APPENDIX A:

SURVEYS AND WATER MEASUREMENTS

1 BACKGROUND

This section describes the data used to support the hydraulic modelling components of the project. Ground elevation data was drawn from existing data sets, and from a series of surveys carried out for this project. The acquisition of topographic, bathymetric, and hydrographic information forms the basis of data inputs for the hydraulic modelling component. The topographic data was mainly LiDAR, and NHC surveys. Bathymetric data included National Oceanic and Atmospheric Administration (NOAA) data for Alberni Inlet, Provincial lake and river surveys, and extensive NHC bathymetric surveys.

NHC set up a series of water level sensors at key locations in the study area to augment existing data sets from Catalyst Paper (Catalyst), and the Water Survey of Canada (WSC). NHC also carried out discharge measurements during the largest flood event in the 2018/19 flood season.

2 DATUM AND COORDINATE SYSTEM DETAILS

Several vertical datums are in use for current and historic data in the Somass study area. The Canadian survey and cartography industry has adopted the Canadian Geographic Vertical Datum 2013 (CGVD 2013), and the province of British Columbia is migrating to this datum as new projects come on line. As such, CGVD 2013 was selected for the project.

In summary, specific coordinate system details are:

- Horizontal Datum: North American Datum 83 (NAD83) CSRS 3.0.0.BC.1.NVI
- Projection: UTM Zone 10 North
- Vertical Datum: CGVD 2013
- Geoid Model: CGG2013a

3 LIDAR

LiDAR (Light detection and ranging) data was used for general terrestrial topography. LiDAR was flown on September 18, 2018 for the initial study area. Over the course of the project the study boundaries were revised to extend up Kitsuksis Creek and further south into the Alberni Inlet. As such the 2018 LiDAR did not cover the revised study area. LiDAR was also flown on July 16, 2014 for a previous study; it covers an area from Kitsuksis Creek in the north, to the Alberni Inlet in the south. The 2014 LiDAR was used to cover the areas the 2018 LiDAR did not cover.

Both the 2018 and 2014 LiDAR datasets were comprised of bare earth and full-feature data. For this project bare earth data was used as it provides a more accurate representation of the topography. For example, in full-feature data forests are represented as large, solid blocks and therefore would be interpreted as such by the hydraulic model. Adopting bare earth data is considered the appropriate option for this project.

The horizontal datum of both datasets is NAD83 (CSRS), and the vertical datum is CGVD28. The vertical datum was transformed to CGVD2013 using a shift grid derived from the NRCAN GPS-H tool for use in this study. Once converted to CGVD2013, both datasets were subjected to a QA/QC process. The accuracy of the shift grid was reviewed by selecting 22 checkpoints on consistently flat surfaces (such as parking lots). It was found that there was between 0.025 and 0.099 m difference between the ground-only datasets. The datasets were then combined with the 2018 data taking priority over the 2014 data.

Elevations were checked at the LiDAR checkpoints in the field and were compared against the 2018 LiDAR data. It was found that there was consistently less than 0.10 m difference in elevations.

All analyses with the LiDAR data was undertaken with ArcGIS Pro 2.2.

4 BATHYMETRIC CHARTS

For the purpose of modelling the tidal and wave effects on flood water levels in the Somass River, a bathymetric map of the Alberni Inlet was acquired from the National Oceanic and Atmospheric Administration (NOAA). Metadata for the NOAA bathymetry indicated surveying of the Inlet began in 1930 and was most recently updated in 2012. The map of the Inlet was produced at a 1/3-arc second grid scale. NOAA bathymetry required shifting from North American Vertical Datum 1988 (NAVD88), geoid 12B datum, to Canadian Geodetic Vertical Datum 2013 (CGDV2013) datum.

Bathymetry data of Sproat Lake was created by stitching together Provincial bathymetry mapping with data collected by Catalyst in the fall of 2018. Catalyst data consists of bathymetric information around their weir on Sproat Lake. The Provincial 1:14,400 scale bathymetric map of Sproat Lake was surveyed in 1951 by the BC Ministry of Environment at.

No bathymetry data of Great Central Lake was required for the study as a one-dimensional wave hindcast was implemented.

