Sagavanirktok River Spring Breakup Observations 2016

Final Report

H. Toniolo, K.D. Tape, T. Tschetter, J.W. Homan, E.K. Youcha, D. Vas, R.E. Gieck, J. Keech, and G. Upton

Prepared for the
Alaska Department of Transportation and Public Facilities
and
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University of Alaska Fairbanks
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Report INE/WERC 16.08

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Front cover photo:

Photo taken May 20, 2016. Water levels on Sagavanirktok River at Franklin Bluffs rise and overtop the diversion berm above its constriction. Flow direction is from bottom to top (north).

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ABSTRACT

In 2015, spring breakup on the Sagavanirktok River near Deadhorse was characterized by high flows that destroyed extensive sections of the Dalton Highway, closing the road for nearly 3 weeks. This unprecedented flood also damaged infrastructure that supports the trans-Alaska pipeline, though the pipeline itself was not damaged. The Alaska Department of Transportation and Public Facilities (ADOT&PF) and the Alyeska Pipeline Service Company made emergency repairs to their respective infrastructure.

In December 2015, aufeis accumulation was observed by ADOT&PF personnel. In January 2016, a research team with the University of Alaska Fairbanks began monitoring and researching the aufeis and local hydroclimatology. Project objectives included determining ice elevations, identifying possible water sources, establishing surface meteorological conditions prior to breakup, measuring hydrosedimentological conditions (discharge, water level, and suspended sediment concentration) during breakup, and reviewing historical imagery of the aufeis feature.

Ice surface elevations were surveyed with Global Positioning System (GPS) techniques in late February and again in mid-April, and measureable volume changes were calculated. However, river ice thickness obtained from boreholes near Milepost 394 (MP394) in late February and mid-April revealed no significant changes. It appears that flood mitigation efforts by ADOT&PF in the area contributed to limited vertical growth in ice at the boreholes. End-of-winter snow surveys throughout the watershed indicate normal or below normal snow water equivalents (SWE ~10 cm). An imagery analysis of the lower Sagavanirktok aufeis from late winter for the past 17 years shows the presence of ice historically at the MP393–MP396 area.

Water levels and discharge were relatively low in 2016 compared with 2015. The mild breakup in 2016 seems to have been due to temperatures dropping below freezing after the flow began. Spring 2015 was characterized by warm temperatures throughout the basin during breakup, which produced the high flows that destroyed sections of the Dalton Highway.

A comparison of water levels at the East Bank Station during 2015 and 2016 indicates that the 2015 maximum water level was approximately 1 m above the 2016 maximum water level.

Maximum measured discharge in 2016 was approximately half of that measured in 2015 in the lower Sagavanirktok River. Representative suspended sediment sizes (D_{50}) ranged from 20 to 50 microns (medium to coarse silt).

An objective of this study was to determine the composition and possible sources of water in the aufeis at the lower Sagavanirktok River. During the winter months and prior to breakup in 2016, overflow water was collected, primarily near the location of the aufeis, but also at upriver locations. Simultaneously possible contributing water sources were sampled between January and July 2016, including snow, glacial meltwater, and river water. Geochemical analyses were performed on all samples. It was found that the overflow water which forms the lower Sagavanirktok aufeis is most similar (R^2 = 0.997) to the water that forms the aufeis at the Sagavanirktok River headwaters (Ivishak River), thought to be fed by relatively consistent groundwater sources.

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ACKNOWLEDGMENTS AND DISCLAIMER

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The use of trade and firm names in this document is for the purpose of identification only and does not imply endorsement by the University of Alaska Fairbanks, ADOT&PF, APSC, or any other sponsor.

CONVERSION FACTORS, UNITS, WATER QUALITY UNITS, VERTICAL AND HORIZONTAL DATUM, ABBREVIATIONS, AND SYMBOLS

Conversion Factors

Multiply	By	To obtain
	Length	
inch (in.)	25.4	millimeter (mm)
inch (in.)	2.54	centimeter (cm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
	Area	
acre	43560.0	square feet (ft^2)
acre	0.405	hectare (ha)
square foot (ft^2)	3.587e-8	square mile (mi^2)
square mile (mi^2)	2.590	square kilometer (km^2)
	Volume	
gallon (gal)	3.785	liter (L)
gallon (gal)	3785.412	milliliter (mL)
cubic foot (ft^3)	28.317	liter (L)
acre-ft	1233.482	cubic meter (m^3)
acre-ft	325851.43	gallon(gal)
gallon(gal)	0.1337	cubic feet (ft^3)
	Velocity and Discharge	
foot per day (ft/d)	0.3048	meter per day (m/d)
square foot per day (ft^2/d)	0.0929	square meter per day (m^2/d)
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/sec)
	Water Density	
kilograms per cubic meter (kg/m^3)	1/1000	grams per cubic centimeter (g/cm^3)
grams per cubic centimeter (g/cm^3)	1.94	slugs per cubic foot (slugs/ft^3

Units

In this report, both metric (SI) and English units were employed. The choice of "primary" units employed depended on common reporting standards for a particular property or parameter measured. The approximate value in the "secondary" units may also be provided in parentheses.

Thus, for instance, runoff was reported in cubic meters per second (m^3/s) followed by the cubic feet per second (ft^3/s) value in parentheses.

Physical and Chemical Water-Quality Units:

Temperature

Water and air temperatures are given in degrees Celsius (°C) and in degrees Fahrenheit (°F). Degrees Celsius can be converted to degrees Fahrenheit by use of the following equation:

$$°F = 1.8(°C) + 32$$

Milligrams per liter (mg/L) or micrograms per liter (μg/L)

Milligrams per liter is a unit of measurement indicating the concentration of chemical constituents in solution as weight (milligrams) of solute per unit volume (liter) of water. One thousand micrograms per liter is equivalent to one milligram per liter. For concentrations less than 7000 mg/L, the numerical value is the same as for concentrations in parts per million (ppm).

Horizontal datum

The horizontal datum for all locations in this report is the North America Datum of 1983 (NAD83).

Vertical datum

"Sea level" in the following report refers to the North American Vertical Datum of 1988 (NAVD88) (GEOID12A) datum for all water level elevations.

ABBREVIATIONS, ACRONYMS, AND SYMBOLS

ADCP	acoustic Doppler current profiler
ADOT&PF	Alaska Department of Transportation and Public Facilities
C	Celsius (°C)
cms	cubic meters per second
CCB	continuing calibration blank
CCV	continuing calibration verification
cm	centimeter
d	day
dd	decimal degrees
DEM	digital elevation model
F	Fahrenheit (°F)
ft	foot
GPS	Global Positioning System
iFSAR	Interferometric Synthetic Aperture Radar
in.	inch
INE	Institute of Northern Engineering
kg	kilogram
km	kilometer
m	meter
mi	mile
mm	millimeter
mph	miles per hour
NAVD	North American Vertical Datum
NOAA	National Oceanic and Atmospheric Administration
NRCS	Natural Resources Conservation Service
NIR	near infrared
RTK	real-time kinematic
s	second
SAR	synthetic aperture radar
SBAS	satellite based augmentation system
SfM	structure from motion
SSC	suspended sediment concentration
SWE	snow water equivalent
TSS	total suspended solids
UAF	University of Alaska Fairbanks
USGS	U.S. Geological Survey
WAAS	Wide Area Augmentation System
WERC	Water and Environmental Research Center

1 INTRODUCTION

Most of Arctic Alaska is mapped as "continuous" permafrost, which functions hydrologically as a thick aquitard, preventing both downwelling and upwelling of water (Jorgenson et al., 2008). However, the permafrost is not literally continuous, since in places groundwater discharges perennially through unfrozen conduits referred to as taliks (Yoshikawa et al., 2007). These springs often occur near or underlie river floodplains, where winter discharge from the springs encounters subfreezing temperatures and forms large ice fields during winter. These ice fields are known as overflow ice, or aufeis. Several dozen of these features occur on the eastern North Slope and north of the Continental Divide in the Brooks Range.

One aufeis feature occurs along the Sagavanirktok River, on the coastal plain, where the river trifurcates into something resembling a river delta before emptying into the Beaufort Sea. The aufeis forms from an accumulation of overflow that freezes over the course of the winter. The Dalton Highway parallels and is near the active river channel at this location. It is thought that aufeis in Arctic Alaska is fed by one of two water sources that remain unfrozen during winter: either deeper subpermafrost groundwater or shallow groundwater moving through taliks (Kane et al., 2013).

In late May and early June 2015, during spring breakup, widespread flooding of the Dalton Highway occurred due to the large buildup of aufeis near Franklin Bluffs. The flooding caused closure of the highway for approximately 3 weeks. Even prior to breakup, in late March and early April, overflow and aufeis accumulation caused highway closures (Toniolo et al., 2015).

