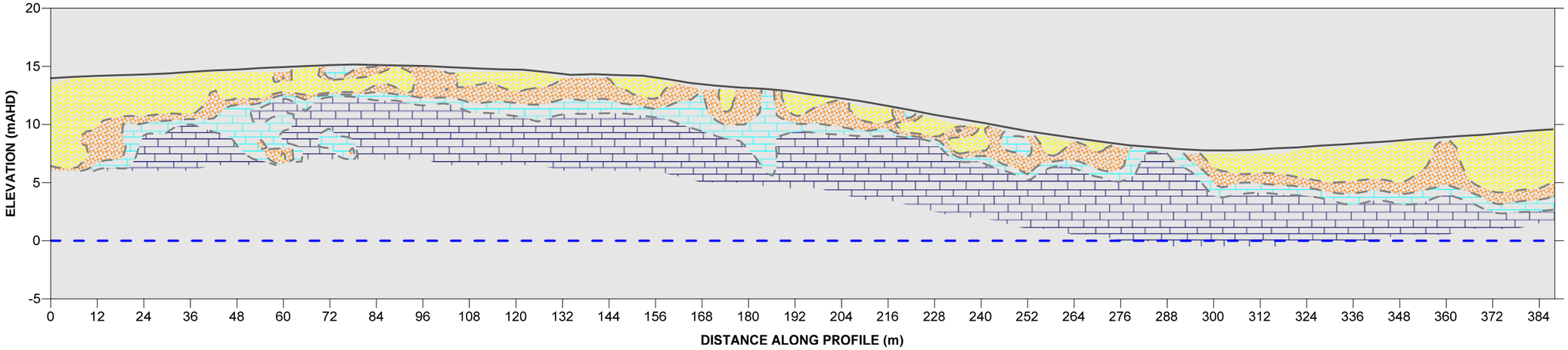
COASTAL MANAGEMENT PLAN - GEOPHYSICAL INVESTIGATION TO DETERMINE ROCK PROFILE

ALONG-SHORE TRANSECT 6

ALONG-SHORE TRANSECT 6
SEISMIC S-WAVE VELOCITY SECTION

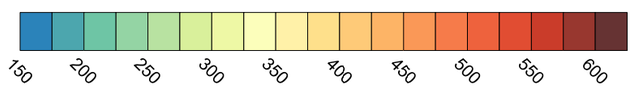


ALONG-SHORE TRANSECT 6
INTERPRETED SECTION



LEGEND

- SAND - LOW COMPACTION S-WAVE VELOCITY < 275 m/s
- SAND - MODERATE COMPACTION S-WAVE VELOCITY 275-350 m/s
- LIMESTONE - INTERPRETTED LOW TO MODERATE ROCK STRENGTH, S-WAVE VELOCITY 350-400 m/s.
- LIMESTONE - INTERPRETED MODERATE ROCK STRENGTH, S-WAVE VELOCITY > 400 m/s.
- MEAN SEA-LEVEL (0mAHD)



NOTES

Map Projection PCG 94.
Refer to Drawing 70428-A02 ACQUIRED SEISMIC TRANSECTS (SHEET 2) for positioning.
Drawing to be used in conjunction with Report 70428.

CLIENT	CITY OF STIRLING	Date	27 June 2018	Paper Size	A3
COASTAL MANAGEMENT PLAN GEOPHYSICAL INVESTIGATION TO DETERMINE BEDROCK PROFILE		Scale	1:400 Ver, 1:1200 Hor	Drawn	TAL
		Drawing	70428-C07	Revision	0

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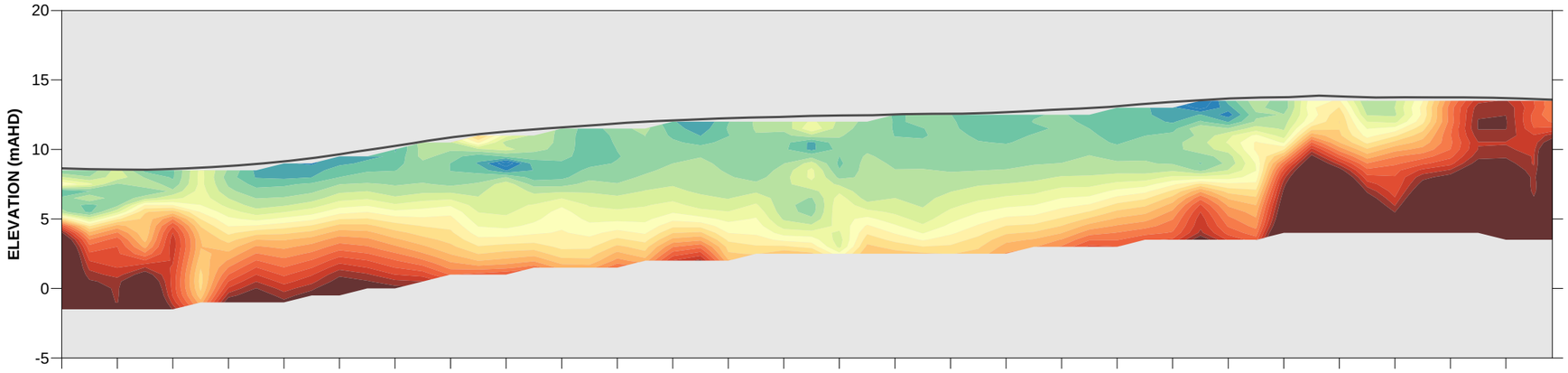
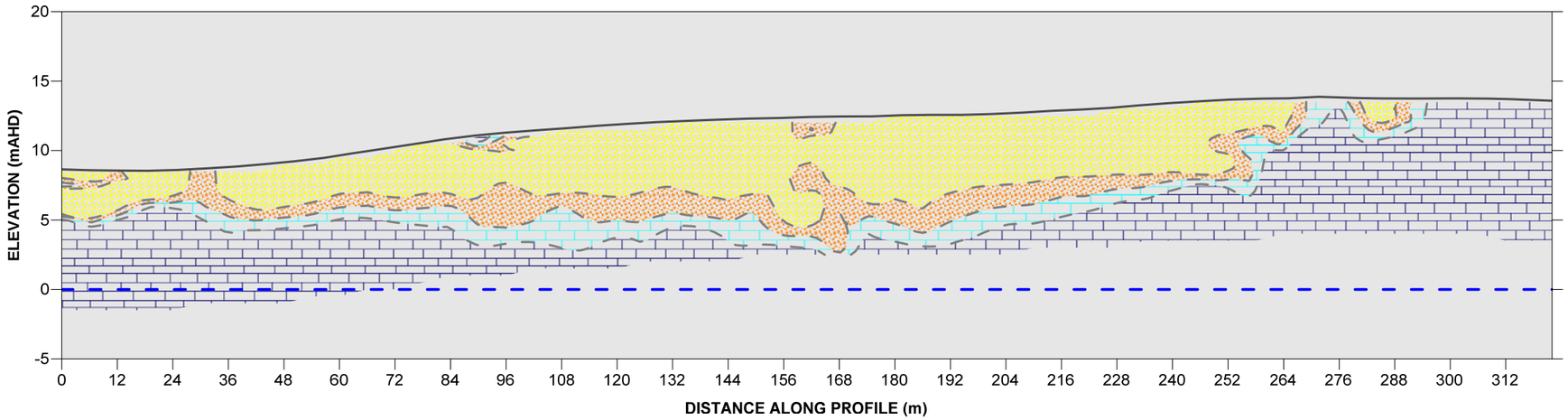
COASTAL MANAGEMENT PLAN - GEOPHYSICAL INVESTIGATION TO DETERMINE ROCK PROFILE

ALONG-SHORE TRANSECT 7

ALONG-SHORE TRANSECT 7
SEISMIC S-WAVE VELOCITY SECTION

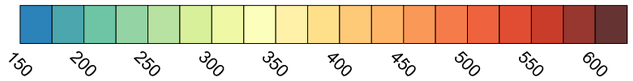


ALONG-SHORE TRANSECT 7
INTERPRETED SECTION



LEGEND

- SAND - LOW COMPACTION S-WAVE VELOCITY < 275 m/s
- SAND - MODERATE COMPACTION S-WAVE VELOCITY 275-350 m/s
- LIMESTONE - INTERPRETTED LOW TO MODERATE ROCK STRENGTH, S-WAVE VELOCITY 350-400 m/s.
- LIMESTONE - INTERPRETED MODERATE ROCK STRENGTH, S-WAVE VELOCITY > 400 m/s.
- MEAN SEA-LEVEL (0mAHD)



NOTES

Map Projection PCG 94.
Refer to Drawing 70428-A04 ACQUIRED SEISMIC TRANSECTS (SHEET 4) for positioning.
Drawing to be used in conjunction with Report 70428.

CLIENT	CITY OF STIRLING	Date	27 June 2018	Paper Size	A3
COASTAL MANAGEMENT PLAN GEOPHYSICAL INVESTIGATION TO DETERMINE BEDROCK PROFILE		Scale	1:400 Ver, 1:1200 Hor	Drawn	TAL
		Drawing	70428-C08	Revision	0

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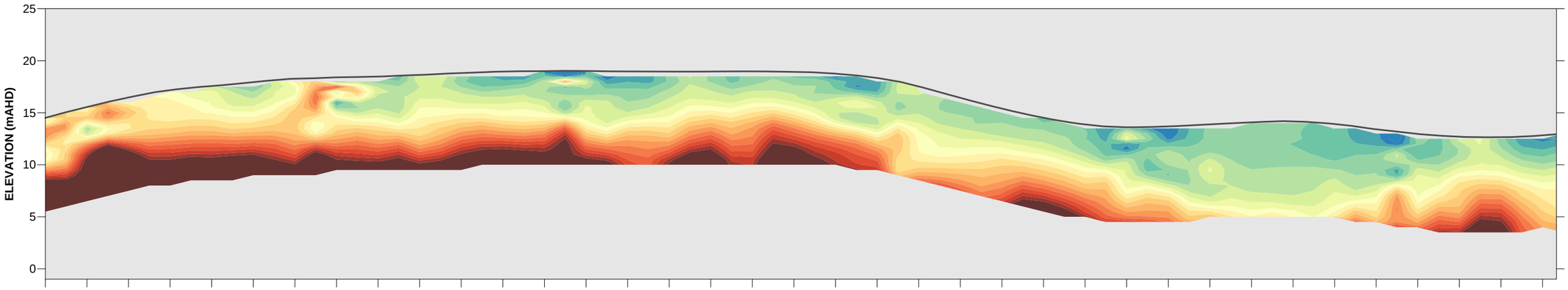
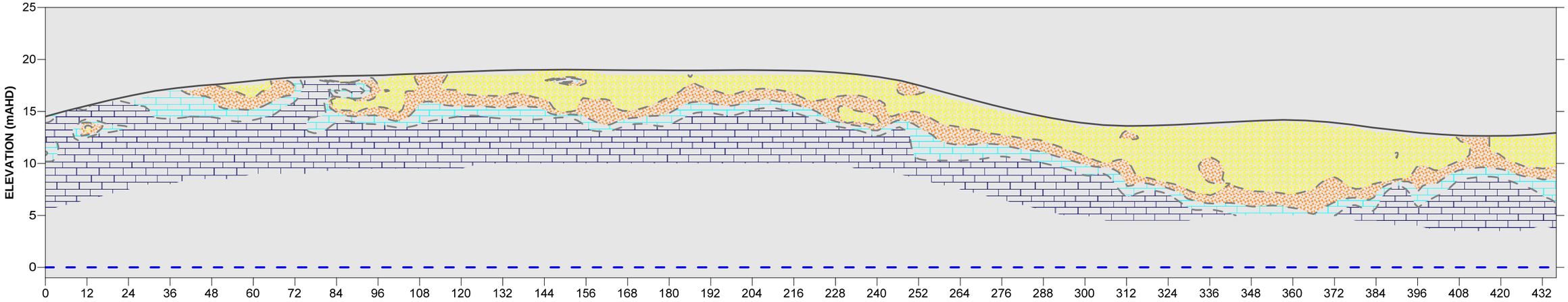
ALONG-SHORE TRANSECT 8

ALONG-SHORE TRANSECT 8
SEISMIC S-WAVE VELOCITY SECTION

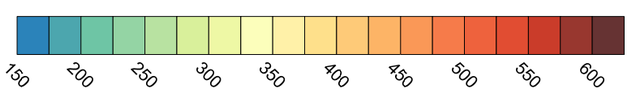


ALONG-SHORE TRANSECT 8
INTERPRETED SECTION



LEGEND

- SAND - LOW COMPACTION S-WAVE VELOCITY < 275 m/s
- SAND - MODERATE COMPACTION S-WAVE VELOCITY 275-350 m/s
- LIMESTONE - INTERPRETTED LOW TO MODERATE ROCK STRENGTH, S-WAVE VELOCITY 350-400 m/s.
- LIMESTONE - INTERPRETED MODERATE ROCK STRENGTH, S-WAVE VELOCITY > 400 m/s.
- MEAN SEA-LEVEL (0mAHD)



NOTES

Map Projection PCG 94.
Refer to Drawing 70428-A05 ACQUIRED SEISMIC TRANSECTS (SHEET 5) for positioning.
Drawing to be used in conjunction with Report 70428.

CLIENT	CITY OF STIRLING	Date	27 June 2018	Paper Size	A3
COASTAL MANAGEMENT PLAN GEOPHYSICAL INVESTIGATION TO DETERMINE BEDROCK PROFILE		Scale	1:400 Ver, 1:1200 Hor	Drawn	TAL
		Drawing	70428-C09	Revision	0

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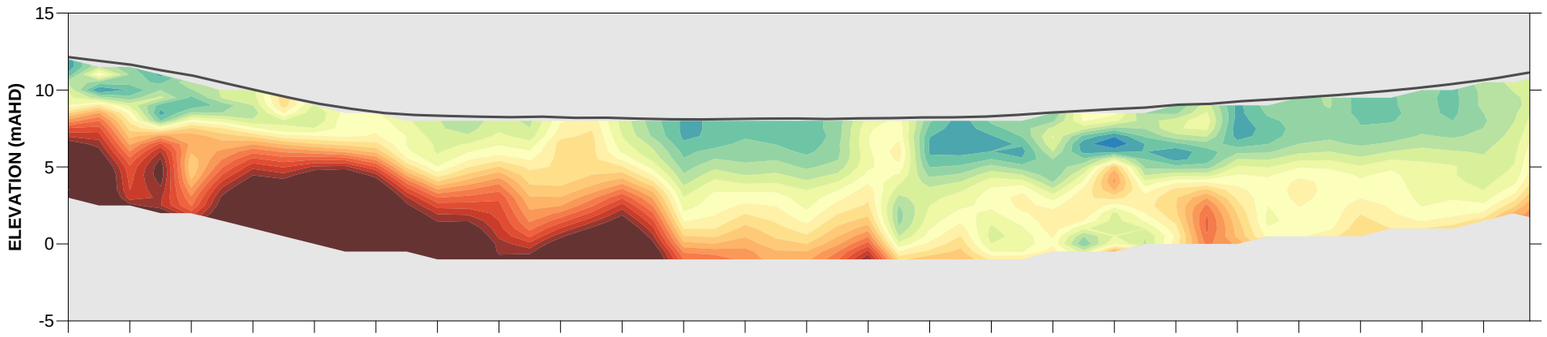
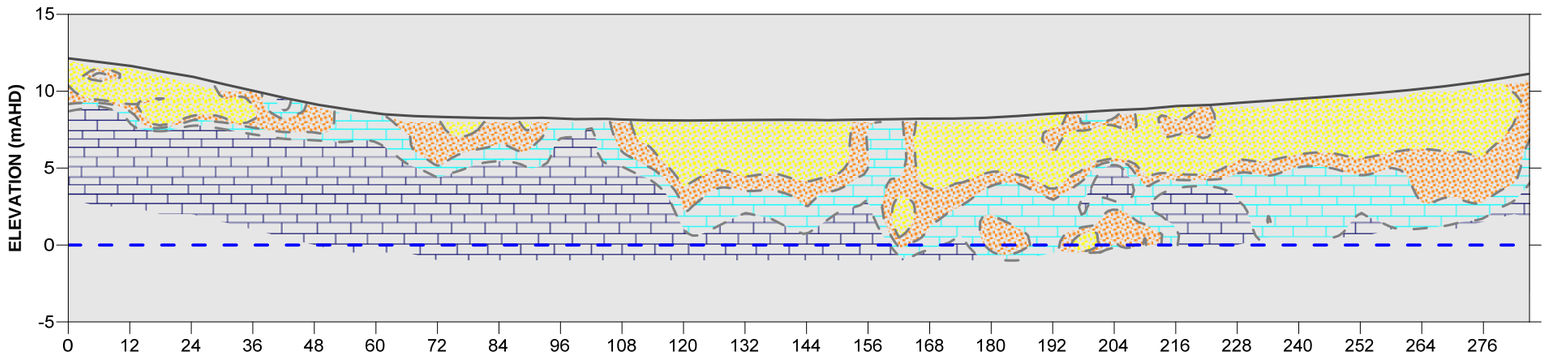
ALONG-SHORE TRANSECT 9

ALONG-SHORE TRANSECT 9
SEISMIC S-WAVE VELOCITY SECTION



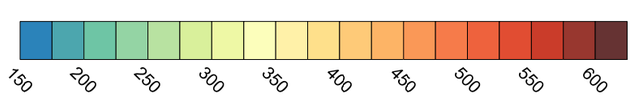
ALONG-SHORE TRANSECT 9
INTERPRETED SECTION



43863.0E	43875.9E	43880.1E	43875.0E	43869.3E	43866.0E
274873.0N	274933.3N	274994.9N	275056.1N	275124.8N	275155.3N

LEGEND

- SAND - LOW COMPACTION S-WAVE VELOCITY < 275 m/s
- SAND - MODERATE COMPACTION S-WAVE VELOCITY 275-350 m/s
- LIMESTONE - INTERPRETTED LOW TO MODERATE ROCK STRENGTH, S-WAVE VELOCITY 350-400 m/s.
- LIMESTONE - INTERPRETED MODERATE ROCK STRENGTH, S-WAVE VELOCITY > 400 m/s.
- MEAN SEA-LEVEL (0mAHD)



NOTES

Map Projection PCG 94.
Refer to Drawing 70428-A06 ACQUIRED SEISMIC TRANSECTS (SHEET 6) for positioning.
Drawing to be used in conjunction with Report 70428.

