GHD

Darwin East Point Sewage Outfall – Bathymetric & Topographic Survey
Larrakeyah Sewage Outfall – Bathymetric Survey

SURVEY REPORT No. 1

28 November 2008

<u>Job References</u>
FPSA HA2AAY
Survey No: 018_08

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Introduction

HydroSurvey Australia was engaged by GHD to undertake a bathymetric survey at two locations in Darwin Harbour – East Point and Larrakeyah.

Bathymetric Surveying

Bathymetric surveying is the measurement and description of the physical features offshore and adjoining coastal areas. When such measurements are taken with special reference to their use for the purpose of navigation it is termed as hydrographic surveying. GPS is used as a primary positioning system and is coupled with a digital single or dual frequency or Geoswath Multi beam echo sounder to record the depth of the water. The depth is collected each second in a regular pattern and stored with a GPS position and time tag. The depths are corrected for the draft of the boat, tidal variation and velocity of sound in water. The raw depths are reduced for tide and calibration parameters from the surface elevation to produce elevations on the bottom of the survey area. The elevations are used to produce a bathymetric contour map and 3-D views.

Objectives

The objectives of the works were to capture fine scale bathymetric data for the East Point Study Area (Map 1, Appendix A) and the Larrakeyah Study Area (Map 3, Appendix A).

The GeoSwath Technology

A 250kHz GeoSwath sonar (Figure 1) includes a pair of transducers (35cm by 15cm by 6cm) mounted on a V bracket, cables, and a sonar control computer which contains all the sonar electronics. The V bracket also houses a TSS DMS05 heave/pitch/roll sensor, or motion reference unit (MRU). Attached to the V plate is a bracket holding a Valeport mini SVS and a Tritech Digital Precision Altimeter.

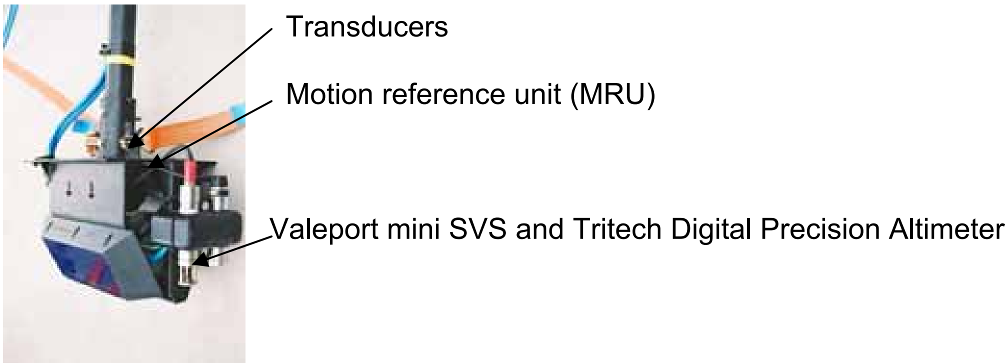


Figure 1 250 kHz GeoSwath Sonar

To use a sonar appropriately and maintain good quality control of the survey data the surveyor should have an appreciation of the sonar technology being used and its capabilities. The GeoSwath uses different techniques from beam forming multibeams in order to overcome the problems they experience when used in shallow waters. This section gives an introduction to the GeoSwath technology in order to make it clear why the GeoSwath does not have the beam former's limitations.

The GeoSwath uses phase comparison angle measurement, commonly described as interferometric multibeam or bathymetric side-scan. The sonar is typically configured with a port facing and a starboard facing transducer, with the boresight of each transducer aligned at about 30 degrees from the horizontal. Each transducer has one transmit stave and multiple receive staves. The transmitted pulse is similar to that used by side-scan sonar: very wide in the across track direction (greater than 150 degrees), narrow in the along track direction (about 1 degree), and about 30 microseconds long (~7.5cm, although this can be adjusted by the user). The beam patterns from the port and starboard transducers overlap under the vessel, giving extra coverage in this area.

The receive staves have a similar beam pattern to the transmit staves. They are connected to electronics that measure the amplitude and phase of the sonar signals scattered from the seafloor. The relative phase delay between the receive staves is decoded to give the angle of return of the sonar signal. Note that phase delay is a time delay measurement so it can be determined very accurately (to a fraction of a percent). These relative phases allow the angle of return of the sonar signal to be measured to a fraction of a degree, and measurements are taken at very short intervals (the interval is user selectable, down to every wavelength). It is this rapid and accurate phase measurement that gives the GeoSwath its very high resolution.

Each sonar ping from the GeoSwath provides a range series of angles to the seafloor. A port and starboard ping together give the seafloor profile under the vessel, and a series of pings taken as the vessel moves along the survey track gives the swath of soundings. The amplitude of the sonar return is also recorded, giving the side-scan image.

Shallow Water Surveys Using the GeoAcoustics GeoSwath

There are two main sources of error in the accurate location of a GeoSwath sounding, arising from the sea noise and the length of the sonar pulse. The pulse length limits the range accuracy, although the measurement interval can be set to be shorter than the pulse length to allow averaging. The sea noise (mainly from short range thermal sources) adds a random, uncorrelated phase component to the sonar signal on each stave of the transducer. The angle error induced by sea noise is usually what limits the sonar range and swath width, as the sound returned from the seafloor dies away at low grazing angles and the sonar pulse is attenuated by absorption in the sea. In shallow water the ranges are comparatively short so the signal strength is high, and the sonar pulse can be kept quite short. This allows the high angle accuracy of the phase measurement technique to be used to its best advantage, and the results of this can be seen in the earlier section on system accuracy.

Two questions are often raised with the phase measurement technique: the issue of simultaneous returns from two features at different angles and the lower data density under the transducers. The keys to overcoming these are the short pulse length, rapid phase measurements and very low noise electronics used in the GeoSwath Sonar. Simultaneous returns from two directions arise in shallow waters at the edges of U-shaped channels and by harbour walls. This is where the range to the vertical structure is the same as the range to the nearby seafloor, so the two returns can interfere at the transducer and cause errors in the phase decodes. The multiple return staves in the GeoSwath transducer give several redundant measurements of the angle, so inconsistent phases caused by interference can be detected. However, phase errors will only occur if the two returns are of very similar intensity. In practice the intensity of sound returned from a patch of seafloor or harbour wall varies rapidly. While interference will cause some data points to be rejected by the phase processing, there are many points where one of the returns is much more intense than the other and can be used. The rapid sample rate of the GeoSwath means that even with several points rejected the data density will be high.

The lower data density directly under the transducers arises because the range change from one measurement to the next is large at this point. Rapid measurement of the phases means this is minimised. For the shallow water surveys being considered here, in 5 m water depth a 30 microsecond sample rate corresponds to an across-track separation of the first two depth measurements of about 50 cm. This sample rate is typical of what is used in a normal survey, and provides at least 2 soundings per metre: further out from the vessel the sounding density rapidly increases, to over 40 soundings per metre.

Survey Methods

Date of Surveys

The bathymetric survey of the East Point study area was undertaken from 26 October to 3 November 2008. This included the inshore area of East Point surveyed on foot using a backpack and RTK GPS technology. The bathymetric survey of the Larrakeyah outfall was undertaken on 3 November 2008.

Extent of Surveys

East Point Bathymetric Survey
The original bathymetric / topographic survey area shown on Map 1 (Appendix A) of approximately 680 ha near East Point is bounded by the coordinates outlined in Table 1.

Table 1 Bounding Coordinates (MGA94, Zone 52) for the East Point Bathymetric Survey

Easting	Northing
695533	8630896
698631	8628579
698371	8627869
694506	8628185

A variation of approximately 135 ha was added to the original East Point bathymetric survey. It covers the area highlighted in Map 2 (Appendix A) and was bounded by approximate coordinates outlined in Table 2 Bounding Coordinates (MGA94, Zone 52) for the variation of works for the East Point Bathymetric Survey.

The extension of works was undertaken to explore the extent of a substrate structure that was assumed to be sand waves identified during the first stage of the bathymetric survey. This structure may be a limiting factor during the design phase of the project and the additional survey area was undertaken to define the extent of the structure. The structure was identified to extend significantly to the north of the East Point study area. The divers later confirmed that the structure was sand waves.

Table 2 Bounding Coordinates (MGA94, Zone 52) for the variation of works for the East Point Bathymetric Survey

Easting	Northing
696215	8630386
698110	8630386
698110	8628969

Larrakeyah Bathymetric Survey

The bathymetric survey undertaken at the Larrakeyah Sewage Outfall of approximately 4 ha was bounded by the coordinates outlined in Table 3 Bounding Coordinates (MGA94, Zone 52) for the Larrakeyah Bathymetric Survey and Map 3 (Appendix A).

Table 3 Bounding Coordinates (MGA94, Zone 52) for the Larrakeyah Bathymetric Survey

Easting	Northing
698725	8621150
698925	8621150
698925	8620950
698725	8620950

Bathymetric surveys

Personnel

Peter Hanson	-	Manager
Peter Woolfall	-	Accredited Hydrographic Surveyor
Greg Pearce	-	Accredited Hydrographic Surveyor / Coxswain
Neil Hewitt	-	Accredited Hydrographic Surveyor
Perry Woodward	-	Coxswain
Adrian Drabsch	-	Draftsman

Vessel and equipment

The survey vessel Felix was used for the bathymetric survey of the areas near East Point and the Larrakeyah Sewage Outfall. The Felix is a twin hulled 5 m vessel, customised for hydrographic survey work. A hinged over the side mount carries the swath transducers and other underwater components of the GeoAcoustics GeoSwath Plus wide swath system. Simultaneous side scan is recorded in the raw data files.

The following equipment was used for the survey:

- Survey vessel Felix;
- GeoAcoustics Geoswath Plus – Swath acquisition and processing system;
- Trimble HydroPro survey guidance, acquisition and processing system;
- Odom DigibarPro velocity of sound profiler;
- Trimble 5700 RTK system;
- Bruttour CeeStar high frequency single beam echo sounder;
- Terramodel Processing Software;
- SG Brown Meridian Gyro Compass;
- TSS DMS 05 motion sensor;
- Trimble AG 132 GPS receiver;
- Bruttour CeeTide logger; and
- AutoCad version 2008.

