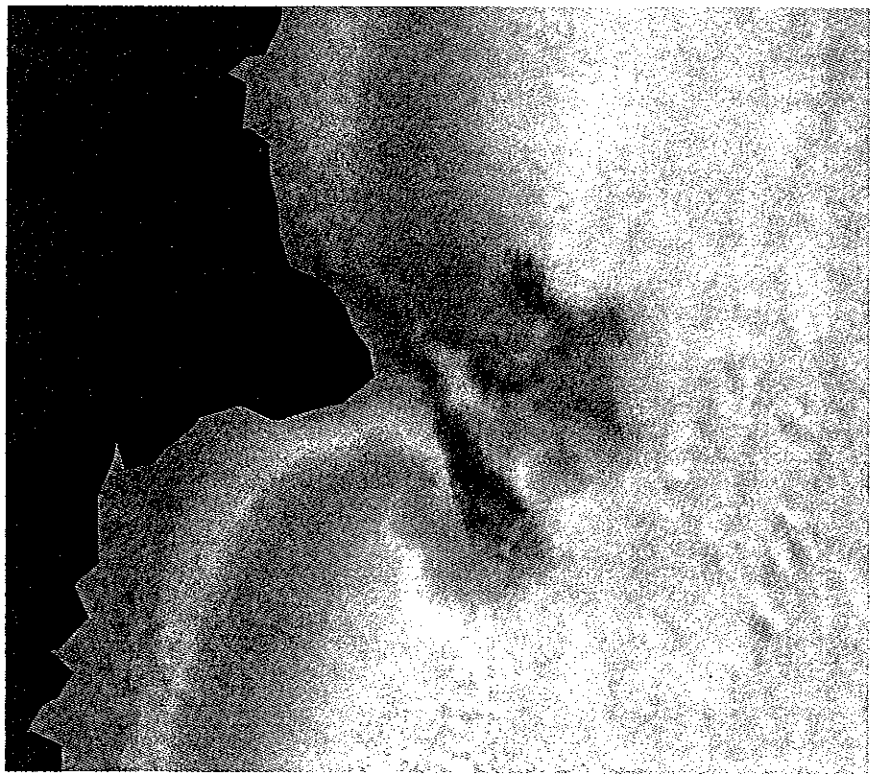
USA – WEST COAST

WASHINGTON

PUGET SOUND

POSSESSION SOUND



Surveyed by Tenix LADS Corporation Pty. Ltd.
April 2001

Submitted to Thales GeoSolutions (Pacific), Inc. - Alaska
for
Kitsap County

NOAA FORM 76-35A

U.S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
NATIONAL OCEAN SERVICE

DESCRIPTIVE REPORT

Type of Survey Hydrographic

Field No

Registry No.

LOCALITY

State Washington

General Locality Puget Sound

Sublocality Possession Sound

2001

CHIEF OF PARTY

MARK SINCLAIR

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DATE

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NOAA FORM 77-28 (11-72)

U.S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

REGISTER NO.

HYDROGRAPHIC TITLE SHEET

FIELD NO.

INSTRUCTIONS – The Hydrographic Sheet should be accompanied by this form, filled in as completely as possible, when the sheet is forwarded to the Office

State WASHINGTON

General Locality Puget Sound

Locality Possession Sound

Scale 1:10,000 Date of Survey 4/28/01

Instructions dated 4/27/01 Project No. NTP Seattle Task Order 2

Vessel LADS Mk II

Chief of Party M.Sinclair

Surveyed by D.Stephenson, N. Hewitt, W. Newsham, G. Rowe, S. Ramsay, R. Curtin

Soundings taken by echo sounder, hand lead, pole Laser Airborne Depth Sounder

Graphic record scaled by N/A

Graphic records checked by Tenix LADS Corporation

Protracted by N/A Automated plot by HP Design Jet 750C

Verification by N/A

Soundings in Meters at MLLW

REMARKS: The purpose of this work was to collect high-resolution lidar data from selected areas in Puget Sound. These areas are inshore between the coastline and the 20 meter isobath. This was a pilot project to link terrestrial airborne laser altimetry with deep water acoustic multibeam bathymetry for geological hazard mapping and research, nearshore aquatic habitat assessment and coastal zone management.

All times are recorded in UTC

TENIX LADS CORPORATION PTY LTD

SECOND AVENUE

TECHNOLOGY PARK

MAWSON LAKES 5095 SOUTH AUSTRALIA.

NOAA FORM 77-28 SUPERSEDES FORM C & GS-537

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Table of Contents

Purpose

The purpose of this work was to collect high-resolution lidar data from selected areas in Puget Sound. These areas are inshore between the coastline and the 20 meter isobath. This was a pilot project to link terrestrial airborne laser altimetry with deep water acoustic multibeam bathymetry for geological hazard mapping and research, nearshore aquatic habitat assessment and coastal zone management. The data was collected on a single LADS Mk II flight for Thales GeoSolutions, prime contractor to the Puget Sound Lidar Consortium comprising US Geological Survey (USGS) Pacific NW Hazards Programme, NASA Earth Observation, Kitsap County, Seattle Public Utilities and Puget Sound Regional Council.

Data was collected in two areas as follows:

Lidar Coverage Area 1	located in Possession Sound on the east side of Whidbey Island between Randall Point and Possession Point. This area was completed.
Lidar Coverage Area Two	located on the east side of Possession Sound between Elliot Point and Edwards Point. This area was partially completed due to low cloud and air traffic control restrictions experienced during the second half of the flight.

A - Area Surveyed

The LADS Mk II aircraft operated from Boeing Field, King County from April 19 to 30, 2001. Survey operations for NOAA were conducted in Shilshole Bay, Puget Sound. This survey for Kitsap County in Possession Sound was conducted on a single flight on Saturday 28 April.

The survey data is provided on four 1: 10,000 sheets. Two sheets cover Area 1 (Sheets 1 and 2) and two sheets cover Area 2 (Sheets 3 and 4). The sheet limits are tabled below:

	WGS 84 Position		UTM N Zone 10	
SHEET 1	Degrees Latitude (N)	Degrees Longitude (W)	Easting (m)	Northing (m)
NW	48°.0003	122°.3861	545 790.6	5 316 520.5
NE	48°.0000	122°.3231	550 490.6	5 316 520.5
SE	47°.9460	122°.3238	550 490.6	5 310 520.5
SW	47°.9464	122°.3868	545 790.6	5 310 520.5

	WGS 84 Position		UTM N Zone 10	
SHEET 2	Degrees Latitude (N)	Degrees Longitude (W)	Easting (m)	Northing (m)
NW	47°.9464	122°.3978	544 969.2	5 310 520.5
NE	47°.9461	122°.3348	549 669.2	5 310 520.5
SE	47°.8921	122°.3355	549 669.2	5 304 520.5
SW	47°.8924	122°.3984	544 969.2	5 304 520.5

SHEET 3	WGS 84 Position		UTM N Zone 10	
	Degrees Latitude (N)	Degrees Longitude (W)	Easting (m)	Northing (m)
NW	47°.9190	122°.3585	547 927.8	5 307 500.0
NE	47°.9187	122°.2956	552 627.8	5 307 500.0
SE	47°.8647	122°.2963	552 627.8	5 301 500.0
SW	47°.8650	122°.3592	547 927.8	5 301 500.0

SHEET 4	WGS 84 Position		UTM N Zone 10	
	Degrees Latitude (N)	Degrees Longitude (W)	Easting (m)	Northing (m)
NW	47°.8652	122°.3930	545 400.0	5 301 500.0
NE	47°.8649	122°.3301	550 100.0	5 301 500.0
SE	47°.8109	122°.3308	550 100.0	5 295 500.0
SW	47°.8113	122°.3936	545 400.0	5 295 500.0

B - Data Acquisition and Processing

Refer to the Data Acquisition and Processing Report for a detailed description of the equipment systems, processing procedures and quality control features. Items specific to this survey are discussed in the following sections.

Equipment

Data collection was conducted using the LADS Mk II Airborne System, data processing using the LADS Mk II Ground System and data visualization using the Generic Mapping Tool (GMT), Kitware Visualization Tool Kit (VTK) and Terramodel.

Airborne System

The LADS Mk II Airborne System (AS) consists of a Dash 8-200 series aircraft which has a transit speed of 250 knots at altitudes of up to 25,000 feet and an endurance of up to eight hours. Survey operations are conducted from heights between 1200 and 1800 feet at ground speeds between 140 and 175 knots. The aircraft is fitted with a Nd: YAG laser which is eye safe in accordance with ANSI 2136.1 – 1993, American National Standard for Safe Use of Lasers. The laser operates at 900 Hertz to provide 4 x 4 meter laser spot spacing in the main line sounding mode of operation, and is mounted on a stabilized platform. This mode requires an aircraft speed of 140 knots over the ground, and operates across a laser swath width of 192 meters. Alternatively, the 4a x 4a mode can be used, which provides 4 x 4 meter laser spot spacing at an aircraft speed of 175 knots over the ground across a laser swath width of 150 meters. This mode is more suitable when operating in areas where strong tail winds are experienced. The electro-mechanical scanner also provides examination modes with laser spot spacings of 3 x 3 and 2 x 2 meters and reduced swath widths. A 5 x 5 meter mode is also available.

Green laser pulses are scanned beneath the aircraft in a rectilinear pattern. The pulses are reflected from the land, sea surface, within the water column and from the seabed. The green returned laser energy is captured by the green receiver and then digitized and logged onto digital linear tape. An infra-red laser is also directed vertically beneath the aircraft. The height of the aircraft is determined by the received infra-red laser reflection, which is supplemented by an Attitude and Heading Reference System inertial height reference and GPS height. The LADS Mk II system can operate by day and night, and operations at night are enhanced by removing a daylight filter from the receiving optics. Real-time positioning is provided by DGPS. The Airborne System also contains off-line DGPS data logging.

Ground System

The LADS Mk II Ground System (GS) consists of a portable Digital Alpha 4100 computer which is transported in the aircraft to the deployment site for data processing. Generally up to six terminals (X-terms) are connected to provide the GS user interface to the hydrographic surveyor. The GS supports survey planning, data processing, quality control and data export. The GS component also includes a DGPS base station which provides an independent post-processed position.

Quality

General

The 4 x 4 meter laser spot spacing mode of operation was used for this survey, which has a swath width of 192 meters. Lines were flown at a line spacing of 160 meters, which provides a 32 meter planned overlap with each adjacent line.

Conditions

Good weather conditions prevailed for the survey. Surface winds of less than 15 knots and slight seas were experienced. A relatively low cloud ceiling reduced ambient light levels which provided good conditions for laser survey.

Water clarity was generally good. Secchi disk observations were taken in Shilshole Bay, Puget Sound on three occasions for the NOAA survey, details of which are provided in Appendix F. It is considered that the water clarity in Areas 1 and 2 was similar to that measured in Shilshole Bay. Maximum lidar depths of up to 20-25 meters were measured (20m after tidal reduction) in the survey area. This equates to 2½ times the measured Secchi disk depth.

Footprint of the Laser Beam

At the sea surface the footprint of the laser beam is approximately 2.5 meters. As the beam passes through the water column it slowly diverges due to scattering.

No Bottom At

In deep areas where the bottom was not detected No Bottom At (NBA) depths have been assigned during data validation from a review of the raw laser waveforms. An NBA value of 10 (meters) was generally allocated, which means depths of less than 10 meters are not considered likely in these areas.

Bottom Object Detection (BOD)

An enhanced bottom object detection capability has been implemented in the LADS Mk II Ground System. It is designed to detect the raw laser waveforms from small objects close to the seabed. The BOD feature was utilized throughout the survey area for all lines.

Shallow Water Algorithm

For very shallow soundings a special shallow water algorithm is used by the Ground System to determine depths that are very close to the surface pulse. This worked very well in most areas and in general, depths continue seamlessly across the sea/land interface. Where the shallow water algorithm failed, these pulses were deleted from the data set. Such areas could be reflown at a different state of tide on a subsequent flight.

Datums

The sea-surface datum was checked carefully each time the data crossed the sea/land interface. In a small number of cases a datum error was detected in the data. These areas have been rejected and appear as gaps along the coastline. Such areas would normally be reflown on a subsequent flight.

Quality Control Checks

Position Checks

Two independent positioning systems were used during the survey. Real-time positions were determined relative to the Racal WADGPS station in Vancouver. Post-processed positions were determined relative to a local DGPS reference station which was established on the rooftop of the Silver Cloud Inn, University Village.

The following position checks were conducted prior to, during and following data collection, as follows:

a. DGPS Site Confirmation. A 24-hour certification was conducted of the local DGPS reference station established at the Silver Cloud Inn, University Village.

b. Static Position Check. Prior to commencing data collection the coordinates of the aircraft GPS antenna were determined relative to three marks which were surveyed on the tarmac at Boeing Field Airport. Data was then logged by each LADS Mk II positioning system; this enabled the positions to be checked against the known surveyed points. The accuracy of the PNAV C/A code + carrier Phase position solution during the static position check was 0.09 meters (95% confidence). The

results and details of the static position check are enclosed in Horizontal and Vertical Control Report.

c. Dynamic Position Check. During the sortie GPS data was logged on the aircraft and at the DGPS reference station. This provided a check between the real-time WADGPS and post-processed positions. The mean difference between the real-time and post-processed position was 1.03 meters, with a mean standard deviation of +/- 0.16 meters. Details are provided in the Horizontal and Vertical Control Report.

d. Position Confidence. The position quality was also monitored by checking a post-processed position confidence (C3), which is determined from the AS platform error, GPS error and residual errors between the actual GPS positions and aircraft position as determined from the line of best fit. No position anomalies were detected.

Depth Checks

A 32 meter overlap exists between adjacent survey lines and the agreement between soundings in the overlapping area is between 0 and 0.3 meters. Cross lines were not flown. It is considered that IHO Order 1 (± 0.5 metres at 95% confidence) was achieved to a maximum depth of 20 meters (17 meters after tidal reduction), which is twice the measured Secchi disk depth. IHO Order 2 was achieved in the deeper areas due to increased noise on the raw laser waveforms.

Corrections to Soundings

Refer to the Data Acquisition and Processing Report for a detailed description of corrections to soundings.

C - Horizontal and Vertical Control

Refer to the Horizontal and Vertical Control Report for a detailed description of the horizontal and vertical control used on this Survey. A summary of the horizontal and vertical control for the survey follows.

Horizontal Control

The horizontal control datum for this survey was the World Geodetic System of 1984 (WGS84). All positions were collected in WGS 84 on the UTM (N) Projection, Zone 10.

Real-time positions were determined using an Ashtech GG24 GPS receiver with WADGPS (Racal Skyfix/LandStar) corrections. The Racal system delivers the differential corrections via the West NAM Satellite spot beam and the corrections are derived from the reference station in Vancouver.

The local Differential GPS reference station was established on the rooftop of the Silver Cloud Inn, University Village, Seattle. The DGPS positions were determined off line using data logged at the reference station and on the aircraft. This data was processed through Ashtech PNAV software to calculate both a DGPS and Coarse Acquisition (C/A) Code + Carrier Phase smoothed position solution. The Coarse Acquisition (C/A) Code + Carrier Phase smoothed positions were then imported into the Ground System and were applied to all soundings. This provided increased sounding position accuracy and horizontal redundancy.

Vertical Control

All sounding data were reduced to Mean Lower Low Water using tidal data supplied from the Seattle Tide Gauge, No. 9447130. This information was sourced from the NOAA Web Page (http:/tidesonline.nos.noaa.gov).

Tide data was supplied in UTC and meters and input to the Ground System for application to all soundings.

D – Results and Recommendations

General

The purpose of the survey was to collect high-resolution lidar data from selected areas in Puget Sound between the coastline and the 20 meter isobath. The survey achieved this aim and two areas were surveyed on a single flight. There are some gaps in the coverage achieved, as the single flight provided under the contract did not provide the opportunity to refly areas where the data was rejected because it failed to meet specification. Such areas would normally be reflown on subsequent flights. Air traffic control restrictions in Area 2 also limited the amount of data that could be collected on this flight.

Test lines were also flown into Port Gamble and along the east coast of Bainbridge Island. The single flight did not allow these areas to be surveyed more fully.

In summary, it is considered that this operation was successful in collecting bathymetric data in Puget Sound along the coastline to a maximum depth of 20 meters. The gaps that exist due to rejected data or air traffic control restrictions would normally be reflown in a subsequent flight. It would be feasible to conduct more extensive LADS Mk II survey operations throughout Puget Sound.

A significant area was also surveyed in the Shilshole Bay area for NOAA. This additional data may be available through NOAA if requested.

Chart Comparison

A comparison has been conducted with chart 18441, 41st Edition (Sep2/00, Scale 1:80,000). The survey contains considerably more detail of the nearshore area than is shown on the chart which is highly generalised. In particular, a number of complex deeper areas exist close to shore on the northern part of Sheet 3, which are not shown on the chart.

Automated Wreck and Observation Information System

No AWOIS items were assigned under this project.

Dangers to Navigation

No new Dangers to Navigation were detected.

Additional Results

Shoreline Verification

The survey covered the MHW and MLLW lines. The Clinton Ferry Terminal is clearly visible on Sheet 1.

Aids to Navigation

No checks on aids to navigation were carried out in the survey area.

Secchi Disk Observations

Secchi disk observations were conducted in Shilshole Bay on December 6, 2000, April 3 and April 22, 2001 to provide water clarity information and assessment of turbidity conditions. Positions and details of all observations are found in Appendix F.

E – Approval Sheet

LETTER OF APPROVAL

for

POSSESSION SOUND

This report and the accompanying smooth sheets are respectfully submitted.

Field operations contributing to the accomplishment of the survey were conducted under my direct supervision with frequent personal checks of progress and adequacy. This report and the accompanying smooth sheets have been closely reviewed and are considered complete and adequate as per the Statement of Work.

Mark Sinclair
Hydrographer
Tenix LADS Corporation

Appendix A – Dangers to Navigation

No new Dangers to Navigation are reported.

Appendix B - List of Geographic Names

Geographical names were not checked during the survey, and no amendments are proposed.

Appendix C – Progress Sheet

No progress sheet is forwarded as the survey is being rendered in its entirety.

Appendix D - Tides and Water Levels

Abstract of Times of Hydrography for Application of Tides
Project Name: Puget Sound – Kitsap County — Registry Number: N/A
Contractor Name: Tenix LADS Corporation — Date: April 28, 2001

The datum used was Mean Lower Low Water.

Abstract of Times of Hydrography

YEAR	DAY	START TIME (UTC)	DAY	END TIME (UTC)
2001	118	15:01:04	118	18:45:49

Appendix E – Shoreline Verification Results and Detached Positions

Shoreline verification was not conducted.

It should be noted that topographic elevations up to 10 meters above the low water line have been measured in both Areas 1 and 2.

Appendix F – Secchi Disk Observations

Secchi disk observations were carried out in the Shilshole Bay area on December 6, 2000, April 3 and April 22, 2001 and are tabled below. The purpose of these observations was to assess water clarity and turbidity levels in that area. It is considered that the water clarity as measured in Shilshole Bay was similar to that in Areas 1 and 2. The significance of the Secchi disk data is that it relates closely to LADS Mk II performance. In broad terms, the relationship between Secchi disk depth (SDD) and LADS Mk II performance is as follows:

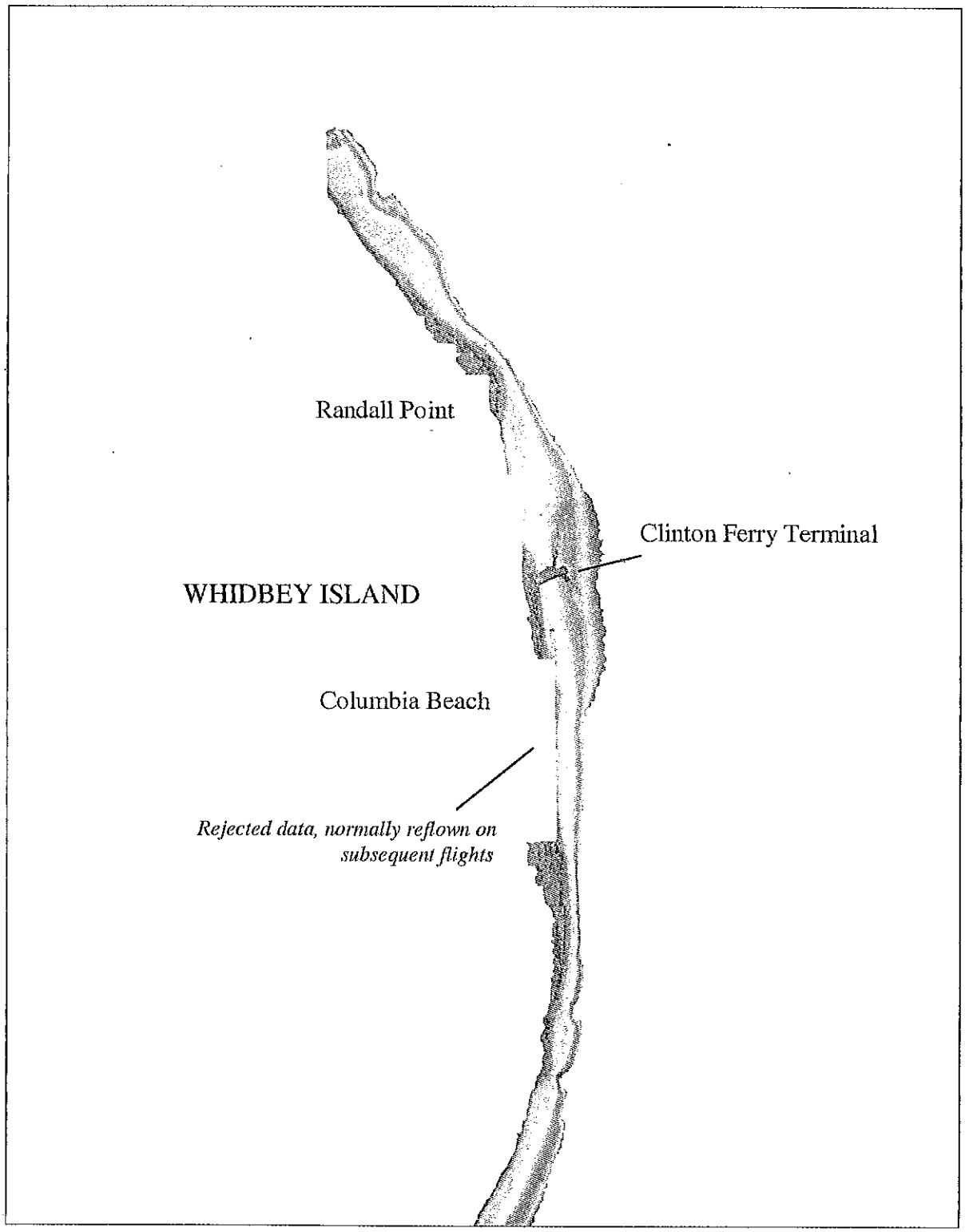
2.5 x SDD	Max LADS Depth
2.0 x SDD	Limit of IHO Order 1 depth precision
1.5 x SDD	Limit of IHO Order 1 target detection.

The relationship is for depths measured prior to the reduction of tide. This relationship may be useful in assessing LADS Mk II performance in other areas.

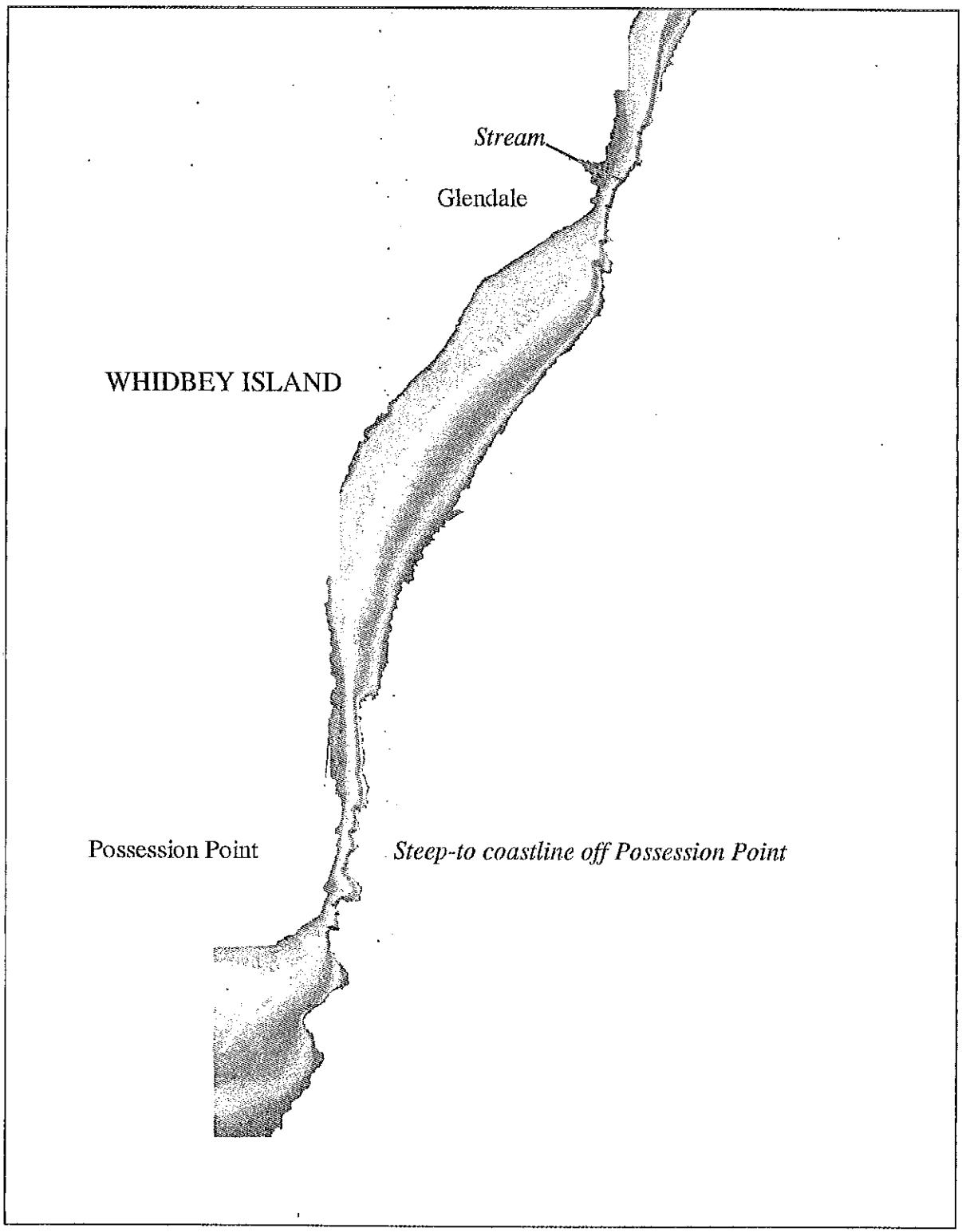
	Approx. Position WGS 84	Secchi Disk Depth (meters)	Water Depth (feet)	Remarks
Dec 6 2000 09:26	47° 40.36' N 122° 25.33' W	10.5	60	Clear sky, wind N 10 kts
09:29	47° 40.28' N 122° 25.17' W	6.5	21	Disk visible on seabed. Kelp close inshore
09:33	47° 40.32' N 122° 25.26' W	11.5	45	Clear sky, wind N 10 kts
09:39	47° 40.48' N 122° 25.52' W	12	112	Clear sky, wind N 10 kts
Apr 3 2001 10:27	47° 40.46' N 122° 25'.44' W	11.5	100	Clear sky, light winds
10:38	47° 40.37' N 122° 25.41' W	11.5	76	Buoy
10:40	47° 40.20' N 122° 25.36' W	9.5	30	Disk visible on seabed
10:52	47° 39.62' N 122° 26.58' W	11.0	122	Off West Point Buoy
11:16	47° 41.77' N 122° 24.63' W	11.5	100/60	Off Meadow Point Buoy
12:15	47° 42.45' N 122° 22.95' W	9.5	50	Between No.1 & No. 2 buoys
12:24	47° 40.43' N 122° 24.58' W	9.5	42	Between No.7 & No. 8 buoys
13:30	47° 38.2' N 122° 20.3' W	9	42	Note: Freshwater plankton bloom
Apr 22,2001 10:45	2 cables SW of Wreck buoy	10	40	Overcast, Rain, Wind S 10 kts

Appendix G – Graphic Images

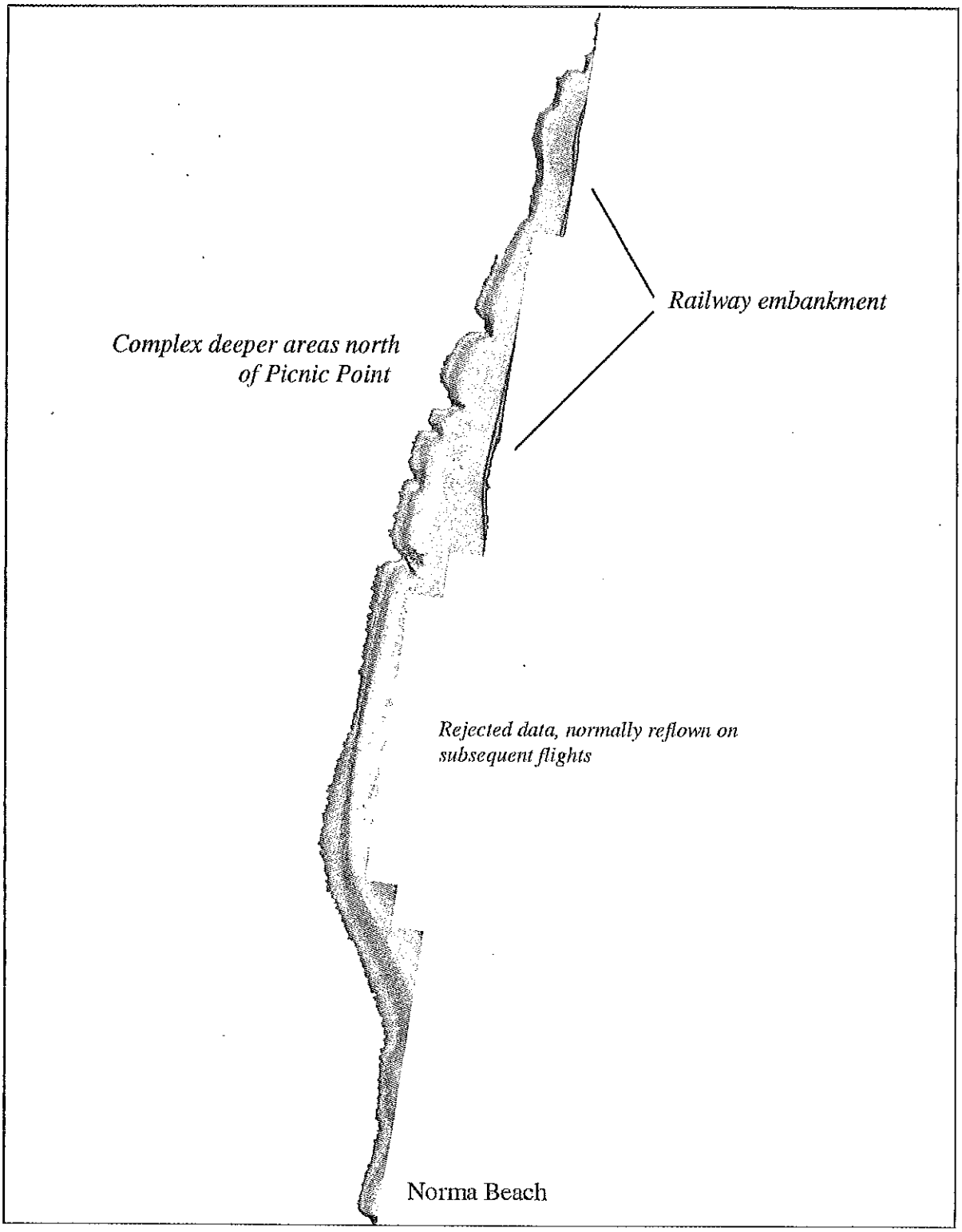
Graphic Image of Sheet 1



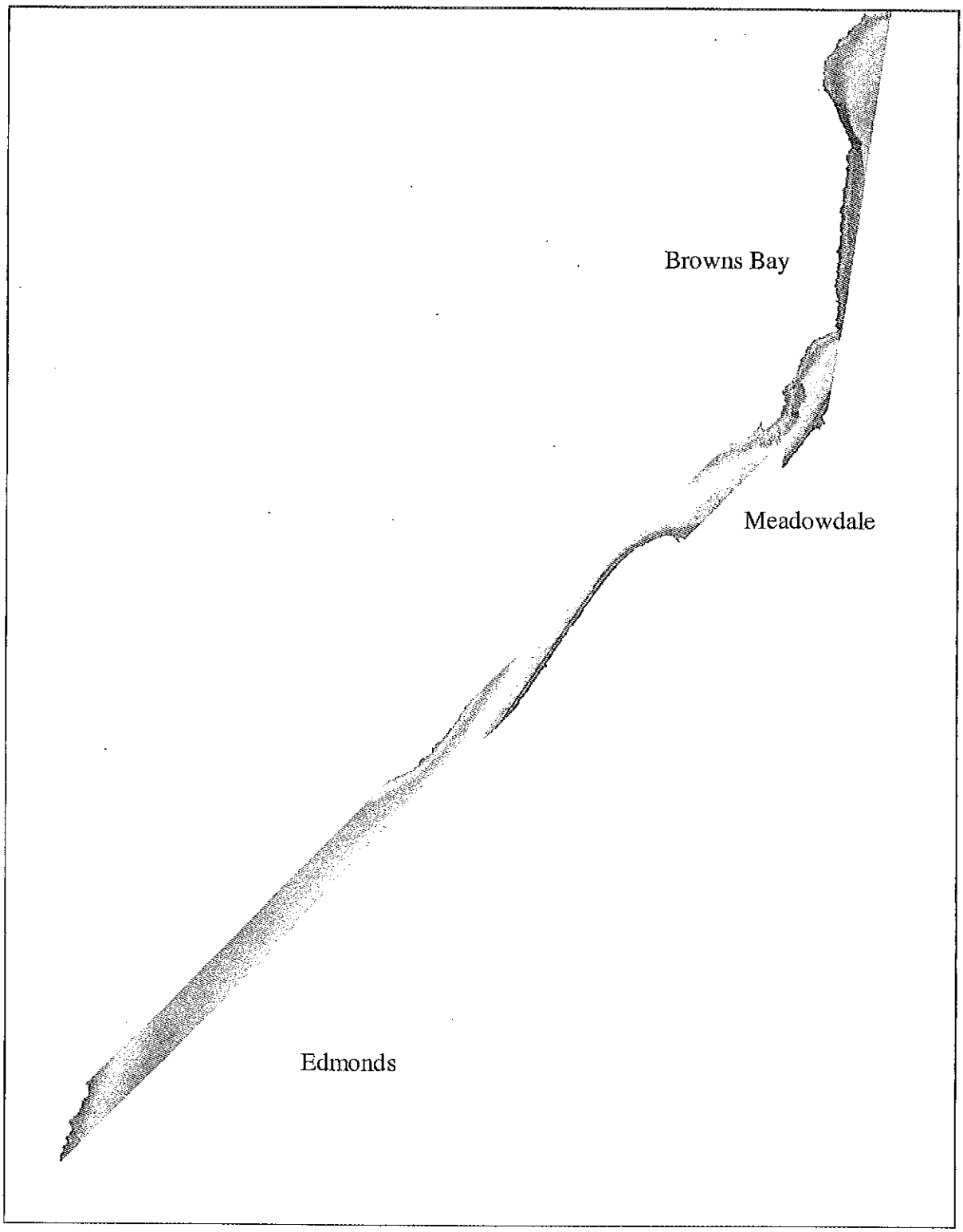
Graphic Image of Sheet 2



Graphic Image of Sheet 3



Graphic Image of Sheet 4



U.S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
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DATA ACQUISITION AND PROCESSING REPORT

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Table of Contents

Introduction

The LADS Mk II hydrographic survey system comprises two main sub-systems; the Airborne System (AS) used for acquiring raw bathymetric data and the Ground System (GS) used to plan operations, extract depth values from the raw data, validate processed depth values, apply tidal corrections, generate smooth sheets and digital survey data and conduct general survey management. These two sub-systems are complemented by other tools required for QC activities, in particular contouring and 3-D visualization, and differential GPS positional post-processing. The general data flow between the sub-systems and tools are illustrated in Figure 1.

All sounding data are acquired by the AS which is mounted in the LADS Mk II DeHavilland Dash-8 fixed wing aircraft, callsign VH-LCL.

The GS software package, used for all survey planning, depth determination, validation and data output operations is supported by the UNIX operating system and operates on a ground based COMPAQ Alpha 4100 series CPU server.

Prior to a sortie, planning information is passed from the GS to the AS on floppy disk. During the sortie, logged raw sounding, positional and AS system data is logged on digital linear tape (DLT). This is processed on the Ground System at the completion of each sortie.

The primary QC tools are:

- Geocomp Terramodel
- the Generic Mapping Tools (GMT) software package and
- in-house utilities based on the Kitware Visualization Tool Kit (VTK) and OpenGL.

Data is output from the GS in a format suitable for the particular QC tool.

Post-processed GPS positioning is accomplished with Ashtech logging and processing software.

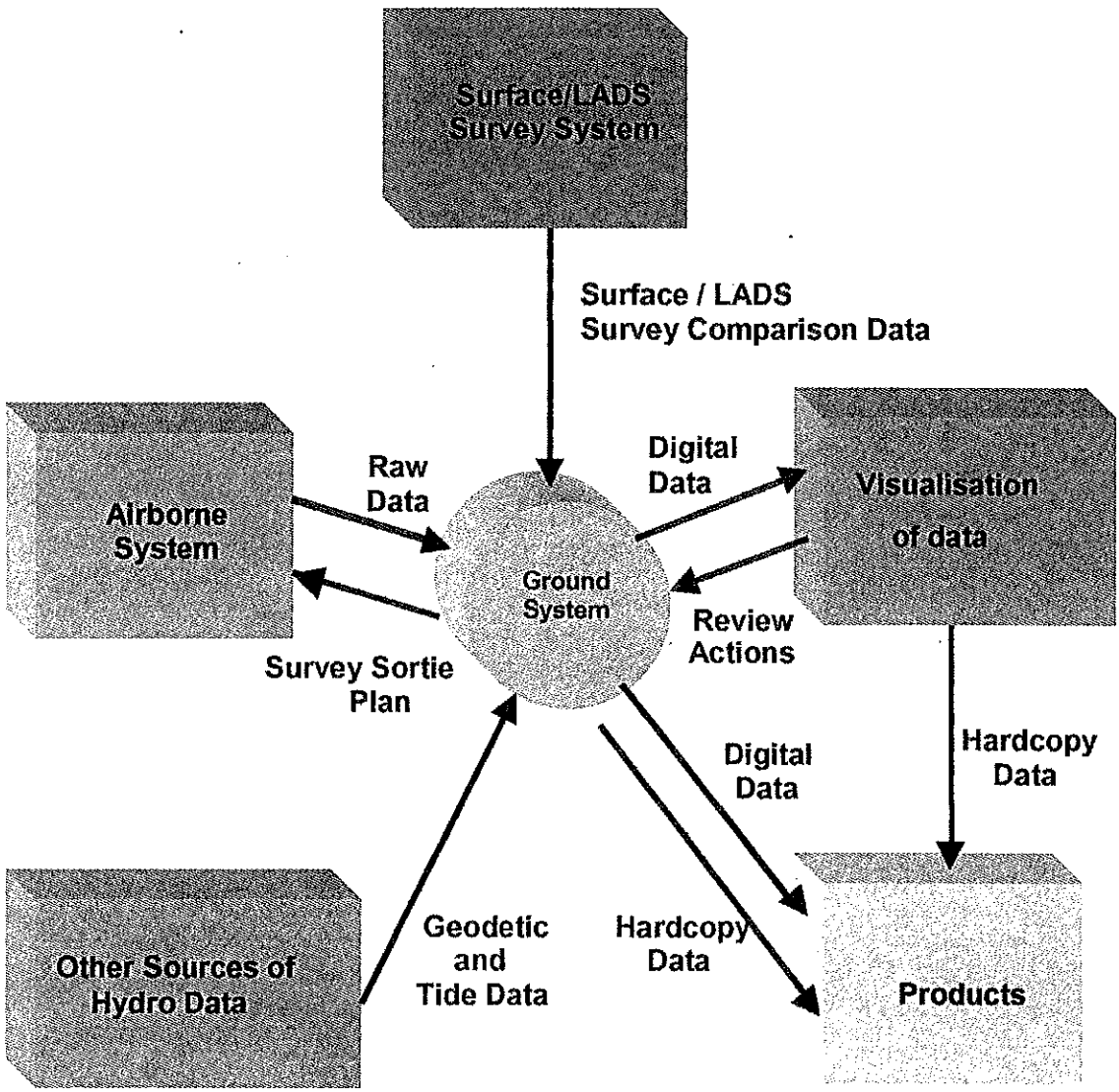


Figure 1 - General data flow within LADS Mk II

A - Equipment

This section provides a comprehensive description of the LADS Mk II Airborne System (AS) and the Ground System (GS).

Airborne System

A laser, scanner, optical system, photo-multiplier tube and conditioning electronics provide the raw sounding signal. These items are mounted on a stabilized platform controlled via servo systems using information from an Attitude and Heading Reference System (AHRS) mounted on the platform. Aircraft position information is obtained from the Global Positioning System. Figure 2 illustrates the major components of the AS.

Three computers, linked via an FDDI optic fiber network, control and monitor the AS operations, namely:

- The System Control Computer (SCC) for operator interface, logging and overall system coordination.
- The Navigation System and Support (NSS) computer for position monitoring and control.
- The Laser Control and Acquisition (LCA) computer for control of the scanner and laser and digitization of raw sounding data. The LCA also synchronises overall AS timing.

AS system time is synchronised with GPS time and all data acquired for logging is appropriately time stamped at the point of acquisition then passed to the SCC to be written to digital linear tape.

Ancillary equipment includes:

- a downward video camera and VCR to provide images below the aircraft and a forward looking video camera
- systems for temperature control of equipment
- VHF transceiver and aircraft intercom.

The operator interface allows the operator to monitor the quality of sounding, positional and other data in order to set appropriate system parameters and control the sequence of sortie operations.

Detailed descriptions of equipment and their function are given under the following headings:

- Sounding Equipment
- Positioning Equipment
- Survey Control
- Ancillary Equipment
- Operator Interface

Sounding Equipment

Soundings in the LADS Mk II system are obtained by the transmission of laser pulses from the aircraft through a scanning system and detecting return signals from land, the sea surface, the water body and the sea bed. The transmission and receiving components are housed on a stabilized platform that compensates for aircraft pitch and roll. The return signals are electronically amplified and conditioned prior to being digitized and logged.

The primary sounding components of the AS are:

- Laser. A Nd: YAG laser producing IR energy at a wavelength of 1064nm at 990 pulses per second of which 900 pulses are used for sounding purposes.
- Optical Coupler. The optical coupler is used to split the IR beam, the original IR being transmitted vertically to the nadir position of the sounding system on the sea surface. The split beam is frequency doubled to produce green laser pulses of wavelength 532nm. The green pulses are transmitted onto the mirror of the scanner.
- Scanning System. The scanning mirror is oscillated in both the major (across track) and minor (along track) axes. The required scan pattern is generated by controlling software. All possible patterns are listed in the Logging Parameters section.
- Optical Receivers. The IR and green return signals are detected by two separate receivers. The IR return is from the surface of the sea and is used to establish a height datum. The IR receiver is a solid state detector producing an electronic signal from the IR return. The green return comprises energy returned from the surface, subsurface and sea bed and is used to determine water depth. The green return is transmitted via the scanner into a photomultiplier tube. The electronic output of the two return signals are electronically mixed prior to digitization.
- Attitude and Heading Reference System (AHRS). The AHRS is a laser gyro INS system providing platform attitude information to the platform servo system that in turn maintains platform stability. In addition, the AHRS reports platform attitude to the LCA computer.
- LCA computer. This controls the laser and scanner operations and digitizes (12 bits at 500Mhz) appropriate sections of the composite electronic red/green return signal along with platform attitude data and other system parameters. This digital information is passed to the System Control Computer (SCC) where it is logged to digital linear tape.
- Waveform Display. This CRT display presents the operator with a visualisation of all the sounding waveforms as digitized and is used by the operator to determine system settings to gain maximum performance.

Positioning Equipment

The center of the scanning mirror is the survey reference point on the aircraft. The AS has one GPS antenna positioned relative to this point as described in Laybacks.

The signal from the antenna is split and fed to two independent GPS receivers, one is used for real-time aircraft position fixing and track keeping, the second to record GPS data for post-processing.

The output of the real-time GPS receiver is fed to the NSS to:

- fix aircraft position and determine ground speed
- calculate aircraft cross track error and automatically maintain track along survey lines
- provide pilot display information
- establish and maintain system UTC time

The NSS passes the received GPS and derived information to the SCC computer for logging.

The GPS receiver used to compute post-processed positions is an Ashtech GG24. The data from this receiver is independently logged and post-processed as described in the Horizontal and Vertical Control Report.

Sortie Control

A sortie plan is generated on a floppy disk by the GS to transfer survey information to the AS. The sortie plan contains spheroidal and grid parameters and a list of survey objectives including the line number, start/end coordinates and coordinates for navigation checks. During the course of the sortie the airborne operator amends the sequence of execution to suit local conditions and can amend the scan pattern parameters for the survey lines to suit survey requirements.

The SC computer controls the sequence of survey operations by:

- planning all required flight paths and communicating these to the NSS
- transmitting required parameters for scan patterns etc. to the LCA
- initiating the starting and stopping of system operations, such as scanner and laser start up, via commands sent to the LCA and NSS at specific waypoints on the run-in and run-out of survey lines.

The operator may abort and restart the sortie operations at any time. The sequence of objectives may be amended at any time. Scan patterns can be amended on all lines except the executing objective.

A display controlled by the NSS from the planned survey line and received GPS data is situated in the cockpit and used to advise the pilots of required aircraft configurations. The display provides an indication of cross track error with required and actual values for altitude and ground speed.

Aircraft position during survey acquisition is under automatic control of the NSS via the aircraft autopilot. Aircraft turns are under pilot control assisted by the display.

Aircraft altitude and speed are under pilot control, and communication between operator and pilots is via the aircraft intercom system.

The management of airborne survey activities can be impacted by both low cloud and/or high ground in the survey area. LADS Mk II provides for variable survey heights so that adequate minimum safe altitudes can be maintained while surveying or, as is more common, survey activities can continue below low cloud ceilings. Survey altitudes at 100ft increments are available from 1200 to 1800 feet (366 to 549m). Altitudes must be constant for the duration of a survey line but may be varied from line to line by the AS operator during the course of a sortie. All operations were conducted at 1600ft (488m) and 1200ft (366m) during this survey.