CLIENT	CITY OF STIRLING	Date	27 June 2018	Paper Size	A3
COASTAL MANAGEMENT PLAN GEOPHYSICAL INVESTIGATION TO DETERMINE BEDROCK PROFILE		Scale	1:400 Ver, 1:1200 Hor	Drawn	TAL
		Drawing	70428-C10	Revision	0

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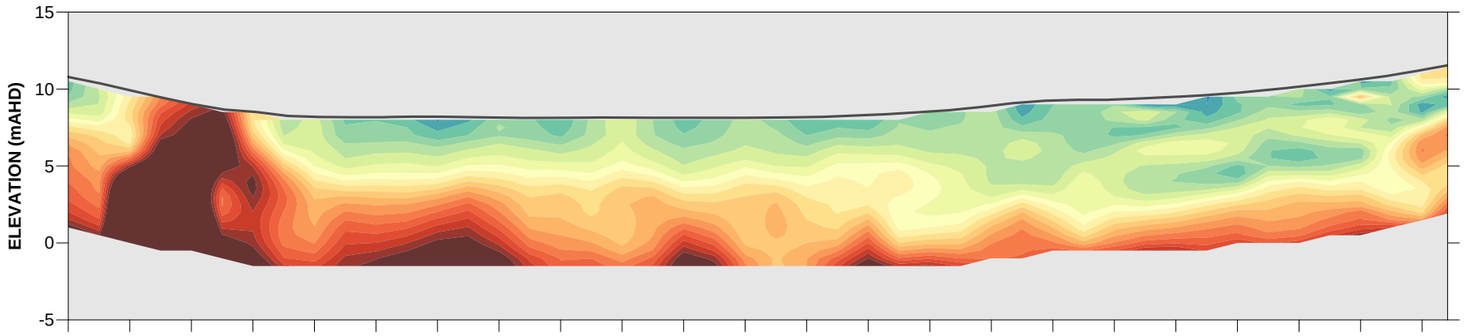
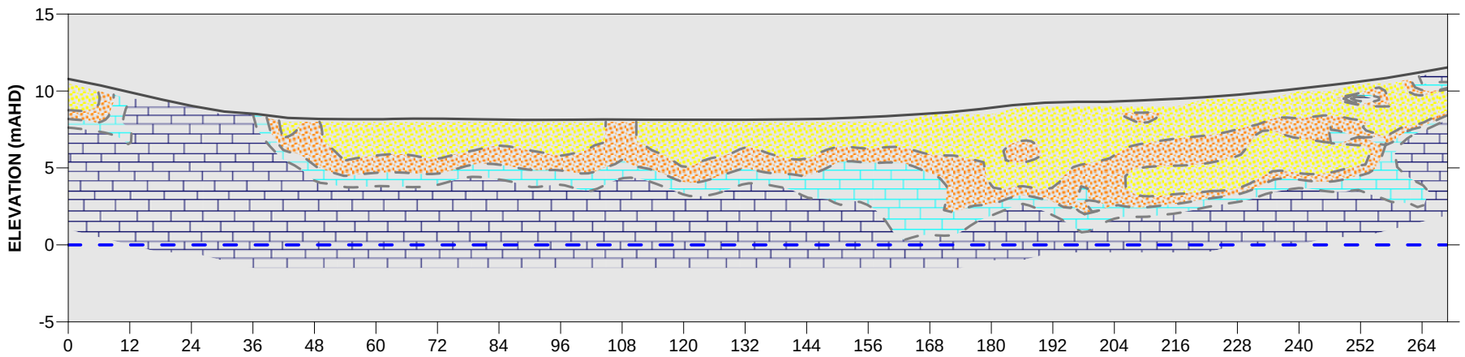
ALONG-SHORE TRANSECT 10

ALONG-SHORE TRANSECT 10
SEISMIC S-WAVE VELOCITY SECTION



ALONG-SHORE TRANSECT 10
INTERPRETED SECTION



LEGEND

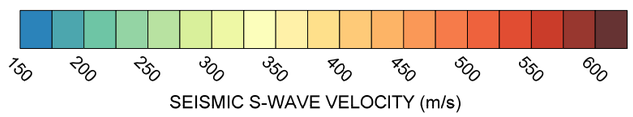
SAND - LOW COMPACTION
S-WAVE VELOCITY < 275 m/s

SAND - MODERATE COMPACTION
S-WAVE VELOCITY 275-350 m/s

LIMESTONE - INTERPRETTED LOW TO MODERATE ROCK STRENGTH, S-WAVE VELOCITY 350-400 m/s.

LIMESTONE - INTERPRETED MODERATE ROCK STRENGTH, S-WAVE VELOCITY > 400 m/s.

MEAN SEA-LEVEL (0mAHD)



NOTES

Map Projection PCG 94.
Refer to Drawing 70428-A06 ACQUIRED SEISMIC TRANSECTS (SHEET 6) for positioning.
Drawing to be used in conjunction with Report 70428.

CLIENT	CITY OF STIRLING	Date	27 June 2018	Paper Size	A3
COASTAL MANAGEMENT PLAN GEOPHYSICAL INVESTIGATION TO DETERMINE BEDROCK PROFILE		Scale	1:400 Ver, 1:1200 Hor	Drawn	TAL
		Drawing	70428-C11	Revision	0

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APPENDIX D.
MODELLED BEDROCK LEVEL CLASSED POST MAPS

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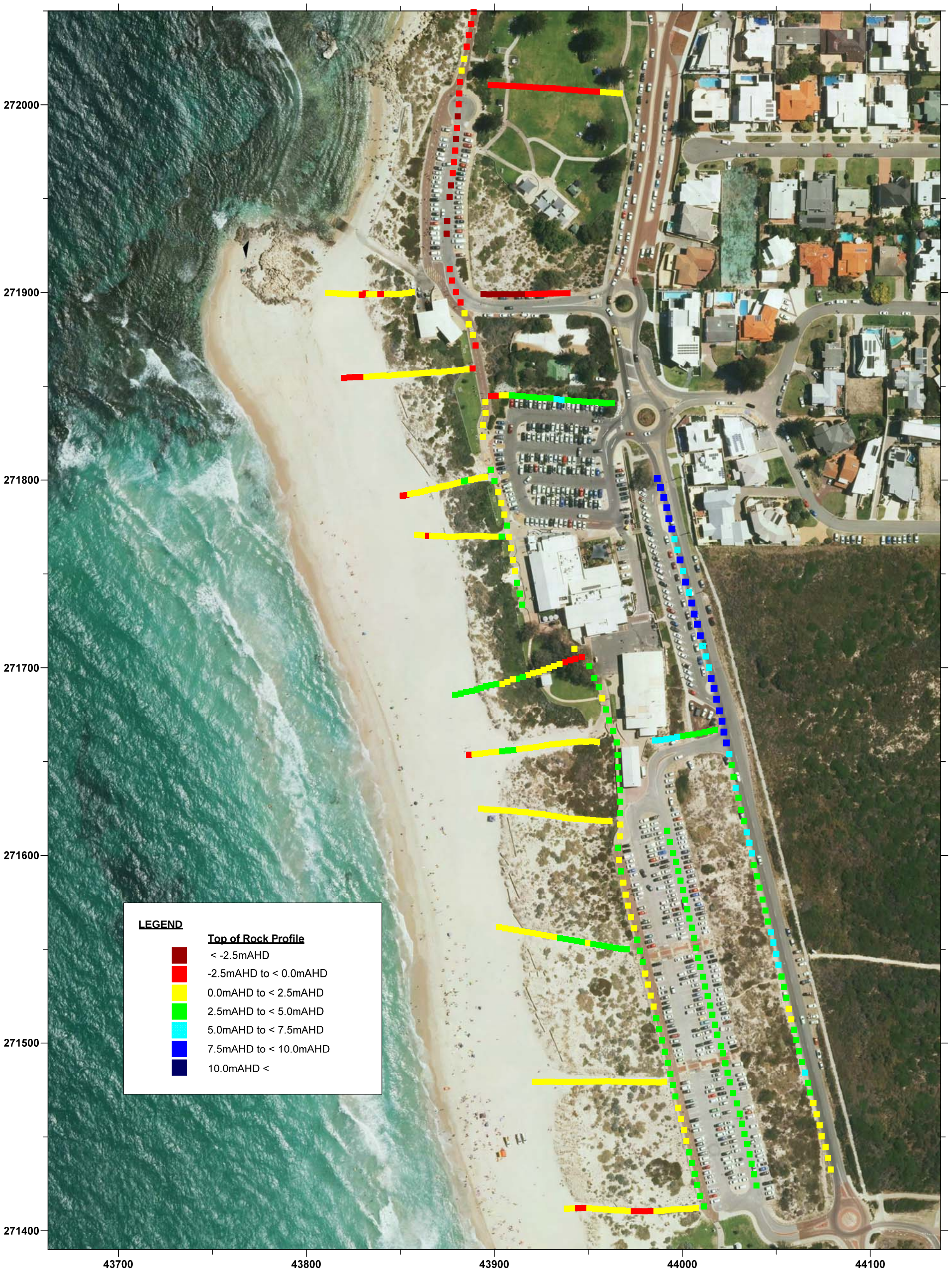
GEOPHYSICAL SUBSURFACE INVESTIGATION TO MAP ROCK PROFILE ALONG COASTLINE

MODELLED LEVELTO TOP OF ROCK - POST MAP



N

0 25 50 75 100
Metres

NOTES

Drawing to be used in conjunction with Report 70428.
Aerial image from Landgate January 2018.
Map Projection: Perth Coastal Grid 1994 (PCG94)
Elevation: Australian Height Datum (mAHD).

Date	04 July 2018	Paper Size	A3	CLIENT	CITY OF STIRLING
Scale	1:2000	Drawn	AHWS	GEOPHYSICAL SUBSURFACE INVESTIGATION TO DETERMINE ROCK PROFILE ALONG COASTLINE	
Drawing	70428-D01	Revision	1		

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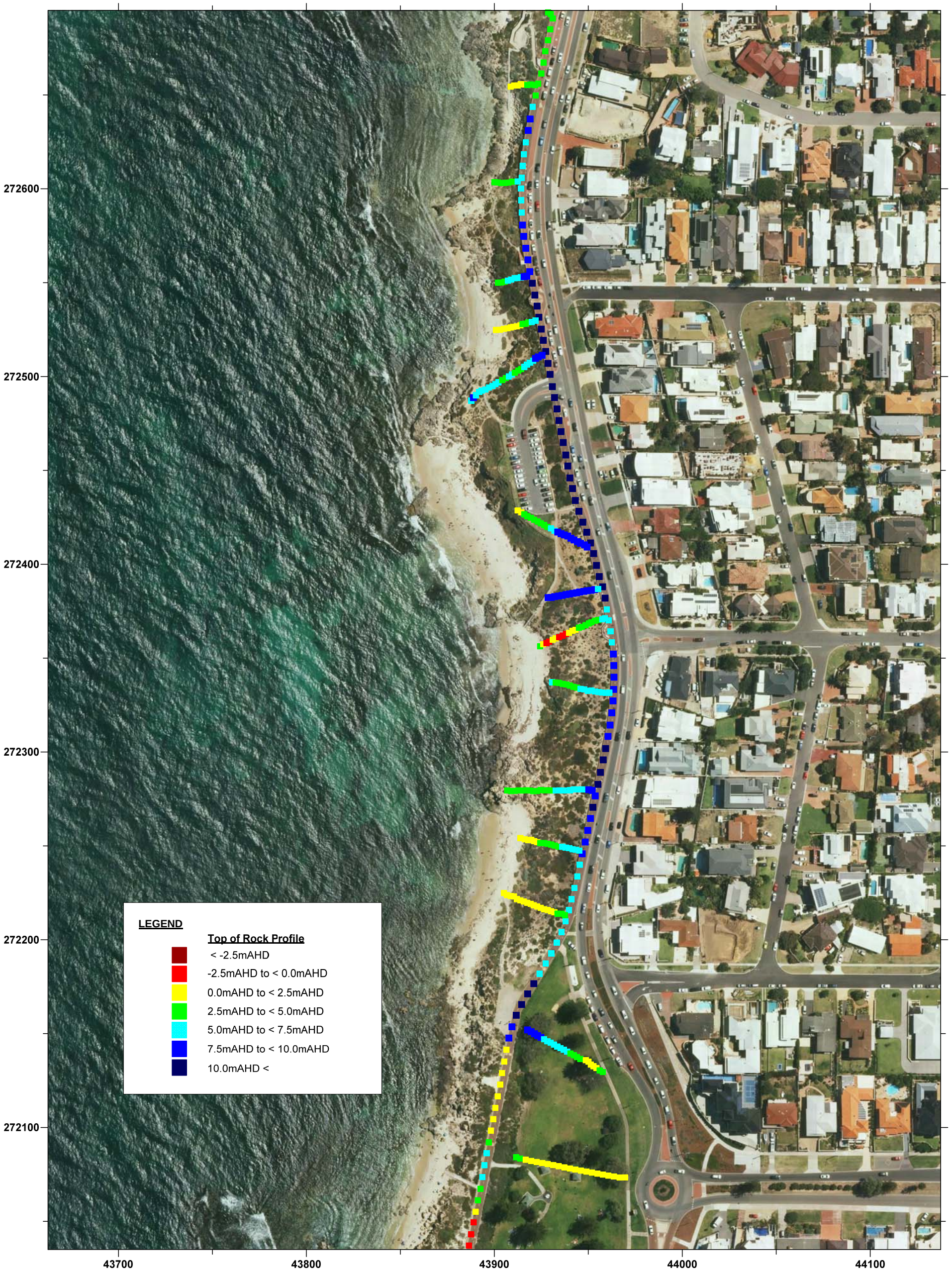
MODELLED LEVELTO TOP OF ROCK - POST MAP



N

0 25 50 75 100
Metres

NOTES

Drawing to be used in conjunction with Report 70428.
Aerial image from Landgate January 2018.
Map Projection: Perth Coastal Grid 1994 (PCG94)
Elevation: Australian Height Datum (mAHD).

Date	28 June 2018	Paper Size	A3
Scale	1:2000	Drawn	AHWS
Drawing	70428-D02	Revision	0

CLIENT: CITY OF STIRLING

GEOPHYSICAL SUBSURFACE INVESTIGATION TO DETERMINE ROCK PROFILE ALONG COASTLINE

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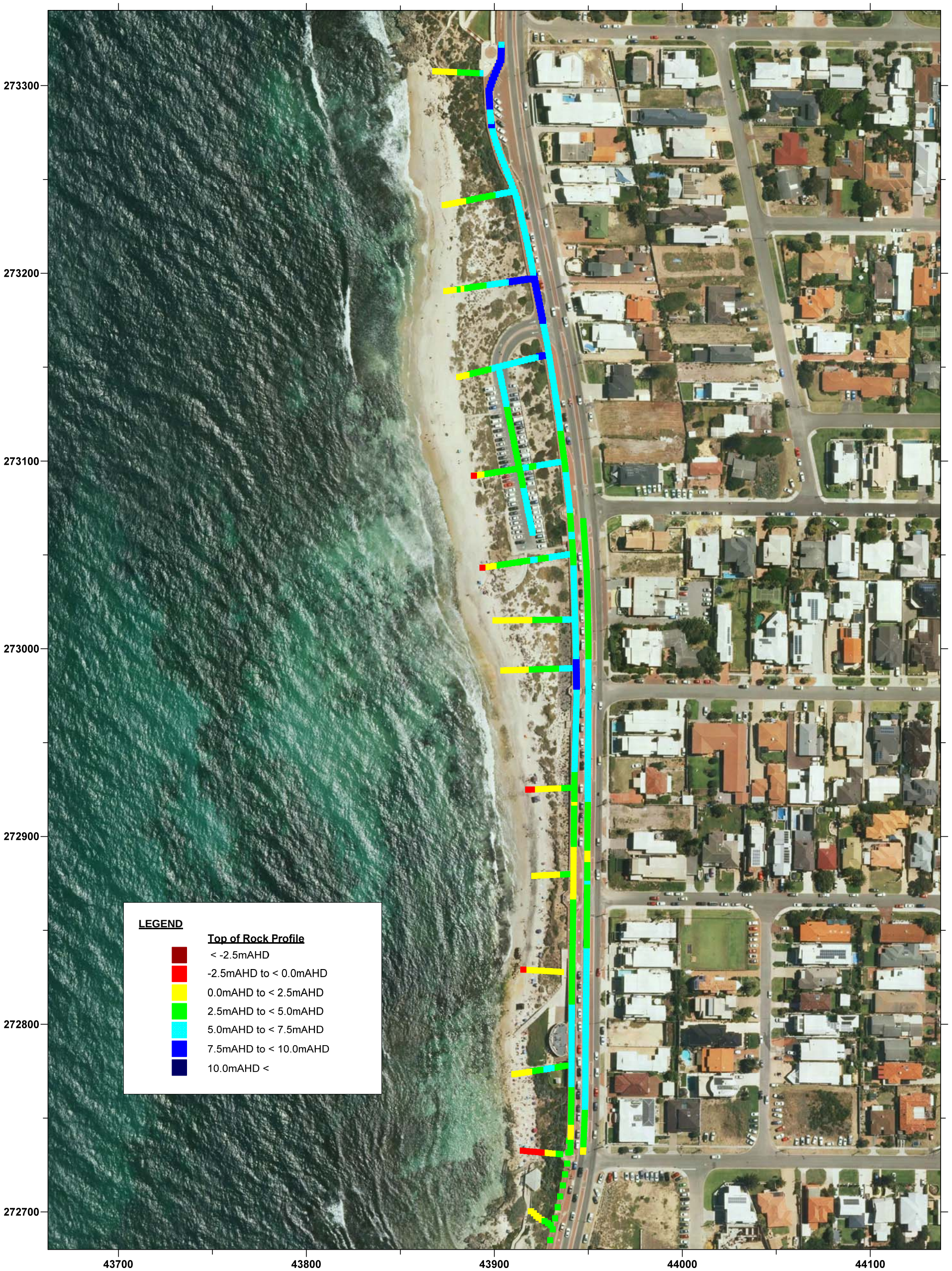
GEOPHYSICAL SUBSURFACE INVESTIGATION TO MAP ROCK PROFILE ALONG COASTLINE

MODELLED LEVELTO TOP OF ROCK - POST MAP



N

0 25 50 75 100
Metres

NOTES

Drawing to be used in conjunction with Report 70428.
Aerial image from Landgate January 2018.
Map Projection: Perth Coastal Grid 1994 (PCG94)
Elevation: Australian Height Datum (mAHD).

