In Cooperation with the National Park Service and the National Aeronautics and Space Administration

Extracting Shorelines from NASA Airborne Topographic Lidar-Derived Digital Elevation Models

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U.S. Department of the Interior
U.S. Geological Survey

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Extracting Shorelines from NASA Airborne Topographic Lidar-Derived Digital Elevation Models

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List of Acronyms

ALPS – Airborne Lidar Processing System

ArcGIS – A family of software products that form a complete GIS (Geographic Information System)

ASIS – Assateague Island National Seashore

ATM – Airborne Topographic Mapper

CCWS – Center for Coastal and Watershed Studies

DEM – Digital Elevation Model

DSAS – Digital Shoreline Analysis System

EAARL – Experimental Advanced Airborne Research Lidar

ESRI – Environmental Systems Research Institute

FGDC – Federal Geographic Data Committee

GIS – Geographic Information System

GPS – Global Positioning System

HWL – High Water Line

IM – Inventory and Monitoring

INS – Inertial Navigation Systems

lidar – Light Detection and Ranging

MHW – Mean High Water

NASA – National Aeronautic and Space Administration

NOAA – National Oceanographic and Atmospheric Administration

NOS – National Ocean Service

NPS – National Park Service

NS – National Seashore

USGS – U.S. Geological Survey

UTM – Universal Transverse Mercator

Section One: Project Overview

1.1 Summary

This report documents part of the National Park Service (NPS)/U.S. Geological Survey (USGS)/National Aeronautics and Space Administration (NASA) Aerial Data Collection and Creation of Products for Park Vital Signs Project. This report is one in a series that describes methods for extracting topographic features from aerial survey data as part of a joint project among the NPS Inventory and Monitoring (IM) Program, the NASA Observational Sciences Branch, and the USGS Center for Coastal and Watershed Studies (CCWS).

One component of the NPS-IM/USGS/NASA project is the collection of NASA aerial surveys over various NPS barrier islands and coastal parks throughout the National Park Service's Northeast Region. These aerial surveys collect optical remote sensing data from a variety of sensors, including the NASA Airborne Topographic Mapper (ATM), the NASA Experimental Advanced Airborne Research Lidar (EAARL), and down-looking digital mapping cameras. These lidar surveys have been incorporated within vital signs and monitoring methods to capture ocean beach features, such as shoreline, dunes, and vegetation, which are indicators of geomorphologic change.

This report provides a detailed account of the methodology used for extracting digital shoreline data from lidar topographic surveys, presented in two main sections. Section 1 describes the study area and discusses the scientific rationale behind the project, providing a brief description of sensors and initial data processing. Section 2 presents detailed techniques used for extracting a datum-referenced shoreline from lidar-derived digital elevation models (DEMs) using ESRI ArcGIS 8.3 software. Although ESRI software was utilized for this project, similar techniques may be applied with other Geographic Information System (GIS) or image processing software.

1.2 Introduction

Tracking changes in terrain along coastal barrier island beaches requires accurate high-resolution topographic data. Traditional products, such as available contour maps or low-resolution digital elevation models (DEMs), could not provide the level of detail or the update frequency necessary to monitor barrier island parks. To address this need, the National Park Service and NASA initiated an experimental beach-mapping program using airborne lidar (light detection and ranging) high-resolution topographic surveys (Figure 1) at Assateague Island National Seashore (Brock et al., 1999; Brock and Krabill, 2001).

NASA began collecting airborne laser surveys over Assateague Island in 1995 using the NASA ATM sensor. Initially, the ATM carried a single-return green wavelength lidar; a down-looking camera was added in 2001 (Brock and Sallenger, 2001). Further innovations in sensor development resulted in a new waveform-resolving green-wavelength lidar (NASA EAARL). The EAARL is a cross-environment sensor, capable of surveying both terrestrial and aquatic environments. Consequently, NASA lidar survey data provides a wide range of information, including but not limited to: 1) bare-earth digital elevation models, 2) first-return digital elevation models, and 3) vegetation canopy height and distribution (Brock and Wright, 2002). Currently, the EAARL system incorporates down-looking cameras for collecting digital photography in conjunction with the lidar survey data.

Data collected by the sensors are referenced to the ground using kinematic differential global positioning system (GPS) methods, providing vertical accuracy to within 20 cm (Brock and Sallenger, 2001). In addition, the orientation of the aircraft is measured using Inertial Navigation Systems (INS). Small laser spot size and high pulse frequency results in DEM products being produced at a 1-m resolution (Nayegandhi and Brock, 2002). The ATM and EAARL sensors are mounted on small aircraft and can be commissioned as needed. Typical flight time required to complete surveys within the NPS Northeast Coastal and Barrier Island network have varied between one to five days. As a result, lidar surveys not only provide accurate, high-resolution

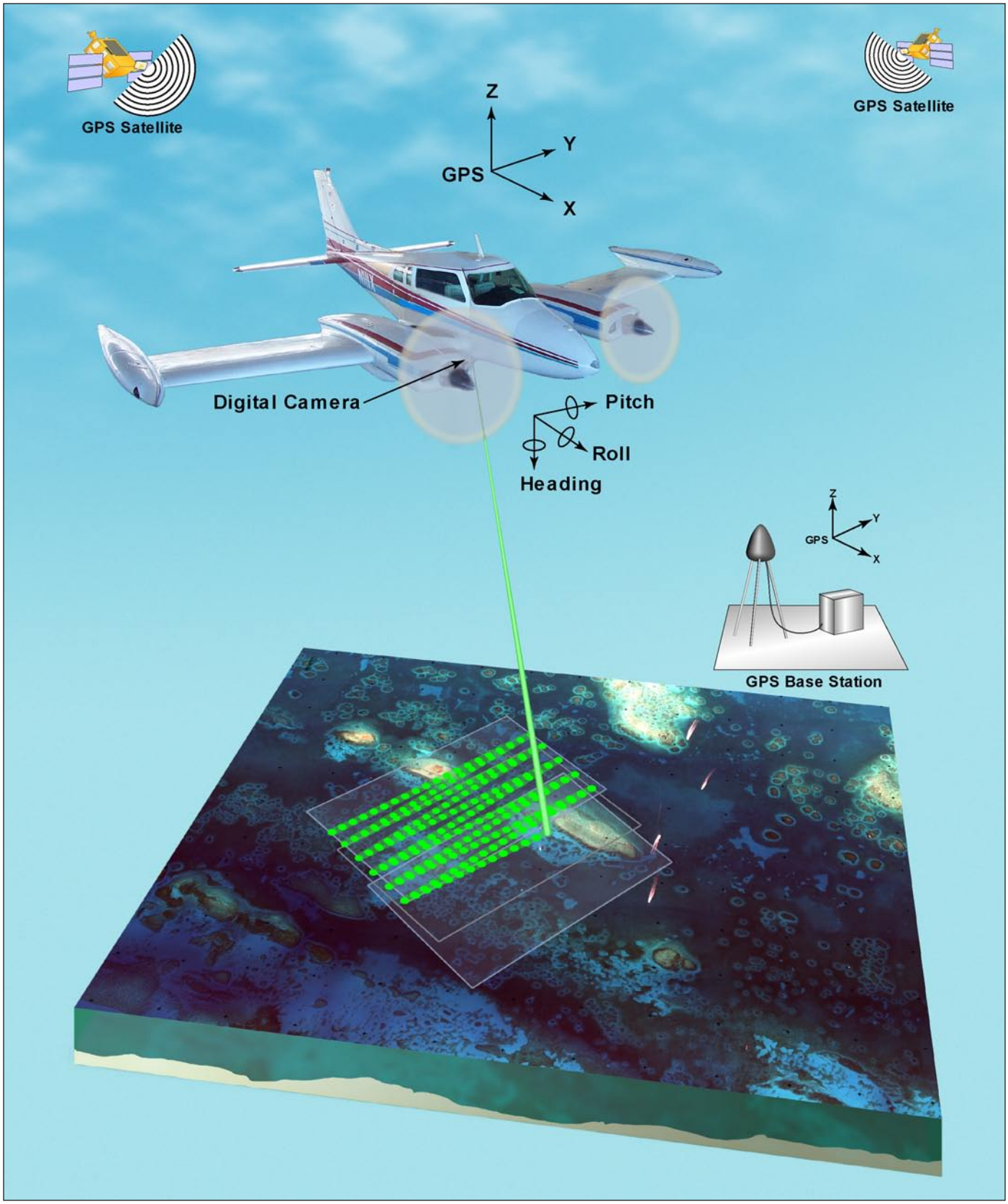


Figure 1. Airborne topographic lidar (ATM) is mounted on a small aircraft and flown along the coast for topographic surveying.

datasets, but also can be acquired frequently in order to meet resource management and monitoring needs.

Over time, the USGS/CCWS project has developed significant relevance to the management needs of NPS. Survey data are being used in a number of park programs, including change detection for shorelines and the high-resolution mapping of topography and bathymetry. Topographic lidar data and aerial photography acquired during NASA overflights of ASIS are being used in the Threatened and Endangered Species Recover Program: Piping Plover and Sea Beach Amaranth, the Geomorphologic Monitoring Program (elevation models, topographic profiles, and beach re-nourishment), and within the Wildlife Management Program: Horse-grazing effects on vegetation and natural dune evolution (DeStoppelaire et al., 2001).

The project has also revealed the importance of it's role in converting raw NASA remote sensing datasets into GIS-compatible information layers. Lidar surveys result in very large datasets, which in their raw format are not compatible with most GIS software. The USGS has taken the lead role in developing methods for processing this data to a level that can be imported into widely used GIS software packages (Brock et al., 2001; Nayegandhi, 2001; Nayegandhi and Brock, 2002). Data are presented to the park in Environmental Systems Research Institute (ESRI) compatible formats. As a result, parks have been able to access these data directly for use in park natural resource management activities.

1.3 Study Area

Assateague Island National Seashore (ASIS) is located on the eastern seaboard along the coasts of Maryland and Virginia (Figure 2). Park boundaries encompass the entire island; management of the island is a partnership among the National Park Service, Assateague State Park, and Chincoteague National Wildlife Refuge.

Given its proximity to NASA and park interest in using the resulting datasets in ongoing resource management activities, Assateague Island has been a focus of data collection and applications development activity. The NASA Wallops Flight Facility, located on Wallops Island, VA, has been collecting aerial survey data over ASIS since 1995, beginning with topographic ATM lidar

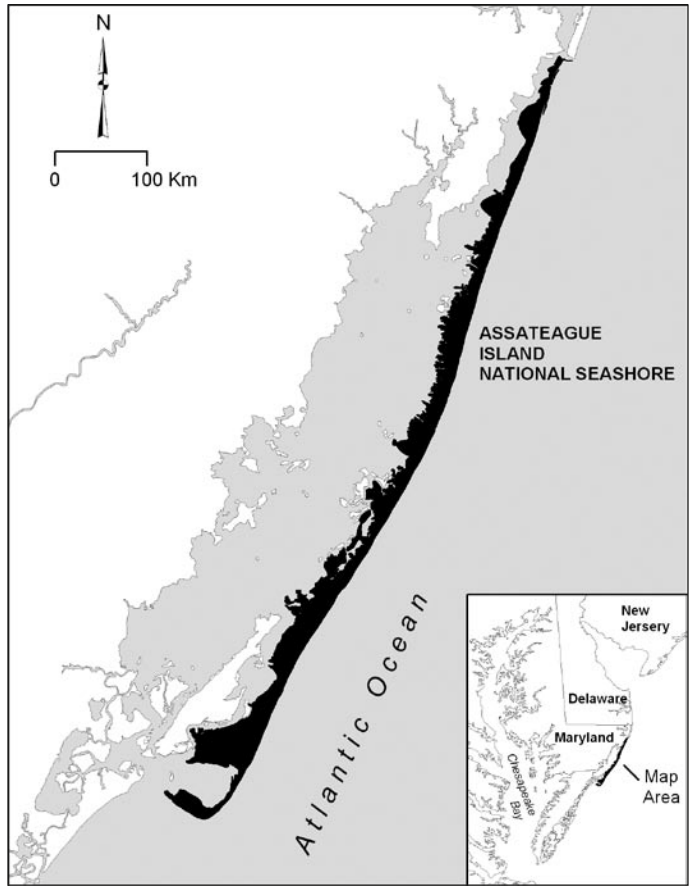


Figure 2. Assateague Island is located on the eastern seaboard along the coast of Maryland and Virginia.

surveys (Krabill et al., 2000; Brock and Sallenger, 2001) and expanding to include digital aerial photography acquisition and additional development of innovative lidar sensors that integrate bathymetric and topographic surveys (Nayegandhi et al., 2005). Lidar surveys provide point ground elevations that are used to construct a three-dimensional representation of the island landscape (Brock et al., 1999; Brock et al., 2002; Nayegandhi, et al., 2005; Nayegandhi, 2002) which is utilized in resource management.