The Alaska Department of Transportation and Public Facilities (ADOT&PF) and the Alyeska Pipeline Service Company (APSC) requested monitoring, recording, and analysis of spring 2016 breakup conditions in the Sagavanirktok River watershed, with particular focus on aufeis accumulation and potential flooding. Tasks included the following:

1) Survey and monitor ice accumulation prior to breakup.
2) Collect end-of-winter snowpack information.
3) Record air temperatures throughout the watershed.
4) Monitor water levels at several locations along the river.

5) Measure runoff during spring breakup throughout the Sagavanirktok River.
6) Collect samples of overflow and other constituents for geochemical analysis.

In February/March, and mid-April 2016, aufeis thickness and extent were surveyed using a differential Global Positioning System (GPS) device. Acoustic sonic ranging (SR50) sensors and cameras were used to continuously record aufeis growth at three locations. In order to document snowpack conditions before breakup, in mid-April 2016, measurements of snow depth and density were conducted, and snow water equivalents (SWEs) were calculated at 32 locations in the Sagavanirktok River watershed. Prior to breakup, a new network of ten water level sensors was installed on the lower Sagavanirktok River and along the Dalton Highway from Milepost 387.5 (MP387.5) near Franklin Bluffs to MP405 near Prudhoe Bay. These water level sensors added to the existing network of water level observations and runoff measurements at stations on the Sagavanirktok River at the East Bank near Franklin Bluffs (DSS5), below the confluence with the Ivishak (DSS2), at Happy Valley (DSS3), and near Dalton Highway MP318 (DSS4).

Overflow water was collected during the winter months and prior to breakup in 2016, primarily near the location of the aufeis, but also at upriver locations. Possible contributing water sources were sampled between January and July 2016, including snow, glacial meltwater, and river water, and geochemical analyses were performed to compare these samples with overflow water that formed the aufeis. The findings are described in the context of regional hydrology.

Table 1 presents a summary of University of Alaska Fairbanks (UAF) hydrometeorological station locations in the Sagavanirktok River watershed where data were collected. Figure 1 is a map of the study area near the Dalton Highway in the vicinity of Deadhorse, and Figure 2 is a map showing other monitoring locations in the entire watershed.

Table 1. UAF hydrometeorological station locations in the Sagavanirktok River watershed in 2016.

Site Name	Latitude (NAD83)	Longitude (NAD83)	Elevation (m) (NAVD88, GEOID12A)	Data Type
East Bank Station (DSS5)	69°56' 46.32936" N	148°40' 17.20520" W	61.597	Discharge, continuous water levels, discrete water levels, ice growth
MP393 (Sag_Ice)	69°57'50.34" N	148°43'10.62" W		Ice growth (SR50)
MP387.5 (Sag_Ice3)	69°51'13.02" N	148°46'22.56" W		Ice growth (SR50)
Sagavanirktok West Channel near MP405 (DSS1)	70°05' 57.04415" N	148°30' 32.69178" W	26.363	Discharge, continuous water levels, discrete water levels, ice growth (SR50)
Sagavanirktok below Ivishak (DSS2)	69°35' 45.08378" N	148°37' 32.86491" W	137.622	Discharge, continuous water levels, discrete water levels
Sagavanirktok at Happy Valley (DSS3)	69°09' 02.39133" N	148°49' 23.31377" W	291.047	Discharge, continuous water levels, discrete water levels
Sagavanirktok at MP318 (DSS4)	68°57' 30.10881" N	148°51' 35.29357" W	374.152	Discharge, continuous water levels, discrete water levels
Sag Water 1	70°4'19.77" N	148°33'40.88" W		Water levels
Sag Water 2	70°3'22.77" N	148°35'9.04" W		Water levels
Sag Water 3	70°1'58.19" N	148°38' 13.80" W		Water levels
Sag Water 4	70° 0'7.20" N	148°40'25.21" W		Water levels
Sag Water 5	69°59'19.79" N	148°41'13.82" W		Water levels
Sag Water 6	69°58'22.18" N	148°42'19.81" W		Water levels
Sag Water 7	69°57'55.19" N	148°43'13.28" W		Water levels
Sag Water 8	69°57'40.20" N	148°43'22.22" W		Water levels
Sag Water 9	69°57'8.98" N	148°43'37.81" W		Water levels
Sag Water 10	69°51'4.23" N	148°45'25.05" W		Water levels
HOBO1	69°57'42.95" N	148°43'42.60" W		Water levels
HOBO2	69°57'40.97" N	148°43'28.20" W		Water levels
HOBO3	69°59'21.41" N	148°41'19.93" W		Water levels

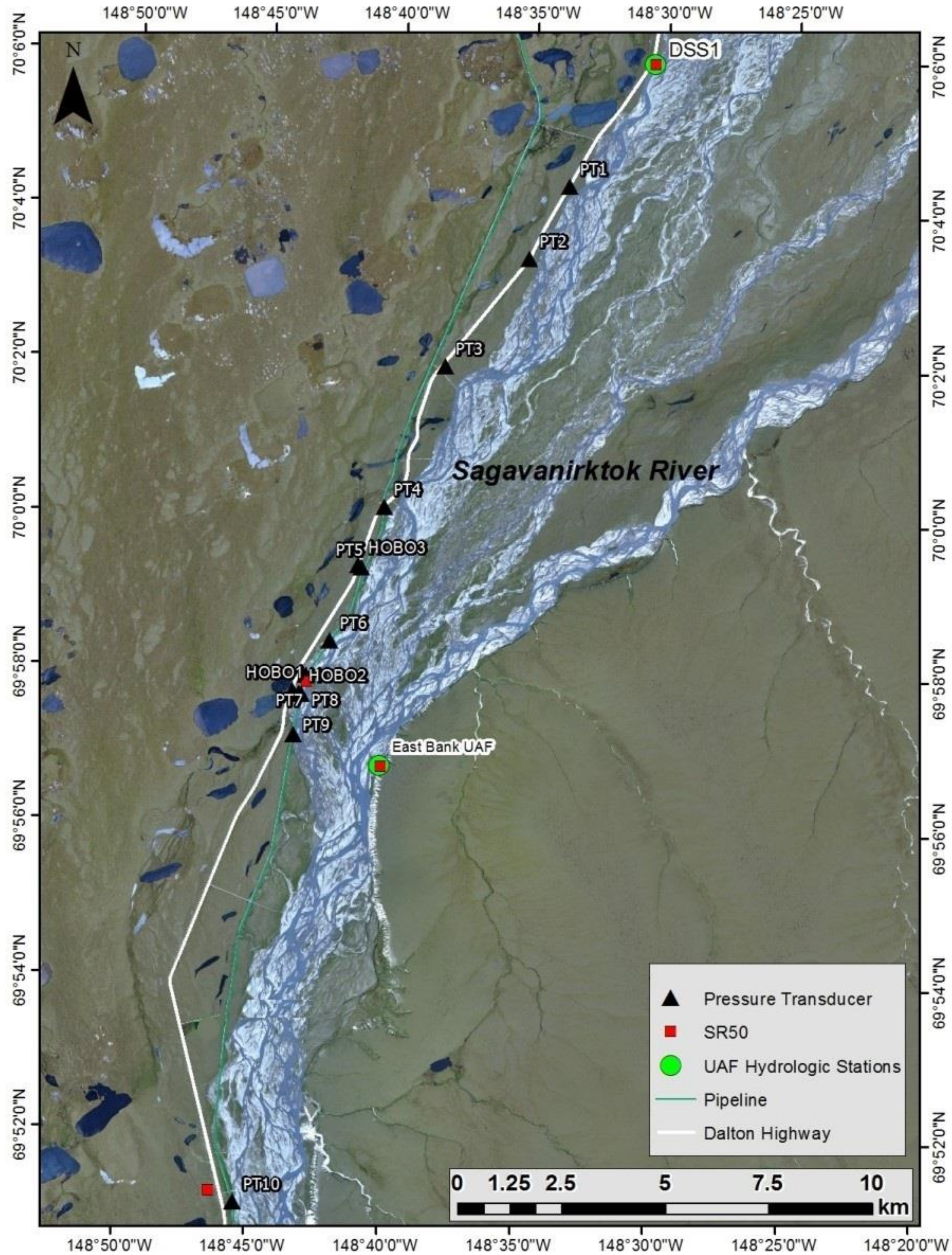


Figure 1. Water level and ice observation network near Franklin Bluffs and Deadhorse in 2016. The white line indicates the location of the Dalton Highway; the green line indicates the trans-Alaska pipeline.