During daytime operations a narrow band green filter is used to filter out other light frequencies from the photomultiplier tube. This filter has a slight attenuating effect on the laser returns thus reducing maximum depth performance. This filter is removed once the ambient sunlight levels drop resulting in improved night time performance.

Glassy sea conditions may result in very strong IR surface returns that can saturate the IR receiver causing a loss of surface datum. The AS monitors the IR surface return performance and advises the operator if IR saturation occurs. The operator can activate an attenuator that provides correct IR surface return amplitudes to be fed to the IR receiver. Should sea surface conditions change resulting in lower IR return amplitudes the AS informs the operator to deactivate the attenuator.

The laser is designed to be eye safe in accordance with ANSI 2136.1 – 1993, American National Standard for Safe Use of Lasers. The laser can be attenuated by a further factor of four for operations that may illuminate populated areas. The operator may activate/deactivate the attenuator at any time.

Ancillary Equipment

A video camera is positioned on the stabilized platform and directed downward at the nadir point. A calibrated graticule is superimposed on the camera image to provide the operator with a scan width and distance reference. The image, graticule and other relevant system information including position and time are presented to the operator and recorded throughout a sortie.

The images as recorded are used as supplemental information during sounding validation.

Operator Interface

The operator monitors and controls system operation from the console.

The following key information is provided to monitor system performance:

- Sortie Information. The Sortie ID, spheroid and grid in use and available survey objectives are displayed. Sortie objective information includes the scan pattern set for the objective and estimated time to complete the objective.
- Objective Information. The Objective ID, selected scan pattern, required speed and altitude pertaining to the current objective being executed and objective status such as time to completion are presented.
- Waveform Display. This display is a CRT on which is displayed each of the mixed red/green sounding return signals as digitized by the LCA (the traces are overlayed). The operator continually assesses this display to determine data quality.
- Depth Profile. A depth profile determined from nadir soundings is available to the operator with an associated confidence factor. As the algorithm is limited by real-time considerations these depths and confidences are only indicative.
- Aircraft Position, Speed, Altitude and Cross Track Error. A number of displays including a copy of the pilot display are available to the operator to determine the aircraft position and performance parameters. Speed and altitude are continually monitored and the pilot informed of deviations from the desired values.
- GPS status. The operator is provided with the data from the GPS receiver including number of satellites, satellite altitudes and azimuths, S/N ratio and which satellites are being used.
- Equipment Status. System status and performance parameters are available to the operator including laser power and temperature, dynamic gain values, AHRS status and scanner performance.

Items controlled by the operator for sortie execution and data acquisition are:

- sequence of objective execution
- scan pattern for each objective
- dynamic gain limits
- IR and Green receiver attenuator

Depth and Topographic Mode

During normal bathymetric survey mode (Depth Mode) LADS Mk II determines the depth of water, with the height datum being determined from the reflected IR laser signal, GPS height and AHRS height. When over land this IR signal is not valid and the height datum is obtained from the GPS and AHRS.

This ancillary height datum allows LADS Mk II to obtain topographic heights up to 50m above mean sea level.

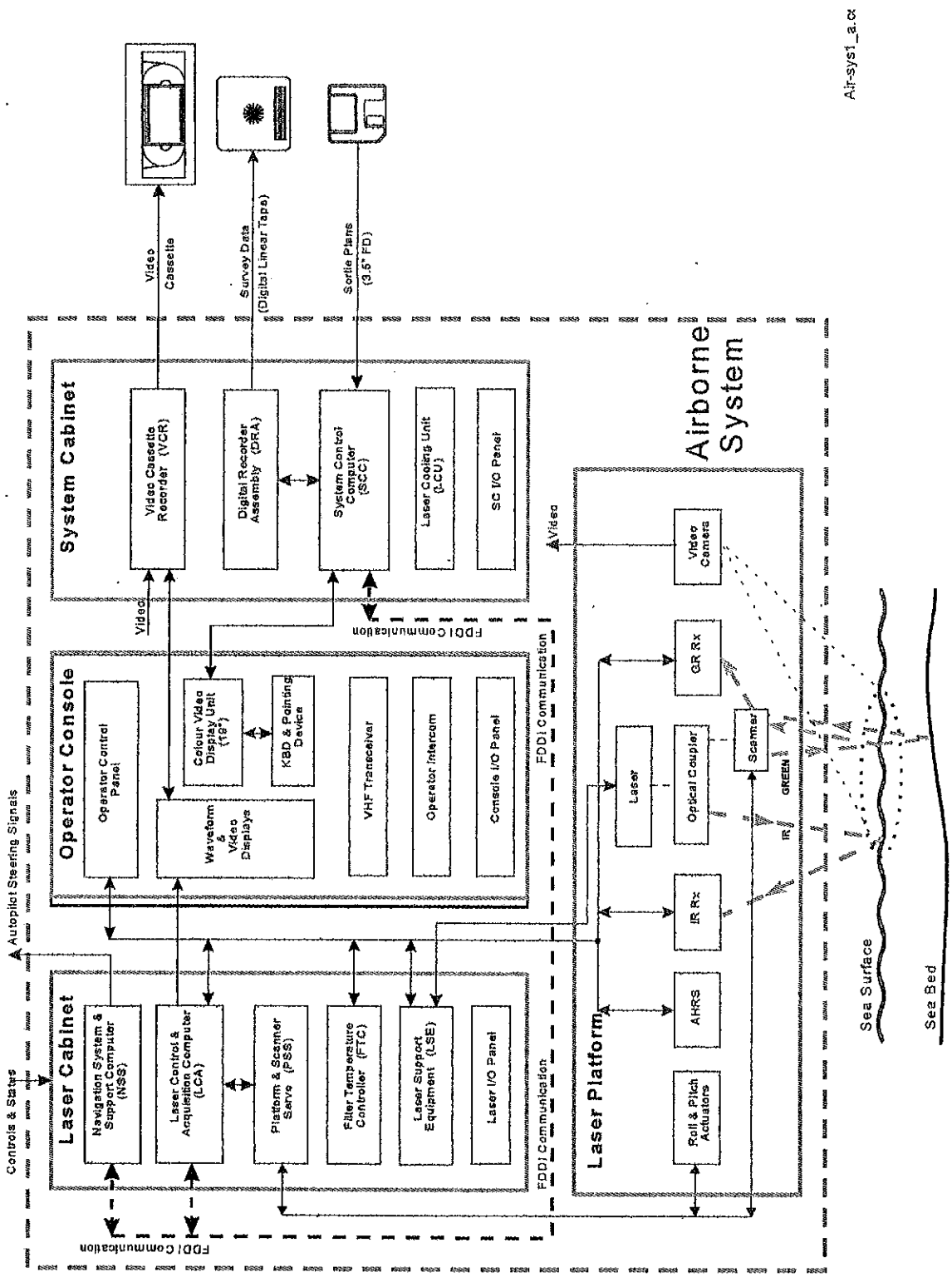


Figure 2 - Airborne System Functional Block Diagram

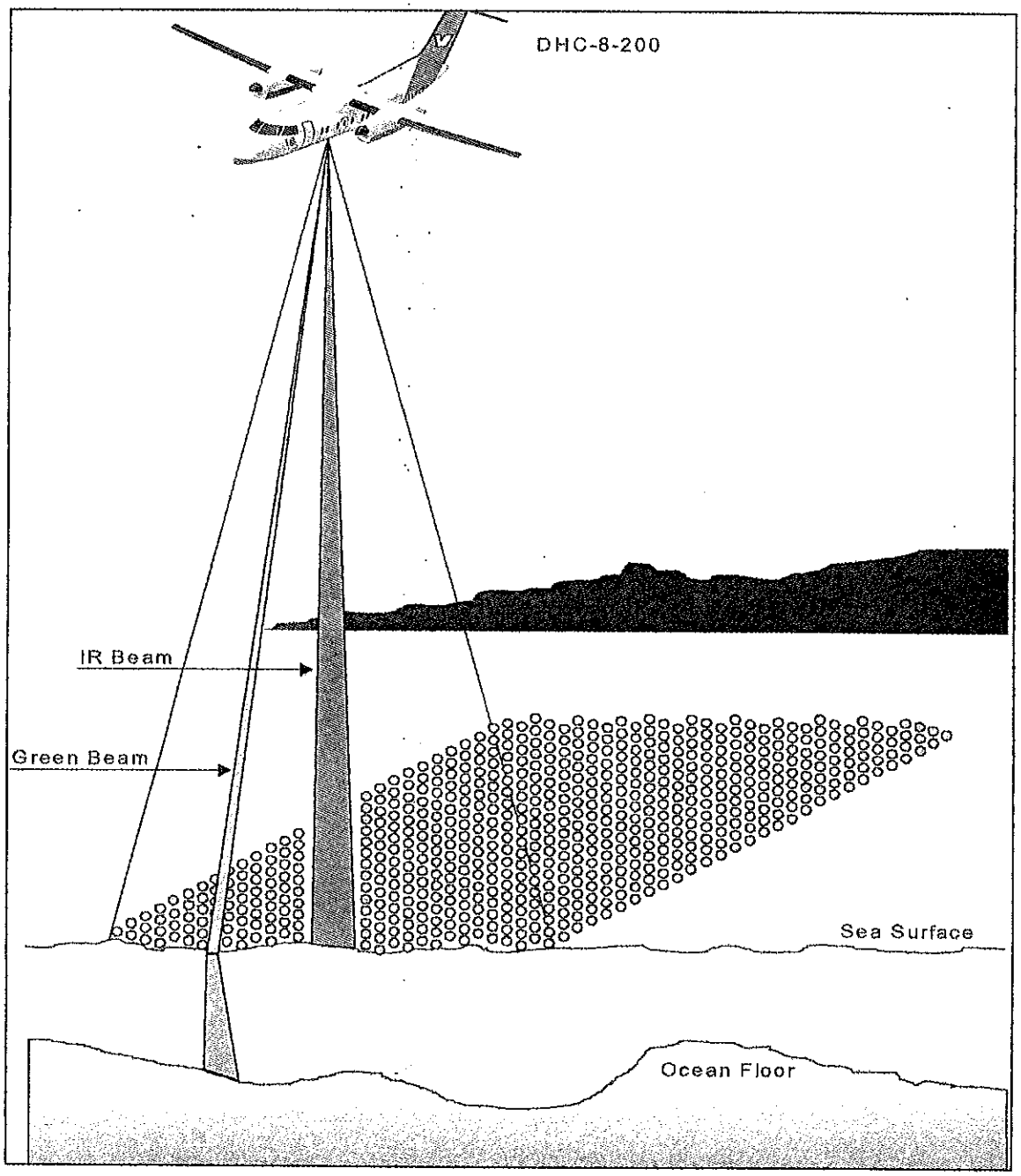


Figure 3 - The Laser scan

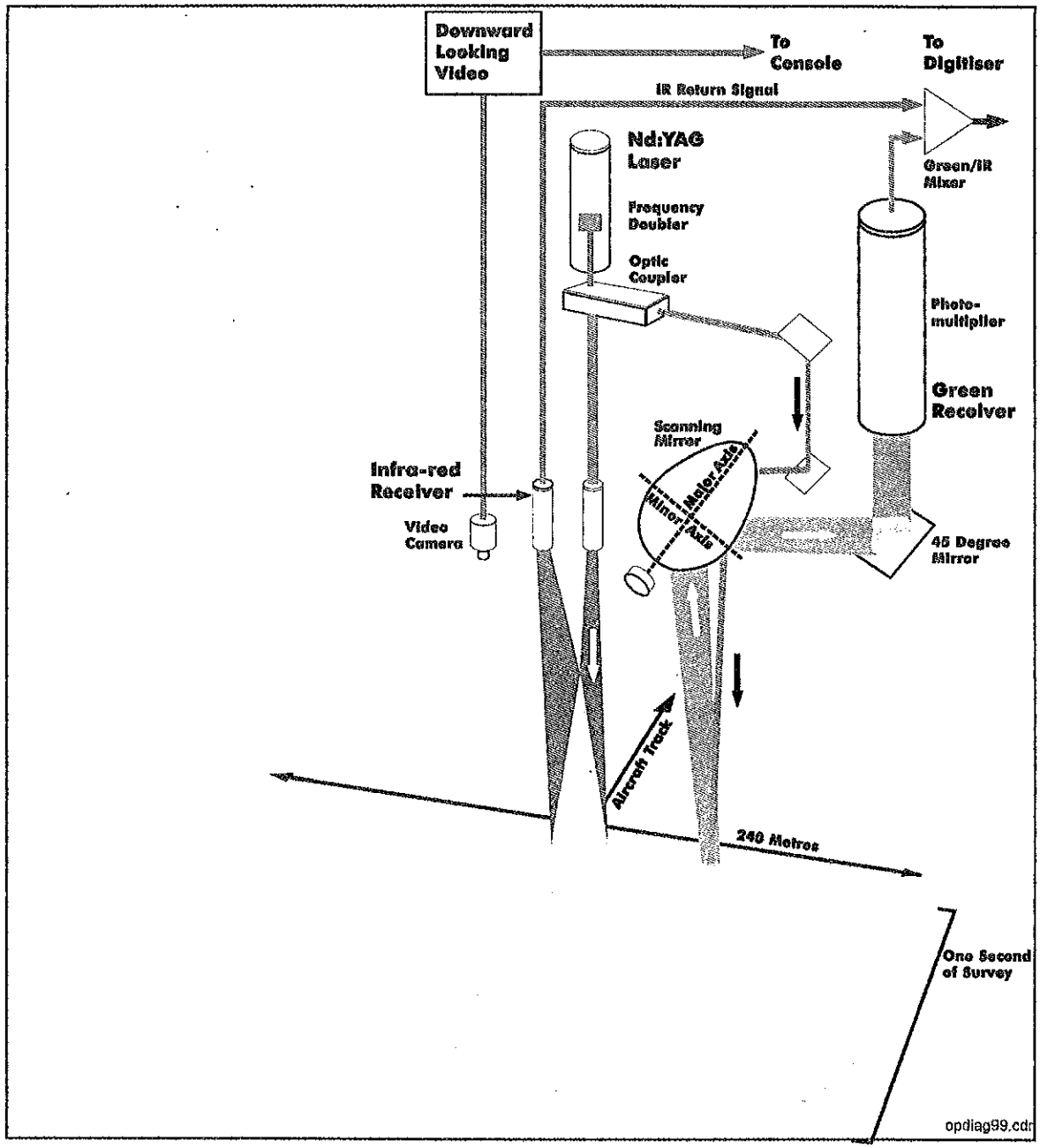


Figure 4 - The Airborne System Scanner, Laser and receivers

LADS Mk II Aircraft and System Specifications

Aircraft Type	DeHavilland Dash 8-200, twin turbo prop, high wing
Aircraft Modifications	Long range tanks, pressurised laser bay window and autopilot interface
Transit Cruise Speed	250 knots (maximum 275 knots)
Transit Altitude	To 25,000 feet
Survey Speed	Dependant on Scan Pattern: Nominal 140 – 210 knots (72-108 meters per second)
Survey Height	1200 feet to 1800 feet (366 meters to 549 meters) in 100 feet increments
Survey Track-Keeping	+/- 5 m (manual or via autopilot coupling)
Survey Endurance	8 hours nominal
Operational Capability	Day/Night Operation
Depth Sounding Rate	900 soundings per second
Swath Width	Dependant on Scan Pattern: 50 – 288 meters (independent of aircraft height and water depth)
Scan Pattern	Rectilinear
Sounding Density	Variable: 6 x 6m, 5 x 5m, 4 x 4m, 3 x 3m and 2 x 2m
Soundings per sq km	Dependant on scan pattern. For 4 x 4m – 75,000/ km^2 (assuming 32m overlap)
Soundings per hour	Up to 3 million
Topographic and Depth Range	-50 meters (topo) to 70 meters (depth)
Area Coverage	Dependant on scan pattern. For 4 x 4m – up to 41.5km^2/hour (12.1 sq nm/hr) assuming 32m overlap
Position Fixing	Real-time GPS and post-processed Coarse Acquisition (C/A) code + carrier phase smoothed position
Recording Media	Digital Linear Tape (DLT) and VHS/PAL Video Tape

Laybacks

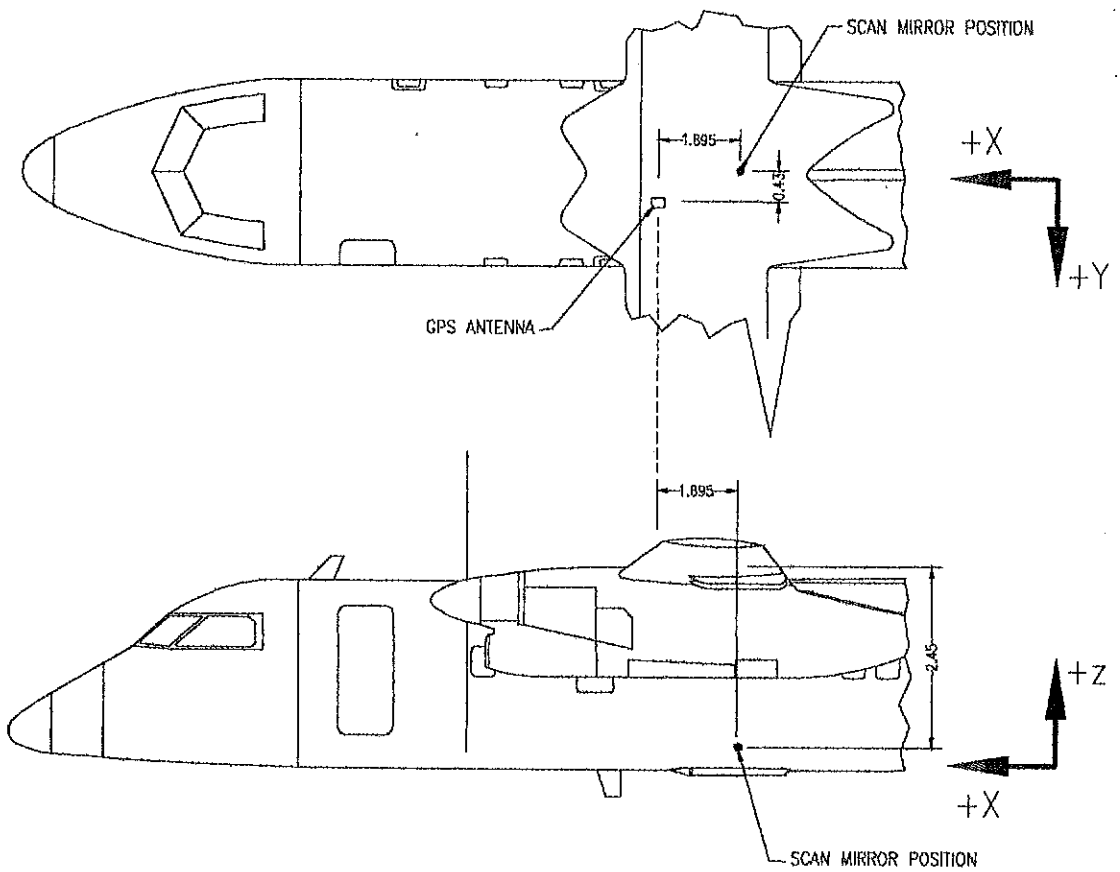
All laybacks are measured relative to the survey reference position on the aircraft which is the center of the scanning mirror. The GPS antenna used for position determinations in the Airborne System is positioned on the upper side of the aircraft fuselage forward and to the left (facing forward) of the sounding reference position. The signal from this antenna is passed to a splitter, one signal going to the GPS receiver in the Navigation Systems computer of the AS and the other passes to the GPS airborne logger.

Offsets are from the sounding reference point to the antenna with the following axis and sign convention assuming the aircraft is level:

X positive toward the nose of the aircraft
Y positive to the left facing forward
Z positive vertically up

The offsets are:

X offset: + 1.895m
Y offset: + 0.43m
Z offset: + 2.45m



Software Versions

System	Date	Version	Remarks
Airborne System	Duration of Survey	7.0.2	
Airborne System GPS Receiving System	Duration of Survey	GG00	Racal LandStar Mk III User Code 1076 and Ashtech GG24
GPS Base Station Receiver	Duration of Survey	GG00	Ashtech GG24
GPS Airborne Receiver	Duration of Survey	GG00	Ashtech GG24
GPS Logging	Duration of Survey	5.6.00	Ashtech PNAV Datalogger Software.
GPS Processing	Duration of Survey	2.5.05	Ashtech PNAV (Precise Differential GPS Navigation Trajectory Software)
Ground System	Duration of Survey	T4.9/014	
Visualisation and QC	Duration of Survey	3.3.1 9.7 3.1	Generic Mapping Tools (GMT) Terramodel Visualization Tool Kit (VTK)

Logging Parameters

Position Fixing

The AS system obtains a position fix every 0.5 seconds.

Navigation Update

While executing a survey line under AS control navigation correction is passed to the aircraft autopilot every 0.5 seconds.

Post-Processed GPS

The GPS airborne and base logging stations log position information from GPS satellites at one second intervals.

Sounding Rates

LADS Mk II obtains depth soundings in a rectilinear pattern where the sounding density is variable (see scan pattern section below) but sounding rate is invariant.

For all sounding patterns the soundings are grouped into one second frames made up of 18 scan lines. Each of the 18 scan lines contain 50 laser pulses, of which 48 pulses are used for depth sounding. The outermost laser pulses are not used for depth sounding. This provides an effective sounding rate of 864 soundings per second.

Sounding Patterns

LADS Mk II has variable scan pattern functionality as detailed in the following table. The 4 x 4 and 4a x 4a patterns both provide 4 x 4 meter spot density but have different swath width and survey speeds. All patterns are available at each of the operational altitudes (1,200 – 1,800ft at 100ft increments).

During the course of this survey the 4 x 4 meter pattern with line spacing for 100% coverage was used at altitudes of 1600 and 1200 feet.

Sounding Density (m)	Swath Width (m)	Line Spacing 200% Cover (m)	Line Spacing 100% Cover (m)	Survey Speed (m/sec & kts)
5 x 5	240	100	200	90 (175)
4 x 4	192	80	160	72 (140)
4a x 4a	150	60	120	90 (175)
3 x 3	100	40	80	77 (150)
2 x 2	50	30	60	72 (140)

Scan Configuration

Ground System

Conversion of raw sounding data from the Airborne System to final data is accomplished on the Ground System.

The Ground System (GS) comprises a 4 CPU Compaq (DEC) Alpha Series 4100 multi-processor server with 256MB ram, up to 750GB disk, DLT drives, DAT drives and networked to a series of X-term operator consoles, HP 750c DesignJet plotter, printers and QC workstations. The hydrographic software is a Tenix LADS Corporation proprietary package written in ADA to operate in a UNIX True-64 (DEC) environment.

The GS provides the facilities for all LADS survey management tasks from initial mission planning through to production of smooth sheets and deliverable digital data.

The primary functions are:

- Mission planning. This includes the specification of the total survey area, spheroid and grid, survey sub-areas, line spacing, swath widths, survey lines to cover the sub-area, individual survey lines, crosslines, tidal areas and navigation check points (coordinated points).
- Sortie planning. A sortie plan is the specification of a series of survey objectives to be executed by the AS. Survey lines and navigation check objectives are selected by the operator and written to floppy disk along with grid and spheroidal information.
- Sortie processing. This function calculates sounding depths and positions from the raw sounding data logged by the AS. Depths and positions are associated with various confidence metrics.
- Data validation, checking and approval. Surveyors validate the calculated soundings on a run by run basis editing soundings as appropriate. The validated data is checked by a second surveyor and finally approved by the Survey Team Leader.
- Data output. Approved data is output to the client in digital form along with hardcopy smooth sheets.

In addition the GS provides facilities for the generation of survey management plots and reports.

Mission Planning

At the commencement of a survey one or more databases are established on the GS. Each database contains the coordinates for the entire survey area in addition to spheroid and grid details.

Sub-areas are defined covering the specific areas to be surveyed. The GS automatically generates runs to cover a sub-area at operator specified line spacing. Other survey lines can be specified by entering their start and end coordinates.

The main line sounding scan pattern used was 4 x 4 meter rectilinear spot spacing covering a swath width of 192m at a speed of 72m/sec. Survey lines are planned for specific patterns with line spacings providing for appropriate overlaps.

Sortie Planning

Prior to each sortie survey objectives are selected from the appropriate database. The start and end coordinates of the required survey lines are written, together with spheroid and grid definitions, to a sortie plan on a floppy disk. This plan is read by the AS and used to control sortie operations.

Data Processing

Processing parameters suitable for the sortie are set prior to processing. Tides may be either observed or predicted and can be reapplied at any time.

Raw sounding data logged by the AS is automatically processed by the GS to produce sounding depth and position accompanied by a series of confidence parameters.

Post-processed differential GPS corrections may be applied at any time after the automatic processing is complete.

On completion of line processing operator validation, checking and approval of the sounding data can be conducted.

Data Organisation

Data within the GS database is held on a line by line basis. Within lines data is grouped into one second frames made up of 18 scans of 48 sounding pulses ie. 864 pulses per frame. (The outer two laser pulses are not used for sounding purposes.)

Primary and Secondary Soundings

All soundings comprise the primary sounding set. Where data set reduction is required a shoal biased subset of the primary soundings called secondary soundings is created. Secondary soundings form a shoal biased sub-set based on operator selected confidence and

secondary selection radius criteria. Only secondary soundings are validated, checked, approved and output.

For this survey a secondary sounding reduction radial of one meter has been used which means all soundings have been hydrographically reviewed and all valid soundings have been provided in the final data set.

Automatic Data Processing

Automatic processing is completed in two stages:

i. Sortie Tape Processing (STP)

STP reads the data on the tape and stores it in the internal GS database for further processing. The data is line based, and consists of raw waveform data, navigation data, platform data, system data, and error and event logs. This process also includes producing a backup of the Raw Data Tape on DAT or DLT.

ii. Sortie Run Processing (SRP).

SRP is the second and major processing phase during which sounding depths and positions are calculated on a line by line basis. The process is normally triggered automatically by STP as each line becomes available but may be invoked later by the operator if reprocessing of lines with different processing parameters is required.

The major processing steps of SRP are:

Process the Raw Waveform to identify surface reflections.

Process the Raw Waveform to identify and calculate initial depths for the two most likely bottom return pulses.

Classify each of the identified bottom return pulses by signal noise ratio, agreement with near neighbours and a maximum likelihood estimator.

Select the most likely bottom return pulse based on the above classification and a shoal weighting function.

Model the sea surface from the available surface pulses.

Correct the bottom depths for sea surface datum including tide, slant range, optical propagation and early/late entry. Tidal corrections may be reapplied later if required.

Calculate position of each sounding on the seabed. This algorithm utilizes corrected GPS fixes, aircraft track and speed, antenna offsets, platform attitude (heading, roll and pitch), beam scan angles and sounding depth.

Where the GS is unable to determine a depth from the raw data the sounding is classified as "No Bottom Detected" (NBD)

Primary Confidence indices (0-9) for each non-NBD sounding and all frames are calculated where:

C0 = Subsurface Pulse Confidence (Signal to Noise)
C1 = Near Neighbour Confidence
C2 = Pulse Type Confidence
C3 = Position Confidence
C4 = Sea Surface Reference Confidence
C5 = Not Used
C6 = Coverage Confidence (confidence that the swath covered the planned width)
CW = Weighted Primary Confidence

Store each sounding and associated confidence data in the database.

Determine the secondary sounding sub-set (it may be appropriate to have all soundings classified as secondary) and for each secondary sounding calculate and store secondary confidences.

CS1 = Secondary Neighbour Confidence (near neighbour agreement)
CS2 = Useable Points Confidence
CS3 = Secondary Area Confidence
CSW = Weighted Secondary Confidence

After SRP is completed, post-processed code + carrier positions are applied.

Bottom Object Detection (BOD)

A particular feature in the SRP improves the ability of the LADS Mk II GS to detect small objects on the seabed.

The BOD algorithm proceeds in two phases, each phase can be independently enabled/disabled and tuned via a series of BOD processing parameters set by the operator prior to SRP processing.

Phase one of the algorithm is designed to detect objects 2-3m in height while phase two is only invoked if phase one fails. Phase two is more sensitive and intended to find objects less than 2m in height.

Line Reprocessing and Segmentation

It may be necessary to reprocess the same raw sounding data with different processing parameters. The run identification scheme adopted in LADS Mk II provides a mechanism to manage the reprocessing of survey line data a number of times. This enables processing parameters to be tuned to maximise the quality of data in different sections of a line.

After a line is reprocessed the required segment can then be set to accepted, and the remaining data can be set to anomalous and is therefore ignored by the system.

Ground System – User Interface

The following displays and their associated operations are the primary tools used for validation, checking and approval.

Composite Depth Profile

The Composite Depth Profile is used for overall assessment of the depths along the line and the general quality of the data. The operator may pan and zoom along/into the line. The position in eastings and northings of the nadir at that point, the distance along track, time of acquisition and frame number of the point under the cross hairs is displayed as the operator pans along the line.

The operator can position cross hairs at the point of interest on this display before invoking more detailed displays. The new displays are initialized at the coordinates of the cross hairs.

Three profiles, with distance along track on the X axis and depth on the Y, are superimposed on this display:

- For each scan the average of all soundings across a scan is graphed as a green line. If the number of NBD soundings in the scan exceeds a specified number (set as a processing parameter) the green line is drawn across the bottom of the display.
- The shoalest secondary sounding in each scan can be displayed as a yellow dot.
- The deepest secondary sounding in each scan can be displayed as a yellow dot.

These profiles enable the operator to rapidly assess where there is a high NBD count and assess where there are areas of noise.

Below the depth profiles two operator selectable profiles are displayed. Each of these can be one of:

- any of the primary or secondary confidences
- parameters related to the integrity of the height datum
- tidal correction and tidal area boundaries

In the example of Figure 5, the shoal soundings are wrecks on the seabed.

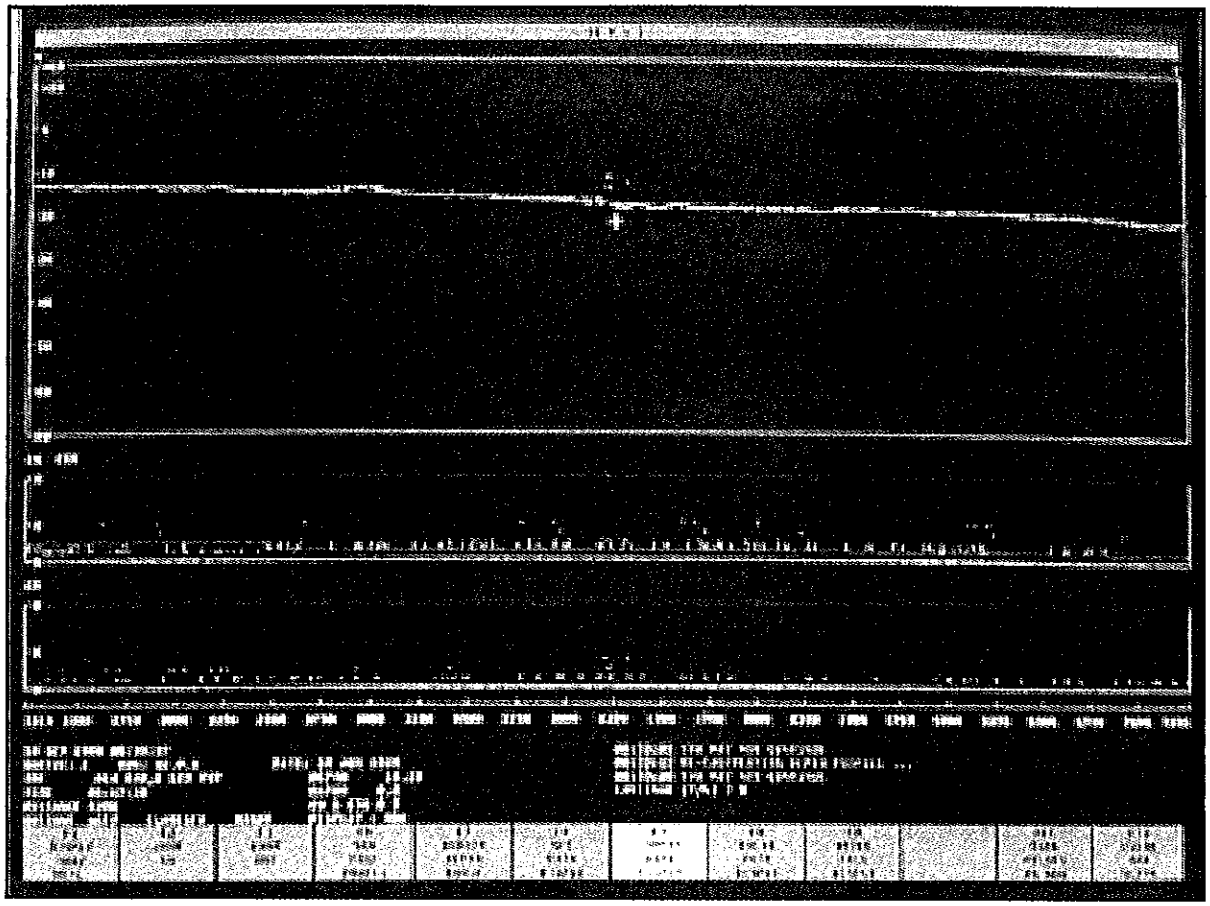


Figure 5 - Composite Depth Profile Display

Primary Depth Display

The Primary Depth Display shows the depths of all soundings across and along one second of the swath. Soundings are arranged logically (not by position) as a row per scan of 48 soundings across the row, a white bar between rows indicates a frame boundary. Primary soundings are green and secondary yellow with NBD soundings marked as "NB".

The length of the bar between the integer and decimal values of the depth of each sounding is proportional to the primary (CW) or secondary weighted confidence (CSW) as appropriate.

The operator may scroll forward or backward along the line and position the cursor over soundings for which detailed displays eg. waveform display or sounding audit display are required.

The position, time, frame, row, column and confidences are displayed for the sounding under the cursor.

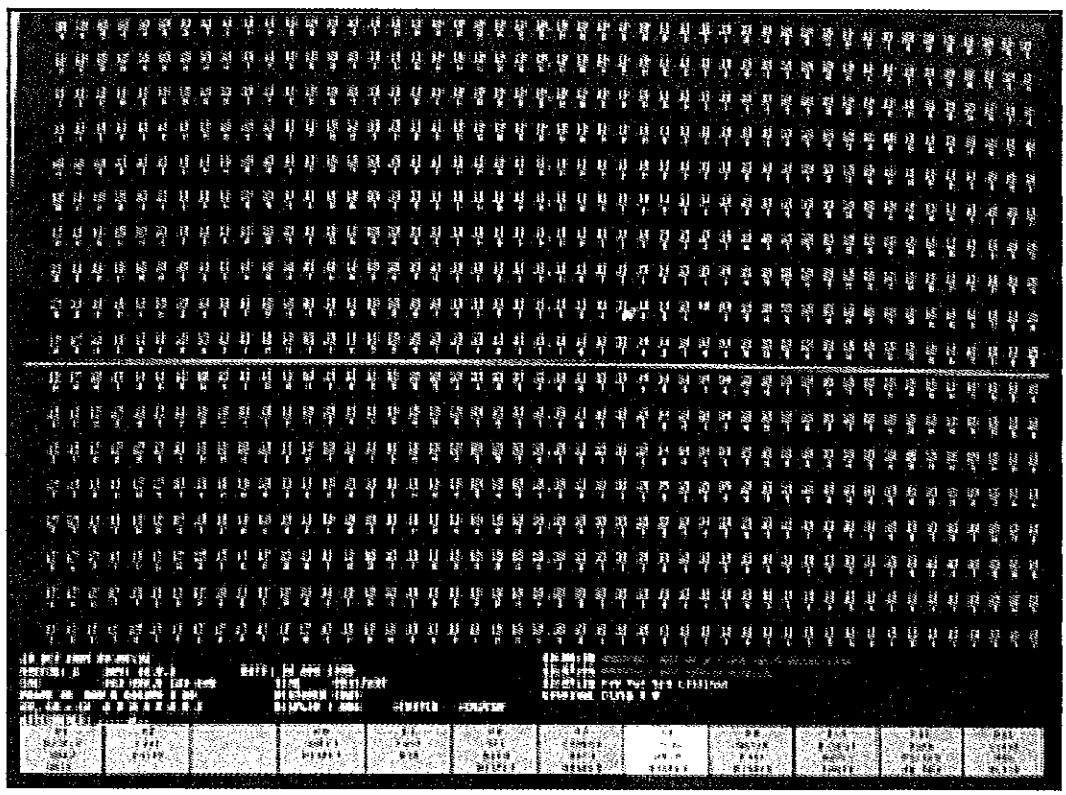


Figure 6 - Primary Data Display

Sounding Waveform Display

The Sounding Waveform Display shows a matrix of nine sounding waveforms centred on the current or nominated sounding. The display is invoked from the primary or waterfall displays and can then be scrolled along or across the swath.
This display allows an operator to assess the actual quality of the data and to resolve or clarify specific sounding values eg. incorrect selection from multiple bottom returns or a false sounding value due to noise in the signal.
Within each waveform window the frame, row, column, gain settings, position, depth, and signal/noise ratio are presented.
A more detailed discussion of the interpretation of waveforms is given in the Laser Waveforms – Nature and Interpretation section.

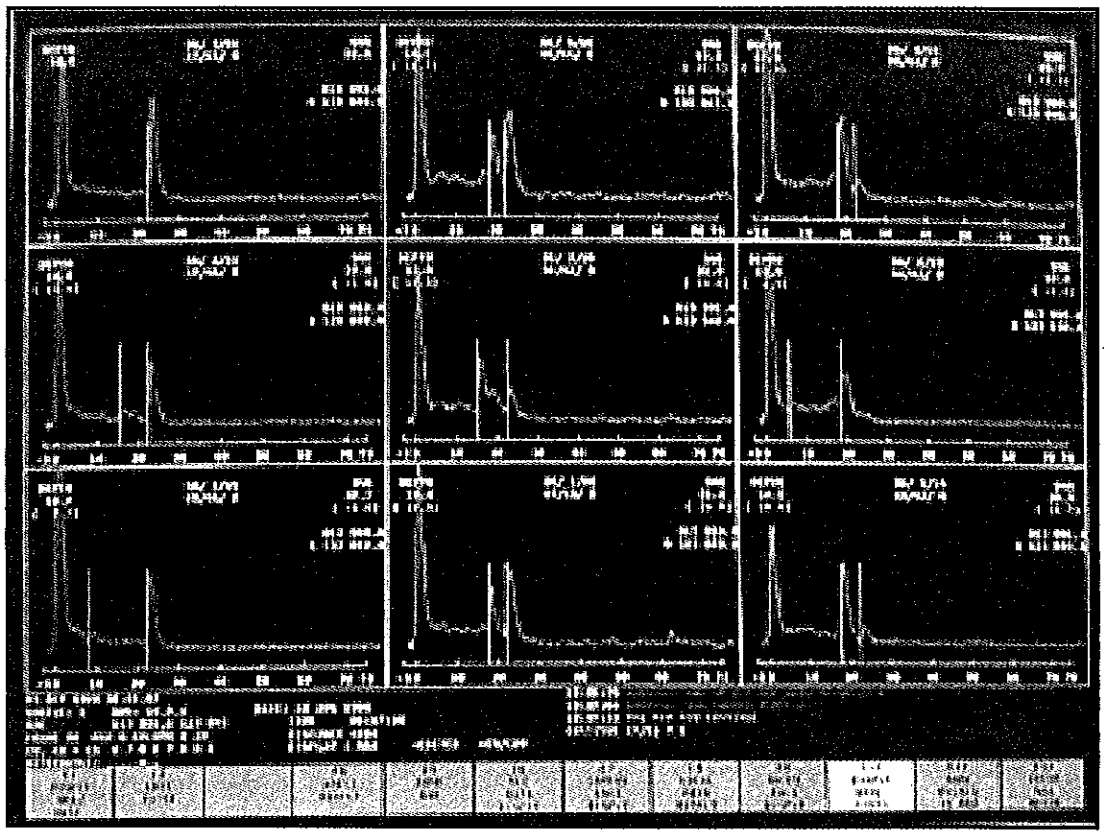


Figure 7 - Sounding Waveform Display for a group of soundings.

Depth Waterfall Display

The Depth Waterfall Display is a pseudo 3-D display constructed from multiple color coded profiles of the depths across each swath for three frames along a line. Secondary soundings are displayed as yellow dots. The operator may scroll forward or back along a line and select an individual sounding for which to invoke the waveform display.

The display allows an operator to gain a general assessment of the shape and nature of the bottom and is particularly good for identifying seafloor objects or anomalous or noisy data.

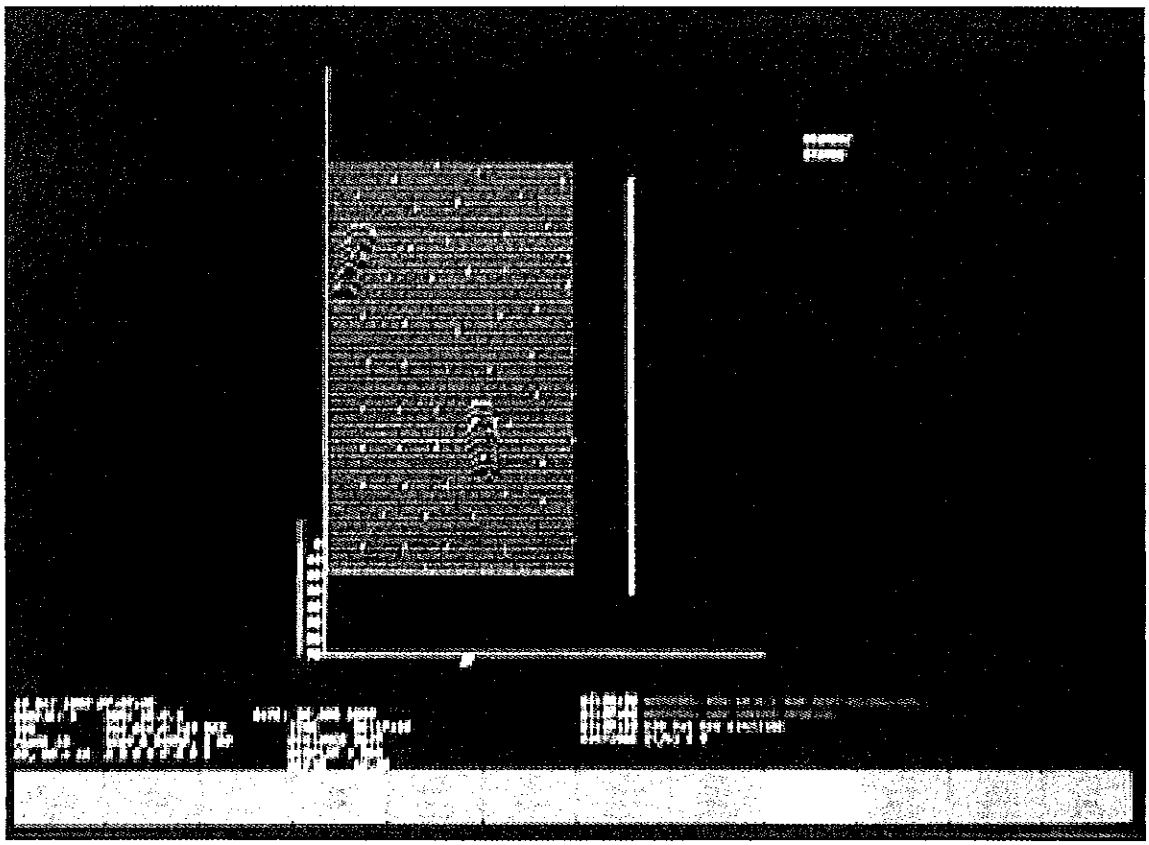


Figure 8 - Depth Waterfall Display

Local Area Display

The local area display is used to check consistency of data across runs.

The display enables the operator to view soundings from the currently selected line and nominated lines that overlap it. Soundings are presented in their true geographic positions and are color banded by depth. Raw waveforms of soundings can also be displayed. In addition, the display facilitates a coverage check of the secondary data at any defined grid size.

The Audit Display

The Audit Display is used to check additional data associated with a sounding. The display enables an operator to check details such as the aircraft height and heading, platform angles, mirror scan angles and tidal reduction of the sounding.

B – Quality Control

Data Processing

Data processing involves the following stages:

- Automatic Data Processing, described earlier.
- Validation of the data by a hydrographic surveyor.
- Checking of the data.
- Visualization of the data.
- Approval of the data.

Validation

Validation proceeds through the following steps:

Examining the Depth Profile for the correct processing of each expected Survey Run.

Examining the Weighted Secondary Confidence (CSW) profile to indicate general areas of good and poor data along the Survey Run.

Examining the Position Confidence (C3) profile to verify that adequate position accuracy is maintained during the Survey Run. Note: Other profiles of supporting data such as EHE, number of satellites, and latency may also be examined as run profiles.

Examining the Coverage Confidence (C6) profile to verify that no coverage gaps exist in the Survey Run.

Resolving anomalous soundings by examining data points in the Survey Run by checking:

a. the Primary Depth Display
b. the Waterfall Display
c. the Waveform Display
d. the Local Area Display

Editing operations include selection of the alternate depth, assignment of NBA or deletion of the sounding as appropriate.

Based on assessments made in the above steps the operator segments the line classifying each segment as:

a. Accepted
b. Anomalous (data not to be used) or
c. Rejected (for refly)

All operator interactions during the Validation phase are logged so that complete traceability is maintained.

Checking

When a line has been validated it is passed to a checker. All edits made by the validator are marked on the line and logged in a validation log. The checker independently assesses the line and checks the validation edits.

Data Visualisation

All validated and approved data is exported from the Ground System in a defined ASCII format for spatial presentation and checking. The position, depth, run and other relevant information are extracted from the line-based data for use in the generation of Triangulated Irregular Networks (TINS) and gridded data sets. Both of these are used to produce contour plots, sun-illuminated colour banded images and coverage check plots. Anomalies found in these plots are reported back to the validators for remedial action in the GS.

A number of software packages are used to produce these QC products namely:

- Generic Mapping Tools (GMT)
- Terramodel package by Spectra Precision Software Inc and
- Visualization Tool Kit (VTK) supplied by Kitware, Inc.

The GMT package is described in:
Wessel, P. and W.H.F. Smith, New, improved version of Generic Mapping Tools released, EOS Trans. Amer. Geophys U., Vol. 79 (47), pp. 579, 1998 and provided by:

The School of Ocean and Earth Science and Technology, University of Hawaii, and
Laboratory for Satellite Altimetry, National Ocean and Atmospheric Administration
http://www.soest.hawaii.edu/gmt.

