

**Dredging Surveys for the Port of Anchorage Expansion Project
utilizing the Reson SeaBat 7101**

Steven MacDonald, TerraSond Ltd

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Introduction

The Port of Anchorage is located near downtown Anchorage, on Knik Arm within Cook Inlet of the Pacific Ocean. The Port first began operations in September of 1961 and has grown to become the principal marine facility of Alaska, handling over ninety percent of goods entering and exiting the State. To keep up with the growing size and technology of large ocean transport vessels the Port has introduced a large scale expansion plan over several years. The expansion will significantly increase the dock facilities effectiveness and capacity.

The Port of Anchorage is a very unique environment due to its tidal ranges that can approach forty feet, strong currents, constant shoaling, and large volumes of suspended sedimentation in the water column.

The survey suite consists of a Reson 7101 multibeam echosounder, Coda Octopus F185 attitude and positioning system, Trimble RTK GPS base and radio, Hypack/Hysweep 2010 collection software, installed on a 24' custom survey vessel. Post processing of the bathymetric data is completed using Caris HIPS & SIPS 7.0 geospatial solutions software.

The project consists of two main activities; surveys for maintenance dredging volume computations and also the surveying of virgin material dredge areas in support of the port expansion. The maintenance dredging is performed using a hopper dredge, which is a tug propelled floating plant which dredges material, stores it on board, transports and dumps it at the designated spoil site. A hopper dredge acts much like a floating vacuum, dragging a large arm off each side of the barge while moving at a speed of approximately two knots; the arms suck up a mud and water mixture known as slurry from the seafloor. Three surveys a week are performed on the maintenance survey area with deliverable turnaround time of forty eight hours, half of the contractual requirement of ninety six hours. The United States Army Corps of Engineers (USACE) manual EM 1110-2-1003 specifies that virgin material dredging and object detection is best suited by the application of multibeam surveys. The expansion area of the Port consisting of virgin dredge material is removed with a clam shell style dredge. The large bucket is operated by a crane from a floating barge which deposits the material into a tug propelled self dumping disposal barge. Virgin material surveys are performed at the Port of Anchorage once a week to monitor material infill at the current dredge areas. The following figure shows a multibeam survey performed within the Port of Anchorage project limits.

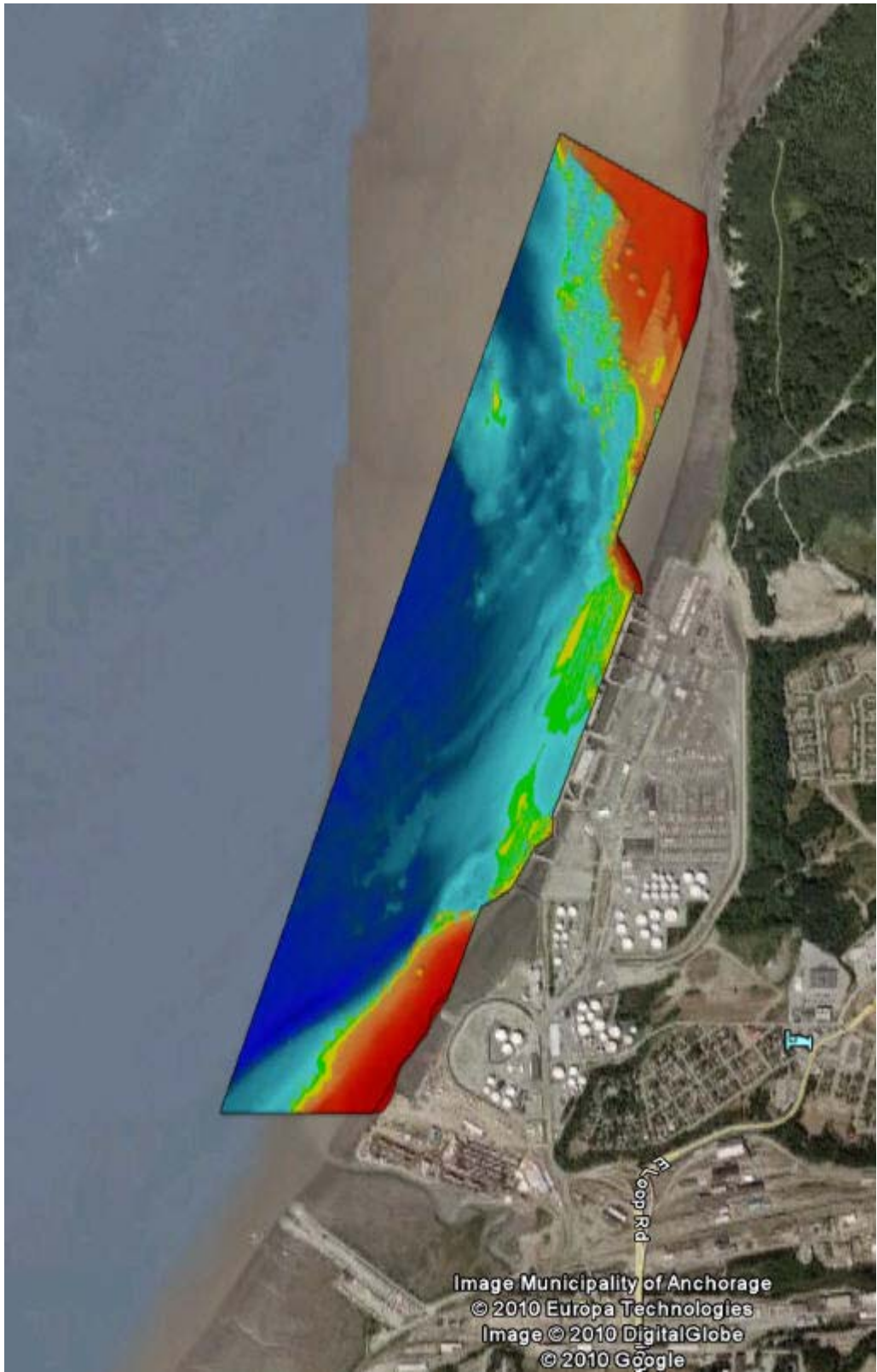


Figure 1 – Port of Anchorage Multibeam survey [TSL, 2010]

The yellow and green region seen in front of the existing dock structures represents the active hopper dredging area, while in the Northeast corner the clam shell digging is visible. The straight line which runs from the existing dock area northeast represents the ongoing construction area bulkhead wall. Depth ranges are from approximately -25m to +3m Mean Lower Low Water (MLLW).

