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

DATA ACQUISITION AND PROCESSING REPORT

Type of Survey	**Hydrographic**
Project	**OPR-N338-KR-08**
Contract No	**DG133C05CQ1078**
Task Order No	**T0006**
Time Frame	**August 2008 - May 2009**

LOCALITY

State	**Oregon**
General Locality	**Columbia River**

2009

CHIEF OF PARTY

Jonathan L. Dasler, PE (OR), PLS (OR,CA)

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NOAA FORM 77-28
(11-72)

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

REGISTRY No
H11854
H11855
H11856
H11857
H11858
H11859

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
David Evans and Associates, Inc.

State: **Oregon**

General Locality: **Columbia River**

Sub-Locality: **Three Tree Point to Sellwood**

Scale: **1:10,000**

Date of Survey: **August 28, 2008 to May 14, 2009**

Instructions dated: **April 1, 2008**

Project No.: **OPR-N338-KR-08**

Vessel: **R/V Theory and R/V Preston**

Chief of party: **Jonathan L. Dasler, PE (OR), PLS (OR,CA)**

Surveyed by: **Michael Hill, John Staly**

Soundings by echo sounder, hand lead, pole: **RESON 7125-B, RESON 8101, Odom CV100**

Graphic record scaled by: **N/A**

Graphic record checked by: **N/A**

Automated Plot: **N/A**

Verification by:

Soundings in Meters at CRD

REMARKS: **All times are UTC.**

The purpose of this contract is to provide NOAA with modern, accurate hydrographic survey data with which to update the nautical charts of the assigned area.

SUBCONSULTANTS: **Zephyr Marine, P.O. Box 1575, Petersburg, AK 99833**

John Oswald and Associates, 2000 E Dowling Road, Suite 10, Anchorage, AK 99507

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

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Acronyms and Abbreviations

AML	Applied Microsystems, Ltd
AWOIS	Automated Wreck and Obstruction Information System
BAG	Bathymetric Attributed Grid
CO-OPS	Center for Operational Oceanographic Products and Services
CRD	Columbia River Datum
CTD	Conductivity, Temperature and Depth
CUBE	Combined Uncertainty and Bathymetry Estimator
DEA	David Evans and Associates, Inc.
DN	Day Number
DXF	Drawing Exchange Format
DTON	Danger to Navigation
GPS	Global Positioning System
HIPS	Hydrographic Information Processing System
HSX	Hypack Hysweep File Format
HVF	HIPS Vessel File
IHO	International Hydrographic Organization
IAKAR	Inertially-Aided Kinematic Ambiguity Resolution
IMU	Inertial Motion Unit
LCU	Link Control Unit
MHW	Mean High Water
MVP	Moving Vessel Profiler
NAD83	North American Datum of 1983
NATSUR	Nature of Surface
NATQUA	Nature of Surface Qualifying Terms
NAVD88	North American Datum of 1988
NGS	National Geodetic Survey
NMEA	National Marine Electronics Association
NOAA	National Oceanic and Atmospheric Administration
NOS	National Ocean Service
OPUS	On-line Positioning User Service
PHB	Pacific Hydrographic Branch
POS/MV	Position and Orientation System for Marine Vessels
PPS	Pulse per Second
R/V	Research Vessel
RPM	Revolutions per Minute
RTK	Real-Time Kinematic
RM	River Mile
RMS	Root Mean Square
SBDARE	Seabed Area

SBET	Smooth Best Estimate and Trajectory
SVP	Sound Velocity Profiler
TPE	Total Propagated Error
TIN	Triangular Irregular Network
USACE	United States Army Corps of Engineers
UTC	Universal Time Coordinated
XTF	Extended Triton Format
ZDA	Global Positioning System timing message

OPR-N338-KR-08
Data Acquisition and Processing Report
Columbia River, Oregon
August 2008 - May 2009
R/V Theory, R/V Preston
David Evans and Associates, Inc.
Lead Hydrographer, Jonathan Dasler, P.E., P.L.S.

INTRODUCTION

This report applies to surveys H11854, H11855, H11856, H11857, H11858 and H11859 located on the Columbia and Willamette Rivers in Oregon. These contract surveys were performed under OPR-N338-KR-08 as specified in the *Statement of Work* dated April 1, 2008. All survey methods meet or exceed requirements as defined in the National Ocean Service (NOS) *Hydrographic Surveys Specifications and Deliverables (*April 2007). The project instructions required three categories of multibeam coverage: Complete, Object Detection, and Set Line Spacing. In water depths greater than four meters, complete multibeam coverage was required. Automated Wreck and Obstruction Information System (AWOIS) items and the main shipping channel were acquired to meet object detection coverage requirements. Twenty-five (25) meter set line spaced multibeam bathymetry was required from the four meter water depths to the "inshore limit of hydrography". The inshore limit of hydrography was defined as the seaward most extent of either the two-meter contour or the equivalent to 0.8 millimeters at the scale of the largest scale nautical chart from the mean high water (MHW) line. Though not required by contract, multibeam side scan data was acquired but not processed.

Due to the Columbia River Datum (CRD), the project chart datum, being a non-tidal gradient datum and the complex hydrodynamics of the Columbia River, OPR-N338-KR-08 was approved as a pilot project for the use of Global Positioning System (GPS) water levels acquired directly at the survey vessel. This change was approved after the receipt of the Statement of Work. GPS water levels were computed using both real-time kinematic (RTK) and post-processing techniques.

A. EQUIPMENT

For this project David Evans and Associates, Inc. (DEA) implemented state-of-the-art data acquisition systems aboard the *Research Vessels (R/V) Theory* and *Preston*, in accordance with National Oceanic and Atmospheric Association (NOAA) standards and modern remote sensing techniques.

Data processing took place at DEA’s office in Vancouver, Washington. Instrumentation and equipment used to conduct the survey and redundant systems to provide confidence checks are listed in Tables 1 and 2 on the following pages.

Table 1. *R/V Theory* Hardware

Multibeam Echosounder						
Equipment	**Manufacturer**	**Model**	**P/N**	**S/N**		**Comments**
	Reson	**7125**				
7P Processor (SP Unit)			85107801	57729		Dual frequency multibeam sonar.
LCU (Bottle)			85001515	52007		
7P Processor (SP Unit)				807099		Dual frequency multibeam sonar used DN276 to DN285.
LCU (Bottle)				58834		
Sound Speed	**Reson**	**SVP 70**		3205687		
Navigation						
Equipment	**Manufacturer**	**Model**	**P/N**	**S/N**	**Firmware Version**	**Comments**
	Applanix	**POSMV V4**				
Deck Unit			PCS-29	3083	4.00	Output Real-Time Kinematic (RTK) corrected positions and inertial reference system.
IMU			LN-200; 10001506-4	750		
STBD Antenna			39105-00-DC4751	60222755		
PORT Antenna			39105-00-DC4751	60222895		
	Trimble	**SPS 750**			3.32	Redundant RTK GPS positioning system.
Receiver			58804-66	706K04156		
Antenna			55550-00-DC-4826	30764174		
	Trimble	**DSM 132**			3.00	Redundant DGPS positioning system.
Receiver			33302-33	224094182		
Antenna			33580-00	220360424		
	Trimble	**TrimMark 3**			N/A	Obtain Real-time Kinematic corrections.
Receiver			46000-46	546101234		
Antenna			11581	24253-46		
Sound Velocity						
Equipment	**Manufacturer**	**Model**	**P/N**	**S/N**		**Comments**
Winch	**Brooke Ocean Technology, Ltd.**	**MVP 30**	MVP30-2	10424		Moving vessel profiler (MVP) for sound velocity profile (SVP) acquisition.
Sheave		**MVP 30**	MVP30-OBS-2	10425		
Controller		**MVP 30**	MVP30-2	10428		
Single Sensor Fish		**AML Smart SVP**		5110		Sound velocity sensor used within MVP DN231 to DN280.
Single Sensor Fish		**AML Smart SVP**		5111		Sound velocity sensor used within MVP DN281 to end of survey.

Table 2. *R/V Preston* Hardware

Multibeam Echosounder						
	Manufacturer	**Model**	**P/N**	**S/N**	**Firmware Version**	**Comments**
	Reson	**8101**				
8P Processer			85107801	17024	8101-2.09-E34D	Sonar processor.
ER Projector Sonar Head			85001515	3507003	8101-1.08-C215	Multibeam sonar head used DN251 to end of project.
Stick Projector Sonar Head			85001515	4603059	8101-1.08-C215	Multibeam sonar head used DN242.
Singlebeam Echosounder						
	Manufacturer	**Model**	**P/N**	**S/N**	**Firmware Version**	**Comments**
	ODOM	**CV-100**			N/A	Singlebeam sonar.
		Processor	85103002	26020		
		Transducer	N/A	N/A		
Navigation						
	Manufacturer	**Model**	**P/N**	**S/N**	**Firmware Version**	**Comments**
	Applanix	**POSMV V4**				Output Real-Time Kinematic (RTK) corrected positions and inertial reference system.
Deck Unit			PCS-29	2204	3.41	
IMU			LN-200	477		
STBD Antenna			39105-00-DC-4525	60078651		
PORT Antenna			38105-00-DC-4703	60188994		
	Trimble	**MS 750**			1.58	Redundant RTK GPS positioning system.
Receiver			36487-00	220291160		
Antenna			3910500-DC-4528	60080535		
	Trimble	**DSM 132**			3.00	Redundant DGPS positioning system.
Receiver			33302-35	224093932		
Antenna			220360503	33580-00		
	Trimble	**TrimMark 3**			N/A	Obtain Real-time Kinematic corrections.
Receiver			46000-46	4.546E+09		
Antenna			11581	24253-46		
Sound Velocity						
	Manufacturer	**Model**	**P/N**	**S/N**		**Comments**
	Applied Microsyste	**SVP Plus SV**		3591		Primary SV profiler.
	Applied Microsyste ms, Inc.	**SVP Plus SV**		3592		Used for weekly check comparisons after DN014.
	Seabird Electronics Inc.	**SBE 19 Seacat Profiler**		4692		Used for weekly check comparisons after DN023.

Table 3. GPS Base Station Hardware

RTK Base Station Equipment							
Item	**Manufacturer**	**Model**	**P/N**	**S/N**	**Antenna Type**	**Firmware Version**	**Comments**
							Dual Frequency/ data logging capable
Receiver	**Trimble**	**NetR5**	62800-10	4750K11594		3.5	
Receiver	**Trimble**	**NetR5**	62800-10	4750K11589		3.5	
Antenna	**Trimble**	**Zephyr-Geodetic Model-2**	57971-00DC4805	30765574	TRM55971.00		
Antenna	**Trimble**	**Zephyr-Geodetic Model-2**	57971-00DC4805	30765531	TRM55971.00		
							Dual Frequency/ data logging capable
Receiver	**Trimble**	**NetRS**	45905-01	4706128342		3.5	
Antenna	**Trimble**	**Zephyr-Geodetic**	41249-00DC 4717	60201334	TRM42149.00		

A1. Survey Vessels

A1.a *R/V Theory*

The *R/V Theory*, which is owned and operated by Zephyr Marine (Figure 1), was used as the primary survey vessel for the project. The *R/V Theory*, hull registration number IAR34CATA808 (official number 1217549), is a 36-foot, 13-gross ton, aluminum catamaran with a 13-foot beam and a draft of three feet. The vessel is equipped with a starboard side custom multibeam pole mount, stern mount A-frame, air-cushioned server station, and acquisition station. No unusual sensor setup configurations were used aboard *R/V Theory*.

