NOAA COASTAL MAPPING PROGRAM
PROJECT COMPLETION REPORT

PROJECT AK0301

CHUKCHI SEA, CAPE PRINCE OF WALES TO CAPE ESPENBERG
ALASKA

INTRODUCTION

This project was undertaken to provide digital shoreline mapping for NOAA nautical charts, erosion studies and other uses. The project includes an area located in western Alaska on the north shore of the Seward Peninsula from Cape Prince of Wales to Cape Espenberg.

The project limits for AK0301 are approximately:

66º35' north latitude, 168º05' west longitude
66º35' north latitude, 163º40' west longitude
65º35' north latitude, 163º40' west longitude
65º35' north latitude, 168º05' west longitude

The area is depicted within NOAA nautical chart 16005. The project includes planning, aerial photography, ground control survey, aerotriangulation, map compilation, LiDAR acquisition, tide gauging, and report writing. Aerial photography was acquired over the project area shoreline and used to produce shoreline mapping. LiDAR data was acquired over the project area shoreline and was processed to a point cloud, DEM and intensity images for delivery. Tidal observations were made during photo acquisition from five tidal stations that were set for this project in 2003. At one of the locations 30-day observations were made, and short-term observations were made at the remaining four locations. One station was re-established during LiDAR acquisition in 2004.

The project database consists of information measured and extracted from Airborne GPS/IMU controlled aerial photography, LiDAR, and tidal observations. Project survey data is referenced to the North American Datum of 1983 (NAD 83). Aerotriangulation was conducted in soft copy. Map compilation was accomplished using Zeiss P1, P2, P3, and DAT/EM IMA Analytical Stereoplotters and a DAT/EM Summit Evolution Softcopy Stereoplotter. Preliminary map review was performed on Pentium 4CPU, 2GHz computer workstations using MicroStation software. The final map editing and formatting was completed using ESRI's ArcGIS software. Preliminary Shapefiles were submitted for NOAA's review. Review comments were incorporated into the digital files and Final Shapefiles were delivered.

PROJECT DESIGN

AERO-METRIC, INC. and AeroMap U.S., a division of AERO-METRIC, INC., designed the project. The design was based on Coastal Mapping Program Specifications for Shoreline Mapping and Project Instructions prepared by NOAA, July 23, 2003. Project Instructions were revised August 14, 2003 in accordance with contract negotiations.

Project Design - Aerial Photography and Mapping

The project limits were overlaid on NOAA Nautical Chart 16005 and were used to depict the approximate locations of the shorelines to be mapped. Color negative photography was planned. Eighteen flight lines were planned at 1:24,000 scale to adequately cover land/water interface in stereo within the project area. Three flight lines were planned at 1:12,000 scale to cover the area of shore erosion approximately 10 miles on either side of the village of Shishmaref. The flight lines were planned with 30% sidelap and 60% forward overlap. Photography was planned for tide-coordinated acquisition at or below Mean High Water (MHW).

Historical photography was to be obtained for use in assessment of shoreline erosion. A report on the erosion within the project area, based on shoreline difference from the historic photography, was to be compiled.

The sun angle for all photography was to be at or above 20 degrees above the horizon. Weather conditions were to be suitable for acquisition with no clouds present. Minimum visibility at the time of exposure was to be 8 miles. Flight crews were to coordinate daily with personnel who were monitoring tide gauges to determine if water level conditions were suitable for photo acquisition.

Airborne GPS/IMU control was planned for the project. Base stations were to be deployed on published geodetic control marks in the northwest Alaska village of Kotzebue at the airport. An additional four GPS receivers were to be operating full time at Wales, Shishmaref, Kivalina and Point Hope during photo acquisition. The maximum range of the aircraft during photo acquisition from the GPS base station at Kotzebue was planned to exceed 280 km, however, the aircraft would never be in excess of 100 km from an operational base station.

Ground checkpoints were to be surveyed at three locations, Wales, Ikpek, and Shishmaref. The checkpoints were to be surveyed by John Oswald & Associates, LLC (JOA). It was planned that photo ID points rather than pre-marked locations would be used, so JOA was to select 3 to 4 check points at each of the three locations with the idea that some of these points could be rejected horizontally or vertically if they could not be read well. Check points were to be used only as ground checks and not to control the photography.

Project Design - LiDAR

LiDAR data was to be obtained at 2 meter spacing for the entire project area. For the barrier island shoreline ten miles on each side of Shishmaref, data was to be obtained at 1 meter spacing. The planned acquisition parameters are as follows.

1 m Point Spacing	
Flying Height AGL	5000’
Ground Speed	150 kts
Scan Angle	12 degrees
Mirror Scan Rate	39 Hz
Laser Pulse Rate	25 kHz
Swath Width	1040’
Side Lap	40%
Line Spacing	623’
Along Track Spacing	0.99 m
Cross Track Spacing	1.00 m

2 m Point Spacing	
Flying Height AGL	6000’
Ground Speed	150 kts
Scan Angle	38 degrees
Mirror Scan Rate	20 Hz
Laser Pulse Rate	25 kHz
Swath Width	4127’
Side Lap	0% (Single Pass)
Along Track Spacing	2.0 m
Cross Track Spacing	1.9 m

Sixty-six ground checkpoints for LiDAR were to be surveyed within the LiDAR acquisition area for projects AK0301 and AK0302. The checkpoints were to be surveyed by JOA. Survey was to be done by GPS static methods. The checkpoints were distributed in six groups with at least five points in each group.

Project Design - Tide Gauging

Ten tide stations were to be established for areas AK0301 and AK0302, five in each project area. The tide stations were to be run and surveyed by JOA. These tide stations were to support the acquisition of a new MHW line along the NW shore of the Seward Peninsula for updating the nautical chart and for the erosion studies. Three of the tide stations, one of which is located within the AK0301 project area, were re-established in the summer of 2004.

