# Data Acquisition and Processing Report
## Columbia River Hydrographic Survey

***Clover Island and Benton-Franklin Intercounty Bridge***

Vessel: ***R/V Kvichak Surveyor***

Survey: **Columbia River Hydrographic Survey**

State: **Washington**

General Locality: **Hanford Reach**

Sublocality: **River Miles 325-343**

Survey Dates: **August 11, 2011 to August 18, 2011**

Project Lead: **Gunnar E. Forsman, USN-NUWC**

Lead Hydrographer: **Steven S. Intelmann, NOAA-AFSC**

# TABLE OF CONTENTS

## *Overview*

The Columbia River Hydrographic Survey was completed to document river elevations between river mile 325 and 343, in the general vicinity of the Hanford Reach (Figure 1). Project guidelines were developed to fulfill specific needs of the Puget Sound Naval Shipyard (PSNS), although when possible, efforts were made to meet the National Oceanic and Atmospheric Administration (NOAA) Hydrographic Surveys Specifications and Deliverables for 2010. No shoreline verification was attempted, only general bathymetry.


***Figure 1 – Survey area for the Columbia River Hydrographic Survey. Background charts are NOAA BSB 18543 and 18542.***

# A. Equipment

## A.1. Vessels

All data for this survey were acquired using the *Research Vessel Kvichak Surveyor.*

### A.1.1. *R/V Kvichak Surveyor*

Multibeam bathymetric and backscatter data for the Columbia River Hydrogaphic Survey were acquired using the *R/V Kvichak Surveyor*.

The *R/V Kvichak Surveyor*, shown in Figure 2, is an approximately 20-meter aluminum catamaran type vessel with a 7 meter beam and minimal draft. The vessel was powered by two 3196 Caterpillar diesel engines with electrical power being supplied by two Northern Lights 32 kW generators. The *R/V Kvichak Surveyor* was outfitted with a pole-mounted Multibeam Echo Sounder System (MBES), Kongsberg Simrad EM 3002D. Detailed vessel drawings showing the location of all primary survey equipment are included in Section C of this report.


***Figure 2 – R/V Kvichak Surveyor, shown in the Foss Shipyard Dry Dock, Seattle, Washington.***

#### A.1.1.1 Equipment Overview

Equipment on board the *R/V Kvichak Surveyor* performed within required specifications during the survey.

#### A.1.1.2 Major Operational Systems

***R/V Kvichak Surveyor* Survey Equipment**

***Table 1 – Listing of the major survey equipment used on the R/V Kvichak Surveyor.***

| *Description* | *Manufacturer* | *Model / Part* | *Serial Number* |
|---|---|---|---|
| Multibeam Echosounder | Kongsberg Simrad | EM 3002D | Port Head-632<br>Stbd Head-595 |
| Sonar Acquisition | Primary: SIS<br>Secondary: QPS | APC12 & SIS 3.4.1<br>QINSY 8.0 | 1103 / 3350<br>N/A |
| Positioning System | Applanix | POS M/V 320 V4 | 2463 |
| Motion Sensor | Applanix | POS M/V - IMU 200 | 507 |
| Zephyr Antennas | Trimble | Zephyr L1/L2 | 60130682<br>30939263 |
| GPS Corrector | DGPS Beacon | Trimble AG332 | 022510948 |
| SV Probes | Seabird<br>AML | SBE19 - profiler<br>Smart SV&P- surface | 198175-1420<br>4366 |

#### A.1.1.3 Sounding Equipment

A Kongsberg Simrad EM3002 dual-head MBES (Table 2) was installed in a pole-mounted configuration (Figure 3) aboard the *R/V Kvichak Surveyor* during the Columbia

***Figure 3. Derrick mounted on aft deck (left) and dual heads shown on retractable pole (right).***

River Hydrographic Survey. The EM3002D is a 508-beam Mill's Cross system operating in the 300kHz band that is dynamically focused and can be configured with equidistant or equiangle beam spacing. To achieve these high density data, the sonar signal is sampled multiple times for each ping.

For this survey, the EM3002D was set to high density equidistant mode, acquiring the full 508 beams. Bathymetric datagrams were output from each transducer via an Ethernet connection to the acquisition software. The system's bottom tracking algorithm automatically adjusted the gain, power, and range dependent parameters as required, using a combination of phase and amplitude bottom detection to provide soundings with the best possible accuracy.

#### A.1.1.4 Technical Specifications

***Table 2 – Kongsberg EM 3002D multibeam echosounder technical specifications.***

| **Kongsberg EM 3002D** | |
|---|---|
| Sonar Operating Frequency | 293 kHz - 307 kHz |
| Beam Width, Across Track | varies |
| Beam Width, Along Track | varies |
| Number of Beams | 508 max |
| Max Swath Coverage | 200° |

## A.2. Tide Gauge

Data from the Clover Island water gauge in Kenniwick, Washington (12514500) was used to provide water level data for the Columbia River Hydrographic Survey; however soundings were not actually corrected by water level since the data were treated as an ellipsoidally referenced survey (ERS). ERS methodology was used because this stretch of the river is highly dynamic and influenced by several dams, including upstream controlled release from Priest Rapids Dam and downstream release at McNary Dam (Figure 4). The Snake River also joins the Columbia River within the survey area, further complicating control of water level due to additional flood release from Ice Harbor Dam. Regardless, the maximum water level fluctuation during the survey was 0.67 meters, as recorded by the water level gauge at Clover Island. To reiterate, water level records were downloaded and reviewed from the USGS National Water Info system website at: http://waterdata.usgs.gov/wa/nwis/uv/?site_no=12514500, but were only used in preliminary processing as a sanity check to the ERS methodology described hereafter.

## A.3. Ellipsoid Referencing using CORS Station

As mentioned above, due to the challenge of controlling for changing water levels related to the several dams within the area, horizontal and vertical control were obtained using Post-Processed Kinematic (PPK) positioning based on a single Continuously Operated Reference Station (CORS) located in Richland, WA. The NGS reference datasheet for the Richland base station is included in the accompanying Vertical and Horizontal Control Report.