Date	28 June 2018	Paper Size	A3
Scale	1:2000	Drawn	AHWS
Drawing	70428-D03	Revision	0

CLIENT **CITY OF STIRLING**

GEOPHYSICAL SUBSURFACE INVESTIGATION TO DETERMINE ROCK PROFILE ALONG COASTLINE

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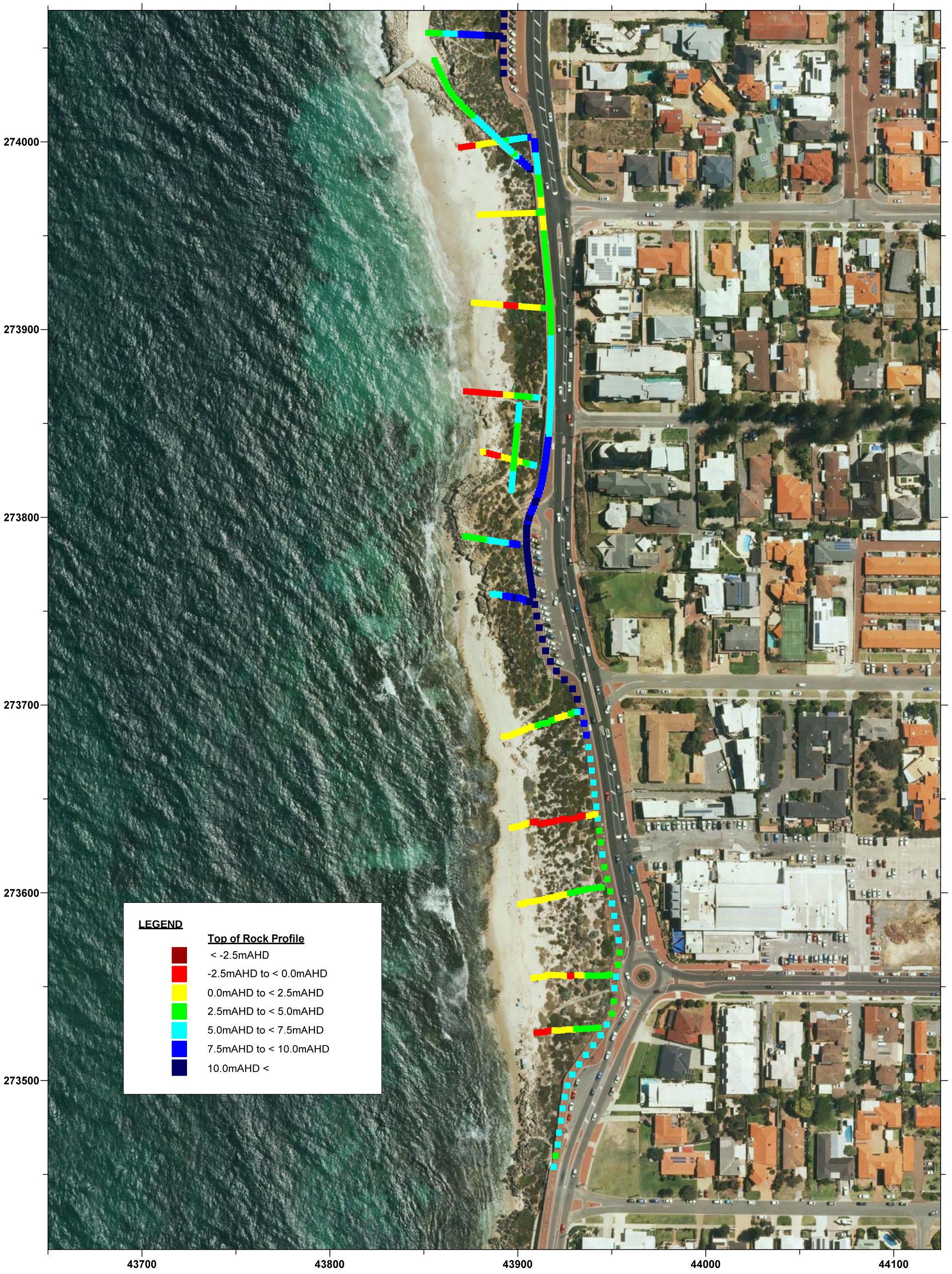
MODELLED LEVELTO TOP OF ROCK - POST MAP



N

0 25 50 75 100
Metres

NOTES

Drawing to be used in conjunction with Report 70428.
Aerial image from Landgate January 2018.
Map Projection: Perth Coastal Grid 1994 (PCG94)
Elevation: Australian Height Datum (mAHD).

Date	28 June 2018	Paper Size	A3
Scale	1:2000	Drawn	AHWS
Drawing	70428-D04	Revision	0

CLIENT: **CITY OF STIRLING**

GEOPHYSICAL SUBSURFACE INVESTIGATION TO DETERMINE ROCK PROFILE ALONG COASTLINE

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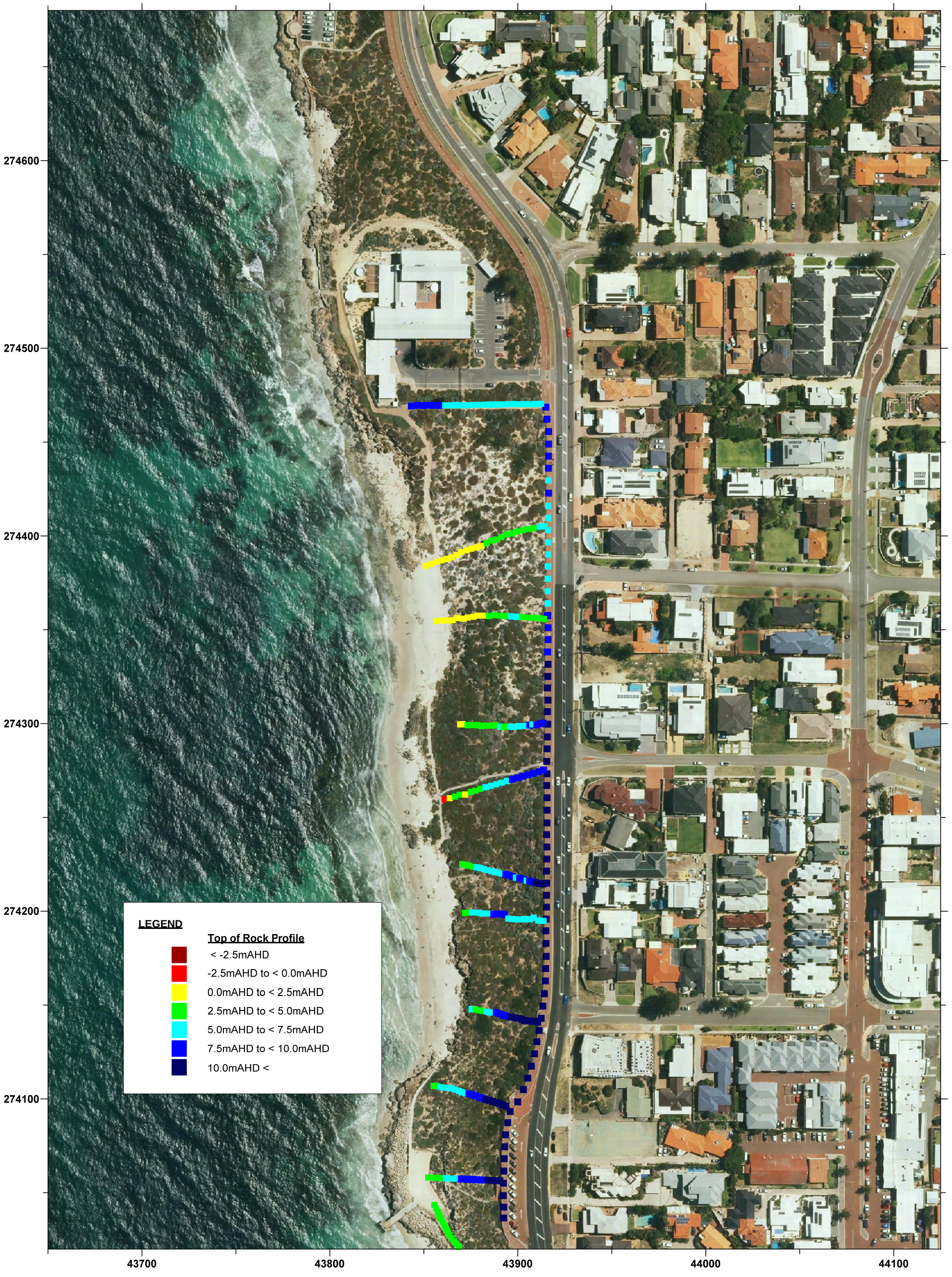
MODELLED LEVELTO TOP OF ROCK - POST MAP



N

0 25 50 75 100
Metres

NOTES

Drawing to be used in conjunction with Report 70428.
Aerial image from Landgate January 2018.
Map Projection: Perth Coastal Grid 1994 (PCG94)
Elevation: Australian Height Datum (mAHD).

Date	04 July 2018	Paper Size	A3
Scale	1:2000	Drawn	AHWS
Drawing	70428-D05	Revision	1

CLIENT: **CITY OF STIRLING**

GEOPHYSICAL SUBSURFACE INVESTIGATION TO DETERMINE ROCK PROFILE ALONG COASTLINE

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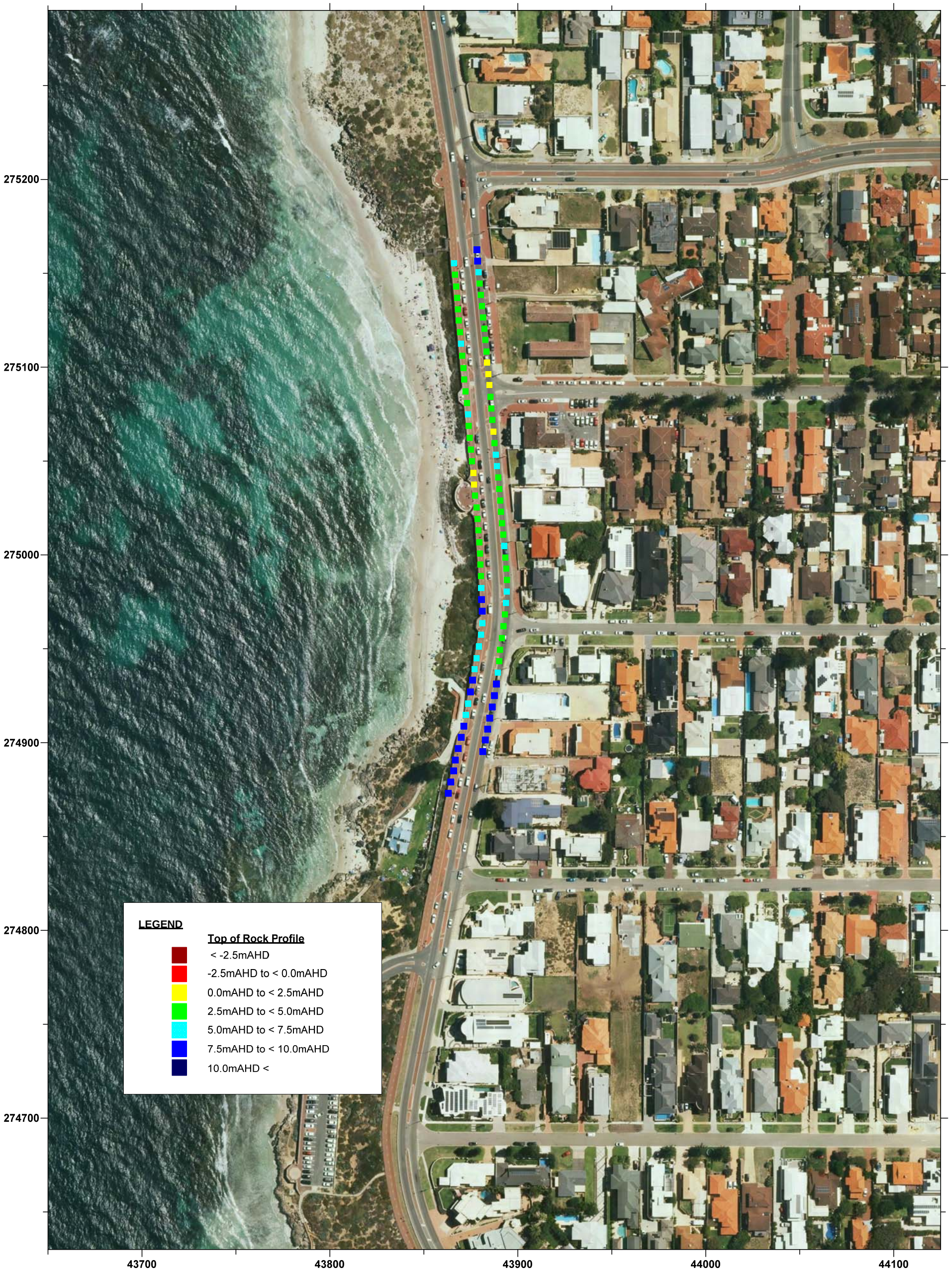
GEOPHYSICAL SUBSURFACE INVESTIGATION TO MAP ROCK PROFILE ALONG COASTLINE

MODELLED LEVELTO TOP OF ROCK - POST MAP



N

0 25 50 75 100
Metres

NOTES

Drawing to be used in conjunction with Report 70428.
Aerial image from Landgate January 2018.
Map Projection: Perth Coastal Grid 1994 (PCG94)
Elevation: Australian Height Datum (mAHD).

Date	28 June 2018	Paper Size	A3
Scale	1:2000	Drawn	AHWS
Drawing	70428-D06	Revision	0

CLIENT **CITY OF STIRLING**

GEOPHYSICAL SUBSURFACE INVESTIGATION TO DETERMINE ROCK PROFILE ALONG COASTLINE

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APPENDIX E.
MODELLED BEDROCK LEVEL COLOUR CONTOURS

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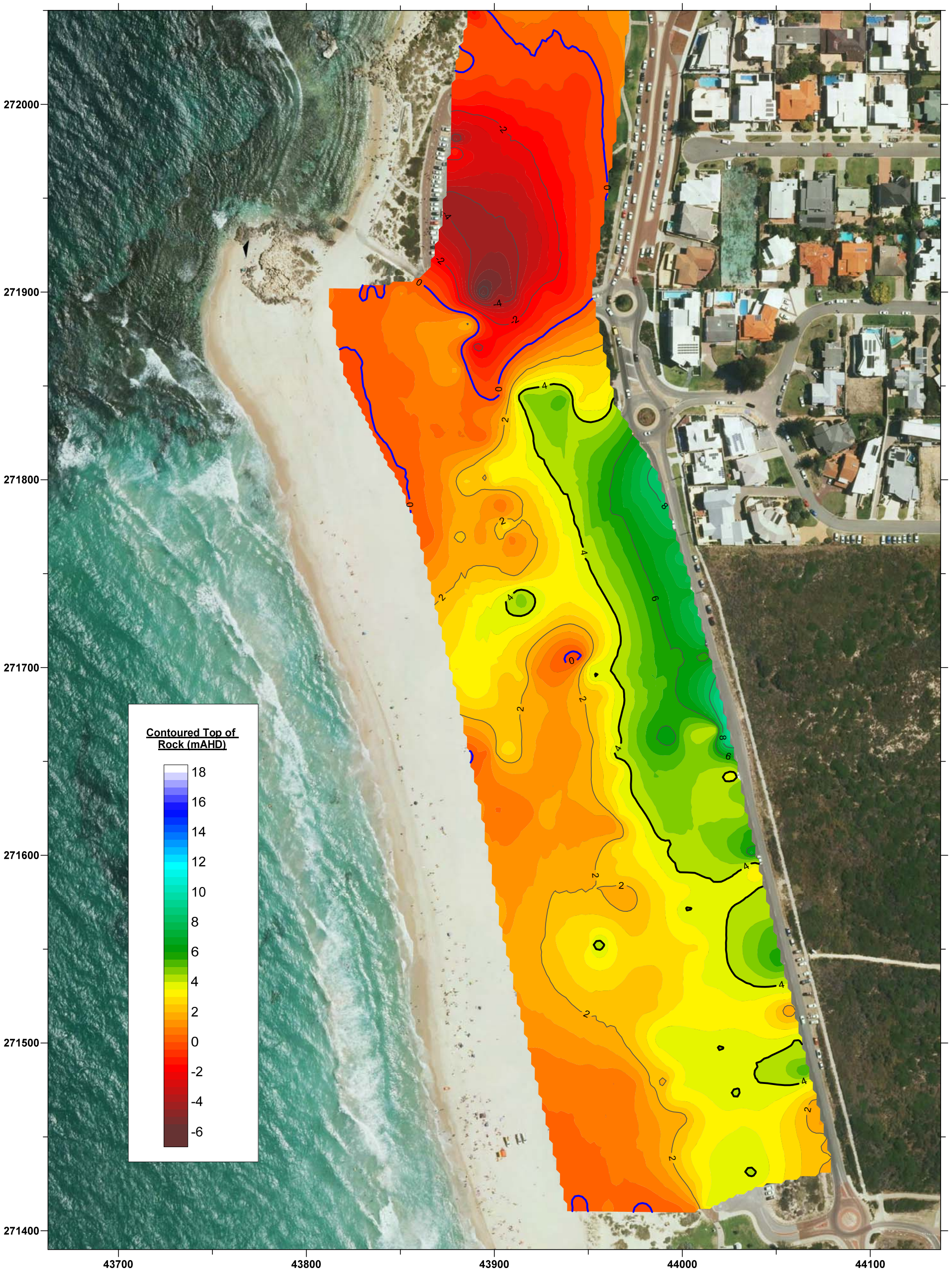
GEOPHYSICAL SUBSURFACE INVESTIGATION TO MAP ROCK PROFILE ALONG COASTLINE

MODELLED LEVEL TO TOP OF ROCK - CONTOUR MAP



N

0 25 50 75 100
Metres

NOTES

Drawing to be used in conjunction with Report 70428.
Aerial image from Landgate January 2018.
Map Projection: Perth Coastal Grid 1994 (PCG94)
Elevation: Australian Height Datum (mAHD).