Positioning was provided by an AG 132 DGPS receiver. Differential corrections were obtained from OmniStar transmissions that ensured sub-metre positional accuracy. Trimble HydroPro software was used for guidance and transformation of GPS positions to MGA94 Zone 52 cartesian coordinates.

Equipment Specifications

GeoAcoustics – GeoSwath Plus 250kHz wide swath system Specifications

GeoSwath is available in three frequency versions, 125 kHz, 250 kHz and 500 kHz. The system accuracy of all versions exceeds the Special Order specifications, as set out in IHO Standards for Hydrographic Surveys, Special Publication 44, 4th Edition, April 1998.

Sonar Frequency 125 kHz 250 kHz 500 kHz (ROV/AUV version)

Recommended Maximum Operating Depth Below Transducers
200 metres 100 metres 50 metres
Maximum Slant Range 390 metres 195 metres 95 metres
Maximum Swath Width 780 metres 390 metres 190 metres
Range Up to 12 x depth Up to 12 x depth Up to 12 x depth
Depth Resolution 6mm 3mm 1.5mm
Two Way Beam Width 0.85º Azimuth 0.75º Azimuth 0.5º Azimuth
Transmit Pulse Length 128 μS to 896 μS 64 μS to 448 μS 32 μS to 224 μS
Swath Update Rate
50m Swath Width 30 swaths per second 30 swaths per second 30 swaths per second
150m Swath Width 10 swaths per second 10 swaths per second 10 swaths per second
300m Swath Width 5 swaths per second 5 swaths per second
600m Swath Width 2.5 swaths per second

TSS – GS Brown – Meridian Surveyor Gyro Compass

Display type 360° compass card and VFD display
Settle point 0.1° secant latitude
Static accuracy 0.05° RMS secant latitude
Dynamic accuracy 0.2° secant latitude
Follow up speed 200°/sec
Settling time <40 minutes, to within 0.7°
Latitude input Automatic – via RS232 or RS422, NMEA 0183 from GPS or Manual
Speed input Automatic – via RS232 or RS422, NMEA 0183 from log or pulse/contact closure at 100, 200 or
400 per NM from log or manual
Latitude compensation 80N to 80S
Speed compensation 0 – 90 knots

TSS Dynamic Motion Sensor

Dynamic accuracy Heave Roll & Pitch
All (except DMS-RP25) DMS-05 DMS-10 DMS-25 DMS-RP25
5cm or 5% whichever is greater 0.05° 0.10° 0.25° 0.25° (period 0 to 20s)
Amplitude ±30°
Maximum range Heave ±10m; Roll & Pitch ±60°
Bandwidth Heave 0.05 to >30 Hz; Roll & Pitch 0 to 30Hz
Data output rate Digital: up to 200 Hz Analogue: up to 500 Hz (with an external repeater)

Bruttour CeeStar Digital Survey Depth Sounder - single beam

Standard HF frequency : 200kHz.
Depth range 0 - 100m.
Accuracy : 0.02% of depth or 1cm (whichever is greater)
Resolution = 1cm

Trimble 5700 RTK Performance Specifications / Measurements

Advanced Trimble Maxwell technology
High-precision multiple correlator L1 and L2 pseudorange measurements
Unfiltered, unsmoothed pseudorange measurement data for low noise, low multipath error, low time domain correlation, and high dynamic response
Very low noise L1 and L2 carrier phase measurements with <1 mm precision in a 1Hz bandwidth
L1 and L2 Signal-to-Noise ratios reported in dB-Hz
Proven Trimble low-elevation tracking technology
24 Channels L1 C/A Code, L1/L2 Full Cycle Carrier, WAAS/EGNOS

Code differential GPS positioning

Horizontal. . . . . ±(0.25 m + 1 ppm) RMS
Vertical. . . . . ±(0.5 m + 1 ppm) RMS
WAAS differential positioning accuracy typically <5 m 3DRMS2
Static and FastStatic GPS surveying1
Horizontal. . . . .±5 mm + 0.5 ppm RMS
Vertical. . . . . ±5 mm + 1 ppm (× baseline length) RMS

Kinematic surveying

Real-time and post-processed kinematic surveys
Horizontal. . . . . . . ±(10 mm + 1 ppm) (× baseline length) RMS
Vertical. . . . . ±(20 mm + 1 ppm) RMS
Initialization time. . . . . Single/Multi-base minimum
10 sec + 0.5 times baseline length in km, up to 30 km
Scalable GPS infrastructure initialization time <30 seconds typical anywhere within coverage area
Initialization reliability.

Calibrations

The survey vessel and sounding equipment had been calibrated to remove systematic errors. This involved squat measurements for the Felix (Attachment A) and compass alignment and motion sensor reference to the transducer plates. Calibration also includes latency measurements for the on board systems and a bar check for the single beam echo sounder (Attachment B).

Speed of sound measurements through the water column were recorded during the course of the survey and applied with tides during processing.

Horizontal control

A static check on the horizontal coordinates generated by the on board survey system was performed at Nightcliff over survey mark S93266017. Northern Territory Department of Planning and Infrastructure (DPI) provided the coordinate values. The results have been recorded in Table 4 Static check of horizontal coordinates generated on board survey vessel.

Table 4 Static check of horizontal coordinates generated on board survey vessel

Description	MGA94 Zone52	
	Easting	Northing
S93266017	700282.900	8630761.129
Felix position	700282.700	8630760.900
Difference	-0.200	-0.229

Vertical control

The location for the Darwin National Tidal Centre (NTC) tide logger (Figure 2) is Fort Hill Wharf. The data from this logger and many others around Australia is used in sea level monitoring and analysis. HydroSurvey Australia was able to obtain the tides from the NTC from this gauge. These data were used in the processing of the bathymetric data from Darwin.

Prior to the field survey commencing HydroSurvey Australia established a Bruttour Ceetide (Figure 3) portable tide logger alongside the NTC gauge as a backup in case of unforeseen breakdown.

Chart Datum or Tide Gauge Zero for the NTC gauge and for this survey is set 10.349m below the Seaframe Sensor Bench Mark (SSBM) (Figure 2) located at the NTC tide gauge.

The Bruttour Ceetide portable logger uses an acoustic sensor to measure the level of the water and reduce it to the tide datum. The Bruttour Ceetide datum was established independently of the NTC logger using bench mark 'C' (top of steel bolt) found on Fort Hill Wharf (Figure 4) which has an Australian Height Datum (AHD) value of 5.892m as supplied by DPI. It's height was then connected to the NTC logger Seaframe Sensor Bench Mark (SSBM) (Figure 2) using traditional spirit levelling and measured to be within 6mm of the NTC value.

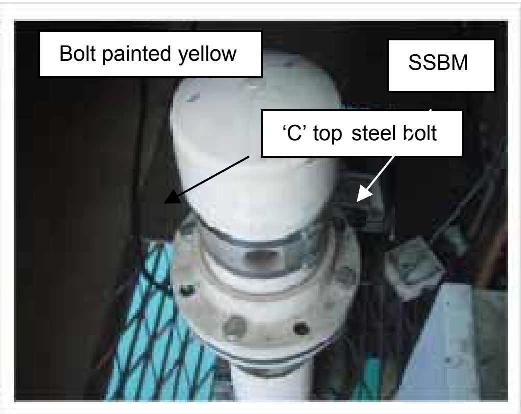


Figure 2 NTC Tide Gauge showing Seaframe Sensor Bench Mark. (Elevation = 6.374mAHD)

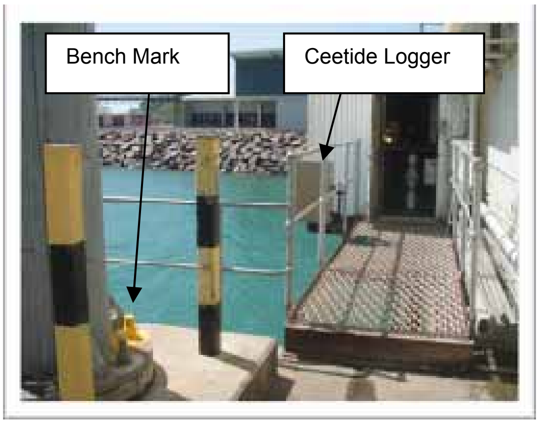


Figure 3 Ceetide portable logger and HydroSurvey Bench Mark. Floodlight bolt painted yellow. (Elevation = 6.085mAHD)

Figure 4 Benchmark on Fort Hill Wharf. (Elevation = 5.892mAHD)

A comparison of tides recorded by the NTC logger and the Ceetide logger produced the results outlined in Figure 5. The two graphs effectively sit on top of each other. There were no significant differences recorded for the duration of the survey.