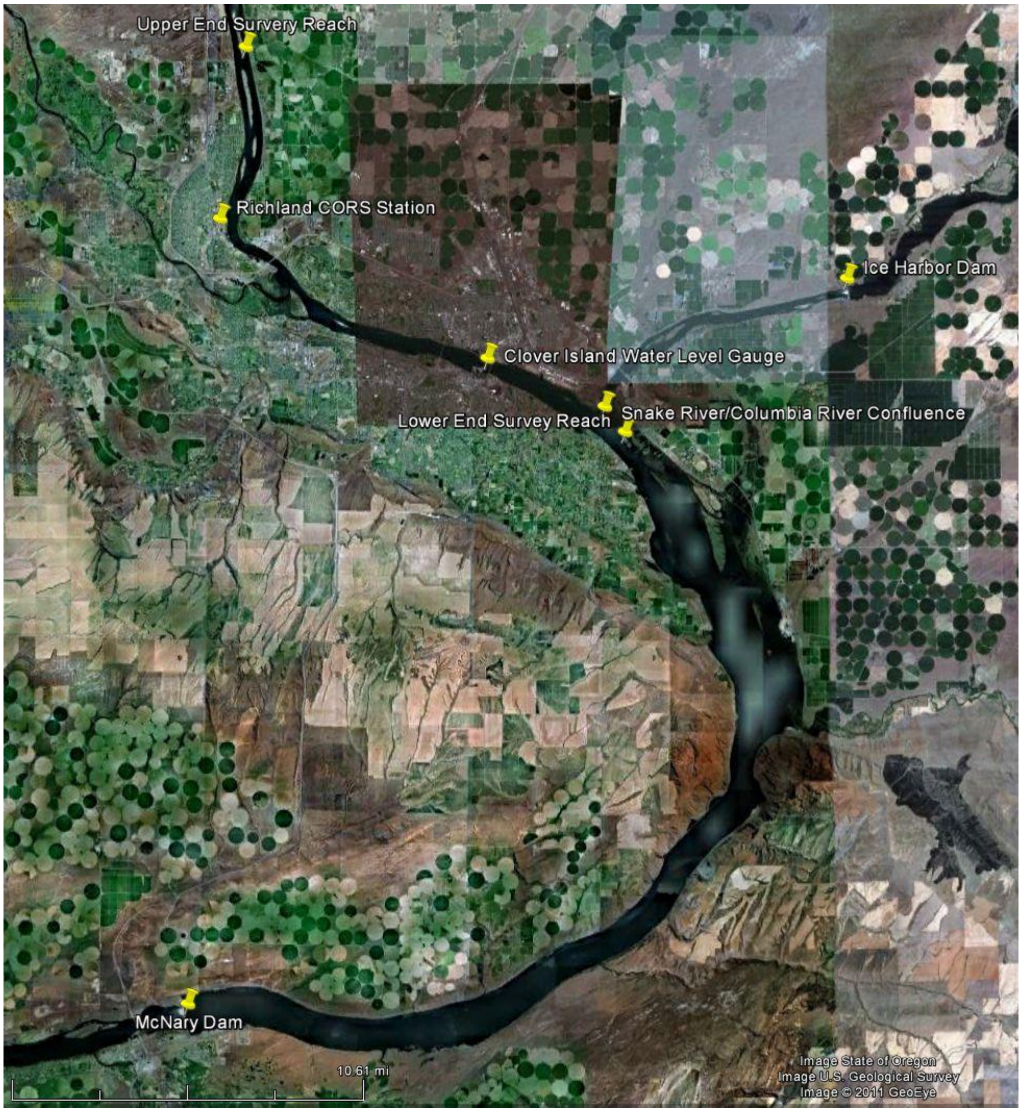



***Figure 4 - Location of the CORS and USGS water level stations and various dams with respect to the Hydrographic Survey reach.***

## A.4. Speed of Sound

Speed of sound data were collected by vertical casts using a Seabird SBE19 sound velocity profiler. An Applied Microsystems (AML) Smart SV&P sensor was additionally mounted to the transducer adapter to aid with beam steering at the heads. Sound speed profiles were geographically distributed within the survey area and taken approximately every four hours. All profiles extended to 100% of the anticipated water depth and were converted and processed using Pydro and Velocipy version 10.3_r2888. Because the SIS acquisition software modifies its absorption coefficient algorithms based on a full ocean range of depths, all casts were extended to 12,000 meters depth by repeating the final valid sound speed reading. No data quality issues related to speed of sound measurements were encountered during the survey or in post-processing. Please refer to the Descriptive Report (DR), *Separate II: Sound Speed Data* for detailed information about specific cast dates and procedures used.

The following instruments were used to collect data for sound speed profiling on the *R/V Kvichak Surveyor*.

***Table 3 – Llisting of the sound speed measuring equipment used during the Columbia River Hydrographic Survey.***

| | |
|---|---|
| Sound Speed Profiler | SBE19 |
| Manufacturer | Seabird Electronics<br>Bellevue, WA |
| Serial number | 198175-1420 |
| Calibrated | 12/31/2009 |

| | |
|---|---|
| Sound Velocity and Temp. Sensor | Smart SV&P |
| Manufacturer | Applied Microsystems Ltd.<br>Sydney, British Columbia, Canada |
| Serial number | 4366 |
| Calibrated | 2/25/2010 |

## A.5. Positioning Systems

Position control for the *R/V Kvichak Surveyor* was provided by an Applanix POS M/V 320 v4 Positioning System. The primary source for navigation during the survey was RTCM DGPS, however PPK were used to produce final positioning by using a CORS located in Richland, WA. The vessel's DGPS position was recorded using both Kongsberg SIS and QPS QINSy acquisition software, logging at 1Hz intervals using the National Marine Electronics Association (NMEA) message $GPGGA.

A positioning confidence check was performed during the survey by simply comparing logged data from two independent devices (corrected to IMU location) within QINSy, namely the RTCM corrected POS M/V and the Trimble Ag332 nodes. The differences in the Northing and Easting values were calculated and graphed and did not exceed 5 meters + 5 percent of the depth as described in section 3.1 of the Specifications and Deliverables April 2010. Results of the DGPS confidence check are provided in the DR, *Separates I: Acquisition and Processing Logs*.

Again, specific details addressing horizontal control activities associated with this project are discussed in the Vertical and Horizontal Control Report.

## A.6. Attitude Sensors

To correct the motion artifacts in the sounding data, an Applanix POS M/V Inertial Measurement Unit (IMU) 200 was used to measure heave, pitch and roll values. Detailed descriptions of all attitude corrections are provided in Section C of this report.

## A.7. Data Collection

### A.7.1 Overview

The survey was conducted using multibeam bathymetry and backscatter collection techniques. No single-beam or side-scan data were acquired. In general, data were gathered on an approximate 12-hour basis, by a single crew of 3 surveyors and 2 vessel operators.

### A.7.2 Coverage

Lines were run to ensure a minimum of 100% multibeam coverage, as described by the requirements of the 2010 NOS Hydrographic Survey Specifications and deliverables, Section 5.2.2.

### A.7.3 Line Planning

Planned lines were initially designed to establish a baseline from which to expand. Beyond this, the technique of “painting” was used to fill holidays. For safety reasons survey lines were restricted to the 6m curve and deeper.

### A.7.4 Ping Rates

MBES ping rate was determined by the SIS acquisition software with vessel speed targeted at 6 to 8 knots SOG. However, due to the high velocity currents in this stretch of the Columbia River, vessel operation varied considerably depending on direction of travel. In a downstream direction, the vessel was travelling at the speed of river flow, with only one engine clutched to maintain steerage. Yet both engines were used during upstream transits, while constantly engaging and disengaging individual clutches to maintain steerage ability at speeds appropriate for achieving desired sounding density.

## A.8. Software and Hardware Summary

Multibeam data were collected on an Intel Pentium IV PC using Kongsberg SIS data collection software (Bathymetric & Backscatter) operating in a Microsoft Windows XP environment. To determine whether complete bottom coverage had been achieved, MBES data were additionally input into QPS QINSy navigation software to generate a real-time digital terrain model (DTM) during each survey line acquired. The QINSy sounding grid was merely used on the vessel in real-time as a field quality assurance tool and “road map” for the helmsman but was not used during any subsequent data processing. All raw bathymetric and backscatter data, as well as position and sensor data were recorded in the SIS native .all format and were processed using CARIS Hydrographic Information Processing System (HIPS) software. Final survey coverage determination was made following data processing and surface generation using the CUBE algorithm in CARIS HIPS 7.1.

CARIS HIPS was also used for MBES quality assurance, with data post-processing procedures being described in further detail in Section B, Quality Control.

Table 4 provides a listing of the software used on the *R/V Kvichak Surveyor* during the actual survey, and Table 5 details the various tools used in the office for pre-survey planning and post-survey processing.

### A.8.1 Vessel Software

***Table 4– Software used aboard the R/V Kvichak Surveyor during survey.***

| Program Name | Version | Date | Primary Function |
|---|---|---|---|
| Kongsberg SIS | 3.8.3 | 2011 | Kongsberg MBES controller and collection software |
| QPS QINSy | 8.0 | 2008 | Multibeam data collection and navigation suite; real-time mosaicing for helmsman |
| POSView | 5.1.0.2 | 2011 | POS M/V setup and monitoring |
| CARIS HIPS | 7.1 | 2011 | Multibeam data processing software |
| Pydro/VelociPy | 10.3 | 2011 | Sound Velocity Processing |

### A.8.2. Office Software

***Table 5 – Software used in the office during post processing.***

| Program Name | Version | Date | Primary Function |
|---|---|---|---|
| CARIS HIPS | 7.1 | 2011 | Multibeam data processing software |
| CARIS BathydataBASE | 3.2.0 | 2011 | Bathymetry compilation and analysis software |
| ESRI ArcMap | 10.0 | 2011 | GIS management software |
| POSPac MMS | 5.4 | 2011 | PPK Positioning |
| Fledermaus / FMGT | 7.1 | 2011 | Backscatter Processing |
| Vertcon | N/A | N/A | Datum conversion algorithm |
| Geoid09 | N/A | N/A | Datum conversion algorithm |

## B. Quality Control

### B.1. Overview

Every effort was made to ensure the integrity and traceability of multibeam bathymetry and backscatter, attitude, and navigational data as it was moved from the acquisition phase through processing. Consistency in file and object naming combined with the use of standardized data processing sequences and methods formed an integral part of this process.

As already mentioned, CARIS HIPS 7.1 was used for the multibeam data processing tasks on this project. HIPS was designed to ensure that all edits and adjustments made to the raw data, and all computations performed with the data follow a specific order and are saved separately from the raw data to maintain the integrity of the original data.

### B.2. Equipment Calibration

Each item of survey equipment was calibrated prior to the survey to assess the accuracy, precision, alignment, timing error, value uncertainty, and residual biases in roll, pitch, heading, and navigation. The EM3002D calibration was completed by conducting a patch test prior to transiting to the survey area. All sound velocity and water surface measurement instruments were factory calibrated. Periodic comparative confidence checks between the two SV probes were also made during their use on the Columbia River Hydrographic Survey.