A1.b *R/V Preston*

The *R/V Preston*, which is owned and operated by DEA (Figure 1), was a secondary survey vessel configured to run shoreline and shallow water acquisition. The *R/V Preston*, hull registration number ABTJOHNB3090 (Official Number WN0437NX), is a 31-foot, 5-gross ton, aluminum monohull vessel with an 8.5-foot beam and a maximum draft of 16 inches. The vessel is equipped with a starboard side custom multibeam pole mount, stern mount A-frame, server station and acquisition station. The multibeam sonar was rotated 15° to starboard to increase shoreline coverage and minimize the need to navigate close to shore.

Figure 1. *R/V Theory* (left) and *R/V Preston* (right)

A2. Multibeam Systems

A2.a *R/V Theory*

The Reson SeaBat 7125 multibeam sonar with dual frequency configuration and integrated SVP-70 sound velocity profiler (SVP) was pole mounted starboard side on the *R/V Theory*. The Triton Isis acquisition system logged Reson 7125 data into an XTF file along with ancillary position and motion data. The Reson 7125 operates at either 400 kHz or 200 kHz producing a 128° swath of 256 uniform beams with a beam width of 0.5° x 1.0° in equiangle mode. Data collected from DN231 to DN240 were acquired using the low frequency 200 kHz setting with equidistant beam spacing. During acquisition using the equidistant mode, it was determined that when over an irregular bottom the sonar was having difficulties computing equidistant beams which resulted in reduced swath width and extra data cleaning. Equidistant beam spacing acquisition was ended and the sonar was switched to 256 equiangle beams using 400 kHz. Data collected from DN241 to DN347 were acquired using equiangle beam spacing at 400 kHz to minimize noise. Range adjustments were made during acquisition as dictated by changes in the depth. The problematic areas resulting from the use of the equidistant beam setting were rerun.

Due to an obvious failure in precise timing of the Reson 7125 owned by DEA, was shipped to Reson for repairs and temporarily replaced with an identical Reson SeaBat 7125 processor and link control unit (LCU) were borrowed from TerraSond Ltd. in order to maintain continuous acquisition. The TerraSond sonar was used from DN276 to DN282 and operated at 400 kHz with 256 equiangle beams. A patch test was performed after the new sonar was installed on DN276. No data resulting from this failure was used for the survey.

Installation of a new Triton Isis 71XXserver.exe file on September 4, 2008 for the Reson SeaBat 7125 multibeam sonar resulted in incorrect recording of angle and across track values for beam number 1 in the XTF file. Acquisition errors were recorded between DN248 and DN260. The original server file was reinstalled upon discovery of the error to repair the acquisition problem. The issue was corrected during data processing by adjusting the *R/V Theory* HIPS Vessel File (HVF) roll value by an additional 0.5 degrees during the impacted time period.

A2.b *R/V Preston*

The Reson SeaBat 8101 multibeam sonar was pole mounted on the *R/V Preston* with the head rotated 15° to starboard in order to acquire data along the shoreline in an efficient and safe manner. The Triton Isis acquisition system logged Reson 8101 data along with ancillary position and motion data into an XTF file. The Reson 8101 operates at 240 kHz producing a 150° swath of 101 uniform beams with a beam width of 1.5° x 1.5°. Range adjustments were made during acquisition as dictated by changes is the depth.

The Reson 8101 sonar head with stick projector was damaged and replaced on DN251 with a Reson 8101 ER projector. Identical settings were used to acquire data after the replacement of the sonar head. A patch test was run after installation and the replacement sonar was used until the end of the project.

A3. Single beam System

The ODOM CV-100 single beam sonar with a three-degree transducer and 200 kHz operating frequency was hull mounted onboard the *R/V Preston*. The ODOM CV-100 single beam data was logged in a RAW data format via the HYPACK acquisition system. Range adjustments were made during acquisition as dictated by depth.

A4. Position, Heading and Motion Reference Systems

Both survey vessels were outfitted with an Applanix position and orientation system for marine vessels (POS/MV) 320 v4 with real-time kinematic (RTK) GPS and inertial reference system which were used to measure attitude, heading, heights, and position. Each system was comprised of an inertial motion unit (IMU), dual GPS antennas, and a data processor.

A Trimble TrimMark 3 receiver onboard each vessel obtained RTK corrections and output them to the POS/MV and to either a Trimble SPS750 (*R/V Theory*) or Trimble MS 750 (*R/V Preston*) GPS receiver, which were used as redundant RTK GPS positioning systems. The POS/MV and inertial reference systems were used to measure attitude, heading, height, and position for the survey. In addition, a Trimble DSM132 was installed onboard each survey vessel and provided differential GPS positions.

As a quality check to RTK positions, Trimble DSM 132 receivers acquired corrections from the U.S. Coast Guard beacon located at Fort Stevens, Washington (287 kHz) or Appleton, WA (300 kHz) and provided differential corrected positions. Positions from all systems were displayed in real-time using Hypack and compared while online. The Trimble DSM 132 status was displayed in the Configuration Display.

A weekly comparison between all positioning systems were observed and documented while the vessel was stationary in port. Logged position data was imported into Excel and a difference computed. Also, transitions between RTK GPS base stations used during acquisition were compared via a position check on sites in moored location where two RTK base stations could be received. These checks validated the coordinates input in the GPS base stations as well as documented RTK system performance at the maximum distances from base stations used for the project (approximately 10 km). Position Check Reports can be found in Descriptive Reports Separate I *Acquisition and Processing Logs* of each survey. RTK GPS confidence checks when switching GPS base stations are documented in Appendix I *RTK GPS Confidence Checks*.

Position, timing, heading, height and motion data were output to the Isis acquisition system using the real-time ethernet option at 25 Hz. Motion and position data were output to the Hypack backup acquisition system over a serial connection with motion data output at 25 Hz; position, height, and heading were output at one Hertz.

The POS/MV provided time synchronization of sonar instruments and logging computers using a combination of outputs. The Reson processors and Hypack logging computers were provided both a pulse per second (PPS) and a National Marine Electronics Association (NMEA) GPS timing message (ZDA) to achieve synchronization with the POS/MV. The Isis logging computers synchronized their time using the proprietary Trimble universal time coordinated (UTC) message provided by the POS/MV. All messages contained time strings and caused the clocks of the computers and sonars to synchronize to the time contained within the message. Time offsets between the instruments and computers, relative to the times contained in POS/MV network packets, were typically sub-millisecond.

Using the ethernet logging controls, each POS M/V was configured to log all of the raw observable groups needed to post process the real-time sensor data. Under typical survey conditions a single POS M/V .000 file was logged by each survey vessel per day though periodic changes in operations or shut down of the POS M/V systems required the creation of several .000 files. The TrueHeave™ data group was also logged to these files. The POS/MV QC plot was displayed and monitored onscreen during data acquisition.

A5. Sound Velocity Measurement Systems

Sound velocity sensors were calibrated prior to the start and at the end of the survey. Factory calibration results are included in the Separates Section II *Sound Speed Data* of the *Descriptive Report* for the survey.

A5.a *R/V Theory*

A SVP-70 mounted on the Reson 7125 sonar head was input into the Reson 7-P processor and velocities from the sensor were used in real-time during acquisition for beam forming on the 7125's flat array. A Brooke Ocean Technology Moving Vessel Profiler (MVP) 30 was mounted on the mid stern of the *R/V Theory*; and it was used as the primary sound speed sensor to correct multibeam data collected onboard. Due to failure, the sound speed sensor was replaced on DN280 with an identical sensor.

A5.b *R/V Preston*

An Applied Microsystems, Ltd. (AML) SVP Plus v2 sound velocity profiler was used as the primary sound speed sensor used to correct multibeam data.

A6. Acquisition and Processing System

Acquisition stations were custom installed and integrated on the *R/V Theory* and *R/V Preston* by DEA and consisted of a Triton Isis data acquisition system, Hypack navigation software, and 'Notes' workstation. In addition, an MVP station was installed aboard the *R/V Theory*. During acquisition, data were logged locally on acquisition PCs and transferred to DEA's office in Vancouver, Washington via external hard drive, where all data processing was performed.

The software and version numbers used throughout the survey are listed in Table 4.

Table 4. Acquisition and Processing Software

Software						
Software	**Manufacturer**	**Program**	**Office Version**	**Preston Version**	**Theory Version**	**Install Date**
Acquisition						
Hypack	Hypack, Inc	Hypack 2008 SP1		8.0.1.2	8.0.1.2	8/15/2008
Isis	Imaging,Inc	Isis Application		7.1.428.52	7.1.500.123	7/1/2008
Isis 7125 Server Only	Triton Imaging,Inc	Reson 71XX.exe		N/A	1.0.3125.26694	7/1/2008 to 9/4/2008 and 9/16/2008 to end of survey
Isis 7125 Server Only	Triton Imaging,Inc	Reson 71XX.exe		N/A	1.0.3159.15958	9/4/2008 to 9/16/2008
LineLog	DEA, Inc	LineLog		1.0.0.6	1.0.6	11/24/2007
MV-POSView	Applanix Corporation	MV-POSView		3.4.0.0	3.3.0.0	4/16/2007
Smart Talk	Applied Microsystems Ltd.	Smart Talk		2.27	N/A	7/5/2006
Reson 8101	Reson			2.09	N/A	8/15/2008
Brook Ocean Technology MVP	Brooke Ocean Technology, Ltd.	Brook Ocean Technology MVP		N/A	2.27	6/11/2008
7k Control Center 7125	Reson	SeaBat-7125-MR6: 7KUI		N/A	3.7.2.5	6/11/2008
		7K Center		N/A	3.0.7.1	6/11/2008
		7K IO		N/A	3.3.0.7	6/11/2008
		FPGA0		N/A	SN: ID 16370103	6/11/2008
Processing						
Caris		HIPS	6.1 SP2 HF1			8/20/2008
			6.1 SP2 HF7			3/20/2009
Caris		Notebook	3.0 HF2			8/10/2008
			3.0 SP1 HF1			4/8/2009
Caris		Bathy DataBASE	2.1 HF6			8/10/2008
			2.1 HF10			4/8/2009
HYPACK	Hypack, Inc.	Hypack Lite	8.0.1.2			8/10/2008
ArcMap	ESRI	ArcGIS	9.2.0.1324			5/20/2007
Applanix	Applanix Corporation	POSPac	5.1.3042.14959			8/10/2008
			5.2.3247.12881			2/9/2009
NOAA	NOAA	Velociwin	8.8.0.0			5/20/2007
Other						
Microsoft Offic	Microsoft	Word SP2	2003			
		Excel	2003			

A7. GPS Reference Station Network

Prior to the start of hydrographic survey operations, GPS base stations were established in order to enable both the broadcast of RTK correctors as well as logging of raw dual frequency observables necessary for GPS post-processing. GPS base stations were installed no greater than 18 kilometers apart in order to keep the maximum possible range from survey vessel to base station, less than one half of the base station spacing or not more than 10 kilometers. Table 5 indicates the locations of the GPS base stations used for the project.

