

**MULTIBEAM SURVEY OF WHEELER NORTH REEF  
SAN CLEMENTE, CALIFORNIA  
(September 2009)**

by

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## TABLE OF CONTENTS

<b>1.0</b>	<b>INTRODUCTION.....</b>	<b>1</b>
<b>2.0</b>	<b>SURVEY METHODS AND INSTRUMENTATION.....</b>	<b>4</b>
2.1	MULTIBEAM SURVEY DATE.....	4
2.2	SURVEY VESSEL.....	4
2.3	DATA ACQUISITION AND INSTRUMENTATION.....	4
2.3.1	GPS Positioning.....	4
2.3.2	Motion Sensor and Vessel Heading.....	6
2.3.3	Sound Velocity Profiler.....	6
2.3.4	Multibeam Echo-sounder System (MBES).....	6
2.4	CALIBRATION AND QUALITY CONTROL OF MULTIBEAM SYSTEM.....	7
2.4.1	Vessel Offset Survey.....	7
2.4.2	MBES Patch Test Calibration.....	7
2.4.3	MBES Tie Line Check.....	7
2.5	DATA PROCESSING.....	7
<b>3.0</b>	<b>MULTIBEAM SONAR SURVEY RESULTS.....</b>	<b>12</b>
<b>4.0</b>	<b>REFERENCES.....</b>	<b>21</b>

## LIST OF APPENDICES

Appendix A	Comparison of Post-Construction (2008) and September 2009 Boundaries from Backscatter Mosaics for Polygons 1-17.....	A-1
Appendix B	Comparison of Module Boundaries from 2005 (Bathymetry) and September 2009 (Backscatter) For Blocks 1–7.....	B-1
Appendix C	Comparison of Post-Construction (2008) and September 2009 Boundaries from Bathymetry Data for Polygons 1–17.....	C-1
Appendix D	Comparison of Module Boundaries from 2005 (Bathymetry) and September 2009 (Bathymetry) for Blocks 1–7.....	D-1
Appendix E	Boundaries from Backscatter Mosaics for Polygons 1–17 (September 2009 Multibeam Survey).....	E-1
Appendix F	Boundaries from Backscatter Mosaics for Module Blocks 1–7 (September 2009 Multibeam Survey).....	F-1
Appendix G	Boundaries from Bathymetric Data for Polygons 1–17 (September 2009 Multibeam Survey).....	G-1
Appendix H	Boundaries from Bathymetric Data for Module Blocks 1–7 (September 2009 Multibeam Survey).....	H-1
Appendix I	Summary of Survey Data in Large-Scale Drawings.....	I-1

## LIST OF FIGURES

Figure 1-1.	Location of Wheeler North Reef at San Clemente, California .....	2
Figure 1-2.	Boundaries of Wheeler North Reef, consisting of 17 polygons (constructed in 2008) and 56 modules (7 blocks constructed in 1999) overlaid on multibeam bathymetric data (September 2009).....	3
Figure 2-1.	Survey boat <i>M/V Locator</i> , Notice Pole Mounted Reson 7101 Multibeam Sonar on the port side.....	5
Figure 3-1.	Bathymetry vs. backscatter interpretation of boundaries for Polygon 1, 2, 3, 12, and 13 (Sep 2009).....	15
Figure 3-2.	Bathymetry vs. backscatter interpretation of boundaries for Polygon 6 (Sep 2009).....	16
Figure 3-3.	Boundaries from 2008 and 2009 bathymetry data for Polygons 1, 2, 3, 12, and 13.....	17
Figure 3-4.	Boundaries from 2008 and 2009 bathymetry data for Polygon 6.....	18
Figure 3-5.	Boundaries from 2008 and 2009 bathymetry data compared with the construction GPS periphery points (x) for the southern portion of Polygon 2 showing an example of an area with some loss of available hard substrate .....	19
Figure 3-6.	Boundaries from 2008 and 2009 bathymetry data compared with the construction GPS periphery points (x) for Polygons 3 and 13 showing some loss of available hard substrate along the eastern edge.....	20
Figure A-1.	Comparison of post-construction (2008) and September 2009 boundaries from backscatter mosaics for Polygons 1, 2, 3, 12, and 13 .....	A-2
Figure A-2.	Comparison of post-construction (2008) and September 2009 boundaries from backscatter mosaics for Polygon 4.....	A-3
Figure A-3.	Comparison of post-construction (2008) and September 2009 boundaries from backscatter mosaics for Polygon 5.....	A-4
Figure A-4.	Comparison of post-construction (2008) and September 2009 boundaries from backscatter mosaics for Polygon 6.....	A-5
Figure A-5.	Comparison of post-construction (2008) and September 2009 boundaries from backscatter mosaics for Polygon 7.....	A-6
Figure A-6.	Comparison of post-construction (2008) and September 2009 boundaries from backscatter mosaics for Polygon 8.....	A-7
Figure A-7.	Comparison of post-construction (2008) and September 2009 boundaries from backscatter mosaics for Polygons 9, 10, 11, and 14 .....	A-8
Figure A-8.	Comparison of post-construction (2008) and September 2009 boundaries from backscatter mosaics for Polygon 15.....	A-9
Figure A-9.	Comparison of post-construction (2008) and September 2009 boundaries from backscatter mosaics for Polygon 16.....	A-10
Figure A-10.	Comparison of post-construction (2008) and September 2009 boundaries from backscatter mosaics for Polygon 17.....	A-11

Figure B-1.	Comparison of module boundaries from 2005 (bathymetry) and September 2009 (backscatter) for Block 1.....	B-2
Figure B-2.	Comparison of module boundaries from 2005 (bathymetry) and September 2009 (backscatter) for Block 2.....	B-3
Figure B-3.	Comparison of module boundaries from 2005 (bathymetry) and September 2009 (backscatter) for Block 3.....	B-4
Figure B-4.	Comparison of module boundaries from 2005 (bathymetry) and September 2009 (backscatter) for Block 4.....	B-5
Figure B-5.	Comparison of module boundaries from 2005 (bathymetry) and September 2009 (backscatter) for Block 5.....	B-6
Figure B-6.	Comparison of module boundaries from 2005 (bathymetry) and September 2009 (backscatter) for Block 6.....	B-7
Figure B-7.	Comparison of module boundaries from 2005 (bathymetry) and September 2009 (backscatter) for Block 7.....	B-8
Figure C-1.	Comparison of post-construction (2008) and September 2009 boundaries from bathymetry data for Polygons 1, 2, 3, 12, and 13.....	C-2
Figure C-2.	Comparison of post-construction (2008) and September 2009 boundaries from bathymetry data for Polygon 4.....	C-3
Figure C-3.	Comparison of post-construction (2008) and September 2009 boundaries from bathymetry data for Polygon 5.....	C-4
Figure C-4.	Comparison of post-construction (2008) and September 2009 boundaries from bathymetry data for Polygon 6.....	C-5
Figure C-5.	Comparison of post-construction (2008) and September 2009 boundaries from bathymetry data for Polygon 7.....	C-6
Figure C-6.	Comparison of post-construction (2008) and September 2009 boundaries from bathymetry data for Polygon 8.....	C-7
Figure C-7.	Comparison of post-construction (2008) and September 2009 boundaries from bathymetry data for Polygons 9, 10, 11, and 14.....	C-8
Figure C-8.	Comparison of post-construction (2008) and September 2009 boundaries from bathymetry data for Polygon 15.....	C-9
Figure C-9.	Comparison of post-construction (2008) and September 2009 boundaries from bathymetry data for Polygon 16.....	C-10
Figure C-10.	Comparison of post-construction (2008) and September 2009 boundaries from bathymetry data for Polygon 17.....	C-11
Figure D-1.	Comparison of module boundaries from 2005 (bathymetry) and September 2009 (bathymetry) for Block 1.....	D-2
Figure D-2.	Comparison of module boundaries from 2005 (bathymetry) and September 2009 (bathymetry) for Block 2.....	D-3
Figure D-3.	Comparison of module boundaries from 2005 (bathymetry) and September 2009 (bathymetry) for Block 3.....	D-4
Figure D-4.	Comparison of module boundaries from 2005 (bathymetry) and September 2009 (bathymetry) for Block 4.....	D-5
Figure D-5.	Comparison of module boundaries from 2005 (bathymetry) and September 2009 (bathymetry) for Block 5.....	D-6



Figure D-6.	Comparison of module boundaries from 2005 (bathymetry) and September 2009 (bathymetry) for Block 6 .....	D-7
Figure D-7.	Comparison of module boundaries from 2005 (bathymetry) and September 2009 (bathymetry) for Block 7 .....	D-8
Figure E-1.	Polygon 1 boundary from backscatter mosaics (September 2009 multibeam survey).....	E-2
Figure E-2.	Polygon 2 boundary from backscatter mosaics (September 2009 multibeam survey).....	E-3
Figure E-3.	Polygon 3 boundary from backscatter mosaics (September 2009 multibeam survey).....	E-4
Figure E-4.	Polygon 4 boundary from backscatter mosaics (September 2009 multibeam survey).....	E-5
Figure E-5.	Polygon 5 boundary from backscatter mosaics (September 2009 multibeam survey).....	E-6
Figure E-6.	Polygon 6 boundary from backscatter mosaics (September 2009 multibeam survey).....	E-7
Figure E-7.	Polygon 7 boundary from backscatter mosaics (September 2009 multibeam survey).....	E-8
Figure E-8.	Polygon 7a boundary from backscatter mosaics (September 2009 multibeam survey).....	E-9
Figure E-9.	Polygon 8 boundary from backscatter mosaics (September 2009 multibeam survey).....	E-10
Figure E-10.	Polygon 9 boundary from backscatter mosaics (September 2009 multibeam survey).....	E-11
Figure E-11.	Polygon 10 boundary from backscatter mosaics (September 2009 multibeam survey).....	E-12
Figure E-12.	Polygon 11 boundary from backscatter mosaics (September 2009 multibeam survey).....	E-13
Figure E-13.	Polygon 12 boundary from backscatter mosaics (September 2009 multibeam survey).....	E-14
Figure E-14.	Polygon 13 boundary from backscatter mosaics (September 2009 multibeam survey).....	E-15
Figure E-15.	Polygon 14 boundary from backscatter mosaics (September 2009 multibeam survey).....	E-16
Figure E-16.	Polygon 15 boundary from backscatter mosaics (September 2009 multibeam survey).....	E-17
Figure E-17.	Polygon 16 boundary from backscatter mosaics (September 2009 multibeam survey).....	E-18
Figure E-18.	Polygon 17 boundary from backscatter mosaics (September 2009 multibeam survey).....	E-19
Figure F-1.	Block 1 module boundaries from backscatter mosaics (September 2009 multibeam survey) .....	F-2
Figure F-2.	Block 2 module boundaries from backscatter mosaics (September 2009 multibeam survey) .....	F-3

Figure F-3.	Block 3 module boundaries from backscatter mosaics (September 2009 multibeam survey) .....	F-4
Figure F-4.	Block 4 module boundaries from backscatter mosaics (September 2009 multibeam survey) .....	F-5
Figure F-5.	Block 5 module boundaries from backscatter mosaics (September 2009 multibeam survey) .....	F-6
Figure F-6.	Block 6 module boundaries from backscatter mosaics (September 2009 multibeam survey) .....	F-7
Figure F-7.	Block 7 module boundaries from backscatter mosaics (September 2009 multibeam survey) .....	F-8
Figure G-1.	Polygon 1 boundary from bathymetric data interpretation (September 2009 multibeam survey) .....	G-2
Figure G-2.	Polygon 2 boundary from bathymetric data interpretation (September 2009 multibeam survey) .....	G-3
Figure G-3.	Polygon 3 boundary from bathymetric data interpretation (September 2009 multibeam survey) .....	G-4
Figure G-4.	Polygon 4 boundary from bathymetric data interpretation (September 2009 multibeam survey) .....	G-5
Figure G-5.	Polygon 5 boundary from bathymetric data interpretation (September 2009 multibeam survey) .....	G-6
Figure G-6.	Polygon 6 boundary from bathymetric data interpretation (September 2009 multibeam survey) .....	G-7
Figure G-7.	Polygon 7 boundary from bathymetric data interpretation (September 2009 multibeam survey) .....	G-8
Figure G-8.	Polygon 7a boundary from bathymetric data interpretation (September 2009 multibeam survey) .....	G-9
Figure G-9.	Polygon 8 boundary from bathymetric data interpretation (September 2009 multibeam survey) .....	G-10
Figure G-10.	Polygon 9 boundary from bathymetric data interpretation (September 2009 multibeam survey) .....	G-11
Figure G-11.	Polygon 10 boundary from bathymetric data interpretation (September 2009 multibeam survey) .....	G-12
Figure G-12.	Polygon 11 boundary from bathymetric data interpretation (September 2009 multibeam survey) .....	G-13
Figure G-13.	Polygon 12 boundary from bathymetric data interpretation (September 2009 multibeam survey) .....	G-14
Figure G-14.	Polygon 13 boundary from bathymetric data interpretation (September 2009 multibeam survey) .....	G-15
Figure G-15.	Polygon 14 boundary from bathymetric data interpretation (September 2009 multibeam survey) .....	G-16
Figure G-16.	Polygon 15 boundary from bathymetric data interpretation (September 2009 multibeam survey) .....	G-17
Figure G-17.	Polygon 16 boundary from bathymetric data interpretation (September 2009 multibeam survey) .....	G-18

Figure G-18.	Polygon 17 boundary from bathymetric data interpretation (September 2009 multibeam survey) .....	G-19
Figure H-1.	Block 1 module boundaries from bathymetric data interpretation (September 2009 multibeam survey) .....	H-2
Figure H-2.	Block 2 module boundaries from bathymetric data interpretation (September 2009 multibeam survey) .....	H-3
Figure H-3.	Block 3 module boundaries from bathymetric data interpretation (September 2009 multibeam survey) .....	H-4
Figure H-4.	Block 4 module boundaries from bathymetric data interpretation (September 2009 multibeam survey) .....	H-5
Figure H-5.	Block 5 module boundaries from bathymetric data interpretation (September 2009 multibeam survey) .....	H-6
Figure H-6.	Block 6 module boundaries from bathymetric data interpretation (September 2009 multibeam survey) .....	H-7
Figure H-7.	Block 7 module boundaries from bathymetric data interpretation (September 2009 multibeam survey) .....	H-8

#### LIST OF TABLES

Table 2-1.	Patch test results.....	8
Table 3-1.	Experimental reef module areas from September 2009 multibeam bathymetry and backscatter data .....	13
Table 3-2.	Polygon areas as-built and estimated from September 2009 multibeam bathymetry and backscatter data .....	14

**MULTIBEAM SURVEY OF WHEELER NORTH REEF,  
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**1.0 INTRODUCTION**

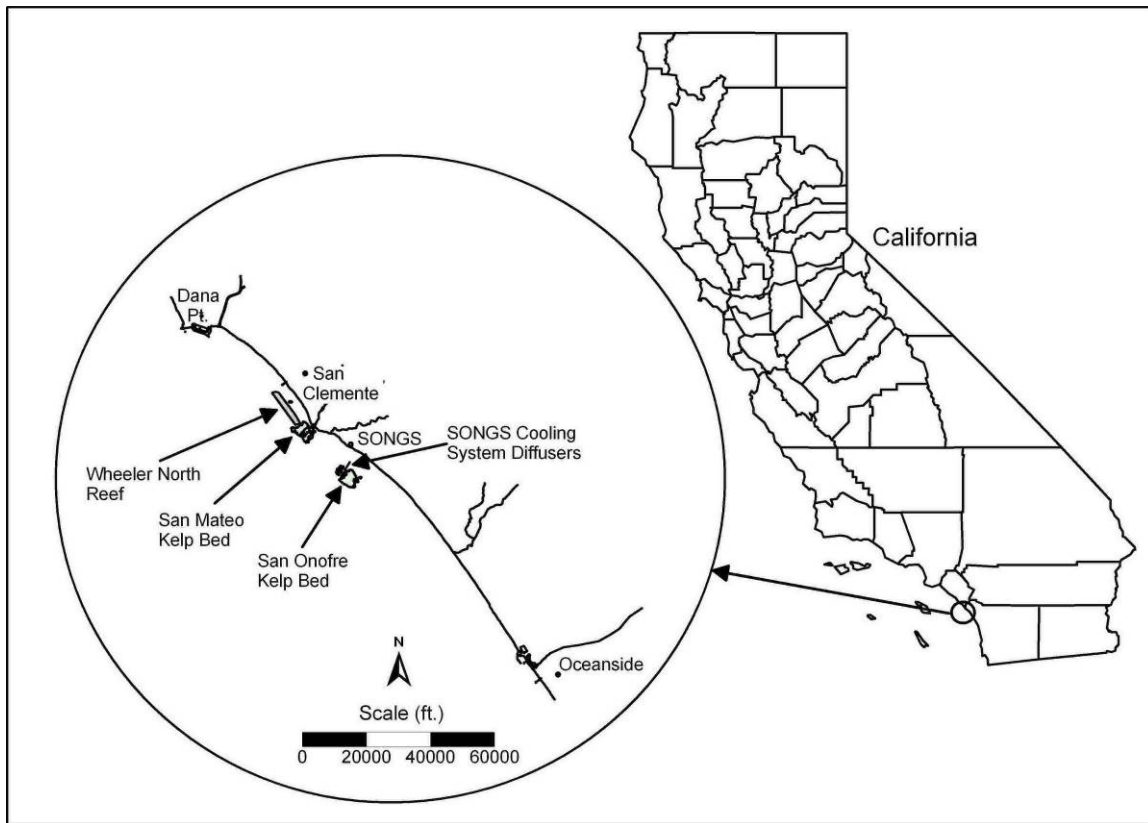
Wheeler North Reef was constructed by Southern California Edison Company (SCE) as part of the mitigation for impacts to marine resources by the San Onofre Nuclear Generating Station. The reef was constructed in 2 phases. Phase 1, the experimental reef with an area of 22.4 acres, consists of 7 blocks of 8 (40 x 40 m) modules and was completed on 29 September 1999 (Coastal Environments, 1999). Phase 2 consists of 17 polygons with a total area of 152 acres (Coastal Environments, 2008a) and was completed on 11 September 2008.

Wheeler North Reef (WNR) is located offshore of San Clemente between the San Clemente Pier and San Mateo Point (Figure 1-1) in approximately 11 to 15 m water depth. Periodic surveys are required by the California Coastal Commission (CCC), according to Special Condition #12 in SCE's CCC construction permit (CDP #E-07-010 dated 2 February 2008), to assure that the reef footprint is maintaining its areal coverage. The purpose of this multibeam survey was to assess the boundaries of the reef approximately one year after its completion. The multibeam coverage included the complete lease area (860 acres) for Wheeler North Reef, which includes the 17 constructed polygons and the 56 experimental reef modules (Figure 1-2). The boundaries from this survey are compared to boundaries determined from the multibeam survey in September 2008 for the polygons and from the 2005 survey for the modules (Coastal Environments et al., 2006a,b).

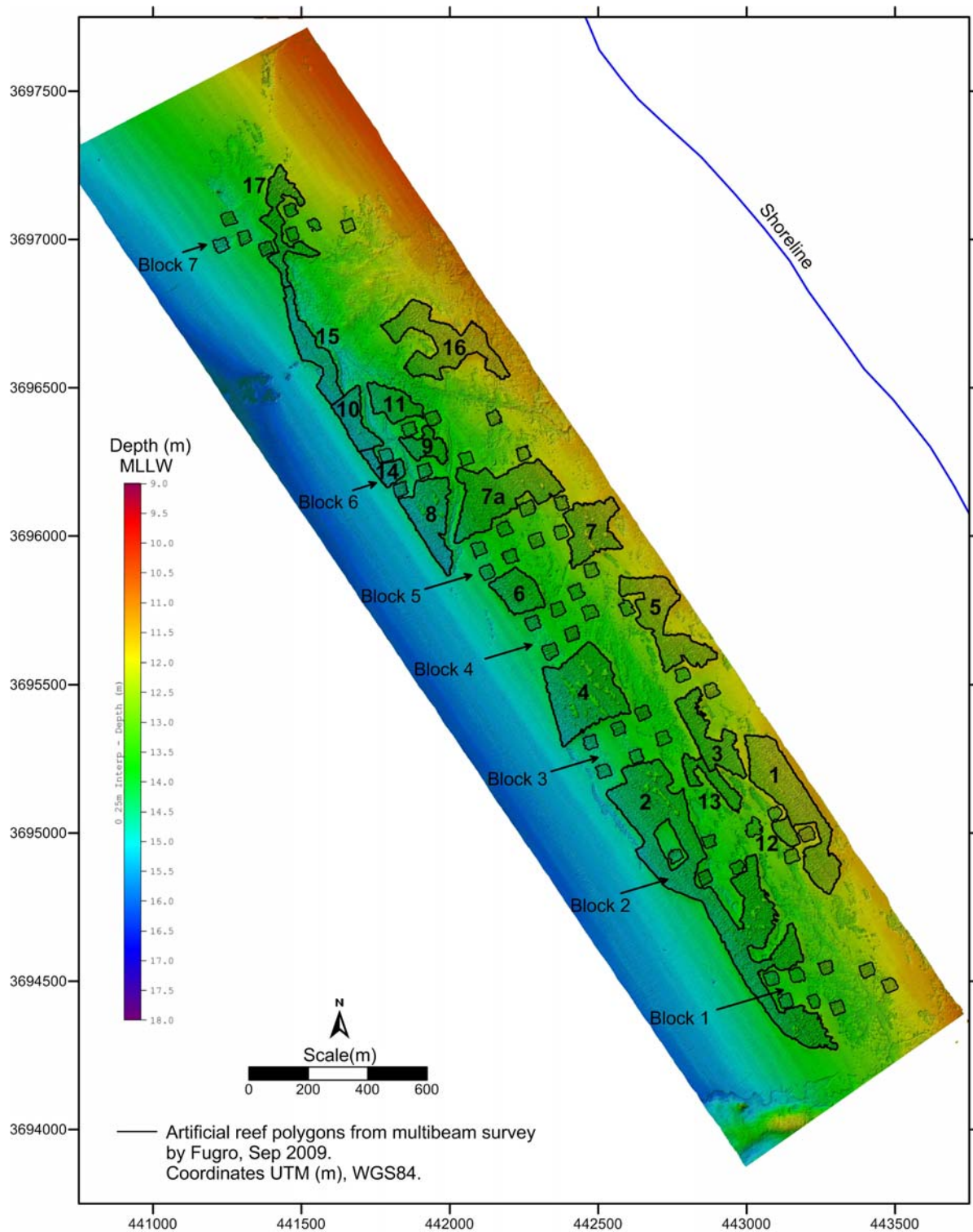
Multibeam survey operations were carried out September 2, 2009 through September 5, 2009. Multibeam bathymetry and backscatter were collected throughout the defined project area. The survey covered a total of 56 modules and 17 polygons. All the data presented in this report are presented in WGS84, UTM Zone 11 (meters). Vertical sounding reference is Mean Lower Low Water (MLLW). Tide corrections are based upon actual NOAA verified tides from station 9410170 (San Diego).

The boundaries of reef modules and polygons were estimated from multibeam bathymetry, three dimensional (3D) graphs and multibeam backscatter images. Total area for the Phase 1 Modules plus Phase 2 Polygons accepted by California Coastal Commission was estimated as 153.4 acres from multibeam bathymetry data and 154.13 acres from multibeam backscatter images. Table 3-2 gives the area of WNR as estimated during 2009 surveys.

This report consists of four chapters and nine appendices. Chapter 1 is an introduction, chapter 2 describes the survey methods and instrumentation and provides details of the equipment calibration method used before the survey. Chapter 3 presents the project results. Chapter 4 provides references. Multibeam survey results are summarized in graphical form and presented in appendices A through I.



**Figure 1-1. Location of the Wheeler North Reef at San Clemente, California.**



**Figure 1-2. Boundaries of Wheeler North Reef, consisting of 17 polygons (constructed in 2008) and 56 modules (7 blocks constructed in 1999) overlaid on multibeam bathymetric data (September 2009).**

## **2.0 SURVEY METHODS AND INSTRUMENTATION**

### **2.1 MULTIBEAM SURVEY DATE**

The fieldwork for this survey was performed during 2-5 September 2009.

### **2.2 SURVEY VESSEL**

The *M/V Locator*, a 25-foot-long Parker boat, was used as the survey vessel for the project (Figure 2-1). The vessel was equipped with the following primary equipment for execution of the survey:

- 1) Reson SeaBat 7101 Multibeam Echosounder (MBES), over-the-side mounted;
- 2) POS/MV 320 positioning, heading, and motion reference sensor;
- 3) 2 x Trimble Zephyr Model 2, L1/L2 GPS antenna;
- 4) Applied Microsystems Limited (AML) SmartProbe for Sound Velocity Profiles (SVP); and
- 5) FPI's WinFrog navigation software.

### **2.3 DATA ACQUISITION AND INSTRUMENTATION**

#### **2.3.1 GPS Positioning**

Primary positioning data was provided by the POS/MV 320 system. Position was determined in real time using a Trimble Zephyr L1/L2 GPS antenna, which was connected to a Trimble BD950 L1/L2 GPS card residing in the POS MV. An Inertial Measurement Unit (IMU) provided velocity values to the POS MV allowing it to compute an inertial position based on DGPS, heading, and motion. The master GPS antenna was mounted atop the MBES over-the-side mount, above the MBES transducer and offset 0.56 m forward.

The POS MV was configured to accept differential corrections, which were output from a CSI MBX-3 DGPS receiver that was tuned to the closest or strongest USCG DGPS station.

The POS MV controller software's real-time QC displays were monitored throughout the survey to ensure that the positional accuracies specified in the NOS Hydrographic Surveys Specifications and Deliverables were achieved. These include, but are not limited to, the following: GPS Status, Position Accuracy, Receiver Status (which included HDOP), and Satellite Status.

WinFrog presented vessel position data in graphical and tabular format for QC purposes. The following display windows were used:

- Graphics – The Graphics window showed navigation information in plan view. This included vessel position and orientation, survey lines, background plots, charts, and waypoints.



**Figure 2-1. Survey boat M/V Locator, Notice Pole Mounted Reson 7101 Multibeam Sonar on the port side.**



- Vehicle – The Vehicle window was configured to show tabular navigation information. Typically, this window was set to display position, time and date, line name, distance to start and end of line, distance off line, heading, course over ground, and speed, as well as data logging and event status.
- Calculations – The Calculation window was used to look at specific data items in tabular or graphical format.

### **2.3.2 Motion Sensor and Vessel Heading**

A POS/MV 320 motion sensor system unit measured vessel dynamic motion and orientations (heave, pitch, roll and heading). The system consists of an inertial motion unit (IMU), two GPS receivers, and a processing unit.

The IMU uses a series of linear accelerometers and angular rate sensors that work in tandem to determine vessel attitude solutions. The combined GPS solution of each antenna is used to estimate the orientation and heading of the vessel (offsets for the IMU and GPS antennae are utilized in the data acquisition software).

Attitude and position data were sent to the WinFrog navigation system during MBES acquisition.

### **2.3.3 Sound Velocity Profiler**

Sound-velocity profile (SVP) data were acquired using an Applied Microsystems Ltd. (AML) Smart Probe. AML Smart Probes measure at a rate of eight velocity and pressure observations per second. For each cast, the probes were held at the surface for two minutes to reach temperature equilibrium. The probes were then manually lowered at the rate of 0.3 meters/second to the seabed and raised to the surface at the same rate. HyperTerminal was used to log the velocity data.

Sound-velocity casts were conducted regularly so that MBES data could be corrected for refraction. A log of all cast times and locations was kept on file.

### **2.3.4 Multibeam Echo-sounder System (MBES)**

The survey boat (*M/V Locator*) was equipped with an over the side pole mounted Reason SeaBat 7101 (240 kHz) as shown in Figure 2-1. The system can operate in nearshore water up to 150 meters water depth. The MBES was used to collect bathymetry and backscatter data from approximately 9.5 to 17.5 meter water depths during the survey. Survey speed was typically between 1.5 to 2.8 m/s in order to ensure low turbulence around the multibeam transducer pole.

Data received by the SeaBat sonar-processing unit was sent to WinFrog, where backscatter and bathymetry data quality were continually monitored during acquisition operations. Various windows displayed backscatter imagery, a 3D bathymetry profile, and swath coverage so that adjustments to sonar settings or vessel speed could be made, if appropriate, to

improve data quality. A parameter window also displayed position, speed, heading, and attitude data received from POS/MV 320, as well as data logging status.

## **2.4 CALIBRATION AND QUALITY CONTROL OF MULTIBEAM SYSTEM**

In addition to the online QC tools and displays available in Pos/MV 320 and WinFrog, as described in previous sections, the following calibrations and checks were also conducted.

### **2.4.1 Vessel Offset Survey**

Dimensions of the vessel were taken after all equipment was mobilized, and offsets between the various sonar systems and sensors were measured.

### **2.4.2 MBES Patch Test Calibration**

A MBES patch test calibration was carried out to derive the mounting offsets between the sonar head and motion reference unit. The processing methods and patch test results can be found in section 2.5.1 and Table 2-1.

### **2.4.3 MBES Tie Line Check**

Tie lines were acquired perpendicular to the main survey lines to quantify the integrity of the data set and ensure that accuracy specifications were met. The tie line data were compared with acquired survey line data.

## **2.5 DATA PROCESSING**

### **2.5.1 Bathymetry**

All multibeam bathymetry soundings were processed using CARIS' Hydrographic Information Processing System (HIPS) on Windows XP workstations. CARIS was used to clean data, produce Digital Terrain Models (DTMs), and generate Sun Illuminated 3D Models. Final data products were imported into ArcGIS 9.3.1 for contour and chart presentation.

#### *Corrections to Bathymetry Data*

Within CARIS HIPS, Reson 7101 multibeam bathymetry soundings were corrected for calibrated patch test results, vessel offsets, vessel motion, draft, sound velocity, and water level.

#### *Vessel Offsets*

Offsets established prior to the survey (Section 2.2.1) were used to correct bathymetry to compensate for differences between the transducer head and GPS antenna position. Offsets were entered into the Vessel Configuration File (VCF) in CARIS HIPS, enabling CARIS to correct the bathymetry during processing.

**Table 2-1. Patch test results.**

<b>Test</b>	<b>Patch Test (274)</b>
Navigation Timing Error	0.0 seconds
Pitch Offset	+0.40°
Azimuth Offset	-0.35°
Roll Offset	+0.85°

### *Sound Velocity Profiles*

Processed sound velocity profiles (SVPs) were used to correct bathymetry for sound refraction or ray bending. SVPs were applied within CARIS. Fugro Pelagos' MBTools Processing Software was used to process the SVP data set, removing duplicated points and noise to generate a smooth interpolation curve that depicted the original profile at the finest resolution available in CARIS.

### *Static Draft*

Static freeboard observations were measured at the MBES over-the-side mount on the *M/V Locator*. Several measurements were averaged to obtain the draft correction, which was then applied to adjust the soundings from the transducer level to the water level. The static freeboard value was entered into the Vessel Configuration file within CARIS.

### *Water Level Changes*

All sounding data were reduced to Mean Lower Low Water (MLLW) by CARIS using verified NOAA tides for the project area.

### *Patch Test*

A multibeam calibration (or patch test) is employed so data can be corrected for navigation timing, pitch, azimuth and roll offsets, which may exist between the MBES transducer and the Motion Reference Unit (MRU).

The PosMV is the master time source for all attitude and navigation data. This allows navigation-timing error to be determined by examining and correcting the roll timing error, which is the most obvious and simplest error to calculate and correct. This is accomplished by examining the sonar swath of two lines run reciprocally over a flat bottom.

The pitch error adjustment was performed on sets of two coincident lines, run at the same velocity, over sloping terrain or a conspicuous object, in opposite directions. The navigation time error was already identified. The nadir beams from each line were compared and brought into alignment by adjusting the pitch error value.

The azimuth error adjustment was performed on sets of two lines, run over a conspicuous topographic feature. Lines were run in opposite directions, at the same velocity with the same outer beams crossing the feature. The navigation time error and pitch error were already identified. Data from the same outer beams for each line were compared and brought into alignment by adjusting the azimuth error value.

The roll error adjustment was performed on sets of two coincident lines, run over flat terrain at the same velocity in opposite directions. The navigation time error, pitch error and

azimuth error were already identified. Data across a swath were compared for each line and brought into agreement, by adjusting the roll error value.

Patch test values were obtained in CARIS HIPS calibration mode. Calculated values were then entered into the vessel configuration file so that data could be corrected during the processing procedure. Correction values used are given in Table 2-1.

### *Cleaning*

The initial raw S7K files were converted to CARIS HIPS format for bathymetry processing. Prior to each survey line being converted from S7K to CARIS' HIPS format, the vessel offsets, patch test calibration values, and static freeboard measurements were entered into the vessel configuration file. The SVP file was then loaded into each line and the line corrected for sound refraction. During SVP correction, the bathymetry was also corrected for dynamic vessel heave, pitch, and roll. The attitude, heading, navigation and bathymetry data were examined for noise and gaps.

After each individual line was examined and cleaned in CARIS' Swath Editor, the water level file (containing observed water level data) was loaded and the lines merged. During merging, water level and draft corrections were applied. Subsets were then created in CARIS' Subset Edit mode and adjacent overlapping lines of corrected bathymetry data examined to identify any water level anomalies, sound velocity errors, motion errors, and data gaps. Any residual noise in the data set was also rejected at this time.

### *Removal of Kelp Artifacts*

The survey area had large areas of surface kelp. This introduced artifacts in the raw sonar data and required extensive cleaning to remove from the datasets.

### *DTM Generation*

After the data were cleaned in both Swath Editor and Subset Mode, DTM grids were created in CARIS for contour production. The DTM grid size was 0.25 meters with an isobath interval of 0.5 meters.

The grids created within CARIS were mean weighted grids, thus depicting a mean surface of the seabed.

Range-weighting is based on a sounding's distance from a grid node, where soundings located closer to the node have a greater weight than soundings further away. The number of grid nodes that each sounding influences is determined by the size of the beam footprint. The beam footprint is calculated using water depth, MBES beam width, and grazing angle. Therefore, MBES type is taken into account during DTM creation.

Grazing-angle weighting is based on a beam's intersection angle with the seafloor, whereby a higher weight is given to beams from the inner part of a swath than to outer beams from adjacent track lines. This weighting value is important in areas with adjacent or overlapping track lines.

Sun-illuminated images of the grids were created within CARIS using the image manager. These images were then exported as geotiffs for use in final charting.

### *Isobath Production*

Once DTMs were generated using the CARIS, the XYZ data were exported in ASCII format and imported into ArcGIS 9.3.1 for final contouring and charting.

## **2.5.2 Backscatter**

### *Creating Backscatter Mosaics in Geocoder*

Once the bathymetry data was cleaned, each multibeam line was exported as a GSF file from CARIS and imported into Geocoder, along with its original raw S7K file. Once imported, the lines were assembled and mosaicked, and a final tiff was exported.

### *Digitized Polygon and Module Boundaries*

Geotiffs of the bathymetric and backscatter data were imported into Golden Software's Surfer v9.2 for digitizing of the boundaries of both the modules and the experimental reef. The different data sets were layered so that in areas that were difficult to interpret for one data set, the other was referenced to aid in interpretation (in this regard, the two measurements of area were not totally independent of each other).

### 3.0 MULTIBEAM SONAR SURVEY RESULTS

Plots for the digitized boundaries from the backscatter data are found in Appendix A (Polygons) and Appendix B (Modules). Plots for the digitized boundaries from the bathymetric data are found in Appendix C (Polygons) and Appendix D (Modules). The areas of modules from both the bathymetric and backscatter digitizing are shown in Table 3-1 and for the polygons in Table 3-2. For comparison purposes the survey results presented in Appendices A through D are overlaid on the boundary results from the 2008 survey for the polygons and on the 2005 survey for the modules. The 2009 backscatter boundaries are overlaid on the backscatter mosaic for both the polygons (Appendix E) and modules (Appendix F). The digitized 2009 bathymetric boundaries are overlaid on the bathymetric color-coded, sun-illuminated images for the polygons (Appendix G) and the modules (Appendix H). A summary of the survey data is presented in Appendix I on large scale drawings.

The two different ways of assessing the boundary, bathymetry and backscatter, yield comparable results with slight differences because they are utilizing a different type of measurement to delineate a boundary. For example, a hard flat bottom can be interpreted as reef from the backscatter but would not be so interpreted in the bathymetric data. Nevertheless, such areas of conflicting interpretation are minimal, and the comparisons of backscatter vs. bathymetry show very good agreement for the polygons, as illustrated in the two examples, Polygons 1, 2, 3, 12, and 13 (Figure 3-1) and Polygon 6 (Figure 3-2), and in a comparison of the areas reported in Table 3-2 for estimates for polygon area accepted by the CCC backscatter mosaic yields 127.95 acres, and bathymetry data yields 128.62 acres). For the modules, the total area estimated from backscatter was 26.19 acres and from bathymetry was 24.79 acres. The difference in the area estimates is greater due to two factors: the larger periphery to area ratio which magnifies possible measurement errors, and the extended length of time that the modules have been in place has led to scouring and complex textural differences that cause more areas of uncertainty in the interpretation of the boundaries. A visual comparison of the backscatter images from Appendix E and F with the bathymetric images from Appendix G and H show very good agreement.

The stability of the reef periphery was addressed by comparing the boundaries from just after the completion of construction of the polygons (September 2008) and the present survey (September 2009). Examples of the comparisons of digitized boundaries are shown for Polygons 1, 2, 3, 12, and 13 (Figure 3-3) and Polygon 6 (Figure 3-4). In general, the boundaries have remained the same with a loss of hard substrate in some areas over the last year; for example, see the southern end of Polygon 2 (Figure 3-5) and the eastern boundary of Polygon 3 (Figure 3-6). Figures 3-5 and 3-6 indicate the location of the rock placement boundaries (x's) from DGPS (Differential Global Position System) measurements taken during construction (Coastal Environments, 2008a,b).

**Table 3-1. Experimental reef module areas from September 2009 multibeam bathymetry and backscatter data.**

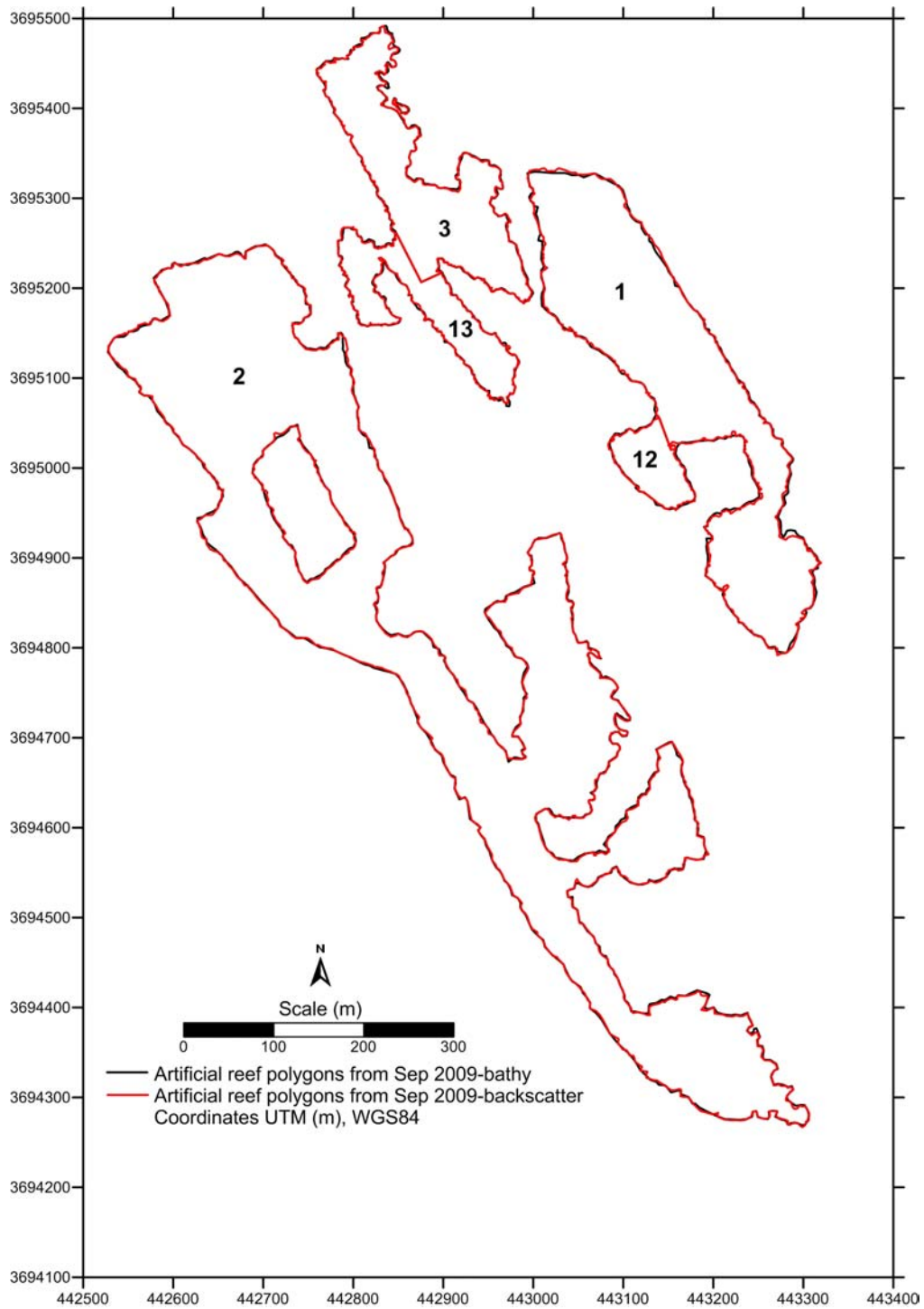
Module ID	Modules areas, acres (Sep 09)		Module ID	Modules areas, acres (Sep 09)	
	Bathymetry	Backscatter		Bathymetry	Backscatter
1	0.48	0.46	29	0.48	0.52
2	0.45	0.46	30	0.49	0.53
3	0.49	0.50	31	0.48	0.49
4	0.36	0.39	32	0.44	0.45
5	0.42	0.44	33	0.45	0.52
6	0.44	0.48	34	0.48	0.52
7	0.47	0.51	35	0.46	0.47
8	0.45	0.49	36	0.45	0.47
9	0.39	0.41	37	0.51	0.51
10	0.42	0.45	38	0.49	0.51
11	0.38	0.44	39	0.43	0.44
12	0.39	0.39	40	0.44	0.44
13	0.60	0.64	41	0.40	0.44
14	0.48	0.51	42	0.45	0.46
15	0.39	0.40	43	0.44	0.46
16	0.51	0.51	44	0.44	0.47
17	0.43	0.46	45	0.49	0.50
18	0.44	0.49	46	0.42	0.44
19	0.41	0.44	47	0.44	0.47
20	0.40	0.46	48	0.40	0.42
21	0.48	0.50	49	0.45	0.47
22	0.46	0.56	50	0.46	0.49
23	0.46	0.46	51	0.39	0.40
24	0.47	0.47	52	0.43	0.45
25	0.46	0.50	53	0.37	0.37
26	0.53	0.62	54	0.38	0.38
27	0.45	0.49	55	0.29	0.29
28	0.45	0.46	56	0.39	0.41
Total area (Phase 1 modules)				24.79	26.19



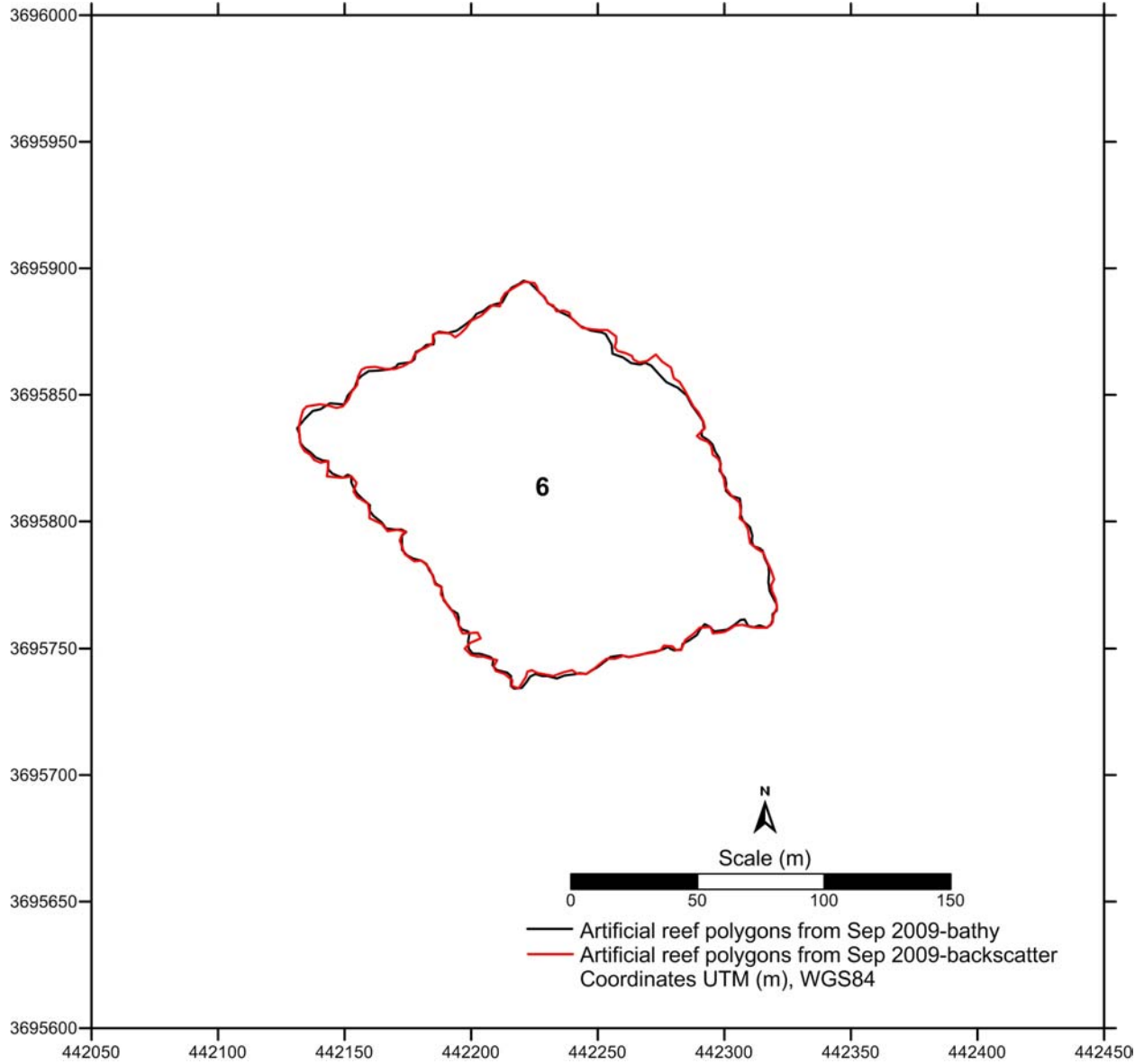
**Table 3-2. Polygon areas as-built and estimated from September 2009 multibeam bathymetry and backscatter data.**