The following image shows the Port prior to construction and the designed expansion of the Port planned to occur in multiple phases. The existing dock structures will be built into the new dock face which will extend the entire length of the facility. The new dock face will broaden out further into Knik Arm, which is expected to reduce the amount of dredging required annually.

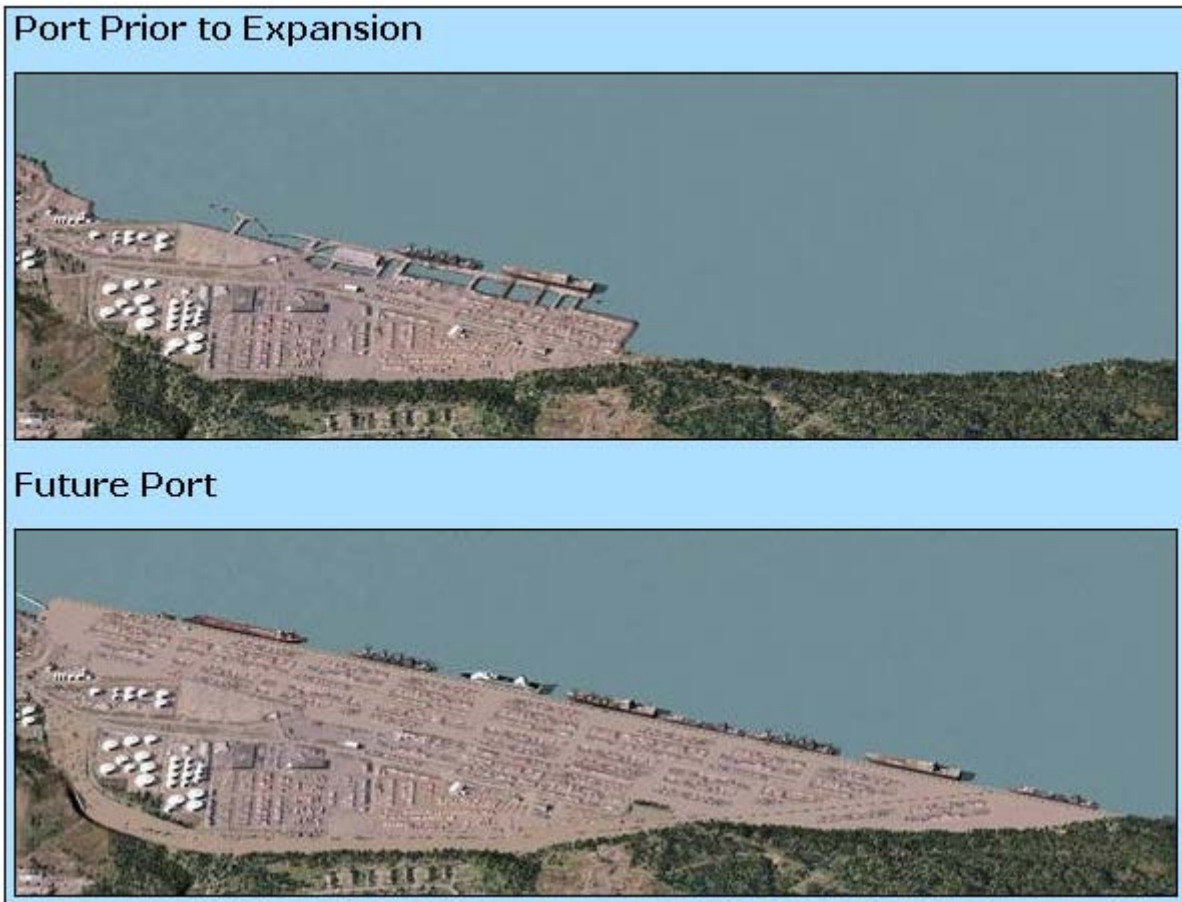


Figure 2 – Port of Anchorage planned expansion [POA, 2010]

The Reson SeaBat 7101 is a 240kHz 150 degree system that benefits this project for a number of reasons. The 7k topside technology which interfaces through windows, offers a large range of options for optimizing survey data collection. The primary feature that enhances performance is the ability to select between beam forming modes of 101 Equi-angle, 239 Equidistant or 511 Equidistant. The obvious choice for this application was the 511 Equi-distant spaced beam forming, which allows for high density

coverage across the entire swath in the varying water depths. The use of adaptive and absolute gates, quality filters and uncertainty output aid in the collection and post processing of the final data sets.

The USACE realizes the effectiveness of using multibeam echosounders for dredging measurement and payment surveys as stated in EM 1110-2-1003:

a. Dredging measurement and payment surveys. Multibeam swath survey systems that provide complete bottom coverage are recommended for use in dredging measurement and payment surveys, i.e., plans and specifications surveys, pre-dredge surveys, post-dredge surveys, and final acceptance/clearance surveys. Multibeam systems are an effective quality control process on dredging projects requiring 100% bottom coverage to assess and certify project clearance. The full digital terrain model (DTM) generated from a multibeam survey provides a more accurate and equitable (to the government and contractor) payment quantity than that obtained from traditional single-beam cross-sections. (11-4, 9)

Challenges

The Port of Anchorage yields some of the greatest tidal ranges in the world, which contributes to strong and unpredictable currents. The area is susceptible to constant shoaling from glacial silt and other soft sediments in Cook Inlet. The constantly changing sea floor consists of soft sediment mud, which offers very little reflectivity for sounding operations, especially in the outer beams. Suspended sediments can cause irregular data and even form a “false bottom” layer near the sea floor. Surveys are performed at all hours of the day and night, during spring break up and during the fall freeze when large ice flows fill the Port area.

Advantages of Multibeam surveys

There are numerous advantages to using multibeam echosounder technology to perform dredging surveys, with full bottom detection being one of the greatest benefits. Previous surveys in the Port were performed utilizing a singlebeam echosounder at one hundred foot line spacing, meaning the Triangulated Irregular Network (TIN) Model was stretching across the one hundred foot spacing with no representation of what was really going on in between the lines. In the multibeam surveys it has been evident the rows the hopper dredge leaves when dredging the maintenance material, and how these affect single beam volume computations. As seen in the figure below full bottom coverage detects all objects and offers a much more accurate depiction of the seafloor.