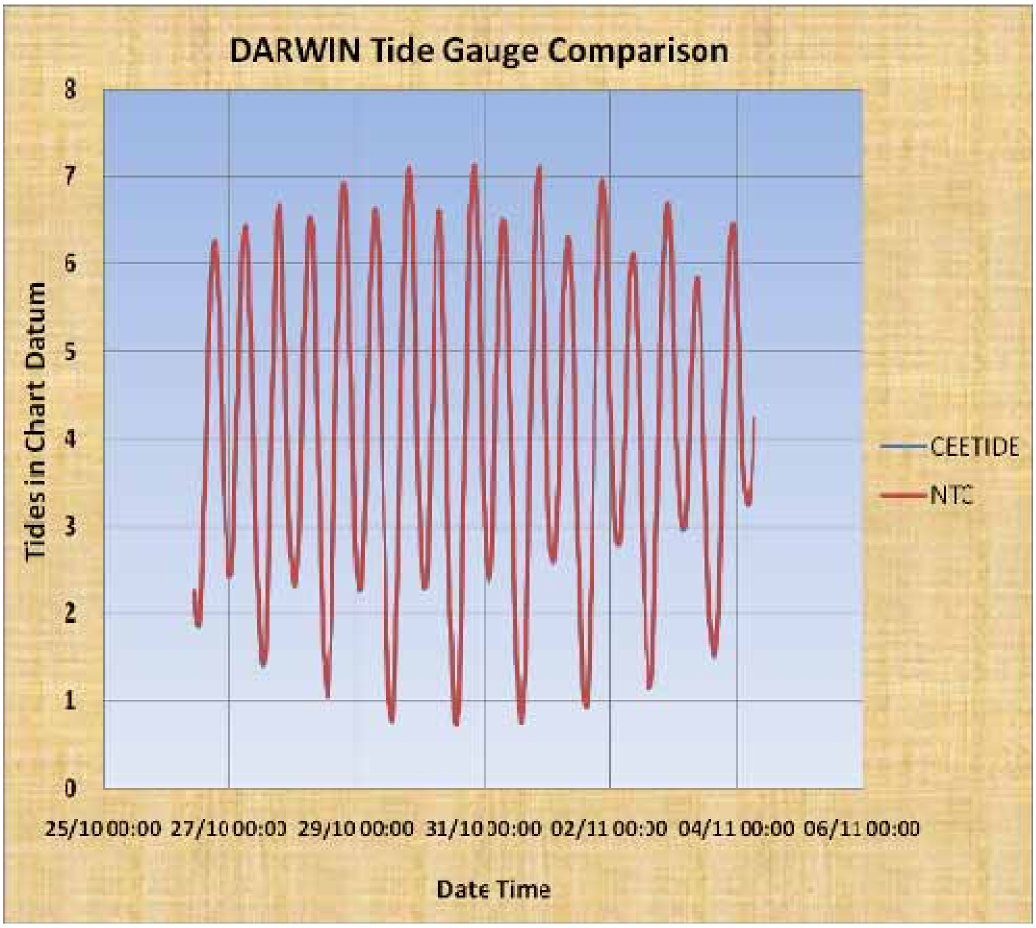


Figure 5 A comparison of NTC logged tides vs Ceetide logged tides (the blue lines lies underneath the red line).

Coverage

East Point Survey

Prior to the commencement of the East Point survey, run lines were created at 10 m spacing to systematically cover the survey area. The final line spacing in the field was then determined according to the conditions and the depth of water at the time. Generally lines were run at 20 m and 30 m intervals to achieve total bottom coverage.

Day to day weather and tidal conditions were very similar during the course of the survey. The high tides in the early morning coincided with the calmer morning conditions and meant that the inshore coverage could be maintained at a 20 m line spacing. The falling tides consistently coincided with the onset of a late morning sea breeze in the opposite direction and caused a confused choppy sea surface. The motion reference unit is designed to remove the roll, pitch and heave up to a point at which time the survey had to be postponed. The deeper areas were surveyed later in the morning as the tide dropped but most of the line spacing was kept to 20 m to minimise the effect of the deteriorating conditions. Figure 6 shows the pattern of survey lines used to achieve full coverage of the study area.

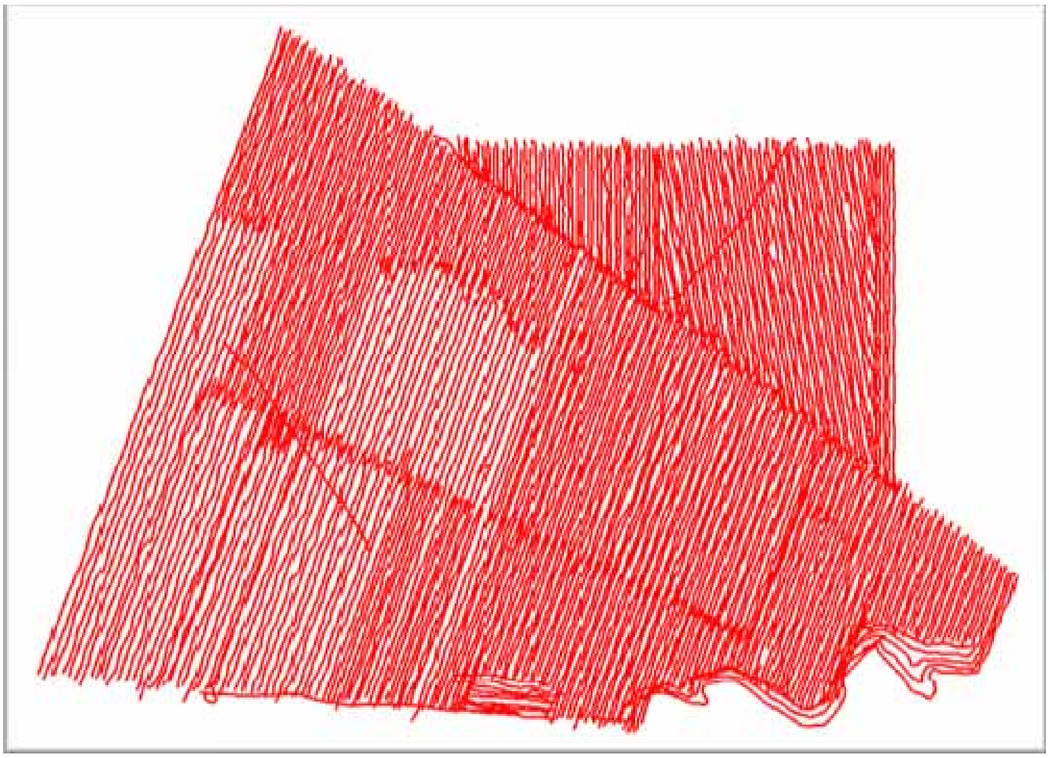


Figure 6 Survey lines used to achieve full coverage of the East Point study area.

The south east corner of the study area was exposed at low tide and the rocky portions of this area were filled in up to the coast line using RTK GPS, back pack mounted technology (vide. P15).

Larrakeyah Survey

The survey over the Larrakeyah Outfall area was undertaken at the completion of the East Point area on 3 November. The wind at the time of the survey was a moderate north westerly. Initially the survey area was covered by running lines 20 m apart in an east west direction. Further lines were then run in a north south direction to provide a good pickup of the pipeline and surrounding area. Figure 7 shows the survey lines that were completed.

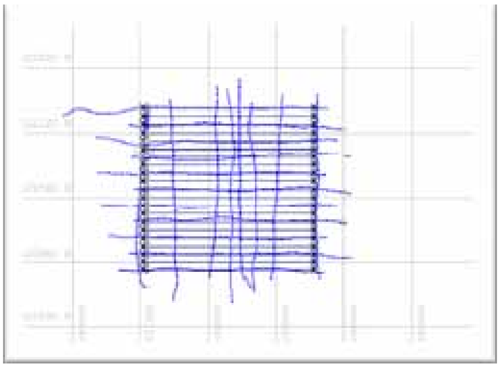


Figure 7 Survey lines completed over the Larrakeyah study area.

Topographic survey

A portion of the inshore area near East Point exposed at low water (Figure 8) was surveyed on foot using the Trimble RTK GPS system with the rover mounted in a backpack (Figure 9). This allowed areas of rock and in particular an exposed steel structure near the existing outfall to be surveyed safely without exposing the vessel to undue risk of grounding or damage. Parts of the area were then overlapped by the Felix at high water so values could be compared. The RTK base or reference station (Figure 10) was erected in the immediate vicinity of the survey over the permanent survey mark NTS676 using coordinate values provided by DPI outlined in Table 5.

The reference station transmits GPS derived coordinate corrections to the rover to provide real time, on the fly horizontal and vertical positions to centimetre accuracy.

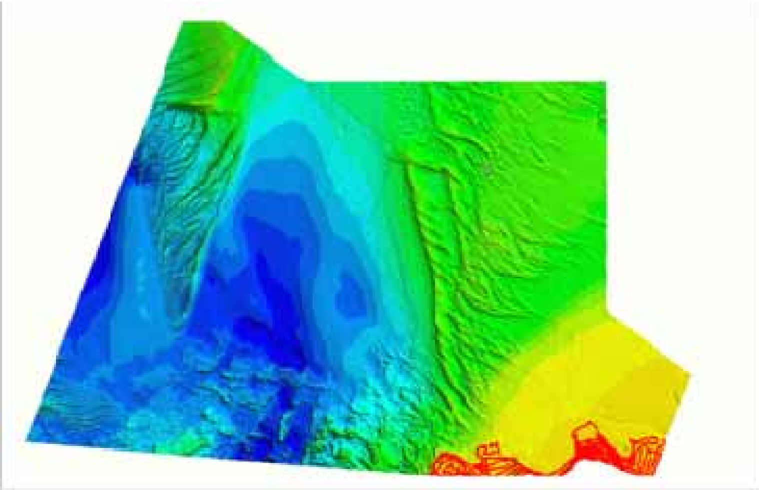


Figure 8 Extent of the East Point topographic survey marked in red.

Figure 9 Backpack mounted RTK GPS.

Figure 10 RTK GPS Reference Station

Table 5 Location of DPI survey mark NTS676 used for the topographic field survey at East Point.

Description	MGA 94 Zone 52		AHD
	Easting	Northing	
NTS676	697893.544	8627974.250	8.148m

Processing

Correcting raw data

Processing of swath sounding data was conducted using GeoAcoustic Geoswath Plus version 3.15p swath sounding system. Prior to processing system calibration parameters are determined and stored as constants within the processing software (Table 6).

Table 6 Settings used for reducing raw data files

Port roll	Starboard roll	Pitch	Yaw	Nav latency	MRU latency	Compass Latency
-0.60˚	-0.95˚	0˚	0˚	0.25 sec	0.018 sec	0.009 sec

During acquisition the attitude of the vessel is constantly monitored by the Motion Reference Unit (MRU) and values for heave, roll, pitch and yaw are stored in the raw data files along with GPS position and time tags.

The speed of sound and tide files recorded in the field are formatted ready for use during processing.

During processing all of the above corrections are applied to each of the soundings that make up the swath survey. The corrected soundings are then put through a number of filters to extract those soundings that represent the seabed. These filtered soundings are then saved to a swath file. The swath files of the individual lines are then combined via binning to form a grid of points.

