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Beach Morphology Monitoring in the Elwha River Littoral Cell, 2004–2006

By Jonathan A. Warrick, Douglas A. George, Andrew W. Stevens, Jodi Eshleman, Guy Gelfenbaum, George M. Kaminsky, Andrew K. Schwartz, and Matt Beirne

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Beach Morphology Monitoring in the Elwha River Littoral Cell, 2004–2006

By Jonathan A. Warrick[1], Douglas A. George[1], Andrew W. Stevens[1], Jodi Eshleman[1], Guy Gelfenbaum[1], George M. Kaminsky[2], Andrew K. Schwartz[2] and Matt Beirne[3]

Summary

This report describes the methods used, data collected, and results of the Beach Morphology Monitoring Program in the Elwha River Littoral Cell, starting in 2004. The U.S. Geological Survey and the Washington State Department of Ecology collaborated in the data collection with the support of the local Lower Elwha Klallam Tribe. Beach monitoring efforts consisted of collecting topographic and bathymetric horizontal and vertical position data by using a Real Time Kinematic Differential Global Positioning System (RTK-DGPS). The monitoring program was designed to characterize the littoral system of the Elwha River before the scheduled removal of two large dams in 2012. A primary objective of this work is to quantitatively describe the topography and bathymetry of the Elwha River littoral system so that the effects of dam removal may be quantified. Sediment inputs following dam removal are hypothesized to result in (A) larger amounts of fine sediment grain-sizes entering the littoral system and, (B) a reduction or reversal of coastal erosion.

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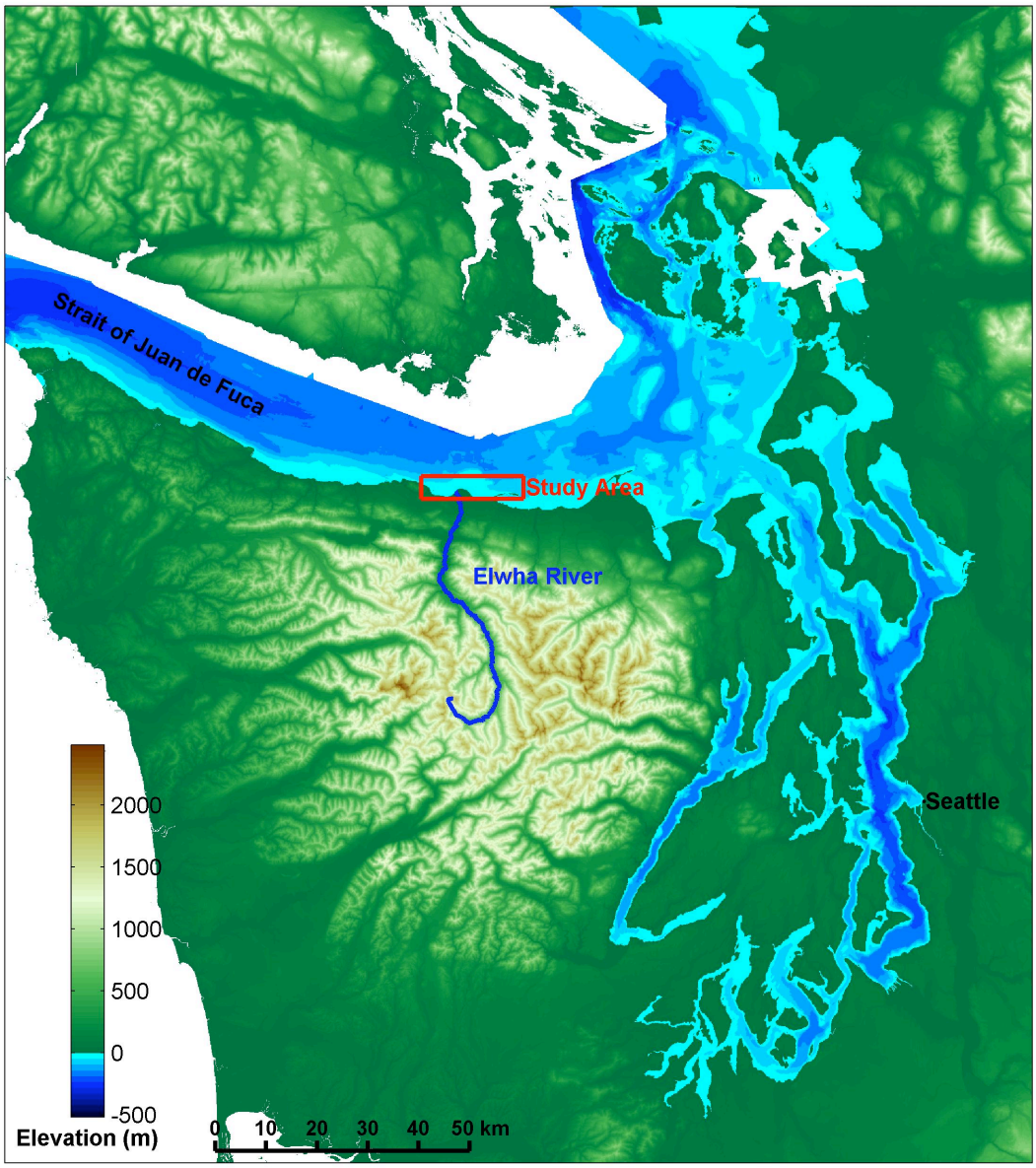
Introduction

The Elwha River of the Olympic Peninsula in Washington has two major dams, built in 1910 and 1926, that have significantly reduced sediment flux to the coast and removed most of the historic spawning habitats of native salmonids (Olympic National Park, 1996). Due to these environmental issues, the dams have been scheduled to be removed during a two-year process beginning in 2012. Investigations suggest that 13 million cubic meters of sediment will be released by the dam removal, and that this material will be deposited in the fluvial and coastal systems downstream (Randle and others, 1996; Childers and others, 2000). Coastal sedimentation is expected to reduce, or perhaps reverse, the current trend of beach erosion in the local littoral cell.

The Coastal and Marine Geology Program (CMG) of the U.S. Geological Survey (USGS) has established a scientific program to characterize the littoral system of the Elwha River. A primary objective of this work is to quantitatively describe the topography and bathymetry of the Elwha River littoral system so that the effects of dam removal may be quantified. Sediment inputs following dam removal are hypothesized to result in (A) larger amounts of fine sediment grain-sizes entering the littoral system and, (B) a reduction or reversal of coastal erosion. To test the latter hypothesis, USGS CMG is collecting high-resolution topography and bathymetry data around the Elwha River delta in collaboration with the Washington Department of Ecology and the Lower Elwha Klallam Tribe (fig. 1).



DEM Source: Finlayson and others (2000)

Figure 1. Study area on the Olympic Peninsula, northwest Washington.

The purpose of this report is to describe and disseminate the topographic and bathymetric data collected in this program. As described in detail below, beach surveys are conducted twice per year during "summer" and "winter" profiles. High resolution bathymetric/topographic surveys are obtained with RTK-DGPS from both watercraft and hiked backpack systems. Following a presentation of the methods in the body of this report, a summary of each survey campaign and the resulting data are included in the Appendices. Each appendix describes an individual survey, and new editions of this report are issued following the completion of additional surveys and associated appendices.

Data Collection

The field data collection effort at the Elwha River mouth began in September 2004. The goal of data collection prior to the proposed dam removal was (1) to investigate topographic changes on seasonal, annual, and multi-annual periods of time for the region, and (2) to collect data that could be utilized to build and calibrate a numerical model to simulate hydrodynamics and sediment transport. Each field collection is described in an appendix attached to this data series.

Nearshore Bathymetry/Topography Data

The Coastal Profiling System (CPS), a hydrographic surveying system mounted on a Personal Watercraft (PWC), was used to collect bathymetric data along a 16-km stretch of coastline surrounding the mouth of the Elwha River. The CPS provides a fast and accurate method to obtain subaqueous bathymetric profiles by combining the high-accuracy positioning of a Differential Global Positioning System (DGPS), the efficiency of an acoustic echo sounder, and the mobility of a personal watercraft. The data were collected by using RTK-DGPS. Horizontal accuracy of approximately ±3 cm and vertical accuracy of ±5 cm are reported by the manufacturer of the survey equipment (Trimble Navigation Limited, 1998). Additional factors, such as multipath satellite obstructions, poor satellite geometry and poor atmospheric conditions, can combine to cause drifts in the vertical GPS by as much as 10 cm (Sallenger, and others

2003). Spatial variations in water temperature and salinity can affect depth estimates by as much as 3 percent of the water depth. Data were initially collected assuming a sound velocity of 1,500 m/s and corrected by using sound-velocity estimates during data processing as detailed below. Combined with the vertical uncertainty described above, a conservative estimate of the total vertical uncertainty for nearshore bathymetry measurements is approximately 15 cm. A more complete discussion of the CPS technology and field techniques is found in MacMahan (2001) and Ruggiero and others (2005).

Topography data was obtained by using two backpack systems consisting of a GPS receiver and mounted antenna. The data also were collected in RTK-DGPS mode and stored in a handheld controller for downloading and data processing.

Geodetic Control

The Lower Elwha Klallam Tribe maintains a geodetic control network around the Elwha River delta. The coordinates of these benchmarks are included in table 1.

Table 1. Benchmark information.

Benchmark	Northing[1]	Easting[1]	Elevation[2]
1	131004.86	296580.06	4.01
2	131207.93	296870.88	3.41
3	131335.42	297184.43	3.34
4	131452.67	297464.30	3.89
5	131502.92	297727.64	3.44
6	131279.86	298095.69	2.76

[1] Wash. State Plane North NAD 83 (m).
[2]NAVD 88 (m).

Sampling Design

A traditional sampling design for the CPS system consists of planned profile lines that are perpendicular to the shoreline and extend from a project-specific water depth to the beach. A line file was developed with line spacing that varied depending on the relative importance of a region to satisfy the project goals (figs. 2*A* - *E*). For example, survey lines were densest in the immediate vicinity of the river

mouth as this area was determined to be the highest priority. The depth at the seaward endpoints of the lines varied but in most cases was deeper than 20 m. The topography lines were extensions of the bathymetry lines from the upper portion of the beach berm to as low on the beach face as the tide allowed sampling.

