U.S. Department of Commerce
National Oceanic and Atmospheric Administration
National Ocean Service

Data Acquisition & Processing Report

Type of Survey:	Navigable Area
Project Number:	OPR-Q350-KR-21
Time Frame:	June - July 2021

LOCALITY

State(s):	Alaska
General Locality:	Unimak Island, AK

2021

CHIEF OF PARTY
Allison Stone

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Data Acquisition and Processing Report

Fugro USA Marine, Inc.
Chief of Party: Allison Stone
Year: 2021
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A. System Equipment and Software

A.1 Survey Vessels

A.1.1 R/V Woldstad

<table>
<tr><td>Vessel Name</td><td colspan="2">R/V Woldstad</td></tr>
<tr><td>Hull Number</td><td colspan="2">IMO 8305640</td></tr>
<tr><td>Description</td><td colspan="2">R/V Woldstad is a multipurpose vessel serving as the primary survey platform for OPR-Q350-KR-21. The vessel is equipped with a port side-mounted pole that is fitted with a standard bracket to hold the Reson 7125 SV2 multibeam echosounder (MBES), Reson SV70 surface sound velocity (SSV) probe, and Applanix IMU model 45.</td></tr>
<tr><td rowspan="3">Dimensions</td><td>LOA</td><td>121'</td></tr>
<tr><td>Beam</td><td>28'</td></tr>
<tr><td>Max Draft</td><td>12'</td></tr>
<tr><td rowspan="2">Most Recent Full Offset Verification</td><td>Date</td><td>2021-06-08</td></tr>
<tr><td>Method</td><td>Conventional verification of offset survey conducted using total station. Refer to vessel offsets for full report.</td></tr>
</table>

Figure 1: R/V Woldstad

A.1.2 Skiff

Vessel Name	Skiff	
Hull Number	AK9414AV	
Description	The Woldstad's skiff is a multipurpose vessel serving as the nearshore survey platform for OPR-Q350-KR-21. The vessel is equipped with a starboard side-mounted pole that is fitted with a standard bracket to hold the Reson 7125 SV2 multibeam echosounder (MBES), Reson SV70 surface sound velocity (SSV) probe, and Applanix IMU model 45.	
Dimensions	*LOA*	23'
	Beam	9'
	Max Draft	1'

Most Recent Full Offset Verification	*Date*	2021-06-08
	Method	Conventional verification of offset survey conducted using total station. Refer to vessel offsets for full report.

Figure 2: Skiff

A.2 Echo Sounding Equipment

A.2.1 Multibeam Echosounders

A.2.1.1 Teledyne Reson 7125 SV2

The pole mounted MBES on R/V Woldstad is attached to the port side of the vessel.

The Reson 7125 SV2 is a dual frequency system operating at 200 to 400 kHz. The system was operated in intermediate beam mode, which forms 512 across-track beams (in 400 kHz), with a maximum swath coverage of 140°. Operating modes such as range scale, gain, power level, ping rates, etc. were a function of water depth and data quality and were noted on the survey line logs (see Descriptive Report Separate I).

The Reson system and IMU were installed on a standard SV2 bracket, which included an SV70 probe (located in the nose cone) and was attached to the mounting plate by a flange. Refer to Appendix I for more information and graphics.

Manufacturer	Teledyne			
Model	Reson 7125 SV2			
Inventory	*R/V Woldstad*	*Component*	Tx	Rx
		Model Number	7125 SV2	7125 SV2
		Serial Number	1012060	3912077
		Frequency	400kHz/200kHz	400kHz/200kHz
		Calibration	2021-06-09	2021-06-09
		Accuracy Check	2021-06-09	2021-06-09

A.2.1.2 Teledyne Reson 7125 SV2

The pole mounted MBES on the skiff is attached to the starboard side of the vessel.

The Reson 7125 SV2 is a dual frequency system operating at 200 to 400 kHz. The system was operated in intermediate beam mode, which forms 512 across-track beams (in 400 kHz), with a maximum swath coverage of 140°. Operating modes such as range scale, gain, power level, ping rates, etc. were a function of water depth and data quality and were noted on the survey line logs (see the Descriptive Report Separate 1).

The Reson system and IMU were installed on a standard SV2 bracket, which included an SV70 probe (located in the nose cone) and was attached to the mounting plate by a flange. Refer to Appendix I for more information and graphics.

Manufacturer	Teledyne			
Model	Reson 7125 SV2			
Inventory	*Skiff*	*Component*	Tx	Rx
		Model Number	7125 SV2	7125 SV2
		Serial Number	1612100	2709002
		Frequency	400kHz/200kHz	400kHz/200kHz
		Calibration	2021-06-09	2021-06-09
		Accuracy Check	2021-06-09	2021-06-09

Figure 3: MBES mounting configuation shown on Skiff

A.2.2 Single Beam Echosounders

No single beam echosounders were utilized for data acquisition.

A.2.3 Side Scan Sonars

No side scan sonars were utilized for data acquisition.

A.2.4 Phase Measuring Bathymetric Sonars

No phase measuring bathymetric sonars were utilized for data acquisition.

A.2.5 Other Echosounders

No additional echosounders were utilized for data acquisition.

A.3 Manual Sounding Equipment

A.3.1 Diver Depth Gauges

No diver depth gauges were utilized for data acquisition.

A.3.2 Lead Lines

No lead lines were utilized for data acquisition.

A.3.3 Sounding Poles

No sounding poles were utilized for data acquisition.

A.3.4 Other Manual Sounding Equipment

No additional manual sounding equipment was utilized for data acquisition.

A.4 Horizontal and Vertical Control Equipment

A.4.1 Base Station Equipment

No base station equipment was utilized for data acquisition.

A.4.2 Rover Equipment

No rover equipment was utilized for data acquisition.

A.4.3 Water Level Gauges

No water level gauges were utilized for data acquisition.

A.4.4 Levels

No levels were utilized for data acquisition.

A.4.5 Other Horizontal and Vertical Control Equipment

No other equipment was utilized for data acquisition.