Binning

Due to the size of the area and the limitations of the systems that are required to handle the data it was decided to bin the filtered soundings to a 2 m grid. In this case there was an average of over 400 soundings per 2 m bin. The average depth of all the soundings in a bin is calculated as the value of that bin. This procedure is in place to provide maximum resolution for the amount of data involved.

DTM

The processing software is then used to create a Digital Terrain Model (DTM) from the binned data. This DTM is then used to create such things as contours at whatever interval is required and 3D visual representations of the data which can be overlayed into the final drawings.

Plotting

To represent the survey on a plan the binned data must be thinned to a spacing to match the selected scale of the drawing.

The software that we use is able to do the thinning of data using a nominated circle of influence. For example, to maintain readability of a 1:500 scale drawing a circle of influence of 5 m is appropriate. The software is also able to extract the shoalest or deepest sounding from within the circle of influence to maintain a selected bias in the data which appears on the drawing. In this case the individual soundings on each of the plans are biased towards shoaling i.e. the binned sounding of least depth has been extracted from within the circle of influence.

Horizontal Datum

For both study areas the horizontal data have been converted to Map Grid of Australia 1994 (MGA94) Zone 52 cartesian coordinates based on the Geocentric Datum of Australia 1994 (GDA94).

Vertical Datums

The data has been converted to Chart Datum (CD) and Australian Height Datum (AHD).

CD or Tide Gauge Zero for this survey is set 10.349m below the Seaframe Sensor Bench Mark (SSBM).

SSBM = 6.374mAHD

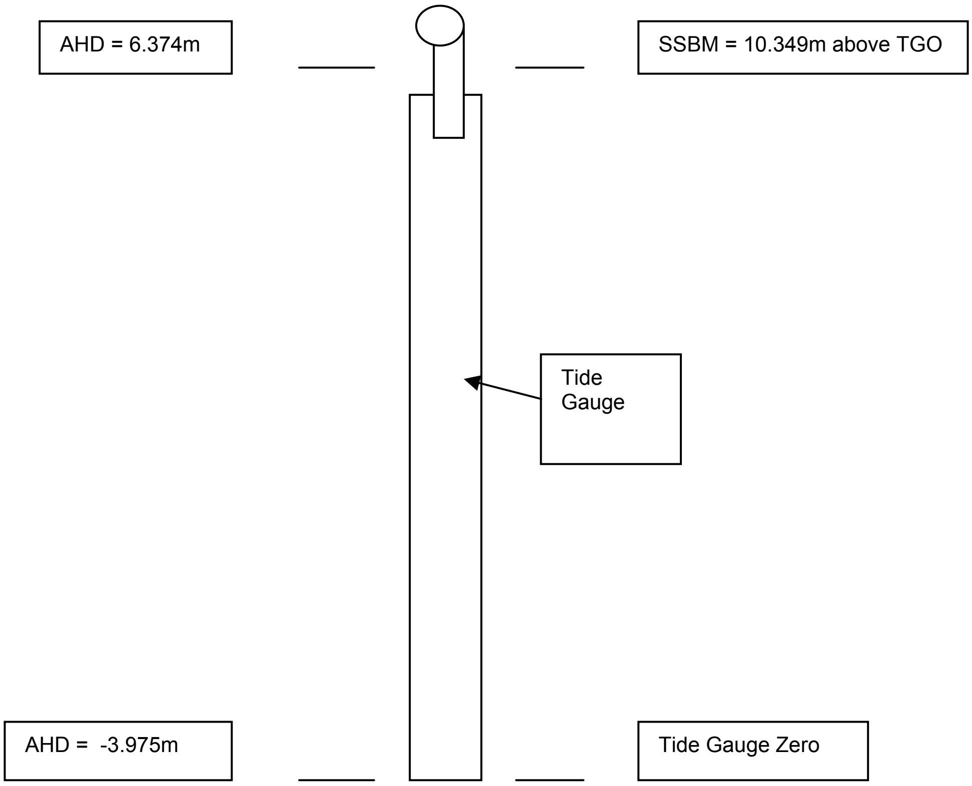


Figure 11 Graphical representation of Vertical Datums

Results

East Point Bathymetric Survey

General Observations

The existing outfall was observed at low water with approximate coordinates of 698110E, 8628375N (Figure 12, 13, 14 and 15).

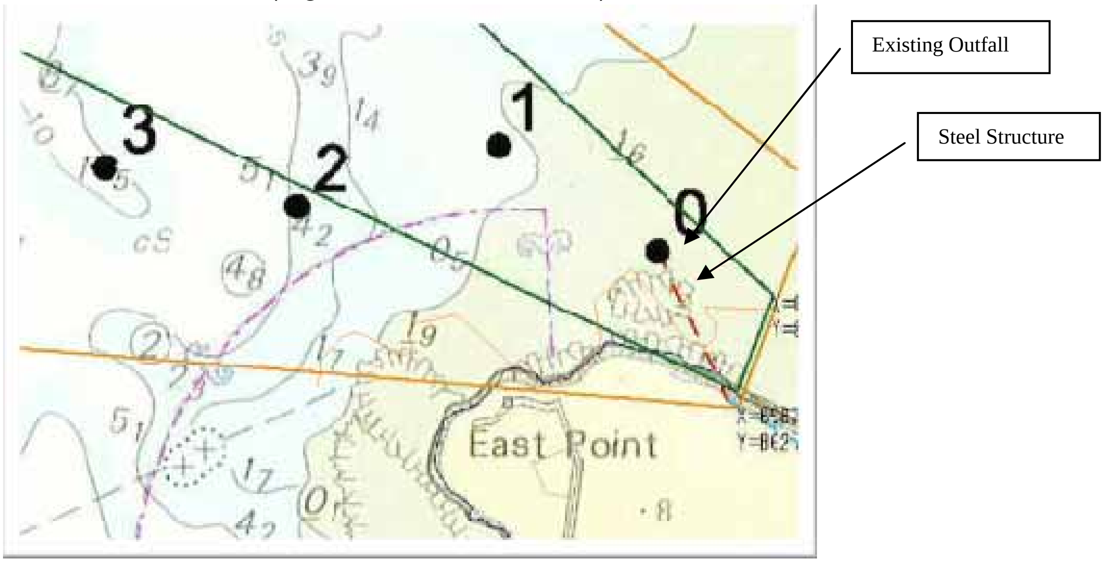


Figure 12 Location of unidentified steel structure

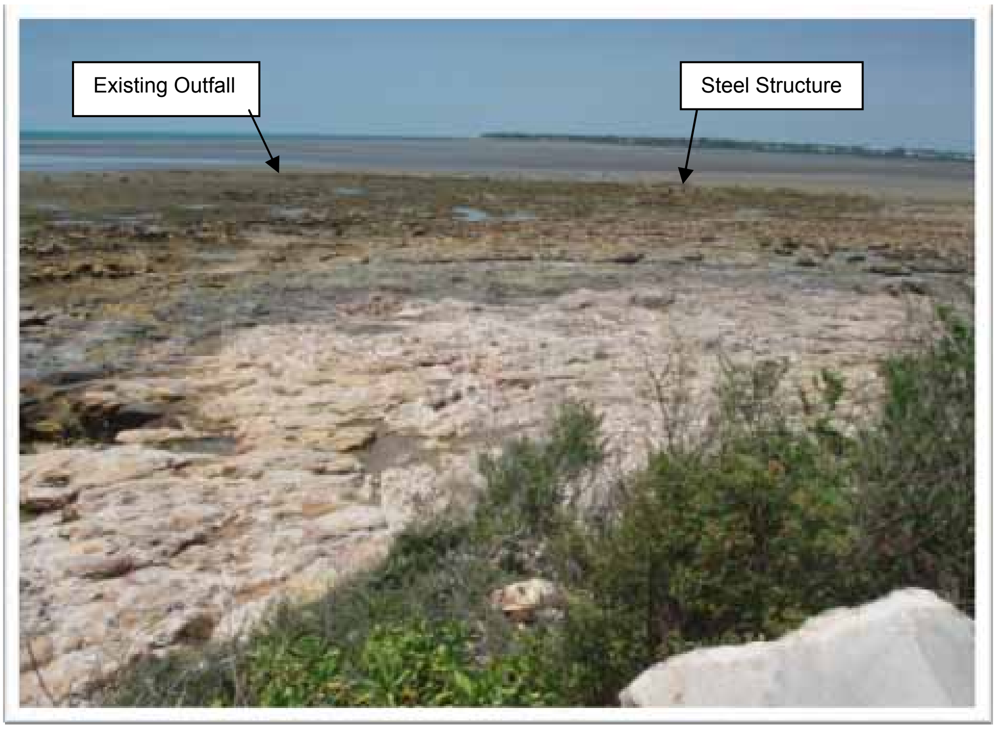


Figure 13 Photograph of the existing East Point outfall and an unidentified steel structure within the intertidal area.

Figure 14 Photograph of the existing East Point outfall

Figure 15 Photograph of the unidentified steel structure

The Intertidal Area

The daily tidal movement within Darwin harbour was approximately 6 m during the duration of the survey. The receding 6 m plus tides also exposed areas of sand, mud, rocky reef and areas where the rock layer below the sand is exposed. As depicted in Figure 16 and 17, a sea bed which is shown as flat by the bathymetric survey may be comprised of sand/mud or of rock. It is not possible from the bathymetric or side scan surveys to determine the extents of this **underlying** layer of rock. However, analysis of the side scan survey including ground truthing may provide an indication of the extents of the **exposed** areas of underlying rock, subject to extensive ground truthing.

Figure 16 Exposed intertidal area of sand and rock at East Point.

Figure 17 Exposed intertidal area of rock at East Point.

The following photos (Figure 18) give an indication of the scattered rocks exposed at low water. The bathymetric survey has been gridded to 2 m and therefore objects smaller than this will not be well defined. However the bathymetry will show areas such as this as distinct from areas of regular forming sand waves (subject to ground truthing).

Figure 18 Photographs providing an indication of the scattered rocks exposed at low water at East Point.