<b>Sequential Polygon ID</b>	<b>As-built (2008) area (acres)</b>	<b>Bathymetry (Sep 2009) area (acres)</b>	<b>Backscatter (Sep 2009) area (acres)</b>
1	13.83	13.48	13.31
2	38.88	37.75	37.48
3	6.61	6.19	6.08
4	14.05	13.99	13.92
5	9.48	9.60	9.59
6	4.19	4.29	4.32
7	6.8	6.69	6.64
7a	12.2	12.24	12.16
8	7.64	7.50	7.43
9	2.52	2.62	2.63
10	3.89	3.88	3.84
11	3.48	3.69	3.68
12	1.35	1.34	1.30
13	2.85	2.92	2.88
14	2.12	2.18	2.14
15	5.54	5.47	5.44
16	11.19	11.22	11.46
17	5.32	5.41	5.39
Total area (Phase 2 polygons)	151.94	150.46	149.7
Total area (CCC polygons)*	130.26	128.62	127.95
Experimental reef modules (Phase 1 modules)		24.79	26.19
Total area (Phase 1 modules + Phase 2 polygons)*		153.41	154.13

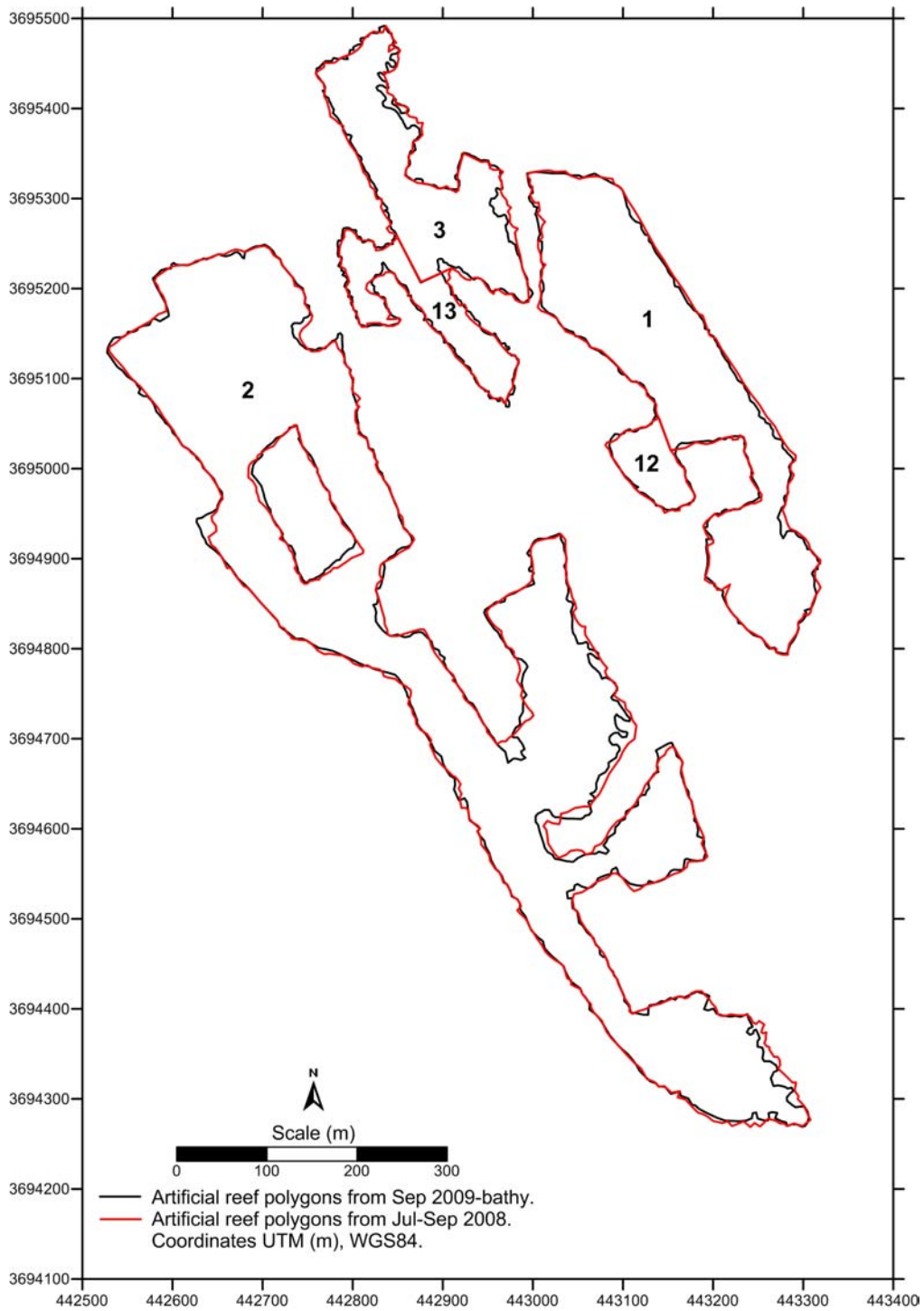
\* without polygons 5 and 7a



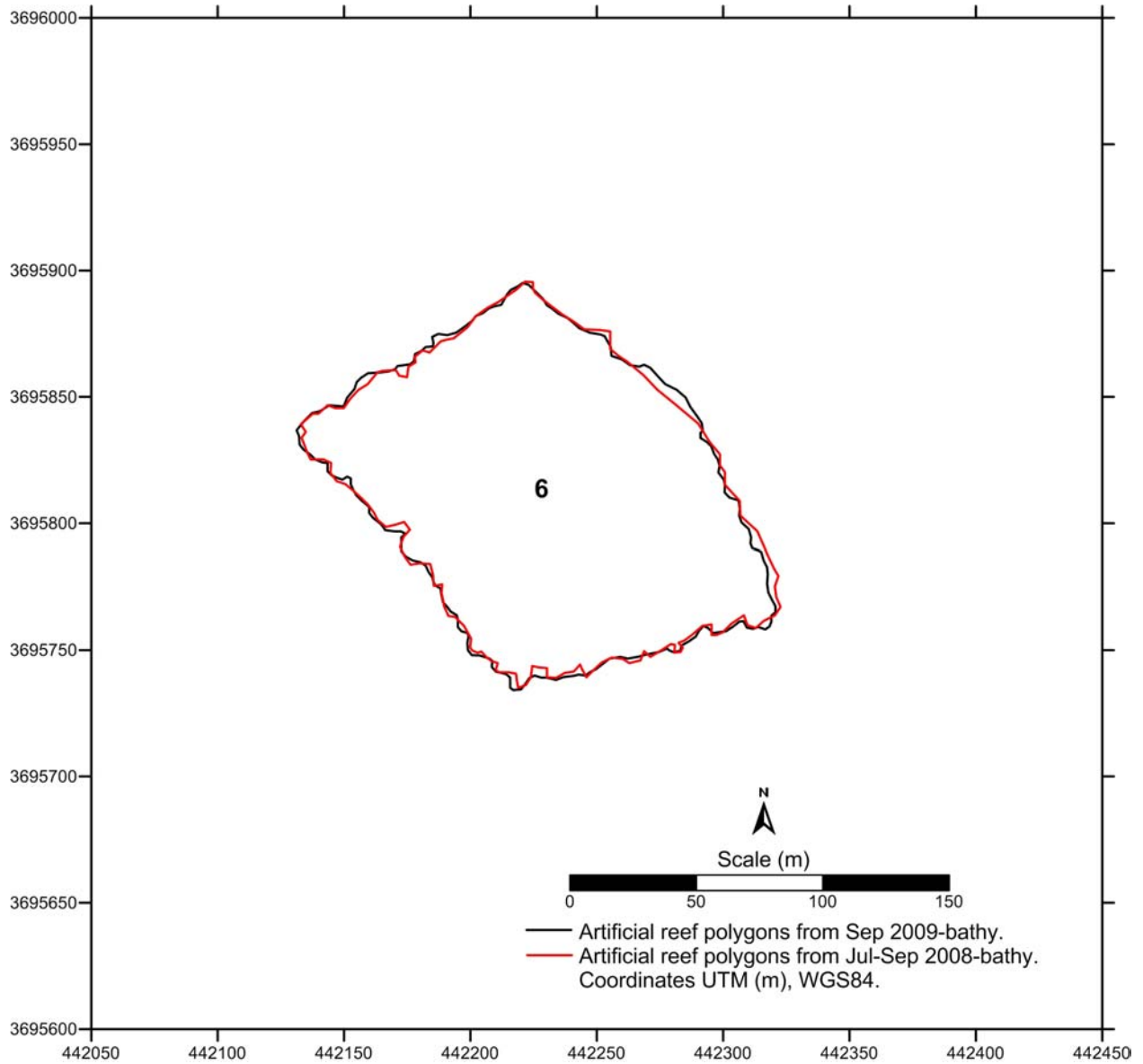
**Figure 3-1. Bathymetry vs. backscatter interpretation of boundaries for Polygon 1, 2, 3, 12, and 13 (Sep 2009).**



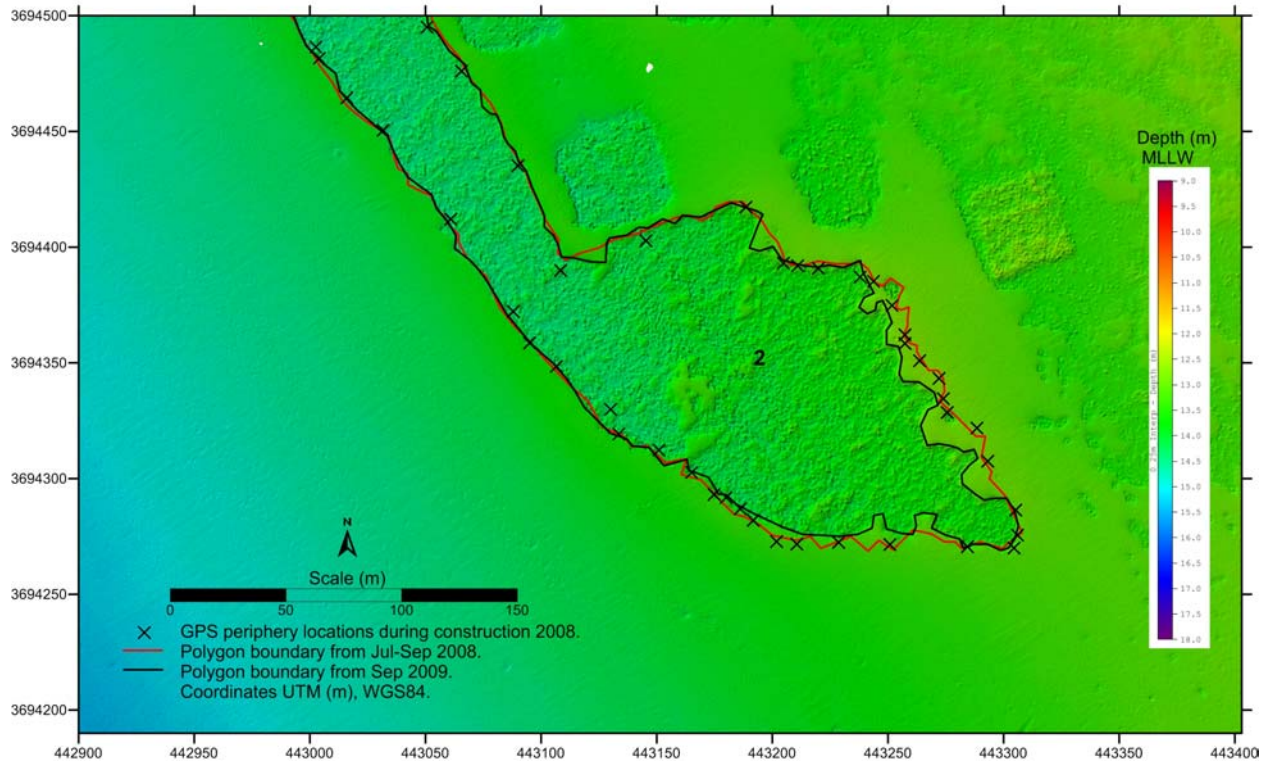
**Figure 3-2. Bathymetry vs. backscatter interpretation of boundaries for Polygon 6 (Sep 2009).**



**Figure 3-3. Boundaries from 2008 and 2009 bathymetry data for Polygons 1, 2, 3, 12, and 13.**

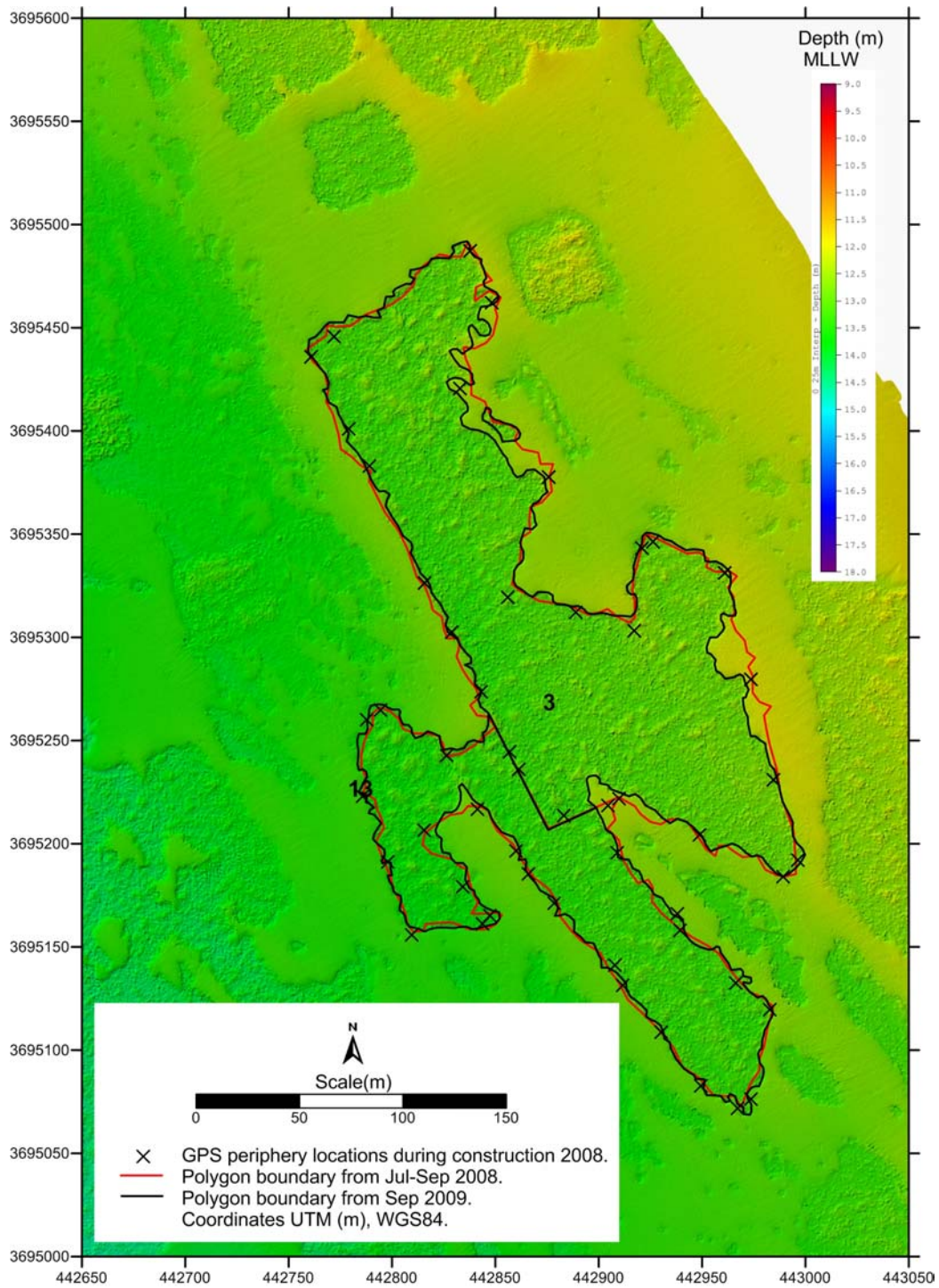


**Figure 3-4. Boundaries from 2008 and 2009 bathymetry data for Polygon 6.**



**Figure 3-5. Boundaries from 2008 and 2009 bathymetry data compared with the construction GPS periphery points (x) for the southern portion of Polygon 2 showing an example of an area with some loss of available hard substrate.**



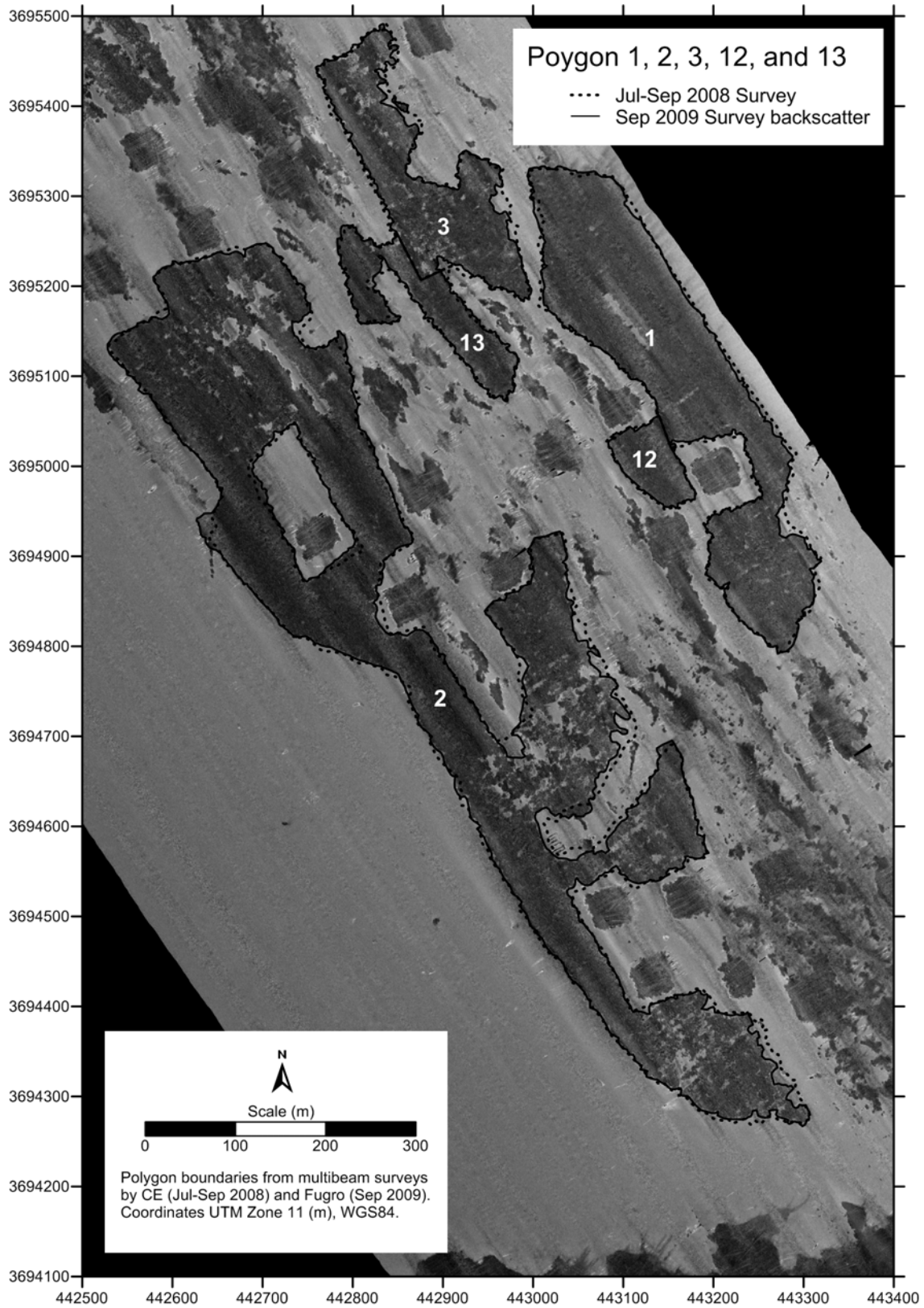


**Figure 3-6. Boundaries from 2008 and 2009 bathymetry data compared with the construction GPS periphery points (x) for Polygons 3 and 13 showing some loss of available hard substrate along the eastern edge.**

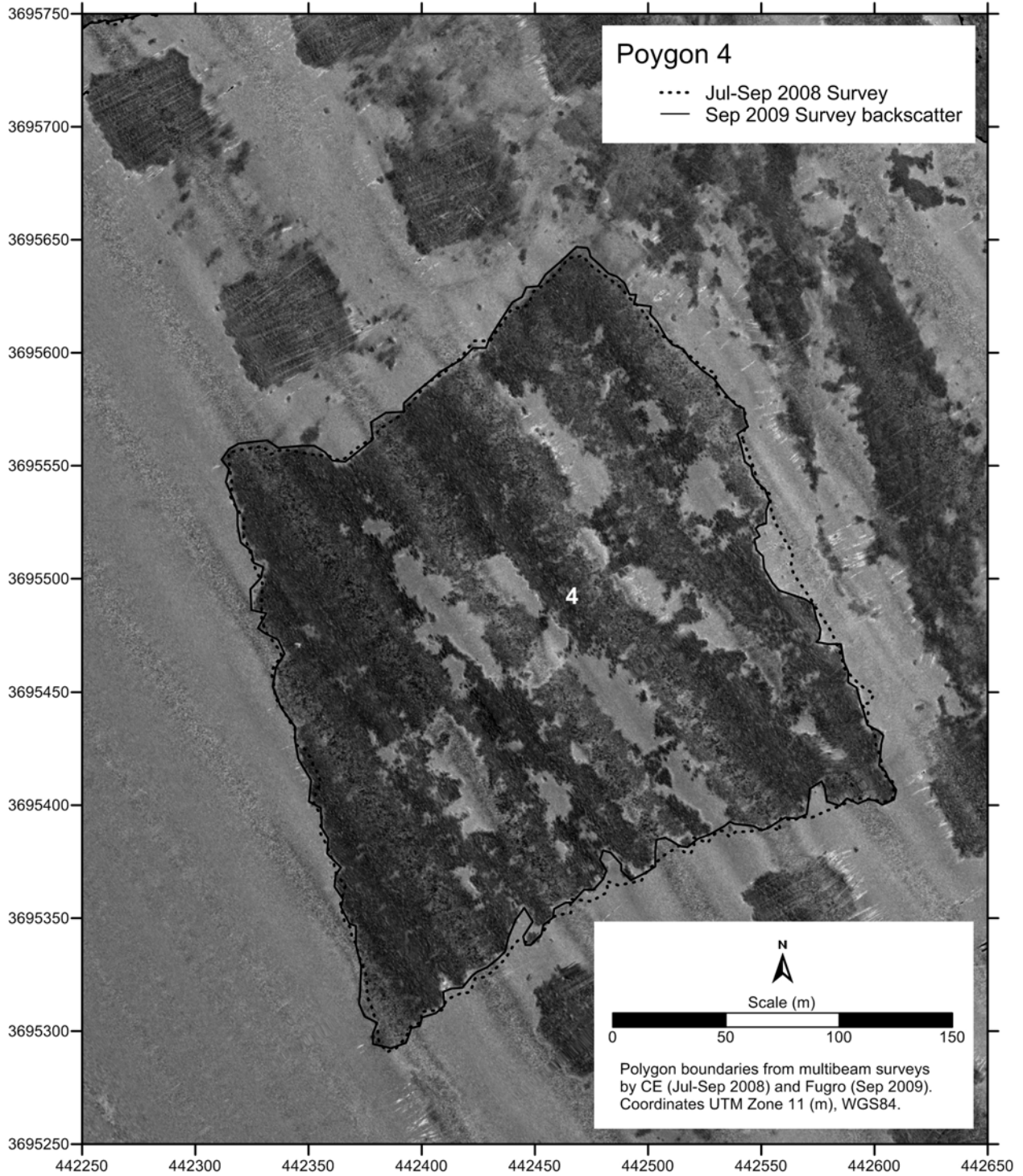
**APPENDIX A**

**COMPARISON OF POST-CONSTRUCTION (2008) AND SEPTEMBER 2009  
BOUNDARIES FROM BACKSCATTER MOSAICS FOR POLYGONS 1-17**

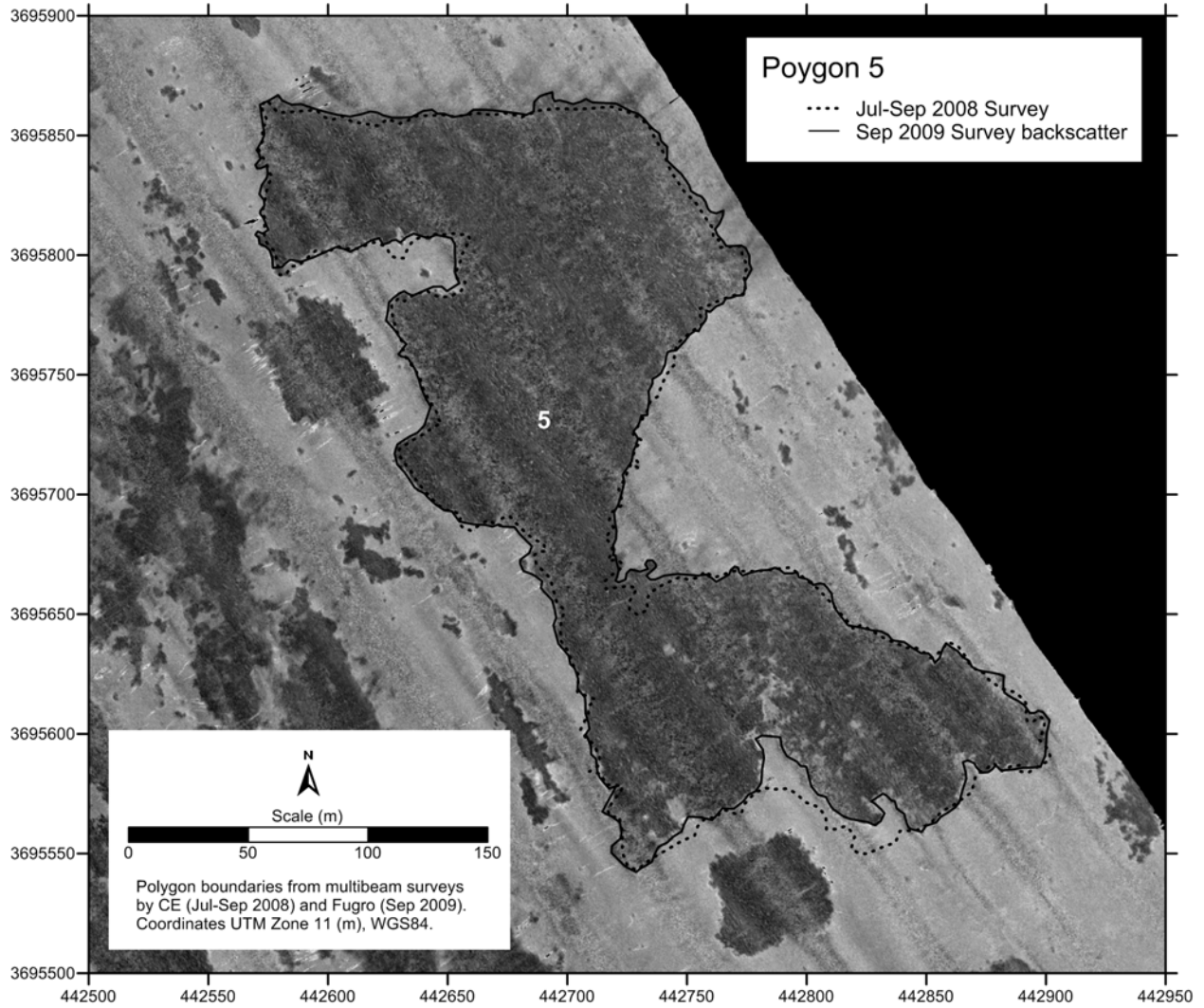




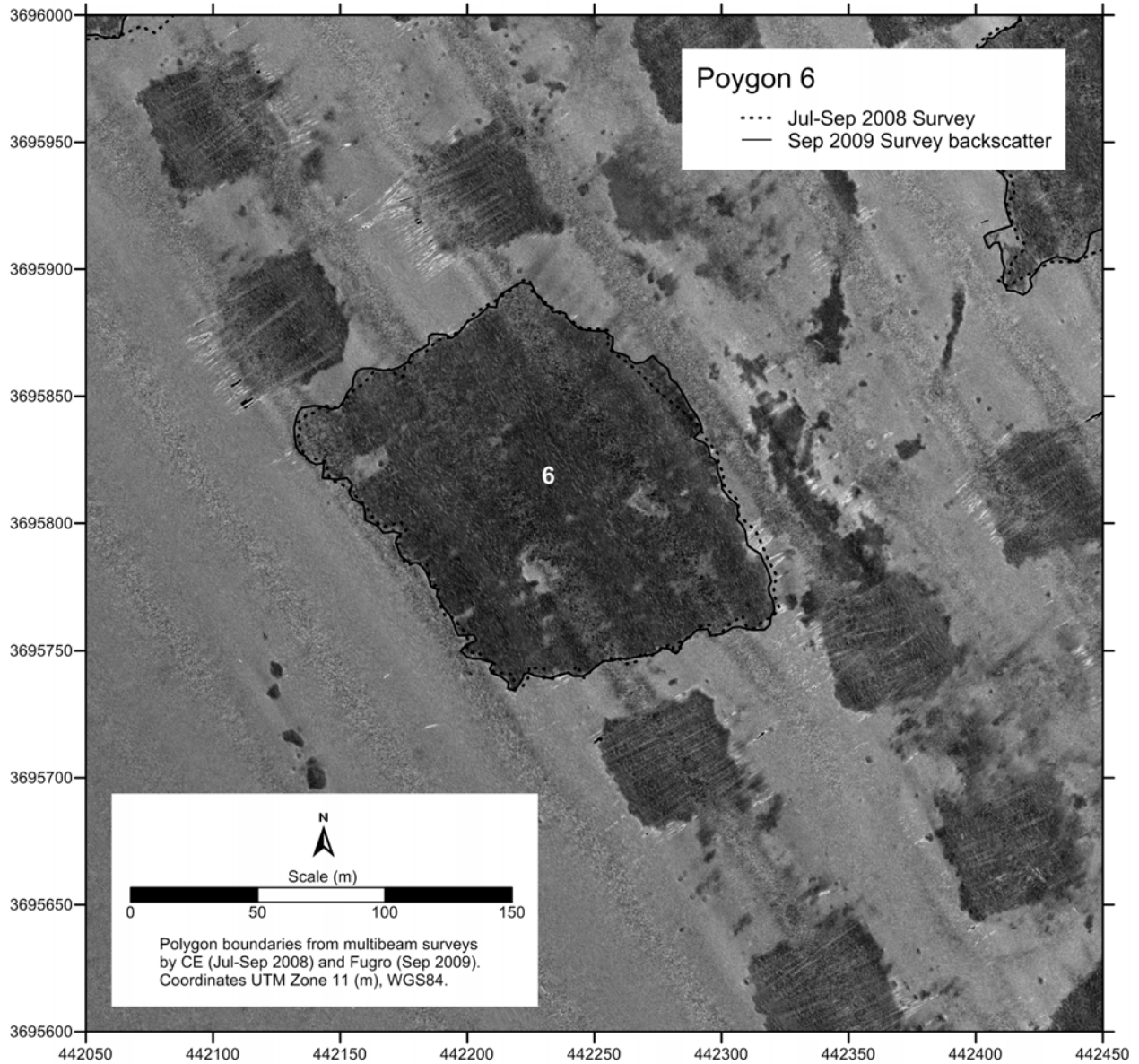
**Figure A-1. Comparison of post-construction (2008) and September 2009 boundaries from backscatter mosaics for Polygons 1, 2, 3, 12, and 13.**



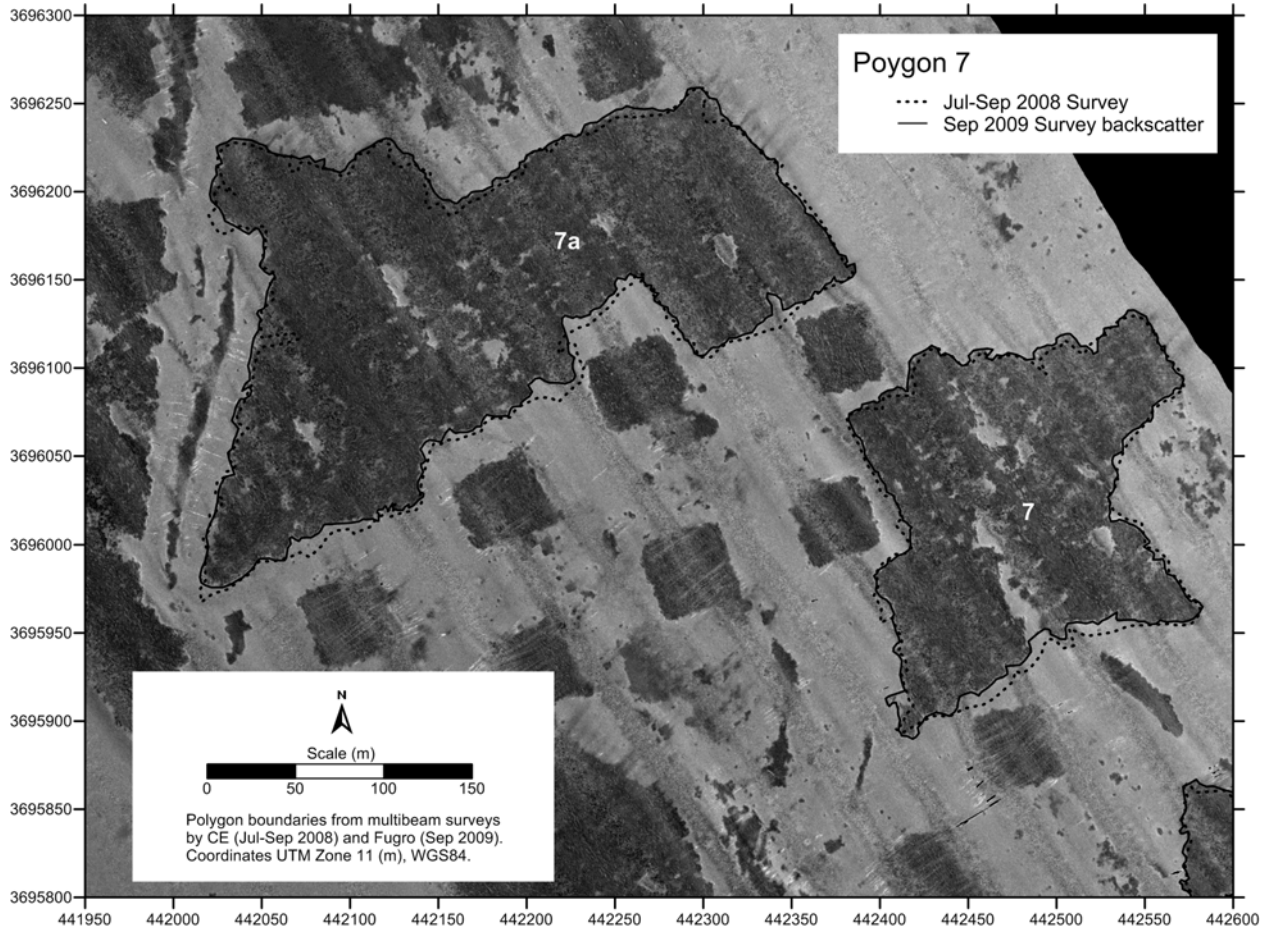
**Figure A-2. Comparison of post-construction (2008) and September 2009 boundaries from backscatter mosaics for Polygon 4.**



**Figure A-3. Comparison of post-construction (2008) and September 2009 boundaries from backscatter mosaics for Polygon 5.**

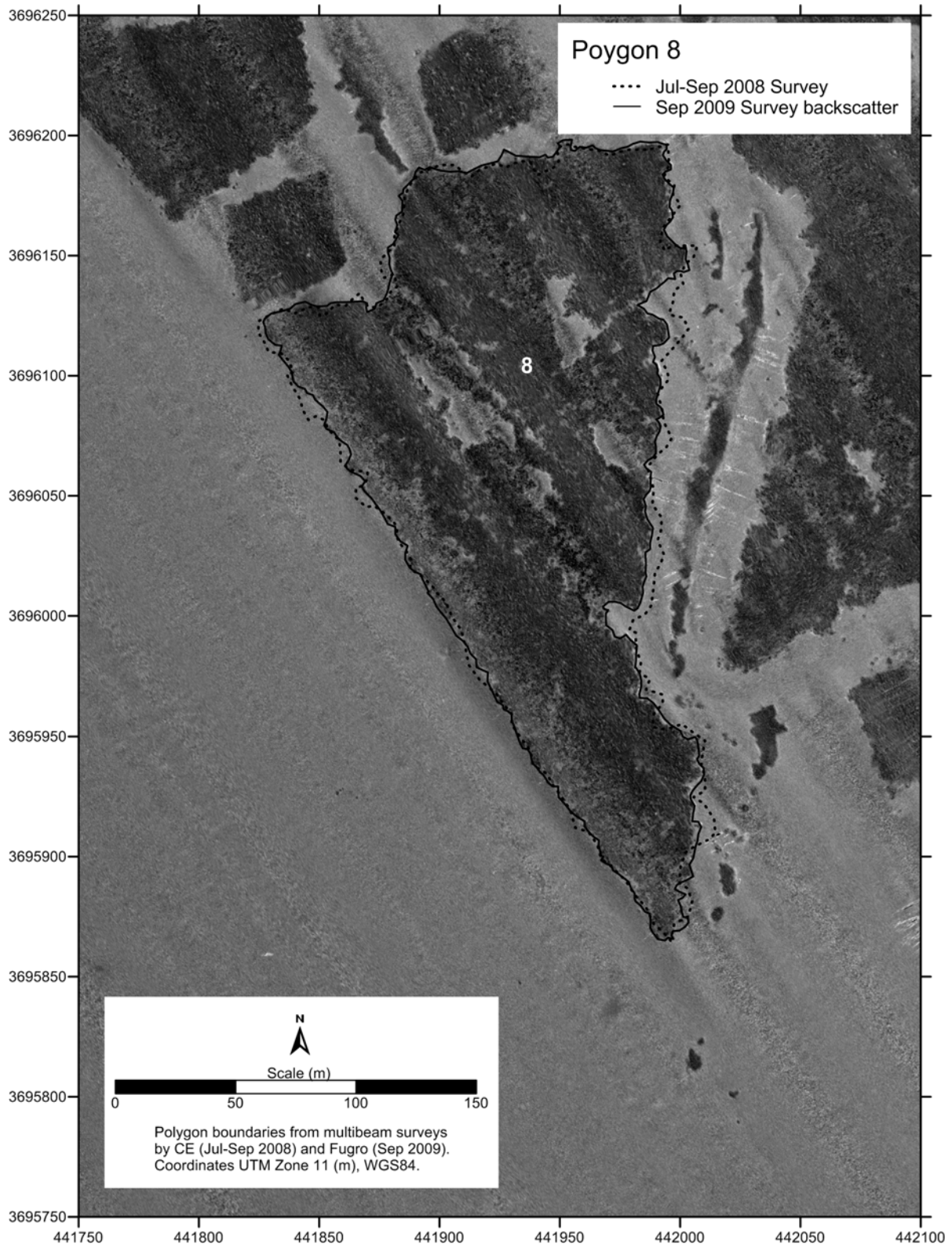


**Figure A-4. Comparison of post-construction (2008) and September 2009 boundaries from backscatter mosaics for Polygon 6.**

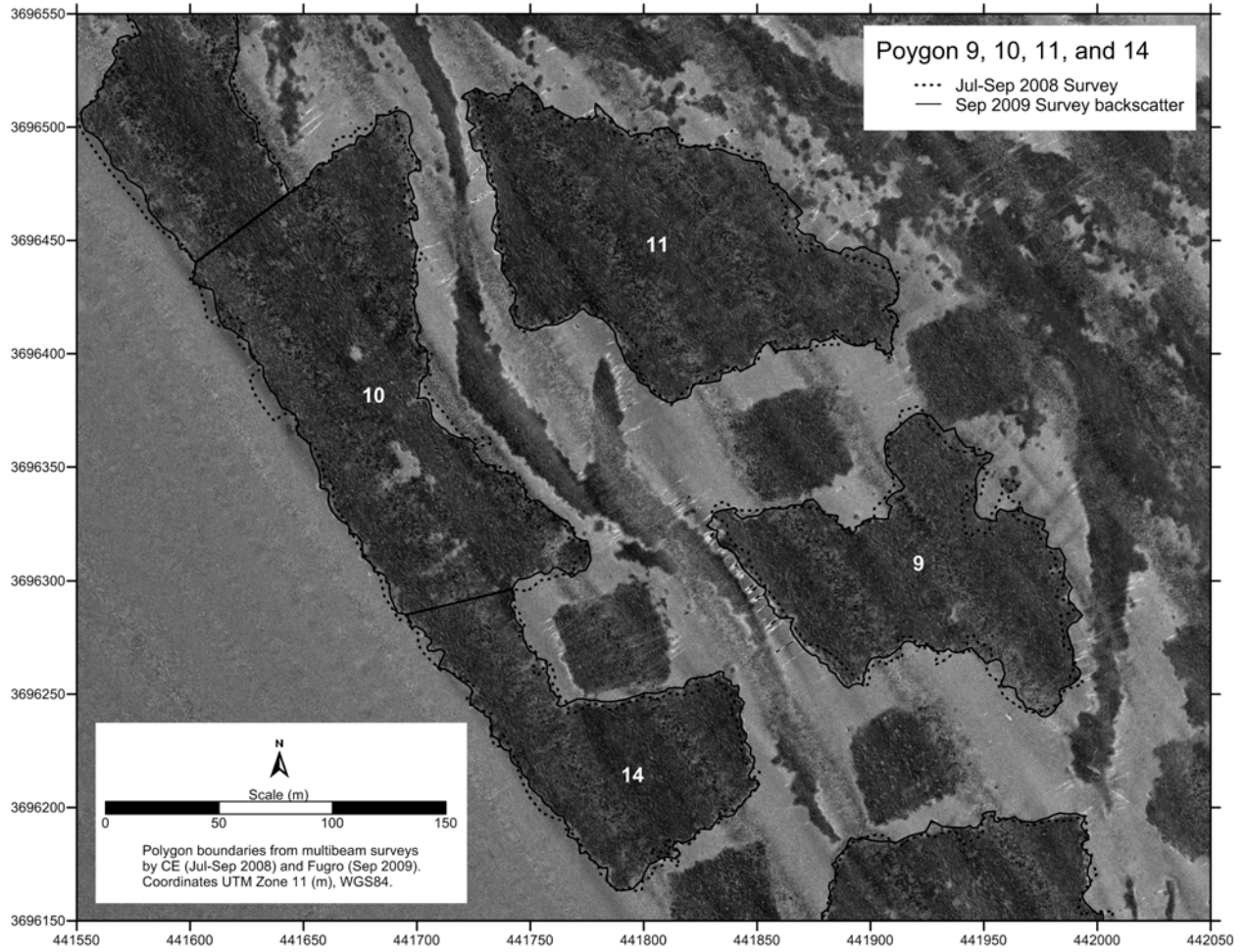


**Figure A-5. Comparison of post-construction (2008) and September 2009 boundaries from backscatter mosaics for Polygon 7.**

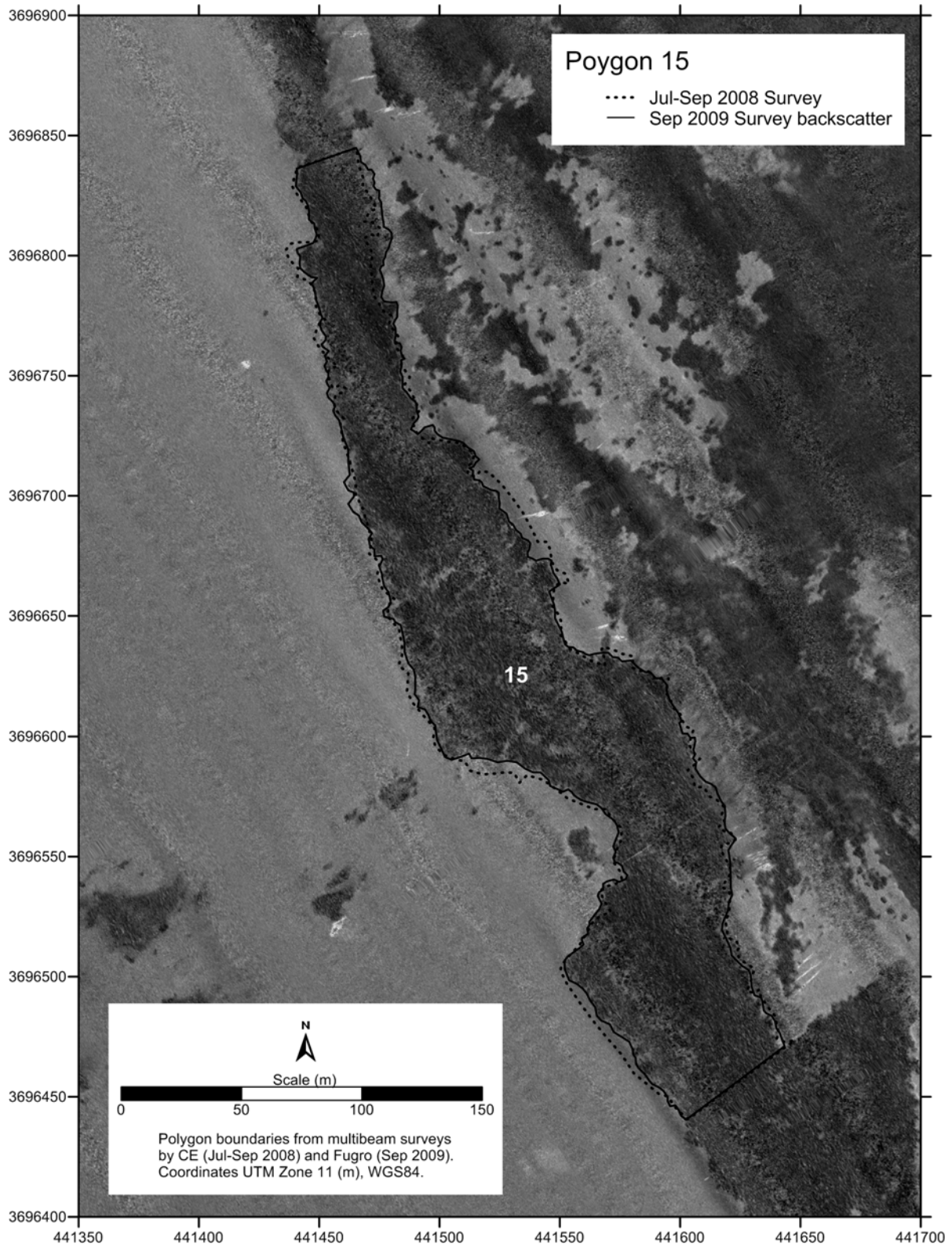




**Figure A-6. Comparison of post-construction (2008) and September 2009 boundaries from backscatter mosaics for Polygon 8.**