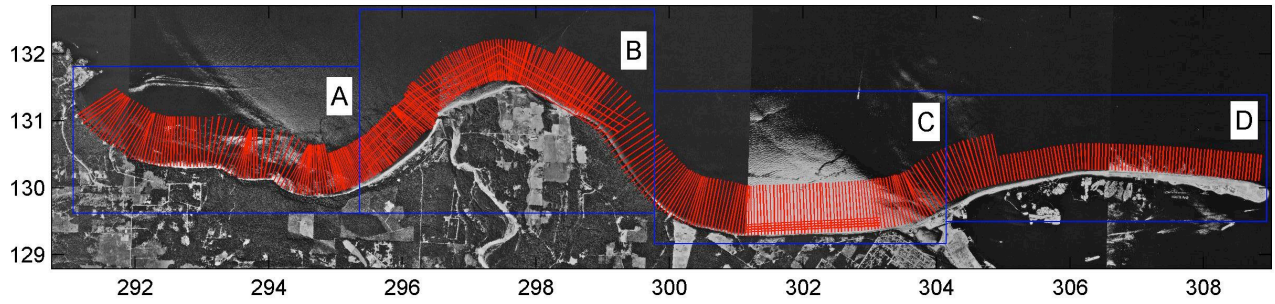


Figure 2*A*. Elwha profile lines shown in red for the entire study area. Inset regions for figures 2*B*-*E* are shown with blue boxes and labeled by A-D. Axes are Washington State Plane North (km).

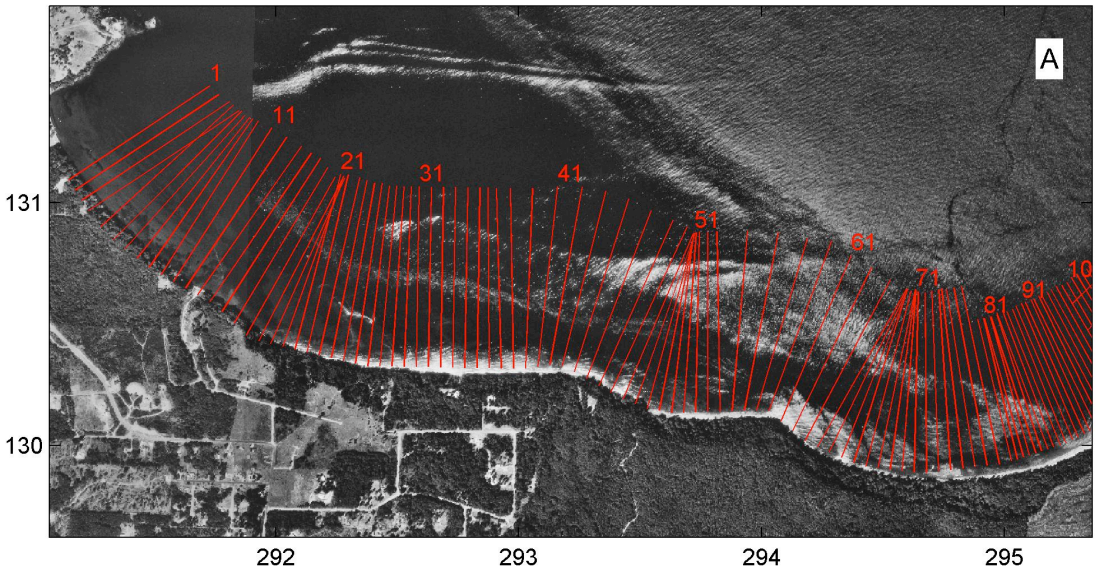


Figure 2*B*. Elwha profile lines for the Freshwater Bay portion of the study area. Every tenth line is labeled with the corresponding line number. Axes are Washington State Plane North (km).

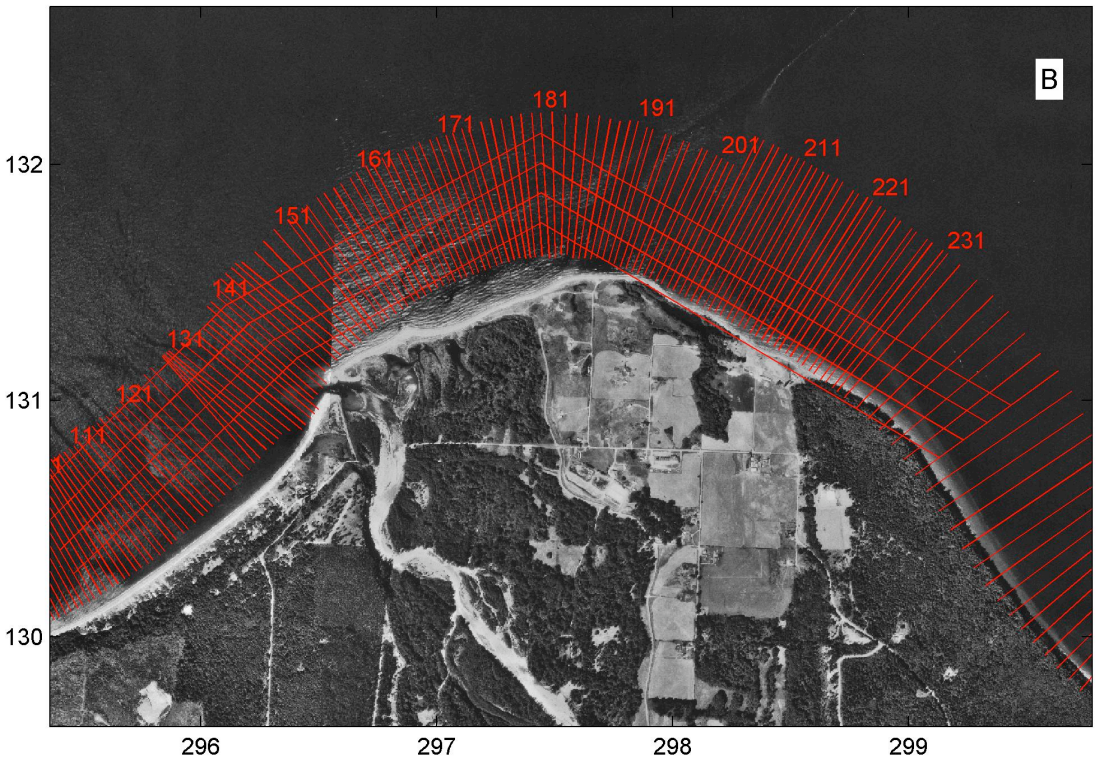


Figure 2*C*. Elwha profile lines for the delta-region portion of the study area. Every tenth line is labeled with the corresponding line number. Axes are Washington State Plane North (km).

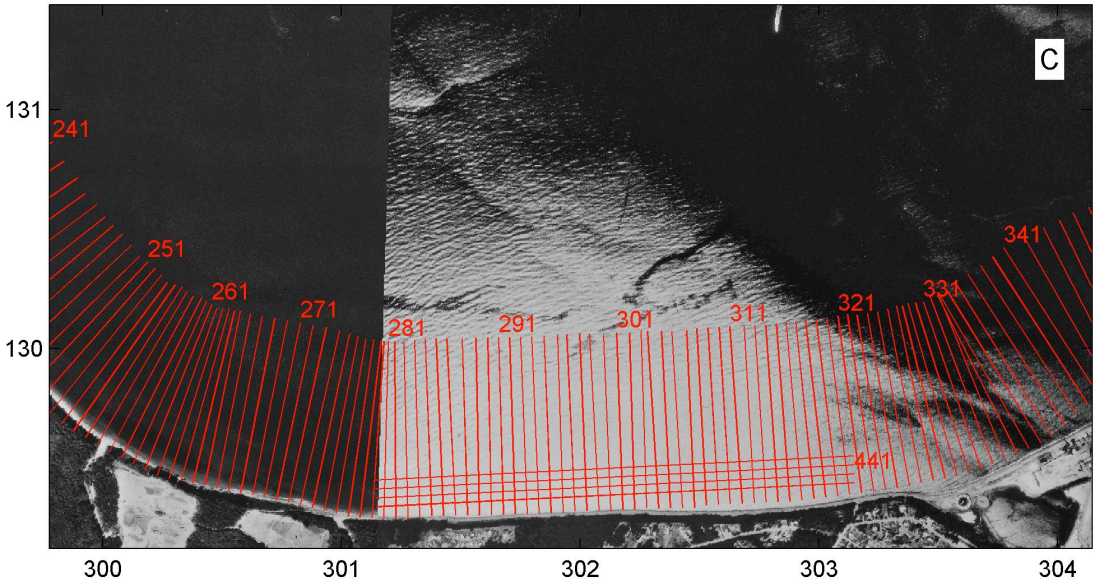


Figure 2*D*. Elwha profile lines for the east delta portion of the study area. Every tenth line is labeled with the corresponding line number. Axes are Washington State Plane North (km).

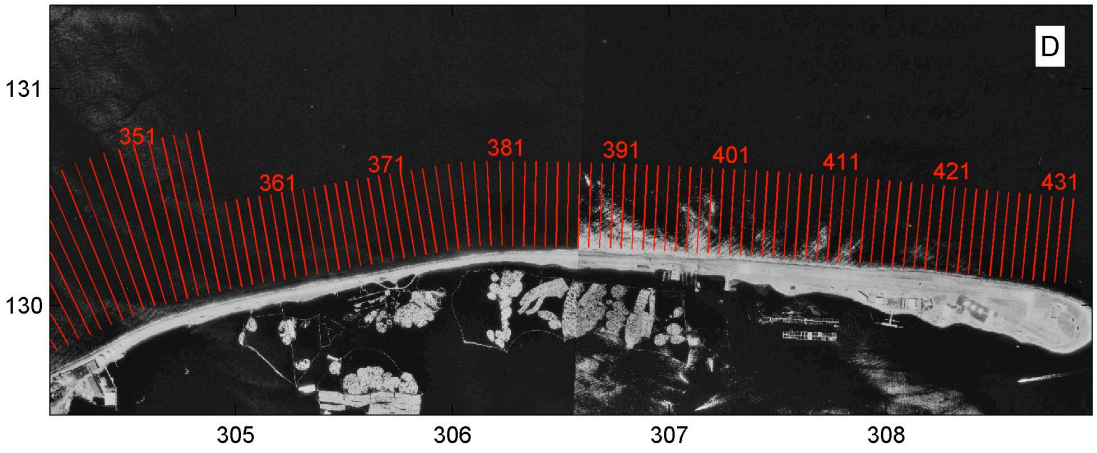


Figure 2*E*. Elwha Planned Lines for the Ediz Hook portion of the study area. Every tenth line is labeled with the corresponding line number. Axes are Washington State Plane North (km).