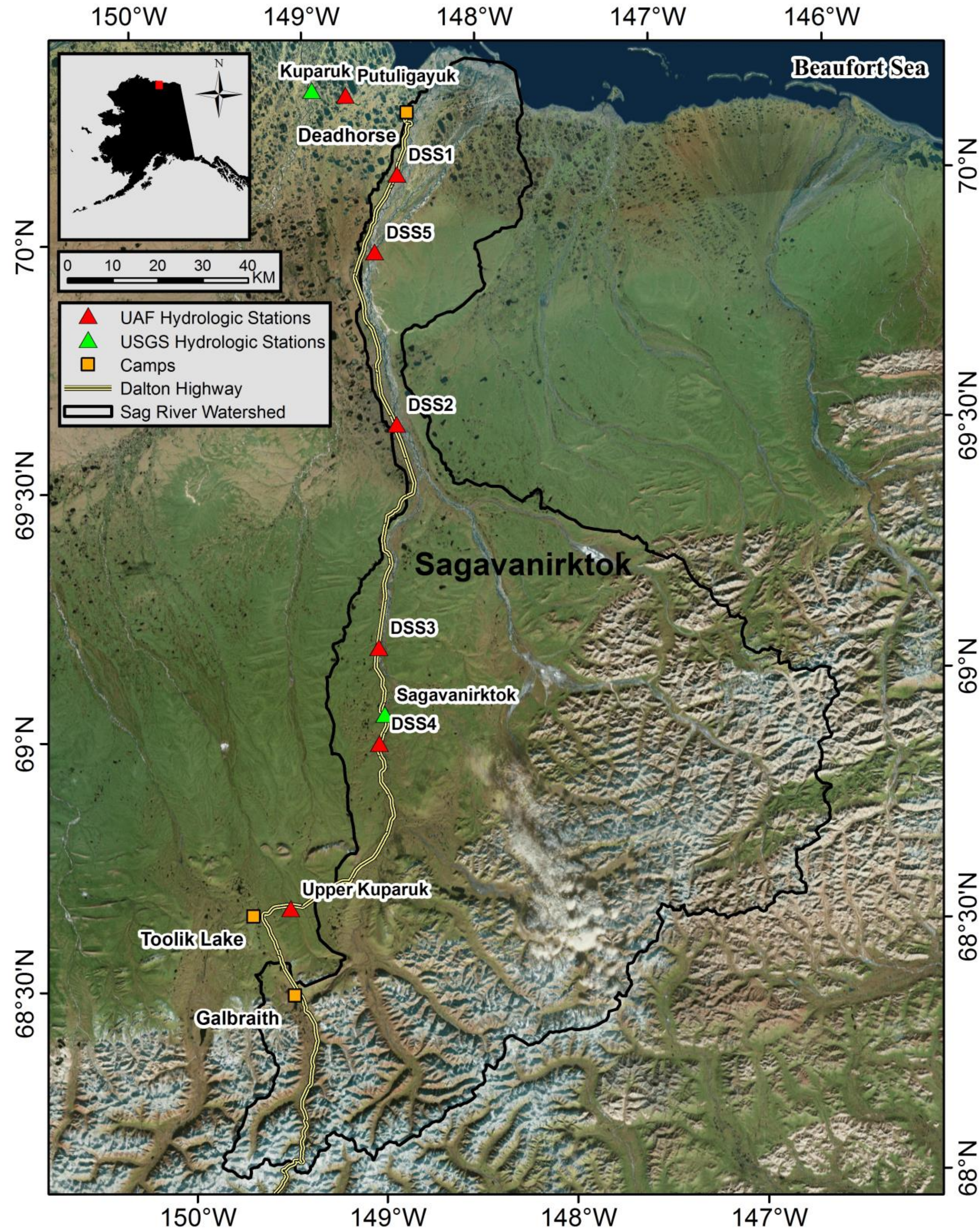


Figure 2. Water level observation network throughout the Sagavanirktok watershed during spring breakup. The yellow double line indicates the location of the Dalton Highway; the black line indicates the watershed boundary.

2 STUDY AREA

The Sagavanirktok River watershed covers approximately 14,900 km^2. The headwaters of the Sagavanirktok River are at the Continental Divide in the Brooks Range; the river delta is in the Beaufort Sea. The lower 100 km of the river parallel the Dalton Highway before the river discharges into the ocean just east of Prudhoe Bay. The main tributary is the Ivishak River, which enters the Sagavanirktok River approximately 95 km from the coast. The landscape of the Sagavanirktok River watershed is of variable age, ranging from relatively young (~12,000 yr) porous glacial deposits in the Brooks Range, to older (~75,000 yr) glacial deposits that reach northward from the mountains to the foothills (Manley and Kaufman, 2002). The mountainous headwaters include 15–20 small and diminishing north-facing glaciers. Approximately 75% of the basin lies in the foothills and mountains regions. The watershed is mapped as continuous permafrost, but widely scattered perennial springs seem to indicate connections to groundwater sources. Most of these springs are located in the younger glacial deposits at the northern front of the mountains (Manley and Kaufman, 2002), though some occur near where the foothills meet the coastal plain, including the one that forms the aufeis studied.

3 METHODOLOGY AND EQUIPMENT

The goals of this project were to observe aufeis growth, characterize surface meteorology and end-of-winter snow conditions in the watershed, monitor river stage, measure streamflow, and provide geochemistry characteristics of water in the Sagavanirktok watershed. Synthetic aperture radar imagery acquired by ADOT&PF was reviewed prior to spring breakup to gain a better understanding of the extent of aufeis. Several field trips occurred during winter and spring 2016.

In late January 2016, sensors were installed to monitor ice growth at three locations within the Sagavanirktok River channel. In February/March and April, prior to breakup, field staff surveyed the elevations of ice in the area where the Sagavanirktok River splits, becoming two channels (approximately MP394.5, near Franklin Bluffs). Thirteen pressure transducers were installed to monitor overflow prior to and during spring breakup. In May, monitoring continued at the water level observation stations on the east bank of the Sagavanirktok River (referred to hereafter as

East Bank station, or DSS5) and at several additional UAF hydrologic stations. Spring runoff measurements were made at four stations within the basin.

Water chemistry samples were collected several times prior to breakup, during breakup, and after breakup. Samples included overflow, ice cores, glacier meltwater, river water, and snow. Samples were analyzed for trace metals and cations/anions.

3.1 Aufeis Extent

One of our objectives was to monitor and delineate the extent of the Sagavanirktok aufeis deposit in 2016. In this section, the methodology and equipment used for the observations are described.

3.1.1 Field Methods

Two separate topographic surveys of the extensive aufeis formation on the Sagavanirktok River between Franklin Bluffs and the Dalton Highway were conducted in late winter of 2016. The first survey was conducted from February 29 through March 4; the second survey was conducted from April 16 through April 19. The primary goal of these surveys was to measure the surface elevation and topography of the formation and determine changes over time between the surveys. The surveyed area along the Dalton Highway extends from MP386 to MP400. Surveys were conducted using a real-time kinematic (RTK) GPS technique. Survey-grade Leica GS14 and GS15 receivers were used, and data were collected by Leica CS15 controller running Leica Viva software. A GPS rover receiver was attached in a fixed position on a PistenBully tracked vehicle, and horizontal and vertical data were automatically collected at 1-second intervals as the vehicle traversed the ice. Point locations, such as boreholes, were recorded manually with the rover on a standard 2 m rover staff. Ice thickness was measured through boreholes in select locations assumed free of channel ice and representative of aufeis accumulation only, i.e., on gravel bars. Holes were bored with a 5 cm diameter ice auger, and ice surface to ground surface was measured with a hand tape. Control datum was pre-established monuments on the Dalton Highway. The expected precision of a RTK GPS technique is ±0.01 m horizontal and ±0.02 m vertical. Personnel with ADOT&PF operated the GPS survey equipment and processed the data. Elevations are reported as NAVD88 (GEOID12A), and horizontal position is reported in Alaska State Plane Zone 4 (NAD83).

Sonic distance sensors (Campbell Scientific SR50A) were installed in late January and early March to observe changes in ice thickness at three sites near Franklin Bluffs and Deadhorse (Figure 1). The sensors, which are aimed downward at the target (ice, snow, or ground surface), determine the distance between the surface and the sensor.

3.1.2 Structure from Motion Imagery

On May 10, 2016, Fairbanks Fodar acquired Fodar data on the aufeis field near the peak of its winter ice volume. Fodar is a proprietary Structure from Motion (SfM) photogrammetric technique that creates directly georeferenced Digital Elevation Models (DEMs) and orthomosaics from a manned aircraft, with spatial accuracies and precision superior to LiDAR. The approximately 170 km^2 area of interest was imaged at approximately 18 cm ground sample distance. These data were processed into an orthomosaic with 18 cm posting and a DEM with 36 cm posting, and were delivered by the contractor about a week after acquisition. These raster products were delivered in WGS84 ellipsoid heights and State Plane Zone 4 (NAD83) projection, per specifications. More information on the acquisition can be found at http://fairbanksfodar.com/mapping-aufeis-on-the-dalton-highway. Three-dimensional data can be browsed interactively at http://fairbanksfodar.com/dots-delivered.