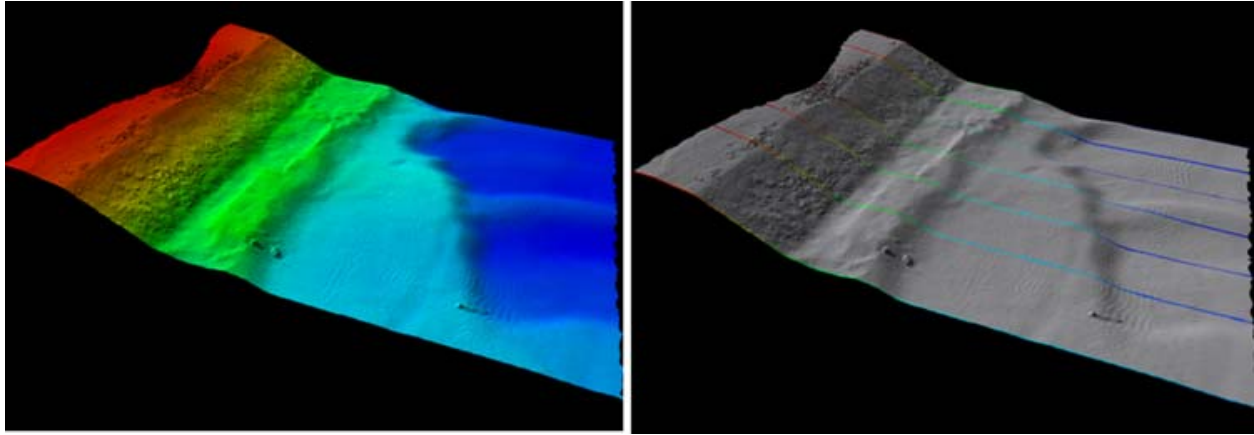


Figure 3 – Multibeam survey vs Single beam [TSL, 2010]

The Buffalo District of the USACE added a Reson multibeam sonar system to its 23 foot survey vessel for use on navigation projects. The following is a brief description from EM 1110-2-1003 of why the Buffalo District chose to upgrade to the use of multibeam sonar for these projects:

(a) The Buffalo District decided that a multibeam was needed for several reasons. The first which was to provide for better surveys of the District’s channels. The multibeam would provide 100% coverage of the channel resulting in a more accurate description of the bottom of the project. For dredging purposes, a more complete volume computation could be obtained using a full-model method of computation—i.e., TIN—rather than the approximate “average end area” method. The multibeam system will provide information between the normal cross-sections—a TIN volume computation method takes into account the whole area; thus providing a better ‘picture’ of what the channel looks like. (11-4, 12)

Digital Elevation Models (DEM) created using singlebeam data appear smooth and are a good visual aid in deliverable representation, however the figure below represents how accurate are they when interpolating over large distances. The singlebeam survey will not pick up on objects that are not surveyed directly over top of and can easily be missed. Several previous single beam surveys had not found the almost two meter high boulder which was picked up in the multibeam survey. Furthermore areas that could occur above or below template may be completely missed in a singlebeam survey, therefore not being accounted for accurately in volume computations.

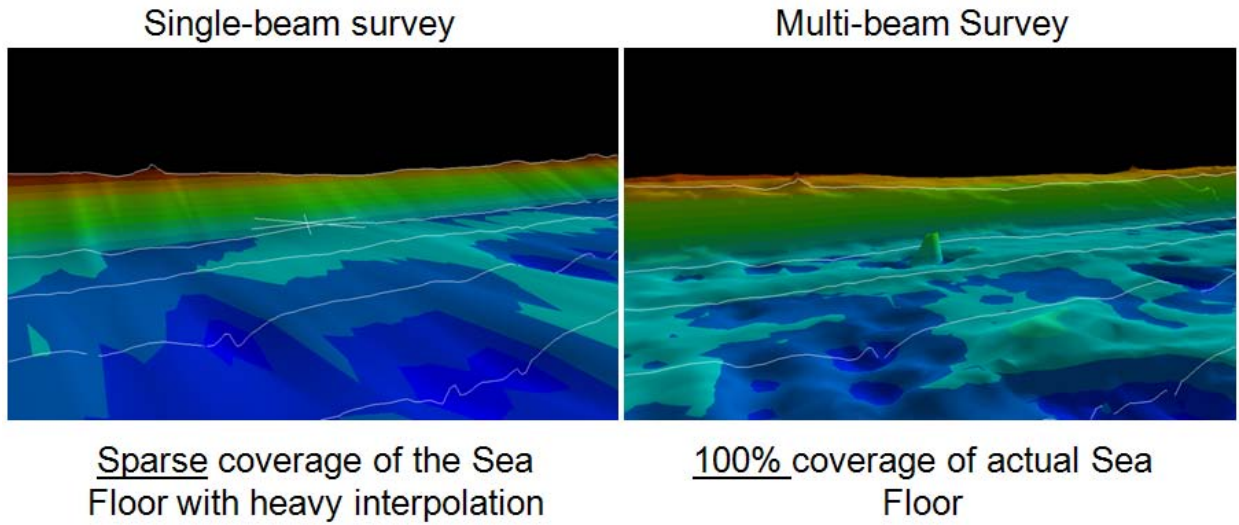


Figure 4 – Advantage of 100% sea floor coverage [TSL, 2010]