5 SURVEY EQUIPMENT

NHC carried out a series of surveys that included setting up a control network, and collecting ground, bridge, bathymetric and hydrographic surveys. The following equipment was used to complete the survey work:

- Trimble R10 GNSS RTK GPS rover receiver
- Nikon NPL 332 total station
- Trimble R10 GNSS RTK GPS base receiver w/ Trimble TDL 450 35-watt radio
- Trimble TSC3 controller w/ Trimble Access field software
- Leupold RX-1200i Rangefinder
- Trimble Business Center desktop software
- Ohmex Sonarmite 200 kHz sounder sounding at 2 Hz

- Castaway CTD Sound Velocity Profiler
- Panasonic CF31 Toughbook w/ Intel I5 processor
- Hypack 2017 hydrographic software
- Aluminum jet boat

6 ACCURACY CONSIDERATIONS

The following are equipment accuracies in ideal field conditions:

- Trimble R10 GPS RTK receivers: +/-0.05 m
- Ohmex Sonarmite sounder: +/- 0.02 m
- Nikon NPL 332 Total Station: +/- 0.02 m

Typically, the overall bathymetry survey accuracy is 0.10 to 0.15 m for the multi-sensor kinematic (moving collection) setup applied. However, with the challenging river conditions on the Stamp and Sproat rivers, specifically during data collection under mobile bed conditions, the accuracy may be +/- 0.30 m in some locations. Ground surveys using GPS have a normal accuracy of +/- 0.05 m. Total station surveys, such as of the bridge structures, have +/- 0.05 m accuracy.

7 CONTROL SURVEYS

The control network for the project area was set using a static survey. A base receiver was set up in the morning each day at a central location and left to log static data for 8 hours. The full day occupation static data was submitted to National Resources Canada Precise Point Positioning (NRCAN PPP) post processing service. The resulting coordinates where checked to British Columbia Provincial survey monument GCM 492173. A correction to the base point was completed to match the published location and elevation of GCM 492173. The corrected results were inserted into the control network as survey grade start points. Raw observations of short roving occupations were uploaded into Trimble Business Center and processed with the dual frequency baseline processor to ensure accuracy through the project area.

8 RIVER BATHYMETRIC SURVEYS

The bathymetric surveys for the Somass, Kitsuksis, Stamp, and lower Sproat were completed by NHC during the period from January 14, 2019 to February 28, 2019. The bathymetric survey for the upper Sproat River (weir to Highway 4 bridge) was completed by NHC during low flows in August 2019. The bathymetric surveys were carried out to collect data to represent the channel geometry for the hydraulic model input, and to support the historical cross section comparisons by re-surveying along the same alignments previously surveyed in the 1997 Province of BC study (BC MELP, 1997). At several locations of historical cross sections (Figure 1), a GPS/Sounder survey was not feasible due to bridge

locations, river flows and current. During the planning phase of the river cross section spacing, the locations were refined to obtain an appropriate hydraulic representation of Kitsuksis Creek, Somass, Sproat, and Stamp rivers. A total of 517 cross sections were surveyed, with 50 cross sections at the same locations as the historical sections (Table 1).

The bathymetric survey was separated into two styles. Each style was tailored to the meet the requirements of a 1D or 2D model, Figure 1. The greatest survey efforts were focused in the 2D model domain. Equipment included a Trimble R10 base and receiver GPS in conjunction with an Ohmex Sonarmite 200kHz sounder. The raw sounder data was connected to a Panasonic CF31 Toughbook with Hypack hydrographic acquisition software. In the lower reaches of the Somass River, a Castaway CTD sound velocity profiler was used to produce an accurate sound velocity profile based on temperature and salinity.

Hypack 2017 Single Beam Editor was used to process the very large amount of bathymetry data collected. Viewed in profile, each bathymetry file was reviewed for outliers, checked for GPS reliability and then finally smoothed over an average of 5 measurements. The smoothing routine addressed some of the noise inherent in the sounding data. All bathymetry data was exported into time-stamped tabular format for import into GIS and DEM integration.

All other survey information was compiled in Trimble Business Center software, filtered with QA/QC measures, and then exported into time-stamped tabular format.

Table 1. Overview of surveyed reaches in the Somass Watershed.

