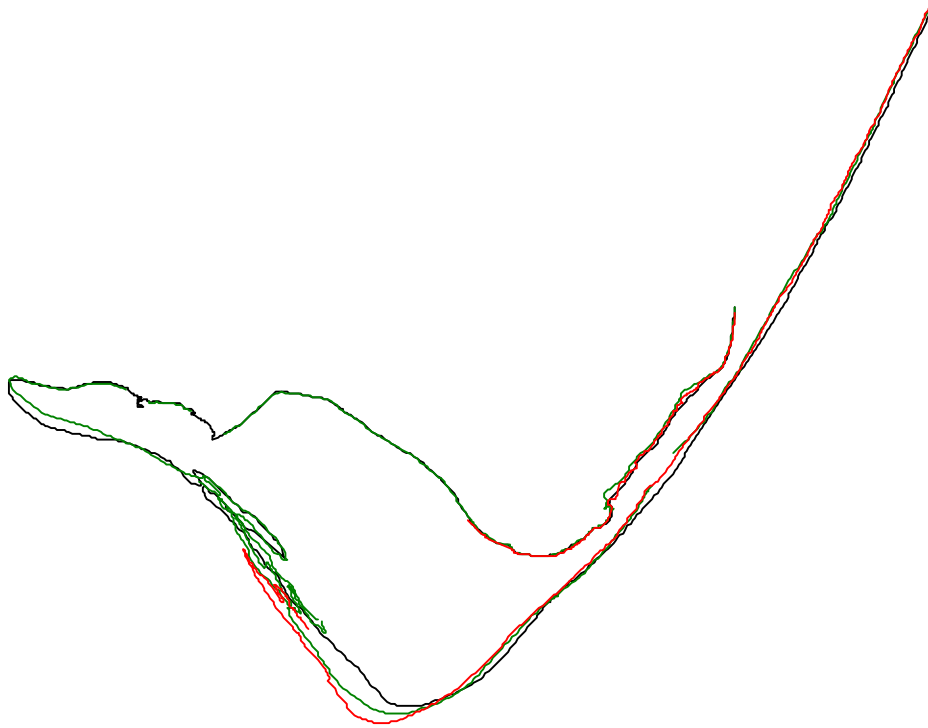


Assateague Island National Seashore

Geomorphologic Monitoring Program

2003 Report



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Abstract

The Geomorphologic Monitoring Program initiated in 1995 was continued at Assateague Island National Seashore in 2003. LiDAR data were collected by NASA on February 25, 2003 and will be processed by USGS and delivered to the Park in 2004. Aerial photographs were taken on October 25, 2003 and will be orthorectified and delivered to the Park in April 2004.

Topographic profiles were collected along 22 transects in April 2003. The shoreline position was mapped in April and July 2003. All survey data were processed, compiled, and archived. Representative graphics were created to illustrate geomorphologic changes that occurred on Assateague Island between 1999 and 2003.

Introduction

The dynamic nature of coastal barriers such as Assateague Island influences nearly every aspect of their ecology. Barrier islands are disturbance-driven ecosystems, and their morphology and ecology are shaped by physical forces on an accelerated time scale in comparison to mainland systems. Because of the rapid pace and scope of change, long term monitoring is crucial to the understanding of natural barrier island conditions as well as anthropogenic influences.

The geomorphology of Assateague Island is influenced by many factors including waves, storm energy, alongshore sediment transport, island overwash, wind, nearshore bathymetry, and engineering projects. Assateague Island is wave-dominated (average 1 m) and microtidal (0-2 m, 4 m spring tide). Wave heights are highest in the fall and winter, when they approach the shoreline from the northeast and east; the smaller summer waves approach the coast from the east and southeast. Winter northeasters occur more frequently and for a longer duration than summer tropical storms and hurricanes. These waves, along with overwash and wind, move sediment onto the island. Longshore transport of sediment is meteorologically driven and has a net southerly littoral drift between 114750 m³ and 214200 m³ (Underwood 1995). The southward transport is evident in the seaward offset of shoreline position north of the Ocean City Inlet jetty, which traps sand as it moves alongshore towards the south.

The National Park Service (NPS) contracted with the U.S. Army Corps of Engineers (COE) in 1991 to develop recommendations for a coastal change monitoring program at Assateague Island. These recommendations were reported in *A Physical Monitoring Plan for Northern Assateague Island, Maryland* (Stauble 1994). In 1995, ASIS initiated a long-term program to begin monitoring key aspects of island geomorphology. At present, the program includes three primary elements:

1. Documentation of the shoreline position on a quarterly basis in order to describe and evaluate trends in shoreline stability, rates of shoreline change, and storm-driven change.
2. Documentation of cross-island topographic profile elevations on a biannual basis in order to describe and evaluate trends in island topographic relief and storm-driven change.
3. Use of LiDAR (Light Detection and Ranging) data, an airborne laser technology that provides detailed topographic data on bare earth areas of the island. This technology has a horizontal resolution of 1 meter and vertical accuracy within 15 cm. The LiDAR data is processed into a three-dimensional GIS layer for analysis. This project, a cooperative effort between NASA, USGS, and NPS, consists of irregularly scheduled aerial surveys. ASIS involvement consists of topographic profiling and shoreline mapping for ground-truthing during aerial surveys. The project has recently moved beyond the research stage

and is now a part of the park's Geomorphologic Monitoring Program. Methodologies involving data management and distribution are still under development.

Information resulting from the Monitoring Program is intended to provide a general description of island conditions and to provide a basis for evaluating long-term management strategies. Data generated by the program will also support coastal processes research, habitat characterization studies, and evaluation of beach and berm restoration projects.

This report summarizes the methods used by ASIS staff to collect, process, analyze, and archive topographic profile and shoreline change data collected during 2003 as part of the long-term Geomorphologic Monitoring Program. Selected results are presented as maps and in graphical format.

Topographic Profile Surveys

Methods

The profile network baseline, established by Taylor, Wisemann and Taylor in 1993, and expanded by NPS personnel in 1995, provides horizontal and vertical controls for all data collection. Individual baseline monuments are numbered consecutively from north to south and are labeled with the prefix "NPS" or "GPS" to denote whether the baseline monument was established by NPS or by Taylor, Wisemann, and Taylor, respectively (Table 1). Spacing between GPS monuments is 2.0 km, with NPS monuments located approximately midway between GPS monuments along the northern 10 km of Assateague Island (Figure 1). This results in 22 profile lines spaced at 1 km intervals on the North End and at 2 km intervals for the remainder of the Maryland coast. There are no profile transects in the Virginia section of Assateague Island.

Profile surveys are conducted from each primary monument along the baseline and are aligned roughly perpendicularly to the ocean shoreline at a 291/111 degree azimuth from true north. A Nikon Top Gun total station (model DTM-A10LG) is used to collect surface elevation points along each transect line at approximately 10 meter intervals and at significant changes in topography. Surveyed points are chosen by a technician traversing the line with a laser-reflective prism pole. Each profile line extends from wading depth oceanside to wading depth bayside (with 0.0 meters above sea level as a goal endpoint on either side) or up to the point where heavy vegetation obstructs the line of sight to the target. All transects are surveyed relative to a control monument or witness point along the baseline. Surveyed transects are identified in Table 2 according to seasonal survey periods for 1995-2003.

Data points are recorded with an HP48/SX scientific calculator equipped with Nikon DR-48 surveying software. Raw data files are downloaded to a PC, converted to a delimited ASCII file format, and exported to Microsoft Excel for graphics production. Data files for individual profile lines are labeled according to the monument number and date of survey, and are organized into subdirectories labeled by the date of survey. For example, GPS2-1099.txt is an ASCII text file containing the data for GPS-2 during the October 1999 survey session. The Excel spreadsheet is imported into a Microsoft Access database that is stored in the ASIS Electronic Library, RM Information & Data Management, Resource Identification Number (RIN) 22.03, Island Profiles Database.

All files are stored as digital NYXZ values (Point Number, Northing, Easting, Elevation). Coordinates are in UTM, meters, referenced to NAD-83. The vertical datum used is NGVD 1929, meters.

Results and Discussion

Transect lines surveyed in April 2003 included GPS-1 through GPS-17 and NPS-1.5 through NPS-5.5. Topographic profiles from Aprils 1999, 2002, and 2003 are graphically presented in Appendix A, Figures A1-A22. Short time spans are chosen in order to avoid comparison with pre-berm¹ profiles, and in order to highlight changes following the first stage of the North End restoration project begun in 2002.²

Of the areas profiled, the northernmost 8 kilometers of Assateague Island has experienced the most significant changes in topography during the past 60 years due to the influence of the adjacent Ocean City inlet and its northern jetty. The North End (Figures A1-A9) is characterized by relatively low topographic relief with surface elevations ranging from 0.0 m or less at the shoreline to approximately 3.0 m (NGVD). Lines GPS1 – NPS4.5 (Figures A1-A8) represent true cross-island profiles in that their extent includes complete surface elevations from the ocean to the bay shoreline.

The profile at NPS 1.5 (Figure A2) is quite different from profiles in previous spring surveys in that it has a winter storm profile shape rather than the summer profile and berm seen in the 1999 and 2002 surveys. This year's profiles may have been surveyed before the beach could recover from one of two major storms in April, a northeaster on April 11 or Tropical Storm Ana on April 21.

The constructed storm protection berm is displayed in Figures A5-A7. Overall, the elevation of the berm is almost a meter higher and 11 m to 50 m wider (11 to 30 m seaward) than in 1999 and 2002. The berm did not undergo any construction or maintenance in 2003; these morphologic changes could be due to natural dune movement, combined with protection of vegetation on the west end to encourage build-up, and/or a lack of overwash. Profiles NPS 4.5 and GPS 5.0 (Figures A8 and A9) show a wider island profile with gentler slopes, possibly due to overwash events.

The 3 km length of Assateague Island that lies immediately south of the Verrazano Bridge is commonly referred to as the “developed zone.” It is dominated by an artificial dune line and steeply sloping beach. Changes in bulldozed dune locations can be seen in profiles NPS 5.5 through GPS 8 (Figures A10-A13).

The remaining 10 km of the Maryland portion of Assateague Island, represented by survey lines GPS9-GPS17 (Figures A14-A22), is characterized by smaller dune features (generally 4.0-6.0 m

¹ Following 1998 storm damage, the NPS implemented an emergency beach restoration project designed to restore the ocean berm within a severely affected area between 5.0 and 7.5 km south of the Ocean City inlet. Between September and October 1998, the US Army Corps of Engineers oversaw the delivery of approximately 200,000 cubic yards of sand to this critical area and constructed a berm just less than 3.5 meters (11 feet NGVD) in elevation. In 1999 this artificially constructed berm attained a more natural topography as it was subjected to the physical forces of wind and water.

² The first, short-term phase of the North End restoration project began in September 2002 with the placement of 1.4 million m³ of sand along the beach between 2.5 and 12 km south of the Ocean City inlet. COE completed the construction in January 2003. The long-term restoration plan calls for biannual sand bypassing of 145,000 m³/yr beginning in February 2004 and continuing for 25 years.

NGVD) separated by low overwash gaps of varying widths and extents. According to the COE analysis, the effects of the inlet jetties are minimized along this entire section of the park, which is open to 4-wheel drive vehicles and is referred to as the off-road vehicle (ORV) zone. Along profiles GPS 16 and GPS 17, at the south end of the ORV zone and subject to less traffic than the northern ORV zone, the 2003 shoreface shows some variation from previous surveys. At GPS 16, the elevation and slope of the 2003 profile has decreased, but the morphology is similar. At GPS 17, the seawardmost 16 m of the 2003 beach is similar to the 1999 profile but is much steeper than the 2002 profile. This profile probably captured a cusp or followed an energetic meteorological event. Along all other ORV zone profiles, the locations of major topographic features did not change much between 2002 and 2003. This continuity is probably due to the stabilizing effects of dune vegetation and the domination of ORV traffic over natural sand movement on the shoreface.

In general, it is difficult to interpret large-scale directional movement with the limited nature of linear transects. Interpretation must consider meteorological conditions, ebb shoal protection, and subjectivity introduced into the profile collection process by various technicians' assessment of a representative profile.

Cross-island profiles will continue to be collected for the Geomorphologic Monitoring Program, and as supplemental data for various programs and projects. Ground-truthing surveys will continue to be scheduled for NASA LiDAR flights, and LiDAR may be included in topographic analyses. Profiles will be important in analyzing the effects of the North End restoration project. All data is saved in the ASIS Electronic Library and on an external hard drive backup.

GPS Shoreline Surveys

Methods

The shoreline position is surveyed four times each year. In winter and summer, only the position of the Maryland ocean shoreline is surveyed. In spring and fall, surveys include the Maryland and Virginia ocean shorelines, the northern 8 kilometers of the Maryland bay shoreline, and the bayside extent of the southern tip of the island, also known as "Toms Cove Hook." Optimally, shoreline mapping is completed at the end of each season. For example, the spring shoreline is surveyed at the end of winter to show pre-season conditions and the effects of the predominating meteorological and tidal conditions of the previous season.

All surveys are executed during near-average tidal ranges when the predicted high tides run close to the Mean High Water, and allowing several days before and after lunar water level extremes. Prior to surveys, tide levels are checked at various local stations (including Ocean City Fishing Pier, Isle of Wight Bay, and Wallops Island) through the NOAA website www.tidesonline.nos.noaa.gov. In addition, a QuickPlan is utilized in the PathFinder Office software to generate a list of observation times that would optimize the accuracy of the desired GPS configuration.

The ocean shoreline is surveyed by driving a four wheel ATV at a relatively constant speed (between 5 and 10 mph) along the high tide line. For the purposes of this monitoring program, "ocean shoreline" is defined as the average position of the most recent high tide as evidenced by the obvious wet/dry sand line or deposited wrack. The GPS receiver is configured to record positions at a very short interval (typically one position every 2 seconds) for the best representation of the shoreline position. The North End bay shoreline is surveyed by walking the actual water line within two hours of the most recent high tide, while the GPS receiver records

positions every 3 seconds. In areas along the bayside that lack dry uplands, the shoreline is identified as the open water/vegetation margin. This allows for tidal creeks and other shoreline irregularities to be included within the surveyed line.

Standard kinematic differential GPS survey methods are employed for all shoreline surveys of Assateague Island. The GPS survey equipment is the Trimble Pathfinder ProXR system, which integrates an updated GPS receiver with MSK beacon real-time differential capability. This system eliminates the need for establishing a local base station while maintaining the sub-meter accuracy standards for field mapping. Within each shoreline survey session, the location of a known surveyed point is occupied and recorded within the data file to serve as an accuracy check for each survey session. The GPS is configured to record points even if radio-link is lost. A detailed Standard Operating Protocol can be found in the ASIS Electronic Library, Resource Identification Number (RIN) 10.07, Geomorphologic Monitoring, SOP's, SOP_Profile_Collection and SOP_Profile_Processing.

GPS data files are downloaded to the PC using the PathFinder Office utility software, and all files are differentially corrected through post-processing. Post-processing accounts for the points that are not real-time corrected, results in generally more accurate position data for all points, and introduces a basic level of consistency to surveys. Base station files were downloaded from the New Jersey Department of Environmental Protection's website, <http://www.state.nj.us/dep/gis/>. Shoreline files were checked for accuracy by comparing the collected known-point positions to actual positions. They were then exported as a GIS shapefile for analysis and mapping.

Individual files for each shoreline segment are labeled according to the survey date and the specific area surveyed, "MD" for Maryland or "VA" for Virginia, followed by an "O" for ocean or "B" for bay. For example, the file labeled "MDO399" contains the data collected along the Maryland ocean shoreline during March 1999. All data files are stored on the hard drive of the PC in the shoreline project of the PathFinder Office software. Shoreline maps are finally combined within their respective seasons as one Arcview GIS shapefile labeled by month and year (e.g., 'Shoreline 0499' for the shoreline position collected in April 1999). New procedures implemented in summer 2002 require checking shoreline shapefiles for errors by scrolling one frame at a time through the entire map at a 1:2,000 view scale. Gaps of less than 5 meters can be joined if they are clearly unintentional or erroneous. If additional vertices are needed, natural line-flow must be mimicked. Clusters of off-line points, such as those recorded while standing still, should be removed carefully. Shorelines and metadata are stored on an external hard drive backup and in the Electronic Library under RIN 10.05, Geomorphology, Shoreline Processes, GIS_Shoreline_Data.

Results and Discussion

Mapping the horizontal shoreline position with GPS can be useful in understanding the dynamics of a barrier system such as Assateague Island. Although patterns of shoreline change are difficult to assess when examining a limited data set, general trends of accretion, erosion, and migration are identifiable. Analysis of shoreline position must consider the subjectivity of the technician's recognition of the high tide line; the role that variable tide levels *within* the average tide window play in shoreline appearance, particularly on the low-lying bay side; and the influence of meteorological events and conditions on shorelines.