1.4 Scientific Significance and Rationale for Project

Shorelines have been mapped from field surveys, aerial photography, global positioning system (GPS) surveys, and more recently lidar surveys (Leatherman, 2003; Parker, 2003). Regardless of the mapping method, the fundamental considerations for shoreline change mapping

and monitoring are the chosen indicator and a consistent measurement technique (Leatherman, 2003). Ideally, this indicator would be easily identifiable both in the field and in easily repeatable remotely sensed data. Such an indicator would provide a consistently measurable definition of the shoreline. Parker (2003) discusses shoreline definition choices, including mean high water (MHW), high water line (HWL), and morphological features, pointing out susceptibility to variability in each. The shoreline as defined by the MHW is deemed suitable by Parker (2003), as it takes into account all high tides over a number of years. Unfortunately, this definition is not directly comparable to historic shorelines as defined by NOAA T-sheets. NOAA T-sheets depict historic shorelines dating back to the mid-1800s for most U.S. coastal beaches. The indicator used by the surveyors at the time that NOAA T-sheets were made was the high water line (HWL). By using the HWL as the indicator, comparisons can be made between modern and historic shoreline positions (Leatherman, 2003, Ruggiero et al., 2003). According to Leatherman (2003), scientific analysis of shoreline trends cannot depend solely upon kinematic GPS and lidar surveys; the HWL shoreline must be utilized to take advantage of the historical information found on the T-sheets. Shoreline trends can only be delineated when the actual change is larger than the uncertainty that results when using the century-scale data that are presented on the T-sheets.

Morphological features such as beach berms, scarps edges, dune or bluff toe, and vegetation line have been proposed as better shoreline indicators than the HWL. The argument is that these features respond to variations in environmental conditions but are not as sensitive as the HWL to short-term changes. Unfortunately, the beaches along Assateague Island do not possess clearly defined berms or scarps, and the vegetation line does not necessarily respond to oceanic changes. Therefore, the NPS has chosen the high water line (HWL), also referred to as the wet/dry line, as the definition of shoreline for Assateague Island National Seashore. The NPS rationale is that the HWL is both visible in the field (Figure 3) and can be interpreted from aerial photography (Figure 4).

Additionally, by using the HWL, the NPS has the opportunity to obtain and compare shoreline positions from historic T-sheets, air photos, and field-based GPS surveys to form an extensive dataset that extends over the last 150 years.

Figure 3. The high water line (HWL) is easily identifiable by color tone differences as depicted by this portion of coast along Assateague Island National Seashore in Maryland. Photo courtesy of John Brock.

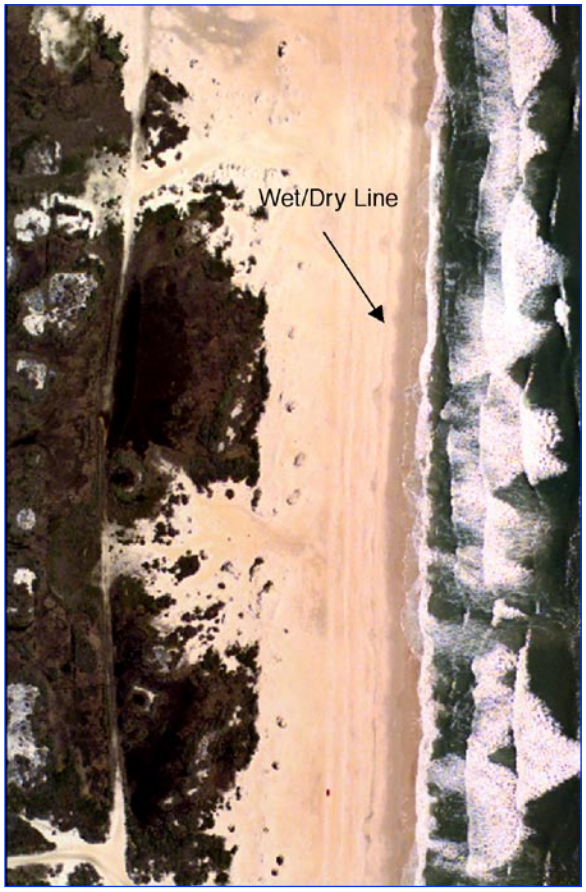


Figure 4. The high water line (HWL) is often interpreted from aerial photography; example from Assateague Island is shown.

1.5 Data

Since 1996, resource managers at Assateague Island National Seashore have been routinely mapping the shoreline of the park as part of their resource management program. The shoreline is mapped by collecting the position of the wet/dry line along the length of the beach using a kinematic global positioning system (GPS) mounted on a "beach buggy." The positions are translated into a complete shoreline that can then be input into a GIS for analysis.

As part of the NPS/USGS/NASA cooperative project, shorelines comparable to GPS-derived shorelines were extracted from aerial lidar surveys. Lidar surveys conducted within a few weeks time of NPS beach surveys were used in an analysis to determine the comparability between the two methods. Table 1 lists the individual shorelines used in the analysis. The methods used to ensure that the shorelines determined by the lidar survey elevations are comparable to the NPS-generated shorelines are described in the Data Analysis section.

1.6 Aims and Objectives of Project

Over time, the seaward edge of barrier islands along the northeast U.S. coast has eroded. Periodically, major storms wash sand over the barrier islands. Coastal erosion resulting from both natural and anthropogenic causes is one of the significant problems facing park management. Change in shoreline position, either through loss or accretion, can alter natural habitats. Shoreline retreat may destroy cultural resources, facilities, and other infrastructure. Inland resources can be affected adversely by coastal erosion because they are not mobile and may be lost. Another basic concern on barrier islands is geomorphologic change that drives change in other NPS natural resource areas of interest, including water quality in ground water and in estuaries, species and habitats of concern, recreational visitor use, and even resource extraction.

This document was created as part of the NPS-IM/USGS/NASA Aerial Data Collection and Creation of Products for Park Vital Signs Monitoring within the Northeast Region Coastal and Barrier Network project. The overall aim of the project is to develop a method for the detection and extraction of the shoreline.

1.7 Data Analysis

Shoreline vector files for Assateague Island National Seashore were obtained from the NPS land-based GPS surveys in an ESRI-compatible format (Table 1). The shorelines are identified by the month and year they were surveyed. Shorelines that matched lidar survey dates, within one month's time, were selected for analysis. Imagery is spatially referenced to the Universal Transverse Mercator (UTM) coordinate system, Zone 18, referenced to the North American Datum 1983.

Analysis was performed using ESRI ArcGIS© and ArcView© software products. Selected shoreline vectors were converted into points using ArcToolbox©, a component of ArcGIS©. Using ArcMap©, another component of ArcGIS©, the point layers were overlain onto concurrent lidar-derived DEMs and the elevation value under each point was extracted. The elevation values were averaged to obtain a contour elevation that could be generated from the DEMs. This process was repeated for each set of matching shoreline/DEM pairs (Table 2), and once a suitable contour elevation was determined, the contour line was generated from the lidar DEMs, thus producing the 'lidar shorelines.' Consequently, the decision was made to use the 1-m contour line as the shoreline definition when using the lidar data. The 1-meter contour is a result of averaging the March 1998 and June 2001 lidar elevations coincident with the NPS GPS-derived shorelines. These 1-m

Table 1. Collection dates for shoreline datasets.

Data Type	Data Collection Date			
	1998	1999	2000	2001
GPS-Derived	March	October	August	June
ATM Lidar	April 3	October 1	September 3	June 5

Table 2. Lidar-derived elevations under NPS shoreline vectors.

DEM Values coincident with NPS Shoreline Vector	Data Collection Date			
	April 3, 1998	October 1, 1999	August 2000	June 5, 2001
Mean Elevation (m)	1.05	1.83		0.95
Maximum Elev. (m)	2.01	4.62		2.04
Minimum Elev. (m)	0.00	0.06		0.00

contour shorelines were extracted from the existing lidar surveys that covered the length of Assateague Island. Resulting shorelines are listed in Table 3.

The NPS shoreline for October 1999 resulted in a higher mean elevation than the other shorelines. A 1.83-m contour was extracted from the October 1999 lidar DEM and compared against the NPS shoreline. These contours were compared against a 1.0-m contour line as well, the average of the April 1998 and June 2001 average elevations. The northern portion of Assateague Island with these lines is shown in Figure 5.

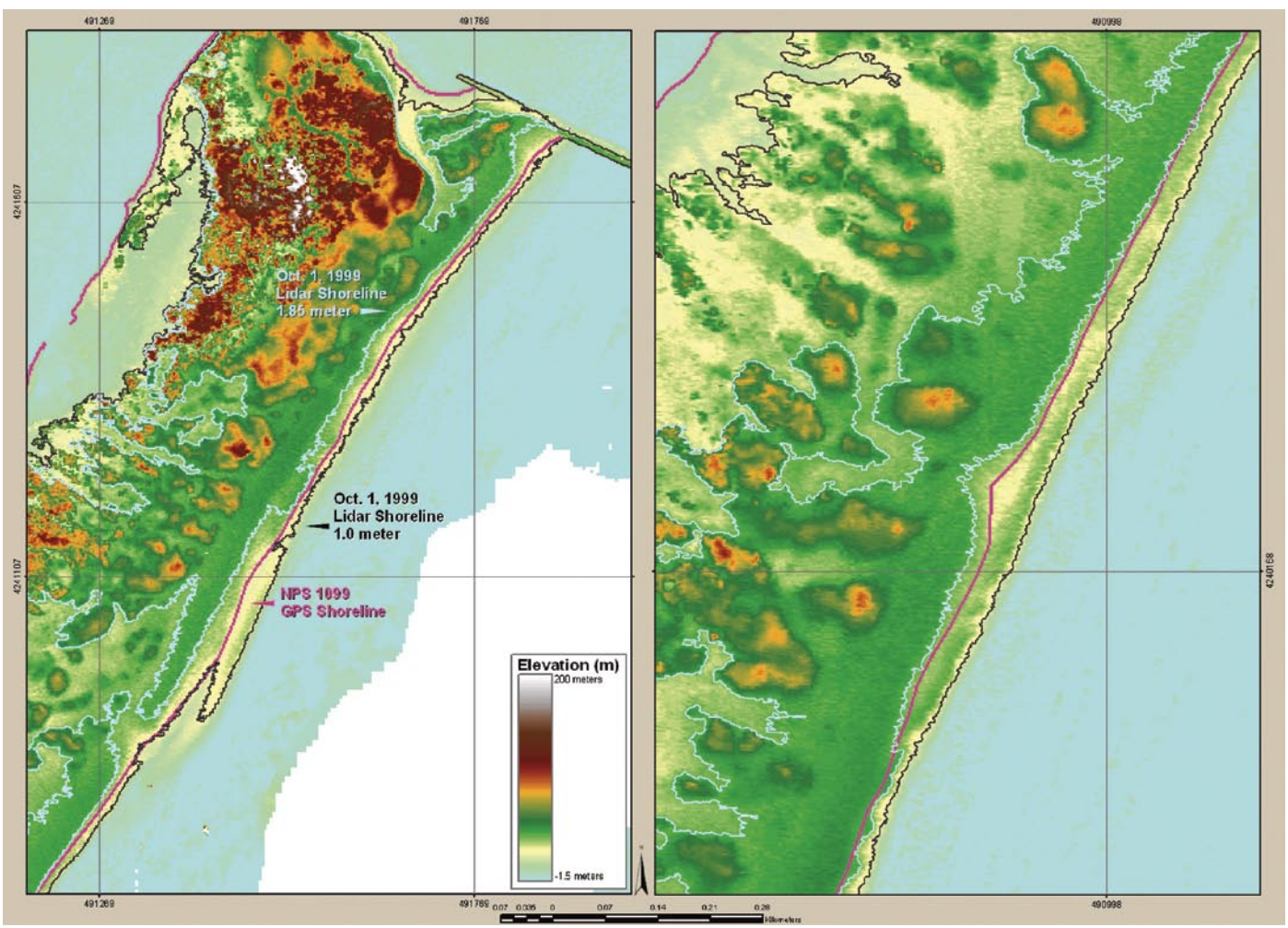


Figure 5. Northern end of Assateague Island. Comparison between October 1999 shorelines: NPS (pink); lidar 1-m contour (black); lidar 1.85-m contour (cyan).

The NPS shoreline is shown in pink, the 1-m lidar contour is shown in black, and the 1.83-m contour is shown in cyan. On the northern end of the island, the lidar-derived 1.83-m contour does not correspond to the NPS-derived shoreline. There may have been a storm event or very high tide when the NPS shoreline was surveyed. Figure 6 shows the positions of the 1-m lidar contour and NPS shoreline farther south on the island.