Table 5. GPS Base Station Positions

Station Name	Latitude (DMS North)	Longitude (DMS West)	GRS-80 Ellipsoid Height
DEMSI	45 36 59.91780	122 38 26.25942	-0.366 m
FAZIO	45 42 56.60629	122 45 34.14311	-7.858 m
STHL	45 51 47.95572	122 47 46.32988	-7.715 m
KLMA	46 00 20.45579	122 50 50.13183	-11.153 m
PLVW	46 07 26.23898	122 58 49.89723	-11.143 m
BEVR	46 10 13.97257	123 09 26.40353	-15.766 m
CATH_base	46 11 27.70015	123 25 24.15551	-12.127 m
T4_RESET	45 35 59.25207	122 46 30.03411	-8.253 m
DEA_ROOF	45 30 24.92647	122 40 21.17159	25.836 m

GPS Base station antennas were mounted on 5/8” bolts that were temporally fixed to stable structures in locations that provided clear access to the sky with no obstructions above 10° from the horizon.

A North American Datum of 1983 (NAD83) (CORS96) (Epoch 2002.0000) position of each base station was determined by acquiring and submitting a 24-hour observation with one second epoch data to the On-line Positioning User Service (OPUS) operated by NGS. The best ephemeris available at the time of submittal was used for the OPUS solution.

More information on the GPS base stations, including site reports, positions, and ephemeris type used by OPUS are included in the OPR-N338-KR-08 *Horizontal and Vertical Control Report*.

A8. Survey Methodology

A8.a Mobilizations

Mobilizations, sensor installations, and calibrations occurred at DEA’s Marine Services headquarters in Vancouver, Washington from August 5, 2008 through August 18, 2008. All sensors were surveyed from multiple locations using a terrestrial land survey total station on August 5, 2008. Values from this survey were used to calculate sensor offsets and uncertainty estimates used in the HIPS vessel files for project OPR-N338-KR-08. Once installations were completed and the hydrographer was confident that all sensors were operational, the vessels underwent system calibration tests, including settlement and squat and patch tests.

A8.b Survey Coverage

During acquisition, the Hypack real-time coverage display was corrected to chart datum using RTK water levels and color coded for a distinct color change at the two-meter and four-meter depth curves. Preplanned survey lines were not used during multibeam data acquisition. Instead, surveyed acquisition was dictated by "painting" a Hypack Hysweep matrix. Matrix settings were adjusted to account for swath width, vessel draft and RTK tides. In addition, survey limits and a 32-meter shoreline buffer were displayed on screen as an aid to determine inshore coverage limits.

A8.c Multibeam Sonar Operations

Multibeam operations met coverage requirements via techniques stated in the OPR-N338-KR-08 *Statement of Work* (April 1, 2008) and defined by the NOS *Hydrographic Surveys Specifications and Deliverables* (April 2007). Complete multibeam coverage was required in areas greater than four meters water depth and 25-meter spaced multibeam or single beam from the four-meter depth curve to the inshore limit of hydrography. Assigned AWOIS items and the main shipping channel required object detection coverage. Both multibeam sonars were operated to meet object detection requirements.

Tables 6 and 7 list the typical sonar settings for the survey.

Table 6. Reson 7125 Sonar Settings

7125 Parameter	Value
Range	Variable, depth dependent
Gain	15 dB
Power	215 dB
Spreading	30 dB
Absorption	70 dB/km
Ping Rate	18 p/s, 24 p/s
Pulse Width	100 µs

Table 7. Reson 8101 Sonar Settings

8101 Parameter	Value
Range	Variable, depth dependent
Gain	Auto
Power	5
Spreading	30 dB
Absorption	20 dB/km
Ping Rate	21 p/s
Pulse Width	42 µs

A8.d Single beam Sonar Operations

Single beam sonar operations occurred in areas shoaler than four meters where water depth or the presence of significant debris prevented the safe and efficient operation of multibeam. The sonar operator monitored the single beam echosounder digital echogram, which was displayed and logged on the Hypack acquisition computer. A traditional paper trace was not recorded during this survey as the full water column return was digitally recorded.

A8.e Bottom Sampling

A total of 109 bottom-sediment grab samples were obtained every 2,000 meters along the edge of the main river channel and every 1,200 meters within charted anchorage areas across all six survey sheets. Samples were obtained with a Ponar grab sampler which collects a sample size of 8.2 liters with a penetration depth of 3.5 inches. Position, depth, date, time, unique identifier, description and photograph were recorded for each sample. Each sample was described in accordance with International Hydrographic Organization (IHO) S-57 requirements for Seabed Area (SBDARE) features with attribution of COLOUR, Nature of Surface Qualifying terms (NATQUA), and Nature of Surface (NATSUR).

A8.f GPS Base Stations

GPS Base stations logged one second epoch GPS observables and broadcast real-time carrier phase correctors to the two survey vessels every second. A repeater radio was used to relay the signal to reach the 10-kilometer range in some areas. Aboard the survey vessels, the correctors were received and processed by a POS/MV with dual frequency (L1/L2) receivers and a redundant dual GPS reciever. Base stations logged raw observables in the Trimble .T00 format with one file created every 24 hours. The Trimble Convert to RINEX utility was used to convert Trimble .T00 files to RINEX format in order to be ingested into Applanix POSPac post-processing software.

A9. Quality Assurance

Acquisition and processing methods followed systematic and standardized workflows established by DEA. These systems include but are not limited to staff training and mentoring, a formalized project management program, record and log keeping standards, software version management, and a multilevel review process.

Survey data were converted and processed in Caris HIPS v6.1 SP2 HF1 through Hotfix 7. Processing methodology followed the standard Caris HIPS CUBE (Combined Uncertainty Bathymetric Estimator) workflow with integration of post-processed sensor data through the HIPS Load Attitude and Navigation Tool.

B. QUALITY CONTROL

B1. Data Acquisition

B1.a Multibeam

The Isis acquisition station operator monitored the multibeam sonar, selected appropriate contacts from the scrolling sonar imagery data into the cursor log and monitored the MVP to determine the frequency of sound velocity casts. The Hypack station operator controlled the Hypack acquisition station, monitored Hypack matrix coverage and maintained the digital line log. Each operator monitored primary and secondary navigation systems to ensure quality position and height data were acquired at all times.

During acquisition, data were monitored in real-time using the 2-D and 3-D data display windows in ISIS and Reson SeaBat displays. Typical windows for monitoring raw sensor information included a waterfall display for the sonar imagery, graphs of vessel motions, GPS quality, and satellite coverage. HYPACK was used to monitor vessel navigation and survey coverage. Raw soundings, attitude, heading, height, and position data were recorded in ISIS XTF format and also in HYPACK Hysweep file (HSX) format, as a supplementary backup. Adjustments to the sonar, including changes in range and gain were made, as necessary, during acquisition to ensure the best bathymetric data quality. Additionally, vessel speed was adjusted in accordance with the NOS *Hydrographic Surveys Specifications and Deliverables* (April 2007) to ensure the required along track coverage.

B1.b Single beam

The ODOM CV-100 single beam sonar was mounted in a sea chest near the vessel reference point on the *R/V Preston*. All single beam data were recorded in HYPACK “RAW” format. A digital echogram and sonar signal voltage were displayed in HYPACK and recorded in the BIN format. A draft correction of 0.36 meters was entered into the ODOM CV-100 echosounder and applied during acquisition and therefore not included in the HVF.

B2. Methodology Used to Maintain Data Integrity

The acquisition system and survey protocols were designed with some redundancy to demonstrate that the required accuracy was being achieved during the survey and provide a backup to primary systems. Data integrity was monitored throughout the survey through system comparisons. Three positioning systems were used to provide real-time monitoring of position data. Position confidence checks, single beam bar checks, and mulitbeam bar checks were conducted weekly to confirm required accuracy was being maintained. Weekly checks of the sound speed profiler integrated into the MVP-30 were conducted by deploying an AML or a SeaBird Conductivity, Temperature and Depth (CTD) profiler in tandem with the MVP-30. Sound speed profiles were computed for each of the sensors and compared to confirm instrumentation was functioning within survey tolerances.

Significant features found in the multibeam side scan sonar record were selected and saved in the ISIS daily cursor log and noted in the digital line log. Additionally, targets were made in

HYPACK where significant features were found. All significant features were compiled for data cleaning purposes into a sheet wide Drawing Exchange Format (DXF) file.

A flow diagram of the data acquisition and processing pipeline is presented in Figure 2. This diagram graphically illustrates the data pipeline and processing workflow from acquisition to delivery.

