Hawaii National Marine Renewable Energy Center (HINMREC)

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Task 1: Management

Geophysical Surveys of the Wave Energy Test Site at MCBH, Kāneʻohe

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GEOPHYSICAL SURVEYS OF THE WAVE ENERGY TEST SITE (WETS) AT MCBH, KANEOHE

OAHU, HI

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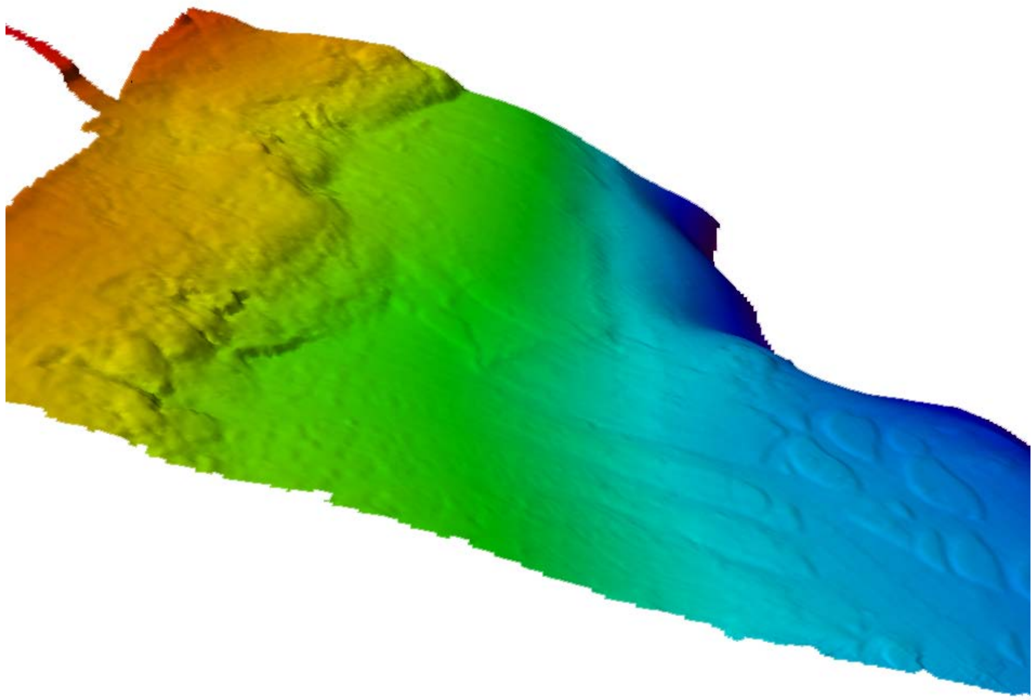

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1. INTRODUCTION

The area north of Mokapu Peninsula, adjacent to Kaneohe Marine Corps Base Hawaii (MCBH), has been utilized by the U.S. Navy and Ocean Power Technologies, Inc. (OPT) for wave energy research since 2002. After a 2 year deployment, a prototype OPT PowerBuoy was recently retrieved from the 30 meter water depth offshore of North Beach at the MCBH. The Hawaii National Marine Renewable Energy Center (HNMREC) at the University of Hawaii, under contract with Department of Energy, desires to expand the present test site to water depths of 100 meters to allow for the testing of other wave energy devices.

Sea Engineering has been contracted by the HNMREC to conduct site investigations in support of the development of the expanded test site. The surveys included multibeam bathymetry, side scan sonar, sub-bottom profiling and remotely operated vehicle (ROV) video. Results of these surveys have been previously submitted as individual survey reports following completion of each survey. This report compiles and describes all of the survey findings, and presents a summary description of the seafloor characteristics of the project site.

The project location is shown in Figure 1-1. An aerial image of the 4.4 km^2 proposed test site is shown in Figure 1-2. The test site is 1,600 to 2,000 meters wide and extends approximately 2,600 meters offshore from the 30 meter depth contour to the approximate 100 meter depth contour.

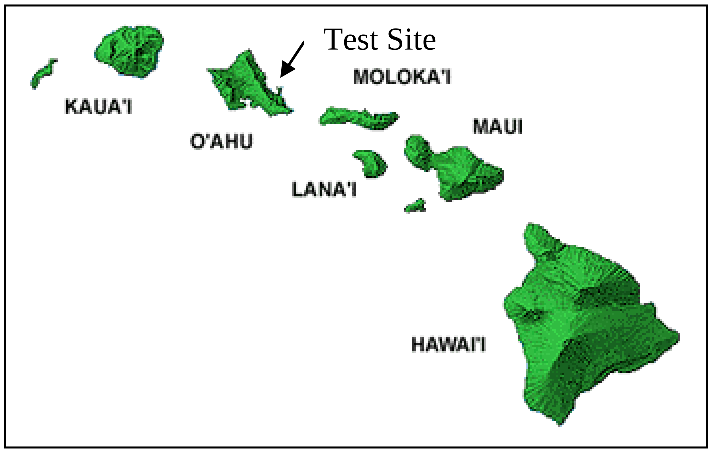

Figure 1-1. Project location.

Figure 1-2. Aerial image of project site (from Google Earth).

2. METHODOLOGY

2.1 Survey Schedule

Surveys were conducted during periods when sea conditions were favorable at the site. The schedule was as follows:

- Side scan sonar – May 16-18, 2011
- Multibeam bathymetry – September 6-9, 2011
- Sub-bottom profiler – November 17-18, 2011
- ROV video – January 12, 2011.

2.2 Units and Coordinate System

The project coordinate system is the Universal Transverse Mercator (UTM), Zone 4, meters, NAD 83.

2.3 Navigation and Positioning

A differential GPS (DGPS) receiver utilizing the U.S. Coast Guard differential beacon correction was used for horizontal positioning. The U.S. Coast Guard operates a network of ground based reference stations that broadcast correction signals on marine radio beacon frequencies to improve the accuracy of GPS-derived positions. The typical accuracy of the DGPS position is 1 to 3 meters.

Hypack survey software was used to integrate the DGPS positions with the hydrographic and geophysical survey data. Static offsets (i.e. "layback") for the towed sub-bottom profiler and side scan sonar were used during post-processing to generate corrected tracklines.

2.4 Multibeam Bathymetry Survey Methods

Sea Engineering and Solmar Hydrographics conducted the multibeam survey using an R2Sonics 2024 multibeam echosounder system. The R2Sonics 2024 provides 0.5 x 1 degree beamwidths and user selectable frequencies. The multibeam was operated at 200 kHz with 256 beams and a 90 degree swath. The system was compensated for boat motion (heave, pitch, roll, and yaw) using an Applanix POS/MV Wavemaster. Numerous quality control and quality assurance procedures are used to calibrate the multibeam system and ensure system accuracy.

2.4.1 Tide Corrections

Multibeam data were corrected to the MLLW datum using tidal data from the NOAA Mokuoloe tide gage (#1612480) in Kaneohe Bay.

2.4.2 System Draft Correction

The distance of the multibeam transducer head below the water surface is called the draft. The draft was measured on installation and checked using a standard hydrographic survey technique known as a "bar check". The bar check consist of lowering a calibration plate a short distance below the multibeam transducer head. A draft correction is input into the system processor until the correct reading is obtained.

2.4.3 Sound Velocity

The velocity of sound is a critical component for hydrographic survey measurement. Sound velocity changes with water temperature and salinity variations. Sound velocity at the water surface was measured directly using a sound velocity probe while surveying (Valeport Mini SVS) and also indirectly using the bar check method. Sound velocity casts to 90 meter were periodically taken with an AML Oceanographic SV Plus sound velocity probe to measure the sound velocity profile in the water column.

2.4.4 Patch Test

The patch test procedure is a standard operational test to determine the installation configuration of the multibeam transducer head. The procedure consists of collecting data over short line segments at various speeds, offsets, and directions. Comparison of the data within the processing software allows calculation of the following parameters:

- System latency – the processing time lag in the GPS navigation device
- Multibeam pitch – the fore and aft angle of the multibeam head
- Multibeam roll - the port and starboard angle of the multibeam head
- Multibeam yaw- the angle of the multibeam with respect to boat heading.

2.4.5 Multibeam processing

The multibeam data were processed by Solmar Hydrographics using CARIS hydrographic survey software. The software incorporates the system correction from the patch test results, as well as the transient corrections for heave, pitch, roll, and heading from the system motion sensors. Data spikes and other errors are edited from the data set. The edited data set is further reduced by dividing the survey area into a grid of cells, and averaging the data within those cells.

The data for this survey were averaged within 2 meter cells for depths shallower than 50 meters and 4 meter cells for depths greater than 50 meters. This grid resolution meets or exceeds specifications established by the National Ocean Service (NOS) and the International Hydrographic Organization.

2.5 Side Scan Sonar Methods

A side scan sonar transmits acoustic signals with wide vertical beam widths out to either side of the sonar towfish. A receiver then records the signals that are reflected back from the seafloor to the towfish. Hard bottom areas and features produce more intense reflections than sediments. The result is a plan view acoustic image of seafloor characteristics. Areas with no reflection, because they lie behind or are blocked by an object, appear white, and are indicative of an object protruding above the seafloor.