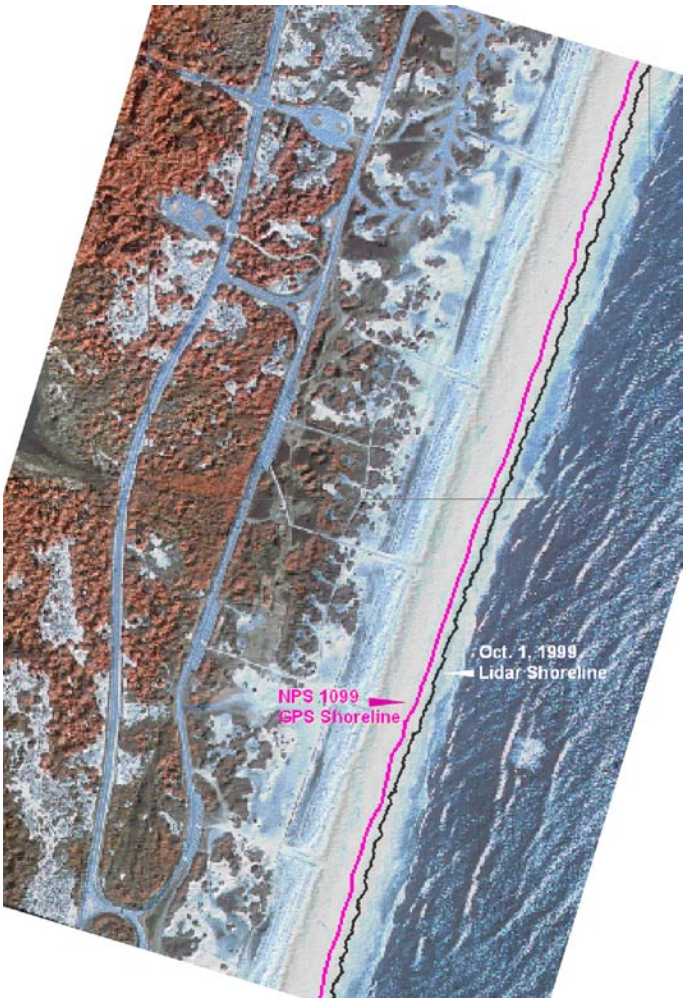


Figure 6. Comparison between October 1999 shoreline: NPS (pink); lidar 1-m contour (black).

A comparison between the June 2001 GPS- and lidar-derived shorelines is shown in Figure 7. The shoreline datasets were collected at the same time. Digital camera images were acquired during the ATM lidar survey as well, providing an excellent opportunity for both a direct comparison between the shoreline files and a visual record of ground conditions.

Figure 7 Comparison between NPS GPS-derived shoreline and lidar 1-m contour for June 5, 2001.

The shorelines derived from both the lidar elevations (shown in orange) and the ground GPS locations (shown in green) overlie very well for the June 5, 2001 surveys. This is the only date on which data for both lidar and NPS ground surveys were acquired.

Another comparison was performed between the GPS-derived shorelines and the lidar elevation-derived shorelines. Again, only those shoreline datasets that were collected within a month of each other were used in the analysis (Table 4). The two sets of shorelines, lidar and GPS, were analyzed for rates of shoreline change on the basis of a linear regression of past shoreline positions.

A computer program called the Digital Shoreline Analysis System v2 (DSAS), developed as an ArcView© extension by the USGS (Thieler et al., 2003), was used to calculate the rate of shoreline change every 25 m alongshore. DSAS automatically draws an oceanward

Table 3. Lidar-derived shorelines for ASIS.

Lidar Sensor	Survey Date
ATM	February 9, 1998
ATM	April 3, 1998
ATM	October 1, 1999
ATM	August 1, 2000
ATM	May 11, 2001
ATM	June 5, 2001
ATM	September 5, 2001
ATM	May 05, 2002
EAARL	September 9-11, 2002 October 7, 2002

Table 4. Shorelines used in the change analysis.

Survey Date	
Lidar-Derived	**GPS-Derived**
April 3, 1998	March 1998
October 1, 1999	October 1999
August 1, 2000	September 2000
June 5, 2001	June 2001
May 6, 2002	April 2002

reference baseline that follows the course of the outermost shoreline at a specified distance offshore. Transects that intersect the shorelines are then generated perpendicular to this baseline (Figure 8). Distances between the shoreline positions along each transect were determined, and a linear regression model was used to calculate the average annual rate of shoreline change (Figure 9). Five shorelines were used in each calculation with the oldest shoreline being 1988 and the most recent being 2002.

Information regarding the DSAS program can be found at the following website: http://woodshole.er.usgs.gov/project-pages/DSAS/. The two sets of linear rates of regression reflecting shoreline change at each point were compared. There was an average difference of 1.09-m between the two (with 1021 total point locations). A plot of the points is shown in Figure 10.

Examples of the shoreline rates of change are illustrated in Figures 11-13. The area shown in Figure 11 is the northern tip of Assateague Island. There is a large span of shoreline where overwash of the island occurred during a storm in 1998. The colored alongshore line depicts shoreline rates of change, with green reflecting increases and red showing loss. The results are comparable between the two sets of shorelines. Figures 12 and 13 also show shoreline changes and are correlated to the sections of the plot in Figure 10. Figure 12 corresponds to section A and Figure 13 corresponds to section B.

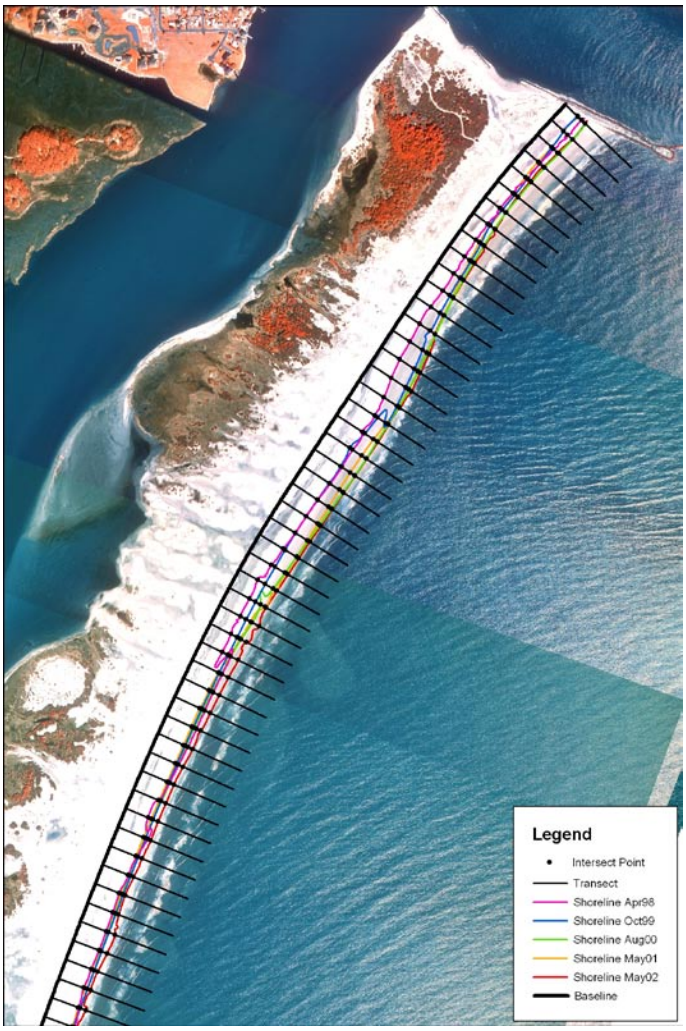


Figure 8. Baseline with transects drawn across shorelines as generated by DSAS.

1.8 Metadata Creation

Federal Geographic Data Committee (FGDC)-compliant metadata records are created for each "final" product. Examples of metadata are included with the sample products shown in Appendix I.

1.9 Conclusions

The lidar-derived shorelines paralleled the NPS GPS-derived shorelines very closely. The differences between the linear rates of regression for the lidar and GPS shorelines averaged 1.09m. The horizontal resolution of the lidar data is 1m. The results of this study demonstrate that it is possible to extract from lidar data shorelines that may be compared to shorelines defined by NPS ground surveys. The resulting lidar-based shoreline does not lend itself to interpretative error and can be used with historical T-sheets for future analysis.

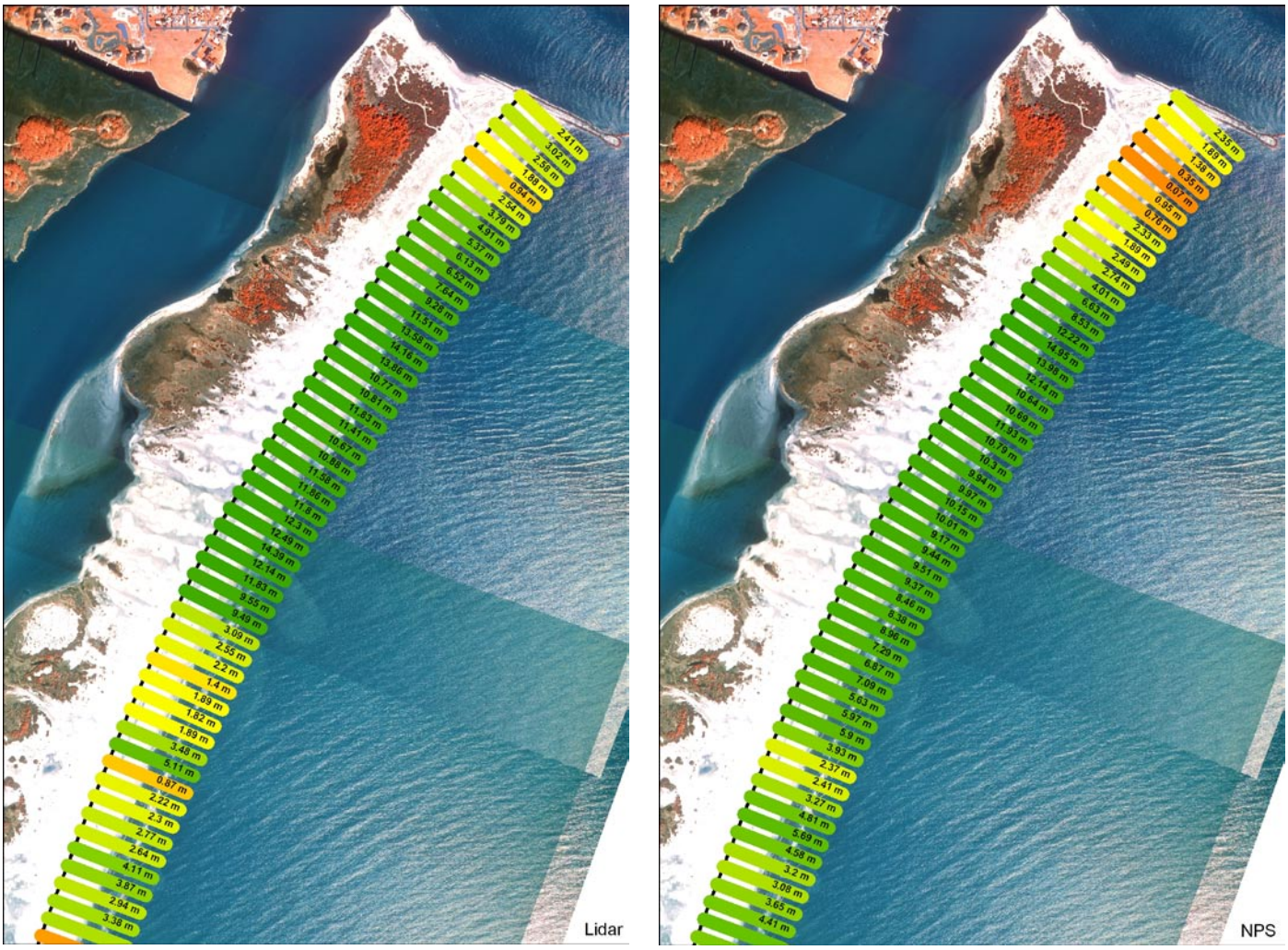


Figure 9. Example of regression rates of change for lidar-derived and NPS-provided shorelines.