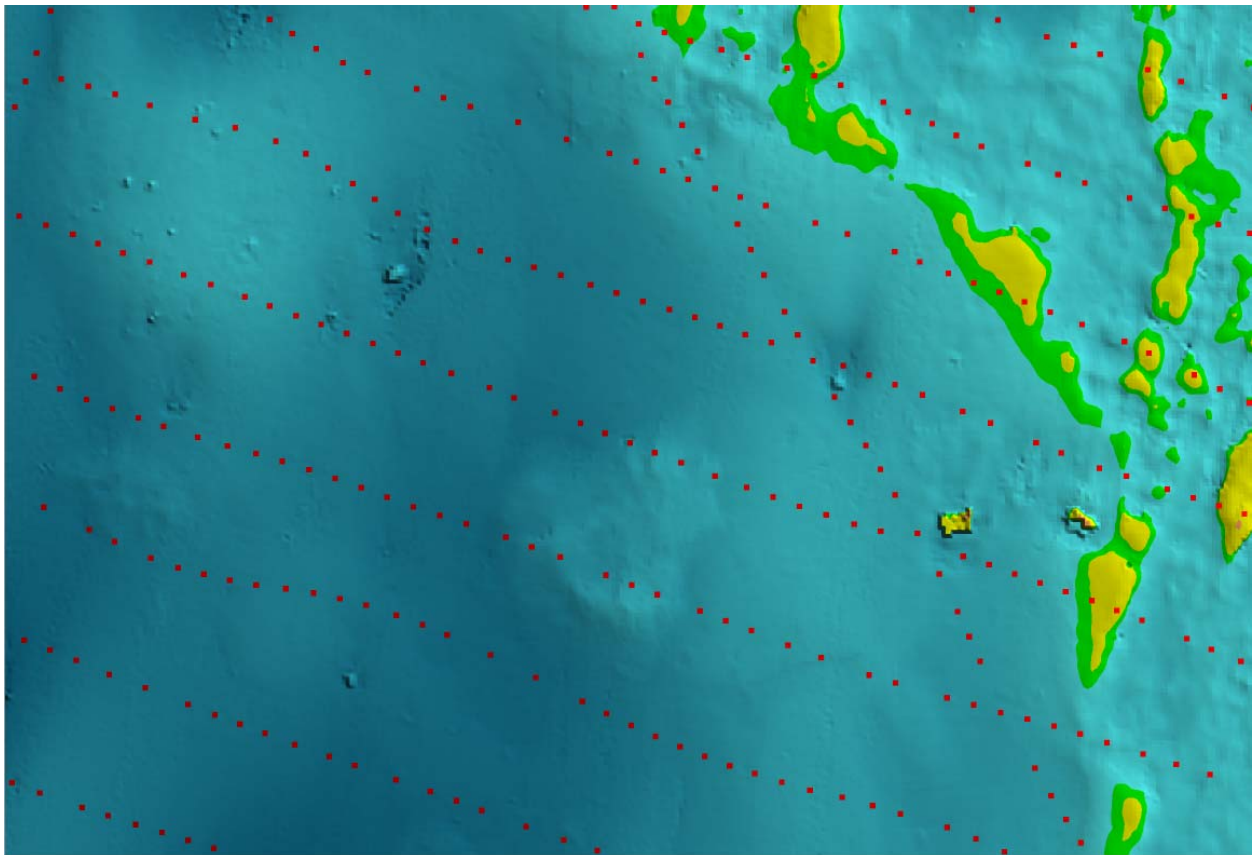


Figure 5 – Advantage of MBES vs SBES [TSL, 2010]

In the above image the red points represent a singlebeam survey overlaid on top of a later multibeam echosounder survey. With the sparse data density of the single beam survey it can be noted how easily features and objects can be missed, and also biases implemented in heights, resulting in less accurate DEM's and volume calculations.

The image seen below is a post dredge survey of a small boat harbor with clearly visible dredge markings in the lower central portion. Through the use of high resolution Reson 7101 multibeam system the entire area was accurately surveyed with no bias based on line planning. With full bottom ensonification all features can be identified and any areas missed in dredging can be easily detected.

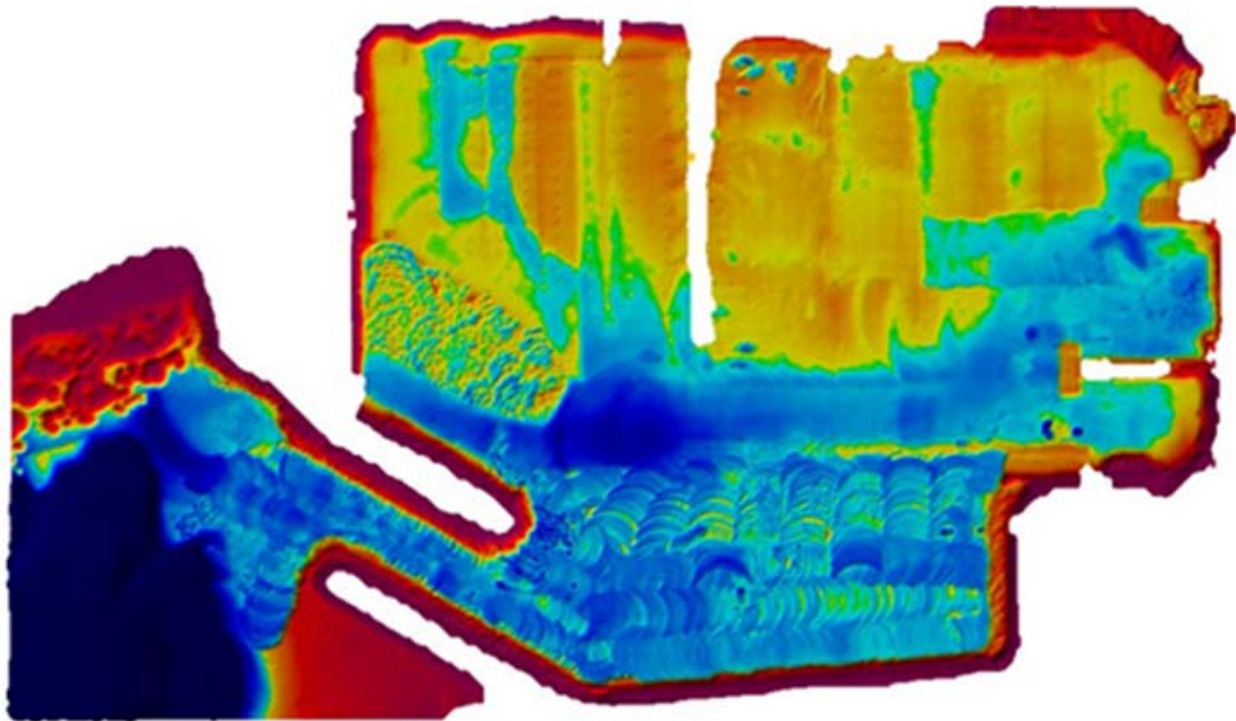


Figure 6 – Multibeam post dredge survey [TSL, 2010]

The multibeam system allows for the accurate computation of dredged material from the clamshell by clearly ensonifying the entire dredged area, not just a cross section of it. Also with the use of multibeam it is possible to survey beneath the barge that is anchored in place while working. The following image is a cross sectional view of four overlapping multibeam surveys. The cross sectional image clearly represents where the clamshell dredge has removed material between surveys. Without the use of multibeam it is not possible to accurately measure the amount of material removed in this scenario.