See Ground Surveys Report, GPS Survey in Support of Coastal Mapping Program, Chukchi, Alaska, NGS Project Nos. AK0301 & AK0302, dated July 12, 2004.
See AK0301 – Shishmaref, Aerial Photography Final Report, dated November 2004.
See AK0301 – Shishmaref, Airborne Positioning and Orientation Report, dated November 2004.
See AK0301 Shishmaref, NOAA Aerotriangulation Report, dated November 2004.
See AK0301 Shishmaref, Erosion Study Report, dated December 27, 2004
See LiDAR Report, AK0301 – Shishmaref, dated May 9, 2005
See GPS Base Stations Report, NGS Projects AK0301 & AK302, Shoreline Mapping Alaska, dated September 22, 2004.
See LiDAR Check Point Report, GPS Survey in Support of Coastal Mapping Program, Chukchi, Alaska, NGS Project Nos. AK0301 & AK0302, dated December 20, 2004.
See Tide Station Reports:

Shishmaref Inlet Inside Station Report (946-9804), NGS Project AK0301, Shoreline Mapping Alaska, dated February 20, 2004.

Lopp Lagoon West, Cape Prince of Wales Station Report (946-9460), NGS Project AK0301, Shoreline Mapping Alaska, dated February 20, 2004.

Ikpek Lagoon Station Report (946-9626), NGS Project AK0301, Shoreline Mapping Alaska, dated February 20, 2004.

Lagoon at 165W Station Report (946-9982), NGS Project AK0301, Shoreline Mapping Alaska, dated February 20, 2004.
Shishmaref Inlet 2 Station Report (946-9854), NGS Project AK0301, Shoreline Mapping Alaska, dated February 20, 2004.
Shishmaref Inlet 2 Station Report (946-9854), NGS Project AK0301, Shoreline Mapping Alaska, dated November 10, 2004.

FIELD OPERATIONS

Field Operations – Aerial Photography

All photography for AK0301 was obtained between September 14, 2003 and September 24, 2003. The photographic mission was conducted with a Piper Navajo Chieftain (PA 31-350) aircraft. Natural color photography was acquired using a Zeiss TOP aerial camera. Flight crews coordinated daily with JOA personnel who were monitoring tide gauges to determine if water level conditions were suitable for photo acquisition at or below the Mean High Water level. Photography was acquired at the nominal scale of 1: 24,000 and at 1:12,000 along with the simultaneous collection of kinematic GPS and IMU positioning and orientation data. Two differential base stations (Stations KOT1 and KOT2) were deployed and used to capture simultaneous GPS data at Kotzebue Airport. An additional four GPS receivers were operating full time at Wales, Shishmaref, Kivalina and Point Hope. All base stations were observed with dual frequency GPS receivers. The number of GPS satellites tracked by the aircraft was six or more at all times and the PDOP never exceeded 4.0. The sun angle for all photography was at or above 30 degrees above the horizon. Weather conditions were suitable for acquisition, though haze was present during some of the photo acquisition. Minimum visibility at time of exposure exceeded 8 miles.

See AK0301 – Shishmaref, Aerial Photography Final Report, dated November 2004.

Field Operations- Mapping Control Survey

Check surveys for photogrammetric mapping were conducted from September 8 through October 10, 2003 by JOA using GPS observations obtained with dual frequency GPS receivers. GPS static techniques were used to survey tidal benchmarks, photo acquisition base stations, and photo ID points. The purpose of the survey was to determine NAD83 horizontal coordinates, ellipsoid heights, and to transfer published NAVD88 orthometric heights to survey points in support of tide coordinated photogrammetric mapping, tide gauging, and the LiDAR check points.

At least two sessions of 5.5 hours duration were observed at all tertiary tidal and control stations with the exception of one station with a 19-hour observation. At least one 4-hour session was observed on a tidal benchmark at each of the short-term tidal stations. Each photo ID and beach profile location had a one-hour observation. All observations were with dual frequency GPS receivers and processed relative to existing local NGS GPS

control with NAVD88 orthometric heights. Baselines were processed with Trimble Total Control v.2.73 and adjusted with NGS Adjust v.4.30.

Three NOAA control stations were observed in Nome. Photogrammetric base stations were set up in Wales, Shishmaref, Kotzebue, Kivalina and Point Hope. Tidal benchmarks were observed at tertiary (30 day) tidal stations in Shishmaref, Kotzebue, Red Dog, and Kivalina. Tidal benchmarks at short-term stations were observed at Lopp Lagoon, Ikpek Lagoon, Shishmaref Inlet Inside, Lagoon at 165 West, and Point Hope. Photo ID points were surveyed at or around Wales, Ikpek, Shishmaref, north of Cape Krusenstern, and at Red Dog. Control stations were observed in Nome, Point Hope, and Noatak.

GPS observations were made using a combination of dual frequency receivers: five Topcon 20 channel Legacy E receivers with Topcon PG-A1 antennae, four Trimble 5700 receivers with Trimble Zephyr Geodetic antennae, two Trimble 4000 receivers with Trimble 22020.00-GP antennae, and three Ashtech ZXII receivers with 700228C antennae. Data was downloaded to laptop computers and archived on CD-R.

All of the observation files were processed using Trimble Total Control version 2.73. All input parameters were applied, HI (ARP) and type of antennae. IGS final orbits were used to process the data. The published NAD83 coordinate for station 8756 (PID DF3653) was used as the "seed coordinate" for processing. The selected interval for processing was 5 seconds. A minimum angle of 15 degrees above the horizon was selected as the cut-off elevation for all carrier phase observations. The troposphere correction model used was the Modified Hopfield Model.

Baselines were exported out of Trimble Total Control as NGS bluebook files. The bluebook files were edited by hand according to Input Formats and Specifications of the National Geodetic Survey Data Base, Annex N and Chapter 2. CR8GG554 was used to update the bfile deck. The bluebook files were run through the NGS checking programs COMPGB, NEWCHKOB and OBSCHK to verify completeness prior to adjustment.