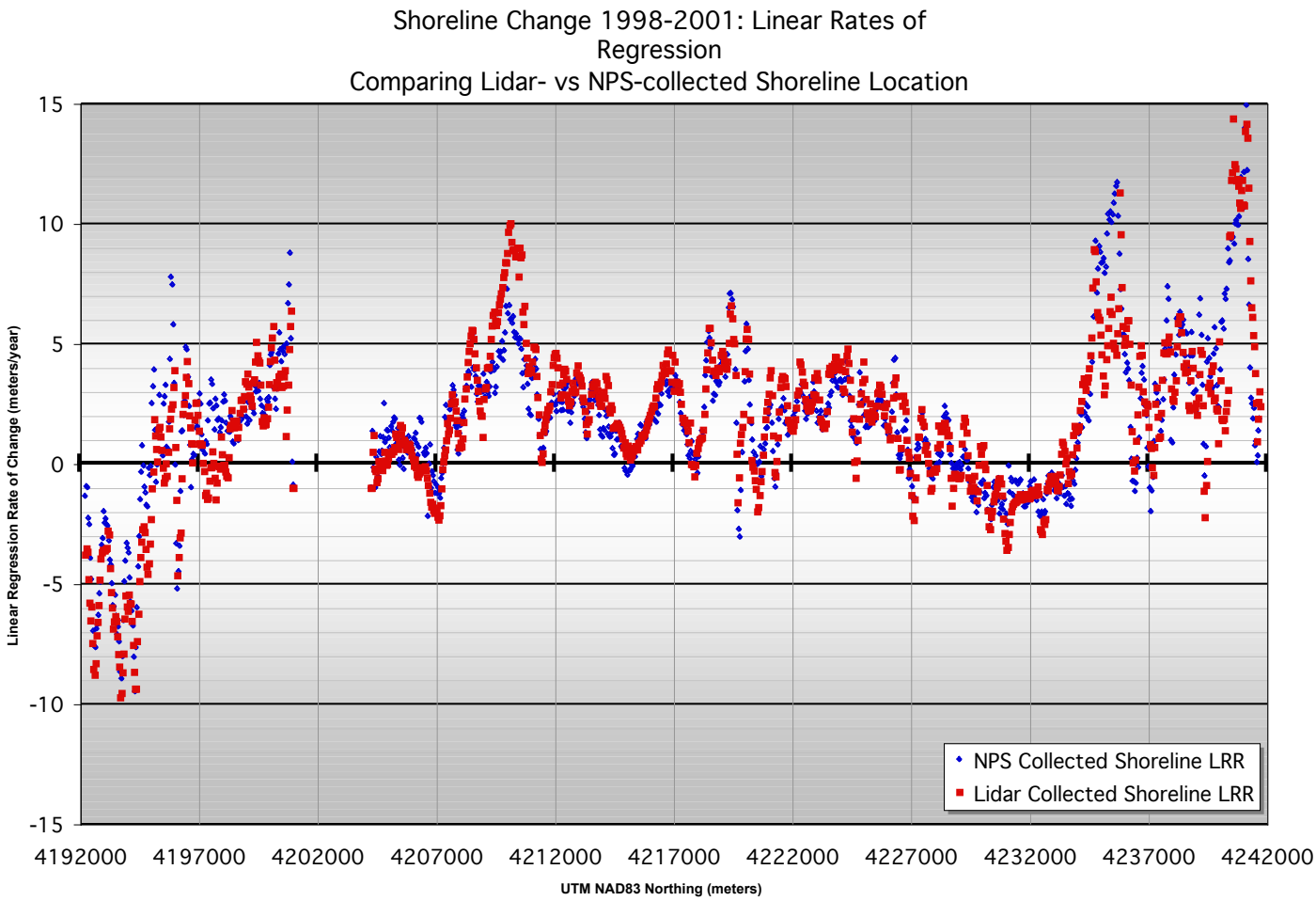


Figure 10. Graph comparing lidar- and GPS-derived shoreline linear regression rates of change. Aerial photographs with alongshore transects along portions of Assateague Island shoreline corresponding to sections A and B are shown in Figures 12 and 13.

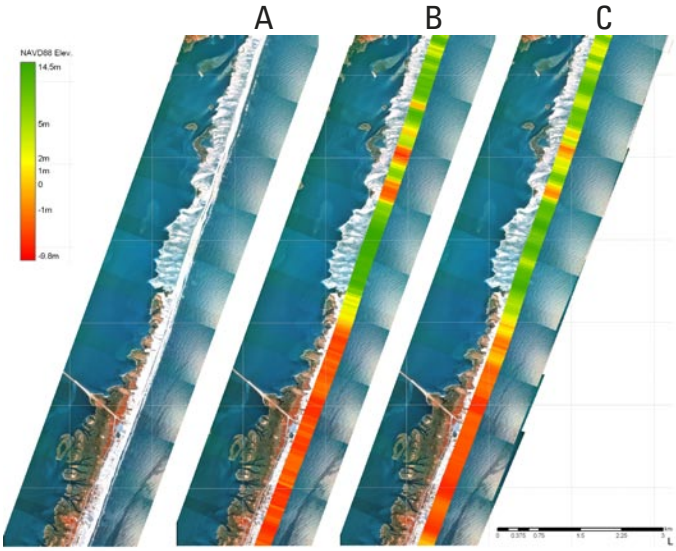


Figure 11. Northern end of Assateague Island where 1998 storm-induced overwash occurred. Images shown are: A) 1998 Aerial photomosaic, and shoreline change linear rates of regression resulting from B) NPS GPS-derived shorelines and C) ATM lidar-derived shorelines.

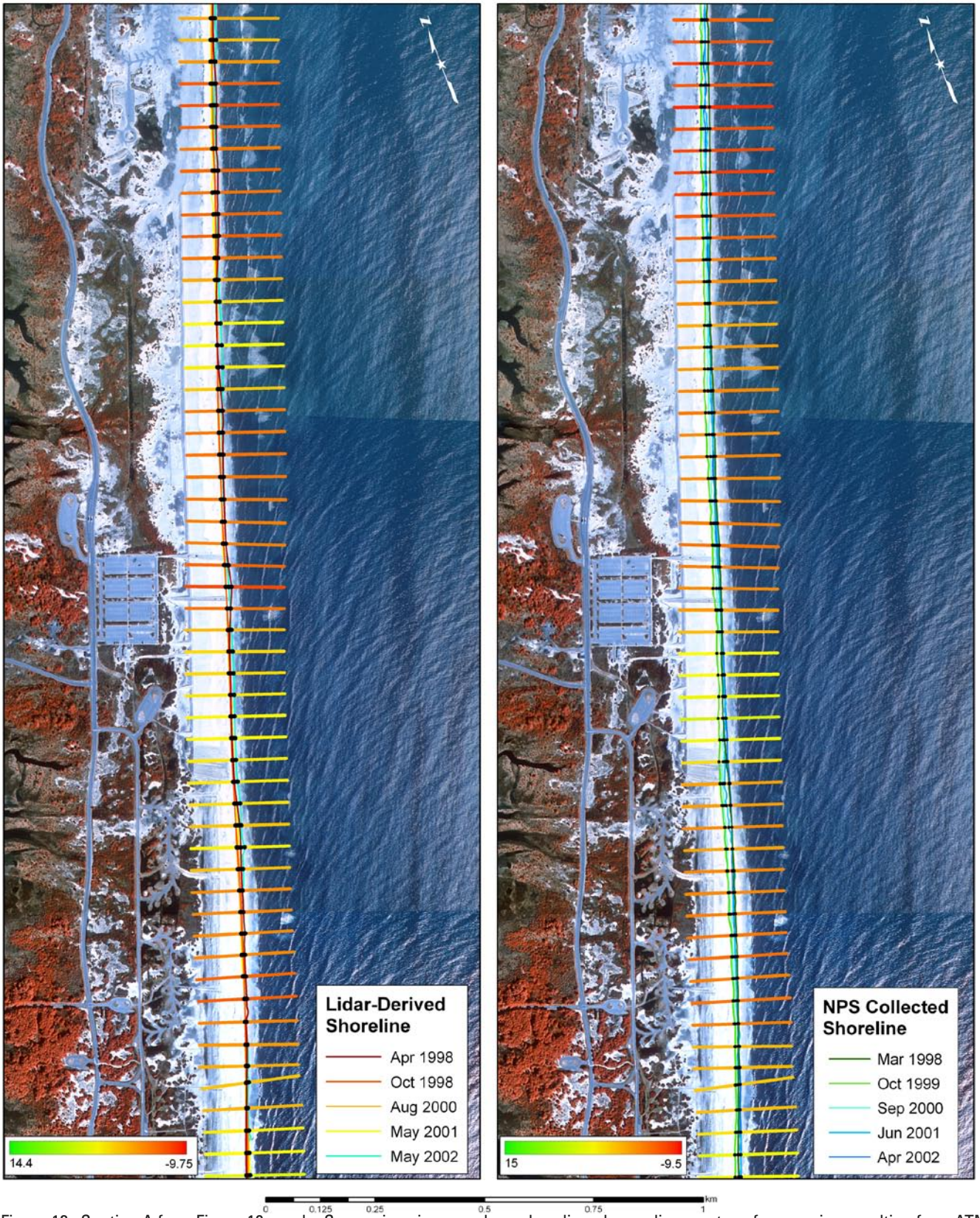


Figure 12. Section A from Figure 10 graph. Comparison images show shoreline change linear rates of regression resulting from ATM lidar-derived shorelines (left) and NPS GPS-derived shorelines (right)

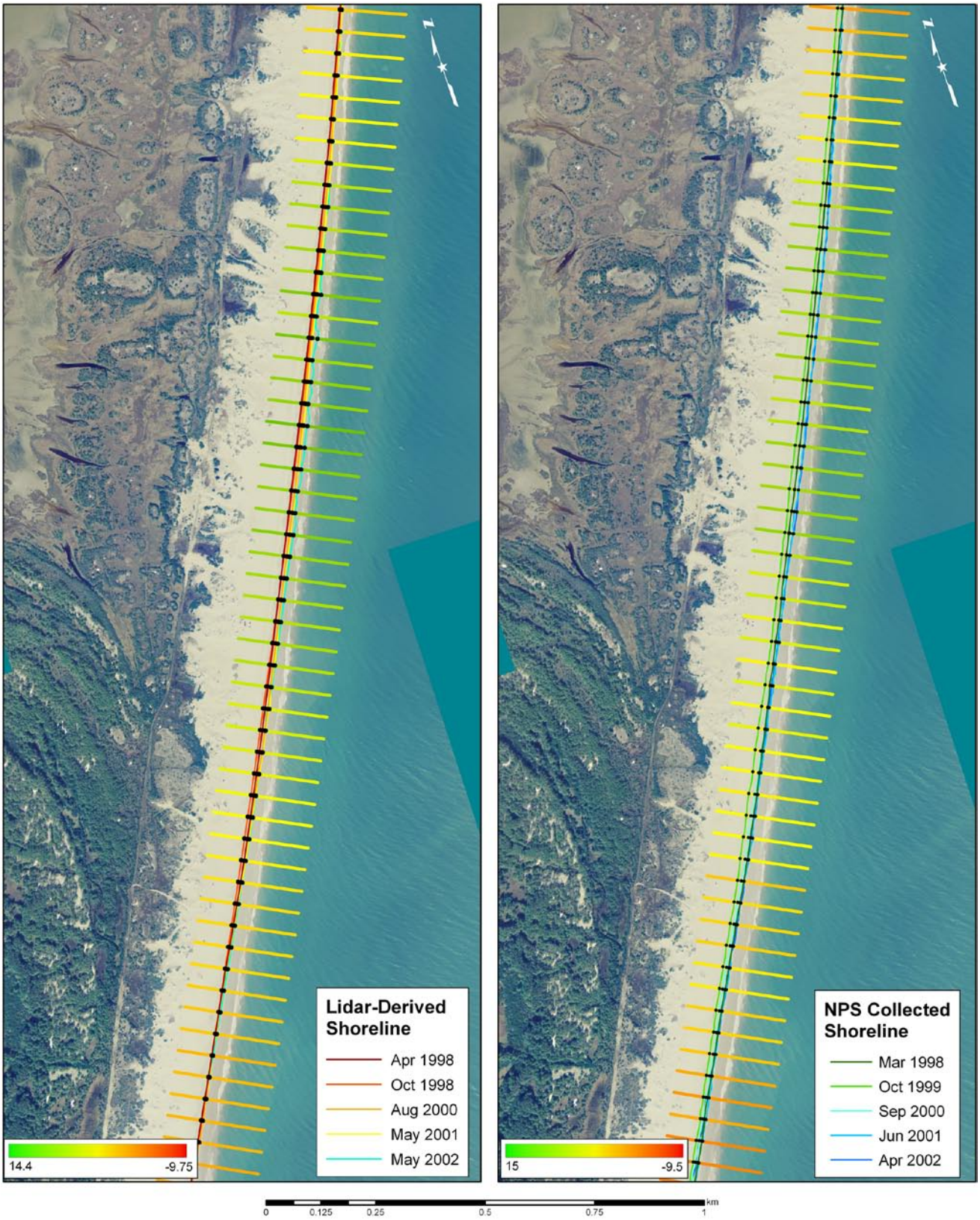


Figure 13. Shoreline rate of change - comparisons between lidar- and GPS-derived data for Section B from graph in Figure 10.