In 2003, the April survey included the ocean shoreline for Maryland and Virginia, and the bay shoreline for the northernmost 8 km of the island. The July survey covered only the ocean side

of the Maryland section. Neither a fall nor a winter survey was performed due to staffing transitions. The shoreline positions in April and July 2003 are compared to those of April 1999 and April 2002 in Appendix B, Figures B1-B9.

Between April 2002 and April 2003, the bay shoreline position did not migrate significantly along the Island's northernmost 4 km (Figure B1). The shoreline from 4-8 km south of the inlet is smoother in 2003 than in 2002 (Figure B2). Water level may have been slightly lower during the 2002 surveys, revealing more topographic lows along the bay shoreline. The two shorelines are quite similar aside from the presence of coves that were delineated in 2002 but not in 2003.

Along the Maryland ocean shoreline, the July 2003 shoreline position is seaward of the July 1999 survey. It is also overlying or seaward of the April 2003 position, with the exception of the area between 0.5 and 1.0 km south of the Ocean City Inlet, where shoreline is highly variable throughout several years of surveys.

Along the shoreline that extends 2 km southward from the jetty (north of NPS 1.5), the April 2003 position is seaward of the April 1999 location and landward of the April 2002 location (Figure B1). Between 2 and 5 km south of the jetty, from NPS 1.5 to GPS 3, the three shorelines have approximately the same position, varying within about 10 m of each other (Figures B1 and B2). From 5 to 10 km south of the jetty, or GPS 3 southward to the developed State Park area, the April 2003 location is seaward of the position in previous years (Figure B3). Within this area, between 5 km and 8 km south of the inlet and in front of the constructed berm, the shoreline position has continued to move seaward. This seaward movement is likely related to the introduction of 1.4 million m³ of sand during the first phase of the North End restoration project.

In the ORV zone, the April 2003 shoreline position was similar to the April 2002 survey, with the exception of gentle (5-11 m amplitude, non-rhythmic) cusps apparent in 2003 in the 2 km just north of GPS 16, the area 29 to 31 km south of the jetty (Figures B5 and B6). Cuspate forms (12 m amplitude, 150-200 m wavelength) are also visible between 6 and 13 km south of the Maryland-Virginia border (Figures B7 and B8).

Toms Cove Hook, a recurved spit complex at the southern end of Assateague Island, has a dynamic shoreline. Its southeast ocean shoreline position continued its retreat in 2003 by as much as 40 m. The southwest-facing shore continued its accretion up to 65 m in the last year, with the exception of the spit's tip, which continued its eastward regression and narrowed 40 m since 2002 (Figure B9).

The ebb shoal around Ocean City Inlet provides some degree of protection for the 0.4 km immediately south of the south jetty by dissipation of incoming wave energy (Underwood 1995, p. 56) and may be a sediment source for the beach. Although Underwood states that it attaches to the island 600 m south of the south jetty (p. 99) and acts as a "sand bridge" (p. 114) to channel material to the North End, it appears that further investigation is needed in the area 0.5 km to 1 km south of the jetty, where shoreline position is highly variable. It is unclear whether these changes, which are particularly visible with the 1999 and 2003 data sets, are related to dredging or engineering activities. In 2003, the outermost leg of the south jetty was modified to increase its overall elevation.

Shoreline position surveys will continue along Assateague Island as part of the long-term Geomorphologic Monitoring program in order to build the necessary database for future analysis. They will be used to assess the new North End restoration project and will also be

valuable as ground-truthing data, along with topographic profiles, for future LiDAR surveys. In the near future, LiDAR data may be used to extract a datum-based shoreline. Aerial photographs may also be used to delineate shorelines. Ground-based shoreline survey efforts may be enhanced in support of COE datum-based shoreline extraction methods.

Recommendations

Several initiatives would enhance the current Geomorphologic Monitoring Program.

1. The baseline monument network should be re-occupied (and repaired if needed) with survey-grade GPS. A quality assessment of existing shoreline and topographic data should identify logical inconsistencies and to determine the range of horizontal and vertical error.
2. Existing data should be used to calculate shoreline, topographic, areal, and volumetric changes on the island, particularly on the North End with respect to the long-term sediment bypassing that began in Fall 2003 as part of the COE restoration plan. Analyses should also identify short-term and long-term morphologic trends and changes. They may also incorporate meteorological data into the analyses.
3. Attempts should be made to standardize survey schedules as much as possible. Barring unforeseen conditions such as extreme tide events, the following is a guide to target starting times for surveys:

Spring:	early – mid-March start (plovers arrive in April)
Summer:	mid June
Fall:	late August – early September
Winter:	late November – early December

Literature Cited

- O’Connell, M., 2002. *Assateague Island National Seashore Geomorphological Monitoring Program 2001 Report*. Berlin, MD.
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- Taylor, Wiseman and Taylor, 1993. *GPS Survey Report*. Taylor, Wiseman and Taylor Engineering Company, Mount Laurel, NJ.
- Underwood, S.G., 1995. *Historical Development of Ocean City Inlet Ebb Shoal and Its Effect on Northern Assateague Island*. U.S. Army Engineer Waterways Experiment Station, Coastal Engineering Research Center, Vicksburg, MS.



Figure 1. Locations of baseline monuments used in topographic profile surveys.

STATION	NORTHING	EASTING	ELEVATION (m)
GPS-1	4240962.45	491103.65	1.575
NPS-1.5	4240045.01	490747.02	3.057
GPS-2	4239099.91	490368.52	2.005
NPS-2.5	4238117.35	490028.8	1.786
GPS-3	4237140.95	489666.85	1.576
NPS-3.5 (reset to COE2)	4236172.39	489464.36	2.02
GPS-4	4235180.94	489046.43	1.298
NPS-4.5 RESET	4234255.36	488775.27	2.175
GPS-5	4233268.28	488444.81	1.942
NPS-5.5	4232371.65	488031.39	2.191
GPS-6	4231472.12	487613.02	1.573
GPS-7	4229625.42	486835.32	1.42
GPS-8	4227683.22	486221.2	1.59
GPS-9	4225844.71	485716.1	1.24
GPS-10	4224012.78	485202.53	1.55
GPS-11	4222115.87	484685.27	1.07
GPS-12	4220078.98	484127.32	1.65
GPS-13	4218245.73	483460.87	0.79
GPS-14	4216307.24	482635.1	1.52
GPS-15	4214448.84	481726.8	1.83
GPS-16	4212759.09	480783.77	1.49
GPS-17	4211025.28	479733.44	1.27

Table 1. Positions and elevations of baseline monuments used in topographic profile surveys. Coordinates are UTM, Zone 18 North, meters, NAD 83; elevations are referenced to NGVD 1929, meters.

Survey Line	March 1995	Sept 1995	March 1996	May 1996	Sept 1996	April 1997	Sept 1997	Feb 1998	April 1998	June 1998	Oct 1998	April 1999	Oct 1999	May 2000	Aug 2000	Oct 2000	April 2001	June 2001	Sept 2001	April 2002	July 2002	Sept 2002	April 2003
GPS-1	*	*	*	*	*	*	*		*	*	*	*	*	*	*	*	*	*	*	*		*	*
NPS-1.5	*	*	*		*	*	*		*		*	*	*	*	*	*	*		*	*		*	*
GPS-2	*	*	*	*	*	*	*		*	*	*	*	*	*	*	*	*		*	*		*	*
NPS2.5	*	*	*		*	*	*	*	*		*	*	*	*	*	*	*		*	*		*	*
GPS-3	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*		*	*
NPS-3.5	*	*	*		*	*	*		*		*	*	*	*		*	*		*	*		*	*
GPS-4	*	*	*	*	*	*	*		*	*	*	*	*	*	*	*	*		*	*		*	*
NPS-4.5	*	*	*		*	*	*		*		*	*	*	*		*	*		*	*		*	*
GPS-5	*	*	*	*	*	*	*	*	*		*	*	*	*		*	*		*	*		*	*
NPS5.5		*	*		*	*	*	*	*		*	*	*	*		*	*		*	*	*	*	*
GPS-6		*	*		*	*	*	*	*		*	*	*	*		*	*		*	*	*	*	*
GPS-7		*	*		*	*	*		*		*	*	*	*		*	*		*	*		*	*
GPS-8		*	*		*	*	*		*		*	*	*	*		*	*		*	*		*	*
GPS-9		*	*		*	*	*		*		*	*	*	*		*	*		*	*		*	*
GPS-10		*	*		*	*	*		*		*	*	*	*		*	*		*	*		*	*
GPS-11		*	*		*	*	*		*		*	*	*	*		*	*		*	*		*	*
GPS-12		*	*		*	*	*		*		*	*	*	*		*			*	*		*	*
GPS-13		*	*		*	*	*		*		*	*	*	*		*	*		*	*		*	*
GPS-14		*	*		*	*	*		*		*	*	*	*		*	*		*	*		*	*
GPS-15		*	*		*	*	*		*		*	*	*	*		*	*		*	*		*	*
GPS-16		*	*		*	*	*		*		*	*	*	*		*	*		*	*		*	*
GPS-17		*	*		*	*	*		*		*	*	*	*		*			*	*		*	*

Table 2. Topographic profile surveys by transect, 1995-2003.

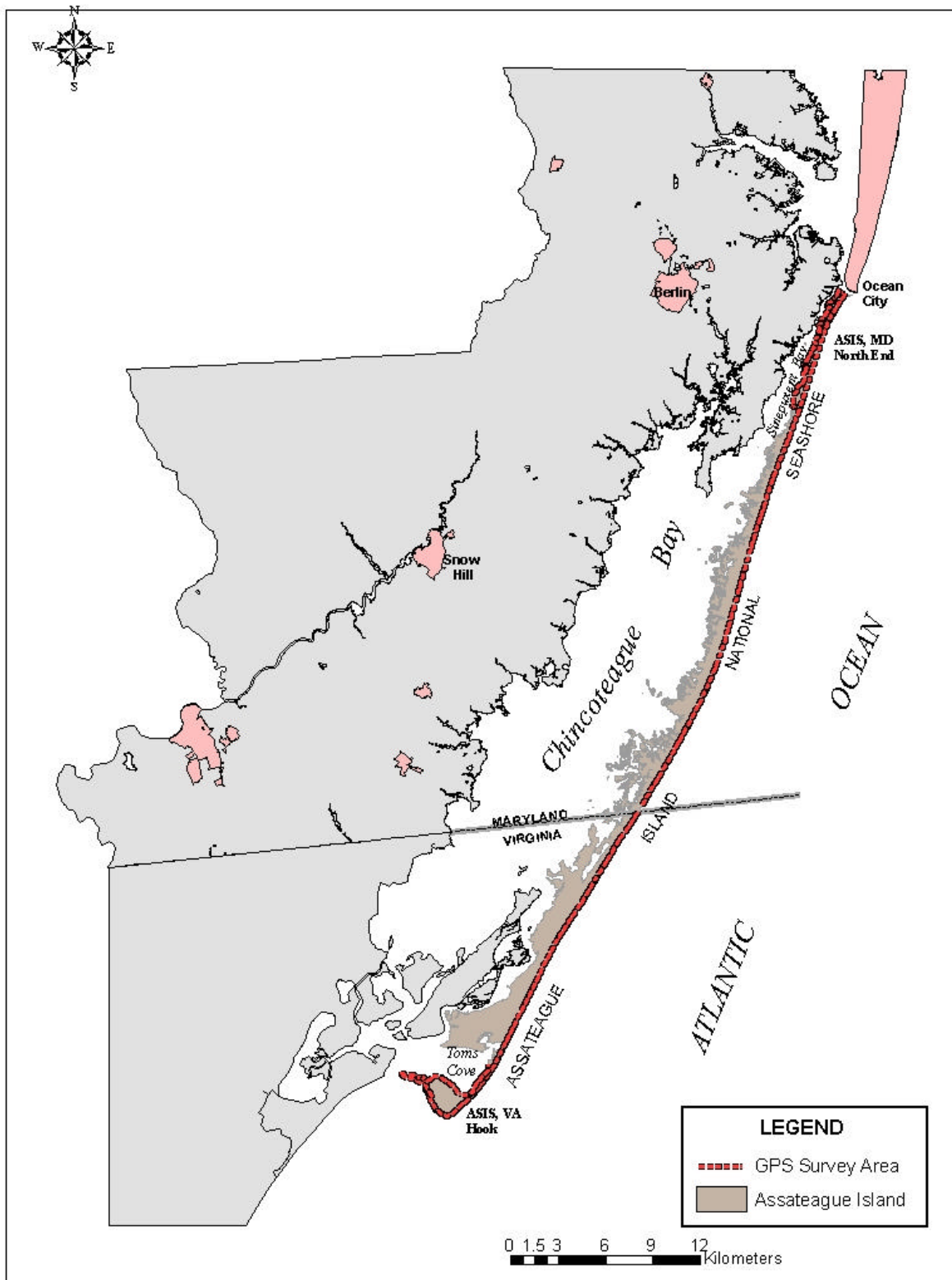


Figure 2. The Extent of GPS shoreline surveys on Assateague Island, 2001.

Appendix A
Topographic Profile Surveys

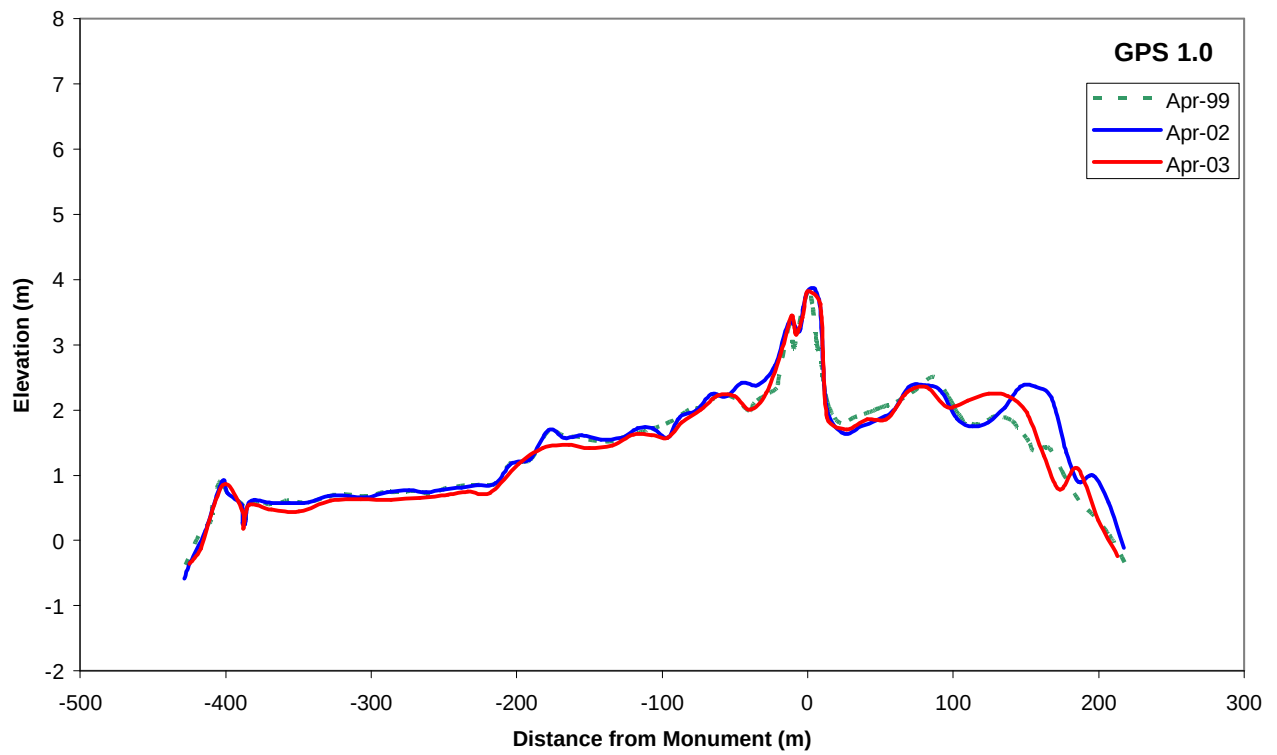


Figure A1. Survey line GPS-1.