### B.3. Survey System Confidence Checks

Additional GPS data from a Trimble Ag332 GPS receiver were collected concurrently with the position and attitude of the POS M/V. Both positioning systems were time-referenced at 1-second intervals and logged in QINSy. An independent positional confidence check was performed during the course of the survey, as described in section A.5 of this report, and presented in the DR, *Separates I: Acquisition and Processing Logs*.

Cross lines were run as a confidence check for the multibeam sonar, however these were limited in scope since it was very difficult, if not impossible, to acquire data perpendicular to the flow of the river, for which the main scheme survey lines were designed around.

Initial data processing was performed aboard the acquisition vessel upon the completion of each survey line. Adjustments were made to equipment settings based on preliminary processing and, if necessary, survey lines were rerun.

A nadir beam confidence check was performed on the MBES prior to the survey by measuring the depth under the ship with a calibrated sounding lead line and comparing the value with the nadir-beam depth recorded by the MBES. All measurements were corrected to the vessel central reference point (CRP), which was the IMU itself. The lead line used for the calibration check was constructed from a metric steel-reinforced survey tape with a steel weight attached to the end in such a way that the bottom of the weight was 0.0 m. The lead line was checked prior to the survey for accurate length. Lead line measurements were taken from punch marks established during the vessel survey. The differences between measured and observed values were well within sounding error limits specified for this survey. The DR, *Separate I: Acquisition and Processing Logs* provide results of the calibration check.

## B.4. Data Collection

Multibeam bathymetry and backscatter data collection was performed using Kongsberg SIS data acquisition software. The file naming convention was inherent to SIS and ensured that individual survey lines had unique names based on time of collection. SIS software generated .all files, which in addition to bathymetry and backscatter, contained positional and attitude information, both surface and full profile sound velocity, and vessel offset and alignment calibration values. All raw data files were stored on the acquisition computer's hard drive for the duration of the survey.

MBES data were also logged by QPS QINSy acquisition software. These files included navigation, attitude and heading data from the POS M/V as well as the secondary positioning data from the Trimble Ag332.

The POS M/V was set up to acquire RTCM DGPS correctors and to log PosPac data for both PPK and TrueHeave during in post processing; however, the latter was not applied since there was no measurable heave encountered on the river.

Sound velocity profiles were acquired with a Seabird SBE19 profiler as .hex and .cnv files. Raw sound velocity files were converted to .asvp format using Pydro/Velocipy, and were input into SIS in real-time. CARIS .svp files were also created but not used within HIPS since SIS had already applied the sound speed data.

Chronological logs containing information specific to each line were maintained as an independent reference to aid in data integration and error tracking. Acquisition logs included the line name, start and end times and any additional comments deemed significant by the operators.

## B.5. Initial File Handling

Shipboard data handling proceeded as follows: As multibeam data collection was conducted, Kongsberg SIS Acquisition software captured the raw .all files. Raw files were organized by Julian day, and moved over Ethernet to the CARIS storage device. The .all files were then converted into CARIS HIPS multibeam data processing format and then saved into the CARIS HDCS library structure. The project data were additionally transferred to an independent external storage device in a directory identifying the project name, vessel name, and Julian date. The back-ups insured data security and the ability of the system to resist catastrophic equipment failure.

## B.6. Field Data Processing

Preliminary MBES data processing was completed aboard the survey vessel. The raw multibeam data were imported into CARIS HIPS using the conversion wizard module. The wizard creates the directory structure for each line and separates the information into sub-files which contain individual sensor information. All data entries were time-referenced using the time associated with the .all file for relating the navigation, azimuth, heave, pitch, roll and slant range depths.

A zero tide file was loaded and each line was merged with the sounding data. Since navigation, heave, pitch, and roll corrections were already applied and accounted for by the Simrad beam steering algorithms, they were simply reexamined in HIPS for blatant outliers. The data were then cleaned using the HIPS subset editor and a BASE Surface was created to verify initial coverage and provide quality control feedback to the survey crew and additional guidance to the helmsman.

## B.7. Office Data Processing

### B.7.1. Initial Processing: Import, QC, and Water Gauge Application

Further to the Field Data Processing section, HIPS was used to re-open the folder structure which had already been organized by project, vessel, and Julian day. The raw multibeam data had already been imported into CARIS HIPS using the CARIS conversion wizard module while on the vessel.

Attitude data were additionally viewed in the CARIS Attitude Editor which displayed simultaneous graphical representation of all attitude sensor data using a common x-axis scaled by time. The Attitude Editor, was used to query the data and reject erroneous values if needed.

Navigation data were then reviewed using the CARIS Navigation Editor. The review consisted of a visual inspection of plotted fixes noting any gaps in the data or unusual jumps in vessel position. Discrepancies were rare and were handled on a case-by-case basis. Unusable data were rejected with interpolation using a loose Bezier curve. Data were queried for time, position, delta time, speed, and status and, if necessary, the status of the data was changed from accepted to rejected. Downloaded water level data from the Clover Island gauge were applied.

### B.7.2. Initial Merging

After inspecting the navigation and attitude data and adding the water level data, all sensors were merged with the navigation and attitude data.

### B.7.3. Area Editing

Following the merge process, additional area-based editing processes were performed in the Subset Editor during the office review of survey soundings. Processors examined the entire survey area and rejected outlying soundings unsupported by data from adjacent survey lines. Simultaneously, the data were scrutinized for any potential sound velocity issues that would require further investigation.

With subset editing, the operator was presented with two and three-dimensional views of the soundings and a moveable bounding box to restrict the number of soundings being reviewed. Soundings were viewed from the south (looking north), from the west (looking east) and in plan view (looking down). These perspectives, as well as controlling the size and position of the bounding box, allowed the operators to compare lines, view features from different angles, measure features, query soundings and change sounding status flags. Soundings were also examined in the three-dimensional window as points, wire frame or a surface which could be rotated on any plane. Vertical exaggeration was increased as required to amplify trends or features. Soundings were flagged as accepted, rejected, designated, outstanding or examined.