Section Two: Detailed Methodology

Steps for Extracting Lidar-Derived Shoreline Using ArcGIS

ESRI ArcGIS 8.3 software was used for the extraction of the shoreline from NASA lidar-derived digital elevation models. Imagery was spatially referenced to the Universal Transverse Mercator (UTM) coordinate system, Zone 18, referenced to the North American Datum 1983. Computer software requirements include ArcGIS 8.2 or higher and a Spatial Analyst Extension License. In order to extract a digital line from the imagery, elevations indicative of the NPS GPS-determined wet/dry line were determined. It was found that these elevations were relatively consistent along an elevation contour. A contour line was created for the corresponding elevation. The contour line was then checked for anomalies and edited, and the final line was then smoothed. Detailed steps for the extraction of shorelines from lidar surveys are presented below.

2.1 Open ArcMap and Load Lidar-Derived DEM

An example from the NASA EAARL 2001 Assateague Island survey is shown in Figure 14. For visual interpretation purposes, the following has been applied to the DEM:

- A hillshade image was created from the DEM using the Spatial Analysis tool. The DEM was then draped over the hillshade. Using the image Properties menu, the transparency of the DEM was set to 50%.
- A color ramp was applied to the DEM elevation values to enhance features.

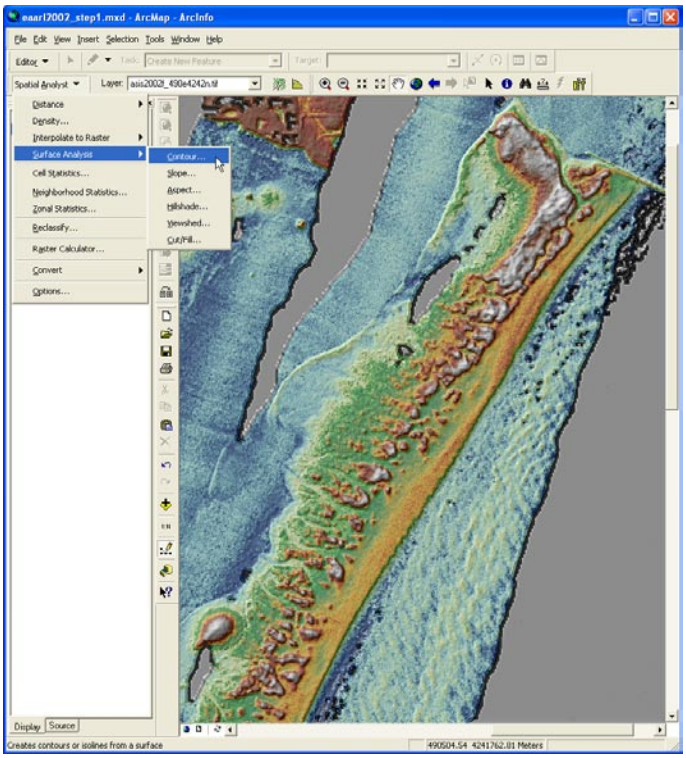


Figure 14. Lidar-derived DEM of the north end of Assateague Island.

2.2 Choose Shoreline Extraction Method

- Depending on computer capabilities to handle large datasets, shoreline extraction may be carried out in two ways:

Extract shorelines tile by tile and merge all into one file, or

- Integrate into a mosaic all the DEM tiles and then extract one shoreline from the image mosaic. The example provided is in the form of tile-by-tile.

2.3 Adjust Spatial Analyst Options

- From the Spatial Analyst dropdown menu, select Options (Figure 15).
- Click the Cell Size tab. From Analysis Cell Size, select As Specified Below. Then, set the Cell Size to 5 (to smooth resulting shoreline).
- Select OK.

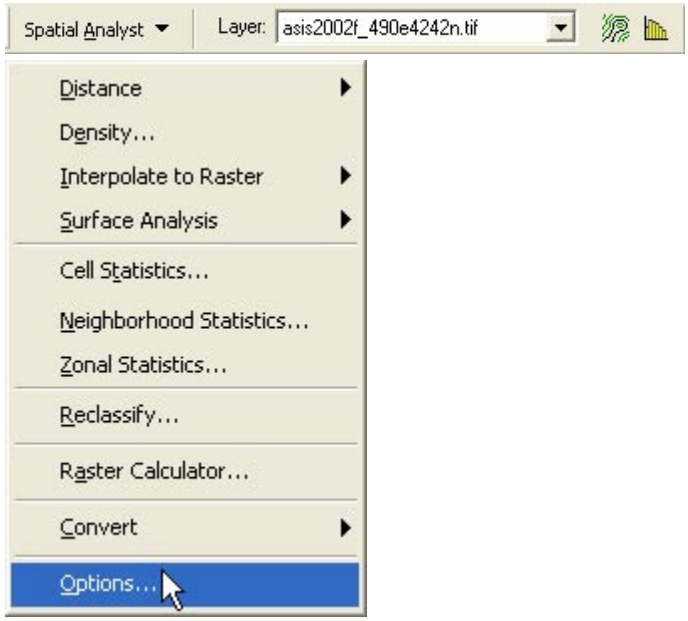


Figure 15. Spatial Analyst Options menu.

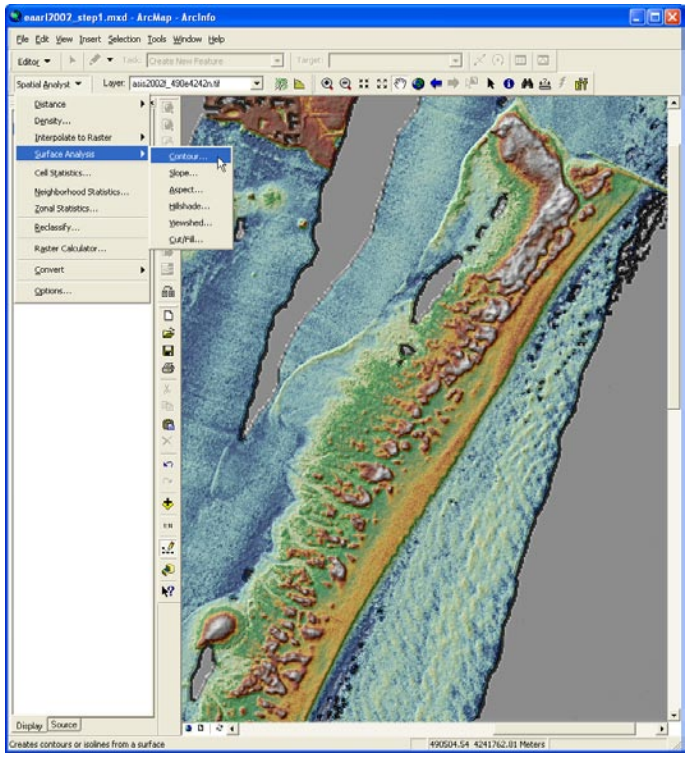


Figure 16. Spatial Analyst Surface Analysis menu.

2.4 Calculate 1m Contour

- Using the Spatial Analyst dropdown menu, under Surface Analysis select Contour (see Figure 16).
- On the Contour panel (Figure 17), make sure the correct Input Surface is selected.

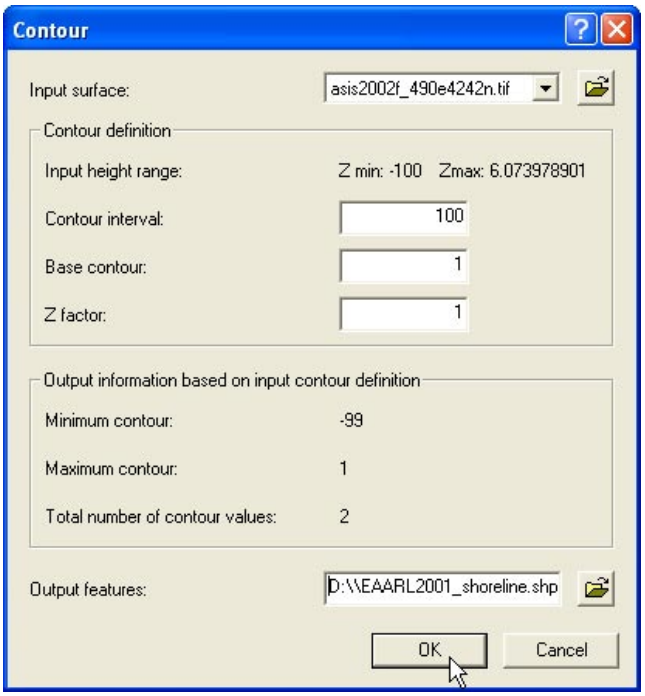


Figure 17. Contour dialog menu.

- Set the Contour Interval to 100. You only need one contour, the shoreline.
- The Base Contour will become the 'shoreline;' for Assateague Island the value is 1.
- For the EAARL data, leave the Z factor set to 1 (default).
- Provide an Output Features file name.
- Click OK.
- The contour shapefile will be automatically added to the data frame (Figure 18).

2.5 Edit Shoreline (1-m contour)

Examine the generated shoreline for inconsistencies and edit as needed. Figure 19 illustrates a portion of the shoreline where a break occurs that probably should not be there.

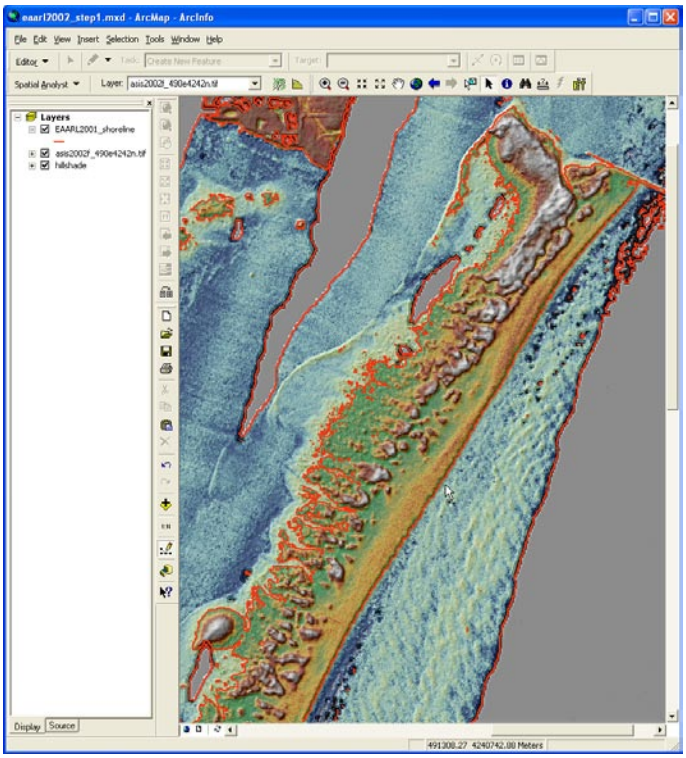


Figure 18. Resulting 1-m contour shown in red.

- Select **Start Editing** from the **Editor** menu.

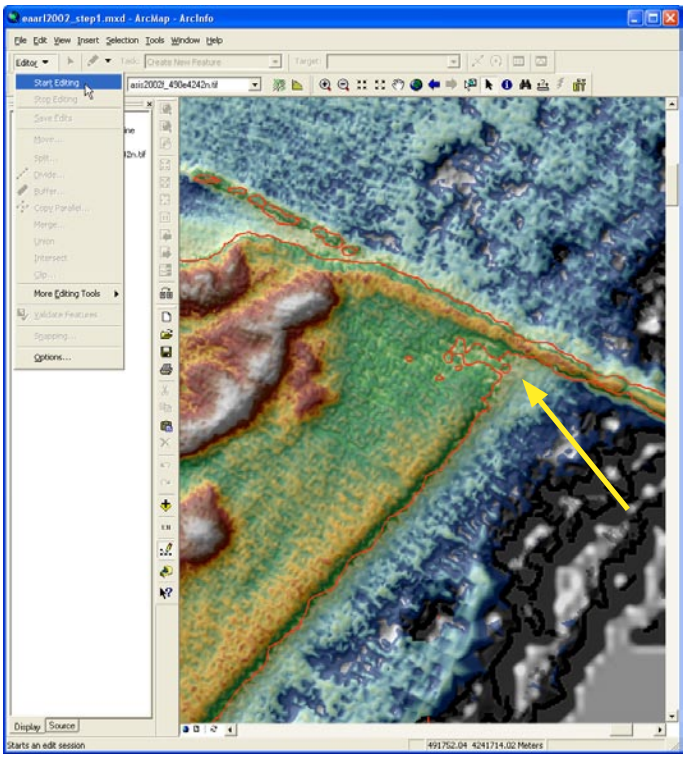
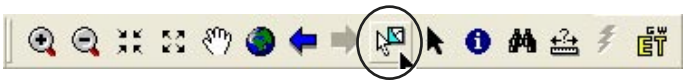


Figure 19. Section of shoreline that requires editing.

- On the Task menu, select **Modify Feature**. Check to insure that the **Target** is correct.

- Activate the **Select Features** tool.
- Select the shoreline. The vertices are visible and can be edited, as shown in Figure 20.
- On the **Editor** toolbar, select the **Split Tool**.