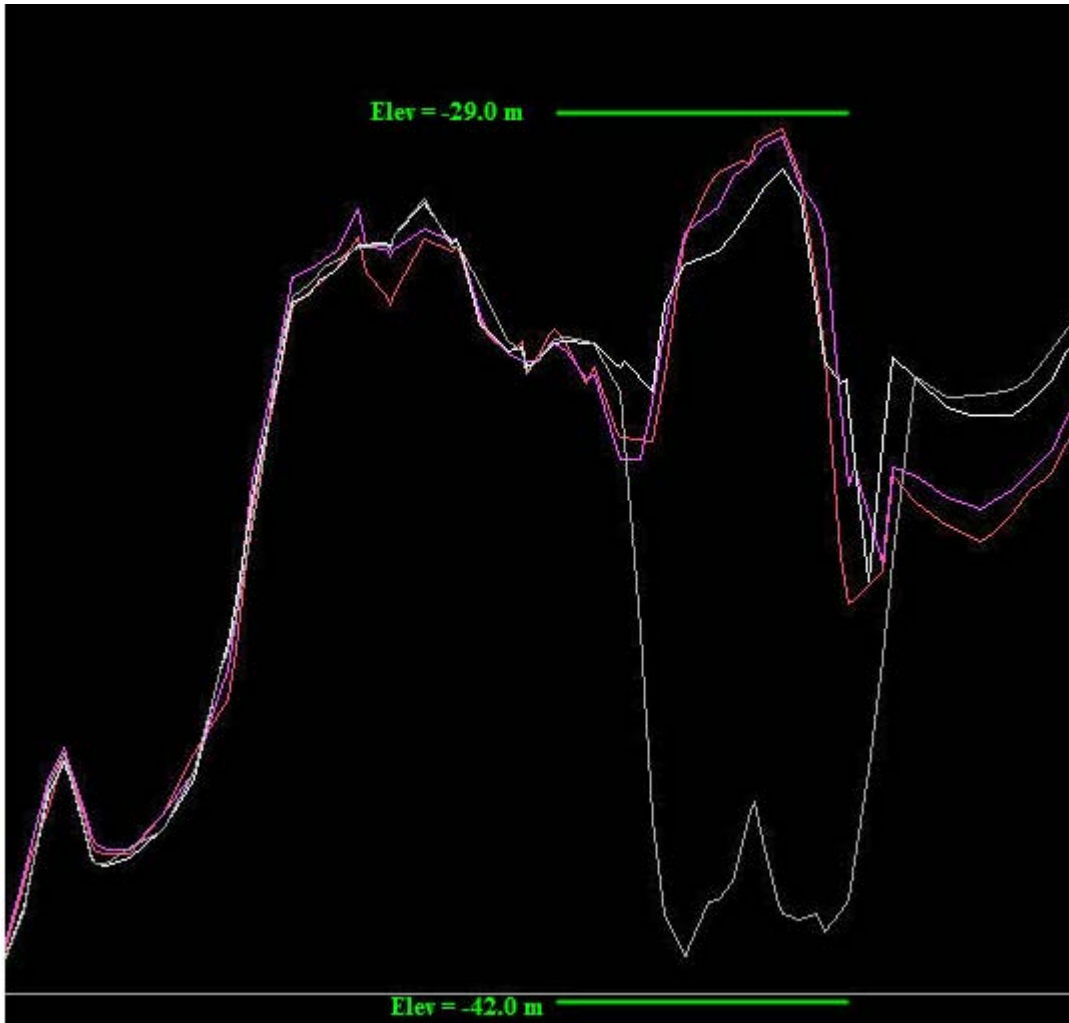


Figure 7 – Multibeam surveys cross section view [TSL, 2010]

Multibeam allows for coverage along dock faces, in tight bends and hazardous navigation areas which would not be achievable with a singlebeam survey system. This saves time from doing manual soundings or not being able to obtain data at all.

The true beam-formed 511 equidistant option over the conventional 101 equi-angular beams increases the survey production significantly. USACE specifications allow for the use of up to 120 degrees of swath width. The 511 equi-distant beam spacing allows for the use of the entire 120 degrees by maintaining consistent data density throughout the range, where in the deeper water significantly more overlap would need to be collected with the 101 equi-angular beams. A considerable amount of survey time is saved by running fewer lines and obtaining more dense survey coverage.

The following image represents two Port of Anchorage surveys several weeks apart from one another in an overhead plan view and also a three dimensional north looking view overlaid with a National Oceanic Atmospheric Administration (NOAA) raster chart referenced to MLLW. Clamshell dredging of virgin

material from a previously shallow and foul area in the Northeast portion of the survey project limits shows the dredging progress.