In turn the GMT package utilises the NetCDF software library produced by:
University Corporation for Atmospheric Research/UNIDATA
Boulder Colorado
http://unidata.ucar.edu.

Terramodel is supplied by:
Spectra Precision Software
5901 Peachtree-Dunwoody Road N.E.
Suite A-300
Atlanta, GA 30328-5548
U.S.A
www.spectraprecision.com

VTK is supplied by:
Kitware, Inc.
469 Clifton Corporate Parkway
Clifton Park, NY 12065
U.S.A: http://www.kitware.com

VTK is described in:
The Visualization Toolkit – An Object-Oriented Approach to 3D Graphics
Will Schroeder, Ken Martin, Bill Lorensen
Prentice Hall PTR 1998

Approval

In the final phase the Survey Team leader assesses each line and all edits made prior to approval of the data.

All actions in validation, checking and approval are logged on appropriate forms and the procedures used have been certified as conforming to ISO-9001 Quality Assurance standards.

Laser Waveforms - Nature and Interpretation

The Sounding Waveform Display (Figure 9) contains the following data:

Graphic of raw laser waveforms showing return from the water surface ① and seabed ② for a matrix of 9 adjacent soundings.

Depth bar showing depth of the seabed ③ and alternative seabed ④ if it exists.

Depth of the seabed ⑤ and alternative seabed ⑥.

Signal noise ratio of the seabed ⑦ and alternative seabed ⑧.

Reference position of sounding in frame/row/column ⑨.

Real time green receiver gain values for sounding measurement ⑩.

Grid coordinates of sounding on the survey spheroid and grid ⑪.

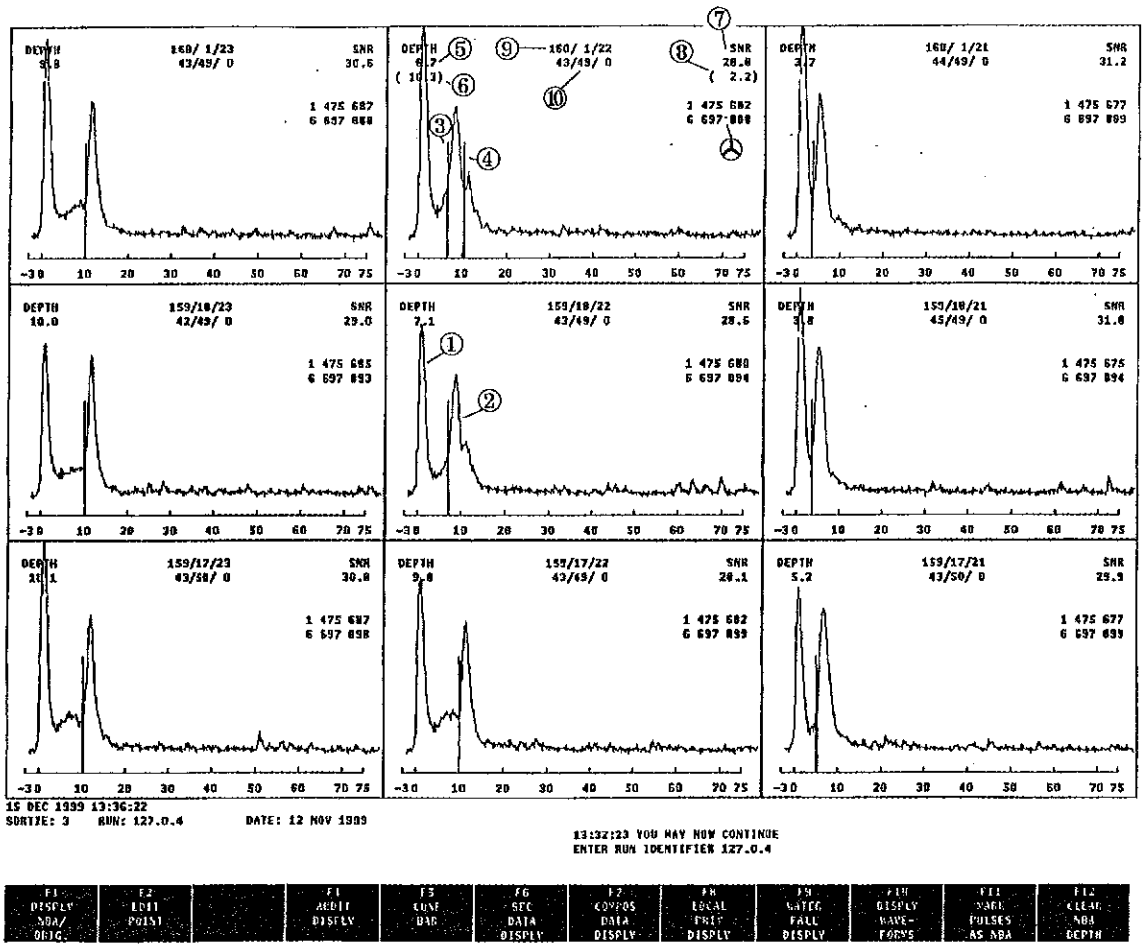


Figure 9 - Annotated Sounding Waveform Display

The raw laser waveform represents the level of energy detected by the green receiver as a function of depth. A surface model, or datum, is then calculated from the infra-red, GPS and inertial (AHRS) heights and filtered green surface returns. The SRP then selects up to two possible seabed returns for each waveform based on signal to noise criteria. If no possible sea bed returns are found the sounding is classified as NBD.

Depths, measured from the surface datum to the 50% point on the leading edge of a seabed return, are calculated for each possible seabed return. These depths are then corrected for the optical path of light through the water and the height of tide.

Where two seabed returns were found the most likely is selected based on S/N versus depth criteria. The selected return is indicated on the waveform display by a white depth bar the other in blue. During validation the operator will check these selections and edit as appropriate.

Objects on the seabed will appear on the raw laser waveform before the seabed. Detection of an object on the seabed will depend on both the density of the scan pattern, backscatter from the water column and the ratio between the level of laser energy reflected from the target and that from the illuminated area of the seabed. The latter is in turn influenced by the size of the target, the depth of water (which effects the area of seabed illuminated) and the reflectance of the target compared with the surrounding seabed.

Backscatter from the water column is received as noise on the raw laser waveform and ultimately limits the maximum depths that can be measured by the system.

Database Management and Survey Line Identification

Sub-Area	Sub-Area Number	Line Spacing (meters)	Run Numbers
Whidbey Island	4	160	600 - 618
Edwards Point	5	160	707
Everett	6	160	803 – 807
Port Gamble	7	160	907
Bainbridge Island	8	160	1007

Run Identifiers

Run identifiers within the LADS Mk II system uniquely define a specific run and are made up of 4 fields separated with a point '.' as follows:

(Items in <> are the generic names for the fields.)

<RunNumber>.<Section>.<Sequence>.<Child>

eg. 523.1.2.3

Maximum fields are
100000.99.99.9

RunNumber – Range 1..100000
This field uniquely defines the run and is chosen by the operator when defining a run.

Section – Range 0..99
This field denotes the section of the run.

Zero indicates the whole original run. When a portion of it is reflown the section number is incremented. Thus:

523.0.x.x is the original run
523.1.x.x is the first part refly and
523.2.x.x is the second part refly.

Sequence – Range 1..99
This field denotes the number of times the logged data for the specific <RunNumber> .<Section> has been processed. Each time a run is processed by the Sortie Run Process (SRP) function the GS allocates a new sequence number for the run. Thus:

523.0.1.x is the first processing of the original run

523.0.2.x is the second processing of the original run

523.1.1.x is the first processing of the first refly and

523.1.2.x is the second processing of the first refly.

Child – Range 1..9
This field denotes the segment (or child section) of a <RunNumber> .<Section>.<Sequence>.

Hydrographic surveyors divide runs into ACCEPTED, REJECTED or ANOMALOUS segments during the Run Validation process. When the run is reconciled these segments are given sequential child numbers. Thus:

523.0.1.1 – is the first child (segment) of the first processing of the original run.

523.1.2.3 – is the third child (segment) of the second processing of the first refly.

The reconciliation process writes the surveyor nominated ACCEPTED, REJECTED or ANOMALOUS flag to each run segment. This provides the mechanism of ensuring only ACCEPTED data is output for products.

Processing Parameters

Each survey line is processed with a specific set of processing parameters, with the set used for the line recorded on the Survey Line History Sheet for the line.

All lines were processed with same set of parameters except for line 600 where the SWA_Turbid_Threshold was increased from the standard 1.5 to 5.0.

C - Data Output

For this survey digital data has been output in LADS Mk II Output Data S3 format. In addition, E, N, depth data is also supplied in simple ASCII format.

There is one OPD file per survey line and these digital files are listed in Section E of Separates - Digital Data.

Details of the smooth sheets and tinned image sheets of all secondary soundings are given in Section D of Separates - Charts, Plots and Graphics.

File naming conventions are detailed in the following sections.

Smooth sheet boundaries in WGS84 UTM-North are provided in the Descriptive Report under Area Surveyed.

LADS Mk II Output Data S3

LADS Mk II Output Data S3 is an ASCII format providing details of the survey spheroid, grid and sounding data positions in latitude longitude and depths in meters. The detailed specification for this format follows this report. File extensions are ".OPD".

Terramodel Smooth Sheets and Tinned Images

The sounding data positions in eastings and northings and depths in meters were extracted from the LADS Mk II Output Data S3 and imported into Terramodel. This data was used to produce the smooth sheets, tinned images and tinned contours.

It should be noted that to produce correctly oriented surfaces used for images the signs of depths and drying heights are inverted (ie. depths negative, heights positive). This is an internal process only and all delivered data and overlayed soundings are in standard hydrographic format with depths positive.

Terramodel XYZ Data

XYZ data in ASCII format (Easting, Northing, Depth in meters, space separated) covering all sheets was exported from Terramodel and is in a single file KP01.pts

File Naming Conventions

Output file names conform to the DOS <file>.<ext> convention where the <file> field is 8 characters long and the <ext> field is 3 characters long.

GS run identifiers are larger than 8 characters and the following is used to overcome this limitation:

File names are of the form KP01<sequence>.OPD where KP01 is the identifier for this survey, <sequence> is a 4 character numeric indicating the sequence in which the files were output and the extension OPD identifies the files as LADS Mk II Output Data.

The file name RUNS.OPD is a 2 column ASCII file that links run identifiers to file names.

For details of the file format refer to Appendix A to this report.

D – Corrections to Soundings

Sounding depths and positions are determined in the Ground System from the raw waveform, aircraft height and platform attitude parameters as logged by the Airborne System.

The GPS antenna laybacks are detailed in the Equipment section.

Tidal and GPS corrections are detailed in the Horizontal and Vertical Control Report.

E – Approval Sheet

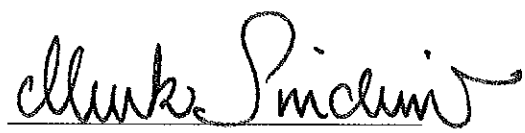
LETTER OF APPROVAL

for

POSSESSION SOUND

This report and the accompanying smooth sheets are respectfully submitted.

Field operations contributing to the accomplishment of the survey were conducted under my direct supervision with frequent personal checks of progress and adequacy. This report and the accompanying smooth sheets have been closely reviewed and are considered complete and adequate as per the Statement of Work.



Mark Sinclair
Hydrographer
Tenix LADS Corporation

Appendix A - LADS Mk II Output Data Specification

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LADS Mark II

DRAFT Format Specification for the Ground System Output Data Function

Document Number: LADS2A05.001.004

Authorised by: _____

Date: _____

Tenix LADS Corporation

Tenix

Amendment Status

As necessary, authorised amendments will be issued to holders of this document. Amendments will take the form of replacement or additional pages.

The amendment status appears at the top right side of each page. For instance, Issue 1.00, where 1 is the Issue and 00 is the Amendment. The next amendment change would appear as 1.01.

Upon receipt, amendment pages are to be inserted in this document and superseded pages removed. For each amendment incorporated, the amendment number, data of incorporation and the signature of the amending officer must be entered in the table below.

Amendment Number	Date Incorporated	Entered By

List of Effective Pages

Page Number	Issue Status	Page Number	Issue Status
Title Page	2.00		
ii	2.00		
iii	2.00		
iv	2.00		
1	2.00		
2	2.00		
3	2.00		
4	2.00		
5	2.00		
6	2.00		
7	2.00		
8	2.00		
9	2.00		
10	2.00		
11	2.00		
12	2.00		

CONTENTS

1. Introduction

1.1 Purpose

The purpose of this document is to specify the format produced by the **Output Data Function** of the Laser Airborne Depth Sounder (LADS) Mk II Ground System (GS).

1.2 Scope

The document applies to the results generated by the **Output Data Function** of the LADS Mk II Ground System.

1.3 Definitions, Acronyms and Abbreviations

1.3.1.1 Definitions

Mission	A mission is defined as a continuous period of operation of the LADS MkII System with the objective of conducting a survey of an area of ocean defined by the customer. Individual survey flights are called sorties.
Easting & Northing	The aircraft position is expressed in metres North and East of the false origin on the Universal Transverse Mercator (UTM) Grid. This implies that a change in easting and northing represents a corresponding movement on the earth's surface expressed in metres. Note: The changes in eastings and northings are related to changes in latitude and longitude via complex translation equations.
Julian Day	The numerical day of the year i.e. January 1 is day 1 and February 28 is day 59.
Soundings	Soundings consist of depth information that results from laser events and, position information corresponding to GPS data. The waveform as seen on the displays is a composite of the Green and IR returns. The soundings, numbered 1 to 48 for each scan, are always numbered from the starboard side.
Survey Run	This is the part of the survey objective where depth soundings are taken.
Fairchart	Hardcopy plot of bathymetric survey data. The soundings appearing on the fairchart are the sub-set of soundings that have the field "Fairchart Selected" set to "Y".
No Bottom At (NBA)	These are secondary soundings where the seabed has not been detected by the Ground System, and a NBA depth has been assigned by a Hydrographic Survey Operator. The depth value assigned is the depth which, in the opinion of the Hydrographic Survey Operator has been swept clear by laser, with depths less than this being detected by the system

1.3.1.2 Acronyms

AS	Airborne System
GS	Ground System
GPS	Global Positioning System
LADS	Laser Airborne Depth Sounder
UTC	Universal Time Co-ordinated
NBA	No Bottom At
UTM	Universal Transverse Mercator
NBD	No Bottom Detected

1.3.1.3 Abbreviations

Nil

1.4 References

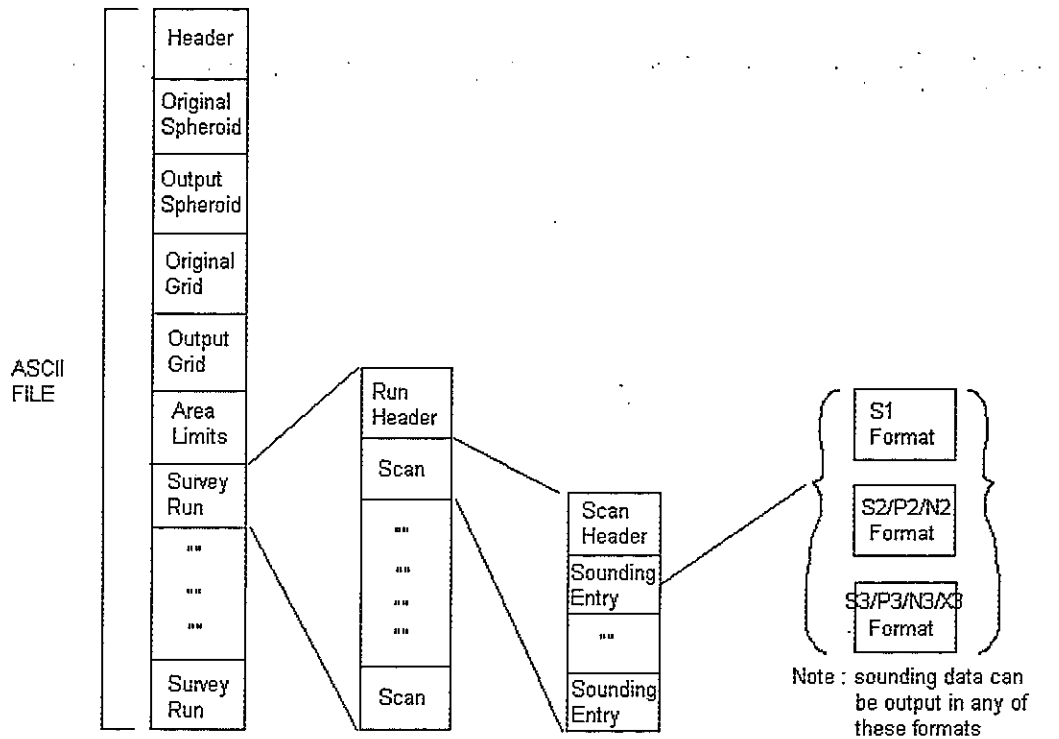
Glossary of LADS Terminology	0006A00005

2. GS Output Format

2.1 Overview

When the **Output Data Function** is run, the results take the form of an ASCII file, the structure of which is shown in Figure 2-1 below. The components that comprise the ASCII file are described in the following sections.

Figure 2-1 Structure of the ASCII file from the Output Data Function



Output Information

2.1.1 Header

The information associated with the **Header** output is listed in Table 2-1 below.

Name	Format	Range	Comments
Header identifier	X(2)	H2	
Specification Issue	F(5,2)		Issue number of the specification
Mission title	X(40)		
Mission ident number	D(3)	1.. 999	
Time of data output	D(7)		Julian date, formatted as dddyyyy
Data scope	X(1)	F,S,P	F – Fairchart Reduced secondary soundings only, S – All secondary soundings, P – All Primary soundings. A – All Primary soundings, including soundings where the sea bed was not found (NBD)
NBA included	X(1)	Y, N	This flag indicates that soundings marked as "No Bottom At" have been included.
Fairchart Reduction radial	D(3)	0 .. 550	Represents the minimum distance in metres between soundings used in the fairchart of this area. Soundings contained in the fairchart are identified with the "fairchart selected" flag in the sounding data. If no reduction processing was performed this value will be 0, and the "fairchart selected" flag will be set true for all soundings.
Position transform applied	X(1)	Y, N	This flag indicates that positions used in this data have been transformed to a spheroid or grid different to that used to collect the data. The values for the original and output spheroid/grid are detailed below.

Table 2-1 Header Output Information

The format of the information associated with the **Header** output is as shown in Table 2-2 below:

Format
X(2) ∧F(5,2) ∧X(40) ∧D(3) ∧D(7) ∧X(1) ∧X(1) ∧D(3) ∧X(1)←

Table 2-2 Format of Header Information

2.1.2 Original/Output Spheroid

The information associated with the **Original/Output Spheroid** output is listed in Table 2-3 below.

Name	Format	Range	Comments
Spheroid entry identifier 1	X(2)	C1,D1	C – Original, D – Output.
Spheroid ident text	X(40)		
Datum identifier	X(30)		
Spheroid entry identifier 2	X(2)	C2,D2	C – Original, D – Output.
Major semi axis	F(10,2)	6_300_000.0 .. 6_500_000.0	
Minor semi axis	F(10,2)	6_300_000.0 .. 6_500_000.0	
Flattening	F(7,2)	250.0 .. 350.0	
Eccentricity	F(14,12)	0.006 .. 0.0075	
Spheroid entry identifier 3	X(2)	C3,D3	C – Original, D – Output.
GPS X offset	F(8,2)	-1000.0 .. 1000.0	The following "GPS" prefixed fields represent the transformation parameters required to move from the WGS84 spheroid to this spheroid.
GPS Y offset	F(8,2)	-1000.0 .. 1000.0	
GPS Z offset	F(8,2)	-1000.0 .. 1000.0	
GPS X rotation	F(10,5)	-206.0 .. 206.0	Uses the Coordinate Axis Rotation sign convention. (ie. rotations effect the axis). A positive rotation is defined as clockwise when viewed from the origin along the axis. (eg for a given position, a positive rotation about the Z axis will result in the transformed position having a longitude with a smaller value)
GPS Y rotation	F(10,5)	-206.0 .. 206.0	see above
GPS Z rotation	F(10,5)	-206.0 .. 206.0	see above
GPS Scale factor	F(8,5)	-1.0 .. 1.0	

Table 2-3 Output Information for Original/Output Spheroid

The format of the information associated with the Original/Output Spheroid **output is as shown in Table 2-4 below:**

Format
X(2) ∧X(40) ∧X(30) ←
X(2) ∧F(10,2) ∧F(10,2) ∧F(7,2) ∧F(14,12) ←
X(2)∧F(8,2) ∧F(8,2) ∧F(8,2) ∧ F(10,5) ∧ F(10,5) ∧ F(10,5) ∧F(8,5) ←

Table 2-4 Format of Original/Output Spheroid Information

2.1.3 Original/Output Grid

The information associated with the **Original/Output Grid** output is listed in Table 2-5 below.

Name	Format	Range	Comments
Grid Entry Identifier	X(2)	F1,G1	F – Original, G – output
Grid ident text	X(20)		
Latitude of true origin	D(3)	-90 .. 90	
Central meridian longitude	D(4)	-180 .. 180	
Zone identifier	X(2)	1 .. 60, SP	1 .. 60 – UTM Zone identifier. SP – identifies a non-standard (special) zone.
False origin easting	D(8)	-5_000_000 .. 5_000_000	
False origin northing	D(9)	-10_000_000 .. 20_000_000	
Central scale factor	F(7,4)	0.5 .. 1.5	

Table 2-5 Output Information for Original/Output Grid

The format of the information associated with the **Original/Output Grid** output is as shown in Table 2-6 below:

Format
X(2) ∧X(20) ∧D(3) ∧D(4) ∧X(2) ∧D(8) ∧D(9) ∧F(7,4) ←

Table 2-6 Format of Original/Output Grid Information

2.1.4 Area Limits

The information associated with the **Area Limits** output is listed in Table 2-7 below.

Name	Format	Range	Comments
Area limits identifier 1	X(2)	L1	
Area limits type	X(4)	GRID or GEO	GRID – grid boundaries were used GEO – geographic boundaries were used
NW corner lat	F(12,8)	-90.0 .. 90.0	
NW corner long	F(13,8)	-180.0 .. 180.0	
NW corner easting	D(8)	-5_000_000 .. 5_000_000	
NW corner northing	D(9)	-10_000_000 .. 20_000_000	
Area limits identifier 2	X(2)	L2	
SE corner lat	F(12,8)	-90.0 .. 90.0	
SE corner long	F(13,8)	-180.0 .. 180.0	
SE corner easting	D(8)	-5_000_000 .. 5_000_000	
SE corner northing	D(9)	-10_000_000 .. 20_000_000	

Table 2-7 Output Information for Area Limits

The format of the information associated with the **Area Limits** output is as shown in Table 2-8 below:

Format:
X(2) ∧X(4) ∧F(12,8) ∧F(13,8) ∧D(8) ∧D(9) ←
X(2) ∧F(12,8) ∧F(13,8) ∧D(8) ∧D(9) ←

Table 2-8 Format of Area Limits Output

2.1.5 Run Header

The information associated with the **Run Header** output is listed in Table 2-9 below.

Name	Format	Range	Comment
Run header identifier	X(2)	R2	
Run identifier	X(14)		The run identifier has a format as follows: Run.section.sequence.child (eg. 100.0.1.1) Where Run = run number Section = section number of main run. Used when a section of the run is reflown. Sequence = identifies the nth flown occurrence of the same run Child = portion of run accepted manually by hydrographic selection
Planned Track	D(3)	0 .. 360	The planned track of the run in degrees, expressed as a grid bearing
Date flown	D(7)		Julian Date, formatted as dddyyyy

Table 2-9 Output Information for Run Header

The format of the information associated with the **Run Header** output is as shown in Table 2-10 below.

Format
X(2) ∧X(14) ∧D(3)∧D(7) ←

Table 2-10 Format of Run Header Output

2.1.6 Scan Header

The information associated with the **Scan Header** output is listed in Table 2-11 below.

Name	Format	Range	Comment
Scan header identifier	X(2)	W1	
Scan Reference Position lat - output spheroid	F(12,8)	-90.0 .. 90.0	Corresponds to position of sounding at column 24 in the Output Spheroid. Expressed in degrees.
Scan Reference Position long - output spheroid	F(13,8)	-180.0 .. 180.0	Corresponds to position of sounding at column 24 in the Output Spheroid. Expressed in degrees.
Time - year	D(4)	0 .. 9999	
Time – Julian Day	D(3)	1 .. 366	
Time – Hour	D(2)	0 .. 23	
Time – Minute	D(2)	0 .. 59	
Time – Second	D(2)	0 .. 59	
Scan Row Number	D(2)	1 .. 18	The Scan Number can be considered as a time component, (1/18th) of a second
Tide Correction	F(6,2)	-20.0 .. 20.0	Represents the tide adjustment made to the observed depth to give the sounding Depth relative to the LAT datum.

Table 2-11 Output Information for Run Header

The format of the information associated with the **Scan Header** output is as shown in Table 2-102 below.

Format
X(2) ∧F(12,8) ∧F(13,8) ∧D(4) ∧D(3) ∧D(2) ∧D(2) ∧D(2) ∧D(2) ∧F(6,2) ←

Table 2-12 Format of Run Header Output

2.1.7 Sounding Entry (S1)

The information associated with the **Sounding Entry (S1)** output is listed in Table 2-11 below.

Name	Format	Range	Comments
Sounding identifier	X(2)	S1,P1,N1	S - secondary sounding, P - primary sounding, N - NBA sounding
Position lat – output spheroid	F(12,8)	-90.0 .. 90.0	Expressed in degrees.
Position long – output spheroid	F(13,8)	-180.0 .. 180.0	Expressed in degrees.
Position easting – output spheroid	D(8)	-5_000_000 .. 5_000_000	
Position northing – output spheroid	D(9)	-10_000_000 .. 20_000_000	
Depth	F(5,1)	-15.0 .. 70.0	
Tide applied	F(5,1)	-20.0 .. 20.0	Represents the tide adjustment made to the collected depth to give the absolute depth. The depth field above contains this adjustment.
Fairchart selected	X(1)	Y,N	Y – indicates that the sounding was selected to be part of a reduced subset of data for use on a fairchart. N – the sounding was not selected. Note that the reduction radial used is provided in the Header information

Table 2-11 Output Information for Sounding Entry

The format of the information associated with the **Sounding Entry (S1)** output is as shown in Table 2-12 below.

Format
X(2) ∧F(12,8) ∧F(13,8) ∧D(8) ∧D(9) ∧F(5,1) ∧F(5,1) ∧X(1) ←

Table 2-12 Format of Sounding Entry Output

2.1.8 Sounding Entry (S2)

The information associated with the **Sounding Entry (S2)** output is listed below in Table 2-13.

Name	Format	Range	Comments
Sounding identifier	X(2)	S2,P2,N2	S - secondary sounding, P - primary sounding, N - NBA sounding
Position lat - original spheroid	F(12,8)	-90.0 .. 90.0	
Position long - original spheroid	F(13,8)	-180.0 .. 180.0	
Position lat - output spheroid	F(12,8)	-90.0 .. 90.0	
Position long - output spheroid	F(13,8)	-180.0 .. 180.0	
Depth	F(5,1)	-15.0 .. 70.0	

Table 2-13 Output Information for Sounding Entry

The format of the information associated with the **Sounding Entry (S2)** output is as shown below in Table 2-14.

Format
X(2) ∧F(12,8) ∧F(13,8) ∧F(12,8) ∧F(13,8) ∧F(5,1) ←

Table 2-14 Format of Sounding Entry Output

2.1.9 Sounding Entry (S3,P3,N3 or X3)

The information associated with the **Sounding Entry (S...X3)** output is listed below in Table 2-13.

Name	Format	Range	Comments
Sounding identifier	X(2)	S3,P3,N3,X3	S - secondary sounding, P - primary sounding, N - NBA sounding X – NBD sounding
Position lat - output spheroid	F(12,8)	-90.0 .. 90.0	Expressed in degrees.
Position long - output spheroid	F(13,8)	-180.0 .. 180.0	Expressed in degrees.
Depth	F(6,2)	-99.9 .. 99.9	Depth to tide datum (includes tide correction)

Table 2-15 Output Information for Sounding Entry

The format of the information associated with the **Sounding Entry (S3)** output is as shown below in Table 2-14.

Format
X(2) ∧F(12,8) ∧F(13,8) ∧F(6,2) ←

Table 2-16 Format of Sounding Entry Output

2.2 Format Legend

The legend for the symbols used in the format tables is shown in Table 2-17 below.

Symbol	Description	Comments
X	Text	
D(max_size)	Integer	Max_size represents the maximum number of characters allowed for the integer, including a leading minus sign if appropriate.
F(max_size,aft_digits)	Float	Max_size represents the maximum number of characters allowed for the float, including a leading minus sign if appropriate. Aft_digits represents the number of digits after the decimal point. Eg " -10.000" would be represented as F(7,3)
^	Field separator	May be comma, space, tab.
←	Line terminator	(may be <CR><LF>, <LF>, <CR>)

Table 2-17 Format Legend

U.S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
NATIONAL OCEAN SERVICE

HORIZONTAL AND VERTICAL CONTROL REPORT

Type of Survey Hydrographic

Field No

Registry No.

LOCALITY

State Washington

General Locality Puget Sound

Sublocality Possession Sound

2001

CHIEF OF PARTY

MARK SINCLAIR

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DATE

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NOAA FORM 77-28 (11-72) | U.S. DEPARTMENT OF COMMERCE NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION | REGISTER NO.

HYDROGRAPHIC TITLE SHEET

INSTRUCTIONS – The Hydrographic Sheet should be accompanied by this form, filled in as completely as possible, when the sheet is forwarded to the Office

FIELD NO.

State WASHINGTON

General Locality Puget Sound

Locality Possession Sound

Scale 1:10,000 Date of Survey 4/28/01

Instructions dated 4/27/01 Project No. NTP Seattle Task Order 2

Vessel LADS Mk II

Chief of Party M.Sinclair

Surveyed by D.Stephenson, N. Hewitt, W. Newsham, G. Rowe, S. Ramsay, R. Curtin

Soundings taken by echo sounder, hand lead, pole Laser Airborne Depth Sounder

Graphic record scaled by N/A

Graphic records checked by Tenix LADS Corporation

Protracted by N/A Automated plot by HP Design Jet 750C

Verification by N/A

Soundings in Meters at MLLW

REMARKS: The purpose of this work was to collect high-resolution lidar data from selected areas in Puget Sound. These areas are inshore between the coastline and the 20 meter isobath. This was a pilot project to link terrestrial airborne laser altimetry with deep water acoustic multibeam bathymetry for geological hazard mapping and research, nearshore aquatic habitat assessment and coastal zone management.

All times are recorded in UTC

TENIX LADS CORPORATION PTY LTD

SECOND AVENUE

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Table of Contents

A – Vertical Control

Tide Gauges

All sounding data was reduced to Mean Lower Low Water using tidal data supplied from the Seattle Tide Gauge, Puget Sound, Washington - Gauge No. 9447130. This information was sourced from the NOAA Web Page (http:/tidesonline.nos.noaa.gov).

Tide data was supplied in Pacific Daylight Saving Time and in decimal feet. This information was then converted to UTC and meters for input to the Ground System for application to soundings.

Tidal Areas

One tide area was created to cover the survey area, and all soundings were reduced using tides from the Seattle gauge.

Sounding Datum

All soundings were reduced to Mean Lower Low Water. The coastline was inserted at the MHW line, which is 3.20 meters (10.49 feet) above MLLW.

Tidal Reductions

A listing of downloaded tides in meters that were applied to sounding data in the Ground System follow:

Date UTC April 28, 2001										
Time UTC	**14:00**	**14:06**	**14:12**	**14:18**	**14:24**	**14:30**	**14:36**	**14:42**	**14:48**	**14:54**
Height (m)	3.029	3.049	3.071	3.090	3.105	3.120	3.132	3.142	3.146	3.149
Time UTC	**15:00**	**15:06**	**15:12**	**15:18**	**15:24**	**15:30**	**15:36**	**15:42**	**15:48**	**15:54**
Height (m)	3.150	3.150	3.145	3.138	3.129	3.116	3.093	3.082	3.054	3.032
Time UTC	**16:00**	**16:06**	**16:12**	**16:18**	**16:24**	**16:30**	**16:36**	**16:42**	**16:48**	**16:54**
Height (m)	3.002	2.974	2.940	2.903	2.862	2.828	2.783	2.738	2.690	2.639
Time UTC	**17:00**	**17:06**	**17:12**	**17:18**	**17:24**	**17:30**	**17:36**	**17:42**	**17:48**	**17:54**
Height (m)	2.589	2.534	2.478	2.424	2.363	2.297	2.236	2.163	2.098	2.023
Time UTC	**18:00**	**18:06**	**18:12**	**18:18**	**18:24**	**18:30**	**18:36**	**18:42**	**18:48**	**18:54**
Height (m)	1.953	1.877	1.802	1.721	1.643	1.558	1.478	1.402	1.311	1.232
Time UTC	**19:00**	**19:06**	**19:12**	**19:18**	**19:24**	**19:30**				
Height (m)	1.148	1.066	0.983	0.902	0.823	0.743				

B – Horizontal Control

Geodetic Control Stations

Racal Skyfix

Throughout the survey real-time positioning of the LADS Mk II system was derived from an Ashtech GG24 GPS receiver. WADGPS corrections from the Vancouver Skyfix reference station were received using the Racal LandStar system and applied to the position in real-time. Both the Vancouver and Portland Racal Skyfix stations were used during the static position check.

The WGS 84 coordinates for the Vancouver Skyfix reference station are:

	Latitude	Longitude	Spheroidal Height
Vancouver	49° 11' 00.7121" N	123° 04' 20.9983" W	-8.535 meters

A full station description of the site is rendered at Enclosure 1.

Differential GPS Reference Station

A DGPS reference site was coordinated by LCMF Incorporated on the roof of the Silver Cloud Inn, University Village, Seattle. Mr John Oswald, LCMF Inc. Geodetic Manager conducted the coordination of the site. A DGPS reference station was then established on this site by Tenix LADS Corporation personnel. This was used to determine post-processed DGPS and C/A code + carrier phase smoothed positions which were applied to all soundings.

In addition, three points were surveyed at the temporary parking bay on the Galvin Flying Service apron at Boeing Field. The points were surveyed by static GPS techniques and marked by pink colored paint. These points were used for the static position check. The reference station and static position check points were coordinated on April 16, 2001 using dual frequency Ashtech Z Surveyor GPS receivers with L1/L2 Ashtech antennae. The DGPS reference site was occupied by the dual frequency antenna for approximately 5 hours and position data was logged at 5 second epochs. The three static position checkpoints were occupied for more than 30 minutes each. Data from three nearby CORS stations was processed against the same logging period to solve for the position of the DGPS reference site and three points. The accuracy of the CORS stations are quoted to be Order A – 1:1,000,000. The accuracy of these control points was suitable to achieve a computed accuracy for the reference station of 5-Centimeter or better under the accuracy standards of the FGDC Standards for Geodetic Networks.

The derived WGS 84 coordinates for the LADS Differential GPS reference station are:

Latitude	47° 39' 56.7260" N
Longitude	122° 18' 00.8060" W
Spheroidal Height	2.68 meters

The LCMF Incorporated report on the coordination of the differential GPS reference station at the Silver Cloud Inn, University Village, is presented as Enclosure 2.

Three Point Control Network

The spheroid / datum used for computations of the static position check was WGS 84. These positions were projected onto a UTM (N) Zone 10 grid for plane distance measurements.

Point	UTM Zone 10 Easting	UTM Zone 10 Northing	WGS 84 Latitude (N)	WGS 84 Longitude (W)
C1	552 768.110	5 264 369.820	47° 31' 50.1981"	122° 17' 56.1989"
N1	552 786.699	5 264 388.111	47° 31' 50.7851"	122° 17' 55.3020"
S1	552 802.786	5 264 359.494	47° 31' 49.8535"	122° 17' 54.5450"

Derived Static Position Check Point

The LADS Mk II aircraft was positioned with the laser bay window within the three point control network on the tarmac on a grid heading of 059°, which was determined from the Ground Compass Alignment using the LADS Mk II AHRS. The position of the laser source was plumbed onto the tarmac and clearly marked. The distance between this point and the three control points was then measured with a tachometric tape. Using the measured distances from each of the control points, three solutions for the position of the laser source were calculated. The mean of these solutions was taken and adjusted for the GPS antenna offset and aircraft heading. This gave the reference coordinates for the comparisons of the static position check on the aircraft GPS antenna.

The derived coordinates for the GPS antenna position during the static position check:

	WGS 84		UTM Zone 10
Latitude	47° 31' 50.3400" N	Easting	552 787.983
Longitude	122° 17' 55.2465" W	Northing	5 264 374.381

The field notes on the determination of the aircraft GPS antenna position are provided in Enclosure 3.

Positioning System Confidence Checks

Position Fixing Systems

Throughout the survey real-time position of the LADS Mk II system was derived from an Ashtech GG24 GPS receiver. WADGPS corrections were received via the Racal LandStar system from the Vancouver Skyfix reference station.

Post-processed DGPS and Coarse Acquisition (C/A) code + carrier phase position data was obtained by simultaneous PNAV data logging throughout each survey sortie with two Ashtech GG24 GPS receivers. The base receiver was located at the coordinated differential GPS reference station at the Silver Cloud Inn, University Village, and the roving receiver onboard the aircraft. The application of PNAV forward and backward post-processed code + carrier phase position data to all survey lines was undertaken following the sortie.

Differential GPS Reference Site Confirmation

A 24-hour reference station check was performed to ensure that no multipath or site specific problems existed at the LADS Differential GPS reference station on the rooftop of the Silver Cloud Inn, University Village.

Once the DGPS reference station was established and coordinated by the LCMF surveyor, a remote site was set up 1.565m NE of the reference station. The remote antenna was mounted on a tripod and connected to the Ashtech GG24 GPS reference receiver. Simultaneous data logging took place at the reference and remote site continuously for 23 hours and 47 minutes. At both the reference and remote receivers the data capture rate was set to 1 second, the minimum number of satellites set to 4 and the elevation mask to 8 degrees.

Taped distance between reference and remote antennae	= 1.565 m
Observed PNAV C/A code (DGPS) distance between reference and remote antennae	= 1.529 m
Horizontal standard deviation of positions (2σ)	= 0.322 m
Observed PNAV C/A code + carrier phase smoothed distance between reference and remote antennae	= 1.574 m
Horizontal standard deviation of positions (2σ)	= 0.016 m

The DGPS Verification Data (included in the Separates Section) contains the scatter plots for the DGPS reference station site confirmation. The results above and scatter plots produced reflect that the LADS differential GPS reference site at the Silver Cloud Inn, University Village, is free from site specific problems such as multipath or signal obstructions.

Static Position Check

Static positioning checks were conducted for the following GPS positions:

a.	GPS	: Stand-alone (real-time)
b.	WADGPS	: Racal Wide Area Differential GPS (real-time) - Vancouver Reference Station - Portland Reference Station
c.	DGPS	: Post-processed smoothed C/A-code phase (off line)
d.	Code + Carrier	: Forward and backward processed L1-only code + carrier phase, float ambiguities (off line)

All logging and comparisons for the static position check were relative to the WGS 84 spheroid, UTM (N) grid using Central Meridian 123° W.

On April 19, 2001, a static position check of the LADS Mk II positioning systems was undertaken using the three point control network on the Galvin Flying Service apron at Boeing Field. Three sessions of observations took place, one using real-time stand-alone GPS and two using Racal LandStar data. In addition, during these periods the PNAV roving receiver at the aircraft logged data simultaneously with the coordinated differential GPS reference station at the Silver Cloud Inn, University Village. Post-processing of this data provided code only (DGPS) and code + carrier phase solutions for the position of the aircraft GPS antenna.

Summary of Results

The following table shows the comparison of different GPS static solutions for the position of the aircraft GPS antenna:

Positioning System	Easting	Northing
Absolute Position of GPS Antenna	552 787.983	5 264 374.381

SESSION 1	Easting +/- Std Dev (2σ)	Northing +/- Std Dev (2σ)	Δ East C - O (m)	Δ North C – O (m)	Absolute Accuracy (95%)
AS Stand Alone GPS	552 786.161 +/- 1.739	5 264 375.196 +/- 3.622	1.822	-0.815	6.014
PNAV DGPS	552 788.294 +/- 0.333	5 264 374.553 +/- 0.241	-0.311	-0.172	0.766
PNAV Code + Carrier	552 787.920 +/- 0.022	5 264 374.435 +/- 0.014	0.063	-0.054	0.109

SESSION 2	Easting +/- Std Dev (2σ)	Northing +/- Std Dev (2σ)	Δ East C - O (m)	Δ North C – O (m)	Absolute Accuracy (95%)
AS WADGPS PORTLAND	552 787.095 +/- 1.115	5 264 375.522 +/- 1.239	0.888	-1.141	3.113
PNAV DGPS	552 787.792 +/- 0.131	5 264 374.500 +/- 0.365	0.191	-0.119	0.613
PNAV Code + Carrier	552 787.968 +/- 0.031	5 264 374.409 +/- 0.024	0.015	-0.028	0.071

SESSION 3	Easting +/- Std Dev (2σ)	Northing +/- Std Dev (2σ)	Δ East C - O (m)	Δ North C – O (m)	Absolute Accuracy (95%)
AS WADGPS VANCOUVER	552 787.355 +/- 1.025	5 264 374.129 +/- 1.188	0.628	0.252	2.246
PNAV DGPS	552 787.804 +/- 0.521	5 264 374.341 +/- 0.337	0.179	0.040	0.803
PNAV Code + Carrier	552 787.942 +/- 0.014	5 264 374.443 +/- 0.020	0.041	-0.062	0.098

Session 1

Session 1 data logging commenced on the differential GPS reference station at the Silver Cloud Inn, University Village at 0700 (PDT) Thursday April 19, 2001. The PNAV roving receiver commenced logging on the aircraft approximately one hour later. Session 1 used

stand-alone GPS as the positioning system for the Airborne System (AS). The GPS only position solution was recorded on Digital Linear Tape using the GPS manual logging function on the AS. This position check period ran for 67 minutes. The roving receiver was shut down following the termination of the GPS manual logging on the AS.

Session 2

The roving receiver commenced recording PNAV data a short time before AS logging. The Airborne System was set to receive differential corrections from the Portland Skyfix Station (561), approximately 230 km away. Portland had been determined to be the secondary real-time positioning system if corrections were unavailable from Vancouver during a sortie. Position data was recorded on DLT using the GPS manual logging function on the AS. The recording period was approximately 98 minutes. The roving receiver was shut down following the termination of the GPS manual logging on the AS.

Session 3

The roving receiver commenced recording PNAV data following shut down after Session 2. Session 3 and subsequent sorties used real-time differential corrections from the Vancouver LandStar station (505), approximately 190 km away, as the positioning system for the AS. The Racal LandStar WADGPS position solution was recorded on DLT using the GPS manual logging function on the AS. This position check period was for 122 minutes. The PNAV logging was prematurely terminated after one hour of logging when both the DGPS reference station and roving receiver locked up at precisely the same time. The coincident timing of the failure was attributed to a common GPS error.

Observations

The observation periods were as follows:

Session	Start Time (UTC)	Stop Time (UTC)	Logging Duration	Average PDOP	Average GPS Satellites
Session 1 Stand Alone GPS	15:32:53	16:40:10	1 hr 07 min	2.9	6
Session 2 WADGPS Portland	16:46:26	18:24:02	1 hr 38 min	2.4	6
Session 3 WADGPS Atlanta	18:27:52	20:30:17	1 hr 37 min	2.1	7

The Airborne System GPS observables were recorded manually every ten minutes. Factors such as the number of GPS satellites used, PDOP, AS Easting and Northing were all observed and recorded.

Session 1 – Stand Alone GPS

UTC Time (PDT + 7)	GPS Satellites	PDOP	WGS 84 UTM Zone 10	
			Easting	Northing
15:30	6	3.2	552 785	5 264 371
15:40	6	3.2	552 786	5 264 374
15:50	7	3.0	552 787	5 264 376
16:00	6	2.9	552 786	5 264 377
16:10	6	2.8	552 786	5 264 376
16:20	6	2.8	552 786	5 264 375
16:30	7	2.1	552 785	5 264 373
Mean	6	2.7	552 786	5 264 375

Session 2 – WADGPS Portland

UTC Time (PDT + 7)	GPS Satellites	PDOP	WGS 84 UTM Zone 10	
			Easting	Northing
16:50	6	2.8	552 787	5 264 374
17:00	7	2.0	552 787	5 264 376
17:10	7	1.9	552 787	5 264 375
17:20	6	2.9	552 787	5 264 375
17:30	6	2.6	552 787	5 264 375
17:40	6	2.4	552 787	5 264 376
17:50	6	2.2	552 788	5 264 374
18:00	7	1.8	552 787	5 264 375
18:10	6	2.6	552 786	5 264 375
18:20	6	2.5	552 787	5 264 375
Mean	6	2.4	552 787	5 264 375

Session 3 – WADGPS Vancouver

UTC Time (PDT + 7)	GPS Satellites	PDOP	WGS 84 UTM Zone 10	
			Easting	Northing
18:30	6	2.3	552 786	5 264 374
18:40	8	1.5	552 787	5 264 373
18:50	7	1.8	552 789	5 264 374
19:00	7	1.9	552 787	5 264 374
19:10	7	2.1	552 787	5 264 373
19:20	7	2.2	552 787	5 264 374
19:30	7	2.3	552 788	5 264 372
19:40	7	2.3	552 787	5 264 373
19:50	7	2.2	552 787	5 264 373
20:00	7	2.2	552 789	5 264 375
20:10	7	2.2	552 787	5 264 375
20:20	7	2.2	552 787	5 264 374
20:30	7	2.1	552 788	5 264 374
Mean	7	2.1	552 787	5 264 374

Processing

The DGPS and code + carrier phase solution files were produced by processing the reference station file and the aircraft file with Ashtech PNAV software. The DGPS solution file is produced by applying differential corrections at each epoch. The code + carrier solution file is produced by solving for the carrier phase ambiguity and using double differencing, forward and backward processing techniques. Both the stand-alone GPS file and the WADGPS files are produced in real-time on the Airborne System and the solution is logged directly to DLT. The Ground System then processes the files using the Position Analysis Software (PAS).