See Ground Surveys Report, GPS Survey in Support of Coastal Mapping Program, Chukchi, Alaska, NGS Project Nos. AK0301 & AK0302, dated July 12, 2004.

Field Operations- LiDAR

In July and August of 2004, AeroMap U.S. acquired LiDAR data for shoreline mapping in northwest Alaska for NOAA task order AK0301-Shishmaref and AK0302-Kivlina. AK0301 was located south of Kotzebue and covered the communities of Wales and Shishmaref. AK0301 and AK0302 were flown as part of one mobilization and sometimes missions for both project areas were flown on the same day. The targeted coastal areas were covered with LiDAR data flown at an altitude of 2,000 meters Above Ground Level (AGL) with an average LiDAR data posting density of 2 meters. In addition, there were missions flown at the communities of Shishmaref and Kivalina at a lower AGL altitude of 1,200 meters with an average LiDAR data posting density of 1 meter.

The missions were all to be tide coordinated for tides below Mean Lower Low Water (MLLW). Because of the small tide range in the area and the difficulties coordinating airborne missions with the complex conditions that influence tides in that region (atmospheric pressure, winds, and currents) the requirement for all data acquisition to be performed at MLLW or below were relaxed by NOAA, first to Mean High Water, and then later in August to any tide window so that all of the targeted shoreline areas could be covered. The base of operations was Kotzebue, Alaska.

The basis for the LiDAR survey and ground truth information was an extensive GPS survey carried out by the firm of John Oswald and Associates (JOA) as a subcontractor to AeroMap. As part of the subcontract survey, JOA established base stations sites KOT5 and KOT6 at the Kotzebue airport. These GPS base station sites were used throughout the project by the AeroMap crew for many of the missions. In addition to the stations at the Kotzebue airport, there were other base GPS sites manned by JOA and used as controlling base stations for some of the missions at locations in Shishmaref and Wales for AK0301 and at Kivalina and Point Hope for AK0302.

JOA also monitored tides and suitable tide windows during the project. While this information was relayed by satellite to an Internet web site, the lag time from when the tide window data was available to when it was posted on the Internet meant that LiDAR mission coordination was handled by phone communications with JOA staff.

Field Operations- LiDAR Check Points Survey

Sixty-six checkpoints were surveyed by JOA for projects AK0301 and AK0302. The checkpoints were distributed in six groups with at least five points in each group. The AK0301 groups were surveyed between July 1 and July 12, 2004 and include Wales, Ikpek, SW of Shishmaref, NE of Shishmaref, Lagoon at 165 West, and Espenberg. The purpose of the survey was to determine NAD83 horizontal coordinates, and ellipsoid heights for LiDAR checkpoints.

Each checkpoint was observed for at least 0.5 hours with dual frequency GPS receivers. One station in each set was observed for the duration of time from the beginning of the first observation until the end of the last observation. GPS observations were measured using four Trimble 5700 dual frequency receivers with Trimble Zephyr antennas. Sealed batteries powered the GPS receivers. Data was downloaded to laptop computers and archived on CD-R.

All of the observation files were processed using Trimble Geomatics Office (TGO) version 1.62. Baselines were processed with the precise ephemeredes from the International GPS Service (IGS) in September 2004 using the Wales and Shishmaref base stations as control. All vectors were adjusted using TGO v1.62. Final coordinates for Wales and Shishmaref base stations were derived from averaging multiple OPUS solutions determined from GPS sessions obtained between June and August 2004 as reported in the GPS base Station Report.

See GPS Base Stations Report, NGS Projects AK0301 & AK0302, Shoreline Mapping Alaska, dated September 22, 2004.

See LiDAR Check Point Report, GPS Survey in Support of Coastal Mapping Program, Chukchi, Alaska, NGS Project Nos. AK0301 & AK0302, dated December 20, 2004.

Field Operations- Tide Stations

A tertiary (30 day) tide station was set at Shishmaref Inlet 2 and short term (7day) tide stations were set up at Ikpek Lagoon, Lagoon at 165W, Lopp Lagoon West – Cape Prince of Wales, and Shishmaref Inlet Inside between August 30 and October 3, 2003. Shishmaref Inlet 2 was re-established June 29 through August 12, 2004.

Ikpek Lagoon (946-9626)

A Coastal Leasing Macrotide submersible pressure gauge was set approximately 130 meters from shore and used to measure the tide. A BLM post monument was recovered and used as the primary tidal benchmark and two 30-inch rebars were driven and used as temporary benchmarks. Spirit leveling was observed between a benchmark and the water. Third order levels were run between the benchmarks and staff, and one hour of staff shots were taken every six minutes at the time the gauge was set and again at demobilization. GPS observations were run on the primary benchmark, and it was tied to other tidal benchmarks and NGS published stations in Nome and Noatak using dual frequency GPS receivers in a relative positioning static mode.

See Ikpek Lagoon Station Report (946-9626), NGS Project AK0301, Shoreline Mapping Alaska, dated February 20, 2004.

Lagoon at 165W (946-9982)

A Coastal Leasing Macrotide submersible pressure gauge was set approximately 600 meters from shore and used to measure the tide. A BLM post monument was recovered and used as the primary tidal benchmark and two 30-inch rebars were driven and used as temporary benchmarks. Spirit leveling was observed between a benchmark and the water. Third order levels were run between the benchmarks, and one hour of staff shots were taken every six minutes at the time the gauge was set and again at demobilization. GPS observations were run on the primary benchmark, and it was tied to other tidal benchmarks and NGS published stations in Nome and Noatak using dual frequency GPS receivers in a relative positioning static mode.

See Lagoon at 165W Station Report (946-9982), NGS Project AK0301, Shoreline Mapping Alaska, dated February 20, 2004.