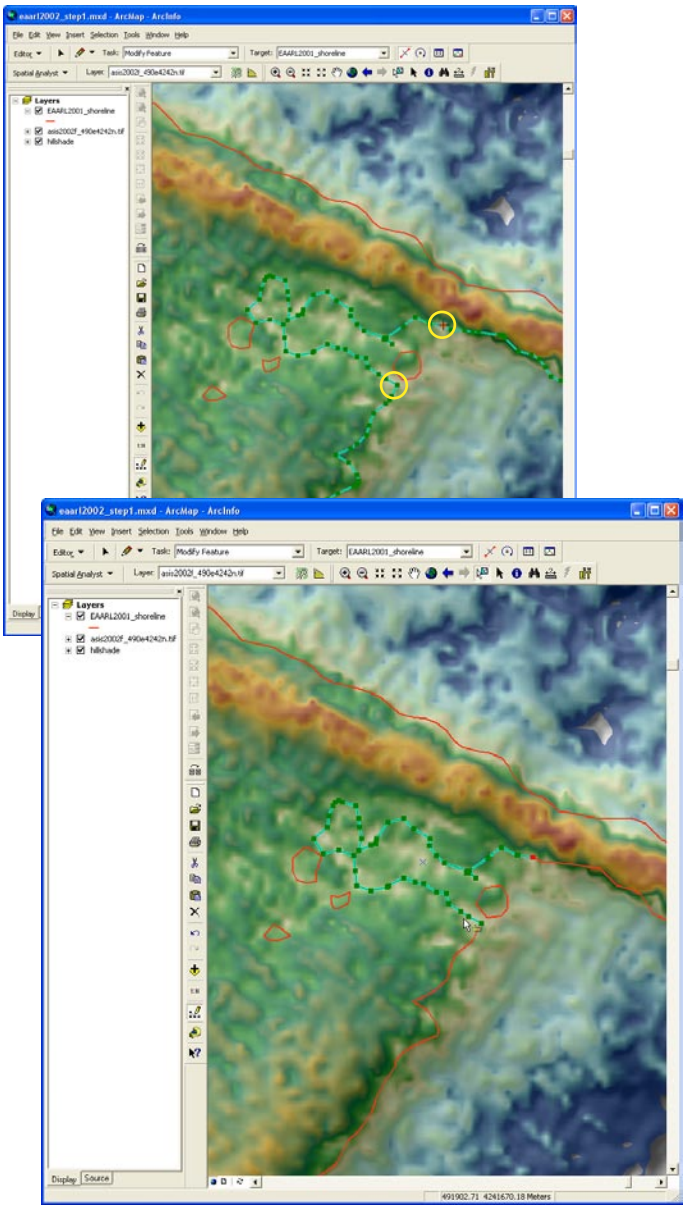


Figure 20. Section of shoreline ready for editing.

- Place the **Split Tool** over the vertex where you would like to split the line and click the mouse. Repeat for second vertex. Figure 20 provides an example showing where to split the shoreline; vertices are circled in yellow.
- Once both sides of the line have been split, the unwanted section can be selected using the selection tool and deleted (see Figure 21).

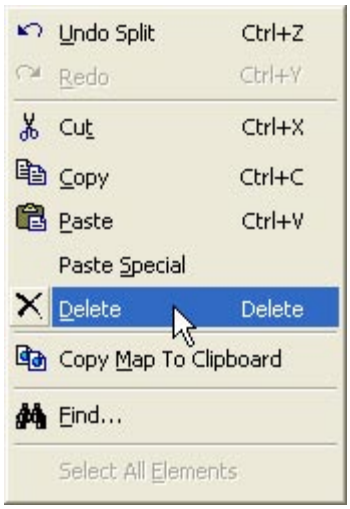


Figure 21. Section of edited shoreline selected for deletion. Delete using command from Edit menu.

- Next, attach the two ends of the broken line segment together by drawing a new section between them using **Editor Tools**.

- Select the line as before, using the **Selection** tool.
- Click on the **Sketch Tool** from the **Editor** toolbar (see above).
- Using the **Sketch Tool**, extend the end of one line to the start of the other. The tool will automatically begin drawing from the end of one of the line segments. Use mouse clicks to add vertices.
- Right click the mouse and from the dropdown menu choose Snap to Feature – Vertex (Figure 22).

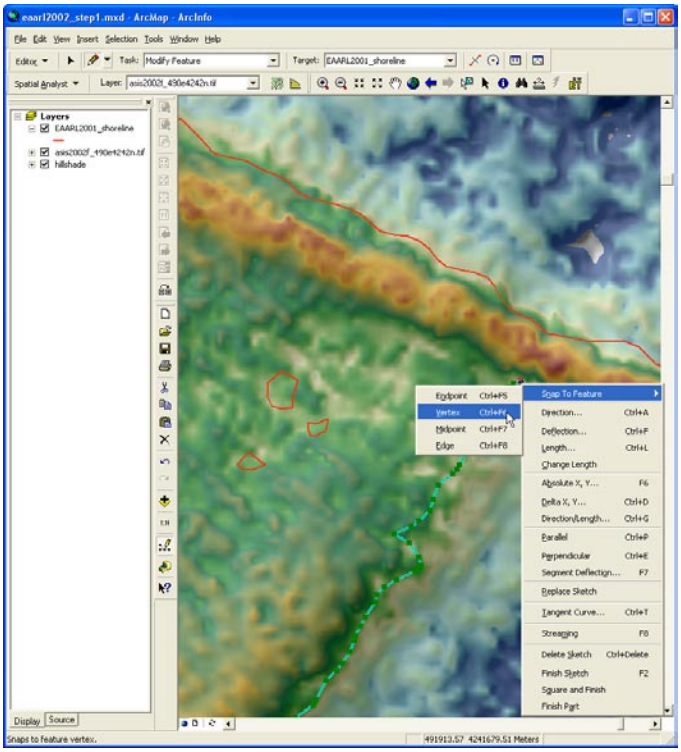


Figure 22. Complete line by snapping to vertex.

- Then right click again and select Finish Sketch (Figure 23).

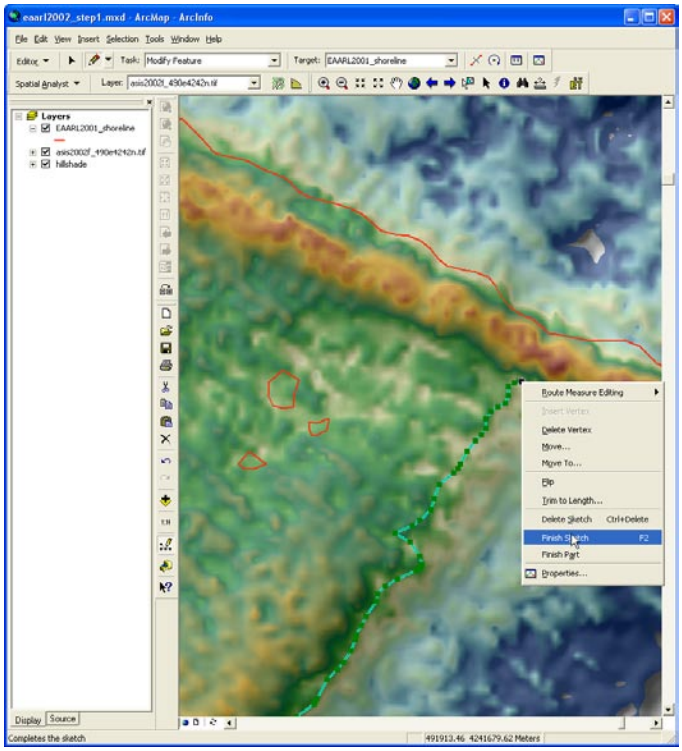


Figure 23. Complete sketch.

- Examine entire shoreline vector, editing as needed.
- Save your edits.

2.6 Remove Excess Contour Lines

Once you have completed editing, remove all but the "shoreline" vector.

- Using the Selection Tool, select the shoreline vector (Figure 24).

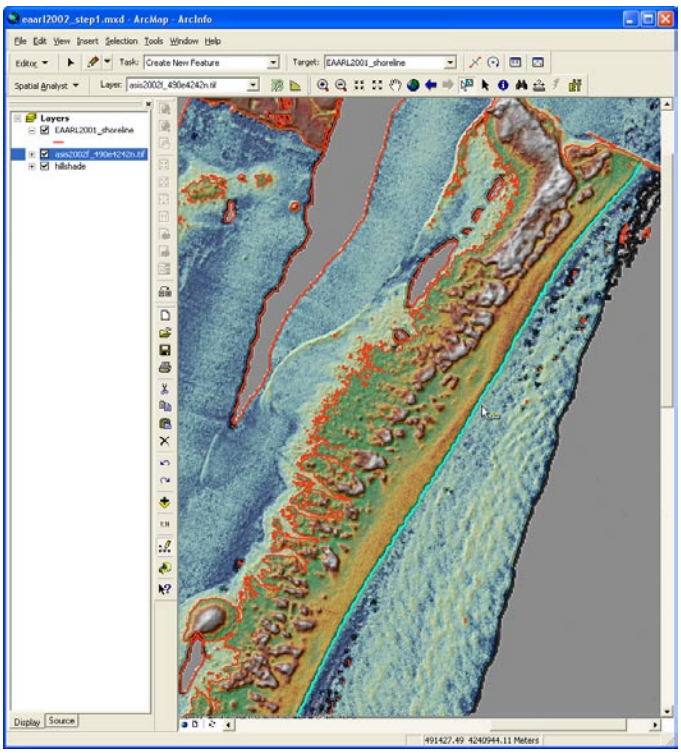


Figure 24. Select desired shoreline, shown highlighted in blue.

- Right click on the vector shapefile in the Table of Contents, scroll to Selection, then select Switch Selection (**Figure 25**).

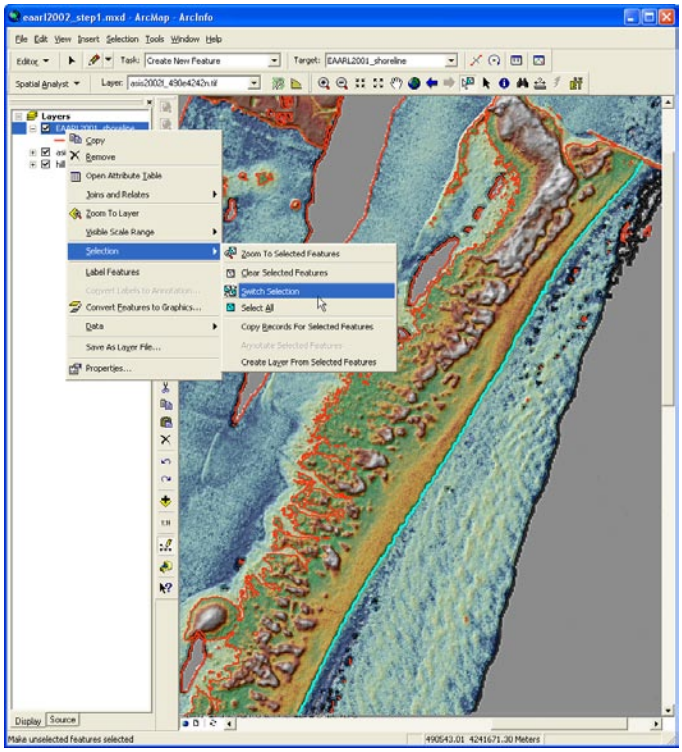


Figure 25. Switch selection menu.

- From the Edit menu, select Delete (Figure 26).

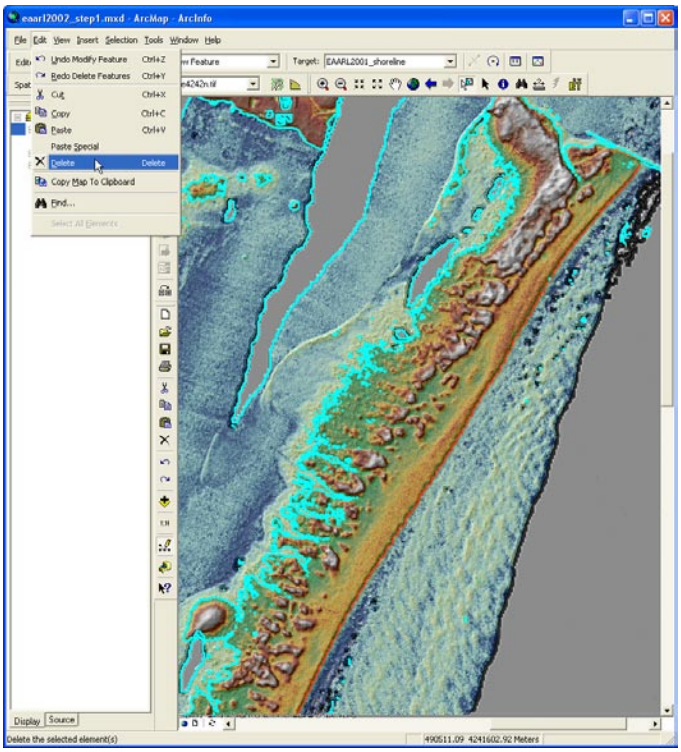


Figure 26. Selected vectors show highlighted in blue.