Results

The processed position files were exported to a commercial spreadsheet/graphical based software package where calculations of means and standard deviations were achieved and scatter plots produced. The stated theoretical accuracy of each of the positioning systems and the practical accuracy achieved by LADS Mk II during previous surveys has been compared against the absolute accuracy achieved during the static position check in the following tables:

Positioning System	Baseline Distance (km)	Theoretical GPS Accuracy (m) (95% confidence)	Absolute Accuracy (m) (95% confidence)	Notes
WADGPS SEATTLE Vancouver	190	1.76	2.25	1
WADGPS SEATTLE Portland	230	1.91	3.11	2
FLORIDA – Tampa Session 1	310	2.22	3.92	
FLORIDA – Tampa Session 2	310	2.22	3.57	
FLORIDA – Atlanta	900	4.52	9.10	
W. AUST – Dampier	9	1.05	1.49	
W. AUST – Broome	650	3.55	5.70	
S. AUST – Adelaide	40	0.78	1.21	
S. AUST – Melbourne	691	3.71	8.32	
FINLAND – Helsinki	160	1.32	3.72	
FINLAND – Copenhagen	780	4.11	6.89	
NORWAY – Helsinki	820	4.29	5.59	
NORWAY – Bronnoysund	240	1.68	3.59	
NORWAY – Copenhagen	870	4.52	4.65	
NZ – Auckland	1200	6.00	5.96	

1. The theoretical accuracy of the Racal LandStar positioning system has been calculated from data supplied by Racal based on empirical tests over 24 hour logging periods. As the logging period for each of the static position check sessions was no more than 2 hours in duration, the observed accuracy would be expected to be slightly less accurate than the calculated theoretical accuracy. In addition, it can be seen from the historical results in the above table that the absolute accuracy falls between 1 and 2 times the theoretical accuracy. WADGPS corrections from Vancouver were used in real-time to control the aircraft navigation during the survey.

2. The absolute accuracy of the Portland WADGPS corrected position was outside the theoretical accuracy. This is believed to be due to two factors; the limited logging duration (~100 minutes) and the low number of satellites observed during this period. The number of satellites directly affects satellite geometry, of which PDOP is a measure. This session resulted in an average PDOP of 2.4, versus 2.1 for the Vancouver session. An average number of six GPS satellites were used in the position solution during this session.

Positioning System	Baseline Distance (km)	Theoretical GPS Accuracy (m) (95% confidence)	Absolute Accuracy (m) (95% confidence)	Notes
DGPS Session 1	15	3.93	0.77	1
Code + Carrier Session 1	15	1.23	0.11	2 , 3
DGPS Session 2	15	3.93	0.61	1
Code + Carrier Session 2	15	1.23	0.07	2 , 3
DGPS Session 3	15	3.93	0.80	1
Code + Carrier Session 3	15	1.23	0.10	2 , 3

1. The DGPS solution was well within the theoretical accuracy. Of the three static position check sessions, the maximum 95% confidence limit was 0.80 meters.

2. This solution may be affected slightly by the aircraft not being totally static during the data logging. The precision of the static position check is affected by wind and personnel movements within the aircraft. It is estimated that the position of the aircraft GPS antenna may move up to 10-15 centimeters at times during data logging due to these movements.

3. The code + carrier phase solution was the most accurate and well within the theoretical accuracy. The 95% confidence limit was equal to or less than 0.11m over the three sessions.

Positioning System	Baseline Distance (km)	Theoretical GPS Accuracy (m) (95% confidence)	Absolute Accuracy (m) (95% confidence)	Notes
Stand Alone GPS	-	14.6	6.01	1
FLORIDA GPS	-	14.6	12.83	
W. AUST GG	-	14.6	20.17	2
S. AUST GG	-	14.6	31.88	2
NEW ZEALAND GG	-	14.6	19.40	2
FINLAND GG	-	14.6	35.18	2

Notes

1. Stand-alone GPS was well within the 95% confidence limit, but less accurate than WADGPS corrected positions. Stand-alone GPS was not used for the real-time positioning of the aircraft.

2. GG = GPS / GLONASS solution. This solution has not been used by LADS Mk II since selective availability (SA) was switched off on May 1 2000. Tests were undertaken on stand-alone GPS using a GPS only and a combined GPS / GLONASS solution. The results of these tests confirmed that the ephemeris data from GLONASS satellites is less accurate than GPS satellites post SA.

A compilation of scatter plots illustrating the spread of solved positions for each positioning system is provided in the DGPS Verification Data (included in the Separates Section). These graphs show the mean point of recorded positions and the position of the actual antenna as determined by the three-point control network coordination and trilateration survey.

Conclusion

The accuracy of the logged WADGPS Vancouver position solution was close to the theoretical accuracy and was sufficient for the real-time positioning of the aircraft. The Portland reference station produced less accurate data than expected, but this station was not used during the survey.

The accuracy achieved by the DGPS positioning system was well within the theoretical accuracy. The code + carrier phase positions yielded the most accurate results and this positioning solution was subsequently applied to all survey lines flown during the survey.

The checks of the five systems show that there are no gross errors in an absolute sense. Most importantly, the static position check demonstrated that the post-application of C/A code + carrier phase positions produced by forward and backward processing with the PNAV utility is the most accurate.

Dynamic Position Check

During the sortie, GPS data was logged on the aircraft and at the DGPS reference station which enabled DGPS and code + carrier positions to be determined (off-line). These result files were then compared to the position as determined by the real-time WADGPS. For each survey line the mean difference and standard deviation have been calculated. The following table shows the mean and standard deviation of the difference in position between the real-time WADGPS from the Vancouver reference station and the post-processed code + carrier for the sortie.

Sortie No.	Max. Difference AS – Code + Carrier (m)	Mean Difference AS – Code + Carrier (m)	Overall Mean Standard Deviation (m)
7	3.39	1.03	0.16

These results show very good agreement between the WADGPS real-time position and the post-processed code + carrier position which was applied to all sounding lines. The dynamic monitoring reports and graphs for the sortie are provided in DGPS Verification Data (included in the Separates Section).

C – Accuracy of Horizontal Positioning of Soundings

Theoretical Accuracy

Theoretical accuracy of the positioning solutions are a function of the distance of the GPS receiver from the base station. The relationship between baseline distance and theoretical accuracy was provided by Ashtech and Racal Survey, and is based on empirical data.

Racal LandStar

Empirical tests undertaken on the GG24 receiver by Racal Survey U.K. have detailed the horizontal standard deviation of positions obtained with LandStar corrections at varying baseline distances. The expected error has been determined to be 1.01m +. 1.4ppm. These standard deviations define the repeatability of the position fixes at various ranges. Racal further advise that the user should also be aware of the following: "DGPS systems are single frequency systems: the DGPS corrections are corrections to the users pseudo-ranges, which are only available on the L1 frequency. Due to this, ionospheric delays cannot be corrected for, and this will cause a bias in the position. This bias is typically about 20-25 centimeters per 100 km, and will be in the same direction as the 'baseline' between reference station and user. Therefore if corrections are taken from a DGPS station due north, the position will be consistently out in latitude. The height is affected little by this. This is a general limitation of DGPS systems, since they are single frequency systems". During periods of high sun spot activity and at latitudes close to the equator it is determined to be 2.5ppm (25cm per 100 km).

The combination of these cumulative bias predictions in the base and roving receivers has led to an expected horizontal accuracy of:

$$\text{WADGPS} = 1.01 + 1.4\text{ppm} + 2.5\text{ppm} = 1.01 + 3.9\text{ppm}$$

This equation as determined by Racal is considered optimistic as the tests were conducted in ideal conditions over a 24 hour logging period. The baseline distance from the Vancouver Skyfix reference station to the survey area is approximately 180 km. Therefore the expected accuracy for the real-time positioning of the aircraft was 1.72 meters.

Ashtech PNAV

The post-processed PNAV positional data has a different theoretical accuracy. This has been determined from the Ashtech PNAV Software User's Manual and through consultation with Ashtech. For a PDOP of less than 4 the following PNAV data processing accuracy has been quoted:

Smoothed C/A-code phase (DGPS) = 1-3 meters
= 3m + 2ppm (worse case)

L1-only C/A code + carrier phase, float ambiguities	=	Best results (0.05 - 0.3 meters overall) can be achieved by forward and backward processing
	=	0.3m + 2ppm (worse case)

The inherent receiver noise is quoted to be constantly 0.9 meters. Therefore, factoring in the inherent receiver noise error of 0.9m, the expected horizontal accuracy of the two processing techniques are:

Smoothed C/A-code phase (DGPS)	=	+0.9 + 3 + 2ppm = 3.9 + 2ppm
L1-only C/A code + carrier phase, float ambiguities, forward and backward processing	=	+0.9 + 0.3 + 2ppm = 1.2 + 2ppm

The maximum baseline distance between the LADS Differential GPS reference station and the survey area is approximately 20 km. Therefore the expected accuracy of the post-processed solutions are:

C/A Code (DGPS)	=	3.94 meters
C/A code + carrier phase	=	1.24 meters

Practical Accuracy

The actual performance of the positioning solutions was checked by the static position and dynamic position checks.

The total expected error of the LADS Mk II system is a combination of the following errors:

a. GPS errors (Egps), as previously stated, have a theoretical maximum of ± 1.24m (95% confidence code + carrier phase).

b. Errors in assigning frame centre reference positions from GPS fixes (Eframe ref) have been assessed as ± 0.66 meters (95%).

c. Platform and laser positioning errors (Eplat, this includes such errors as gimbal angles, optical alignment, AHRS angles, AHRS mount, Optical Coupler mount, Scanner mount, Laser output, Laser mount, Major, Minor and Delta scan mirrors, timing and aircraft height). The resultant error in position has been assessed as ± 2.14 meters (95%).

d. Position errors of detecting objects due to the distance between laser spots (Espot). With a 4m laser spot spacing it is considered the worse case for the position is ± 2.0 meters based on the sample interval.

e. Sea surface errors (Esurface) due to swell. These are variable and dependant on the angle of incidence of the laser beam at the air/sea boundary, the depth of water and sea state. They have been assessed to be:

Depth	Sea State	1	2	3	4
5		0	0.03	0.31	0.55
10		0.01	0.06	0.62	1.10
15		0.01	0.09	0.93	1.65
20		0.02	0.12	1.24	2.20

Total Expected Error $= ((Egps)^2 + (Eframe\ Ref)^2 + (Eplat)^2 + (Espot)^2 + (Esurface)^2)^{½}$

Taking the worst case scenario, at the most easterly point of the survey area from the DGPS reference station, in a depth of 20m, with Sea State 2, the total error is expected to be:

Total Expected Error $= ((1.24)^2 + (0.66)^2 + (2.14)^2 + (2.00)^2 + (0.12)^2)^{1/2}$
$= 3.3$ meters at the 95% confidence level.

Analysing the positional data obtained from both the static and dynamic position checks it has been concluded that during the survey IHO Order 1 precision for position was achieved.

GPS Positional Accuracy - Summary

Static Position Check

Mean Absolute Accuracy of PNAV code + carrier (3 sessions, 15km baseline) = 0.09 m

Maximum Absolute Accuracy of PNAV code + carrier = 0.11 m

Dynamic Position Check

Mean value of range distances over all lines of survey
between Racal WADGPS and PNAV code + carrier positions = 1.03 ± 0.16 m (1σ)

Maximum value of range distance at one epoch for all lines of survey
between Racal WADGPS and PNAV code + carrier positions = 3.39 m

LADS Mk II System Positional Accuracy

Theoretical Accuracy

Maximum (Depth = 20m, Sea State 1, Baseline 20km)	= 3.3m
IHO Order 1 Horizontal Accuracy (95% confidence)	= 5 meters + 5% of the depth
Survey Horizontal Accuracy (95% confidence)	= better than 4 meters

Enclosures:

The following enclosures are provided:

Enclosure 1 - Vancouver Skyfix station description.

Enclosure 2 - LCMF Inc. report on the coordination of the LADS DGPS reference station and three point control network.

Enclosure 3 - Field notes of the determination of the aircraft GPS antenna position for the static position check

D – Approval Sheet

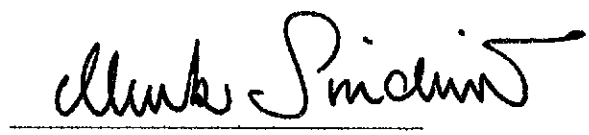
LETTER OF APPROVAL

for

POSSESSION SOUND

This report and the accompanying smooth sheets are respectfully submitted.

Field operations contributing to the accomplishment of the survey were conducted under my direct supervision with frequent personal checks of progress and adequacy. This report and the accompanying smooth sheets have been closely reviewed and are considered complete and adequate as per the Statement of Work.



Mark Sinclair
Hydrographer
Tenix LADS Corporation

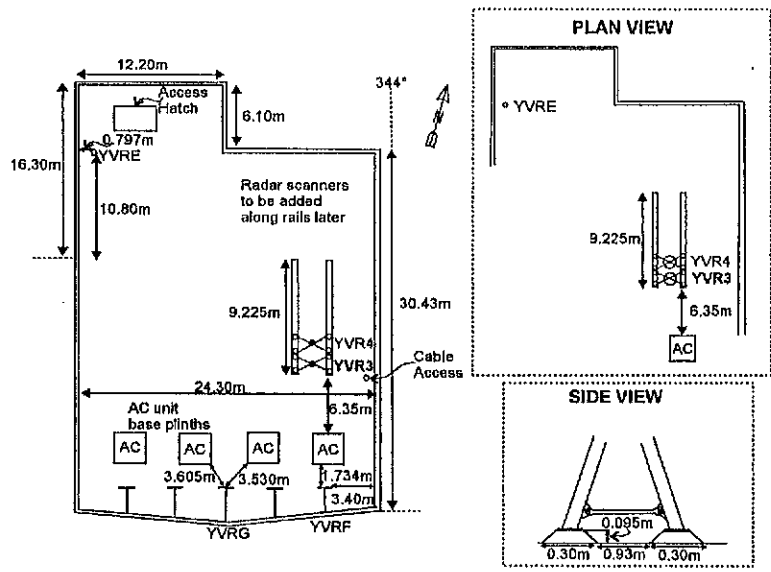
Enclosure 1

Vancouver Skyfix station description

SURVEY STATION DESCRIPTION

COUNTRY	STATION NAME		STATION TYPE
CANADA	VANCOUVER SYSTEM 1		ANTENNA
Area Region BRITISH COLUMBIA		**Additional Names:** YVR3	
SkyFix ID No: 0505	**Co-ordinates System 1**	**Co-ordinates System 2**	**Grid Co-ordinates System 2**
Datum	ITRF92(Epoch 94.0)		**Proj/Grid**
Spheroid	WGS84		
Latitude	49° 11' 00.71207" N		**East**
Longitude	123° 04' 20.99830" W		**North**
Spheroidal Height	-8.535m		**Height**
X	-2279390.164m		
Y	-3500248.656m		
Z	4803918.267m		
Geoid Separation			**Geoid Model**
Elevation			
Date of Survey	Apr-99	**Date of Latest Revision**	17 June 1999
Source of Co-ordinates	L1 Phase Carrier Phase GPS relative to YVRG.		
Description of Station Mark	L1 Phase Centre of Compact Dome Antenna.		

STATION DIAGRAM



Surveyor	J. Taylor	Checked	M. Kellett

STN/084/17th June 1999/MK

Page 1 of 1

Enclosure 2

Coordination report of LADS DGPS reference station and three point control

April 18, 2001

Bob Richards
Thales Geosolutions Inc.
911 W. 8th Avenue
Anchorage, Alaska 99501

Bob:

This is the preliminary documentation of the GPS survey done in Seattle, Washington performed in support of the Tenix LADS testing. I will forward a final report with additional documentation next week.

Scope: Establish NAD 1983 coordinates and ellipsoid heights at four stations in Seattle, Washington. One station on rooftop of Silver Cloud Hotel at 25th Ave NE and Blakeley St to be used by LADS for a DGPS station during lidar flights. Establish three stations in a small triangle on the tarmac of Boeing Field. When the LADS Dash 8 aircraft arrives from the east coast, it will be parked in the vicinity of these tarmac points, which will be used to transfer precise values to the reference point of the onboard aircraft navigation system. All GPS units are Ashtech Z Surveyors, dual frequency phase measuring systems with dual frequency antennae.

Operations: John Oswald traveled from Anchorage to Seattle, Sunday April 15, 2001, with three GPS units, batteries, computer, and tripods. John met briefly with Scott Ramsey and Chad Wescombe, the advance survey team from LADS, this evening. Monday morning, April 16, the three of us met up at the Silver Cloud Hotel and established station BASE on the SW corner of the roof parapet of the four-story hotel. A short aluminum rod was bolted to a metal flashing and the GPS antenna was screwed to the top of the rod. A receiver was set up and observations relative to three local CORS stations commenced. Next, we all traveled to Boeing Field and checked in with Galvin Airport Services and were escorted to the tarmac where the Dash 8 will be based. Three points were painted on the tarmac, and designated as stations NORTH, SOUTH, and CENTER. Observations were made radially using one receiver at station NORTH, and the other receiver first at station CENTER, then moved to station SOUTH. Static survey techniques were employed using 5-second data rate. Cloth tape distances were also made on the flat surface of the concrete tarmac for quality control. After the observations were complete all gear was picked up from the tarmac and the base station removed. Receivers were downloaded and data processed.

Data Processing: Data was downloaded, and archived, the site files edited with correct HI's and S/N's. Data was then emailed to Anchorage where it was "mixed" with the three nearby CORS sites: SEAT, SEAW, and RPT1. Data from the CORS was available the next day after the observations. These CORS stations provide the basis of the NAD 83 coordinates and ellipsoid heights and are based on epoch 1997.0 published values of the ARP's by the National Geodetic Survey. Vectors were processed using the broadcast

ephemeris in Ashtech Office Suite (TerraSat). All vectors processed as double difference, fixed solutions. Least squares adjustments were performed holding one, then all CORS sites. The CORS stations are believed to be order A, 1,000,000, but have not been readjusted since the march 2001 6.8 earthquake. The results indicated CORS stations to be consistent within 1-2 centimeters, as well as the four points surveyed on this project.

Final coordinates and ellipsoid heights (NAD 1983 epoch 1997.0):

Point	Latitude	Longitude	E. Ht(m)	Description
1	47-39-56.7260	122-18-00.8060	2.68	BASE
2	47-31-50.1981	122-17-56.1989	-17.59	CENTER
3	47-31-50.7851	122-17-55.3020	-17.70	NORTH
6	47-31-49.8535	122-17-54.5450	-17.81	SOUTH

CORS Stations:

Point	Latitude	Longitude	E. Ht(m)	Description
4	47-39-14.29990	122-18-34.05463	44.679	SEAT
5	47-41-13.19990	122-15-22.62878	-3.611	SEAW
7	47-23-15.00509	122-22-29.10144	-9.502	RPT1

Geodetic Inverses of adjusted data (in meters):

Description:	Inverse	Tape	Delta
Points 2 to 3 (Center to North)	26.087	26.106	-0.019
Points 2 to 6 (Center to South)	36.193	36.204	-0.011
Points 3 to 6 (North to South)	32.841	32.851	-0.010

These above values were given to Scott Ramsey on April17, 2001.

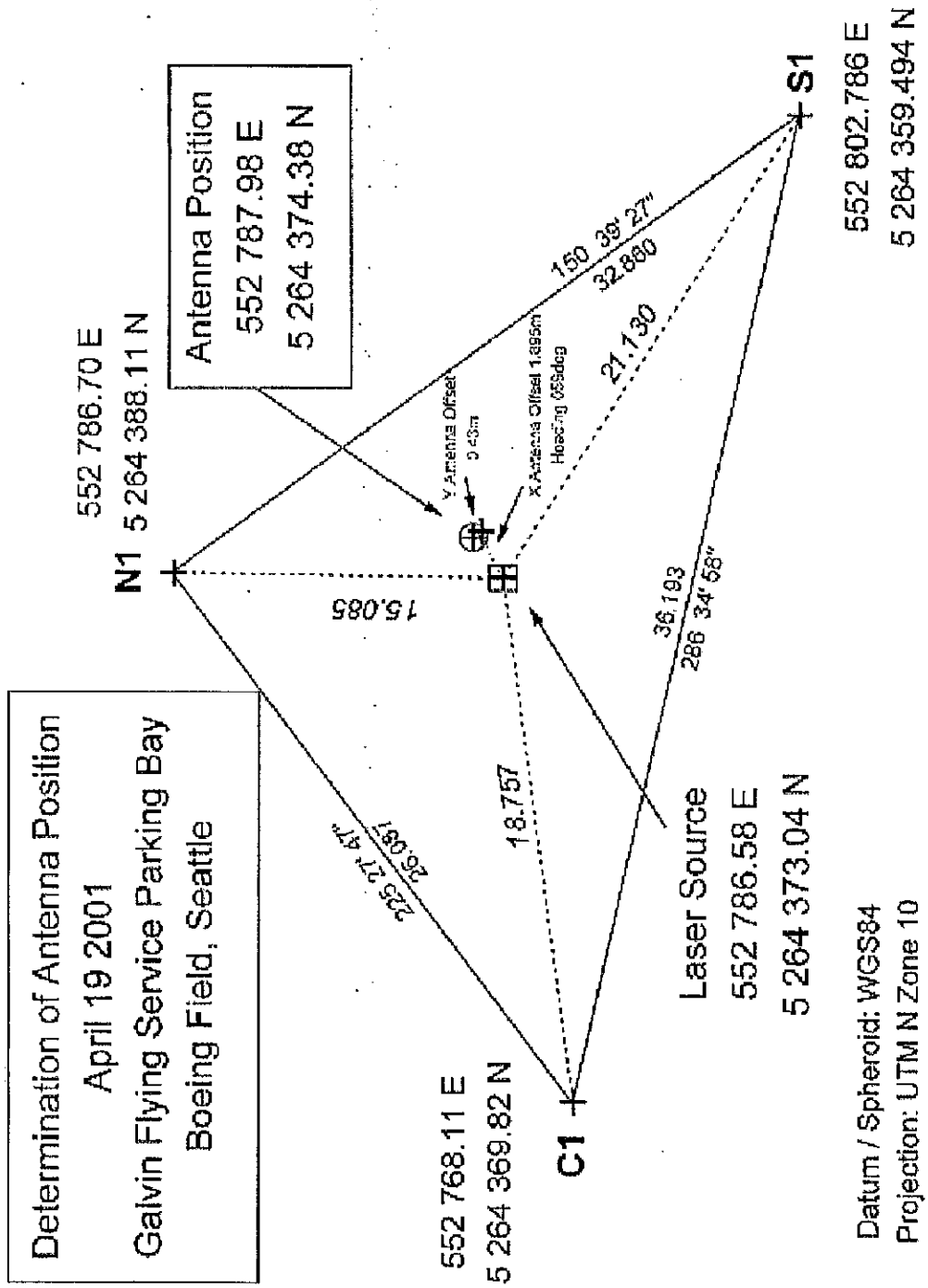
A final report will be prepared and forwarded next week that will include photos, CORS, documentation, and a copy of the LCMF field book #1078, pages 35-36.

Prepared by:

John Oswald
LCMF Inc.
4/18/01

Enclosure 3

Determination of the aircraft GPS antenna position for static position check.



NOAA FORM 76-35A

U.S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
NATIONAL OCEAN SERVICE

SEPARATES

Type of Survey Hydrographic

Field No

Registry No.

LOCALITY

State Washington

General Locality Puget Sound

Sublocality Possession Sound

2001

CHIEF OF PARTY

MARK SINCLAIR

LIBRARY & ARCHIVES

DATE

☆U.S. GOV. PRINTING OFFICE: 1985—566-054

NOAA FORM 77-28 (11-72) U.S. DEPARTMENT OF COMMERCE NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

REGISTER NO.

HYDROGRAPHIC TITLE SHEET

FIELD NO.

INSTRUCTIONS – The Hydrographic Sheet should be accompanied by this form, filled in as completely as possible, when the sheet is forwarded to the Office

State WASHINGTON

General Locality Puget Sound

Locality Possession Sound

Scale 1:10,000 Date of Survey 4/28/01

Instructions dated 4/27/01 Project No. NTP Seattle Task Order 2

Vessel LADS Mk II

Chief of Party M.Sinclair

Surveyed by D.Stephenson, N. Hewitt, W. Newsham, G. Rowe, S. Ramsay, R. Curtin

Soundings taken by echo sounder, hand lead, pole Laser Airborne Depth Sounder

Graphic record scaled by N/A

Graphic records checked by Tenix LADS Corporation

Protracted by N/A Automated plot by HP Design Jet 750C

Verification by N/A

Soundings in Meters at MLLW

REMARKS: The purpose of this work was to collect high-resolution lidar data from selected areas in Puget Sound. These areas are inshore between the coastline and the 20 meter isobath. This was a pilot project to link terrestrial airborne laser altimetry with deep water acoustic multibeam bathymetry for geological hazard mapping and research, nearshore aquatic habitat assessment and coastal zone management.

All times are recorded in UTC

TENIX LADS CORPORATION PTY LTD

SECOND AVENUE

TECHNOLOGY PARK

MAWSON LAKES 5095 SOUTH AUSTRALIA.

NOAA FORM 77-28 SUPERSEDES FORM C & GS-537 U.S. GOVERNMENT PRINTING OFFICE: 1986 - 652-007/41215

Table of Contents

A – Statement of Work

THALES

Thales GeoSolutions (Pacific) Inc. - Alaska

Formerly Racal Pelagos, Inc. - Alaska

Thales GeoSolutions (Pacific), Inc. - Alaska
911 West 8th Avenue, Suite 208
Anchorage, AK, USA, 99501
Tel: +00 (1) 907 258 1799
Department Fax: +00 (1) 907 258 3422
Email Address: Bob.Richards@thales-geosolutions.com

To:	**Silver Cloud Inns**	**From:**	**Bob Richards**
Attn:	**Mark Sinclair**	**Ref:**	
Fax No:	**206.522.1450**	**Date:**	**4/27/01**
cc:		**Pages:**	**2**

Urgent Routine Confidential Authorised

Subject: NTP Seattle Task Order 2

This is your notice to proced on Seattle Task Order 2 IAW your attached proposal. I transmitted the following conditions to the client with our proposal:

- **We will conduct one 5.5-hour flight weather permitting and collect as much data as possible in that time frame and under those conditions. The flight will be conducted on Saturday, April 28 at approximately 1400.**
- **Completion of this flight will be accepted as full completion of the field effort for this project.**
- **The first priority is Area 1. The survey area is defined by the length of the area shown along the coast with the target data between the Mean High Water (MHW) mark and approximately 20 meters depth. The maximum depth of sounding we expect to achieve is 20 meters. This will result in maximum Mean Lower Low Water (MLLW) depths of 17 to 20 meters. All data will be relative to the MLLW datum.**
- **When Area 1 is completed, we will move to the next survey area. We only expect to complete a portion of one other area in addition to Area 1. We list these in the following priorities in the event that air traffic or weather precludes the next area. In order of priority: Areas 3, 5, 4 and 2.**
- **Data delivery is expected to be 30 days following completion of the survey.**
- **If data collection is unsuccessful or weather precludes data collection, there will be no charge for our services and we will be completely relieved of the provision of the data collection.**
- **Invoicing will be 50% following the completion of the flight, the remaining 50% to be invoiced following the delivery of the Data. We request that payments be made within 7 working days of receipt of invoice.**

Tenix

Proposal

to

Thales GeoSolutions (Pacific), Inc
(formerly Racal Pelagos, Inc)

by

Tenix LADS Corporation Pty Limited
(TLC)

for

Certain Areas in Puget Sound

for Kitsap County, Washington

26 April 2001

Tenix LADS Corporation Pty Ltd
Second Avenue
Technology Park
MAWSON LAKES SA 5095

Tom Spurling
General Manager
Phone: +61 8 8300 4447
Fax: +61 8 8349 7528

Puget Sound
For Kitsap County

Tenix

KITSAP COUNTY SURVEY AREA PROPOSAL

1. PROJECT DESCRIPTION

This project is being conducted to survey areas in Puget Sound, Wa for Kitsap County.

2. DATA COLLECTION

The data will be collected on a single LADS Mk II flight of up to 7 hours duration subject to conditions in the survey areas. The data will be collected from one or more priority areas as agreed between the County and the Thales/TLC team. In the event that no suitable data is collected there will be no charge and the Thales/TLC team will be relieved of any further requirement. The primary responsibility for determination of the suitability of the data rests with the TLC Survey Manager.

3. TIDES

Soundings will be reduced using observed tides from the Seattle Wa tide gauge (9447130).

4. POSITIONING

Soundings will be positioned in real time using the Racal WADGPS Vancouver base station. In addition, a local DGPS reference station will be established, and post processed positions will be applied to soundings following data collection.

5. LOGISTICS

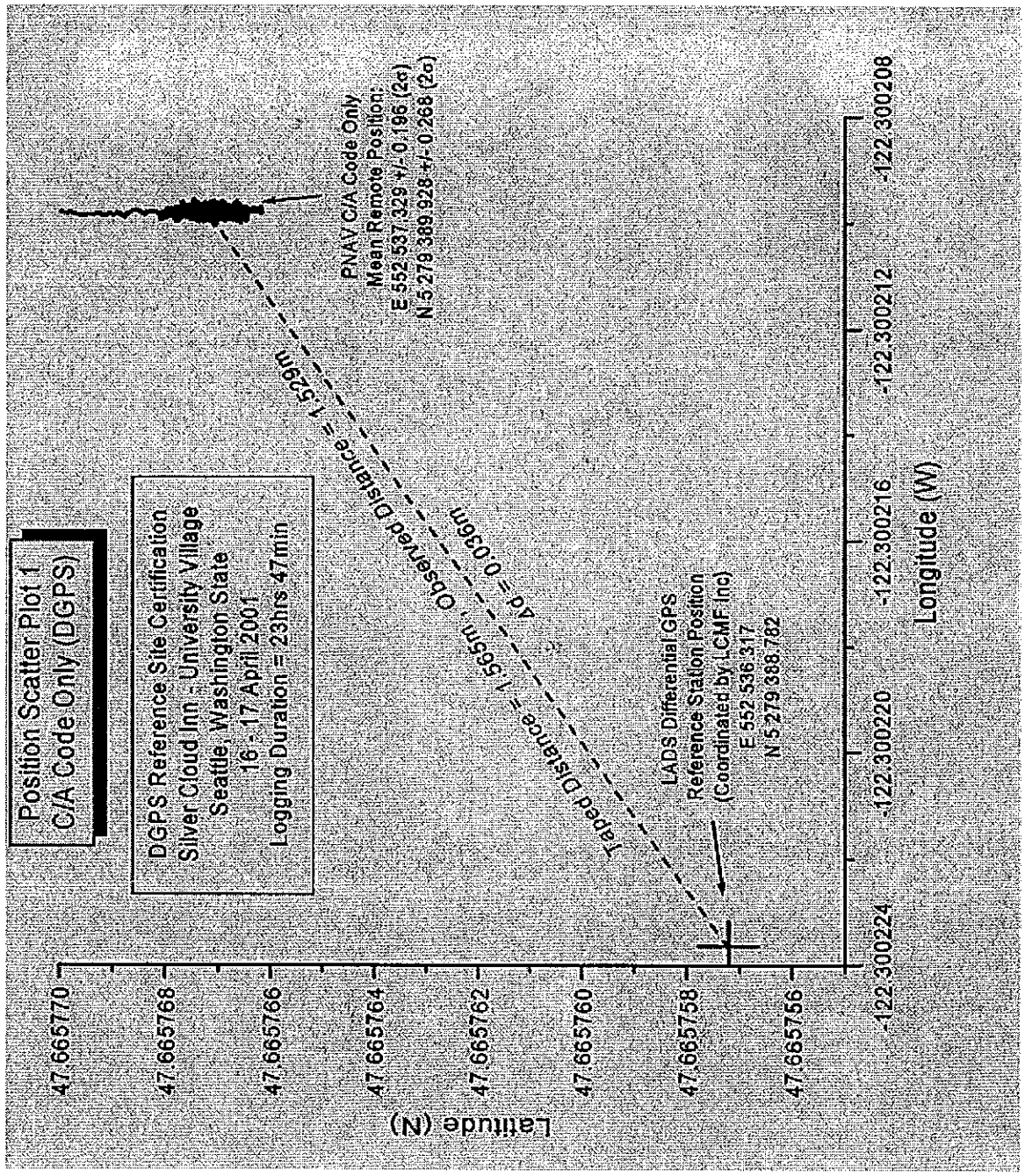
The Aircraft will operate from Boeing Field, Seattle. Initial data processing will be conducted at the Field Processing Facility at the Silver Cloud Inn, University. Final data processing and reporting will be conducted at the survey depot in Adelaide, South Australia.

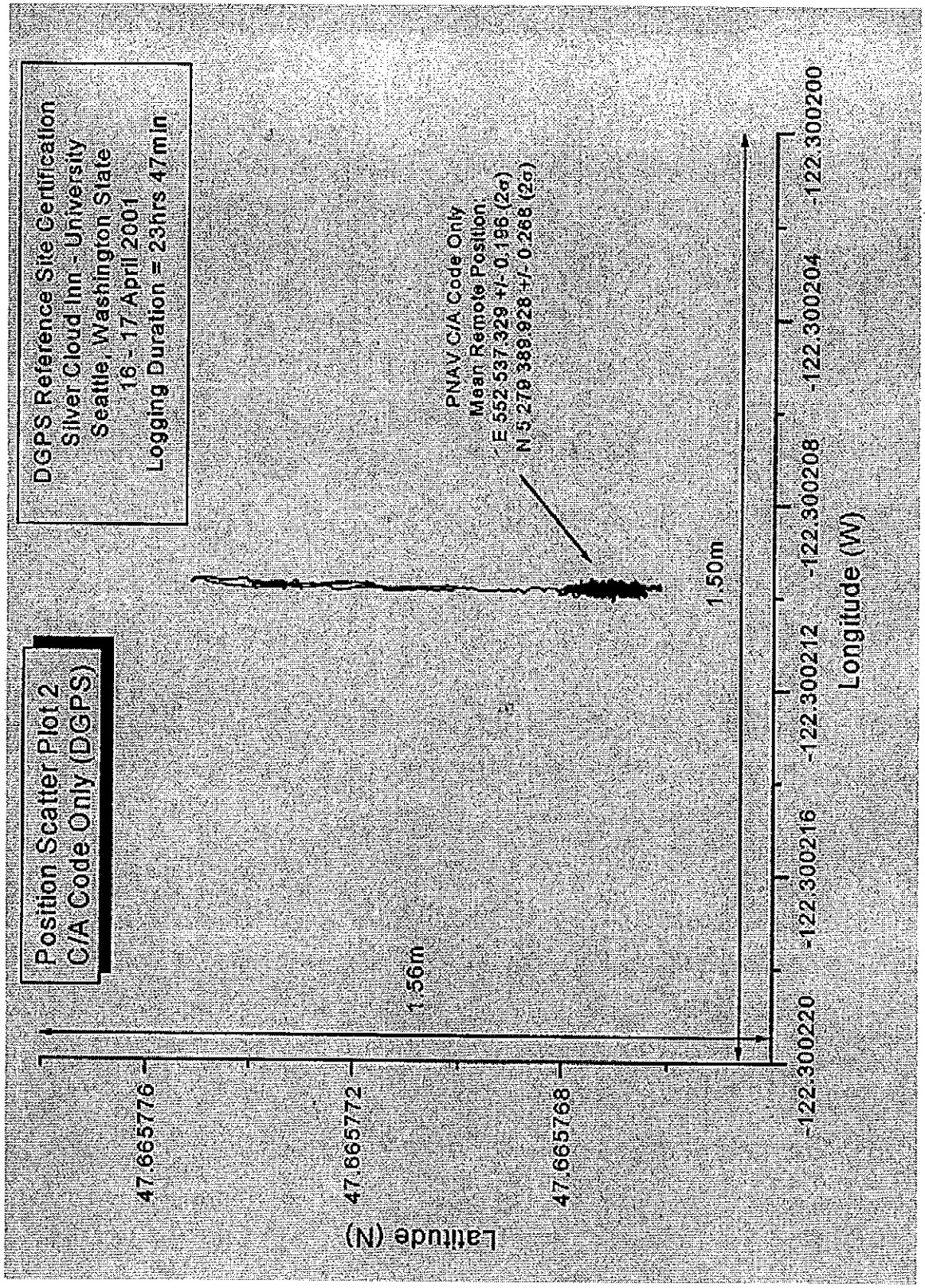
6. DATA PROCESSING

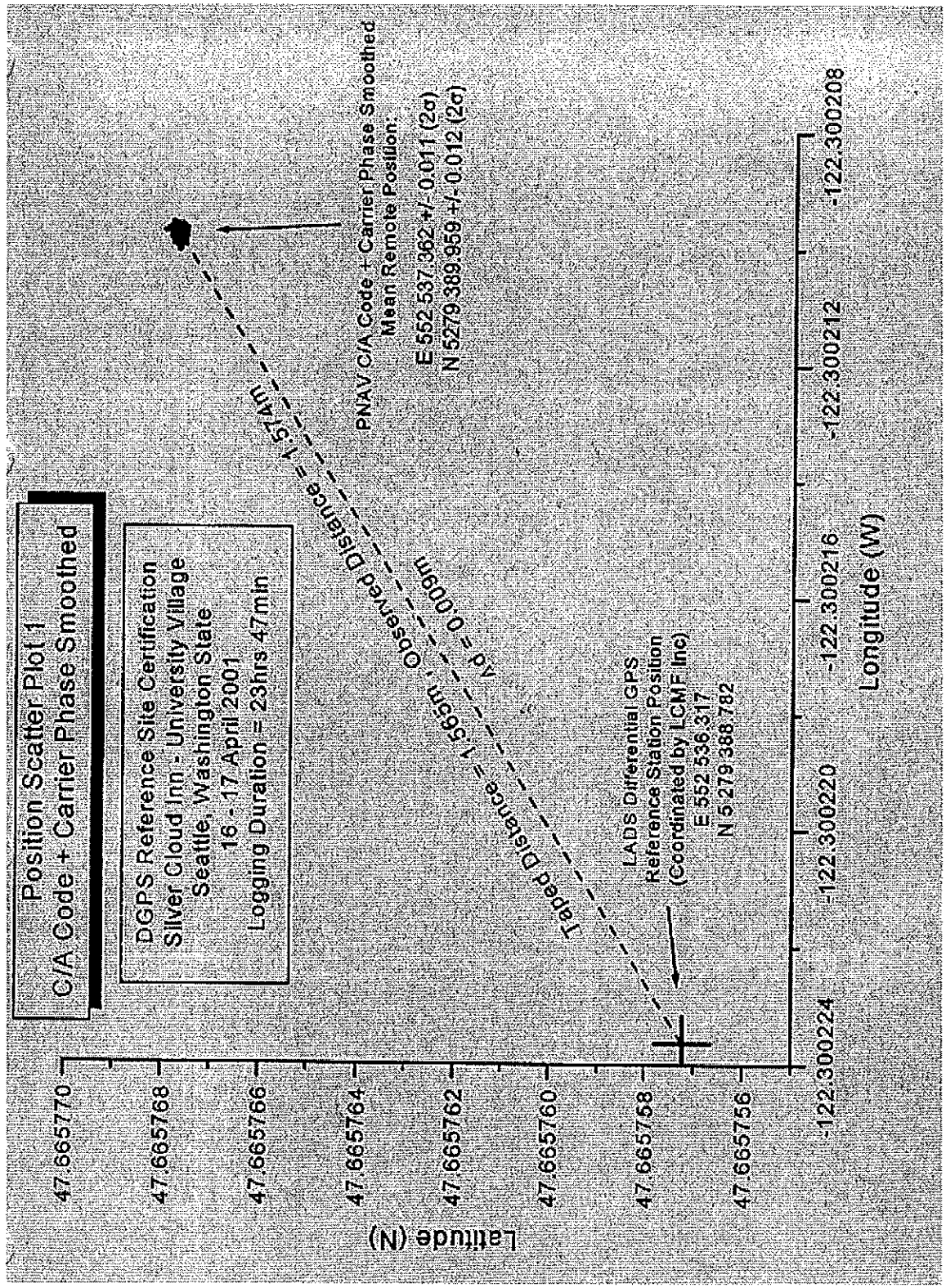
Data will be processed at the Field Processing Facility on the LADS Mk II Ground System. Processed data will be validated, checked and approved in accordance with the LADS Mk II ISO 9001 quality procedures. Data will be output in x,y,z ASCII format suitable for use on other processing systems.