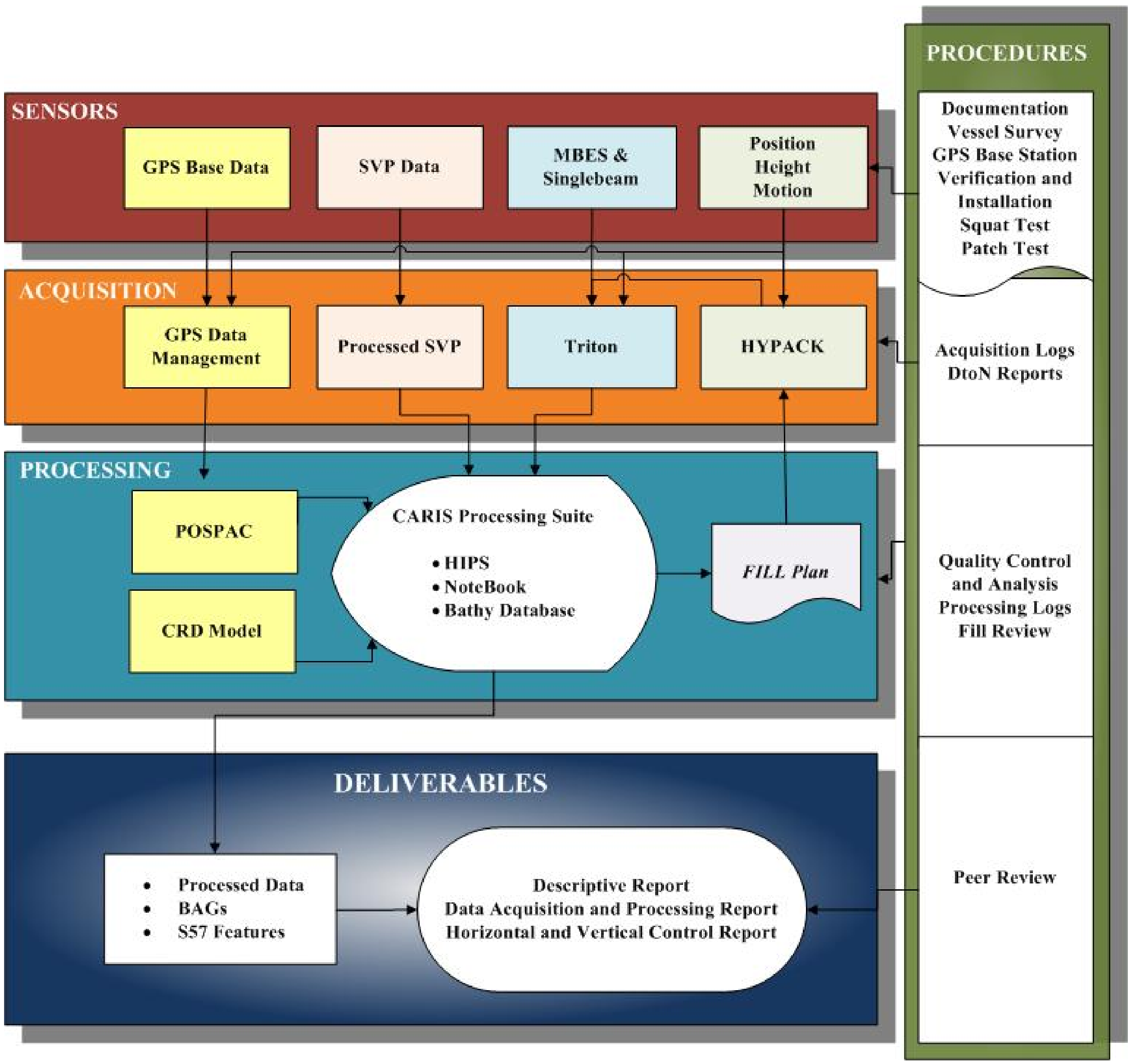

Figure 2. Flowchart of data acquisition and processing pipeline

B2.a HIPS Conversion

Multibeam data were converted from XTF format to Caris HDCS format using the HIPS conversion wizard (XTF converter 6.1.2.0 to 6.1.2.3) with ship navigation, attitude, and gyro from the raw navigation datagrams. RTK GPS height was also converted. No data were rejected based on quality flags during conversion.

Single beam data were converted from RAW format to Caris HDCS format using HIPS conversion wizard (Hypack converter 6.1.2.0) with navigation and height data from the primary navigation device (sensor 1).

The Caris output window was reviewed for failures during conversion.

B2.b Vessel Files

Three (3) HVFs (Table 8) were created to correspond to each vessel configuration used during the survey. The vessel file contains all offsets and system biases for the survey vessels and its systems, as well as, error estimates for latency, sensor offset measurements, attitude and navigation measurements, and draft measurements.

Table 8. HIPS Vessel Files

HIPS Vessel File	HIPS Converter	Sonar Type	Comment
N338-KR-08_MBES_Preston.hvf	XTF 6.1.2.0 to .3	Multibeam	MBES hvf
N338-KR-08_MBES_Theory.hvf	XTF 6.1.2.0 to .3	Multibeam	MBES hvf
N338-KR-08_VBES_Preston.hvf	Hypack 6.1.2.0	Single beam	VBES hvf

Sensor offsets values were calculated from the vessels surveys (08/05/2008). Draft (water line) was measured and entered daily from draft marks on the port and starboard side of each vessel's hull. Morning and evening, port and starboard draft readings were averaged to obtain the vessel draft. Draft changes relative to the vessel reference point were entered into the multibeam vessel configuration files. As previously noted, the *R/V Preston* single beam Z offset was applied real-time and not included in the HVF to avoid double applying the offset.

Dynamic draft (settlement and squat) values were calculated through the use of RTK GPS observations, but were not included in the hvf or applied during processing due to the use of GPS water levels. One of the many benefits of GPS water levels is that dynamic draft is incorporated in the GPS height measurements that are recorded at the survey vessel. These offsets are listed in tabular format in Section C of this document.

Best estimates for total propagated error (TPE) values were entered into the vessel file based on current knowledge of the TPE/CUBE processing model. The manufactures' published values were entered into the sensor accuracy fields. Other values were either calculated or estimated.

Table 9 represents HVF TPE values for each vessel. The dynamic draft uncertainty for the project was zero since traditional dynamic draft corrections based on vessel speed were not entered in the vessel file.

Table 9. Hydrographic Vessel File TPE Values

Manufacturer Accuracy Values for Total Propagation Error Computation HIPS Vessel File (HVF)*		
Vessel	***R/V Theory***	***R/V Preston***
Motion Sensor	POS/MV	POS/MV
Position System 1	POS/MV Model 320 V 4.00	POS/MV Model 320 V 4.00
Position System 2	SPS 750	MS 750
Gyro - Heading		
Gyro (°)	0.02	0.02
Heave		
Heave % Amplitude	5	5
Heave (m)	0.05	0.05
Roll and Pitch		
Roll (°)	0.02	0.02
Pitch (°)	0.02	0.02
Navigation		
Position Navigation (m)	0.5	0.5
Latency		
Timing Trans (s)	0.005	0.005
Nav Timing (s)	0.005	0.005
Gyro Timing (s)	0.005	0.005
Heave Timing (s)	0.005	0.005
Pitch Timing (s)	0.005	0.005
Roll Timing (s)	0.005	0.005
Measurement		
Offset X (m)	0.005	0.005
Offset Y (m)	0.005	0.005
Offset Z (m)	0.005	0.005
Speed		
Vessel Speed (m/s)	0.030	0.030
Draft and Loading		
Loading	0.000	0.000
Draft (m)	0.010	0.010
Delta Draft (m)	0.000	0.000
Physical Alignment Errors*		
Alignment		
MRU align Stdev gyro	0.000	0.000
MRU align roll/pitch	0.000	0.000
*All values given as 1 sigma.		

The use of GPS water levels drastically reduced the vertical total propagated uncertainty of surveyed depths by removing several vertical uncertainty components from total propagated uncertainty calculations. By removing the need to use discrete zoning, which is the largest source of vertical uncertainty for the survey, and making water level measurements directly at the survey vessel significant reductions in vertical uncertainty were made. In addition, since GPS height measurements were made in real-time on the survey platforms there was no need to account for changes in vessel loading, draft, and settlement and squat using traditional processing methodology or accounting for these components when total propagated uncertainty was computed.

Sound speed uncertainty estimates were modified for each survey sheet in an attempt to account for the geographic variability of sound speed within the river system. Higher sound speed uncertainty estimates were used on downriver survey sheets near the Columbia River Estuary which experienced more tidal influence and fresh water input which can lead to stratification of the water column. Sound speed TPE values are listed in Table 10.

Table 10. TPE Values for Tide and Sound Speed

Total Propagation Error Computation in CARIS HIPS Survey Specific Parameters						
Tide Value	**H11854**	**H11855**	**H11856**	**H11857**	**H11858**	**H11859**
Tide Value Measured	0.03	0.03	0.03	0.03	0.03	0.03
Tide Value Zoning	0.00	0.00	0.00	0.00	0.00	0.00
Sound Speed Values						
Sound Speed Measured	1.00	1.00	0.75	0.75	0.50	0.50
Surface Sound Speed	0.50	0.50	0.50	0.50	0.50	0.50
*All values given as 1 sigma.						

B2.c Static Draft

Static draft marks were surveyed and painted on the port and starboard sides of the *R/V Theory* and *R/V Preston* and on the multibeam pole mounts. Port and starboard draft readings were averaged to obtain the draft in relation to the center of the vessel.

During survey operations, vessel draft was observed at the beginning and end of daily survey operations to compute average draft for the day. This provided an accurate draft reading during survey operations with the majority of the fuel load change during the day being burned during transit out and return from the survey area. The start and end of day draft values for port and starboard were calculated daily, averaged, and entered into the waterline field in the HVF.

B2.d Sound Velocity

Sound speed profiles were applied to each line using the nearest in distance within time (two hours) option in the Caris SVP correct routine. Velocity casts were taken at frequent intervals through the use of the MVP-30 or manually with the AML SVP Plus. A real-time comparison of sound velocity measurements was made during survey operations between the SVP-70 mounted on the sonar head and the MVP-30 when being towed near the surface.

B3. Caris Data Processing

Multibeam data processing followed the standard Hydrographic Information Processing System (HIPS) workflow for Combined Uncertainty and Bathymetry Estimate (CUBE) editing except that the hypothesis surface was not edited. Instead, fliers influencing the CUBE surface were rejected and critical soundings not incorporated in the CUBE surface were designated. Charted baring point features, such as single piles, dolphins, etc., were rejected and flagged “Examined” at the shoalest and seaward most point. The use of the “Examined” status flag enabled DEA hydrographers to denote baring items during processing and then resolve their charting status during review.

Below is the list of correctors and filters applied to the bathymetric data in HIPS. Several of the steps are interim processes (such as the water levels) and were re-applied as needed. The TPE was re-computed for the multibeam data as needed to reflect changes in the correctors.

1. Apply true heave
2. Compute, filter RTK GPS tides
3. Apply sheet wide concatenated sound speed profiles
    - “Nearest in time, with in two hours”
4. Load post-processed attitude, navigation, and heading
5. Compute, filer post-processed GPS Tides
6. Merge vessel offsets, apply GPS tides
7. Compute TPE via values listed in Table
8. Filters applied based on the following criteria:
    - Reject soundings with poor quality flags (0 and 1 for Reson)
    - Reject TPE greater than the horizontal and vertical error limits specified in the NOS *Hydrographic Surveys Specifications and Deliverables* (April 2007).
    - Add data to field sheet
        - Half meter “CUBE” weighted surface
            - IHO S-44 Order 1
            - Density & Local Disambiguation method
            - Shallow Advanced settings

After filtering, each survey sheet was subdivided by creating multiple Caris field sheets to reduce processing time and the computer power required to generate the CUBE surfaces. The field sheets were created to fall within the recommended 25 million node limit for each CUBE surface. High resolution, 50-centimeter CUBE surfaces were created over the entire survey area. The disambiguation method selected to create all 50-centimeter CUBE surfaces was “Shoal,” which corresponds to the NOS *Hydrographic Surveys Specifications and Deliverables* (April 2007) Object Detection Coverage requirements. Survey coverage was reviewed to ensure that no data gaps (more than 3 connected open nodes) were present within AWOIS radii and maintained navigation channels.