Lopp Lagoon West – Cape Prince of Wales (946-9460)

A Seabird SBE26 submersible pressure gauge with a ParoScientific sensor was set approximately 60 meters from shore and used to measure the tide. One stainless steel rod tidal benchmark was established and two 30-inch rebars were driven and used as temporary benchmarks. A stainless steel rod was driven into the lagoon bottom for use as a tide staff. Staff readings were made by using a tape to measure from the top of the rod to the water surface. Spirit leveling was observed between a benchmark and the water. Third order levels were run between the benchmarks and the staff, and one hour of staff shots were taken every six minutes at the time the gauge was set and again at demobilization. GPS observations were run on the primary benchmark, and it was tied to

other tidal benchmarks and NGS published stations in Nome and Noatak using dual frequency GPS receivers in a relative positioning static mode.

See Lopp Lagoon West, Cape Prince of Wales Station Report (946-9460), NGS Project AK0301, Shoreline Mapping Alaska, dated February 20, 2004.

Shishmaref Inlet Inside (946-9804)
A Coastal Leasing Macrotide submersible pressure gauge was set approximately 1 mile from shore and used to measure the tide. A BLM post monument was recovered and used as the primary tidal benchmark and two 30-inch rebars were driven and used as temporary benchmarks. Spirit leveling was observed between a benchmark and the water. Third order levels were run between the benchmarks, and one hour of staff shots were taken every six minutes at the time the gauge was set and again at demobilization. GPS observations were run on the primary benchmark, and it was tied to other tidal benchmarks and NGS published stations in Nome and Noatak using dual frequency GPS receivers in a relative positioning static mode.

See Shishmaref Inlet Inside Station Report (946-9804), NGS Project AK0301, Shoreline Mapping Alaska, dated February 20, 2004.

Shishmaref Inlet 2 (946-9854) tertiary (30 day) tide gauge 2003
Two tide gauges were originally installed at this site. Each was a digital bubbler type with Sutron data logger and ParoScientific pressure sensor, powered by two 12-volt batteries charged by solar cells. Both had GOES telemetry. Gauge 2 developed a nitrogen leak and was replaced by H350XL Design Analysis Associates digital bubbler tide gauge. The historic Shishmaref Inlet tide gauge was searched for but not found. The new tide station was established in the same vicinity. The tide gauges were housed in a Rubbermaid shed, with the orifice of gauge 1 attached to an aluminum rod driven into the channel bottom, and the orifice of gauge 2 attached to an anchor and placed on the bottom. Five stainless steel rods driven to refusal were set as tidal benchmarks. Spirit leveling was observed between a benchmark and the water. Third order levels were run between the benchmarks, and one hour of staff shots were taken every six minutes at the time the gauge was set and again at demobilization. GPS observations were run on the primary benchmark, and it was tied to other tidal benchmarks and NGS published stations in Nome and Noatak using dual frequency GPS receivers in a relative positioning static mode. Twice weekly staff shot observations of at least one-hour duration was made.

See Shishmaref Inlet 2 Station Report (946-9854), NGS Project AK0301, Shoreline Mapping Alaska, dated February 20, 2004.

Shishmaref Inlet 2 (946-9854) tertiary (30 day) tide gauge 2004
Three H350XL Design Analysis Associates digital bubbler tide gauge were installed approximately 7 meters from shore. Each tide gauge was powered by two 12-volt batteries with a 15W solar panel for recharging, and was equipped with a GOES radio. The orifices were mounted on aluminum rods driven into the channel bottom. Spirit leveling was observed between a benchmark and the water. Third order levels were run between the five existing benchmarks, and one hour of staff shots were taken every six minutes at the time the gauge was set and again at demobilization. The primary

benchmark was tied to other tidal benchmarks and NGS published stations in Nome and Noatak during the 2003 survey. Twice weekly staff shot observations of at least one-hour duration was made.

See Shishmaref Inlet 2 Station Report (946-9854), NGS Project AK0301, Shoreline Mapping Alaska, dated November 10, 2004.

GPS DATA REDUCTION (AIRBORNE)

During the aerial photography mission, six GPS base stations were collecting data. The two base stations at Kotzebue (KOT3 and KOT4) were deployed for each photo mission, the remaining four stations at Wales, Shishmaref, Kivalina and Point Hope were operating around the clock from September 10 to September 25, 2003. The baseline separation from the base stations at the Kotzebue airport (KOT3 and KOT4) to the southern extent of the AK0301 project area exceeded 280 km but by integrating the base stations at Shishmaref and Wales in to the GPS trajectories the aircraft was never more than 100 km from an operational base station during data acquisition.

For details regarding the deployment, collection and processing of the static GPS data see Ground Surveys Report, GPS Survey in Support of Coastal Mapping Program, Chukchi, Alaska, NGS Project Nos. AK0301 & AK0302, dated July 12, 2004.

The processing of the airborne positioning data was carried out using the suite of software supplied by Applanix that is collectively called POSPac. POSPac version 4.02 was used for the processing of this data set.

The raw airborne data is logged in a series of time sequential files each approximately 12.2 MB in size. The first step in the processing stream is to combine these files together and then extract them into individual data files that contain the raw GPS data, raw IMU data and camera event times. During this step the raw GPS data and the raw IMU data are checked for any lapses in data continuity.

When the data extraction is completed the next step is to process the airborne GPS data. For this project a total of four GPS trajectories were processed and then combined to create the final GPS positions for the aircraft antenna. For each base station the forward and reverse solutions were combined using a weighting scheme based upon the quality of the solution for each epoch. The combined solutions from each base station were then combined to create the final position file.

The GPS data was processed using a 12.5-degree elevation cutoff. The L2 frequency was utilized for kinematic ambiguity resolution as well as for ionospheric correction of the long trajectory. No satellites were rejected from the solution. The general quality of the airborne GPS trajectories was excellent. The solutions were all fixed integer and the trajectory comparisons were mostly less than 5 centimeters and never exceeded 15 cm.