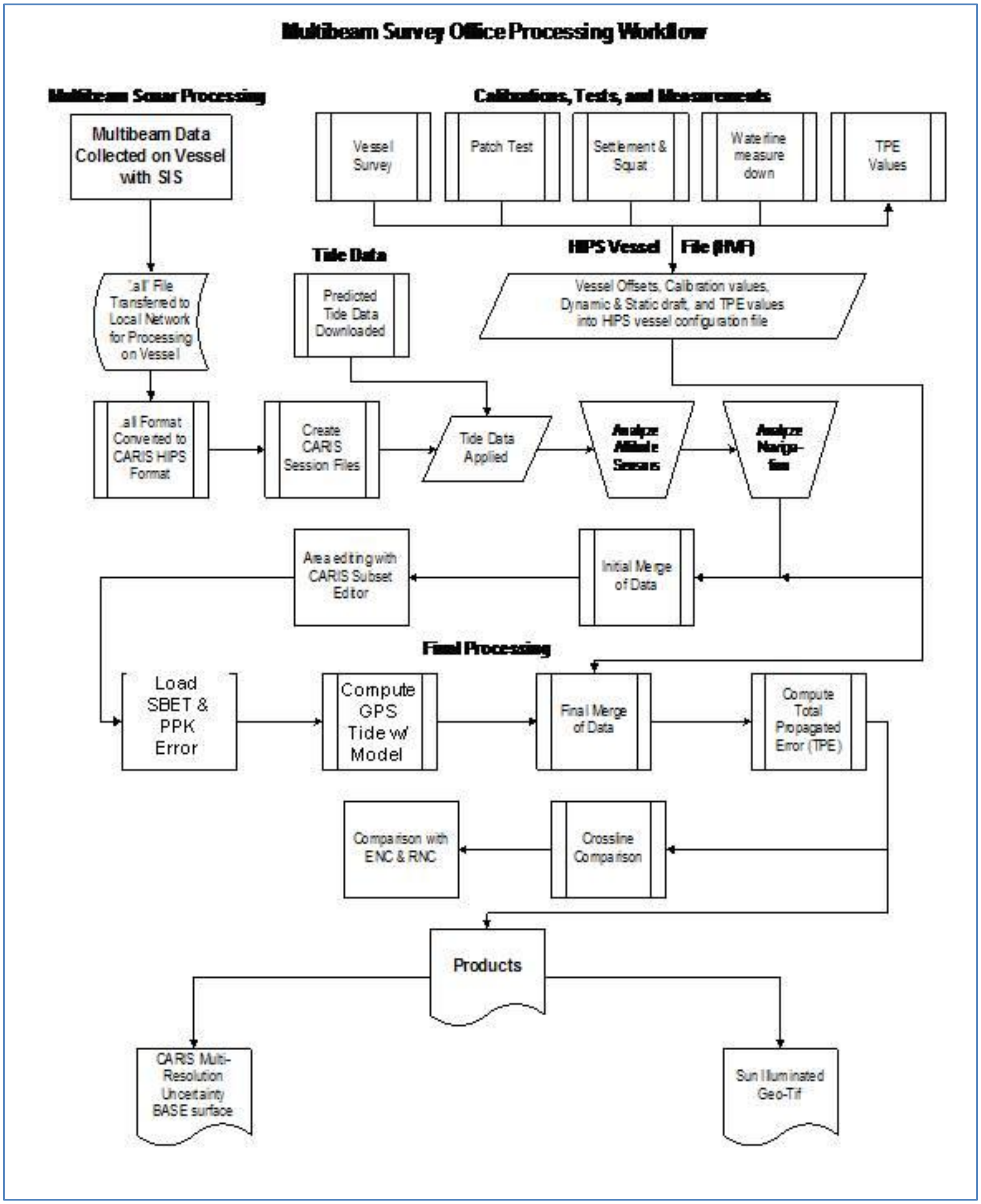



***Figure 5 illustrates the major steps in the data acquisition and reduction process with further explanation of each step being provided in the following section.***

## B.7.4. Application of PPK SBET and Error Data

The processing scheme for the Columbia River Hydrographic Survey differed from conventional methodologies in that water level correctors were ultimately not used to reduce the soundings to MLLW. Instead, ellipsoid to chart datum separations were applied to the ellipsoid heights of the sounding data to reduce the soundings to chart datum, defined as 340 feet above MSL (NGVD29). Refer to the Vertical and Horizontal Control Report for details of PPK processing and creation of the chart datum separation model.

HIPS settings for loading the PPK navigation solution and associated error data are presented in Figures 6 and 7, respectively. It is important to note that a -15 second offset was applied in HIPS to account for the fact that the POS/MV time tagged all data to GPS Time during acquisition, but POSPac PPK processing was accomplished in Applanix MMS by assuming the data were time tagged to UTC Time. This -15 second offset represents the difference between UTC and GPS Time and corrects for this invalid assumption.

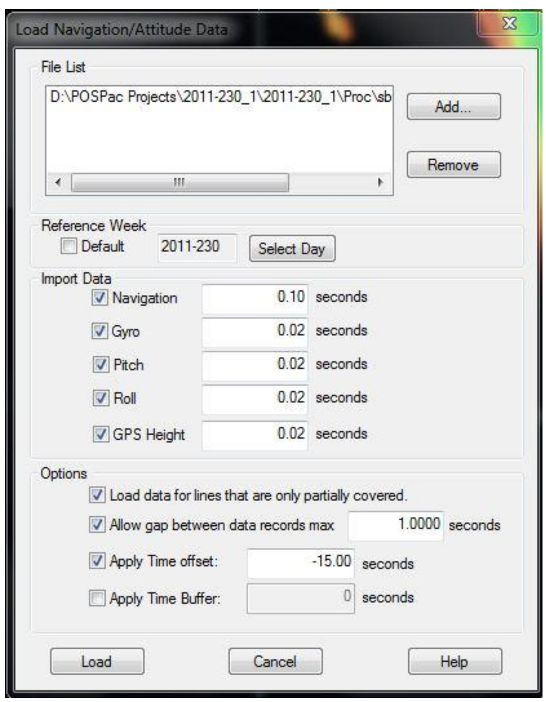



*Figure 6 . HIPS settings to import the SBET produced by Applanix POSpac MMS.*

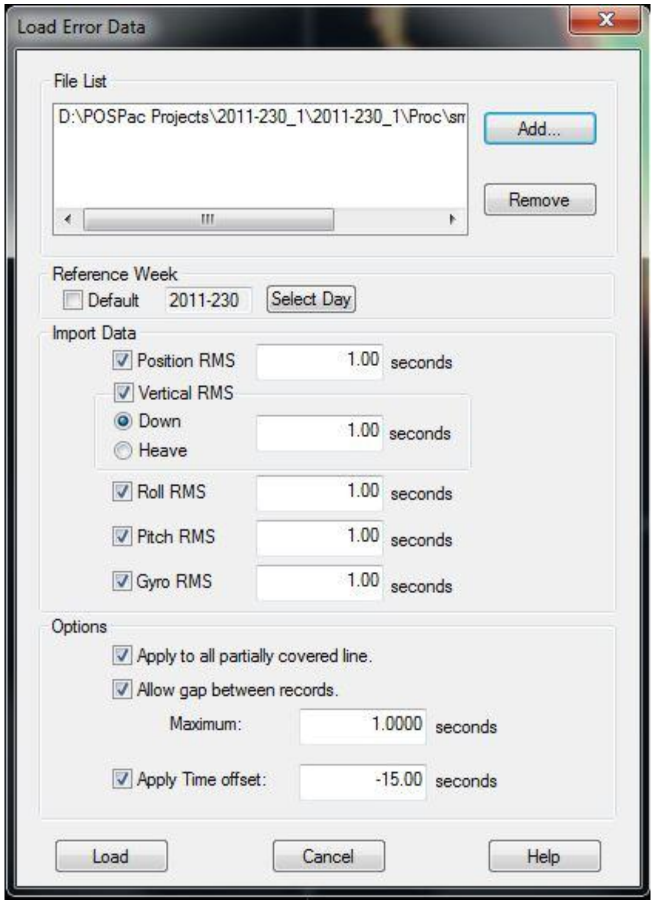



***Figure 7. SBET Error import settings in HIPS.***

## B.7.5. HIPS Final Processing

To finalize values in the last stages of data processing, a user-defined ellipsoid to chart datum separation model was applied during the Compute GPS Tide function (Figure 8). Details of creating the user-defined chart separation model are described in the <u>Vertical and Horizontal Control Report.</u> Note that several options were checked to effectively undo settings from the HVF that were used by the water level method of reduction.

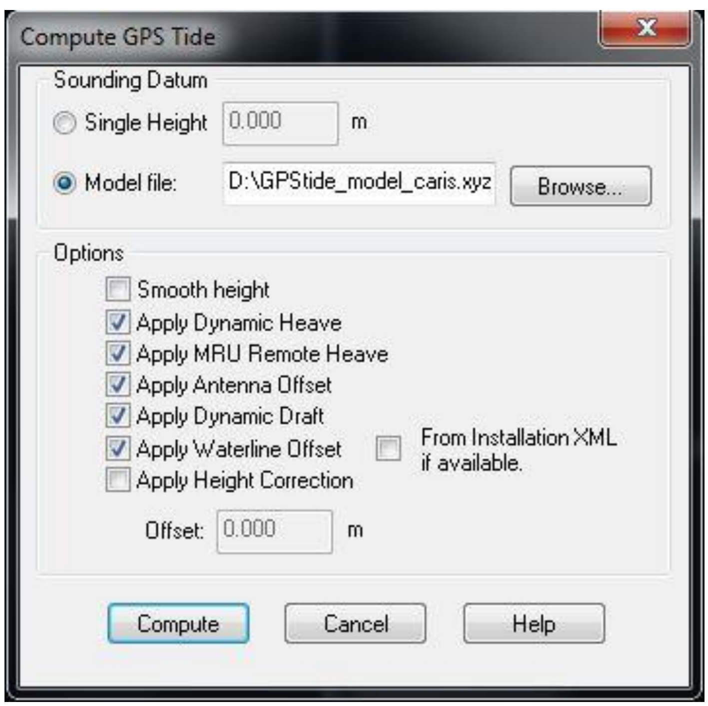



***Figure 8. SBET Error import settings in HIPS.***

Upon applying the SBET and associated errors, the GPS Tide was applied during a final merge process before Total Propagated Uncertainty (TPU) was calculated and the finalized BASE surfaces were exported. This last merge step produced final geographic positions for each sounding relative (horizontally) to the NAD83 ellipsoid, in the UTM Zone 11N projection, and to the pool/chart datum (vertically) which was 340 feet above MSL (NGVD29).