Distinguishing Features

In the 3D image below (Figure 19) sand waves appear as regular shaped features while a bottom of exposed rock or reef appears more scattered. Areas that appear flat or featureless would indicate compacted sand, although exposed areas of flat rock were observed in the inshore area at low water.

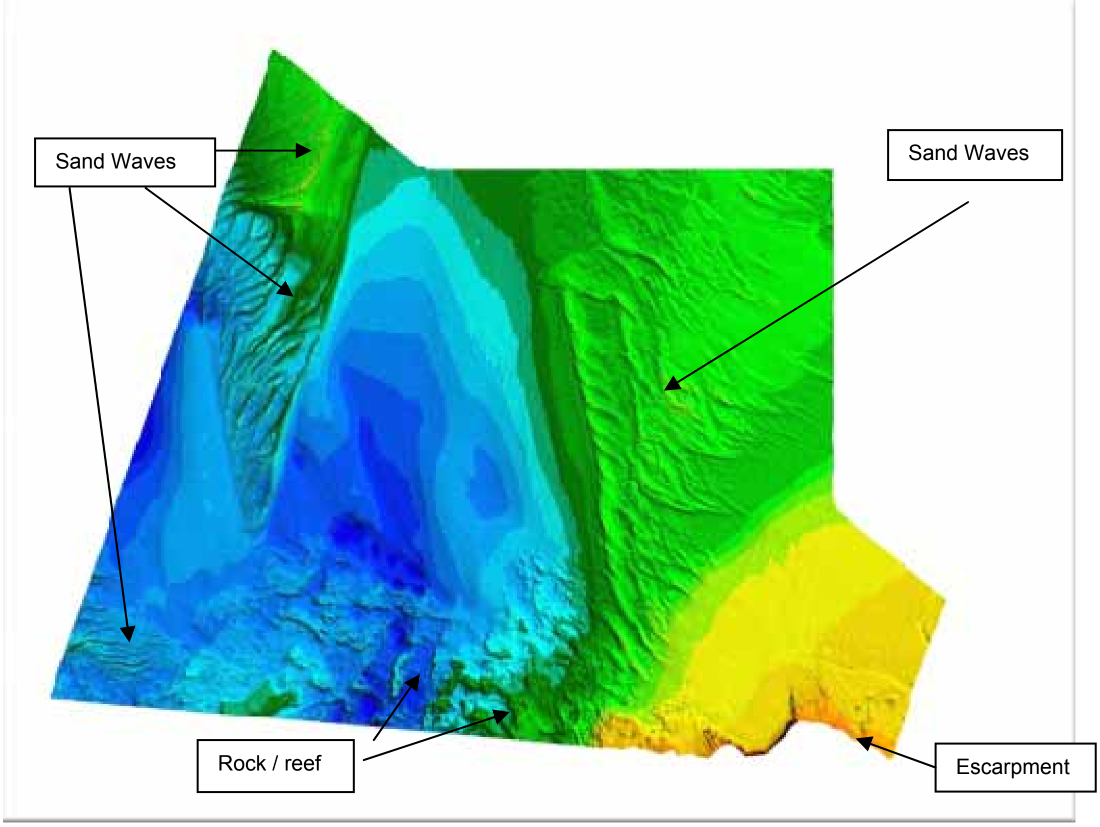


Figure 19 A 3D image of the bathymetric data indicating distinguishing features of sand waves, rock/reef patches and the escarpment.

The Charts

The data collected across the East Point study area have been presented in 2 datums. The chart which has been labeled in the vertical datum box as being reduced to Chart Datum (Map 4, Appendix A) show individual soundings. A sounding value represents a depth or distance to the sea bed below Tide Gauge Zero. A negative sounding represents a distance above Tide Gauge Zero and may represent areas that are exposed at very low tides. The contours appear in the same datum as the soundings.

The chart which has been labeled in the vertical datum box as being reduced to AHD (Map 5, Appendix A) shows individual levels of the sea bed surface. Most of the levels across these areas are negative because Tide Gauge Zero occurs at -3.975 mAHD (Figure 11). The contours appear in the same datum as the levels.
The 3D overlays have been coloured and shaded to try to accentuate any features in the survey areas and the colours have been matched to the contours. The 3D overlays should be viewed with the individual soundings or the contours to determine colour band values.

Tide Anomaly

The survey data for East Point contains some slight error caused by the large variation in the tide and the distance of the tide logger from the survey area. The survey was completed over several days and where a survey from one day abuts the survey from another day a slight difference in the values may be evident due to the tidal plane. The error is quite small but shows up in the 3D image due to the vertical exaggeration that has been applied. It would generally occur at times when the abutting section was surveyed mid tide when the current and therefore the difference between the tide at the tide gauge and the tide on site is greatest.

The error which is up to +/- 10 cm has been accounted for in the accuracy statement.

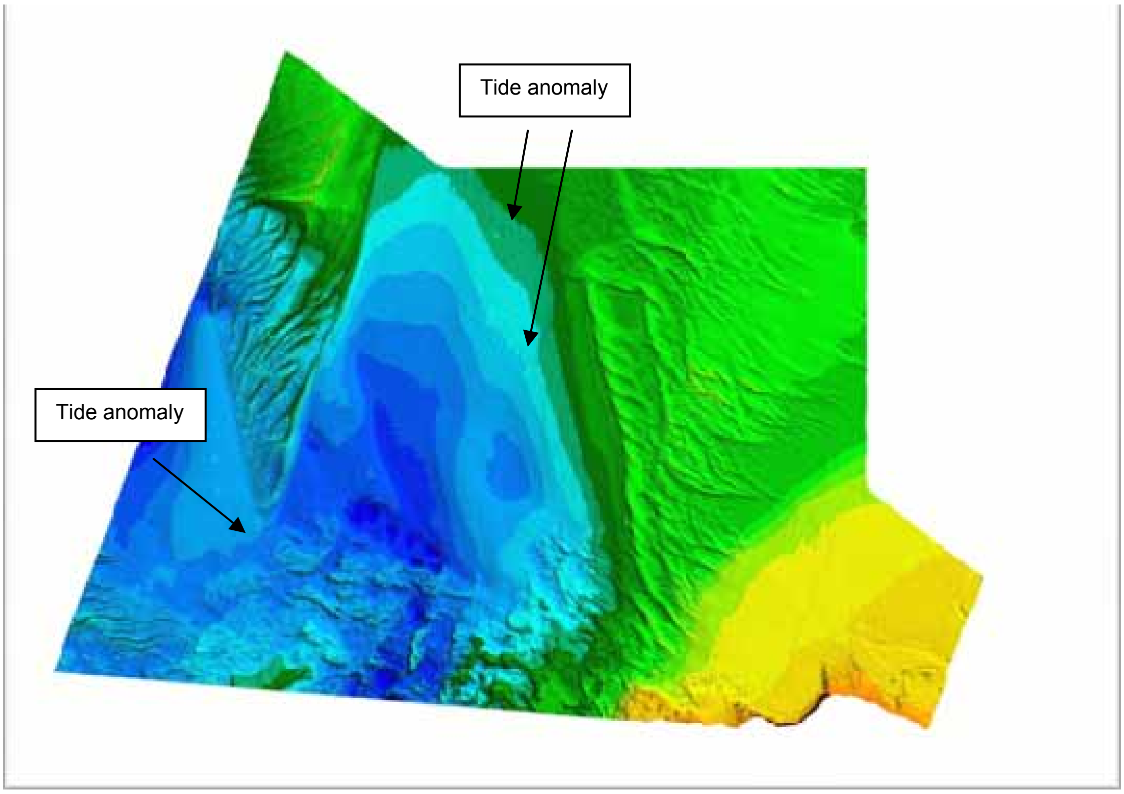


Figure 20 3D image of data indicating the location of tide anomalies.

Motion artifacts

Also apparent in the 3D model of the survey data are motion artefacts. These are slight variations that occur along the track of the vessel, particularly in very shallow water. They are of the order of only a few centimetres but become visible in the 3D model as a result of the vertical exaggeration that has been applied.

Where possible the soundings beneath the transducers have been clipped and replaced by overlapping swaths to minimise the artefact.

By keeping line spacing to a minimum and maximising the overlaps of the swath data, motion artefacts have been diluted. Generally these artefacts can only be observed in the flatter sandy areas.

By taking the above precautions while surveying in very shallow water the motion artefacts do not detract from the quality of the survey. Motion artefacts have been accounted for in the accuracy statement.

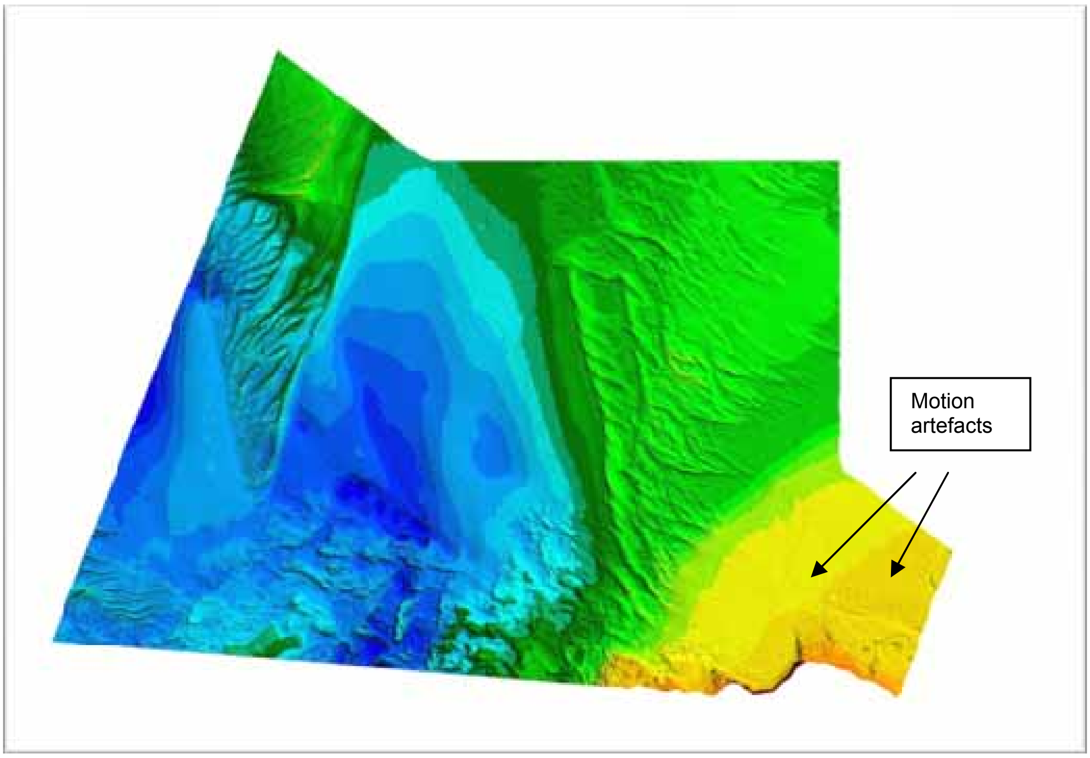


Figure 21 3D image of data indicating the location of motion artefacts in very shallow water.