Outside maintained navigation channels Complete Coverage requirements were demonstrated by creating one meter CUBE surfaces with “Deep” disambiguation method selected, which corresponds to the NOS *Hydrographic Surveys Specifications and Deliverables* (April 2007). Complete Coverage requirements. Survey coverage was reviewed to ensure that no data holidays (more than 3 connected open nodes) were present. In a telephone conversation on January 7, 2009 between the Pacific Hydrographic Branch (PHB) and DEA it was agreed that the one meter surfaces would be created and reviewed by DEA hydrographers, but not submitted with the delivered dataset in order to reduce data storage needs.

Other holidays caused by vessels at berth, log rafts, or other features limiting coverage may also exist with the surfaces. These holidays are discussed in detail in the Descriptive Reports of each survey.

All data were reviewed in HIPS 2D subset with the 0.5m CUBE reference surface visible. Fliers making the CUBE surface shoaler than expected by more than the allowable IHO Order 1 error were rejected. Any legitimate sounding that was not incorporated into the CUBE surface and shoaler than the surface by more than half the allowable IHO Order 1 error was flagged as a critical sounding. Data processors used an IHO Order 1 Error Calculator macro developed by David Evans and Associates, Inc. to determine the acceptable error relative to depth. Subset tiles were used to track the progress of processing activities. In addition, data processors reviewed sounding data and CUBE surfaces for excessive motion artifacts or systematic biases. All crosslines were manually reviewed to ensure high internal consistency between the datasets and comparison statistics were also computed using the HIPS crossline QC tool.

Contacts derived from the daily cursor logs and target files were displayed in the background in HIPS as a DXF file and reviewed for multibeam coverage and significance. Designated soundings were created for each contact least depth.

B4. GPS Water Levels

The vertical datum for this project is the Columbia River Datum (CRD), an adopted low-water gradient datum relative to North American Vertical Datum of 1988 (NAVD88). There are known problems in the National Geodetic Survey (NGS) level lines between Oregon and Washington due to the long level runs without the ability to run tie lines across the Columbia River. GPS observations have documented large vertical differences in published bench mark elevations across the Columbia River. Whereas, Center for Operational Oceanographic Products (CO-OPS) water level gauges are located in Oregon and Washington and are directly referenced to NGS published bench mark elevations, and the known issue with the level lines between Oregon and Washington, a decision was jointly made by the U.S. Army Corps of Engineers (USACE) and NOAA to use NGS OPUS solutions to establish vertical consistency in the relationship of CRD relative to NAVD88. The USACE, Portland District (designated stewards of CRD) conducted surveys that established OPUS derived NAVD88 elevations on historic bench marks referencing CRD. A result of these surveys was a profile of Columbia River Datum relative to OPUS derived NAVD 88 elevations which were consistent across the Columbia River. The profile defined CRD relative to NAVD88 for each River Mile (RM) from RM 23 to RM 145 on the Columbia River and RM 0 to RM 26 on the Willamette River. This profile is used by the USACE, Portland District for hydrographic surveys and dredging operations to maintain the Federal Channel on the Columbia and Willamette rivers.

B4a. Model File

A critical component for any hydrographic survey using GPS heights is a separation model from the reference ellipsoid to the chart datum. For this survey DEA developed a high resolution separation model of the relationship between NAD83 (GRS-80 ellipsoid) and CRD. The resulting model files were used during both acquisition and processing to reduce GPS heights relative to the ellipsoid to GPS water levels relative to CRD.

The USACE, Portland District provided David Evans and Associates, Inc. with a profile of Columbia River Datum relative to NAVD 88 derived from OPUS observations.

The first step in generation of the separation model was to convert the profile down the river into a Triangular Irregular Network (TIN) spatial model of CRD relative to NAVD 88. The river profile was offset at 600-meter intervals perpendicular to the profile and modeled down back channels of islands.

The next step in the generation of the model was to convert the TIN model into a high resolution grid. A series of three models were generated at a three-second arc resolution in order to capture the high definition of the TIN model in small channels and at the confluence with the Willamette River. The high resolution grid nodes that defined the CRD surface relative to NAVD 88 were converted to NAD 83 ellipsoid heights using GEOID03. The grid model was converted to the same format as geoid grid models generated by the NGS, which can be used by Hypack and Caris HIPS to convert ellipsoid heights directly to a mapping datum. CRD Model files have been included with the respective survey’s digital deliverables. Table 11 lists the model files used for each survey sheet.

Table 11. CRD Model File Use by Survey

Model File	Surveys	Coverage by River Mile
CR30-74.bin	H11854 H11855 H11856	Columbia River RM 30-74
CR74-101.bin	H11857 H11858	Columbia River RM 74-101
W26CR110.bin	H11859	Columbia River RM 101-110 Willamette River RM 1-26

B4.b GPS Post-processing

Applanix POSPac MMS was used to create a post-processed Inertially-Aided Kinematic Ambiguity Resolution (IAKAR) navigation solution. This post-processed solution included new position, GPS height, and attitude measurements which used the reference station observables to mitigate atmospheric and satellite biases and to resolve integer ambiguities. The software also used a forward and backwards smoother to blend the inertial position and sensor data into a smoothed best estimate trajectory (SBET).

POSPac processing followed the workflow recommended by Applanix with each .000 file processed independently. Base RINEX files were loaded from the appropriate base station for the day being processed. The only deviation from standard procedures was the use of the NAD83 coordinate system which is required by NOS *Hydrographic Surveys Specifications and Deliverables* (April 2007). Since POSPac only works with real-time sensor navigation using the WGS-84 coordinate system the software's default settings for WGS-84 real-time input and post-processed output were used even though the real-time input navigation was relative to NAD83. NAD83 coordinates of the DEA installed GPS reference stations were used even though the software assumed the coordinates were relative to WGS-84. This processing configuration resulted in a post-processed navigation solution (SBET file) relative to NAD83 without the need of a transformation. A POSPac station database file with the NAD83 project coordinates for each base station was created and distributed to all processing computers in order to remove the need to manually enter the coordinates during each processing session.

After the post-processed solution was created it was reviewed to insure that the optimum solution was achieved. Processing review included graphical review of the vessel track while color coded by position RMS (Root Mean Square) and the creation of a NAV-DIFF graph which showed the difference between the real-time and post-processed solutions in the X, Y, and Z coordinates.

PosPAC processing logs were kept for each survey sheet. The logs were used to record PosPAC project information, vessel and base station used, and major processing steps. These logs have been included in Separate I *Acquisition and Processing Logs* of each survey.

B4c. Computation of GPS Water Levels

During preliminary processing GPS water levels were computed using RTK GPS heights which were logged to the Extended Triton Format (XTF) raw navigation datagram. After post-processing the IAKAR solution was applied and a new GPS water level was computed using the same dialogue.

GPS water levels from both the RTK and IAKAR solutions were computed using the HIPS Compute GPS Tide dialogue. During this step the appropriate NAD 83 to CRD model file was selected as well as options necessary to apply HIPS water line offsets and remove heave from the GPS signal. This resulted in a water level signal that was then reviewed, edited, and smoothed with a 30-second moving average using the HIPS Attitude Editor. During the HIPS Merge process GPS Tides were applied with the smooth GPS Tide sensor selected. Traditional heave and/or delayed heave (TrueHeave™) was applied in preference of using the heave component of the GPS height signal due to concerns about the impact of GPS outages and multipath caused by the high number of structures along the shoreline within the survey area.

Data gaps in the Position and Orientation System for Marine Vessels (POS M/V) real-time .000 file prevented the creation of a continuous SBET solution for some survey days. In these cases the survey line that was impacted by the outage did not have the post-processed solution applied in HIPS and instead used real-time navigation, attitude, and RTK GPS heights and water levels. This error occurred infrequently and survey lines impacted by the issue are listed in the Horizontal and Vertical Control section of each descriptive report. The use of RTK where an IAKAR solution is unavailable has been validated both during acquisition and processing, including the comprehensive NAV-DIFF analysis performed during post-processing.

B5. Final Bathymetric Processing

Upon the completion of editing multibeam data in HIPS, finalized CUBE grids were generated using the "greater of the two" option for the final uncertainty value. Depths and contours were generated from the surfaces and used for chart comparison purposes, but are not included with the deliverables. Finalized surfaces were reviewed in the HIPS 3D graphics window with an extreme vertical exaggeration to verify that all fliers have been removed from the surfaces. Bathymetric Attributed Grids (BAGs) for each CUBE surface were exported from HIPS for submittal.

Designated soundings were used as a starting point for S-57 feature creation. Designated soundings that were determined to be obstructions, rocks or wrecks were imported into the S-57 feature files and attributed. S-57 objects were created for all new and incorrectly charted baring features such as piles and dolphins. Shoreline features such as piers, seawalls, and docks were not included in the S-57 feature file. Many items included in the S-57 feature file have already been submitted as Dangers to Navigation (DtoNs). In some cases an obstruction that is depicted in an S-57 feature file was not reported as a DtoN because it was found to be deeper than currently charted soundings.

The feature file also includes bottom samples (SBDARE) and required meta-objects (M_COVR and M_QUAL).

C. CORRECTIONS TO ECHO SOUNDINGS

C1. Static Draft

With the vessels out of the water, markings were surveyed and painted on the port and starboard sides of the hull directly abeam with the multibeam sonar providing a means to monitor vessel draft. Static draft readings from the port and starboard side were recorded at the start and end of each survey day, while the ship was alongside the pier and where an accurate draft reading could be obtained. The start and end of day draft values for the sonar were calculated from the average of the port and starboard draft readings. The draft marks were directly abeam of the multibeam head mounted in the center of the vessel. The vessel's fuel and ballast levels were maintained to control the vessel draft. An average of the start and end of day draft values was calculated daily and entered into the waterline field in the Caris HVF. The average draft value best approximates the true draft value during acquisition due to loading changes from fuel consumption during transit to and from the survey area at the start and end of each day. Ultimately, the daily draft values were used to calculate daily draft relative the HIPS reference point which was entered into the waterline field in the Caris HVF files.

At the start of the project the approximate draft of the *R/V Preston* single beam transducer was 0.36 meters. This value was entered into the single beam sonar and used throughout the survey enabling the output of a depth relative to the approximate vessel waterline, therefore enabling quick review of depths at time of acquisition. Ultimately the daily draft values were used to calculate the daily draft relative to the 0.36-meter value that was used during acquisition. These differences relative to the assumed 0.36-meter single beam draft were entered into the waterline field in the Caris HVF for that vessel.

C2. Dynamic Draft

Settlement and squat are measured real-time using RTK. These values were not added to the Caris HVFs. However, dynamic draft values for both survey vessels have been computed and are presented in Figure 3 and Table 12.

