

## *Supplementary Material*

### **1 Supplementary Text, Figures and Tables**

#### **1.1 Supplementary Text**

##### **1.1.1 GNSS receiver and antenna**

WaSP has been deployed using Trimble 5700 and R7 GPS receivers with Zephyr Geodetic antennas and Septentrio PolaRX-5 GNSS receivers with Septentrio PolaNt-x MF antennas. While the form factor of these receivers is similar, the port configurations are different. The 5700/R7 has antenna and power ports on the same short end of the receiver, while the PolaRX-5 has these ports on opposite short ends. Therefore, the internal antenna cable for the PolaRX-5 is an 18-24" RG-58 with a right angle TNC connector on the receiver end, while the 5700 and R7 use a 12" RG-58 cable with straight male TNC connectors on both ends. Both Zephyr Geodetic and PolaNt-x MD antennas have TNC cable connections, so no additional modifications are required for the external antenna cable. We deployed RG-58 TNC(m)-TNC(m), 12-24" cables, with the internal and external antenna cables both connected to a female-female TNC bulkhead mounted to the pelican case enclosure.

The standard mount for most GPS antennas is a 5/8 x 11 threaded rod or bolt. We recommend using a stopper (such as a nut) to prevent the mount from bottoming out against the antenna casing. A lock washer may also be used in high vibration environments to prevent the antenna from working loose on the mount.

##### **1.1.2 Power system**

In ideal conditions at peak battery health, a 7 Ah battery should run a Trimble 5700/R7 for ~22.7 h, and the Septentrio PolaRX-5 for ~26.3 to 38.2 h. The UNAVCO Polar group assumes up to 50% battery capacity reduction due to extreme cold temperatures (tested to -40 °C). Therefore, the 7 Ah battery should power WaSP for a full workday deployment in most conditions.

Power consumption for the Trimble 5700/R7 was approximately 3.7 W (<http://kb.unavco.org/kb/article/trimble-r7-5700-resource-page-472.html>). The 5700/R7 can be powered either by internal Li-ion rechargeable batteries or an external power source. UNAVCO Polar experience suggests that the Li-ion batteries are unreliable in cold conditions.

Power consumption calculations with various receiver configurations for Septentrio PolaRX-5 can be found at: <http://kb.unavco.org/kb/article/septentrio-polarx5-power-consumption-841.html>. For this project, with logging rates of 1 Hz and no external communications, power draw was 2.2 to 3.2 W, depending on constellation tracking.

##### **1.1.3 WaSP Float**

The WaSP float thicknesses varies between ~11 cm and ~13 cm. The float widens to ~46 cm at ~23 cm from the nose and a width of ~46 to ~47 cm is maintained throughout the float before pulling into a wide swallow tail with ~7.5 cm tail blocks, and a ~30.5 cm wide and ~18 cm deep swallow. The float has hard rails, resulting in a step-deck with aggressive angles between the deck and the vertical side rail.

### 1.1.4 TEQC pseudo code

Pseudo syntax for executing a splicing operation in TEQC is:

```
teqc InputFile00.obs InputFile01.obs InputFileN.obs > OutputFile.obs
```