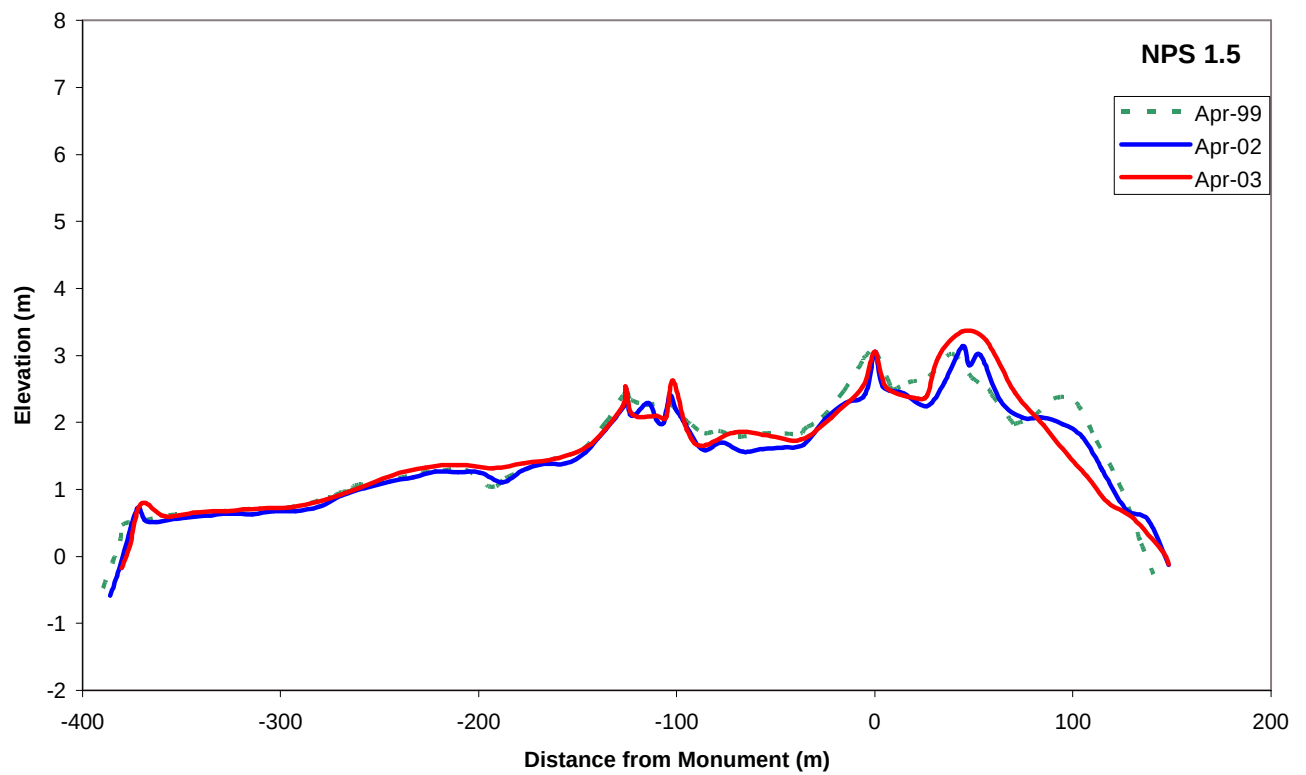


Figure A2. Survey line NPS-1.5.

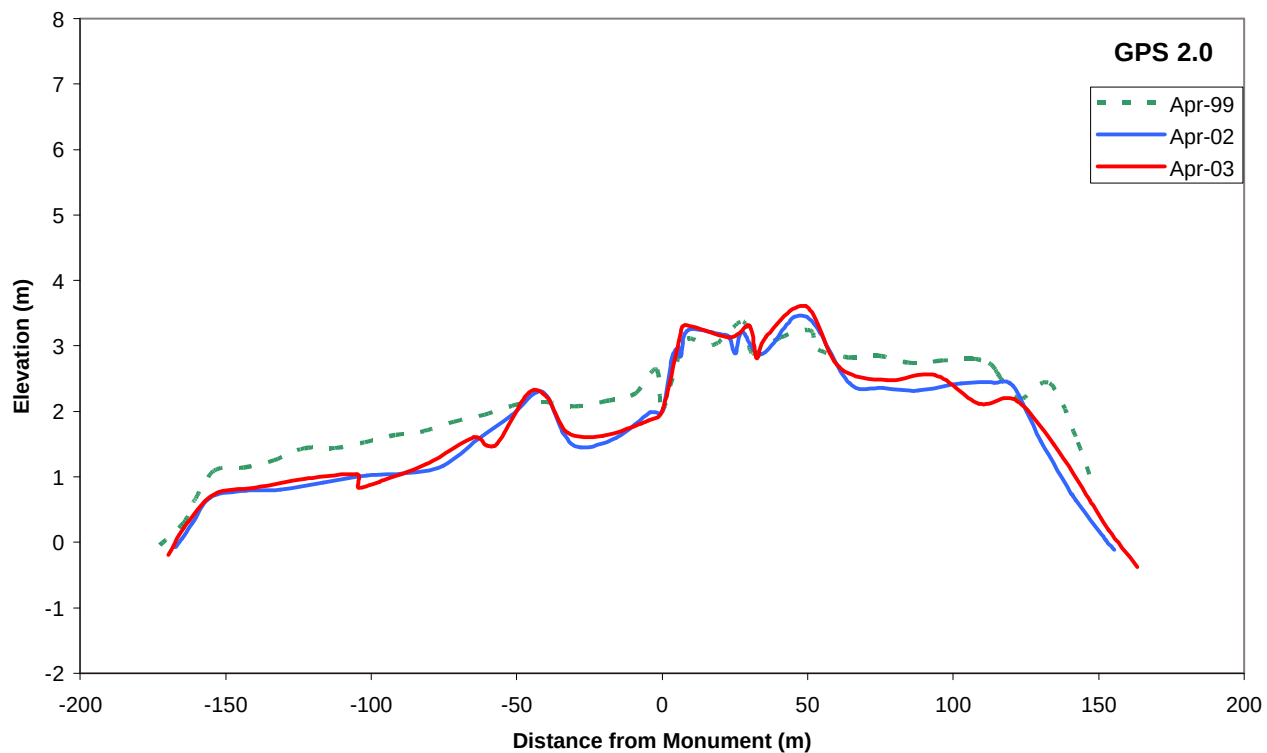


Figure A3. Survey line GPS-2.

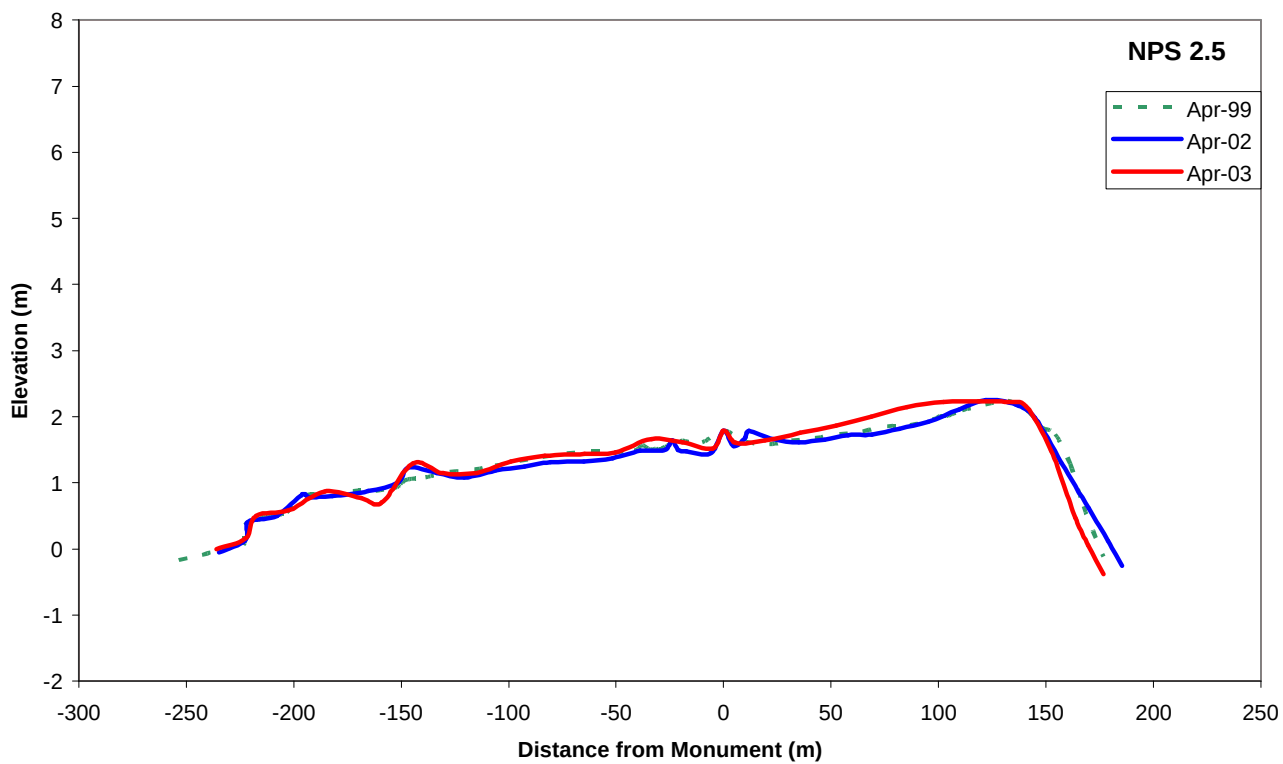


Figure A4. Survey line NPS-2.5.

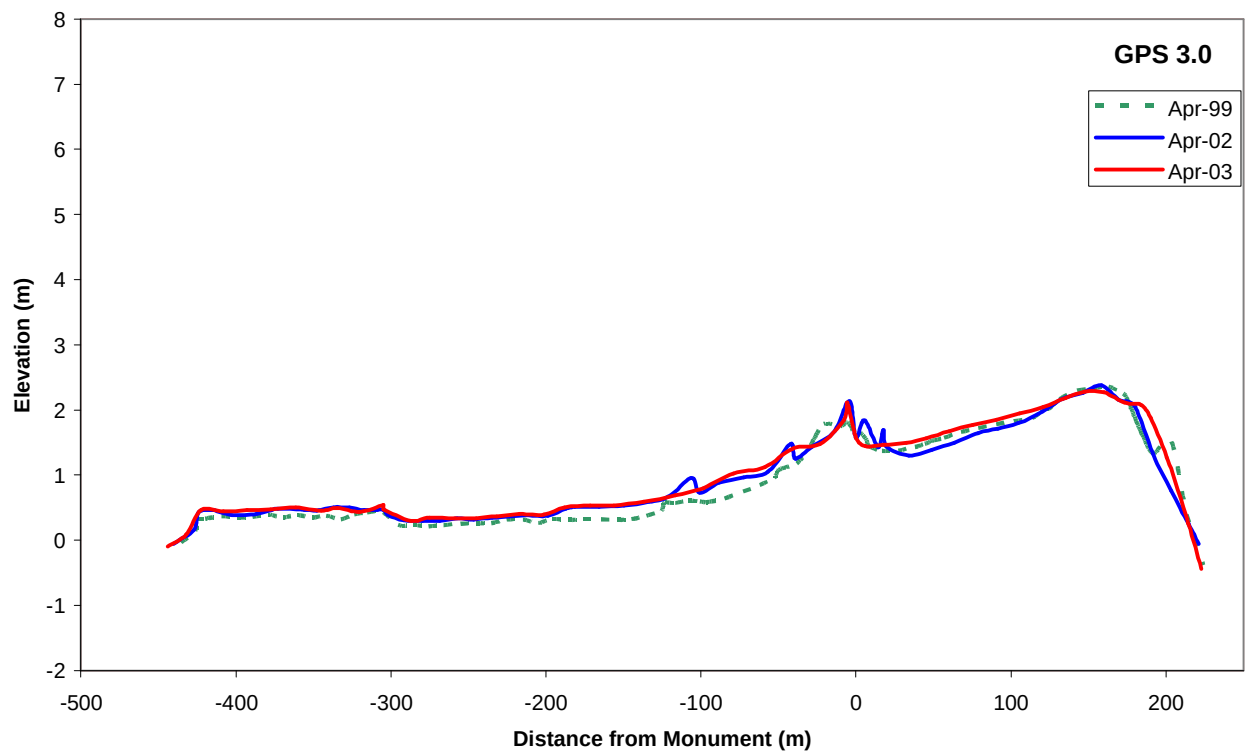


Figure A5. Survey Line GPS-3

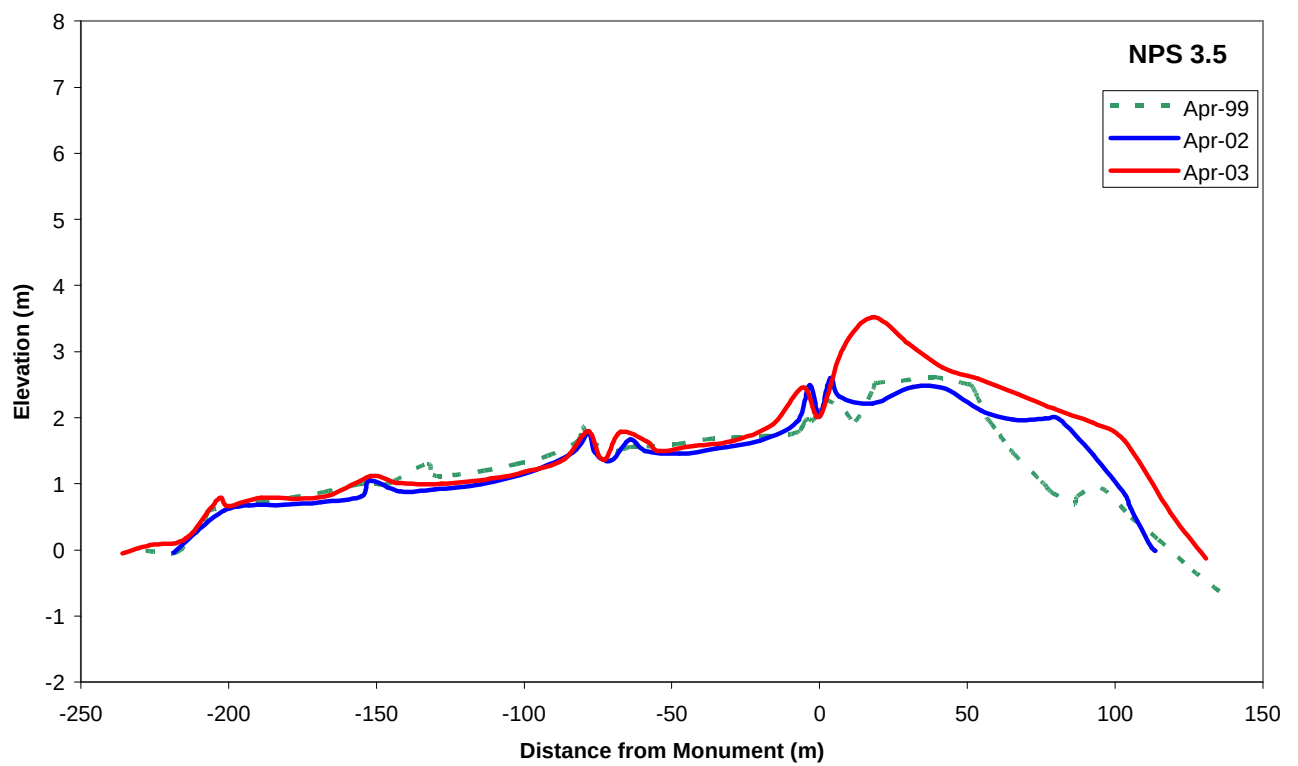


Figure A6. Survey Line COE2 (NPS-3.5 reset)