## B.7.6. TPU

The finalized BASE surfaces incorporate uncertainty values derived from TPU. The CARIS HIPS TPU calculation assigned a horizontal and depth error estimate to each sounding using the error values produced by the POSPac PPK process (Figure 9).

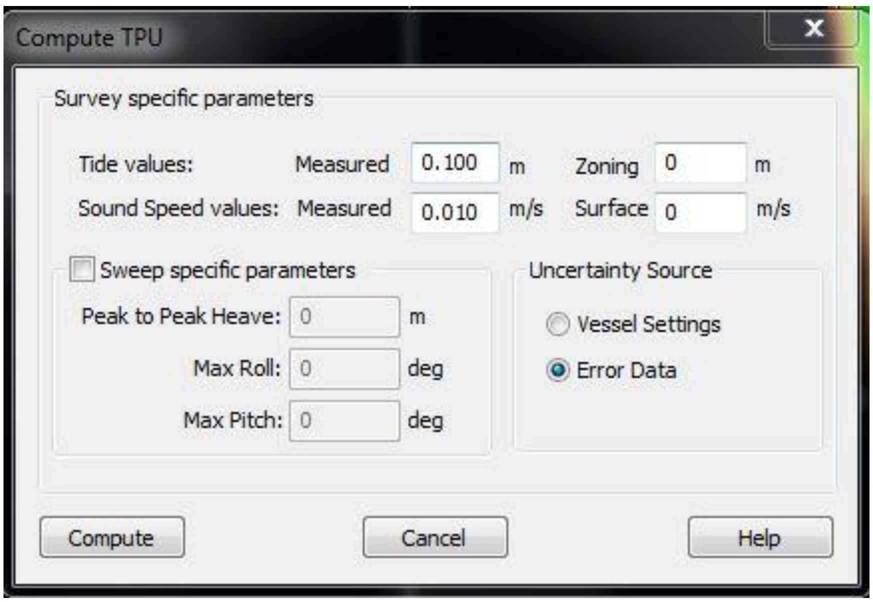



***Figure 9. TPU settings applied in HIPS.***

TPU values represent the difference between computed horizontal and vertical sounding positions and their true values at a 95% confidence level. HIPS computed TPU error values by aggregating individual error sources from the navigation, gyro (heading), heave, pitch, roll, latency, sensor offsets and individual sonar model characteristics. These error sources were obtained from a variety of sources including the manufacturer's instrument calibration process, the component spatial relationship survey (ie sensor offsets and waterline), or while running pre-survey operational tests (ie patch test, dynamic draft).

The error budgets for the *R/V Kvichak Surveyor* are presented in Table 6.

***Table 6– R/V Kvichak Surveyor error values used in computing Total Propagated Uncertainty (TPU).***

| Error Source | Method | Error Value |
|---|---|---|
| Motion Gyro | Published by Manufacturer | 0.020 (deg) |
| Heave | Published by Manufacturer | 5% amp |
| Roll | Published by Manufacturer | 0.020 (deg) |
| Pitch | Published by Manufacturer | 0.020 (deg) |
| Position Navigation | Published by Manufacturer | 1.000 (m) |
| Transducer Timing | Estimated | 0.01 (sec) |
| Navigation Timing | Estimated | 0.01 (sec) |
| Gyro Timing | Estimated | 0.01 (sec) |
| Heave Timing | Estimated | 0.01 (sec) |
| Pitch Timing | Estimated | 0.01 (sec) |
| Roll Timing | Estimated | 0.01 (sec) |
| Offset X | Direct Measurement | 0.02 (m) |
| Offset Y | Direct Measurement | 0.02 (m) |
| Offset Z | Direct Measurement | 0.02 (m) |
| Vessel Speed | Published by Manufacturer | 1.00 (m/s) |
| Loading | Published by Manufacturer | 0.010 (m) |
| Draft | Published by Manufacturer | 0.010 (m) |
| Delta Draft | Direct Measurement | 0.01 (m) |
| MRU Alignment Gyro | Estimated | 0.5 (deg) |
| MRU Alignment Roll/Pitch | Estimated | 0.5 (deg) |
| Sound Velocity | Published by Manufacturer | 0.01 (m/sec) |

Uncertainty values derived from the CARIS HIPS TPU computation were used to create International Hydrographic Organization (IHO) S-44 compliant datasets as well as calculate depth surfaces weighted by uncertainty. All soundings were shoaler than 100m and were filtered to reject soundings with uncertainty values that did not meet IHO Order 1 standards.

IHO uncertainty thresholds were determined using the following equation:

$$\pm\sqrt{[a^2 + (b*d)^2]}$$

**where:** **<u>for d < 100 meters</u>**
**a=0.5 m**
**b=0.013 m**
**d=depth (m)**

### B.7.7. Gridded Base Surfaces

Final depth information for the Columbia River Hydrographic Survey are in the form of single resolution CARIS BASE surfaces, which include uncertainty, and represent river elevations at the time of survey. BASE surfaces were produced at 1m resolution and were weighted by the greater of either the standard deviation of sounding values, or *a priori* uncertainty values derived from TPU calculation. Additionally, one sun-illuminated, geographically referenced Digital Terrain Model image depicting the coverage of the survey area was submitted. All grids were projected to UTM Zone 11 North, NAD 1983.

All steps have been taken to ensure the data have been correctly processed, however it should be noted that minimal selection of designated soundings was undertaken since the original PSNS Scope of Work did not require this procedure.

### B.7.8. Chart Compare

A sounding selection process was performed as a final quality control check and to provide a means of effectively comparing processed survey depths to those appearing on the current editions of the Electronic Navigation Charts (ENC) of the area. Contours from soundings were examined for general agreement with contours on historic ENCs.

### B.7.9. Crossline Analysis

Crossline analysis was conducted using the CARIS HIPS QC Report routine. In this beam by beam depth analysis, the crossline is compared to the finalized base surface. The differences in depth were grouped by beam number, and statistics were computed for the percentage of soundings whose depth differences fall within IHO survey Order 1.

A summary of the crossline results for the survey are provided in the <u>DR</u>. The QC Reports are included in the *Separate IV: Checkpoint Summary & Crossline Reports*.

### B.7.10. Shoreline Verification

There was no shoreline verification attempted.

## C. Corrections to Echo Soundings

The following methods were used to determine, evaluate and apply corrections to instruments and soundings:

### C.1. Vessel Offsets

Sensor locations were established by a precise survey of the vessel using conventional survey instruments, and are detailed in the associated Component Spatial Relationship Survey Report.

#### C.1.1. Vessel Survey

All sensors were referenced to the IMU onboard the *R/V Kvichak Surveyor*. Separation distances between the two POS M/V GPS antennas were measured during the component spatial survey and then verified during the Applanix POS M/V internal GAMS calibration. Sensor positional and angular offsets were determined during the patch test, and applied during collection in Kongsberg SIS acquisition software (Figures 10-13 and Table 7).