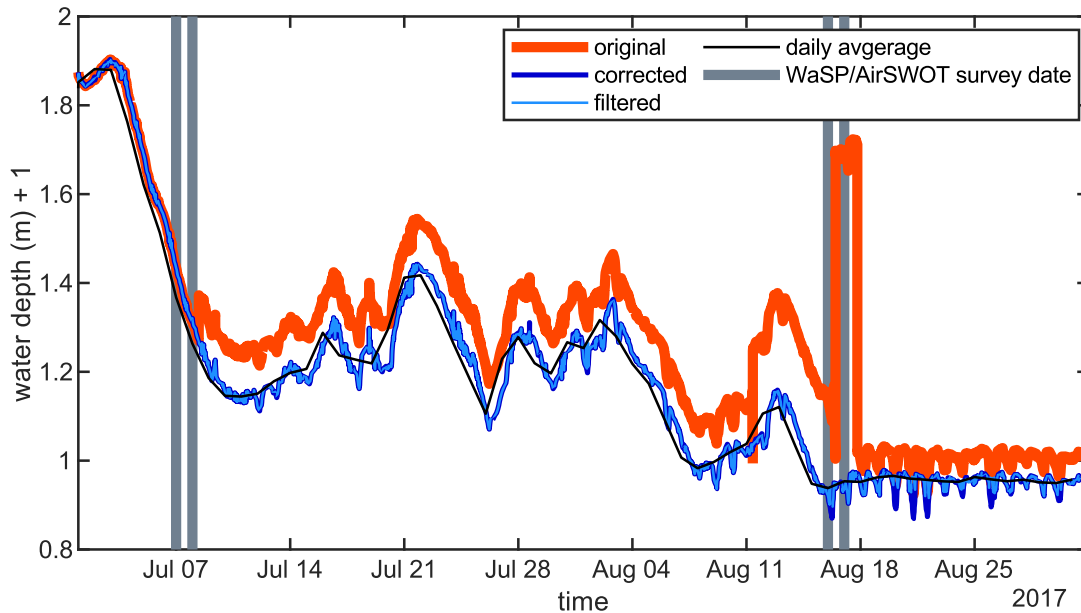
where `InputFile00.obs` through `InputFileN.obs` is a list of input files to be spliced and `OutputFile.obs` denotes the name of the output file after splicing.

Pseudo syntax for clipping or time windowing in TEQC is:

```
teqc +st YYMMDDHHMMSS.ssss +dh * InputFile.obs > OutputFile.obs
```

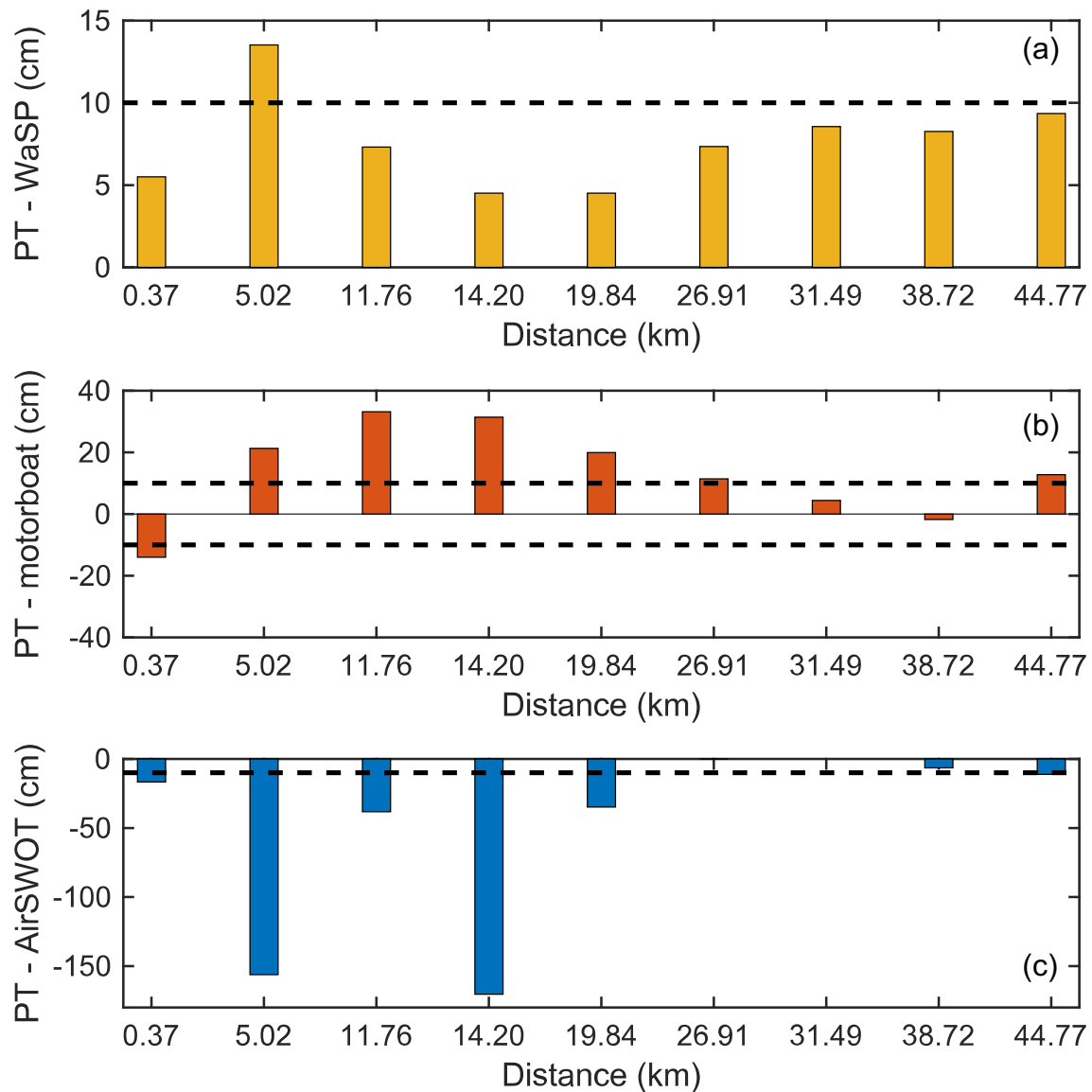
where `+st` denotes the desired survey start time, `YY` is the last two digits of the start year and `MM`, `DD`, `HH`, `MM`, `SS` are the start month, day, hour, minute, and second, respectively. `+dh` refers to the duration in hours from start time and `*` denotes the number of hours. Finally, `InputFile.obs` refers to the input RINEX file to be windowed and `OutputFile.obs` is the name of the output file after the time windowing operation.