A.5 Positioning and Attitude Equipment

A.5.1 Positioning and Attitude Systems

A.5.1.1 Applanix POS M/V v.5

Positioning Suite

<table>
<tr><td>Manufacturer</td><td colspan="6">Applanix</td></tr>
<tr><td>Model</td><td colspan="6">POS M/V v.5</td></tr>
<tr><td rowspan="4">Inventory</td><td rowspan="4">R/V Woldstad</td><td>Component</td><td>IMU</td><td>Applanix Box</td><td>Port Ant (primary)</td><td>Stbd Ant (secondary)</td></tr>
<tr><td>Model Number</td><td>45</td><td>POSM/V v.5</td><td>GA830</td><td>GA830</td></tr>
<tr><td>Serial Number</td><td>5455</td><td>12341</td><td>20893</td><td>20939</td></tr>
<tr><td>Calibration</td><td>2021-06-09</td><td>2021-06-09</td><td>2021-06-09</td><td>2021-06-09</td></tr>
</table>

A.5.1.2 Applanix POS M/V v.5

Positioning Suite

<table>
<tr><td>Manufacturer</td><td colspan="6">Applanix</td></tr>
<tr><td>Model</td><td colspan="6">POS M/V v.5</td></tr>
<tr><td rowspan="4">Inventory</td><td rowspan="4">Skiff</td><td>Component</td><td>IMU</td><td>Applanix Box</td><td>Port Ant (primary)</td><td>Stbd Ant (secondary)</td></tr>
<tr><td>Model Number</td><td>45</td><td>POSM/V v.5</td><td>GA830</td><td>GA830</td></tr>
<tr><td>Serial Number</td><td>BGR604003</td><td>9940</td><td>12422</td><td>17001</td></tr>
<tr><td>Calibration</td><td>2021-06-09</td><td>2021-06-09</td><td>2021-06-09</td><td>2021-06-09</td></tr>
</table>

A.5.2 DGPS

DGPS equipment was not utilized for data acquisition.

A.5.3 GPS

Additional GPS equipment was not utilized for data acquisition.

A.5.4 Laser Rangefinders

US Camel Rangefinder/compass binoculars were utilized from the skiff to obtain fixes and heights on any significant exposed rocks.

A.5.5 Other Positioning and Attitude Equipment

No additional positioning and attitude equipment was utilized for data acquisition.

A.6 Sound Speed Equipment

A.6.1 Moving Vessel Profilers

A.6.1.1 Teledyne RapidCast

Teledyne RapidCast allows for full water column sound velocity profiling while the vessel remains underway. This asset allows the continuous collection of multibeam data without the need to waste any operational time for static SVP casts; this is particularly valuable on larger vessels.

The mechanism was mounted to the aft starboard stern railing to allow for the safest deployment and recovery of the probe while the vessel remained underway. The probe would be deployed by personnel on the stern and operated by the person on acquisition watch, then recovered by personnel on stern. The probe was not left in the water continuously.

Raw data files were downloaded via Bluetooth, logged, and processed by acquisition personnel.

Manufacturer	Teledyne		
Model	RapidCast		
Inventory	*R/V Woldstad*	*Component*	RapidCAST
		Model Number	RapidProbeSVT
		Serial Number	73646
		Calibration	2020-10-19

Figure 4: Teledyne Oceanscience RapidCast

A.6.2 CTD Profilers

A.6.2.1 AML AML-3 RT

The RT designation (ie. AML-3 RT) stream data while in-situ. Power and communication to this instrument is facilitated via a waterproof connector. These instruments rely on external power for operation and the application of this power is automatic when voltage is applied.

Manufacturer	AML			
Model	AML-3 RT			
Inventory	*Component*	CTD	CTD	CTD
	Model Number	AML-3 RT	AML-3 RT	AML-3 RT
	Serial Number	A30079	A30078	A30071
	Calibration	2020-09-03	2020-09-03	2020-08-20
	Component	CTD	CTD	CTD
	Model Number	AML-3 RT	AML-3 RT	AML-3 RT
	Serial Number	A30067	A30020	A30018
	Calibration	2020-10-02	2020-08-20	2020-09-03