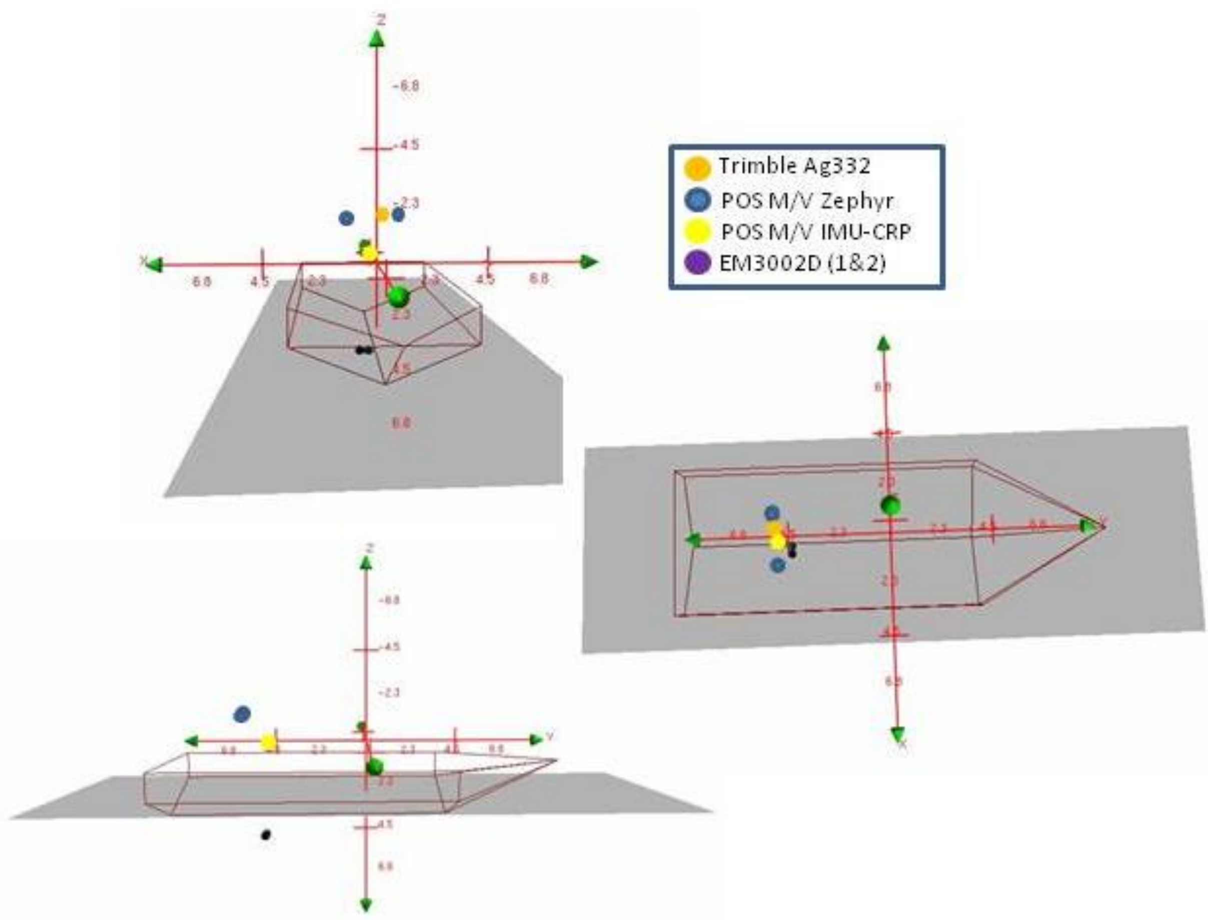



***Figure 10 - R/V Kvichak Surveyor vessel survey showing the relative positions of the installed survey equipment.***

***Table 7 – R/V Kvichak Surveyor offset measurements determined during the initial spatial component survey. The CARIS convention of + down (z), + starboard (x) and + forward (y) was used for all measurements.***

| Offset from CRP (m) using CARIS Convention | | | | |
|---|---|---|---|---|
| **Equipment** | **Manufacturer / Model** | **X** | **Y** | **Z** |
| IMU | Applanix POS M/V | 0.000 | 0.000 | 0.000 |
| MB Transducer1 | Kongsberg EM 3002D | -0.262 | -0.338 | 4.786 |
| MB Transducer2 | Kongsberg EM 3002D | 0.164 | -0.348 | 4.782 |
| GPS1 (Primary) | Applanix POS M/V | -1.005 | -0.268 | -1.861 |
| GPS2 (Secondary) | Applanix POS M/V | 1.009 | -0.312 | -1.883 |
| Ag332(Antennae) | Trimble | -0.273 | -0.289 | -2.016 |
| Waterline | | | | 2.620 |

The measured offset values listed in Table 7 were entered into SIS, although the X and Y coordinates were reversed, conforming to proper software conventions (Figure 11).

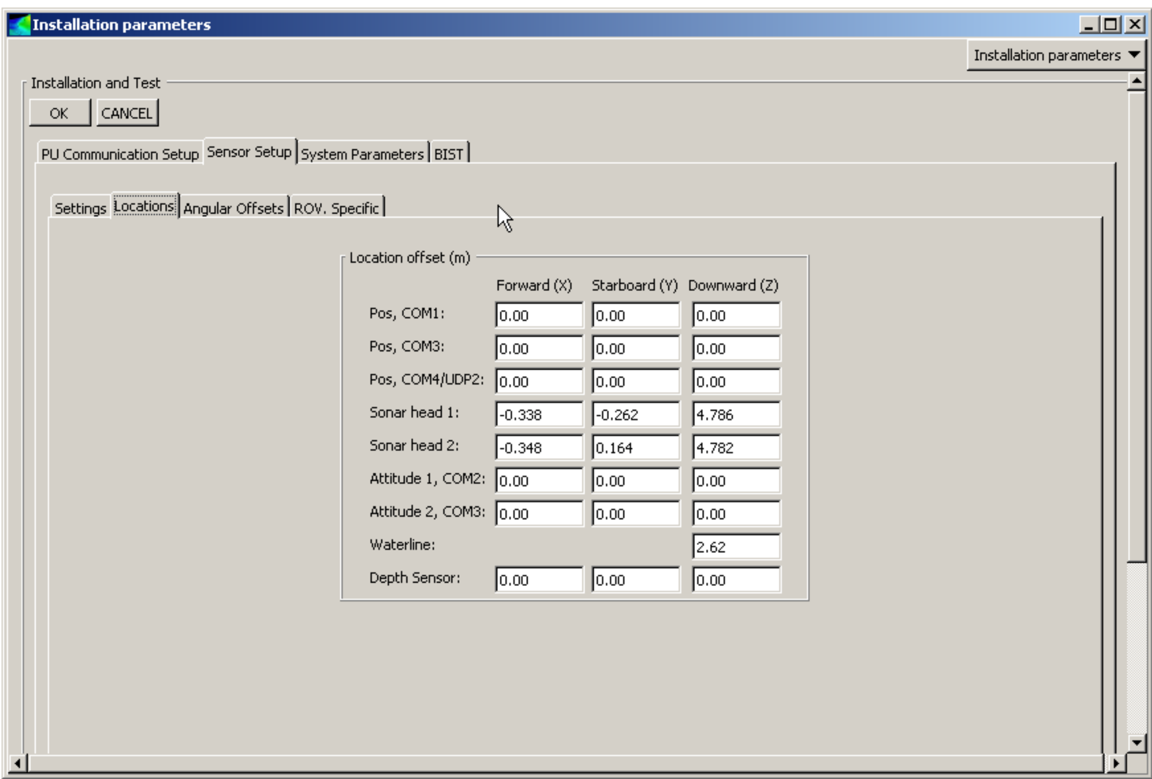



***Figure 11 – R/V Kvichak Surveyor offset measurements entered in the SIS installation parameters.***

The primary GPS1 lever arm was solely entered in the POS M/V controller (Figure 12); thus was left as zero in both SIS (Figure 11) and the CARIS HVF. Moreover, offsets for the MBES transducer heads were left as zero in the CARIS HVF, since they were already entered in SIS during acquisition.