Data Processing

Topography Data

The topographic profiles were exported from the handheld GPS unit and calibrated into the geodetic network by using Trimble Geomatics Software. Quantities important to data quality were checked for errors during this operation. As the topographic data were much less dense than the bathymetric profiles, no smoothing was required. One data file per transect was saved as an Easting, Northing, Elevation (x, y, z) ASCII triplet in Washington State Plane North (NAD 83) and NAVD 88.

Bathymetry Data

Each individual bathymetric transect was examined to detect and remove any obvious outliers from the raw files that were either shallower than the echo sounder blanking interval or deeper than a user-defined cutoff value. Individual files were then exported in Easting, Northing, Elevation (x, y, z) ASCII triplets with one data file per transect in Washington State Plane North (NAD 83) and NAVD 88.

The sound velocity in seawater varies in the water column depending on water density, which is a function of salinity and temperature. The variability affects the echosounder travel time from the sensor to the bed and hence, the computed elevation. Large variabilities in seawater temperature (~10ºC) can affect depth estimates by as much as 20 cm in 12 m of water. To correct for this phenomenon, a constant salinity of 31 practical salinity units (psu) was assumed, and water temperature at the time of data collection was derived from an average of daily temperatures recorded by at National Data Buoy Center (NDBC) Station 46088 in New Dungeness, Wash. This station is the nearest active buoy at approximately 40 km from the Elwha River delta. The water-density correction was conducted by using accepted algorithms for calculation of sound velocity in seawater (Fofonoff and Millard Jr., 1983). In addition to water temperature, other meteorological and marine conditions (for example, wave height and period, wind speed and direction, air temperature and barometric pressure) also were extracted from NDBC Station 46088 during the dates and times of sampling and saved as spreadsheet files.

A smoothing operation was then performed on the corrected bathymetric data by using a LOWESS (Cleveland, 1979) filter on the z-coordinate in the alongline direction to reduce high-frequency fluctuations from interferences, such as seaweed, and the effect of vehicle pitch and roll on the bed elevation. A moving, non-overlapping window size of seven data points was used, regardless of the length of the profile line. A simple polynomial regression function was used to extrapolate data at both ends of the line where less than seven data points exist. In a small number of profiles, the LOWESS filter could not resolve short segments of the seabed due to poor echsounder returns. The data were removed from these areas of the profiles while the remaining sections were processed with the filtering algorithm.

Finished Products

The following data are supplied on the online USGS Data Series Report at http://pubs.usgs.gov/ds/288/data/. Data can be obtained by using an Internet browser and the following directory structure.

Bathymetric/Topographic Profile Data Files

One data file exists for each final collected bathymetry line in the directory structure: data_{year of survey]/{month of survey}/bathy/ew{year of survey}_line{number}_b.xyz. For example, Line 151, collected in September 2006, can be found at data_06/septb/bathy/ew06_line151_b.xyz. Each file contains easting, northing, and elevation values in the coordinate system Washington State Plane North NAD 83 (m). Elevation data are represented in meters, NAVD 88, as this was the datum of the benchmark control point used in the survey. One data file for each collected topography line also is presented in the directory structure: data_{year of survey]/{month of survey}/topo/ew{year of survey}_line{number}_t.xyz. The topography data files are in the same format and coordinate system as the bathymetric data files.

The individual bathymetric and topographic profiles can be combined to examine how successful the lines align and data overlap. For example, the bathymetric and topographic profiles of Line 151, collected September 2006, show reasonably good alignment and overlap (fig. 3).

Metadata

Metadata is included for all bathymetry and topography data collected at the Elwha River mouth. Data for the environmental-condition files were extracted from NDBC, and the headers for the data can be found in table 2.

Table 2. Standard meteorological-data headers for NDBC files.

ATMP	Air temperature (Celsius). For sensor heights on buoys, see *Hull Descriptions*. For sensor heights at C-MAN stations, see *C-MAN Sensor Locations*
WTMP	Sea surface temperature (Celsius). For sensor depth, see *Hull Description*.
DEWP	Dewpoint temperature taken at the same height as the air-temperature measurement.
PRES	Sea-level pressure (hPa). For C-MAN sites and Great Lakes buoys, the recorded pressure is reduced to sea level by using the method described in *NWS Technical Procedures Bulletin 291* (11/14/80).
WSPD	Wind speed (m/s) averaged during an eight-minute period for buoys and a two-minute period for land stations. Reported hourly. See *Wind Averaging Methods*.
WDIR	Wind direction (the direction the wind is coming from in degrees clockwise from true N) during the same period used for WSPD. See *Wind Averaging Methods*
GST	Peak 5- or 8-second gust speed (m/s) measured during the eight-minute or two-minute period. The 5- or 8-second period can be determined by payload. See the *Sensor Reporting, Sampling, and Accuracy* section.
WVHT	Significant wave height (meters) is calculated as the average of the highest one-third of all of the wave heights during the 20-minute sampling period. See the *Wave Measurements* section.
DPD	Dominant wave period (seconds) is the period with the maximum wave energy. See the *Wave Measurements* section.
MWD	Mean wave direction corresponding to energy of the dominant period (DOMPD). The units are degrees from true North just like wind direction. See the *Wave Measurements* section.
VIS	Station visibility (statute miles). Note that buoy stations are limited to reports from 0 to 1.9 miles.
PTDY	Pressure tendency is the direction (plus or minus) and the amount of pressure change (hPa) for a three-hour period ending at the time of observation.

Source: http://www.ndbc.noaa.gov/measdes.shtml

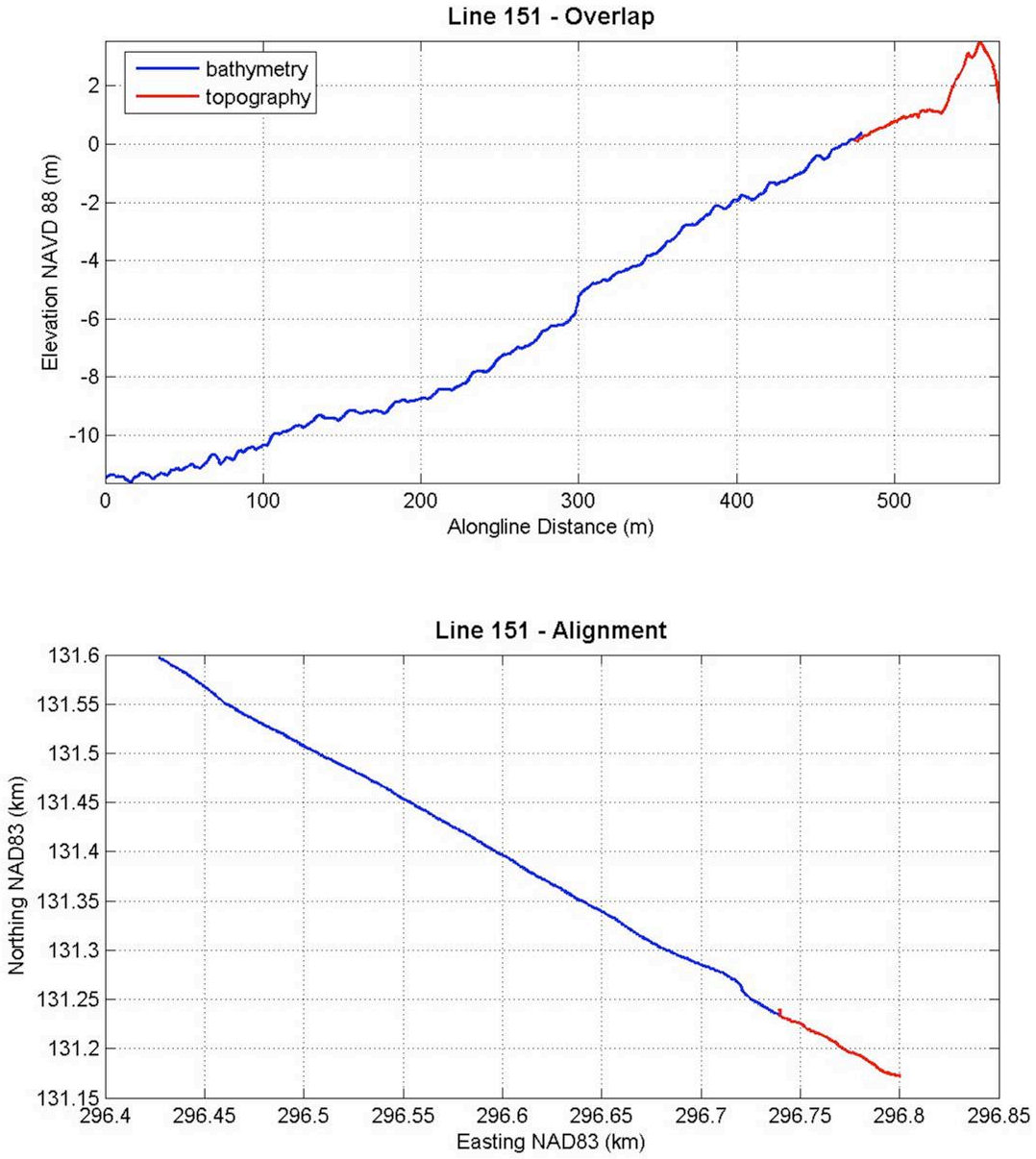


Figure 3. Overlap and alignment of bathymetric and topographic Line 151, September 2006.

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Appendix A - September 2004 Field Collection

In September 2004, profiles were collected spanning a 16-km stretch from Freshwater Bay to Ediz Hook. Several alongshore bathymetric lines also were driven around the delta to serve as a cross-check for data accuracy. Some additional alongshore lines were collected near Easting 302 km to try to resolve sand waves that were observed in sonar data collected in that region. On September 7–9, 119 bathymetric and 52 topographic profiles were collected between line 1 on the west and line 430 on the east at varying spacing intervals (figs. A1–A2). Bathymetric and topographic lines are enumerated in Table A. Detailed information about when and where profiles were collected and weather parameters at the time of data collection is included in the attached spreadsheet: ew_enviro_cond_04.xls.