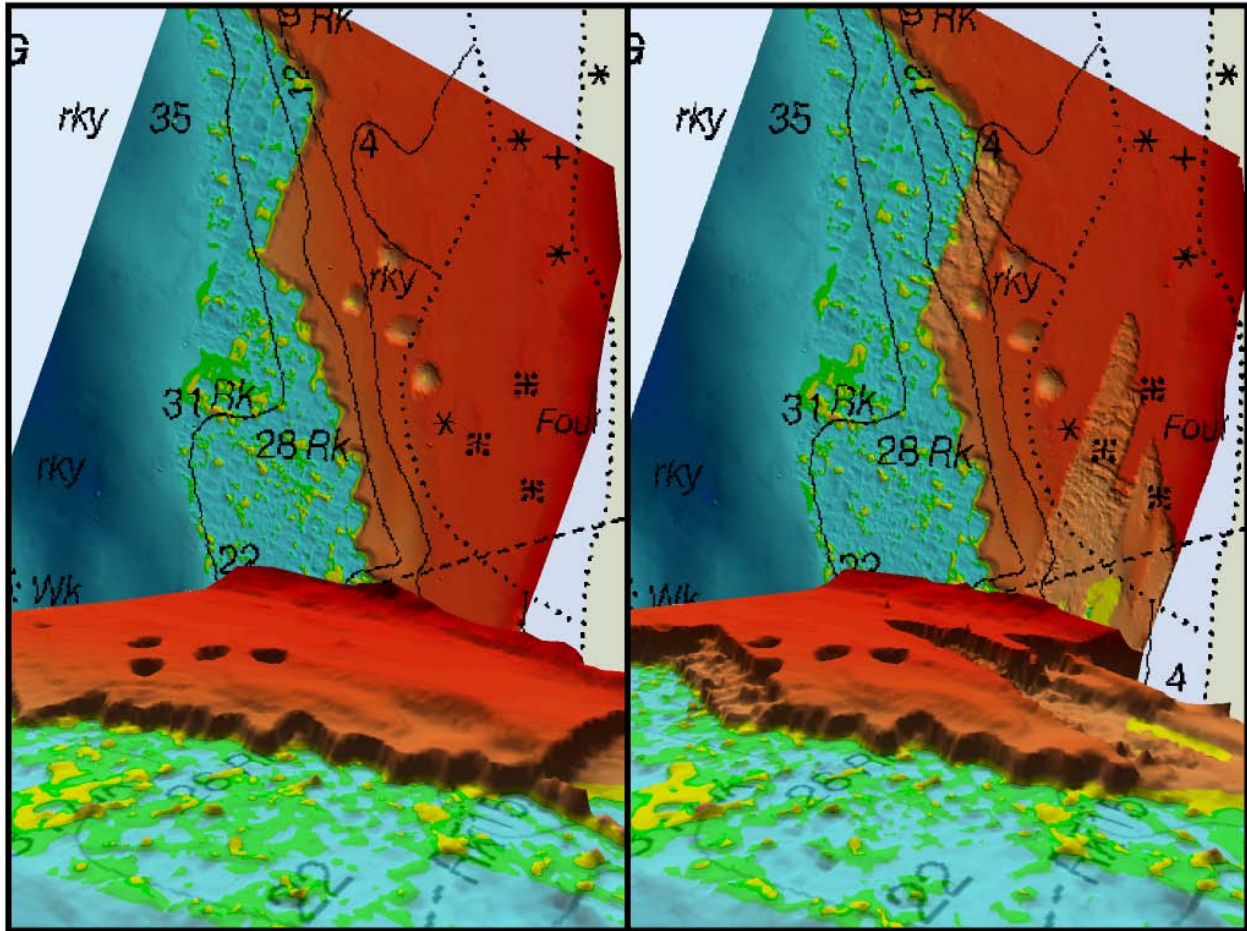


Figure 8 – MBES surveys several weeks apart [TSL, 2010]

Successes

One of the largest successes of the project to date has been the exceptional consistency of data from survey to survey. This is seen on solid features such as rocks and hard bottom undisturbed areas that are not subject to dredging or have been affected by shoaling or scouring. Through the use of high resolution multibeam over one hundred rocks, a barge and other sea floor debris were identified and dimensioned. Successful object detection helps to identify hazards that could potentially damage dredging equipment, which may not be detected using single beam survey methods. Consistent data has been a large component in the excellent turnaround times in deliverables. The cross sectional image below represents surveys over a four week period and shows areas consisting of hard bottom that are undisturbed by dredging remain consistent.

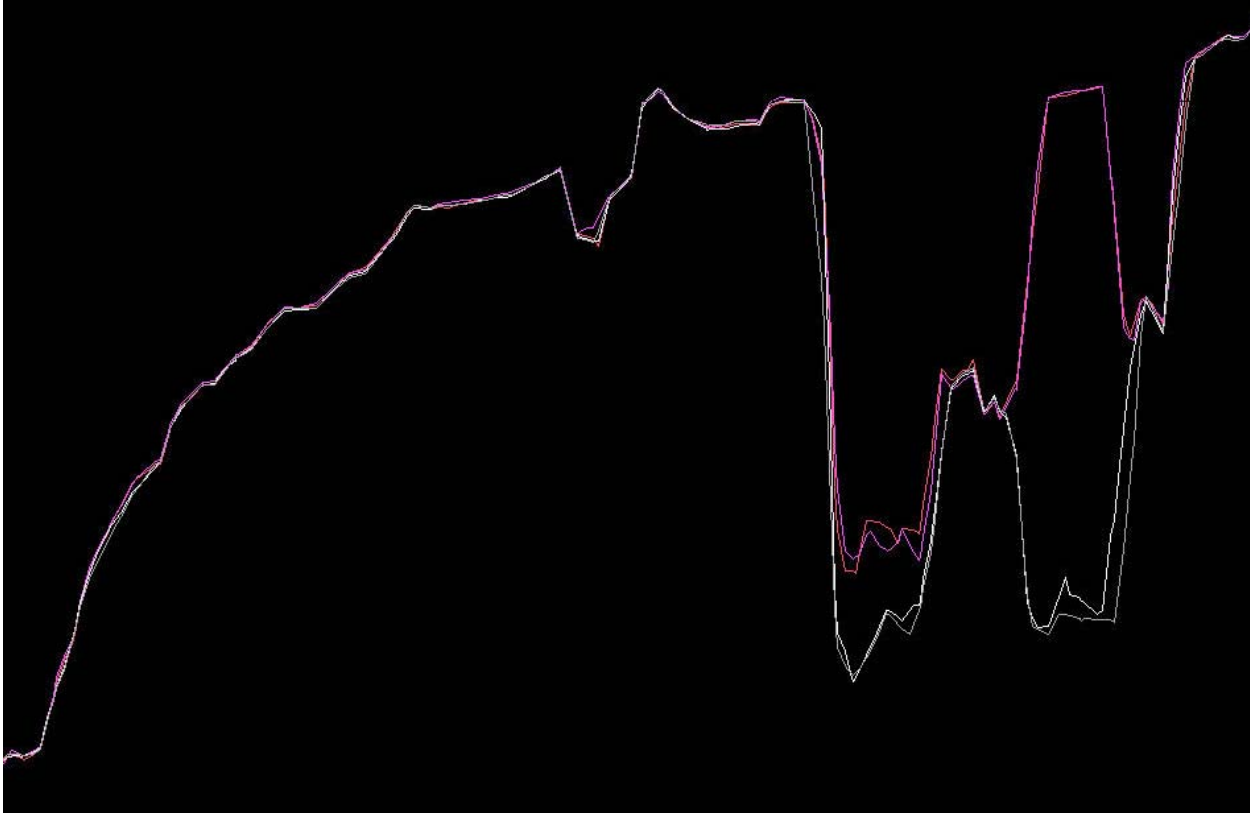


Figure 9 – Cross section showing survey consistency [TSL, 2010]

The use of multibeam has increased the accuracy of highly complex dredge volume calculations. Due to the constant shoaling in some locations and scouring in others, undredged areas can experience significant changes above or below template. Three multibeam surveys a week allowed for the ability to track shoaling rates in areas currently being dredged. This enabled the calculation of ratios to compensate for infill in areas currently being dredged, helping the dredgers get compensated for material that had been dredged but infilled before the survey took place.