Accuracy Statement

The following have been calculated for a swath of 30 m each side of the vessel in 10 m of water. The greater part of the survey of East Point was performed using a 20 m swath in less than 10 m of water.

Horizontal Sounding Accuracy

Factors to consider in assessing the horizontal accuracy of the sounding data are listed below:

- The Trimble AG132 has an accuracy of +/-0.5 m for this application using the OmniStar differential corrections.
- The motion reference unit has a quoted accuracy for pitch and roll of +/- 0.05°. This equates to a positional error in 10 metres of water at 30 m swath width of:
  Pitch: 1 cm (approx)
  Roll: 10 cm (approx)
- The Meridian gyro compass has a quoted accuracy of +/- 0.5°. This equates to a positional error at 30 m swath width of +/-26 cm (approx)

Therefore an estimation of the horizontal error at 30 m swath width in 10 m of water can be calculated as:

$\sqrt{(50^2 + 1^2 + 10^2 + 26^2)}$ = +/-57.24 m.

Vertical Sounding Accuracy

An assessment of the total sounding accuracy can be determined by combining the errors due to the sounding system and tidal model. The tide gauge has a specified resolution of 1 cm, however it should be noted that due to the high variation in tide and the distance of the survey area from the tide gauge the error estimate for tide has been increased 2 cm to 12 cm. The errors associated with this survey have been assessed as follows:

Error (in 10 MOW)	Value
Sound Velocity	0.010
System	0.020
Draft	0.030
Bottom composition	0.030
Squat	0.030
Roll	0.03
Tide	0.12
Heave	0.05

An estimation of total error can then be calculated as follows:
Total error in 10 m of water $=\sqrt{(0.01^2+0.02^2+0.03^2+0.03^2+0.03^2+0.03^2+0.12^2+0.05^2)}1.96$
= **+/-0.284 m at 95% confidence**

The International Hydrographic Organisation (IHO) has developed a series of standards for hydrographic surveys to help improve the safety of navigation. Within these standards the accuracy of a survey can be classified according to it's order of survey. The 4 orders of survey are Special, 1a, 1b, and 2. Special order surveys must be achieved where under keel clearances are critical to safe navigation. Order 1a surveys are for areas where under keel clearances are less critical. This survey falls within IHO guidelines for order 1a surveys that state accuracy in depths less than 10m should be less than:

$$\pm \sqrt{[a^2+(b*d)^2]}$$

Where *a = 0.5 m b = 0.013 d = depth in metres*
Therefore in 10 metres of water, accuracy must be within:
$\pm \sqrt{[0.5^2+(0.013*10)^2]}$ = 0.517 m to meet IHO Order 1a.

Larrakeyah Bathymetric Survey

General Observations
The Larrakeyah Outfall study area is an area of approximately 4 hectares ranging in depth from approximately 18 m in the south west corner to 14 m in the north east corner.

Distinguishing Features
The only distinguishing feature is the outfall pipeline (Figure 22), the coordinates of which are: 698842E,8621058N. There does not appear to be any scarring to the surrounding area the outfall caused by the discharge. The pipeline sits above the level of the surrounding seabed by an average of approximately 40 cm.

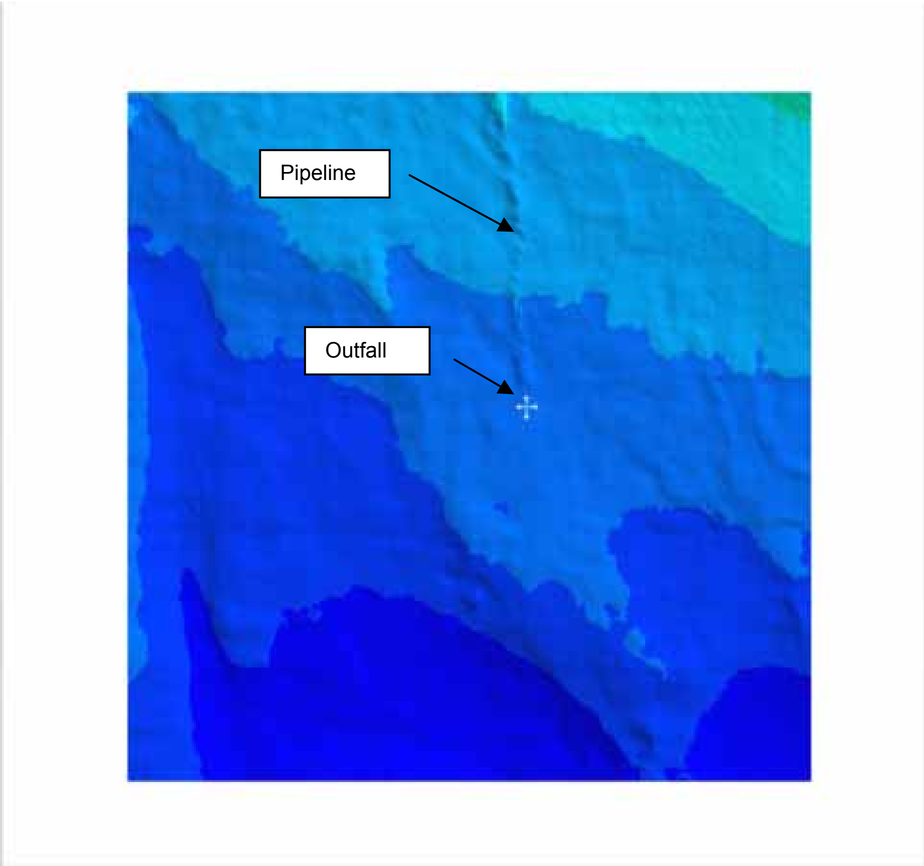


Figure 22 3D image of Larrakeyah study area indicating the position of the sewage outfall.

The charts

The data collected across the Larrakeyah study area has been presented in 2 datums.
The chart which has been labelled in the vertical datum box as being reduced to Chart Datum (Map 6, Appendix A) show individual soundings. A sounding value represents a depth or distance to the sea bed below Tide Gauge Zero. The contours appear in the same datum as the soundings.
The chart which has been labelled in the vertical datum box as being reduced to AHD (Map 7, Appendix A) shows individual levels of the sea bed surface. The levels are negative because Tide Gauge Zero occurs at -3.975 mAHD (Figure 11). The contours appear in the same datum as the levels.
The 3D overlays have been coloured and shaded to try to accentuate any features in the survey areas and the colours have been matched to the contours. The 3D overlays should be viewed with the individual soundings or the contours to determine colour band values.

Tide Anomaly

The survey of the Larrakeyah study area was performed during slack water at low tide when the level of water at the tide gauge and on site were in equilibrium. The Larrakeyah study area is also much closer to the tide gauge than East Point and therefore the tidal plane would be negligible. The data collected for the Larrakeyah study area were not affected by the tidal plane.

Motion Artifacts

The data collected in the Larrakeyah study area are not affected by motion artefacts because of the depth of the water and the density of the data. The relatively small survey area meant that extra lines could be run to maximise coverage and resolution.

Accuracy Statement

The following have been calculated for a swath of 30m each side of the vessel in 10m of water. The Larrakeyah survey area is deeper but lines were run at 20m spacing and extra lines were run over the area to achieve excellent resolution.

Horizontal Sounding Accuracy

Factors to consider in assessing the horizontal accuracy of the sounding data are listed below:

- The Trimble AG132 has an accuracy of +/-0.5 m for this application using the OmniStar differential corrections.
- The motion reference unit has a quoted accuracy for pitch and roll of +/- 0.05°. This equates to a positional error in 10 metres of water at 30m swath width of:
  Pitch: 1 cm (approx)
  Roll: 10 cm (approx)
- The Meridian gyro compass has a quoted accuracy of +/- 0.5°. This equates to a positional error at 30 m swath width of +/-26 cm (approx)

Therefore an estimation of the horizontal error at 30m swath width in 10m of water can be calculated as:

$\sqrt{(50^2 + 1^2 + 10^2 + 26^2)}$ = +/-57.24 cm.

Vertical Sounding Accuracy

An assessment of the total sounding accuracy can be determined by combining the errors due to the sounding system and tidal model. The errors associated with this survey have been assessed as follows:

Error (in 10 MOW)	Value
Sound Velocity	0.010
System	0.020
Draft	0.030
Bottom composition	0.030
Squat	0.030
Roll	0.03
Tide	0.02
Heave	0.05

An estimation of total error can then be calculated as follows:
Total error in 10m of water = $\sqrt{(0.01^2+0.02^2+0.03^2+0.03^2+0.03^2+0.03^2+0.02^2+0.05^2)}1.96$
= **+/-0.163 m at 95% confidence**.