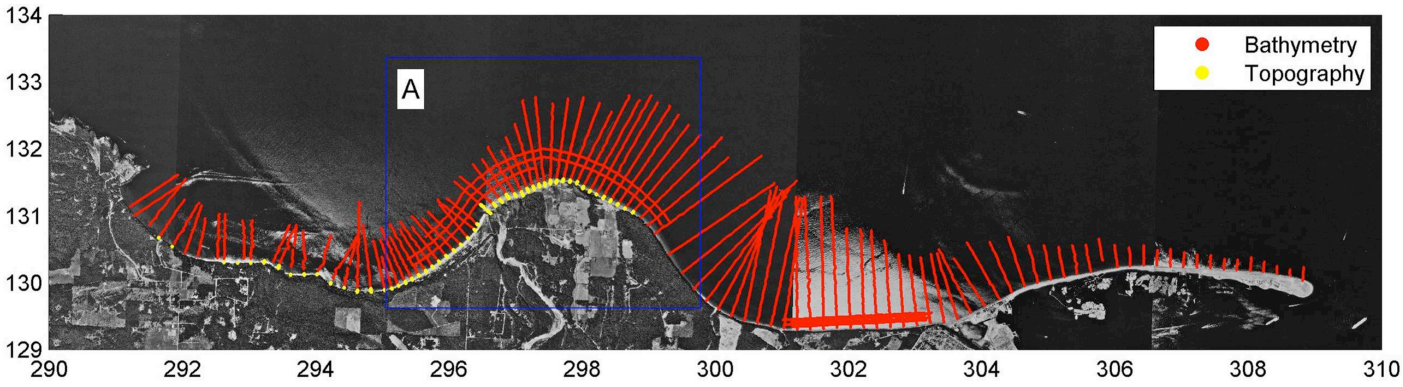

Figure A1. Elwha September 2004 surveyed lines.

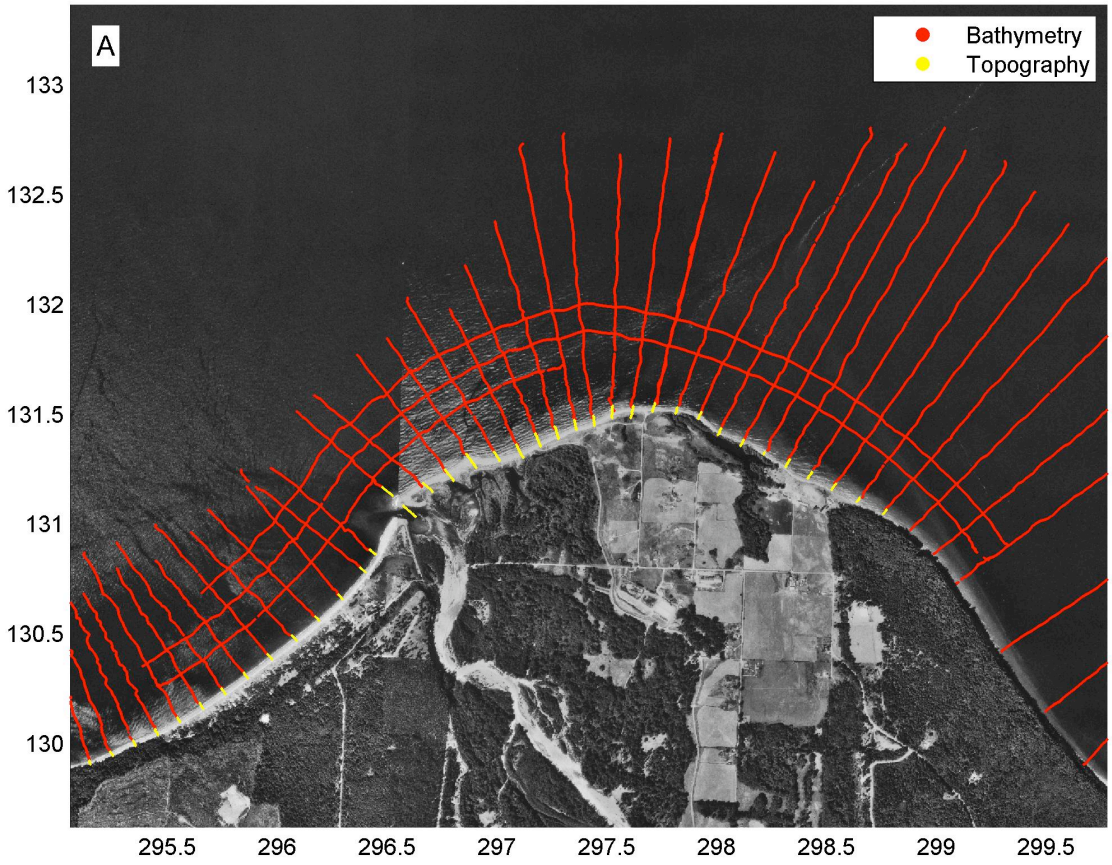

Figure A2. Elwha September 2004 surveyed lines (delta region).

Table A. Bathymetric and topographic lines for September 2004 survey.

Bathymetric line	Topographic line
ew04_line001_b.xyz	
ew04_line001_b2.xyz	
ew04_line004_b.xyz	
ew04_line008_b.xyz	
ew04_line012_b.xyz	ew04_line012_t.xyz
ew04_line016_b.xyz	ew04_line016_t.xyz
ew04_line020_b.xyz	
ew04_line024_b.xyz	
ew04_line030_b.xyz	
ew04_line032_b.xyz	ew04_line032_t.xyz
	ew04_line036_t.xyz
ew04_line038_b.xyz	
ew04_line040_b.xyz	ew04_line040_t.xyz
	ew04_line044_t.xyz
ew04_line046_b.xyz	
ew04_line048_b.xyz	ew04_line048_t.xyz

ew04_line052_b.xyz	ew04_line052_t.xyz
ew04_line056_b.xyz	ew04_line056_t.xyz
ew04_line060_b.xyz	ew04_line060_t.xyz
ew04_line064_b.xyz	ew04_line064_t.xyz
ew04_line068_b.xyz	ew04_line068_t.xyz
ew04_line072_b.xyz	ew04_line072_t.xyz
ew04_line076_b.xyz	ew04_line076_t.xyz
ew04_line080_b.xyz	ew04_line080_t.xyz
ew04_line084_b.xyz	ew04_line084_t.xyz
ew04_line088_b.xyz	ew04_line088_t.xyz
ew04_line092_b.xyz	ew04_line092_t.xyz
ew04_line096_b.xyz	ew04_line096_t.xyz
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ew04_line104_b.xyz	ew04_line104_t.xyz
ew04_line108_b.xyz	ew04_line108_t.xyz
ew04_line112_b.xyz	ew04_line112_t.xyz
ew04_line116_b.xyz	ew04_line116_t.xyz
ew04_line120_b.xyz	ew04_line120_t.xyz
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ew04_line180_b.xyz	ew04_line180_t.xyz
ew04_line184_b.xyz	ew04_line184_t.xyz
ew04_line188_b.xyz	ew04_line188_t.xyz
ew04_line192_b.xyz	ew04_line192_t.xyz
ew04_line192_b2.xyz	
ew04_line196_b.xyz	ew04_line196_t.xyz
ew04_line200_b.xyz	ew04_line200_t.xyz
ew04_line204_b.xyz	ew04_line204_t.xyz
ew04_line208_b.xyz	ew04_line208_t.xyz
ew04_line212_b.xyz	ew04_line212_t.xyz
ew04_line216_b.xyz	ew04_line216_t.xyz
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ew04_line441_b.xyz	
ew04_line442_b.xyz	

Appendix B - March 2005 Field Collection

For the March 2005 survey, the focus was shifted to resolving the delta at the river mouth in greater detail. On March 15-17, 75 bathymetric and 61 topographic profiles were collected between lines 92 on the west and 232 on the east (figs. B1–B2). Two alongshore bathymetric profiles also were collected. Bathymetric and topographic lines are enumerated in table B. Detailed information about when and where profiles were collected and weather parameters at the time of data collection is included in the attached spreadsheet: ew_enviro_cond_05.xls.

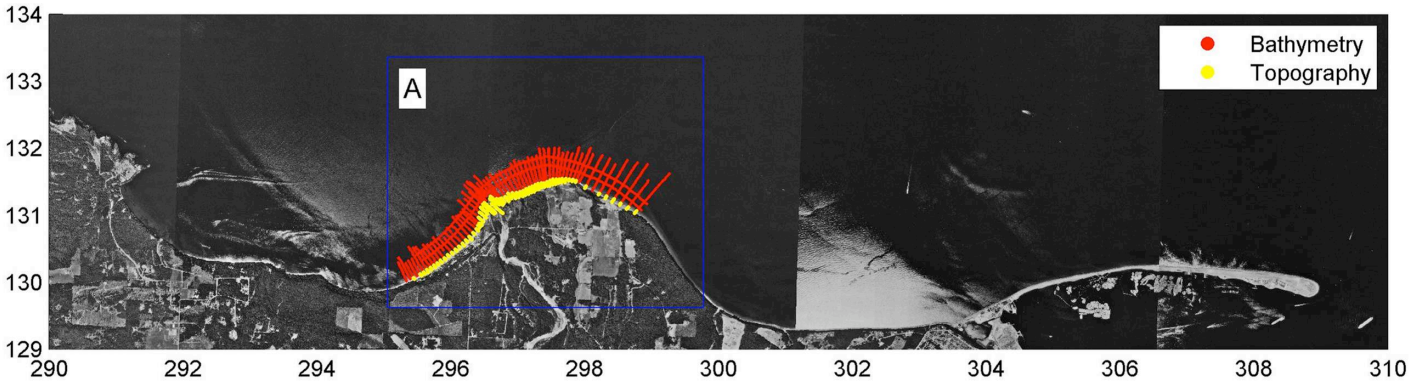

Figure B1. Elwha March 2005 surveyed lines.