- Save Edits (Figure 27).

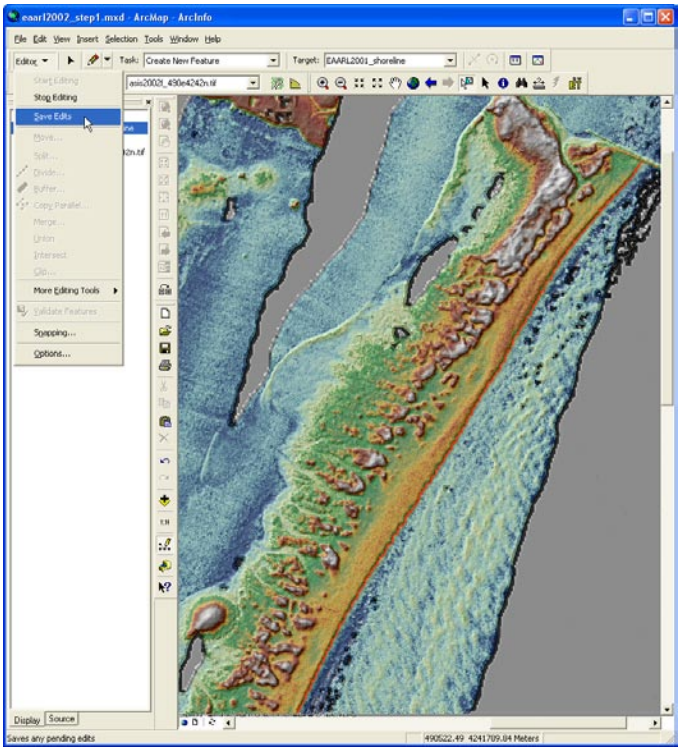


Figure 27. Resulting shoreline shown in red.

- Stop Editing.

2.7 Generalize and Smooth Shoreline.

Because the contour line was created from the 1-m resolution DEM, it follows the shoreline very closely, as illustrated in Figure 28. This processing step results in a line that is not very smooth when compared to the shorelines plotted manually by the Park Service. Since the desired result is a shoreline similar to shorelines plotted by park staff, the lidar-derived shoreline can be generalized and smoothed. The very detailed shoreline may be used as well, depending on resource management needs.

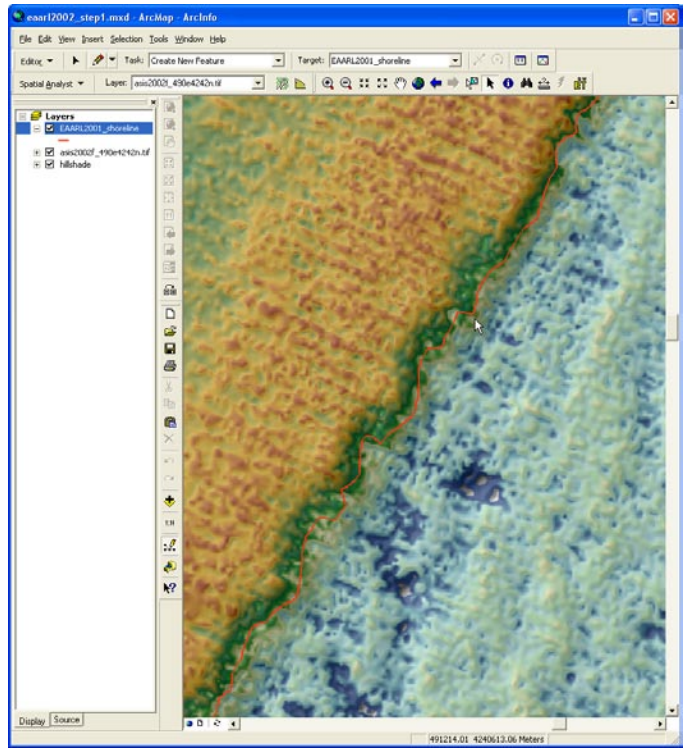


Figure 28. Detail of shoreline vector.

- Generalize and smooth the shoreline vector using ET Geo Wizards™ (Figure 29). ET Geo Wizards™ can be downloaded from the internet. The web address is http://ww.ian-do.com.

Figure 29. ET Geo Wizards GUI

- Select the Polyline tab.
- Select Generalize (Figure 30).

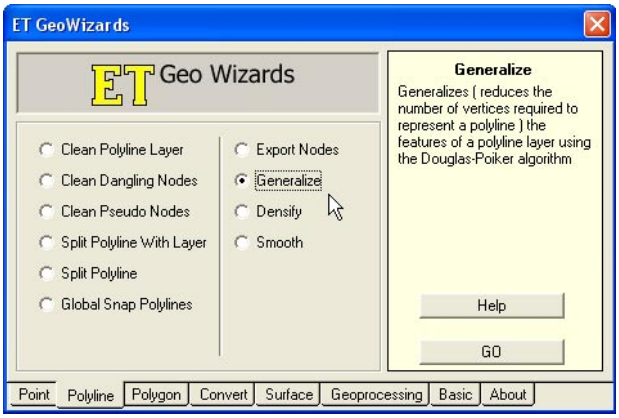


Figure 30. Select generalize option.

- Select Polyline Layer and provide Output Name (Figure 31).

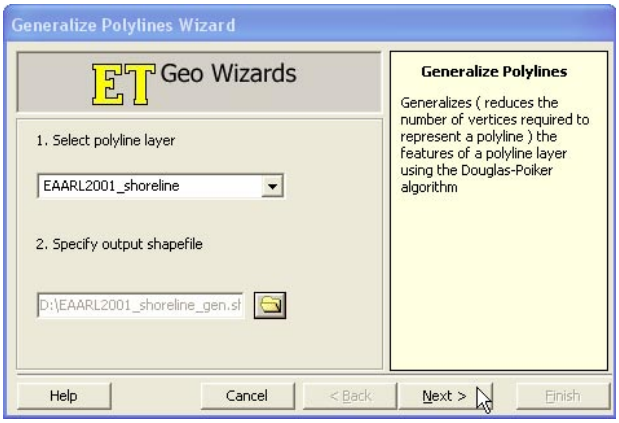


Figure 31. Select layer and provide output name.

- Assign Generalize Tolerance. Leave 'Generalize selected features only' box unchecked (Figure 32).

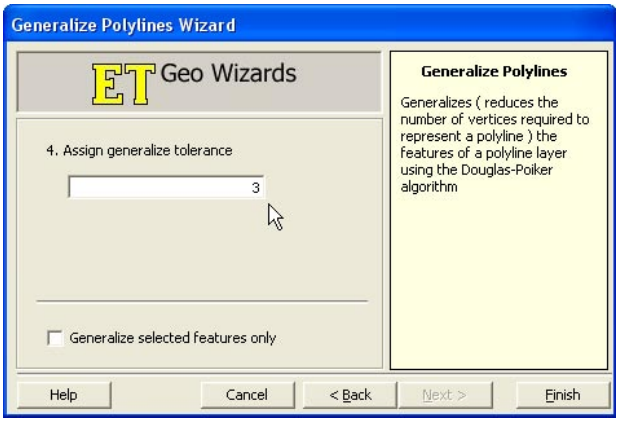


Figure 32. Assign generalize tolerance and finish.

- Select Finish. The resulting line is shown in Figure 33.

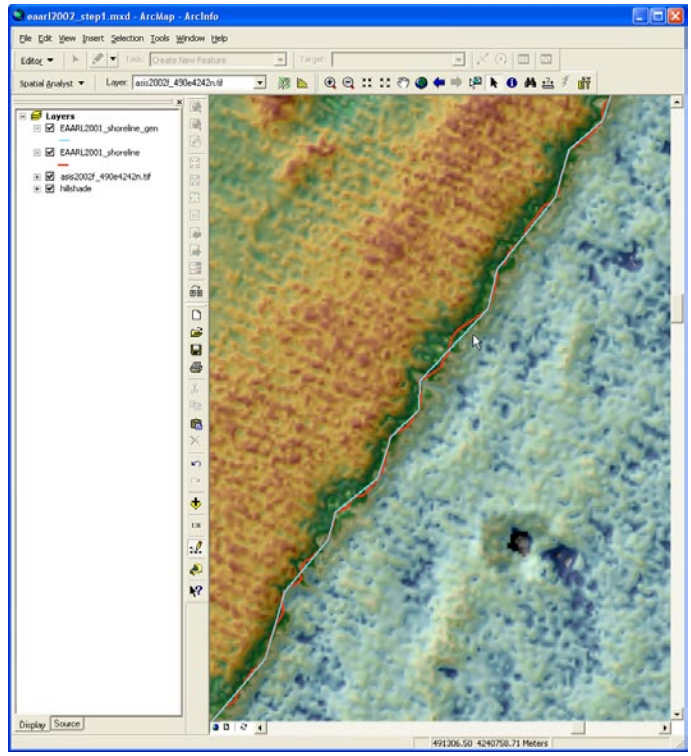


Figure 33. Generalized shoreline (in blue) overlain on initial shoreline (in red).

- Now, smooth the generalized shoreline. On the Polyline tab, select Smooth (Figure 34).

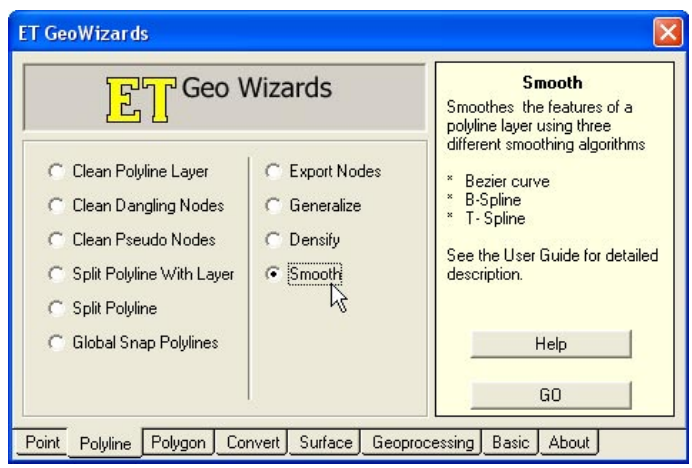


Figure 34. Smooth option.

- Select the polyline layer – the new generalized line.
- Select an Output Shapefile (Figure 35).

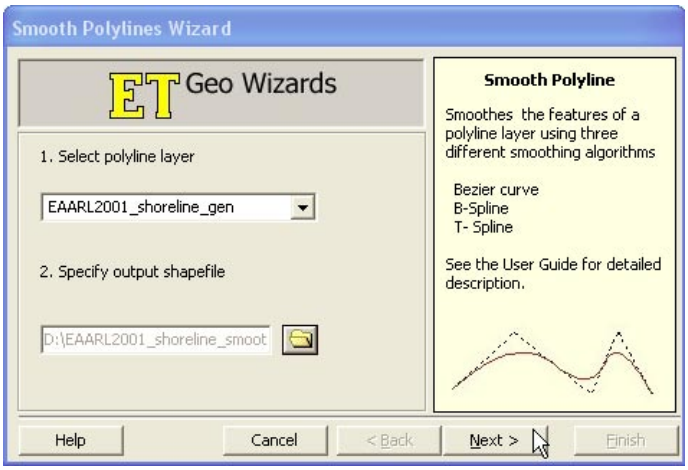


Figure 35. Select layer and provide output name.

- Select smooth method (Figure 36).

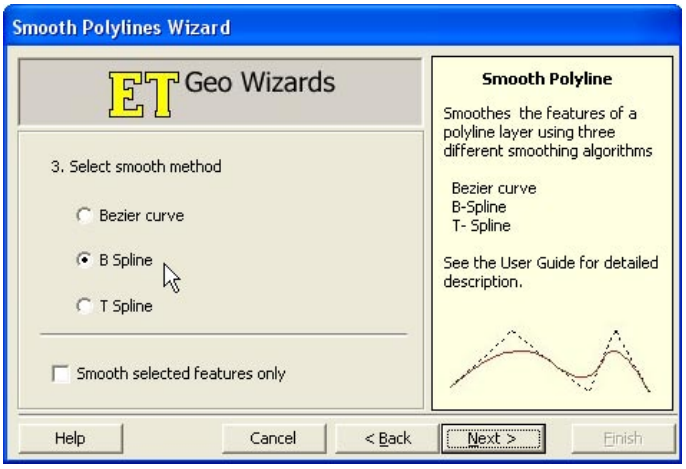


Figure 36. Select smooth method.

- Select Next.
- Assign curve parameters – smoothness and freedom (Figure 37).