Description	Reach length (km)	Reach start stationing (km)	Reach end stationing (km)	Number of historic sections resurveyed	1D or 2D Model
Somass River and the Alberni Inlet	9.85	0	9.85	25	2D
Lower Sproat River	2.04	0	2.04	2	2D
Upper Sproat River/Sproat Lake	0.50	2.37	2.95	N/A	1D
Lower Stamp River	4.2	0	4.2	11	2D
Upper Stamp River/Great Central Lake	2.6	13.8	16.4	N/A	1D
Kitsuksis Creek	1.8	0	1.8	12	2D

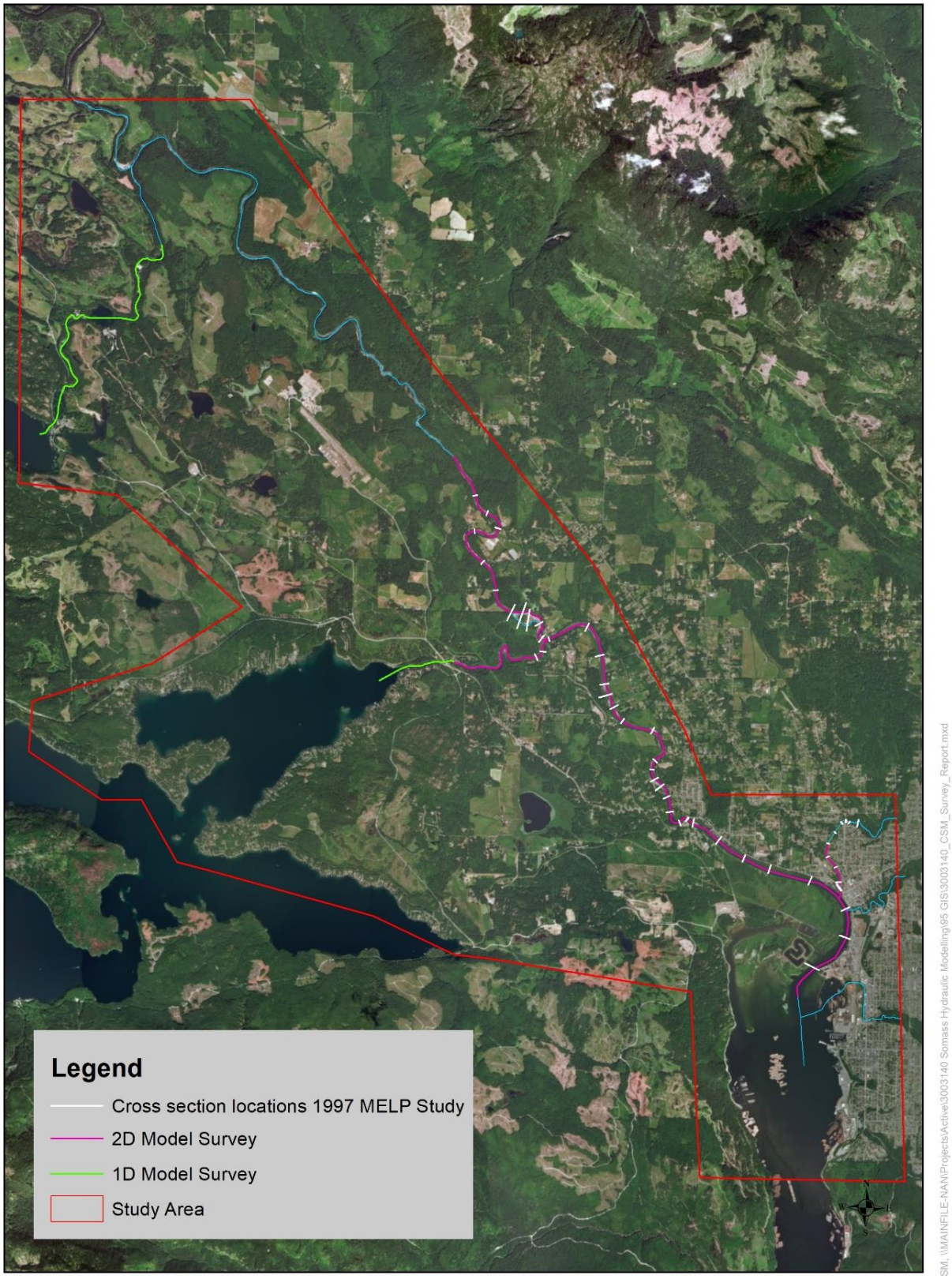

Figure 1 **Overview of bathymetric survey locations for 1D and 2D model reaches. Historical cross section locations shown in white.**

9 BRIDGE SURVEYS

Eight bridges were surveyed. At each bridge location, the following items were recorded:

- Top of bridge deck
- Span length
- Span width
- Top elevation (top of curb or solid guardrail – upstream and downstream)
- Low Chord elevation
- Any constricting factors of the river at the bridge locations upstream and downstream
- Piers
    - Number
    - Location
    - Width
    - Type (e.g., concrete, pile bent, etc.)
    - Shape (e.g., round nose, wedge shape, etc)

The bridges that were surveyed for this project are shown in Table 2.