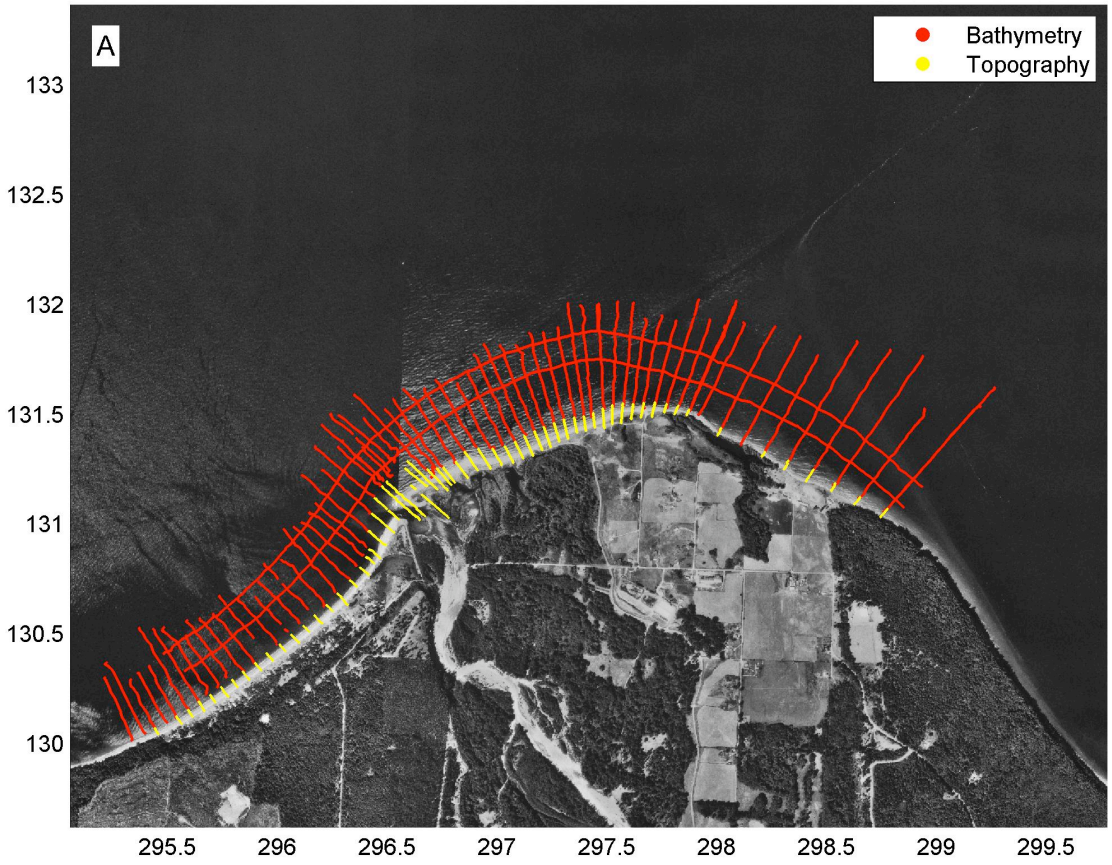

Figure B2. Elwha March 2005 surveyed lines (delta region).

Table B. Bathymetric and topographic lines for March 2005 survey.

Bathymetric line	Topographic line
ew05_line092_b.xyz	
ew05_line094_b.xyz	
ew05_line096_b.xyz	ew05_line096_t.xyz
ew05_line098_b.xyz	
ew05_line100_b.xyz	ew05_line100_t.xyz
ew05_line102_b.xyz	ew05_line102_t.xyz
ew05_line104_b.xyz	ew05_line104_t.xyz
ew05_line106_b.xyz	ew05_line106_t.xyz
ew05_line108_b.xyz	ew05_line108_t.xyz
ew05_line110_b.xyz	ew05_line110_t.xyz
ew05_line112_b.xyz	ew05_line112_t.xyz
ew05_line114_b.xyz	ew05_line114_t.xyz
ew05_line116_b.xyz	ew05_line116_t.xyz
ew05_line118_b.xyz	ew05_line118_t.xyz
ew05_line120_b.xyz	ew05_line120_t.xyz
ew05_line122_b.xyz	ew05_line122_t.xyz

ew05_line124_b.xyz	ew05_line124_t.xyz
ew05_line126_b.xyz	ew05_line126_t.xyz
ew05_line128_b.xyz	ew05_line128_t.xyz
ew05_line130_b.xyz	ew05_line130_t.xyz
ew05_line132_b.xyz	ew05_line132_t.xyz
ew05_line134_b.xyz	ew05_line134_t.xyz
ew05_line135_b.xyz	ew05_line135_t.xyz
ew05_line137_b.xyz	ew05_line137_t.xyz
ew05_line140_b.xyz	ew05_line140_t.xyz
ew05_line142_b.xyz	ew05_line142_t.xyz
ew05_line144_b.xyz	ew05_line144_t.xyz
ew05_line145_b.xyz	ew05_line145_t.xyz
ew05_line145_b2.xyz	
ew05_line146_b.xyz	
ew05_line147_b.xyz	ew05_line147_t.xyz
ew05_line148_b.xyz	ew05_line148_t.xyz
ew05_line149_b.xyz	ew05_line149_t.xyz
ew05_line150_b.xyz	ew05_line150_t.xyz
ew05_line150_b2.xyz	
ew05_line151_b.xyz	ew05_line151_t.xyz
ew05_line152_b.xyz	ew05_line152_t.xyz
ew05_line154_b.xyz	ew05_line154_t.xyz
ew05_line156_b.xyz	ew05_line156_t.xyz
ew05_line158_b.xyz	ew05_line158_t.xyz
ew05_line160_b.xyz	ew05_line160_t.xyz
ew05_line162_b.xyz	ew05_line162_t.xyz
ew05_line164_b.xyz	ew05_line164_t.xyz
ew05_line166_b.xyz	ew05_line166_t.xyz
ew05_line168_b.xyz	ew05_line168_t.xyz
ew05_line170_b.xyz	ew05_line170_t.xyz
ew05_line172_b.xyz	ew05_line172_t.xyz
ew05_line174_b.xyz	ew05_line174_t.xyz
ew05_line176_b.xyz	ew05_line176_t.xyz
ew05_line178_b.xyz	ew05_line178_t.xyz
ew05_line180_b.xyz	ew05_line180_t.xyz
ew05_line182_b.xyz	ew05_line182_t.xyz
ew05_line182_b2.xyz	
ew05_line184_b.xyz	ew05_line184_t.xyz
ew05_line186_b.xyz	ew05_line186_t.xyz
ew05_line188_b.xyz	ew05_line188_t.xyz
ew05_line190_b.xyz	ew05_line190_t.xyz
ew05_line192_b.xyz	ew05_line192_t.xyz
ew05_line194_b.xyz	ew05_line194_t.xyz
ew05_line196_b.xyz	ew05_line196_t.xyz
ew05_line198_b.xyz	ew05_line198_t.xyz
ew05_line198_b2.xyz	
ew05_line198_b3.xyz	
ew05_line200_b.xyz	
ew05_line204_b.xyz	ew05_line204_t.xyz
ew05_line208_b.xyz	
ew05_line212_b.xyz	ew05_line212_t.xyz
ew05_line216_b.xyz	ew05_line216_t.xyz
ew05_line220_b.xyz	ew05_line220_t.xyz
ew05_line224_b.xyz	ew05_line224_t.xyz
ew05_line228_b.xyz	ew05_line228_t.xyz
ew05_line232_b.xyz	ew05_line232_t.xyz

ew05_line232_b2.xyz	
ew05_line435_b.xyz	
ew05_line436_b.xyz	

Appendix C - August–September 2005 Field Collection

In Fall 2005, a broader sampling was attempted. On August 30–September 1, 101 bathymetric profiles and 74 topographic profiles were collected from the Elwha River delta between line numbers 8 to the west and 402 to the east (figs. C1–C2). Two alongshore bathymetric profiles also were collected. Bathymetric and topographic lines are enumerated in table C. Detailed information about when and where profiles were collected and weather parameters at the time of data collection is included in the attached spreadsheet: ew_enviro_cond_05.xls.

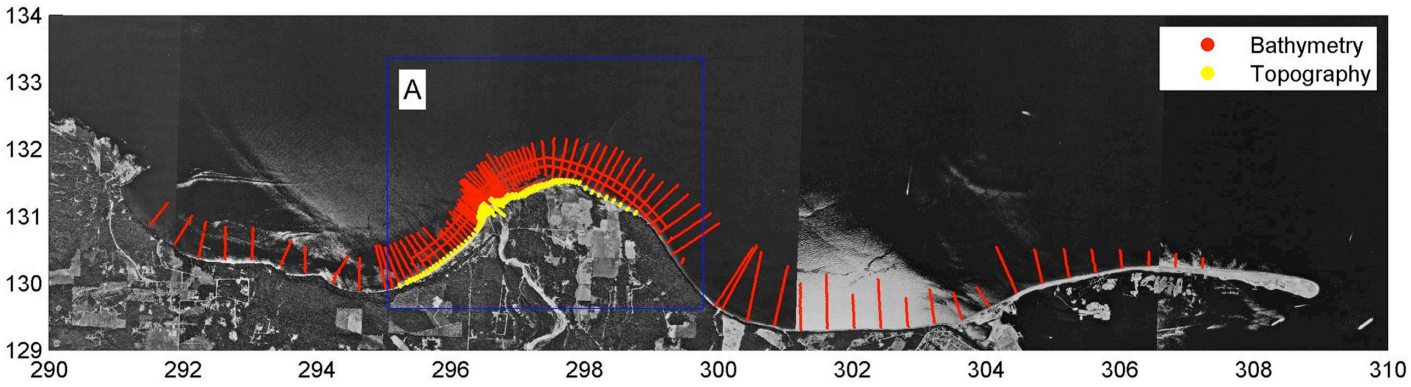

Figure C1. Elwha August–September 2005 surveyed lines.