## 1.2 Supplementary Figures



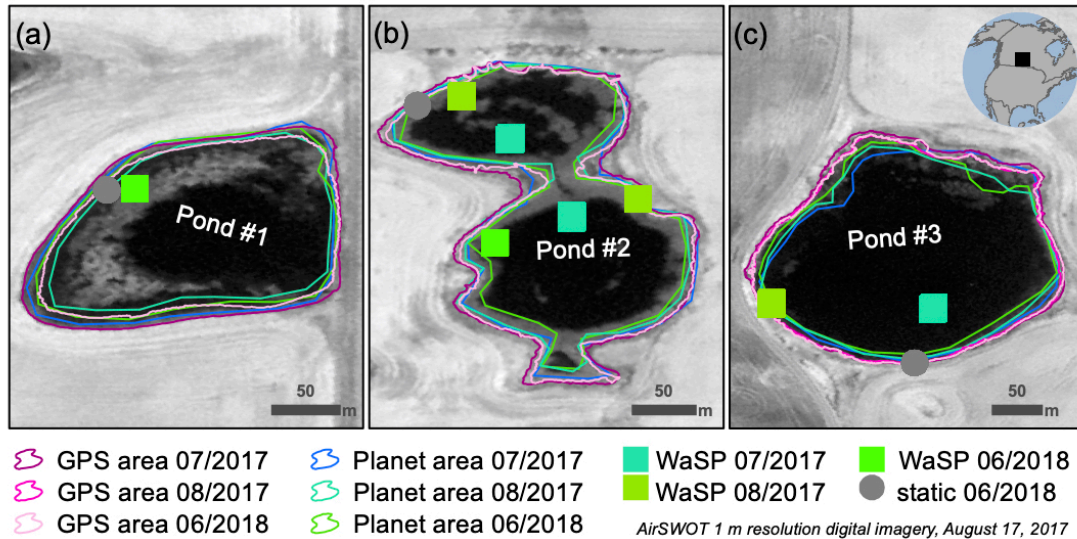
**Supplementary Figure 1.** Environment and Climate Change Canada (ECCC) pressure transducer (PT) water level record for one PT located 0.37 km from the start of our study reach. The original pressure data series (5-minute logging interval) was manually converted to water depth using a barometric pressure logger located near Wingard Ferry at the end of the study reach (orange line). Notable jumps in the data series suggest that the PT location shifted between installation and recovery. To rectify this, jumps in the data series were manually identified and a constant offset, calculated as the difference between high-quality neighboring measurements was applied to