The mid-April aufeis surface elevation data (collected with GPS surveys described earlier) was compared with the SfM aufeis surface elevation recorded on May 10. As previously mentioned, the native vertical reference datum for the SfM dataset was the WGS84 ellipsoid, so the vertical datum was transformed to NAVD88 Geoid 12A using VDatum (NOAA's vertical datum transformation tool) before comparison with the GPS survey data. The May 10 aufeis elevation was extracted from the SfM raster (36 cm resolution) at the location of each April survey point and compared with the April aufeis surface.

3.1.3 Imagery

Landsat satellite imagery was used to estimate the aufeis extent near Franklin Bluffs for the recent historical record (2000–2016). Since 2000, Landsat satellites have collected multispectral images of the site approximately every 7 days starting in early March each year (imagery from November to late February is not available due to winter darkness). Because water and ice absorb energy in the near-infrared (NIR) portion of the spectrum and dry snow does not, the NIR band of the Landsat images can be used to delineate the extent of the aufeis (Harden et al., 1977; Dean, 1984).

All available Landsat 7 and Landsat 8 images from early March to late April were inspected, and images were selected for analysis based on maximum visible aufeis extent. Clouds and/or snow obscured aufeis in many of the available images. For each NIR image, the area of visible icing was inspected to determine a minimum pixel value associated with aufeis; any pixel with a value greater than this minimum threshold was categorized as aufeis. Images were then visually inspected to check if the calculated aufeis extent matched the visible aufeis extent. While laborious, this method allowed better agreement between observed and calculated aufeis than using a universal threshold or an automated method such as the Normalized Difference Water Index of McFeeters (1996). The method used in this study may underestimate the extent of aufeis because aufeis that underlies fresh or windblown snow is not recognized or because additional aufeis may have formed after the date of imagery. This method may overestimate the extent of aufeis by including snow-free river ice as aufeis.

Aufeis extent area was calculated from the categorized images (pixel size for the Landsat 7 and 8 NIR images was 30 m). The area of this investigation extends from the confluence of the Ivishak River to the Beaufort Sea. The Landsat 7 images from 2004 to 2012 contain strips of missing data due to an equipment malfunction. A ratio of missing pixels to total pixels in the area of interest was used to correct for missing pixels in the area extent calculation.

Ice thickness and volume were estimated for both 2015 and 2016 by comparing ice surface elevation with a digital elevation model. Ice surface elevation was surveyed on May 7, 2015, using LiDAR, and on May 10, 2016, using the SfM photogrammetric techniques described in Section 3.1.2. The ground surface elevation dataset was collected on July 20, 2014, using airborne Interferometric Synthetic Aperture Radar (IfSAR). The native vertical datum for the 2015 LiDAR and the 2014 IfSAR is NAVD88 (GEOID9). The SfM data from May 10, 2016, use the WGS84 ellipsoid. After the LiDAR and IfSAR elevation datasets were transformed to WGS84 ellipsoid heights using VDatum (NOAA’s vertical datum transformation tool), the aufeis thickness was determined by subtracting the ice surface elevations from the ground surface elevations. To determine approximate aufeis volume near Franklin Bluffs and exclude snow-covered ground from the calculations, aufeis extents were manually delineated using available imagery.

3.2 Surface Meteorology

Several UAF stations within or near the Sagavanirktok basin collect surface meteorology data including air temperature, relative humidity, wind speed and direction, rainfall, and snow depth. The UAF meteorological stations used in this study are located at the Sagavanirktok River near MP405 (DSS1), Sagavanirktok River East Bank (DSS5), Franklin Bluffs, Sagavanirktok River below Ivishak (DSS2), Sagavanirktok River at Happy Valley (DSS3), Sagavanirktok River at MP318 (DSS4), Alyeska Stream Station 1 (near MP347), and Accomplishment Creek (ASM1). Sensor specifications at these stations are described in Toniolo et al. (2015), Kane et al. (2014), and Youcha et al. (2015), and summarized in Table 2. Precipitation and air temperature data from the Natural Resources Conservation Service (NRCS) Atigun Pass station and the U.S. Geological Survey (USGS) Sagavanirktok River gauging station were examined also.

Table 2. Details of equipment used on the Sagavanirktok River breakup study.

Category	Item	Model	Accuracy	Remarks
Met	Wind Direction	RM Young 05103	± 3 degrees	
Met	Wind Speed	RM Young 05103	± 0.3 m/s	
Met	Air Temperature	HMP45C	± 0.5°C at −40°C	
Met	Air Temperature backup	CR1000 Panel Temperature (Betatherm 10K3A1A)	± 0.3°C from -25 to −50°C	Inside logger box, not aspirated
Met	Air Relative Humidity	HMP45C	± 3% at 20°C	
Met	Barometric Pressure	CS106	± 1.5 mb @ −40 to +60°C	
Hydro	Water Level	INW AquiStar PT12 SDI-12	± 0.5 cm (5 psi), ± 1.6 cm (15 psi)	vented to atmosphere
Hydro	Water Level	HOBO U20	± 0.6 cm	absolute pressure, barometric corrections required
Hydro	Water Levels	CS451	± 0.7 cm (7 psig)	vented to atmosphere
Hydro	Water Levels, Ice Growth	Sonic Ranging Sensor (SR50A)	±1 cm (0.4 in.) or 0.4% of distance to target (whichever is greatest)	
Hydro	ADCP	RDI River Pro		
Hydro	ADCP	RDI Rio Pro		
Hydro	ADCP Software	WinRiver II		

Category	Item	Model	Accuracy	Remarks
Hydro	ADCP GPS Reference	Novatel Smart-V1 and Geneq SX Blue		
Hydro	ADCP Manned Boat	15-foot aluminum Jon boat		35 HP jet motor, Kentucky-type ADCP mount
Hydro	Computer	Panasonic Toughbook CF19		
Station	Datalogger	CR1000		
Station	Camera	CC640 or PlantCam		
Station	Radio	FreeWave FGR or DGR		
Station	Solar Panel	Sharp 85 W, typical		
Station	Batteries	Concorde 104 AH		3 batteries
Station	Charge Controller	SunSaver 10 or 12		
Station	Tripod	CM110		

Historical snow survey sites within the Sagavanirktok basin (Kane et al., 2006; Berezovskaya et al., 2007; Berezovskaya et al., 2008; Berezovskaya et al., 2010a; Berezovskaya et al., 2010b; Stuefer et al., 2011; Stuefer et al., 2012; Stuefer et al., 2014) were re-established in April 2016 to gain a better understanding of end-of-winter snowpack conditions. Snow water equivalent (SWE) is defined as

$$SWE = (\text{snow depth} * \text{snow density}) / (\text{water density}).$$

To measure SWE, the double sampling technique (Rovansek et al., 1993) was used. In this sampling technique, 5 snow density and 50 snow depth measurements are collected. Snow cores for density measurements were collected using an Adirondack tube. Snow depth measurements were made along an L-shaped transect, with samples approximately 1 m apart (Derry et al., 2009).

3.3 Water Levels

Water level sensors (HOBO) were deployed in February and March to monitor winter overflow on the lower Sagavanirktok River near Franklin Bluffs (Figure 3). New water level sensors (CS451 from Campbell Scientific) were installed at the end of April to monitor the Sagavanirktok River at ten locations from MP405 to MP386 (Figure 1 and Figure 3) near Prudhoe Bay and Franklin Bluffs.

Figure 3. Water level sensor installed at spur dikes near Franklin Bluffs to monitor water levels from overflow and spring breakup.

In early May, monitoring at the water level observation station on the east bank of the Sagavanirktok River near Franklin Bluffs continued. Water level monitoring during spring breakup also occurred at three additional stations along the Sagavanirktok River (DSS2, DSS3, DSS4) that are part of a UAF study of material sites along the river. Time-lapse cameras were used at the stations to document spring breakup and confirm water level data from station pressure transducers. Accuracy information for each sensor is presented in Table 3. The two largest errors that result from manually measuring water levels are associated with (1) surveying and (2) vertical datum related to the control point. Survey levels may be read incorrectly, but also rod levels may be difficult to read because of wave action, which can yield an error in water level of plus or minus several centimeters. Differential GPS survey techniques were used in 2015 to establish temporary benchmarks at the station for level loop surveys.

Table 3. Specifications of the pressure transducers.