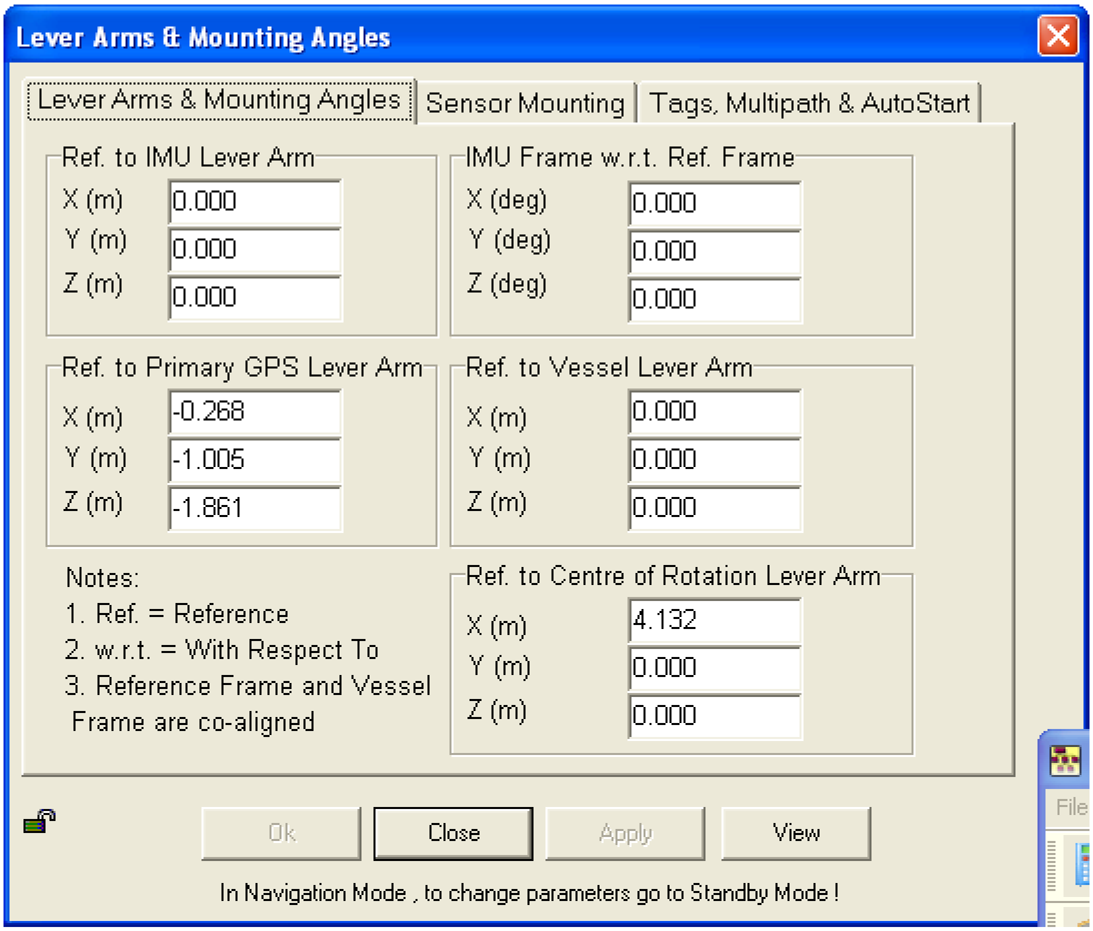



***Figure 12 – IMU to Primary GPS offset entered in the POS M/V setup.***

To correct for misalignment between the motion sensor and multibeam transducers, angular offset shifts resulting from the patch test were additionally entered into SIS as shown in Figure 13.

Refer to Section C.1.3 – C.1.7 for specifics relating to the patch test.

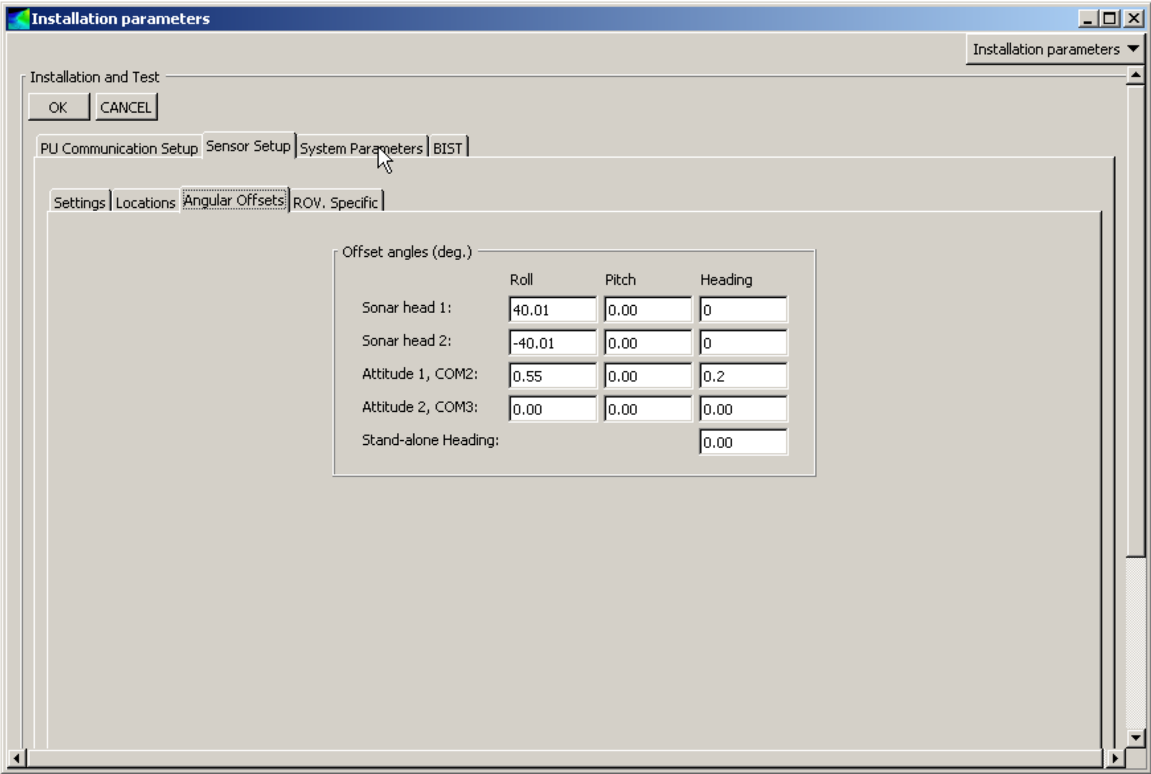



***Figure 13 –Angular offset corrections resulting from the pre-survey patch tests.***

## C.1.2. Heave, Pitch and Roll

As already mentioned, heave, pitch, and roll (HPR) data for the *R/V Kvichak Surveyor* were measured using an Applanix POS M/V 320 Attitude and Positioning System. The POS M/V output HPR values using the Simrad 3000 Tate Bryant message. Positions were relative to the IMU since a primary antenna lever arm was provided (Figure 12) in the POS Controller. The system provided output as a binary data string via RS-232 serial cable to both the SIS and QINSy acquisition stations at 100Hz.

Once again, heave, roll and pitch corrections were applied during acquisition in SIS, where the SIMRAD system used attitude values to steer both incoming and outgoing beams.

## C.1.3. Patch Test Data

Patch tests were performed on *R/V Kvichak Surveyor* to determine system latency, and composite offset angles (roll, pitch and azimuth) for the transducers and motion sensor. The offset values for pitch, azimuth, roll and navigation latency from the positioning system were resolved using the calibration editor in CARIS Subset Editor. The time-referenced values were then stored in the appropriate CARIS HVF file (needed for TPU calculation only) and entered into the SIS acquisition software where they were applied to the raw soundings during acquisition.

Patch test lines were run as described below to account for the following offsets:

### C.1.4. Navigation Latency

A single survey line was run twice, in the same direction, at different speeds over a sloping feature.

### C.1.5. Pitch

Pitch offset was determined by running two pairs of reciprocal lines at the same speed, perpendicular to a sloping feature.

### C.1.6. Azimuth

Azimuth (yaw) offset was calculated by running two adjacent pairs of reciprocal lines at the same speed along a sloping feature.

### C.1.7. Roll

The roll was calculated and compensated for by running two pairs of reciprocal survey lines at the same speed over a regular and flat sea floor.

## C.2. Speed of Sound through Water

Sound Velocity profiles were collected using a Seabird SBE19. An AML Smart probe was additionally used to verify the accuracy of the SBE19, and was input into SIS to real-time correct surface sound speed at the head.

Twenty two sound velocity profiles were taken over the course of the survey. Sound velocity casts were spaced geographically to represent the spatial distribution of data.

Sound speed profiles were loaded into the Kongsberg SIS acquisition software and applied in real-time to the raw sounding data. The DR, *Separate II: Sound Speed Data* contains a detailed listing of the sound speed profiles and applicable cast dates used during the survey.

## C.3. Waterline

Waterline was determined by measuring down from a survey punch directly below the IMU through the moon pool to the waterline. Measure-down was conducted in calm water prior to commencing survey, as rough water precluded accurate measurement while underway. This static draft measurement was entered in the CARIS HIPS Vessel File (but was not applied) and in SIS where it was applied during acquisition.