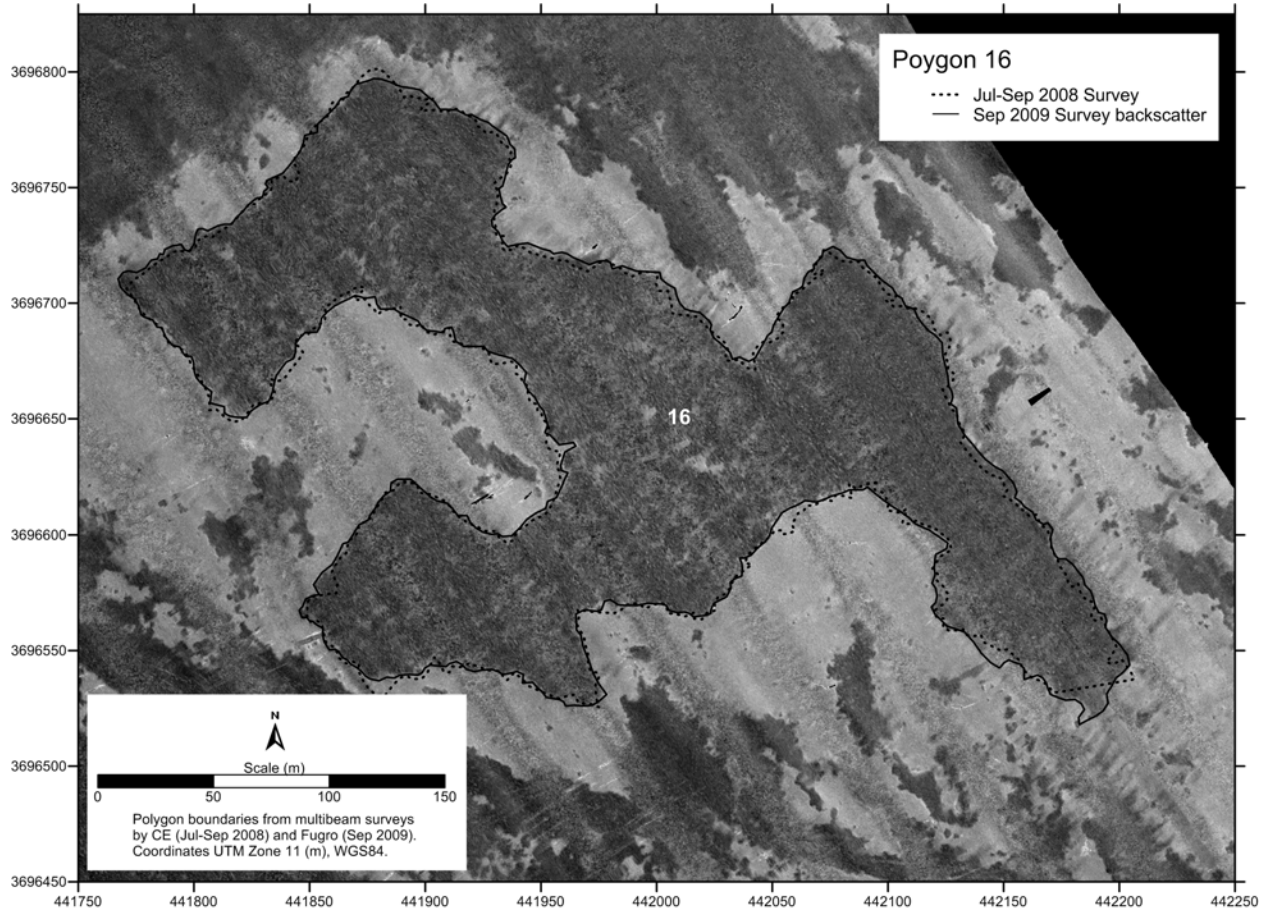


**Figure A-7. Comparison of post-construction (2008) and September 2009 boundaries from backscatter mosaics for Polygons 9, 10, 11, and 14.**

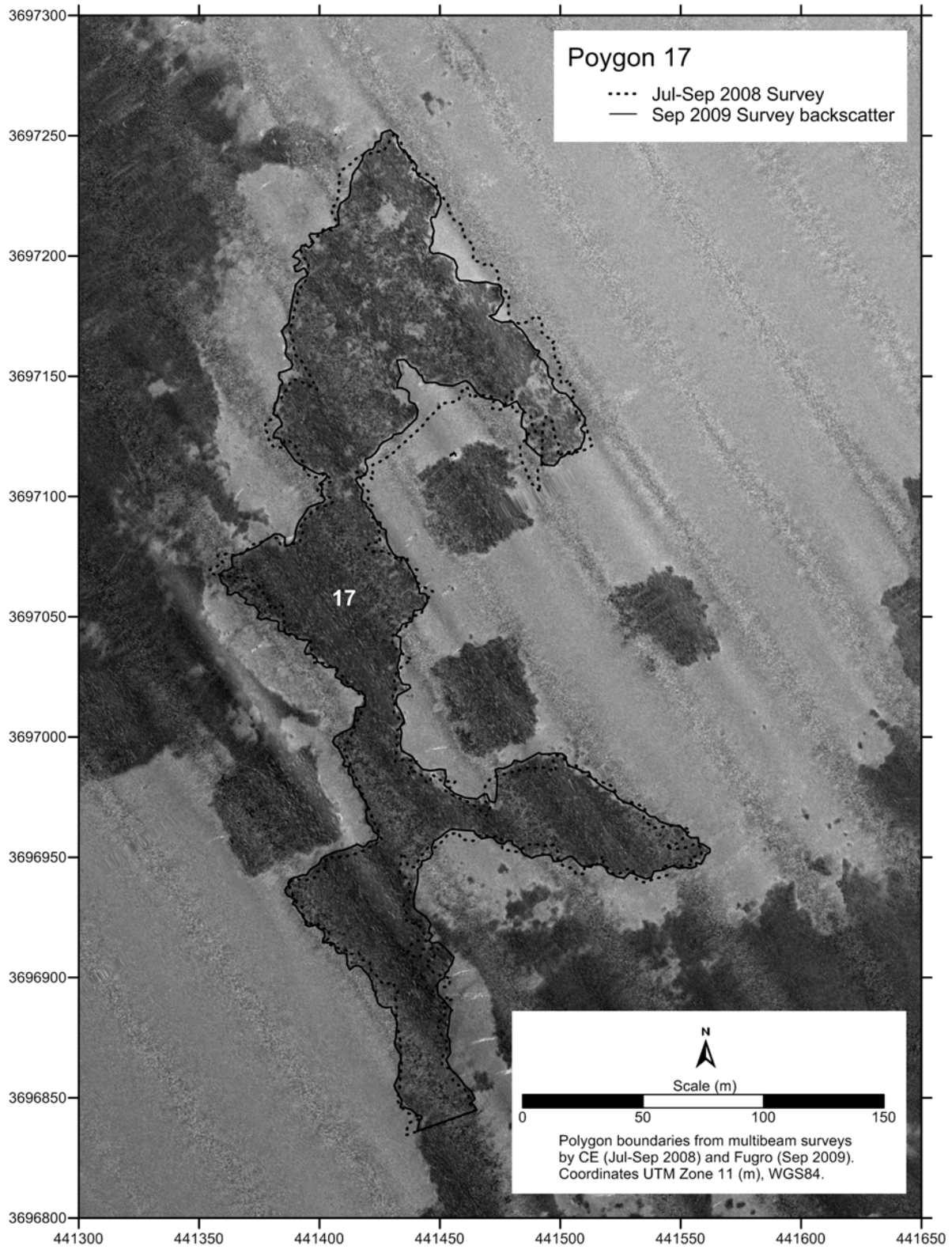


**Figure A-8. Comparison of post-construction (2008) and September 2009 boundaries from backscatter mosaics for Polygon 15.**





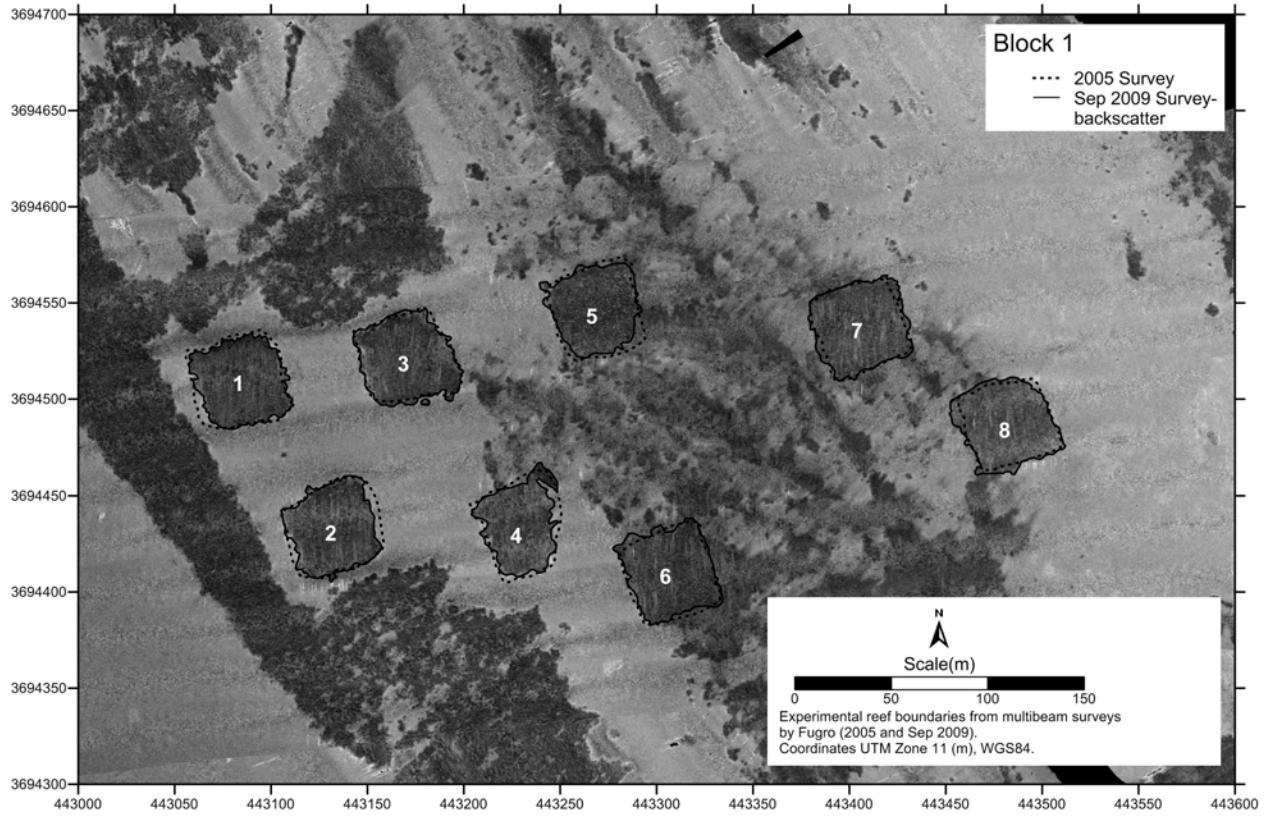
**Figure A-9. Comparison of post-construction (2008) and September 2009 boundaries from backscatter mosaics for Polygon 16.**



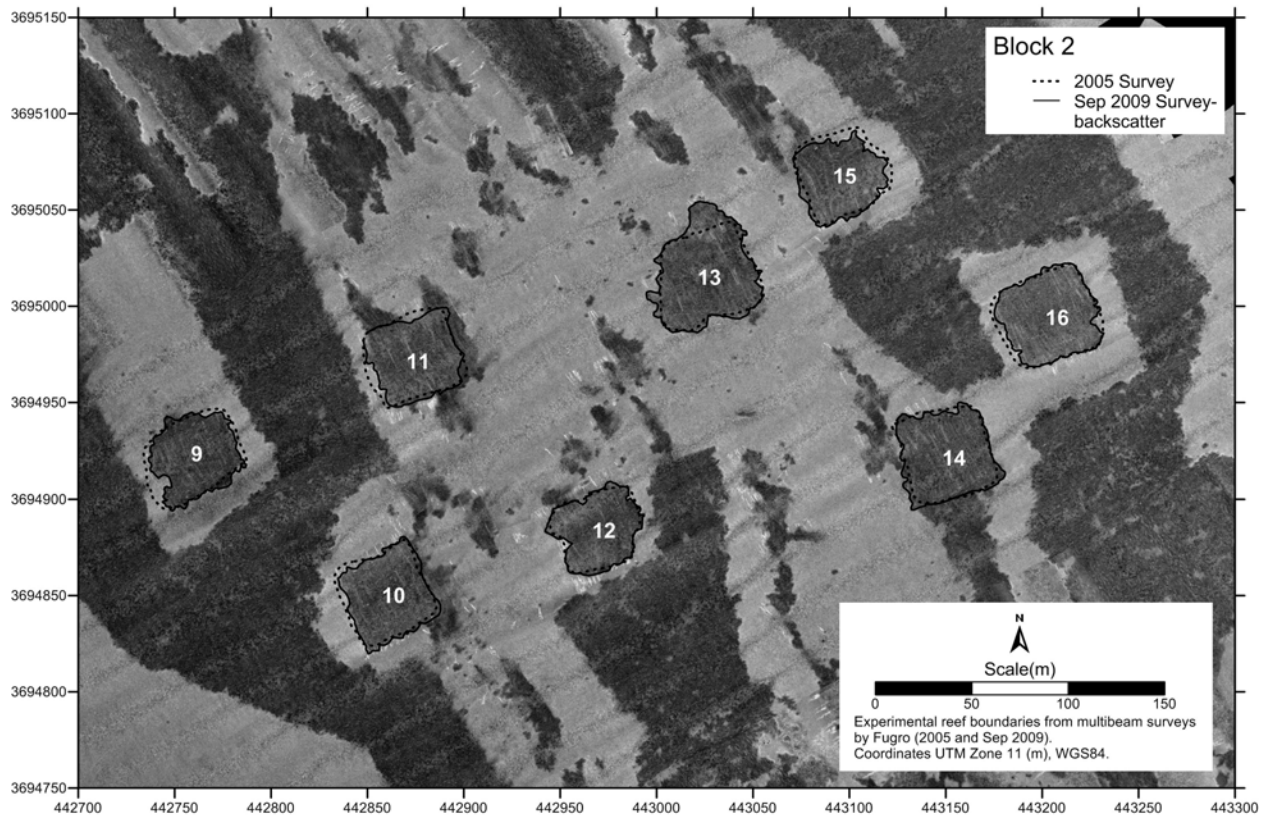
**Figure A-10. Comparison of post-construction (2008) and September 2009 boundaries from backscatter mosaics for Polygon 17.**

**APPENDIX B**

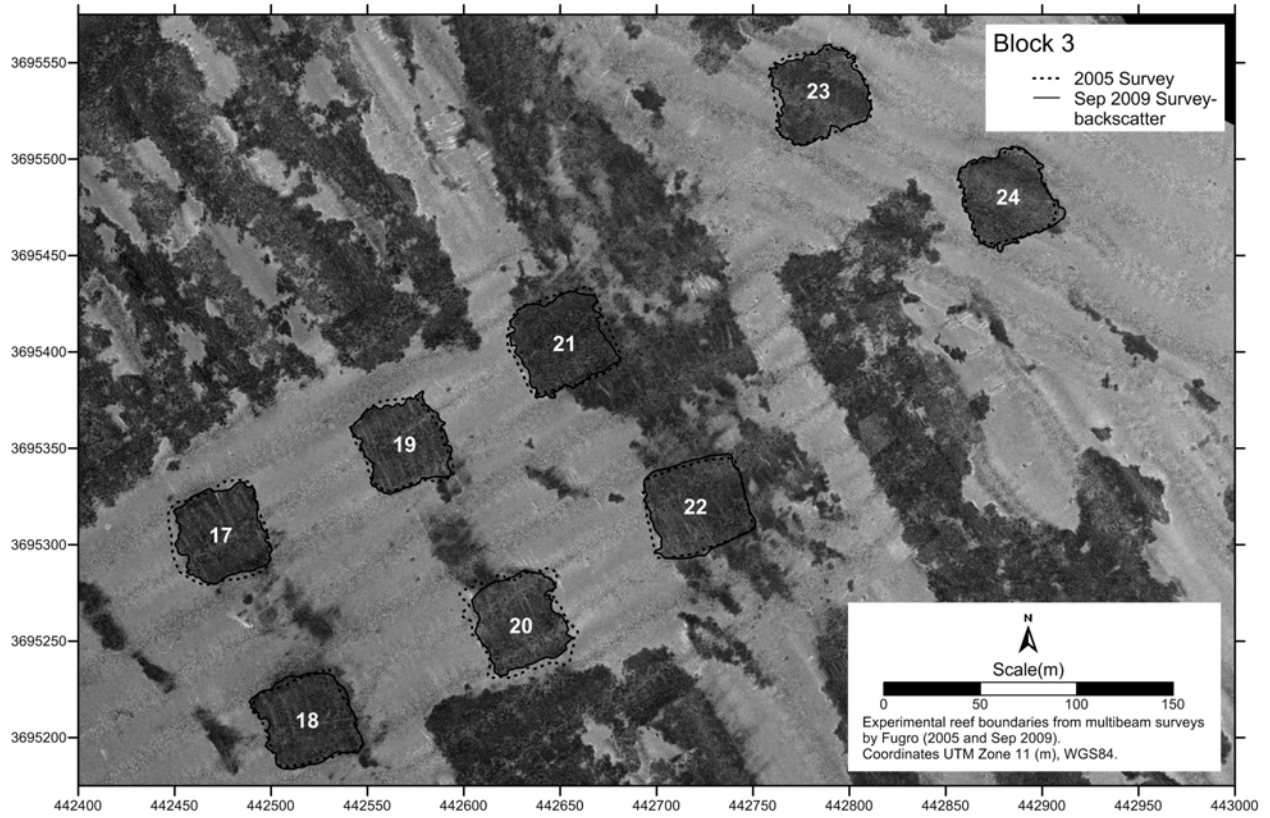
**COMPARISON OF MODULE BOUNDARIES FROM 2005 (BATHYMETRY) AND  
SEPTEMBER 2009 (BACKSCATTER) FOR BLOCKS 1-7**



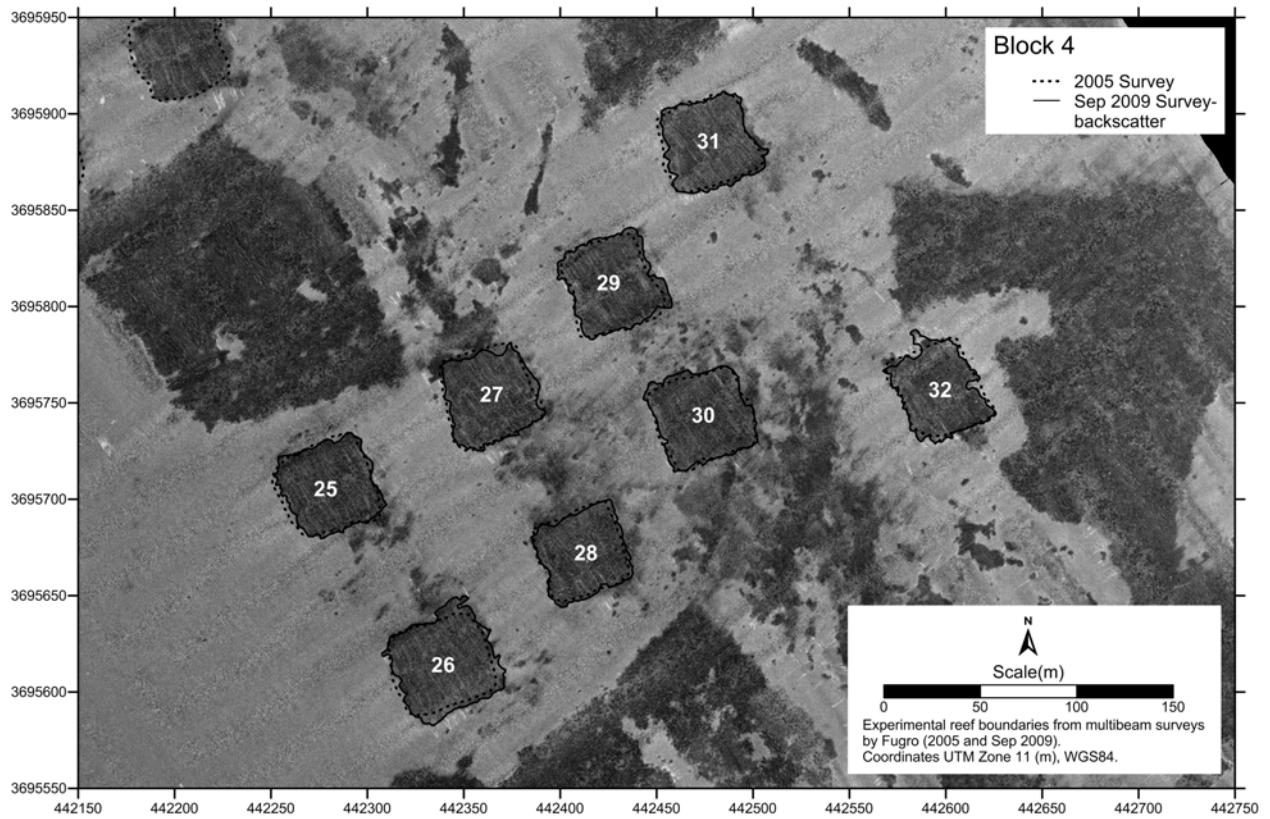
**Figure B-1. Comparison of module boundaries from 2005 (bathymetry) and September 2009 (backscatter) for Block 1.**



**Figure B-2. Comparison of module boundaries from 2005 (bathymetry) and September 2009 (backscatter) for Block 2.**

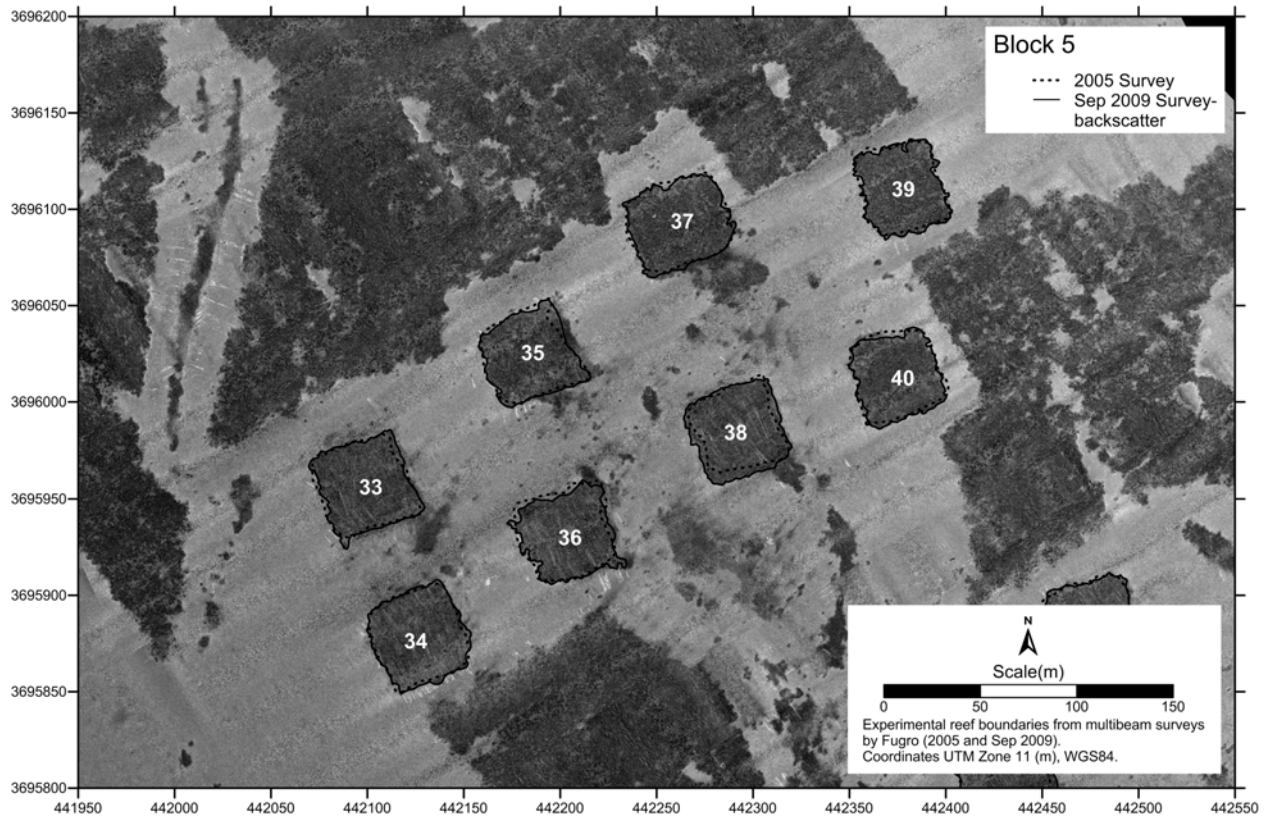


**Figure B-3.** Comparison of module boundaries from 2005 (bathymetry) and September 2009 (backscatter) for Block 3.



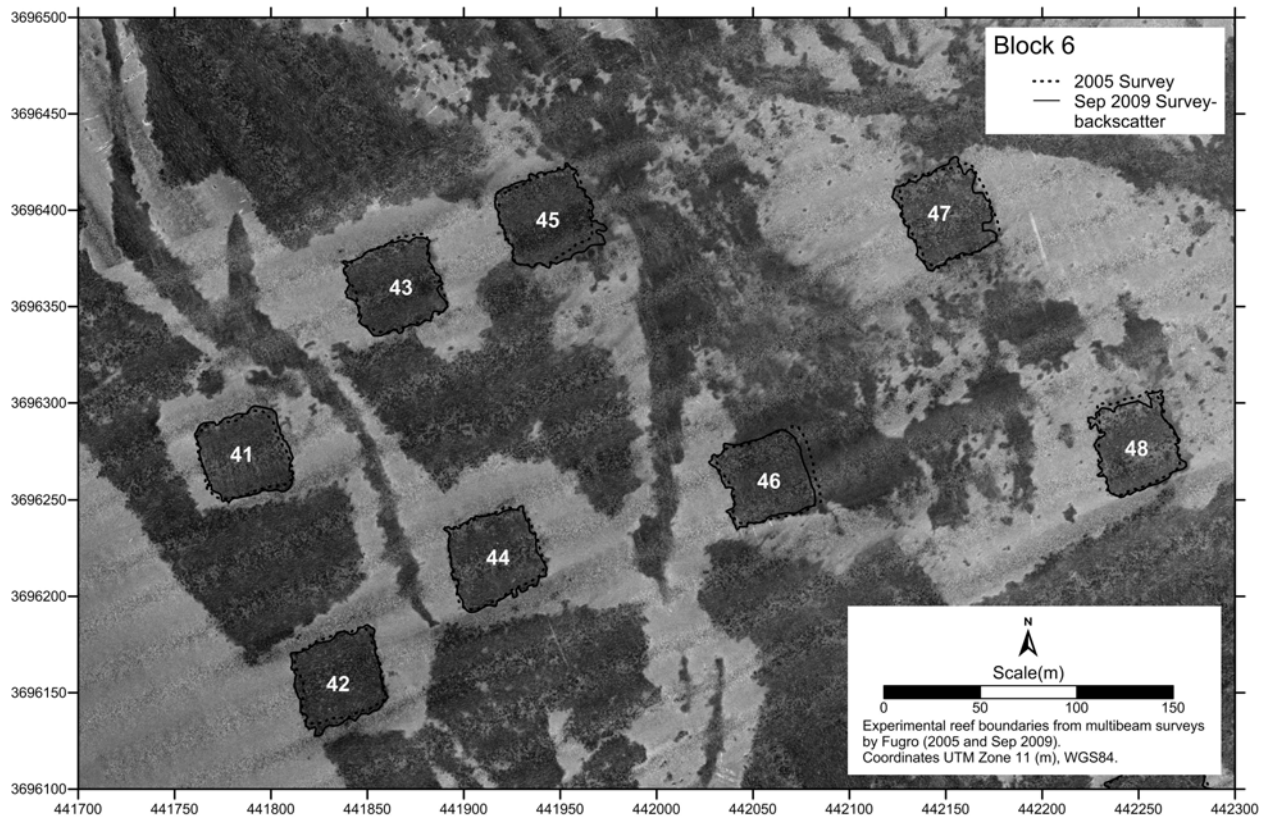
**Figure B-4.** Comparison of module boundaries from 2005 (bathymetry) and September 2009 (backscatter) for Block 4.



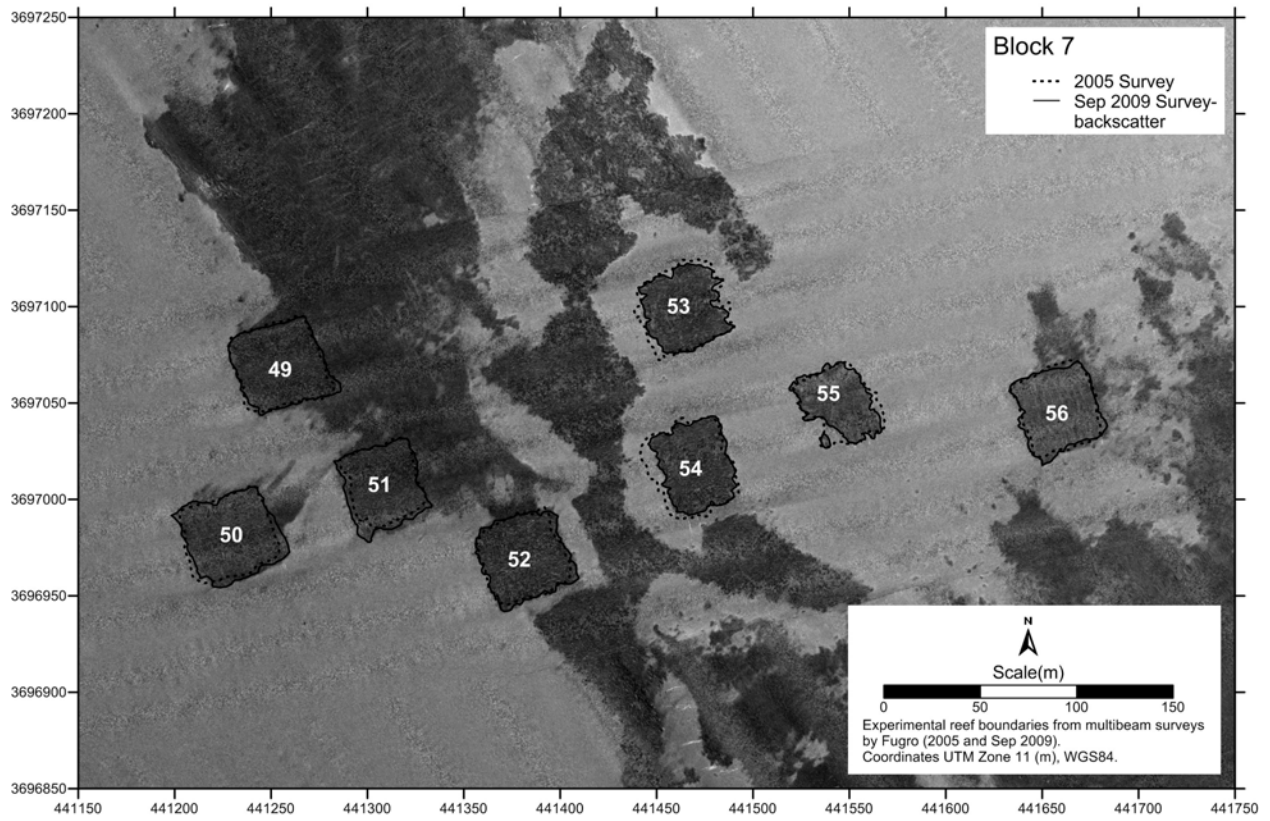


**Figure B-5. Comparison of module boundaries from 2005 (bathymetry) and September 2009 (backscatter) for Block 5.**





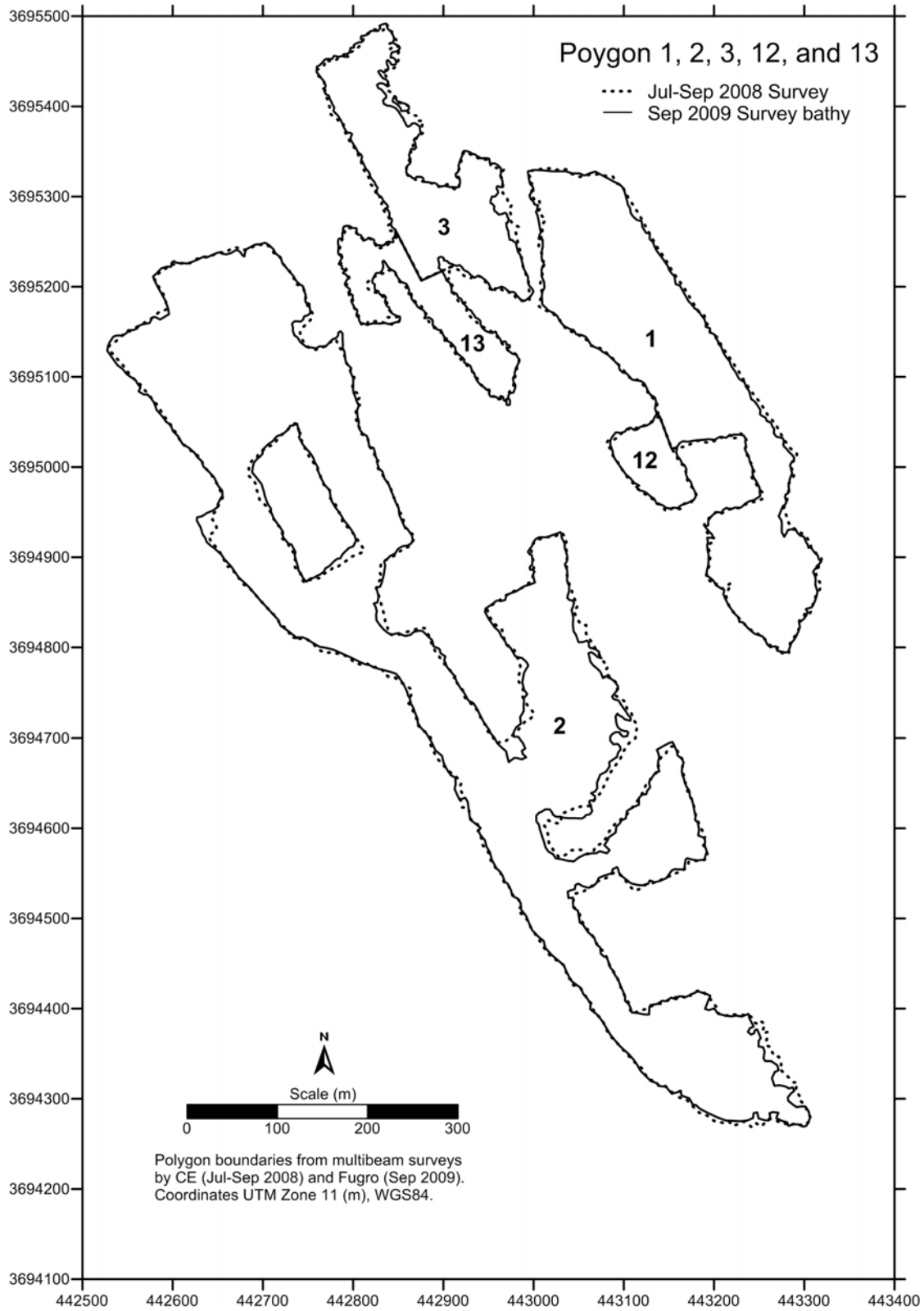
**Figure B-6. Comparison of module boundaries from 2005 (bathymetry) and September 2009 (backscatter) for Block 6.**



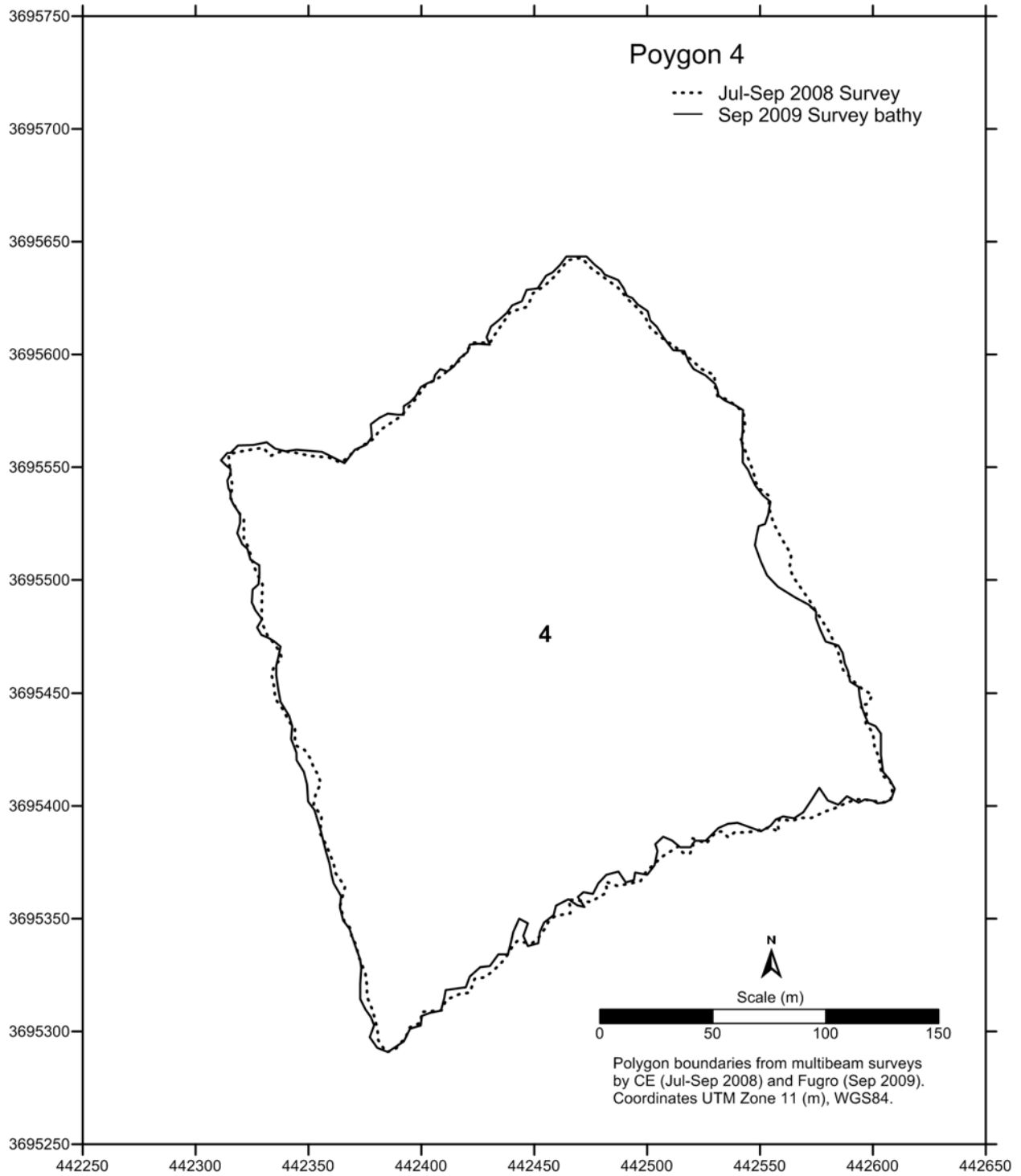
**Figure B-7.** Comparison of module boundaries from 2005 (bathymetry) and September 2009 (backscatter) for Block 7.

**APPENDIX C**

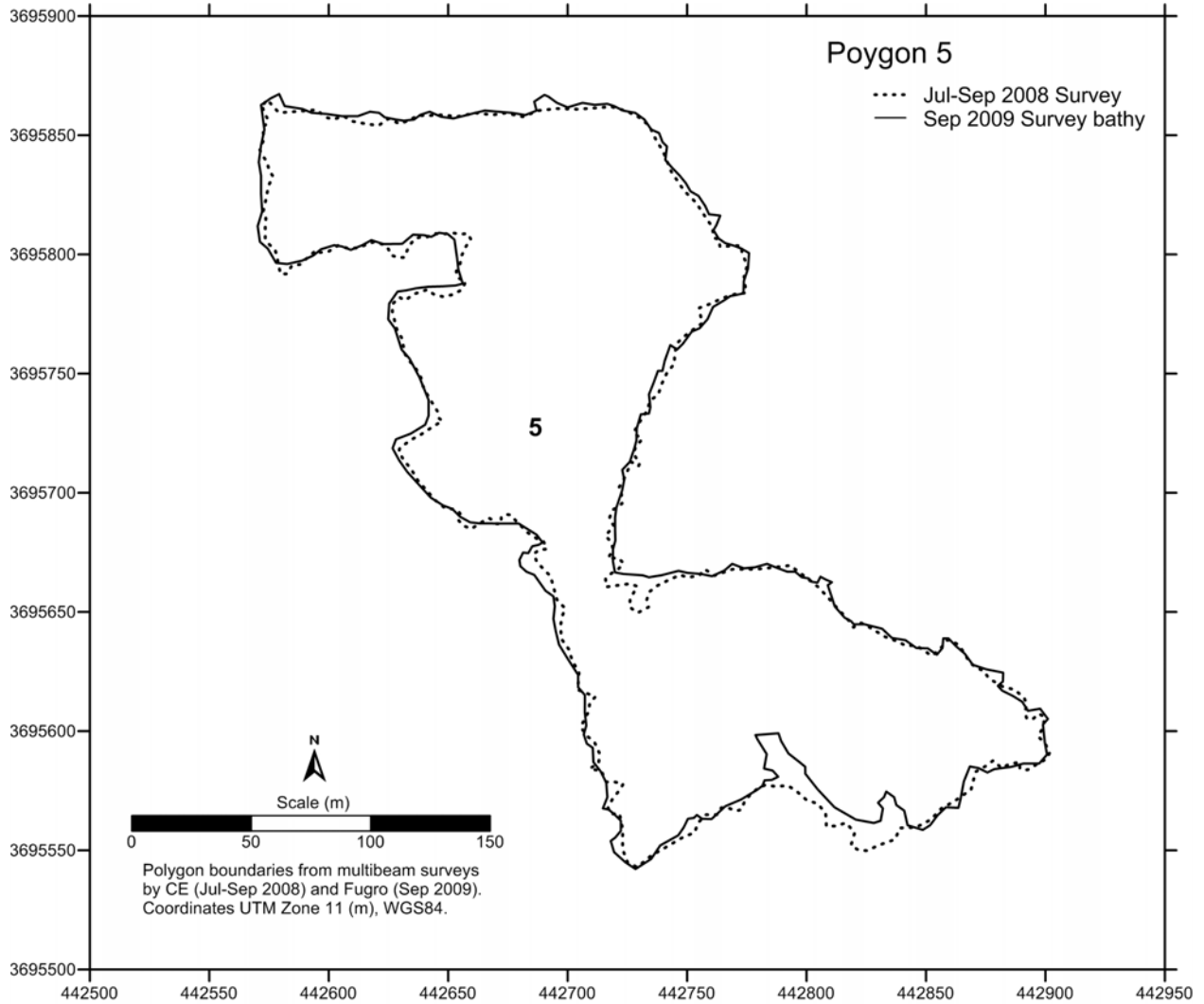
**COMPARISON OF POST-CONSTRUCTION (2008) AND SEPTEMBER 2009  
BOUNDARIES FROM BATHYMETRY DATA FOR POLYGONS 1-17**



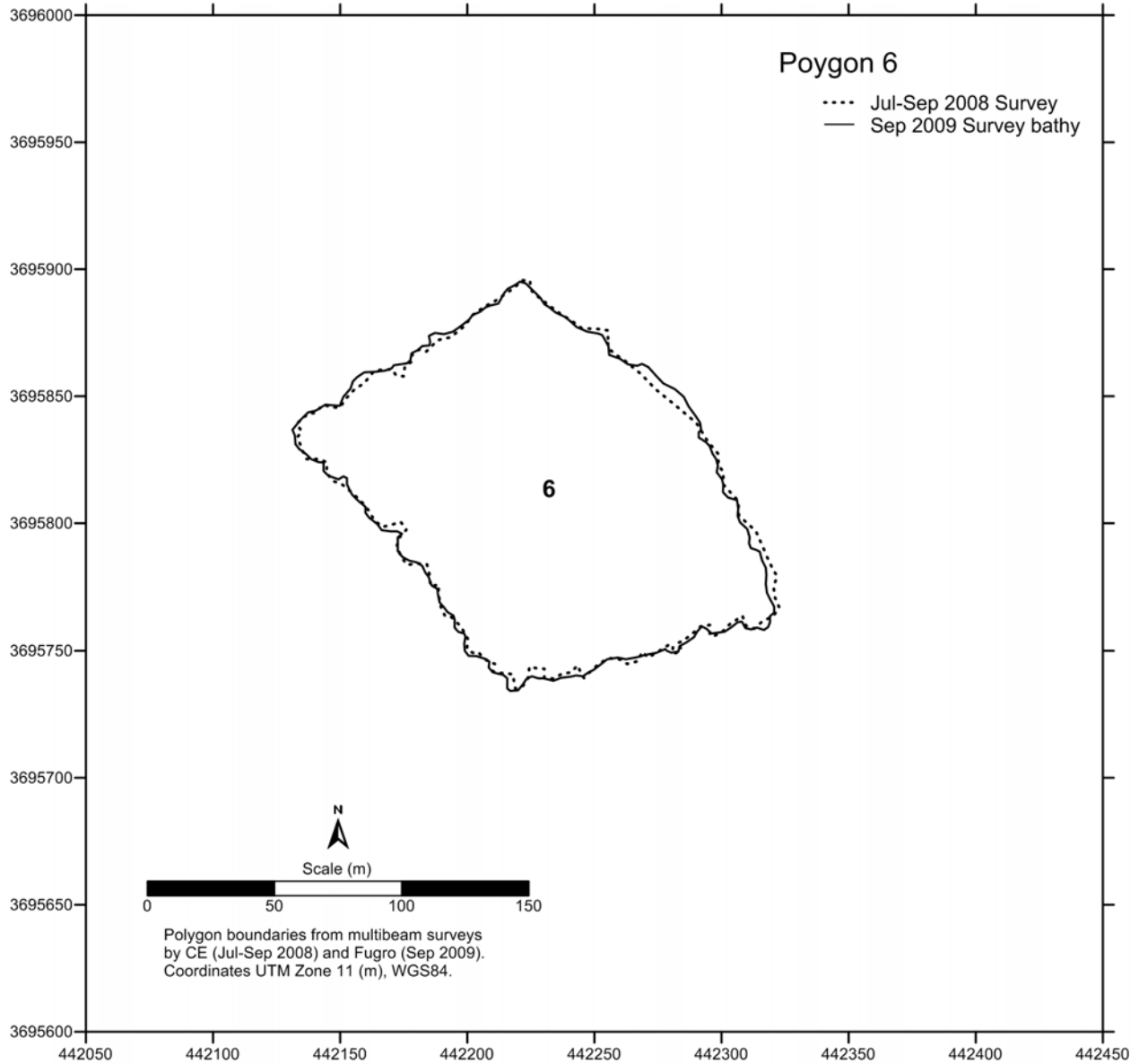
**Figure C-1. Comparison of post-construction (2008) and September 2009 boundaries from bathymetry data for Polygons 1, 2, 3, 12, and 13.**