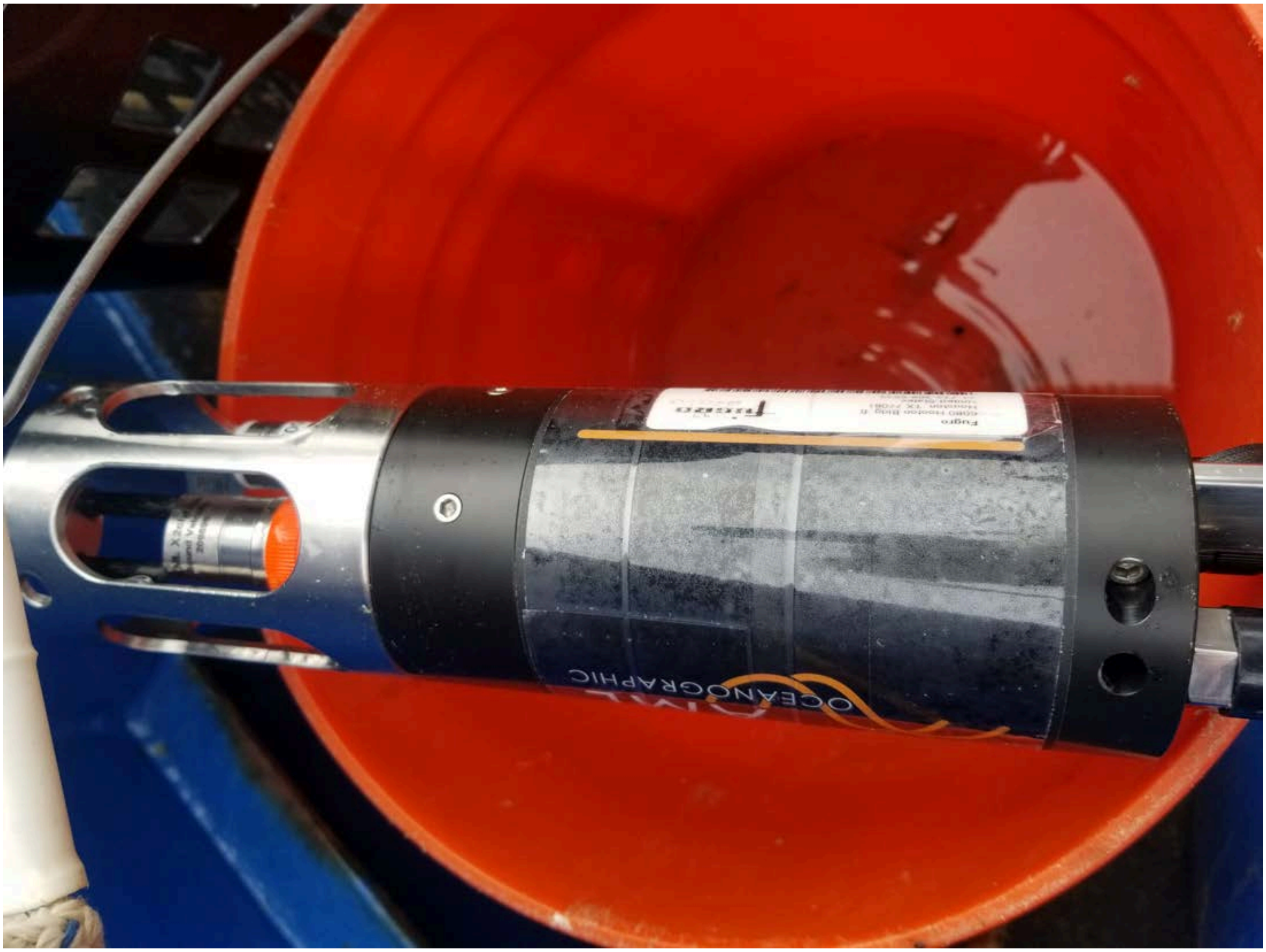

Figure 5: AML-3 RT

Figure 6: AML-3 RT

A.6.2.2 Sea Bird Scientific SBE 19+

The SBE 19+ SeaCAT Profiler measures conductivity, temperature, and pressure (depth).

Manufacturer	Sea Bird Scientific	
Model	SBE 19+	
Inventory	*Component*	CTD
	Model Number	SBE 19+
	Serial Number	5018
	Calibration	2021-02-27
	Component	CTD
	Model Number	SBE 19+
	Serial Number	5018
	Calibration	2021-02-27

Figure 7: Sea Bird SBE 19+

A.6.3 Sound Speed Sensors

A.6.3.1 Reson Surface Sound Velocity

SSVS mounted at head of MBES.

<table>
<tr><td>Manufacturer</td><td colspan="3">Reson</td></tr>
<tr><td>Model</td><td colspan="3">Surface Sound Velocity</td></tr>
<tr><td rowspan="8">Inventory</td><td rowspan="4">R/V Woldstad</td><td>Component</td><td>SSVS</td></tr>
<tr><td>Model Number</td><td>SV70</td></tr>
<tr><td>Serial Number</td><td>2711079</td></tr>
<tr><td>Calibration</td><td>2021-05-10</td></tr>
<tr><td rowspan="4">Skiff</td><td>Component</td><td>SSVS</td></tr>
<tr><td>Model Number</td><td>SV70</td></tr>
<tr><td>Serial Number</td><td>4506001</td></tr>
<tr><td>Calibration</td><td>2021-04-15</td></tr>
</table>

Figure 8: Reson SV70

A.6.4 TSG Sensors

No thermosalinograph (TSG) sensors were utilized for data acquisition.

A.6.5 Other Sound Speed Equipment

No other surface sound speed sensors were utilized for data acquisition.

A.7 Computer Software

Manufacturer	*Software Name*	*Version*	*Use*
Fugro	WinFrog	3.10.26	Acquisition
Fugro	POSLogger	2.0	Acquisition
Applanix	POSView Controller	10.5	Acquisition
Applanix	POSPac MMS	8.5	Processing
Fugro	Multibeam Survey Tools	N/A	Acquisition and Processing
Teledyne	CARIS HIPS	10.4.29	Processing
UNH/NOAA	PydroXL	19.4	Processing
ESRI	ArcGIS	10.4	Processing
Teledyne Ocean Science	RapidCAST Interface	1.5.1	RapidCAST underway SVP data control
Teledyne	RapidCAST Motion	1.3.2.22	RapidCAST underway SVP winch control
Valeport	Valeport Connect	1.0.7.10	CTD processing software

A.8 Bottom Sampling Equipment

A.8.1 Bottom Samplers

A.8.1.1 Van Veen Petite Ponar Grab

The R/V Woldstad and Skiff were each equipped with a 2.4L Van Veen Grab bottom sampler and 200m of line. The sampler was winch deployed and retrieved via a davit that was installed on the starboard side of the vessel; samples acquired from the Skiff required the sampler to be lowered and raised by hand. All samples were discarded after the sample information was documented.

Figure 9: Van Veen sediment sampler

B. System Alignment and Accuracy

B.1 Vessel Offsets and Layback

B.1.1 Vessel Offsets

All vessel and sensor offsets were derived via conventional survey techniques (total station), with reference to the IMU. The results yielded standard deviations of 0.010m. Refer to Appendix I-Vessel Reports.

B.1.1.1 Vessel Offset Correctors

Vessel	R/V Woldstad			
Echosounder	Teledyne Reson 7125 SV2 200kHz			
Date	2021-06-05			
Offsets			*Measurement*	*Uncertainty*
	MRU to Transducer	*x*	0.000 meters	0.010 meters
		y	0.090 meters	0.010 meters
		z	0.338 meters	0.010 meters
		x2	0.000 meters	0.010 meters
		y2	0.269 meters	0.010 meters
		z2	0.362 meters	0.010 meters
	Nav to Transducer	*x*	3.040 meters	0.010 meters
		y	3.110 meters	0.010 meters
		z	15.410 meters	0.010 meters
		x2	3.040 meters	0.010 meters
		y2	2.931 meters	0.010 meters
		z2	15.434 meters	0.010 meters
	Transducer Roll	*Roll*	0.000 degrees	

Vessel	R/V Woldstad			
Echosounder	Teledyne Reson 7125 SV2 400kHz			
Date	2021-06-05			
Offsets			*Measurement*	*Uncertainty*
	MRU to Transducer	*x*	0.000 meters	0.010 meters
		y	0.090 meters	0.010 meters
		z	0.338 meters	0.010 meters
		x2	0.000 meters	0.010 meters
		y2	0.269 meters	0.010 meters
		z2	0.362 meters	0.010 meters
	Nav to Transducer	*x*	3.040 meters	0.010 meters
		y	3.110 meters	0.010 meters
		z	15.410 meters	0.010 meters
		x2	3.040 meters	0.010 meters
		y2	2.931 meters	0.010 meters
		z2	15.434 meters	0.010 meters
	Transducer Roll	*Roll*	0.000 degrees	