subsequent data readings (dark blue line). Vertical grey bars denote WaSP and AirSWOT survey days.



**Supplementary Figure 2.** The water surface elevation (WSE) difference between Environment and Climate Change Canada (ECCC) pressure transducer (PT) water level loggers and (a) WaSP, (b) motorboat, and (c) AirSWOT for 20 m reaches centered on each PT. Differences of  $\pm 10$  cm are

noted by dashed black line. Comparison is for surveys conducted on July 7-8, 2017 only. Analogous PT data is not available for August 2017 surveys.




**Supplementary Figure 3.** Three Prairie Pothole ponds near Saskatoon, Saskatchewan, Canada (a-c) were surveyed in July and August 2017, and June 2018 using WaSP (green squares) and near-shore static tripod surveys (grey circles). Outer shorelines were manually mapped in situ using handheld Garmin eTrex GPS's (pink vector lines) and also hand digitized ignoring floating and/or inundated vegetation within the pond using Planet 3.125 m resolution satellite imagery (Planet Team, 2019) collected on July 4, 2017, August 18, 2017, and June 16, 2018 (green and blue vector lines). The base map is a 1 m resolution digital orthomosaic collected by AirSWOT on August 17, 2017 as part of the NASA Arctic Boreal Vulnerability Experiment (ABOVE).

### 1.3 Supplementary Tables

Table S1.								
PT	Lat.	Lon.	distance (km)	Ellipsoidal height ( $h$ )		EGM96 geoid correction ( $n$ )	Orthometric height ( $H$ )	
				July 7, 2017	July 8, 2018		July 7, 2017	July 8, 2018
05GEX01	52.649	-106.84	0.37	413.67	413.56	-22.53	436.20	436.09
05GEX02	52.683	-106.81	5.02	413.03	412.84	-22.62	435.65	435.46
05GEX03	52.726	-106.75	11.76	411.72	411.58	-22.74	434.46	434.32
05GEX04	52.743	-106.72	14.20	411.35	411.22	-22.78	434.13	434.00
05GEX05	52.784	-106.67	19.84	410.37	410.26	-22.89	433.26	433.15
05GEX06	52.824	-106.59	26.91	409.37	409.26	-23.00	432.37	432.26
05GEX07	52.861	-106.57	31.49	408.56	408.46	-23.10	431.66	431.56
05GEX08	52.899	-106.48	38.72	407.58	407.48	-23.21	430.79	430.69
05GEX09	52.944	-106.43	44.77	406.54	406.44	-23.34	429.88	429.78

**Supplementary Table 3.** Location, ellipsoidal ( $h$ ) and orthometric ( $H$ ) water surface elevations (WSE) on July 7-8, 2017 from a temporary array of nine pressure transducers (PTs) surveyed in

along the North Saskatchewan River by the Water Survey of Canada (WSC), a branch of Environment and Climate Change Canada (ECCC) during spring/summer 2017. The distance (km) field refers to downstream distance along our study reach, which runs from Petrofka Bridge to Wingard Ferry.  $H \approx h - n$ , where  $H$  is the orthometric height,  $h$  is the ellipsoidal height, and  $n$  is the height of the EGM96 geoid.