## C.4. Settlement and Squat

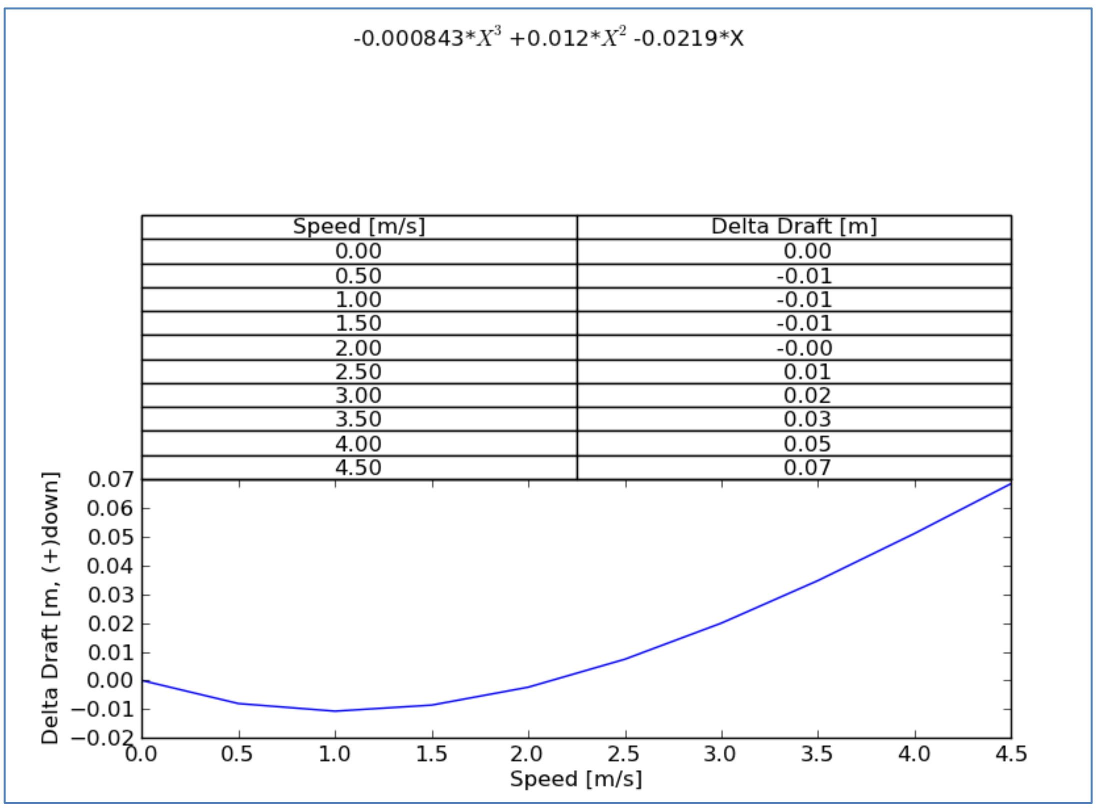
***R/V Kvichak Surveyor***

Even though the survey was conducted as an ERS, settlement and squat measurements for *R/V Kvichak Surveyor* were conducted in an effort to model dynamic draft for the simple use of verifying the ERS methodology and final output. Post Processing Kinematic (PPK) GPS Survey Techniques were employed in Puget Sound, Washington on August 6, 2011 to create the Dynamic Draft model for the vessel. The measurements were made using a POS M/V attitude and positioning sensor following the ERDDM procedure described in the NOS Field Procedures Manual. Approximately one hour was dedicated to acquire Ellipsoid Referenced Dynamic Draft Model (ERDDM) estimates at speeds ranging from 0-8 knots. These speeds were selected to represent the practical operational limits of the vessel during survey. While the POS M/V was operating in RTCM DGPS mode, POSPac file recording was initiated approximately 5 minutes prior to increasing speeds from 0 to 2, 4, 6 and 8 knots. Data were logged for approximately two minutes at each speed jump and then repeated in the exact order using a reciprocal direction.

PPK analysis was accomplished in Applanix POSPac MMS 5.4 . The Smart Select and Smart Base were used in MMS to select several CORS stations and to generate an additional local virtual base reference station (VRBS) near the operational area in Elliott Bay.

The PPK solution created a Smooth Best Estimate of Trajectory (SBET) and associated errors which were imported into Pydro v. 11.3. The dynamic draft table was then calculated using the ProcSBETDynamicDraft.py script (Figures 14-15).

Since the ERDDM test was conducted in a tidally influenced area, tide correctors were also applied in Pydro using data a TCARI model of the Puget Sound.



| Speed [m/s] | Delta Draft [m] |
|---|---|
| 0.00 | 0.00 |
| 0.50 | -0.01 |
| 1.00 | -0.01 |
| 1.50 | -0.01 |
| 2.00 | -0.00 |
| 2.50 | 0.01 |
| 3.00 | 0.02 |
| 3.50 | 0.03 |
| 4.00 | 0.05 |
| 4.50 | 0.07 |



*Figure 14 - R/V Kvichak Surveyor Draft vs. Speed Plot.*

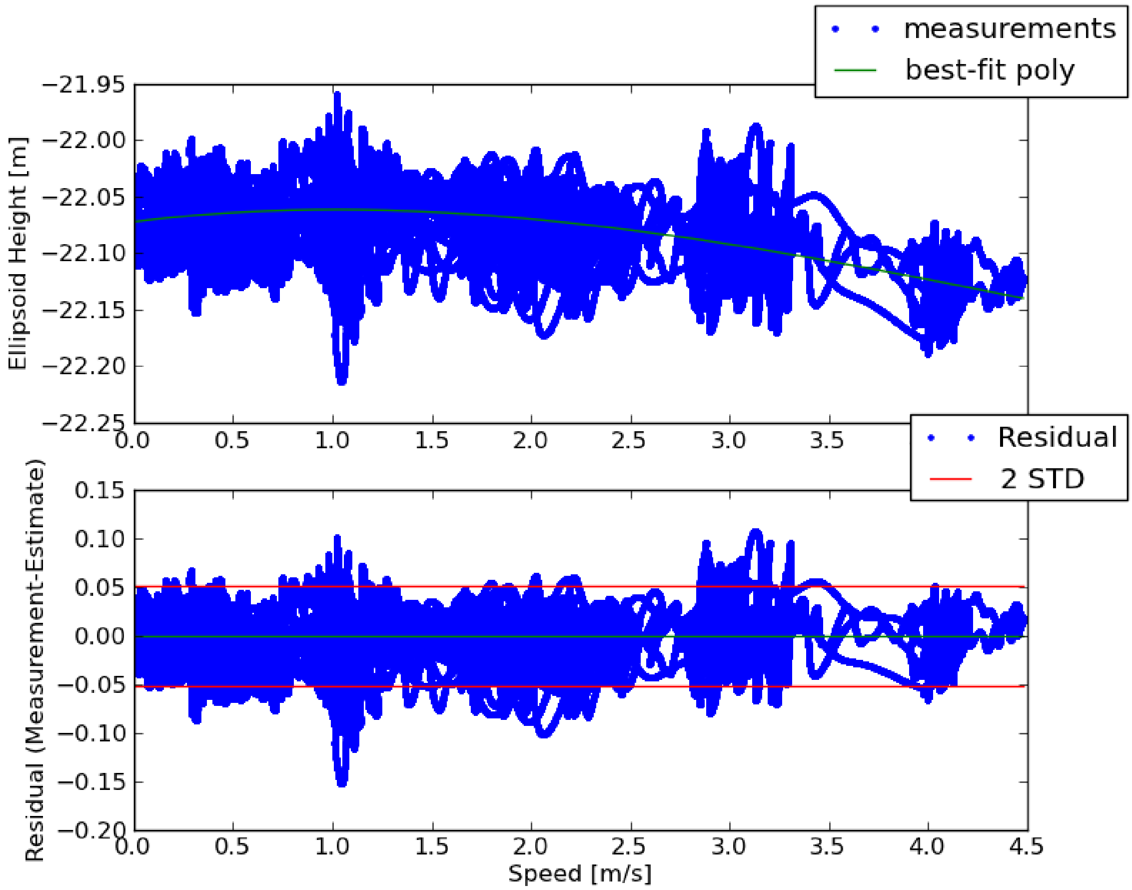



*Figure 15 – Regression Analysis of Ellipsoid Height versed Speed*

In the end, influence of dynamic draft was ultimately removed during the final sounding reduction (see Figure 8) during the Compute GPS Tide function since water levels were not used during sounding reduction.

## C.5. GPS Tide Corrector

Water level data from the Clover Island gauge (USGS National Water Information System 12514500) were obtained and corrected to chart datum (defined as 340 feet above Mean Sea Level), but were only used during preliminary analysis and to verify validity of the GPS Tide process. Final soundings were corrected to chart datum (defined above) by using GPS Tide corrections and a custom model. See the associated Vertical and Horizontal Control Report for additional details.

## C.6. Project Wide Tide Correction Methodology

A single base station PPK solution was applied to vertically correct soundings to chart datum.

# LETTER OF APPROVAL

REGISTRY Numbers: N/A (Survey Name: Columbia River Hydrographic Survey)

This report and the accompanying digital data are respectfully submitted.

Field operations contributing to the accomplishment of the Columbia River Hydrographic Survey were conducted under my direct supervision with frequent personal checks of progress and adequacy. This report, digital data, and accompanying records have been closely reviewed and are considered complete and adequate.

Other reports submitted with the Columbia River Hydrographic Survey include the Descriptive Reports, the Vertical and Horizontal Control Report, and the Spatial Relationship Components Survey.

I believe this survey is complete and adequate for its intended purpose.

______________________________________________

**Steven S. Intelmann, Physical Scientist**
NOAA

9 December 2011
Date________________________