Vessel	Skiff			
Echosounder	Teledyne Reson 7125 SV2 400kHz			
Date	2021-06-03			
Offsets			*Measurement*	*Uncertainty*
	MRU to Transducer	*x*	0.040 meters	0.010 meters
		y	0.257 meters	0.010 meters
		z	0.231 meters	0.010 meters
		x2	0.040 meters	0.010 meters
		y2	0.436 meters	0.010 meters
		z2	0.255 meters	0.010 meters
	Nav to Transducer	*x*	0.578 meters	0.010 meters
		y	2.859 meters	0.010 meters
		z	3.554 meters	0.010 meters
		x2	0.578 meters	0.010 meters
		y2	3.038 meters	0.010 meters
		z2	3.587 meters	0.010 meters
	Transducer Roll	*Roll*	0.000 degrees	

B.1.2 Layback

This section is not applicable to OPR-Q350-KR-21.

Layback correctors were not applied.

B.2 Static and Dynamic Draft

B.2.1 Static Draft

For each vessel, static draft measurement point was located on the MBES pole directly above the CRP (IMU), which allowed for a precise static draft measurement. Offset values for the CRP (IMU) to the sonar and waterline were applied to the data in CARIS HIPS as specified in the HIPS vessel file (HVF).

Offsets between the GPS antennas and the CRP were applied internally by the POS/MV by entering a GPS lever arm offset. Note that the HVF does not contain navigation offsets, because the position provided by the POS/MV is already corrected to the CRP. Vessel offsets used are shown in the offset diagram included in separate Appendix.

Static Draft measurements were not acquired daily as accuracy was not achievable due to excessive sea state. The most accurate readings were recorded while in port, before and after bunkering.

B.2.1.1 Static Draft Correctors

Vessel		R/V Woldstad	Skiff
Date		2021-06-09	2021-06-09
Loading		0.000 meters	0.000 meters
Static Draft	*Measurement*	-2.378 meters	-0.800 meters
	Uncertainty	0.050 meters	0.050 meters

B.2.2 Dynamic Draft

All surveys within the scope of OPR-Q350-KR-21 were reduced via a VDatum separation model; dynamic draft measurements were not performed.

B.2.2.1 Dynamic Draft Correctors

Dynamic draft correctors were not applied.

B.3 System Alignment

B.3.1 System Alignment Methods and Procedures

Vessel heading and dynamic motion were measured by the Applanix POS/MV V5 on R/V Woldstad and the Skiff. The system calculated heading by inversing between two GPS-generated antenna positions. An accelerometer block (the IMU), which measured vessel attitude, was mounted directly above the multibeam transducer.

Misalignment between the IMU and the vessel reference frame was estimated to be 0.10°. This value was also used for Gyro, Roll and Pitch Standard Deviation. For all vessel and sonar configurations, patch tests were conducted to identify alignment errors (timing, pitch, heading, and roll) between the motion sensor and the multibeam transducers.

Comparison between the soundings collected by R/V Woldstad and the Skiff were performed to verify vertical consistency. Data collected by the different systems over the same area were processed using the CARIS routine and Combined Uncertainity and Bathymetric Estimator (CUBE) surfaces were created. Depth difference surfaces were created and statistics computed. Good correlation between the different datasets was observed. Any difference in depth between the surfaces can be attributed to error in the sound velocity profile, the static draft measurement procedure, the vessel offset survey, and/or the sonar system’s internal capabilities.

A patch test was completed for each MBES system to determine and correct navigation timing, pitch, azimuth, and roll offsets, which may exist between the MBES transducer and the Motion Reference Unit (MRU).

No adjustment was required for navigation timing error. Fugro has implemented a specific timing protocol for multibeam data acquisition. In this method, UTC time tags generated within the POS/MV are applied to all position, heading, and attitude data. The POS/MV ZDA+1 PPS (pulse per second) string is also sent to the Reson SeaBat sonar system, where the ping data are tagged. The architecture of the POS/MV ensures that there is zero latency between the position, heading, and attitude strings. The only latency possible is in the ping time. In addition, the navigation-to-ping latency will be identical to the attitude-to-ping and latencies. Navigation latency is generally difficult to measure using standard timing and patch testing techniques. However, using Fugro’s timing protocol, the navigation latency will be the same as the roll latency.

Fortunately, roll latencies are very easy to identify. Data with a roll timing latency will have a rippled appearance along the edge of the swath. During patch test analysis, the roll latency is adjusted until the ripple is gone. This latency value is then applied to the ping time, synchronizing it with the position, attitude, and heading data.

The pitch error adjustment was performed on sets of two coincident lines, run at the same velocity, over a conspicuous object, in opposite directions. The nadir beams from each line were compared and brought into alignment, by adjusting the pitch error value.

The azimuth error adjustment was performed on sets of two lines, run over a conspicuous topographic feature. Lines were run in opposite directions, at the same velocity with the same outer beams crossing the feature. Since the pitch error has already been identified, data from the same outer beams for each line were compared and brought into alignment, by adjusting the azimuth error value.

The roll error adjustment was performed on sets of two coincident lines, run over flat terrain, at the same velocity, in opposite directions. The pitch error and azimuth error were already identified. Data across a swath were compared for each line and brought into agreement by adjusting the roll error value.

Patch test data was then corrected using the identified values, and the process repeated to check the validity of values obtained. Patch test values were obtained in CARIS HIPS calibration mode. Calculated values were then entered into the HVF so that data could be corrected during routine processing. For survey platforms using Reson 7125 echosounders, the Installations Parameters 7030 record was implemented into the acquisition workflow. The 7030 record is the Installation Parameter of the sonar, which includes the transmit and receiver offsets. Most of the information stored in the 7030 record is not used by CARIS. To fully utilize the 7027 record, the 7030 record was essential and written to the raw .s7k files during data collection.