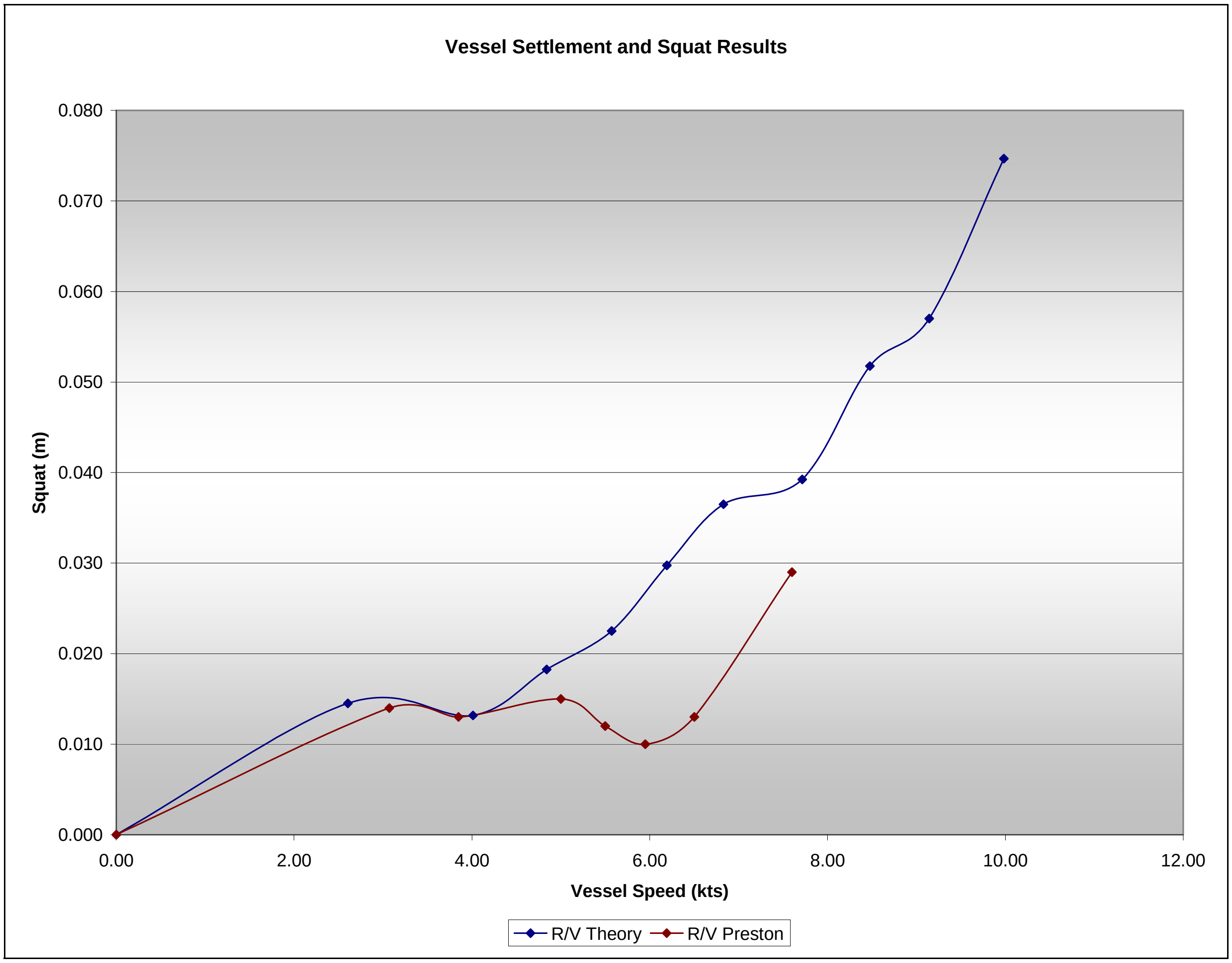

Figure 3. Vessel settlement and squat results

Table 12. Dynamic Draft Values

R/V Preston		*R/V Theory*	
Speed (kts)	**Squat (m)**	**Speed (kts)**	**Squat (m)**
0.00	0.000	0.00	0.000
3.07	0.014	2.61	0.015
3.85	0.013	4.01	0.013
5.00	0.015	4.84	0.018
5.50	0.012	5.57	0.023
5.95	0.010	6.19	0.030
6.50	0.013	6.83	0.037
7.60	0.029	7.72	0.039
		8.48	0.052
		9.14	0.057
		9.98	0.075

C2.a *R/V Theory*

A settlement and squat test for the *R/V Theory* using post-processed GPS height observations was performed on the Columbia River just east of Hayden Island on August 15, 2008 (DN228). Data from these measurements are displayed graphically in Figure 3 and in tabular format in Table 10 and are included in Appendix V *Supplemental Survey Records and Correspondence* of the *Descriptive Reports*.

The settlement and squat values were obtained by computing a three minute GPS height average at different ship speeds, measured in knots and revolutions per minute (RPM) during transects near the east end of Hayden Island. Transects were run twice at each RPM interval; once at a westerly heading and once at an easterly heading.

Vessel speeds in increments of 200 RPMs were observed from 600 to 2400 RPM with GPS height recorded at 25 Hz. With the vessel at rest static GPS height observations were recorded between each RPM interval in order to have a baseline GPS height value not affected by tide changes during the test. Three minute running averages of GPS height were calculated to remove any heave bias from the calculations. Each transect was run for approximately five minutes. The difference between the GPS height and an interpolated static GPS height (to account for changing tide) at the time of the average height value were used to calculate the dynamic draft for each transect. An average dynamic draft corrector was then calculated from the average of the two values for each RPM interval. Because GPS water levels were used for this project TPE values for dynamic draft were not entered into the HVFs.

C2.b *R/V Preston*

A settlement and squat test for the *R/V Preston* was completed on February 1, 2005 (DN032). Data from these measurements are displayed graphically in Figure 3 and in tabular format in Table 10 and are included in Appendix V *Supplemental Survey Records and Correspondence* of the *Descriptive Report*.

Settlement and squat values were obtained by computing the average of GPS height observations recorded at 1 hertz for vessel transects run at different ship speeds, measured in knots and RPM. Transects were run twice at each RPM interval with the second line run at a heading that was opposite to the first.

Vessel speeds in increments of 200-300 RPMs were observed from 0 to 2300 RPM. With the vessel at rest static GPS height observations were recorded at the start and end of the test in order to have base line GPS height values not affected by tide changes during the test. Each transect was run for approximately one minute and an average height was computed. The transect correctors was then computed from difference between the transect height average and an interpolated static tide for the time of the transect. The dynamic draft corrector was then calculated from the average of the two values for each RPM interval. Because GPS water levels were used for this project TPE values for dynamic draft were not entered into the HVFs.

C3. Bar Check Comparisons

Weekly bar checks were performed to ensure that sonars were functioning properly and static drafts were accurately documented. Two (2) bar check plates were constructed using a 20-inch diameter, 0.25-inch thick steel disc, and an 8-inch diameter, 0.5-inch thick steel disc. Each disc was attached to a metric reel fiberglass tape. The 20-inch diameter disc was used for *R/V Theory* checks and the 8-inch disc was used for *R/V Preston* checks. Checks enabled depths to be read to within five millimeters.

Each bar check device was lowered to a point above the bottom where it could be clearly ensonified. The depths of the devices reported on the tape was compared to the depth of the disc or bar reported by the sonar. Observations were recorded in a comparison log. Table 13 below details the average difference, standard deviation equal and maximum deviations for each vessel. Maximum deviations were attributed to strong currents inhibiting the 20-inch steel disc from sitting completely flat due to increased surface area. In conditions of high current, only the 8-inch steel disc was utilized.

Table 13. Vessel Bar Check Summary

	Theory MBES	Preston MBES	Preston VBES
Average Difference	-0.011	-0.012	0.023
Standard Deviation	0.022	0.026	0.012
Maximum Deviation	-0.055	-0.062	0.048

Tabulated bar check comparisons may be found in the Weekly Bar Check logs included in Separate 1 *Acquisition and Processing Logs* of the Descriptive Reports.

C4. Heave, Roll and Pitch Corrections

An Applanix POS/MV 320 version 4 integrated RTK GPS and inertial reference system was used for the motion sensor for this survey. The POS/MV 320 is a 6° of freedom motion unit, with a stated accuracy of 0.05-meter or five percent for heave, 0.01° for roll and pitch and heading. Real-time displays of the vessel motion accuracy were monitored throughout the survey with the POS/MV controller program. If any of the vessel motion accuracy degraded to greater than 0.05° RMS, survey operations would be suspended until the inertial unit was able to regain the higher degree of accuracy. Manufacturer reported accuracies as published on the Caris HIPS TPE website (http://www.caris.com/tpe/) were entered into the HVF and used for TPE computations. A schematic of the vessel and sensor set-up is shown in Figures 4, 5 and 6 on the following pages.

As previously discussed, attitude and heading were reapplied after post-processing navigation and inertial sensor data in POSPac SBET files were applied in HIPS with the Load Attitude/Navigation data tool.

Installation bias and patch test results were computed at the start of the survey. Additionally, patch tests were performed throughout the survey to monitor known values and account for changes due to sensor replacements or sonar strikes on objects in the water column or on the river bottom. All values were stored in the Caris HVF files.