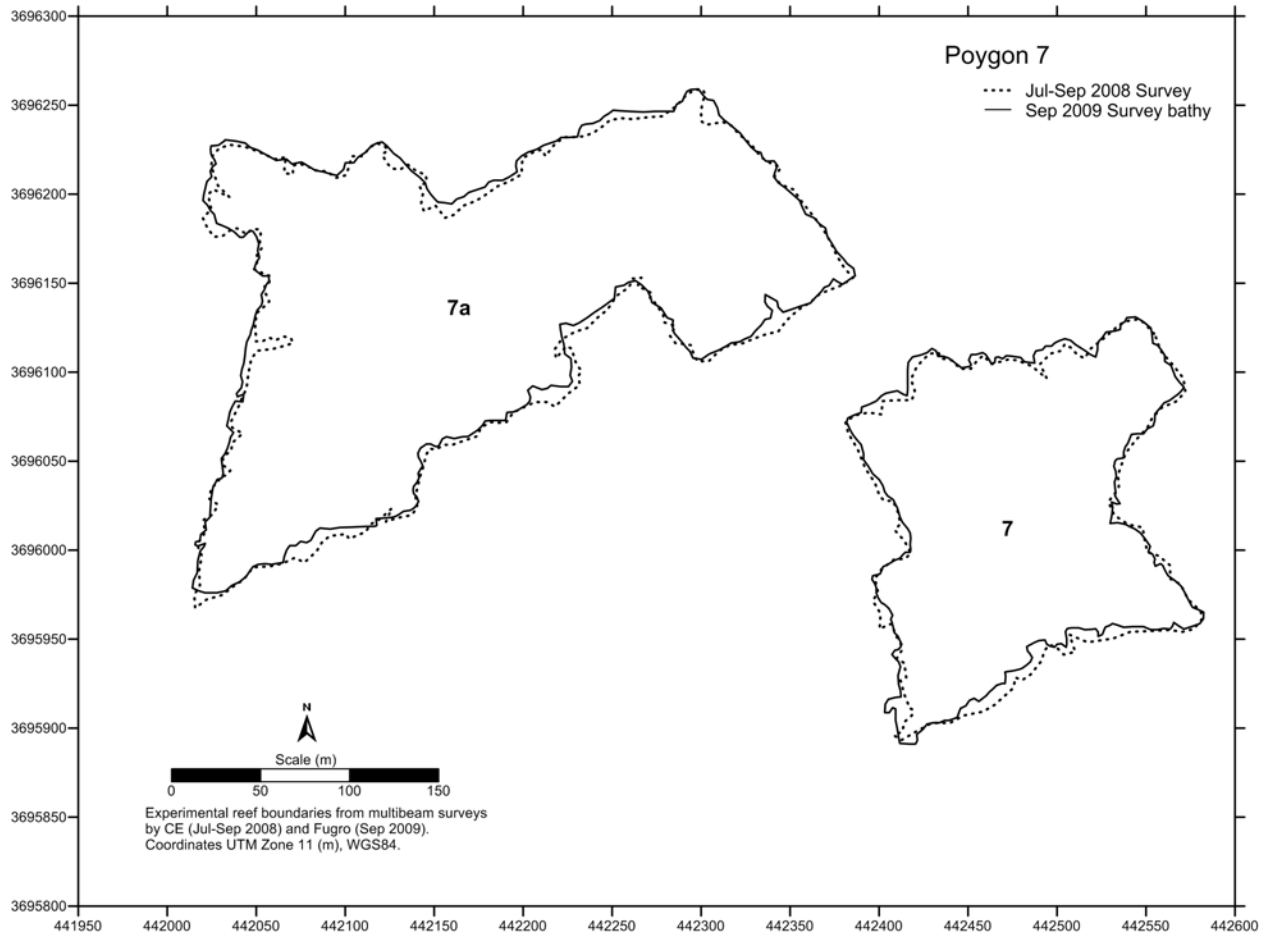
**Figure C-2. Comparison of post-construction (2008) and September 2009 boundaries from bathymetry data for Polygon 4.**



**Figure C-3. Comparison of post-construction (2008) and September 2009 boundaries from bathymetry data for Polygon 5.**

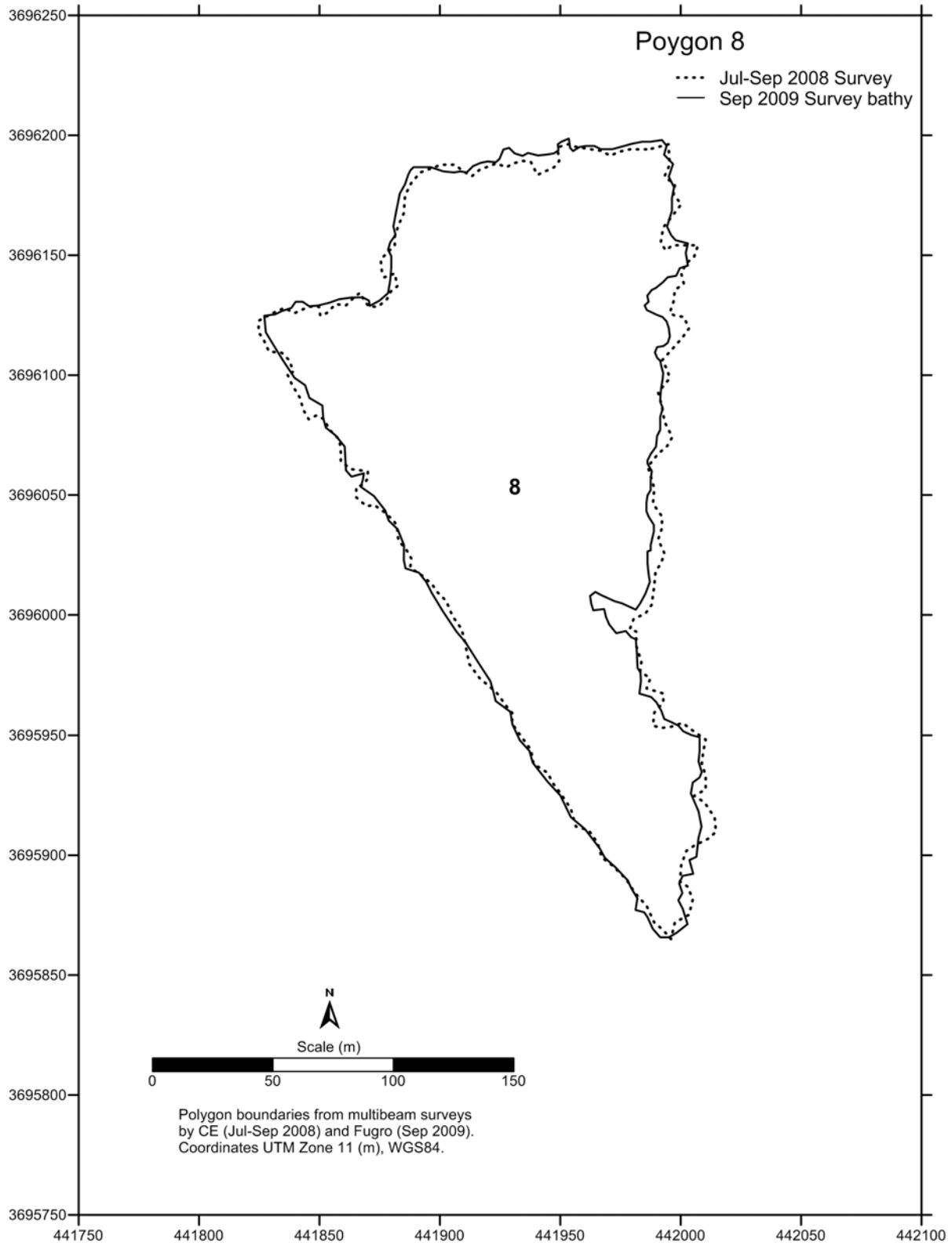


**Figure C-4. Comparison of post-construction (2008) and September 2009 boundaries from bathymetry data for Polygon 6.**

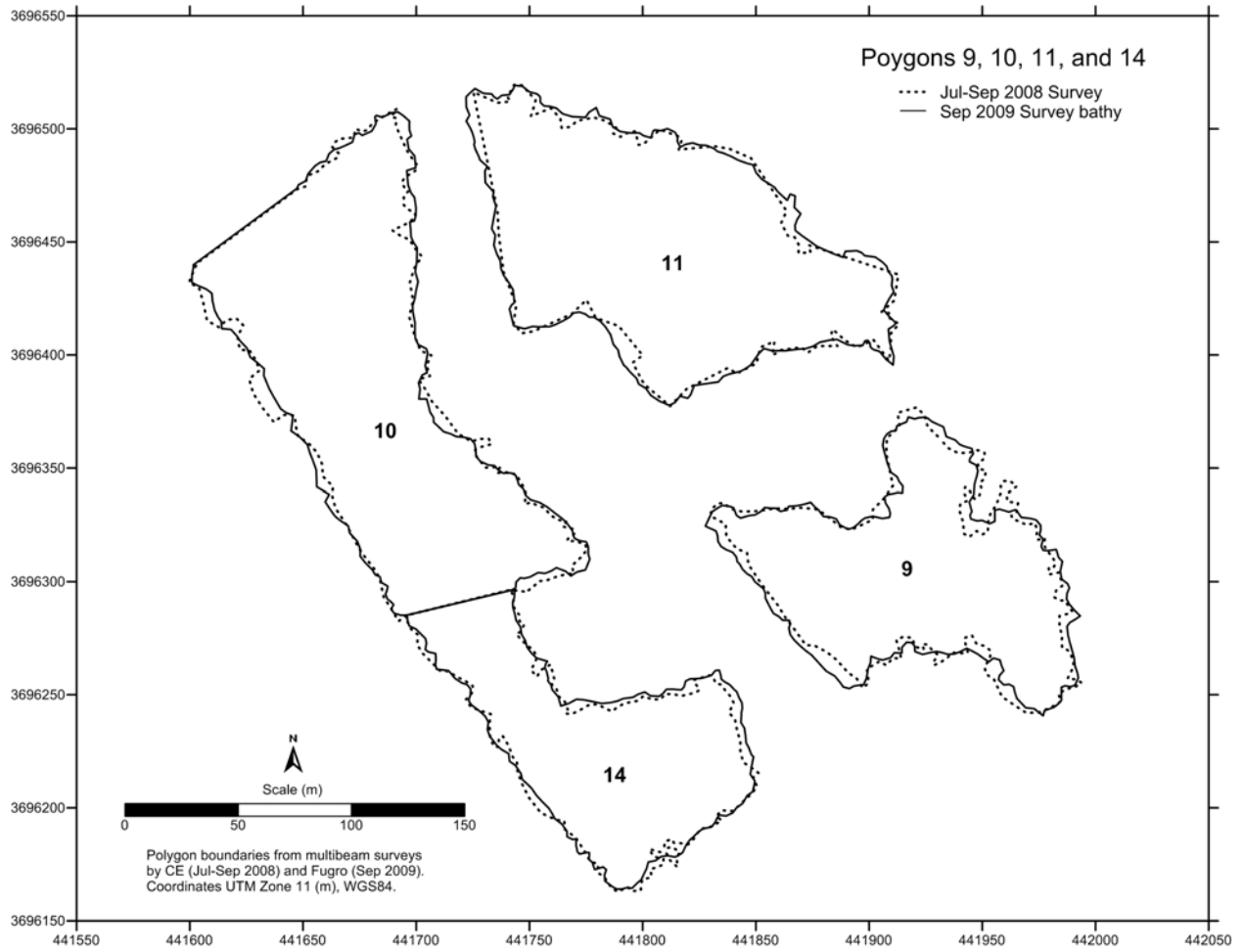


**Figure C-5. Comparison of post-construction (2008) and September 2009 boundaries from bathymetry data for Polygon 7.**

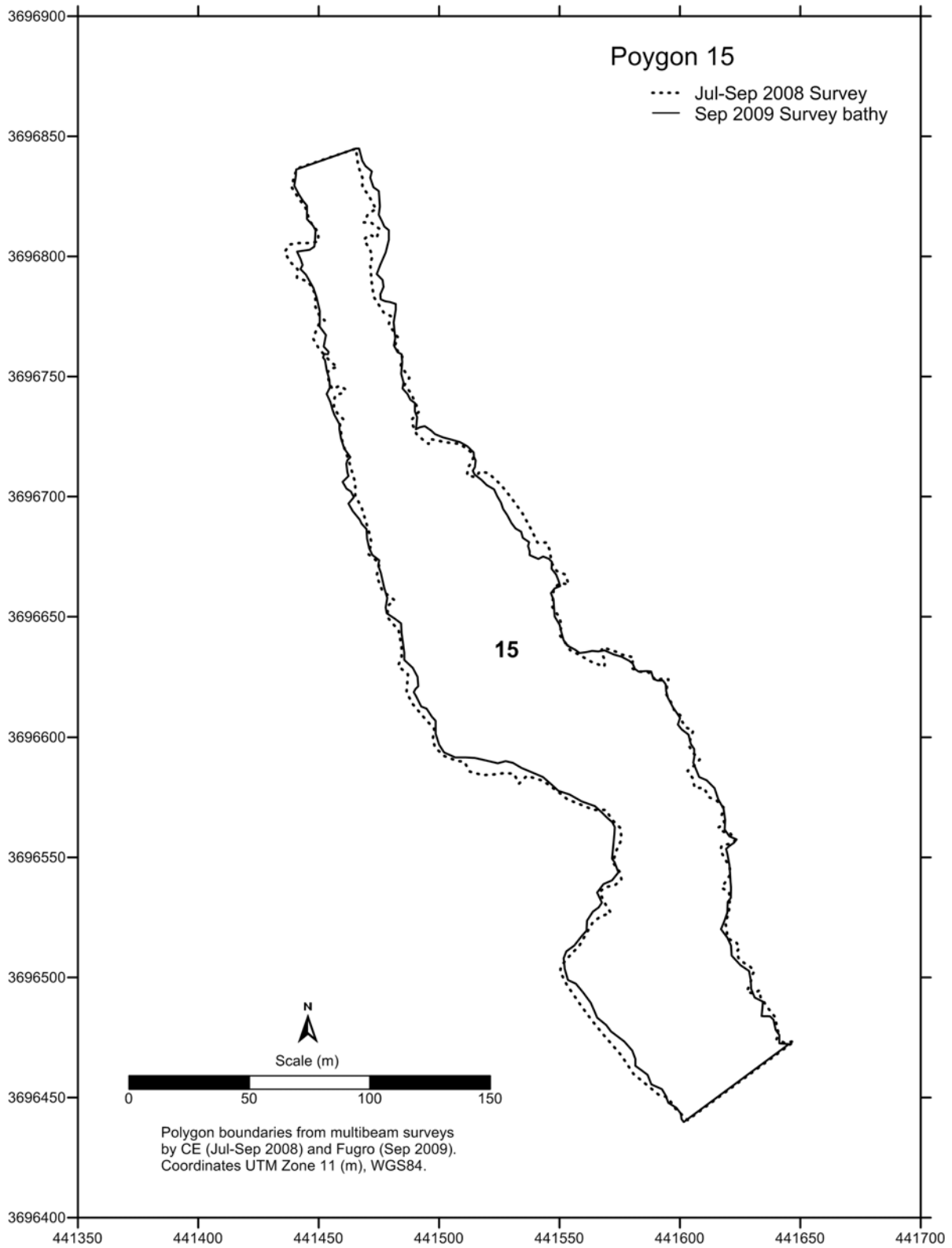




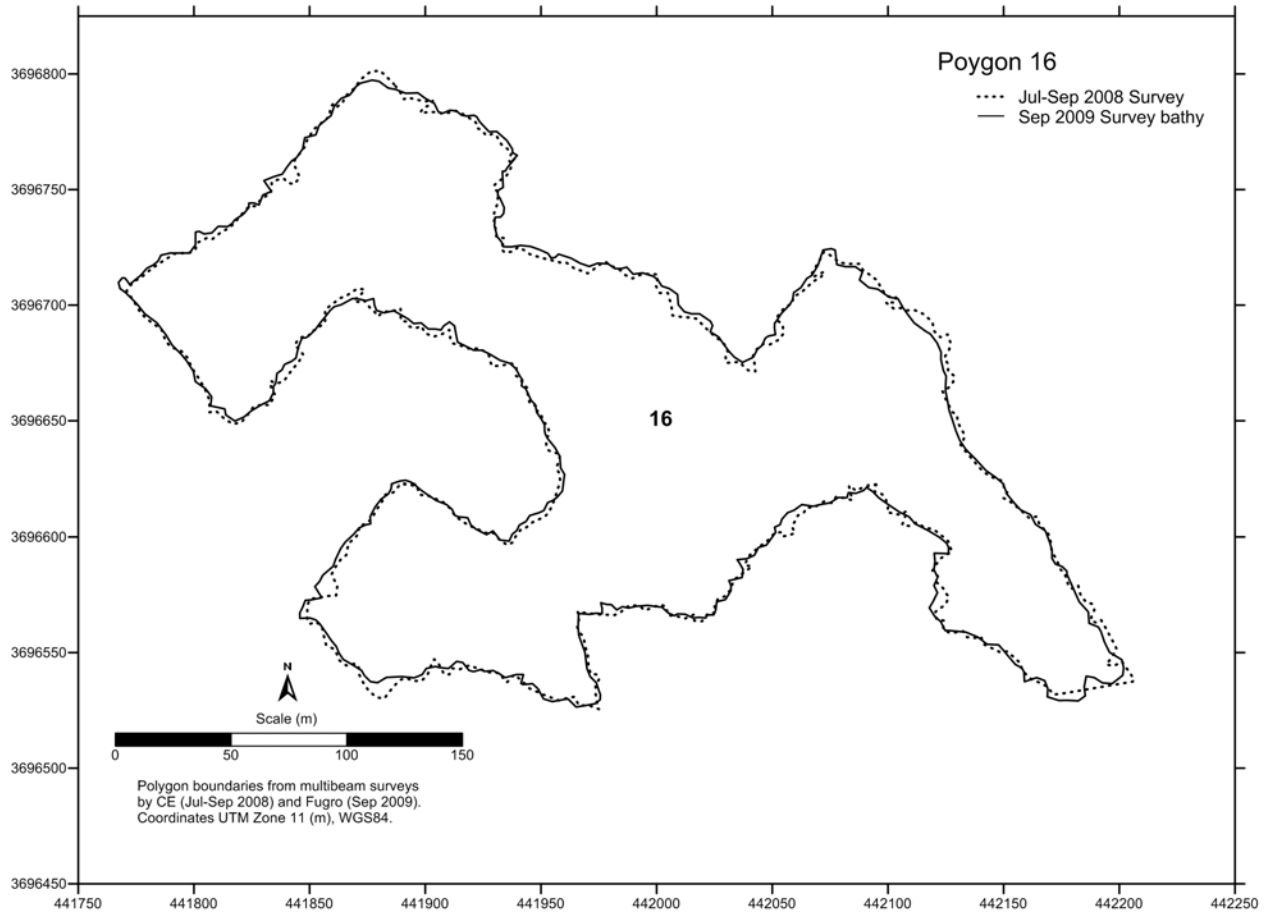
**Figure C-6. Comparison of post-construction (2008) and September 2009 boundaries from bathymetry data for Polygon 8.**



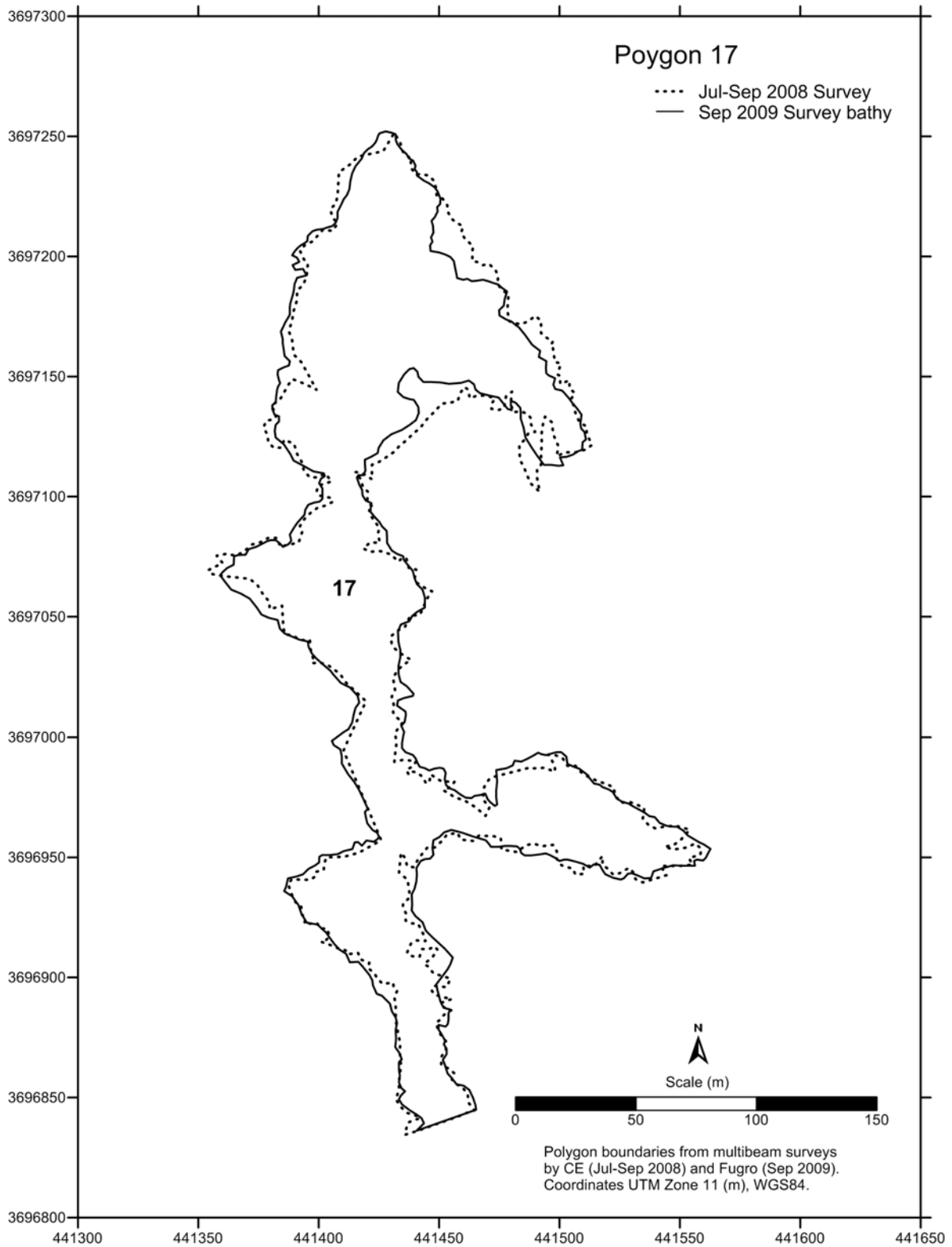
**Figure C-7. Comparison of post-construction (2008) and September 2009 boundaries from bathymetry data for Polygons 9, 10, 11, and 14.**



**Figure C-8. Comparison of post-construction (2008) and September 2009 boundaries from bathymetry data for Polygon 15.**



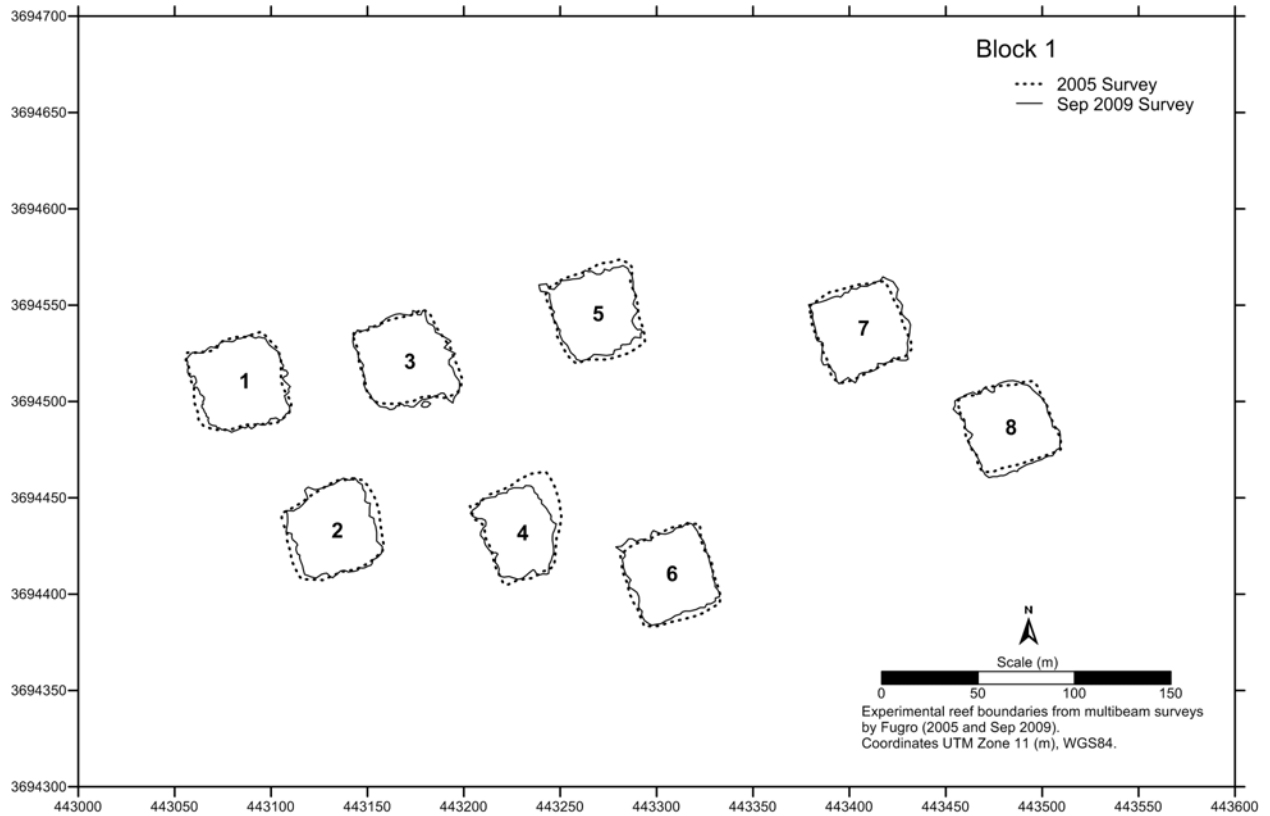
**Figure C-9. Comparison of post-construction (2008) and September 2009 boundaries from bathymetry data for Polygon 16.**



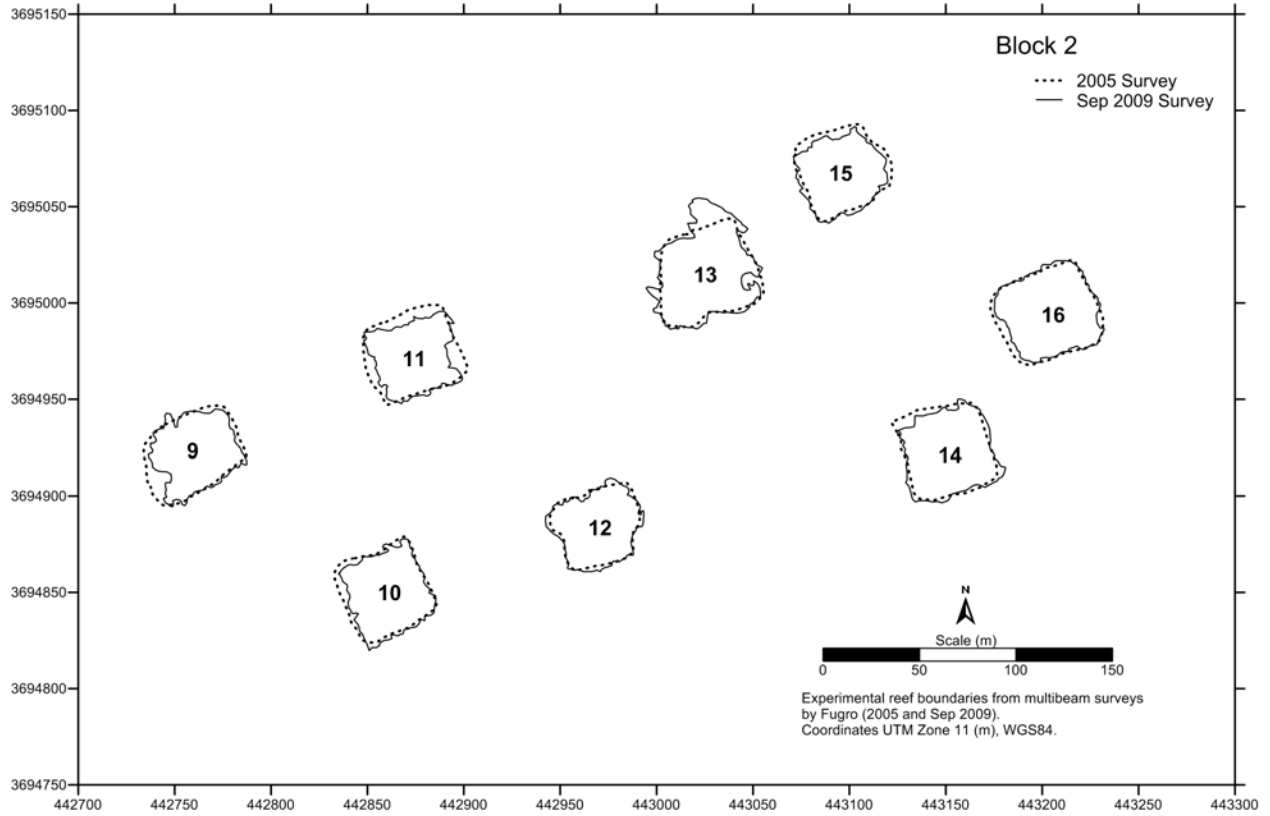
**Figure C-10. Comparison of post-construction (2008) and September 2009 boundaries from bathymetry data for Polygon 17.**

## **APPENDIX D**

### **COMPARISON OF MODULE BOUNDARIES FROM 2005 (BATHYMETRY) AND SEPTEMBER 2009 (BATHYMETRY) FOR BLOCKS 1-7**

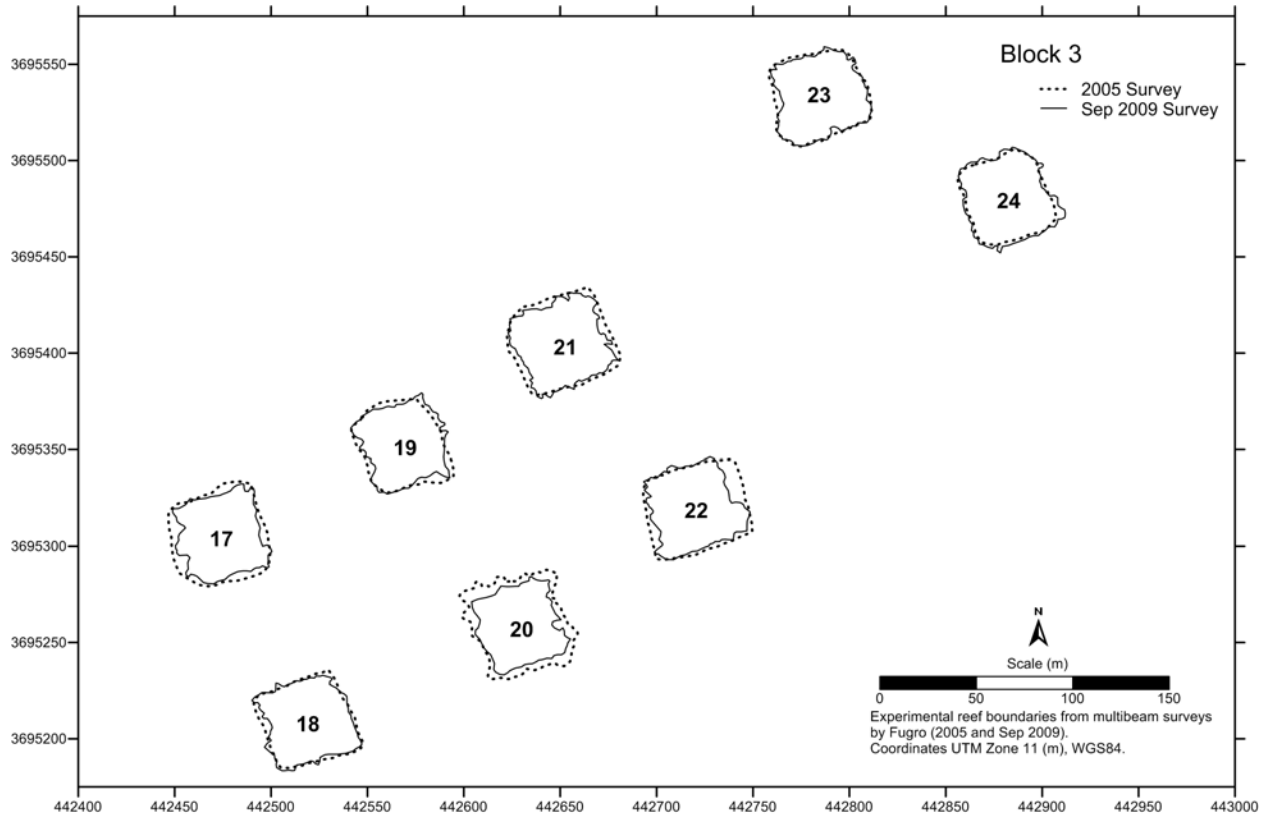


**Figure D-1. Comparison of module boundaries from 2005 (bathymetry) and September 2009 (bathymetry) for Block 1.**

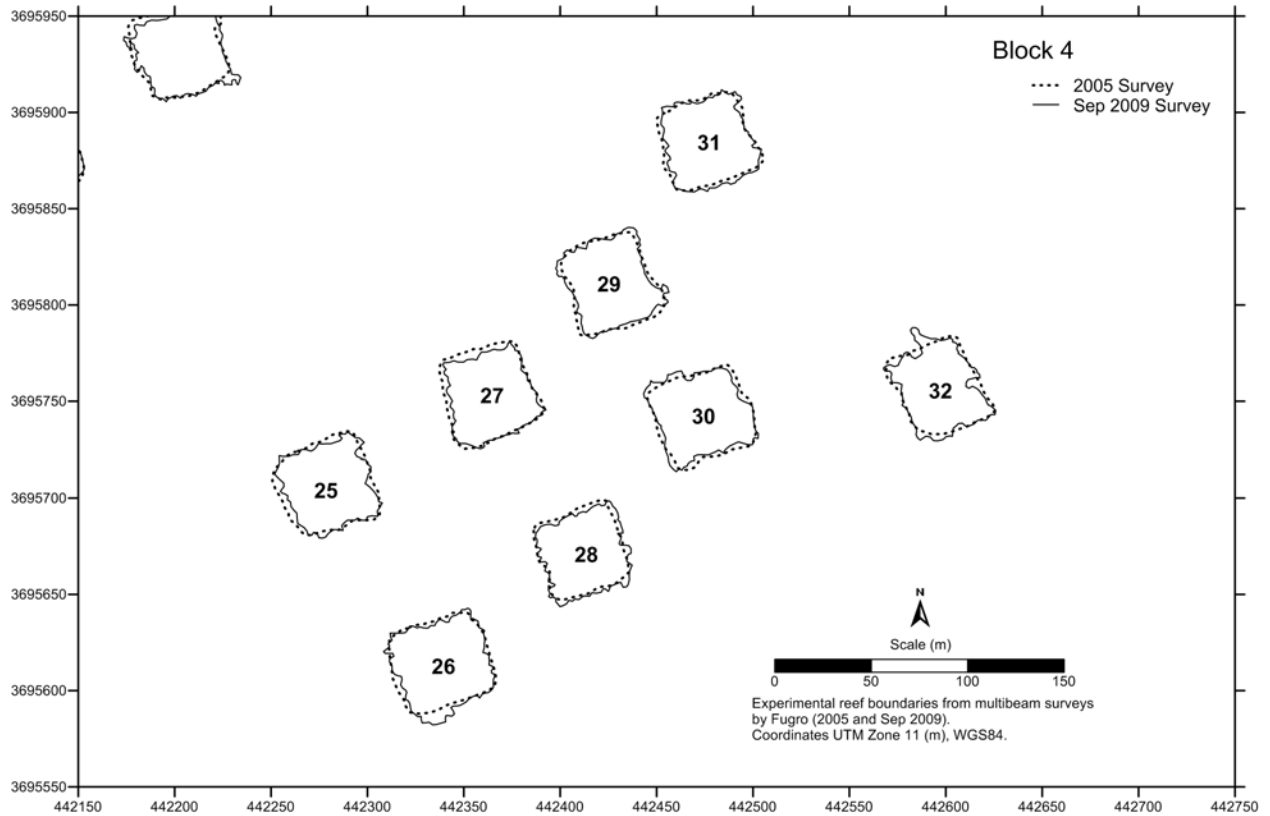


**Figure D-2. Comparison of module boundaries from 2005 (bathymetry) and September 2009 (bathymetry) for Block 2.**

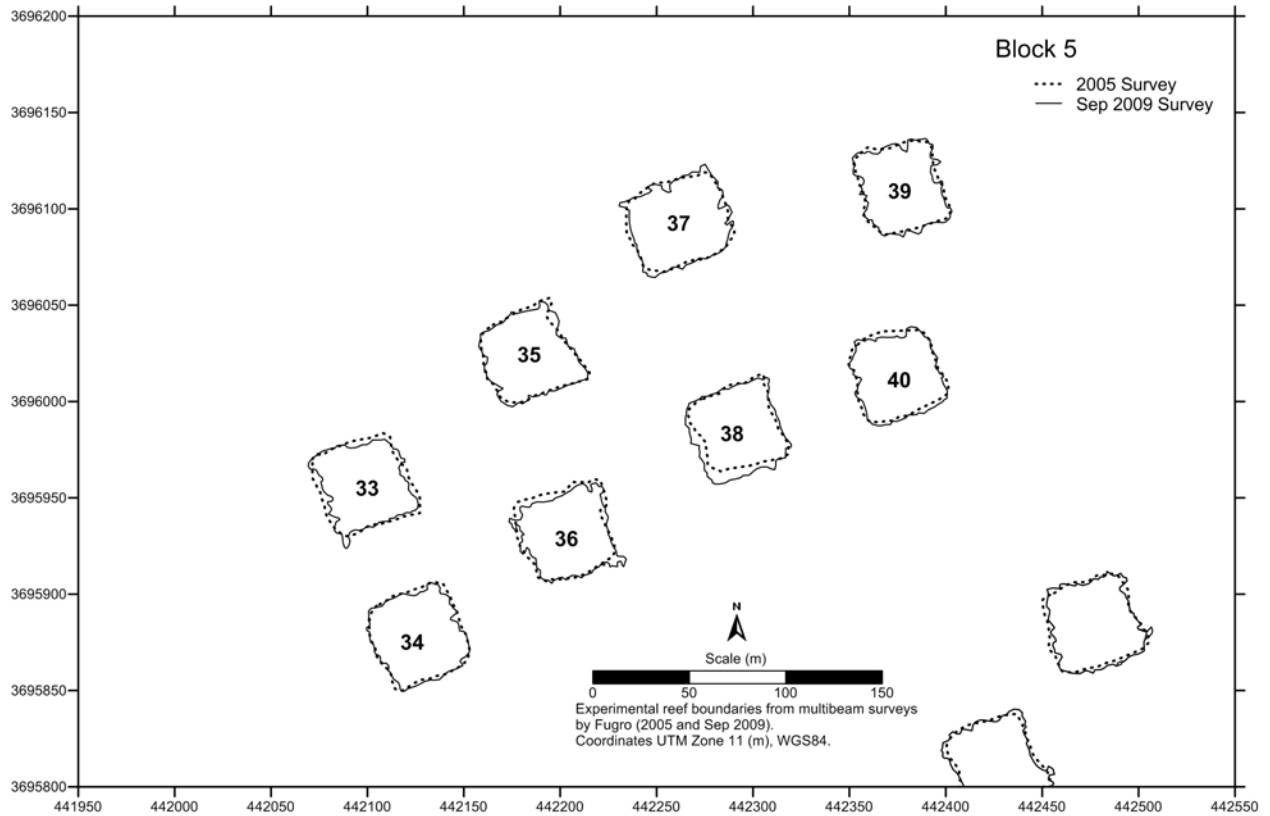




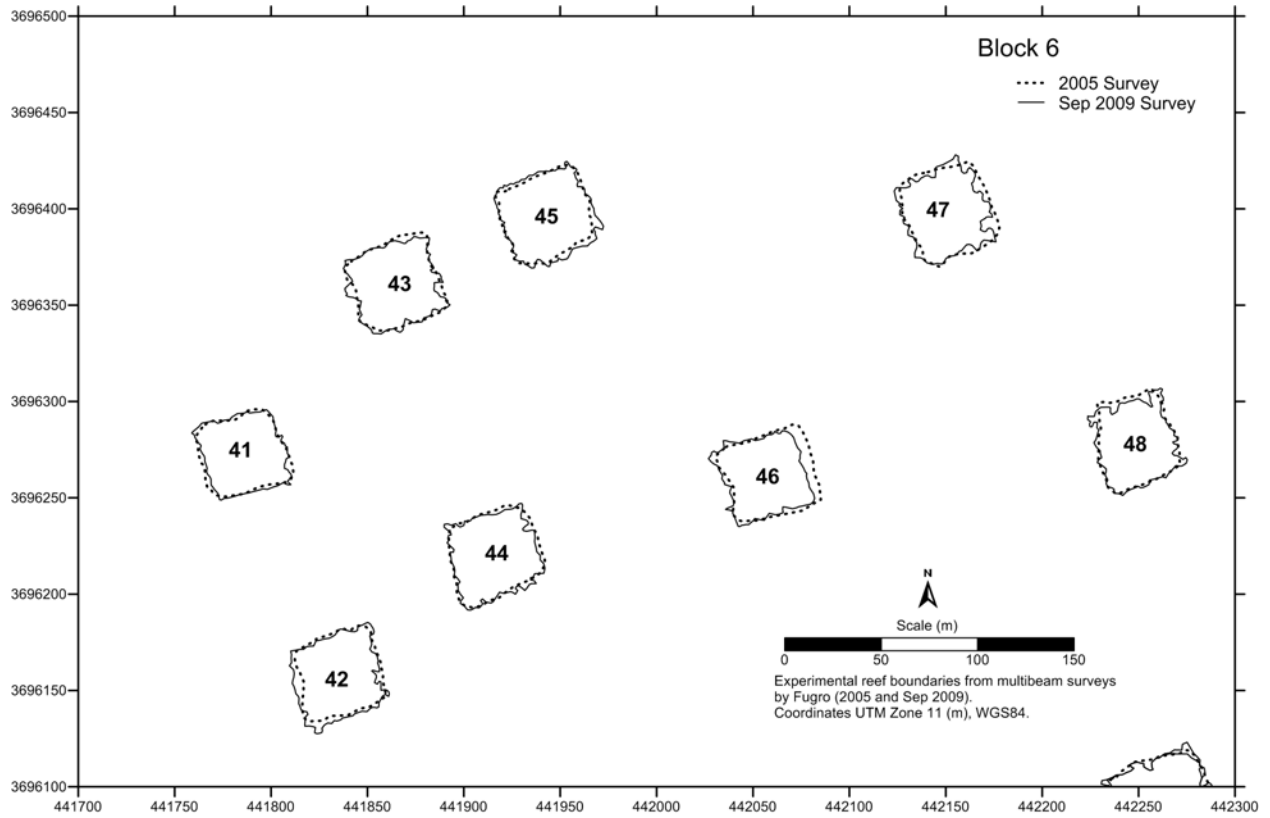
**Figure D-3. Comparison of module boundaries from 2005 (bathymetry) and September 2009 (bathymetry) for Block 3.**



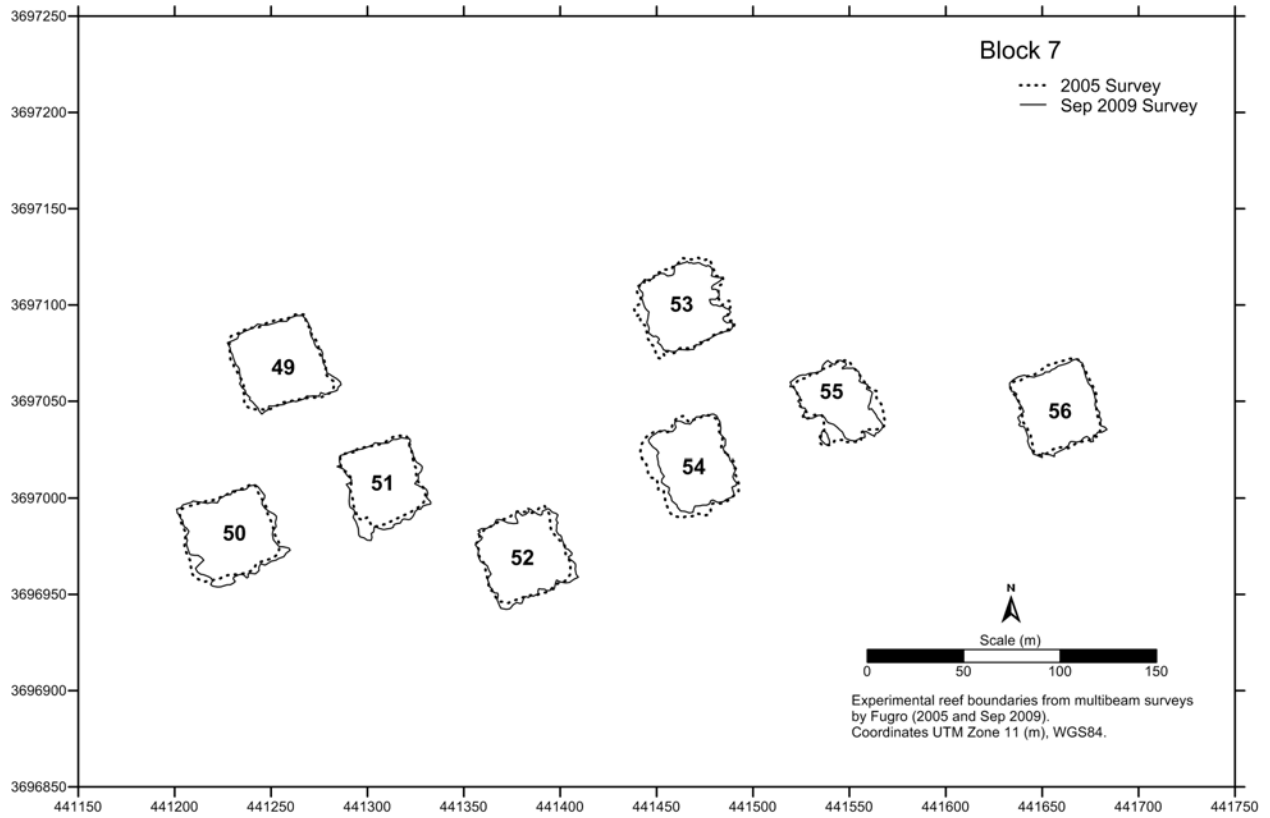
**Figure D-4. Comparison of module boundaries from 2005 (bathymetry) and September 2009 (bathymetry) for Block 4.**