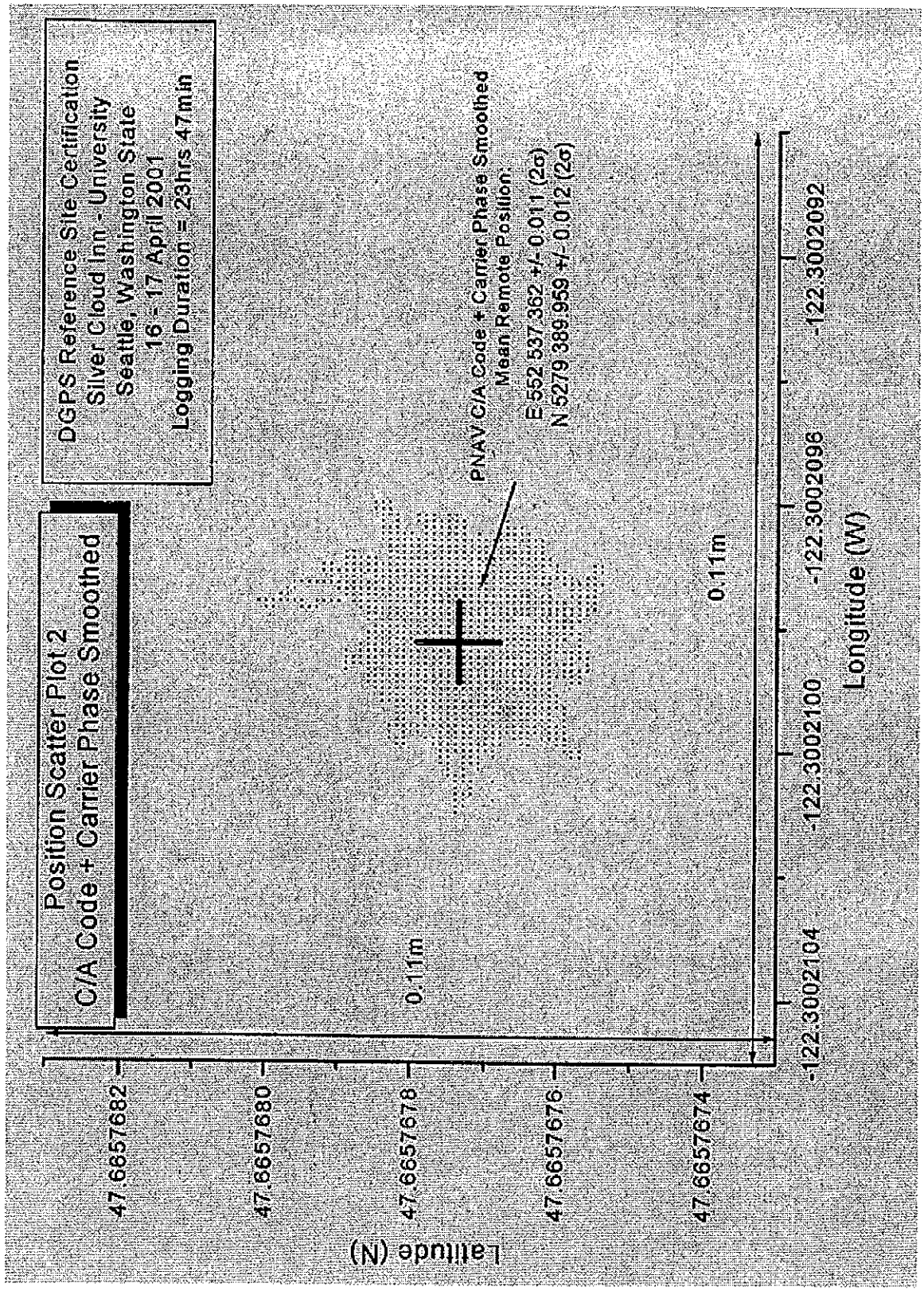
B – DGPS Verification Data

24–Hour DGPS Reference Site Confirmation




Position Scatter Plot 2
C/A Code Only (DGPS)
DGPS Reference Site Certification
Silver Cloud Inn - University
Seattle, Washington State
16 - 17 April 2001
Logging Duration = 23hrs 47min
PNAV C/A Code Only
Mean Remote Position
E 552 537.329 +/- 0.196 (2σ)
N 5 270 389.928 +/- 0.268 (2σ)
1.56m
1.50m
Latitude (N)
47.665776
47.665772
47.665768
Longitude (W)
-122.300220
-122.300216
-122.300212
-122.300208
-122.300204
-122.300200


Position Scatter Plot 1
C/A Code + Carrier Phase Smoothed
DGPS Reference Site Certification
Silver Cloud Inn - University Village
Seattle, Washington State
16 - 17 April 2001
Logging Duration = 23hrs 47min
Observed Distance = 1.571m
Tapped Distance = 1.569m, Δ = 0.002m
PNAV C/A Code + Carrier Phase Smoothed
Mean Remote Position:
E 552,537.362 +/- 0.011 (2σ)
N 5279,389.959 +/- 0.012 (2σ)
LADS Differential GPS
Reference Station Position
(Coordinated by LCMF Inc)
E 552,536.317
N 5,279,388.782
47.665770
47.665768
47.665766
47.665764
47.665762
47.665760
47.665758
47.665756
Latitude (N)
-122.300224
-122.300220
-122.300216
-122.300212
-122.300208
Longitude (W)


Position Scatter Plot 2
C/A Code + Carrier Phase Smoothed
DGPS Reference Site Certification
Silver Cloud Inn - University
Seattle, Washington State
16 - 17 April 2001
Logging Duration = 23hrs 47min
PNAV C/A Code + Carrier Phase Smoothed
Mean Remote Position
E552 537.362 +/- 0.011 (2σ)
N 5279 389.959 +/- 0.012 (2σ)
0.11m
0.11m
Latitude (N)
47.6657682
47.6657680
47.6657678
47.6657676
47.6657674
-122.3002104
-122.3002100
-122.3002096
-122.3002092
Longitude (W)

Static Position Check – Session 1

GS VERSION T4.8/002
POSITION ANALYSIS REPORT FOR STATIC CALIBRATION
MISSION TITLE: NOAA TEST PATCH
RUN COUNT: 0
SPHEROID: WORLD GEODETIC SYSTEM 1984
GRID: UTM-NORTHERN
ZONE: 10 CM: -123 DEG

Statistics for STATIC CALIBRATION
GPS Start Time 15:32:53 End Time 16:40:10

DGPS_HRMS Min= 0.028m Max= 0.067m
KGPS_HRMS Min= 0.033m Max= 0.035m
AS_EHE Min= 5.300m Max= 12.400m
AS_PDOP Min= 2.10m Max= 3.20m
POST_PROCESSED_PDOP Min= 2.80m Max= 8.00m
AS_SVS Min= 6 Max= 7
POST_PROCESSED_SVS Min= 5 Max= 7
AS_LATENCY_OF_CORRECTIONS Min=999s Max=999s

Analysis of Reported GPS Position

Airborne System - DGPS (Sample Size: AS = 4038 DGPS = 4038)
Latitude Min= -5.254m Max= 5.202m Mean= 0.679m Stdev= 1.843m
Longitude Min= -4.631m Max= 0.250m Mean= -2.073m Stdev= 0.846m
RMS Min= 0.713m Max= 6.934m Mean= 2.824m Stdev= 0.948m

Airborne System - KGPS (Sample Size: AS = 4038 KGPS = 4038)
Latitude Min= -4.990m Max= 5.396m Mean= 0.762m Stdev= 1.851m
Longitude Min= -4.356m Max= 0.684m Mean= -1.763m Stdev= 0.890m
RMS Min= 0.250m Max= 6.555m Mean= 2.633m Stdev= 0.987m

DGPS - KGPS (Sample Size: DGPS = 4038 KGPS = 4038)
Latitude Min= -0.090m Max= 0.514m Mean= 0.118m Stdev= 0.125m
Longitude Min= 0.175m Max= 1.076m Mean= 0.374m Stdev= 0.176m
RMS Min= 0.179m Max= 1.192m Mean= 0.408m Stdev= 0.187m

DGPS - AS Height (Sample Size: AS = 4038 DGPS = 4038)
WGS84 Ht Min=-27.284m Max=-10.824m Mean=-17.865m

KGPS - AS Height (Sample Size: AS = 4038 KGPS = 4038)
WGS84 Ht Min=-26.130m Max=-10.257m Mean=-17.232m

Airborne System GPS Mode : raw
Airborne System Recal Basestation : N/A

----------END OF DATA----------

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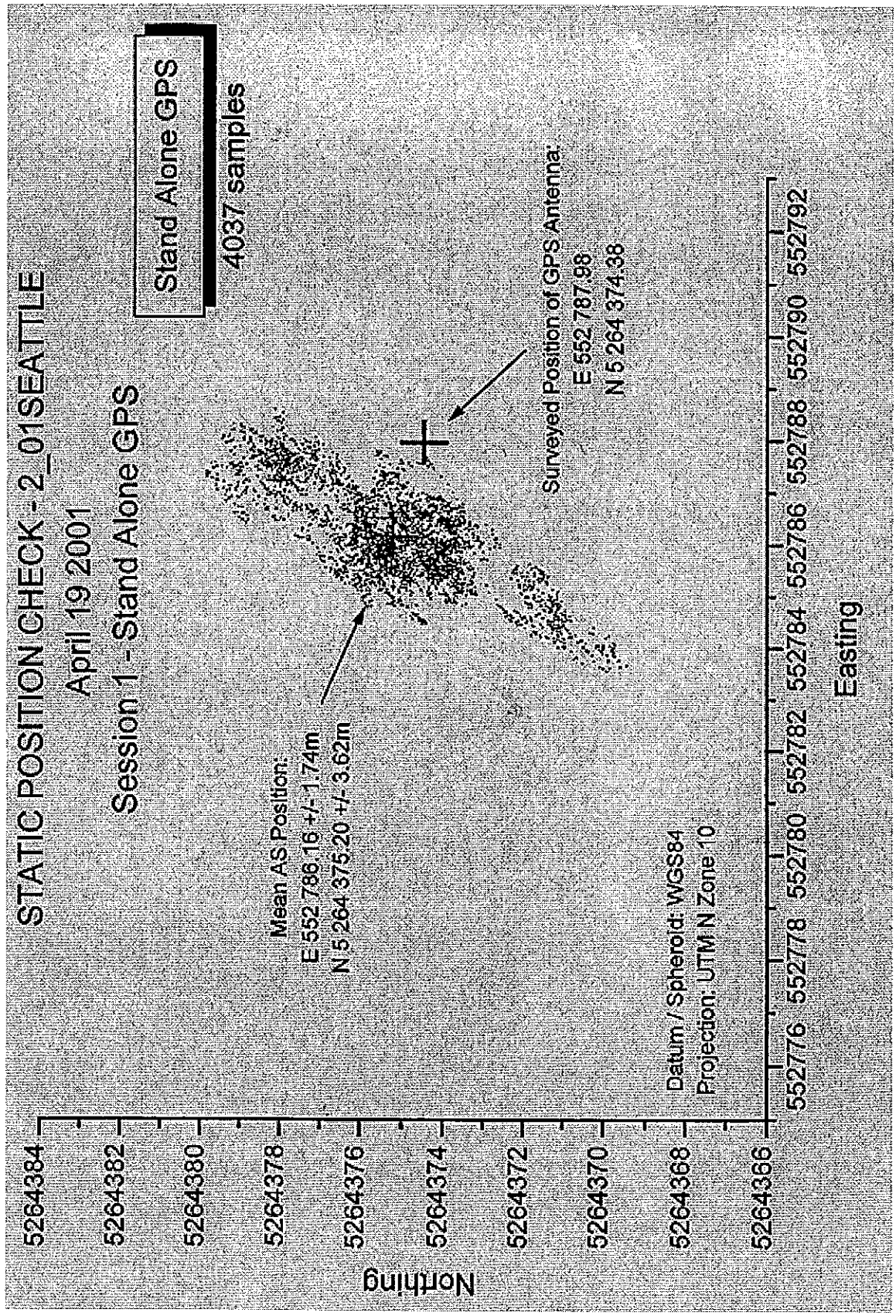
STATIC POSITION CHECK - 2_01SEATTLE
April 19 2001
Session 1 - Stand Alone GPS
Stand Alone GPS
4037 samples
Mean AS Position:
E 552 786.16 +/- 1.74m
N 5 264 375.20 +/- 3.62m
Surveyed Position of GPS Antenna:
E 552 787.88
N 5 264 374.38
Northing
Easting
Datum / Spheroid: WGS84
Projection: UTM N Zone 10
5264384
5264382
5264380
5264378
5264376
5264374
5264372
5264370
5264368
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552786
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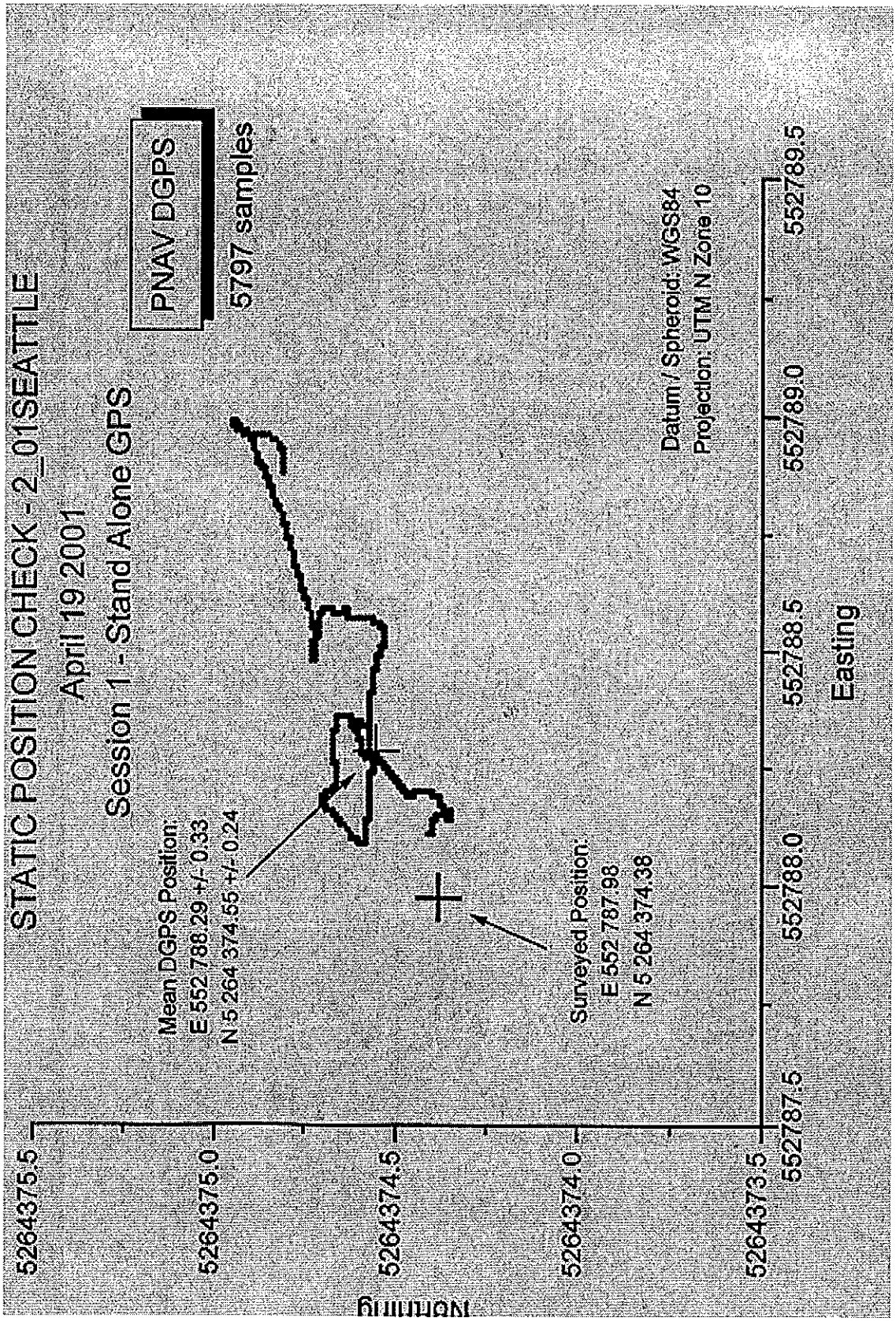
552790
552792


STATIC POSITION CHECK - 2_01SEATTLE
April 19 2001
Session 1 - Stand Alone GPS
PNAV DGPS
5797 samples
Mean DGPS Position:
E 552 788.29 +/- 0.33
N 5 264 374.55 +/- 0.24
Surveyed Position:
E 552 787.98
N 5 264 374.38
Datum / Spheroid: WGS84
Projection: UTM N Zone 10
5264375.5
5264375.0
5264374.5
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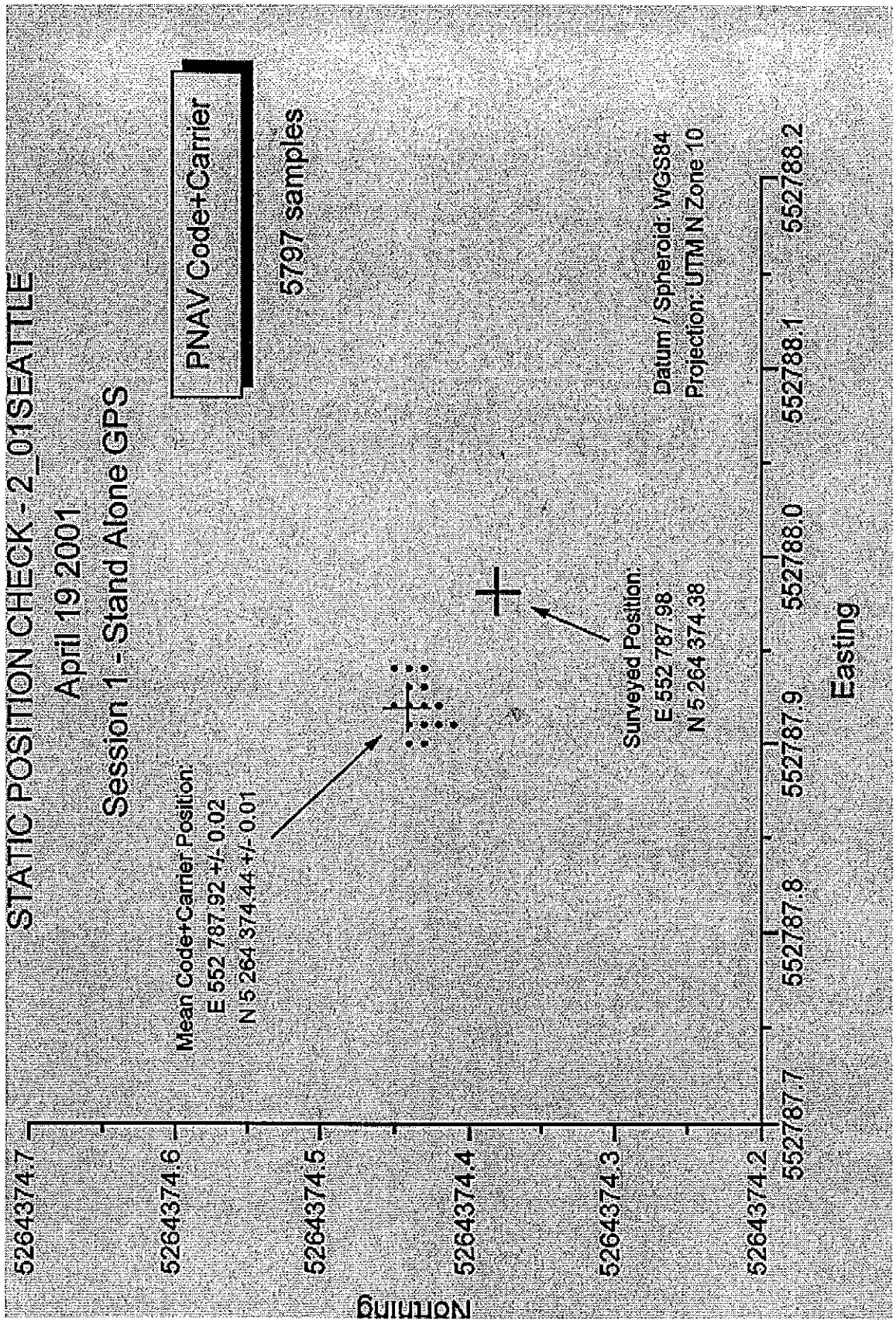
Northing
Easting


STATIC POSITION CHECK - 2_01SEATTLE
April 19 2001
Session 1 - Stand Alone GPS
PNAV Code+Carrier
5797 samples
Mean Code+Carrier Position:
E 552 787.92 +/- 0.02
N 5 264 374.44 +/- 0.01
Surveyed Position:
E 552 787.98
N 5 264 374.38
Datum / Spheroid: WGS84
Projection: UTM N Zone 10
Northing
Easting
5264374.7
5264374.6
5264374.5
5264374.4
5264374.3
5264374.2
552787.7
552787.8
552787.9
552788.0
552788.1
552788.2

Static Position Check – Session 2

GS VERSION T4.8/008
POSITION ANALYSIS REPORT FOR STATIC CALIBRATION
MISSION TITLE: NOAA TEST PATCH
RUN COUNT: 0
SPHEROID: WORLD GEODETIC SYSTEM 1984
GRID: UTM-NORTHERN
ZONE: 10 CM: -123 DEG

Statistics for STATIC CALIBRATION
GPS Start Time 16:46:25 End Time 18:24:02

DGPS_HRMS Min= 0.028m Max= 0.498m
KGPS_HRMS Min= 0.031m Max= 0.041m
AS_EHE Min= 2.083m Max= 4.000m
AS_PDOP Min= 1.80m Max= 3.00m
POST_PROCESSED_PDOP Min= 1.80m Max= 3.00m
AS_SVS Min= 6 Max= 7
POST_PROCESSED_SVS Min= 6 Max= 7
AS_LATENCY_OF_CORRECTIONS Min= 2s Max= 24s

Analysis of Reported GPS Position

Airborne System - DGPS (Sample Size: AS = 5857 DGPS = 5857)
Latitude Min= -0.961m Max= 3.018m Mean= 1.024m Stdev= 0.666m
Longitude Min= -2.606m Max= 1.626m Mean= -0.697m Stdev= 0.576m
RMS Min= 0.022m Max= 3.373m Mean= 1.400m Stdev= 0.593m

Airborne System - KGPS (Sample Size: AS = 5857 KGPS = 5857)
Latitude Min= -0.867m Max= 3.113m Mean= 1.114m Stdev= 0.631m
Longitude Min= -2.764m Max= 1.408m Mean= -0.873m Stdev= 0.567m
RMS Min= 0.019m Max= 3.524m Mean= 1.539m Stdev= 0.595m

DGPS - KGPS (Sample Size: DGPS = 5857 KGPS = 5857)
Latitude Min= -0.119m Max= 0.953m Mean= 0.091m Stdev= 0.182m
Longitude Min= -0.317m Max= 0.009m Mean= -0.176m Stdev= 0.065m
RMS Min= 0.004m Max= 0.966m Mean= 0.241m Stdev= 0.137m

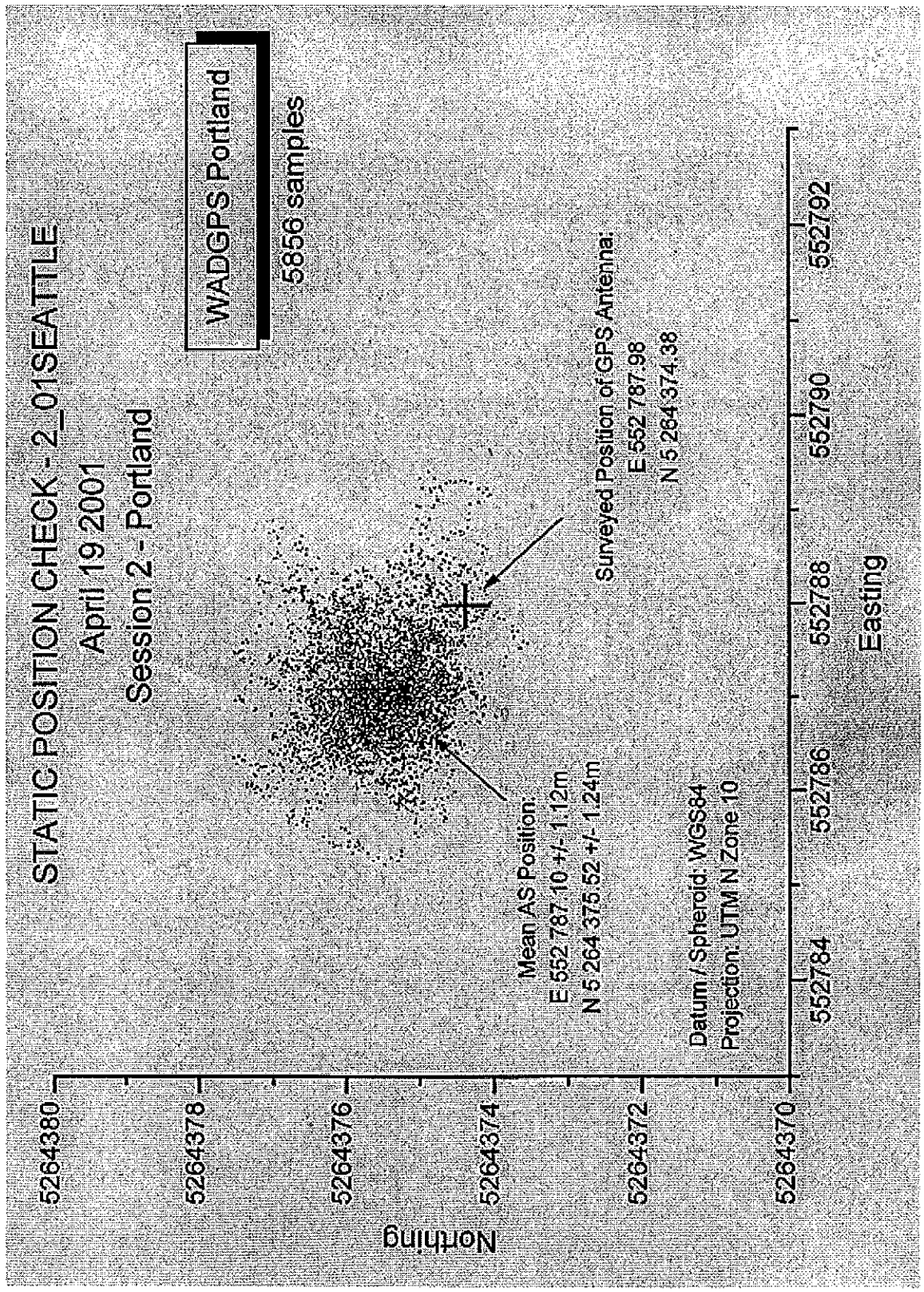
DGPS - AS Height (Sample Size: AS = 5857 DGPS = 5857)
WGS84 Ht Min= -4.600m Max= 5.515m Mean= 0.636m

KGPS - AS Height (Sample Size: AS = 5857 KGPS = 5857)
WGS84 Ht Min= -4.959m Max= 4.923m Mean= 0.340m

Airborne System GPS Mode : diff
Airborne System Racal Basestation : 0561

----------END OF DATA----------

This report was generated on 21 APR 2001 at 05:24:38 AM


STATIC POSITION CHECK - 2_01SEATTLE
April 19 2001
Session 2 - Portland
WADGPS Portland
5856 samples
Mean AS Position:
E 552 787.10 +/- 1.12m
N 5 264 375.52 +/- 1.24m
Surveyed Position of GPS Antenna:
E 552 787.98
N 5 264 374.38
Datum / Spheroid: WGS84
Projection: UTM N Zone 10
Northing
Easting
5264380
5264378
5264376
5264374
5264372
5264370
552784
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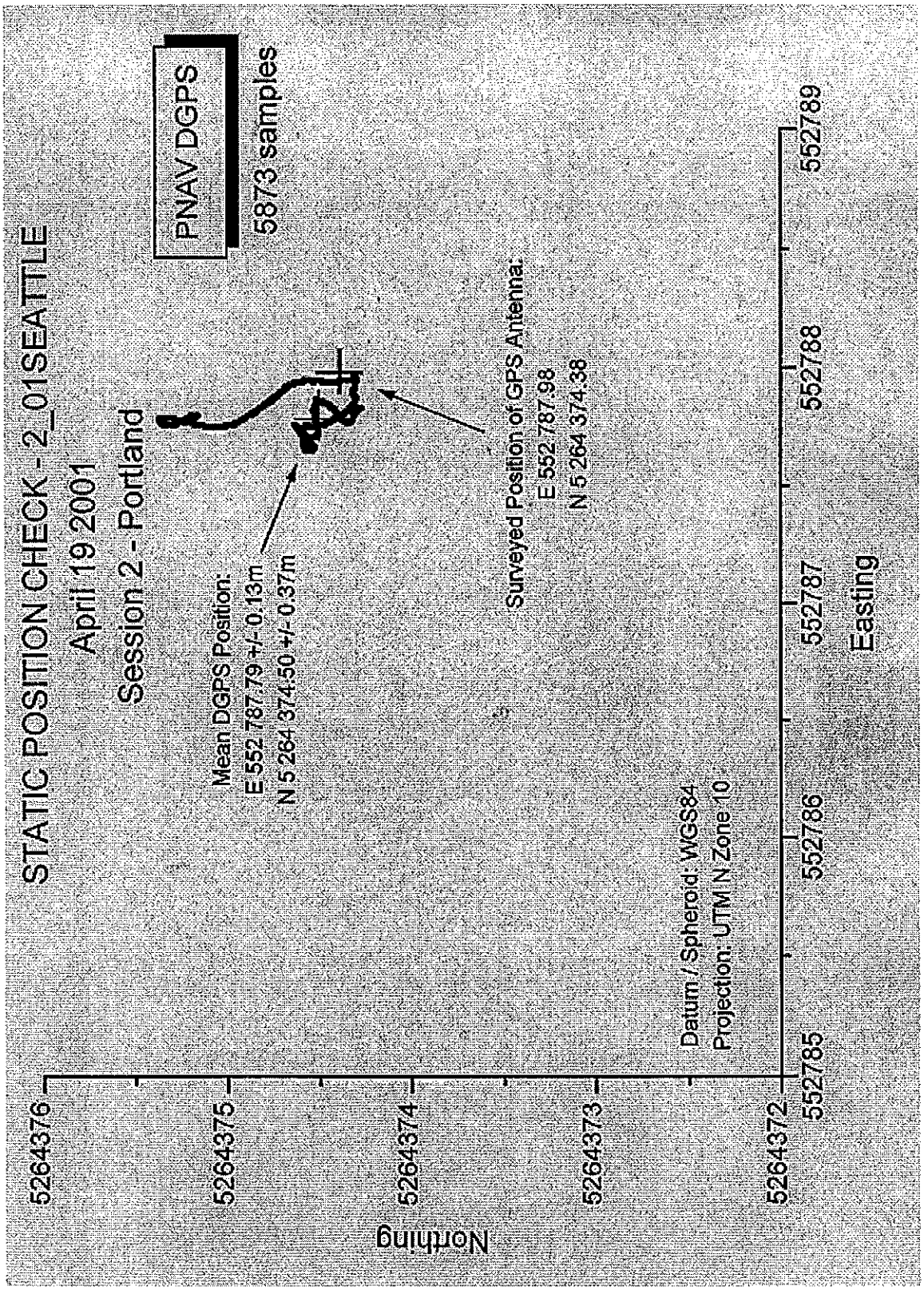
552788
552790
552792


STATIC POSITION CHECK - 2_01SEATTLE
April 19 2001
Session 2 - Portland
PNAV DGPS
5873 samples
Mean DGPS Position:
E 552 787.79 +/- 0.13m
N 5 264 374.50 +/- 0.37m
Surveyed Position of GPS Antenna:
E 552 787.98
N 5 264 374.38
Datum / Spheroid: WGS84
Projection: UTM N Zone 10
Northing
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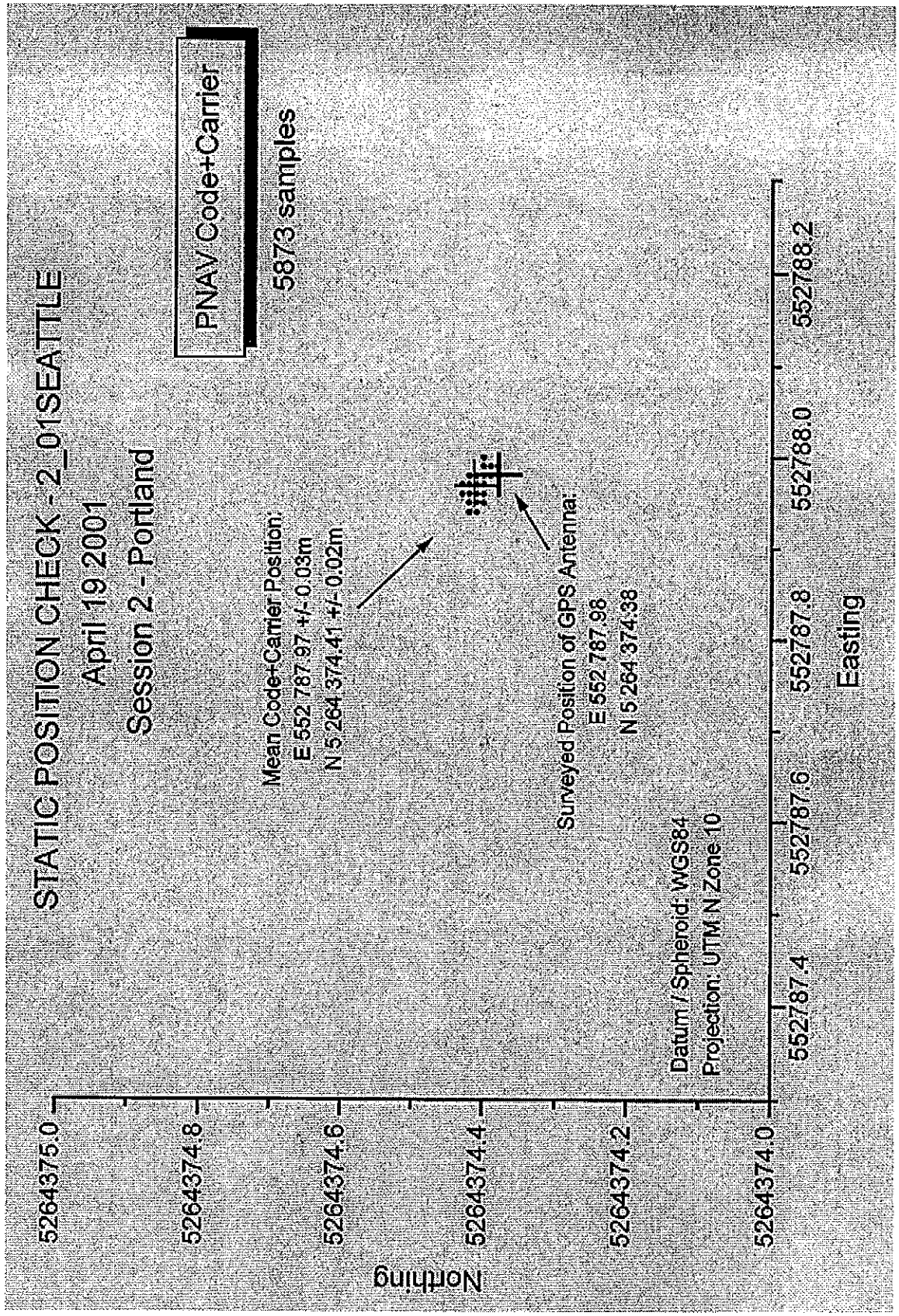
552785
552786
552787
552788
552789
Easting


STATIC POSITION CHECK - 2_01SEATTLE
April 19 2001
Session 2 - Portland
PNAV Code+Carrier
5873 samples
Mean Code+Carrier Position:
E 552 787.97 +/- 0.03m
N 5 264 374.41 +/- 0.02m
Surveyed Position of GPS Antenna:
E 552 787.98
N 5 264 374.38
Datum / Spheroid: WGS84
Projection: UTM N Zone 10
Northing
5264375.0
5264374.8
5264374.6
5264374.4
5264374.2
5264374.0
552787.4
552787.6
552787.8
552788.0
552788.2
Easting

Static Position Check – Session 3

GS VERSION T4.8/002
POSITION ANALYSIS REPORT FOR STATIC CALIBRATION
MISSION TITLE: NOAA TEST PATCH
RUN COUNT: 0
SPHEROID: WORLD GEODETIC SYSTEM 1984
GRID: UTM-NORTHERN
ZONE: 10 CM: -123 DEG

Statistics for STATIC CALIBRATION
GPS Start Time 18:27:52 End Time 20:30:17

DGPS_HRMS Min= 0.029m Max= 0.165m
KGPS_HRMS Min= 0.017m Max= 0.018m
AS_EHE Min= 1.250m Max= 3.708m
AS_PDOP Min= 1.50m Max= 2.30m
POST_PROCESSED_PDOP Min= 1.50m Max= 2.30m
AS_SVS Min= 6 Max= 8
POST_PROCESSED_SVS Min= 7 Max= 8
AS_LATENCY_OF_CORRECTIONS Min= 2s Max= 67s

Analysis of Reported GPS Position

Airborne System - DGPS (Sample Size: AS = 7346 DGPS = 3938)
Latitude Min= -2.427m Max= 1.542m Mean= -0.217m Stdev= 0.612m
Longitude Min= -1.856m Max= 1.185m Mean= -0.412m Stdev= 0.584m
RMS Min= 0.027m Max= 2.839m Mean= 0.839m Stdev= 0.479m

Airborne System - KGPS (Sample Size: AS = 7346 KGPS = 3938)
Latitude Min= -2.403m Max= 1.381m Mean= -0.329m Stdev= 0.588m
Longitude Min= -1.863m Max= 1.171m Mean= -0.527m Stdev= 0.533m
RMS Min= 0.022m Max= 2.817m Mean= 0.886m Stdev= 0.480m

DGPS - KGPS (Sample Size: DGPS = 3938 KGPS = 3938)
Latitude Min= -0.658m Max= 0.371m Mean= -0.102m Stdev= 0.170m
Longitude Min= -0.984m Max= 0.053m Mean= -0.139m Stdev= 0.266m
RMS Min= 0.017m Max= 1.066m Mean= 0.209m Stdev= 0.293m

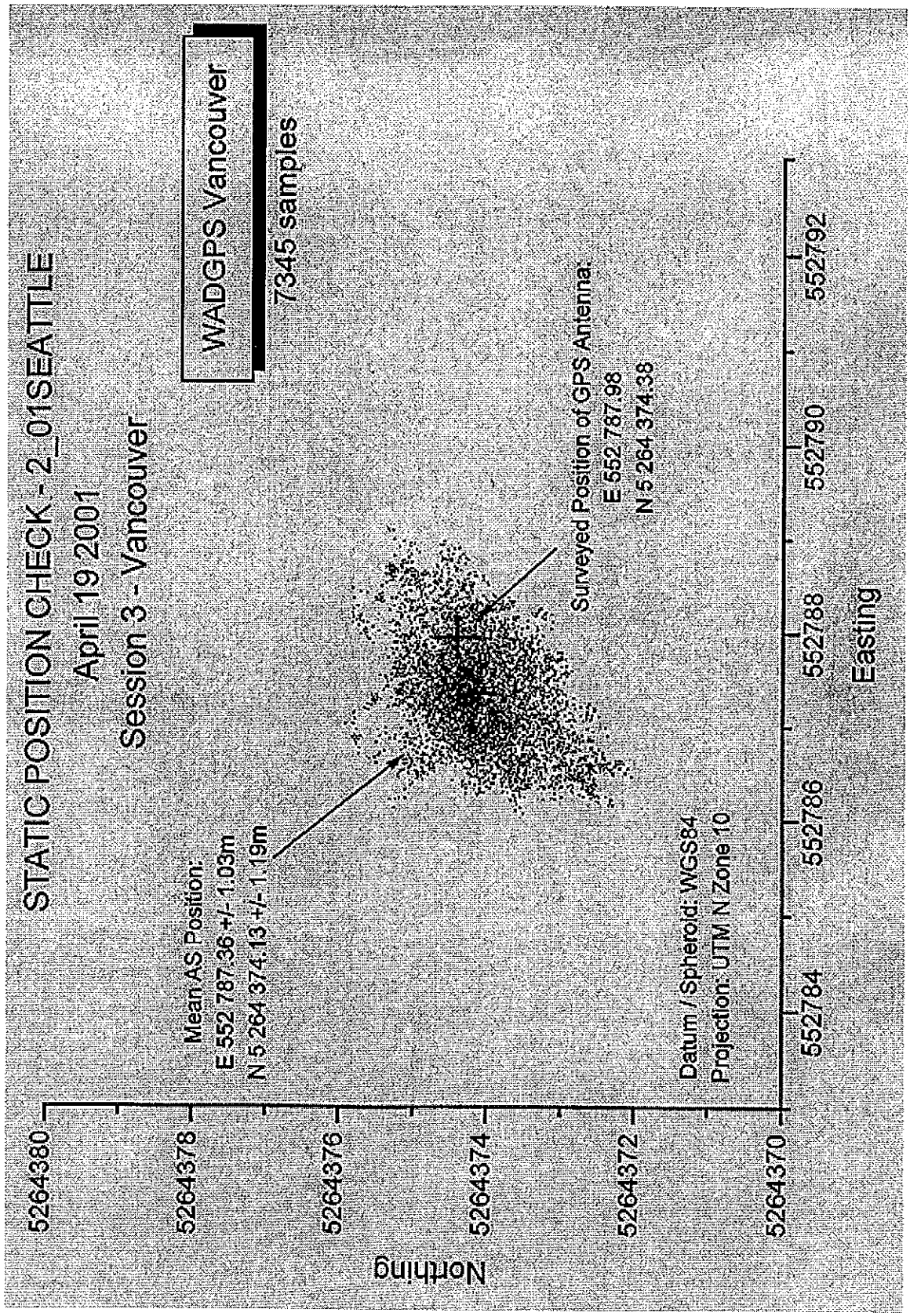
DGPS - AS Height (Sample Size: AS = 7346 DGPS = 3938)
WGS84 Ht Min= -3.063m Max= 3.791m Mean= 0.108m

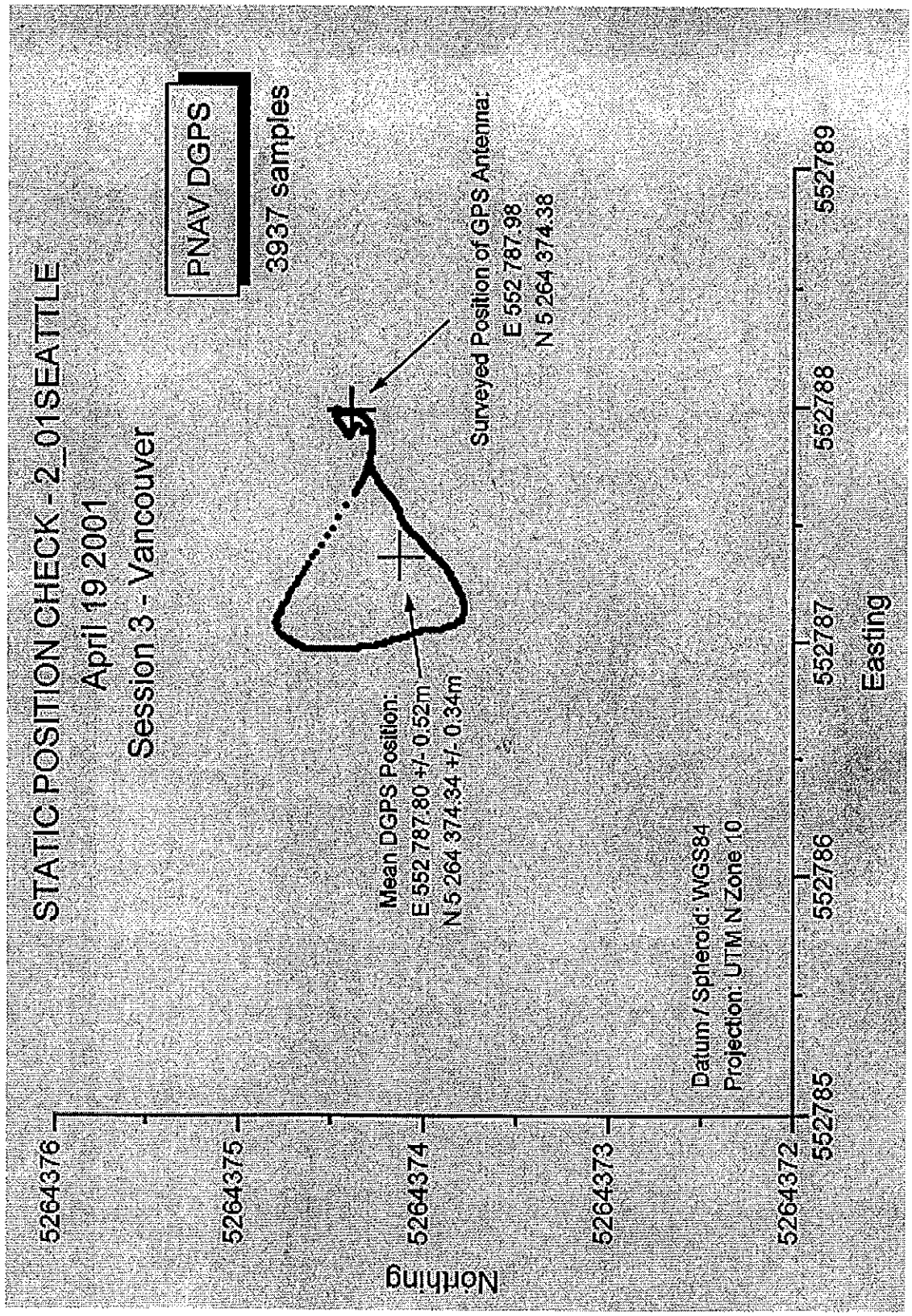
KGPS - AS Height (Sample Size: AS = 7346 KGPS = 3938)
WGS84 Ht Min= -3.020m Max= 3.657m Mean= 0.147m

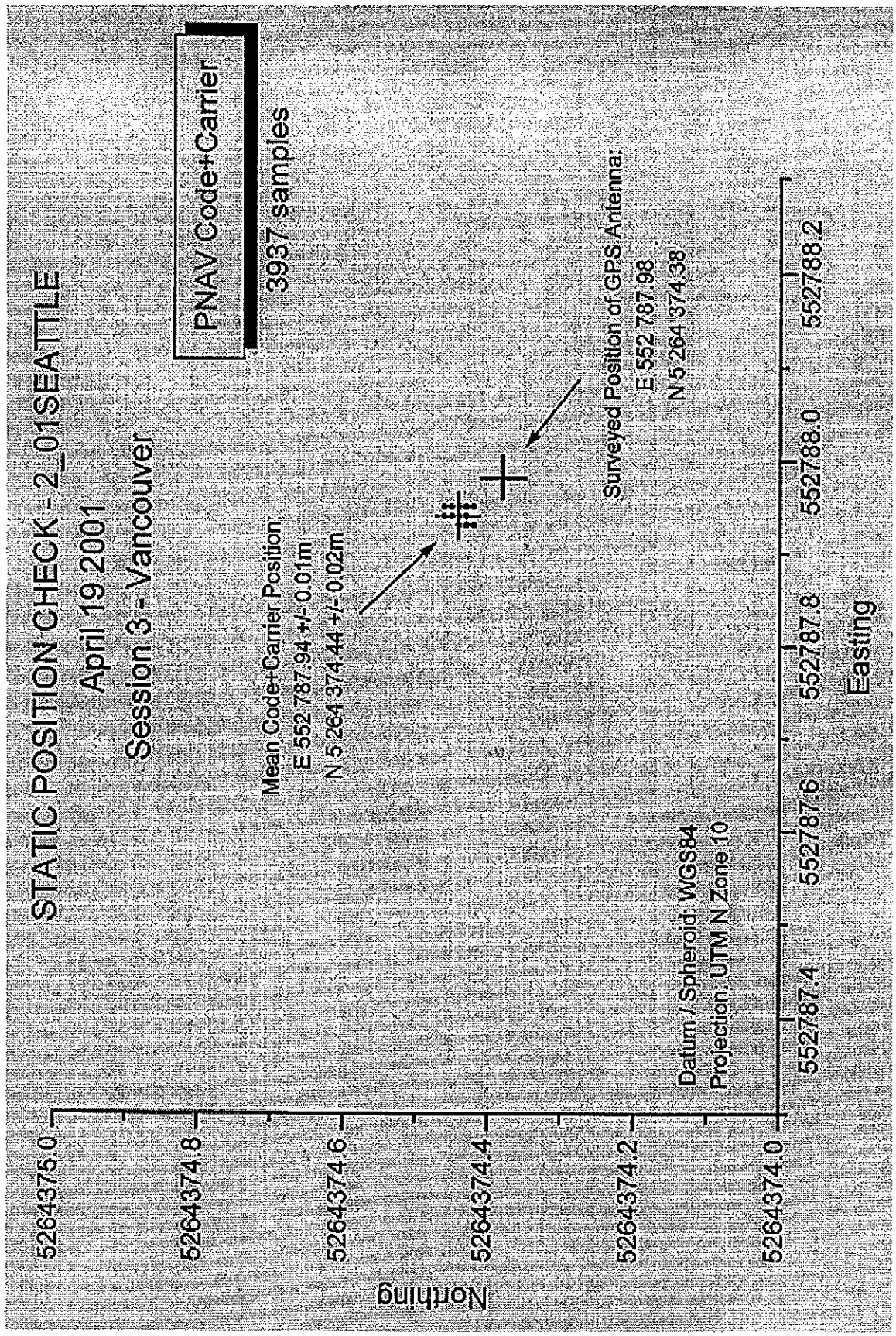
Airborne System GPS Mode : diff
Airborne System Racal Basestation : 0505

----------END OF DATA----------

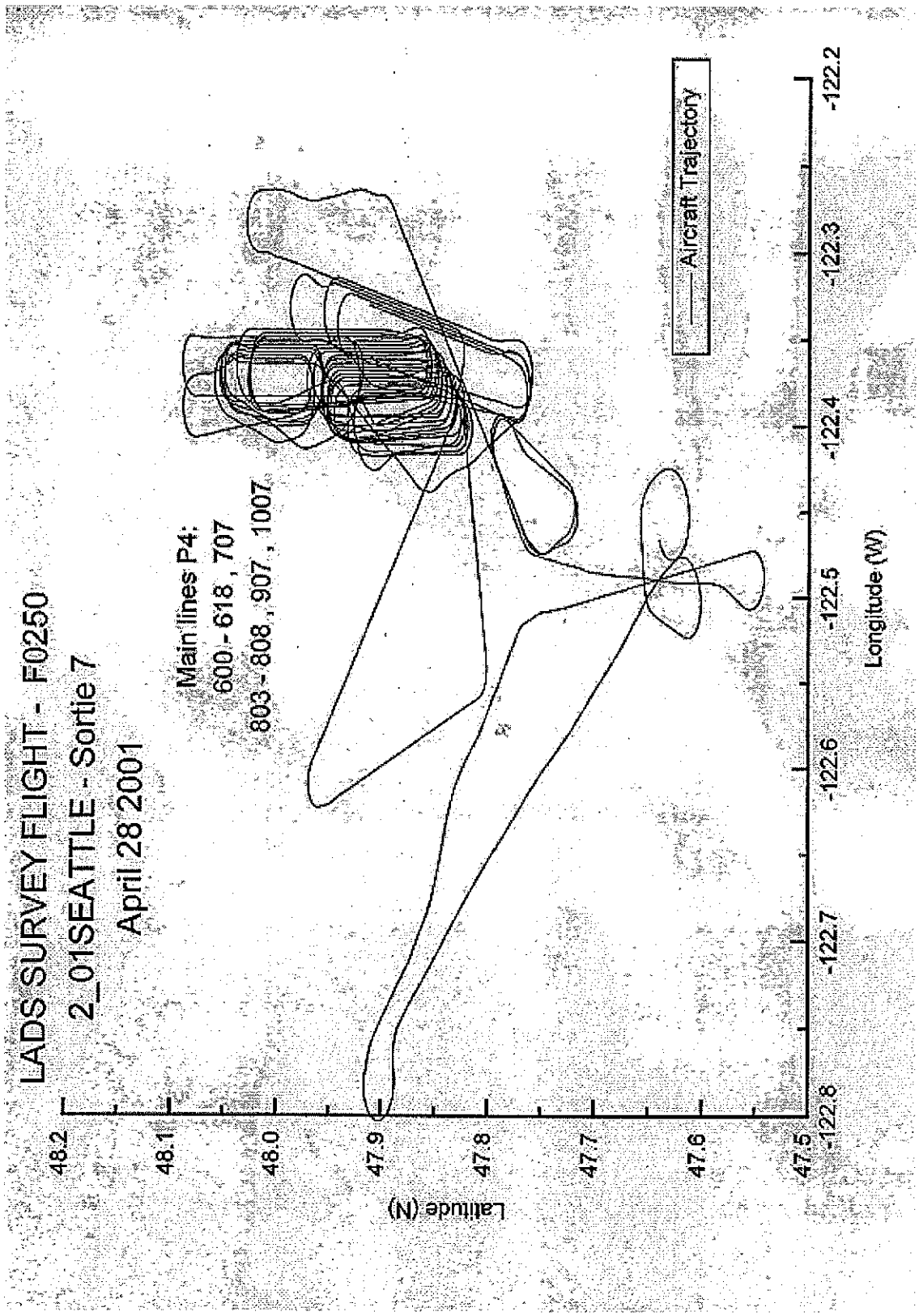
This report was generated on 20 APR 2001 at 09:37:21 AM