LEGEND

Rock Level 0 mAHD
Rock Level 4 mAHD

Date	04 July 2018	Paper Size	A3	CLIENT	CITY OF STIRLING
Scale	1:2000	Drawn	AHWS	GEOPHYSICAL SUBSURFACE INVESTIGATION TO DETERMINE ROCK PROFILE ALONG COASTLINE	
Drawing	70428-E01	Revision	1		

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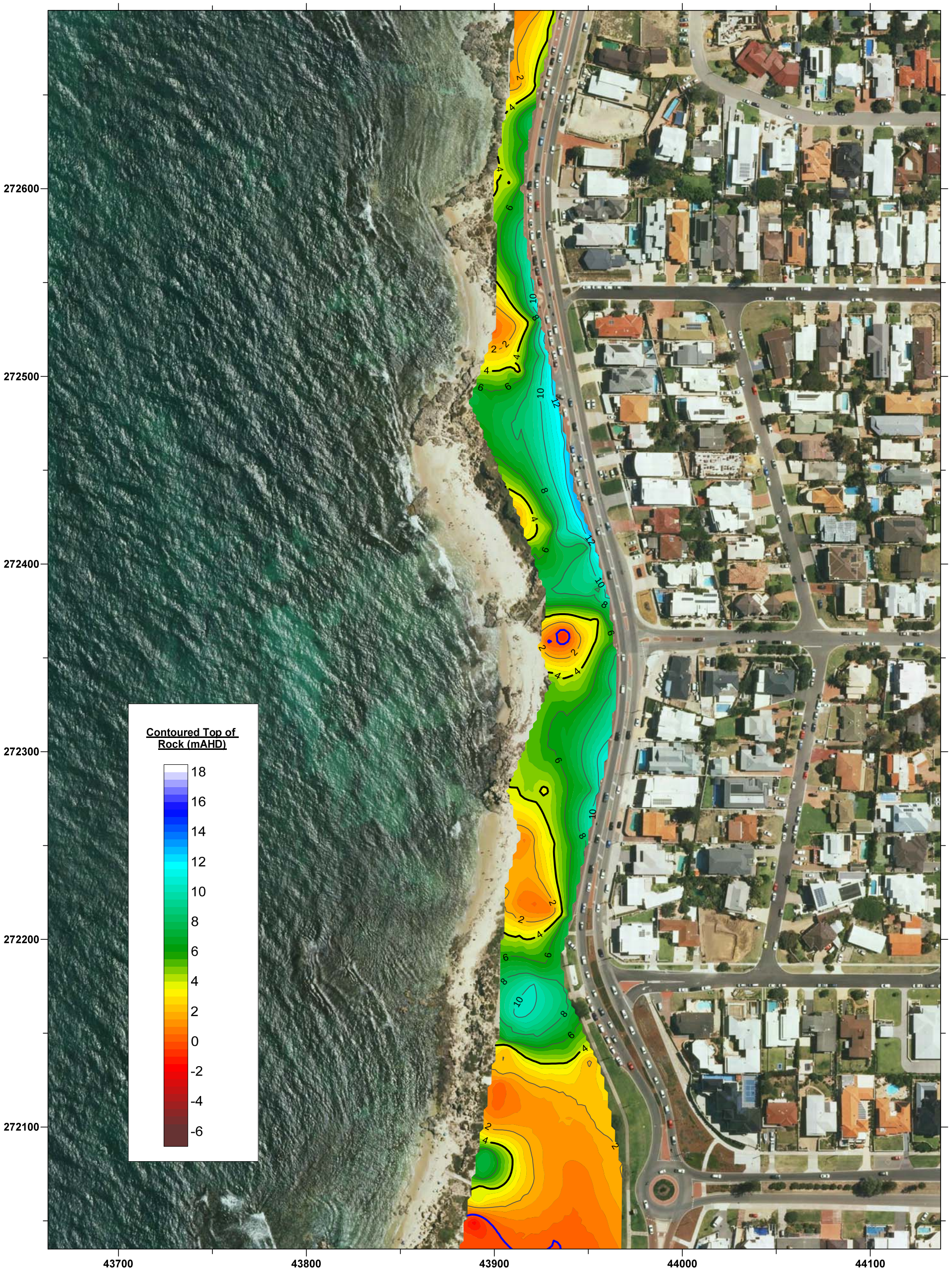
MODELLED LEVEL TO TOP OF ROCK - CONTOUR MAP



N

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Metres

NOTES

Drawing to be used in conjunction with Report 70428.
Aerial image from Landgate January 2018.
Map Projection: Perth Coastal Grid 1994 (PCG94)
Elevation: Australian Height Datum (mAHD).

LEGEND

Rock Level 0 mAHD
Rock Level 4 mAHD

Date	04 July 2018	Paper Size	A3
Scale	1:2000	Drawn	AHWS
Drawing	70428-E02	Revision	1

CLIENT: CITY OF STIRLING

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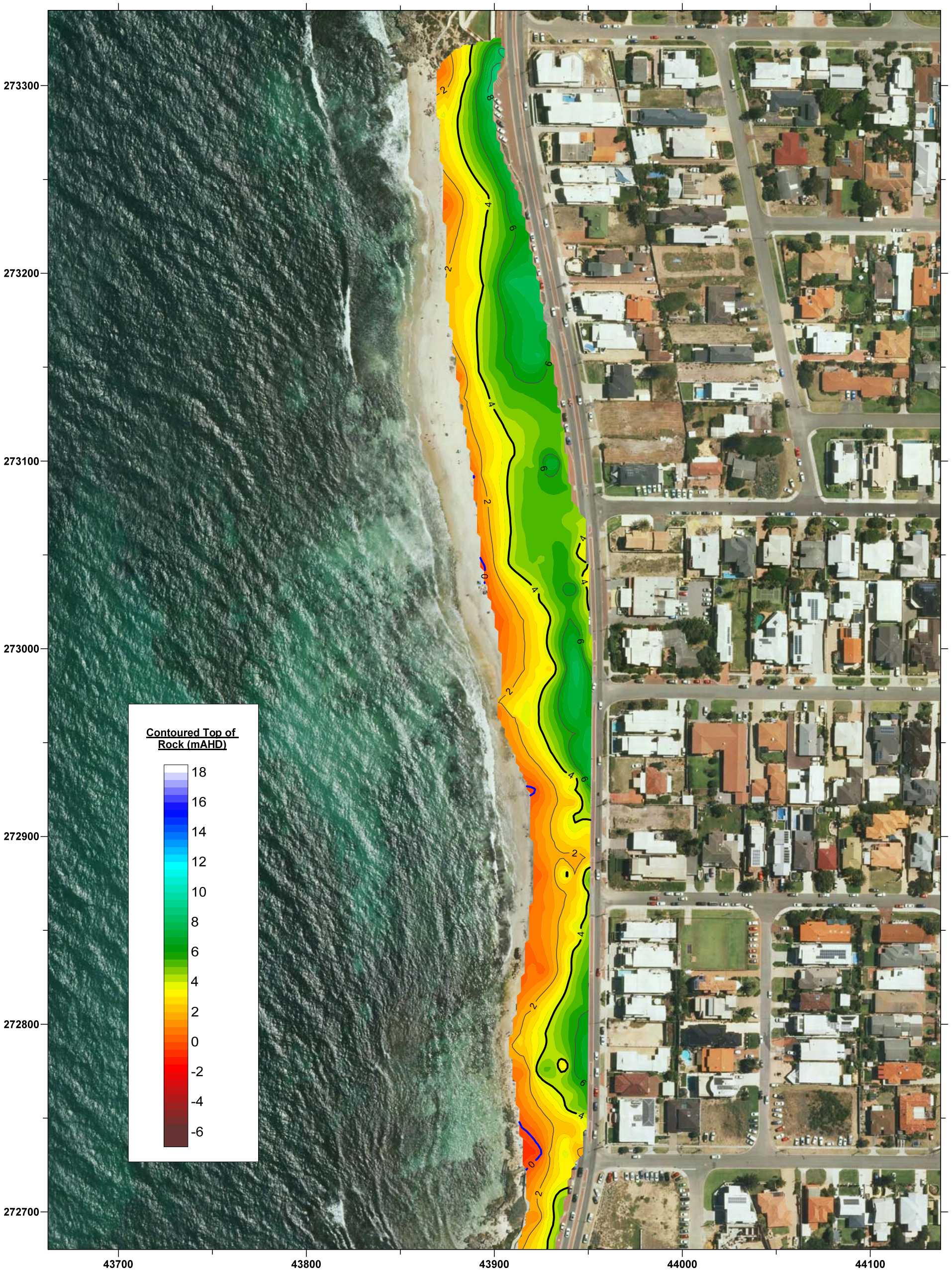
MODELLED LEVEL TO TOP OF ROCK - CONTOUR MAP



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Metres

NOTES

Drawing to be used in conjunction with Report 70428.
Aerial image from Landgate January 2018.
Map Projection: Perth Coastal Grid 1994 (PCG94)
Elevation: Australian Height Datum (mAHD).

LEGEND

Rock Level 0 mAHD
Rock Level 4 mAHD

Date	04 July 2018	Paper Size	A3	CLIENT	CITY OF STIRLING
Scale	1:2000	Drawn	AHWS	GEOPHYSICAL SUBSURFACE INVESTIGATION TO DETERMINE ROCK PROFILE ALONG COASTLINE	
Drawing	70428-E03	Revision	1		

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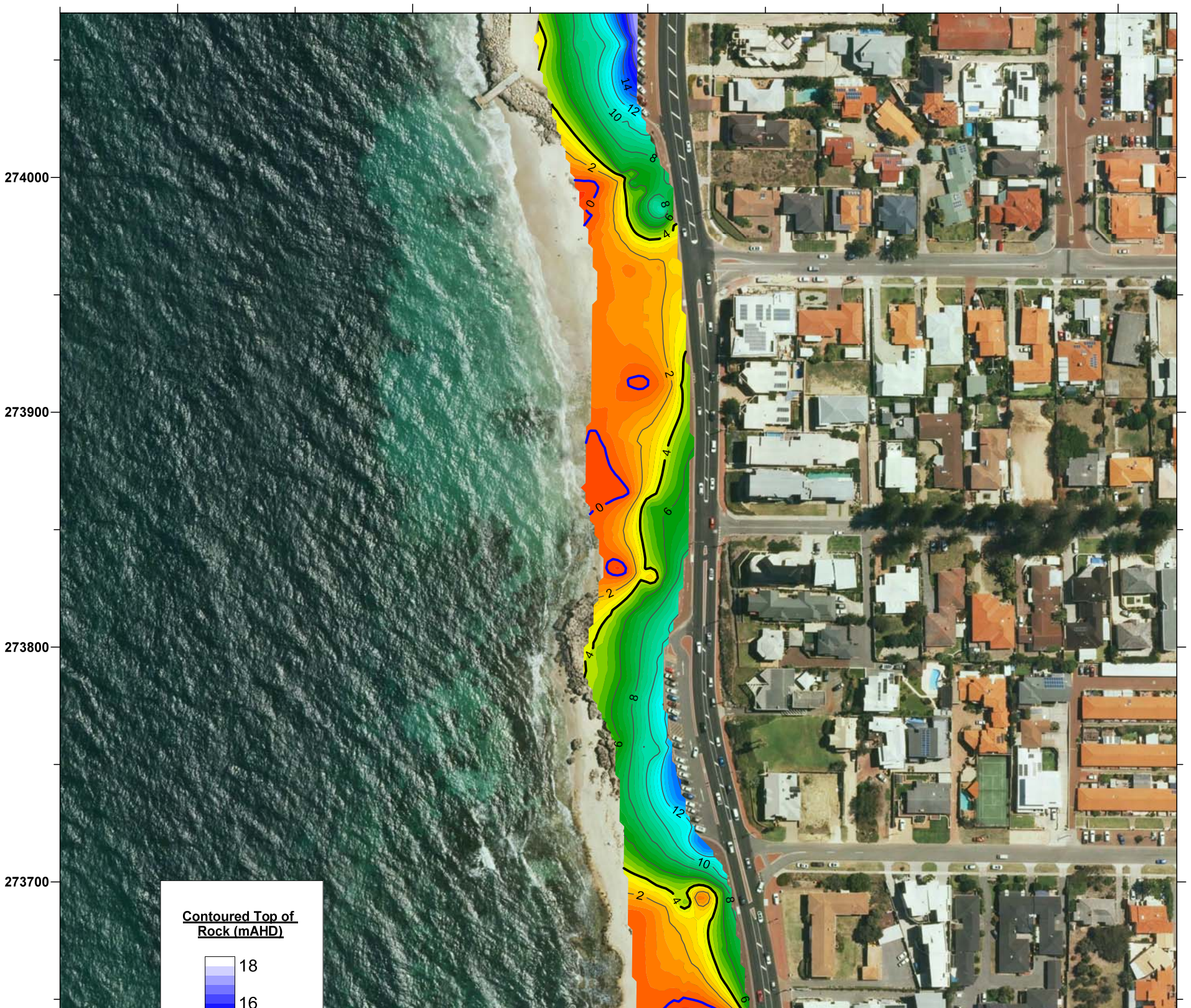
MODELLED LEVEL TO TOP OF ROCK - CONTOUR MAP



N

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Metres

NOTES

Drawing to be used in conjunction with Report 70428.
Aerial image from Landgate January 2018.
Map Projection: Perth Coastal Grid 1994 (PCG94)
Elevation: Australian Height Datum (mAHD).