**Figure D-5. Comparison of module boundaries from 2005 (bathymetry) and September 2009 (bathymetry) for Block 5.**



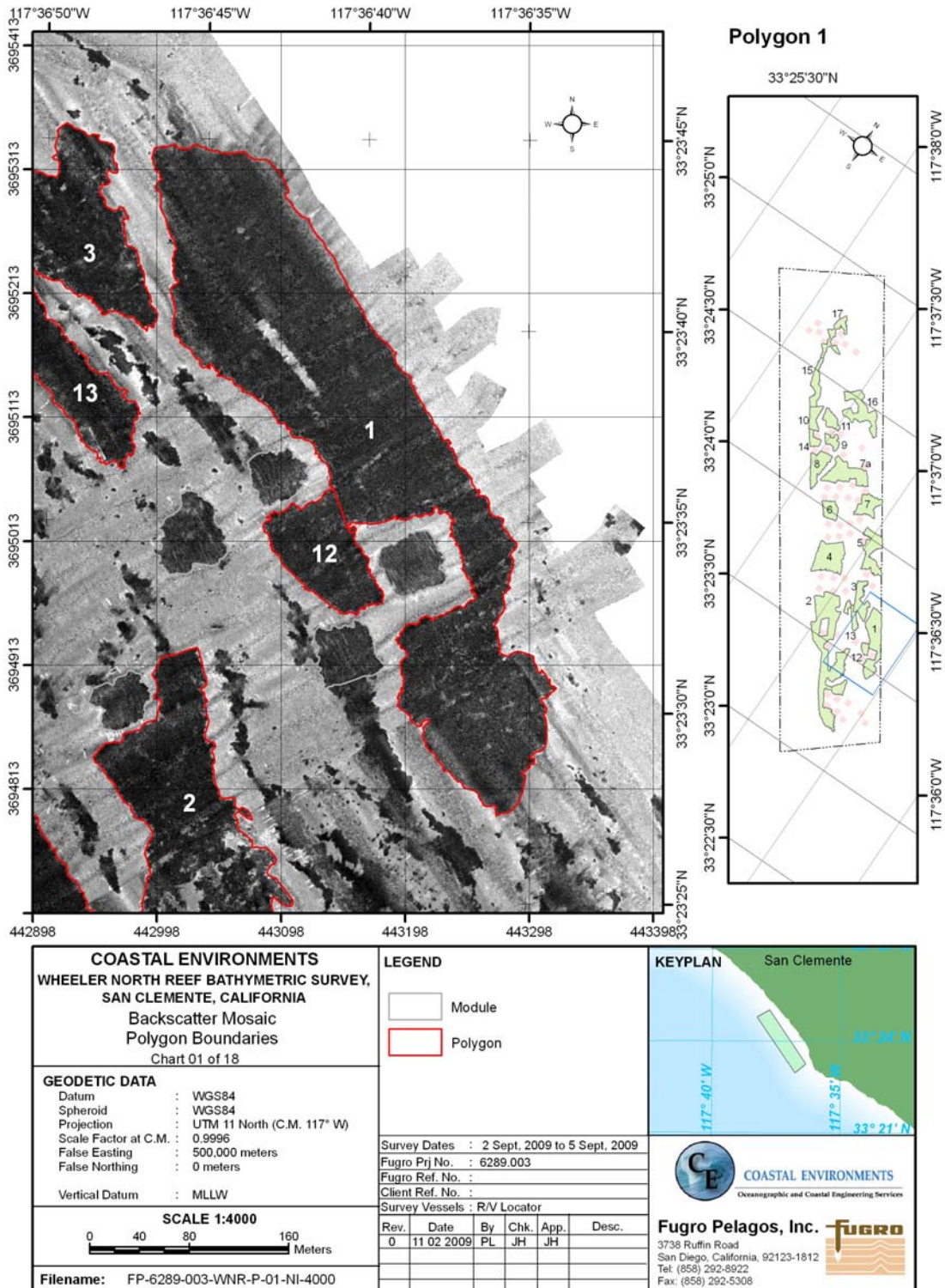
**Figure D-6. Comparison of module boundaries from 2005 (bathymetry) and September 2009 (bathymetry) for Block 6.**



**Figure D-7. Comparison of module boundaries from 2005 (bathymetry) and September 2009 (bathymetry) for Block 7.**

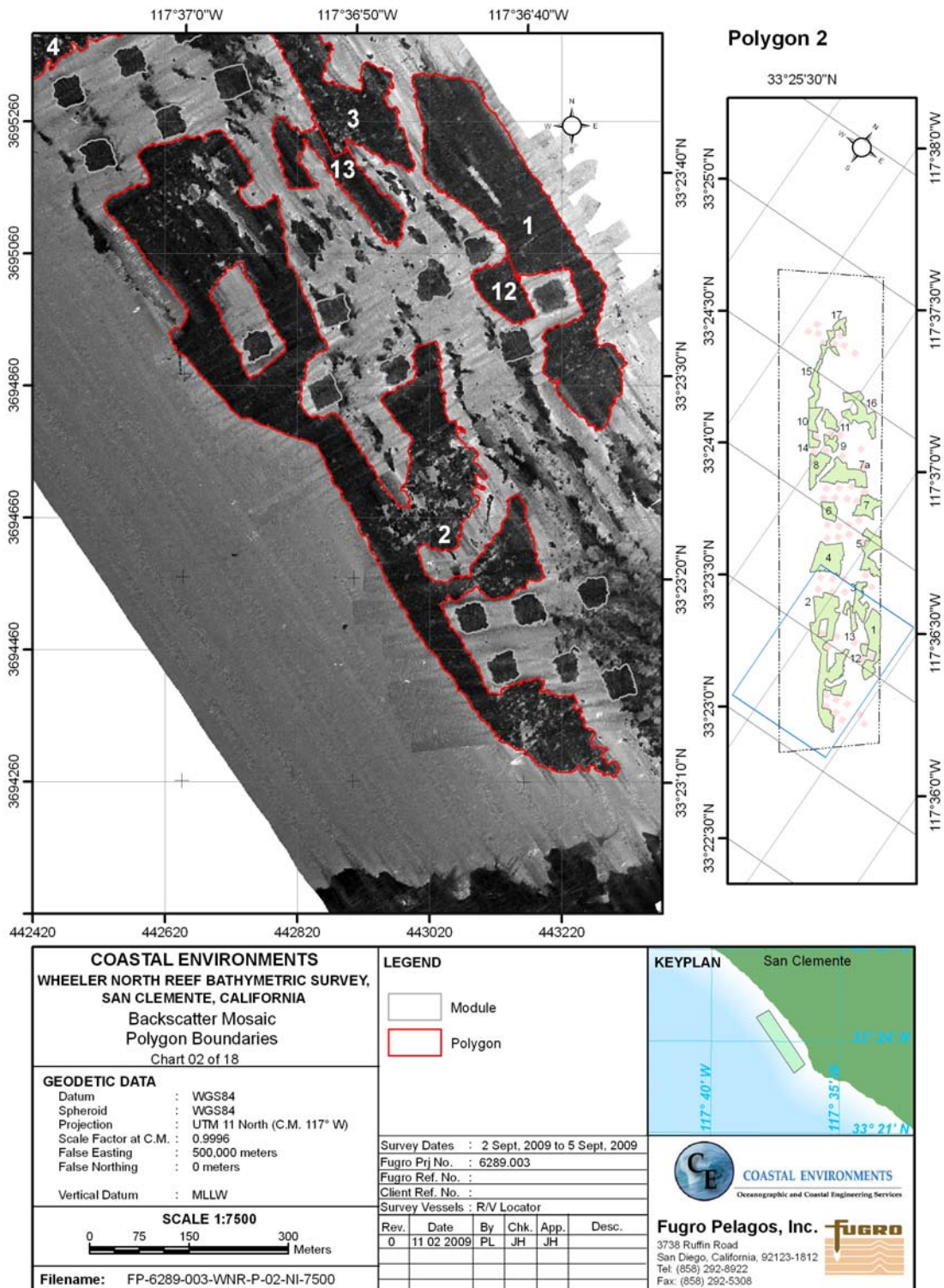
**APPENDIX E**

**BOUNDARIES FROM BACKSCATTER MOSAICS FOR POLYGONS 1–17  
(SEPTEMBER 2009 MULTIBEAM SURVEY)**



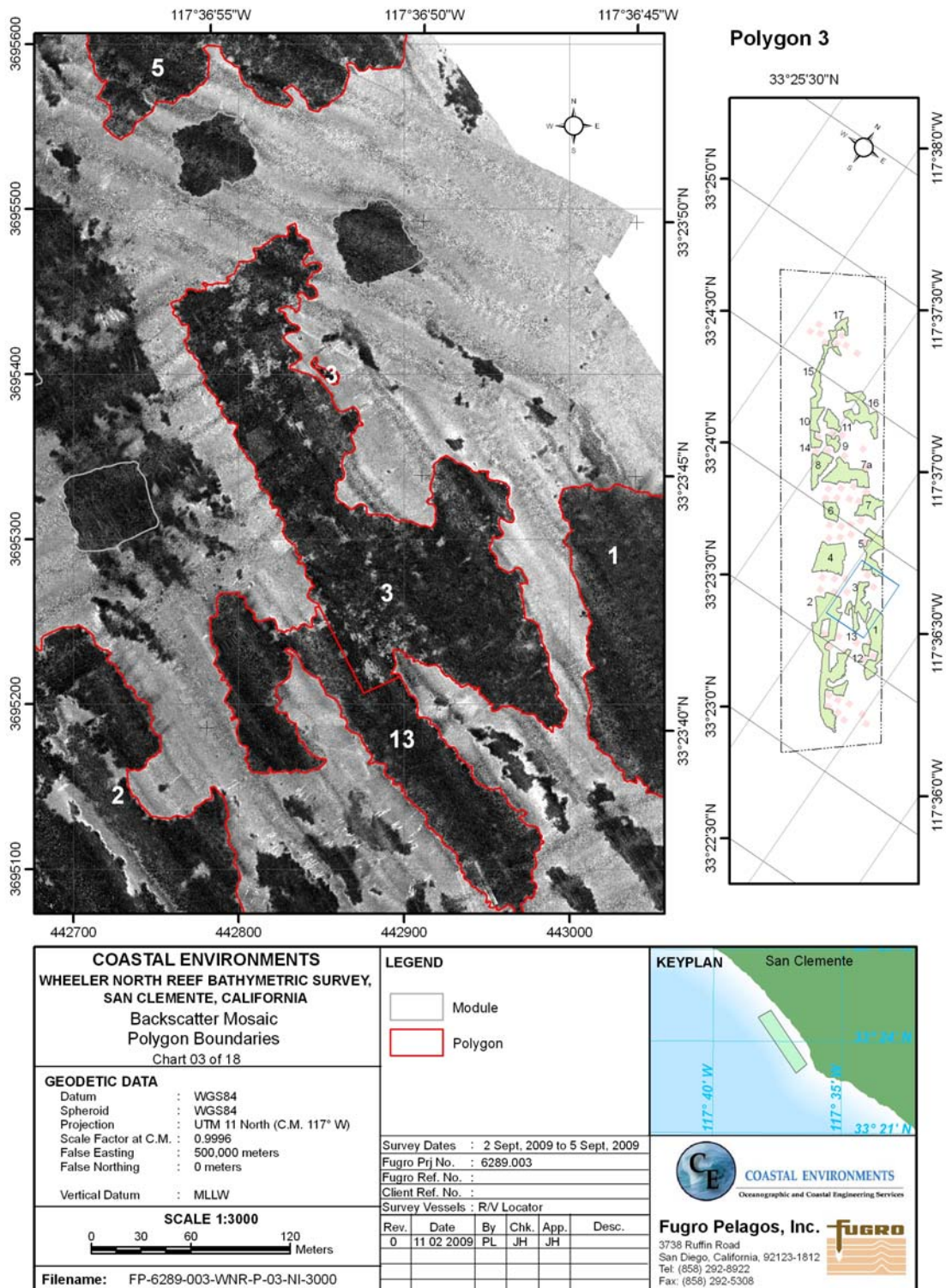
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**Figure E-1. Polygon 1 boundary from backscatter mosaics (September 2009 multibeam survey).**

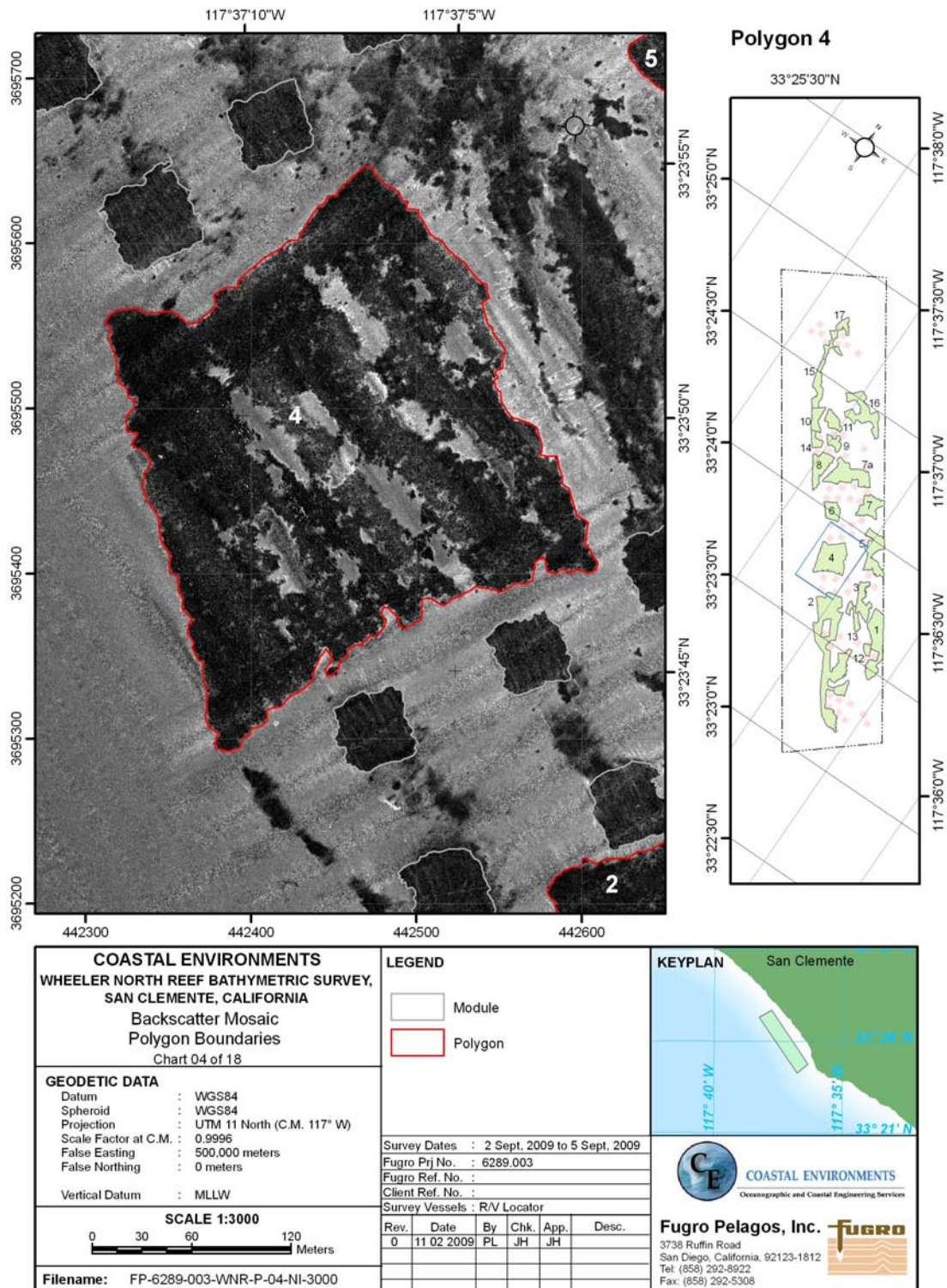


**Figure E-2. Polygon 2 boundary from backscatter mosaics (September 2009 multibeam survey).**



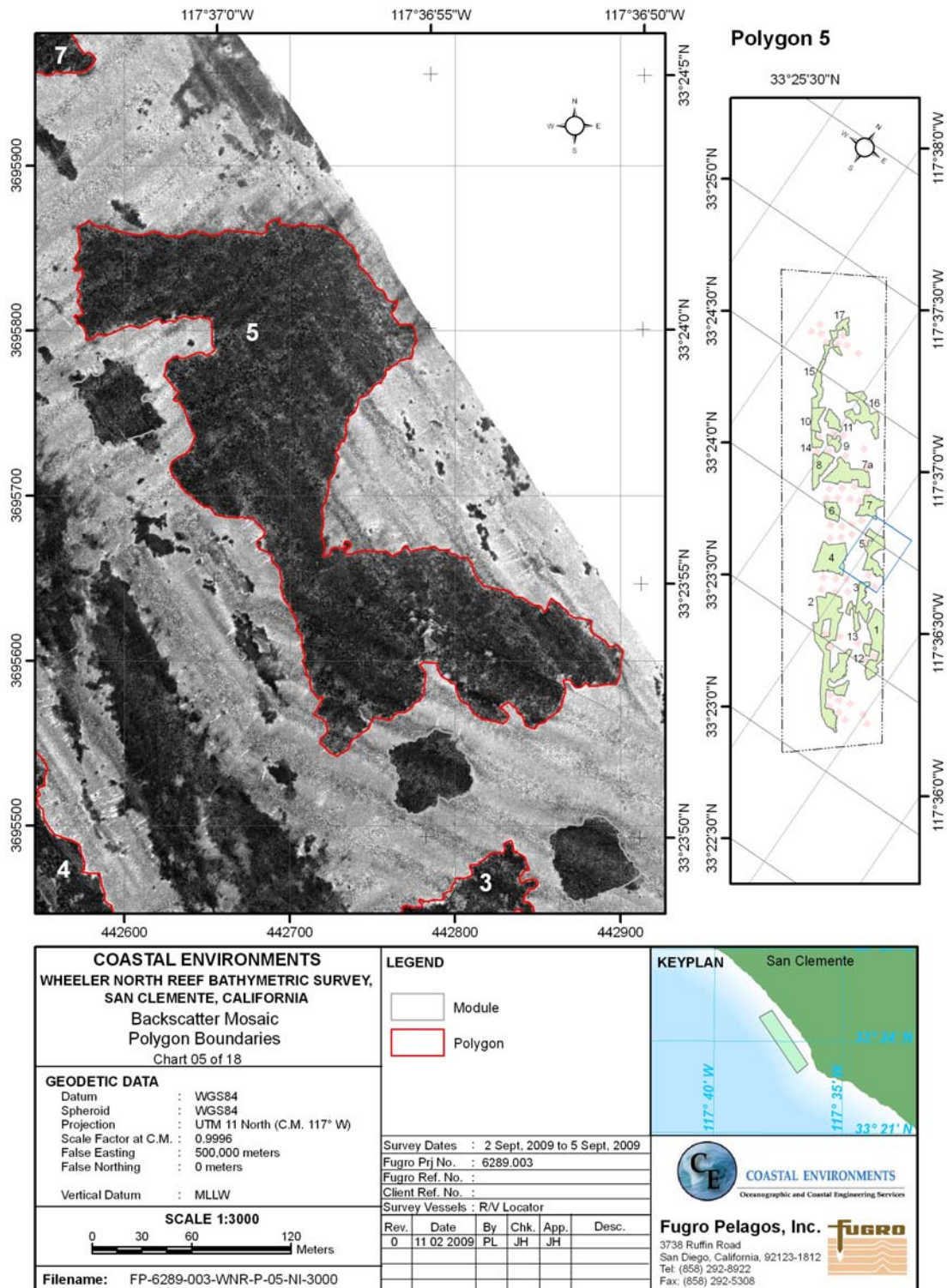


**Figure E-3. Polygon 3 boundary from backscatter mosaics (September 2009 multibeam survey).**

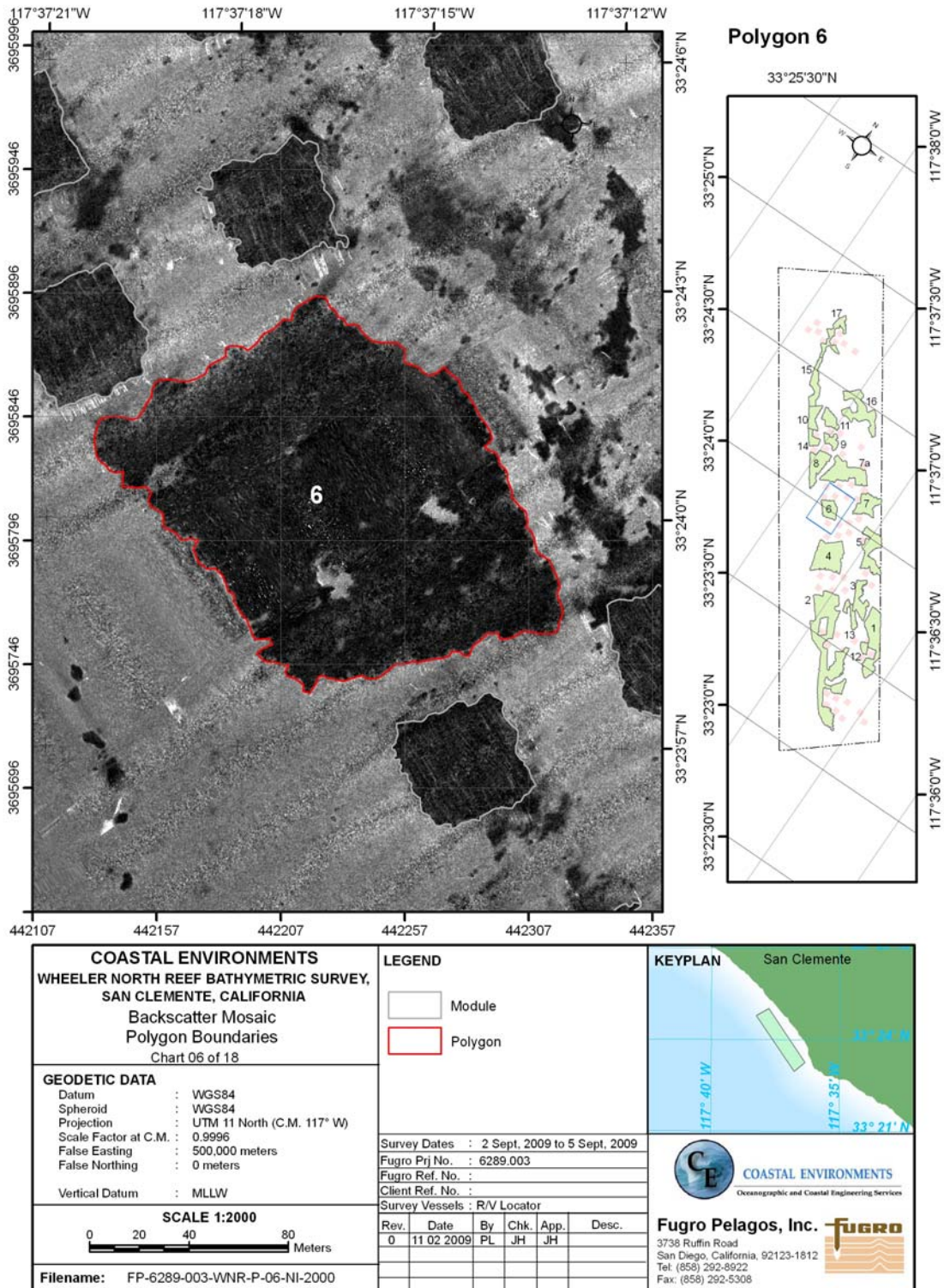


**Figure E-4. Polygon 4 boundary from backscatter mosaics (September 2009 multibeam survey).**



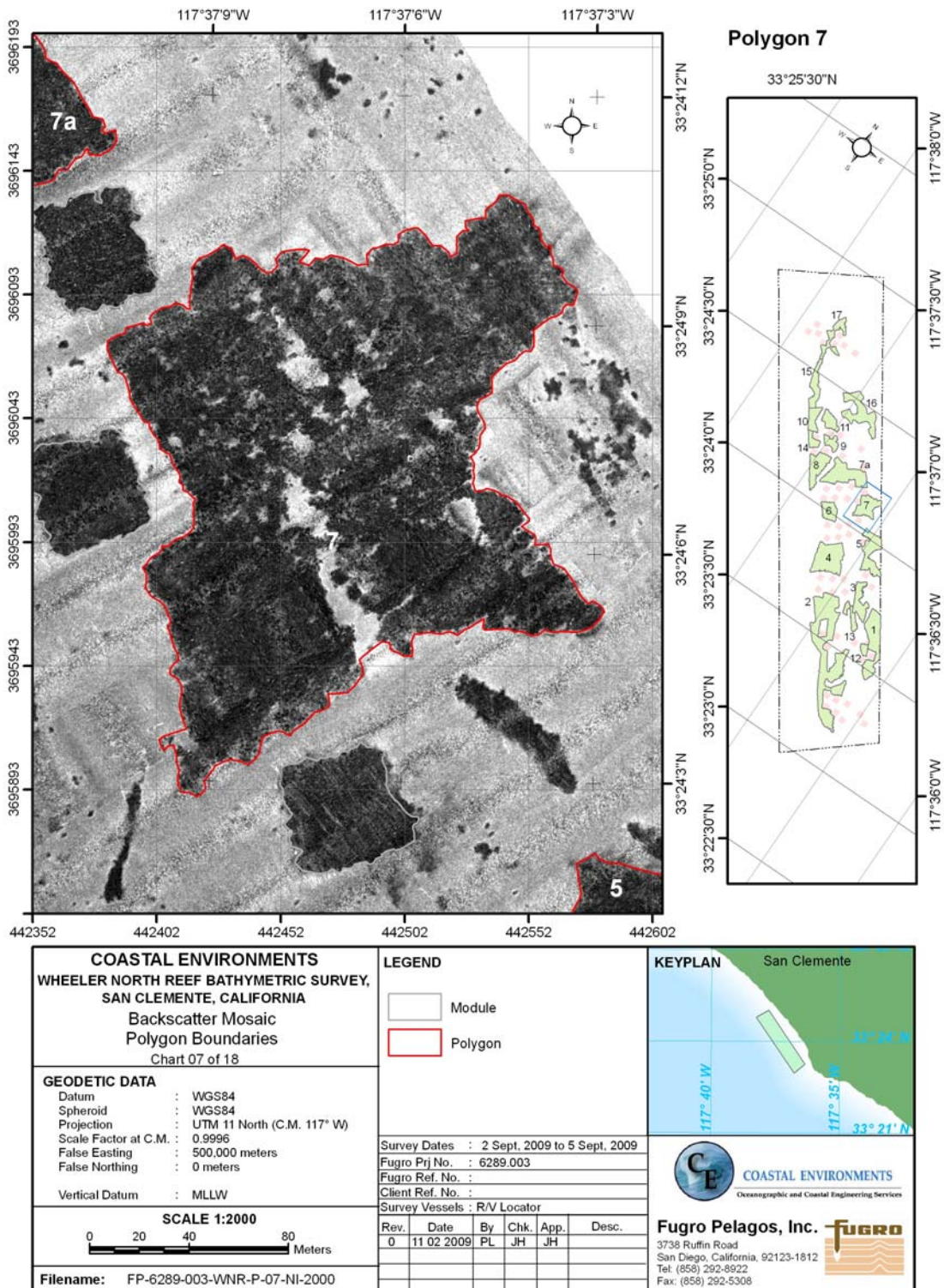


**Figure E-5. Polygon 5 boundary from backscatter mosaics (September 2009 multibeam survey).**

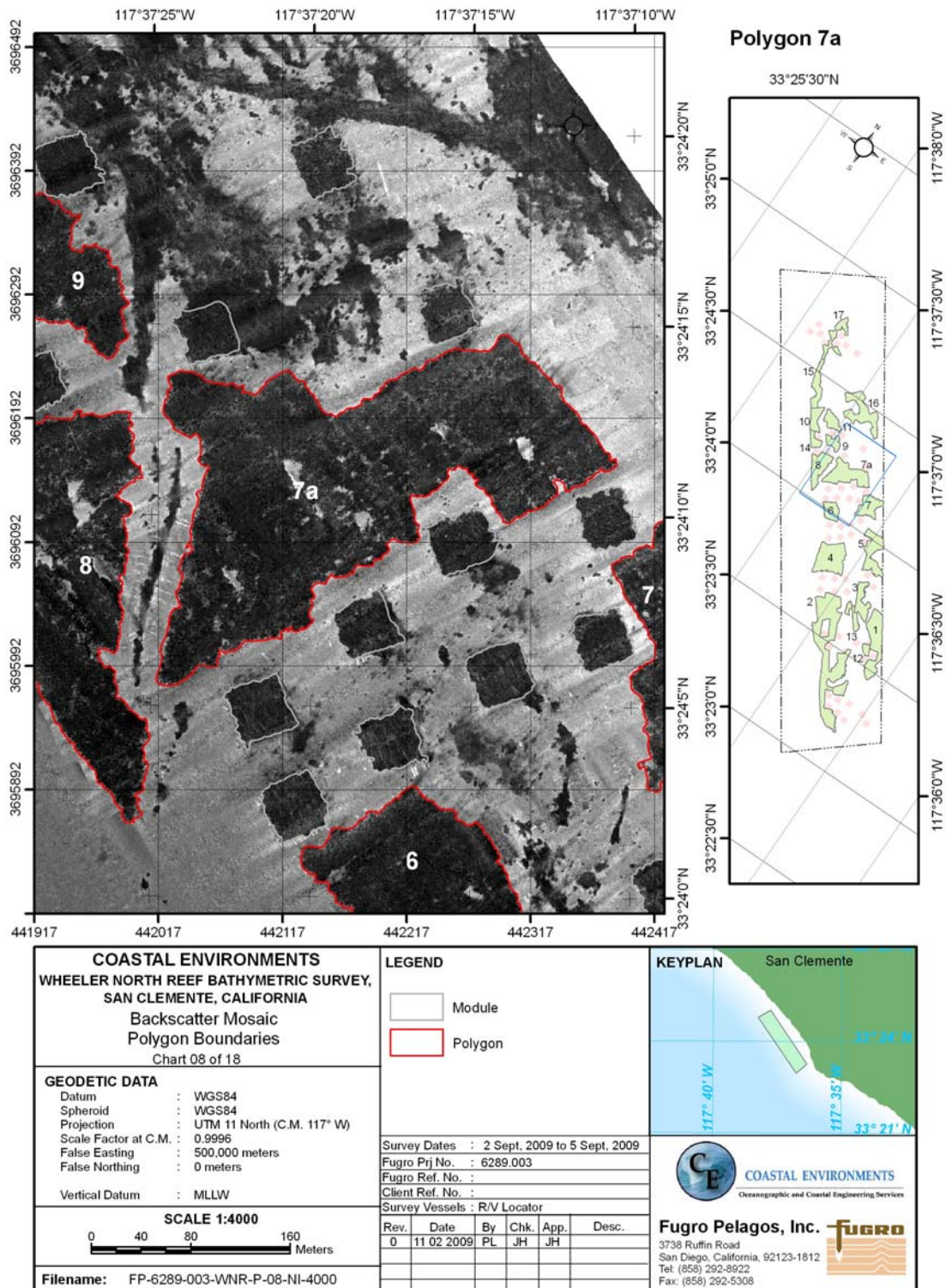


**Figure E-6. Polygon 6 boundary from backscatter mosaics (September 2009 multibeam survey).**





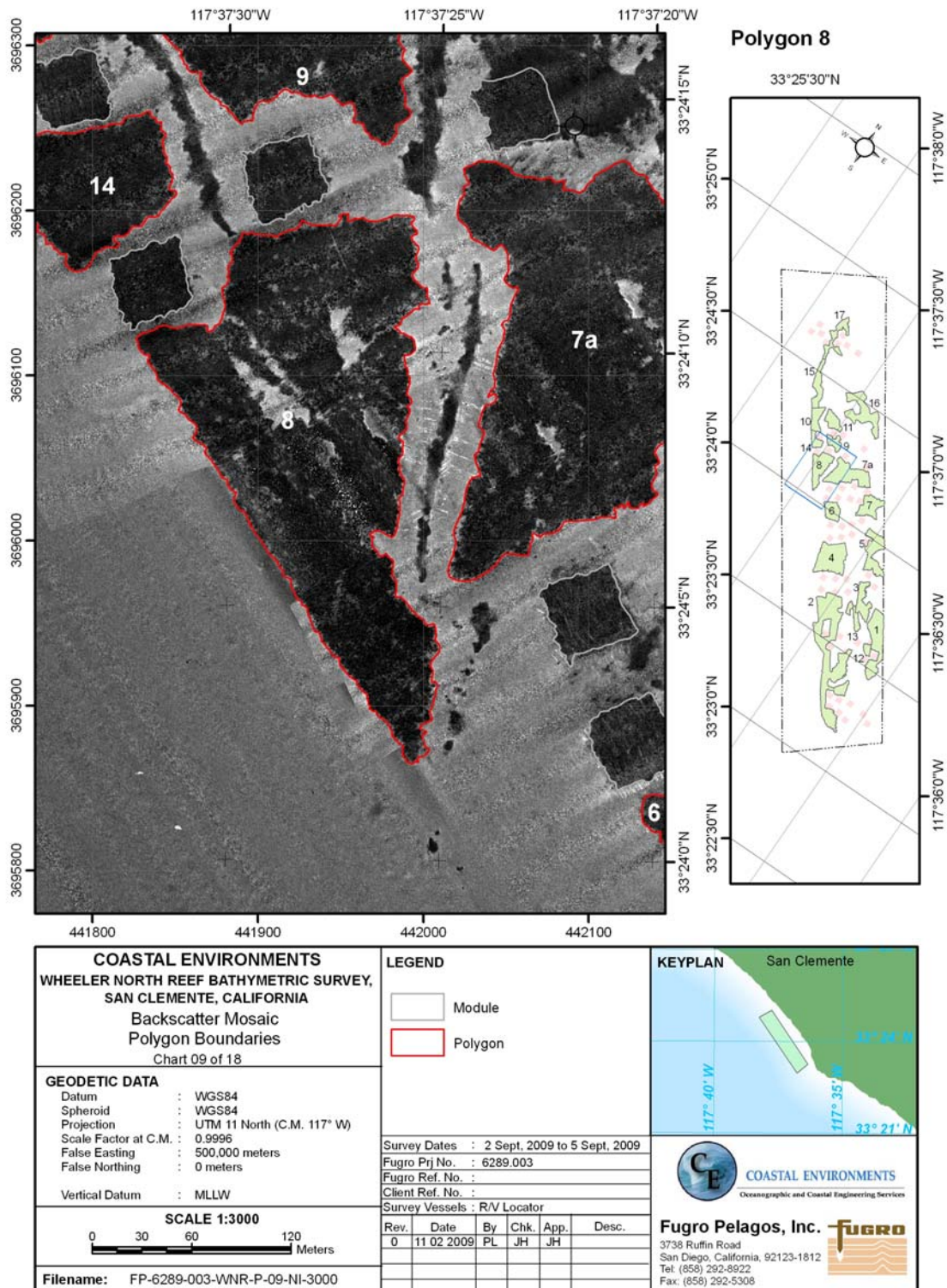
**Figure E-7. Polygon 7 boundary from backscatter mosaics (September 2009 multibeam survey).**



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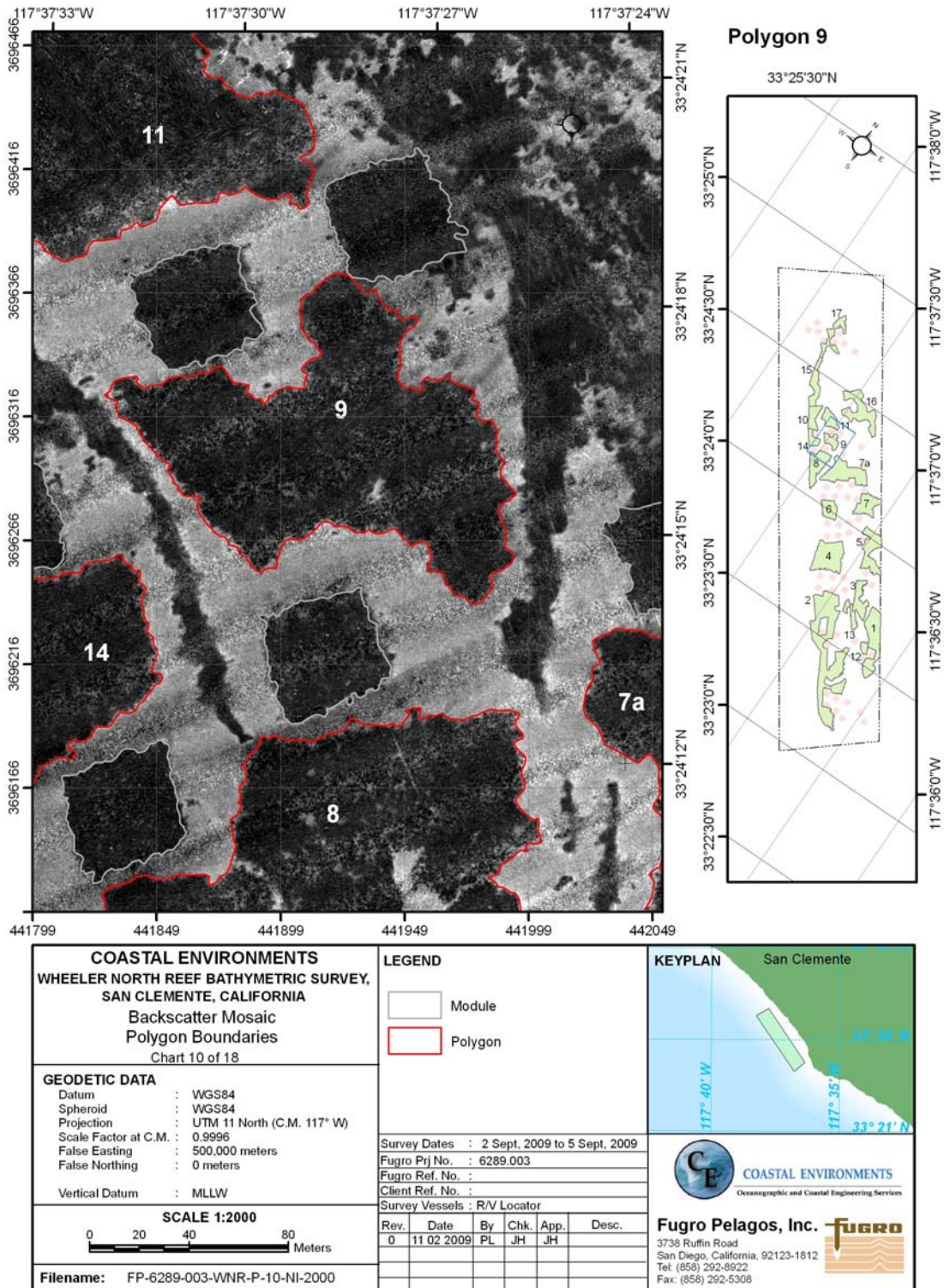
**Figure E-8. Polygon 7a boundary from backscatter mosaics (September 2009 multibeam survey).**





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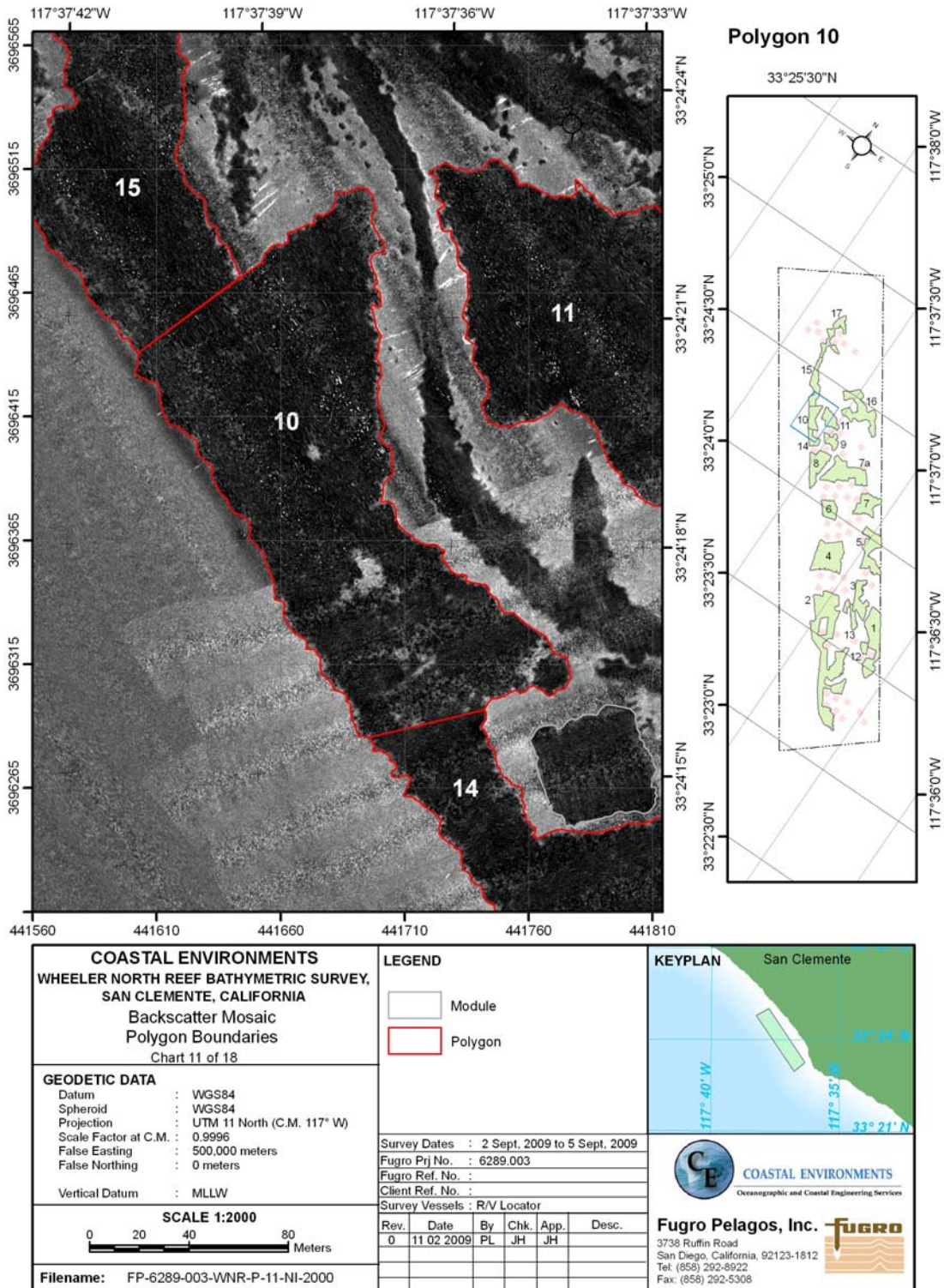
**Figure E-9. Polygon 8 boundary from backscatter mosaics (September 2009 multibeam survey).**



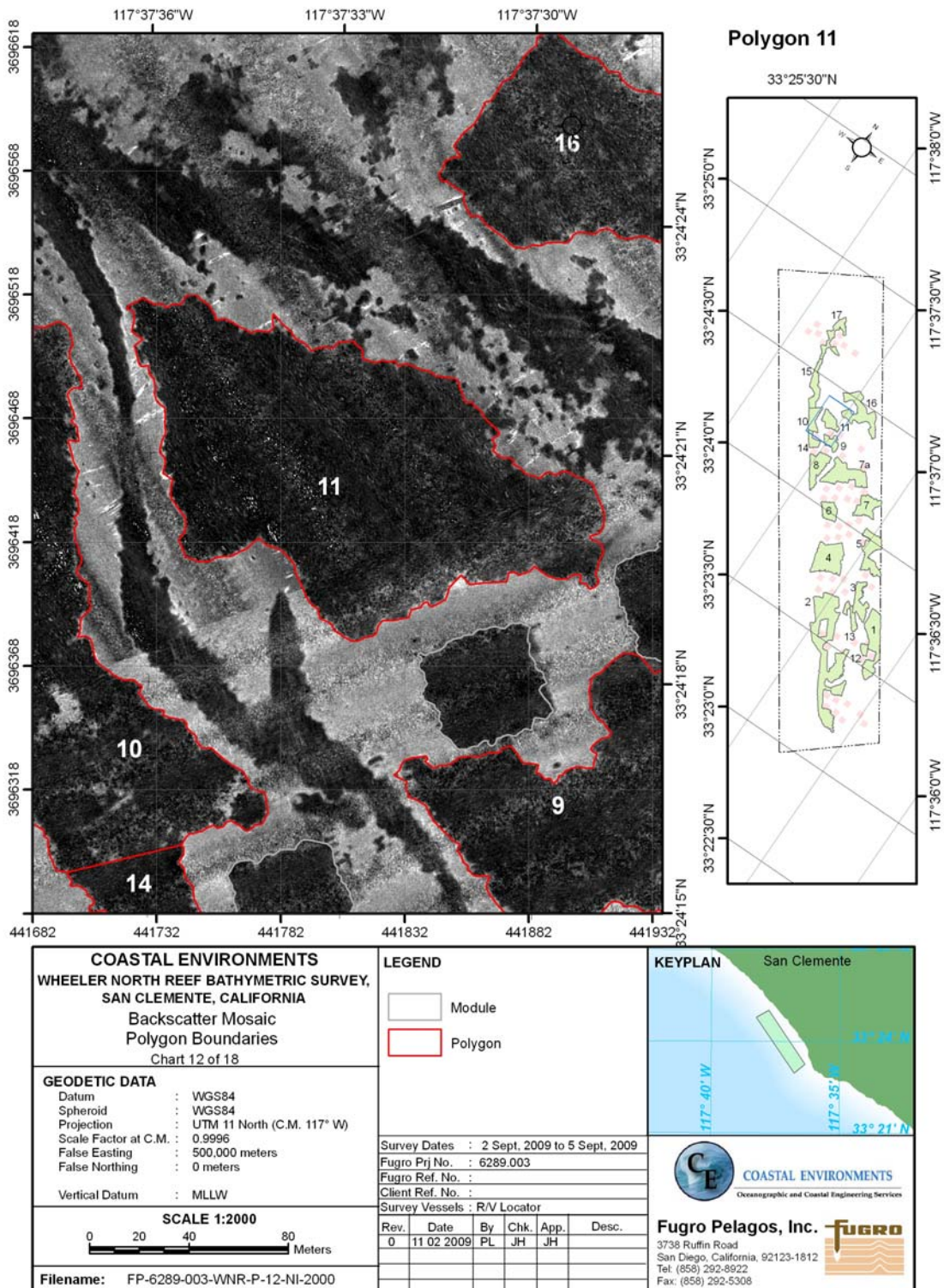
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**Figure E-10. Polygon 9 boundary from backscatter mosaics (September 2009 multibeam survey).**