For this survey a C-MAX CM2 Side Scan Sonar system was utilized. The CM2 system contains dual 325 and 780 kHz transducers. The 325 kHz transducer was used for the survey. Survey lines were conducted at intervals of 75 meters in water depths shallower than 70 meters, and 100 meters between water depths of 70 to 100 meters. The side scan range was set at 100 meters (328 feet) per side, for a 200 meter (656 foot) swath width for the lines spaced 75 meters apart in water depths shallower than 70 meters. In deeper water where the lines were spaced 100 meters apart, the range was set at 150 meters This allowed a data overlap of over 100% per side, or over 200% total coverage – i.e. each point on the bottom was imaged at least two times.

Side scan data were reviewed on-site using C-Max Maxview software and post processed into a GeoTiff mosaic imagery using SonarWiz software. The data lines with the best overall imagery were selected for inclusion into the sonar mosaic.

2.6 Sub-bottom Profiling Methods

Geophysical sub-bottom profiling systems are a form of echo-sounder that uses lower acoustic frequencies to penetrate into the substrate. A sub-bottom system transmits an acoustic signal directly below the towfish. A portion of the acoustic signal is reflected back from the seafloor while a portion penetrates the sediment layer. A receiver records the signals that are reflected back from the seafloor and underlying substrate. The time delay between the signal returns allows for the differentiation of sediment layers. Where common echo-sounders may use an acoustic frequency in the vicinity of 200 kHz, sub-bottom system frequencies are typically between 500 Hz and 20 kHz. The term sub-bottom refers to a generally hard layer of sediment or rock that underlies recent soft sediment deposition. The lower the acoustic frequency, the deeper into the bottom the system can penetrate.

For this survey, an EdgeTech 0512i “chirp” sub-bottom profiler was used with an EdgeTech 3200XS processing system. The EdgeTech 0512i system is a specialized system for use in coarse sand environments. Different signal pulses are available with the system for use in different terrains. The optimal pulses for substrates in Hawaii have been found to be 500 Hz to 7 kHz and 700 Hz to 12.0 kHz. This is a low frequency range, but necessary for penetration into the coralline limestone sands and gravels found in Hawaii. The 500 Hz to 7 kHz pulse was used for this survey.

Survey tracklines were spaced 100 meters apart, oriented both parallel and perpendicular to shore.

The sub-bottom data were reviewed with EdgeTech software and sub-bottom horizons were digitized for processing. Sediment thickness data were contoured using Digital Terrain Model (DTM) software, and final charts created using AutoCAD.

2.7 Remotely Operated Vehicle Methods

Remotely operated vehicles are camera and thruster equipped vehicles linked to a vessel with an umbilical control and electrical cable, and operated from the vessel to investigate the seafloor and underwater objects. They are used for a variety of underwater tasks ranging from underwater searches to plugging oil wells. They can be equipped with different equipment including manipulators, acoustic positioning systems, and multiple cameras.

For this survey, an Outland Technology Model 1000 ROV was utilized. This ROV is equipped with two forward facing cameras, a color and a black and white low light, which can rotate 360°; and one rear facing fixed camera. The forward facing color camera was used for the majority of this project with a small portion of the video done with the rear facing camera.

3. SURVEY RESULTS

3.1 Multibeam Bathymetry Survey

Results of the multibeam survey are presented in Figure 3-1 and Figure 3-2. Figure 3-1 shows the bathymetry of the entire area with 1-meter contour intervals; Figure 3-2 is a color-shaded relief perspective image of the results with 3x vertical exaggeration.

Key features of the seafloor in the area include the following:

- The nearshore portion of the project area, between depths of 30 to 35 meters is relatively featureless and flat, with slopes ranging from 1V:34H to 1V:54H.
- A steeply sloping, irregular bottom is present at water depths between 35 and 45 meters. Slopes as steep as 1V:8H occurs between 40 and 45 meter water depths.
- Between depths of 50 to 75 meters, the seafloor appears featureless, with little vertical relief, and typical slopes of 1V:25H.
- Between depths of 75 and 85 meters in the northeastern corner of the project site, the bottom is relatively flat (1V:65H), and has barchan bedform features. The multibeam results indicate that the barchans are approximately 1.5 meters high, 150 to 200 meters long, and up to 100 meters wide. They do not appear to be connected. Barchans are arcuate, isolated dune forms, characteristic of an environment with a limited supply of sand.
- At water depths deeper than 90 meters, the seafloor slopes steeply to the northwest into a pronounced marine canyon. Slopes of 1V:10H to 1V:7H are typical in this zone.

3.2 Side Scan Sonar

Figure 3-3 and Figure 3-4 present composite mosaics of the side scan sonar imagery overlain on the bathymetry contours. Figure 3-3 illustrates the entire project site, while Figure 3-4 presents a larger scale chart of the northern half of the project area, from the 50-meter depth to the 100-meter depth, using a 0.5 meter contour interval. The most prominent features revealed by the side scan survey are the arcuate, barchan dunes present in the northeast corner of the site in water depths of 75 to 90 meters, and linear sand ribbons or grooves present in water depths of 50 to 75 meters. These are bedforms indicative of sediment covered bottom. Barchans are characteristic of environments with limited sediment supply. Irregular bottom and small scattered rock or coral outcrops are apparent in water depths of 40 to 45 meters, along the steeply sloping escarpment identified in the multibeam survey. A rock outcrop or escarpment is also indicated at the 90 meter water depth along the steeply sloping northern margin of the project site. Other areas of the project site appear to be relatively featureless with little relief.

The present OPT wave buoy site is visible in the southwest corner of the side scan image.

3.3 Sub-bottom Profiler Survey

The sub-bottom survey was completed along tracklines spaced 100 meters apart, oriented both parallel and perpendicular to shore, as shown in Figure 3-5. The subbottom survey showed an offshore morphology consisting of a series of terraces, or shelves formed during ancient low sea level stands by wave-induced erosion of the reef limestone. The terraces have a stair-step appearance, with the wide, gently sloping surfaces separated by steeper slopes or scarps. The terrace surfaces are often buried by wedge-like deposits of sediment, typically sand. This morphology is common in the Hawaiian Islands.

Figure 3-6 to Figure 3-9 are representative sub-bottom profile images. Figure 3-6 to Figure 3-8 present profiles measure in the north-south (inshore-offshore) direction, while Figure 3-9 presents a profile measured in the east-west direction. Tick marks on the images are spaced 10 meters apart vertically, and 100 meters apart horizontally. The vertical scale represents distance in meters below the sub-bottom towfish. The sub-bottom towfish was towed approximately 3 meters below the water surface, therefore addition of 3 meters to the vertical scale in the images is required to determine seafloor or sediment horizon depths referenced to sea level.

The sub-bottom images indicate that hard substrate composed of reef limestone extends from shallow water to the approximate 50 meter water depth. Seaward of this, the reef limestone slopes steeply downward to a wide, gently sloping terrace at the approximate 65 to 70 meter water depth. This terrace is buried by up to 10 meters of sediment.

Figure 3-10 to Figure 3-11 present contour charts of the measured sediment thickness. Sediment thickness is greatest along the west side of the project area and in a band 200 to 300 meters wide along the 60 meter depth contour. With the exception of the steeply sloping west side of the project site, the sediment thins or pinches out at the 70 to 75 meter water depth.

Key findings of the sub-bottom survey include the following:

- Reef limestone hard bottom is prevalent inshore of the 50 meter depth contour
- A band of sediment, 5 to 12 meters thick and approximately 250 meters wide, is present at water depths of 55 to 65 meters.
- One to 2 meters of sand is typical from 65 to 75 meters of water depth in the eastern part of the project site, and from 70 to 80 meters in the western part of the project site.
- Sediment greater than 10 meters thick is present along the western margin of the project area in water depths greater than 55 meters.
- Minimal sand is present in the eastern part of the project area seaward of the 75-meter contour.
- The barchan featurs in the northeastern corner of the site are only 1-2 meters in thickness.