Sensor	Full Scale Range	Accuracy (typical)	Accuracy (typical)	Water Level Range
AquiStar	0–15 PSI Gauge	0.06% Full Scale	0.009 PSIG, 0.6 cm	0–10 m
AquiStar	0–5 PSI Gauge	0.06% Full Scale	0.003 PSIG, 0.2 cm	0–3.5 m
HOBO	0–21 PSI Absolute	0.075% Full Scale	0.016 PSIA, 0.3 cm	0–4 m
CS451	0–7 PSI Gauge	0.1% Full Scale	0.1 PSIG, ± 0.7 cm	0–5 m

3.4 Discharge Measurements

During breakup 2016, discrete discharge measurements were made using an RDI River Pro and a Rio Pro acoustic Doppler current profiler (ADCP) at four locations along the Sagavanirktok River (DSS2, DSS3, DSS4, DSS5). Figure 4 through Figure 7 show transects made during the discharge measurement at each station. High flow measurements are made by driving a boat with a motor slowly across the river. The ADCP is mounted to the side of the boat (Jon boat or Zodiac) or center of the boat (cataraft). Additionally, several measurements were made with an ADCP and a trimaran, tethered to a helicopter. Typically, a minimum of four transects are made per measurement (or a total measurement duration of 720 seconds in steady-state conditions), and an average discharge is calculated from multiple transects (Mueller et al., 2013). To calculate river discharge and determine any directional bias, multiple transects are attempted from both the left-to-right-bank direction and the right-to-left-bank direction when possible. Each manual measurement is given a rating of good, fair, or poor, based on the variability of the transects, the accuracy and percentage of unmeasured areas, and the quality of the boat navigation reference (Mueller, 2012). Because the ADCP measurements were made during spring breakup conditions, the coefficient of variation or COV (standard deviation/average) for a given measurement was often greater than 5%, or there was high directional bias, or the percentage of unmeasured area was high; therefore, the measurement was given a lower rating (fair or poor).

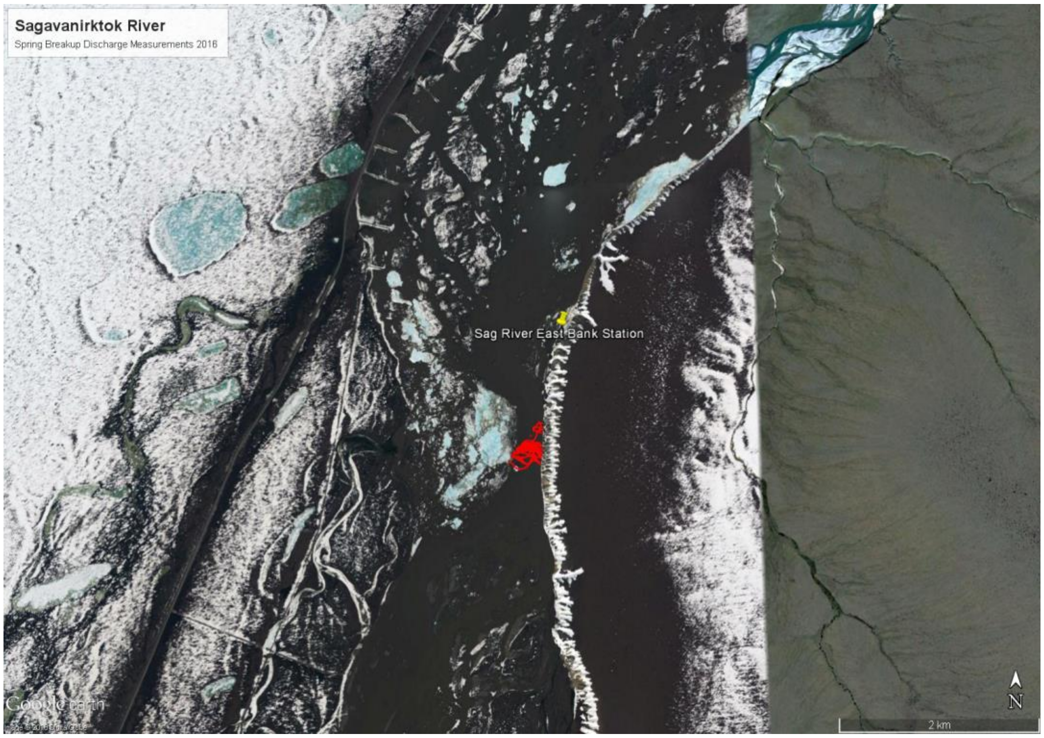


Figure 4. Locations of spring 2016 breakup flow measurement transects at Franklin Bluffs and the East Bank station (DSS5). All measurements were made in the main channel less than 1 mile upstream of the UAF station. An ice berm formed when ADOT&PF dug trenches directed all flow toward the bluffs. Measurements accounted for nearly all river flow. Though this aerial photograph was taken in May 2009, it gives an idea of what the conditions are like during a typical breakup.

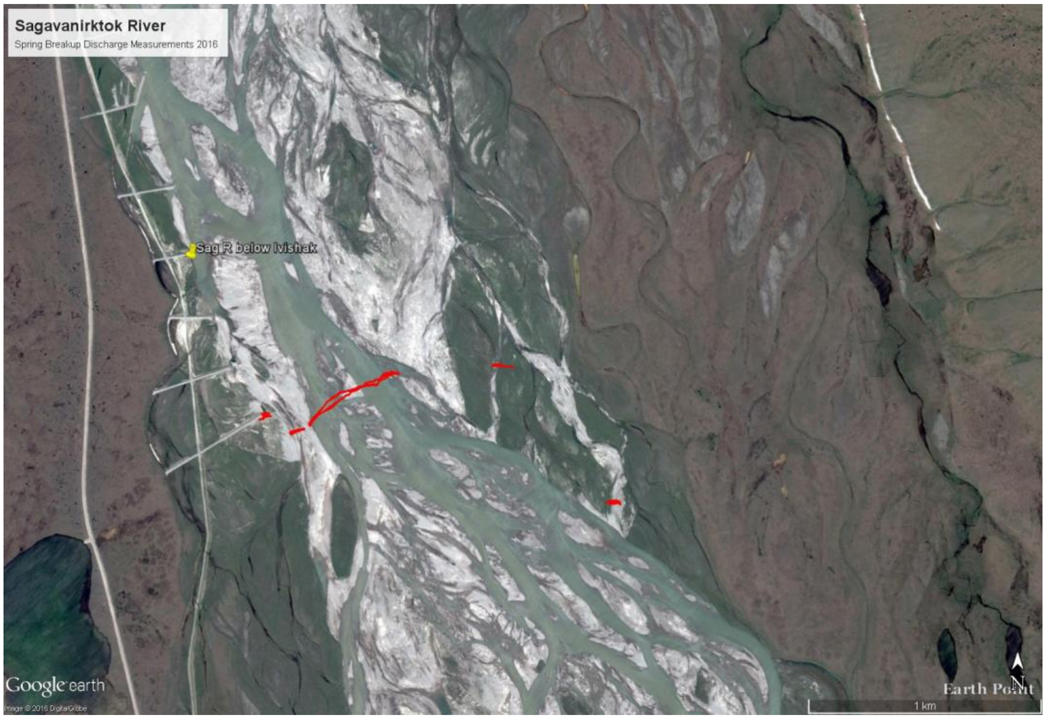


Figure 5. Locations of 2016 flow measurements on the Sagavanirktok River below the confluence with the Ivishak (DSS2).