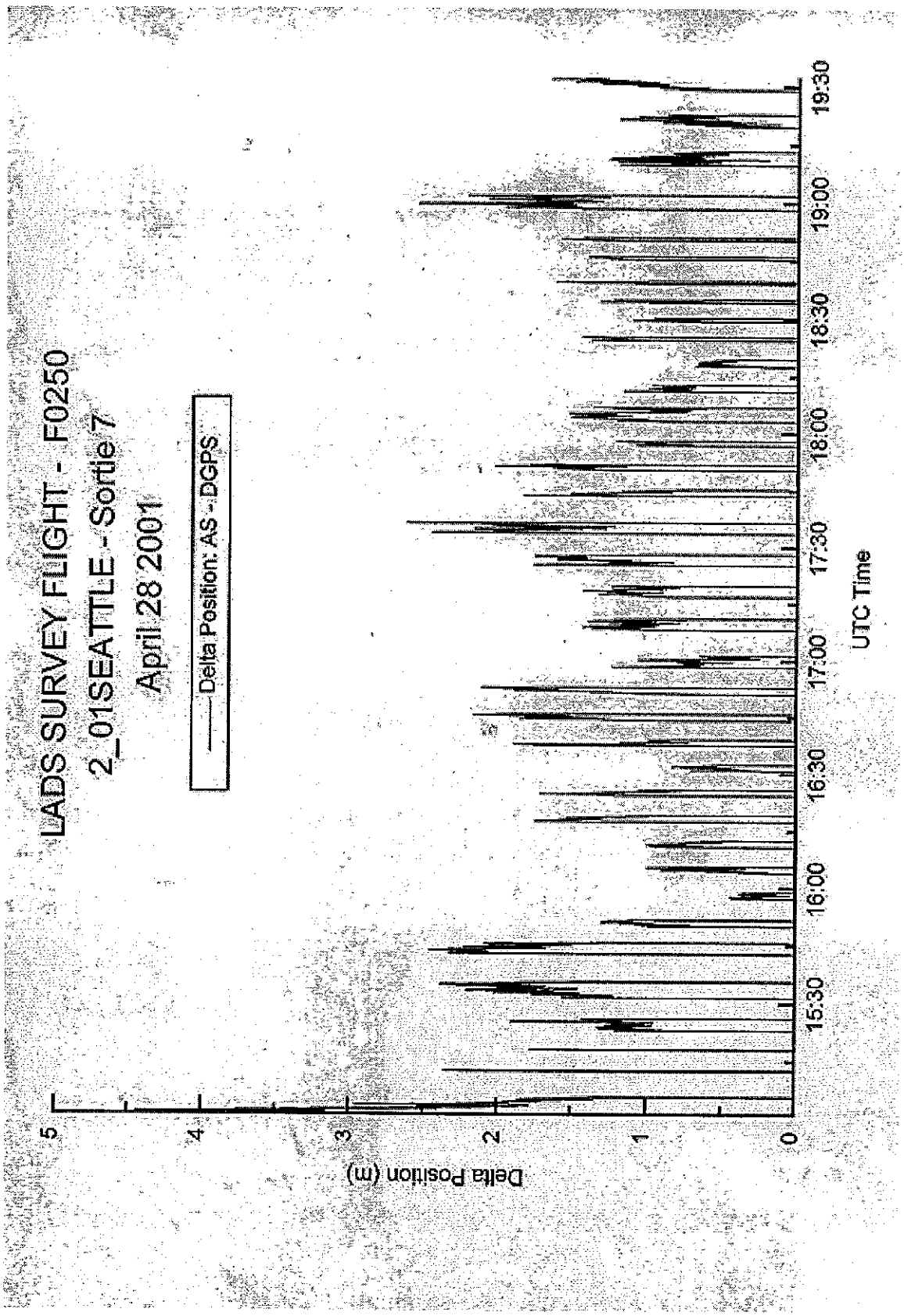

STATIC POSITION CHECK - 2_01SEATTLE
April 19 2001
Session 3 - Vancouver
WADGPS Vancouver
7345 samples
Mean AS Position:
E 552 787.36 +/- 1.03m
N 5 264 374.13 +/- 1.19m
Surveyed Position of GPS Antenna
E 552 787.98
N 5 264 374.38
Datum / Spheroid: WGS84
Projection: UTM N Zone 10
Northing
Easting
5264380
5264378
5264376
5264374
5264372
5264370
552784
552786
552788
552790
552792

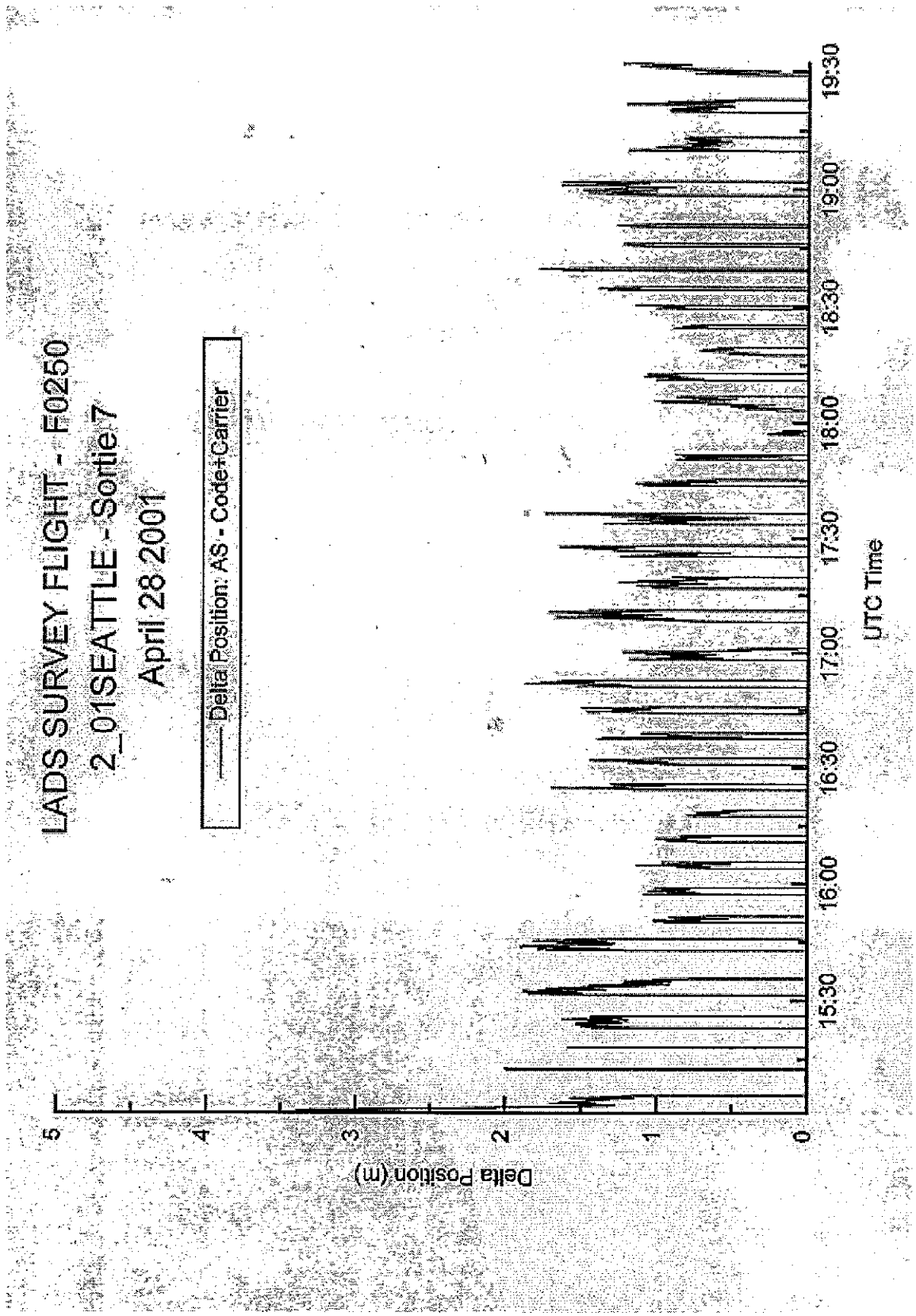

STATIC POSITION CHECK - 2_01SEATTLE
April 19 2001
Session 3 - Vancouver
PNAV DGPS
3937 samples
Surveyed Position of GPS Antenna:
E 552 787.98
N 5 264 374.38
Mean DGPS Position:
E 552 787.80 +/- 0.52m
N 5 264 374.34 +/- 0.34m
Northing
5264376
5264375
5264374
5264373
5264372
Datum / Spheroid: WGS84
Projection: UTM N Zone 10
552785
552786
552787
552788
552789
Easting

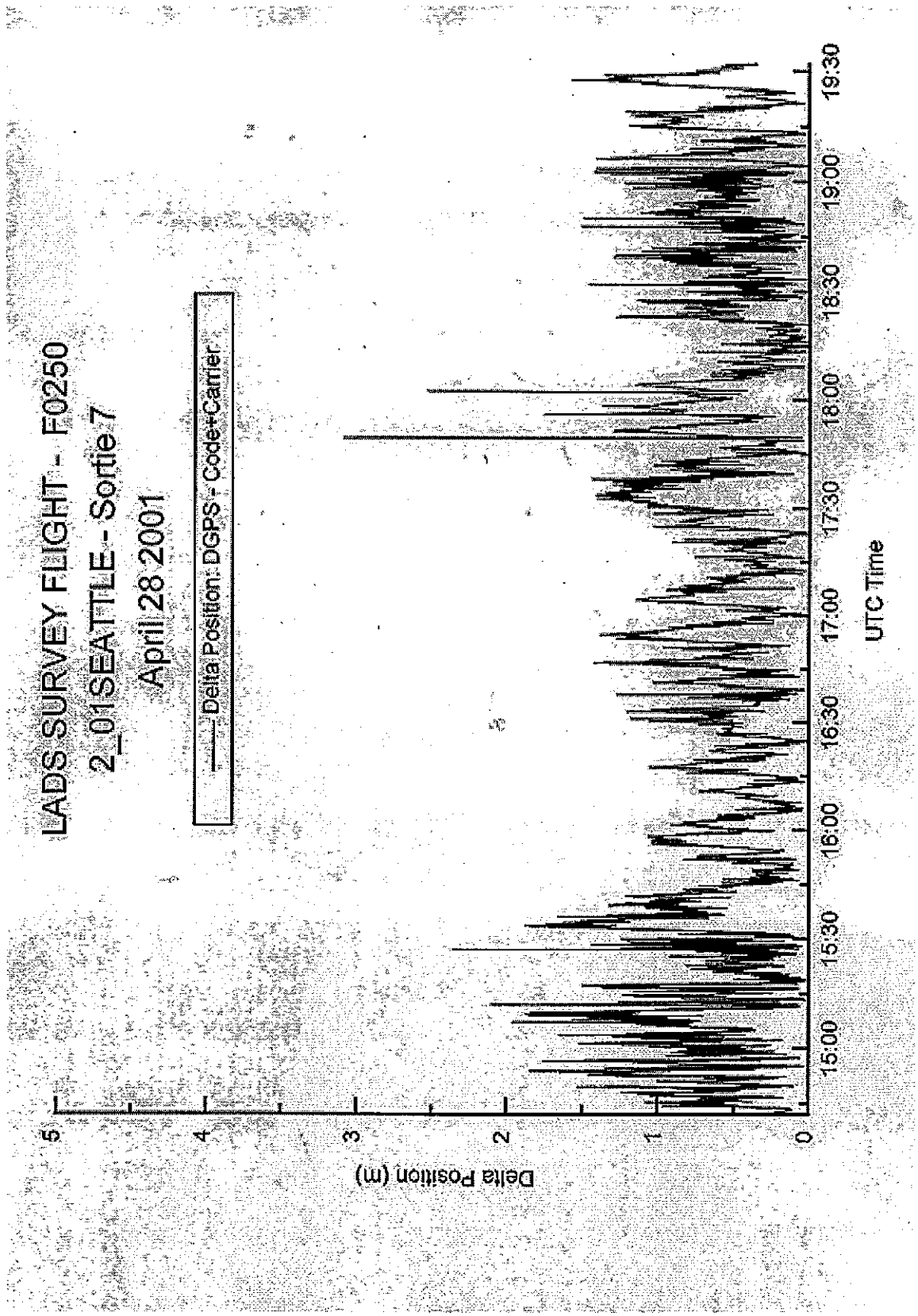

STATIC POSITION CHECK - 2_01SEATTLE
April 19 2001
Session 3 - Vancouver
PNAV Code+Carrier
3937 samples
Mean Code+Carrier Position
E 552 787.94 +/- 0.01m
N 5 264 374.44 +/- 0.02m
Surveyed Position of GPS Antenna:
E 552 787.98
N 5 264 374.38
Datum / Spheroid: WGS84
Projection: UTM N Zone 10
Northing
Easting
5264375.0
5264374.8
5264374.6
5264374.4
5264374.2
5264374.0
552787.4
552787.6
552787.8
552788.0
552788.2

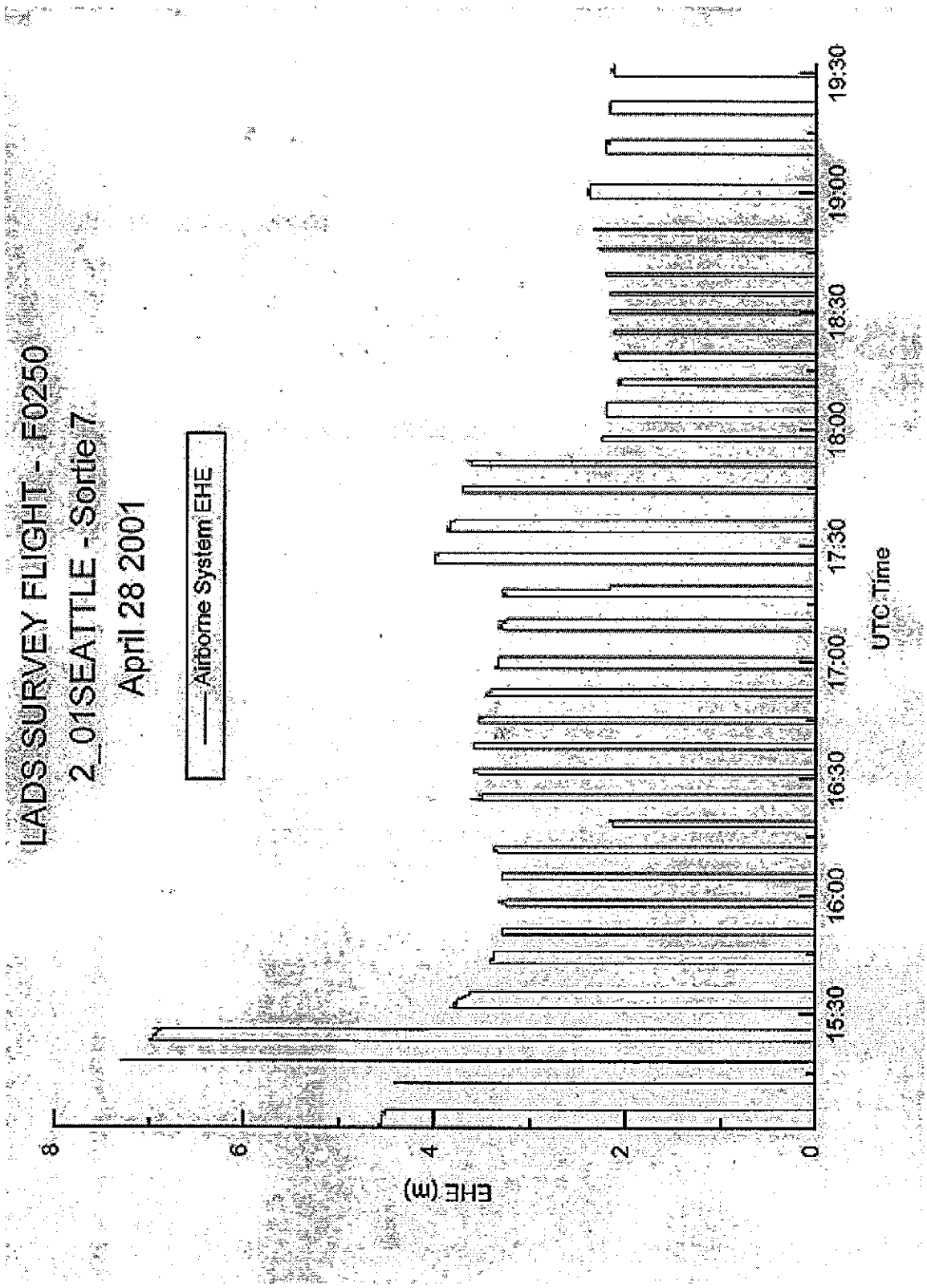
Dynamic Position Check

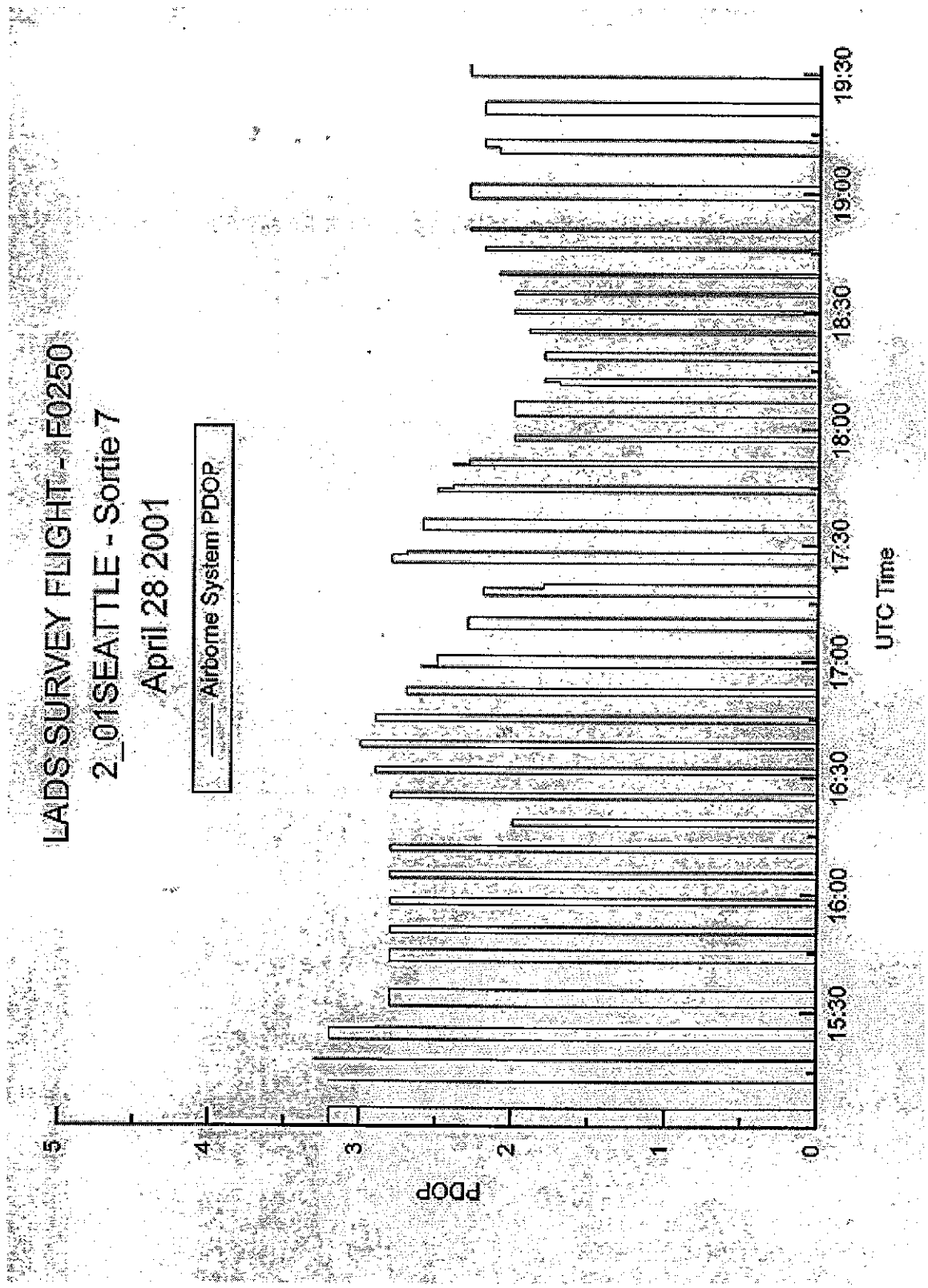


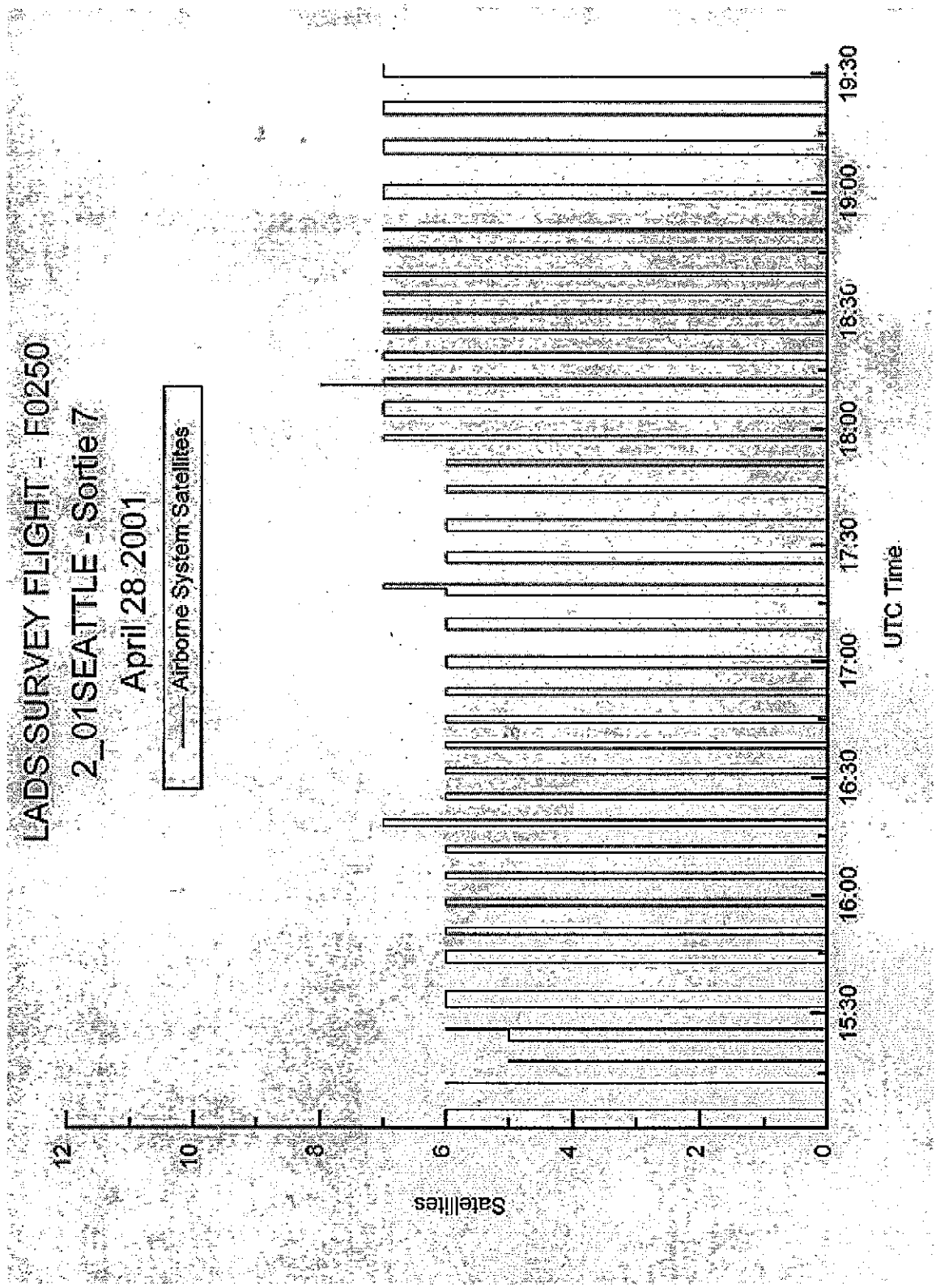

LADS SURVEY FLIGHT - F0250
2_01SEATTLE - Sortie 7
April 28 2001
Delta Position: AS - DGPS
Delta Position (m)
0
1
2
3
4
5
15:30
16:00
16:30
17:00
17:30
18:00
18:30
19:00
19:30
UTC Time

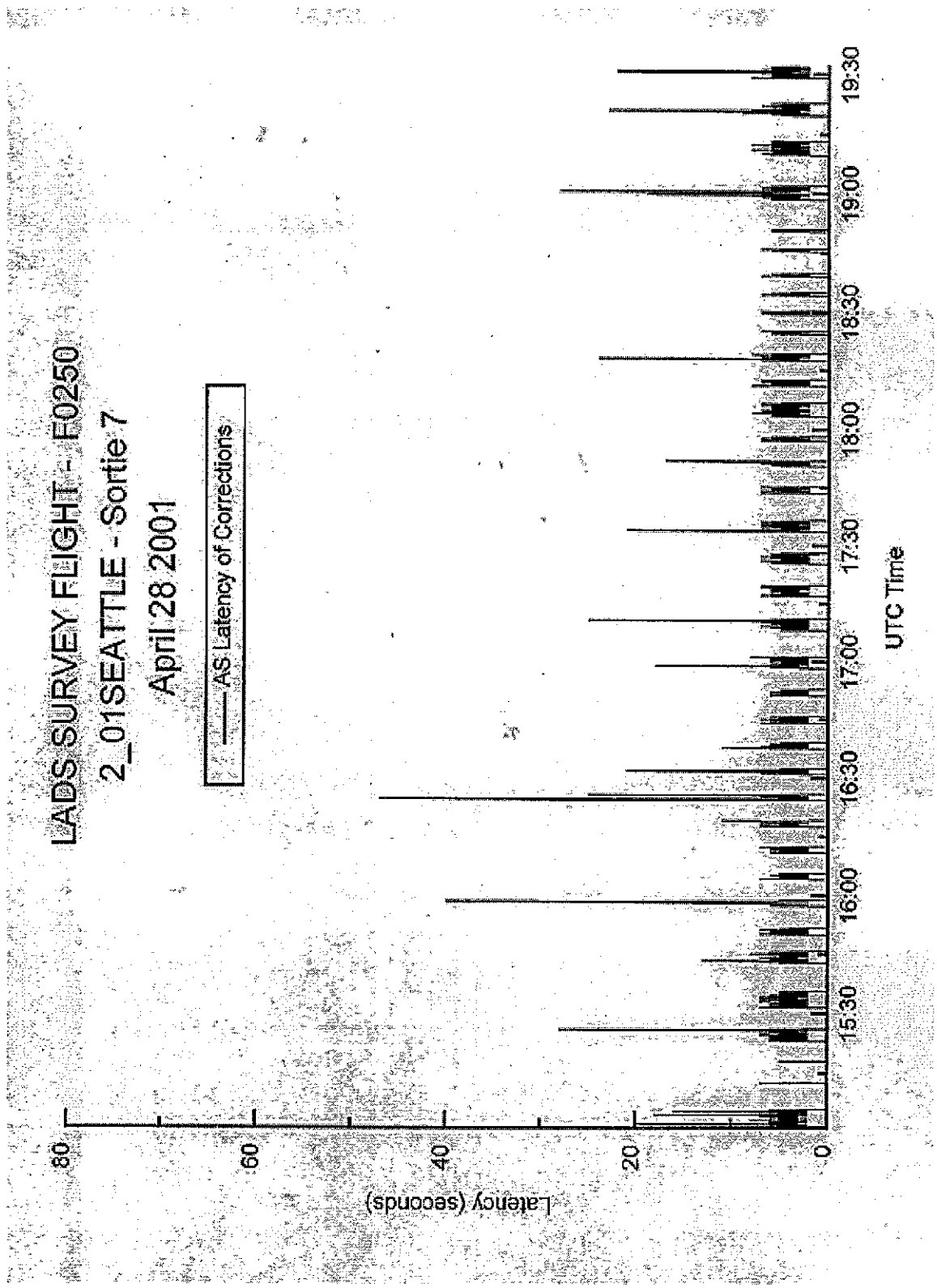

LADS SURVEY FLIGHT - F0250
2_01SEATTLE - Sortie 7
April 28 2001
Delta Position: AS - Code+Carrier
Delta Position (m)
UTC Time
0
1
2
3
4
5
15:30
16:00
16:30
17:00
17:30
18:00
18:30
19:00
19:30

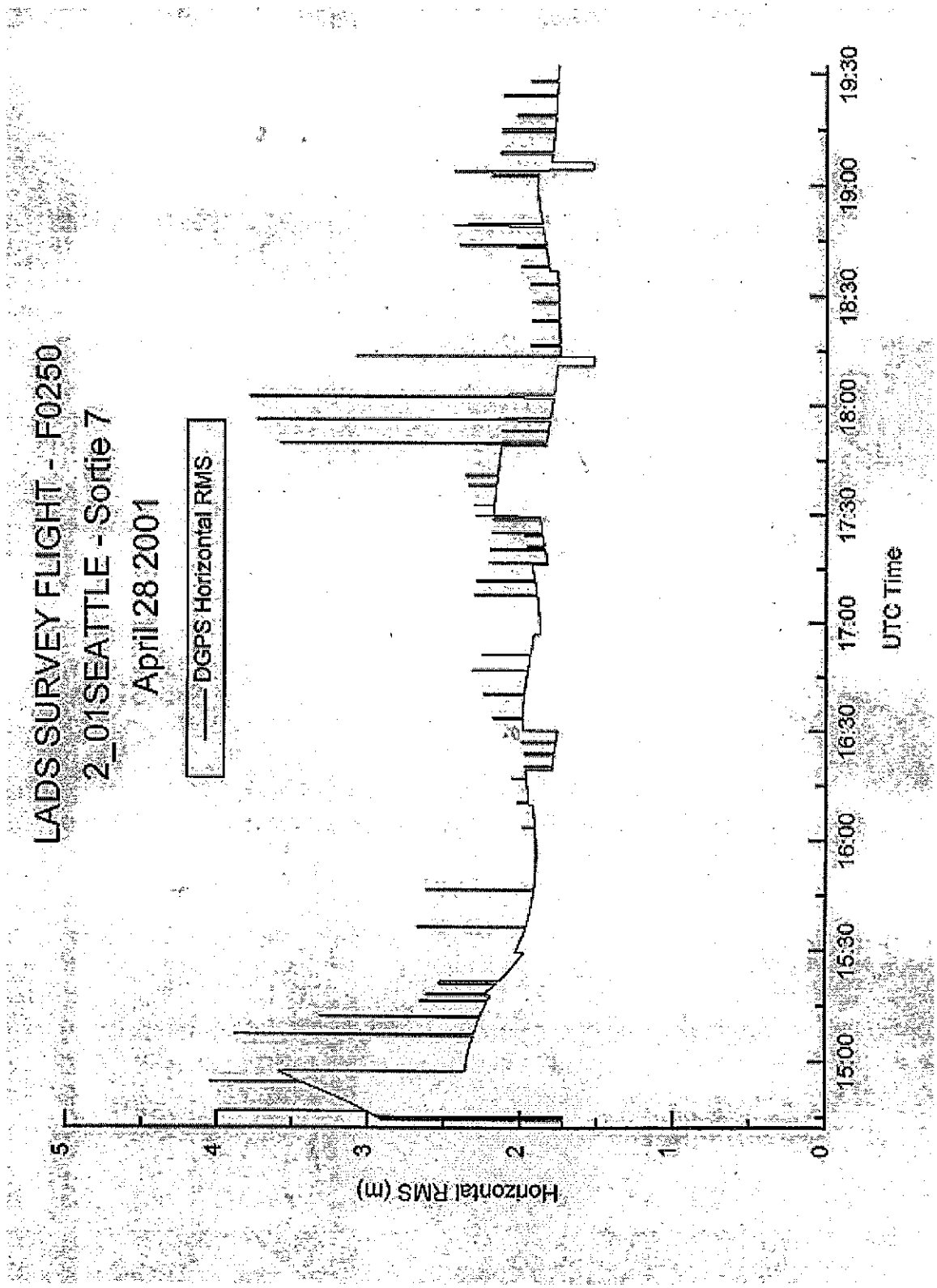

LADS SURVEY FLIGHT - F0250
2_01SEATTLE - Sortie 7
April 28 2001
Delta Position: DGPS - Code+Carrier
Delta Position (m)
0
1
2
3
4
5
15:00
15:30
16:00
16:30
17:00
17:30
18:00
18:30
19:00
19:30
UTC Time

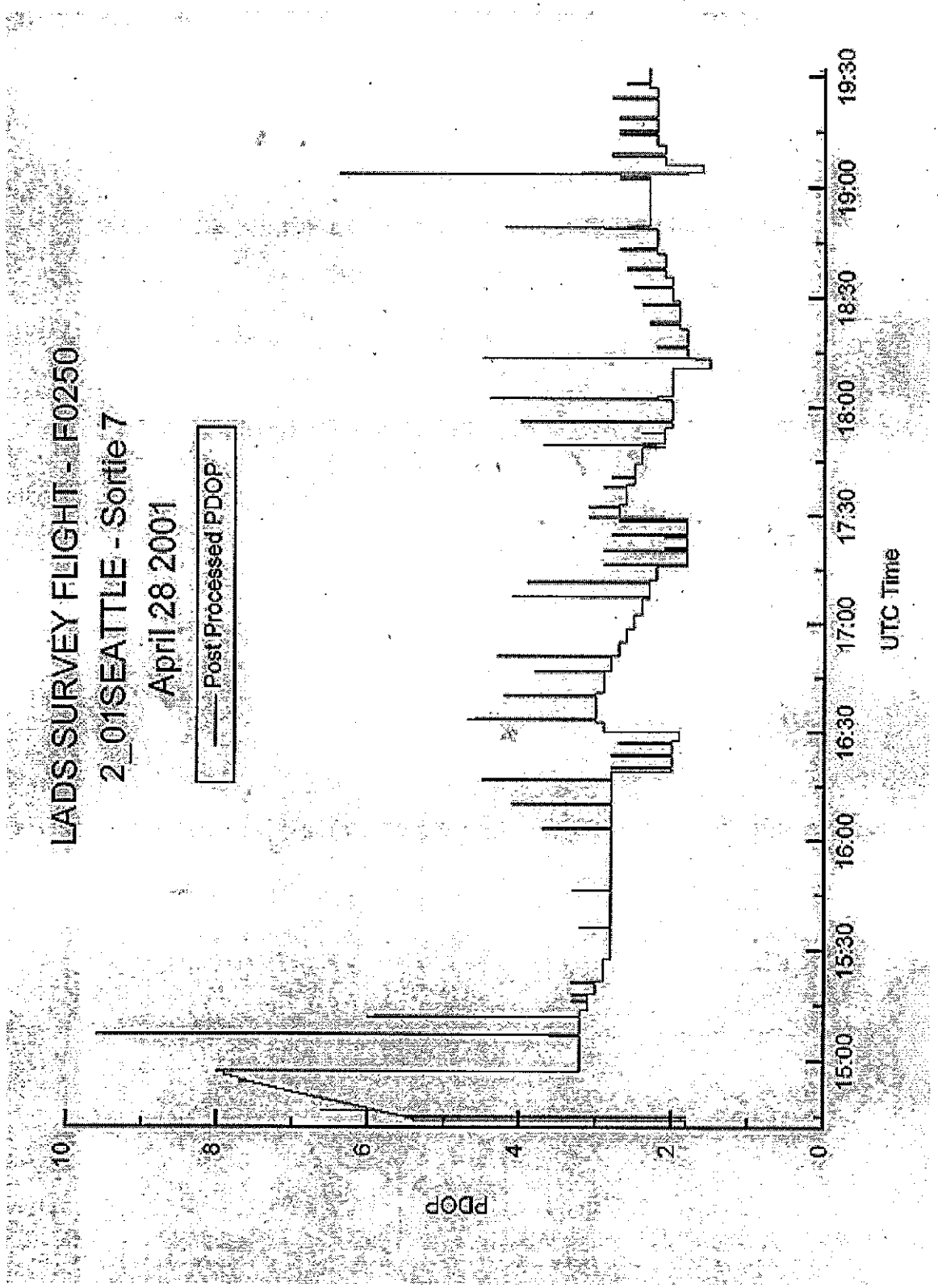

LADS SURVEY FLIGHT - F0250
2_01SEATTLE - Sortie 7
April 28 2001
Airborne System EHE
EHE (m)
0
2
4
6
8
15:30
16:00
16:30
17:00
17:30
18:00
18:30
19:00
19:30
UTC Time

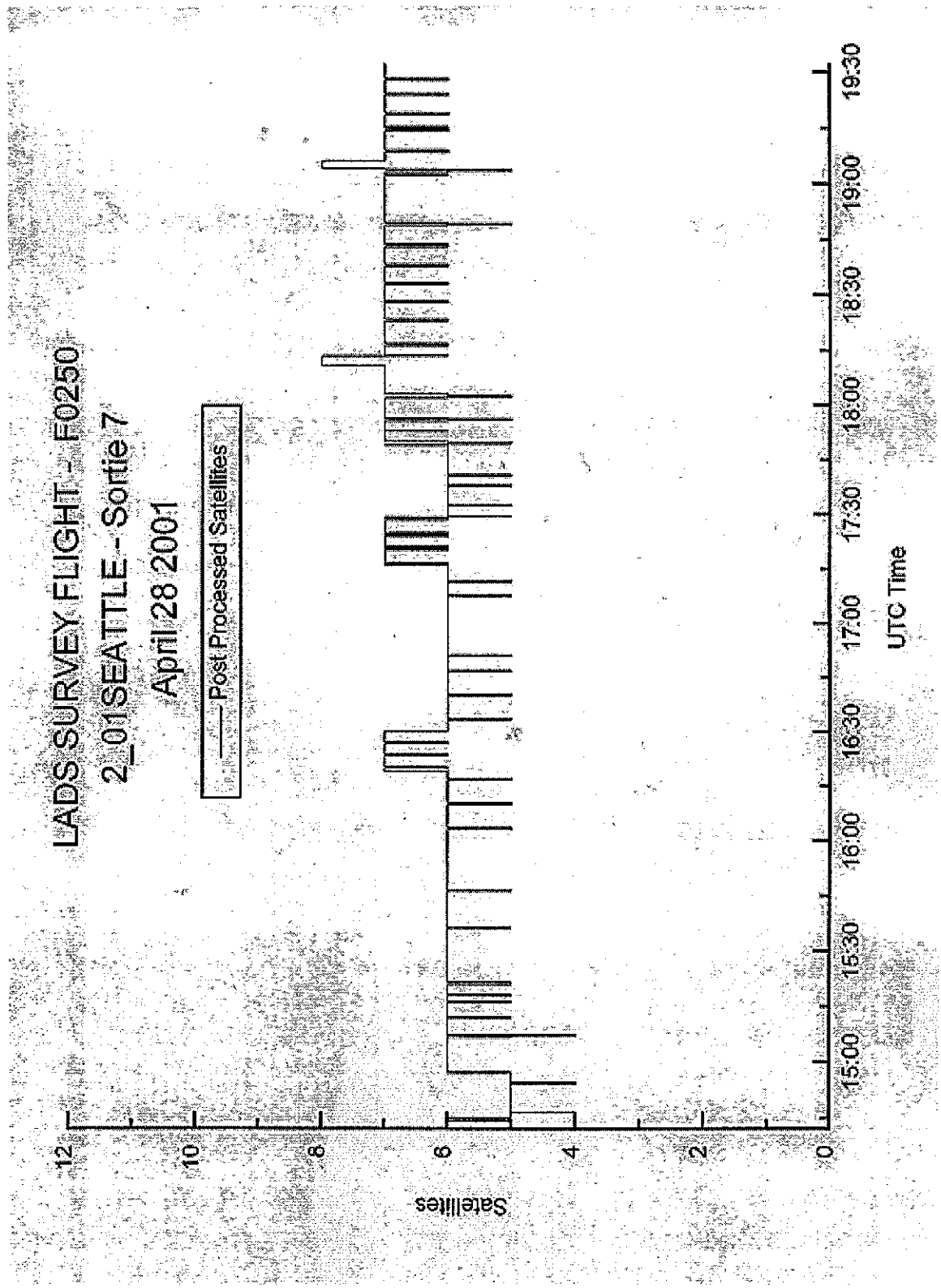

LADS SURVEY FLIGHT - F0250
2_01SEATTLE - Sortie 7
April 28 2001
Airborne System PDOP
PDOP
0
1
2
3
4
5
15:30
16:00
16:30
17:00
17:30
18:00
18:30
19:00
19:30
UTC Time

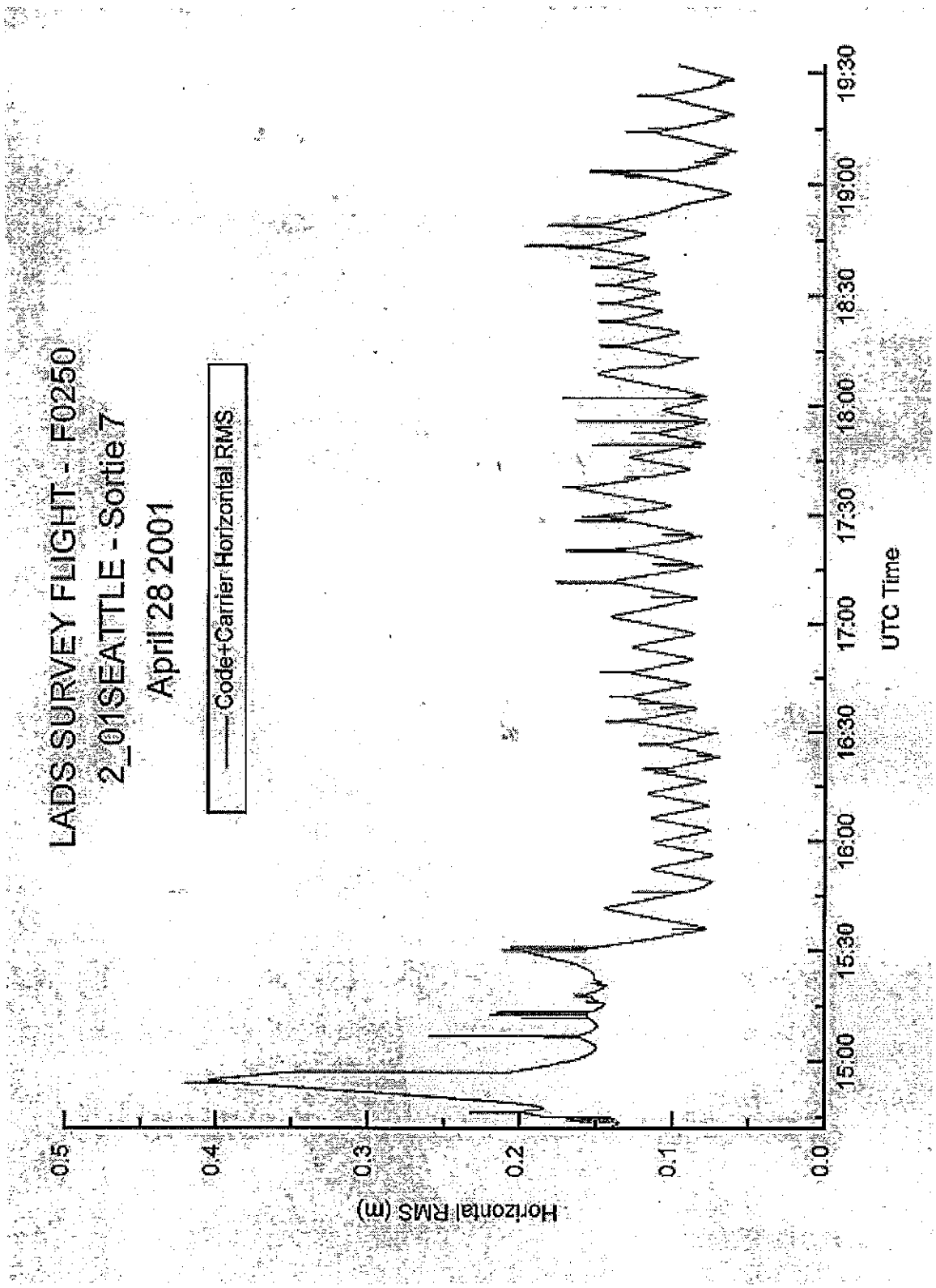

LADS SURVEY FLIGHT - F0250
2_01SEATTLE - Sortie 7
April 28 2001
Airborne System Satellites
Satellites
0
2
4
6
8
10
12
15:30
16:00
16:30
17:00
17:30
18:00
18:30
19:00
19:30
UTC Time