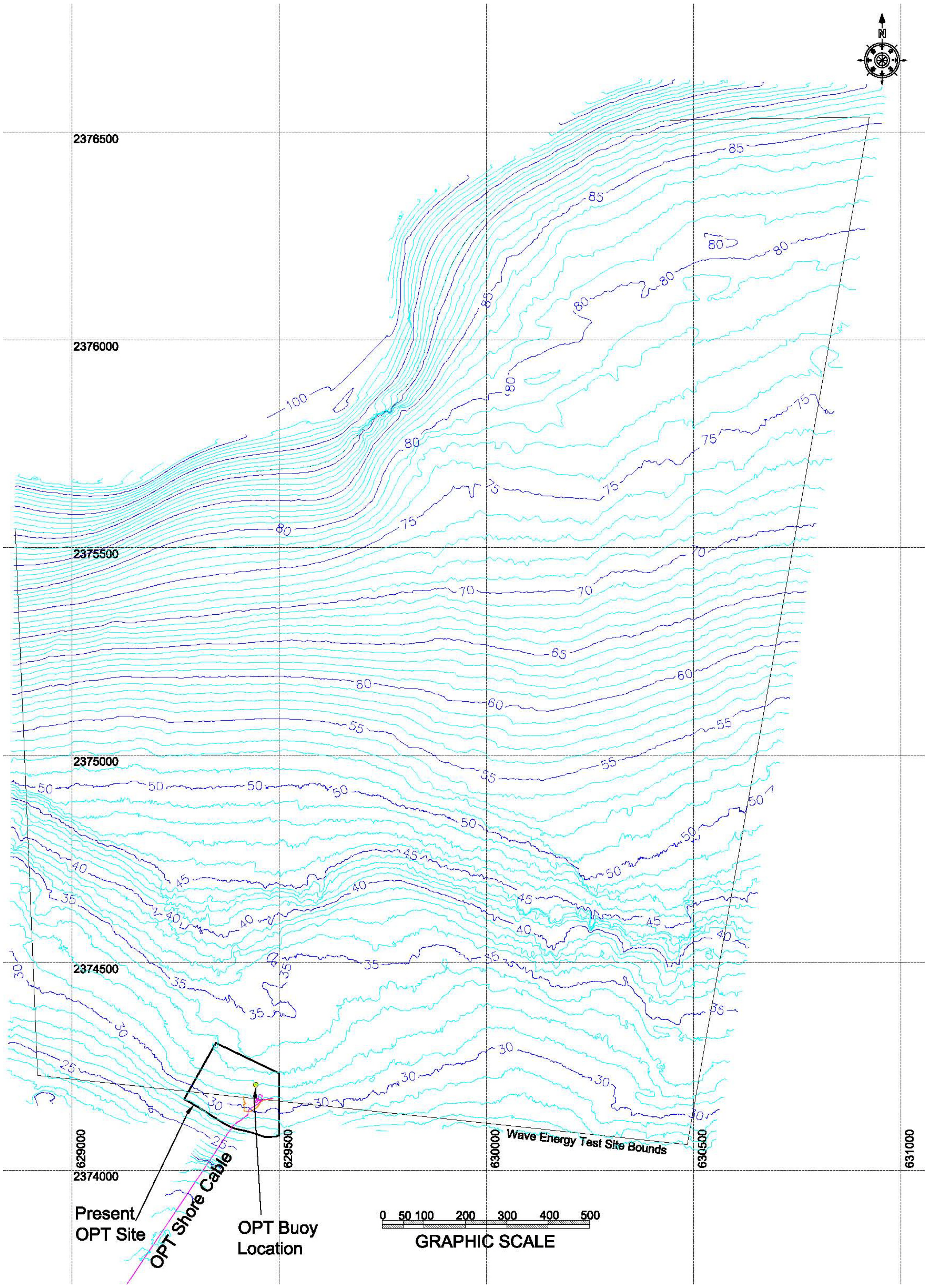

Figure 3-1. Wave energy test site bathymetry (1 meter contour interval).

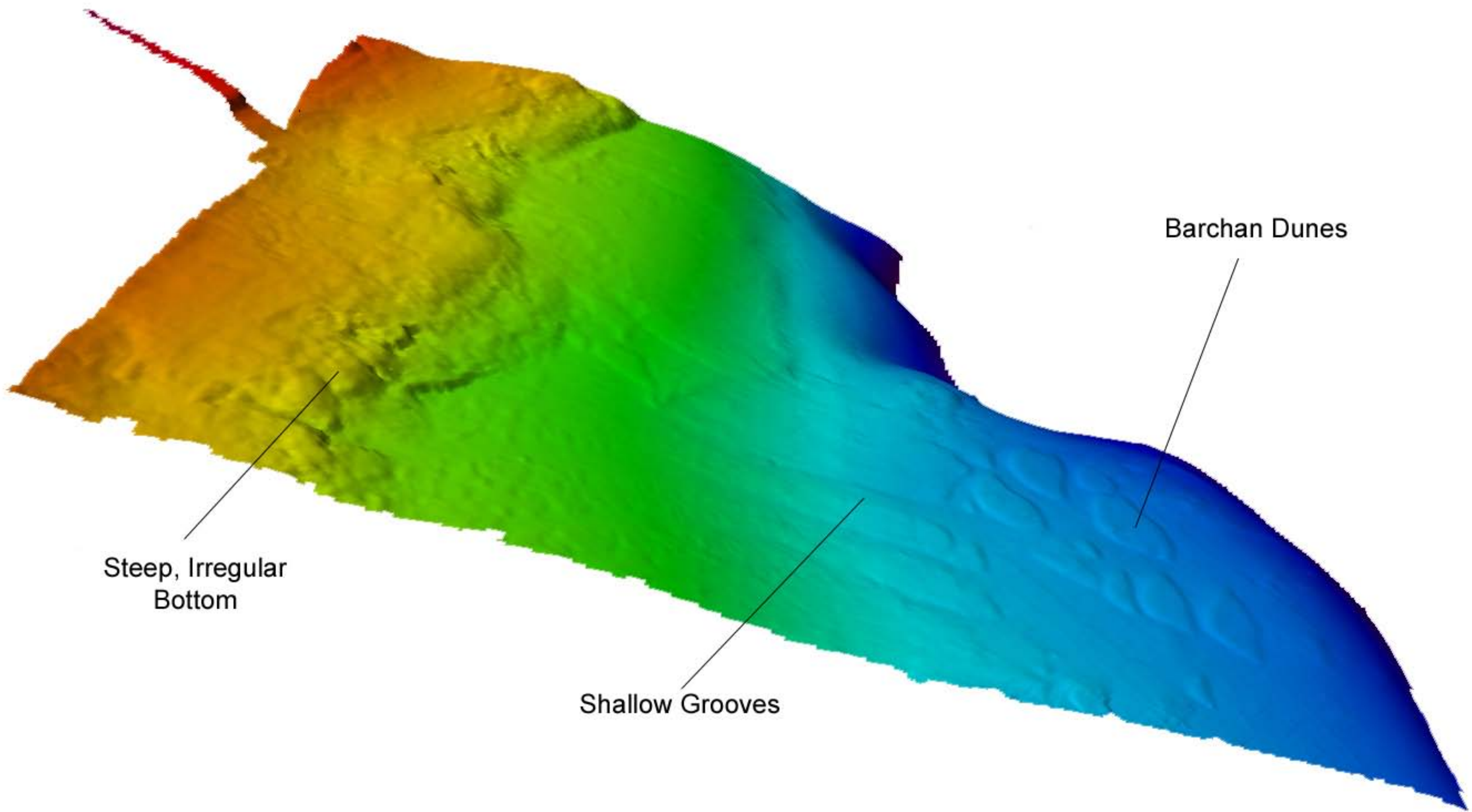

Figure 3-2. Color-shaded relief perspective of the survey area.

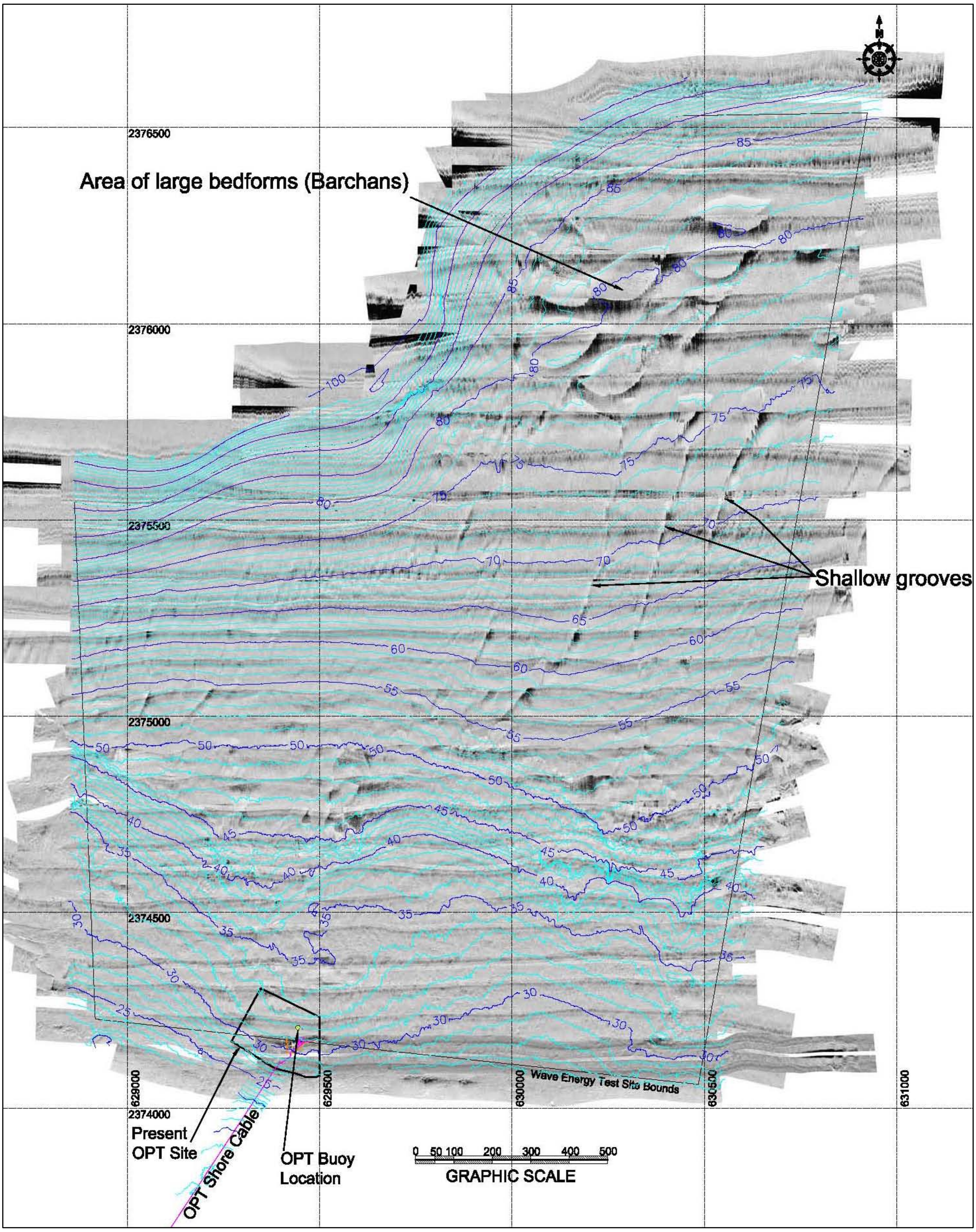

Figure 3-3. Side scan image of northern half of test site with 0.5 meter depth contours.