Table 2. Overview of bridges surveyed for this study.

NHC ID	Bridge	Stream Name	River Station	Road/Trail	Owner
1	Rogers Creek vehicle traffic bridge	Rogers Creek	100	Victoria Quay	City of Port Alberni
2	Kitsuksis Creek vehicle traffic bridge	Kitsuksis Creek	185	River Road	Ministry of Transportation and Infrastructure
3	Kitsuksis Creek pedestrian traffic bridge	Kitsuksis Creek	165	Pedestrian Path	City of Port Alberni
4	Somass River Highway 4 vehicle traffic bridge	Somass River	6085	Highway 4	Ministry of Transportation and Infrastructure
5	Stamp River Ash main vehicle traffic bridge	Stamp River	21,121	Ash Main	Unknown
6	Boot Lagoon Ash main vehicle traffic bridge	Boot Lagoon	na	Ash Main	Unknown

10 WATER LEVEL RECORDERS

Five water level recorders were deployed in the study area to supplement existing data from Catalyst and WSC. The water level recorders were deployed in the fall of 2018 to capture the 2018/2019 flood season. The water level recorder locations were selected to best support the model verification and calibration processes (Figure 2).

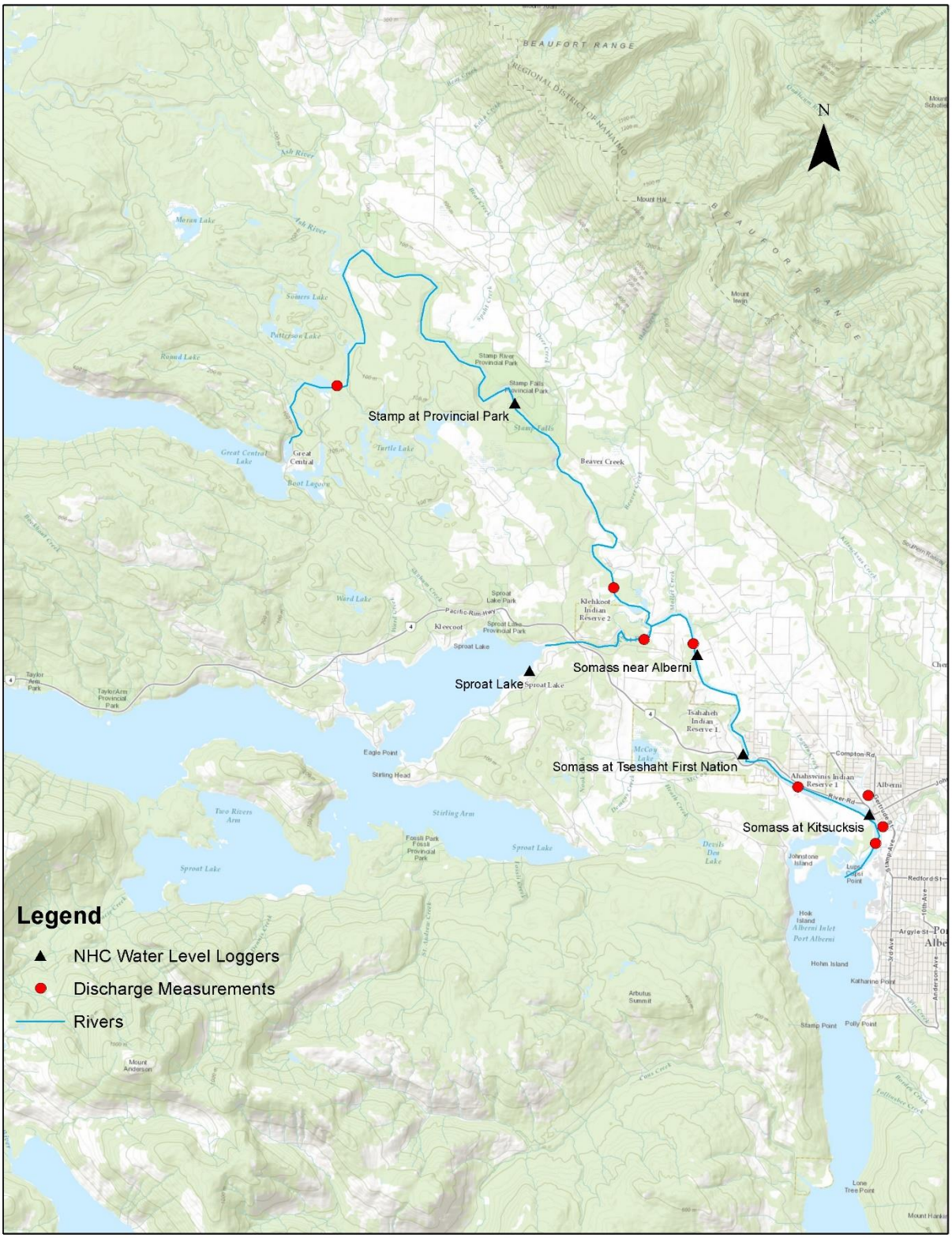

Figure 2 **Map of hydrometrics within the study area. Water level sensors and discharge measurement locations are highlighted.**

10.1 Access Agreements

BC Parks approved the installation of the Stamp River Provincial Park site (Figure 2). A Letter of Authorization was granted the Clayoquot Area Supervisor at the BC Parks West Coast Region. This authorization permitted the installation and maintenance of a water level sensor within Stamp River Provincial Park, with conditions that protected the natural state of the park.

Island Timberlands provided an access agreement for sensors that were installed on the river that required access through their property.