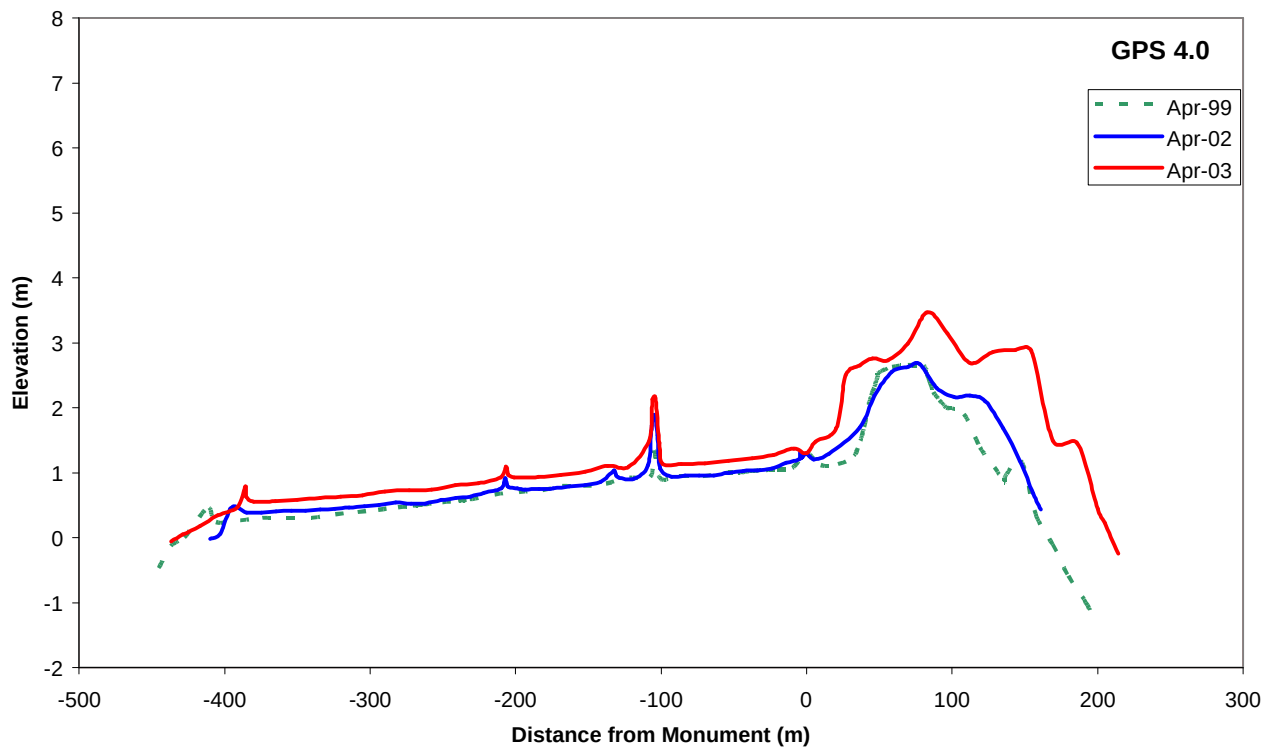


Figure A7. Survey Line GPS-4

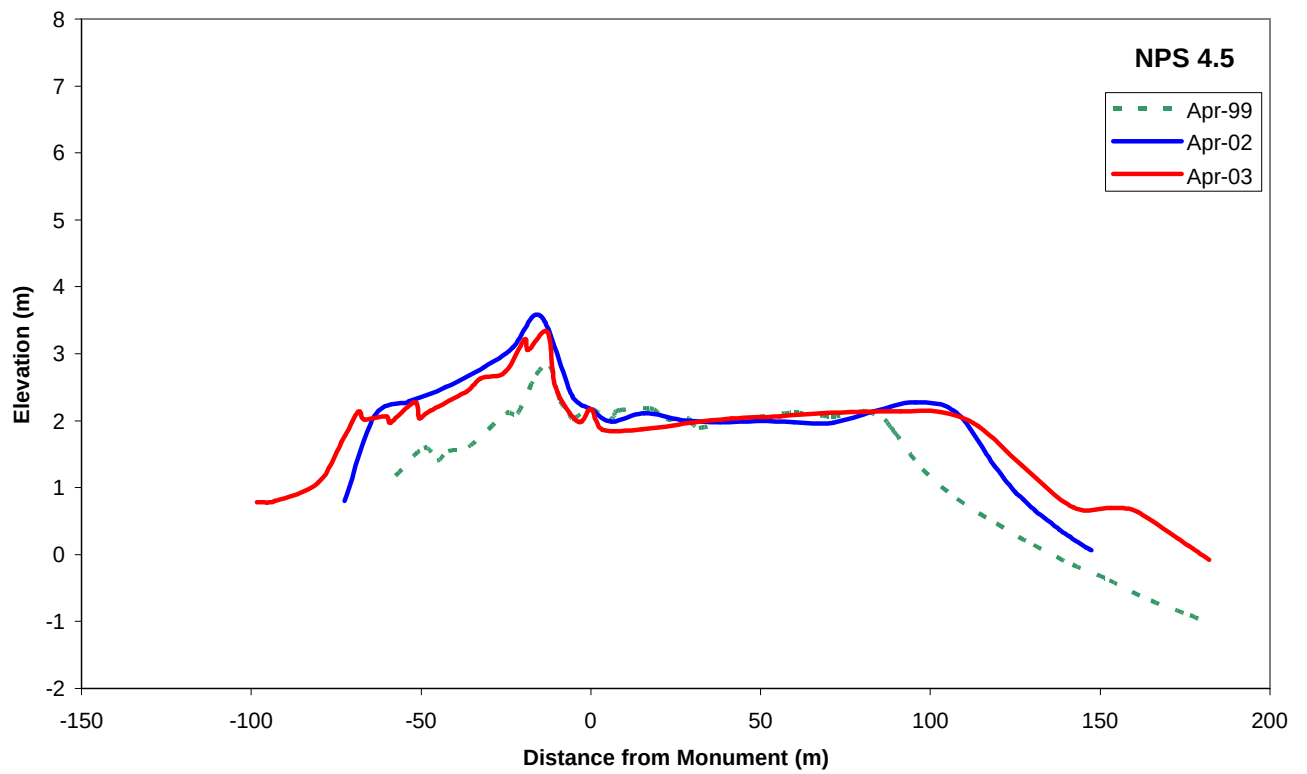


Figure A8. Survey Line NPS-4.5

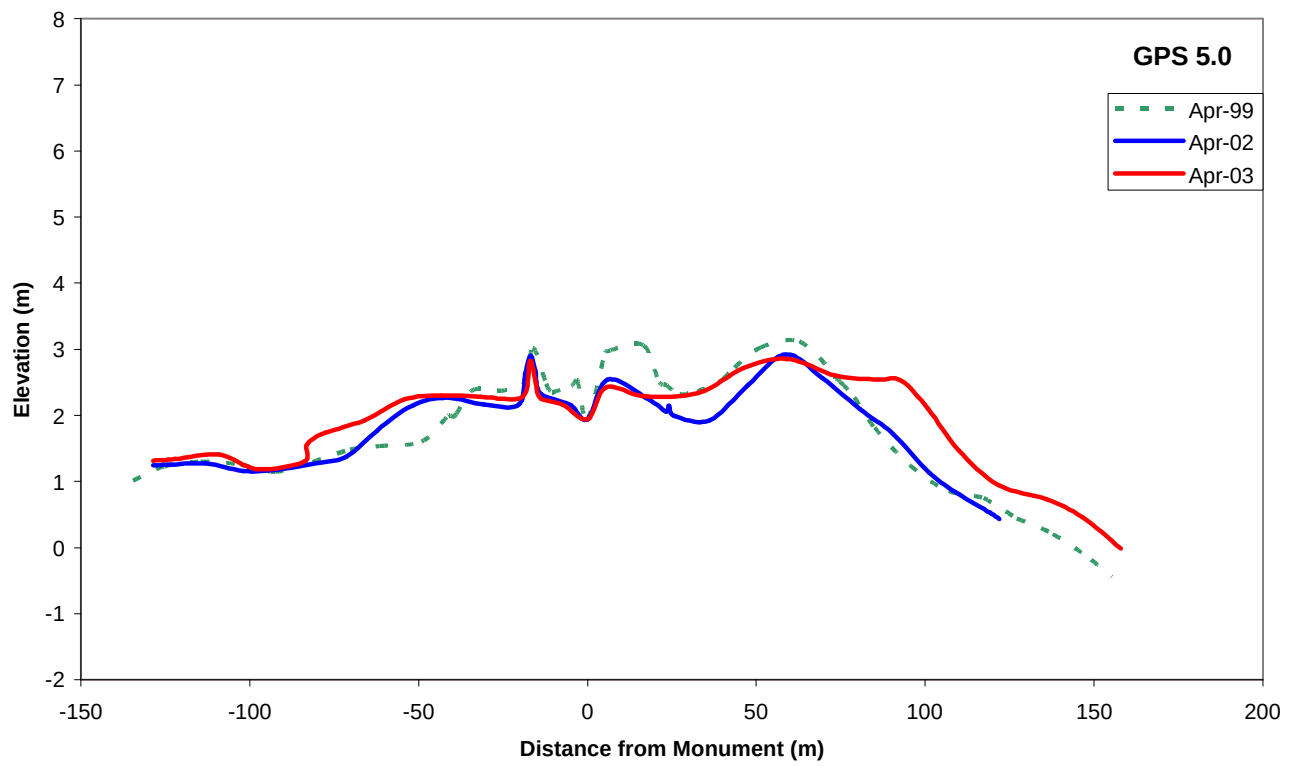


Figure A9. Survey Line GPS-5

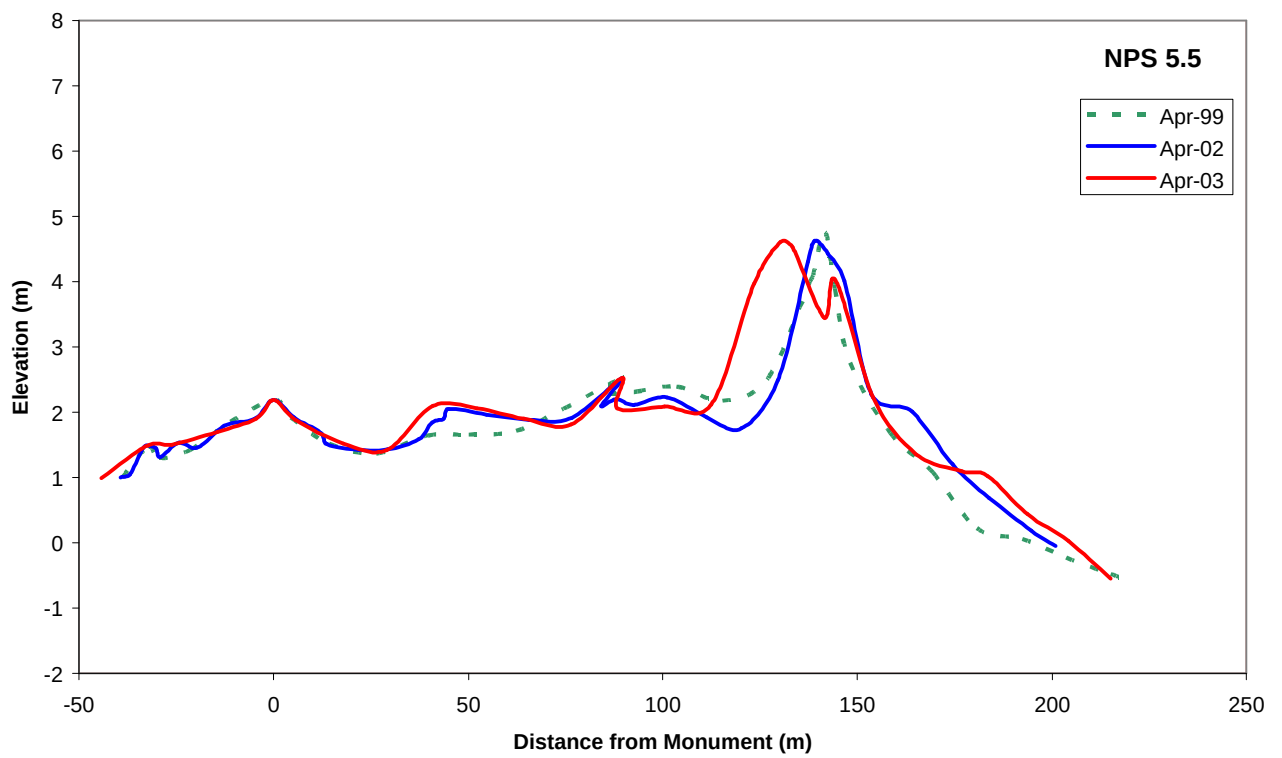


Figure A10. Survey Line NPS-5.5

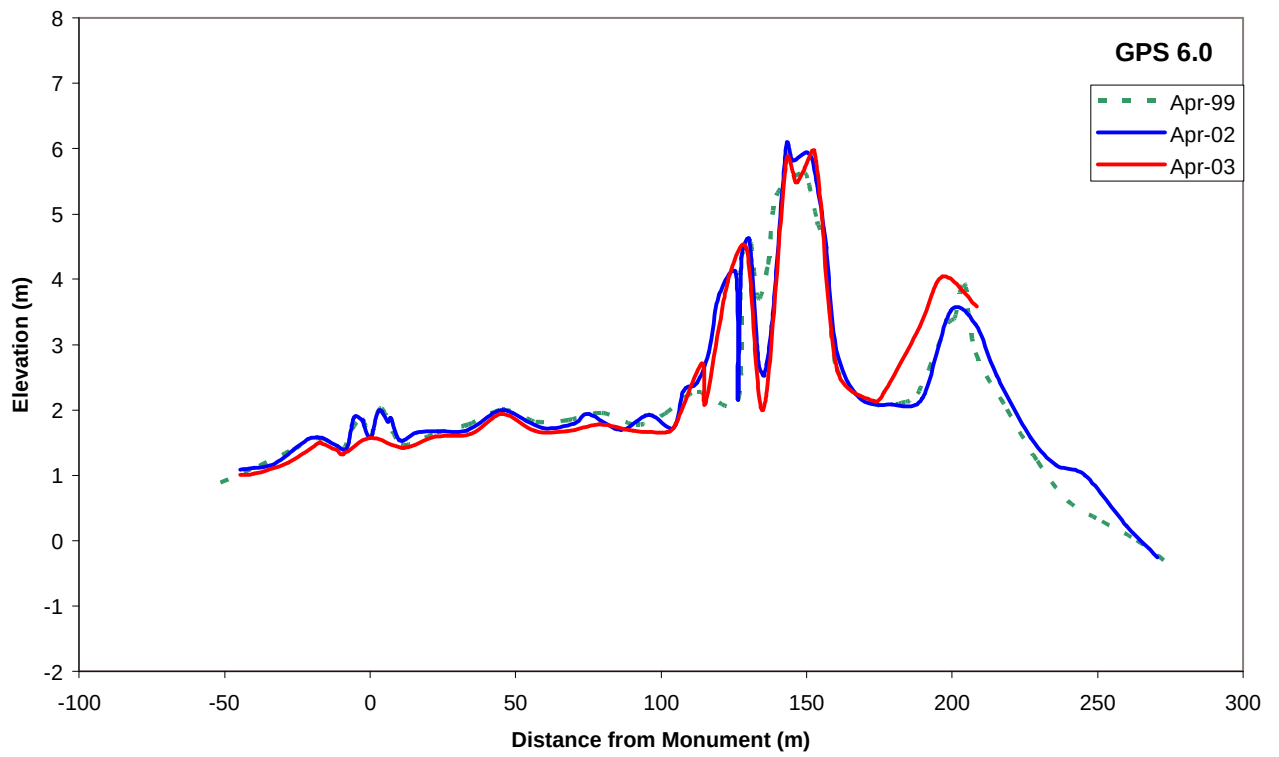


Figure A11. Survey line GPS-6

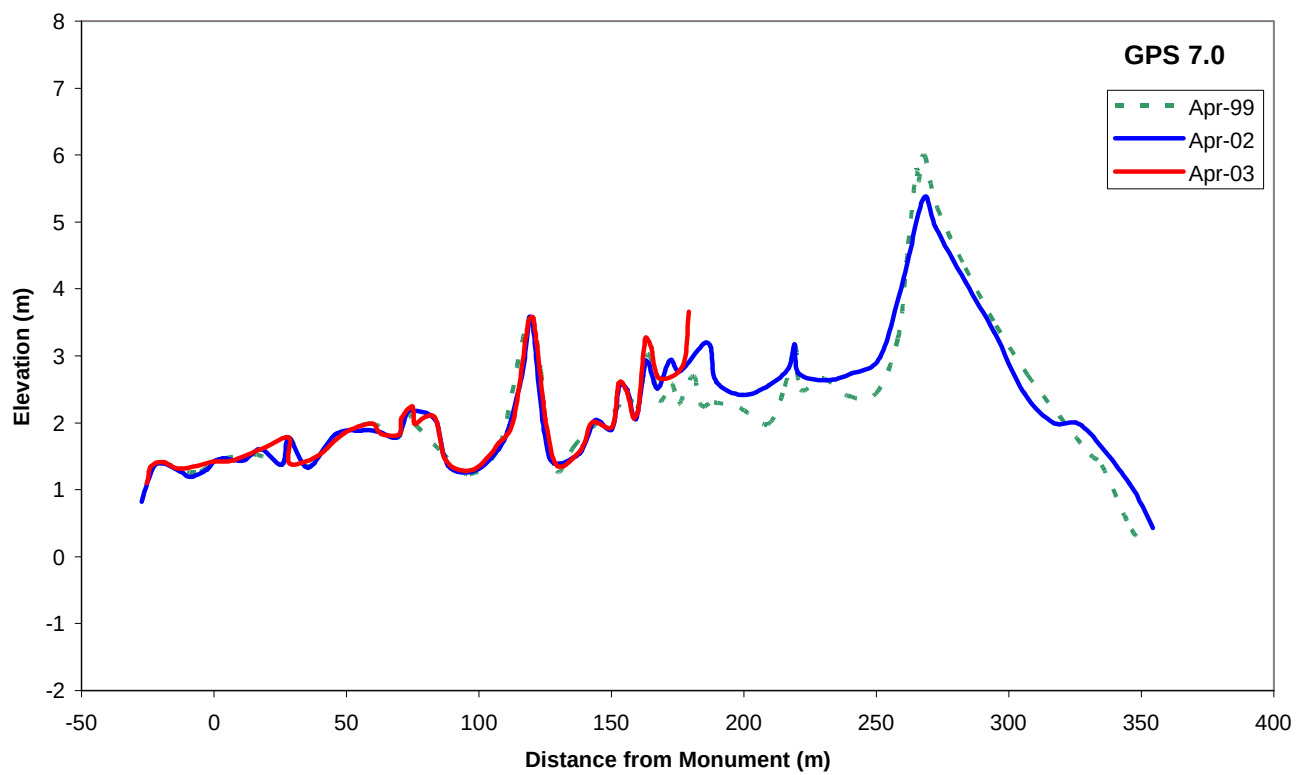


Figure A12. Survey Line GPS-7

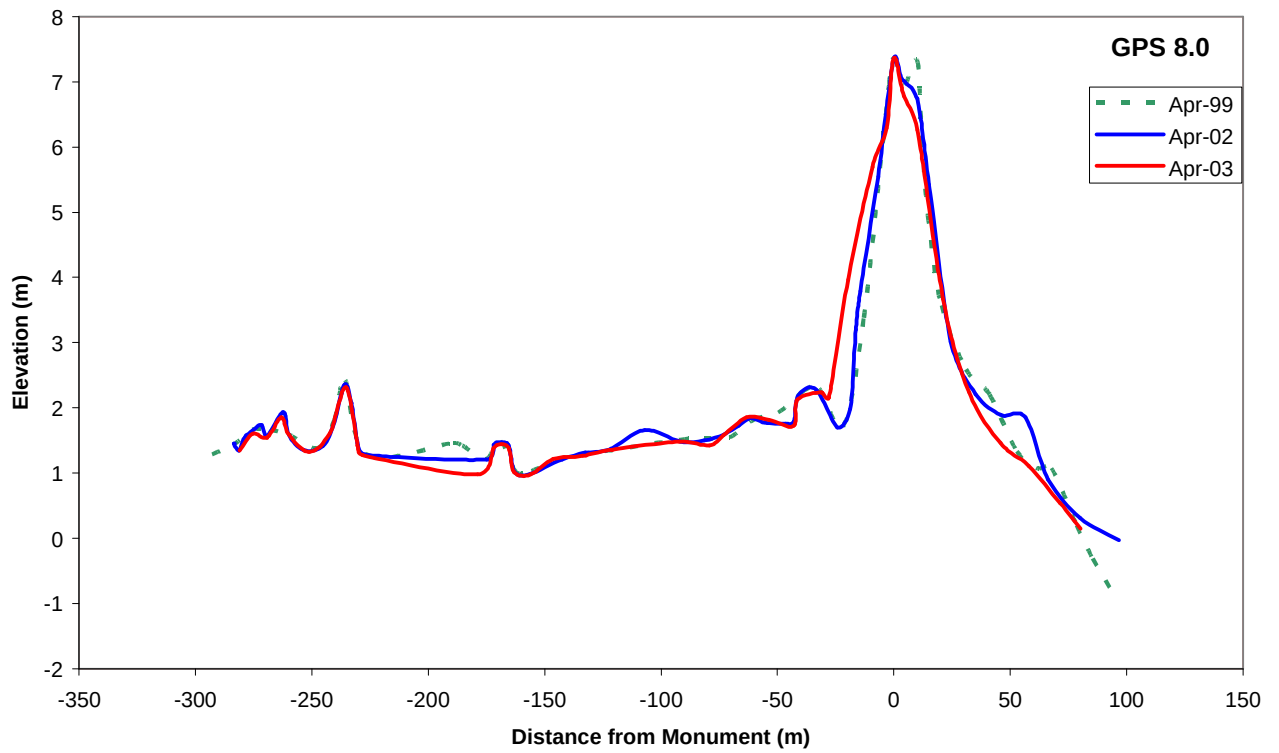


Figure A13. Survey Line GPS-8