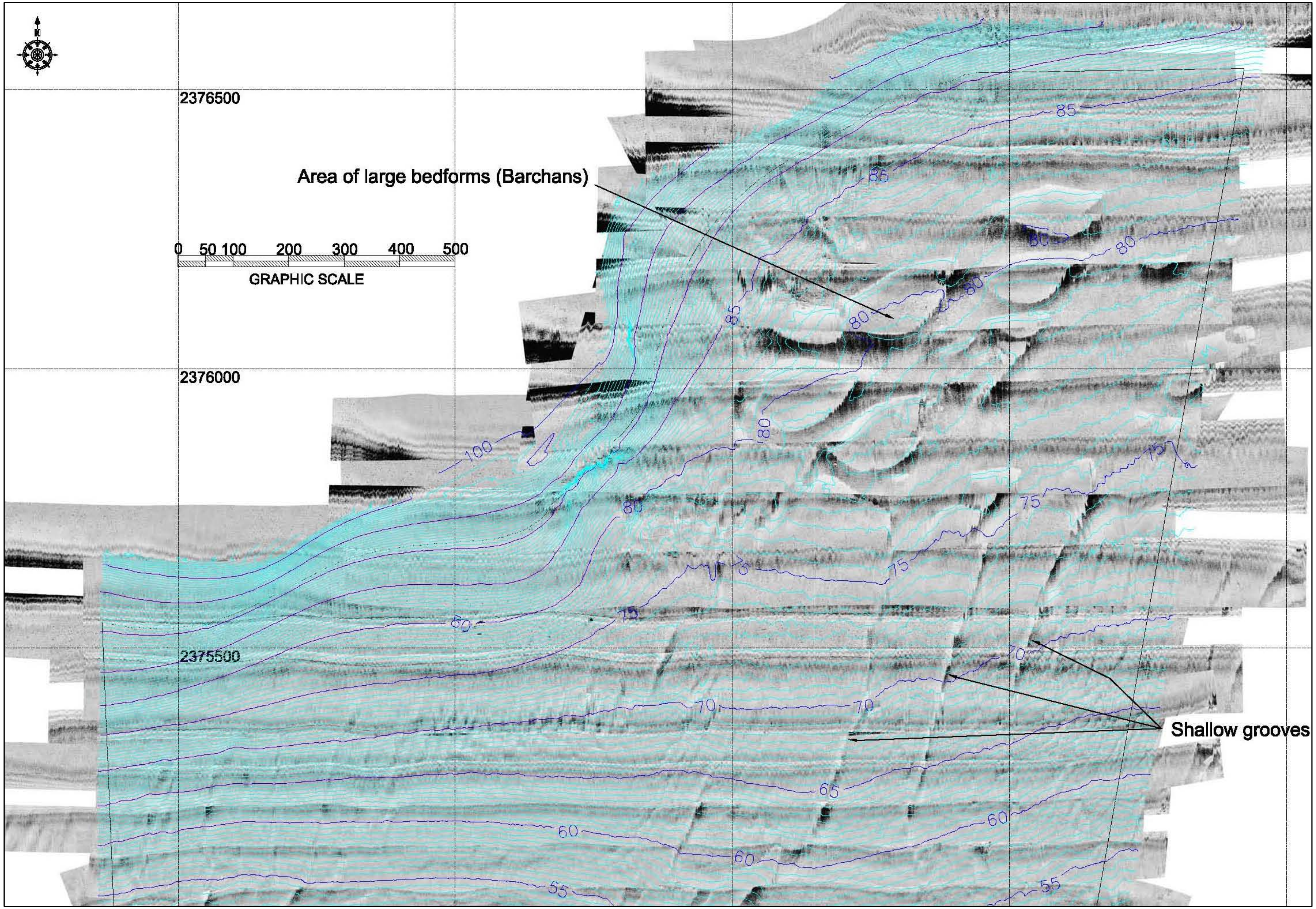

Figure 3-4. Side scan image of northern half of test site with 0.5 m depth contours

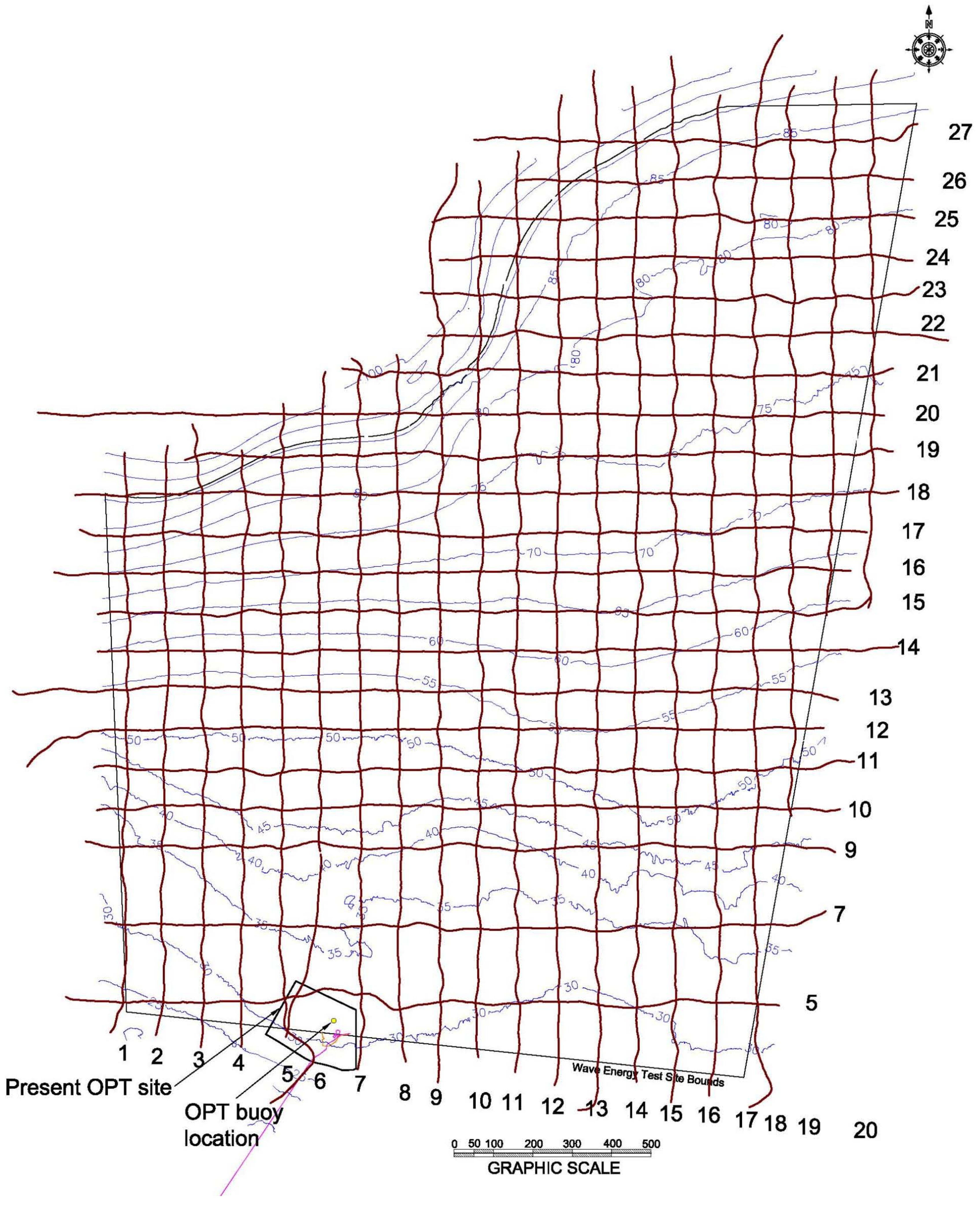

Figure 3-5. Wave energy test site sub-bottom track lines.