LEGEND

Rock Level 0 mAHD
Rock Level 4 mAHD

Date	04 July 2018	Paper Size	A3
Scale	1:2000	Drawn	AHWS
Drawing	70428-E04	Revision	1

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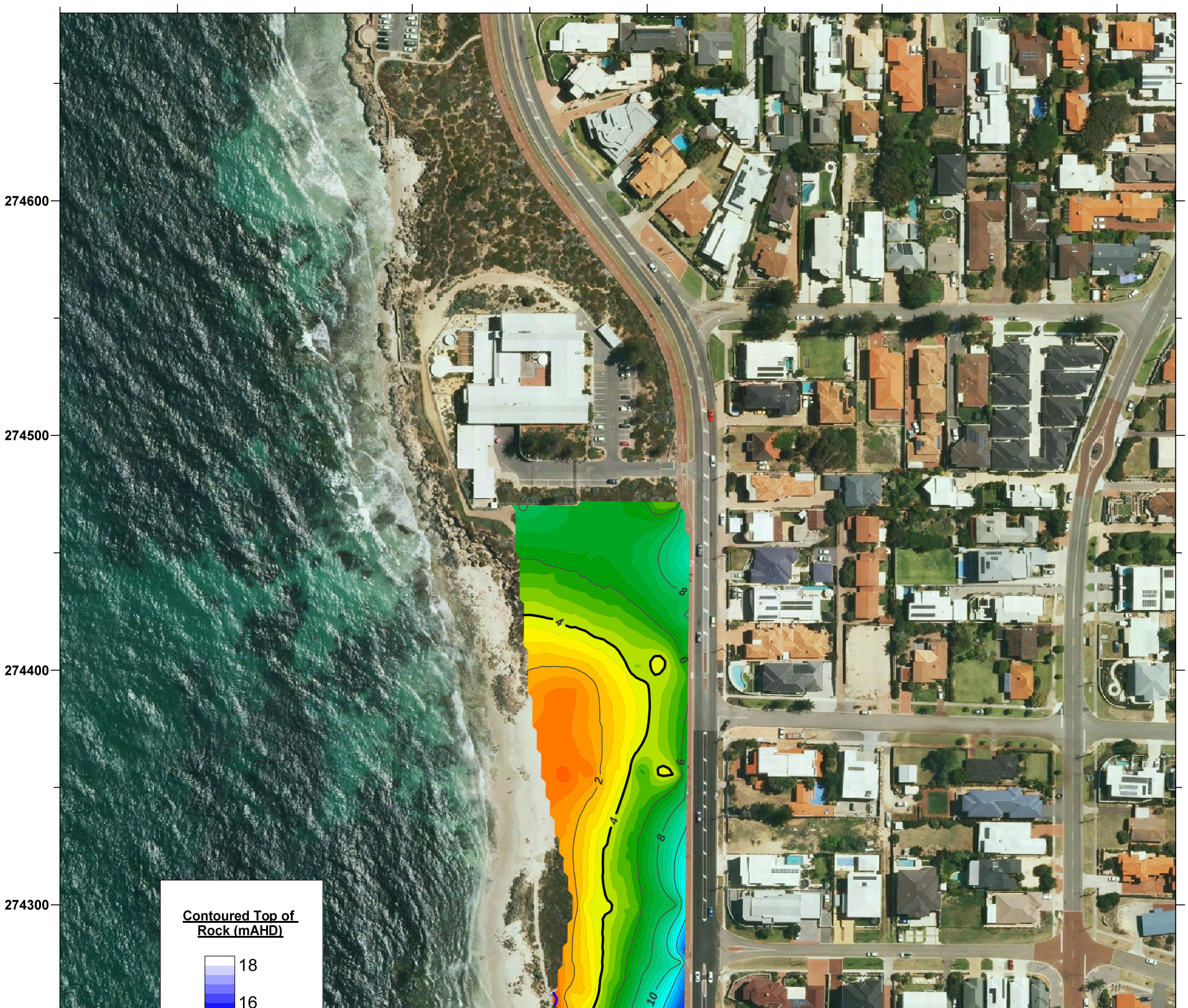
MODELLED LEVEL TO TOP OF ROCK - CONTOUR MAP



N

0 25 50 75 100
Metres

NOTES

Drawing to be used in conjunction with Report 70428.
Aerial image from Landgate January 2018.
Map Projection: Perth Coastal Grid 1994 (PCG94)
Elevation: Australian Height Datum (mAHD).

LEGEND

Rock Level 0 mAHD
Rock Level 4 mAHD

Date	04 July 2018	Paper Size	A3
Scale	1:2000	Drawn	AHWS
Drawing	70428-E05	Revision	1

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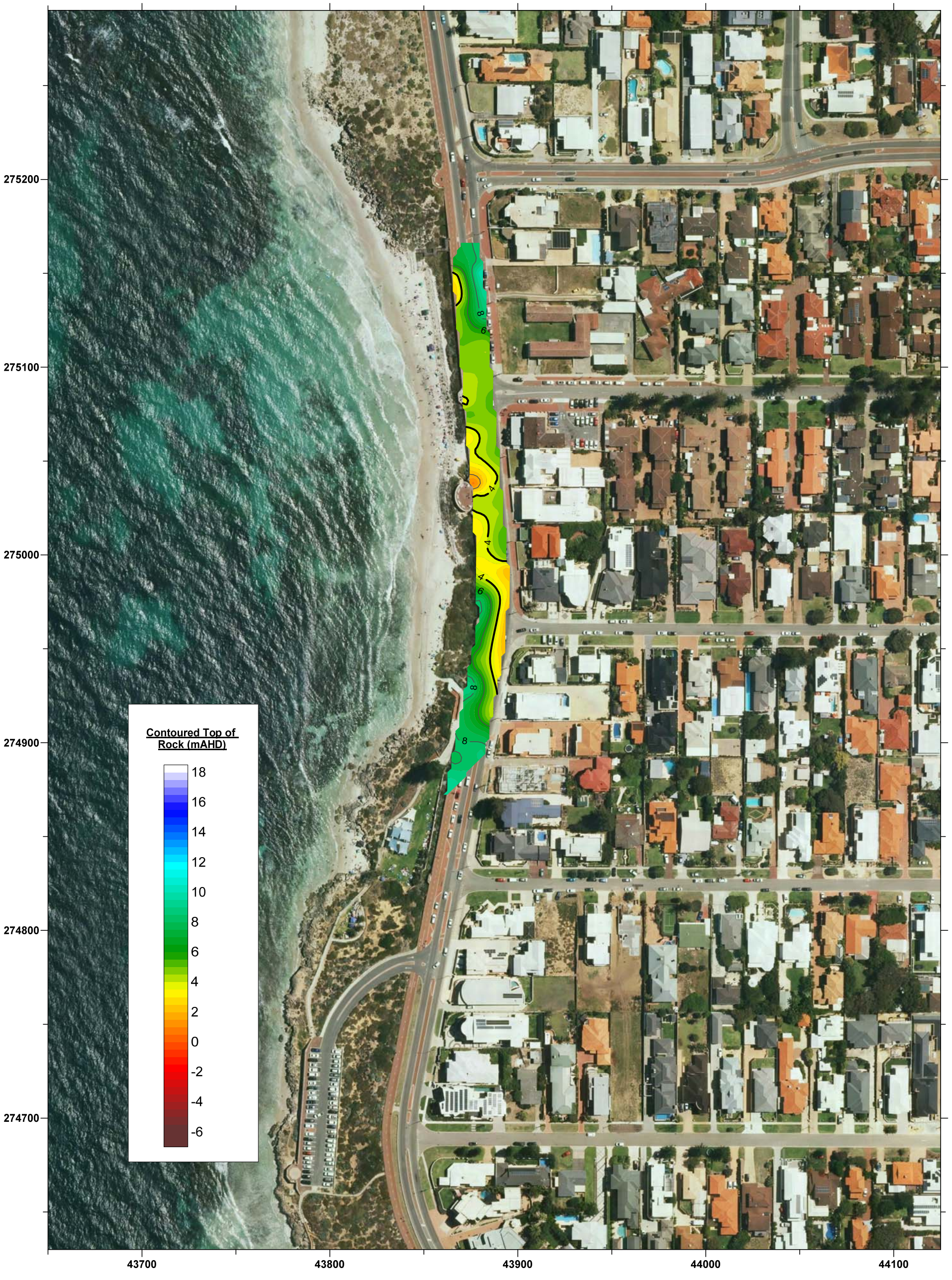
MODELLED LEVEL TO TOP OF ROCK - CONTOUR MAP



N

0 25 50 75 100
Metres

NOTES

Drawing to be used in conjunction with Report 70428.
Aerial image from Landgate January 2018.
Map Projection: Perth Coastal Grid 1994 (PCG94)
Elevation: Australian Height Datum (mAHD).

LEGEND

Rock Level 0 mAHD
Rock Level 4 mAHD

Date	04 July 2018	Paper Size	A3	CLIENT	CITY OF STIRLING
Scale	1:2000	Drawn	AHWS	GEOPHYSICAL SUBSURFACE INVESTIGATION TO DETERMINE ROCK PROFILE ALONG COASTLINE	
Drawing	70428-E06	Revision	1		

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APPENDIX F.
MODELLED SAND THICKNESS CONTOURS

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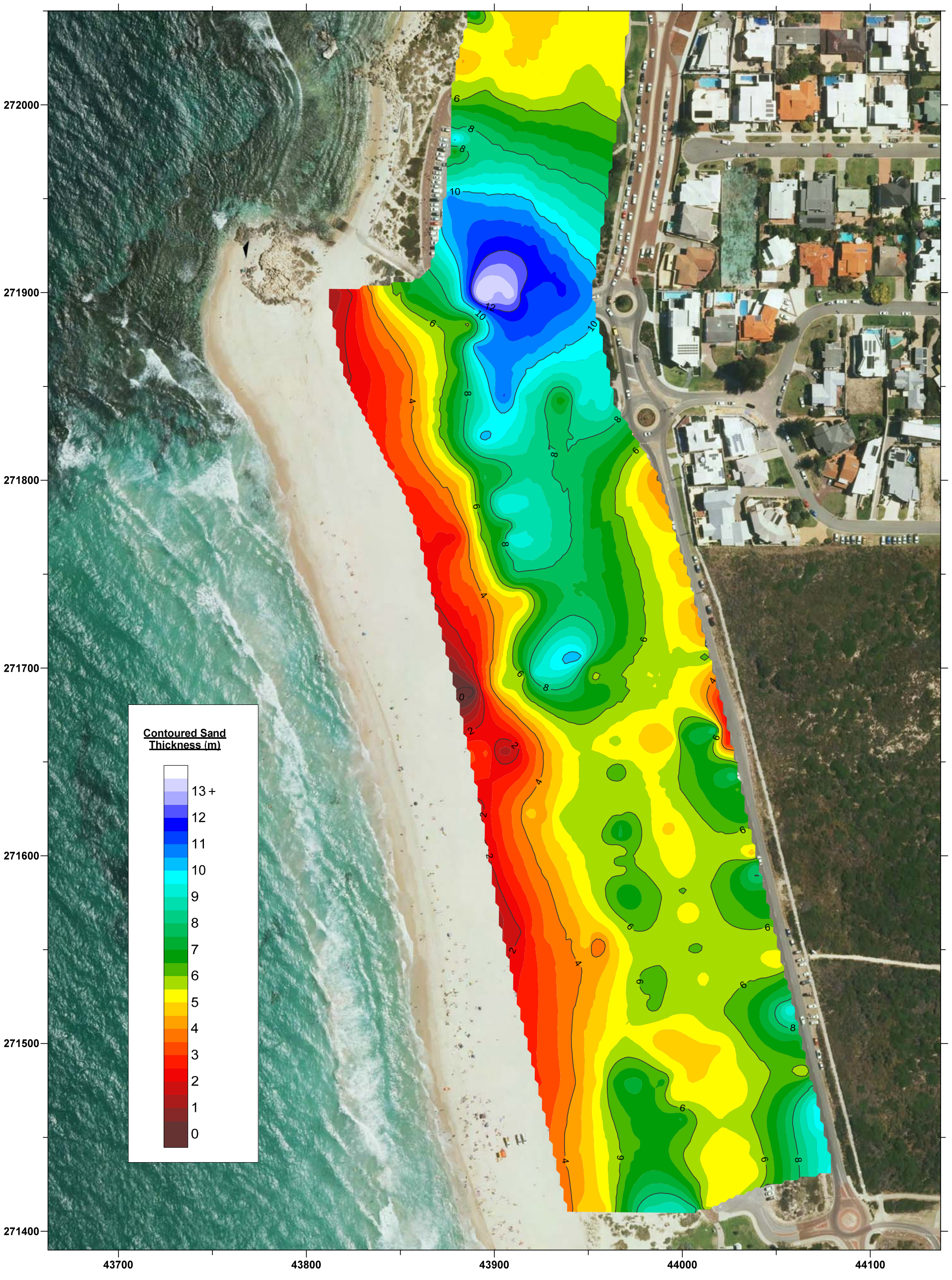
GEOPHYSICAL SUBSURFACE INVESTIGATION TO MAP ROCK PROFILE ALONG COASTLINE

MODELLED THICKNESS OF OVERLYING SAND



N

0 25 50 75 100
Metres

NOTES

Drawing to be used in conjunction with Report 70428.
Aerial image from Landgate January 2018.
Map Projection: Perth Coastal Grid 1994 (PCG94)
Elevation: Australian Height Datum (mAHD).

Date	04 July 2018	Paper Size	A3	CLIENT	CITY OF STIRLING
Scale	1:2000	Drawn	AHWS	GEOPHYSICAL SUBSURFACE INVESTIGATION TO DETERMINE ROCK PROFILE ALONG COASTLINE	
Drawing	70428-F01	Revision	1		

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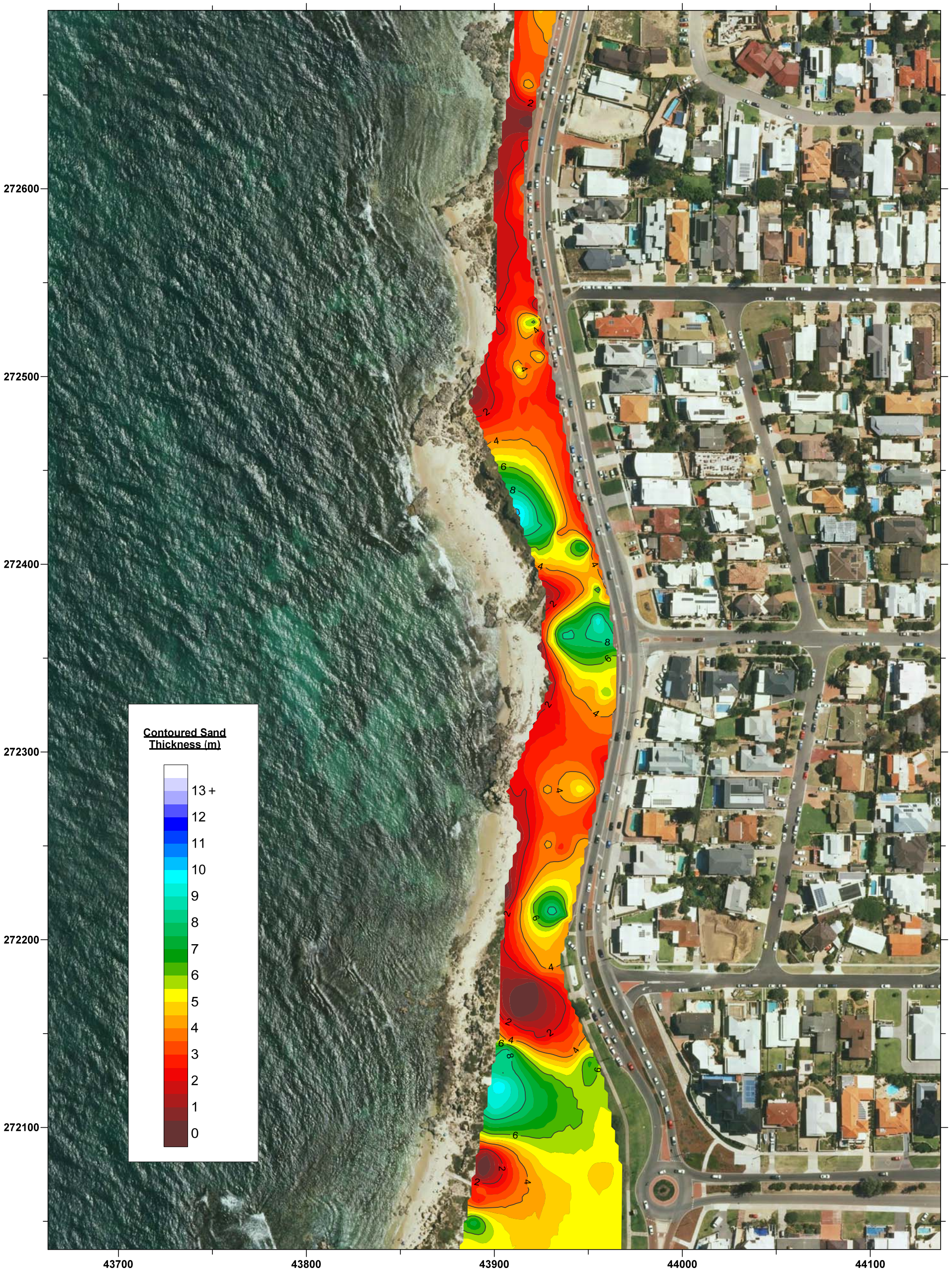
GEOPHYSICAL SUBSURFACE INVESTIGATION TO MAP ROCK PROFILE ALONG COASTLINE

MODELLED THICKNESS OF OVERLYING SAND



NOTES

Drawing to be used in conjunction with Report 70428.
Aerial image from Landgate January 2018.
Map Projection: Perth Coastal Grid 1994 (PCG94)
Elevation: Australian Height Datum (mAHD).