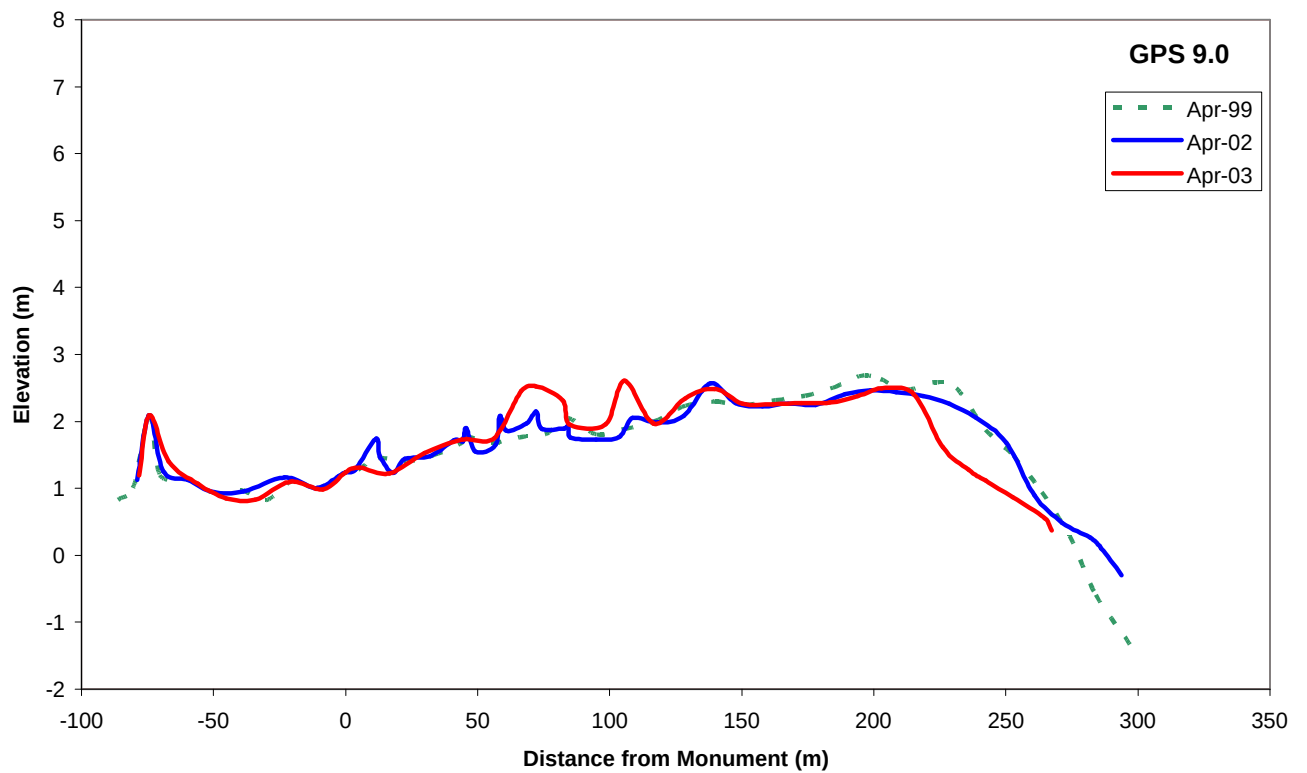


Figure A14. Survey Line GPS-9

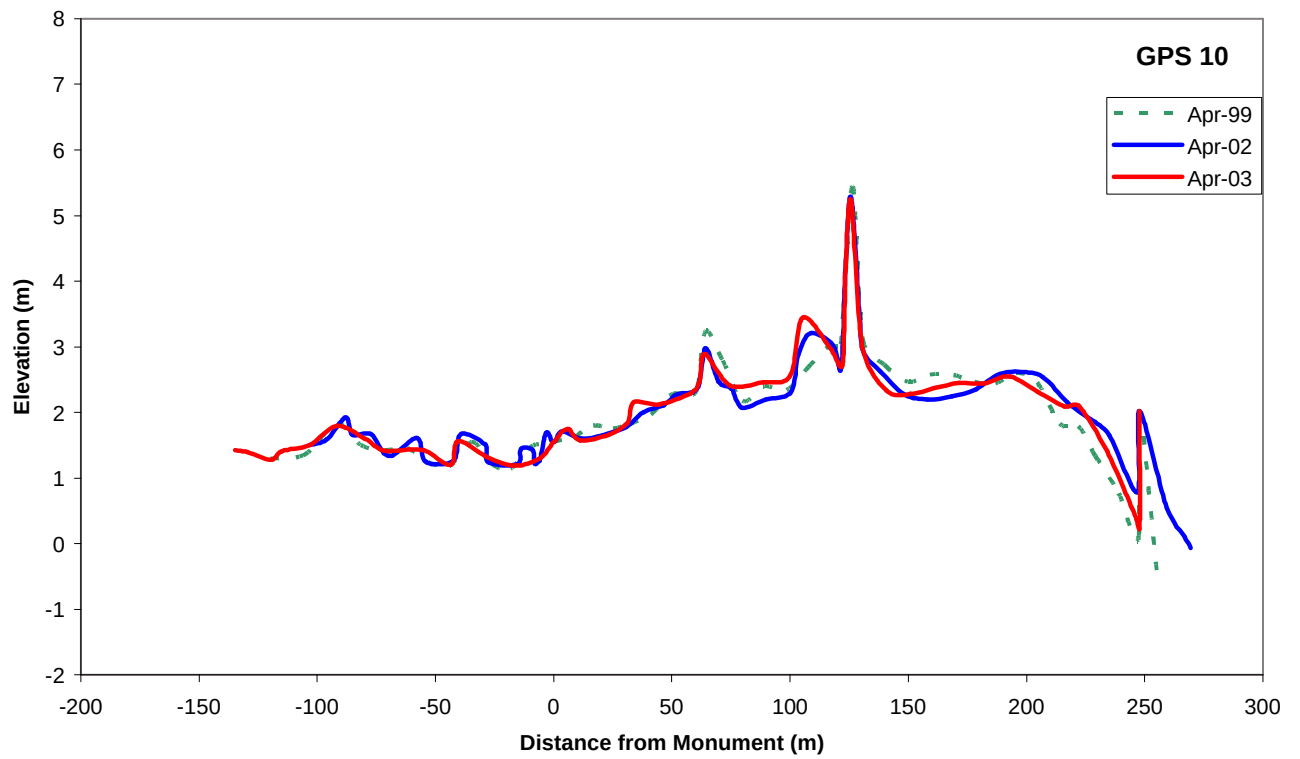


Figure A15. Survey Line GPS-10

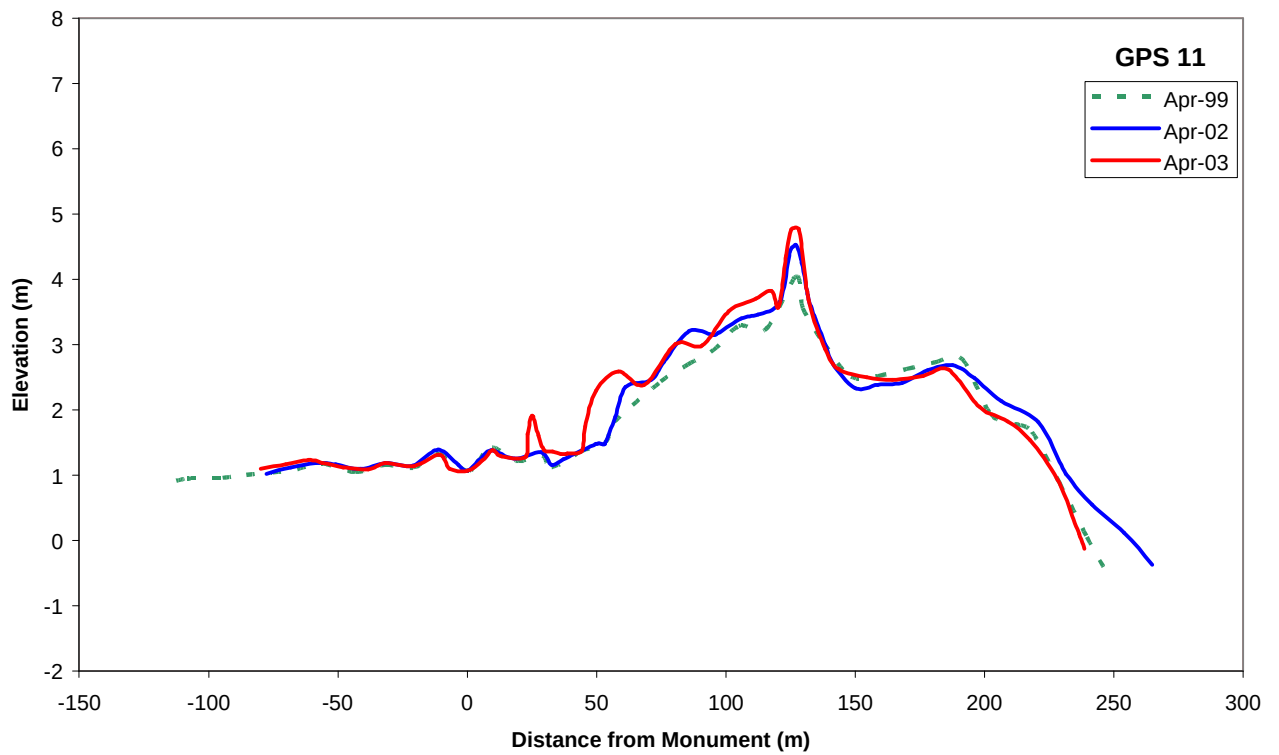


Figure A16. Survey Line GPS-11

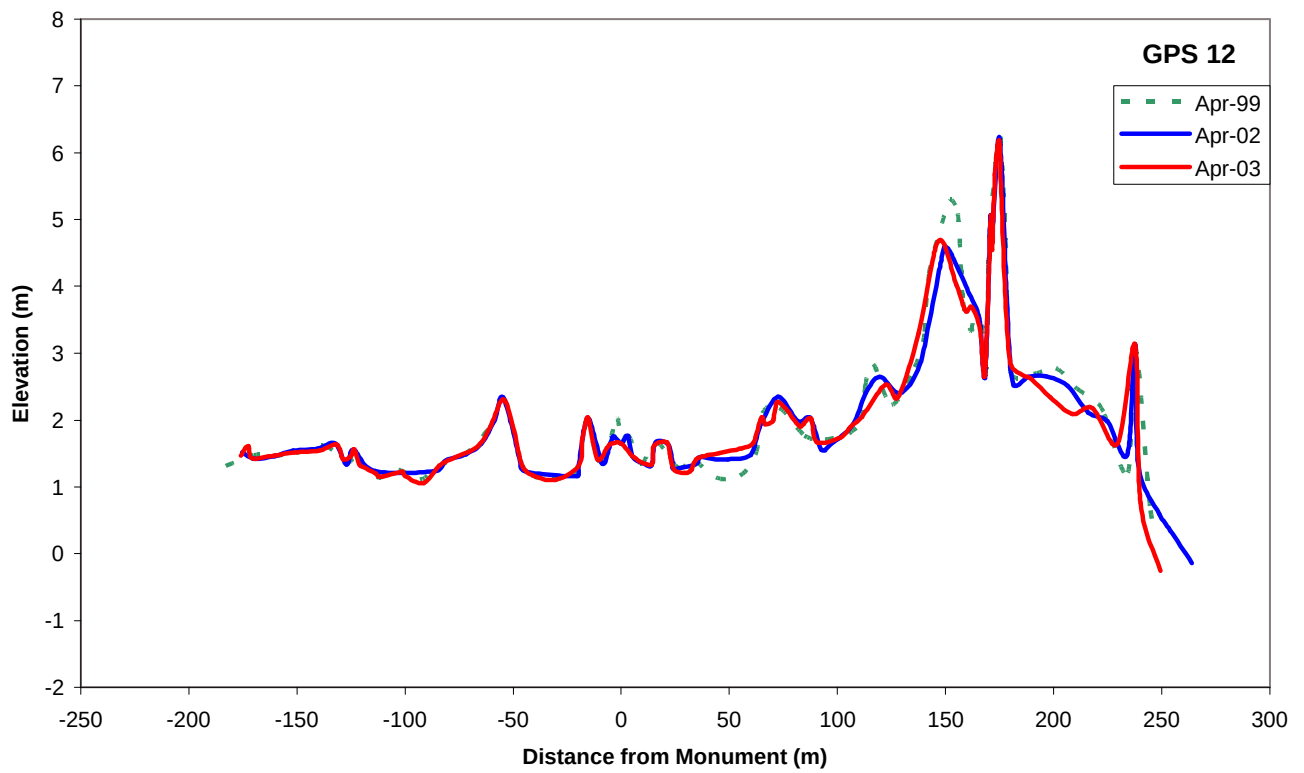


Figure A17. Survey Line GPS-12

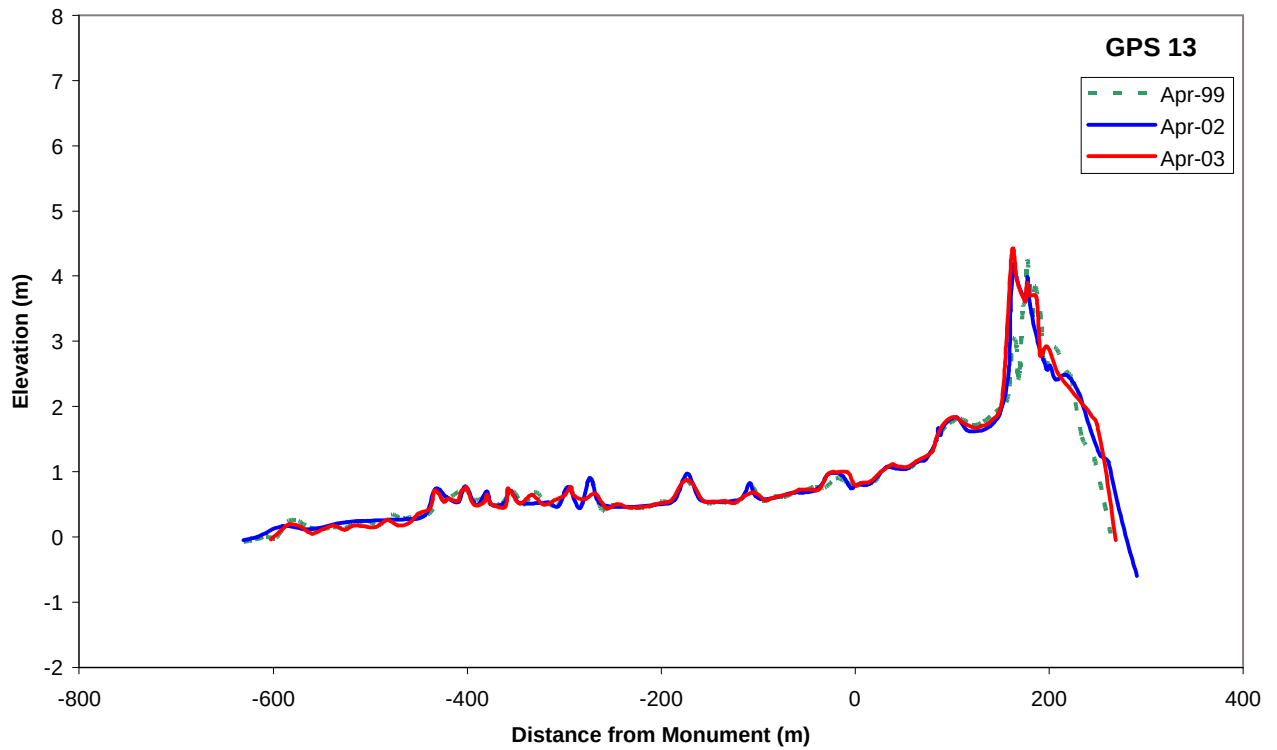


Figure A18. Survey Line GPS-13

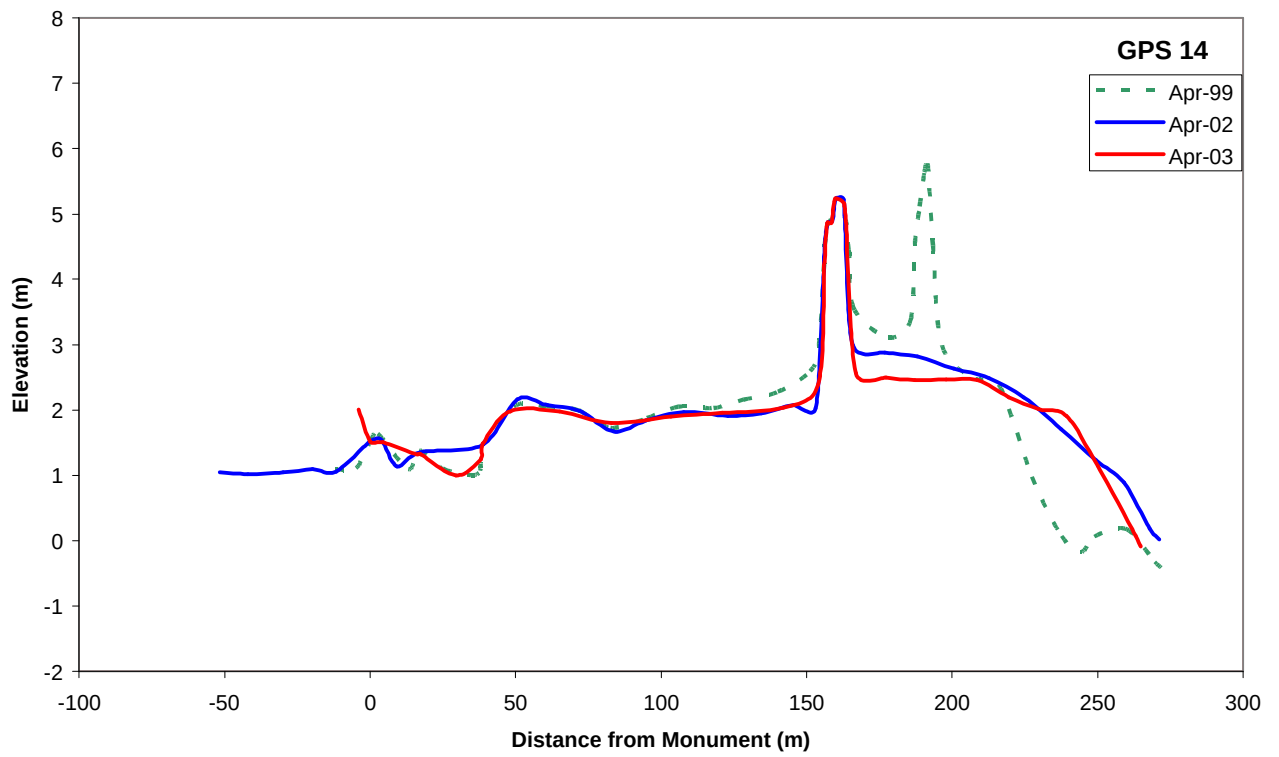


Figure A19. Survey Line GPS-14

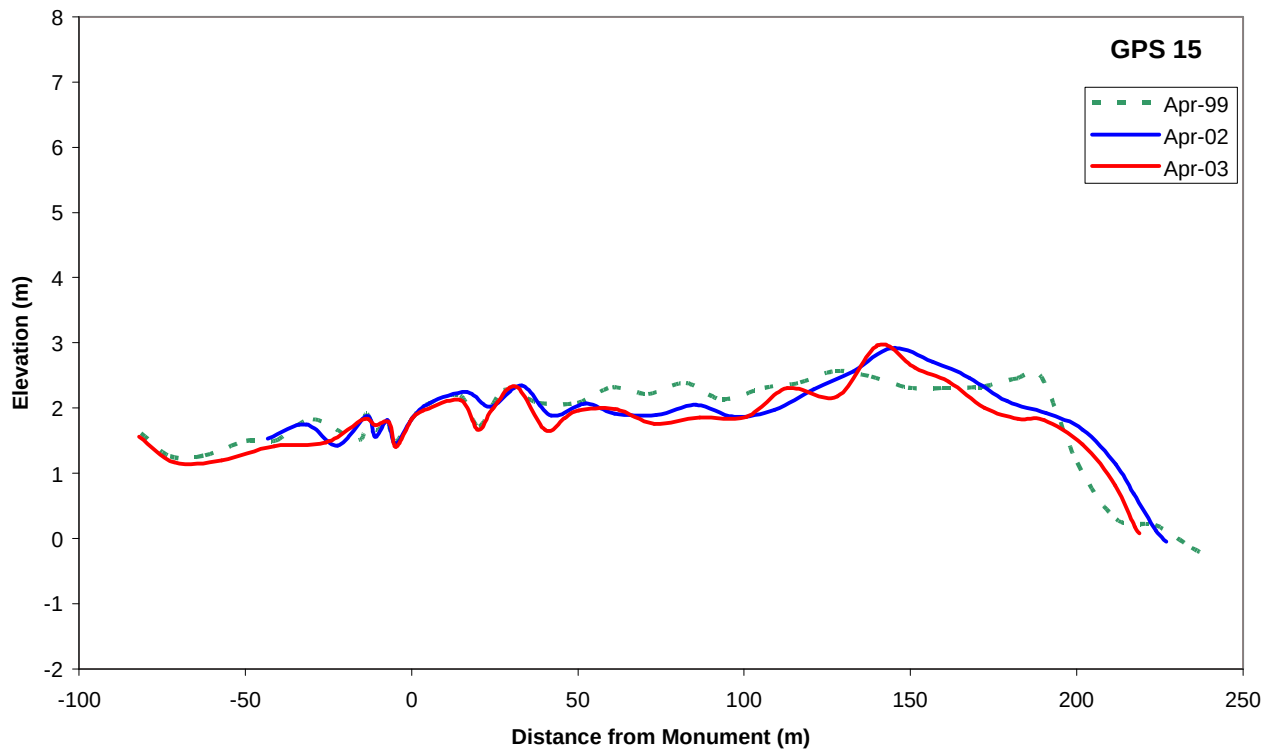


Figure A20. Survey Line GPS-15