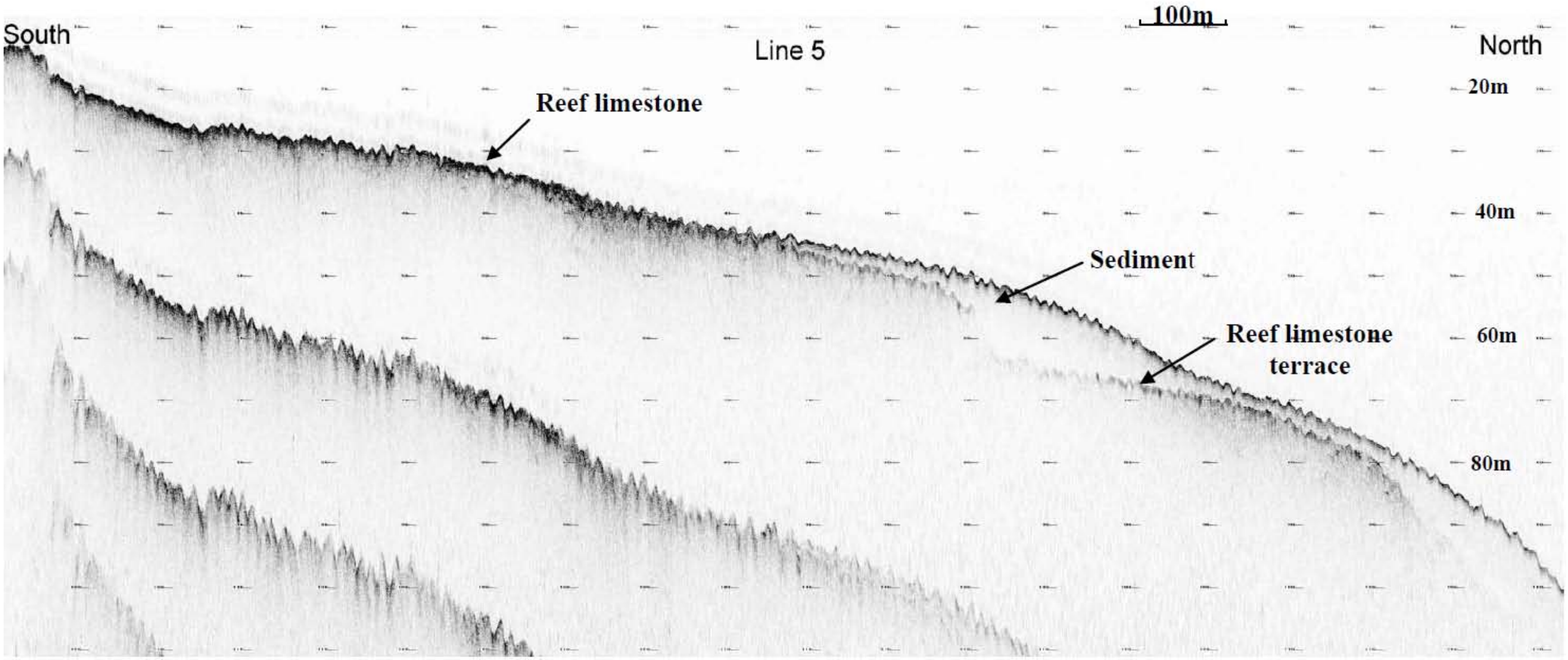

Figure 3-6. Sub-bottom profile along Line 5.

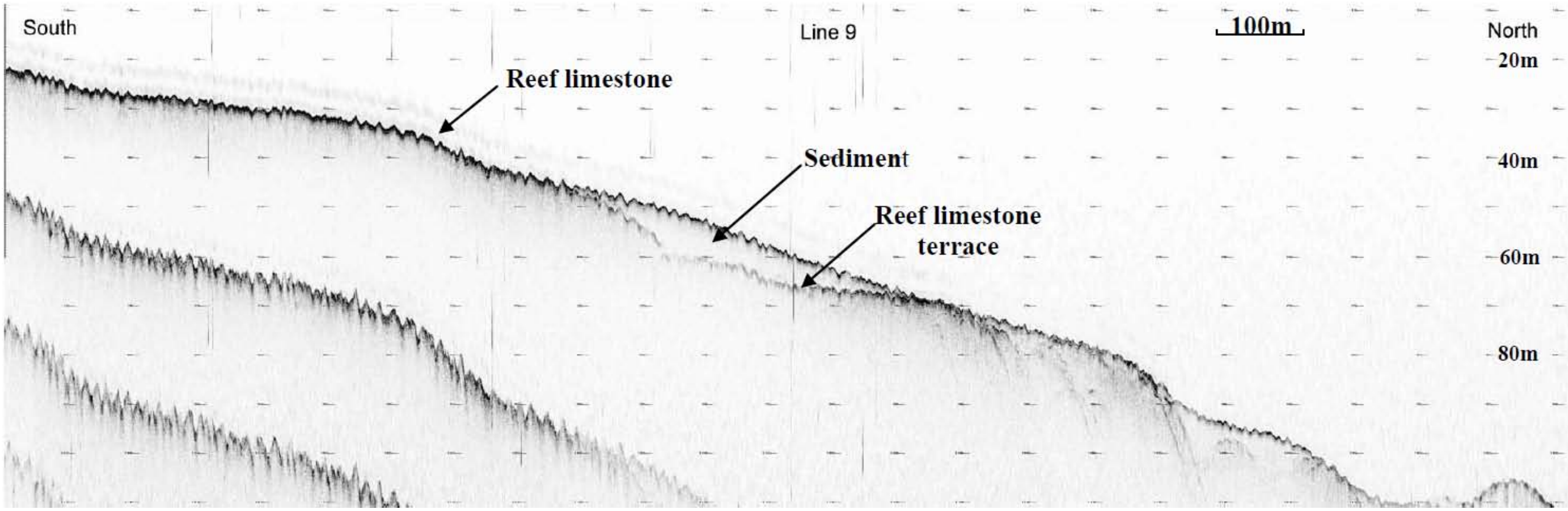

Figure 3-7 Sub-bottom profile along Line 9.