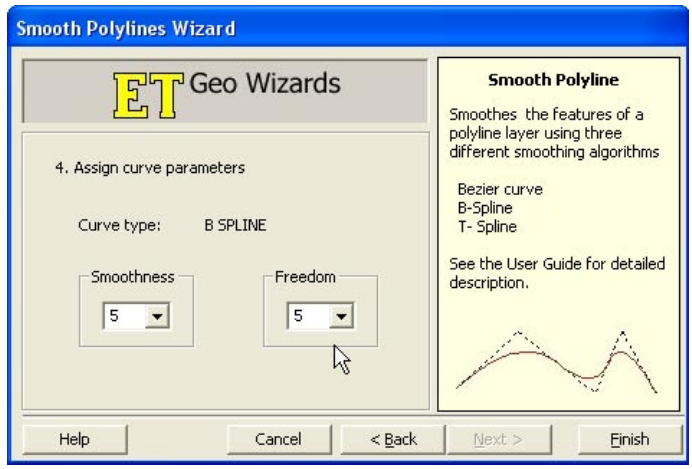


Figure 37. Assign curve parameters.

- Select Finish. Resulting generalized and smoothed line is shown in Figure 38.

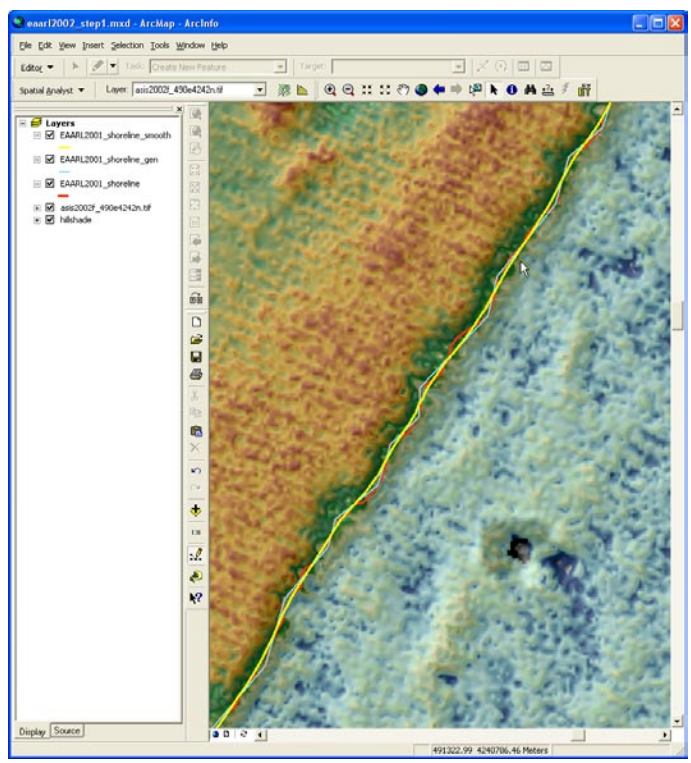


Figure 38. Generalized and smoothed line shown in yellow.

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Krabill, W.B., Wright, C.W., Swift, R.N., Fredreck, E., Manizade, S., Yungel, J., Martin, C., Sonntag, J., Duffy, M., Hulslander, W., and Brock, J.C., 2000, Airborne laser mapping of Assateague National Seashore Beach: Photogrammetric Engineering and Remote Sensing, Vol. 66, p. 65-71.

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Nayegandhi, A., 2002, Lidar mapping of vegetation at Assateague Island National Seashore: A first look: Sound Waves Coastal Science and Research News from Across the USGS (http://soundwaves.usgs.gov).

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Thieler, E.R., Martin, D., and Ergul, A., 2003, The digital shoreline analysis system (DSAS) version 2.0: Shoreline change measurement software extension for ArcView: U.S. Geological Survey Open-File Report 03-076 (http://woodshole.er.usgs.gov/project-pages/dsas/).

Appendix I

asis02_eaarl

Metadata also available as

Metadata:

- *Identification_Information*
- *Data_Quality_Information*
- *Spatial_Data_Organization_Information*
- *Spatial_Reference_Information*
- *Entity_and_Attribute_Information*
- *Distribution_Information*
- *Metadata_Reference_Information*

Identification_Information:

Citation:

Citation_Information:

Originator:

U.S. Geological Survey, Center for Coastal and Watershed Studies, 600 4th Street South, St. Petersburg, FL 33701

Publication_Date: 2004

Title: asis02_eaarl

Edition: First

Geospatial_Data_Presentation_Form: vector digital data

Other_Citation_Details:

The USGS, in cooperation with the National Park Service (NPS) and the National Aeronautics and Space Administration (NASA), is to provide the coastal management community with usable, useful digital elevation products. The USGS processes aircraft lidar data (provided by NASA), develops software tools and algorithms to use and analyze the data, and makes products available to the coastal management community through a variety of media, including the internet, CD-ROMs, and data reports.

Online_Linkage: none

Description:

Abstract:

Dataset contains datum-referenced shoreline derived from airborne lidar surveys. These data were collected during the September 2001 NASA EAARL (Experimental Advance Airborne Research Lidar) survey mission over Assateague Island National Seashore.

Purpose:

The digital camera imagery is collected in conjunction with lidar elevation data in order to provide a more complete dataset to be used in resource management for National Seashores.

Time_Period_of_Content:

Time_Period_Information:

Single_Date/Time:

Calendar_Date: 20010905

Currentness_Reference: 20010905

Status:

Progress: Complete

Maintenance_and_Update_Frequency: Unknown

Spatial_Domain:

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West_Bounding_Coordinate: -75.382457

East_Bounding_Coordinate: -75.091974

North_Bounding_Coordinate: 38.323213

South_Bounding_Coordinate: 37.854042

Keywords:

Theme:

Theme_Keyword_Thesaurus:

REQUIRED: Reference to a formally registered thesaurus or a similar authoritative source of theme keywords.

Theme_Keyword: Airborne Topographic Mapper

Theme_Keyword: coastal management

Theme_Keyword: elevation change

Theme_Keyword: Digital Camera

Theme_Keyword: resource management

Place:

Place_Keyword: Assateague Island National Seashore

Place_Keyword: Atlantic Coast

Place_Keyword: Maryland

Place_Keyword: United States East Coast

Place_Keyword: Virginia

Access_Constraints:

Any use of these data signifies a user's agreement to comprehension and compliance of the USGS Standard Disclaimer. Ensure all portions of metadata are read and clearly understood before using these data in order to protect both user and USGS interests. See section 6.3 Distribution Liability.

Use_Constraints:

Although the USGS is making these datasets available to others who may find the data of value, the USGS does not warrant, endorse, or recommend the use of these data for any given purpose. The user assumes the entire risk related to the use of these data. These datasets are not for navigational purposes. USGS is providing these data "as is," and USGS disclaims any and all warranties, whether expressed or implied, including (without limitation) any implied warranties of merchantability or fitness for a particular purpose. In no event will USGS be liable to you or to any third party for any direct, indirect, incidental, consequential, special, or exemplary damages or lost profits resulting from any use or misuse of these data.

Acknowledgment of the U.S. Geological Survey Center for Coastal and Watershed Studies as a data source would be appreciated in products developed from these data, and such acknowledgment as is standard for citation and legal practices for data source is expected by users of this data. Sharing new data layers developed directly from these data would also be appreciated by USGS staff. Users should be aware that comparisons with other datasets for the same area from other time periods may be inaccurate due to inconsistencies resulting from changes in photo interpretation, mapping conventions, and digital processes over time. These data are not legal documents and are not to be used as such.

Point_of_Contact:

Contact_Information:

Contact_Organization_Primary:

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Contact_Position: National Coastal Assessment Project Chief

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Address: 600 4th Street South

City: St. Petersburg

State_or_Province: Florida

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Country: USA

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Hours_of_Service: Monday-Friday, 8-5, EST

Data_Set_Credit:

The USGS Center for Coastal and Watershed Studies would like to acknowledge NASA Goddard Space Flight Center for their cooperation and assistance in the development of the data.

Native_Data_Set_Environment:

Microsoft Windows XP Version 5.1 (Build 2600) Service Pack 2; ESRI ArcCatalog 9.0.0.535

Cross_Reference:

Citation_Information:

Originator: John Brock and Asbury Sallenger, U.S. Geological Survey

Publication_Date: 2001

Title:

Airborne Topographic Lidar Mapping for Coastal Science and Resource Management

Geospatial_Data_Presentation_Form: USGS Open-File Report

Publication_Information:

Publication_Place: St. Petersburg, FL

Publisher: U.S. Geological Survey

Citation_Information:

Originator:

Brock, J.C.; Wright, C.W.; Sallenger, A.H; Krabill, W.B., and Swift, R.N

Publication_Date: 2003

Title:

Basis and Methods of NASA Airborne Topographic Mapper Lidar Surveys for Coastal Studies

Geospatial_Data_Presentation_Form: journal article

Publication_Information:

Publication_Place: West Palm Beach, FL

Publisher: Journal of Coastal Research

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Process_Description: Metadata imported.

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SDTS_Terms_Description:

SDTS_Point_and_Vector_Object_Type: String

Point_and_Vector_Object_Count: 606

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Grid_Coordinate_System:

Grid_Coordinate_System_Name: Universal Transverse Mercator

Universal_Transverse_Mercator:

UTM_Zone_Number: 18

Transverse_Mercator:

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Longitude_of_Central_Meridian: -75.000000

Latitude_of_Projection_Origin: 0.000000

False_Easting: 500000.000000

False_Northing: 0.000000

Planar_Coordinate_Information:

Planar_Coordinate_Encoding_Method: coordinate pair

Coordinate_Representation:

Abscissa_Resolution: 0.000128

Ordinate_Resolution: 0.000128

Planar_Distance_Units: meters

Geodetic_Model:

Horizontal_Datum_Name: North American Datum of 1983

Ellipsoid_Name: Geodetic Reference System 80

Semi-major_Axis: 6378137.000000

Denominator_of_Flattening_Ratio: 298.257222

Entity_and_Attribute_Information:

Detailed_Description:

Entity_Type:

Entity_Type_Label: asis02_eaarl

Attribute:

Attribute_Label: FID

Attribute_Definition: Internal feature number.

Attribute_Definition_Source: ESRI

Attribute_Domain_Values:

Unrepresentable_Domain:

Sequential unique whole numbers that are automatically generated.

Attribute:

Attribute_Label: Shape

Attribute_Definition: Feature geometry.

Attribute_Definition_Source: ESRI

Attribute_Domain_Values:

Unrepresentable_Domain: Coordinates defining the features.

Attribute:

Attribute_Label: ID

Attribute:

Attribute_Label: Id

Attribute:

Attribute_Label: ET_ID

Attribute:

Attribute_Label: Id_1

Attribute:

Attribute_Label: Length

Distribution_Information:

Distributor:

Contact_Information:

Contact_Organization_Primary:

Contact_Organization: U.S. Geological Survey

Contact_Position: GIS Specialist

Contact_Address:

Address_Type: Mailing Address

Address: 600 4th Street South

City: St. Petersburg

State_or_Province: FL

Postal_Code: 33701

Country: USA

Contact_Voice_Telephone: 727-803-8747

Contact_Instructions: Call Office for Details

Resource_Description: Downloadable Data

Distribution_Liability:

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The information contained in these data is dynamic and may change over time. The data are not better than the original sources from which they were derived. It is the responsibility of the data user to use the data appropriately and consistent within the limitations of geospatial data in general and these data in particular. The related graphics are intended to aid the data user in acquiring relevant data; it is not appropriate to use the related graphics as data.

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Standard_Order_Process:

Digital_Form:

Digital_Transfer_Information:

Transfer_Size: 0.098

Custom_Order_Process: Call USGS for Details

Metadata_Reference_Information:

Metadata_Date: 20050715

Metadata_Contact:

Contact_Information:

Contact_Organization_Primary:

Contact_Organization: U.S. Geological Survey

Contact_Person: REQUIRED: The person responsible for the metadata information.

Contact_Position: GIS Specialist

Contact_Address:

Address_Type: Mailing

Address: 600 4th Street South

City: St. Petersburg

State_or_Province: Florida

Postal_Code: 33704

Country: USA

Contact_Voice_Telephone: 727-803-8747

Contact_Instructions: Call Survey for Details

Metadata_Standard_Name: FGDC Content Standards for Digital Geospatial Metadata

Metadata_Standard_Version: FGDC-STD-001-1998

Metadata_Time_Convention: local time

Metadata_Extensions:

Online_Linkage: <http://www.esri.com/metadata/esriprof80.html>

Profile_Name: ESRI Metadata Profile

Metadata_Extensions:

Online_Linkage: <http://www.esri.com/metadata/esriprof80.html>

Profile_Name: ESRI Metadata Profile

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[1] National Park Service Inventory and Monitoring Program: Northeast Coastal And Barrier Network Vital Signs Monitoring Plan (NCBC) – Phase II, October 2003