The International Hydrographic Organisation (IHO) has developed a series of standards for hydrographic surveys to help improve the safety of navigation. Within these standards the accuracy of a survey can be classified according to it's order of survey. The 4 orders of survey are Special, 1a, 1b, and 2. Special order surveys must be achieved where under keel clearances are critical to safe navigation. Order 1a surveys are for areas where under keel clearances are less critical. This survey falls within IHO guidelines for order 1a surveys that state accuracy in depths less than 10m should be less than:

$$\pm \sqrt{[a^2+(b*d)^2]}$$

Where *a = 0.5 m b = 0.013 d = depth in metres*

Therefore in 10 metres of water, accuracy must be within:

$\pm \sqrt{[0.5^2+(0.013*10)^2]}$ = 0.517 m to meet IHO Order 1a.

Constraints to Pipeline Development

The East Point bathymetric survey was undertaken in an area identified by GHD (Map 1 and Map 2, Appendix A). A proposed pipeline corridor was identified by GHD (Map 8, Appendix A) in the area for a proposed extension of the existing sewage outfall. In terms of the bathymetry data the following comments are made regarding the bathymetry along the proposed route of the pipeline (Figure 23 and Figure 24):

- The majority of the route is gently sloping and should not pose any significant problem to a surface laid pipeline.
- Two areas of particular note between chainage 700 m – 1200 m and 2600 m – 3050 m are likely to cause areas of significant free span due to the existence of considerable sand wave fields. Sand waves are created in areas of sandy seabed where tidal current is high and therefore can vary in position and height on a daily basis at times. The sand waves in these two areas have heights of up to 6 m from the surrounding seabed at the time they were surveyed. There were no significant change in position and height of the sand waves during the survey period.
- Although seabed composition is not able to be assessed from the bathymetry, no reef or rocky areas above the general level of the seabed are evident along the proposed route. Seabed type should be determined by a combination of acoustic and ground truthing sampling methods.

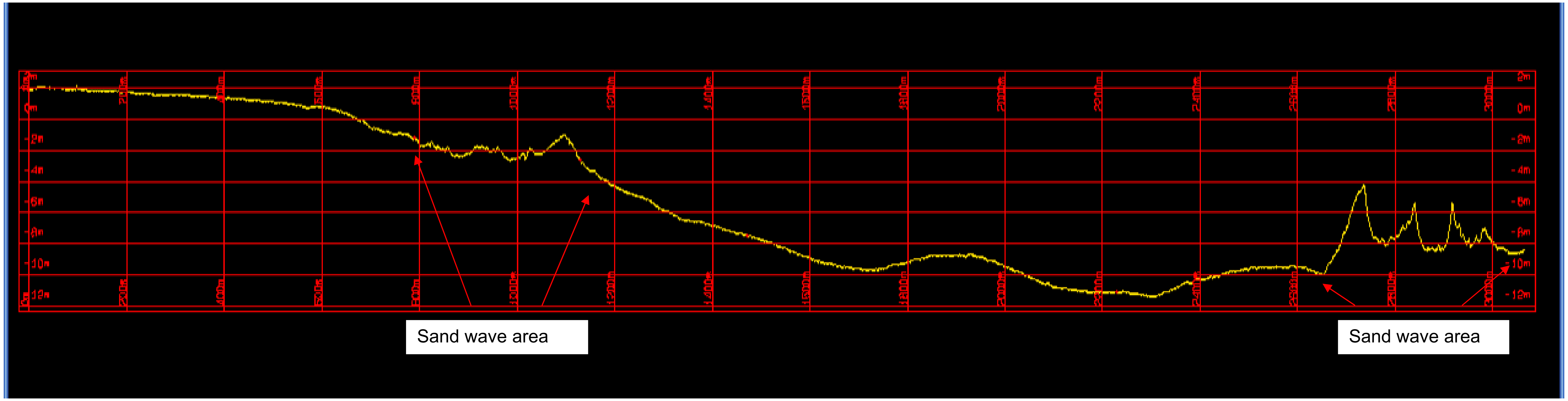


Figure 23 Profile of pipeline corridor as identified by GHD (Map 8, Appendix A)

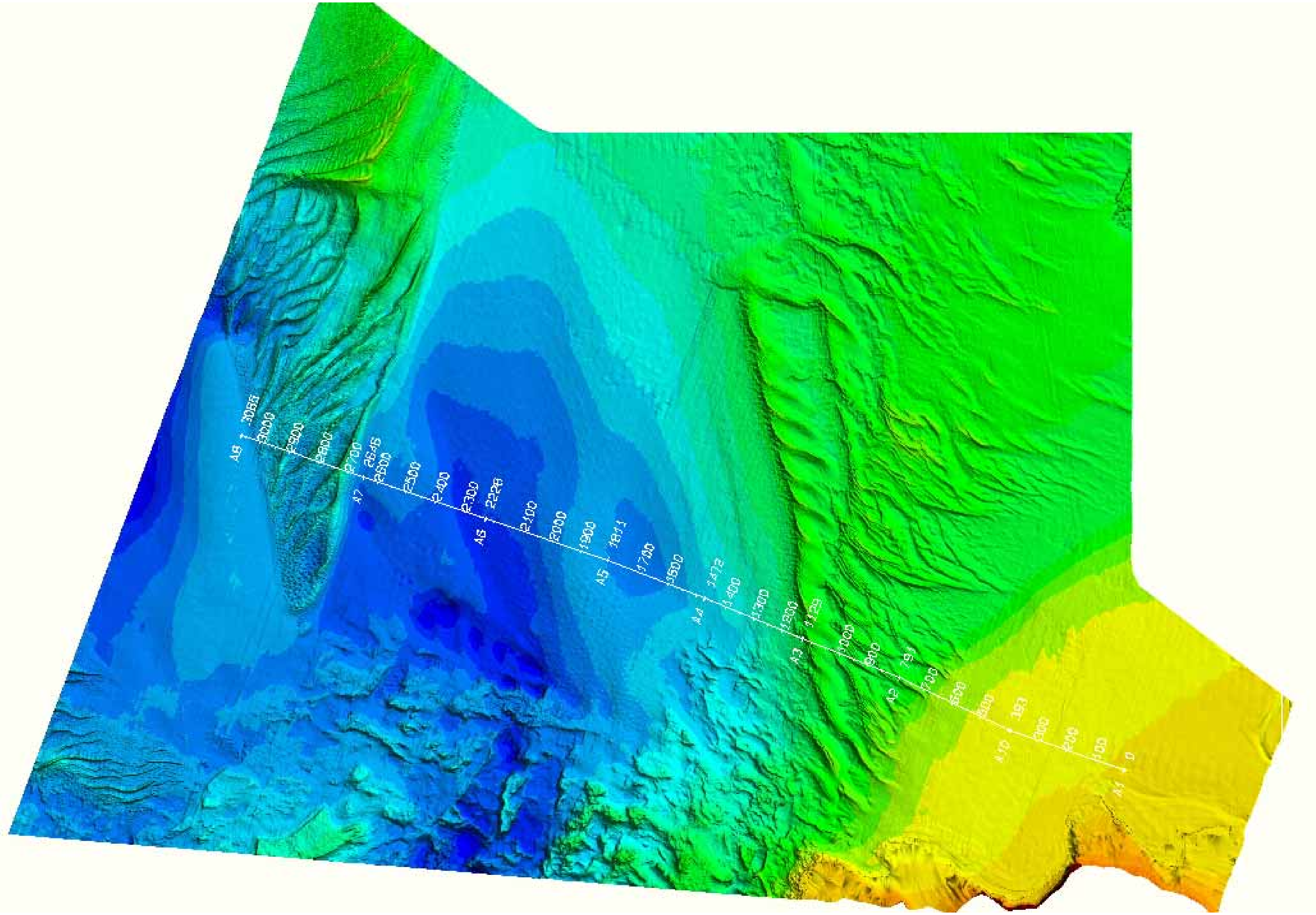


Figure 24 Plan View of pipeline corridor

Supplied Data

Paper and electronic copies of the report

Hard copy of plan of East Point survey area @ 1:5000 showing soundings to chart datum with 3D bathymetric overlay **(Drg No. FP1679)**

Hard copy of plan of East Point survey area @ 1:5000 showing soundings to AHD with 3D bathymetric overlay. **(Drg No. FP1678)**

Hard copy of plan of Larrakeyah survey area @ 1:500 showing soundings to chart datum with 3D bathymetric overlay. **(Drg No. FP1681)**

Hard copy of plan of Larrakeyah survey area @ 1:500 showing soundings to AHD with 3D bathymetric overlay **(Drg No. FP1680)**

AutoCad drawing files of the survey plans

Image files used in creation of plan

1 Swath sounding file of East Point survey area (2m grid). Format: E,N,Z(AHD heights) **(Darwin_East Point_nov08_MGA94Z52_AHD_2mbin.txt)**

1 Swath sounding file of East Point survey area (2m grid). Format: E,N,Z(Chart Datum) **(Darwin_East Point_nov08_MGA94Z52_CD_2mbin.txt)**

1 Swath sounding file of East Point survey area (1:5000 plottable). Format: E,N,Z(AHD heights) **(Darwin_East Point_nov08_MGA94Z52_AHD_45mCOI.txt)**

1 Swath sounding file of East Point survey area (1:5000 plottable). Format: E,N,Z(Chart Datum) **(Darwin_East Point_nov08_MGA94Z52_CD_45mCOI.txt)**

1 Swath sounding file of Larrakeyah survey area (1m grid). Format: E,N,Z(AHD heights) **(Darwin_Larrakeyah_nov08_MGA94Z52_AHD_1mbin.txt)**

1 Swath sounding file of Larrakeyah survey area (1m grid). Format: E,N,Z(CD heights) **(Darwin_Larrakeyah_nov08_MGA94Z52_CD_1mbin.txt)**

1 Swath sounding file of Larrakeyah survey area (1:500 plottable). Format: E,N,Z(AHD heights) **(Darwin_Larrakeyah_nov08_MGA94Z52_AHD_5mCOI.txt)**

1 Swath sounding file of Larrakeyah survey area (1:500 plottable). Format: E,N,Z(Chart Datum) (**Darwin_Larrakeyah_nov08_MGA94Z52_CD_5mCOI.txt)**

Photos: A selection of photos of the Felix, site control and general interest.