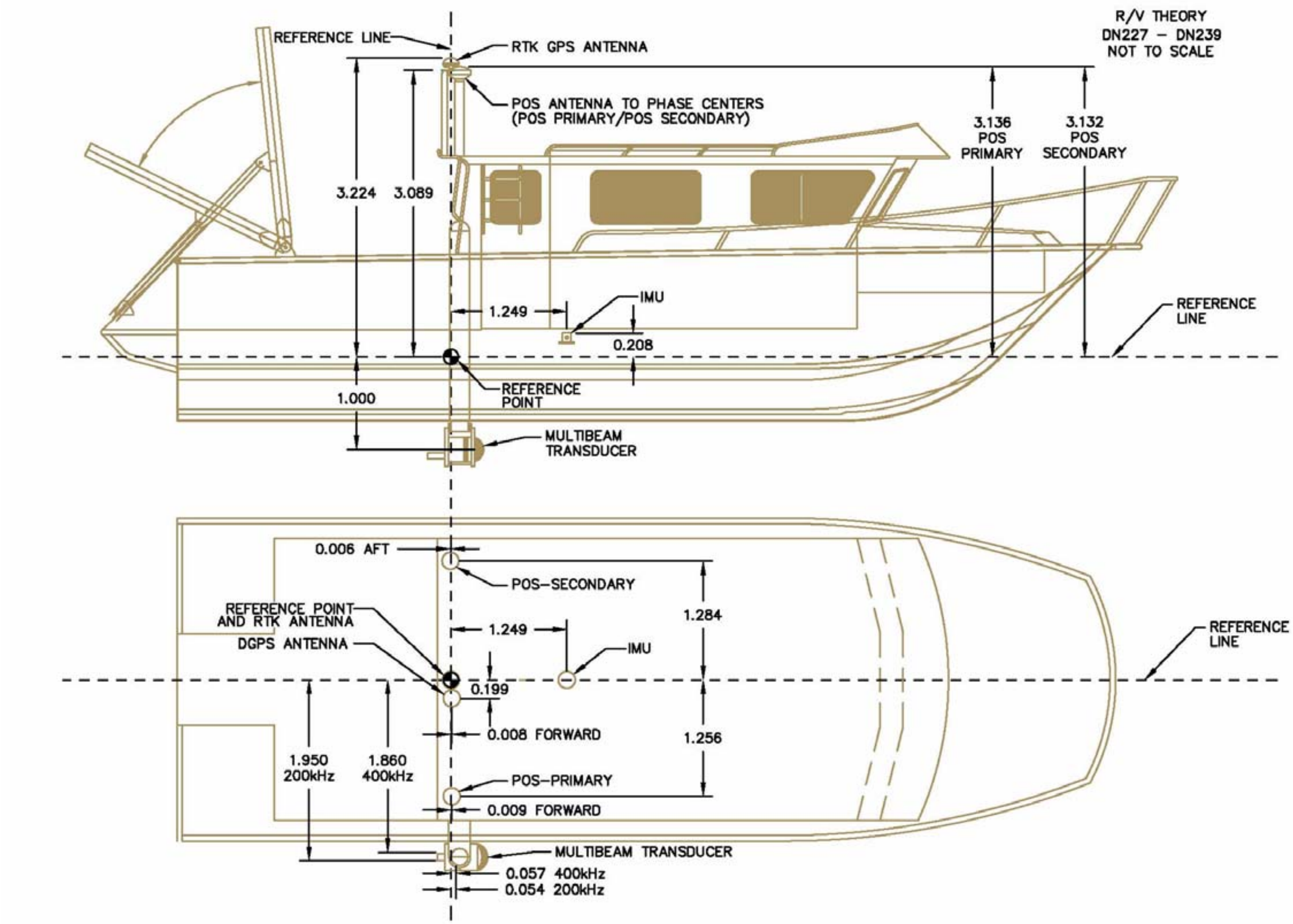

Figure 4. Pre-bend Schematic of *R/V Theory* and Sensor Setup

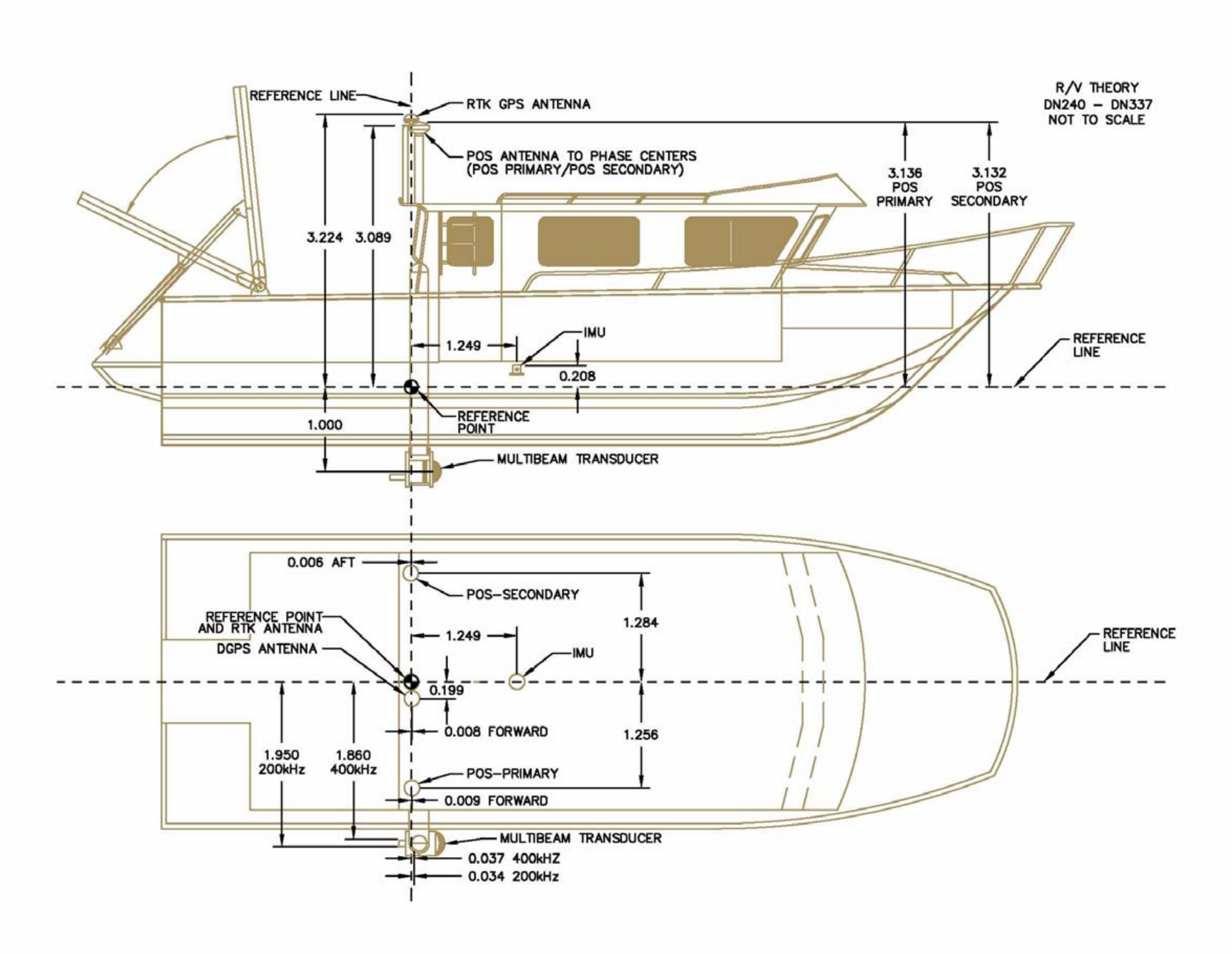

Figure 5. Post-bend Schematic of *R/V Theory* and Sensor Setup

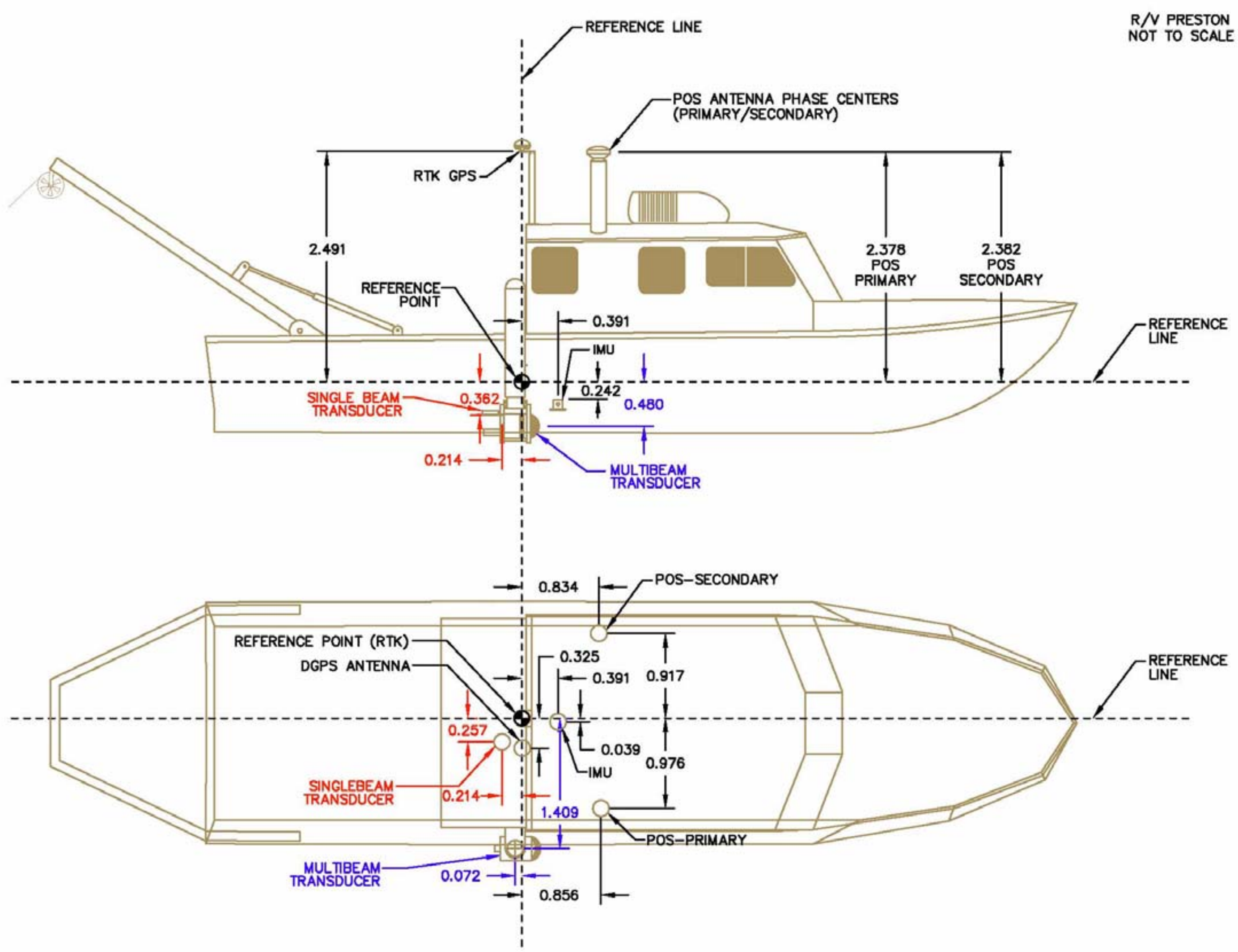

Figure 6. Schematic of *R/V Preston* and Sensor Setup

C5. Patch Tests

Multibeam patch tests were conducted for the *R/V Theory* and *R/V Preston* to measure alignment offsets between the IMU sensor and the multibeam transducer and to determine time delays between the time-tagged sensor data. Multiple patch tests were performed throughout the project to verify the adequacy of the system biases. Patch tests were performed at the beginning of the project, at the end of each month, after any contact between a sonar and the bottom of another object, and again, at the end of the project. Each patch test consisted of a series of lines run in a specific pattern, which were then used in pairs to analyze roll, pitch and heading alignment bias angles.

A precise timing latency test was performed by running a single line over a flat bottom with induced vessel motion. The line was then opened in the HIPS calibration editor (after applying tide and SVP corrections) and a small along-track slice of data was evaluated in the outer swath of the line for motion artifacts. Incremental changes to the roll time offset were made to evaluate the performance of the precise timing setup and to determine if a latency correction was needed. No latency was found in the system.