Date	28 June 2018	Paper Size	A3
Scale	1:2000	Drawn	AHWS
Drawing	70428-F02	Revision	0

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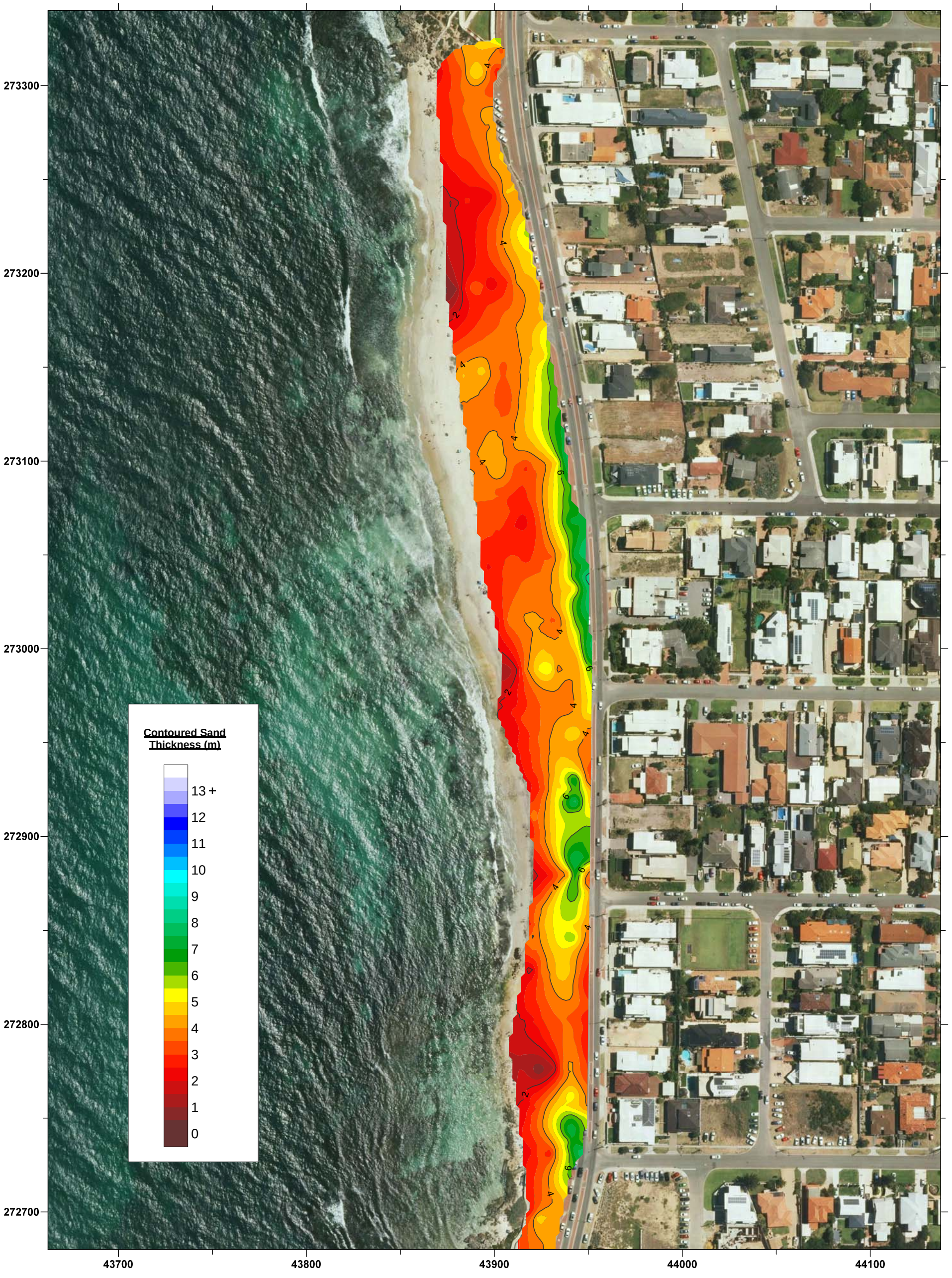
GEOPHYSICAL SUBSURFACE INVESTIGATION TO MAP ROCK PROFILE ALONG COASTLINE

MODELLED THICKNESS OF OVERLYING SAND



N

0 25 50 75 100
Metres

NOTES

Drawing to be used in conjunction with Report 70428.
Aerial image from Landgate January 2018.
Map Projection: Perth Coastal Grid 1994 (PCG94)
Elevation: Australian Height Datum (mAHD).

Date	28 June 2018	Paper Size	A3
Scale	1:2000	Drawn	AHWS
Drawing	70428-F03	Revision	0

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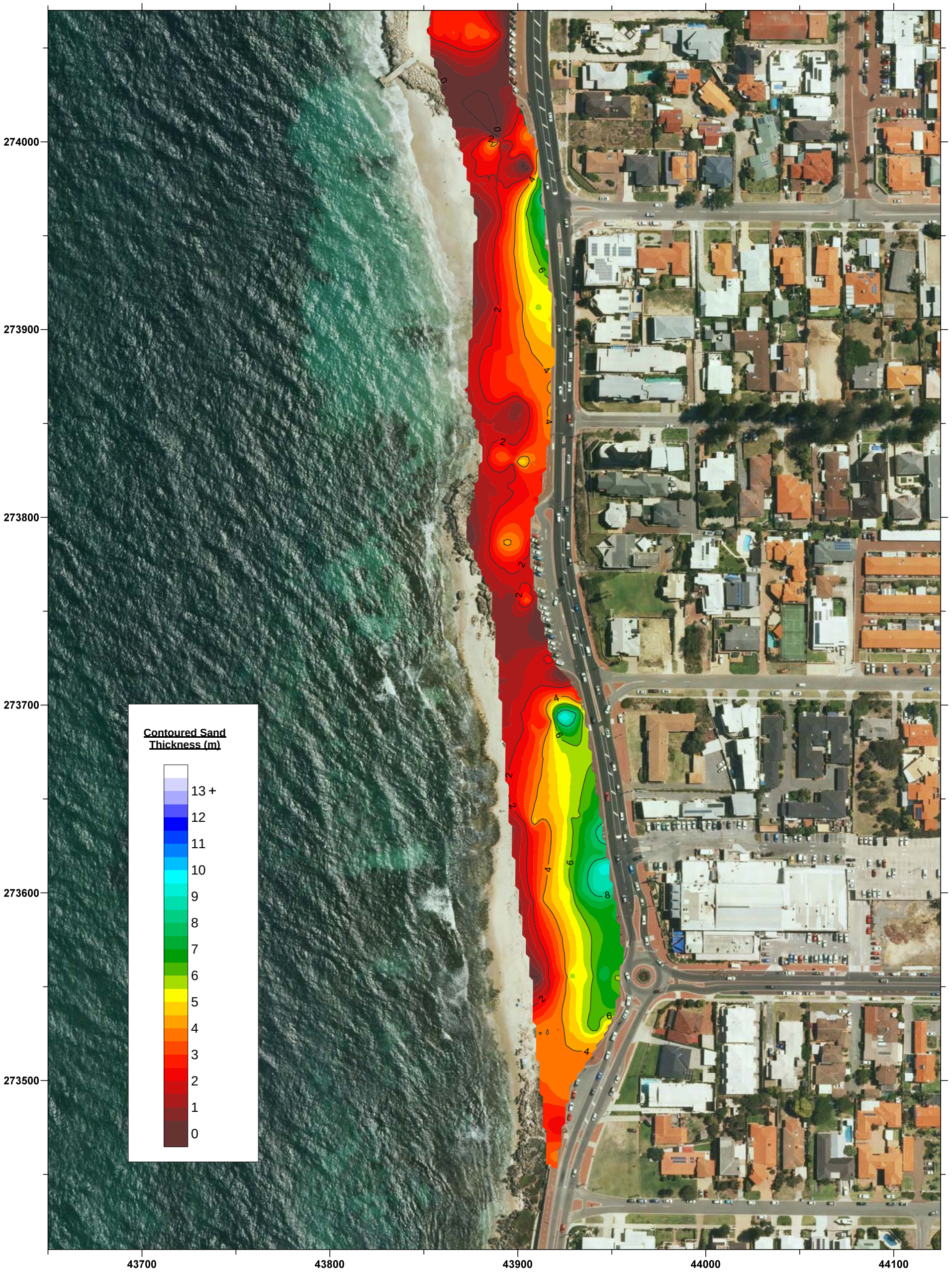
GEOPHYSICAL SUBSURFACE INVESTIGATION TO MAP ROCK PROFILE ALONG COASTLINE

MODELLED THICKNESS OF OVERLYING SAND



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Metres

NOTES

Drawing to be used in conjunction with Report 70428.
Aerial image from Landgate January 2018.
Map Projection: Perth Coastal Grid 1994 (PCG94)
Elevation: Australian Height Datum (mAHD).

Date	28 June 2018	Paper Size	A3
Scale	1:2000	Drawn	AHWS
Drawing	70428-F04	Revision	0

CLIENT: CITY OF STIRLING

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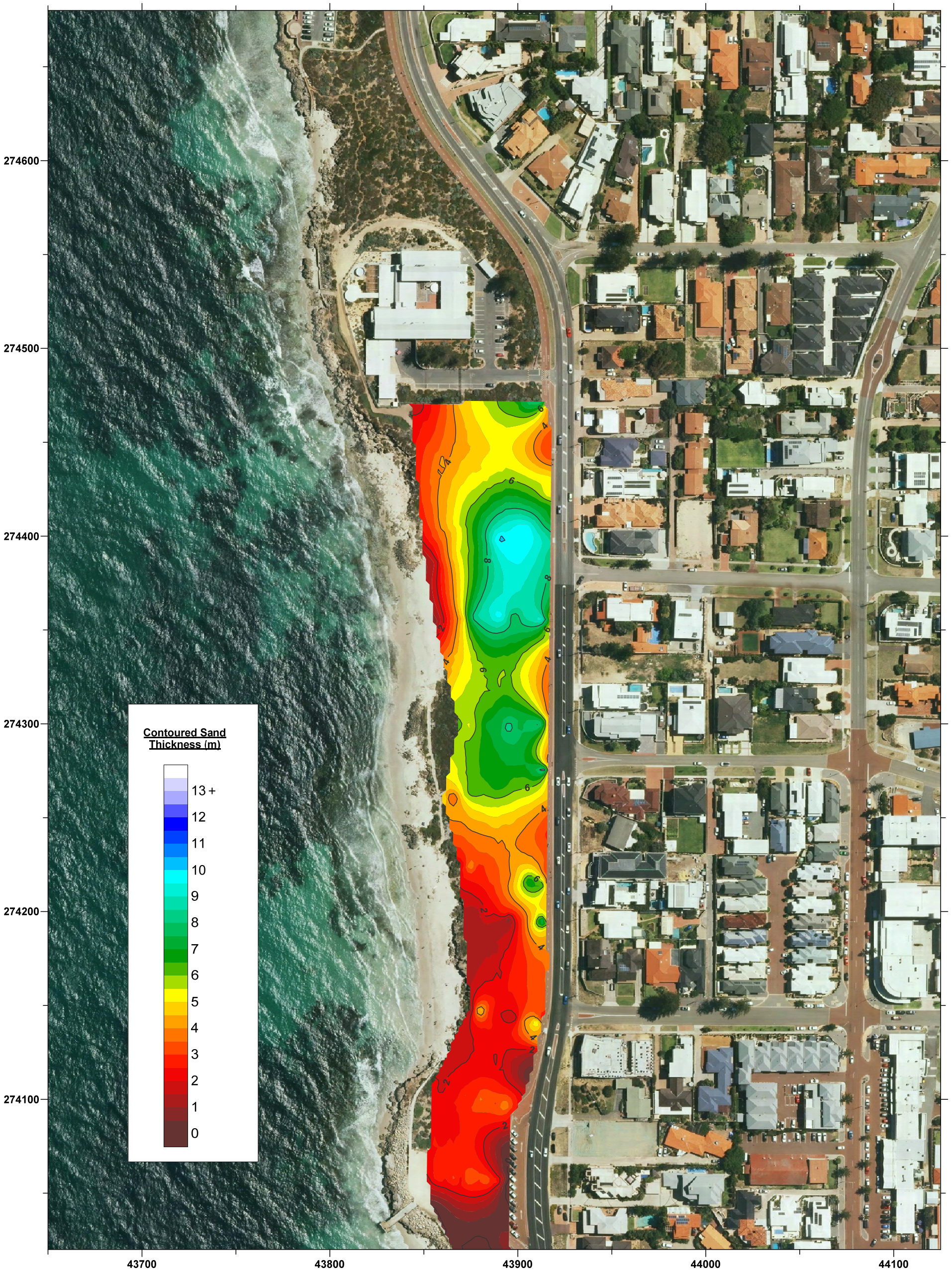
GEOPHYSICAL SUBSURFACE INVESTIGATION TO MAP ROCK PROFILE ALONG COASTLINE

MODELLED THICKNESS OF OVERLYING SAND



N

0 25 50 75 100
Metres

NOTES

Drawing to be used in conjunction with Report 70428.
Aerial image from Landgate January 2018.
Map Projection: Perth Coastal Grid 1994 (PCG94)
Elevation: Australian Height Datum (mAHD).

Date	04 July 2018	Paper Size	A3	CLIENT	CITY OF STIRLING
Scale	1:2000	Drawn	AHWS	GEOPHYSICAL SUBSURFACE INVESTIGATION TO DETERMINE ROCK PROFILE ALONG COASTLINE	
Drawing	70428-F05	Revision	1		

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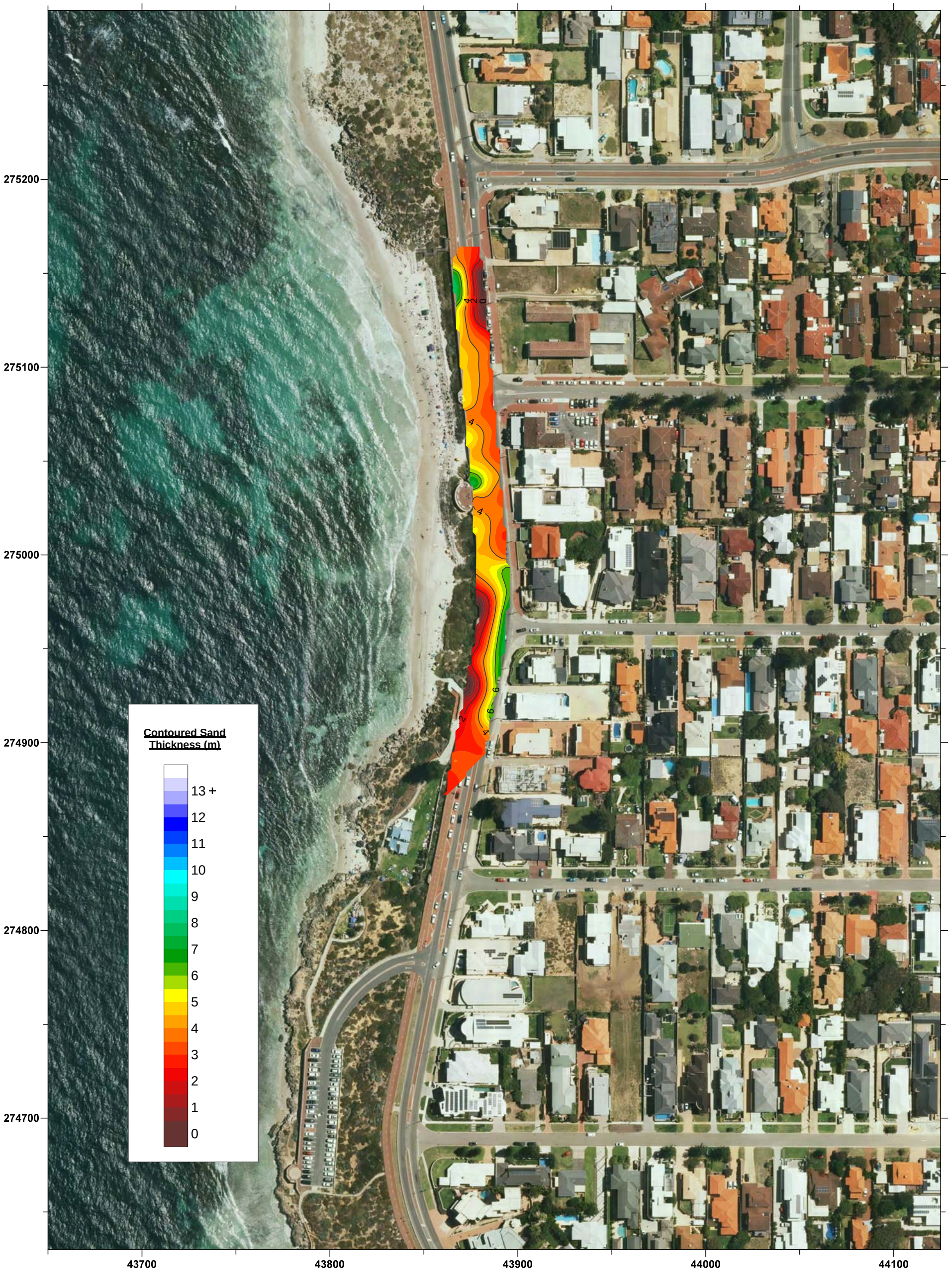
MODELLED THICKNESS OF OVERLYING SAND



N

0 25 50 75 100
Metres

NOTES

Drawing to be used in conjunction with Report 70428.
Aerial image from Landgate January 2018.
Map Projection: Perth Coastal Grid 1994 (PCG94)
Elevation: Australian Height Datum (mAHD).

Date	28 June 2018	Paper Size	A3
Scale	1:2000	Drawn	AHWS
Drawing	70428-F06	Revision	0

CLIENT: **CITY OF STIRLING**

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APPENDIX G.
MODELLED BEDROCK LEVEL LINE CONTOURS

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GEOPHYSICAL SUBSURFACE INVESTIGATION TO MAP ROCK PROFILE ALONG COASTLINE

MODELLED LEVEL TO TOP OF ROCK - CONTOUR MAP

N

0 25 50 75 100
Metres

NOTES

Drawing to be used in conjunction with Report 70428.
Aerial image from Landgate January 2018.
Map Projection: Perth Coastal Grid 1994 (PCG94)
Elevation: Australian Height Datum (mAHD).