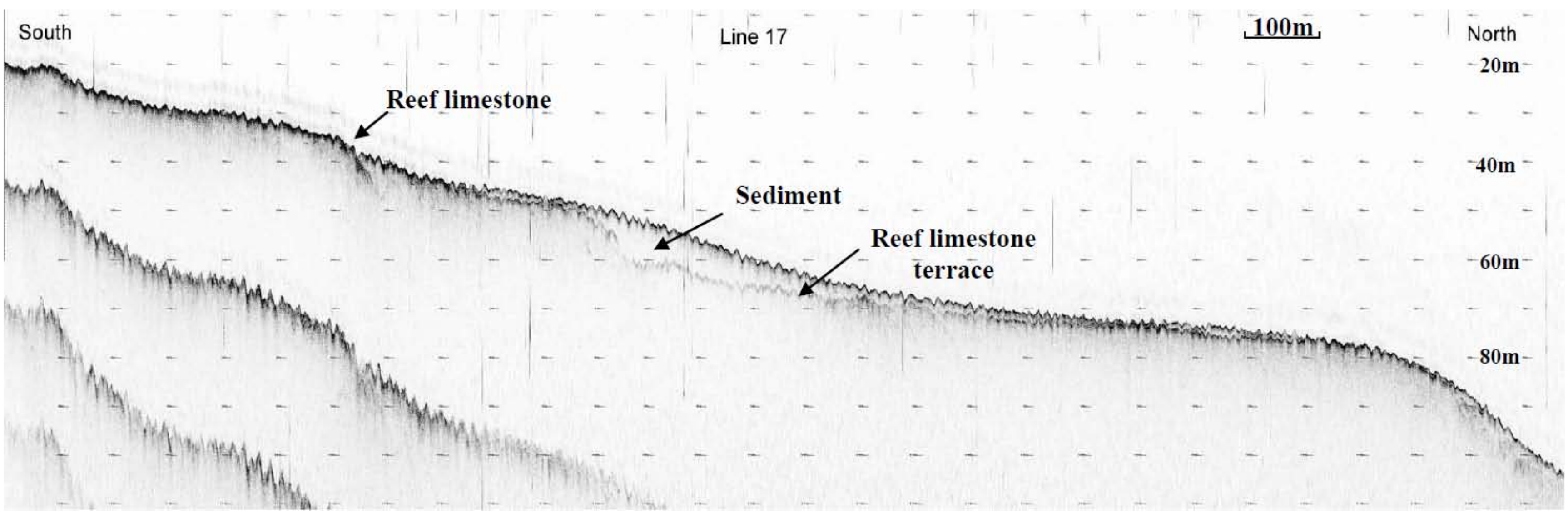

Figure 3-8. Sub-bottom profile along Line 17

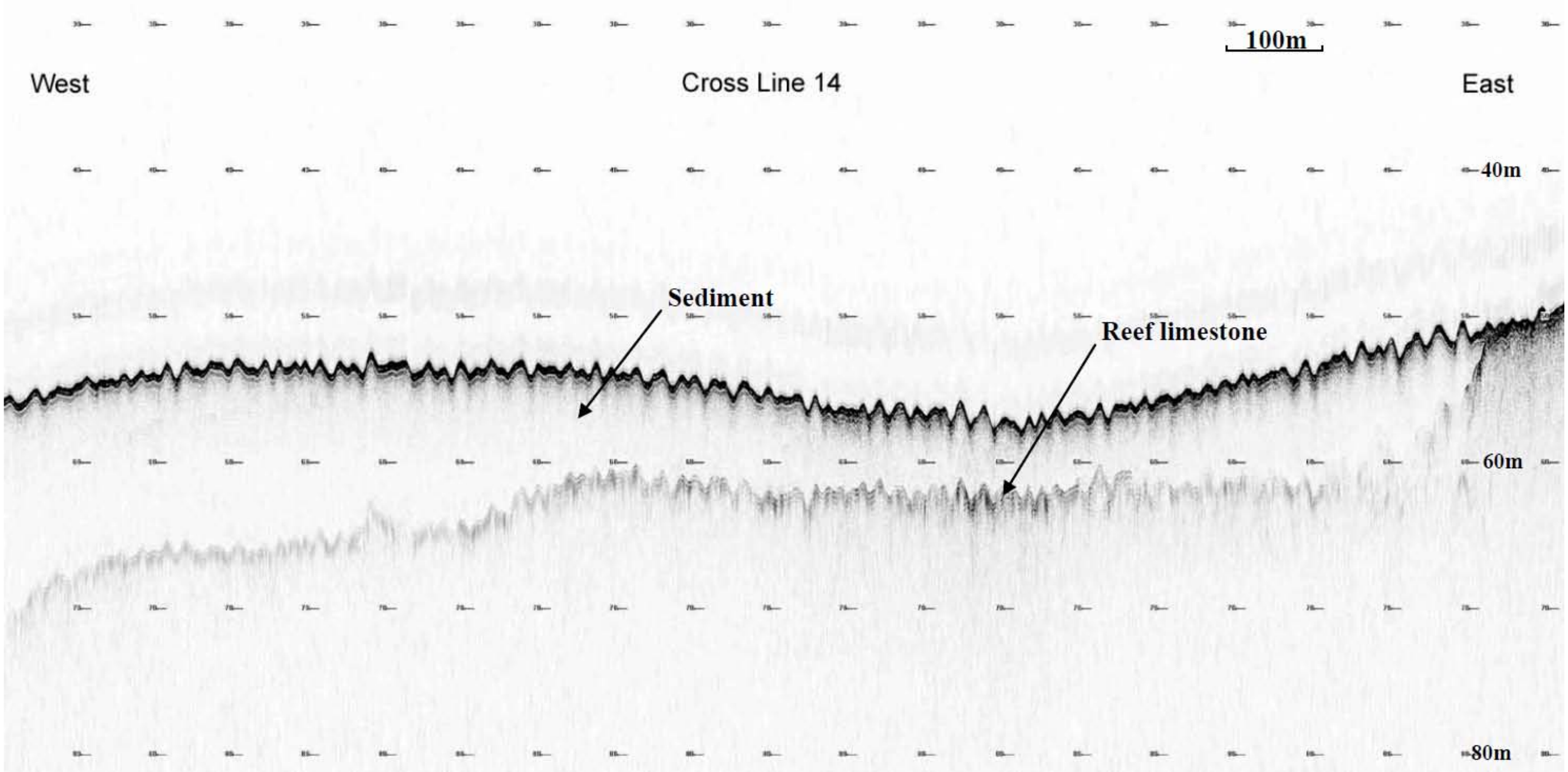

Figure 3-9. Sub-bottom profile from west to east at the approximate 60 meter depth contour (Cross Line 14).

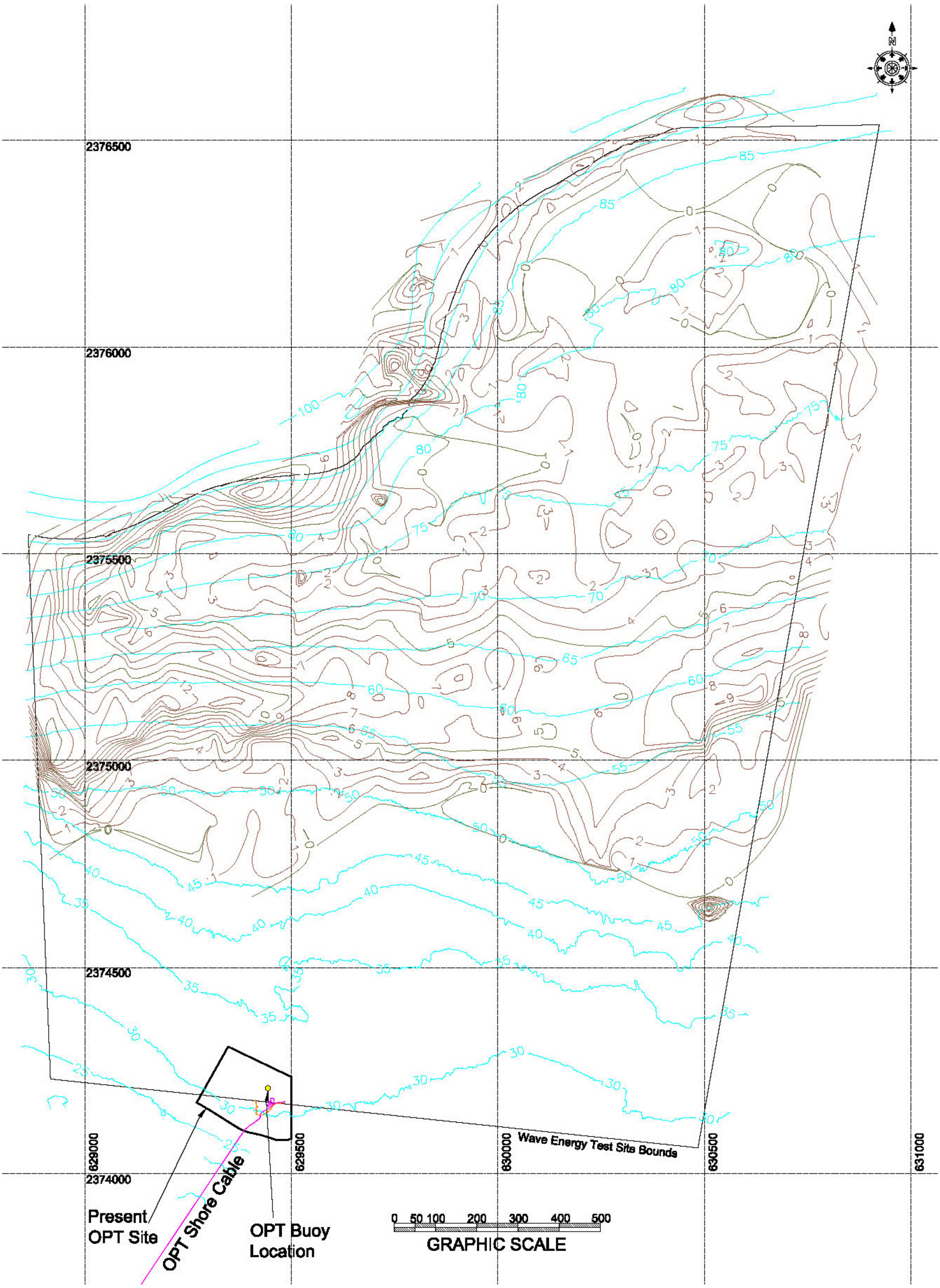

Figure 3-10. Sediment thickness in project area. Brown lines indicate sediment thickness, blue lines water depth, both in meters.

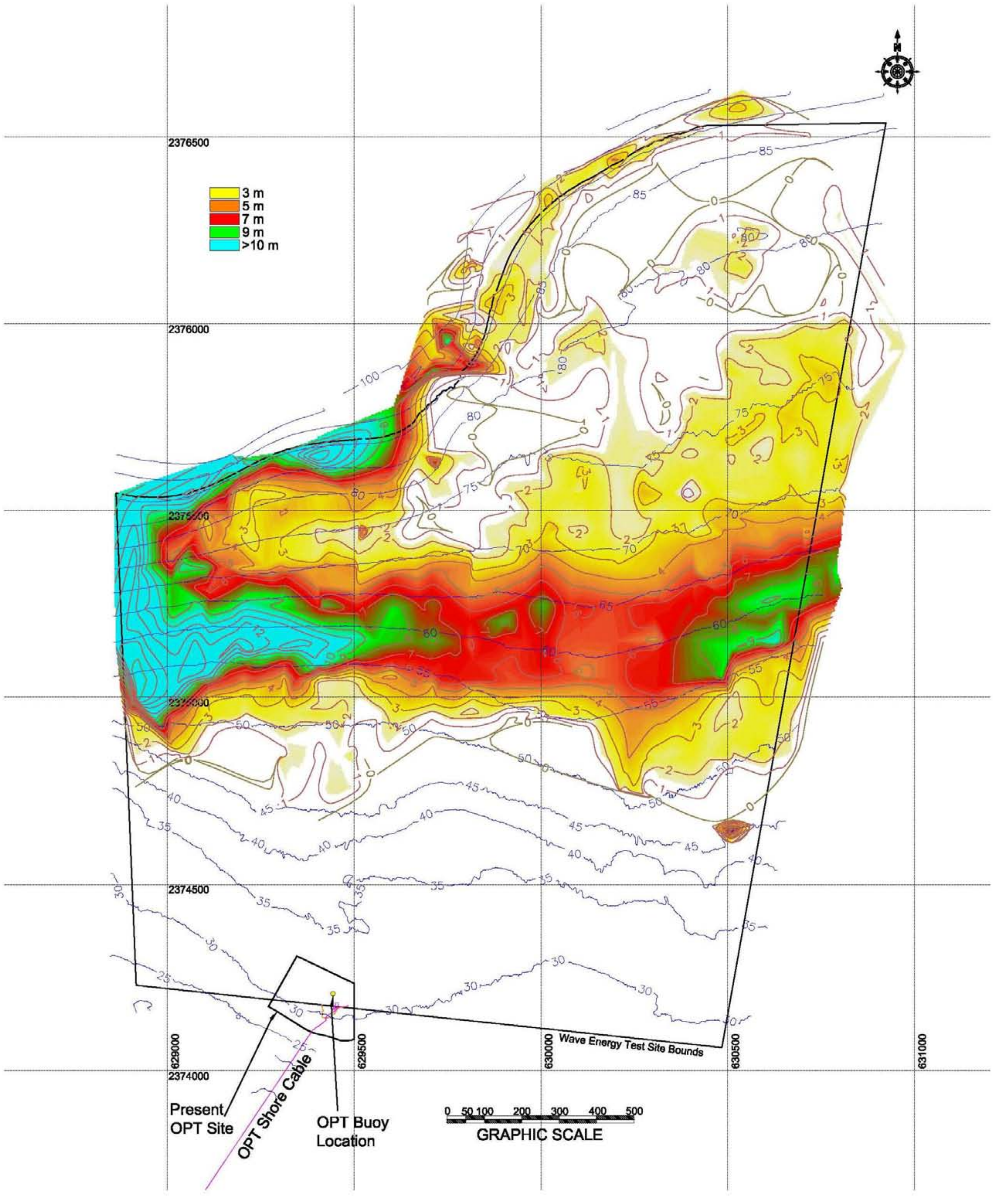

Figure 3-11. Color representation of sediment thickness in the project area.