A formal access agreement was not required to install a water level sensor at Kitsuksis Marina. The Director of Operations at the Port Alberni Port Authority participated in an initial assessment and provided permission to install the sensors on their structures.

Tseshat First Nation provided access to their land for installation of a water level sensor just upstream of the Highway 4 bridge.

10.2 Instrumentation

NHC installed five water level loggers and one barometric pressure sensor (Table 3). Installation dates and site visits are recorded in Table 4. Solinst Levelogger Edge water level sensors were installed in a galvanized steel pipe bolted to an existing permanent structure. Where possible, the sensors were sheltered from high flow velocities and vandalism. Some of the sensor locations were upstream of hydraulic control features such as weirs or riffles.

Three benchmarks were established at each site and used to verify water level and instrument position during installation and subsequent site visits. The benchmarks, the bottom of the sensor, and the water surface were surveyed at each site to provide elevations in CGVD2013 datum. These measurements were used to shift the water level records into CGVD2013 datum.

Table 3. NHC water level data network summary.

Site	Sensor*	Model	Units	Sampling Interval	Lat. (°)	Lon. (°)
Sproat Lake	Levelogger	M5	M	5 minutes	49.28423	-124.91833
Stamp Provincial Park	Levelogger	M1	m	15 min.	49.33692	-124.92485
Stamp Provincial Park	Barologger	N/A	kPa	15 min.	49.33692	-124.92473
Somass near Alberni	Levelogger	M1	m	15 min.	49.28827	-124.86797
Somass near Tseshaht	Levelogger	M1	m	15 min.	49.26893	-124.85339
Somass near Kitsuksis	Levelogger	M1	m	15 min.	49.25757	-124.81490

Notes: *all sensor types are manufactured by Solinst; Edge models.

Table 4. Summary of hydrometric site visits and work completed.