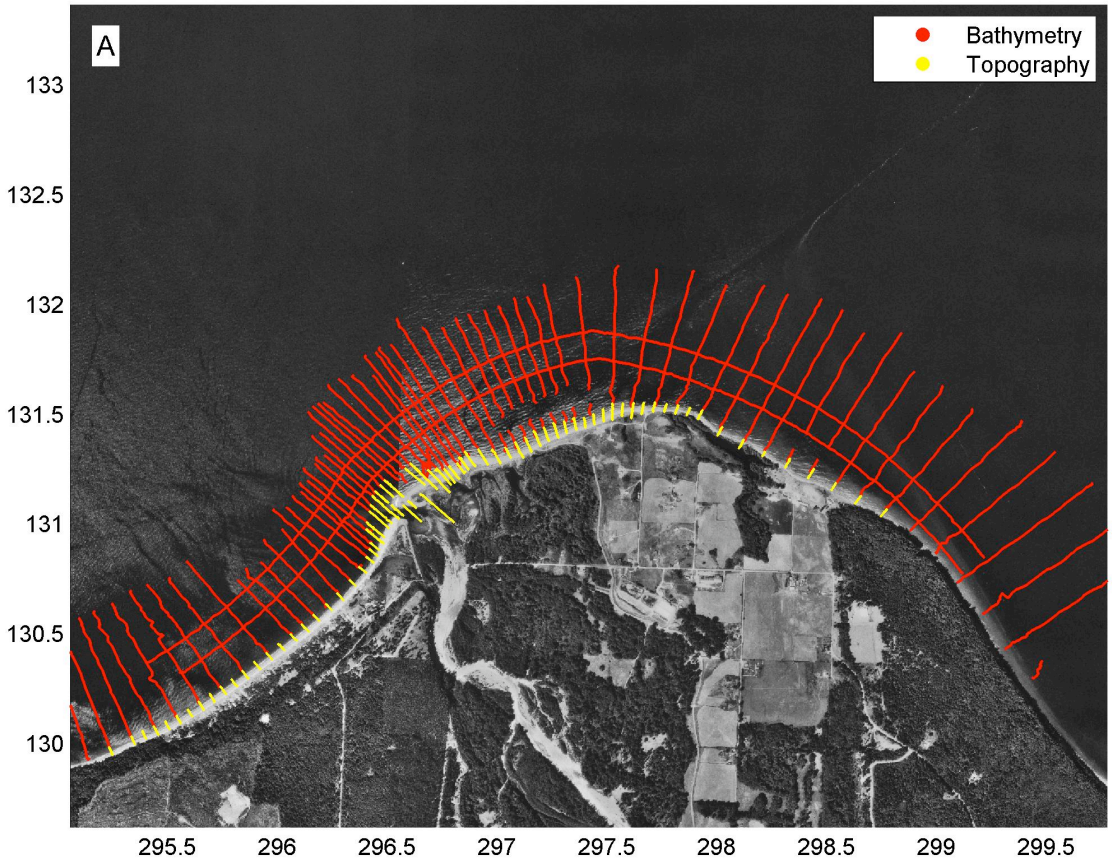

Figure C2. Elwha August–September 2005 surveyed lines (delta region).

Table C. Bathymetric and topographic lines for August–September 2005 survey.

Bathymetric line	Topographic line
ew05_line008_b.xyz	
ew05_line016_b.xyz	
ew05_line024_b.xyz	
ew05_line032_b.xyz	
ew05_line040_b.xyz	
ew05_line048_b.xyz	
ew05_line056_b.xyz	
ew05_line064_b.xyz	
ew05_line072_b.xyz	
ew05_line080_b.xyz	
ew05_line084_b.xyz	
ew05_line088_b.xyz	ew05_line088_t.xyz
ew05_line092_b.xyz	ew05_line092_t.xyz
	ew05_line094_t.xyz
ew05_line096_b.xyz	ew05_line096_t.xyz
	ew05_line098_t.xyz

ew05_line100_b.xyz	ew05_line100_t.xyz
	ew05_line102_t.xyz
ew05_line104_b.xyz	ew05_line104_t.xyz
	ew05_line106_t.xyz
ew05_line108_b.xyz	ew05_line108_t.xyz
	ew05_line110_t.xyz
ew05_line112_b.xyz	ew05_line112_t.xyz
	ew05_line114_t.xyz
ew05_line116_b.xyz	ew05_line116_t.xyz
	ew05_line118_t.xyz
ew05_line120_b.xyz	ew05_line120_t.xyz
ew05_line122_b.xyz	ew05_line122_t.xyz
ew05_line124_b.xyz	ew05_line124_t.xyz
ew05_line126_b.xyz	ew05_line126_t.xyz
ew05_line128_b.xyz	ew05_line128_t.xyz
ew05_line130_b.xyz	ew05_line130_t.xyz
ew05_line132_b.xyz	ew05_line132_t.xyz
ew05_line134_b.xyz	ew05_line134_t.xyz
ew05_line135_b.xyz	ew05_line135_t.xyz
ew05_line136_b.xyz	ew05_line136_t.xyz
	ew05_line136_t2.xyz
ew05_line137_b.xyz	ew05_line137_t.xyz
ew05_line138_b.xyz	ew05_line138_t.xyz
ew05_line140_b.xyz	ew05_line140_t.xyz
ew05_line141_b.xyz	ew05_line141_t.xyz
ew05_line142_b.xyz	ew05_line142_t.xyz
ew05_line143_b.xyz	ew05_line143_t.xyz
ew05_line144_b.xyz	ew05_line144_t.xyz
ew05_line145_b.xyz	ew05_line145_t.xyz
ew05_line146_b.xyz	
ew05_line147_b.xyz	ew05_line147_t.xyz
ew05_line148_b.xyz	ew05_line148_t.xyz
ew05_line148_b2.xyz	
ew05_line149_b.xyz	ew05_line149_t.xyz
ew05_line150_b.xyz	ew05_line150_t.xyz
ew05_line151_b.xyz	ew05_line151_t.xyz
ew05_line152_b.xyz	ew05_line152_t.xyz
ew05_line153_b.xyz	ew05_line153_t.xyz
ew05_line154_b.xyz	ew05_line154_t.xyz
ew05_line155_b.xyz	ew05_line155_t.xyz
ew05_line156_b.xyz	ew05_line156_t.xyz
ew05_line158_b.xyz	ew05_line158_t.xyz
ew05_line160_b.xyz	ew05_line160_t.xyz
ew05_line162_b.xyz	ew05_line162_t.xyz
ew05_line164_b.xyz	ew05_line164_t.xyz
ew05_line166_b.xyz	ew05_line166_t.xyz
ew05_line168_b.xyz	ew05_line168_t.xyz
ew05_line170_b.xyz	ew05_line170_t.xyz
ew05_line172_b.xyz	ew05_line172_t.xyz
ew05_line174_b.xyz	ew05_line174_t.xyz
ew05_line176_b.xyz	ew05_line176_t.xyz
	ew05_line178_t.xyz
ew05_line180_b.xyz	ew05_line180_t.xyz
	ew05_line182_t.xyz
ew05_line184_b.xyz	ew05_line184_t.xyz
	ew05_line186_t.xyz

ew05_line188_b.xyz	ew05_line188_t.xyz
	ew05_line190_t.xyz
ew05_line192_b.xyz	ew05_line192_t.xyz
	ew05_line194_t.xyz
ew05_line196_b.xyz	ew05_line196_t.xyz
	ew05_line198_t.xyz
ew05_line200_b.xyz	ew05_line200_t.xyz
ew05_line204_b.xyz	ew05_line204_t.xyz
ew05_line208_b.xyz	ew05_line208_t.xyz
ew05_line212_b.xyz	ew05_line212_t.xyz
ew05_line216_b.xyz	ew05_line216_t.xyz
ew05_line220_b.xyz	ew05_line220_t.xyz
ew05_line224_b.xyz	ew05_line224_t.xyz
ew05_line228_b.xyz	ew05_line228_t.xyz
ew05_line232_b.xyz	ew05_line232_t.xyz
ew05_line234_b.xyz	
ew05_line236_b.xyz	
ew05_line238_b.xyz	
ew05_line240_b.xyz	
ew05_line242_b.xyz	
ew05_line244_b.xyz	
ew05_line256_b.xyz	
ew05_line258_b.xyz	
ew05_line266_b.xyz	
ew05_line274_b.xyz	
ew05_line282_b.xyz	
ew05_line290_b.xyz	
ew05_line298_b.xyz	
ew05_line306_b.xyz	
ew05_line314_b.xyz	
ew05_line322_b.xyz	
ew05_line330_b.xyz	
ew05_line338_b.xyz	
ew05_line346_b.xyz	
ew05_line354_b.xyz	
ew05_line362_b.xyz	
ew05_line370_b.xyz	
ew05_line378_b.xyz	
ew05_line386_b.xyz	
ew05_line394_b.xyz	
ew05_line402_b.xyz	
ew05_line435_b.xyz	
ew05_line436_b.xyz	

Appendix D - January 2006 Field Collection

During January 2006, a special survey was conducted to characterize the coastal response to a large storm. A series of large storms and high tides during December 26, 2005, to January 5, 2006, produced coastal erosion and flooding along the delta east of the river mouth. Following this event, a survey was conducted during the low tides occurring during the nights and early mornings of January 11 and 12, 2006. Because this was a rapid-response survey, the watercraft-based bathymetric surveys could not be included. Further, the survey was conducted only along a 1-km stretch of beach in the region of greatest reported erosion and flooding. A total of 41 topographic profiles were obtained at a spacing of 25 m (figure D1–D2). Topographic lines are enumerated in table D.

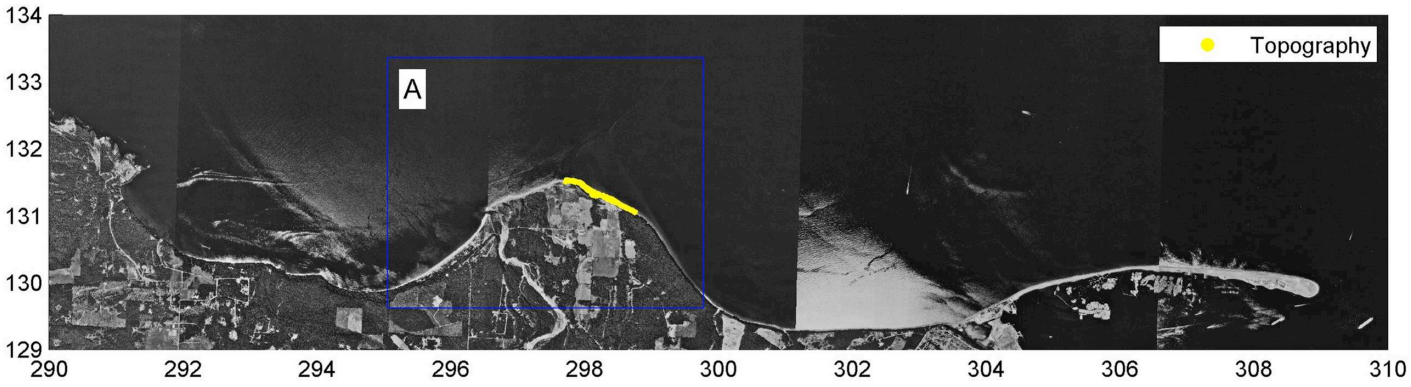

Figure D1. Elwha January 2006 surveyed lines. Only topography data were collected.

Figure D2. Elwha January 2006 surveyed lines (delta region). Only topography data were collected.

Table D. Topographic lines for January 2006 survey.