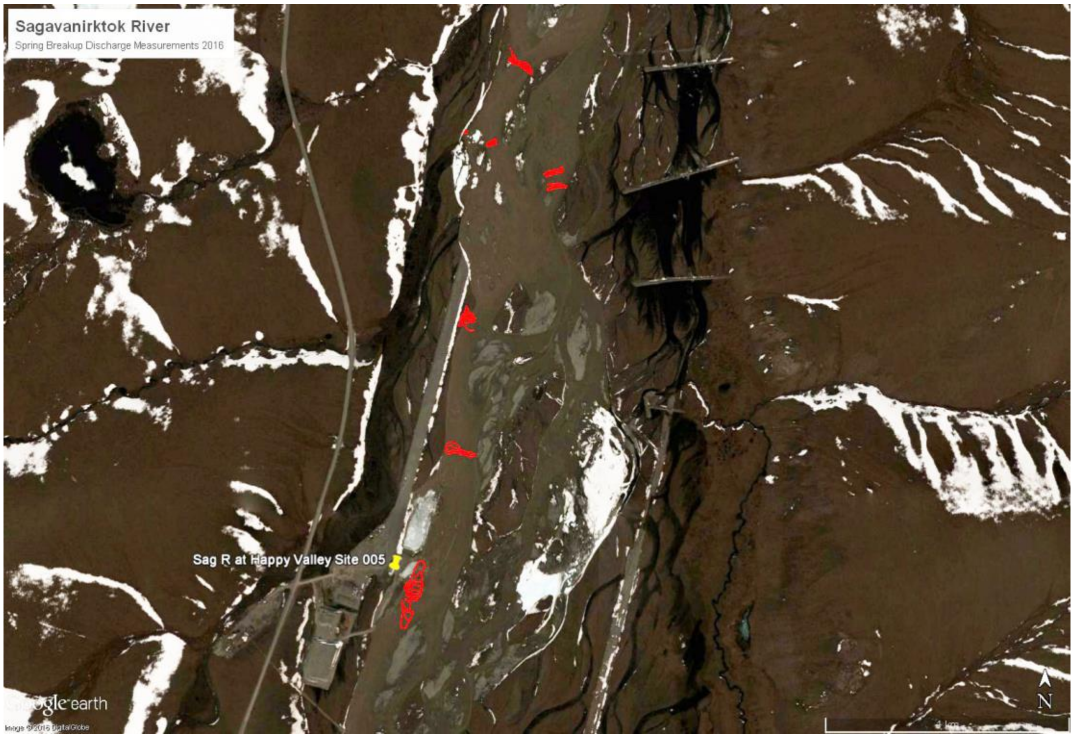


Figure 6. Locations of 2016 flow measurements on the Sagavanirktok River at Happy Valley (DSS3).

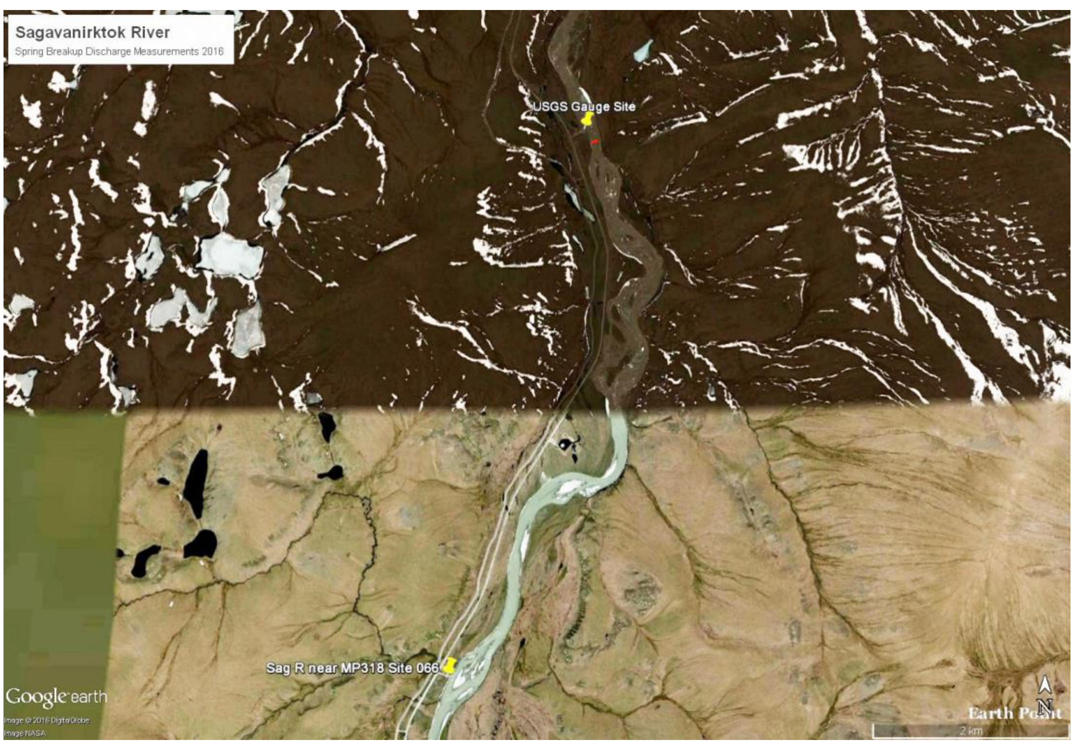


Figure 7. Locations of 2016 flow measurements on the Sagavanirktok River near MP318 (DSS4). Most of the measurements were made at the USGS gauge site during breakup.

Both ADCP bottom tracking and ADCP GPS options were used as references to measure river velocity. Usually, the GPS is preferred, but if technical problems occur with it, bottom tracking may be used. If bottom tracking is the reference, a test is conducted to determine if there is a moving bed and correct the discharge for the moving bed; however, the test is not always possible due to river conditions, particularly during breakup. Oftentimes, bottom tracking during a loop or stationary moving bed test cannot be maintained by the ADCP. The GPS model used during measurements was either the Novatel Smart V1-2US-L1 or the Geneq SX Blue II. Typically, a base station is set up and a RTK GPS is used, but satellite-based augmentation system (SBAS) or wide area augmentation system (WAAS) differential correction can also be used and is considered acceptable (Wagner and Mueller, 2011). The horizontal position accuracy of RTK is 0.2 m and 1.2 m when using SBAS/WAAS with Novatel units. For the Geneq SX Blue GPS unit, the horizontal accuracy is 0.60 m for SBAS/WAAS. Kane et al. (2012) discuss the methods and challenges associated with making discharge measurements using an ADCP.

Typically, a stream stage–discharge relationship is developed to estimate continuous discharge at the measurement reach. However, because of ice that had accumulated in the channel, the natural braided-river environment, and the constantly changing channel geometry, a stream stage–discharge relationship was not developed for the measurement reaches during spring breakup.

3.5 Suspended Sediment

Grab water samples were collected manually from the river on May 11, 2016 (East Bank [DSS5]). Water samples were collected by an ISCO Model 4700 automated sampler every 6 hours (3 A.M., 9 A.M., 3 P.M., 9 P.M.) from May 12 to June 1 (DSS3), from May 14 to June 1 (DSS2), from May 16 to May 27 (DSS5), and from May 14 to June 1 (DSS4). Many samples were not collected by the ISCOs due to frozen water inside the intake pipes (below-freezing temperatures originated this issue).

The suspended sediment concentration (SSC) was determined at the UAF Water and Environmental Research Center (WERC) using ASTM Methods D3977-B and D2974-C. Selected water samples were sent to Particle Tech Labs in Downers Grove, Illinois, for particle-size distribution testing with an AccuSizer 780 AD optical sensor that has a working range of 0.5 µm to 400 µm.

3.6 Water Chemistry

An objective of this study was to determine the composition and possible sources of water in the aufeis formation at the lower Sagavanirktok River. Overflow water and ice cores were collected during winter months and prior to breakup in 2016, primarily near the location of the aufeis feature, but also at upriver locations. These samples represent the source water responsible for the ice accumulation that caused the road to wash out the previous year. Water samples were analyzed for concentrations of numerous trace elements. Simultaneously, possible contributing water sources were sampled between January and July 2016, including snow, glacial meltwater, and river water. Similar geochemical analyses were performed to compare the water sources with the overflow water that formed the aufeis.

3.6.1 Sampling

Samples were collected in 100 mL centrifuge tubes or 0.5 L plastic bottles, and classified as *Sagavanirktok overflow* (water), *headwater overflow* (water), *river ice*, *river water*, *snow*, and *glacier* (melt) *water*. Samples of *Sagavanirktok overflow* (n = 28) were collected in 100 mL centrifuge tubes or 0.5 L plastic bottles between February and May, when the river channel was otherwise frozen. Most of these samples were collected on the lower part of the river, though some came from as far upstream as the Sagavanirktok USGS gauge station. *Headwater overflow* was sampled by helicopter from multiple locations where the Ivishak (n = 4) and the Sagavanirktok (n = 1) Rivers exit the Brooks Range. On April 29, *river ice* cores (n = 9) were collected from the aufeis area using a SIPRE corer. *Snow* samples (n = 17) were collected throughout the Sagavanirktok River watershed by helicopter in April, using a plastic scoop, and later melted for analysis. Samples of *glacier* (melt) *water* (n = 6) were collected by helicopter on July 12, immediately downstream of several small glaciers feeding the Sagavanirktok and Ivishak River headwaters. Figure 8 shows the sampling locations inside the watershed.