<b>Table S2.</b>					
July 2017			August 2017		
Date	Day of year	Average depth (m) + 1 (m)	Date	Day of year	Average depth (m) + 1 (m)
1-Jul-17	182	1.85	1-Aug-17	213	1.25
2-Jul-17	183	1.88	2-Aug-17	214	1.32
3-Jul-17	184	1.88	3-Aug-17	215	1.28
4-Jul-17	185	1.76	4-Aug-17	216	1.22
5-Jul-17	186	1.62	5-Aug-17	217	1.17
6-Jul-17	187	1.51	6-Aug-17	218	1.09
7-Jul-17	188	1.37	7-Aug-17	219	1.01
8-Jul-17	189	1.26	8-Aug-17	220	0.98
9-Jul-17	190	1.19	9-Aug-17	221	1.00
10-Jul-17	191	1.15	10-Aug-17	222	1.02
11-Jul-17	192	1.14	11-Aug-17	223	1.04
12-Jul-17	193	1.15	12-Aug-17	224	1.11
13-Jul-17	194	1.18	13-Aug-17	225	1.12
14-Jul-17	195	1.20	14-Aug-17	226	1.03
15-Jul-17	196	1.21	15-Aug-17	227	0.95
16-Jul-17	197	1.29	16-Aug-17	228	0.94
17-Jul-17	198	1.24	17-Aug-17	229	0.95
18-Jul-17	199	1.23	18-Aug-17	230	0.95
19-Jul-17	200	1.22	19-Aug-17	231	0.96
20-Jul-17	201	1.30	20-Aug-17	232	0.97
21-Jul-17	202	1.41	21-Aug-17	233	0.96
22-Jul-17	203	1.42	22-Aug-17	234	0.96
23-Jul-17	204	1.35	23-Aug-17	235	0.95
24-Jul-17	205	1.27	24-Aug-17	236	0.95
25-Jul-17	206	1.18	25-Aug-17	237	0.96
26-Jul-17	207	1.11	26-Aug-17	238	0.96
27-Jul-17	208	1.23	27-Aug-17	239	0.95
28-Jul-17	209	1.28	28-Aug-17	240	0.96
29-Jul-17	210	1.22	29-Aug-17	241	0.95
30-Jul-17	211	1.20	30-Aug-17	242	0.95
31-Jul-17	212	1.27	31-Aug-17	243	0.96
Legend		 WaSP and motorboat surveys			

	AirSWOT survey only
	WaSP, motorboat and AirSWOT surveys
* data from PT 05GEX01 (see Table s1)	

**Supplementary Table 2.** Manually corrected, outlier removed, daily mean water level (+ 1 m) from one pressure transducer (PT) located near the Petrofka Bridge in the North Saskatchewan River. Cell shading denotes accompanying WaSP, AirSWOT and motorboat surveys.

<b>Table S3.</b>		
<b>Date</b>	<b>Planet area (m<sup>2</sup>)</b>	<b>GPS area (m<sup>2</sup>)</b>
<b>Pond #1</b>		
4-Jul-17	14691.46	15665.67
18-Aug-17	13702.76	NA
16-Jun-18	11970.84	13272.35
<b>Pond #2</b>		
4-Jul-17	18458.63	20134.70
18-Aug-17	15356.06	NA
16-Jun-18	17184.79	18304.89
<b>Pond #3</b>		
4-Jul-17	26531.98	30927.92
18-Aug-17	25325.65	29409.88
16-Jun-18	25574.53	29794.04

**Supplementary Table 3.** Pond shoreline areas (m<sup>2</sup>) as manually digitized using Planet satellite imagery (Planet Team, 2019) and mapped in situ using handheld Garmin eTrex GPSs.

## References

Planet-Team (2019). Planet Application Program Interface: In Space For Life On Earth. Available at: <https://api.planet.com>.