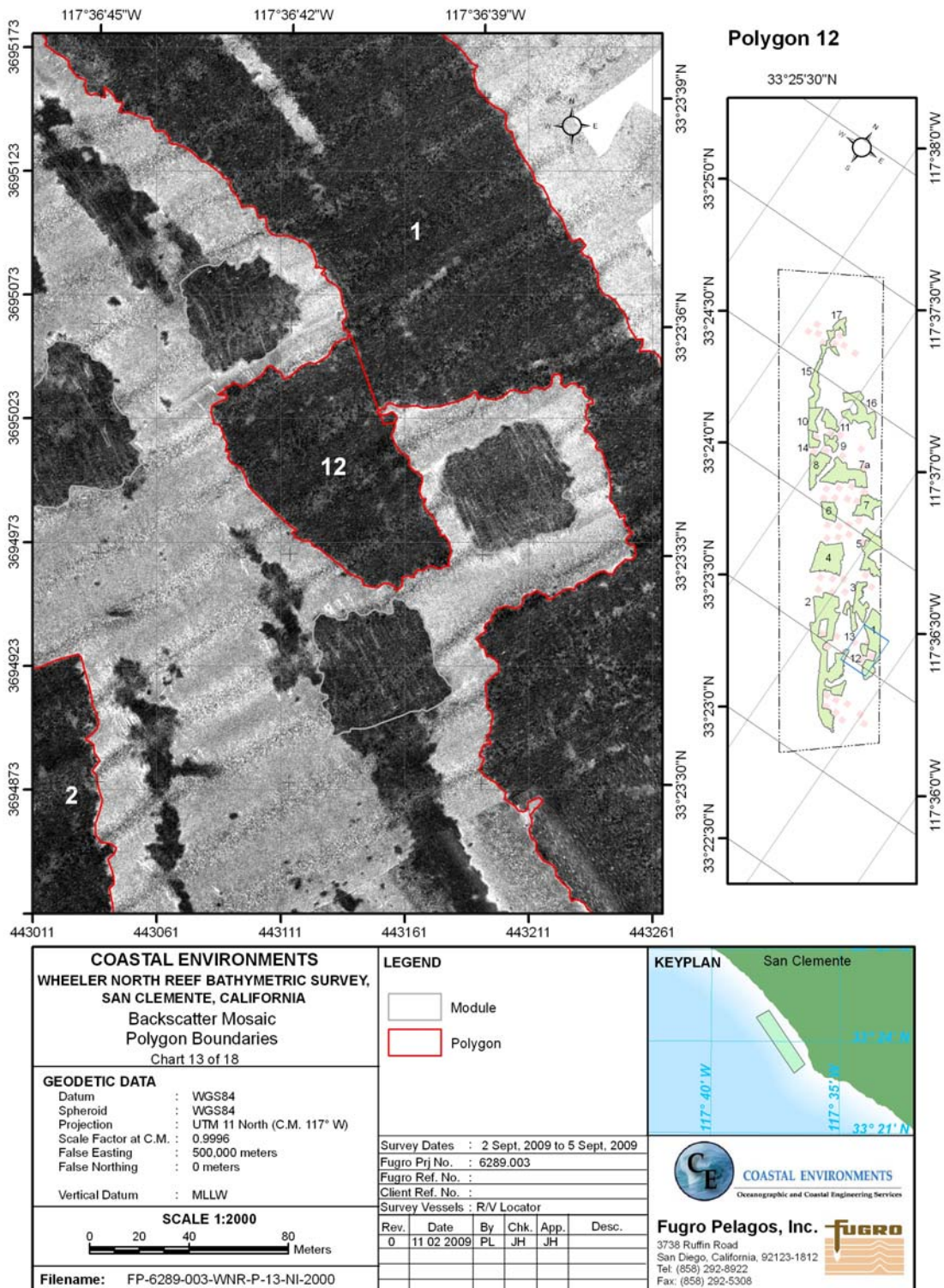


**Figure E-11. Polygon 10 boundary from backscatter mosaics (September 2009 multibeam survey).**



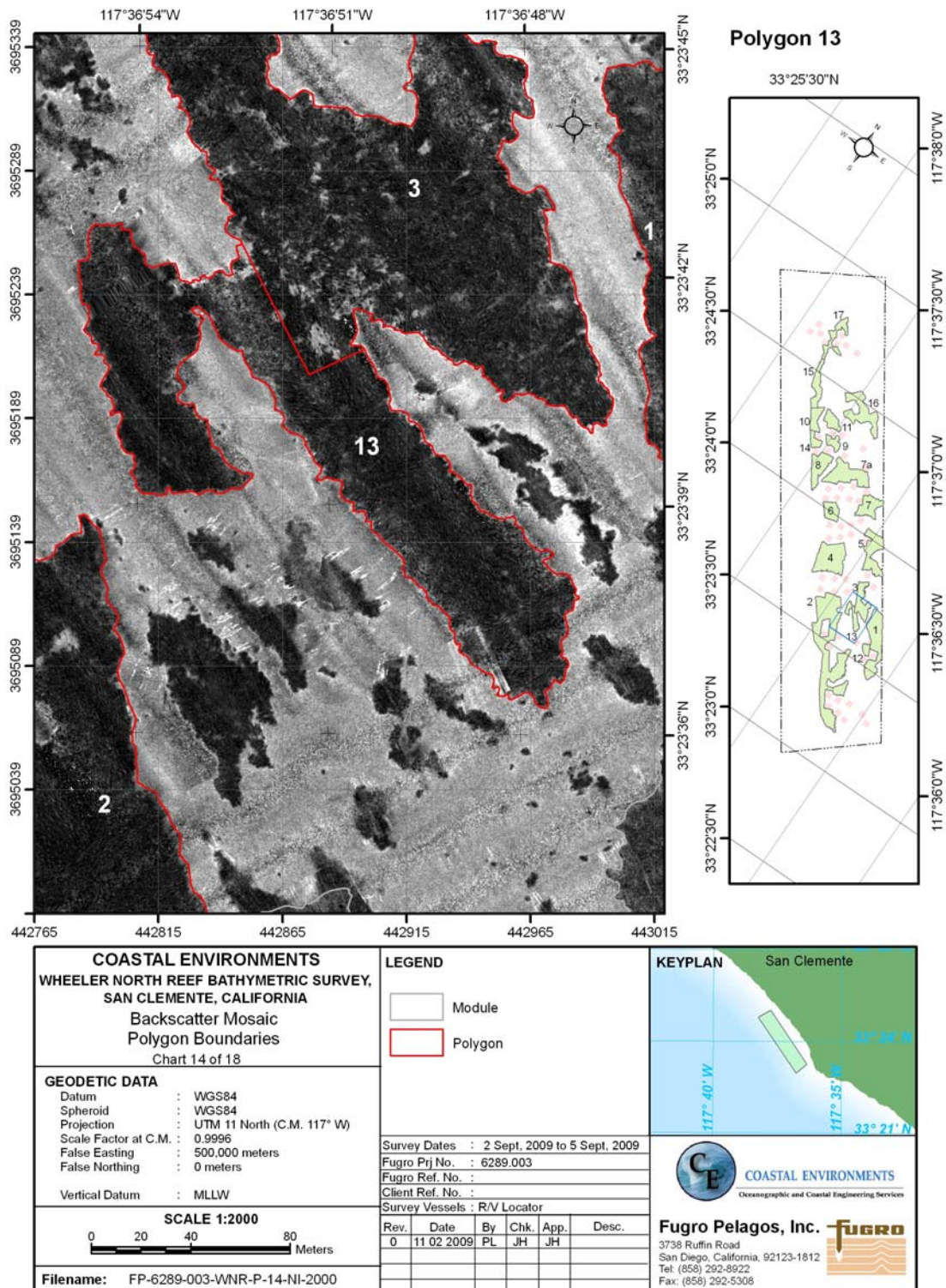
**Figure E-12. Polygon 11 boundary from backscatter mosaics (September 2009 multibeam survey).**





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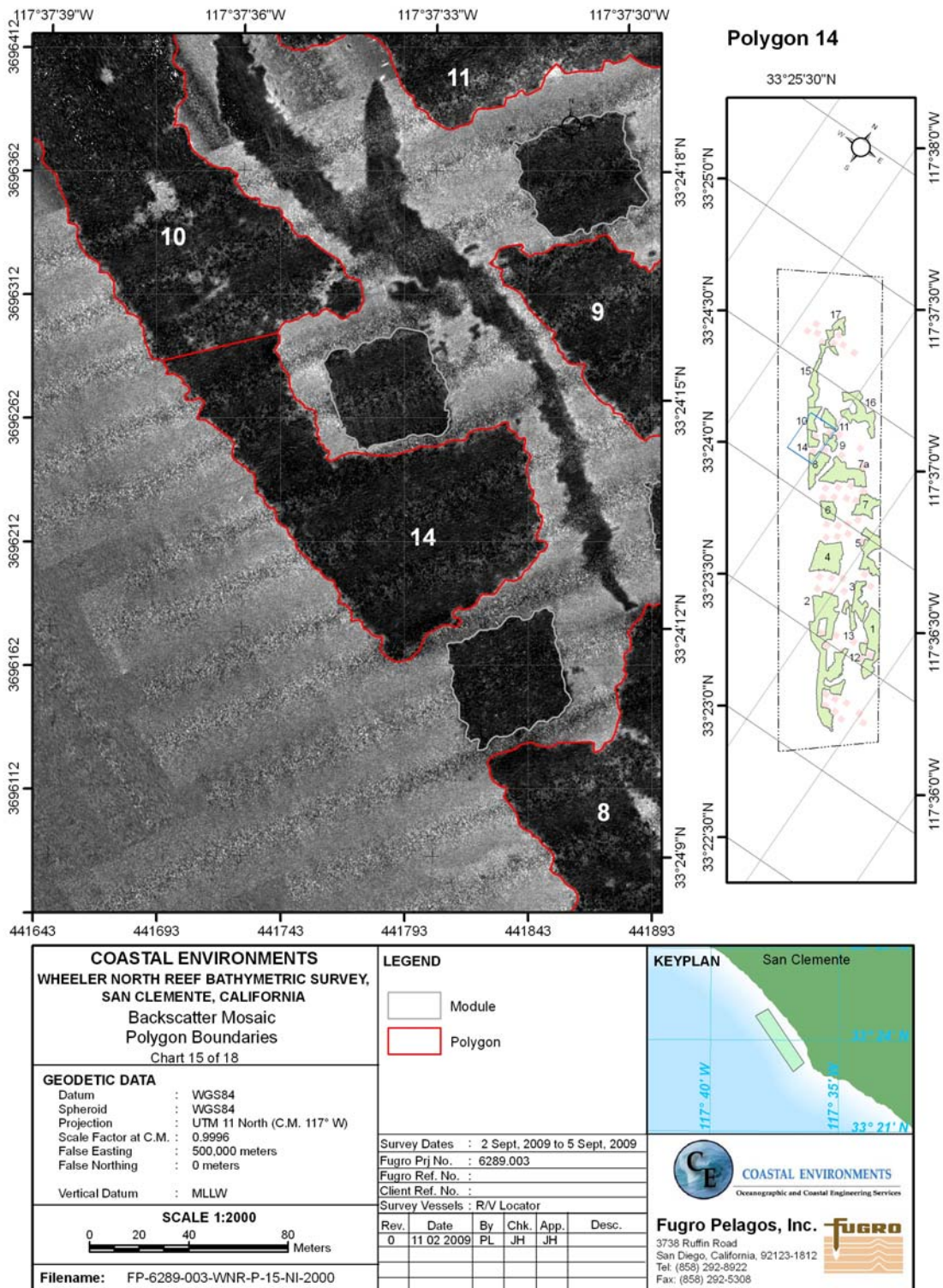
**Figure E-13. Polygon 12 boundary from backscatter mosaics (September 2009 multibeam survey).**



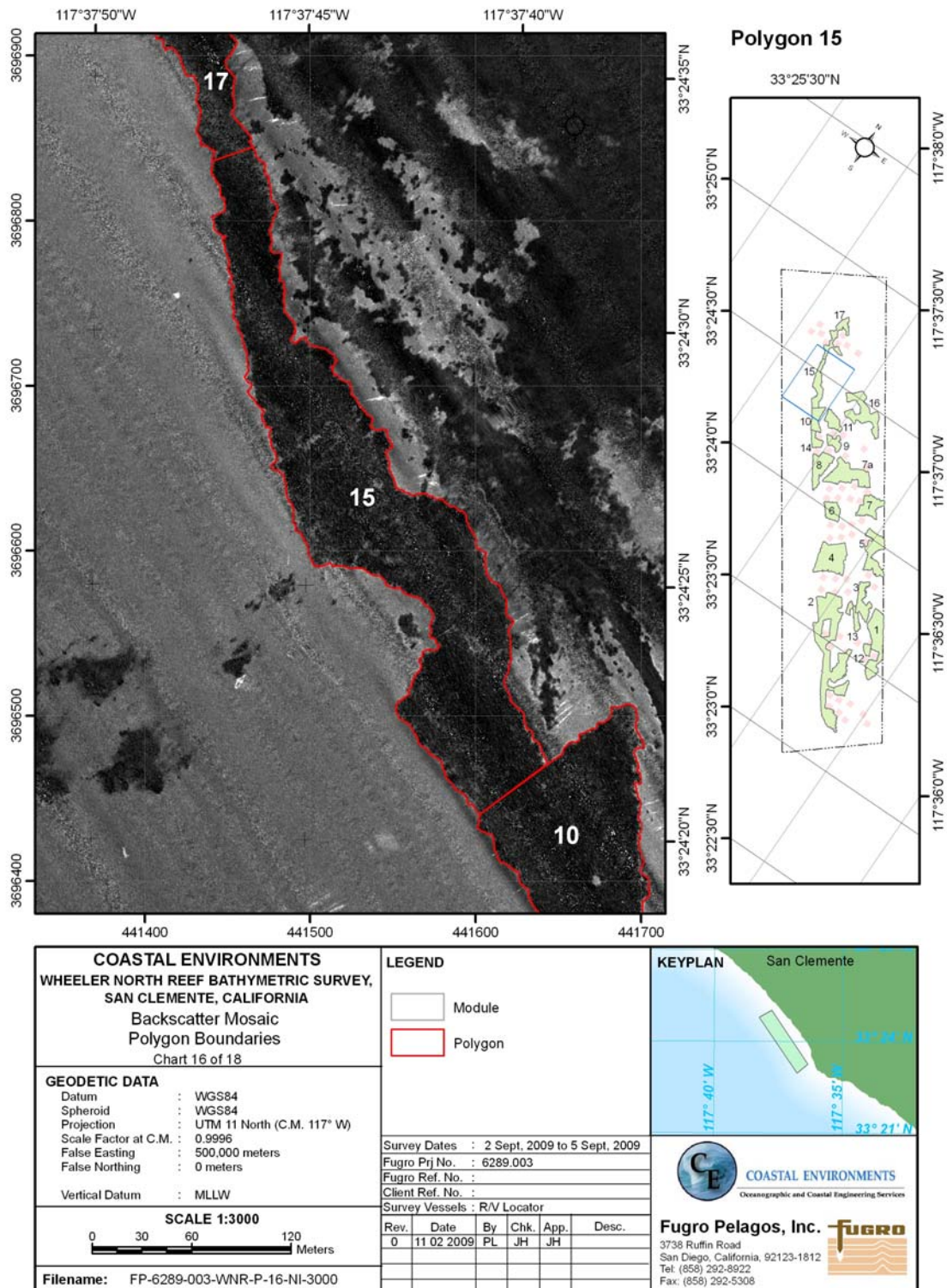
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**Figure E-14. Polygon 13 boundary from backscatter mosaics (September 2009 multibeam survey).**





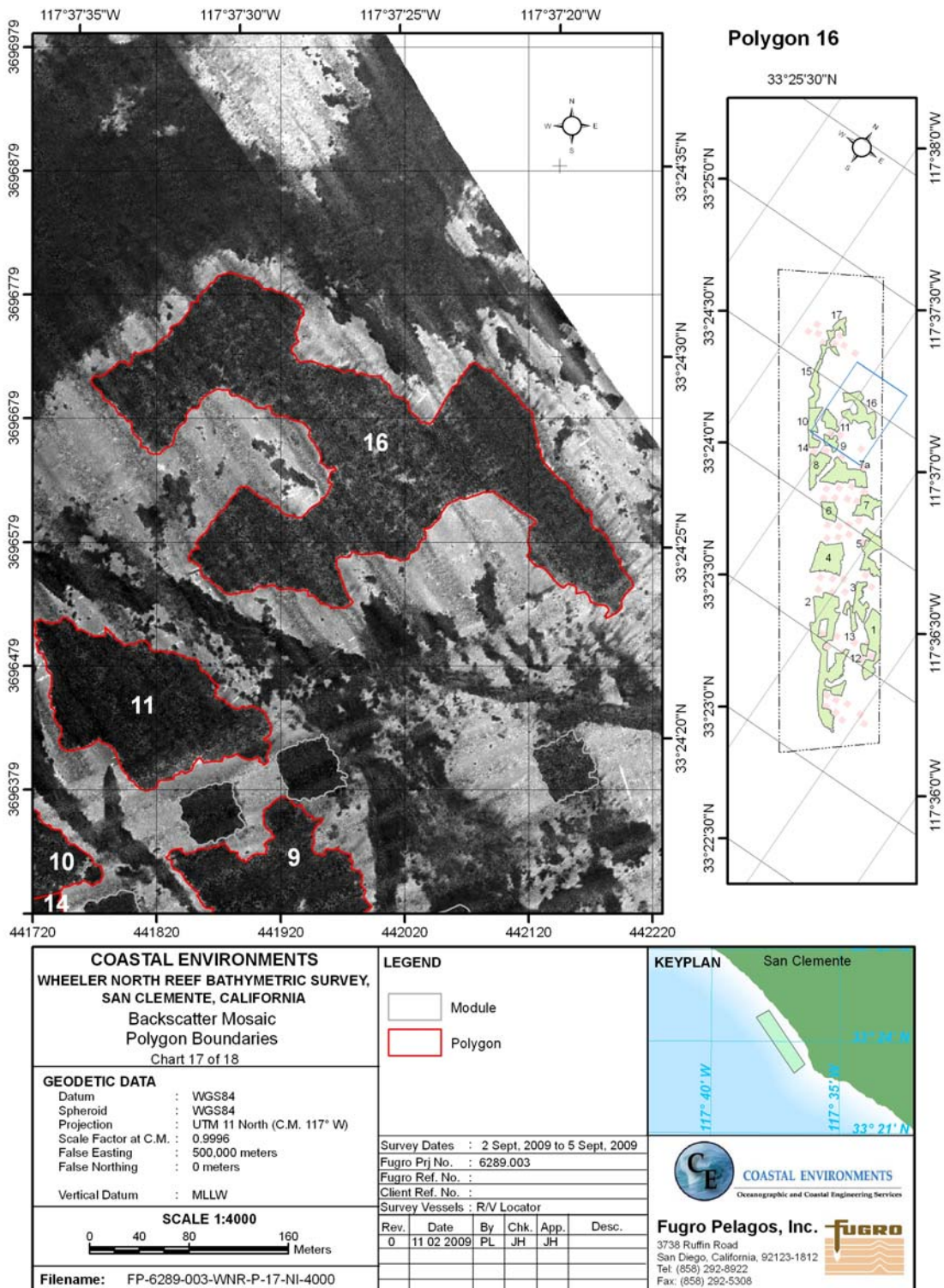
**Figure E-15. Polygon 14 boundary from backscatter mosaics (September 2009 multibeam survey).**



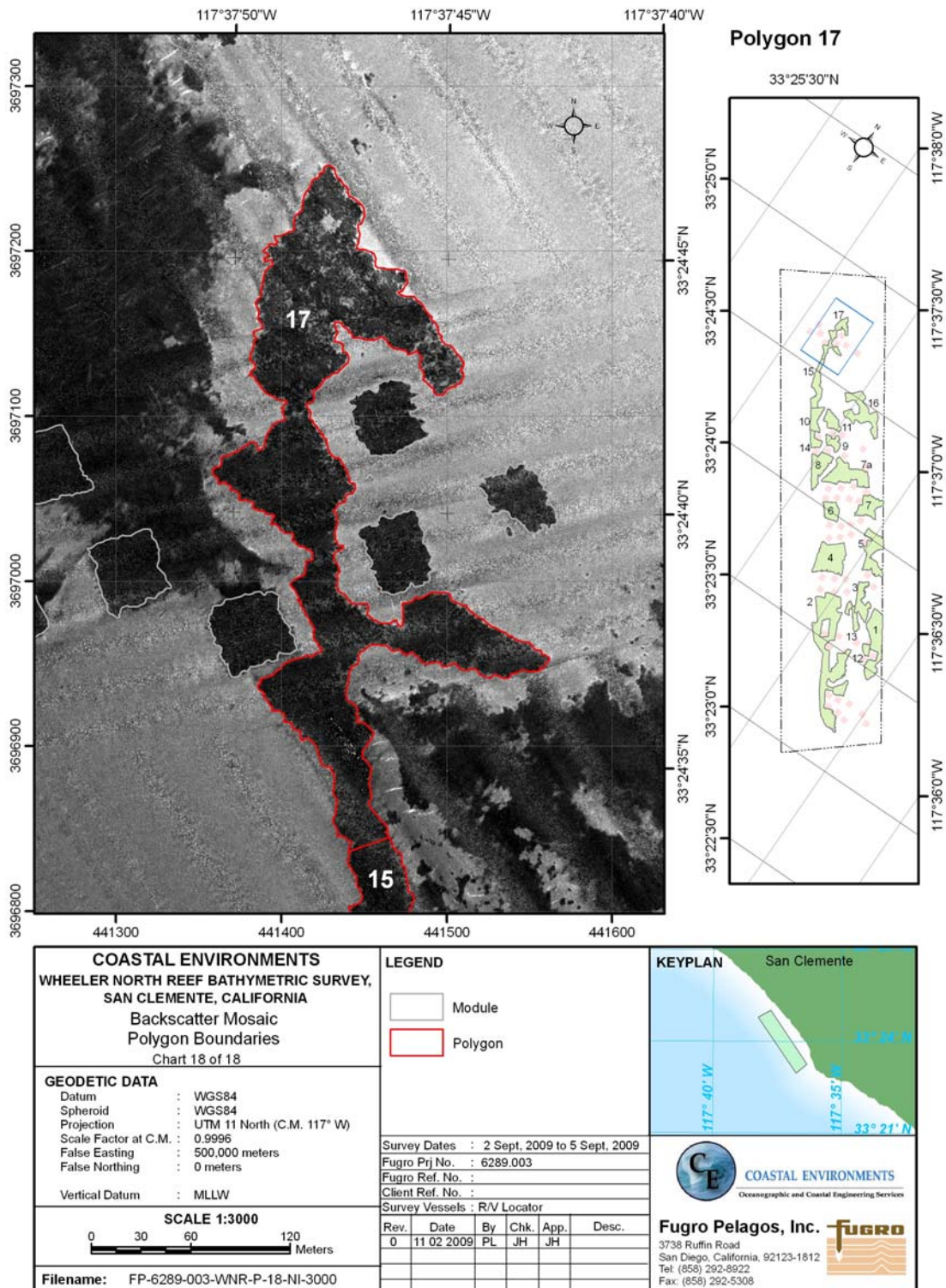
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**Figure E-16. Polygon 15 boundary from backscatter mosaics (September 2009 multibeam survey).**





**Figure E-17. Polygon 16 boundary from backscatter mosaics (September 2009 multibeam survey).**



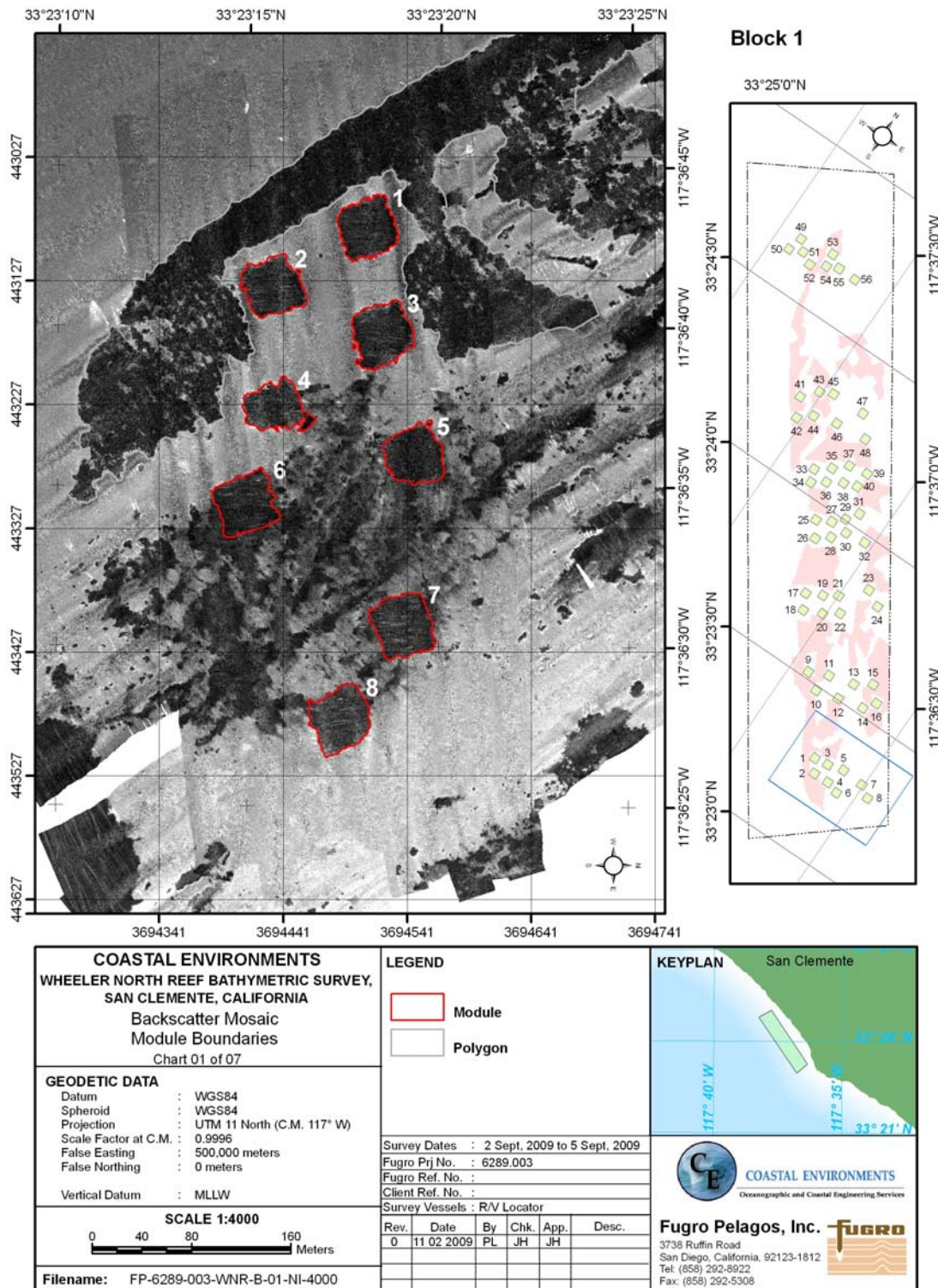
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**Figure E-18. Polygon 17 boundary from backscatter mosaics (September 2009 multibeam survey).**



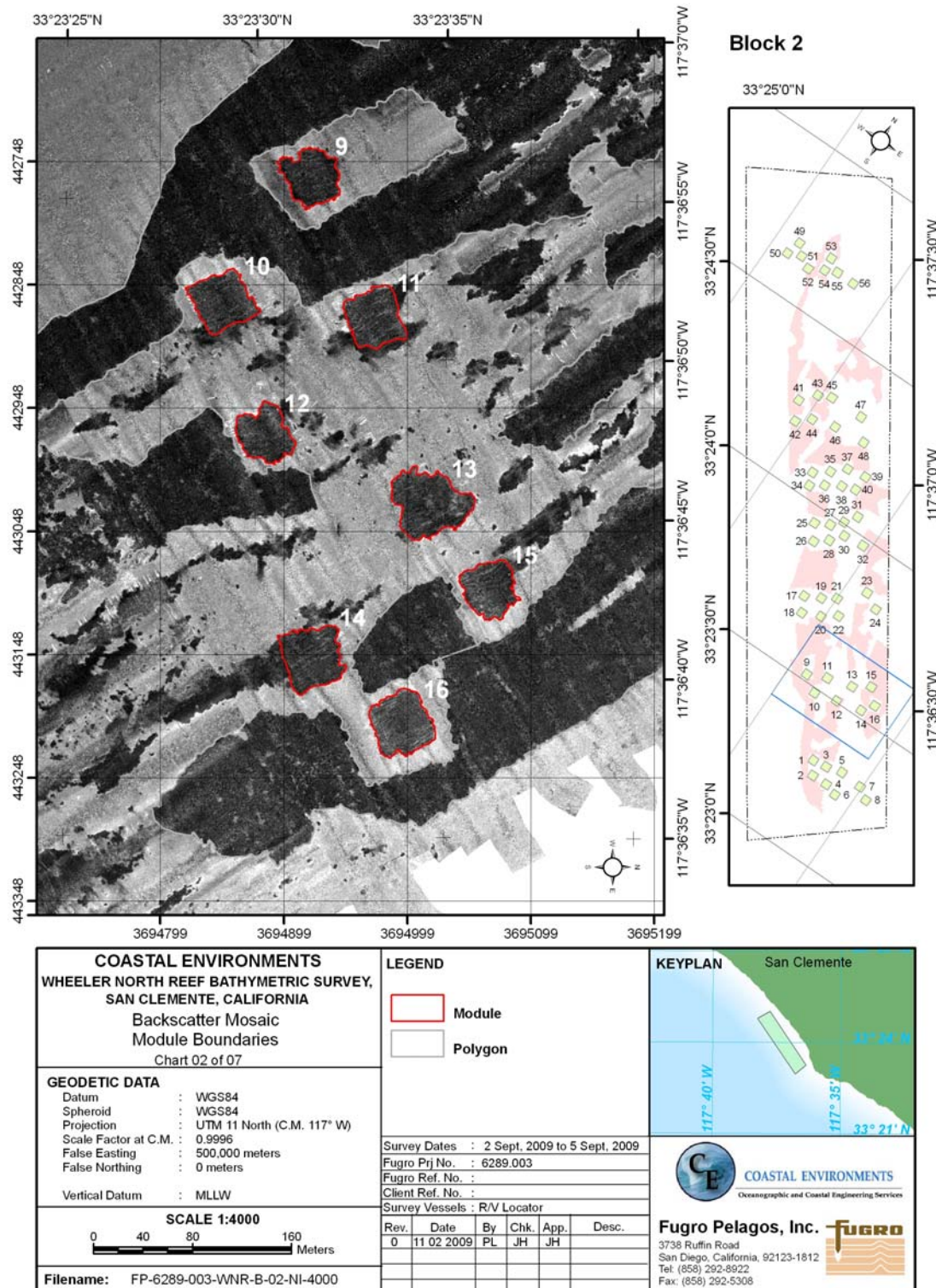
**APPENDIX F**

**BOUNDARIES FROM BACKSCATTER MOSAICS FOR MODULE BLOCKS 1-7  
(SEPTEMBER 2009 MULTIBEAM SURVEY)**



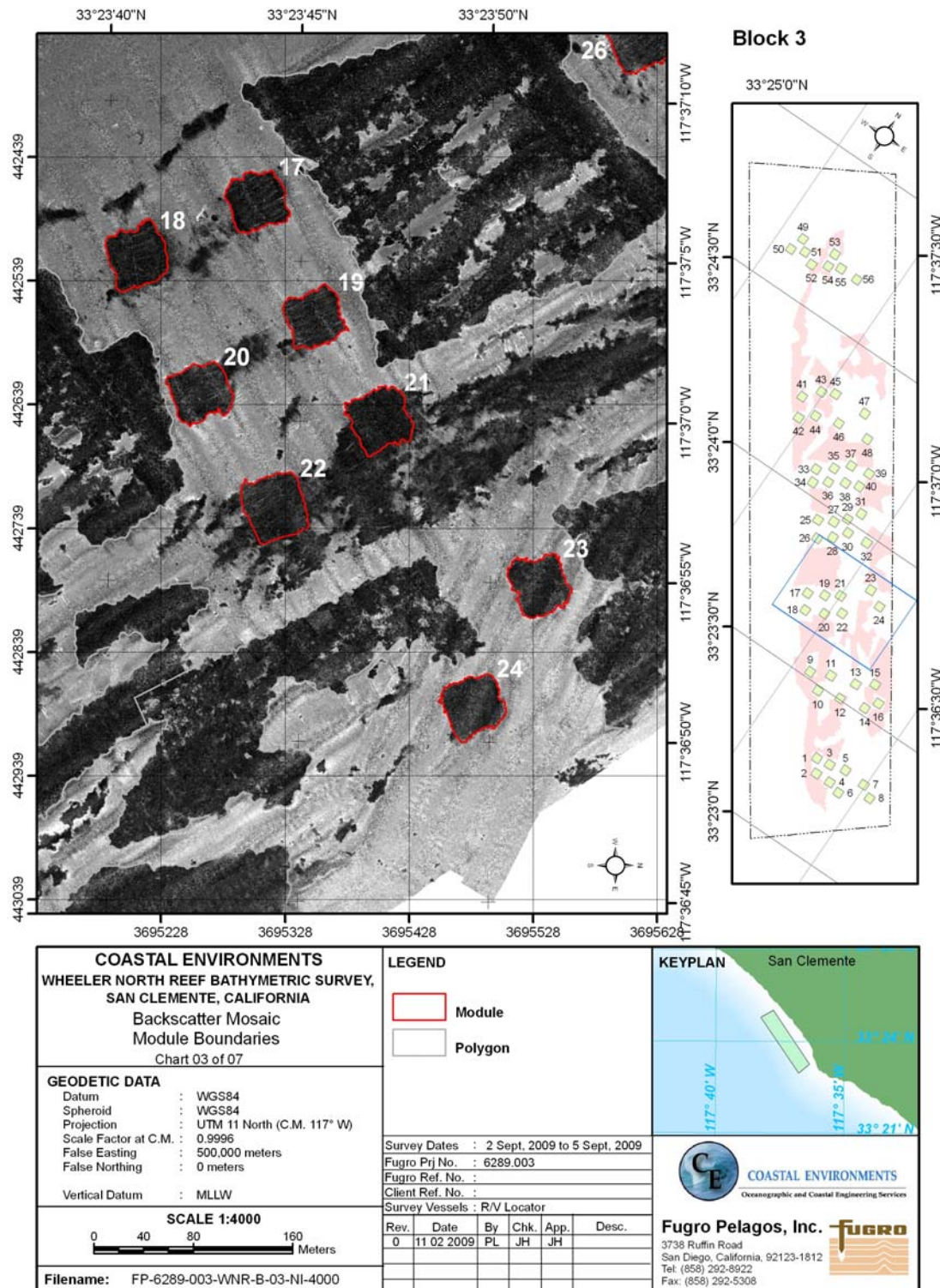
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**Figure F-1. Block 1 module boundaries from backscatter mosaics (September 2009 multibeam survey).**

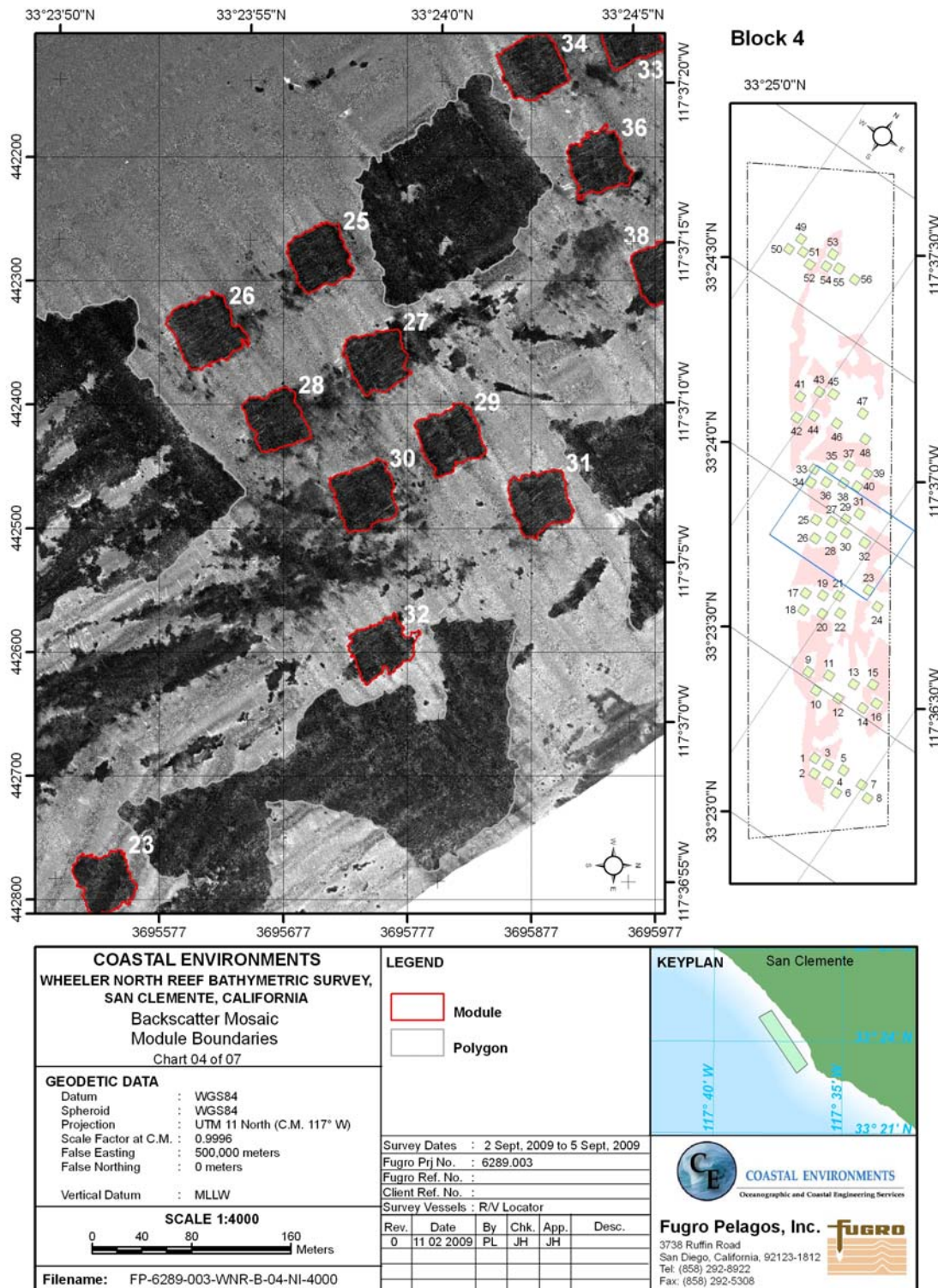


**Figure F-2. Block 2 module boundaries from backscatter mosaics (September 2009 multibeam survey).**



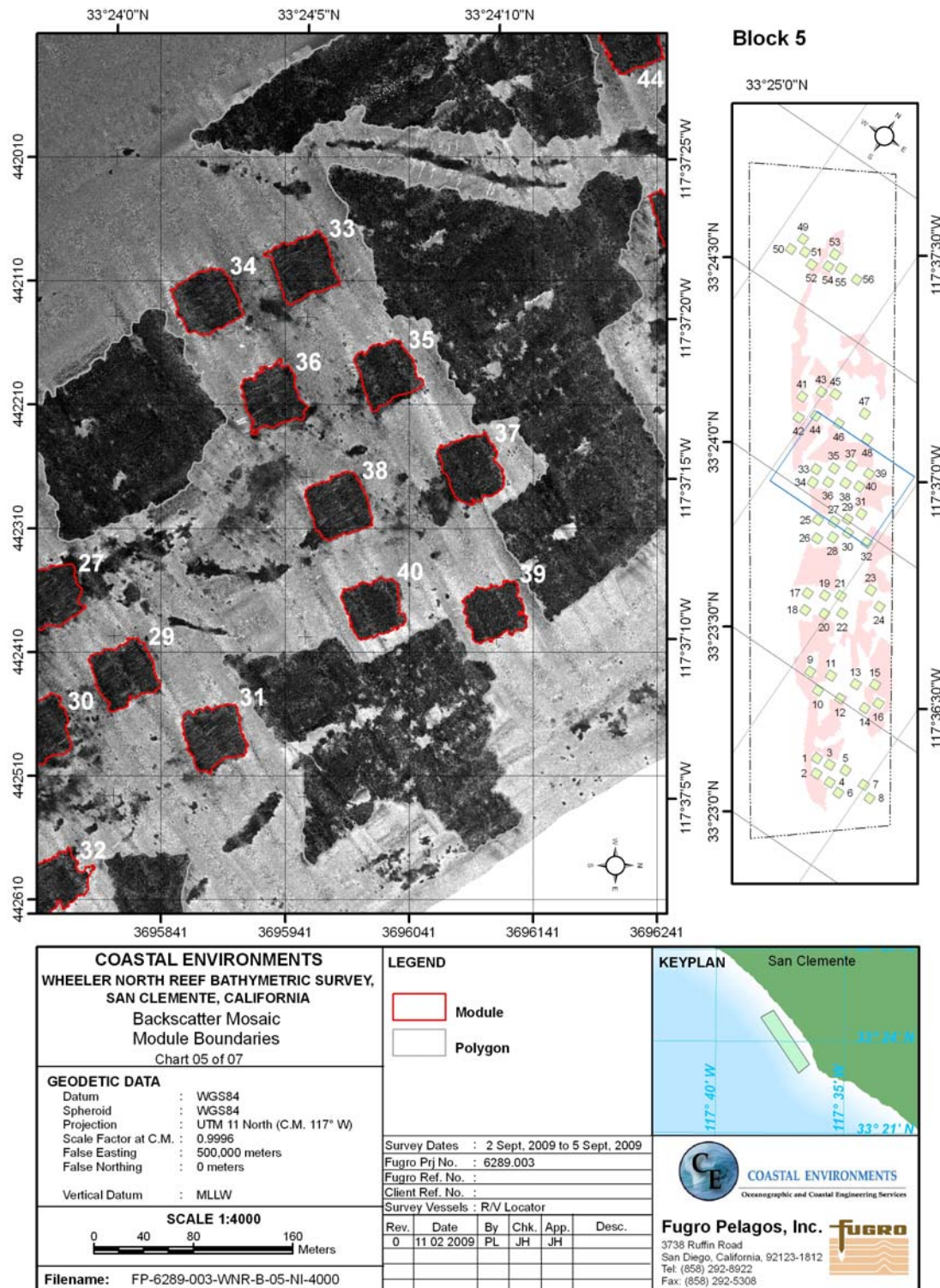


**Figure F-3. Block 3 module boundaries from backscatter mosaics (September 2009 multibeam survey).**



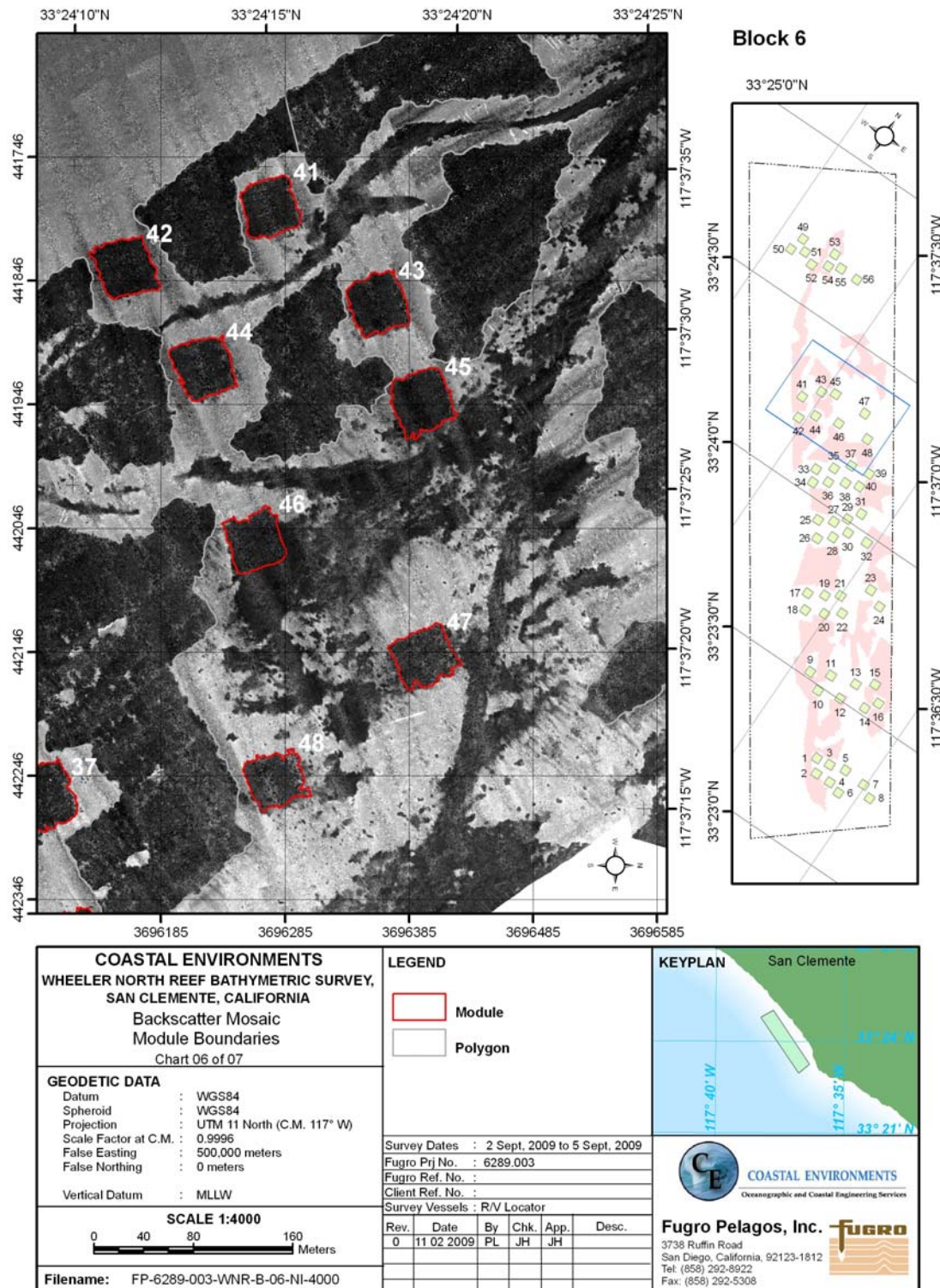
**Figure F-4. Block 4 module boundaries from backscatter mosaics (September 2009 multibeam survey).**





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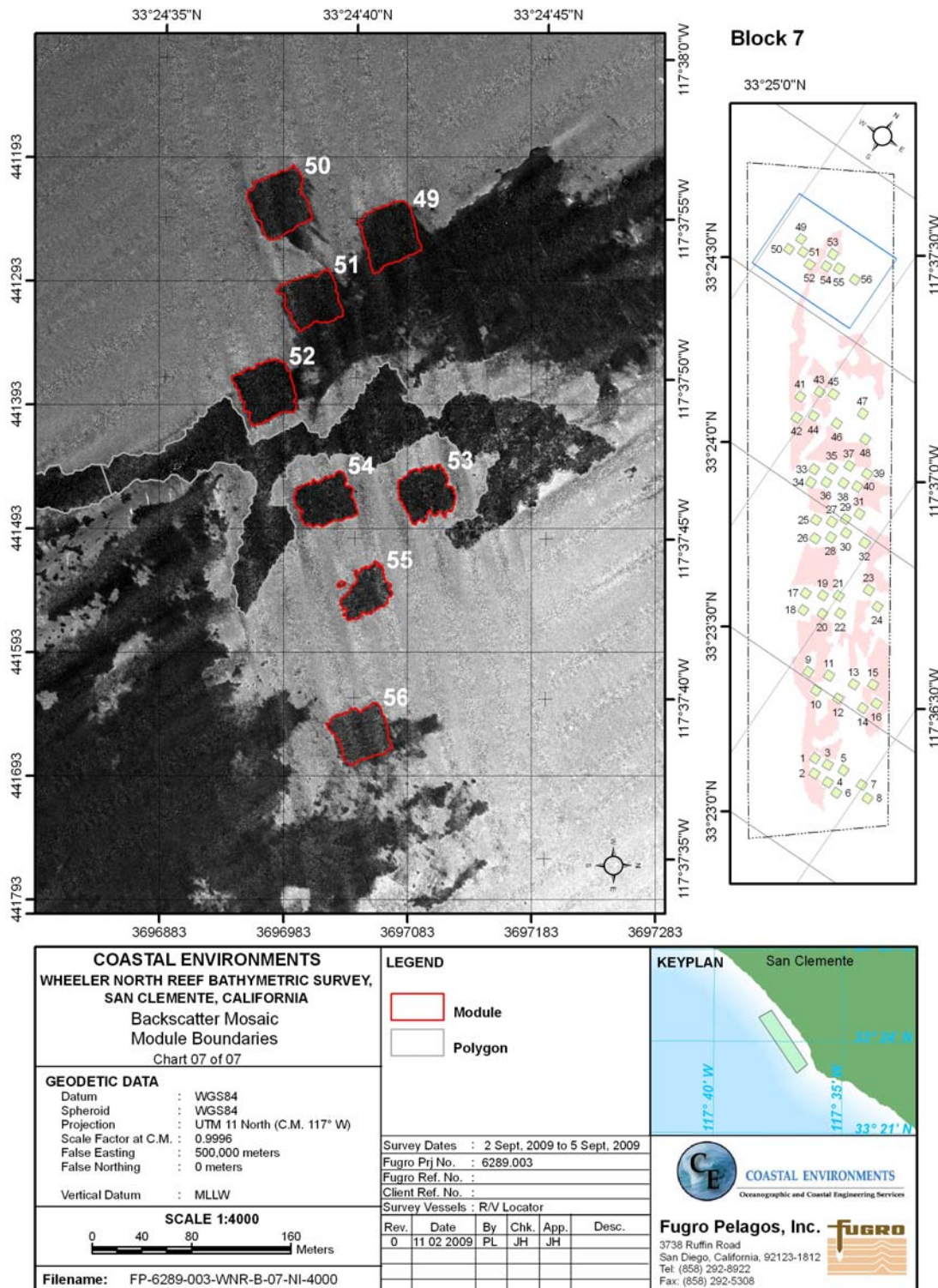
**Figure F-5. Block 5 module boundaries from backscatter mosaics (September 2009 multibeam survey).**