The next step in the processing flow was to take the final GPS trajectory and blend this with the IMU data collected during the mission. This step is carried out using the program POSProc that is also part of the POSPac suite. The general theory behind the POSProc processing is to create a blended solution that utilizes the strengths of the two systems to create an optimum solution.

The blending of these solutions is done in three steps. First the data is processed forward in time, and then reverse in time and finally these two solutions are blended to create the final output. The other task that POSProc does in this step is to transfer the measurements from their source to the perspective center of the camera.

The end result of the POSProc processing is an SBET (Smoothed Best Estimated Trajectory) file. This file contains x,y,z coordinates as well as roll, pitch and yaw orientation angles for every 0.005 seconds during the entire mission.

The final step in the data processing stream is to create x,y,z coordinates and roll, pitch and yaw orientation angles for the exact moment the camera shutter opened for each picture. This step is carried out using POSEO. The undulations for each exposure station were calculated from Alaska Geoid 99 and the final EO file was output with NAD83-UTM Zone 3 coordinates and NAVD88 elevations. Coordinates and elevations were expressed in meters. The results of this step produce a text file which can be imported to a software package for the airborne triangulation process. The reformatted form of the POSEO is contained in the Aerotriangulation Reports for AK0301 and AK0302.

See AK0301 – Shishmaref, Airborne Positioning and Orientation Report, dated November 2004.

LiDAR DATA REDUCTION

LiDAR data processing is divided into the three main categories of 1) "Point Cloud" processing, 2) Classification, and 3) Specialized processing. The process for each of these categories is summarized as follows.

1. "Point Cloud" processing. This step involves downloading the data, computing the trajectory, and then deriving the "Point Cloud" of LiDAR data. The raw data for a mission are stored onboard on a removable disk drive in an Optech proprietary format. These data were downloaded either in the field or in the AeroMap Anchorage office. The steps for processing to a "Point Cloud" follow.
    a. Download data using Optech proprietary download program
    b. Separate data into strips representing each flight line
    c. Import data into Optech's proprietary main processing program "REALM"
    d. Compute GPS trajectory
    e. Compute blended GPS/inertial trajectory
    f. Process LiDAR points into "Point Cloud" in ASPRS standard .las format.
2. Classification. The classification data processing involves importing the .las files into the Terrasolid suite of software for project setup, tiling, and initial classification. The main Terrasolid module used for classification is TerraScan that runs in the Bentley MicroStation environment. TerraScan is a very flexible

package that allows the data processor to set up macro processes to classify the data into first return, bare earth, and vegetation/building classes based on the different types of terrain and ground cover. The data is visualized with a separate software application called QT Viewer that allows for viewing the data from many perspectives in different classes. As part of the automated classification process, the LiDAR data goes through a Quality Control check to insure that the LiDAR data meets the project requirements for accuracy by using the QC surveys performed earlier. When the automated classification is complete, the data tiles are then sent to the manual-editing phase. For the manual-editing phase it is best interpreted and edited by people who have had extensive experience working with Photogrammetric data. They are familiar with looking at various types of terrain, and they are best suited to make sure that the LiDAR data is classified properly.

3. Specialized processing. After the data was classified to bare earth and manually edited, the data deliverables were generated and written to a portable external USB 2.0 disk drive for delivery to NOAA.

AEROTRIANGULATION

AeroMap U.S. acquired photography for AK0301 and AK0302 in conjunction with each other between September 14, 2003 and September 24, 2003. Photography was good quality with 60% forward overlap and 30% sidelap. The camera used was a Zeiss RMK TOP 15 camera equipped with Forward Motion Compensation, serial number 145841, with a calibrated focal length of 153.272mm. Both complete project areas were flown at a scale of 1:24,000. In addition the area of shoreline 10 miles on both sides of the villages of Shishmaref and Kivalina was acquired at 1:12,000 scale. The photography is airborne GPS/IMU controlled, natural color film. Another NOAA contractor completed the scanning at 25 microns and digital copies were delivered to AeroMap. The current camera calibration report for this camera (dated November 28, 2000 by the US Geological Survey) was submitted to NOAA.

As part of the shoreline study, historic black and white photography flown between 1949 and 1952 was utilized. This film is at a scale of 1:40,000. The historic photography covers the same section of shoreline as the 1:12,000 images from 2003. The historic photography was controlled using the 2003 airborne GPS/IMU controlled photography. Duplicate film negatives were received by AeroMap U.S. and scanned at 24 microns.

Aerotriangulation was conducted in soft copy using a Pentium 4CPU 3.00GHz computer using INPHO MATCH-AT software. The fiducials were measured using an automatic Interior Orientation routine. Automatic tie point generation was used to create image tie points between overlapping images, within and between strips. Several points in the water were removed due to image miss-match. Additional points were added manually where the auto tie points were thin, mainly on the sandy offshore islands where the imagery does not have much contrast.

The checkpoints were measured and analyzed with good horizontal residuals, but a vertical bias. The bias was about the same in both the 1:24,000 and 1:12,000 scale photography. The elevations of the AGPS photo centers were lowered by .3m to remove the vertical bias. The shift was accomplished by adding a .3m eccentricity to the *Z*

component of the GPS antennae within the MATCH-AT software rather than by changing the actual input data to the aerotriangulation blocks.

For the 1:24,000 photography the bundle solution is acceptable. The Image RMS is 3.3640 microns. The 95% confidence circle radius for the horizontal accuracy of all ground points is 0.2m. The RMS of the checkpoints are: X=0.487 Y=0.338 Z=0.453

For the 1:12,000 photography the bundle solution is acceptable. The Image RMS is 3.1790 microns. The 95% confidence circle radius for the horizontal accuracy of all ground points is 0.2m. The RMS of the checkpoints are: X=0.306 Y=0.452 Z=0.372

To provide control for the historical photography photo identifiable points were selected, measured, and added to the 1:12,000 block. These points were identified as the "5000" series points. The resulting adjusted coordinates of these points were used as control for the historic photography. For the historical photography no calibration report was available. The photos have a placard that states an EFL (estimated focal length?). The 1949 imagery EFL is 153.42 and the 1950 imagery EFL is 153.61. These EFL values were used in the bundle solution for these images.