4. SUMMARY SEAFLOOR COMPOSITION & ROV BOTTOM PHOTOGRAPHS

Figure 4-1 is a summary chart of seafloor composition in the project area, as derived from the multibeam, sub-bottom, side scan, and ROV video surveys conducted for this investigation. The figure shows that the project area is characterized by five different bottom zonations as described below.

1. Gently sloping reef limestone with scattered thin sand patches - The nearshore portion of the project area, between depths of 30 to 35 or 40 meters is relatively featureless and flat, with slopes ranging from 1V:34H to 1V:54H. Thin patches of sand and widely scattered small live coral heads occur within the reef limestone. Figure 4-2 is an ROV photograph of the bottom.

2. Steeply sloping escarpment - A steeply sloping, irregular escarpment is present at water depths between approximately 40 and 45 meters. Slopes as steep as 1V:8H occur between 40 and 45 meter water depths. Relief of 1 to 2 meters, spur and groove morphology, small ledges and scattered coral heads are typical in this zone. Figure 4-3 and Figure 4-4 are photographs of the bottom in this zone.

3. Gently sloping reef limestone and thin sand - Seaward of the base of the 40-45 meter limestone escarpment, at a water depth of 45-50 meters is gently sloping reef limestone with thin sand cover, algae and isolated patches of coral. This zone transitions seaward into the thick sand deposit. Figure 4-5 and Figure 4-6 present representative photographs of the seafloor in this area.

4. Sand Deposit - A band of sediment, 5 to 12 meters thick, is present between the approximate water depths of 55 to 70 meters in the eastern two-thirds of the project area. In the western third of the project area, the sand deposit is generally thicker and extends from water depths shallower than 55 meters to the limit of the survey at a water depth of 100 meters. The ROV video indicated that the sand is poorly sorted with high silt content and interspersed coarse carbonate flakes. Scattered patches of algae were observed growing in the sand. Figure 4-7 and Figure 4-8 are photographs of the sand bottom in this zone.

5. Reef limestone and sand less than 3 meters thick – Thin sand, typically less than 2 to 3 meters thick, with exposures of reef limestone bottom occurs seaward of the 70-meter depth in the eastern part of the project site. The barchan dune bedforms are present in water depths of 72 to 82 meters in the northeastern corner of the site. The dunes are only 1-2 meters thick, and 150 to 200 meters long, and up to 100 meters wide. Figure 4-9 and Figure 4-10 are representative photographs of the bottom in this zone.

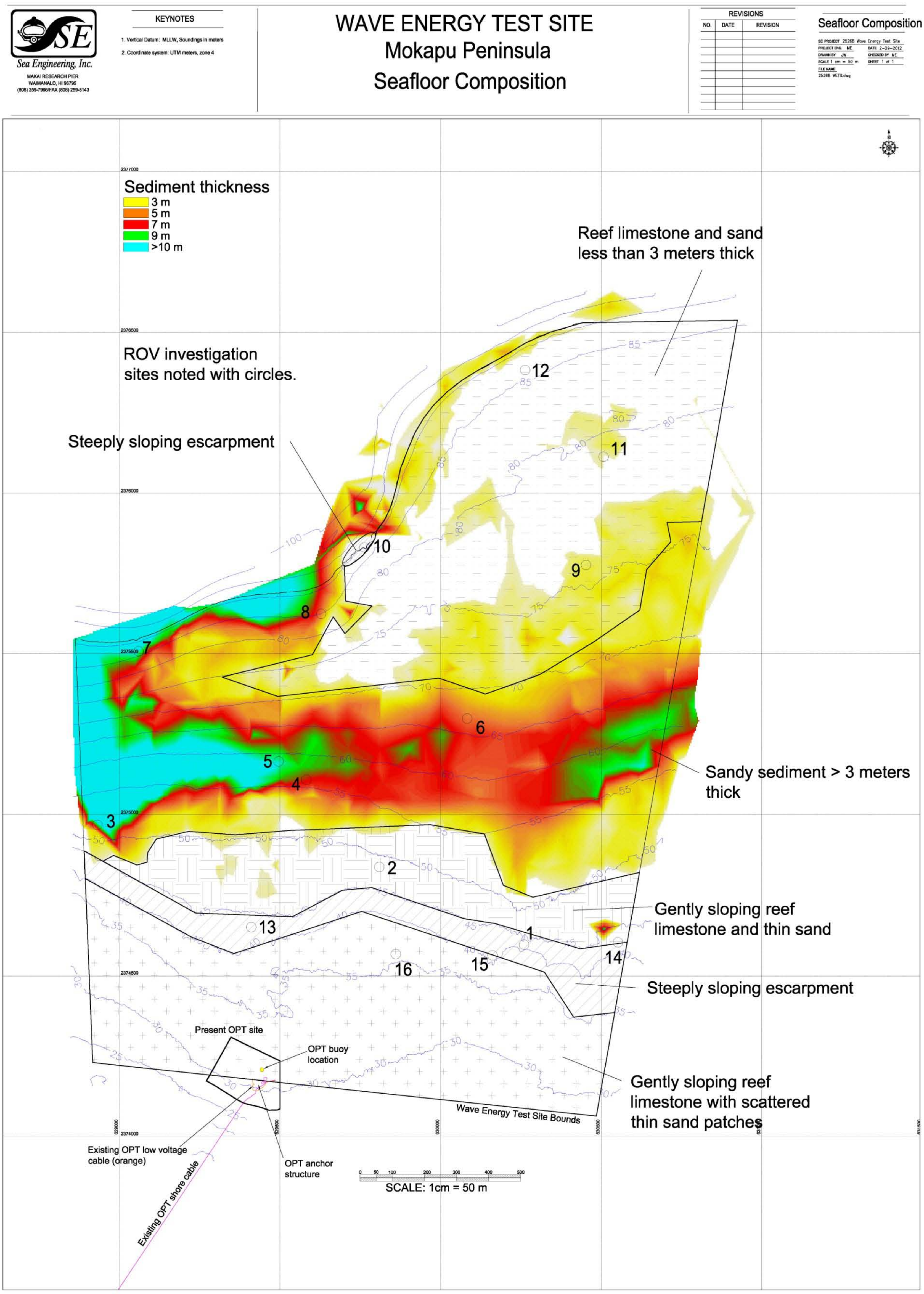

Figure 4-1. Seafloor composition. ROV photograph locations are indicated by the small circles with the bold number labels.

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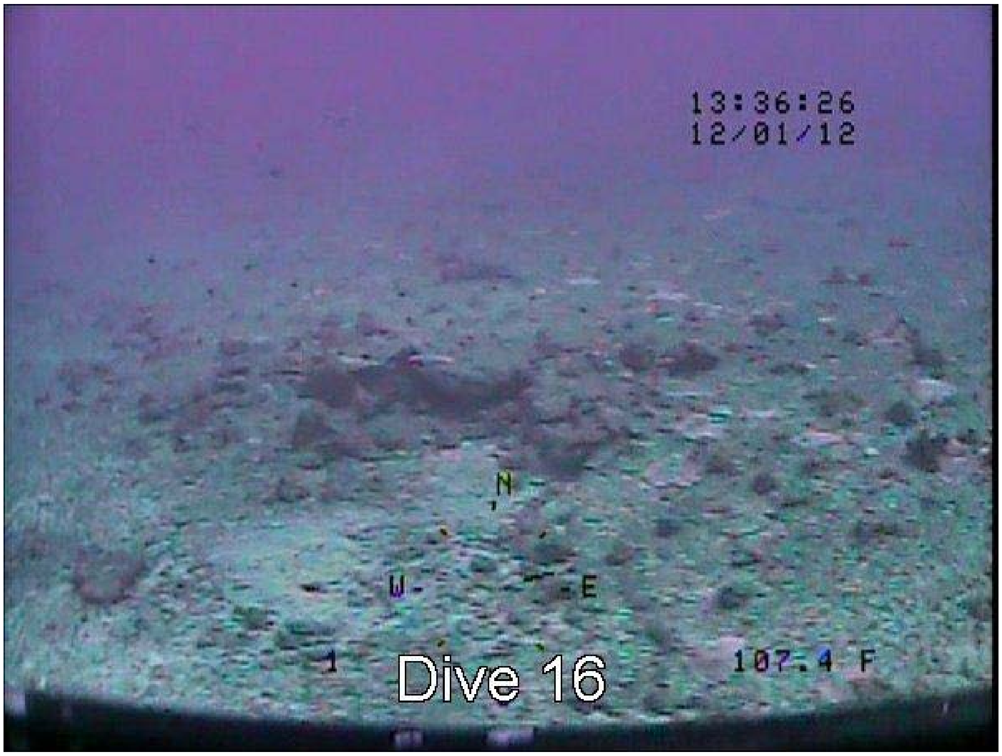

Figure 4-2. Flat reef limestone bottom with widely scattered small coral heads (Site 16).