B.3.1.1 System Alignment Correctors

Vessel	R/V Woldstad		
Echosounder	Teledyne Reson 7125 SV2 200kHz		
Date	2021-06-10		
Patch Test Values		*Corrector*	*Uncertainty*
	Transducer Time Correction	0.000 seconds	0.000 seconds
	Navigation Time Correction	0.000 seconds	0.000 seconds
	Pitch	0.425 degrees	0.020 degrees
	Roll	-1.080 degrees	0.020 degrees
	Yaw	-0.890 degrees	0.020 degrees
	Pitch Time Correction	0.000 seconds	0.000 seconds
	Roll Time Correction	0.000 seconds	0.000 seconds
	Yaw Time Correction	0.000 seconds	0.000 seconds
	Heave Time Correction	0.000 seconds	0.000 seconds

Vessel	R/V Woldstad		
Echosounder	Teledyne Reson 7125 SV2 400kHz		
Date	2021-06-10		
Patch Test Values		*Corrector*	*Uncertainty*
	Transducer Time Correction	0.000 seconds	0.000 seconds
	Navigation Time Correction	0.000 seconds	0.000 seconds
	Pitch	0.425 degrees	0.020 degrees
	Roll	-1.080 degrees	0.020 degrees
	Yaw	-0.890 degrees	0.020 degrees
	Pitch Time Correction	0.000 seconds	0.000 seconds
	Roll Time Correction	0.000 seconds	0.000 seconds
	Yaw Time Correction	0.000 seconds	0.000 seconds
	Heave Time Correction	0.000 seconds	0.000 seconds

Vessel	Skiff		
Echosounder	Teledyne Reson 7125 SV2		
Date	2021-06-12		
Patch Test Values		*Corrector*	*Uncertainty*
	Transducer Time Correction	0.000 seconds	0.000 seconds
	Navigation Time Correction	0.000 seconds	0.000 seconds
	Pitch	0.430 degrees	0.020 degrees
	Roll	0.130 degrees	0.020 degrees
	Yaw	-0.620 degrees	0.020 degrees
	Pitch Time Correction	0.000 seconds	0.000 seconds
	Roll Time Correction	0.000 seconds	0.000 seconds
	Yaw Time Correction	0.000 seconds	0.000 seconds
	Heave Time Correction	0.000 seconds	0.000 seconds

C. Data Acquisition and Processing

C.1 Bathymetry

C.1.1 Multibeam Echosounder

Data Acquisition Methods and Procedures

The survey line orientation for all vessels was generally perpendicular to the coastline and bathymetric contours of the area. Set line spacing MBES was acquired per Project Instructions (PI) and HSSD 2020 5.2.2.4 Option A and was acquired dependent on assigned values to meet the set line spacing requirement of surveys H13445 (240m), H13446 (320m), H13447 (240m), H13448 (320m), H13449 (500m), H13450 (500m), H13451 (500m), and H13452 (500m). H13444 was acquired to full coverage specifications as outlined in the PI and the HSSD 2020.

Reson 7125 multibeam sonars are a dual frequency system operating at 200 and 400 kHz. The systems were operated in the intermediate beam mode option, which forms 512 across-track beams (in 400 kHz), with a maximum swath coverage of 140°. Operating modes such as range scale, gain, power level, ping rates, etc. were a function of water depth and data quality and were noted on the survey line logs.

All 7125 multibeam data files were logged in the .s7k format using WinFrog Multibeam (WFMB) v3.10.24; containing all multibeam bathymetry, position, attitude, heading, and UTC time stamp data required by CARIS to process the soundings. Snippet data required by FMGT to process the backscatter data are also included within .s7k packets.

A separate WFMB module (PosMVLogger) on the same PCs recorded all raw POS/MV data for the post processing of vessel positions in Applanix POSPac MMS software. WFMB also provided a coverage display for real-time QC and data coverage estimation.

WFMB offers the following display windows for operators to monitor data quality:

1. Devices: The Devices window shows the operator which hardware is attached to the PC. It also allows the operator to configure the devices, determine whether they are functioning properly, and to view received data.
2. Graphic: The Graphics window shows navigation information in plan view. This includes vessel position, survey lines, background vector plots, and raster charts.
3. Vehicle: The Vehicle window can be configured to show any tabular navigation information required. Typically, this window displays position, time, line name, heading, HDOP, speed over ground, distance to start of line, distance to end of line, and distance off line. Many other data items are selectable.
4. Calculation: The Calculations window is used to look at specific data items in tabular or graphical format. Operators look here to view the status of the GPS satellite constellation and position solutions, real-time SV, tidal values, etc.

5. MBES Coverage Map: The Coverage Map provides a real-time graphical representation of the multibeam data. This allows the user to make judgments and corrections to the data collection procedure based on current conditions.
6. MBES QC View: The QC View contains four configurable windows for real-time display of any of the following: 2D or 3D multibeam data, snippets, pseudo sidescan, or backscatter amplitude. In addition to this, it contains a surface sound speed utility that is configurable for real-time SV monitoring at the sonar head.

Applanix POS/MV v5 controller software was used to monitor the POS/MV systems. The software has various displays that allow the operator to check real-time position, attitude and heading accuracies, and GPS status. POS/MV configuration and calibration, when necessary, was also done using this program.

Fugro's PosMvLogger v2.0 was used to provide uninterrupted logging of all IMU, dual frequency GPS, and diagnostic data. Additionally, the Delayed Heave data applied in post-processing was collected concurrently in the same file. The program also provided real-time QC and alarms for excessive HDOP, PDOP, and DGPS outages.

Fugro's MB Survey Tools v3.1.16 was used to aid in file administration and reporting during data acquisition. This program created a daily file that contained survey line, SVP, static draft records, and relevant recordable events throughout the survey. These logs were stored digitally in a database format and later used to create the log sheets in PDF format located in the Descriptive Report Separate I.

Fugro's Back2Base software is a package that facilitates the transfer of large data sets from the survey location to an Amazon Workspace (AWS) PCoIP cloud file server. Back2Base was used to send the daily raw data collected and CARIS HDCS data with initial correctors to the file server where processing operations took place.

Data Processing Methods and Procedures

All .s7k files were initially processed on the vessel within a reasonable time frame of acquisition on a line-by-line basis. Initial correctors applied include: predicted tide, acquired SVP, merge, and standard TPU values.