Each camera definition requires fiducial coordinates to facilitate an interior orientation. The following procedure was used to calculate fiducial coordinates for each camera. An interior orientation was measured using an approximate camera definition. The software used only reports the photo coordinates in pixels, so the pixel coordinates were multiplied by 24 to convert the coordinates to microns. Since 0,0 is the upper left pixel, the sign of the Y coordinate was changed to negative to maintain the correct geometry. There are four side fiducials on these cameras. A line was drawn between opposing side fiducials with the intersection being assumed the point of symmetry. The fiducial points and connecting lines were moved from the intersecting point to 0,0. The axis was then rotated using a "best fit" based on the average divergence of the cross-fiducial line angles to an orthometric grid. The resulting coordinates of the fiducial points (and the endpoints of the cross-fiducial lines) were used as the fiducial coordinates to create a camera definition file.

The "5000 series" points selected on the 1:12,000 scale photography were used as ground control for this aerotriangulation block. The ID points located along the offshore islands are distributed well enough to control the horizontal, but since these flights run north – south, water points were added to the mainland shoreline to use as additional vertical control. The 1:12,000 photos do not reach the mainland shore. The water was given an elevation of 0.5m based on the elevation observed near the photo ID points.

Approximate photo center coordinates were entered in the aerotriangulation block to give the auto tie point generation a starting point. Enough photo control points were measured on each strip to control the individual strips. A preliminary run through the aerotriangulation was performed where auto tie points are selected and a block adjustment was done. The resulting exterior orientation coordinates were used in subsequent runs for the photo center coordinates, but were not constrained in any way. The rest of the ID points were measured. The block was run through the aerotriangulation and auto tie point generation module and the results were analyzed.

Several points were in the water and were removed. Additional points were manually added in areas where the auto correlation did not find tie points, mainly on sandy areas that have little contrast.

For the 1:40,000 historic photography the Image RMS is 11.830 microns. This value is rather high, but considering the factors going into this bundle solution it is not unexpected. However the overall bundle solution seems solid. The 95% confidence circle radius for the horizontal accuracy of all ground points is 1.9m. The constraints on the control points are: Horizontal = 1.5m Vertical = 1.5m. The RMS of the Control Points are: X=0.961 Y=1.542 Z=0.696

The project database consists of project parameters and selected options, camera calibration data, control file data, refined image coordinates, Airborne GPS data, IMU orientation angles of camera centers, adjusted exterior orientation parameters for each frame, a positional listing of all ground points used in the projects, and a stereo model review. Positional data is based on the North American Datum of 1983, and is referenced to the UTM Coordinate System.

See AK0301 Shishmaref, NOAA Aerotriangulation Report, dated November 2004.

COMPILATION

The Compilation Phase of AK0301, Shishmaref, was accomplished by the AERO-METRIC, INC. GEO-SPATIAL Department during the period of September through December 2004. Digital mapping was accomplished using Zeiss P1, Zeiss P2, and DAT/EM IMA Analytical Stereoplotters and a DAT/EM Summit Evolution Softcopy Stereoplotter. On the Zeiss Analytical Stereoplotters the software used was Zeiss' PCAP and Boeing Autometric's KDMS mapping system. On the DAT/EM Analytical and Softcopy Stereoplotters the software used was DAT/EM's CAPTURE. Feature identification and the assignment of cartographic codes were based on image analysis of 1:24,000 scale natural color and color negative photographs and information extracted from the appropriate NOAA Nautical Charts and US Coast Guard Light List. Cartographic feature attribution was assigned in compliance with the Coastal Cartographic Object Attribute Source Table (C-COAST). Nomenclature was assigned to selected cartographic features to refine general classification.

Cartographic features were compiled to meet a horizontal accuracy of 0.4 meters at a 95% confidence level. The cartographic features were produced according to procedures that have been demonstrated to produce data of this accuracy.

The shoreline erosion study was accomplished by comparison of September 2003 aerial photography to September 1949 and August 1950 aerial photography. The 1949 photos covered the north and south portions of the project area and the 1950 photos covered the center portion.

The current shoreline was mapped from 1:12,000 scale color aerial photography obtained in 2003. This photography was controlled by the GPS/IMU method with 10 surveyed photo ID checkpoints. The historic shoreline was mapped from USGS black and white

mapping photos at 1:40,000 scale from 1949 and 1950. The historic photos were controlled through 24 photo ID points derived from the 2003 photos and 4 of the checkpoints. For more detail see aerotriangulation report "AK0301 Shishmaref, NOAA Aerotriangulation Report, Nov. 2004". The historic photos were grainy compared to 2003, the scale was much smaller, and the camera calibration was improvised as described in the aerotriangulation report. In spite of these drawbacks the historic photos matched up with the 2003 images reasonably well for the purpose of calculating surface area of erosion and accretion.

The compilation data from the 1:12,000 erosion study area was merged and integrated with the other compilation.