Site	Date	Work Completed
Sproat Lake	4 Dec. 2018	station installation and survey
	29 Jan. 2019	sampling interval changed to 5 min., data downloaded
	6 Feb 2019	data downloaded, survey completed
Stamp Provincial Park	4 Dec. 2018	station installation and survey
	7 Feb 2019	data downloaded, survey completed
Somass near Alberni	29 Nov. 2018	station installation and survey
	7 Feb 2019	data downloaded, survey completed
Somass near Tseshaht	23 Nov. 2018	station installation and survey
	6 Feb. 2019	data downloaded, survey completed
Somass near Kitsuksis	23 Nov. 2018	station installation and survey
	6 Feb. 2019	data downloaded, survey completed

10.3 Catalyst Paper Data

Catalyst Paper operates two water level sensors utilized by NHC in this study; one at the Great Central Lake Stamp River Dam, and the second at the deactivated WSC gauge on the Stamp River downstream of the Robertson Creek Hatchery (Table 5). Catalyst data are collected via an ultrasonic sensor by Miltronics and data are transferred via a telemetry system to a computer at Great Central Lake Dam. The sensor at Great Central Lake Dam is mounted on a metal arm extending from Bay 3 on the upstream side of the dam. At the Stamp River site, the sensor is mounted in a concrete stilling well with an intake pipe extended into the river.

In order to verify water level data and complete a datum shift from Catalyst's dam datum to CGVD2013 datum, benchmarks were established at both Great Central Lake Dam and Stamp River Catalyst sites. At the Stamp River site, two existing WSC benchmarks were surveyed. Surveyed benchmarks and water surface elevations were used to verify water level measurements. The average difference between the surveyed water surface elevation at a minimum of two points were used to shift the data to the CGVD2013 datum.

Table 5. Catalyst Paper water level data sources, including sensor type, model, units, sampling interval, data record, and latitude and longitude.

Site	Sensor	Model	Units	Sampling Int.	Record	Lat. (°)	Lon. (°)
Great Central Lake Dam	Miltronics	Multiranger Plus	m	Daily	2007-2019	49.32858	-124.99168
Stamp near Robertson	Miltronics	Multiranger Plus	m	Daily	2007-2019	49.33912	-12497766

10.4 Quality Assurance

Water level data processing was completed in Aquarius, a water data management software. The following post-processing steps were applied to each dataset:

- Barometric compensation to water level data
- Spike removal
- Gap-filling via linear interpolation for short gaps
- Unit conversion (for Catalyst data only)
- Data offset to shift data to surveyed water level

Additional data corrections tools such as accounting for sensor drift were not applied because manual verification of the water level on several occasions confirmed its position.

11 DISCHARGE MEASUREMENTS

Discharge measurements were made throughout the Somass watershed to relate water levels to flow (Figure 2). A local company was contracted to operate their jetboat on the 18th and 19th of December during high flows. Discharge measurements were made by NHC on the Somass River, Stamp River, Sproat River, Kitsuksis, and Rogers and Kitsuksis Creeks (Table 6). Discharge was measured using a Sontek M9 acoustic doppler current profiler (ADCP) fitted with a GPS unit mounted to the side of the jetboat.

River Surveyor Live software was used to process the discharge measurements and to make QA/QC adjustments. Because the riverbed was moving due to high flows at the time of measurement, the GPS track was used to provide a spatial reference. A moving bed test can also provide an estimate for the rate of movement of the riverbed. At least four transects were used to calculate discharge for each site, two from each bank where possible.

Table 6. ADCP discharge measurement summary. Measurements include discharge (Q), date, time, site name, and latitude and longitude.

Measurement	Q (m^3/s)	Date/Time (PST)	Site	Lat. (°)	Lon. (°)
ADCP-5	650.554	18-Dec-2018 15:21	Somass River d/s Rogers Creek	49.25188	-124.813
ADCP-4	589.207	18-Dec-2018 14:54	Somass near Kitsuksis/Hwy 4	49.26259	-124.837
ADCP-3	586.492	18-Dec-2018 11:55	Somass below Confluence	49.29039	-124.869
ADCP-2	178.152	18-Dec-2018 10:56	Sproat River	49.29098	-124.884
ADCP-1	390.231	18-Dec-2018 13:22	Stamp River	49.30102	-124.894
ADCP-hatchery	207.973	19-Dec-2018 10:09	Stamp near Robertson Hatchery	49.33944	-124.979
ADCP-Kitsuksis	18.813	18-Dec-2018 15:44	Kitsuksis Creek	49.26092	-124.815
ADCP-Rogers	17.47	18-Dec-2018 16:04	Rogers Creek	49.25518	-124.811

12 REFERENCES

BC MELP (1997). *A Design Brief on the Floodplain Mapping Project for Somass River and Tributaries at Port Alberni, BC* (35100-30/100-5229). Prepared by Ministry of Environment, Lands and Parks, Victoria, BC.