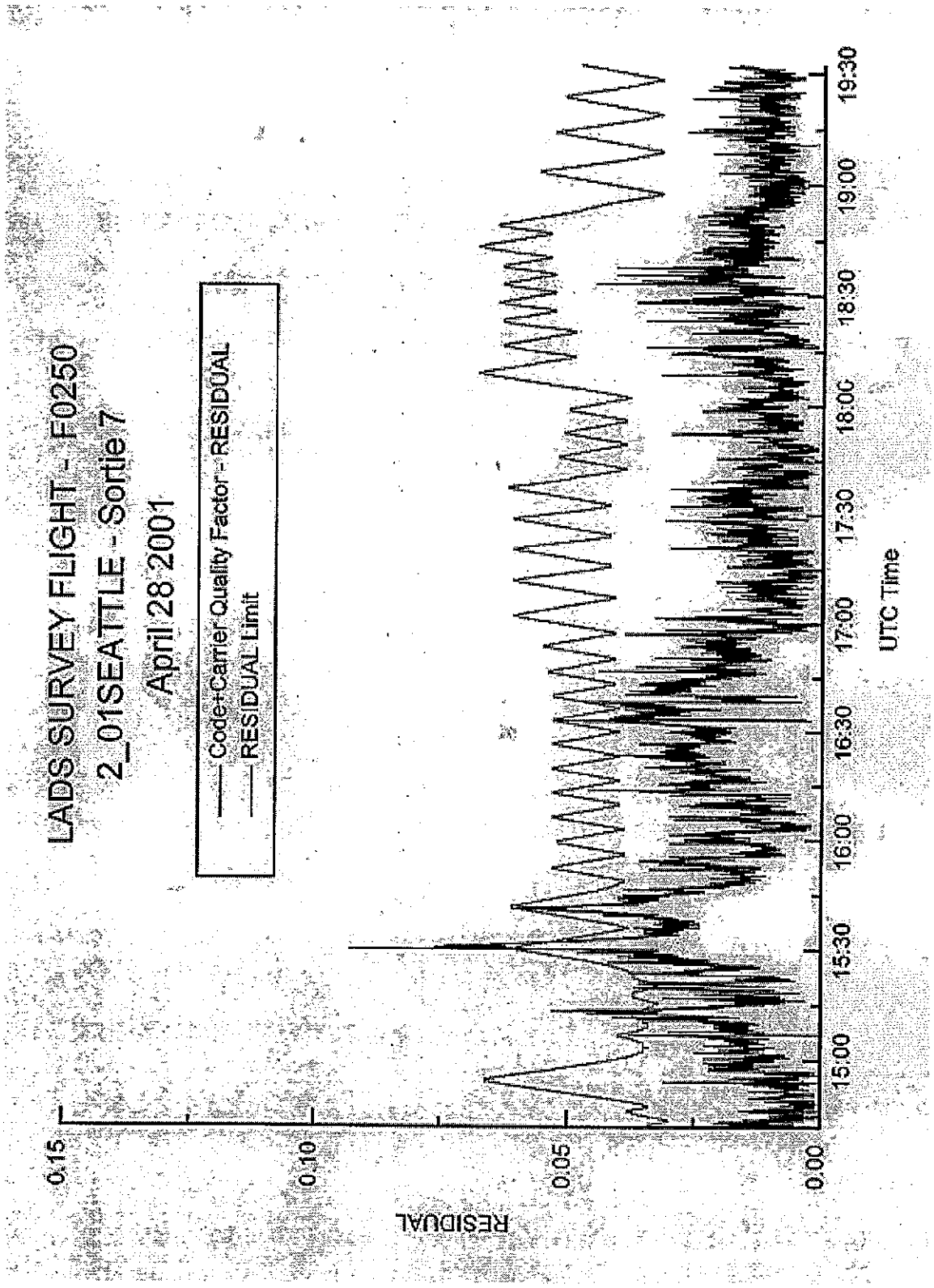

LADS SURVEY FLIGHT - F0250
2_01SEATTLE - Sortie 7
April 28 2001
AS Latency of Corrections
Latency (seconds)
0
20
40
60
80
15:30
16:00
16:30
17:00
17:30
18:00
18:30
19:00
19:30
UTC Time

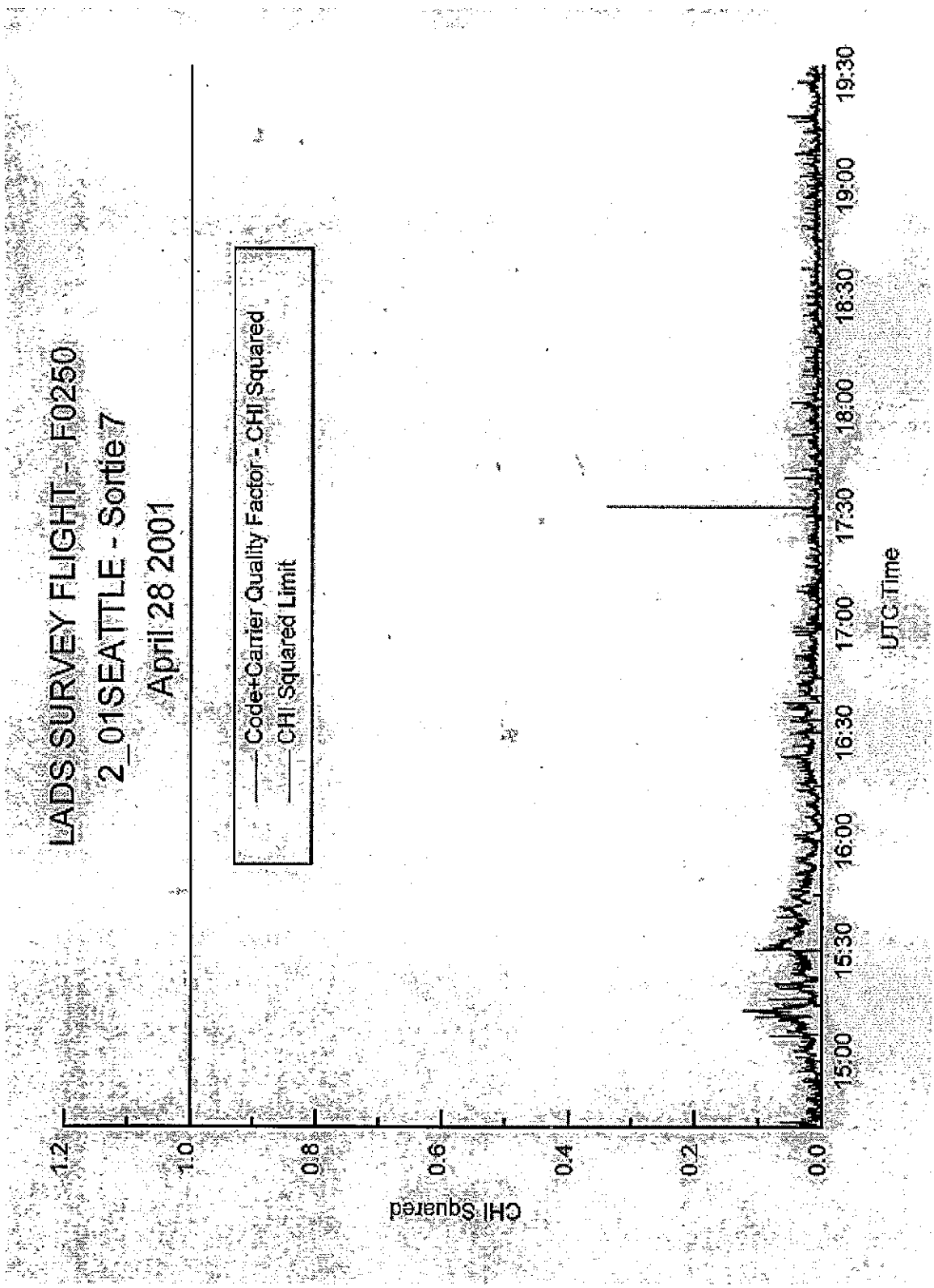

LADS SURVEY FLIGHT - F0250
2_01SEATTLE - Softie 7
April 28 2001
DGPS Horizontal RMS
Horizontal RMS (m)
0
1
2
3
4
5
15:00
15:30
16:00
16:30
17:00
17:30
18:00
18:30
19:00
19:30
UTC Time


LADS SURVEY FLIGHT - F0250
2_01SEATTLE - Sortie 7
April 28 2001
Post Processed PDOP
PDOP
UTC Time
0
2
4
6
8
10
15:00
15:30
16:00
16:30
17:00
17:30
18:00
18:30
19:00
19:30


LADS SURVEY FLIGHT - F0250
2_01SEATTLE - Sortie 7
April 28 2001
Post Processed Satellites
Satellites
UTC Time
0
2
4
6
8
10
12
15:00
15:30
16:00
16:30
17:00
17:30
18:00
18:30
19:00
19:30


LADS SURVEY FLIGHT - F0250
2_01SEATTLE - Sortie 7
April 28 2001
Code+Carrier Horizontal RMS
Horizontal RMS (m)
0.5
0.4
0.3
0.2
0.1
0.0
15:00
15:30
16:00
16:30
17:00
17:30
18:00
18:30
19:00
19:30
UTC Time


LADS SURVEY FLIGHT - F0250
2_01SEATTLE - Sortie 7
April 28 2001
Code+Carrier Quality Factor - RESIDUAL
RESIDUAL Limit
RESIDUAL
0.15
0.10
0.05
0.00
15:00
15:30
16:00
16:30
17:00
17:30
18:00
18:30
19:00
19:30
UTC Time


LADS SURVEY FLIGHT - F0250
2_01SEATTLE - Sortie 7
April 28 2001
Code+Carrier Quality Factor - CHI Squared
CHI Squared Limit
CHI Squared
1.2
1.0
0.8
0.6
0.4
0.2
0.0
15:00
15:30
16:00
16:30
17:00
17:30
18:00
18:30
19:00
19:30
UTC Time

Position Analysis Report – Sortie 7

POSITION ANALYSIS REPORT FOR SORTIE 7 FLOWN ON 118 2001 (28/04/01)
MISSION TITLE: SEATTLE
RUN COUNT: 37

Statistics for Run 1007.0.1
GPS Start Time 15:01:18 End Time 15:05:50

DGPS_HRMS Min= 2.314m Max= 2.346m
KGPS_HRMS Min= 0.150m Max= 0.158m
AS_EHE Min= 4.500m Max= 4.583m
AS_PDOP Min= 3.20m Max= 3.20m
POST_PROCESSED_PDOP Min= 3.20m Max= 3.20m
AS_SVS Min= 6 Max= 6
POST_PROCESSED_SVS Min= 6 Max= 6
AS_LATENCY_OF_CORRECTIONS Min= 2s Max= 20s

Analysis of Reported GPS Position

Airborne System - DGPS (Sample Size: AS = 273 DGPS = 273)
Latitude Min= -2.626m Max= 1.108m Mean= -0.511m Stdev= 0.986m
Longitude Min= -3.574m Max= -0.948m Mean= -2.172m Stdev= 0.545m
RMS Min= 1.347m Max= 4.435m Mean= 2.395m Stdev= 0.713m

Airborne System - KGPS (Sample Size: AS = 273 KGPS = 273)
Latitude Min= -1.692m Max= 1.130m Mean= -0.200m Stdev= 0.725m
Longitude Min= -2.940m Max= -0.988m Mean= -1.679m Stdev= 0.516m
RMS Min= 1.060m Max= 3.392m Mean= 1.813m Stdev= 0.602m

DGPS - KGPS (Sample Size: DGPS = 273 KGPS = 273)
Latitude Min= -1.302m Max= 1.765m Mean= 0.254m Stdev= 0.542m
Longitude Min= -0.855m Max= 1.273m Mean= -0.046m Stdev= 0.413m
RMS Min= 0.024m Max= 1.994m Mean= 0.644m Stdev= 0.340m

DGPS - AS Height (Sample Size: AS = 273 DGPS = 273)
WGS84 Ht Min= -2.951m Max= 1.331m Mean= -0.477m

KGPS - AS Height (Sample Size: AS = 273 KGPS = 273)
WGS84 Ht Min= -2.778m Max= 1.351m Mean= -0.466m

Airborne System GPS Mode : diff
Airborne System Racal Basestation : 0505

Statistics for Run 707.0.1
GPS Start Time 15:12:27 End Time 15:12:36

DGPS_HRMS Min= 2.260m Max= 2.261m
KGPS_HRMS Min= 0.155m Max= 0.155m
AS_EHE Min= 4.417m Max= 4.417m
AS_PDOP Min= 3.20m Max= 3.20m
POST_PROCESSED_PDOP Min= 3.20m Max= 3.20m
AS_SVS Min= 6 Max= 6
POST_PROCESSED_SVS Min= 6 Max= 6
AS_LATENCY_OF_CORRECTIONS Min= 3s Max= 7s

Analysis of Reported GPS Position

Airborne System - DGPS (Sample Size: AS = 10 DGPS = 10)
Latitude Min= -1.166m Max= -0.938m Mean= -1.056m Stdev= 0.072m
Longitude Min= -2.051m Max= -1.903m Mean= -1.990m Stdev= 0.051m
RMS Min= 2.151m Max= 2.359m Mean= 2.253m Stdev= 0.064m

Airborne System - KGPS (Sample Size: AS = 10 KGPS = 10)
Latitude Min= -0.649m Max= -0.381m Mean= -0.487m Stdev= 0.085m

Longitude Min= -1.938m Max= -1.750m Mean= -1.844m Stdev= 0.063m
RMS Min= 1.791m Max= 2.001m Mean= 1.909m Stdev= 0.072m

DGPS - KGPS (Sample Size: DGPS = 10 KGPS = 10)
Latitude Min= -2.061m Max= 0.682m Mean= -0.754m Stdev= 0.536m
Longitude Min= -1.095m Max= 0.255m Mean= -0.419m Stdev= 0.326m
RMS Min= 0.058m Max= 2.096m Mean= 0.966m Stdev= 0.452m

DGPS - AS Height (Sample Size: AS = 10 DGPS = 10)
WGS84 Ht Min= -0.316m Max= 0.322m Mean= -0.053m

KGPS - AS Height (Sample Size: AS = 10 KGPS = 10)
WGS84 Ht Min= 0.221m Max= 0.818m Mean= 0.505m

Airborne System GPS Mode : diff
Airborne System Racal Basestation : 0505

Statistics for Run 707.0.2
GPS Start Time 15:17:49 End Time 15:18:03

DGPS_HRMS Min= 2.616m Max= 2.621m
KGPS_HRMS Min= 0.162m Max= 0.163m
AS_EHE Min= 7.292m Max= 7.292m
AS_PDOP Min= 3.30m Max= 3.30m
POST_PROCESSED_PDOP Min= 3.30m Max= 3.30m
AS_SVS Min= 5 Max= 5
POST_PROCESSED_SVS Min= 5 Max= 5
AS_LATENCY_OF_CORRECTIONS Min= 2s Max= 5s

Analysis of Reported GPS Position

Airborne System - DGPS (Sample Size: AS = 15 DGPS = 15)
Latitude Min= -0.564m Max= 0.034m Mean= -0.294m Stdev= 0.166m
Longitude Min= -1.744m Max= -1.439m Mean= -1.646m Stdev= 0.088m
RMS Min= 1.439m Max= 1.775m Mean= 1.679m Stdev= 0.099m

Airborne System - KGPS (Sample Size: AS = 15 KGPS = 15)
Latitude Min= -0.383m Max= 0.072m Mean= -0.136m Stdev= 0.134m
Longitude Min= -1.581m Max= -1.354m Mean= -1.496m Stdev= 0.068m
RMS Min= 1.356m Max= 1.587m Mean= 1.508m Stdev= 0.070m

DGPS - KGPS (Sample Size: DGPS = 15 KGPS = 15)
Latitude Min= -0.191m Max= 1.310m Mean= 0.586m Stdev= 0.370m
Longitude Min= -0.251m Max= 0.794m Mean= 0.167m Stdev= 0.242m
RMS Min= 0.020m Max= 1.499m Mean= 0.650m Stdev= 0.379m

DGPS - AS Height (Sample Size: AS = 15 DGPS = 15)
WGS84 Ht Min= -3.696m Max= -2.559m Mean= -3.150m

KGPS - AS Height (Sample Size: AS = 15 KGPS = 15)
WGS84 Ht Min= -1.598m Max= -0.557m Mean= -1.115m

Airborne System GPS Mode : diff
Airborne System Racal Basestation : 0505

Statistics for Run 707.0.3
GPS Start Time 15:22:57 End Time 15:26:02

DGPS_HRMS Min= 2.041m Max= 2.107m
KGPS_HRMS Min= 0.151m Max= 0.161m
AS_EHE Min= 4.042m Max= 7.000m
AS_PDOP Min= 2.90m Max= 3.20m
POST_PROCESSED_PDOP Min= 2.90m Max= 2.90m
AS_SVS Min= 5 Max= 6
POST_PROCESSED_SVS Min= 6 Max= 6
AS_LATENCY_OF_CORRECTIONS Min= 2s Max= 28s

Analysis of Reported GPS Position

Airborne System - DGPS (Sample Size: AS = 186 DGPS = 186)
Latitude Min= -0.232m Max= 1.865m Mean= 0.457m Stdev= 0.332m
Longitude Min= -1.423m Max= -0.389m Mean= -1.027m Stdev= 0.189m
RMS Min= 0.885m Max= 1.906m Mean= 1.179m Stdev= 0.141m

Airborne System - KGPS (Sample Size: AS = 186 KGPS = 186)
Latitude Min= -0.166m Max= 1.185m Mean= 0.711m Stdev= 0.244m
Longitude Min= -1.490m Max= -0.775m Mean= -1.143m Stdev= 0.142m
RMS Min= 1.122m Max= 1.622m Mean= 1.372m Stdev= 0.091m

DGPS - KGPS (Sample Size: DGPS = 186 KGPS = 186)
Latitude Min= -0.680m Max= 0.686m Mean= 0.101m Stdev= 0.259m
Longitude Min= -0.695m Max= 0.235m Mean= -0.184m Stdev= 0.195m
RMS Min= 0.017m Max= 0.918m Mean= 0.347m Stdev= 0.169m

DGPS - AS Height (Sample Size: AS = 186 DGPS = 186)
WGS84 Ht Min= -3.340m Max= 0.897m Mean= -2.014m

KGPS - AS Height (Sample Size: AS = 186 KGPS = 186)
WGS84 Ht Min= -3.303m Max= -0.321m Mean= -2.071m

Airborne System GPS Mode : diff
Airborne System Racal Basestation : 0505

Statistics for Run 806.0.1
GPS Start Time 15:31:29 End Time 15:35:33

DGPS_HRMS Min= 1.971m Max= 2.012m
KGPS_HRMS Min= 0.083m Max= 0.143m
AS_EHE Min= 3.625m Max= 3.833m
AS_PDOP Min= 2.80m Max= 2.80m
POST_PROCESSED_PDOP Min= 2.80m Max= 2.80m
AS_SVS Min= 6 Max= 6
POST_PROCESSED_SVS Min= 6 Max= 6
AS_LATENCY_OF_CORRECTIONS Min= 2s Max= 7s

Analysis of Reported GPS Position

Airborne System - DGPS (Sample Size: AS = 245 DGPS = 245)
Latitude Min= 0.308m Max= 2.388m Mean= 1.544m Stdev= 0.525m
Longitude Min= -1.482m Max= 0.020m Mean= -0.537m Stdev= 0.407m
RMS Min= 1.215m Max= 2.388m Mean= 1.744m Stdev= 0.267m

Airborne System - KGPS (Sample Size: AS = 245 KGPS = 245)
Latitude Min= -0.044m Max= 1.026m Mean= 0.527m Stdev= 0.225m
Longitude Min= -1.855m Max= -0.551m Mean= -1.194m Stdev= 0.389m
RMS Min= 0.788m Max= 1.885m Mean= 1.347m Stdev= 0.299m

DGPS - KGPS (Sample Size: DGPS = 245 KGPS = 245)
Latitude Min= -1.651m Max= 1.940m Mean= -0.254m Stdev= 0.832m
Longitude Min= -0.909m Max= 1.347m Mean= -0.164m Stdev= 0.494m
RMS Min= 0.040m Max= 2.362m Mean= 0.884m Stdev= 0.495m

DGPS - AS Height (Sample Size: AS = 245 DGPS = 245)
WGS84 Ht Min= -0.024m Max= 3.454m Mean= 1.848m

KGPS - AS Height (Sample Size: AS = 245 KGPS = 245)
WGS84 Ht Min= -1.216m Max= 1.392m Mean= 0.161m

Airborne System GPS Mode : diff
Airborne System Racal Basestation : 0505

Statistics for Run 907.0.1
GPS Start Time 15:42:45 End Time 15:45:43

DGPS_HRMS Min= 1.914m Max= 1.927m
KGPS_HRMS Min= 0.096m Max= 0.132m
AS_EHE Min= 3.375m Max= 3.417m
AS_PDOP Min= 2.80m Max= 2.80m
POST_PROCESSED_PDOP Min= 2.80m Max= 2.80m
AS_SVS Min= 6 Max= 6
POST_PROCESSED_SVS Min= 6 Max= 6
AS_LATENCY_OF_CORRECTIONS Min= 2s Max= 13s

Analysis of Reported GPS Position

Airborne System - DGPS (Sample Size: AS = 179 DGPS = 179)
Latitude Min= 1.291m Max= 2.461m Mean= 1.952m Stdev= 0.264m
Longitude Min= -0.343m Max= 0.381m Mean= 0.008m Stdev= 0.152m
RMS Min= 1.322m Max= 2.464m Mean= 1.958m Stdev= 0.263m

Airborne System - KGPS (Sample Size: AS = 179 KGPS = 179)
Latitude Min= 1.170m Max= 1.882m Mean= 1.515m Stdev= 0.160m
Longitude Min= -0.553m Max= 0.082m Mean= -0.261m Stdev= 0.111m
RMS Min= 1.222m Max= 1.902m Mean= 1.542m Stdev= 0.152m

DGPS - KGPS (Sample Size: DGPS = 179 KGPS = 179)
Latitude Min= -1.511m Max= 0.107m Mean= -0.734m Stdev= 0.266m
Longitude Min= -0.696m Max= 0.467m Mean= -0.010m Stdev= 0.297m
RMS Min= 0.172m Max= 1.663m Mean= 0.799m Stdev= 0.244m

DGPS - AS Height (Sample Size: AS = 179 DGPS = 179)
WGS84 Ht Min= 0.705m Max= 4.887m Mean= 2.961m

KGPS - AS Height (Sample Size: AS = 179 KGPS = 179)
WGS84 Ht Min= 1.443m Max= 4.359m Mean= 2.782m

Airborne System GPS Mode : diff
Airborne System Racal Basestation : 0505

Statistics for Run 604.0.1
GPS Start Time 15:49:56 End Time 15:51:35

DGPS_HRMS Min= 1.902m Max= 1.904m
KGPS_HRMS Min= 0.084m Max= 0.105m
AS_EHE Min= 3.292m Max= 3.292m
AS_PDOP Min= 2.80m Max= 2.80m
POST_PROCESSED_PDOP Min= 2.80m Max= 2.80m
AS_SVS Min= 6 Max= 6
POST_PROCESSED_SVS Min= 6 Max= 6
AS_LATENCY_OF_CORRECTIONS Min= 2s Max= 7s

Analysis of Reported GPS Position

Airborne System - DGPS (Sample Size: AS = 100 DGPS = 100)
Latitude Min= 0.509m Max= 1.168m Mean= 0.864m Stdev= 0.170m
Longitude Min= -0.782m Max= -0.374m Mean= -0.579m Stdev= 0.080m
RMS Min= 0.702m Max= 1.300m Mean= 1.047m Stdev= 0.149m

Airborne System - KGPS (Sample Size: AS = 100 KGPS = 100)
Latitude Min= 0.423m Max= 0.975m Mean= 0.689m Stdev= 0.125m
Longitude Min= -0.622m Max= -0.181m Mean= -0.408m Stdev= 0.095m
RMS Min= 0.520m Max= 1.027m Mean= 0.809m Stdev= 0.107m

DGPS - KGPS (Sample Size: DGPS = 100 KGPS = 100)
Latitude Min= -0.607m Max= 0.540m Mean= 0.007m Stdev= 0.217m
Longitude Min= -0.363m Max= 0.309m Mean= -0.050m Stdev= 0.181m
RMS Min= 0.065m Max= 0.635m Mean= 0.266m Stdev= 0.109m

DGPS - AS Height (Sample Size: AS = 100 DGPS = 100)
WGS84 Ht Min= 0.263m Max= 2.388m Mean= 1.320m

KGPS - AS Height (Sample Size: AS = 100 KGPS = 100)

WGS84 Ht Min= -0.257m Max= 1.957m Mean= 0.715m

Airborne System GPS Mode : diff
Airborne System Racal Basestation : 0505

Statistics for Run 605.0.1
GPS Start Time 15:57:10 End Time 15:58:50

DGPS_HRMS Min= 1.900m Max= 1.901m
KGPS_HRMS Min= 0.085m Max= 0.106m
AS_EHE Min= 3.250m Max= 3.333m
AS_PDOP Min= 2.80m Max= 2.80m
POST_PROCESSED_PDOP Min= 2.80m Max= 2.80m
AS_SVS Min= 6 Max= 6
POST_PROCESSED_SVS Min= 6 Max= 6
AS_LATENCY_OF_CORRECTIONS Min= 2s Max= 40s

Analysis of Reported GPS Position

Airborne System - DGPS (Sample Size: AS = 101 DGPS = 101)
Latitude Min= -0.401m Max= 0.325m Mean= -0.143m Stdev= 0.149m
Longitude Min= -0.414m Max= 0.164m Mean= -0.145m Stdev= 0.122m
RMS Min= 0.037m Max= 0.444m Mean= 0.264m Stdev= 0.093m

Airborne System - KGPS (Sample Size: AS = 101 KGPS = 101)
Latitude Min= 0.508m Max= 1.014m Mean= 0.730m Stdev= 0.111m
Longitude Min= -0.767m Max= -0.193m Mean= -0.478m Stdev= 0.122m
RMS Min= 0.708m Max= 1.090m Mean= 0.884m Stdev= 0.084m

DGPS - KGPS (Sample Size: DGPS = 101 KGPS = 101)
Latitude Min= -0.776m Max= 1.008m Mean= 0.280m Stdev= 0.583m
Longitude Min= -0.595m Max= 0.486m Mean= -0.173m Stdev= 0.244m
RMS Min= 0.086m Max= 1.067m Mean= 0.656m Stdev= 0.277m

DGPS - AS Height (Sample Size: AS = 101 DGPS = 101)
WGS84 Ht Min= -2.658m Max= -0.453m Mean= -1.547m

KGPS - AS Height (Sample Size: AS = 101 KGPS = 101)
WGS84 Ht Min= -0.317m Max= 1.660m Mean= 0.635m

Airborne System GPS Mode : diff
Airborne System Racal Basestation : 0505

Statistics for Run 606.0.1
GPS Start Time 16:03:58 End Time 16:05:34

DGPS_HRMS Min= 1.908m Max= 1.911m
KGPS_HRMS Min= 0.083m Max= 0.105m
AS_EHE Min= 3.292m Max= 3.292m
AS_PDOP Min= 2.80m Max= 2.80m
POST_PROCESSED_PDOP Min= 2.80m Max= 2.80m
AS_SVS Min= 6 Max= 6
POST_PROCESSED_SVS Min= 6 Max= 6
AS_LATENCY_OF_CORRECTIONS Min= 2s Max= 7s

Analysis of Reported GPS Position

Airborne System - DGPS (Sample Size: AS = 97 DGPS = 97)
Latitude Min= 0.166m Max= 0.992m Mean= 0.522m Stdev= 0.215m
Longitude Min= -0.282m Max= 0.362m Mean= 0.049m Stdev= 0.129m
RMS Min= 0.171m Max= 1.001m Mean= 0.543m Stdev= 0.204m

Airborne System - KGPS (Sample Size: AS = 97 KGPS = 97)
Latitude Min= 0.497m Max= 1.130m Mean= 0.725m Stdev= 0.127m
Longitude Min= -0.541m Max= 0.176m Mean= -0.040m Stdev= 0.186m
RMS Min= 0.504m Max= 1.135m Mean= 0.750m Stdev= 0.120m

DGPS - KGPS (Sample Size: DGPS = 97 KGPS = 97)
Latitude Min= -0.100m Max= 0.745m Mean= 0.257m Stdev= 0.189m
Longitude Min= -0.846m Max= 0.270m Mean= -0.389m Stdev= 0.257m
RMS Min= 0.048m Max= 0.919m Mean= 0.526m Stdev= 0.206m

DGPS - AS Height (Sample Size: AS = 97 DGPS = 97)
WGS84 Ht Min= 0.009m Max= 3.040m Mean= 1.210m

KGPS - AS Height (Sample Size: AS = 97 KGPS = 97)
WGS84 Ht Min= -0.472m Max= 1.330m Mean= 0.360m

Airborne System GPS Mode : diff
Airborne System Racal Basestation : 0505

Statistics for Run 607.0.1
GPS Start Time 16:10:47 End Time 16:12:23

DGPS_HRMS Min= 1.951m Max= 1.955m
KGPS_HRMS Min= 0.086m Max= 0.108m
AS_EHE Min= 3.333m Max= 3.375m
AS_PDOP Min= 2.80m Max= 2.80m
POST_PROCESSED_PDOP Min= 2.80m Max= 2.80m
AS_SVS Min= 6 Max= 6
POST_PROCESSED_SVS Min= 6 Max= 6
AS_LATENCY_OF_CORRECTIONS Min= 2s Max= 7s

Analysis of Reported GPS Position

Airborne System - DGPS (Sample Size: AS = 97 DGPS = 97)
Latitude Min= -0.670m Max= 0.070m Mean= -0.324m Stdev= 0.193m
Longitude Min= -0.856m Max= -0.417m Mean= -0.644m Stdev= 0.106m
RMS Min= 0.422m Max= 1.009m Mean= 0.739m Stdev= 0.147m

Airborne System - KGPS (Sample Size: AS = 97 KGPS = 97)
Latitude Min= -0.124m Max= 0.380m Mean= 0.144m Stdev= 0.113m
Longitude Min= -0.993m Max= -0.579m Mean= -0.804m Stdev= 0.091m
RMS Min= 0.602m Max= 1.006m Mean= 0.824m Stdev= 0.088m

DGPS - KGPS (Sample Size: DGPS = 97 KGPS = 97)
Latitude Min= -0.246m Max= 0.719m Mean= 0.279m Stdev= 0.220m
Longitude Min= -0.368m Max= 0.482m Mean= -0.061m Stdev= 0.132m
RMS Min= 0.039m Max= 0.731m Mean= 0.348m Stdev= 0.163m

DGPS - AS Height (Sample Size: AS = 97 DGPS = 97)
WGS84 Ht Min= -0.276m Max= 2.756m Mean= 1.112m

KGPS - AS Height (Sample Size: AS = 97 KGPS = 97)
WGS84 Ht Min= 1.271m Max= 3.192m Mean= 1.964m

Airborne System GPS Mode : diff
Airborne System Racal Basestation : 0505

Statistics for Run 608.0.1
GPS Start Time 16:17:25 End Time 16:19:04

DGPS_HRMS Min= 1.804m Max= 1.972m
KGPS_HRMS Min= 0.089m Max= 0.112m
AS_EHE Min= 2.125m Max= 2.167m
AS_PDOP Min= 2.00m Max= 2.00m
POST_PROCESSED_PDOP Min= 2.00m Max= 2.80m
AS_SVS Min= 7 Max= 7
POST_PROCESSED_SVS Min= 6 Max= 7
AS_LATENCY_OF_CORRECTIONS Min= 2s Max= 11s

Analysis of Reported GPS Position

Airborne System - DGPS (Sample Size: AS = 100 DGPS = 100)

Latitude Min= 0.771m Max= 1.749m Mean= 1.343m Stdev= 0.245m
Longitude Min= -0.567m Max= 0.043m Mean= -0.293m Stdev= 0.125m
RMS Min= 0.868m Max= 1.753m Mean= 1.386m Stdev= 0.213m

Airborne System - KGPS (Sample Size: AS = 100 KGPS = 100)
Latitude Min= 0.171m Max= 0.785m Mean= 0.551m Stdev= 0.139m
Longitude Min= -0.505m Max= -0.040m Mean= -0.221m Stdev= 0.104m
RMS Min= 0.367m Max= 0.801m Mean= 0.612m Stdev= 0.090m

DGPS - KGPS (Sample Size: DGPS = 100 KGPS = 100)
Latitude Min= -1.058m Max= 0.414m Mean= -0.366m Stdev= 0.399m
Longitude Min= -0.324m Max= 0.360m Mean= 0.029m Stdev= 0.124m
RMS Min= 0.029m Max= 1.059m Mean= 0.473m Stdev= 0.292m

DGPS - AS Height (Sample Size: AS = 100 DGPS = 100)
WGS84 Ht Min= 0.820m Max= 2.785m Mean= 1.908m

KGPS - AS Height (Sample Size: AS = 100 KGPS = 100)
WGS84 Ht Min= -0.079m Max= 1.027m Mean= 0.386m

Airborne System GPS Mode : diff
Airborne System Racal Basestation : 0505

Statistics for Run 609.0.1
GPS Start Time 16:24:16 End Time 16:25:50

DGPS_HRMS Min= 1.778m Max= 1.784m
KGPS_HRMS Min= 0.078m Max= 0.097m
AS_EHE Min= 3.500m Max= 3.625m
AS_PDOP Min= 2.80m Max= 2.80m
POST_PROCESSED_PDOP Min= 2.00m Max= 2.00m
AS_SVS Min= 6 Max= 6
POST_PROCESSED_SVS Min= 7 Max= 7
AS_LATENCY_OF_CORRECTIONS Min= 2s Max= 47s

Analysis of Reported GPS Position

Airborne System - DGPS (Sample Size: AS = 95 DGPS = 95)
Latitude Min= -0.046m Max= 0.984m Mean= 0.517m Stdev= 0.270m
Longitude Min= -1.437m Max= -0.507m Mean= -0.994m Stdev= 0.279m
RMS Min= 0.764m Max= 1.717m Mean= 1.166m Stdev= 0.213m

Airborne System - KGPS (Sample Size: AS = 95 KGPS = 95)
Latitude Min= 0.017m Max= 0.959m Mean= 0.515m Stdev= 0.227m
Longitude Min= -1.401m Max= -0.757m Mean= -1.065m Stdev= 0.165m
RMS Min= 0.935m Max= 1.698m Mean= 1.206m Stdev= 0.155m

DGPS - KGPS (Sample Size: DGPS = 95 KGPS = 95)
Latitude Min= -0.766m Max= 0.668m Mean= 0.069m Stdev= 0.387m
Longitude Min= -0.304m Max= 0.222m Mean= 0.014m Stdev= 0.105m
RMS Min= 0.009m Max= 0.770m Mean= 0.362m Stdev= 0.186m

DGPS - AS Height (Sample Size: AS = 95 DGPS = 95)
WGS84 Ht Min= -0.645m Max= 1.389m Mean= 0.621m

KGPS - AS Height (Sample Size: AS = 95 KGPS = 95)
WGS84 Ht Min= -1.218m Max= 1.169m Mean= 0.113m

Airborne System GPS Mode : diff
Airborne System Racal Basestation : 0505

Statistics for Run 610.0.1
GPS Start Time 16:30:51 End Time 16:32:23

DGPS_HRMS Min= 1.989m Max= 1.991m
KGPS_HRMS Min= 0.094m Max= 0.116m
AS_EHE Min= 3.542m Max= 3.583m

AS_PDOP Min= 2.90m Max= 2.90m
POST_PROCESSED_PDOP Min= 2.90m Max= 2.90m
AS_SVS Min= 6 Max= 6
POST_PROCESSED_SVS Min= 6 Max= 6
AS_LATENCY_OF_CORRECTIONS Min= 2s Max= 21s

Analysis of Reported GPS Position

Airborne System - DGPS (Sample Size: AS = 93 DGPS = 93)
Latitude Min= -0.702m Max= 0.444m Mean= -0.035m Stdev= 0.239m
Longitude Min= -0.757m Max= 0.072m Mean= -0.467m Stdev= 0.187m
RMS Min= 0.195m Max= 0.837m Mean= 0.536m Stdev= 0.153m

Airborne System - KGPS (Sample Size: AS = 93 KGPS = 93)
Latitude Min= -0.100m Max= 0.730m Mean= 0.270m Stdev= 0.216m
Longitude Min= -1.328m Max= -0.840m Mean= -1.060m Stdev= 0.114m
RMS Min= 0.841m Max= 1.445m Mean= 1.109m Stdev= 0.159m

DGPS - KGPS (Sample Size: DGPS = 93 KGPS = 93)
Latitude Min= -0.218m Max= 0.723m Mean= 0.160m Stdev= 0.180m
Longitude Min= -0.942m Max= -0.150m Mean= -0.544m Stdev= 0.127m
RMS Min= 0.190m Max= 1.182m Mean= 0.586m Stdev= 0.160m

DGPS - AS Height (Sample Size: AS = 93 DGPS = 93)
WGS84 Ht Min= 2.680m Max= 5.309m Mean= 3.809m

KGPS - AS Height (Sample Size: AS = 93 KGPS = 93)
WGS84 Ht Min= 1.648m Max= 3.125m Mean= 2.298m

Airborne System GPS Mode : diff
Airborne System Racal Basestation : 0505

Statistics for Run 611.0.1
GPS Start Time 16:37:29 End Time 16:39:03

DGPS_HRMS Min= 1.981m Max= 1.986m
KGPS_HRMS Min= 0.094m Max= 0.122m
AS_EHE Min= 3.583m Max= 3.583m
AS_PDOP Min= 3.00m Max= 3.00m
POST_PROCESSED_PDOP Min= 3.00m Max= 3.00m
AS_SVS Min= 6 Max= 6
POST_PROCESSED_SVS Min= 6 Max= 6
AS_LATENCY_OF_CORRECTIONS Min= 2s Max= 11s

Analysis of Reported GPS Position

Airborne System - DGPS (Sample Size: AS = 95 DGPS = 95)
Latitude Min= -0.183m Max= 1.378m Mean= 0.520m Stdev= 0.382m
Longitude Min= -1.424m Max= -0.584m Mean= -0.946m Stdev= 0.168m
RMS Min= 0.721m Max= 1.899m Mean= 1.119m Stdev= 0.294m

Airborne System - KGPS (Sample Size: AS = 95 KGPS = 95)
Latitude Min= -0.297m Max= 0.998m Mean= 0.246m Stdev= 0.277m
Longitude Min= -1.189m Max= -0.433m Mean= -0.894m Stdev= 0.189m
RMS Min= 0.436m Max= 1.396m Mean= 0.960m Stdev= 0.222m

DGPS - KGPS (Sample Size: DGPS = 95 KGPS = 95)
Latitude Min= -0.965m Max= 0.908m Mean= 0.017m Stdev= 0.361m
Longitude Min= -0.797m Max= 0.837m Mean= -0.232m Stdev= 0.266m
RMS Min= 0.076m Max= 1.275m Mean= 0.448m Stdev= 0.234m

DGPS - AS Height (Sample Size: AS = 95 DGPS = 95)
WGS84 Ht Min= -0.035m Max= 3.379m Mean= 2.119m

KGPS - AS Height (Sample Size: AS = 95 KGPS = 95)
WGS84 Ht Min= 0.243m Max= 2.296m Mean= 1.450m

Airborne System GPS Mode : diff

Airborne System Racal Basestation : 0505

Statistics for Run 612.0.1
GPS Start Time 16:44:06 End Time 16:45:48

DGPS_HRMS Min= 1.959m Max= 1.967m
KGPS_HRMS Min= 0.098m Max= 0.120m
AS_EHE Min= 3.500m Max= 3.542m
AS_PDOP Min= 2.90m Max= 2.90m
POST_PROCESSED_PDOP Min= 2.90m Max= 2.90m
AS_SVS Min= 6 Max= 6
POST_PROCESSED_SVS Min= 6 Max= 6
AS_LATENCY_OF_CORRECTIONS Min= 2s Max= 7s

Analysis of Reported GPS Position

Airborne System - DGPS (Sample Size: AS = 103 DGPS = 103)
Latitude Min= 0.730m Max= 1.901m Mean= 1.364m Stdev= 0.261m
Longitude Min= -1.071m Max= -0.413m Mean= -0.817m Stdev= 0.151m
RMS Min= 0.943m Max= 2.174m Mean= 1.592m Stdev= 0.294m

Airborne System - KGPS (Sample Size: AS = 103 KGPS = 103)
Latitude Min= 0.579m Max= 1.248m Mean= 0.919m Stdev= 0.151m
Longitude Min= -0.871m Max= -0.584m Mean= -0.753m Stdev= 0.066m
RMS Min= 0.905m Max= 1.503m Mean= 1.190m Stdev= 0.145m

DGPS - KGPS (Sample Size: DGPS = 103 KGPS = 103)
Latitude Min= -0.886m Max= 1.020m Mean= 0.159m Stdev= 0.470m
Longitude Min= -0.445m Max= 0.603m Mean= 0.049m Stdev= 0.226m
RMS Min= 0.027m Max= 1.032m Mean= 0.494m Stdev= 0.236m

DGPS - AS Height (Sample Size: AS = 103 DGPS = 103)
WGS84 Ht Min= -3.654m Max= -0.722m Mean= -2.321m

KGPS - AS Height (Sample Size: AS = 103 KGPS = 103)
WGS84 Ht Min= -1.602m Max= -0.009m Mean= -0.909m

Airborne System GPS Mode : diff
Airborne System Racal Basestation : 0505

Statistics for Run 613.0.1
GPS Start Time 16:51:05 End Time 16:52:49

DGPS_HRMS Min= 1.930m Max= 1.939m
KGPS_HRMS Min= 0.097m Max= 0.118m
AS_EHE Min= 3.417m Max= 3.458m
AS_PDOP Min= 2.70m Max= 2.70m
POST_PROCESSED_PDOP Min= 2.70m Max= 2.70m
AS_SVS Min= 6 Max= 6
POST_PROCESSED_SVS Min= 6 Max= 6
AS_LATENCY_OF_CORRECTIONS Min= 2s Max= 6s

Analysis of Reported GPS Position

Airborne System - DGPS (Sample Size: AS = 105 DGPS = 105)
Latitude Min= -0.154m Max= 1.210m Mean= 0.553m Stdev= 0.243m
Longitude Min= -2.023m Max= -0.549m Mean= -1.403m Stdev= 0.366m
RMS Min= 0.644m Max= 2.116m Mean= 1.521m Stdev= 0.389m

Airborne System - KGPS (Sample Size: AS = 105 KGPS = 105)
Latitude Min= 0.292m Max= 1.441m Mean= 0.870m Stdev= 0.244m
Longitude Min= -1.430m Max= -1.049m Mean= -1.186m Stdev= 0.078m
RMS Min= 1.170m Max= 1.872m Mean= 1.484m Stdev= 0.164m

DGPS - KGPS (Sample Size: DGPS = 105 KGPS = 105)
Latitude Min= -1.278m Max= 0.733m Mean= -0.224m Stdev= 0.508m
Longitude Min= -0.651m Max= 0.958m Mean= 0.339m Stdev= 0.247m

RMS Min= 0.128m Max= 1.423m Mean= 0.648m Stdev= 0.254m

DGPS - AS Height (Sample Size: AS = 105 DGPS = 105)
WGS84 Ht Min= 0.869m Max= 4.047m Mean= 2.441m

KGPS - AS Height (Sample Size: AS = 105 KGPS = 105)
WGS84 Ht Min= -2.546m Max= 0.117m Mean= -1.066m

Airborne System GPS Mode : diff
Airborne System Racal Basestation : 0505

Statistics for Run 614.0.1
GPS Start Time 16:58:13 End Time 17:01:14

DGPS_HRMS Min= 1.880m Max= 1.882m
KGPS_HRMS Min= 0.095m Max= 0.133m
AS_EHE Min= 3.333m Max= 3.375m
AS_PDOP Min= 2.50m Max= 2.60m
POST_PROCESSED_PDOP Min= 2.50m Max= 2.60m
AS_SVS Min= 6 Max= 6
POST_PROCESSED_SVS Min= 6 Max= 6
AS_LATENCY_OF_CORRECTIONS Min= 2s Max= 18s

Analysis of Reported GPS Position

Airborne System - DGPS (Sample Size: AS = 182 DGPS = 182)
Latitude Min= -0.315m Max= 0.999m Mean= 0.301m Stdev= 0.267m
Longitude Min= -1.118m Max= -0.074m Mean= -0.549m Stdev= 0.230m
RMS Min= 0.243m Max= 1.235m Mean= 0.688m Stdev= 0.205m

Airborne System - KGPS (Sample Size: AS = 182 KGPS = 182)
Latitude Min= -0.180m Max= 1.129m Mean= 0.513m Stdev= 0.246m
Longitude Min= -0.842m Max= 0.049m Mean= -0.469m Stdev= 0.239m
RMS Min= 0.065m Max= 1.228m Mean= 0.729m Stdev= 0.265m

DGPS - KGPS (Sample Size: DGPS = 182 KGPS = 182)
Latitude Min= -0.115m Max= 1.040m Mean= 0.322m Stdev= 0.168m
Longitude Min= -0.167m Max= 1.245m Mean= 0.550m Stdev= 0.412m
RMS Min= 0.049m Max= 1.384m Mean= 0.688m Stdev= 0.363m

DGPS - AS Height (Sample Size: AS = 182 DGPS = 182)
WGS84 Ht Min= 1.092m Max= 4.085m Mean= 2.663m

KGPS - AS Height (Sample Size: AS = 182 KGPS = 182)
WGS84 Ht Min= -1.172m Max= 2.168m Mean= 0.553m

Airborne System GPS Mode : diff
Airborne System Racal Basestation : 0505

Statistics for Run 615.0.1
GPS Start Time 17:08:02 End Time 17:11:02

DGPS_HRMS Min= 1.899m Max= 1.909m
KGPS_HRMS Min= 0.095m Max= 0.132m
AS_EHE Min= 3.250m Max= 3.333m
AS_PDOP Min= 2.30m Max= 2.30m
POST_PROCESSED_PDOP Min= 2.30m Max= 2.30m
AS_SVS Min= 6 Max= 6
POST_PROCESSED_SVS Min= 6 Max= 6
AS_LATENCY_OF_CORRECTIONS Min= 2s Max= 25s

Analysis of Reported GPS Position

Airborne System - DGPS (Sample Size: AS = 181 DGPS = 181)
Latitude Min= 0.023m Max= 0.940m Mean= 0.433m Stdev= 0.165m
Longitude Min= -1.367m Max= -0.653m Mean= -0.992m Stdev= 0.168m
RMS Min= 0.679m Max= 1.433m Mean= 1.095m Stdev= 0.170m

Airborne System - KGPS (Sample Size: AS = 181 KGPS = 181)
Latitude Min= 0.305m Max= 1.395m Mean= 0.886m Stdev= 0.212m
Longitude Min= -1.240m Max= 0.057m Mean= -0.745m Stdev= 0.251m
RMS Min= 0.306m Max= 1.720m Mean= 1.171m Stdev= 0.279m

DGPS - KGPS (Sample Size: DGPS = 181 KGPS = 181)
Latitude Min= -0.286m Max= 0.665m Mean= 0.301m Stdev= 0.213m
Longitude Min= -0.228m Max= 0.990m Mean= 0.512m Stdev= 0.310m
RMS Min= 0.100m Max= 1.146m Mean= 0.660m Stdev= 0.242m

DGPS - AS Height (Sample Size: AS = 181 DGPS = 181)
WGS84 Ht Min= -0.162m Max= 3.716m Mean= 1.393m

KGPS - AS Height (Sample Size: AS = 181 KGPS = 181)
WGS84 Ht Min= -1.153m Max= 1.129m Mean= -0.015m

Airborne System GPS Mode : diff
Airborne System Racal Basestation : 0505

Statistics for Run 616.0.1
GPS Start Time 17:16:51 End Time 17:19:44

DGPS_HRMS Min= 1.832m Max= 1.844m
KGPS_HRMS Min= 0.090m Max= 0.124m
AS_EHE Min= 2.167m Max= 3.292m
AS_PDOP Min= 1.80m Max= 2.20m
POST_PROCESSED_PDOP Min= 1.80m Max= 1.80m
AS_SVS Min= 6 Max= 7
POST_PROCESSED_SVS Min= 7 Max= 7
AS_LATENCY_OF_CORRECTIONS Min= 2s Max= 7s

Analysis of Reported GPS Position

Airborne System - DGPS (Sample Size: AS = 174 DGPS = 174)
Latitude Min= 0.382m Max= 1.161m Mean= 0.846m Stdev= 0.181m
Longitude Min= -0.981m Max= -0.151m Mean= -0.653m Stdev= 0.220m
RMS Min= 0.783m Max= 1.436m Mean= 1.098m Stdev= 0.130m