Figure 4-3. Reef ledge at 40 meter water depth (Site 14).

Figure 4-4. Ledge at 40 meter depth (Site 1).

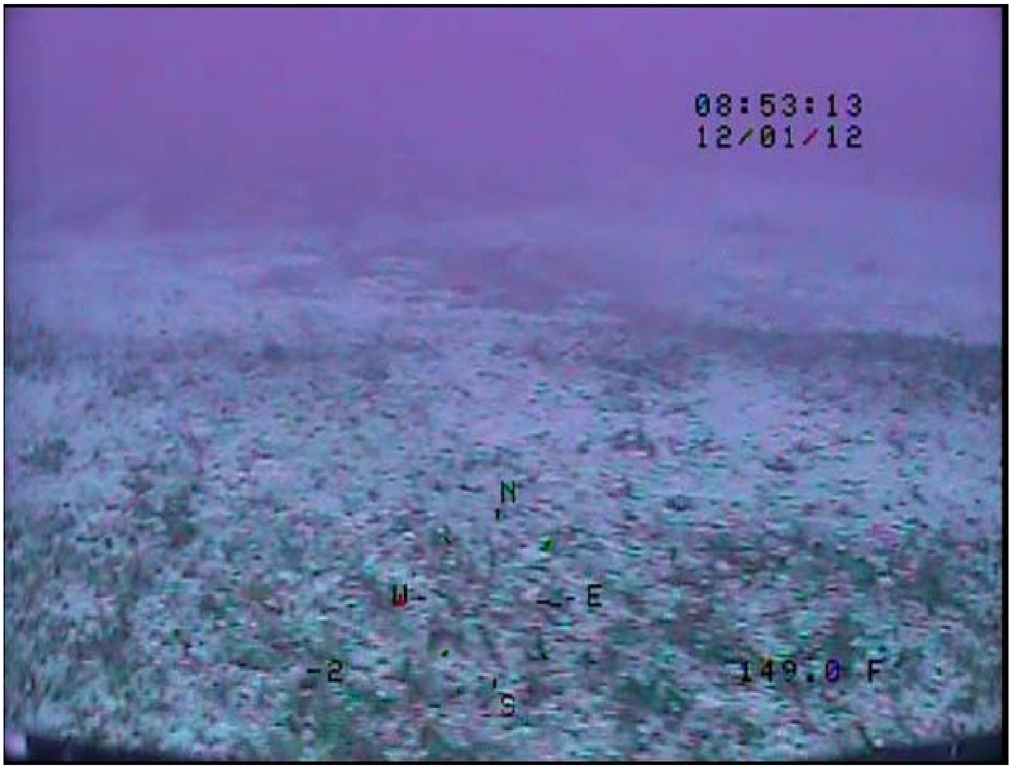

Figure 4-5. Reef limestone with thin sand and algae at 46 meter water depth (Site 2).

Figure 4-6. Transition from reef limestone bottom with algae (left side of photograph) to thick sandy bottom (right) at a water depth of 47 meters (Site 3).

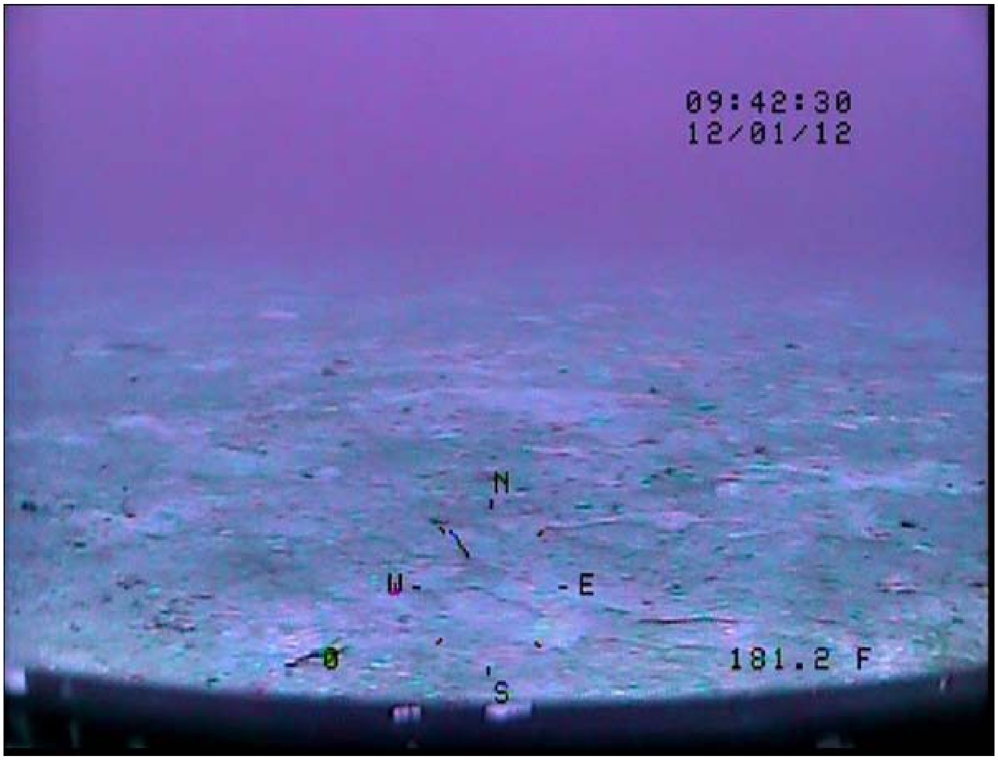

Figure 4-7. Algae coated sand at a water depth of 56 meters (Site 4).

Figure 4-8. Algae growing within sand deposit at a water depth of 85 meters (Site 8).

Figure 4-9. Edge of a Barchan feature at Site 11 at a water depth of 77 meters. Barchan sand is visible in the foreground. Thin sand with ripples with pebbles and algae in the trough are visible beyond the Barchan.

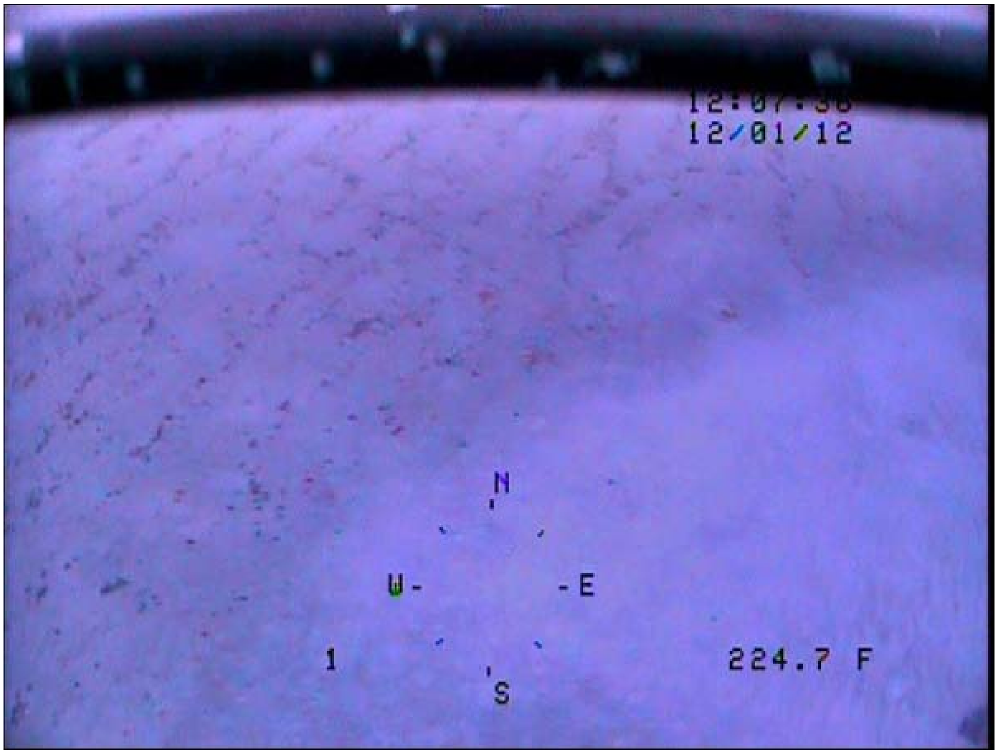

Figure 4-10. Transition from thin, rippled sand with cobbles (upper left) to thick sand (lower right) at Site 9 in a water depth of 76 meters.