Topographic line
ew06_line192_t.xyz
ew06_line193_t.xyz
ew06_line194_t.xyz
ew06_line195_t.xyz
ew06_line196_t.xyz
ew06_line197_t.xyz
ew06_line198_t.xyz
ew06_line199_t.xyz
ew06_line200_t.xyz
ew06_line201_t.xyz
ew06_line202_t.xyz
ew06_line203_t.xyz
ew06_line204_t.xyz
ew06_line205_t.xyz
ew06_line206_t.xyz
ew06_line207_t.xyz

ew06_line208_t.xyz
ew06_line209_t.xyz
ew06_line210_t.xyz
ew06_line211_t.xyz
ew06_line212_t.xyz
ew06_line213_t.xyz
ew06_line214_t.xyz
ew06_line215_t.xyz
ew06_line216_t.xyz
ew06_line217_t.xyz
ew06_line218_t.xyz
ew06_line219_t.xyz
ew06_line220_t.xyz
ew06_line221_t.xyz
ew06_line222_t.xyz
ew06_line223_t.xyz
ew06_line224_t.xyz
ew06_line225_t.xyz
ew06_line226_t.xyz
ew06_line227_t.xyz
ew06_line228_t.xyz
ew06_line229_t.xyz
ew06_line230_t.xyz
ew06_line231_t.xyz
ew06_line232_t.xyz

Appendix E - April 2006 Field Collection

No bathymetric data were collected during this survey due to unsafe weather, as the winds and waves were too large to sample the nearshore by watercraft. Topographic data were collected (table E), however, between lines 119 to 232 for a total of 110 profiles (figs. E1–E2).

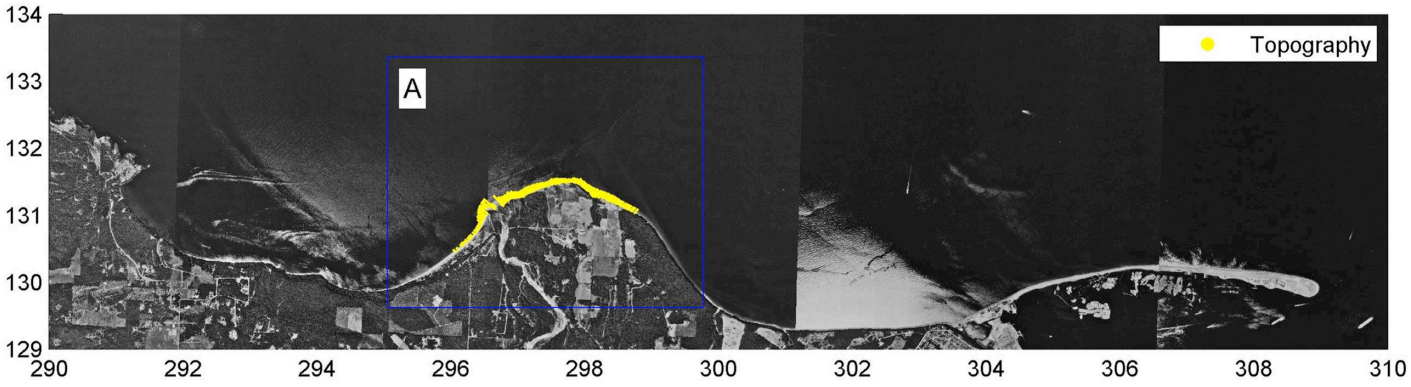

Figure E1. Elwha April 2006 surveyed lines.

Figure E2. Elwha April 2006 surveyed lines (delta region).

Table E. Topographic lines for April 2006 survey.

Topographic line
ew06_line119_t.xyz
ew06_line121_t.xyz
ew06_line123_t.xyz
ew06_line124_t.xyz
ew06_line125_t.xyz
ew06_line126_t.xyz
ew06_line127_t.xyz
ew06_line128_t.xyz
ew06_line129_t.xyz
ew06_line130_t.xyz
ew06_line131_t.xyz
ew06_line132_t.xyz
ew06_line133_t.xyz
ew06_line134_t.xyz
ew06_line135_t.xyz
ew06_line136_t.xyz

ew06_line137_t.xyz
ew06_line138_t.xyz
ew06_line139_t.xyz
ew06_line140_t.xyz
ew06_line141_t.xyz
ew06_line142_t.xyz
ew06_line143_t.xyz
ew06_line144_t.xyz
ew06_line145_t.xyz
ew06_line146_t.xyz
ew06_line147_t.xyz
ew06_line150_t.xyz
ew06_line151_t.xyz
ew06_line152_t.xyz
ew06_line153_t.xyz
ew06_line154_t.xyz
ew06_line155_t.xyz
ew06_line156_t.xyz
ew06_line157_t.xyz
ew06_line158_t.xyz
ew06_line159_t.xyz
ew06_line160_t.xyz
ew06_line161_t.xyz
ew06_line162_t.xyz
ew06_line163_t.xyz
ew06_line164_t.xyz
ew06_line165_t.xyz
ew06_line166_t.xyz
ew06_line167_t.xyz
ew06_line168_t.xyz
ew06_line169_t.xyz
ew06_line170_t.xyz
ew06_line171_t.xyz
ew06_line172_t.xyz
ew06_line173_t.xyz
ew06_line174_t.xyz
ew06_line175_t.xyz
ew06_line176_t.xyz
ew06_line177_t.xyz
ew06_line178_t.xyz
ew06_line179_t.xyz
ew06_line180_t.xyz
ew06_line181_t.xyz
ew06_line182_t.xyz
ew06_line183_t.xyz
ew06_line184_t.xyz
ew06_line185_t.xyz
ew06_line186_t.xyz
ew06_line187_t.xyz
ew06_line188_t.xyz
ew06_line189_t.xyz
ew06_line190_t.xyz
ew06_line191_t.xyz
ew06_line192_t.xyz
ew06_line193_t.xyz
ew06_line194_t.xyz

ew06_line195_t.xyz
ew06_line196_t.xyz
ew06_line197_t.xyz
ew06_line198_t.xyz
ew06_line199_t.xyz
ew06_line200_t.xyz
ew06_line201_t.xyz
ew06_line202_t.xyz
ew06_line203_t.xyz
ew06_line204_t.xyz
ew06_line205_t.xyz
ew06_line206_t.xyz
ew06_line207_t.xyz
ew06_line208_t.xyz
ew06_line209_t.xyz
ew06_line210_t.xyz
ew06_line211_t.xyz
ew06_line212_t.xyz
ew06_line213_t.xyz
ew06_line214_t.xyz
ew06_line215_t.xyz
ew06_line216_t.xyz
ew06_line217_t.xyz
ew06_line218_t.xyz
ew06_line219_t.xyz
ew06_line220_t.xyz
ew06_line221_t.xyz
ew06_line222_t.xyz
ew06_line223_t.xyz
ew06_line224_t.xyz
ew06_line225_t.xyz
ew06_line226_t.xyz
ew06_line227_t.xyz
ew06_line228_t.xyz
ew06_line229_t.xyz
ew06_line230_t.xyz
ew06_line231_t.xyz
ew06_line232_t.xyz

Appendix F - September 2006 Field Collection

In September 2006, the area around the delta was heavily sampled. On September 18–19, 103 bathymetric profiles and 153 topographic profiles were collected between line numbers 80 to the west and 240 to the east (figs. F1–F2). Additionally, data were collected within the river mouth by driving the PWCs through the river mouth and traversing from one side of the river to the other. Bathymetric and topographic lines are enumerated in table F. Detailed information about when and where profiles were collected and weather parameters at the time of data collection is included in the attached spreadsheet: ew_enviro_cond_06.xls.

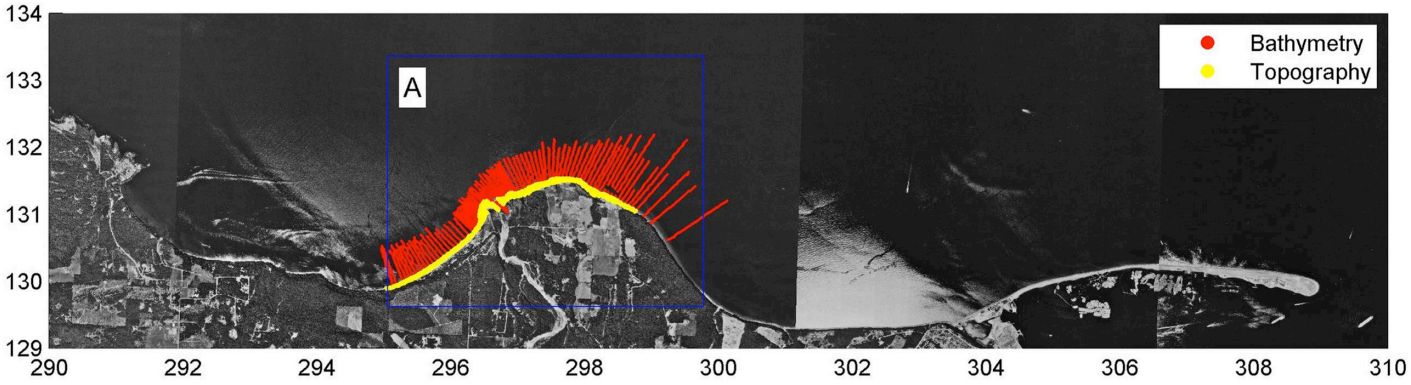

Figure F1. Elwha September 2006 surveyed lines.