Airborne System - KGPS (Sample Size: AS = 174 KGPS = 174)
Latitude Min= 0.103m Max= 0.914m Mean= 0.476m Stdev= 0.161m
Longitude Min= -1.135m Max= -0.287m Mean= -0.759m Stdev= 0.206m
RMS Min= 0.532m Max= 1.263m Mean= 0.921m Stdev= 0.154m

DGPS - KGPS (Sample Size: DGPS = 174 KGPS = 174)
Latitude Min= -0.563m Max= 0.333m Mean= -0.201m Stdev= 0.173m
Longitude Min= -0.667m Max= 0.459m Mean= -0.138m Stdev= 0.181m
RMS Min= 0.020m Max= 0.763m Mean= 0.328m Stdev= 0.121m

DGPS - AS Height (Sample Size: AS = 174 DGPS = 174)
WGS84 Ht Min= -0.941m Max= 2.991m Mean= 0.757m

KGPS - AS Height (Sample Size: AS = 174 KGPS = 174)
WGS84 Ht Min= 0.886m Max= 2.048m Mean= 1.535m

Airborne System GPS Mode : diff
Airborne System Racal Basestation : 0505

Statistics for Run 617.0.1
GPS Start Time 17:25:13 End Time 17:28:03

DGPS_HRMS Min= 1.866m Max= 1.876m
KGPS_HRMS Min= 0.090m Max= 0.125m
AS_EHE Min= 3.958m Max= 4.000m
AS_PDOP Min= 2.70m Max= 2.80m
POST_PROCESSED_PDOP Min= 1.80m Max= 1.80m
AS_SVS Min= 6 Max= 6

POST_PROCESSED_SVS Min= 7 Max= 7
AS_LATENCY_OF_CORRECTIONS Min= 1s Max= 7s

Analysis of Reported GPS Position

Airborne System - DGPS (Sample Size: AS = 171 DGPS = 171)
Latitude Min= 0.603m Max= 1.717m Mean= 1.104m Stdev= 0.201m
Longitude Min= -1.150m Max= 0.608m Mean= -0.606m Stdev= 0.433m
RMS Min= 0.834m Max= 1.771m Mean= 1.326m Stdev= 0.234m

Airborne System - KGPS (Sample Size: AS = 171 KGPS = 171)
Latitude Min= 0.056m Max= 1.239m Mean= 0.513m Stdev= 0.243m
Longitude Min= -1.429m Max= 0.049m Mean= -0.935m Stdev= 0.338m
RMS Min= 0.515m Max= 1.651m Mean= 1.115m Stdev= 0.260m

DGPS - KGPS (Sample Size: DGPS = 171 KGPS = 171)
Latitude Min= -0.812m Max= 0.269m Mean= -0.258m Stdev= 0.298m
Longitude Min= -0.963m Max= 0.185m Mean= -0.301m Stdev= 0.223m
RMS Min= 0.005m Max= 1.033m Mean= 0.470m Stdev= 0.274m

DGPS - AS Height (Sample Size: AS = 171 DGPS = 171)
WGS84 Ht Min= -0.688m Max= 3.158m Mean= 0.661m

KGPS - AS Height (Sample Size: AS = 171 KGPS = 171)
WGS84 Ht Min= -0.541m Max= 2.550m Mean= 0.681m

Airborne System GPS Mode : diff
Airborne System Racal Basestation : 0505

Statistics for Run 618.0.1
GPS Start Time 17:33:34 End Time 17:36:29

DGPS_HRMS Min= 2.170m Max= 2.177m
KGPS_HRMS Min= 0.111m Max= 0.151m
AS_EHE Min= 3.792m Max= 3.875m
AS_PDOP Min= 2.60m Max= 2.60m
POST_PROCESSED_PDOP Min= 2.60m Max= 2.60m
AS_SVS Min= 6 Max= 6
POST_PROCESSED_SVS Min= 6 Max= 6
AS_LATENCY_OF_CORRECTIONS Min= 2s Max= 21s

Analysis of Reported GPS Position

Airborne System - DGPS (Sample Size: AS = 176 DGPS = 176)
Latitude Min= -0.364m Max= 1.525m Mean= 0.388m Stdev= 0.412m
Longitude Min= -2.629m Max= -1.208m Mean= -1.789m Stdev= 0.268m
RMS Min= 1.223m Max= 2.629m Mean= 1.872m Stdev= 0.297m

Airborne System - KGPS (Sample Size: AS = 176 KGPS = 176)
Latitude Min= 0.184m Max= 1.166m Mean= 0.634m Stdev= 0.219m
Longitude Min= -1.623m Max= -0.168m Mean= -0.703m Stdev= 0.286m
RMS Min= 0.396m Max= 1.745m Mean= 0.977m Stdev= 0.269m

DGPS - KGPS (Sample Size: DGPS = 176 KGPS = 176)
Latitude Min= -1.070m Max= 0.844m Mean= -0.349m Stdev= 0.498m
Longitude Min= -0.876m Max= 1.393m Mean= 0.620m Stdev= 0.577m
RMS Min= 0.241m Max= 1.412m Mean= 1.009m Stdev= 0.261m

DGPS - AS Height (Sample Size: AS = 176 DGPS = 176)
WGS84 Ht Min= -1.343m Max= 1.685m Mean= 0.539m

KGPS - AS Height (Sample Size: AS = 176 KGPS = 176)
WGS84 Ht Min= 0.367m Max= 2.695m Mean= 1.937m

Airborne System GPS Mode : diff
Airborne System Racal Basestation : 0505

Statistics for Run 603.0.1
GPS Start Time 17:43:32 End Time 17:45:11

DGPS_HRMS Min= 2.147m Max= 2.152m
KGPS_HRMS Min= 0.098m Max= 0.121m
AS_EHE Min= 3.667m Max= 3.708m
AS_PDOP Min= 2.40m Max= 2.50m
POST_PROCESSED_PDOP Min= 2.40m Max= 2.50m
AS_SVS Min= 6 Max= 6
POST_PROCESSED_SVS Min= 6 Max= 6
AS_LATENCY_OF_CORRECTIONS Min= 2s Max= 7s

Analysis of Reported GPS Position

Airborne System - DGPS (Sample Size: AS = 100 DGPS = 100)
Latitude Min= 0.222m Max= 1.135m Mean= 0.651m Stdev= 0.225m
Longitude Min= -1.549m Max= -0.499m Mean= -1.008m Stdev= 0.243m
RMS Min= 0.728m Max= 1.841m Mean= 1.213m Stdev= 0.279m

Airborne System - KGPS (Sample Size: AS = 100 KGPS = 100)
Latitude Min= 0.290m Max= 0.921m Mean= 0.594m Stdev= 0.149m
Longitude Min= -0.840m Max= -0.297m Mean= -0.573m Stdev= 0.139m
RMS Min= 0.605m Max= 1.143m Mean= 0.838m Stdev= 0.141m

DGPS - KGPS (Sample Size: DGPS = 100 KGPS = 100)
Latitude Min= -0.394m Max= 1.115m Mean= 0.335m Stdev= 0.370m
Longitude Min= -0.136m Max= 1.032m Mean= 0.542m Stdev= 0.215m
RMS Min= 0.100m Max= 1.434m Mean= 0.719m Stdev= 0.268m

DGPS - AS Height (Sample Size: AS = 100 DGPS = 100)
WGS84 Ht Min= -2.052m Max= -0.009m Mean= -0.772m

KGPS - AS Height (Sample Size: AS = 100 KGPS = 100)
WGS84 Ht Min= -0.327m Max= 0.989m Mean= 0.425m

Airborne System GPS Mode : diff
Airborne System Racal Basestation : 0505

Statistics for Run 602.0.1
GPS Start Time 17:50:24 End Time 17:51:46

DGPS_HRMS Min= 1.831m Max= 1.836m
KGPS_HRMS Min= 0.086m Max= 0.102m
AS_EHE Min= 3.625m Max= 3.667m
AS_PDOP Min= 2.30m Max= 2.40m
POST_PROCESSED_PDOP Min= 2.10m Max= 2.10m
AS_SVS Min= 6 Max= 6
POST_PROCESSED_SVS Min= 7 Max= 7
AS_LATENCY_OF_CORRECTIONS Min= 2s Max= 17s

Analysis of Reported GPS Position

Airborne System - DGPS (Sample Size: AS = 83 DGPS = 83)
Latitude Min= 0.565m Max= 1.799m Mean= 1.159m Stdev= 0.295m
Longitude Min= -1.345m Max= -0.357m Mean= -0.913m Stdev= 0.261m
RMS Min= 1.149m Max= 2.035m Mean= 1.515m Stdev= 0.188m

Airborne System - KGPS (Sample Size: AS = 83 KGPS = 83)
Latitude Min= -0.153m Max= 0.555m Mean= 0.203m Stdev= 0.152m
Longitude Min= -0.852m Max= 0.069m Mean= -0.508m Stdev= 0.252m
RMS Min= 0.108m Max= 0.881m Mean= 0.578m Stdev= 0.227m

DGPS - KGPS (Sample Size: DGPS = 83 KGPS = 83)
Latitude Min= -1.244m Max= 3.033m Mean= -0.149m Stdev= 0.705m
Longitude Min= -0.734m Max= 0.552m Mean= 0.241m Stdev= 0.235m
RMS Min= 0.021m Max= 3.095m Mean= 0.576m Stdev= 0.547m

DGPS - AS Height (Sample Size: AS = 83 DGPS = 83)

WGS84 Ht Min= -0.274m Max= 1.439m Mean= 0.448m

KGPS - AS Height (Sample Size: AS = 83 KGPS = 83)
WGS84 Ht Min= 0.694m Max= 2.183m Mean= 1.558m

Airborne System GPS Mode : diff
Airborne System Racal Basestation : 0505

Statistics for Run 601.0.1
GPS Start Time 17:56:50 End Time 17:58:07

DGPS_HRMS Min= 1.808m Max= 1.811m
KGPS_HRMS Min= 0.085m Max= 0.099m
AS_EHE Min= 2.250m Max= 2.250m
AS_PDOP Min= 2.00m Max= 2.00m
POST_PROCESSED_PDOP Min= 2.00m Max= 2.00m
AS_SVS Min= 7 Max= 7
POST_PROCESSED_SVS Min= 7 Max= 7
AS_LATENCY_OF_CORRECTIONS Min= 2s Max= 7s

Analysis of Reported GPS Position

Airborne System - DGPS (Sample Size: AS = 78 DGPS = 78)
Latitude Min= -0.533m Max= 0.143m Mean= -0.254m Stdev= 0.171m
Longitude Min= -1.144m Max= -0.671m Mean= -0.950m Stdev= 0.100m
RMS Min= 0.707m Max= 1.217m Mean= 0.997m Stdev= 0.114m

Airborne System - KGPS (Sample Size: AS = 78 KGPS = 78)
Latitude Min= -0.138m Max= 0.247m Mean= 0.087m Stdev= 0.086m
Longitude Min= -0.171m Max= 0.170m Mean= -0.036m Stdev= 0.077m
RMS Min= 0.030m Max= 0.270m Mean= 0.139m Stdev= 0.054m

DGPS - KGPS (Sample Size: DGPS = 78 KGPS = 78)
Latitude Min= -1.622m Max= 1.323m Mean= -0.244m Stdev= 0.542m
Longitude Min= -0.655m Max= 1.246m Mean= 0.111m Stdev= 0.575m
RMS Min= 0.231m Max= 1.754m Mean= 0.777m Stdev= 0.302m

DGPS - AS Height (Sample Size: AS = 78 DGPS = 78)
WGS84 Ht Min= 0.478m Max= 1.611m Mean= 1.076m

KGPS - AS Height (Sample Size: AS = 78 KGPS = 78)
WGS84 Ht Min= 0.822m Max= 1.500m Mean= 1.184m

Airborne System GPS Mode : diff
Airborne System Racal Basestation : 0505

Statistics for Run 600.0.1
GPS Start Time 18:03:09 End Time 18:06:48

DGPS_HRMS Min= 1.778m Max= 1.789m
KGPS_HRMS Min= 0.082m Max= 0.126m
AS_EHE Min= 2.208m Max= 2.208m
AS_PDOP Min= 2.00m Max= 2.00m
POST_PROCESSED_PDOP Min= 2.00m Max= 2.00m
AS_SVS Min= 7 Max= 7
POST_PROCESSED_SVS Min= 7 Max= 7
AS_LATENCY_OF_CORRECTIONS Min= 2s Max= 8s

Analysis of Reported GPS Position

Airborne System - DGPS (Sample Size: AS = 220 DGPS = 220)
Latitude Min= -0.131m Max= 0.990m Mean= 0.357m Stdev= 0.220m
Longitude Min= -1.490m Max= -0.425m Mean= -1.049m Stdev= 0.275m
RMS Min= 0.617m Max= 1.531m Mean= 1.139m Stdev= 0.232m

Airborne System - KGPS (Sample Size: AS = 220 KGPS = 220)
Latitude Min= -0.112m Max= 0.881m Mean= 0.430m Stdev= 0.219m

Longitude Min= -0.703m Max= 0.008m Mean= -0.294m Stdev= 0.170m
RMS Min= 0.114m Max= 1.018m Mean= 0.547m Stdev= 0.221m

DGPS - KGPS (Sample Size: DGPS = 220 KGPS = 220)
Latitude Min= -0.506m Max= 2.525m Mean= 0.230m Stdev= 0.422m
Longitude Min= 0.136m Max= 1.196m Mean= 0.717m Stdev= 0.230m
RMS Min= 0.297m Max= 2.529m Mean= 0.827m Stdev= 0.338m

DGPS - AS Height (Sample Size: AS = 220 DGPS = 220)
WGS84 Ht Min= -0.530m Max= 3.221m Mean= 1.844m

KGPS - AS Height (Sample Size: AS = 220 KGPS = 220)
WGS84 Ht Min= 1.176m Max= 2.793m Mean= 2.118m

Airborne System GPS Mode : diff
Airborne System Racal Basestation : 0505

Statistics for Run 616.0.2
GPS Start Time 18:11:00 End Time 18:12:45

DGPS_HRMS Min= 1.525m Max= 1.527m
KGPS_HRMS Min= 0.089m Max= 0.104m
AS_EHE Min= 1.250m Max= 2.083m
AS_PDOP Min= 1.50m Max= 1.80m
POST_PROCESSED_PDOP Min= 1.50m Max= 1.50m
AS_SVS Min= 7 Max= 8
POST_PROCESSED_SVS Min= 8 Max= 8
AS_LATENCY_OF_CORRECTIONS Min= 2s Max= 8s

Analysis of Reported GPS Position

Airborne System - DGPS (Sample Size: AS = 106 DGPS = 106)
Latitude Min= -0.201m Max= 0.259m Mean= 0.003m Stdev= 0.093m
Longitude Min= -1.164m Max= -0.651m Mean= -0.852m Stdev= 0.114m
RMS Min= 0.690m Max= 1.169m Mean= 0.857m Stdev= 0.111m

Airborne System - KGPS (Sample Size: AS = 106 KGPS = 106)
Latitude Min= 0.022m Max= 0.479m Mean= 0.273m Stdev= 0.119m
Longitude Min= -1.053m Max= -0.663m Mean= -0.878m Stdev= 0.089m
RMS Min= 0.694m Max= 1.091m Mean= 0.928m Stdev= 0.081m

DGPS - KGPS (Sample Size: DGPS = 106 KGPS = 106)
Latitude Min= -0.543m Max= 0.578m Mean= 0.169m Stdev= 0.183m
Longitude Min= -0.184m Max= 0.468m Mean= 0.193m Stdev= 0.171m
RMS Min= 0.030m Max= 0.661m Mean= 0.338m Stdev= 0.118m

DGPS - AS Height (Sample Size: AS = 106 DGPS = 106)
WGS84 Ht Min= -1.001m Max= 0.645m Mean= 0.130m

KGPS - AS Height (Sample Size: AS = 106 KGPS = 106)
WGS84 Ht Min= -1.056m Max= 0.268m Mean= -0.267m

Airborne System GPS Mode : diff
Airborne System Racal Basestation : 0505

Statistics for Run 615.0.2
GPS Start Time 18:17:32 End Time 18:19:25

DGPS_HRMS Min= 1.752m Max= 1.755m
KGPS_HRMS Min= 0.101m Max= 0.120m
AS_EHE Min= 2.083m Max= 2.125m
AS_PDOP Min= 1.80m Max= 1.80m
POST_PROCESSED_PDOP Min= 1.80m Max= 1.80m
AS_SVS Min= 7 Max= 7
POST_PROCESSED_SVS Min= 7 Max= 7
AS_LATENCY_OF_CORRECTIONS Min= 2s Max= 24s

Analysis of Reported GPS Position

Airborne System - DGPS (Sample Size: AS = 114 DGPS = 114)
Latitude Min= 0.130m Max= 0.685m Mean= 0.423m Stdev= 0.118m
Longitude Min= -0.461m Max= -0.014m Mean= -0.279m Stdev= 0.108m
RMS Min= 0.246m Max= 0.691m Mean= 0.525m Stdev= 0.083m

Airborne System - KGPS (Sample Size: AS = 114 KGPS = 114)
Latitude Min= 0.098m Max= 0.526m Mean= 0.343m Stdev= 0.115m
Longitude Min= -0.604m Max= -0.058m Mean= -0.394m Stdev= 0.143m
RMS Min= 0.303m Max= 0.721m Mean= 0.543m Stdev= 0.105m

DGPS - KGPS (Sample Size: DGPS = 114 KGPS = 114)
Latitude Min= -0.738m Max= 0.463m Mean= -0.039m Stdev= 0.142m
Longitude Min= -0.326m Max= 0.274m Mean= -0.042m Stdev= 0.116m
RMS Min= 0.007m Max= 0.748m Mean= 0.165m Stdev= 0.099m

DGPS - AS Height (Sample Size: AS = 114 DGPS = 114)
WGS84 Ht Min= -0.915m Max= 0.368m Mean= -0.438m

KGPS - AS Height (Sample Size: AS = 114 KGPS = 114)
WGS84 Ht Min= -1.428m Max= -0.478m Mean= -0.867m

Airborne System GPS Mode : diff
Airborne System Racal Basestation : 0505

Statistics for Run 614.0.2
GPS Start Time 18:24:17 End Time 18:25:11

DGPS_HRMS Min= 1.756m Max= 1.758m
KGPS_HRMS Min= 0.112m Max= 0.123m
AS_EHE Min= 2.125m Max= 2.125m
AS_PDOP Min= 1.90m Max= 1.90m
POST_PROCESSED_PDOP Min= 1.90m Max= 1.90m
AS_SVS Min= 7 Max= 7
POST_PROCESSED_SVS Min= 7 Max= 7
AS_LATENCY_OF_CORRECTIONS Min= 2s Max= 7s

Analysis of Reported GPS Position

Airborne System - DGPS (Sample Size: AS = 55 DGPS = 55)
Latitude Min= 0.008m Max= 0.500m Mean= 0.268m Stdev= 0.131m
Longitude Min= -1.426m Max= -0.946m Mean= -1.188m Stdev= 0.114m
RMS Min= 1.000m Max= 1.447m Mean= 1.226m Stdev= 0.102m

Airborne System - KGPS (Sample Size: AS = 55 KGPS = 55)
Latitude Min= 0.281m Max= 0.631m Mean= 0.475m Stdev= 0.088m
Longitude Min= -0.758m Max= -0.453m Mean= -0.610m Stdev= 0.071m
RMS Min= 0.674m Max= 0.892m Mean= 0.779m Stdev= 0.058m

DGPS - KGPS (Sample Size: DGPS = 55 KGPS = 55)
Latitude Min= -0.548m Max= 0.589m Mean= 0.069m Stdev= 0.187m
Longitude Min= -0.343m Max= 1.276m Mean= 0.363m Stdev= 0.396m
RMS Min= 0.005m Max= 1.277m Mean= 0.492m Stdev= 0.293m

DGPS - AS Height (Sample Size: AS = 55 DGPS = 55)
WGS84 Ht Min= -0.521m Max= 1.220m Mean= 0.524m

KGPS - AS Height (Sample Size: AS = 55 KGPS = 55)
WGS84 Ht Min= -0.176m Max= 0.488m Mean= 0.215m

Airborne System GPS Mode : diff
Airborne System Racal Basestation : 0505

Statistics for Run 613.0.2
GPS Start Time 18:29:18 End Time 18:30:14

DGPS_HRMS Min= 1.761m Max= 1.762m
KGPS_HRMS Min= 0.114m Max= 0.125m
AS_EHE Min= 2.167m Max= 2.167m
AS_PDOP Min= 2.00m Max= 2.00m
POST_PROCESSED_PDOP Min= 2.00m Max= 2.00m
AS_SVS Min= 7 Max= 7
POST_PROCESSED_SVS Min= 7 Max= 7
AS_LATENCY_OF_CORRECTIONS Min= 2s Max= 7s

Analysis of Reported GPS Position

Airborne System - DGPS (Sample Size: AS = 57 DGPS = 57)
Latitude Min= -0.680m Max= 0.375m Mean= -0.243m Stdev= 0.242m
Longitude Min= -0.957m Max= -0.557m Mean= -0.738m Stdev= 0.086m
RMS Min= 0.570m Max= 1.113m Mean= 0.810m Stdev= 0.116m

Airborne System - KGPS (Sample Size: AS = 57 KGPS = 57)
Latitude Min= -0.073m Max= 0.286m Mean= 0.152m Stdev= 0.091m
Longitude Min= -1.134m Max= -0.767m Mean= -0.896m Stdev= 0.078m
RMS Min= 0.816m Max= 1.150m Mean= 0.913m Stdev= 0.074m

DGPS - KGPS (Sample Size: DGPS = 57 KGPS = 57)
Latitude Min= -1.139m Max= 0.808m Mean= -0.072m Stdev= 0.441m
Longitude Min= -0.308m Max= 0.835m Mean= 0.185m Stdev= 0.300m
RMS Min= 0.045m Max= 1.140m Mean= 0.519m Stdev= 0.233m

DGPS - AS Height (Sample Size: AS = 57 DGPS = 57)
WGS84 Ht Min= -0.647m Max= 2.451m Mean= 1.120m

KGPS - AS Height (Sample Size: AS = 57 KGPS = 57)
WGS84 Ht Min= 0.897m Max= 1.651m Mean= 1.248m

Airborne System GPS Mode : diff
Airborne System Racal Basestation : 0505

Statistics for Run 612.0.2
GPS Start Time 18:34:09 End Time 18:34:55

DGPS_HRMS Min= 1.765m Max= 1.767m
KGPS_HRMS Min= 0.117m Max= 0.126m
AS_EHE Min= 2.167m Max= 2.167m
AS_PDOP Min= 2.00m Max= 2.00m
POST_PROCESSED_PDOP Min= 2.00m Max= 2.00m
AS_SVS Min= 7 Max= 7
POST_PROCESSED_SVS Min= 7 Max= 7
AS_LATENCY_OF_CORRECTIONS Min= 2s Max= 7s

Analysis of Reported GPS Position

Airborne System - DGPS (Sample Size: AS = 47 DGPS = 47)
Latitude Min= -1.017m Max= 0.078m Mean= -0.464m Stdev= 0.280m
Longitude Min= -0.926m Max= -0.623m Mean= -0.759m Stdev= 0.086m
RMS Min= 0.635m Max= 1.330m Mean= 0.916m Stdev= 0.192m

Airborne System - KGPS (Sample Size: AS = 47 KGPS = 47)
Latitude Min= -0.574m Max= -0.078m Mean= -0.339m Stdev= 0.139m
Longitude Min= -1.317m Max= -1.011m Mean= -1.189m Stdev= 0.054m
RMS Min= 1.028m Max= 1.396m Mean= 1.243m Stdev= 0.076m

DGPS - KGPS (Sample Size: DGPS = 47 KGPS = 47)
Latitude Min= -0.529m Max= 1.451m Mean= 0.237m Stdev= 0.261m
Longitude Min= -0.541m Max= 0.385m Mean= -0.200m Stdev= 0.179m
RMS Min= 0.016m Max= 1.462m Mean= 0.402m Stdev= 0.184m

DGPS - AS Height (Sample Size: AS = 47 DGPS = 47)
WGS84 Ht Min= 0.897m Max= 3.326m Mean= 2.041m

KGPS - AS Height (Sample Size: AS = 47 KGPS = 47)

WGS84 Ht Min= 2.309m Max= 2.929m Mean= 2.669m

Airborne System GPS Mode : diff
Airborne System Racal Basestation : 0505

Statistics for Run 611.0.2
GPS Start Time 18:38:58 End Time 18:39:40

DGPS_HRMS Min= 1.827m Max= 1.830m
KGPS_HRMS Min= 0.120m Max= 0.128m
AS_EHE Min= 2.208m Max= 2.208m
AS_PDOP Min= 2.10m Max= 2.10m
POST_PROCESSED_PDOP Min= 2.10m Max= 2.10m
AS_SVS Min= 7 Max= 7
POST_PROCESSED_SVS Min= 7 Max= 7
AS_LATENCY_OF_CORRECTIONS Min= 2s Max= 7s

Analysis of Reported GPS Position

Airborne System - DGPS (Sample Size: AS = 43 DGPS = 43)
Latitude Min= 0.383m Max= 1.472m Mean= 0.904m Stdev= 0.328m
Longitude Min= -1.009m Max= -0.376m Mean= -0.727m Stdev= 0.151m
RMS Min= 0.939m Max= 1.621m Mean= 1.199m Stdev= 0.189m

Airborne System - KGPS (Sample Size: AS = 43 KGPS = 43)
Latitude Min= 0.495m Max= 1.003m Mean= 0.751m Stdev= 0.153m
Longitude Min= -1.550m Max= -1.276m Mean= -1.433m Stdev= 0.066m
RMS Min= 1.487m Max= 1.786m Mean= 1.624m Stdev= 0.087m

DGPS - KGPS (Sample Size: DGPS = 43 KGPS = 43)
Latitude Min= -0.794m Max= 0.416m Mean= -0.116m Stdev= 0.208m
Longitude Min= -1.027m Max= 0.681m Mean= -0.483m Stdev= 0.238m
RMS Min= 0.089m Max= 1.299m Mean= 0.544m Stdev= 0.225m

DGPS - AS Height (Sample Size: AS = 43 DGPS = 43)
WGS84 Ht Min= -2.191m Max= 1.550m Mean= -0.200m

KGPS - AS Height (Sample Size: AS = 43 KGPS = 43)
WGS84 Ht Min= 0.975m Max= 1.649m Mean= 1.332m

Airborne System GPS Mode : diff
Airborne System Racal Basestation : 0505

Statistics for Run 610.0.2
GPS Start Time 18:45:22 End Time 18:46:03

DGPS_HRMS Min= 1.853m Max= 1.856m
KGPS_HRMS Min= 0.123m Max= 0.131m
AS_EHE Min= 2.250m Max= 2.292m
AS_PDOP Min= 2.20m Max= 2.20m
POST_PROCESSED_PDOP Min= 2.20m Max= 2.20m
AS_SVS Min= 7 Max= 7
POST_PROCESSED_SVS Min= 7 Max= 7
AS_LATENCY_OF_CORRECTIONS Min= 2s Max= 7s

Analysis of Reported GPS Position

Airborne System - DGPS (Sample Size: AS = 42 DGPS = 42)
Latitude Min= 0.175m Max= 0.667m Mean= 0.382m Stdev= 0.150m
Longitude Min= -1.394m Max= -1.054m Mean= -1.178m Stdev= 0.097m
RMS Min= 1.149m Max= 1.405m Mean= 1.249m Stdev= 0.063m

Airborne System - KGPS (Sample Size: AS = 42 KGPS = 42)
Latitude Min= 0.370m Max= 0.602m Mean= 0.487m Stdev= 0.067m
Longitude Min= -1.148m Max= -0.936m Mean= -1.033m Stdev= 0.056m
RMS Min= 1.023m Max= 1.229m Mean= 1.144m Stdev= 0.051m

DGPS - KGPS (Sample Size: DGPS = 42 KGPS = 42)
Latitude Min= -1.003m Max= 0.606m Mean= -0.252m Stdev= 0.285m
Longitude Min= -0.870m Max= 0.760m Mean= -0.045m Stdev= 0.311m
RMS Min= 0.024m Max= 1.280m Mean= 0.421m Stdev= 0.258m

DGPS - AS Height (Sample Size: AS = 42 DGPS = 42)
WGS84 Ht Min= 0.180m Max= 1.682m Mean= 1.032m

KGPS - AS Height (Sample Size: AS = 42 KGPS = 42)
WGS84 Ht Min= 0.423m Max= 1.019m Mean= 0.763m

Airborne System GPS Mode : diff
Airborne System Racal Basestation : 0505

Statistics for Run 609.0.2
GPS Start Time 18:50:18 End Time 18:50:56

DGPS_HRMS Min= 1.871m Max= 1.874m
KGPS_HRMS Min= 0.126m Max= 0.134m
AS_EHE Min= 2.333m Max= 2.333m
AS_PDOP Min= 2.30m Max= 2.30m
POST_PROCESSED_PDOP Min= 2.30m Max= 2.30m
AS_SVS Min= 7 Max= 7
POST_PROCESSED_SVS Min= 7 Max= 7
AS_LATENCY_OF_CORRECTIONS Min= 2s Max= 6s

Analysis of Reported GPS Position

Airborne System - DGPS (Sample Size: AS = 39 DGPS = 39)
Latitude Min= -0.080m Max= 0.571m Mean= 0.278m Stdev= 0.176m
Longitude Min= -1.591m Max= -1.164m Mean= -1.371m Stdev= 0.109m
RMS Min= 1.237m Max= 1.593m Mean= 1.412m Stdev= 0.085m

Airborne System - KGPS (Sample Size: AS = 39 KGPS = 39)
Latitude Min= 0.569m Max= 0.867m Mean= 0.731m Stdev= 0.076m
Longitude Min= -1.025m Max= -0.691m Mean= -0.883m Stdev= 0.083m
RMS Min= 1.015m Max= 1.272m Mean= 1.150m Stdev= 0.065m

DGPS - KGPS (Sample Size: DGPS = 39 KGPS = 39)
Latitude Min= -0.682m Max= 1.343m Mean= 0.241m Stdev= 0.340m
Longitude Min= -0.856m Max= 0.760m Mean= 0.211m Stdev= 0.286m
RMS Min= 0.033m Max= 1.508m Mean= 0.492m Stdev= 0.241m

DGPS - AS Height (Sample Size: AS = 39 DGPS = 39)
WGS84 Ht Min= 2.115m Max= 3.413m Mean= 2.772m

KGPS - AS Height (Sample Size: AS = 39 KGPS = 39)
WGS84 Ht Min= 0.751m Max= 1.344m Mean= 1.076m

Airborne System GPS Mode : diff
Airborne System Racal Basestation : 0505

Statistics for Run 805.0.1
GPS Start Time 18:58:20 End Time 19:01:55

DGPS_HRMS Min= 1.896m Max= 1.898m
KGPS_HRMS Min= 0.070m Max= 0.112m
AS_EHE Min= 2.375m Max= 2.417m
AS_PDOP Min= 2.30m Max= 2.30m
POST_PROCESSED_PDOP Min= 2.30m Max= 2.30m
AS_SVS Min= 7 Max= 7
POST_PROCESSED_SVS Min= 7 Max= 7
AS_LATENCY_OF_CORRECTIONS Min= 2s Max= 28s

Analysis of Reported GPS Position

Airborne System - DGPS (Sample Size: AS = 216 DGPS = 216)

Latitude Min= -1.899m Max= -0.333m Mean= -1.069m Stdev= 0.325m
Longitude Min= -1.920m Max= -0.765m Mean= -1.259m Stdev= 0.248m
RMS Min= 1.078m Max= 2.562m Mean= 1.682m Stdev= 0.254m

Airborne System - KGPS (Sample Size: AS = 216 KGPS = 216)
Latitude Min= -1.220m Max= 0.129m Mean= -0.464m Stdev= 0.321m
Longitude Min= -1.423m Max= -0.846m Mean= -1.114m Stdev= 0.127m
RMS Min= 0.881m Max= 1.639m Mean= 1.246m Stdev= 0.147m

DGPS - KGPS (Sample Size: DGPS = 216 KGPS = 216)
Latitude Min= 0.113m Max= 1.160m Mean= 0.543m Stdev= 0.183m
Longitude Min= -0.534m Max= 0.775m Mean= 0.198m Stdev= 0.266m
RMS Min= 0.153m Max= 1.229m Mean= 0.633m Stdev= 0.192m

DGPS - AS Height (Sample Size: AS = 216 DGPS = 216)
WGS84 Ht Min= 0.743m Max= 3.483m Mean= 2.170m

KGPS - AS Height (Sample Size: AS = 216 KGPS = 216)
WGS84 Ht Min= 0.972m Max= 3.182m Mean= 2.124m

Airborne System GPS Mode : diff
Airborne System Racal Basestation : 0505

Statistics for Run 807.0.1
GPS Start Time 19:09:42 End Time 19:13:12

DGPS_HRMS Min= 1.789m Max= 1.798m
KGPS_HRMS Min= 0.066m Max= 0.103m
AS_EHE Min= 2.167m Max= 2.208m
AS_PDOP Min= 2.10m Max= 2.20m
POST_PROCESSED_PDOP Min= 2.10m Max= 2.20m
AS_SVS Min= 7 Max= 7
POST_PROCESSED_SVS Min= 7 Max= 7
AS_LATENCY_OF_CORRECTIONS Min= 2s Max= 8s

Analysis of Reported GPS Position

Airborne System - DGPS (Sample Size: AS = 211 DGPS = 211)
Latitude Min= -0.263m Max= 0.608m Mean= 0.141m Stdev= 0.182m
Longitude Min= -1.265m Max= -0.106m Mean= -0.778m Stdev= 0.199m
RMS Min= 0.198m Max= 1.267m Mean= 0.812m Stdev= 0.194m

Airborne System - KGPS (Sample Size: AS = 211 KGPS = 211)
Latitude Min= 0.053m Max= 0.616m Mean= 0.337m Stdev= 0.144m
Longitude Min= -1.090m Max= -0.379m Mean= -0.640m Stdev= 0.144m
RMS Min= 0.510m Max= 1.197m Mean= 0.738m Stdev= 0.141m

DGPS - KGPS (Sample Size: DGPS = 211 KGPS = 211)
Latitude Min= -1.036m Max= 1.315m Mean= -0.019m Stdev= 0.382m
Longitude Min= -1.404m Max= 0.683m Mean= -0.222m Stdev= 0.404m
RMS Min= 0.013m Max= 1.428m Mean= 0.493m Stdev= 0.339m

DGPS - AS Height (Sample Size: AS = 211 DGPS = 211)
WGS84 Ht Min= -0.581m Max= 3.866m Mean= 1.088m

KGPS - AS Height (Sample Size: AS = 211 KGPS = 211)
WGS84 Ht Min= -0.273m Max= 1.031m Mean= 0.494m

Airborne System GPS Mode : diff
Airborne System Racal Basestation : 0505

Statistics for Run 804.0.1
GPS Start Time 19:19:35 End Time 19:22:45

DGPS_HRMS Min= 1.773m Max= 1.778m
KGPS_HRMS Min= 0.066m Max= 0.098m
AS_EHE Min= 2.167m Max= 2.167m

AS_PDOP Min= 2.20m Max= 2.20m
POST_PROCESSED_PDOP Min= 2.20m Max= 2.20m
AS_SVS Min= 7 Max= 7
POST_PROCESSED_SVS Min= 7 Max= 7
AS_LATENCY_OF_CORRECTIONS Min= 2s Max= 23s

Analysis of Reported GPS Position

Airborne System - DGPS (Sample Size: AS = 191 DGPS = 191)
Latitude Min= -0.083m Max= 0.597m Mean= 0.296m Stdev= 0.140m
Longitude Min= -1.042m Max= -0.008m Mean= -0.537m Stdev= 0.235m
RMS Min= 0.128m Max= 1.201m Mean= 0.641m Stdev= 0.200m

Airborne System - KGPS (Sample Size: AS = 191 KGPS = 191)
Latitude Min= -0.026m Max= 0.718m Mean= 0.298m Stdev= 0.131m
Longitude Min= -0.973m Max= -0.314m Mean= -0.648m Stdev= 0.135m
RMS Min= 0.472m Max= 1.209m Mean= 0.725m Stdev= 0.136m

DGPS - KGPS (Sample Size: DGPS = 191 KGPS = 191)
Latitude Min= -1.034m Max= 0.271m Mean= -0.116m Stdev= 0.239m
Longitude Min= -1.220m Max= 0.292m Mean= -0.532m Stdev= 0.411m
RMS Min= 0.032m Max= 1.221m Mean= 0.637m Stdev= 0.341m

DGPS - AS Height (Sample Size: AS = 191 DGPS = 191)
WGS84 Ht Min= -2.546m Max= 1.565m Mean= 0.040m

KGPS - AS Height (Sample Size: AS = 191 KGPS = 191)
WGS84 Ht Min= -0.674m Max= 0.935m Mean= 0.148m

Airborne System GPS Mode : diff
Airborne System Racal Basestation : 0505

Statistics for Run 803.0.1 GPS Start Time 19:29:03 End Time 19:32:00

DGPS_HRMS Min= 1.761m Max= 1.766m
KGPS_HRMS Min= 0.066m Max= 0.096m
AS_EHE Min= 2.125m Max= 2.167m
AS_PDOP Min= 2.30m Max= 2.30m
POST_PROCESSED_PDOP Min= 2.30m Max= 2.30m
AS_SVS Min= 7 Max= 7
POST_PROCESSED_SVS Min= 7 Max= 7
AS_LATENCY_OF_CORRECTIONS Min= 2s Max= 22s

Analysis of Reported GPS Position

Airborne System - DGPS (Sample Size: AS = 178 DGPS = 178)
Latitude Min= 0.455m Max= 1.423m Mean= 0.921m Stdev= 0.203m
Longitude Min= -0.966m Max= 0.532m Mean= -0.309m Stdev= 0.430m
RMS Min= 0.558m Max= 1.657m Mean= 1.051m Stdev= 0.253m

Airborne System - KGPS (Sample Size: AS = 178 KGPS = 178)
Latitude Min= 0.075m Max= 0.881m Mean= 0.430m Stdev= 0.191m
Longitude Min= -0.941m Max= 0.025m Mean= -0.590m Stdev= 0.243m
RMS Min= 0.185m Max= 1.235m Mean= 0.746m Stdev= 0.267m

DGPS - KGPS (Sample Size: DGPS = 178 KGPS = 178)
Latitude Min= -0.739m Max= 0.361m Mean= -0.249m Stdev= 0.263m
Longitude Min= -1.546m Max= 0.521m Mean= -0.490m Stdev= 0.507m
RMS Min= 0.100m Max= 1.576m Mean= 0.708m Stdev= 0.356m

DGPS - AS Height (Sample Size: AS = 178 DGPS = 178)
WGS84 Ht Min= -2.522m Max= 1.402m Mean= -0.288m

KGPS - AS Height (Sample Size: AS = 178 KGPS = 178)
WGS84 Ht Min= -0.707m Max= 2.333m Mean= 0.687m

Airborne System GPS Mode : diff
Airborne System Racal Basestation : 0505 ----------END OF DATA----------
This report was generated on 29 APR 2001 at 10:09:31 AM

C – Tides : Ground System Printouts

Sortie Tides

```
HIN : 002   19/07/01 02:51:24                    SEATTLE
GS VERSION T4.9/014                       TIDE MONITOR DATA REPORT

TIDAL STATION         1,   SEATTLE              SORTIE      7

DATE (GMT)     DAY   118
               YEAR  2001

SOUNDING DATUM  READING ON POLE       0.00
                LOCAL JULIAN DATE     19 APR 2001
                LOCAL TIME            00:01
```

TIME	OBSERVED TIDE	TIME	OBSERVED TIDE
14:00	3.03	17:24	2.36
14:12	3.07	17:36	2.23
14:24	3.11	17:48	2.10
14:36	3.13	18:00	1.95
14:48	3.15	18:12	1.80
15:00	3.15	18:24	1.64
15:12	3.15	18:36	1.48
15:24	3.13	18:48	1.31
15:36	3.09	19:00	1.15
15:48	3.05	19:12	0.98
16:00	3.00	19:24	0.82
16:12	2.94	19:36	0.67
16:24	2.86	19:48	0.52
16:36	2.78	20:00	0.37
16:48	2.69	20:12	0.23
17:00	2.59	20:24	0.10
17:12	2.48		

Survey lines flown in Sortie

HIN : 002 19/07/01 02:51:14 SEATTLE
GS VERSION T4.9/014 SORTIE TIDE APPLICATION REPORT

SORTIE: 7

RUN	STATUS	PRIMARY AVAIL	TIDE AREA INFORMATION
1007.0.1	RECONCILED	Y	10
707.0.1	FLOWN	Y	N/A
707.0.2	FLOWN	Y	N/A
707.0.3	RECONCILED	Y	10
806.0.1	RECONCILED	Y	10
907.0.1	RECONCILED	Y	10
604.0.1	RECONCILED	Y	10
605.0.1	RECONCILED	Y	10
606.0.1	RECONCILED	Y	10
607.0.1	RECONCILED	Y	10
608.0.1	RECONCILED	Y	10
609.0.1	RECONCILED	Y	10
609.0.2	RECONCILED	Y	10
610.0.1	RECONCILED	Y	10
610.0.2	RECONCILED	Y	10
611.0.1	RECONCILED	Y	10
611.0.2	RECONCILED	Y	10
611.0.3	RECONCILED	Y	10
612.0.1	RECONCILED	Y	10
612.0.2	RECONCILED	Y	10
612.0.3	RECONCILED	Y	10
613.0.1	RECONCILED	Y	10
613.0.2	RECONCILED	Y	10
613.0.3	RECONCILED	Y	10
614.0.1	RECONCILED	Y	10
614.0.2	RECONCILED	Y	10
615.0.1	RECONCILED	Y	10
615.0.2	RECONCILED	Y	10
615.0.3	RECONCILED	Y	10
616.0.1	RECONCILED	Y	10
616.0.2	RECONCILED	Y	10
617.0.1	RECONCILED	Y	10
618.0.1	RECONCILED	Y	10
603.0.1	RECONCILED	Y	10
602.0.1			

HIN : 002 19/07/01 02:51:17 SEATTLE
GS VERSION T4.9/014 SORTIE TIDE APPLICATION REPORT

	RECONCILED	Y	10
601.0.1	RECONCILED	Y	10
600.0.1	RECONCILED	Y	10
600.0.2	RECONCILED	Y	10
803.0.1	RECONCILED	Y	10
804.0.1	RECONCILED	Y	10
805.0.1	RECONCILED	Y	10
805.0.2	RECONCILED	Y	10
807.0.1	RECONCILED	Y	10

D – Charts, Plots and Graphics

The following graphic products are provided:

Tinned Surface Plots

Reference	Scale	Remarks
001V01	1:10 000	Possession Sound Sounding Pattern P4 UTM (N)
002V01	1:10 000	Possession Sound Sounding Pattern P4 UTM (N)
003V01	1:10 000	Possession Sound Sounding Pattern P4 UTM (N)
004V01	1:10 000	Possession Sound Sounding Pattern P4 UTM (N)

Preliminary Smooth Sheets

Reference	Scale	Remarks
001V01	1:10 000	Possession Sound Sounding Pattern P4 UTM (N) Depths in meters
002V01	1:10 000	Possession Sound Sounding Pattern P4 UTM (N) Depths in meters
003V01	1:10 000	Possession Sound Sounding Pattern P4 UTM (N) Depths in meters
004V01	1:10 000	Possession Sound Sounding Pattern P4 UTM (N) Depths in meters

E – Digital Data

The following digital products are provided:

Output Data S3 Files

Reference	Remarks
KP01.OPD	Possession Sound Sounding Pattern P4 Data of all soundings in Output Data format S3 WGS 84, UTM (N). Depths in meters. (one file per run)

XYZ Data File

Reference	Remarks
KP01.pts	Possession Sound Sounding Pattern P4 Data of all secondary soundings in Easting Northing Depth format WGS 84, UTM (N) Depths in meters

Image Files

Reference	Remarks
West.tif	Tiff image of tinned secondaries Western side of Possession Sound
East.tif	Tiff image of tinned secondaries Eastern side of Possession Sound

World Files

Reference	Remarks
West.tfw	Geo reference files for Tiff image WGS 84 UTM (N)
East.tfw	Geo reference files for Tiff image WGS 84 UTM (N)

FLIGHT OBJECTIVES

Planned Date : 28APR01 **JD :** 118 **Sortie No :** 7 F0250

Briefing : 0700 **ETD :** 0730 **ETA :** 1300 **Latest :**

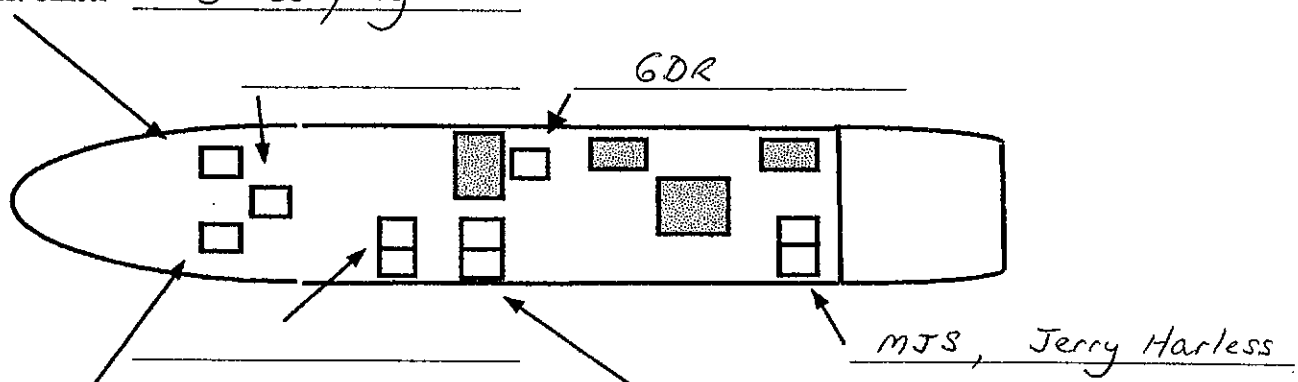
Issue Number : **Sunset :**

Area : NORTH SEATTLE – PUGET SOUND

Alternative :

Sequence No	Objective Description / Remarks
1	7000 line, followed by 700 line, 800 line and 900 line
2	Sub area 4 - 600 lines
	Sub area 9 - 650 lines
	Sub area 6 - 800 lines.
	Furthers lines as required.

First Officer G Godfrey



Captain N Balding Dr Peter Ruggiero

Distribution :

1. Coordinator (Original)
2. Pilots
3. Logistics Support Manager

APPROVED : Mark Smelser

Date: 27/4/01