All acquisition files for R/V Woldstad and the Skiff were uploaded daily via Back2Base.

All soundings were processed using CARIS v.10.4.29. Multibeam data were converted from .s7k files to HIPS format, soundings corrected for sound velocity, motion, tide, and vessel offset. Data was then cleaned as necessary using Swath filters and directed editing. HIPS also produced the final Bathymetry Associated with Statistical Error (BASE) surfaces.

PydroXL_19 was utilized to check for data outliers, holidays, and to ensure data specifications were meeting or exceeding standards set forth by NOAA.

CARIS HIPS and SIPS v.10.4.29 with NOAA Profile Version 2021 was used to generate all S-57 Final Feature Files.

Applanix 8.5 was used to post-process acquired positioning data and create SBET and RMS files to correct for vessel motion.

QPS FMGT v7.9.3 was used to QC acoustic backscatter data.

ESRI ArcGIS v10.3 was used for survey planning, reviewing coverage plots, creating both infills and crosslines, and creating production graphics.

MB Survey Tools v3.1.18 allowed processors to track changes and add comments while processing. MB Survey Tools was also used to process all sound velocity profiles and to convert them into a CARIS format.

C.1.2 Single Beam Echosounder

Single beam echosounder bathymetry was not acquired.

C.1.3 Phase Measuring Bathymetric Sonar

Phase measuring bathymetric sonar bathymetry was not acquired.

C.1.4 Gridding and Surface Generation

C.1.4.1 Surface Generation Overview

CARIS HIPS v10.4 was used to increase efficiency with the daily processing effort. After the completion of each line of data acquisition, data was converted and initial correctors applied. A daily DTM was also updated as each line was processed. Once data became accessible to processors on board R/V Woldstad, final correctors were applied, and QC assessed.

C.1.4.2 Depth Derivation

In order for the .s7k files to be used by CARIS, they must be first converted to HDCS format using the CARIS conversion routine. Prior to the files being converted, vessel offsets, patch test calibration values, TPU values, and static draft were entered into the HVF for both vessels.

Once converted lines were received by processors, delayed heave, a concatenated SVP file, SBET, and RMS were applied to the data. GPS tide was then computed and data merged. The TPU was then computed for each sounding and attitude checked. Bathymetry data for each individual line were examined for noise as well as to ensure the completeness and correctness of the data set. The data was filtered using a swath angle filter and a Reson quality flag filter. Filters used varied between vessels and data quality. The beam numbers filter soundings based on a specified beam number that is entered in the field. The Reson quality flag filter rejected soundings based on the collinearity and brightness of each ping. Note that “rejected” does not mean the sounding was deleted – it was instead flagged as rejected so as not to be included in subsequent processing such as surface creation. Data flagged as rejected contained valid data but were flagged to remove noise and to speed the processing flow. Valid data points were manually re-accepted into the data set occasionally during line and subset editing as required. Subset Tiles (to track areas examined) were created in CARIS HIPS. Adjacent lines of data were examined to identify any potential systemic errors, as well as to reject any remaining noise in the data set that incorrectly characterized bathymetry represented by the CUBE surface.

C.1.4.3 Surface Computation Algorithm

CUBE surfaces were created at required resolutions for each priority area. Each CUBE surface was finalized using the depth thresholds specific to its resolution and acquisition requirement using CUBEParams_NOAA_2020.

While examining the data in subset mode, soundings were designated wherever the CUBE surface did not adequately depict the shoalest point of a feature. Soundings were designated when they met or exceeded the criteria for designation set forth in the NOAA HSSD (2020). Designation ensured that soundings were carried through to the finalized BASE surface and or used to add or modify features.

A statistical analysis of the sounding data was conducted via the CARIS Quality Control Report (QCR) routine. Crosslines were run in each survey and compared with CUBE surfaces created from the mainscheme lines. The IHO S-44 criteria for an Order 1a survey, as specified in the Project Instructions, were used in the CARIS QCR comparison on a beam by beam basis. Quality Control results are found in Separate 2 of each survey's Descriptive Report directory.

C.2 Imagery

C.2.1 Multibeam Backscatter Data

Data Acquisition Methods and Procedures

Towed sidescan sonar (SSS) operations were not required by this contract, but the backscatter and beam imagery snippet data from all multibeam systems were logged and are stored in the .s7k files. All beam imagery snippet data was logged in the 7028 record of the .s7k file for the project.

Data Processing Methods and Procedures

Multibeam backscatter deliverables were not created for OPR-Q350-KR-21.

C.2.2 Side Scan Sonar

Side scan sonar imagery was not acquired.

C.2.3 Phase Measuring Bathymetric Sonar

Phase measuring bathymetric sonar imagery was not acquired.

C.3 Horizontal and Vertical Control

C.3.1 Horizontal Control

C.3.1.1 GNSS Base Station Data

GNSS base station data was not acquired.

C.3.1.2 DGPS Data

DGPS data was not acquired.

C.3.2 Vertical Control

C.3.2.1 Water Level Data

Water level data was not acquired.

C.3.2.2 Optical Level Data

Optical level data was not acquired.

C.4 Vessel Positioning

Data Acquisition Methods and Procedures

For R/V Woldstad and the Skiff, standalone WFMB module (PosMVLogger) on the same PC logged all raw POS/MV data for the post-processing of vessel positions in Applanix POSPac MMS software. WFMB also provided a coverage display for realtime QC and data coverage estimation.

Data Processing Methods and Procedures

GPS data collected by Applanix POS/MV v.5 was post-processed using the Applanix POSPac PPRTX routine to create an SBET and RMS file. Following creation, the SBET and RMS data were then applied to the data in CARIS HIPS, replacing the real-time GPS navigation position with a post-processed GPS position. The separation model was provided by NOAA and applied in CARIS HIPS using the GPS tide function to reduce the post processed ellipsoidal heights to MLLW.

C.5 Sound Speed

C.5.1 Sound Speed Profiles

Data Acquisition Methods and Procedures

Sound velocity casts were normally performed every two hours and spatially distributed throughout the survey area. Two methods of sound velocity collection were utilized for this survey. Both vessels were equipped with AML RT-3 probes. When using this equipment, prior to each cast the probes were held at the surface for one to two minutes to achieve temperature equilibrium. The probes were then lowered and raised at a rate of 1 m/s. Between casts, the sound velocity sensors were stored in fresh water to minimize salt-water corrosion and to hold them at an ambient water temperature. After several AML issues with cables and software interface, a SeaBird 19+ was shared between the vessels for static casts.