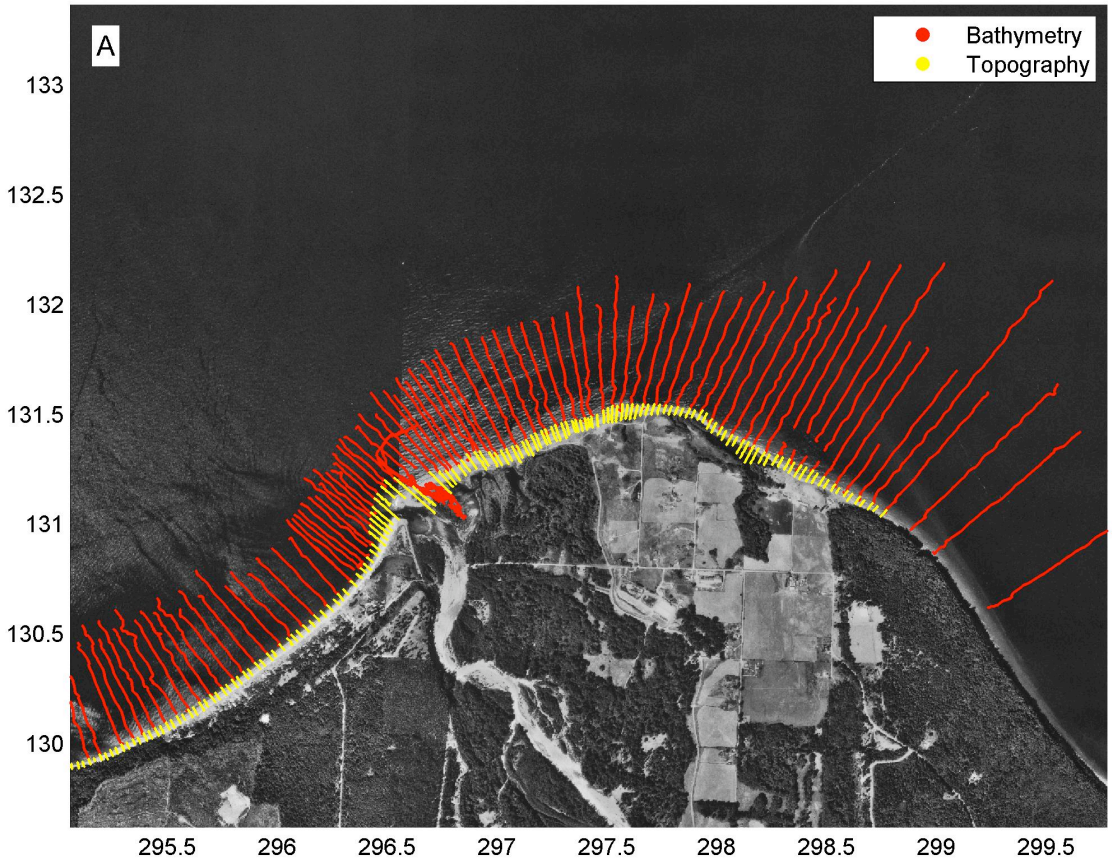

Figure F2. Elwha September 2006 surveyed lines (delta region).

Table F. Bathymetric and topographic lines for September 2006 survey.

Bathymetric line	Topographic line
	ew06_line080_t.xyz
	ew06_line081_t.xyz
	ew06_line082_t.xyz
	ew06_line083_t.xyz
ew06_line084_b.xyz	ew06_line084_t.xyz
	ew06_line085_t.xyz
ew06_line086_b.xyz	ew06_line086_t.xyz
	ew06_line087_t.xyz
	ew06_line088_t.xyz
	ew06_line089_t.xyz
ew06_line090_b.xyz	ew06_line090_t.xyz
	ew06_line091_t.xyz
ew06_line092_b.xyz	ew06_line092_t.xyz
	ew06_line093_t.xyz
ew06_line094_b.xyz	ew06_line094_t.xyz

	ew06_line095_t.xyz
ew06_line096_b.xyz	ew06_line096_t.xyz
	ew06_line097_t.xyz
ew06_line098_b.xyz	ew06_line098_t.xyz
	ew06_line099_t.xyz
ew06_line100_b.xyz	ew06_line100_t.xyz
	ew06_line101_t.xyz
ew06_line102_b.xyz	ew06_line102_t.xyz
	ew06_line103_t.xyz
ew06_line104_b.xyz	ew06_line104_t.xyz
	ew06_line105_t.xyz
ew06_line106_b.xyz	ew06_line106_t.xyz
	ew06_line107_t.xyz
ew06_line108_b.xyz	ew06_line108_t.xyz
	ew06_line109_t.xyz
ew06_line110_b.xyz	ew06_line110_t.xyz
	ew06_line111_t.xyz
ew06_line112_b.xyz	ew06_line112_t.xyz
	ew06_line113_t.xyz
ew06_line114_b.xyz	ew06_line114_t.xyz
	ew06_line115_t.xyz
ew06_line116_b.xyz	ew06_line116_t.xyz
	ew06_line117_t.xyz
ew06_line118_b.xyz	ew06_line118_t.xyz
	ew06_line119_t.xyz
ew06_line120_b.xyz	ew06_line120_t.xyz
	ew06_line121_t.xyz
ew06_line122_b.xyz	ew06_line122_t.xyz
	ew06_line123_t.xyz
ew06_line124_b.xyz	ew06_line124_t.xyz
	ew06_line125_t.xyz
ew06_line126_b.xyz	ew06_line126_t.xyz
	ew06_line127_t.xyz
ew06_line128_b.xyz	ew06_line128_t.xyz
	ew06_line129_t.xyz
ew06_line130_b.xyz	ew06_line130_t.xyz
ew06_line130_b2.xyz	
ew06_line131_b.xyz	ew06_line131_t.xyz
ew06_line132_b.xyz	ew06_line132_t.xyz
ew06_line133_b.xyz	ew06_line133_t.xyz
ew06_line134_b.xyz	ew06_line134_t.xyz
ew06_line135_b.xyz	ew06_line135_t.xyz
ew06_line136_b.xyz	ew06_line136_t.xyz
ew06_line137_b.xyz	ew06_line137_t.xyz
ew06_line138_b.xyz	ew06_line138_t.xyz
ew06_line139_b.xyz	ew06_line139_t.xyz
ew06_line140_b.xyz	ew06_line140_t.xyz
ew06_line141_b.xyz	ew06_line141_t.xyz
ew06_line142_b.xyz	ew06_line142_t.xyz
ew06_line143_b.xyz	ew06_line143_t.xyz
ew06_line144_b.xyz	ew06_line144_t.xyz
ew06_line145_b.xyz	ew06_line145_t.xyz
ew06_line146_b.xyz	ew06_line146_t.xyz
ew06_line147_b.xyz	ew06_line147_t.xyz
ew06_line147_b2.xyz	

ew06_line147_b3.xyz	
ew06_line148_b.xyz	ew06_line148_t.xyz
ew06_line149_b.xyz	ew06_line149_t.xyz
ew06_line150_b.xyz	ew06_line150_t.xyz
ew06_line151_b.xyz	ew06_line151_t.xyz
ew06_line152_b.xyz	ew06_line152_t.xyz
ew06_line153_b.xyz	ew06_line153_t.xyz
ew06_line154_b.xyz	ew06_line154_t.xyz
ew06_line155_b.xyz	ew06_line155_t.xyz
ew06_line156_b.xyz	ew06_line156_t.xyz
ew06_line157_b.xyz	ew06_line157_t.xyz
ew06_line158_b.xyz	ew06_line158_t.xyz
ew06_line159_b.xyz	ew06_line159_t.xyz
ew06_line160_b.xyz	ew06_line160_t.xyz
	ew06_line161_t.xyz
ew06_line162_b.xyz	ew06_line162_t.xyz
	ew06_line163_t.xyz
ew06_line164_b.xyz	ew06_line164_t.xyz
	ew06_line165_t.xyz
ew06_line166_b.xyz	ew06_line166_t.xyz
	ew06_line167_t.xyz
ew06_line168_b.xyz	ew06_line168_t.xyz
	ew06_line169_t.xyz
ew06_line170_b.xyz	ew06_line170_t.xyz
	ew06_line171_t.xyz
ew06_line172_b.xyz	ew06_line172_t.xyz
	ew06_line173_t.xyz
ew06_line174_b.xyz	ew06_line174_t.xyz
	ew06_line175_t.xyz
ew06_line176_b.xyz	ew06_line176_t.xyz
	ew06_line177_t.xyz
ew06_line178_b.xyz	ew06_line178_t.xyz
	ew06_line179_t.xyz
ew06_line180_b.xyz	ew06_line180_t.xyz
	ew06_line181_t.xyz
ew06_line182_b.xyz	ew06_line182_t.xyz
	ew06_line183_t.xyz
ew06_line184_b.xyz	ew06_line184_t.xyz
	ew06_line185_t.xyz
ew06_line186_b.xyz	ew06_line186_t.xyz
	ew06_line187_t.xyz
ew06_line188_b.xyz	ew06_line188_t.xyz
	ew06_line189_t.xyz
ew06_line190_b.xyz	ew06_line190_t.xyz
	ew06_line191_t.xyz
ew06_line192_b.xyz	ew06_line192_t.xyz
	ew06_line193_t.xyz
ew06_line194_b.xyz	ew06_line194_t.xyz
	ew06_line195_t.xyz
ew06_line196_b.xyz	ew06_line196_t.xyz
	ew06_line197_t.xyz
ew06_line198_b.xyz	ew06_line198_t.xyz
	ew06_line199_t.xyz
ew06_line200_b.xyz	ew06_line200_t.xyz
	ew06_line201_t.xyz

ew06_line202_b.xyz	ew06_line202_t.xyz
	ew06_line203_t.xyz
ew06_line204_b.xyz	ew06_line204_t.xyz
	ew06_line205_t.xyz
ew06_line206_b.xyz	ew06_line206_t.xyz
	ew06_line207_t.xyz
ew06_line208_b.xyz	ew06_line208_t.xyz
	ew06_line209_t.xyz
ew06_line210_b.xyz	ew06_line210_t.xyz
	ew06_line211_t.xyz
ew06_line212_b.xyz	ew06_line212_t.xyz
	ew06_line213_t.xyz
ew06_line214_b.xyz	ew06_line214_t.xyz
ew06_line214_b2.xyz	
	ew06_line215_t.xyz
ew06_line216_b.xyz	ew06_line216_t.xyz
ew06_line216_b2.xyz	
	ew06_line217_t.xyz
ew06_line218_b.xyz	ew06_line218_t.xyz
ew06_line218_b2.xyz	
	ew06_line219_t.xyz
ew06_line220_b.xyz	ew06_line220_t.xyz
ew06_line220_b2.xyz	
	ew06_line221_t.xyz
ew06_line222_b.xyz	ew06_line222_t.xyz
	ew06_line223_t.xyz
ew06_line224_b.xyz	ew06_line224_t.xyz
	ew06_line225_t.xyz
ew06_line226_b.xyz	ew06_line226_t.xyz
	ew06_line227_t.xyz
ew06_line228_b.xyz	ew06_line228_t.xyz
	ew06_line229_t.xyz
ew06_line230_b.xyz	ew06_line230_t.xyz
	ew06_line231_t.xyz
ew06_line232_b.xyz	ew06_line232_t.xyz
ew06_line234_b.xyz	
ew06_line236_b.xyz	
ew06_line240_b.xyz	