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**Figure F-6. Block 6 module boundaries from backscatter mosaics (September 2009 multibeam survey).**





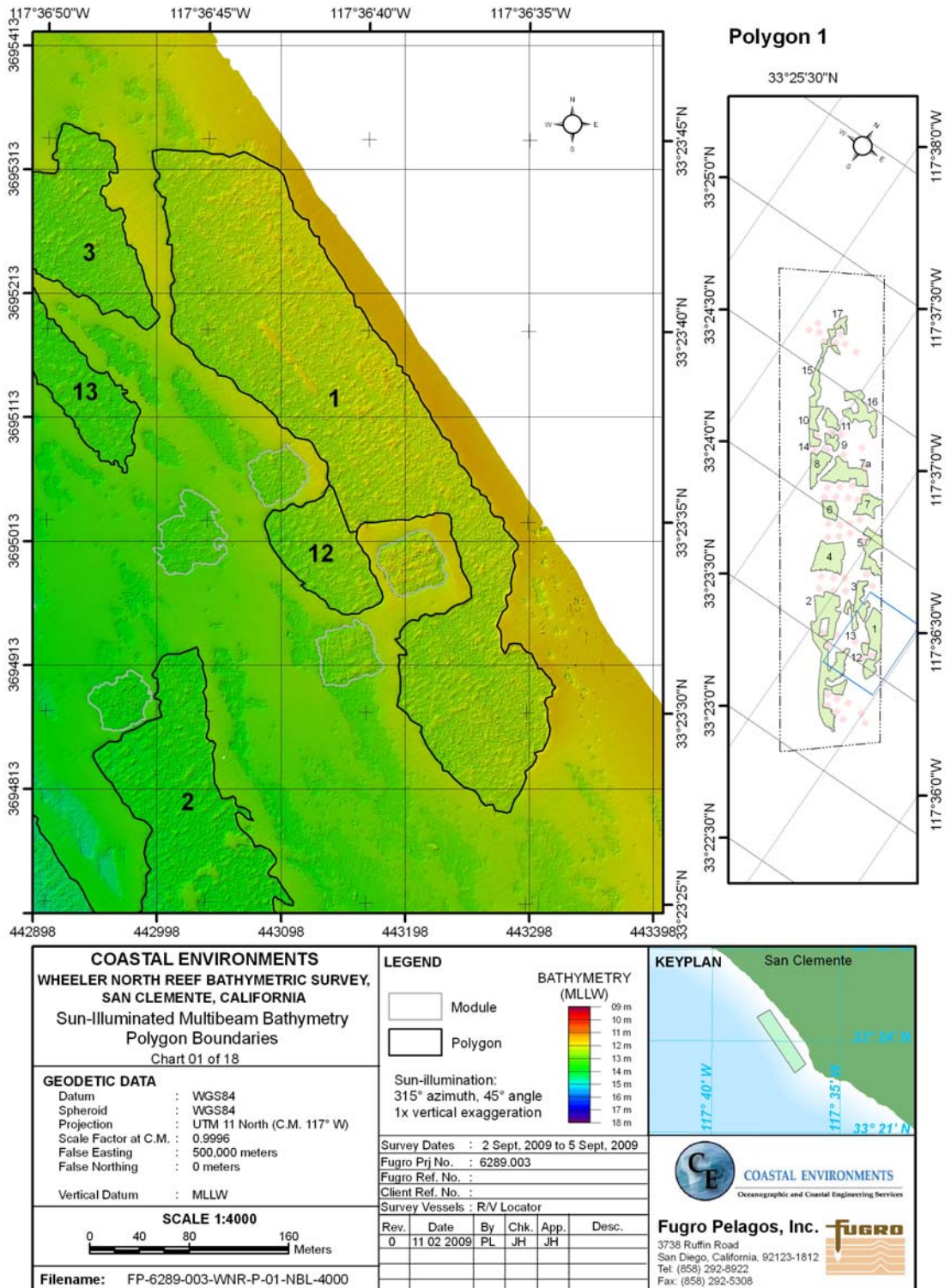
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**Figure F-7. Block 7 module boundaries from backscatter mosaics (September 2009 multibeam survey).**

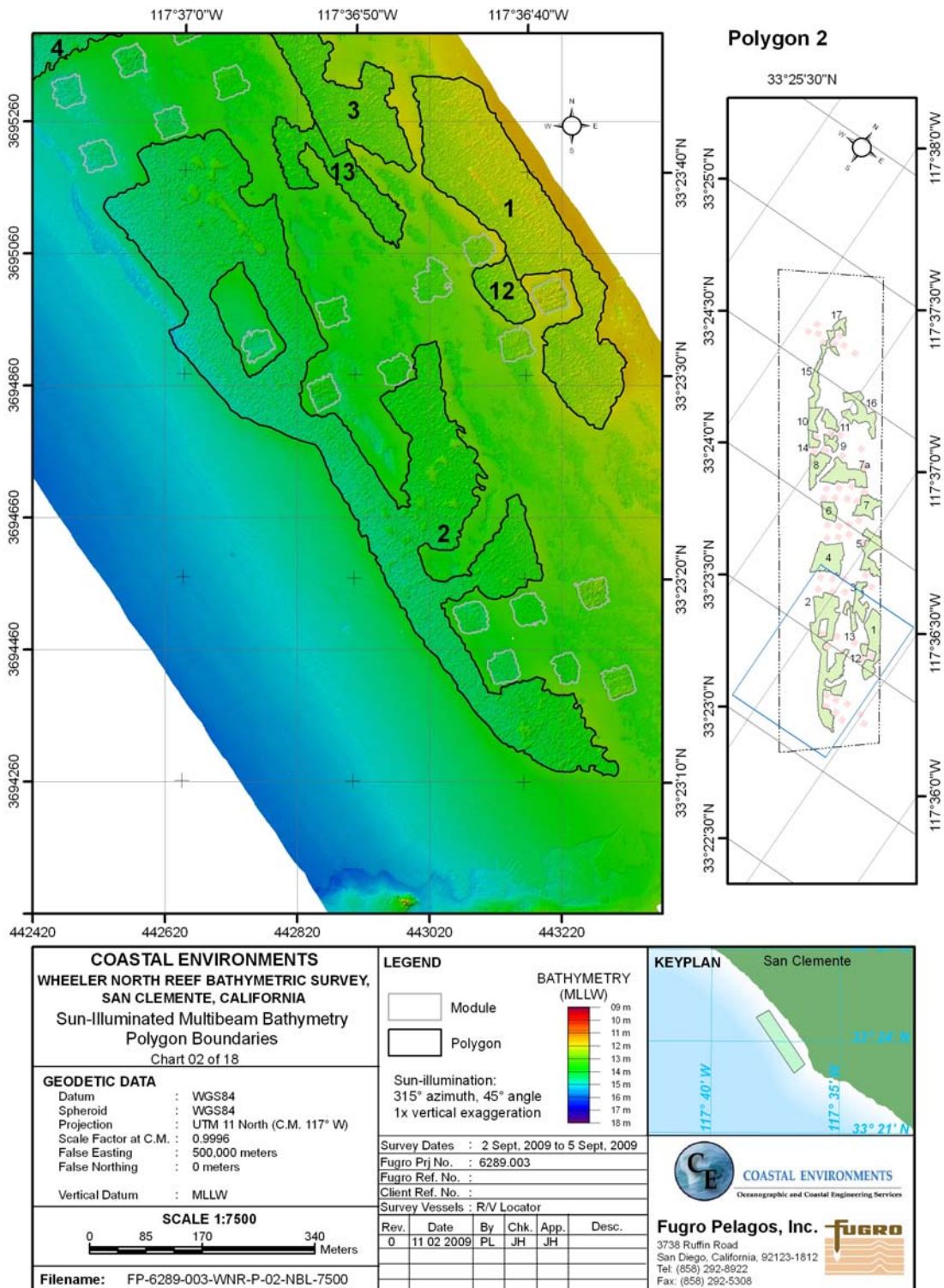


**APPENDIX G**

**BOUNDARIES FROM BATHYMETRIC DATA FOR POLYGONS 1-17  
(SEPTEMBER 2009 MULTIBEAM SURVEY)**



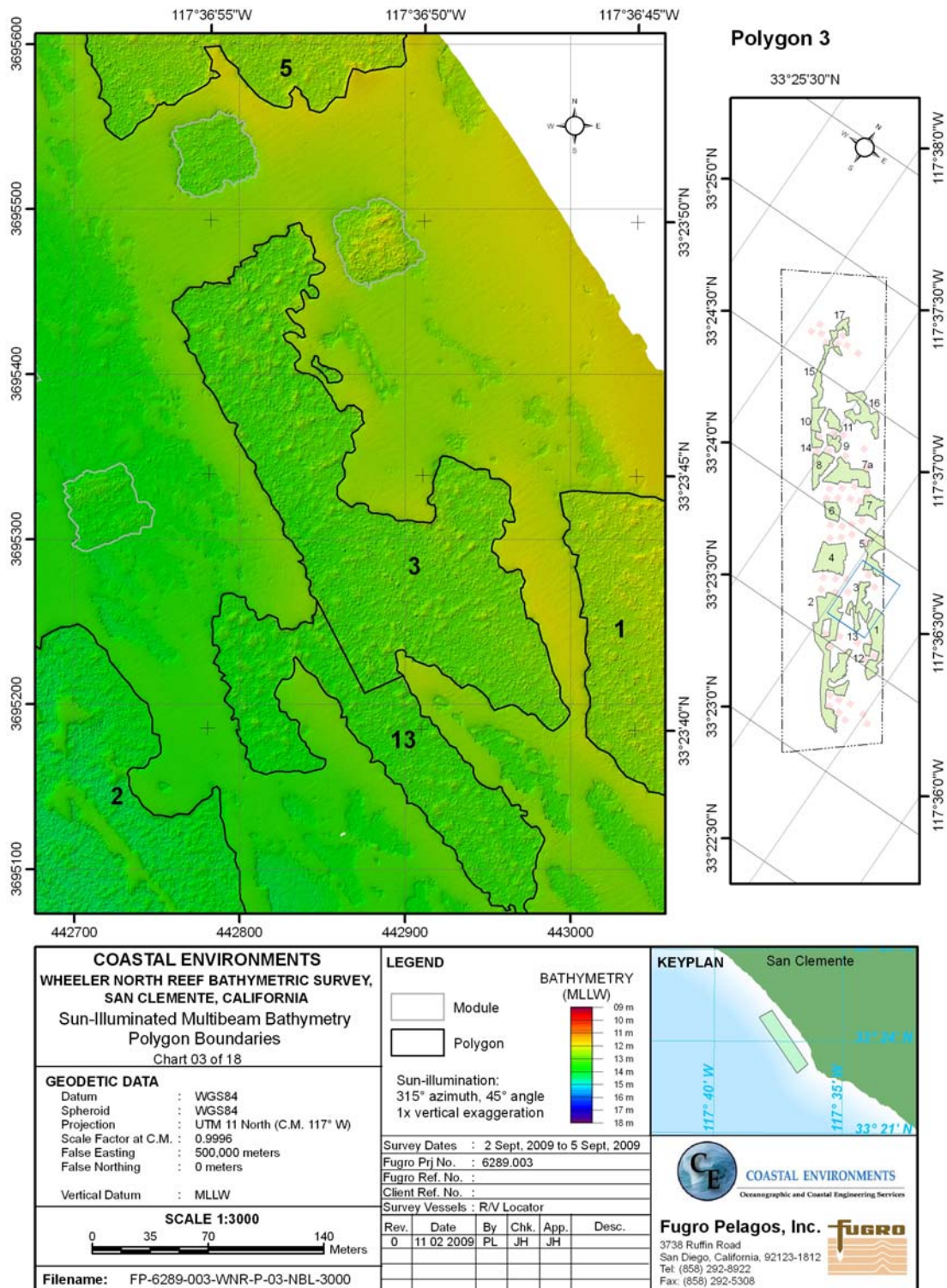
**Figure G-1. Polygon 1 boundary from bathymetric data interpretation (September 2009 multibeam survey).**



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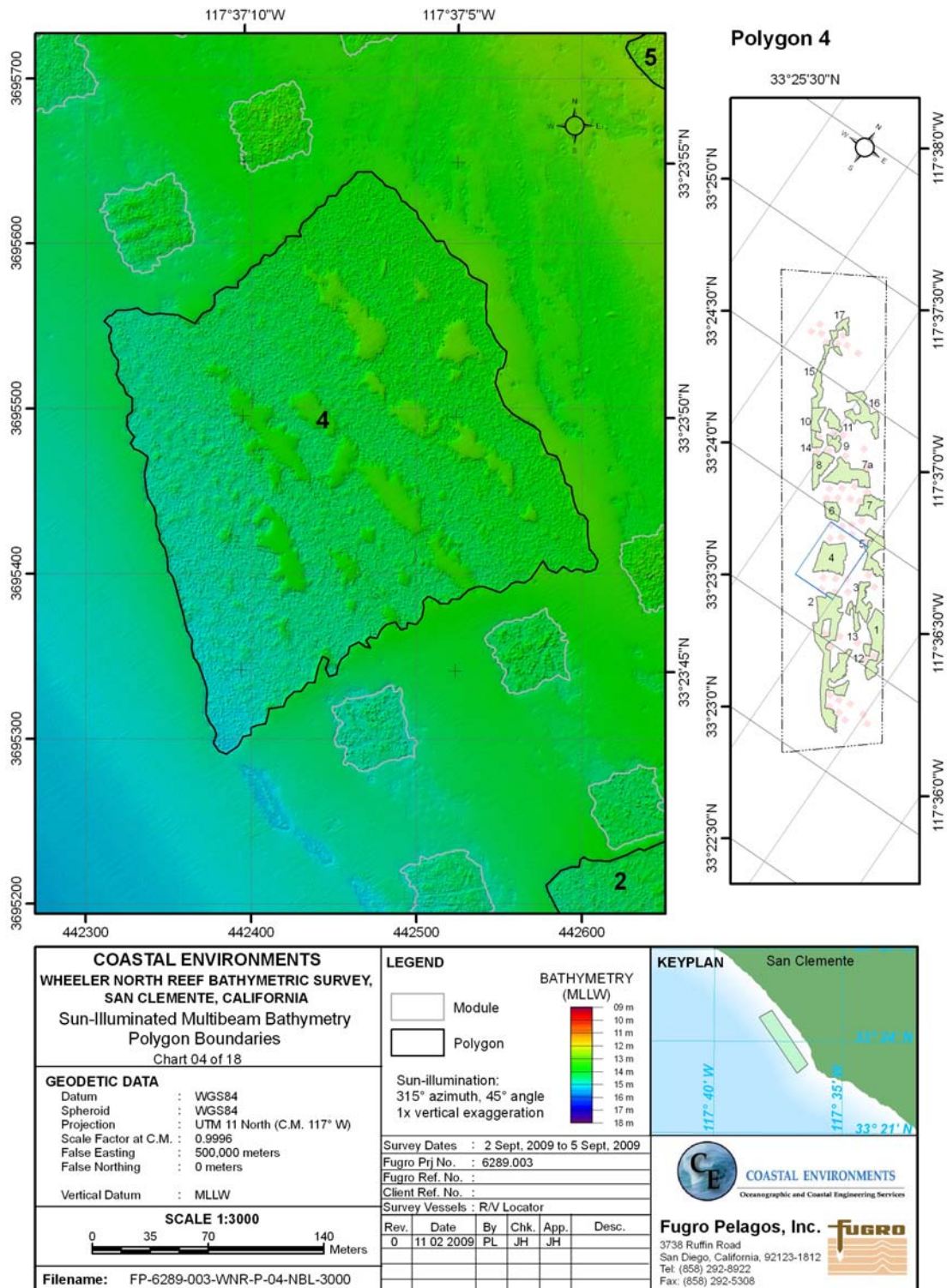
**Figure G-2. Polygon 2 boundary from bathymetric data interpretation (September 2009 multibeam survey).**





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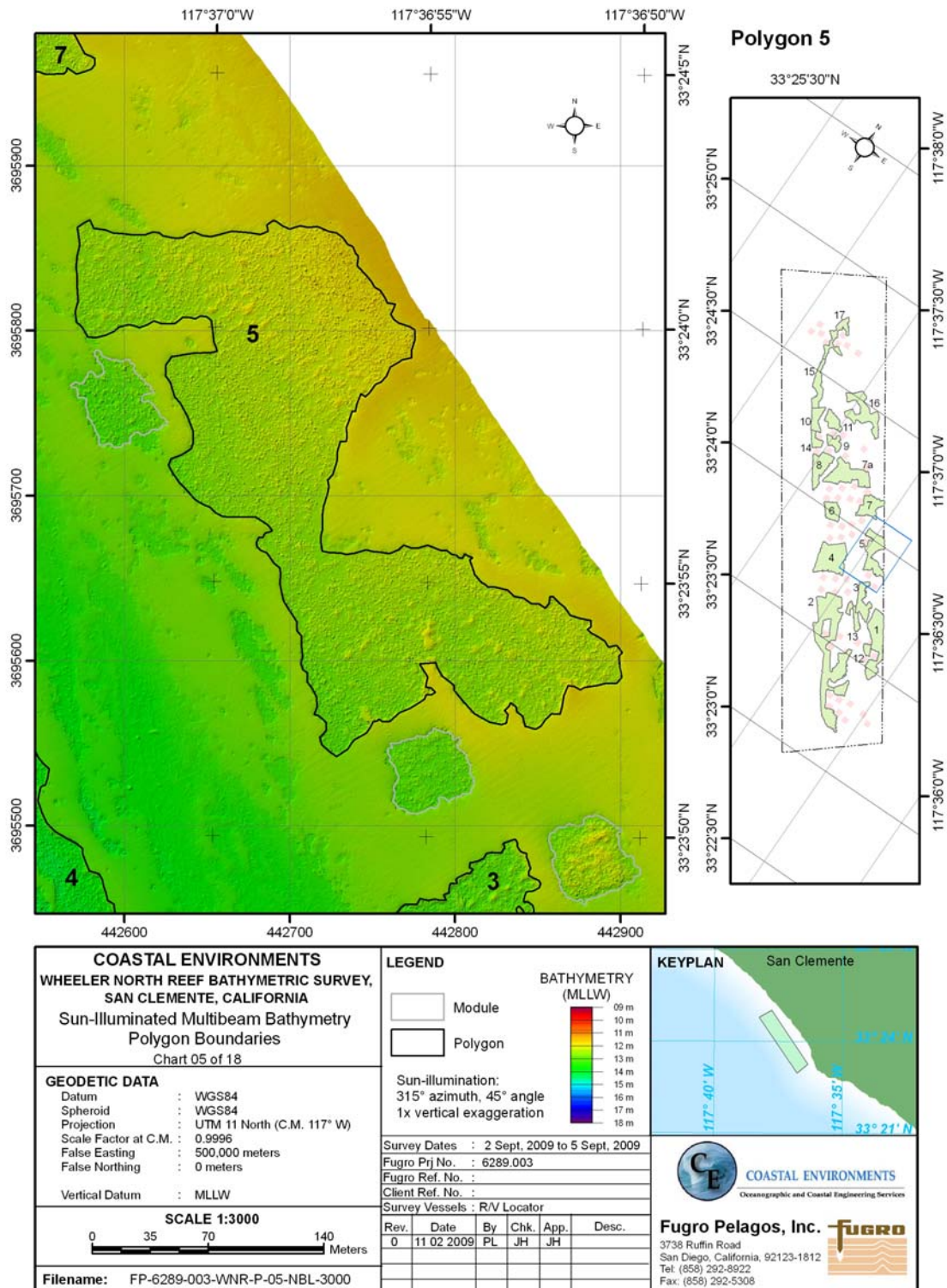
**Figure G-3. Polygon 3 boundary from bathymetric data interpretation (September 2009 multibeam survey).**



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**Figure G-4. Polygon 4 boundary from bathymetric data interpretation (September 2009 multibeam survey).**

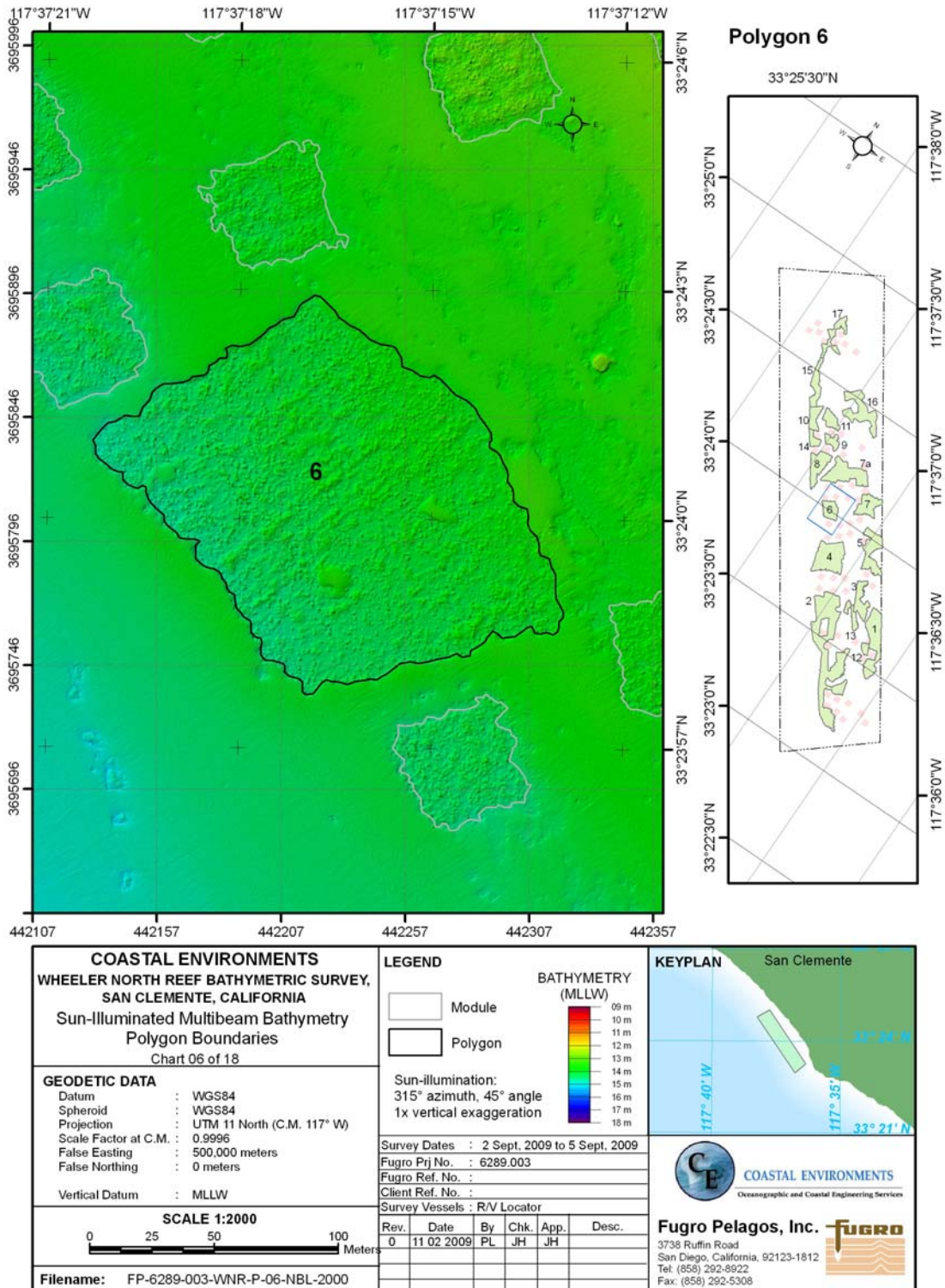




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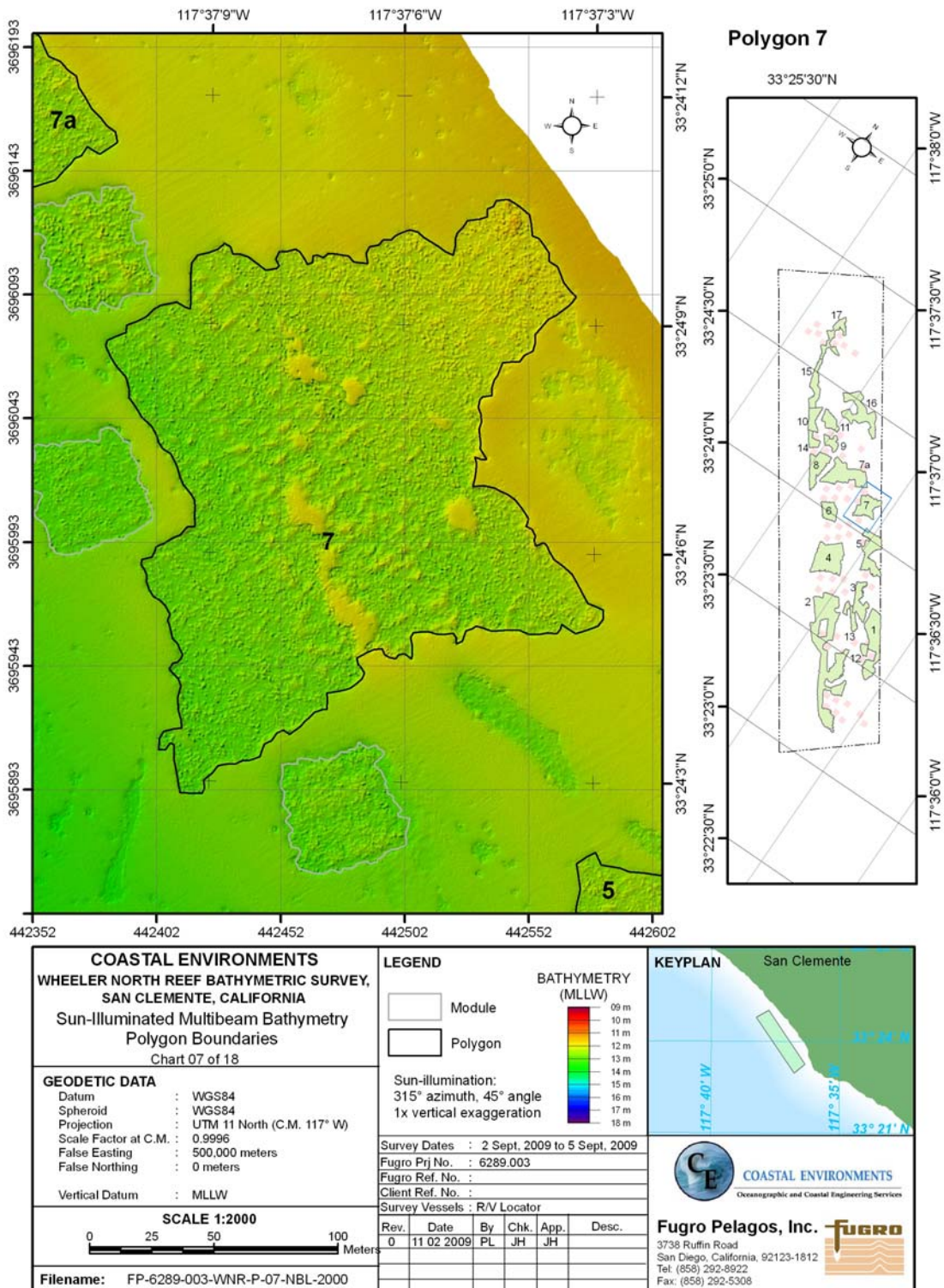
**Figure G-5. Polygon 5 boundary from bathymetric data interpretation (September 2009 multibeam survey).**





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**Figure G-6. Polygon 6 boundary from bathymetric data interpretation (September 2009 multibeam survey).**

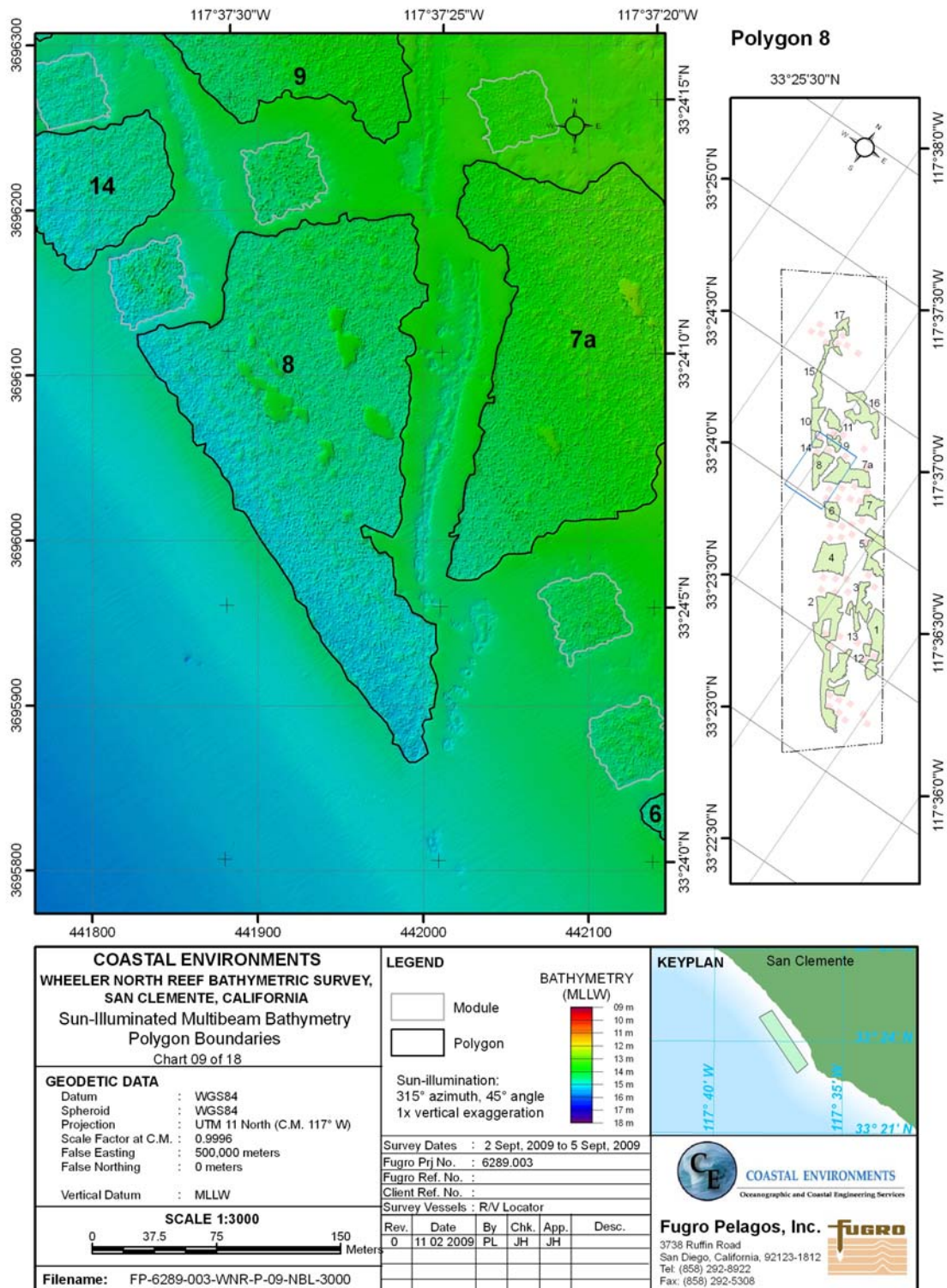


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**Figure G-7. Polygon 7 boundary from bathymetric data interpretation (September 2009 multibeam survey).**



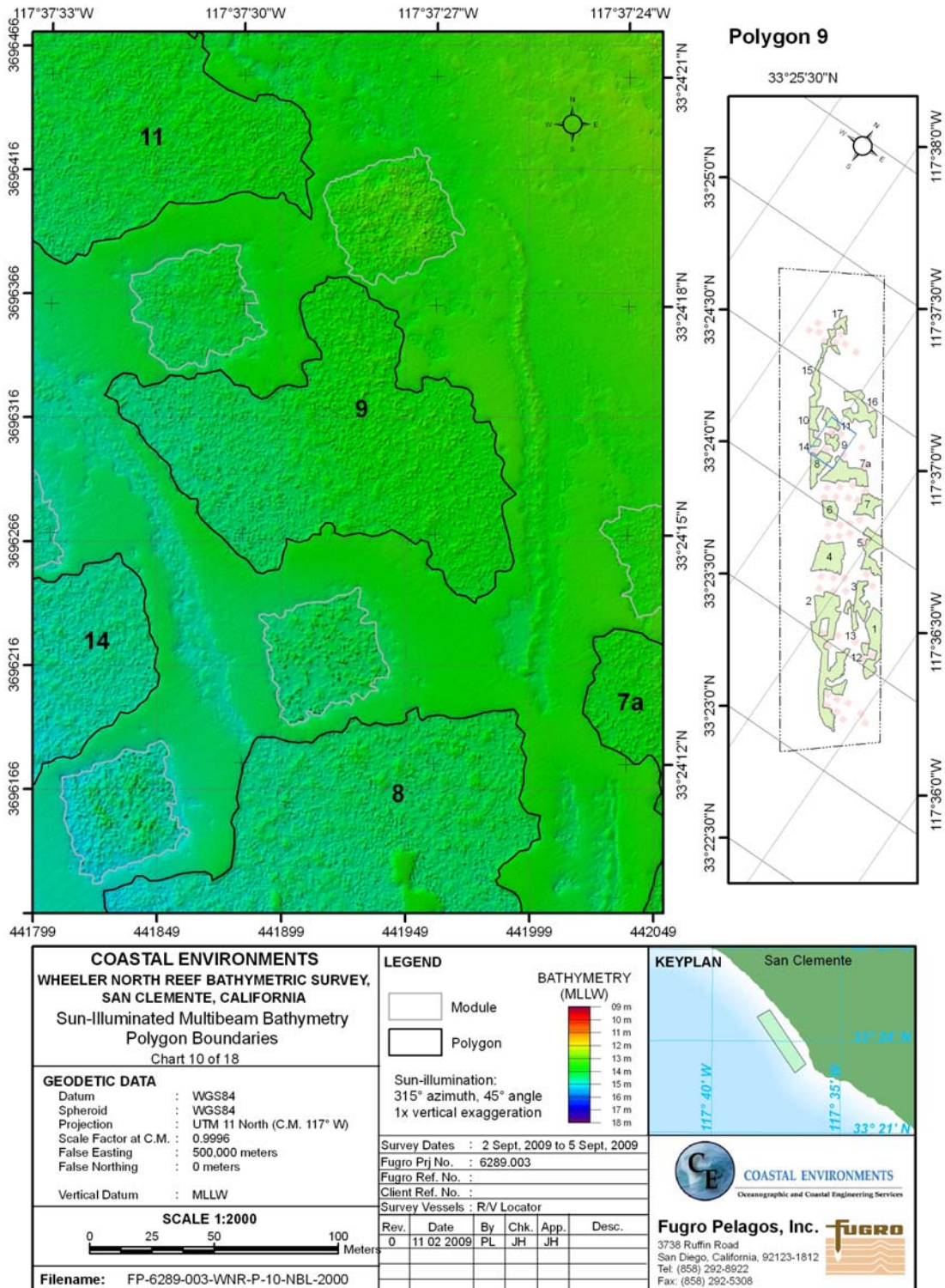




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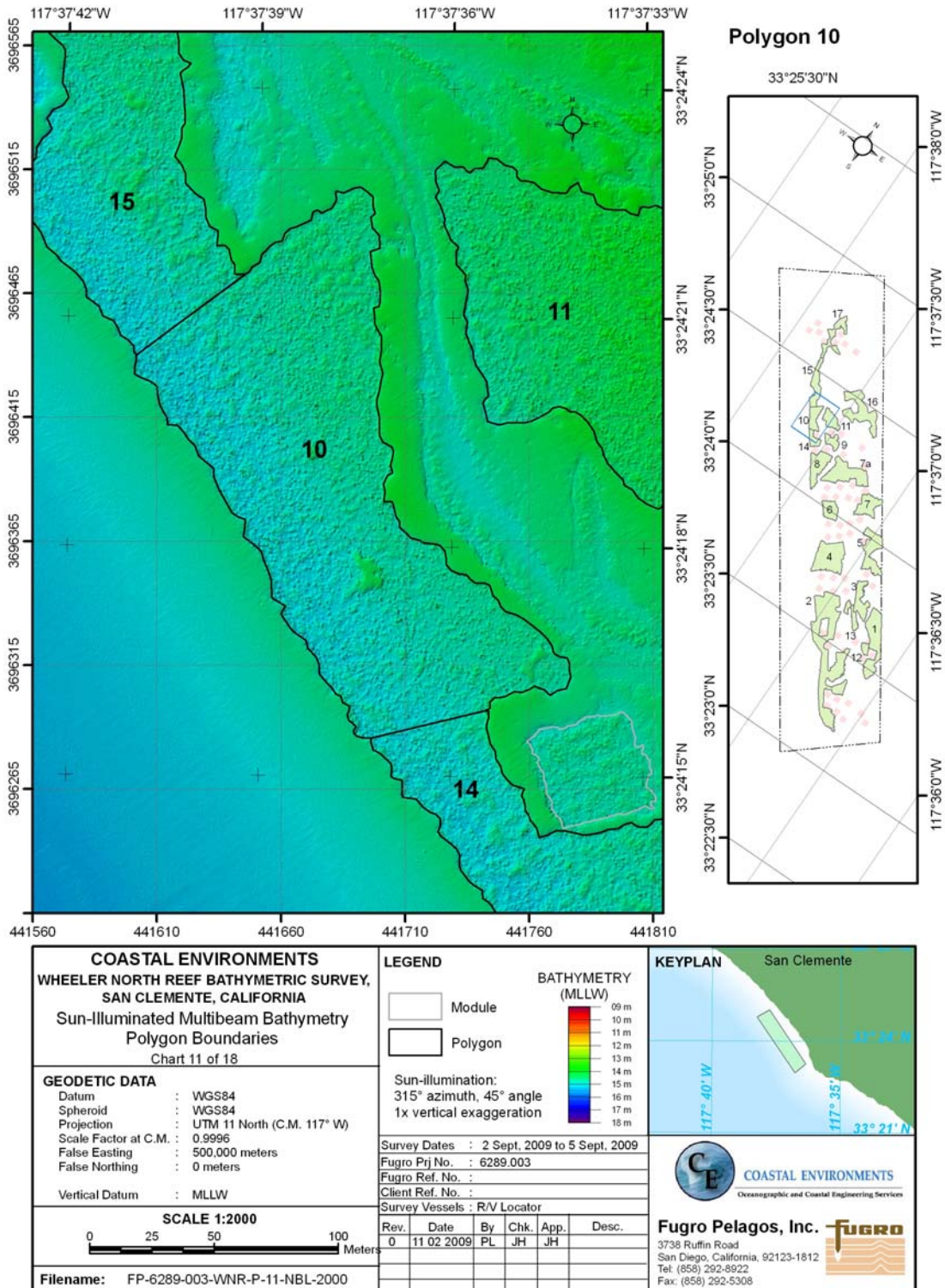
**Figure G-9. Polygon 8 boundary from bathymetric data interpretation (September 2009 multibeam survey).**





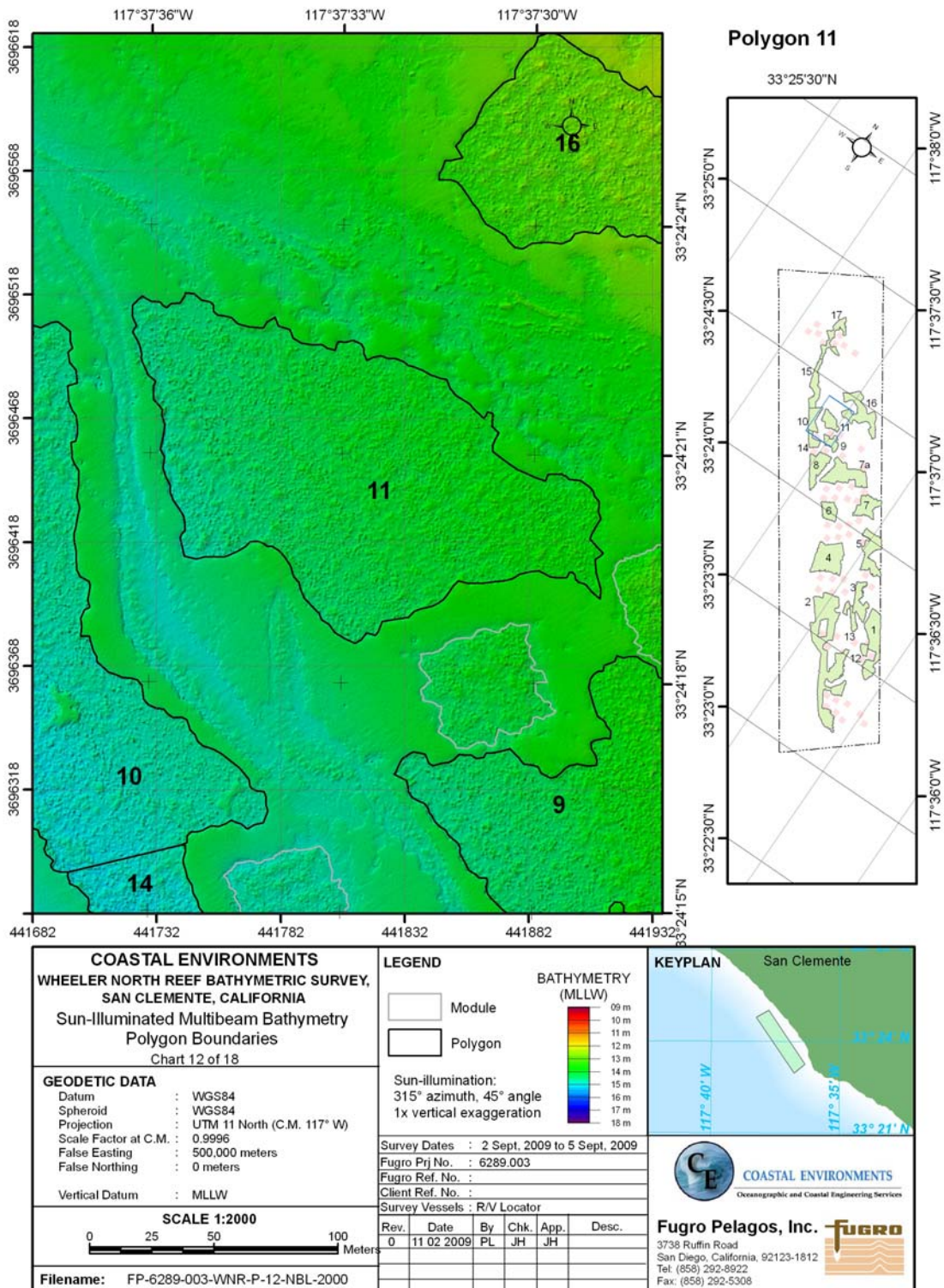
**Figure G-10. Polygon 9 boundary from bathymetric data interpretation (September 2009 multibeam survey).**





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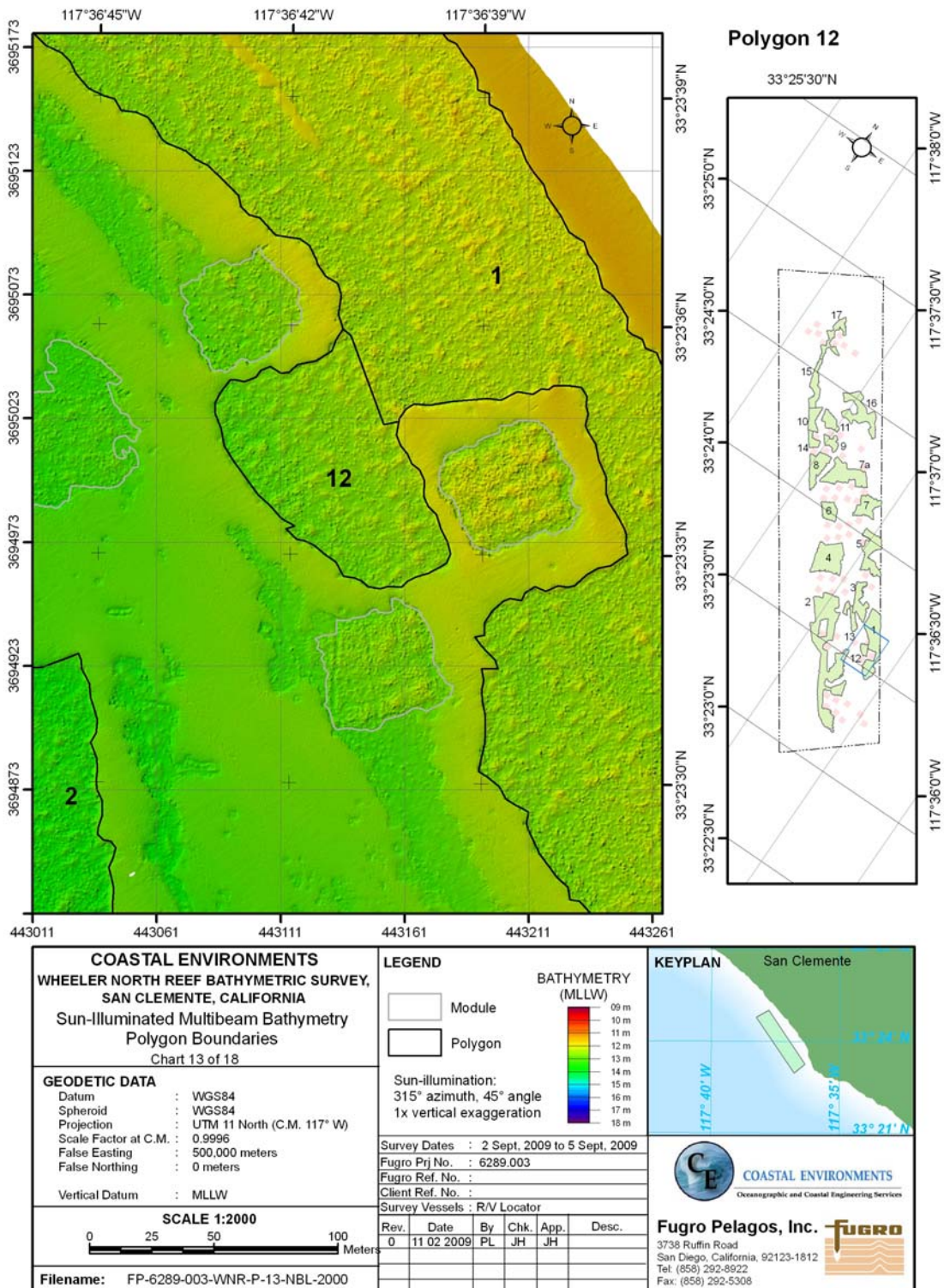
**Figure G-11. Polygon 10 boundary from bathymetric data interpretation (September 2009 multibeam survey).**