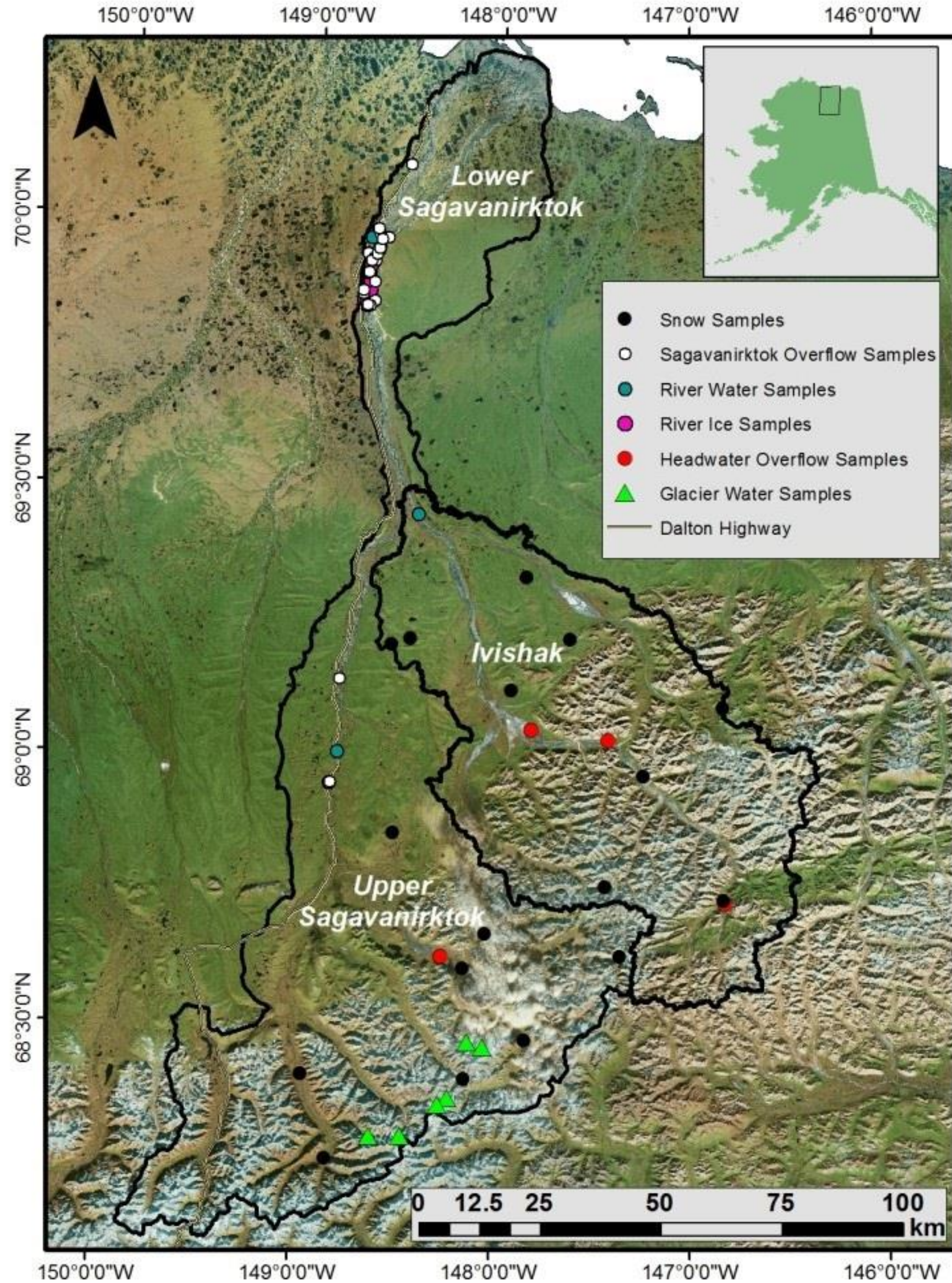


Figure 8. Map of the Sagavanirktok River basin showing locations of water chemistry samples collected for this study.

3.6.2 Trace Element Analysis

Water samples were refrigerated after collection; ice core and snow samples were melted. The outside of ice cores was melted using distilled water to remove possible contamination by the core barrel, and the remainder of the sample was melted and used for analysis. Samples were filtered through a polypropylene 0.45 micron filter (VWR 28145-485) using polypropylene syringes and then acidified to 2% nitric acid using Aristar plus nitric acid. Analyses were performed on an Agilent 7500ce ICP-MS at the UAF Advanced Instrumentation Laboratory. Samples were diluted 2:1 in 2% Aristar ultra nitric acid prior to analysis. Se_{78}, Fe_{56}, and Te_{125} were analyzed in H_2 mode; Na_{23}, Mg_{24}, K_{39}, V_{51}, Ni_{60} Cu_{63} and As_{75} were analyzed in helium mode; and Be_9, Al_{27}, Ca_{44}, Cr_{53}, Mn_{55}, Co_{59}, Ti_{47}, Zn_{66}, Sr_{88}, Mo_{95}, Ag_{107}, Cd_{111}, Sn_{118}, Sb_{121}, Ba_{137}, Au_{197}, Tl_{205}, Pb_{208}, Bi_{209}, Th_{232} and U_{238} were analyzed in no gas mode. Calibration standards were made from single element standards (Ultra Scientific) ranging from 0.01–50 ppb for all elements except for Na (0.2–2690), Mg (0.2–25000), K (0.2–2000), Ca (0.2–10500), Sr (0.1–700), and Ba (0.1–100). Continuing calibration verifications (CCVs) and continuing calibration blanks (CCBs) were analyzed every 10 samples and were within 20% of the midrange calibration standards and less than five times the calibration blank, respectively. NIST 1640 was analyzed as a secondary standard, and all elements were within 10% of the certificate values, except for Ag, Se, and Zn.

3.6.3 Data Analysis

Sample groups were compared with each other by plotting graphically and testing for correlation. The water, snow, and ice traveled vastly different distances prior to being sampled and analyzed. To account for these differences, the proportions of elements in each sample—the fraction of a particular element in a sample to the total of all elements in that sample—were calculated, such that all element concentrations summed to 1. The data were log transformed to facilitate analysis of disparate concentrations. The suite of proportions in a sample is referred to as the sample's geochemical signature. Correlations among groups were then calculated to compare the signatures. Only the twelve most frequently occurring trace elements were used to calculate correlations. Finally, because information was sought on where the Sagavanirktok overflow originated, a mixing model was used to determine the amounts of the other sampled groups needed to produce the geochemistry observed in the overflow.

Let N_{ij} be the total for element *j* over the samples for source *i*. The proportions, P_{ij}, for that source are given by

$$P_{ij} = N_{ij} / \sum_j N_{ij}$$

Let *i* = 0 correspond to *Sagavanirktok overflow*. In order to determine what combination of the four other sources (*i* = 1, 2, 3, 4) creates the proportions seen for *Sagavanirktok overflow*, find α, β, and γ (fractions from each source) such that

$$P_{0j} \approx \alpha P_{1j} + \beta P_{2j} + \gamma P_{3j} + (1 - \alpha - \beta - \gamma)P_{4j} \text{ for all } j.$$

To do this, the following function must be minimized:

$$S = \sum_j [P_{0j} - (\{\alpha P_1 + \beta P_{2j} + \gamma P_{3j} + (1 - \alpha - \beta - \gamma)P_{4j}\}]^2.$$

4 RESULTS

In this chapter, all hydrological, meteorological, and water chemistry data collected on this and related projects in 2016 are presented. Selected data can be found in Appendices A, B, and C.

4.1 Air Temperature

Air temperature was measured at the following stations within the Sagavanirktok River basin: Accomplishment Creek Met, Sagavanirktok River near MP318 (DSS4), Alyeska Stream Station 1 (near MP347), Sagavanirktok River at Happy Valley (DSS3), Sagavanirktok River below the Ivishak (DSS2), Sagavanirktok River at East Bank (DSS5), and Sagavanirktok River at MP405 (DSS1). Due to datalogger programming issues, ambient air temperature data are not available for several of the stations where air temperature was below -11°C. Instead, the datalogger panel temperature for winter months is provided. The programming issue was resolved by April 1, 2016.

Historical mean monthly air temperature and hourly air temperature from long-term observation stations Franklin Bluffs (*n* = 29 years [Arp and Stuefer, 2016]), Sagavanirktok River gauge site (*n* = 18 years [USGS, 2016]), Accomplishment Creek (*n* = 8 years [Kane et al., 2014]), and Atigun Pass (*n* = 34 years [NRCS, 2016a]), along with data from short-term stations (DSS4, DSS3, DSS2, Alyeska Sagavanirktok River near MP347, East Bank stations) are presented in Figure 9 through Figure 18.

Air temperatures in the upper Sagavanirktok basin at Accomplishment Creek and at the NRCS station at Atigun Pass increased to above freezing beginning in late April 2016. The upper basin stayed warm until May 13, when air temperatures dropped below freezing for about a week. Air temperatures warmed again on May 20 and remained above freezing. Air temperatures in the mid basin (near the Sagavanirktok River USGS gauge) and lower basin (Franklin Bluffs, East Bank) were close to average in late April and early May, and did not significantly warm up until May 8. The late April warmup in the Sagavanirktok River headwaters allowed runoff in the basin to initiate early, with flows reaching the southern observation stations by May 10. Breakup was observed at DSS5 on May 13; however, the cooler temperatures that occurred in the upper basin beginning on May 13 decreased subsequent runoff.