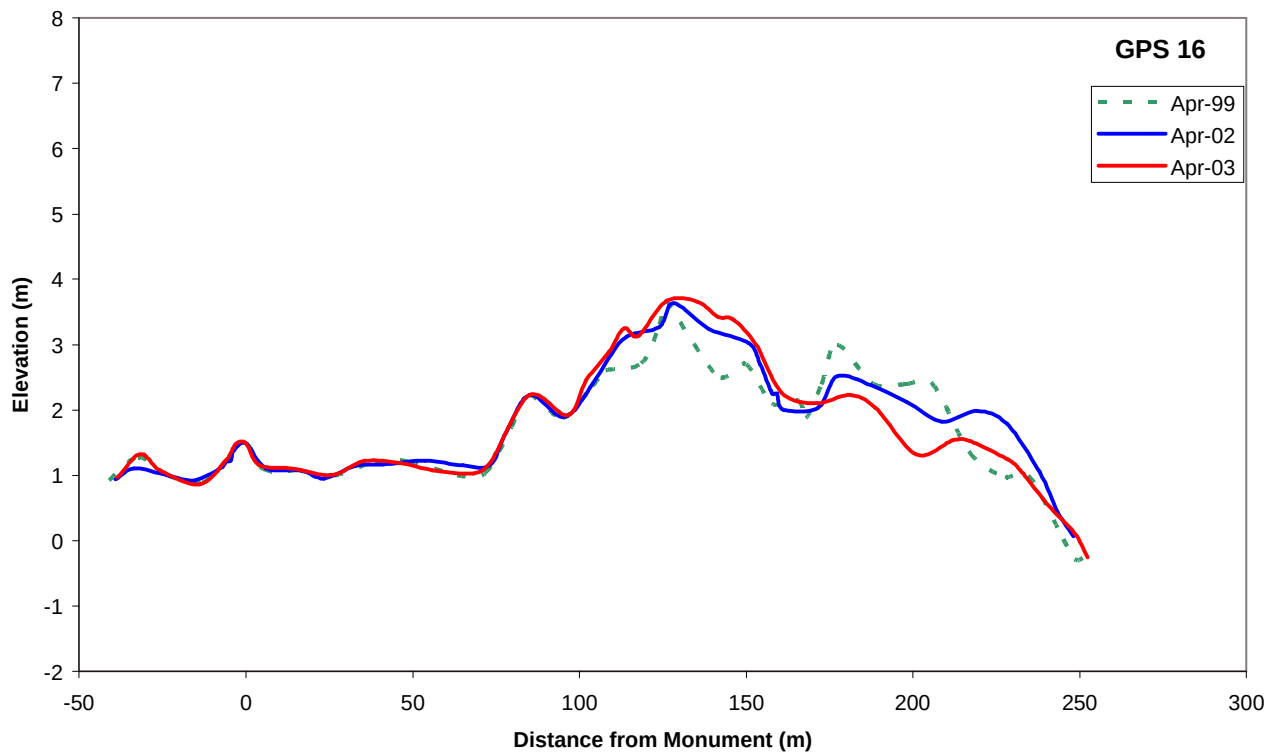


Figure A21. Survey Line GPS-16

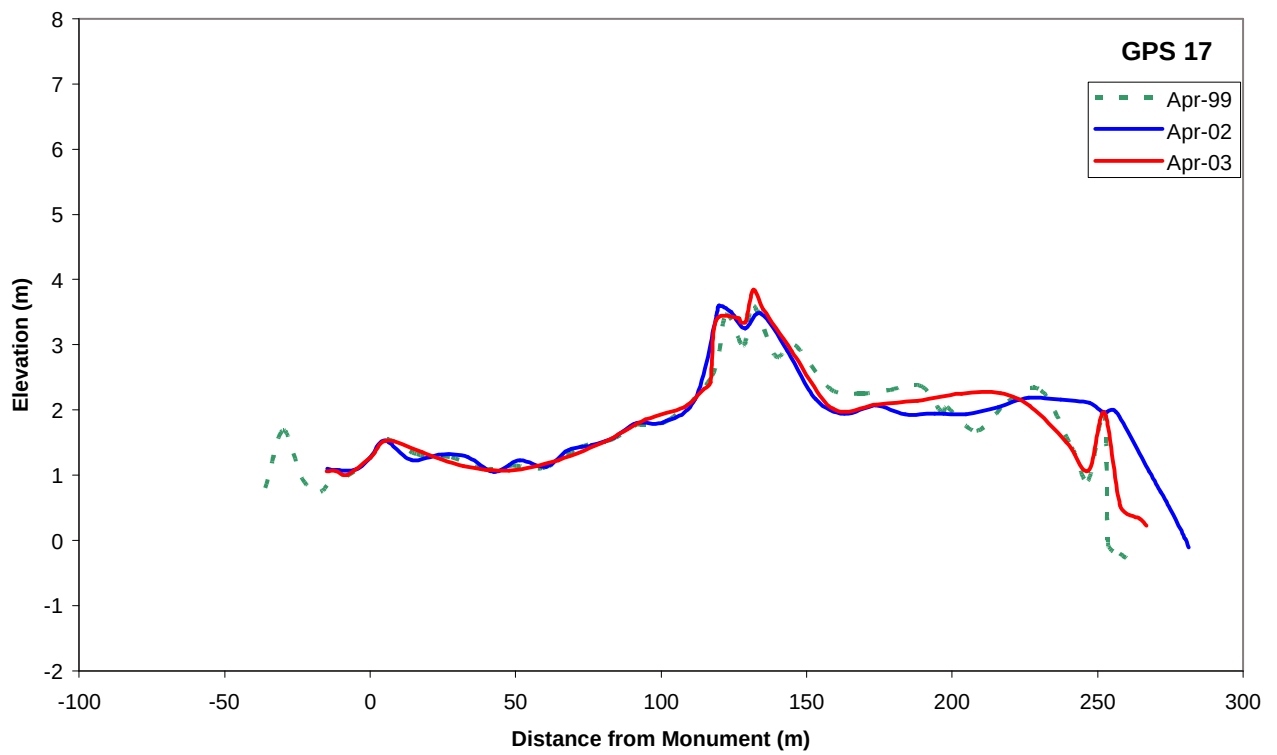


Figure A22. Survey Line GPS-17

Appendix B
GPS Shoreline Surveys

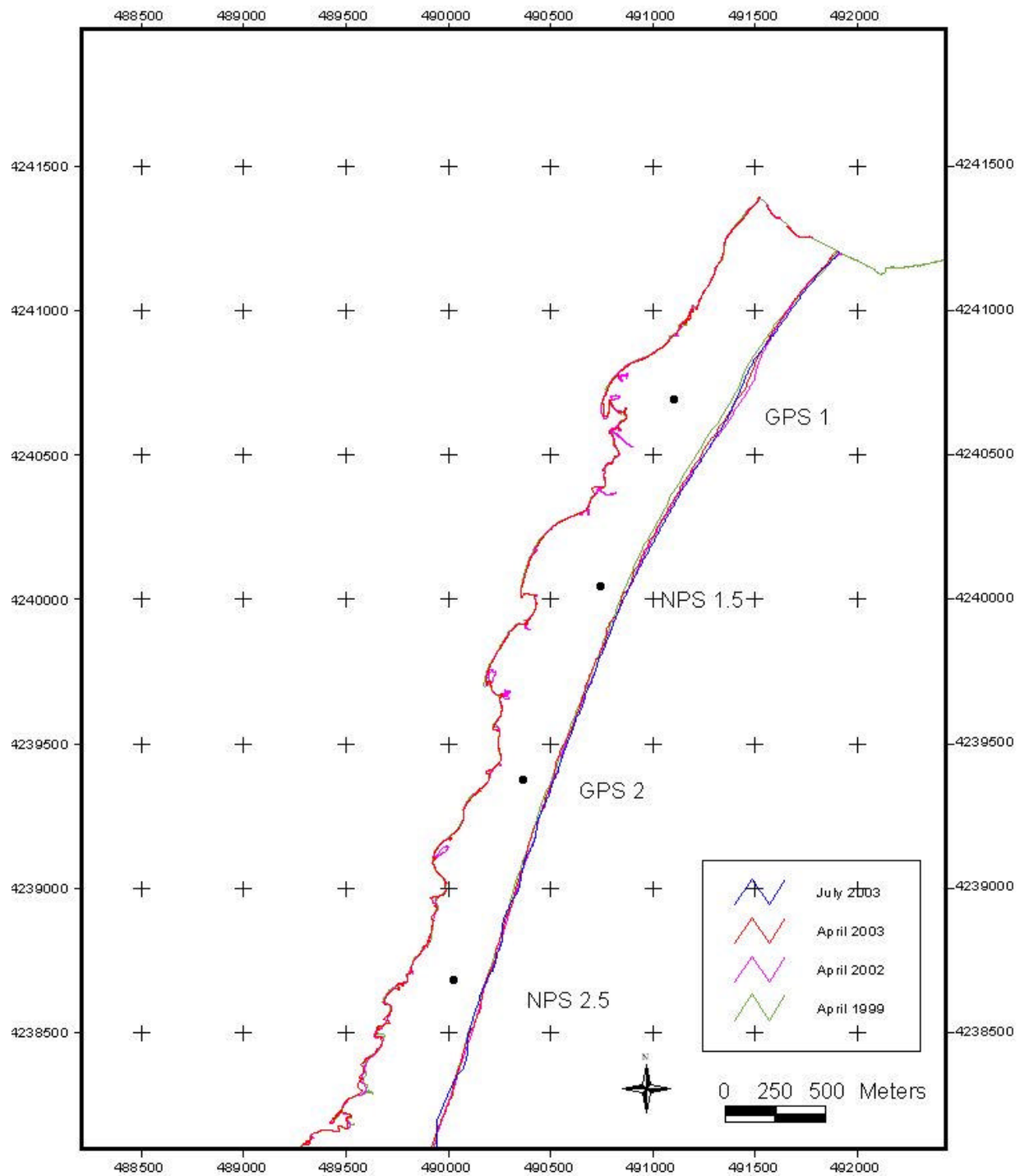


Figure B1. Shoreline position along the northern section of the North End. Position of baseline monuments shown for reference purposes.

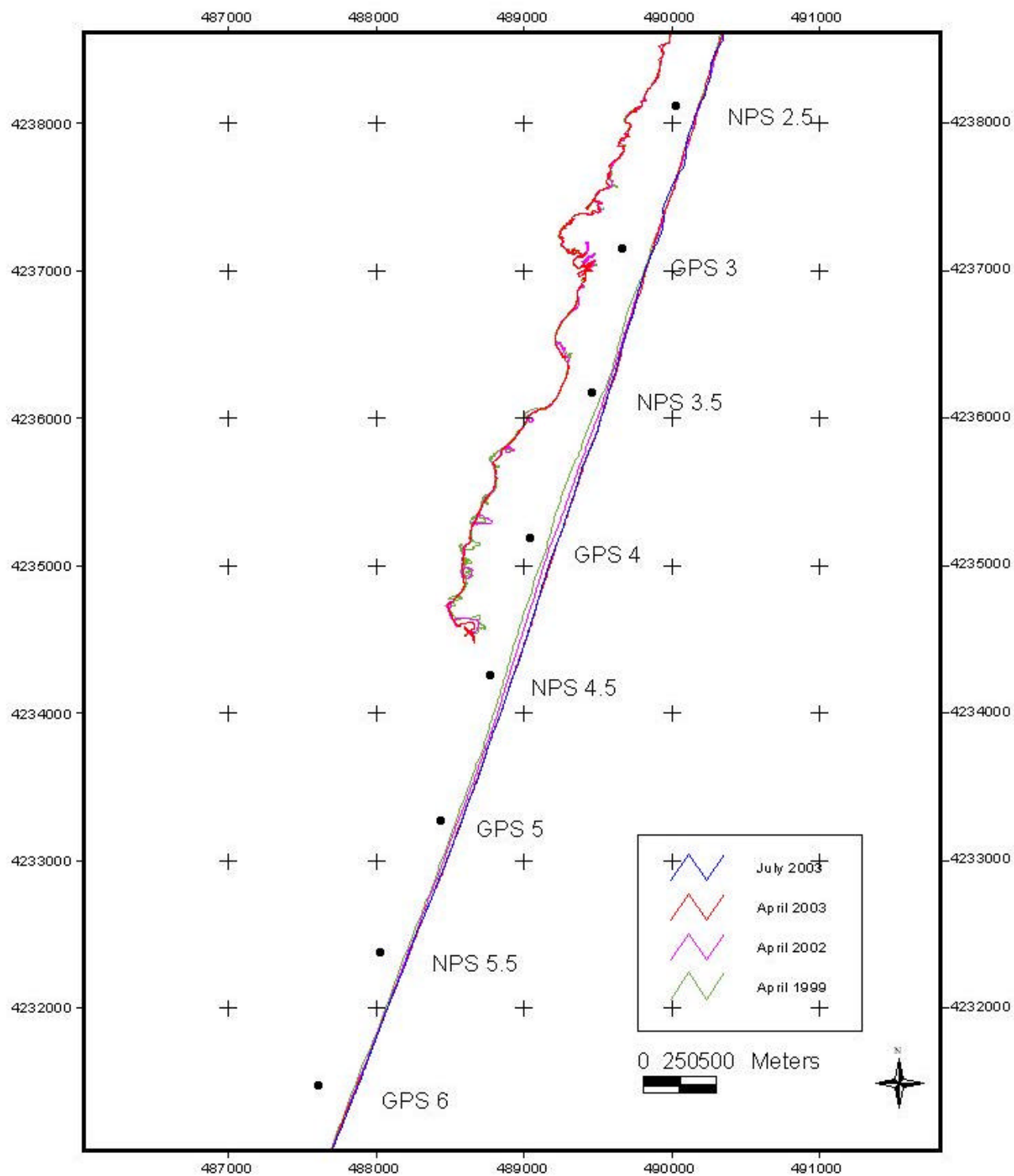


Figure B2. Shoreline position along the southern portion of the North End. Position of baseline monuments shown for reference purposes.