Technical

The bathymetry resolution was increased by using the 511 equidistant beam forming over the 101 equi-angular beams. At project depths the 511 equidistant beam forming offers an equal distance between nodes in the across track, that is significantly closer node to node than the 101 equi-angular beams. This applies even at Nadir where the 101 equi-angular beams are closest to one another across track. The further away from Nadir the equal angle beams become the larger the distance between individual nodes, where the equidistant remains constant.

Typical survey speed is approximately 10 kilometers per hour, which is one of the driving factors in along track beam spacing. The other dynamics are sound velocity and the sonar range scale setting which is

determined based on water depth. In the following equations SV represents Sound Velocity, RS for Range Scale in meters, and SOG for Speed Over Ground.

$$Ping / s = \frac{SV}{2 * RS}$$

$$m / ping = \frac{SOG}{Ping / s}$$

For example, surveying in 20 meters of water using a range scale of 75 meters and a speed of 10kmh the sonar is able to ping approximately ten times per second. This equates to roughly 0.28m between pings along track. The distance between each node across track is approximately 0.29m. In the case of the 101 equi-angular beams the distance node to node at Nadir is roughly 0.52m and at sixty degrees approximately 2.19m.

Along Track Node to Node Spacing	
<i>Range Scale (m)</i>	75
<i>Two Way Travel</i>	150
<i>Approx Speed of Sound (m/s)</i>	1500
<i>Ping per second (p/s)</i>	10
<i>Speed over ground (kmh)</i>	10
<i>Speed over ground (m/s)</i>	2.8
<i>Pings per meter (p/m)</i>	3.6
<i>Meters between pings (m/p)</i>	0.28

Table 1 – Along track node to node spacing

Across Track Node to Node Spacing	
Equidistant 511	WD (m)= 20
<i>Node to Node Equidistant spacing (m)</i>	
0.29 m	

Table 2 – Equidistant across track spacing

Across Track Node to Node Spacing			
Equi-Angle 101		WD = 20m	
Angle (degrees)	Node to Node Distance (m)	Angle (degrees)	Node to Node Distance (m)
0	0.00		
1.5	0.52	39	0.89
3	0.53	40.5	0.93
4.5	0.53	42	0.97
6	0.53	43.5	1.02
7.5	0.53	45	1.08
9	0.54	46.5	1.14
10.5	0.54	48	1.20
12	0.55	49.5	1.28
13.5	0.56	51	1.37
15	0.57	52.5	1.46
16.5	0.57	54	1.57
18	0.58	55.5	1.70
19.5	0.59	57	1.84
21	0.61	58.5	2.00
22.5	0.62	60	2.19
24	0.63	61.5	2.42
25.5	0.65	63	2.68
27	0.67	64.5	2.99
28.5	0.69	66	3.36
30	0.71	67.5	3.82
31.5	0.73	69	4.38
33	0.76	70.5	5.08
34.5	0.79	72	5.97
36	0.82	73.5	7.12
37.5	0.85		

Table 3 – Equi-angle across track spacing

Beam footprint size is a direct function of the transmit and receive beamwidths, which for the Seabat 7101 these are both equal to 1.5°. As the water depth increases so does the beam footprint size. The following image demonstrates the beam footprint for one beam within a single ping, shown in blue. The intersection of the transmit and receive beams yields an average depth node for each individual beam footprint.

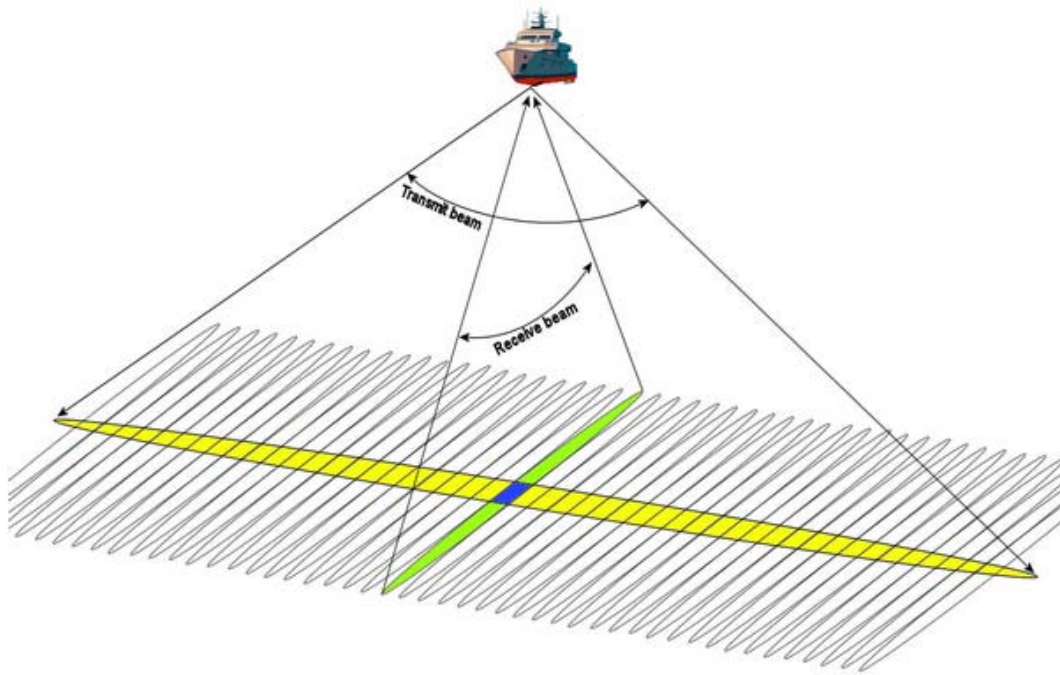


Figure 10 – Multibeam beam footprint [AML, 2010]

Total Propagated Uncertainty (TPU) was calculated based on the sensor accuracies supplied by manufacturers at one sigma. The individual uncertainty value for each sensor is used in the Caris Vessel file for use in Uncertainty surfaces and Cube applications. Tide and Sound Velocity parameters are taken into consideration in the TPU computation procedure.