The following provides information on the 2003 aerial photographs used in the project completion process:

					FRAME NUMBERS		PHOTO TIME (UTC)			
LOCATION	FILM TYPE	DATE	FLIGHT LINE	ROLL NUMBER	START	END	START	END	SCALE (NOMINAL)	TIDE HT (ft)
SHISHMAREF	Color Neg.	14-Sep-03	24013	0314CN03	175	183	2133	2136	1:24,000	-0.33
SHISHMAREF	Color Neg.	14-Sep-03	24012	0314CN03	184	199	2145	2151	1:24,000	-0.31
SHISHMAREF	Color Neg.	14-Sep-03	24010	0314CN03	200	211	2156	2201	1:24,000	-0.27
SHISHMAREF	Color Neg.	14-Sep-03	24017	0314CN03	212	217	2224	2226	1:24,000	-0.27
SHISHMAREF	Color Neg.	14-Sep-03	12003	0314CN03	218	231	2248	2251	1:12,000	0.05
SHISHMAREF	Color Neg.	14-Sep-03	24017	0314CN03	232	237	2316	2318	1:24,000	-0.15
SHISHMAREF	Color Neg.	14-Sep-03	24016	0314CN03	238	250	2326	2331	1:24,000	-0.15
SHISHMAREF	Color Neg	21-Sep-03	24007	0314CN06	440	448	2212	2215	1:24,000	-0.38
SHISHMAREF	Color Neg	21-Sep-03	24008	0314CN06	449	456	2220	2223	1:24,000	-0.33
SHISHMAREF	Color Neg	21-Sep-03	24011	0314CN06	457	462	2237	2239	1:24,000	-0.29
SHISHMAREF	Color Neg	21-Sep-03	24015	0314CN06	463	484	2248	2257	1:24,000	-0.35
SHISHMAREF	Color Neg	21-Sep-03	24018	0314CN06	485	499	2306	2311	1:24,000	-0.33
SHISHMAREF	Color Neg	22-Sep-03	take up	0314CN06	500	504	0050	0052	1:24,000	
SHISHMAREF	Color Neg	22-Sep-03	24014	0314CN06	505	536	0059	0113	1:24,000	-0.35
SHISHMAREF	Color Neg	22-Sep-03	24009	0314CN06	537	548	0118	0122	1:24,000	-0.23
SHISHMAREF	Color Neg	22-Sep-03	12002	0314CN06	549	557	0132	0134	1:12,000	-0.31
SHISHMAREF	Color Neg	22-Sep-03	12003	0314CN06	558	562	0138	0139	1:12,000	-0.34

SHISHMAREF	Color Neg	23-Sep-03	take up	0314CN06	563	564				
SHISHMAREF	Color Neg	23-Sep-03	24003	0314CN07	611	625	2332	2339	1:24,000	-0.07
SHISHMAREF	Color Neg	23-Sep-03	24004	0314CN07	626	660	2346	0002	1:24,000	-0.16
SHISHMAREF	Color Neg	24-Sep-03	24005	0314CN07	661	670	0007	0010	1:24,000	0.03
SHISHMAREF	Color Neg	24-Sep-03	24005	0314CN07	671	684	0010	0015	1:24,000	0.50
SHISHMAREF	Color Neg	24-Sep-03	24002	0314CN07	685	701	0017	0022	1:24,000	0.52
SHISHMAREF	Color Neg	24-Sep-03	24001	0314CN07	702	718	0028	0035	1:24,000	0.52
SHISHMAREF	Color Neg	24-Sep-03	24006	0314CN07	719	728	0038	0042	1:24,000	0.48
SHISHMAREF	Color Neg	24-Sep-03	12001	0314CN07	729	741	0052	0055	1:12,000	-0.35
SHISHMAREF	Color Neg	24-Sep-03	take up	0314CN07	742	743				

The "Stage of Tide" is referenced to MLLW. The range of tide (MLLW to MHW) is 0.265m (0.9').

As the compilation was being completed, preliminary review of the data collected was performed on Pentium 4CPU, 2GHz computer workstations using MicroStation software. Paper check plots were produced and edited off-line. Corrections and additions were incorporated and the final editing and formatting was completed using ArcMap software. Preliminary Shapefiles were submitted for NOAA's review. Review comments were received from NOAA and there were some corrections to incorporate. A second submittal of the Preliminary Shapefiles was required. The Final Shapefiles were prepared and delivered. Corrections based on NOAA comments were made during the period of April and May 2005. The Shapefiles were accepted as final in June 2005.

EROSION STUDY

The shoreline study was accomplished by comparing the September 2003 aerial photography to September 1949 and August 1950 aerial photography. The 1949 photos covered the north and south portions of the project area and the 1950 photos covered the center portion.

Within the study area, Shishmaref Inlet is connected to the sea through two gaps between three barrier islands. On the shoreline that faces the Chukchi Sea and within the gaps / entrances to Shishmaref Inlet there are 6 segments where the shore has eroded alternating with 6 segments of accretion. The length of all these erosion segments is 18.7 miles and the length of accretion segments is 2.6 miles. The upland area of erosion is approximately 442 acres and the area of upland accretion is approximately 74 acres. The areas of accretion are located mostly within the entrances to Shishmaref Inlet. The areas of erosion are uniformly spread across the Chukchi Sea beaches with the exception of one area of accretion located just to the south of the southern entrance (1.1 miles long).

On the Shishmaref inlet side of the barrier islands approximately 40 % of the shoreline has little or no change from 1949-1950 to 2003. The differences that were noted include a 169 acre area of accretion located on the north end of the north island, an 11 acre area of erosion on the north side of the north entrance, on the center island 44 acres of erosion to the north and 68 acres of accretion to the south, and on the south island 246 acres of erosion and 35 acres of accretion.

Within the study area approximately 368 acres of upland area has been lost on the Chukchi Sea side of the barrier islands and approximately 28 acres has been lost on the inlet side of the islands for a total loss of 396 acres of upland area.

See AK0301 Shishmaref, Erosion Study Report, dated December 27, 2004

FINAL REVIEW

Senior members of the AERO-METRIC, INC. Geo-Spatial and Image/Terrain Departments initiated the final review in November 2004. The digital cartographic feature file (DCFF) was evaluated for completeness and accuracy. Data review consisted of an on-line and off-line evaluation of digital compilation and hard copy products. The on-line review was comprised of reviewing stereo models on DAT/EM IMA and Summit Evolution Stereoplotters for cartographic feature codes selection, positional accuracies of features, and nomenclature. The cartographic feature attribution was judged to conform to C-COAST specifications. The off-line evaluation compared hard-copy plots of project data with the largest scale nautical chart available and the natural color photographs. The NOAA nautical charts available for this project area were not useful for the chart comparison process. NOAA nautical charts 16005, Cape Prince of Wales to Point Barrow, 1:700,000, 9th Edition; 16200, Norton Sound to Bering Strait, 1:400,000, 13th Edition; and 16204, Port Clarence and Approaches, 1:100,000, 6th Edition were used for general comparison. Hard-copy plots at a scale of 1:100,000 were provided as chart maintenance prints.