LEGEND

Rock Level 0 mAHD
Rock Level 4 mAHD

Date	04 July 2018	Paper Size	A3
Scale	1:2000	Drawn	AHWS
Drawing	70428-E01	Revision	1

CLIENT: **CITY OF STIRLING**

GEOPHYSICAL SUBSURFACE INVESTIGATION TO DETERMINE ROCK PROFILE ALONG COASTLINE

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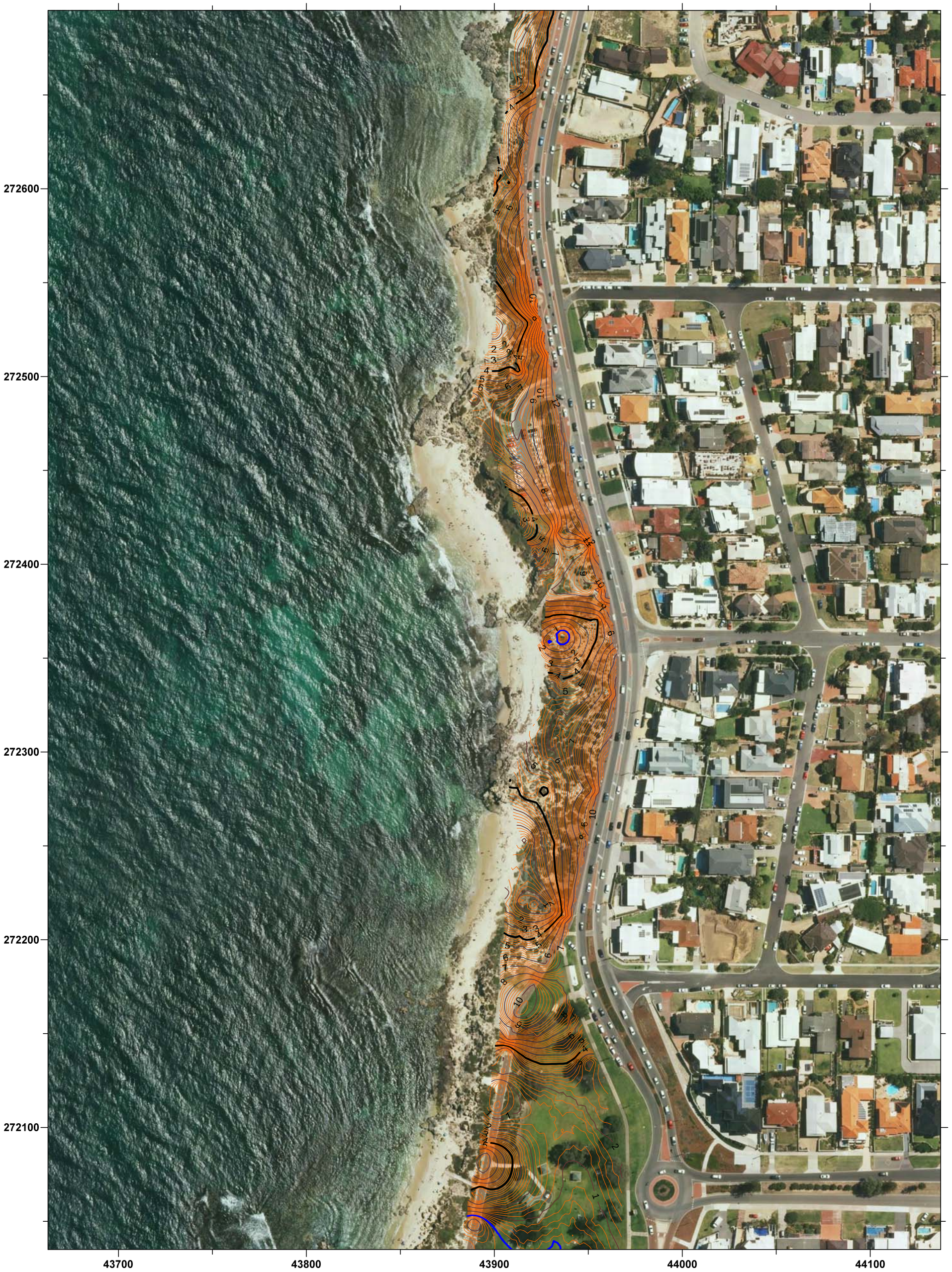
GEOPHYSICAL SUBSURFACE INVESTIGATION TO MAP ROCK PROFILE ALONG COASTLINE

MODELLED LEVEL TO TOP OF ROCK - CONTOUR MAP



N

0 25 50 75 100
Metres

NOTES

Drawing to be used in conjunction with Report 70428.
Aerial image from Landgate January 2018.
Map Projection: Perth Coastal Grid 1994 (PCG94)
Elevation: Australian Height Datum (mAHD).

LEGEND

Rock Level 0 mAHD
Rock Level 4 mAHD

Date	02 July 2018	Paper Size	A3
Scale	1:2000	Drawn	AHWS
Drawing	70428-E02	Revision	0

CLIENT: CITY OF STIRLING

GEOPHYSICAL SUBSURFACE INVESTIGATION TO DETERMINE ROCK PROFILE ALONG COASTLINE

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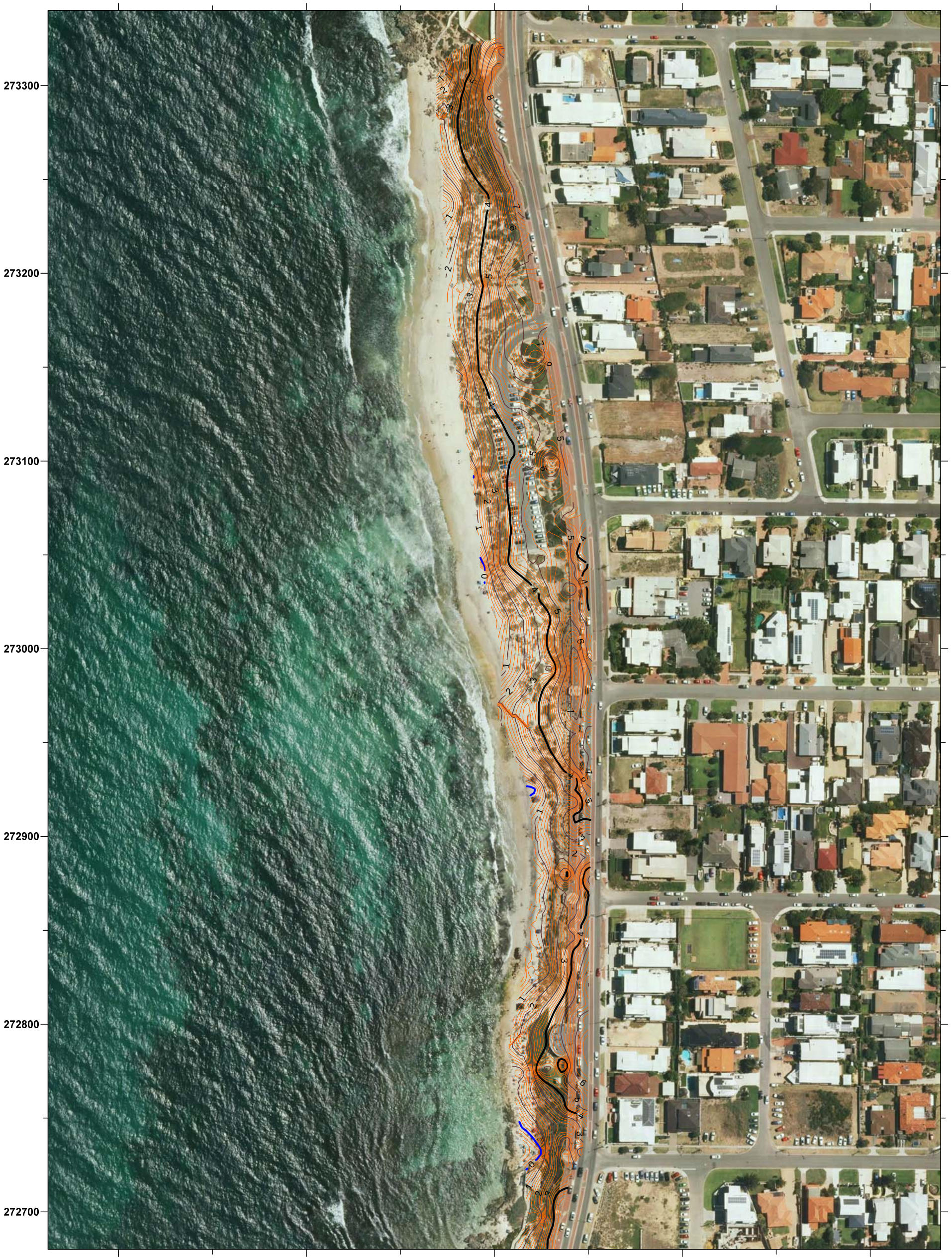
GEOPHYSICAL SUBSURFACE INVESTIGATION TO MAP ROCK PROFILE ALONG COASTLINE

MODELLED LEVEL TO TOP OF ROCK - CONTOUR MAP



N

0 25 50 75 100
Metres

NOTES

Drawing to be used in conjunction with Report 70428.
Aerial image from Landgate January 2018.
Map Projection: Perth Coastal Grid 1994 (PCG94)
Elevation: Australian Height Datum (mAHD).

LEGEND

Rock Level 0 mAHD
Rock Level 4 mAHD

Date	02 July 2018	Paper Size	A3
Scale	1:2000	Drawn	AHWS
Drawing	70428-E03	Revision	0

CLIENT: CITY OF STIRLING

GEOPHYSICAL SUBSURFACE INVESTIGATION TO DETERMINE ROCK PROFILE ALONG COASTLINE

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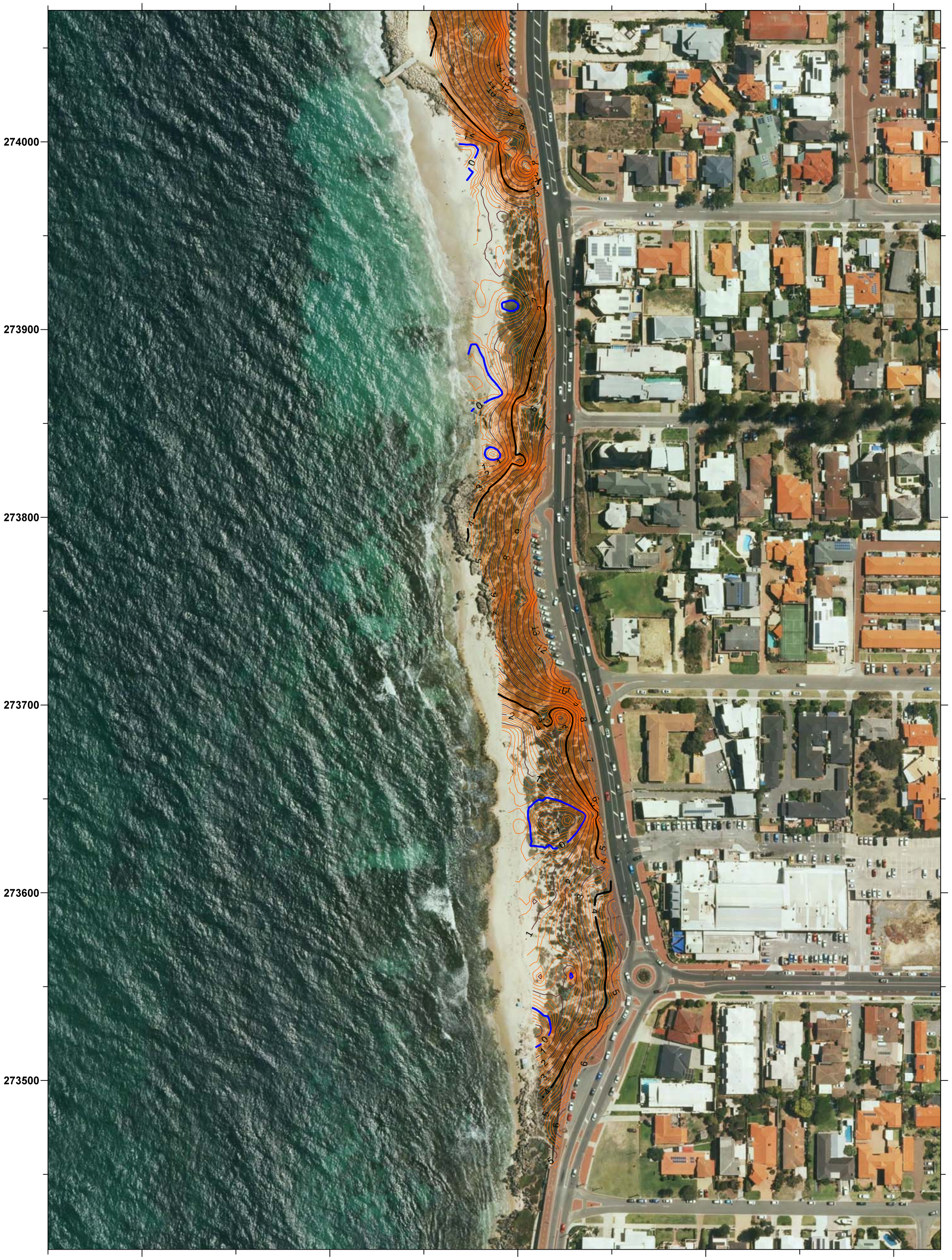
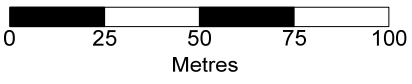
MODELLED LEVEL TO TOP OF ROCK - CONTOUR MAP





NOTES

Drawing to be used in conjunction with Report 70428.
Aerial image from Landgate January 2018.
Map Projection: Perth Coastal Grid 1994 (PCG94)
Elevation: Australian Height Datum (mAHD).

LEGEND

Rock Level 0 mAHD
Rock Level 4 mAHD

Date	02 July 2018	Paper Size	A3	CLIENT	CITY OF STIRLING
Scale	1:2000	Drawn	AHWS	GEOPHYSICAL SUBSURFACE INVESTIGATION TO DETERMINE ROCK PROFILE ALONG COASTLINE	
Drawing	70428-E04	Revision	0		

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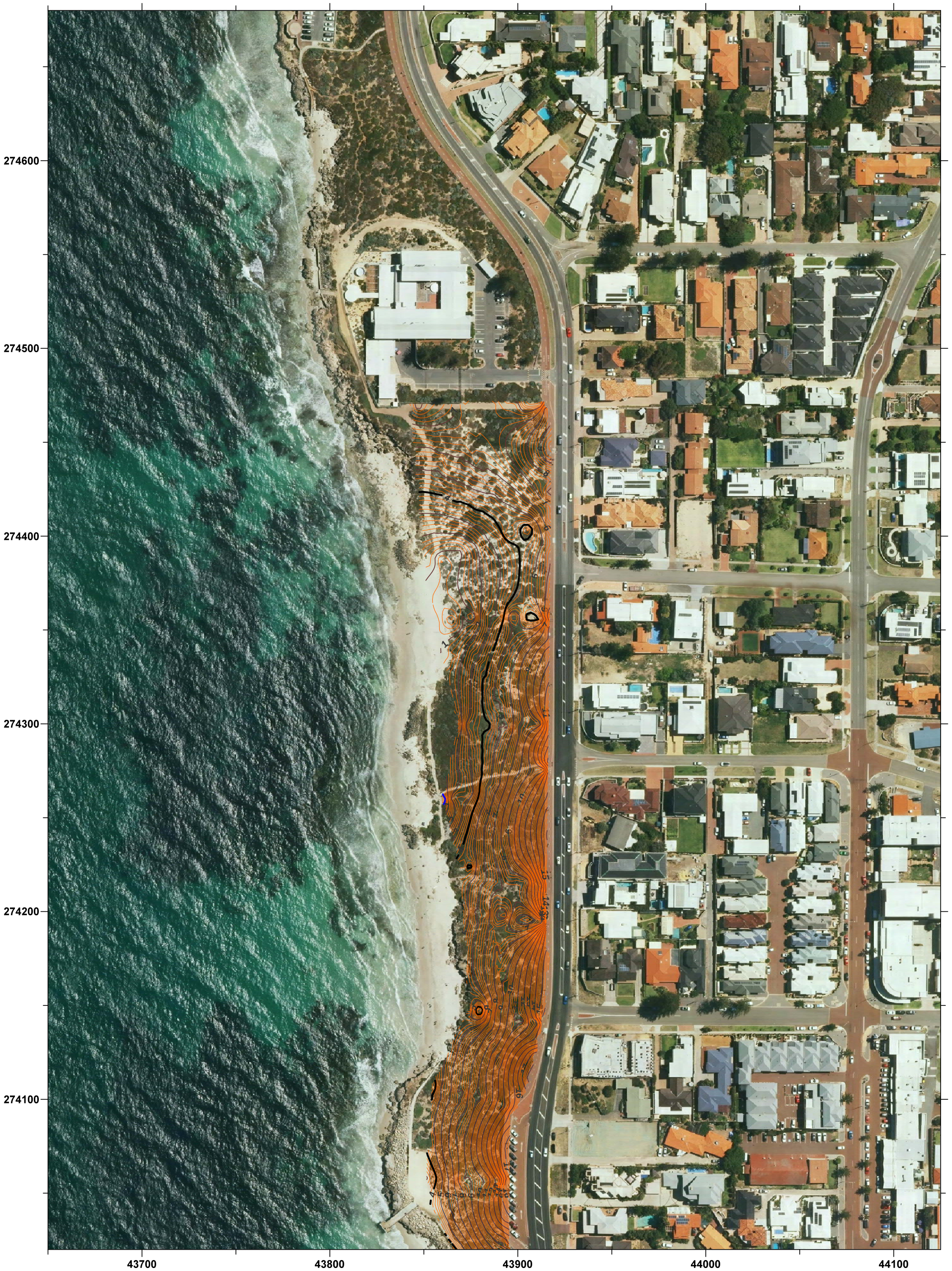
MODELLED LEVEL TO TOP OF ROCK - CONTOUR MAP



N

0 25 50 75 100
Metres

NOTES

Drawing to be used in conjunction with Report 70428.
Aerial image from Landgate January 2018.
Map Projection: Perth Coastal Grid 1994 (PCG94)
Elevation: Australian Height Datum (mAHD).