Appendix A Summary

Map 1 : East Point Sewage Outfall (Drg No. B08-1731)
Map 2 : East Point – Darwin Additional bathymetric survey area
Map 3 : Larrakeyah Sewage Outfall (Drg No. B08-6946)
Map 4 : East Point (Drg No. FP1679)
Map 5 : East Point (Drg No. FP1678)
Map 6 : Larrakeyah (Drg No. FP1681)
Map 7 : Larrakeyah (Drg No. FP1680)
Map 8 : Pipeline Corridor

Approval

LETTER OF APPROVAL

This report and the accompanying data are respectfully submitted. Field operations contributing to the accomplishment of this survey were conducted under my direct supervision with frequent personal checks of progress and adequacy. This report and the accompanying data have been closely reviewed and are considered complete and adequate as per the job specification.

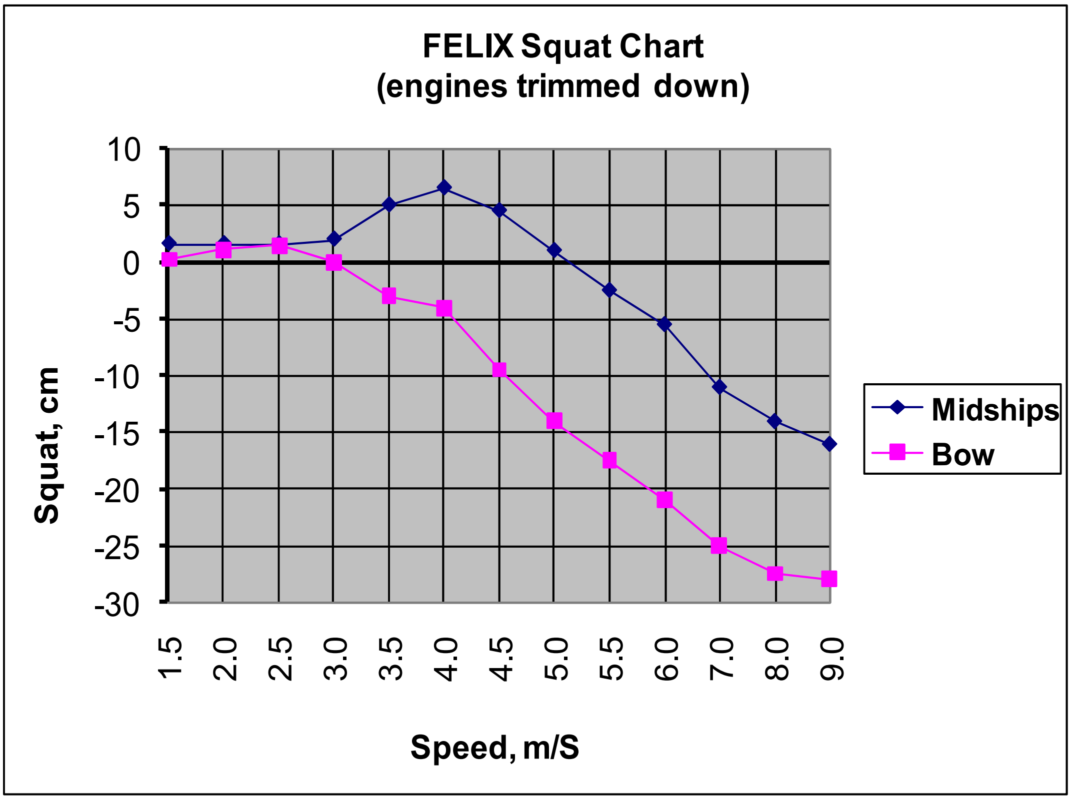
____

Jeff Heppner
Chief Hydrographic Surveyor
HydroSurvey Australia

Date__________________________

Attachment A

FELIX Squat Chart				
Full tanks, Two men, Engines trimmed down.				
6th Oct. 1999				
	Squat, cm:		Engine RPM	
Speed, m/S	Midships	Bow	(approx.)	
1.5	1.6	0.3	1100	
2.0	1.6	1.1	1450	
2.5	1.6	1.5	1800	
3.0	2.0	0.0	2300	
3.5	5.0	-3.0	2800	
4.0	6.5	-4.0	3250	
4.5	4.5	-9.5	3400	
5.0	1.0	-14.0	3600	
5.5	-2.5	-17.5	3800	
6.0	-5.5	-21.0	4000	
7.0	-11.0	-25.0	4350	
8.0	-14.0	-27.5	4700	
9.0	-16.0	-28.0	5100	



Attachment B

Echo sounder calibration – summary table (October 2008)

The summary table lists the latest bar check calibrations on the various echo sounders and the date when the calibration was conducted.

Echo sounder	Draft index	DigibarPro Index	Date
Echotrac Mk2 - HF - LF	-0.05m -0.20m	-6 m/s -6 m/s	8 April 2008
CeeStar Felix - HF CeeStar Felix - LF	- 0.07m - 0.12m	0 m/s 0 m/s	9 April 2008 9 April 2008
CeeStar Jet Ski - HF CeeStar Jet Ski - LF	-0.05m -0.09m	-5m/s -5m/s	17 April 2008 17 April 2008
Tritech - HF Tritech approx cal	- 0.03m	- 28 m/s Factor = 1.10900 1501/1473	21 July 2003

Note: Echotrac Mk2 set LF draft 15cm below HF draft
CeeStar Felix set LF draft 4 cm below HF draft

Usual draft on the vessels at rest:

Pathfinder = 0.73m
Felix = 0.45m
Jet Ski = 0.20m (draft = 0.328m – distance from W/L to fender groove)

Echotrac Mk1 is unreliable – unable to obtain a consistent bar check

Echotrac Mk1 (2) - HF	-0.01m	-11 m/s	19 Jan 2005

Checking digibars – 15 April 2008

Digibar	S/N	Temp	Reading	Temp	Report
Pathfinder (2) new	98460-081606	19	1481.0	19 19.5	1479.21 1480.77
Felix old	141-101703	19	1480.6	19 19.5	1479.21 1480.77

Attachment C

Survey Vessel 'Felix' Certificate of Survey :

MR 700
02/08

Government of South Australia
Department for Transport, Energy and Infrastructure

Certificate of Survey

This vessel has been surveyed pursuant to the Uniform Shipping Laws Code.
Any exemptions granted by the issuing authority may not be accepted by another jurisdiction.

Name of vessel		Type of vessel		Certificate Id.
FELIX		TRADING OTHER		28004
Measured length: 5	Measured Breadth: 2.6	Measured depth: .5	GRT(if applicable)	Survey class: 2C
Engine make/type: MERCURY OUTBOARD		Engine power (KW): 37.5	Hull material: FIBREGLASS	Identifying No.

Owner's details
FLINDERS PORTS PTY LTD, 296 ST VINCENT STREET PORT ADELAIDE 5015 SA

Operational Limits
NOT MORE THAN 15 NAUTICAL MILES FROM THE COASTLINE AND WITHIN A 20 NAUTICAL MILE RADIUS OF AN OPERATIONAL VHF RADIO COAST OR LIMITED COAST STATION

Exemptions (variations from USL code)
1 VESSEL NOT REQUIRED TO HAVE A BILGE PUMP IN ACCORDANCE WITH USL CODE
2 COMPASS NOT ADJUSTED EVERY 3 YEARS FOR CLASS C VESSELS

Special conditions
1 This Certificate of Survey / Certificate of Inspection / Certificate of Registration is immediately rendered void if items of equipment required under the current Harbors and Navigations Acts and Regulations are not maintained in accordance with the manufacturers instructions and/or applicable conventions and/or standards (e.g. AS 1851). Safety critical items must remain 'in-date' and failure to comply renders this certificate void. These include the Liferaft(s), Hydrostatic Releases, EPIRB, Fixed and Portable Fire Appliances, Flares, Radios, First Aid Kits, Lifejacket Lights (as applicable). If any doubt exists as to this requirement, owners are advised to immediately contact DTEI Commercial Marine for clarification. A vessel requires a valid Certificate to legally operate.
2 OWNER MUST ENSURE THAT THE VESSEL IS MAINTAINED IN GOOD ORDER AND CONDITION AND IS FIT FOR PURPOSE FOR WHICH IT IS TO BE USED SO THAT IT DOES NOT CAUSE DANGER TO ANY PERSON OR PROPERTY
3 VESSEL OPERATION LIMITED TO WIND SPEEDS NO GREATER THAN 25 KTS AND SEA STATES NO GREATER THAN 1.5 M
4 BOTH PONTOONS OF THE CATAMARAN REMAIN FILLED UP COMPLETELY WITH BUOYANT FOAM

Number of persons this vessel is certified to carry

Op Limit	Crew	Unberthed passengers	Berthed passengers	Special/other personnel
	4			

Minimum safety crewing and certification

This is to certify that the provisions of the *Harbors and Navigation Act and Regulations* with respect to the survey of the vessel have been complied with.

Please be advised that the information provided on this application may be disclosed to emergency services in the event of an emergency or for safety purposes.

Unless revoked or cancelled, this certificate is valid until 31/07/2009

Date of issue 31/07/2008

Authorised Officer

Signature	Printed Name	Date	Page
			1 of 2

MR 700
02/08

Government of South Australia
Department for Transport, Energy and Infrastructure

Certificate of Survey

This vessel has been surveyed pursuant to the Uniform Shipping Laws Code.
Any exemptions granted by the issuing authority may not be accepted by another jurisdiction.

Minimum safety crewing and certification

Op Limit	Crew Req	Qualification
	1	COXSWAIN

Survey status at date of issue of this certificate

Due date - next periodic survey	Due date - out of water survey	Due date - compass adjustment	Due date - radio survey
31/07/2009	31/07/2010	N/A	N/A
Due date - load line	Due date - next shaft survey	Due date - next liferaft survey	Due date - ICP
N/A	N/A	N/A	N/A

This is to certify that the provisions of the *Harbors and Navigation Act and Regulations* with respect to the survey of the vessel have been complied with.

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Date of issue 31/07/2008

Initials	Certificate Id.	Page
	28004	2 of 2