Roll alignment was determined by evaluating the reciprocal lines run over a flat bottom used for the latency test. The pitch tests consisted of set of reciprocal lines located on a steep slope. The yaw error was determined by running parallel lines over the same area. All lines were run at approximately 4 knots to 6 knots. Patch tests were run in the local survey area. Due to long transit times, tests were not necessarily run in the same location each time.

Selected pairs of lines were then analyzed in HIPS Calibration editor to measure the angular sensor bias values. Visual inspection of the data confirmed each adjustment. Two (2) sets of lines were run and analyzed for each of the mounting biases with the second set was used to confirm the results of the data.

A single beam latency patch test was run on DN321 for the *R/V Preston*. Patch tests were conducted in accordance with NOAA standards and on day numbers (DNs) listed in Tables 14 and 15 on the following page. Each vessel's patch test data was evaluated in HIPS after loading post-processed navigation, attitude, and heading.

Due to significant amounts of debris and migrating sand shoals, vessels unexpectedly hit debris or ran aground. After each incident, a patch test was conducted to calibrate for potential changes to the pitch, yaw, and/or roll offsets. Changes for both vessels are also documented in Tables 14 and 15.

Table 14. *R/V Theory* biases applied when using POS/MV

DN	Latency	Pitch	Yaw	Roll	X (m)	Y (m)	Z (m)	Comments
227	0.000s	-0.600°	-0.150°	0.700°	1.950	0.054	1.000	Begin Columbia River; 200 kHz ED
238	0.000s	-0.600°	-0.150°	0.700°	1.950	0.054	1.000	200 kHz ED
241	0.000s	-2.700°	-0.150°	-0.480°	1.860	0.037	1.000	400 kHz EA ; pole repair
248	0.000s	-2.700°	-0.150°	-0.980°	1.860	0.037	1.000	Beginning bad beam 1 data
253	0.000s	-2.700°	-0.150°	-1.160°	1.860	0.037	1.000	400 kHz EA; pole bracket repair
256	0.000s	-2.700°	-0.150°	-0.980°	1.860	0.037	1.000	Aground on sandbar
260	0.000s	-2.700°	-0.150°	-0.480°	1.860	0.037	1.000	Beam 1 corrected
268	0.000s	-2.700°	-0.150°	-0.480°	1.860	0.037	1.000	Missing bolt on MB mount
271	0.000s	-3.300°	-0.900°	-0.550°	1.860	0.037	1.000	MB bumped log
276	0.000s	-3.300°	-0.900°	-0.550°	1.860	0.037	1.000	New Reson processor and bottle
321	0.000s	-3.300°	-0.900°	-0.550°	1.860	0.037	1.000	Completed Columbia River Mainscheme
337	0.000s	-3.300°	-0.900°	-0.550°	1.860	0.037	1.000	Beginning Willamette River Mainscheme

Table 15. *R/V Preston* biases applied when using POS/MV

DN	Latency	Pitch	Yaw	Roll	X (m)	Y (m)	Z (m)	Comments
242	0.000s	-0.300°	0.200°	0.900°	1.409	-0.072	0.480	Begin Columbia River
250	0.000s	0.330°	0.700°	0.170°	1.409	-0.072	0.480	Replaced Reson 8101
253	0.000s	0.330°	0.700°	0.220°	1.409	-0.072	0.480	Boat touch bottom
281	0.000s	-0.300°	-0.100°	0.190°	1.409	-0.072	0.480	
291	0.000s	-0.300°	-0.100°	0.420°	1.409	-0.072	0.480	Bump MB head on deadhead
296	0.000s	0.750°	-0.400°	0.120°	1.409	-0.072	0.480	
307	0.000s	0.000°	0.350°	0.120°	1.409	-0.072	0.480	Bumped MB on a log at end of previous day
308	0.000s	-0.600°	1.500°	0.320°	1.409	-0.072	0.480	Bumped MB on a log at end of previous day
339	0.000s	-1.100°	0.890°	0.320°	1.409	-0.072	0.480	Beginning Willamette River Mainscheme
345	0.000s	-1.100°	0.890°	0.320°	1.409	-0.072	0.480	Completed Willamette River Mainscheme
014	0.000s	-1.100°	0.890°	0.320°	1.409	-0.072	0.480	Willamette River Fill
019	0.000s	-1.100°	0.890°	0.720°	1.409	-0.072	0.480	Bumped MB head
065	0.000s	-1.100°	0.890°	0.720°	1.409	-0.072	0.480	Closing Patch
132	0.000s	-1.300°	0.890°	0.430°	1.409	-0.072	0.480	Closing Patch

C6. Tide and Water Level Corrections

To verify RTK correctors were providing position data within survey specifications, the RTK positions and elevations were logged as the vessel was static and a comparison was made from the values obtained from each station as each survey vessel switched between base stations. The average vertical difference for both survey vessels was 3 centimeters. This check verified that there were no errors in base positions input into the receivers and also provided a relative RTK accuracy assessment for maximum distance from the survey vessel to the base stations.

As an overall confidence check for GPS tide computation, GPS tide readings were logged for an hour at all CO-OPS water level stations within the survey area while the vessel held station or was secured to a dock in the vicinity of the water station. Comparisons at each station were made between water levels relative to CRD recorded at the gauge and those computed using both RTK and post-processed GPS water levels. To obtain water levels relative to the CO-OPS defined CRD, the hydrographer selected Station Datum when downloading data from the CO-OPS web site. This is consistent with obtaining CRD values for any CO-OPS station on the Columbia River above river mile 23. Adjustments were required to correct CO-OPS water level data to CRD based on the updated USACE CRD profile used to maintain the Columbia and Willamette rivers.

An additional adjustment was applied to correct local tidal bench marks with orthometric heights based on NGS level lines to OPUS derived NAVD88 elevations to match the USACE profile and eliminate errors from distorted level lines. Table 16 lists the average difference between the comparisons for each water level station. CO-OPS water levels used in the comparison have been adjusted for the application of the updated USACE CRD profile relative to NAVD88 and, in some cases, the application of OPUS derived NAVD88 elevations on tidal bench marks.

As a result of these comparisons, the Hydrographer discovered a large deviation from the CO-OPS data reported from station 9440422 in Longview, WA. After running digital levels and recording a one hour series of water level observations with an optical level, it has been determined that the CO-OPS water level station in Longview, WA (9440422) is incorrectly reporting water levels relative to the station tidal bench marks and should be corrected by -0.071 meters to match CO-OPS tidal bench marks. CO-OPS is aware of these issues and is working toward resolving this problem. It should be noted that these adjustments were applied to CO-OPS water level data for comparison purposes of water level data relative to the revised USACE profile relative to OPUS derived NAVD88 elevations. This method was approved for project OPR-N388-KR-08 by the Office of Coast Survey, Hydrographic Surveys Division Chief as it is consistent with the USACE, Portland District, methods for maintaining the Federal Channel in the Columbia and Willamette rivers. Further, CO-OPS should adjust water level stations on Columbia River Datum and part of the Columbia PORTS® system to be consistent with the defined CRD profile by the Portland District.

Table 16. Comparison between CO-OPS and GPS Water Levels

Tide Gauge (Vessel Logged)	Station Number	RTK Average Delta (m)	Post Processed Average Delta (m)	CO-OPS Tidal Correction (m)
Morrison Bridge (PR)	9439221	-0.012	-0.007	0
Morrison Bridge (TH)	9439221	0.016	0.007	0
Skamokawa (PR)	9440569	0.026	-0.060	0.018
Wauna (PR)	9439099	0.014	0.052	0.038
Longview (PR)	9440422	-0.042	-0.009	-0.163
St Helens (PR)	9439201	-0.004	-0.003	-0.005
Vancouver (TH)	9440083	0.034	0.017	0.034

C7. Sound Velocity Correction

While underway during data acquisition the MVP-30 was deployed as needed to obtain an adequate number of sound velocity profiles to properly correct the survey data during data processing. At the start of each survey day a cast was taken right before coming online with additional casts being taken on a periodic basis, usually every 2 hours, or when passing tributaries that could significantly alter sound speed, in which case additional casts were taken. In areas of significant debris the MVP was not deployed while underway. The boat remained stationary and casts were taken in the deepest area near the lines acquired within the previous 2-hour time frame. At least one deep cast (extending to 95% of depth) was taken per day.

After each cast the sound speed data was reviewed for outliers or anomalies such as a sharp thermocline which could impact data quality. The sound speed measured by the MVP at 1.0 meter depth was also compared to the Reson 7125 head velocity for agreement to ensure that both systems were working properly. In addition to these periodic comparisons, weekly check casts were taken to verify proper performance of the MVP 30. For this check a SeaBird Instruments SBE 19 – CTD profiler or AML was attached to the MVP fish and the two probes were simultaneously deployed. Corrections for the speed of sound through the water column were computed for each sensor. Sound speed profiles were imported and overlaid for comparison into an Excel file. Comparisons showed a constant a 0.6m/s bias. With the exception of the AML SV Plus (serial number 3591), each sensor had been calibrated prior to the start survey and again at the end of the survey. The post-survey calibration report for the AML SV Plus (serial number 3591) had not been received from the manufacturer when this document was prepared. The AML 3591 was compared to another AML SV Plus (Serial Number 3592) as well as both AML Smart SV&Ps (Serial Numbers 5110 and 5111) as part of a weekly confidence check for sound speed determination. All comparisons were well within survey specification. Factory calibration results are included in Separate II *Sound Speed* of the Descriptive Reports.

The sound speed correction was applied to each line using the nearest in distance within time (two hours) option in the HIPS SVP correct routine. All casts were concatenated into a daily HIPS SVP file for each survey day. Daily HIPS SVP files were concatenated into a sheet wide file. Time, position, and sound speed for each profile were included in the HIPS file.

D. LETTER OF APPROVAL

DAVID EVANS AND ASSOCIATES INC.

LETTER OF APPROVAL

OPR-N338-KR-08
DATA ACQUISITION AND PROCESSING REPORT

This report and the accompanying data are respectfully submitted.

Field operations contributing to the accomplishment of OPR-N338-KR-08 were conducted under my direct supervision with frequent personal checks of progress and adequacy. This report and associated data have been closely reviewed and are considered complete and adequate as per the OPR-N338-KR-08 *Statement of Work* (April 1, 2008).

Digitally signed by Jon Dasler
DN: cn=Jon Dasler, email=jld@deainc.com, o=David Evans and Associates, Inc., c=US
Date: 2009.06.17 11:30:13 -07'00'

Jonathan L. Dasler, PE (OR), PLS (OR,CA)
ACSM/THSOA Certified Hydrographer
Chief of Party

Digitally signed by Jason Creech
DN: cn=Jason Creech, email=jasc@deainc.com, o=David Evans and Associates, Inc., c=US
Date: 2009.06.17 11:30:39 -07'00'

Jason Creech
Lead Hydrographer

David Evans and Associates, Inc.
May 2009