LEGEND

Rock Level 0 mAHD
Rock Level 4 mAHD

Date	04 July 2018	Paper Size	A3
Scale	1:2000	Drawn	AHWS
Drawing	70428-E05	Revision	1

CLIENT: **CITY OF STIRLING**

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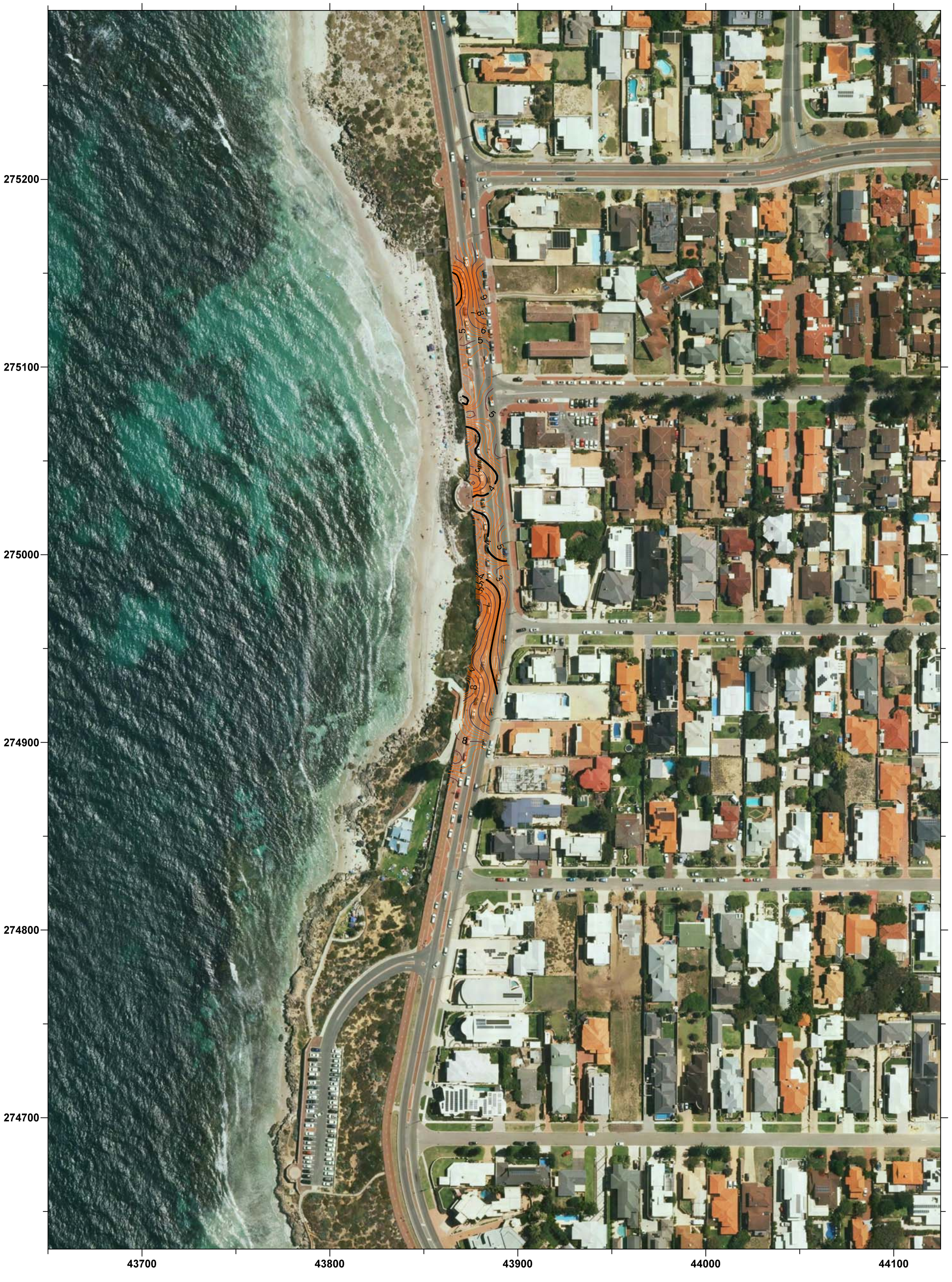
MODELLED LEVEL TO TOP OF ROCK - CONTOUR MAP



N

0 25 50 75 100
Metres

NOTES

Drawing to be used in conjunction with Report 70428.
Aerial image from Landgate January 2018.
Map Projection: Perth Coastal Grid 1994 (PCG94)
Elevation: Australian Height Datum (mAHD).

LEGEND

Rock Level 0 mAHD
Rock Level 4 mAHD

Date	02 July 2018	Paper Size	A3
Scale	1:2000	Drawn	AHWS
Drawing	70428-E06	Revision	0

CLIENT: **CITY OF STIRLING**

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APPENDIX H.
GEOPHYSICAL METHODS

MULTI-CHANNEL ANALYSIS OF SURFACE WAVES

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APPLICATIONS

- ✓ Bedrock mapping
- ✓ Degree of sediment compaction
- ✓ Determination of geotechnical parameters (e.g. shear modulus)
- ✓ Void detection
- ✓ Liquefaction potential
- ✓ Subsurface profiling
- ✓ Imaging velocity inversions (hard layer overlying softer layer)

METHOD

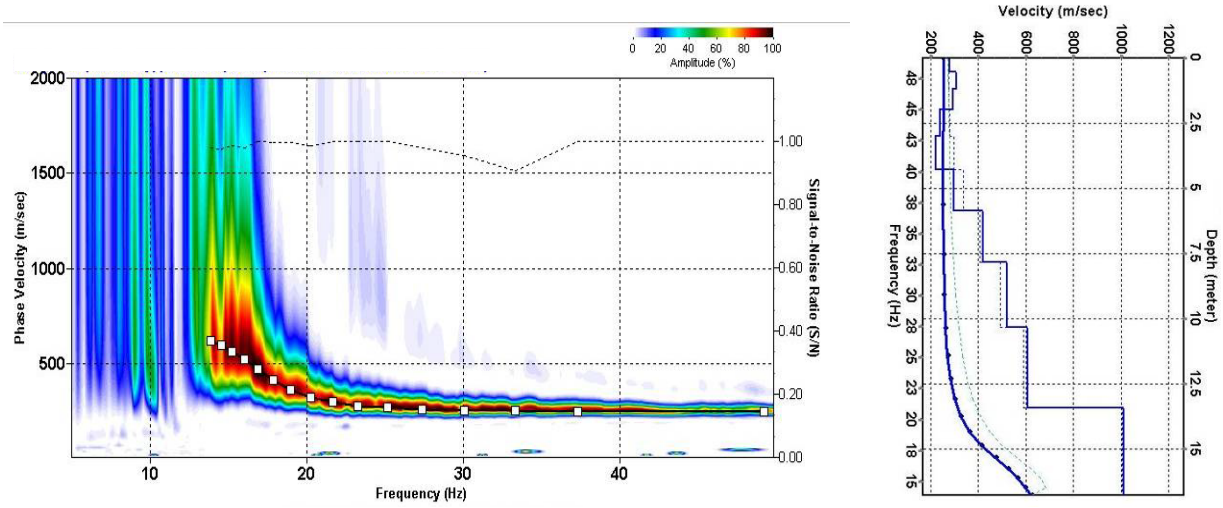
The Multi-channel Analysis of Surface Waves method (MASW) is a non-destructive seismic method which uses the elastic properties of subsurface materials to determine subsurface structure. By analysis of the dispersive properties of varying frequencies from a single seismic source, shear-wave velocity (Vs) and associated geotechnical parameters can be determined.

MASW uses an active seismic source such as a hammer or weight drop impact to produce seismic energy consisting predominantly of Pressure (P-) waves and Shear (S-) waves. MASW uses the S-wave dispersion component to provide information on the shear velocity to a depth determined by frequency range of the energy source and array configuration.

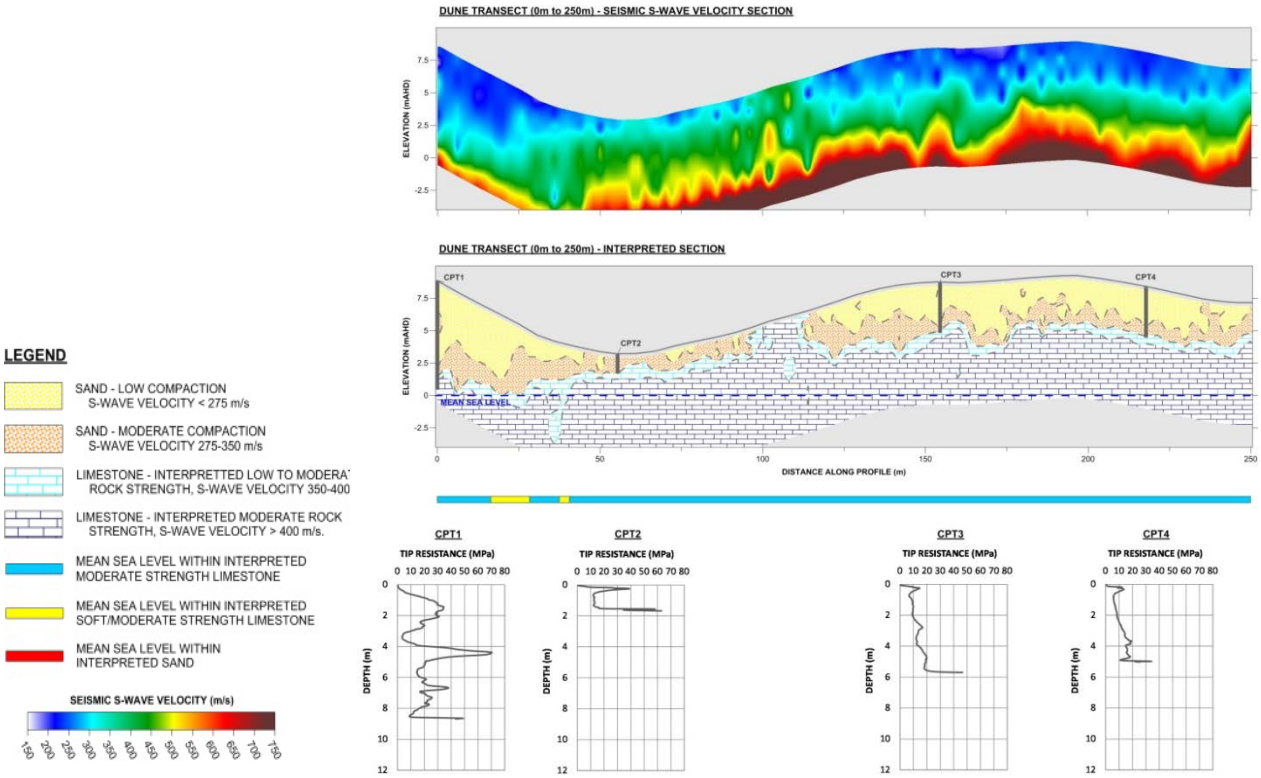
Seismic surface waves have dispersion properties that traditionally utilized body waves lack. Differing wavelengths/frequencies have different depth of penetration, and therefore propagates with different phase velocity, with an increase in wavelength being proportional to increased depth of penetration. As the surface wave is the dominant wave generated from any seismic source, MASW data quality (signal to noise) tends to be higher than other seismic methods such as seismic reflection or refraction.

DATA ANALYSIS & PRESENTATION

Analysis of the collected MASW seismic records is concentrated on the S-wave dispersion component. Dispersion curves are extracted for each collected record from the overtone image showing the percentage intensity of phase velocity versus frequency. These curves are then inverted to produce 1D S-wave soundings typically to a depth of up to 30 m. The calculated 1D soundings can then be compiled and gridded to produce 2D sections showing the variation in S-wave velocity both laterally along the profile and with depth.



Dispersion curve generated from an MASW sounding (left image), modelled S-wave velocity sounding generated from inversion of the picked dispersion curve



MASW seismic S-wave 2D velocity section with interpretation.

SEISMIC REFRACTION

GBGMAPS
Advanced Subsurface Investigations

APPLICATIONS

- ✓ Bedrock mapping
- ✓ Mapping weathered zones
- ✓ Stratigraphic mapping
- ✓ Indicative material hardness for piling, tunnelling and excavation works
- ✓ Identification of fault / fractured zones

METHOD

The Seismic Refraction method involves the measurement of travel times of seismic compressional waves (P-waves) that are generated at the surface, propagate through the subsurface and return to the surface after being refracted at the interface between layers of contrasting seismic velocity. Seismic wave velocities are controlled by the fundamental parameters of elastic strength and density of the material it propagates through.

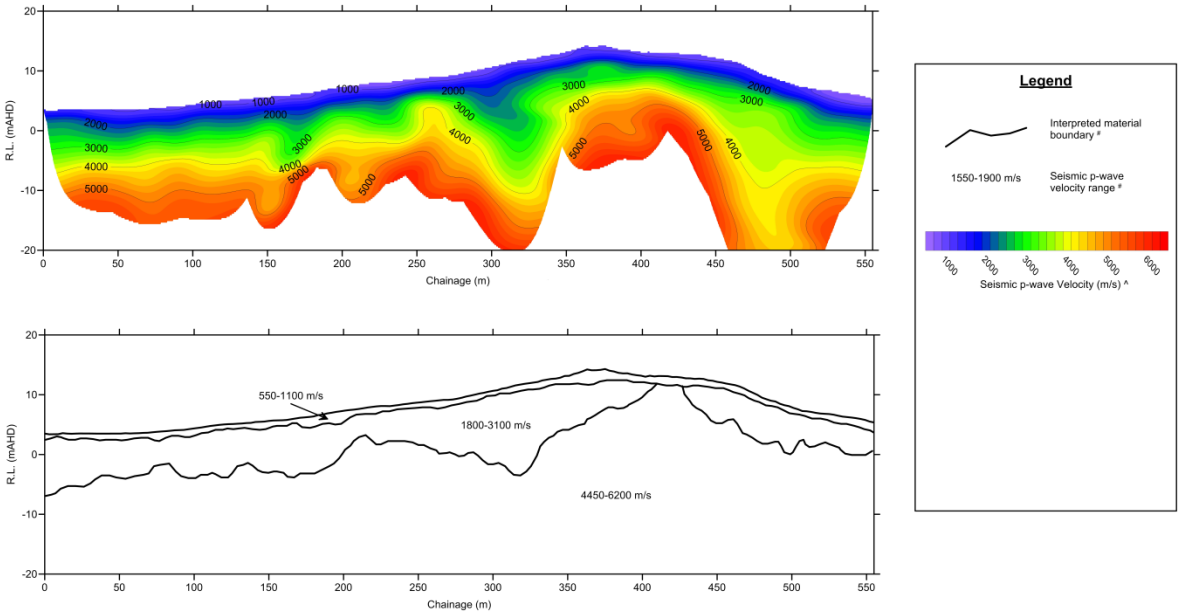
For near surface investigations seismic energy is generated on the surface using a sledge hammer. More powerful sources such as accelerated drop weight, down-hole airguns, or explosives are required for deeper investigations. The generated seismic waves propagate through the subsurface at a certain velocity. On reaching a geological boundary marked by an increase in seismic velocity, at a specific angle the wave is critically refracted and travels along the top of the lower layer at a greater velocity. This generates head waves in the upper layer which return to the surface where it is detected as vibrations by a linear array of geophones spaced at regular intervals.

By measuring the travel times of these refracted waves from multiple source points to multiple receivers, the seismic refraction method can resolve lateral changes in the depth to the top of a refracting interface as well as the seismic velocity within it. Furthermore being related to elastic strength and density, the velocities calculated from a seismic refraction survey can be a useful guide to the rippability of a rock for excavation.

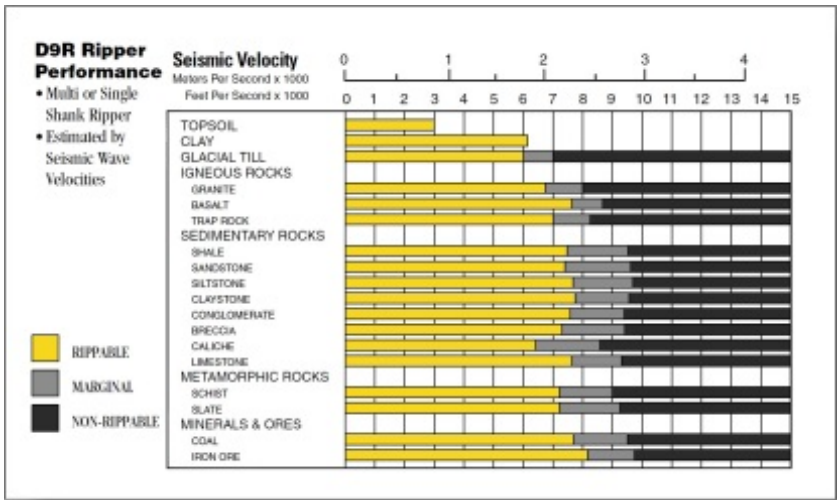
DATA ANALYSIS & PRESENTATION

Processing and analysing seismic refraction data can be carried out using a layered model assuming distinct refractive boundaries or tomographic approach assuming a gradual increase in seismic velocity with depth. Both approaches have benefits and are typically carried out in unison to generate the most detailed geological model possible.

The output is a cross-section showing lateral changes in the depth to the various refracting interfaces and the seismic velocities within them. When correlated with core logs, this information can be related to geological boundaries in the subsurface. This can be particularly useful for planning excavation with the depth to the different layers giving an idea of quantity of rock needed to be removed and the seismic velocities giving an idea of the rock's hardness and hence rippability.



Modelled seismic p-wave velocity section (top) and corresponding layer model section (bottom)



Rippability chart, displays the relationship between rippability and P-wave velocity, taken from Handbook of Ripping, Twelfth Edition, Caterpillar Inc. 2000.