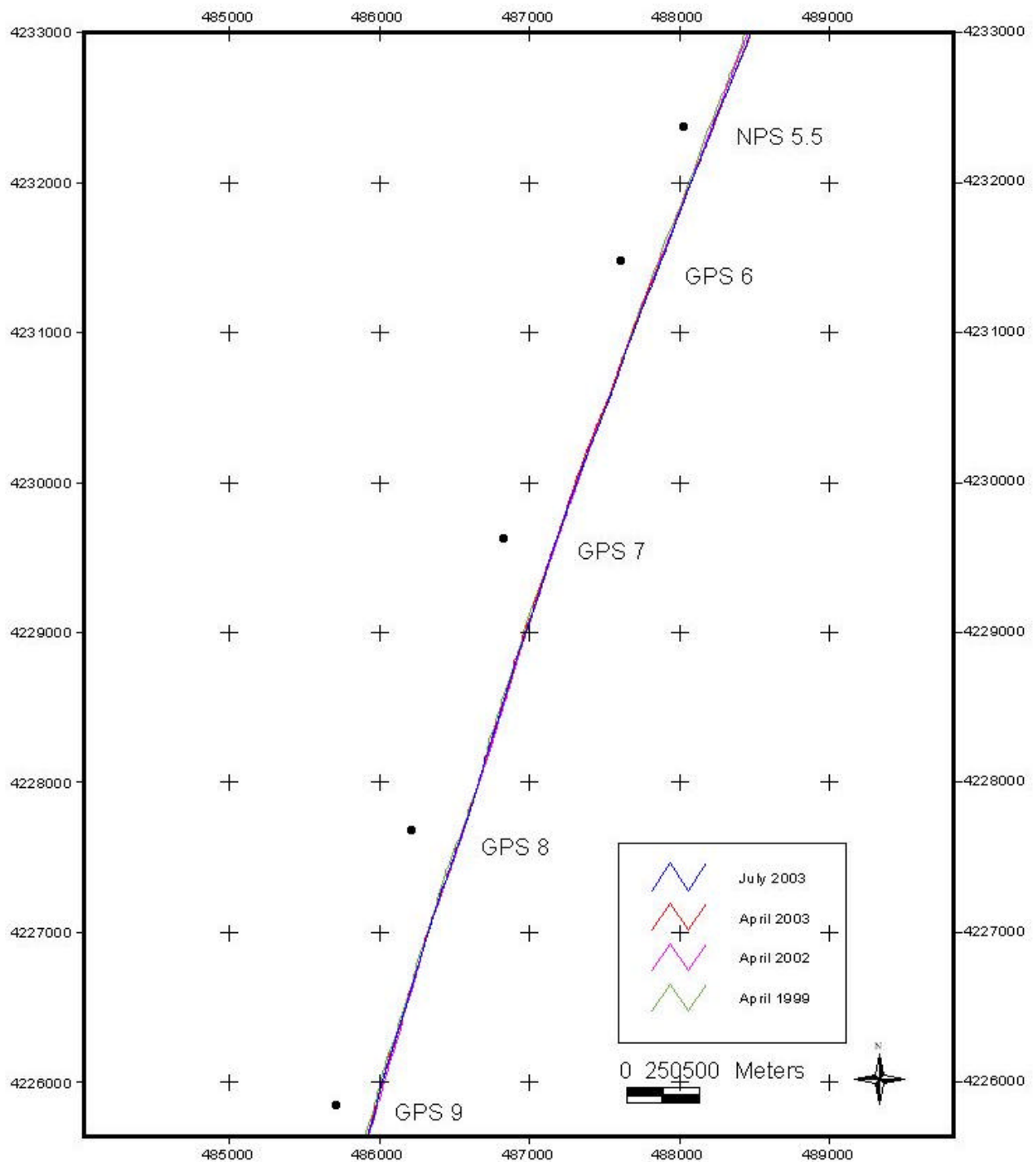


Figure B3. Shoreline position fronting Assateague State Park. Position of baseline monuments shown for reference purposes.

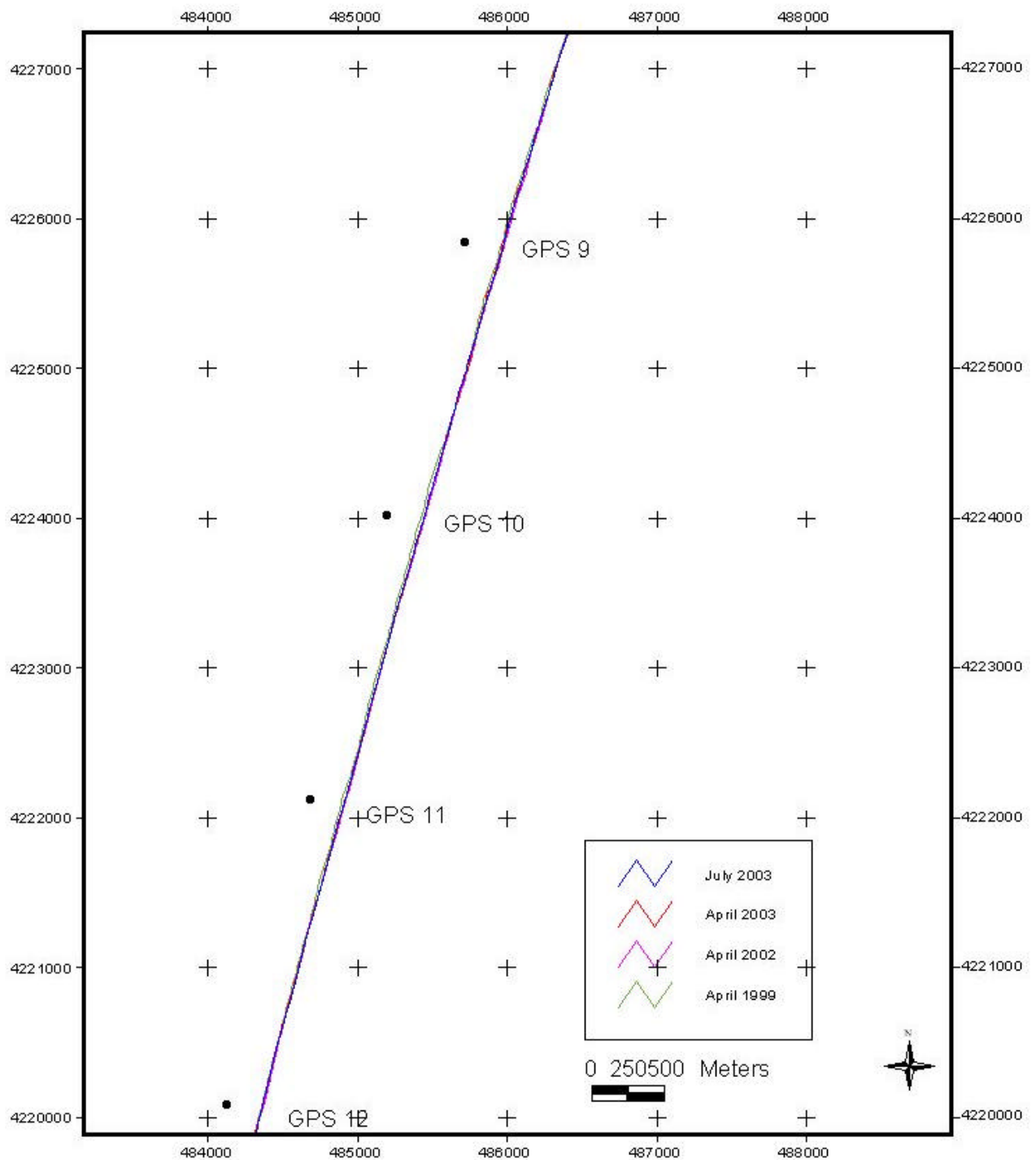


Figure B4. Shoreline position south of Assateague State Park. Position of baseline monuments shown for reference purposes.

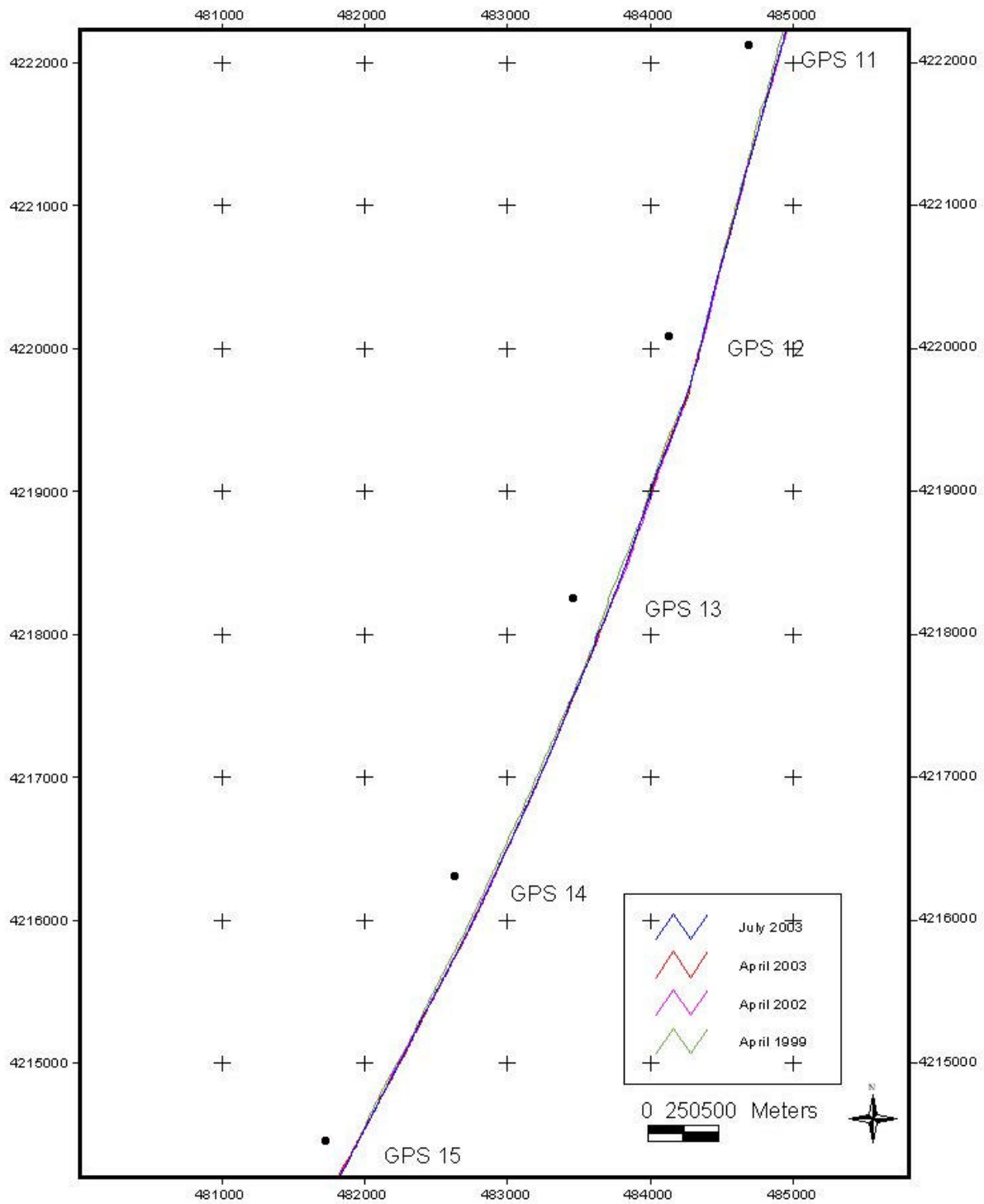


Figure B5. Shoreline position in the northern section of the ORV zone. Position of baseline monuments shown for reference purposes.