PROJECT FINAL DATA AND PROJECTS

The following specifies the location and identification of the products generated during the completion of this project:

RSD Applications Branch Project Archive
- -Hardcopy of Ground Survey Report
- -Hardcopy of Aerial Photography Report
- -Hardcopy of Airborne Positioning and Orientation Report
- -Hardcopy of Aerotriangulation Report
- -Hardcopy of GPS Base Stations Report
- -Hardcopy of Tidal Station Report
- -Hardcopy of LiDAR Check Point Report
- -Hardcopy of Erosion Study Report
- -Hardcopy of LiDAR Report
- -Hardcopy of Project Completion Report, including Project Diagram

RSD Electronic Data Library:

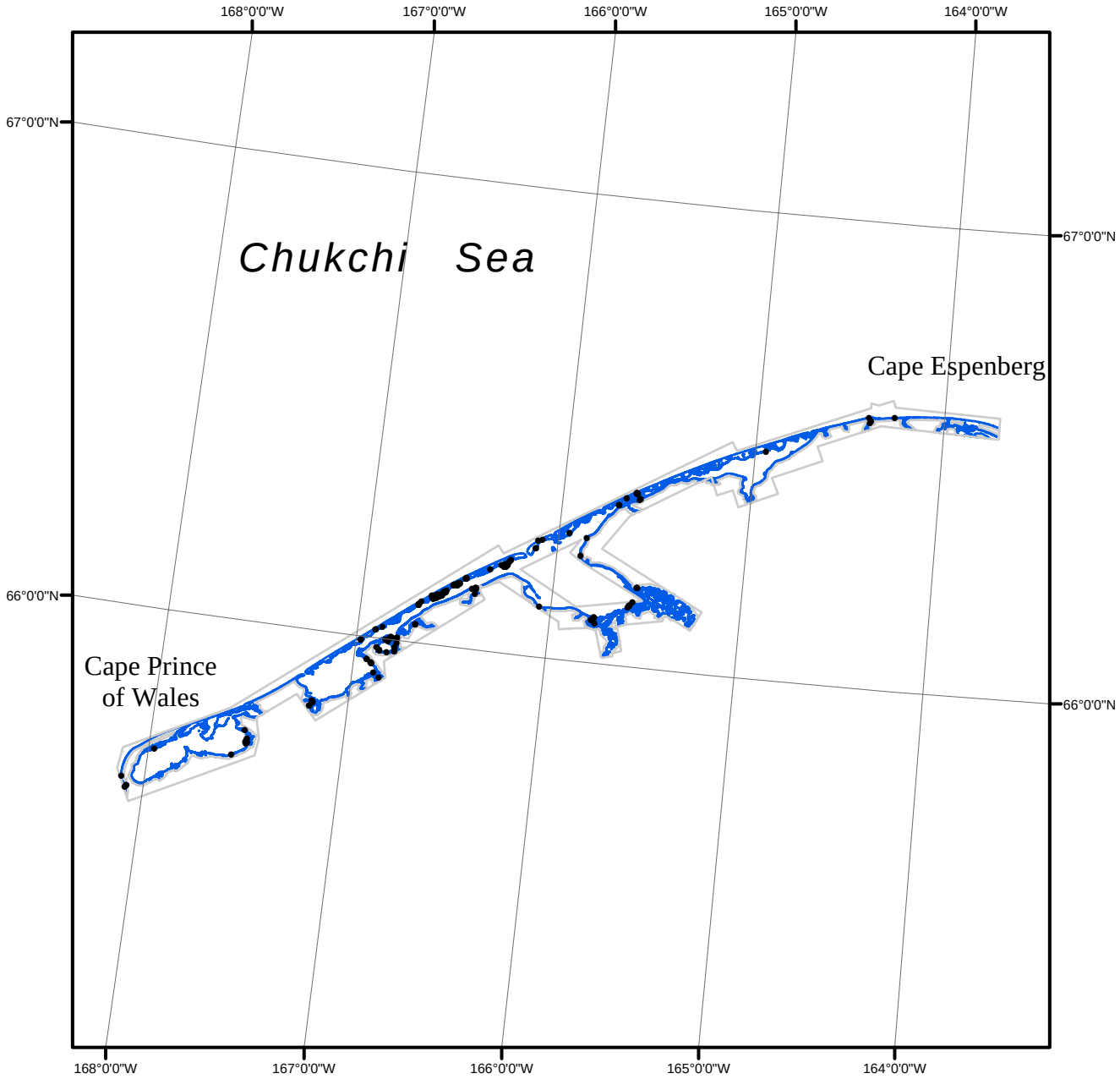
-Project Database
-DCFF: GC-10567
-Digital copy of DCFF in Shapefile format
-Digital copy of Project Completion Report in Adobe PDF Format

NOAA Shoreline Data Explorer

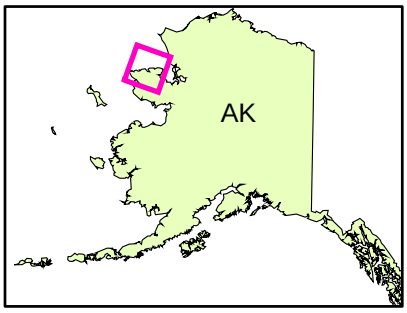
-DCFF: GC-10567
-Metadata file for GC-10567
-Digital copy of the Project Completion Report in Adobe PDF Format

CHUKCHI SEA, CAPE PRINCE OF WALES TO CAPE ESPENBERG

ALASKA



Overview



AK0301

GC10567