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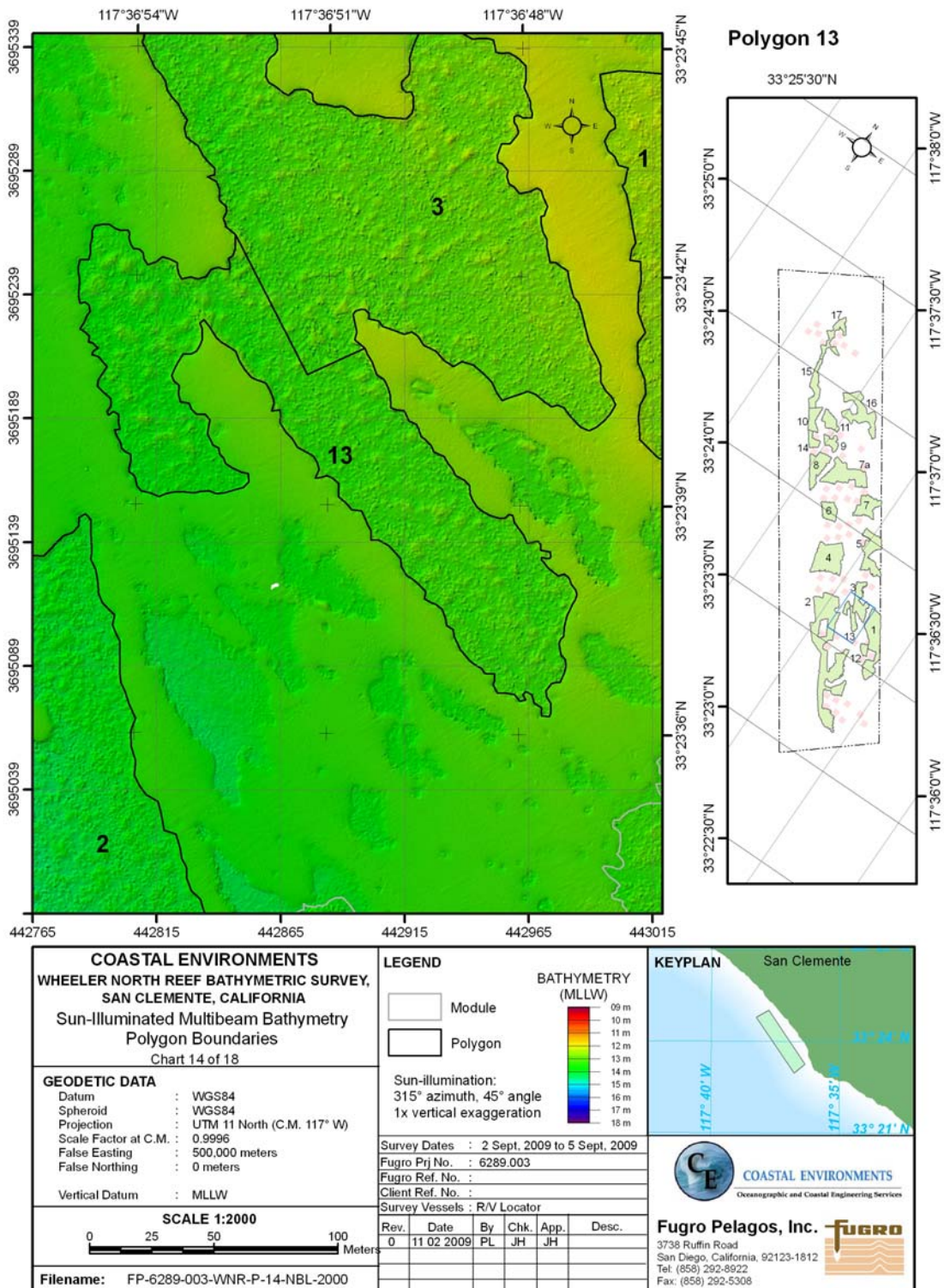
**Figure G-12. Polygon 11 boundary from bathymetric data interpretation (September 2009 multibeam survey).**





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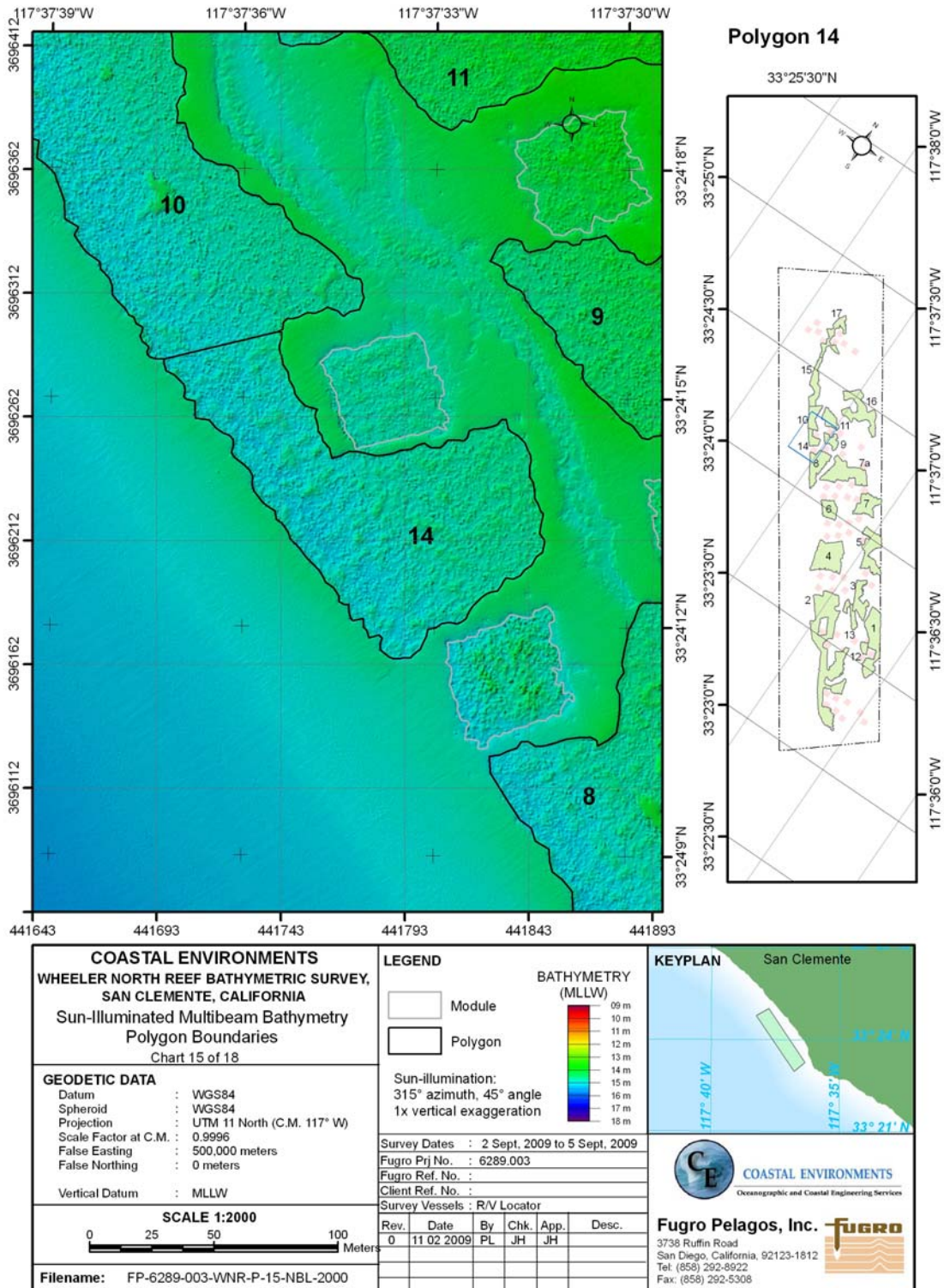
**Figure G-13. Polygon 12 boundary from bathymetric data interpretation (September 2009 multibeam survey).**



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**Figure G-14. Polygon 13 boundary from bathymetric data interpretation (September 2009 multibeam survey).**

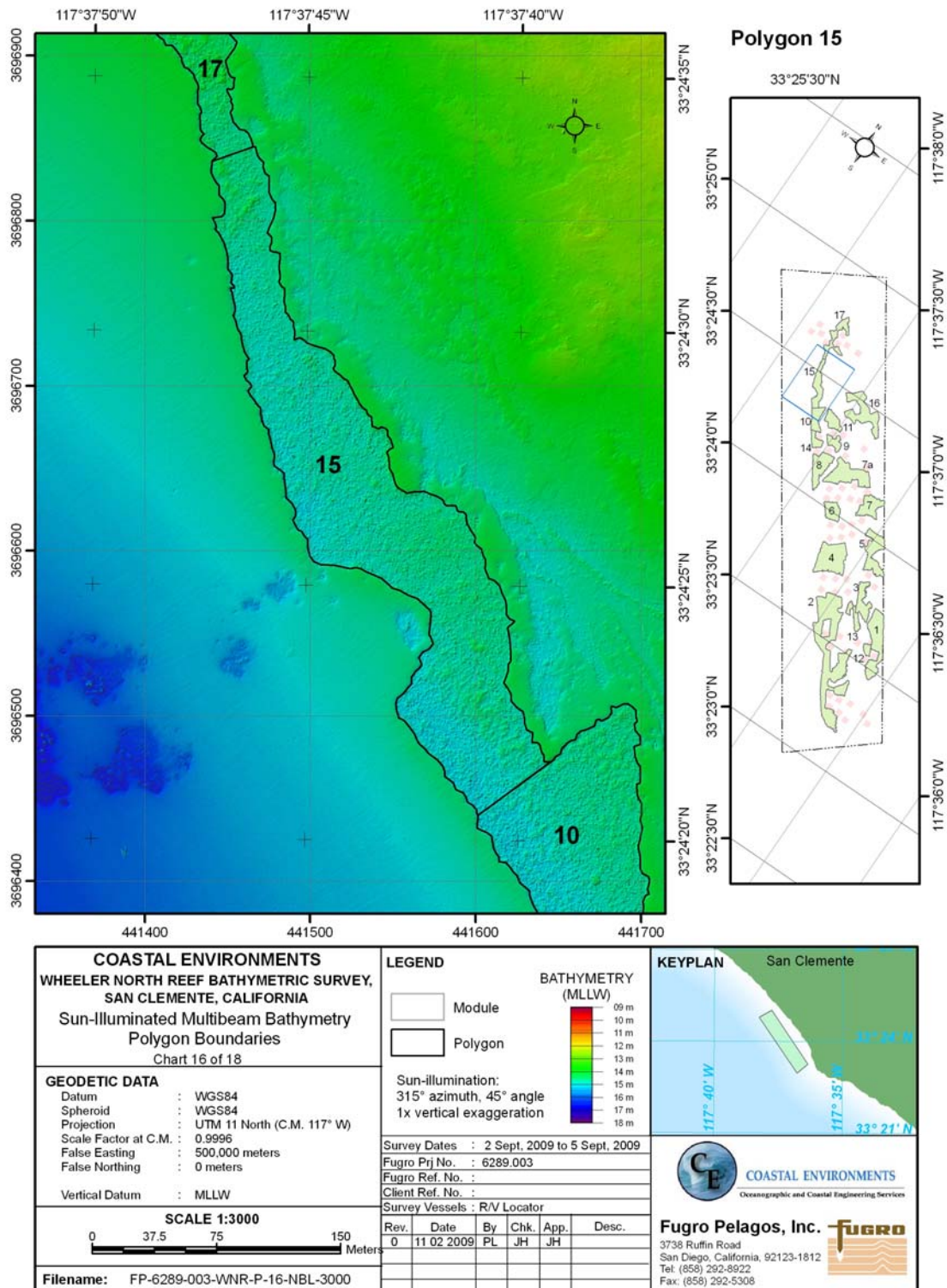




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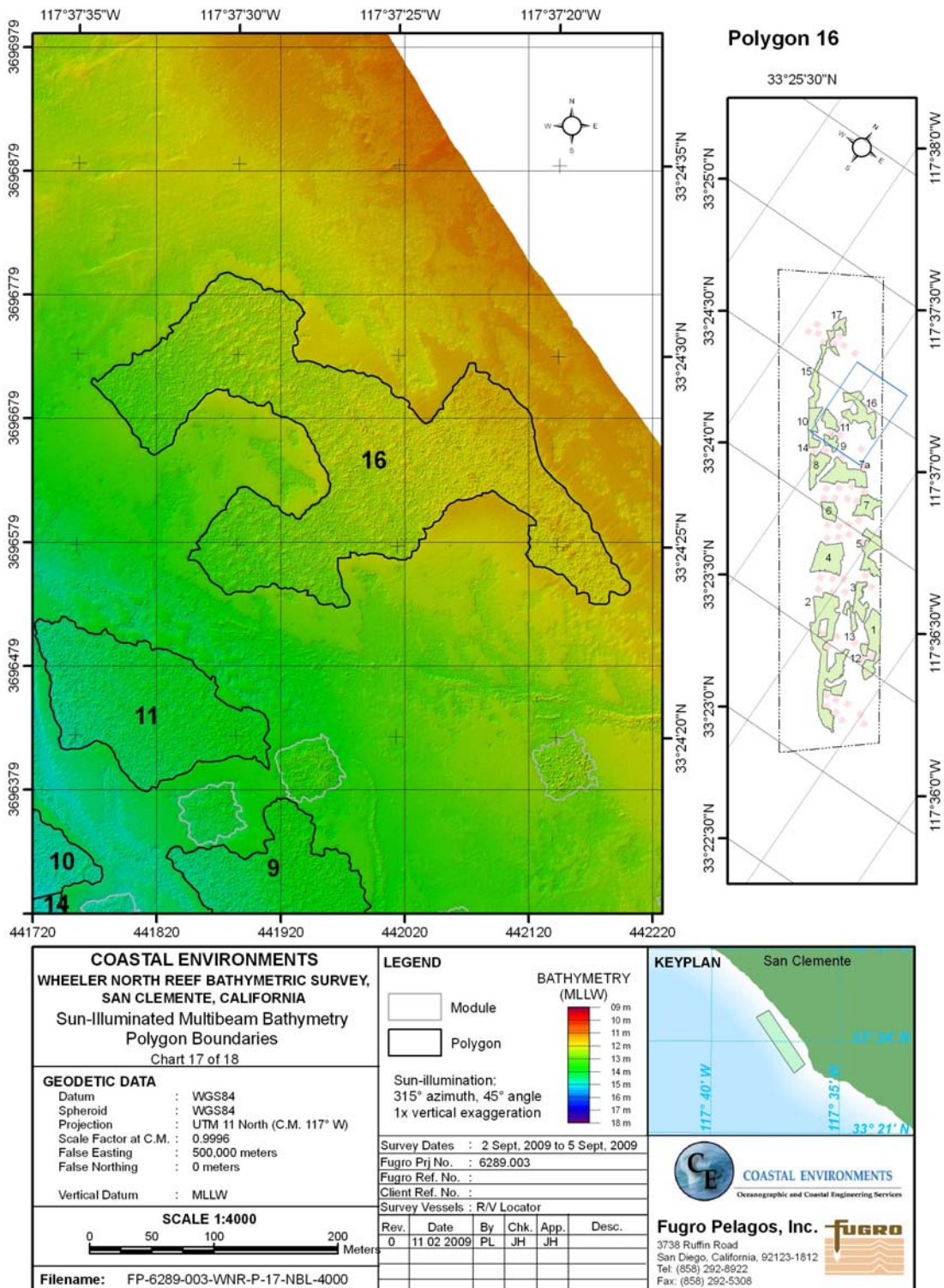
**Figure G-15. Polygon 14 boundary from bathymetric data interpretation (September 2009 multibeam survey).**





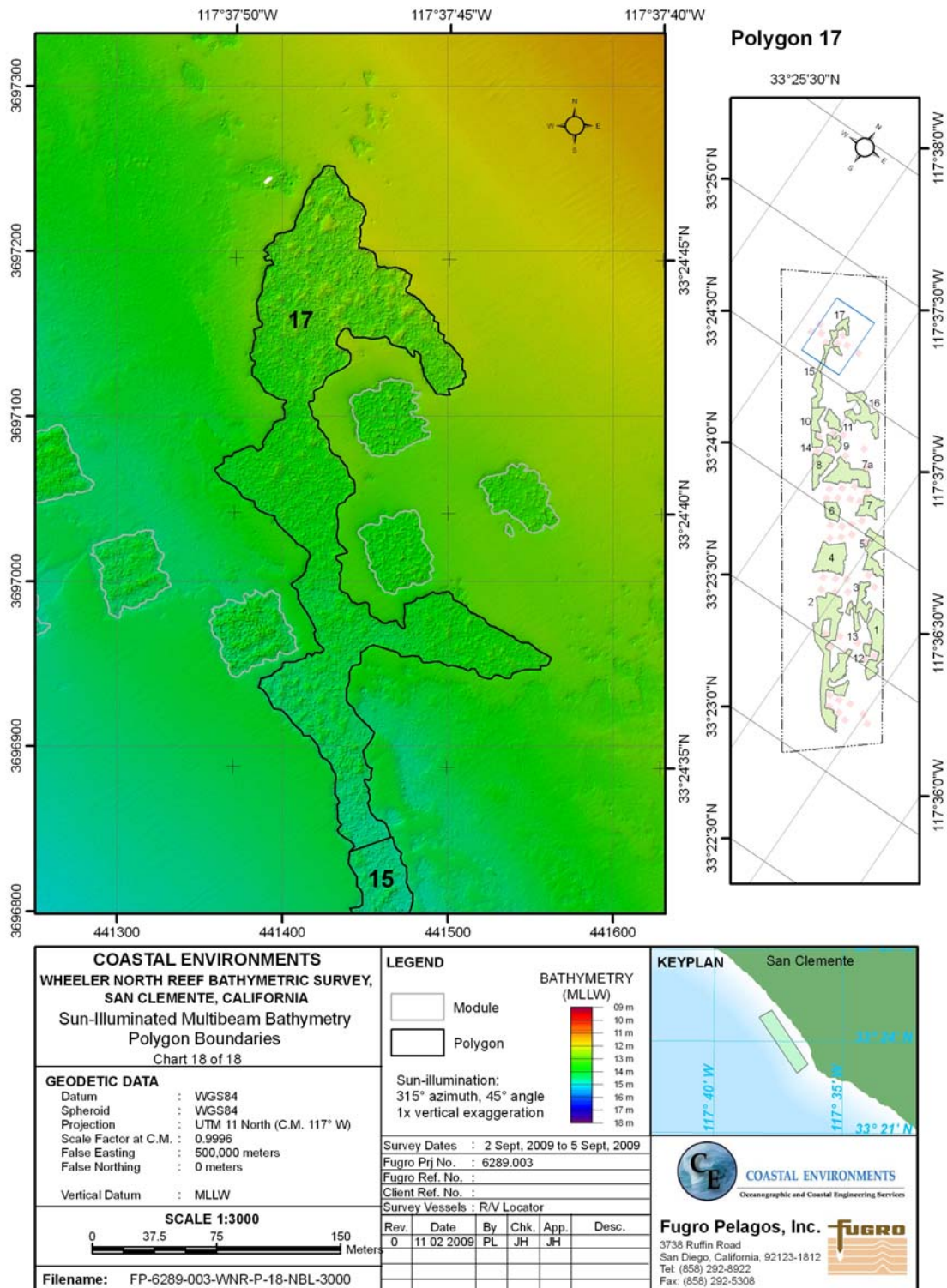
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**Figure G-16. Polygon 15 boundary from bathymetric data interpretation (September 2009 multibeam survey).**



**Figure G-17. Polygon 16 boundary from bathymetric data interpretation (September 2009 multibeam survey).**





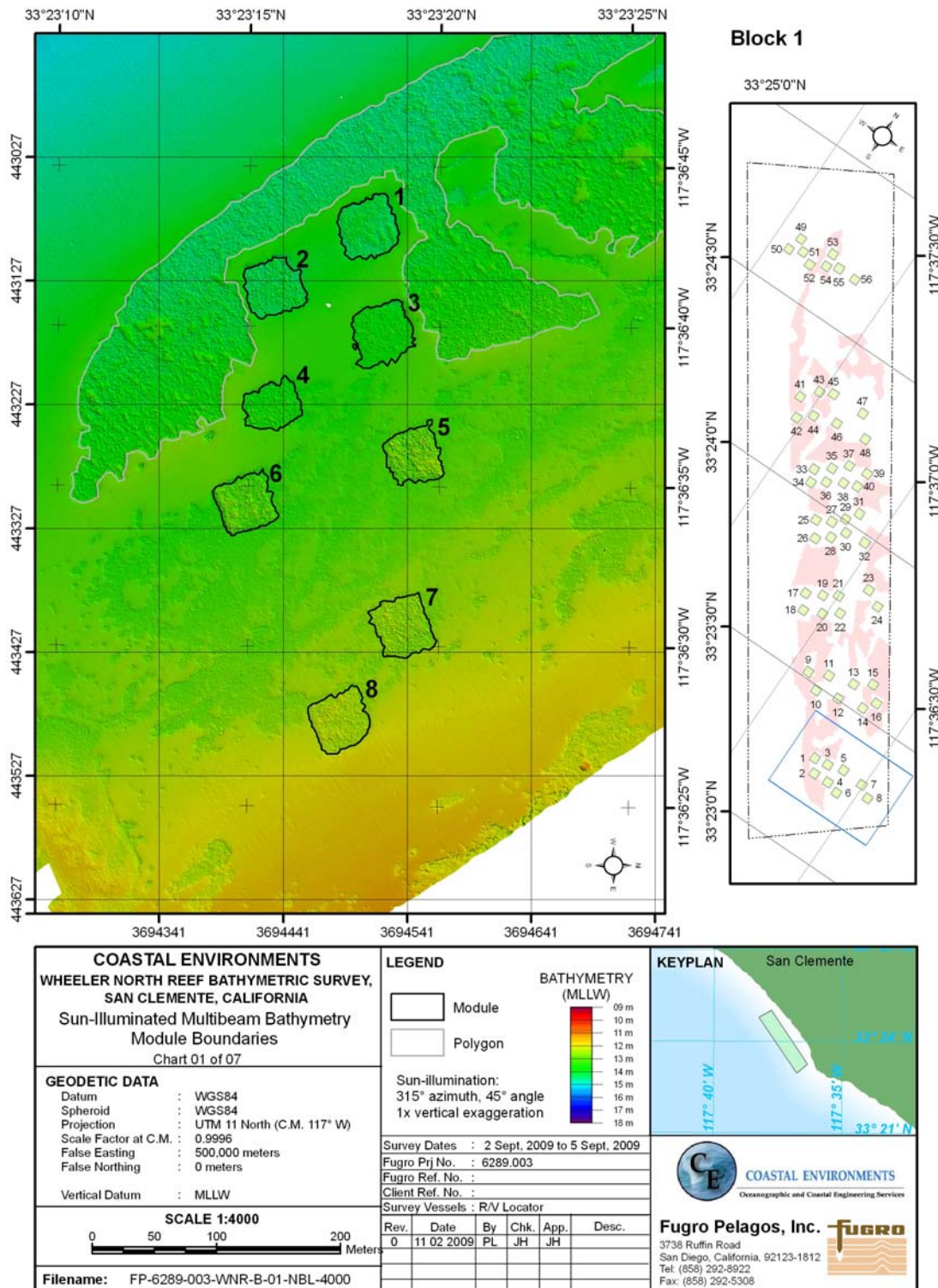
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**Figure G-18. Polygon 17 boundary from bathymetric data interpretation (September 2009 multibeam survey).**

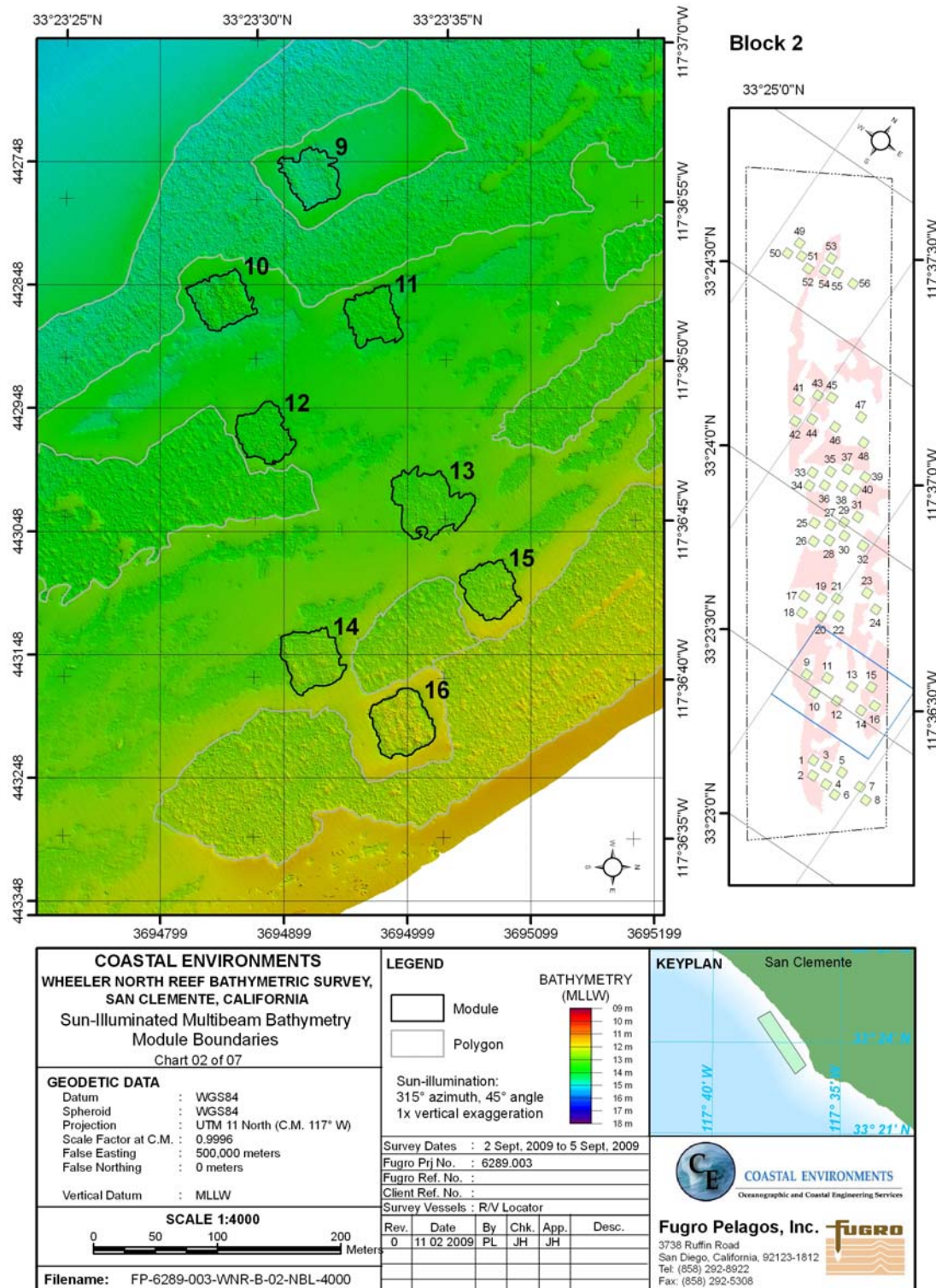
**APPENDIX H**

**BOUNDARIES FROM BATHYMETRIC DATA FOR MODULE BLOCKS 1-7  
(SEPTEMBER 2009 MULTIBEAM SURVEY)**





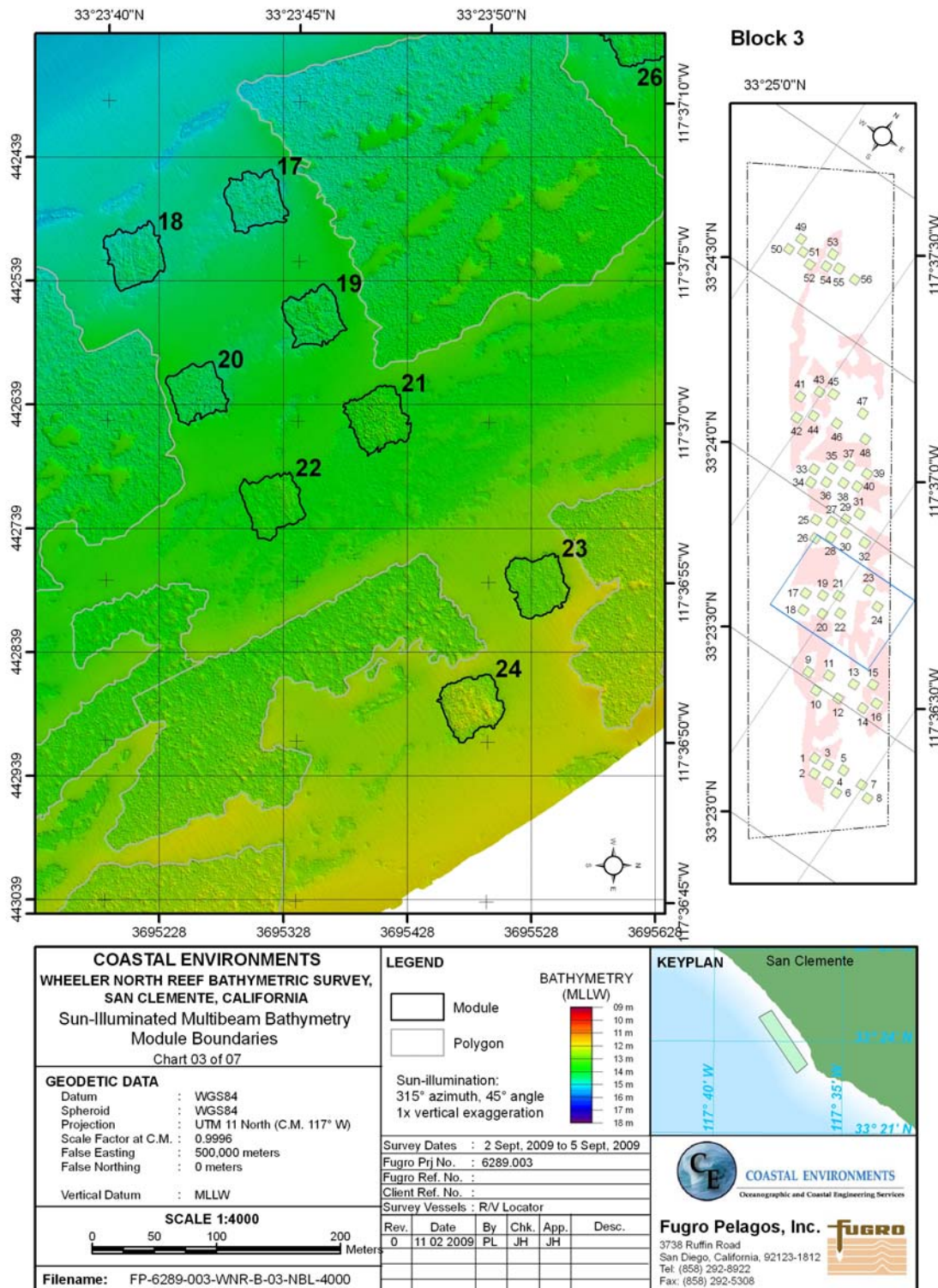
**Figure H-1. Block 1 module boundaries from bathymetric data interpretation (September 2009 multibeam survey).**



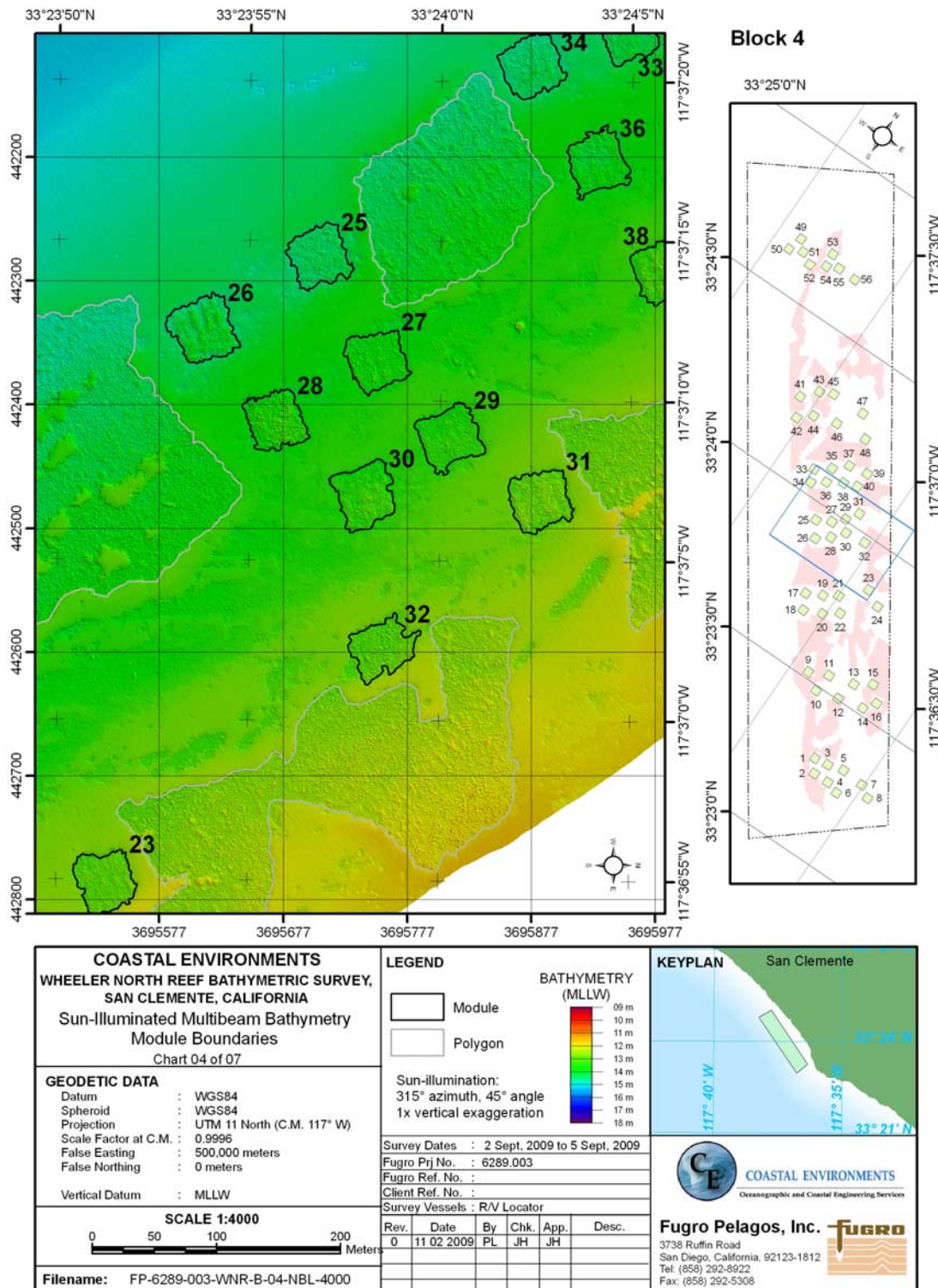
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**Figure H-2. Block 2 module boundaries from bathymetric data interpretation (September 2009 multibeam survey).**



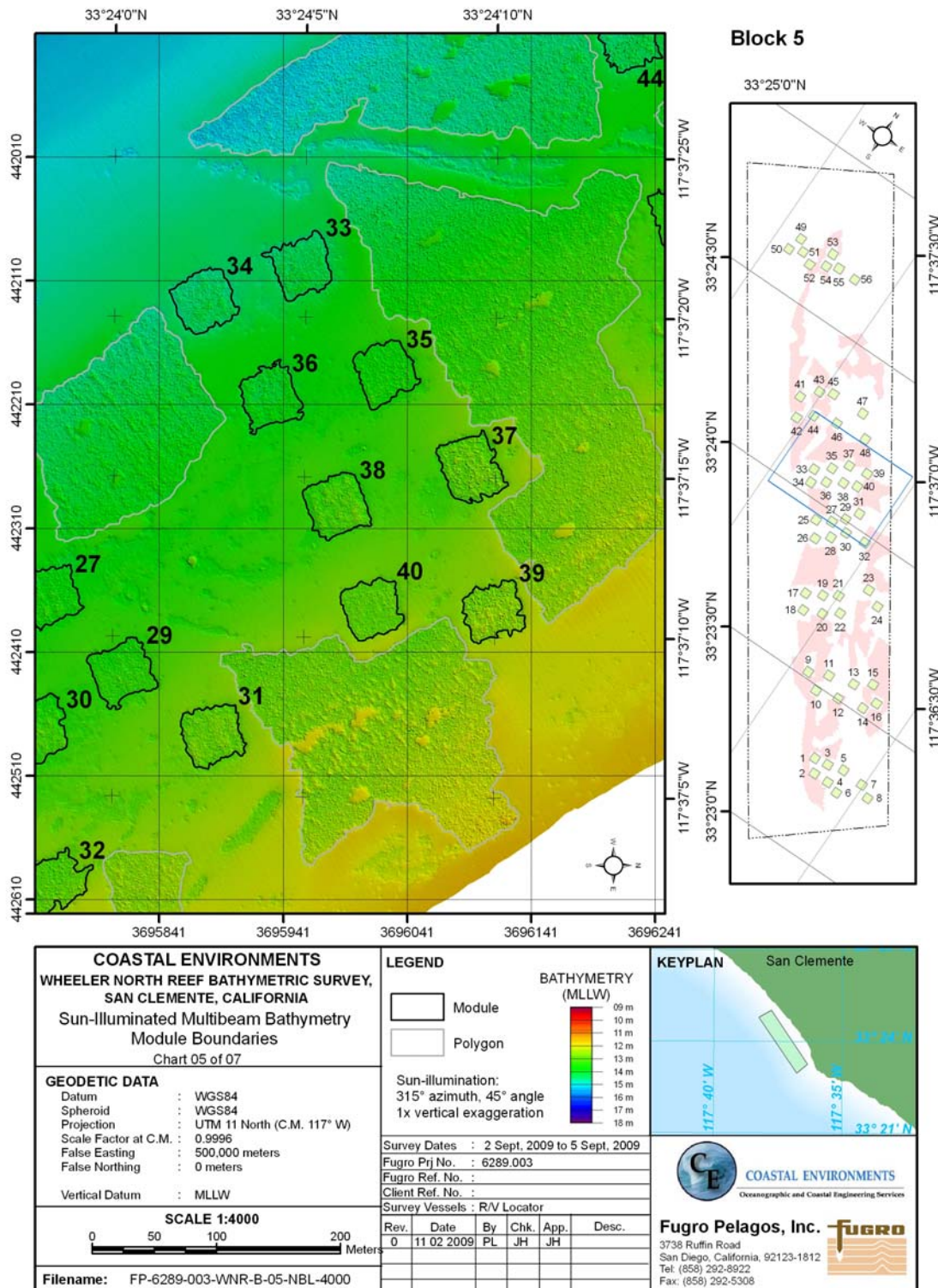


**Figure H-3. Block 3 module boundaries from bathymetric data interpretation (September 2009 multibeam survey).**



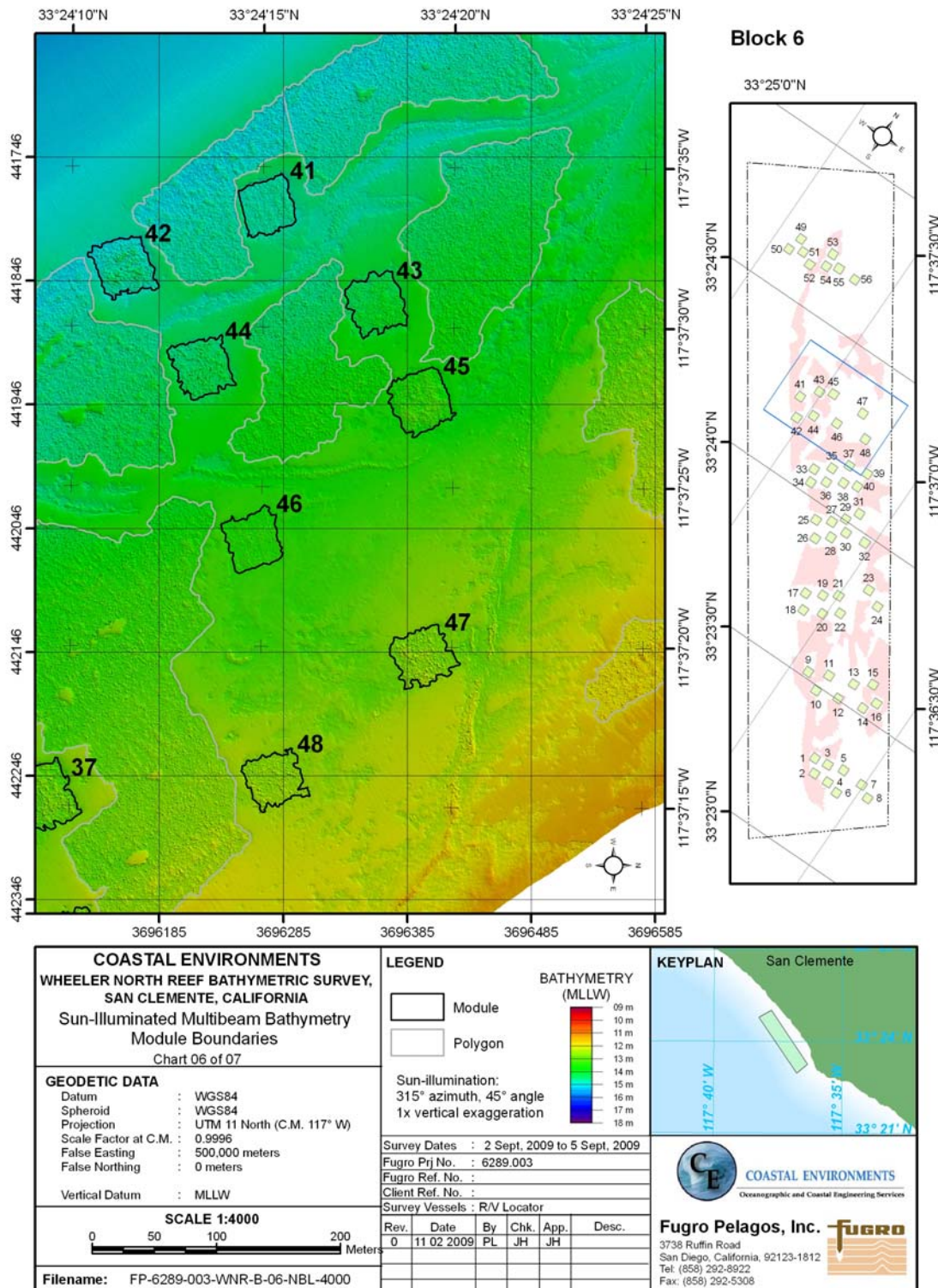
**Figure H-4. Block 4 module boundaries from bathymetric data interpretation (September 2009 multibeam survey).**





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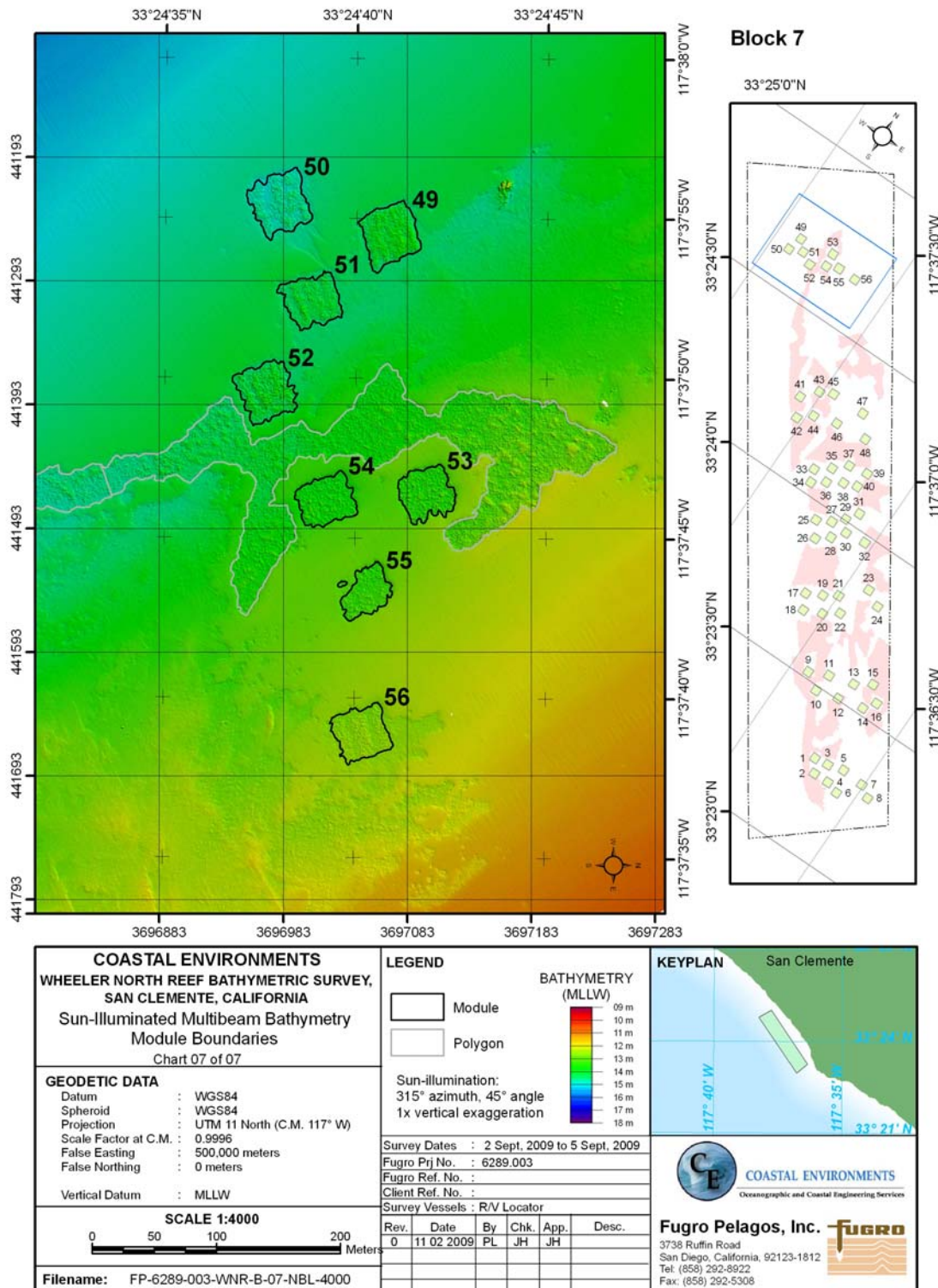
**Figure H-5. Block 5 module boundaries from bathymetric data interpretation (September 2009 multibeam survey).**



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**Figure H-6. Block 6 module boundaries from bathymetric data interpretation (September 2009 multibeam survey).**





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**Figure H-7. Block 7 module boundaries from bathymetric data interpretation (September 2009 multibeam survey).**