Aboard the R/V Woldstad, CTD casts were primarily collected using a Teledyne OceanScience Rapid Cast system. The probe was deployed manually off the stern and controlled deployment was conducted by personnel on acquisition watch. The probe was allowed to free fall after deployment was initialized for an amount of time relative to reaching the target depth (based on Teledyne-provided dive tables) then auto-winched back toward the ship where it was recovered manually. The raw data was then converted to a sound velocity profile readable by CARIS.

Fugro's MB Survey Tools software was used to check the profiles graphically for outliers or other anomalies, and to produce an SVP file compatible with CARIS HIPS. The WFMB acquisition package also provided QC for surface sound velocity. This was accomplished by creating a real- time plot from the sound velocity probe at the Reson sonar head and notifying the user (via a flashing warning message) if the head sound velocity differed by more than 2m/s from a defined reference sound velocity. This alarm was used as an indication that the frequency of casts may need to be increased. This reference sound velocity was determined by averaging 50 sound velocities produced at the head. The reference sound velocity was reset after each cast and also reset when a cast was performed due to a significant deviation from the reference sound velocity.

Refer to Appendix IV for SVP Calibration Reports.

Data Processing Methods and Procedures

MB Survey Tools was used to process all sound velocity profiles and to convert them from raw SV1 files into .SVP files readable by CARIS. Raw sound velocity data was imported into MB Survey Tools, checked for outliers and any spikes were rejected. Moving average of down and up casts was also computed within MB Survey Tools utility. Sound velocity profiles, containing time and position were then exported into a

CARIS format. CARIS routine was used to correct all soundings for sound velocity using the "Nearest in distance within time" method.

C.5.2 Surface Sound Speed

<u>Data Acquisition Methods and Procedures</u>

Surface sound velocity was recorded within s7k packets. Surface sound speed was monitored in WinFrog and Reson's SeaBat throughout the survey and compared with the value of SVP at the depth of the MBES transducer with every CTD cast.

<u>Data Processing Methods and Procedures</u>

Surface sound speed was not processed but was applied in CARIS.

C.6 Uncertainty

C.6.1 Total Propagated Uncertainty Computation Methods

Error estimates for all MBES survey sensors were entered in the CARIS Hips Vessel File (HVF). Additionally, measured uncertainty values were applied to the data where possible. These measured values included delayed heave RMS from the raw POS/MV files, positioning and attitude uncertainties from the Applanix POSPac MMS RMS files, and calculated surface sound velocity values. These error estimates were used in CARIS to calculate the TPU at the 95% confidence level for the horizontal and vertical components of each individual sounding. The values that were entered in the CARIS HVF for the survey sensors are the specified manufacturer accuracy values and were downloaded from the CARIS website. The following is a breakdown and explanation on the manufacturer and Fugro derived values used in the error model:

· Navigation – A value of 0.10m was entered for the positional accuracy. This value was selected since all positions were post-processed, with X, Y, and standard deviation values better than 0.10m.
· Gyro/Heading – Vessel was equipped with a (POS/MV) 320 V4 or V5 and had a baseline < 4 m, therefore, a value of 0.020 was entered in the HVF as per manufacturer specifications.
· Heave – The heave percentage of amplitude was set to 5% and the Heave was set to 0.05m, as per manufacturer specifications.
· Pitch and Roll - As per the manufacturer accuracy values, both were set to 0.02 degrees.
· Timing – All data were time-stamped when created (not when logged) using a single clock/epoch (Pelagos Precise Timing method). Position, attitude (including True Heave), and heading were all time-stamped in the POS/MV. A ZDA+1 PPS string was also sent to the Reson 7125 processor, yielding timing accuracies on the order of 1 millisecond. Therefore, a timing error of 0.001 seconds was entered for all sensors on all vessels.
· All vessel and sensor offsets were derived via conventional survey techniques (total station), while the vessel was dry docked. The results yielded standard deviations of 0.005m to 0.010m, vessel and survey dependent.

· Vessel speed – set to 0.10m/s since a POS/MV with a 50 Hz output rate was in use.
· Loading – estimated vessel loading error set to 0.05m. This was the best estimate of how the measured static draft changed through the survey day.
· Draft – it was estimated that draft could be measured to within 0.01m to 0.03m.
· Tide error was dependent upon the VDatum model and the post processing of the raw POS M/V data using Applanix PP-RTX. The Tide Zoning value was provided by NOAA in the project instructions to be 0.101m.
· The Tide Measured was derived from the PP-RTX's solutions during the project and was calculated to be 0.100m.
· Sound Speed Values were determined in MB Survey Tools, via the SVP Statistics utility. This utility calculated the Mean, Variance, Standard Deviation, and Min/Max values at a user-specified depth interval. A separate value was also taken from the manufacturer's specifications.
· MRU Align Standard Deviation for the Gyro and Roll/Pitch were set to 0.10° since this is the estimated misalignment between the IMU and the vessel reference frame.
The calculated vertical and horizontal error or TPU values were then used to create finalized CUBE (Combined Uncertainty Bathymetry Estimator) surfaces; only soundings meeting or exceeding project accuracy specifications were included in this process.

C.6.2 Uncertainty Components

C.6.2.1 A Priori Uncertainty

Vessel		R/V Woldstad	Skiff
Motion Sensor	*Gyro*	0.02 degrees	0.02 degrees
	Heave	5.00% 0.05 meters	5.00% 0.05 meters
	Roll	0.02 degrees	0.02 degrees
	Pitch	0.02 degrees	0.02 degrees
Navigation Sensor		0.10 meters	0.10 meters

C.6.2.2 Real-Time Uncertainty

Real-time uncertainty was not applied. Post-processed uncertainty values (in the form of the RMS file exported from Applanix) were imported via the Import Auxiliary Data function in Caris 10.4.29.