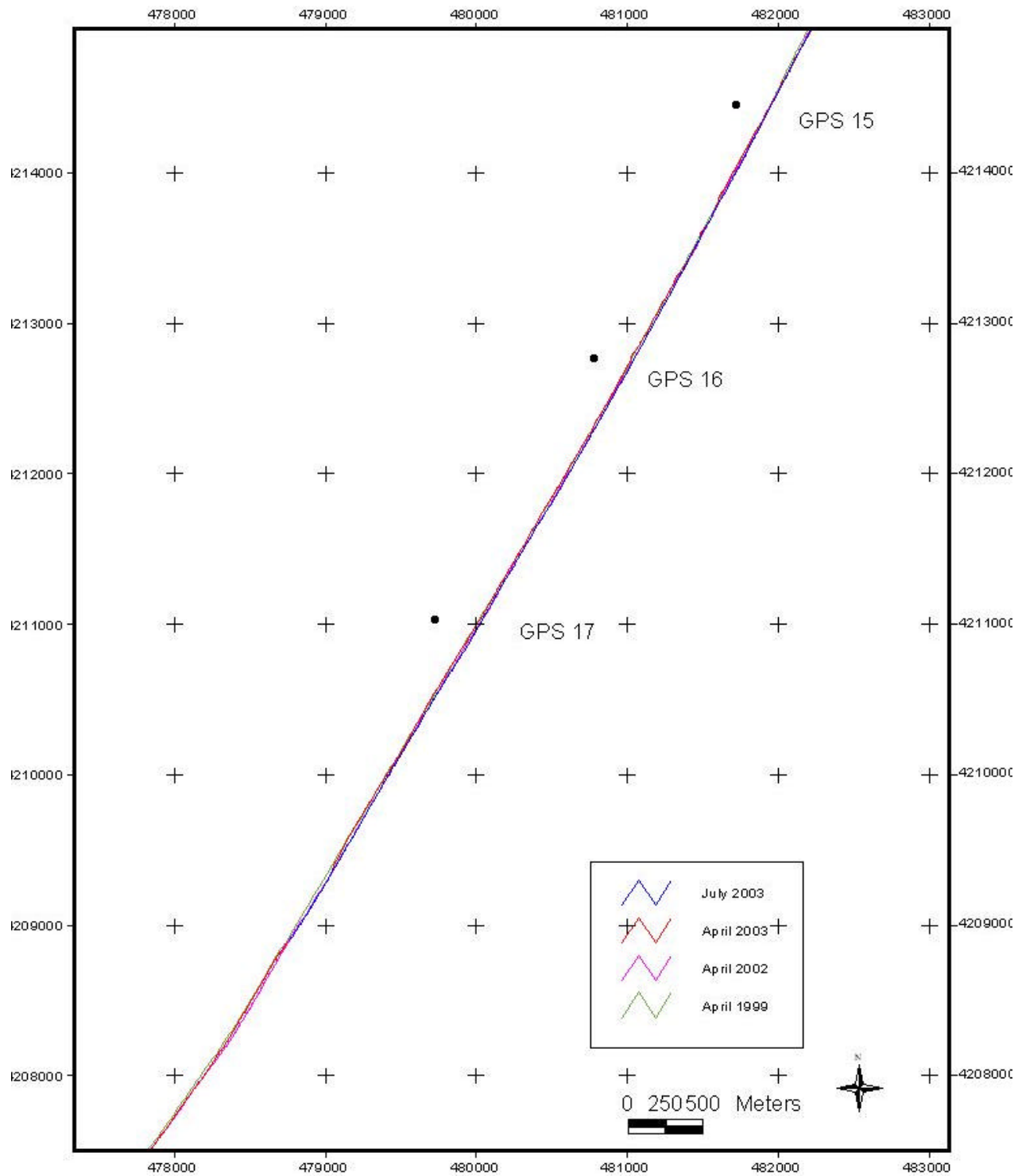


Figure B6. Shoreline position in the southern section of the ORV zone. Position of baseline monuments shown for reference purposes.

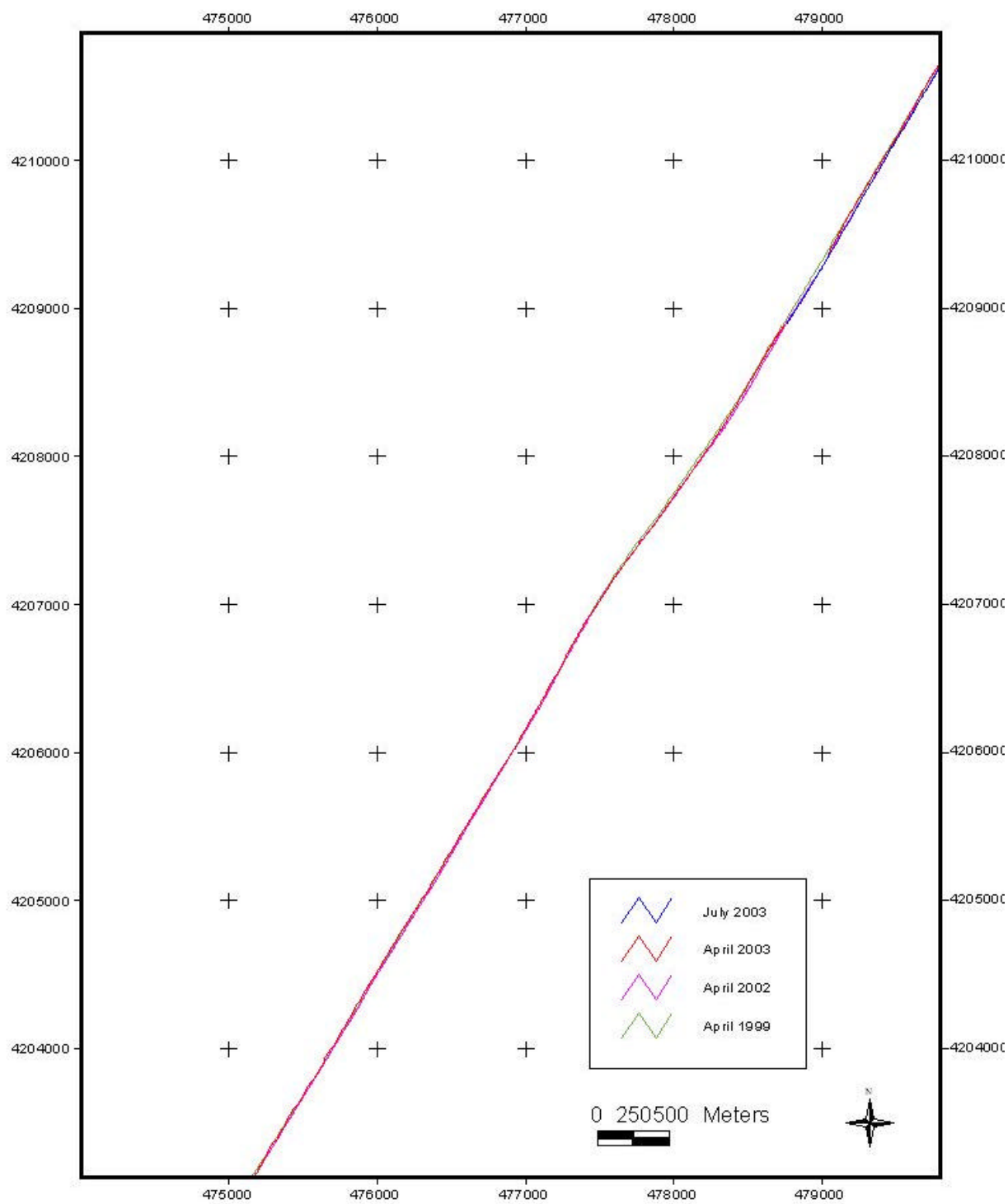


Figure B7. Shoreline position in the northern section of the Virginia coast.

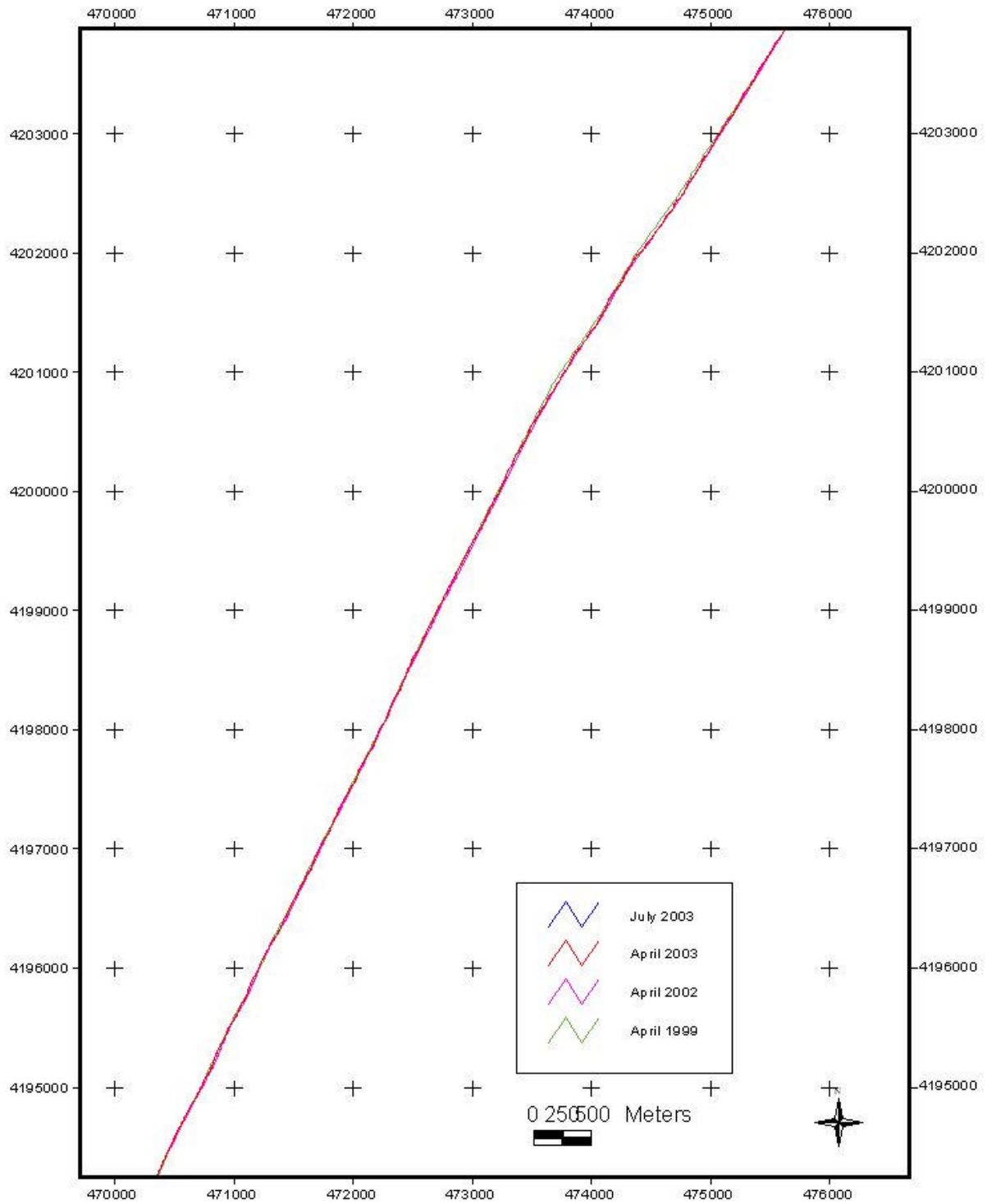


Figure B8. Shoreline position in the southern section of the Virginia coast.

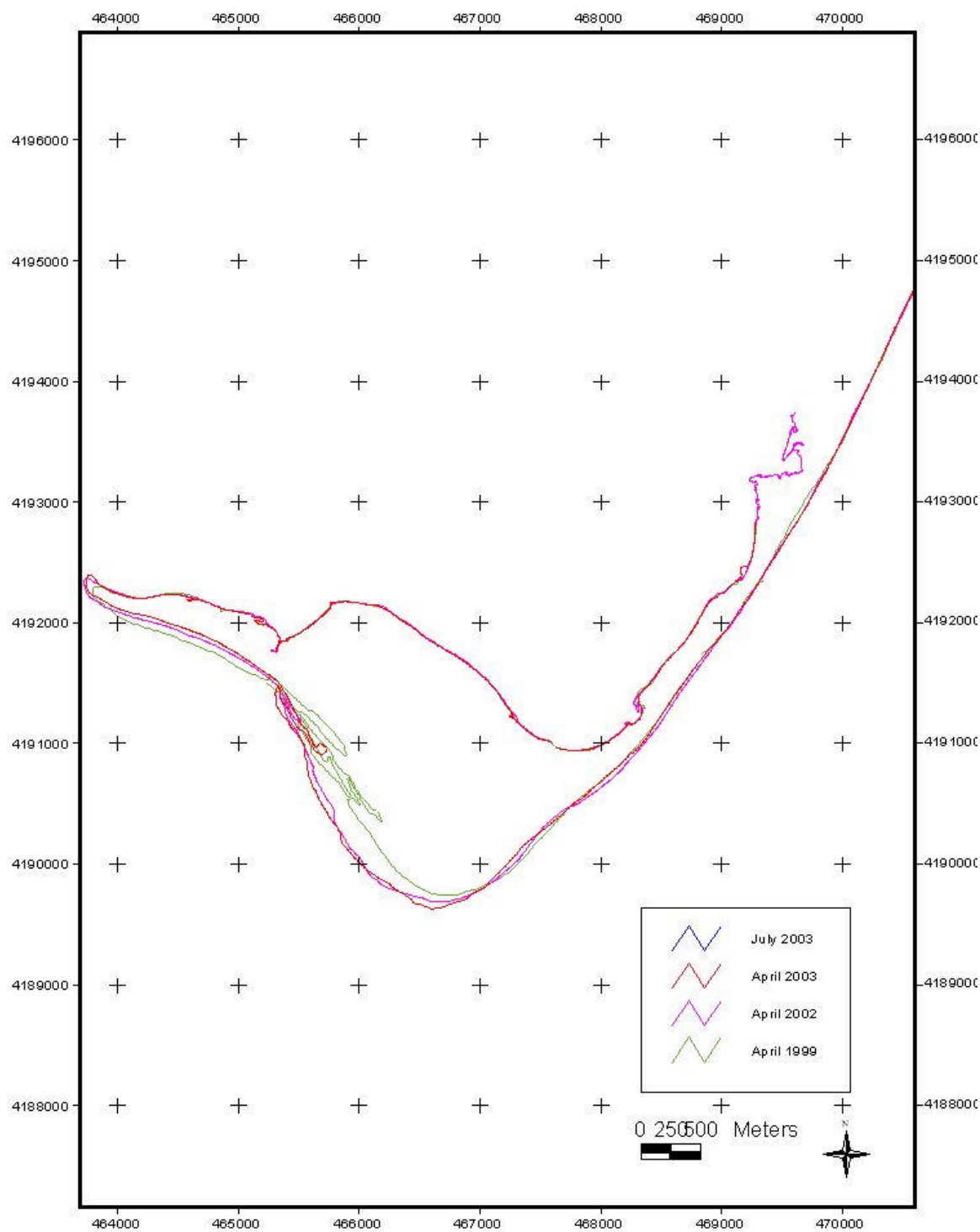


Figure B9. Shoreline position in the Toms Cove Hook region at the southern extent of Assateague Island.