TPU Values	
<i>Motion Gyro (deg)</i>	0.050
<i>Heave % Amp</i>	5.000
<i>Heave (m)</i>	0.050
<i>Roll (deg)</i>	0.025
<i>Pitch (deg)</i>	0.025
<i>Position Nav (m)</i>	0.020
<i>Timing Trans (s)</i>	0.001
<i>Nav Timing (s)</i>	0.001
<i>Gyro Timing (s)</i>	0.001
<i>Heave Timing (s)</i>	0.001
<i>Pitch Timing (s)</i>	0.001
<i>Roll Timing (s)</i>	0.001
<i>Offset X (m)</i>	0.003
<i>Offset Y (m)</i>	0.003
<i>Offset Z (m)</i>	0.003
<i>MRU Align StdDev gyro</i>	0.100
<i>MRU Align StdDev Roll / Pitch</i>	0.100
<i>SVP (m/s)</i>	1.000
<i>Tide (m)</i>	0.020

Table 4 – Total Propagated Uncertainty Table

The following TPU surface was created in Caris. In the shallower water where the line spacing is tighter the uncertainty is significantly lower than it is in the outer beams in the deeper waters. TPU values increase with beam angle from nadir. The dark pink represents the lowest values of TPU, with the bright yellow having the largest. These TPU values fall meet the USACE specifications for soft sediment full bottom coverage surveys for critical areas.

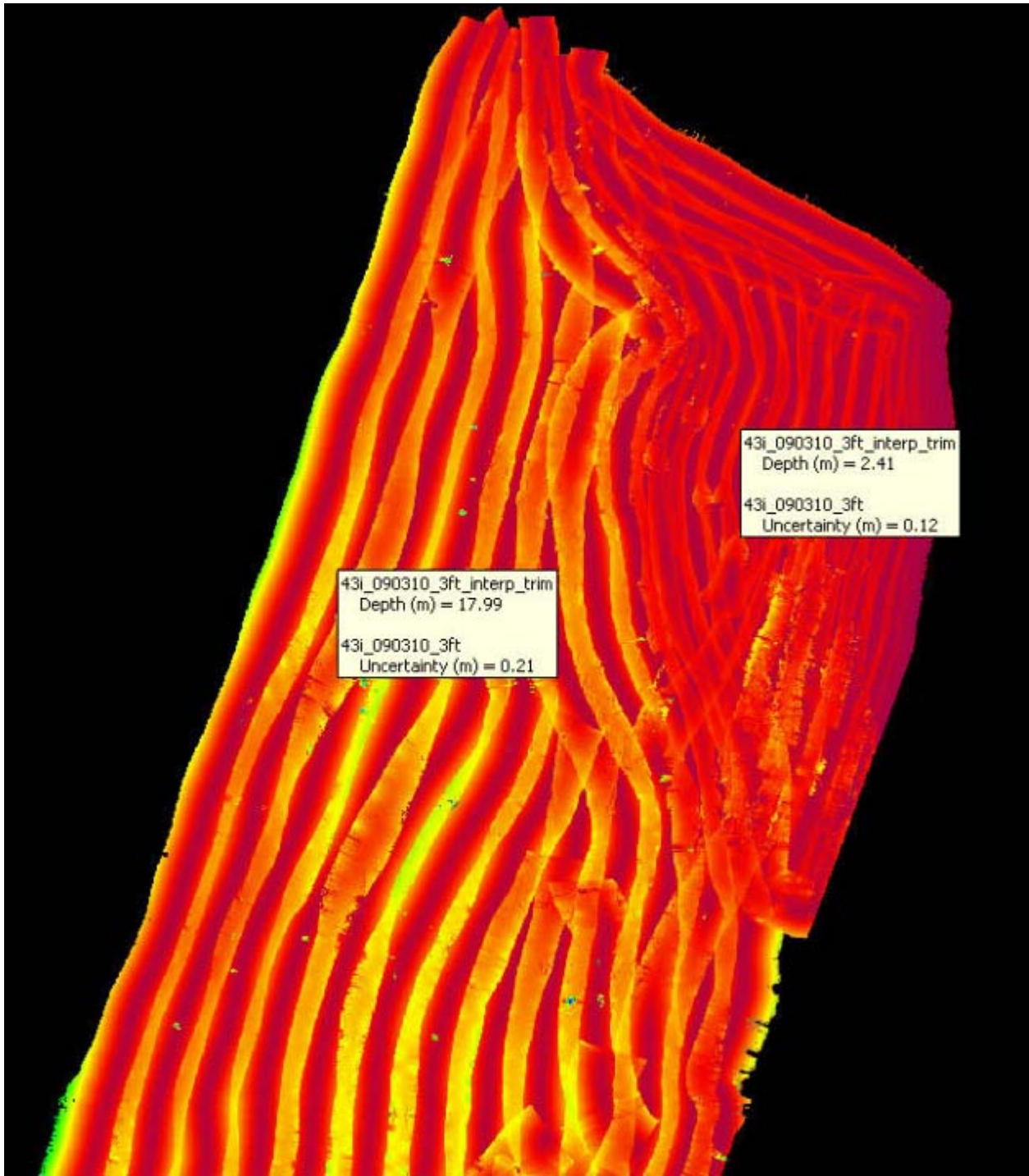


Figure 11 – Cross section showing survey consistency [TSL, 2010]

Conclusion

The use of the Reson SeaBat 7101 high resolution multibeam echosounder has increased accuracy and productivity in the Port of Anchorage maintenance surveys and expansion project. The high level of accuracy in volume computations and survey to survey consistency demonstrates that if the correct system is chosen, multibeam echosounders are an ideal choice for volume computation surveys.

The ability to detect seafloor objects, survey underneath moored vessels, survey along and behind dock structures, are just a few of the main advantages seen in this project through the use of multibeam echosounding. The greatest advantage may lie in being able to measure the “in between” in lieu of guessing what is truly occurring between singlebeam survey lines, yielding higher accuracy of the true sea floor.

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