C.7 Shoreline and Feature Data

Data Acquisition Methods and Procedures

Investigation of shoreline features occurred both concurrent to and after primary multibeam acquisition. Generally, the area of H13445 was approached with extreme caution. The entire shoreline is essentially kelp covered rock, and so great care was taken not to put the crew, the vessel, or the equipment in any precarious situations. As such, the vast majority of features will be flagged with a description of "Not Addressed". Identical conditions exist within the entrance to Chernofski Harbour, H13444, and the same approach was taken there. In H13444 several man-made features exist, which were investigated by both multibeam (where applicable) and shore party. Special care was taken to capture the extents of the rocky points that mark the outer limits of the many coves and bights in H13445. Heights were attempted with a laser range finder, but the hydrographers reported that any meaningful measurements could not be obtained given the small size of the Skiff and the general conditions of the work environment. In H13447 kelp was present in the westernmost area, and cautions were taken there. The same effort to capture the furthest projecting extents of rocks or outcrops were attempted in this area. Any submerged features in the data were reduced to MLLW via VDatum before a designated sounding was selected.

Data Processing Methods and Procedures

CARIS HIPS and SIPS v10.4.29 with NOAA Support Files 2021 was used to produce the S-57 Final Feature File (FFF).

Assigned features were separated from the provided CSF for each priority area into a file designated H134XX_AFF; any assigned investigation items from the PRF were also included in the "AFF" file per priority area. Investigation methods and results are described in CARIS HIPS under the S-57 attributes acronym “remrks”. Specific recommendations are described under the S-57 attributes acronym “recomd”.

Features that do not exist or were determined to be a duplicate were given a “delete” value in the “descrp” attribute. Features that were positioned incorrectly were also given the “delete” value in the “descrp” attribute, and a new feature with a “new” value in the “descrp” attribute was added in its correct location. The TECSOU field was populated with the “found by multi-beam attribute” for any feature verified by multibeam.

The geometry of foul areas was altered to reflect areas not safe for navigation by the survey vessel, extending from the survey limit to the inshore limit of multibeam acquired.

C.8 Bottom Sample Data

Data Acquisition Methods and Procedures

The R/V Woldstad was equipped with a 2.4L Van Veen Grab bottom sampler and 200 meters of line. The sampler was deployed and retrieved via a davit installed on the starboard side of the vessel. To maximize time efficiency, the Skiff was tasked with acquiring some of the nearshore samples by hand deploying and recovering the sampler. All samples were discarded after the sample information was recorded. Samples were described based on Bottom Classification chart provided in HSSD_2020 and the information was recorded in CARIS hob files, later combined into the Final Feature File (FFF) for each priority area. Photos of each sample were included in the FFF.

Figure 10: Van Veen bottom sampler

Data Processing Methods and Procedures

Bottom samples were described and attributed using S-57 object SBDARE for classification of bottom characteristics. CARIS HIPS 10.4 with Caris_Support_Files_2021 was used to produce the S-57 final feature file (FFF).

D. Data Quality Management

D.1 Bathymetric Data Integrity and Quality Management

D.1.1 Directed Editing

During acquisition, CARIS HIPS 10.4.29 was used to convert bathymetric data, preliminary corrections were applied and a CUBE surface was generated. Child layers of the CARIS BASE surface were examined as part of initial data quality control. It was ascertained that the data density per bin meets the requirement as specified in the Project Instructions and HSSD 2020. Standard deviation, uncertainty and hypothesis strength surfaces were evaluated and any areas of concern were further examined. Pydro XL QCTools was also utilized to identify fliers, holidays, and check that the standards of the data met or exceeded the uncertainty and density standards of NOAA. Shoreline features were examined thoroughly by comparing created CUBE surfaces, with orthoimagery, allowing recognition for non-navigationable areas, as well as prominent features which may serve as a danger to navigation.

D.1.2 Designated Sounding Selection

While examining the data in subset mode, soundings were designated wherever the CUBE surface did not adequately depict the shoalest point of a feature. Soundings were designated when they met or exceeded the criteria for designation set forth in the NOAA HSSD (2020). Designation ensured that soundings were carried through to the finalized BASE surface.

D.1.3 Holiday Identification

Holidays were identified using Pydro QC Tools Holiday Finder, using a defined color palette to distinguish which bins are containing less than required number of accepted soundings.

D.1.4 Uncertainty Assessment

Pydro QC Tools Uncertainty QC was used to identify any short-comings of acquired data.

D.1.5 Surface Difference Review

D.1.5.1 Crossline to Mainscheme

A statistical analysis of the sounding data was conducted via the CARIS Quality Control Report (QCR) routine. Crosslines were run in each survey and compared with CUBE surfaces created from the mainscheme lines. The IHO S-44 criteria for an Order 1a survey, as specified in the Project Instructions, were used in the CARIS QC comparison on a beam by beam basis. Each survey area also underwent the creation and analysis of a difference surface between mainscheme data and crossline data. The statistical output in CARIS was examined for difference outliers, and general agreement in depths. Quality Control results for crossline comparisons are found in Separate 2 and Descriptive Report section B.2.1 of each survey.

D.1.5.2 Junctions

The Depth difference BASE surface was created between the overlapping datasets at survey junctions. Results are found in section B.2.2 of each survey’s Descriptive Report.

D.1.5.3 Platform to Platform

Platform to platform comparison was achieved by creating a difference surface between the area surveyed by applicable vessels (R/V Woldstad, and Skiff). Results are included in the separate Appendix. (Sonar/ Survey system confidence check)

D.2 Imagery data Integrity and Quality Management

Imagery data integrity and quality management were not conducted for this survey.

E. Approval Sheet

As Chief of Party, field operations for this hydrographic survey were conducted under my direct supervision, with frequent personal checks of progress and adequacy. I have reviewed the attached survey data and reports.

The survey data meets or exceeds requirements as set forth in the NOS Hydrographic Surveys Specifications and Deliverables, Field Procedures Manual, Letter Instructions, and all HSD Technical Directives.

Approver Name	Approver Title	Date	Signature
Allison C Stone	Chief of Party	09/30/2021	Allison C Stone Digitally signed by Allison C Stone Date: 2021.10.24 18:00:53 -05'00'

List of Appendices:

Mandatory Report	***File***
Vessel Wiring Diagram	Appendix II
Sound Speed Sensor Calibration	Appendix IV
Vessel Offset	Appendix I
Position and Attitude Sensor Calibration	Appendix III
Echosounder Confidence Check	Appendix III
Echosounder Acceptance Trial Results	N/A