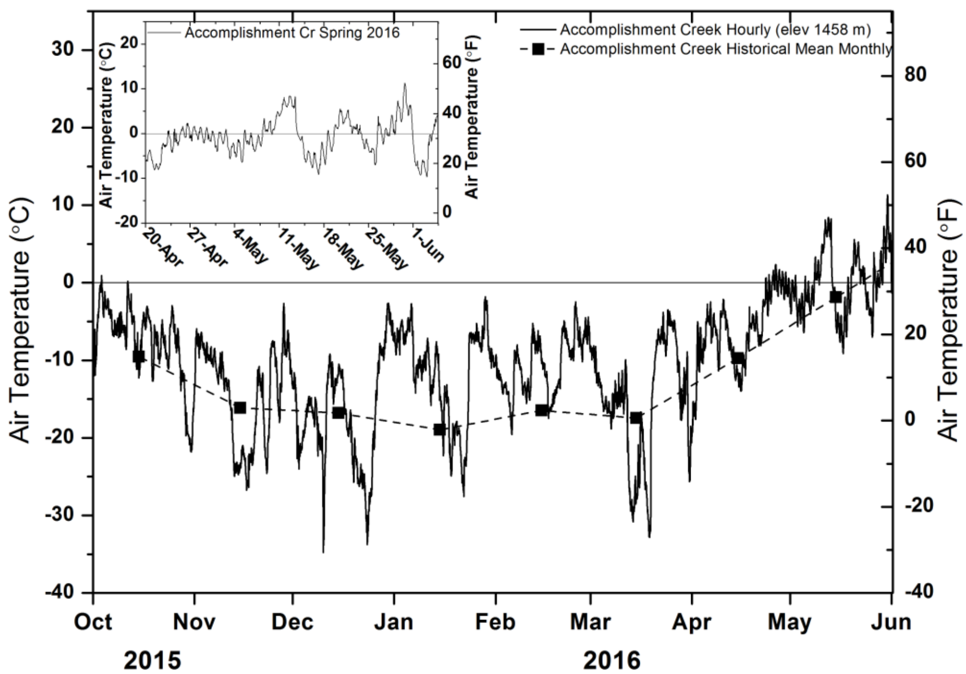


Figure 9. Hourly air temperature at UAF Accomplishment Creek station winter 2015–2016. Station was installed in fall 2015.

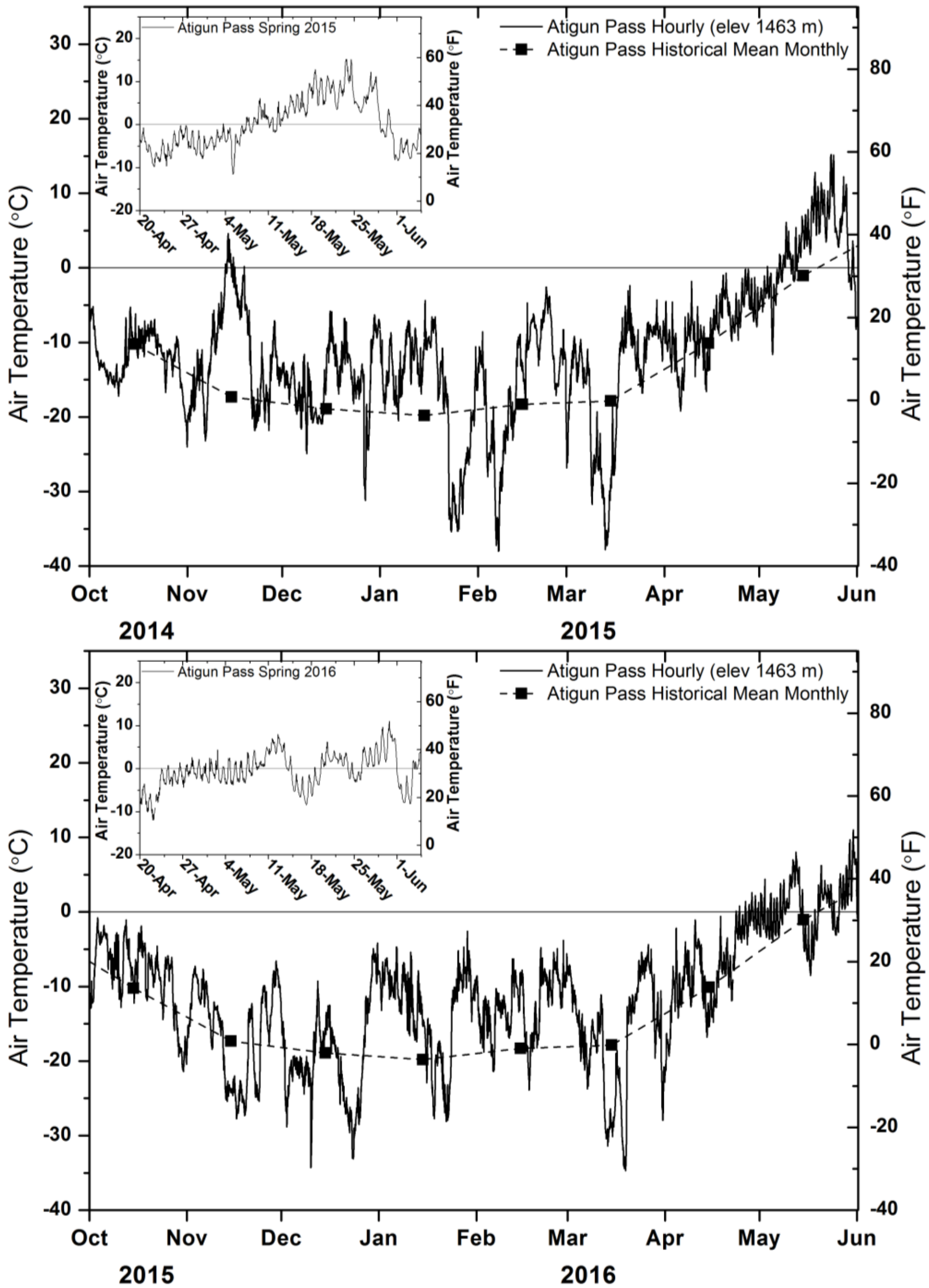


Figure 10. Hourly air temperature at NRCS Atigun Pass station winter 2014–2015 and 2015–2016. Data courtesy of NRCS (2016b).

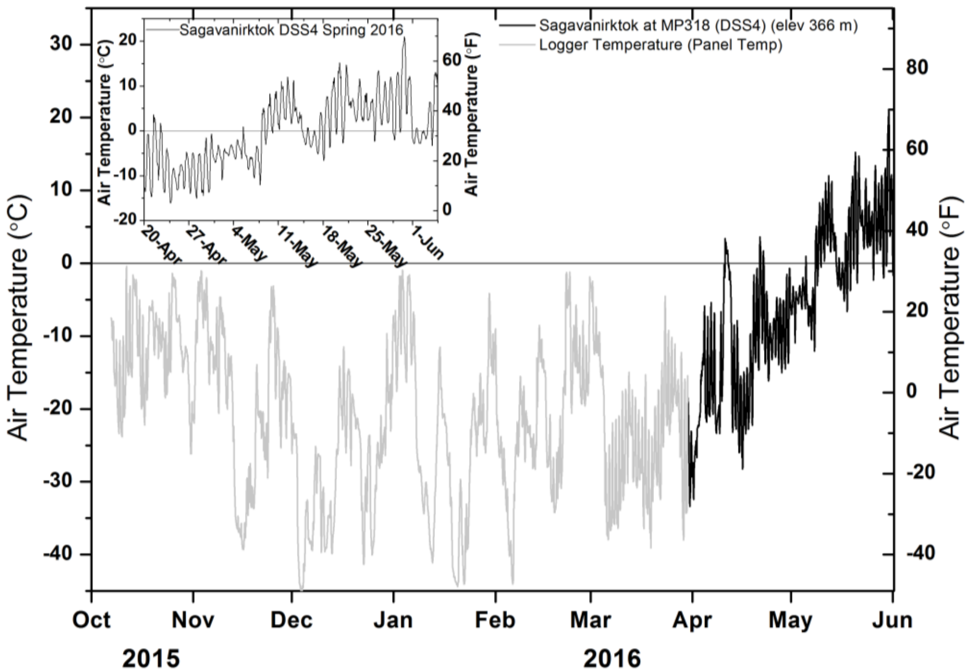


Figure 11. Hourly air temperature at Sagavanirktok River at MP318 (DSS4) station winter 2015–2016.

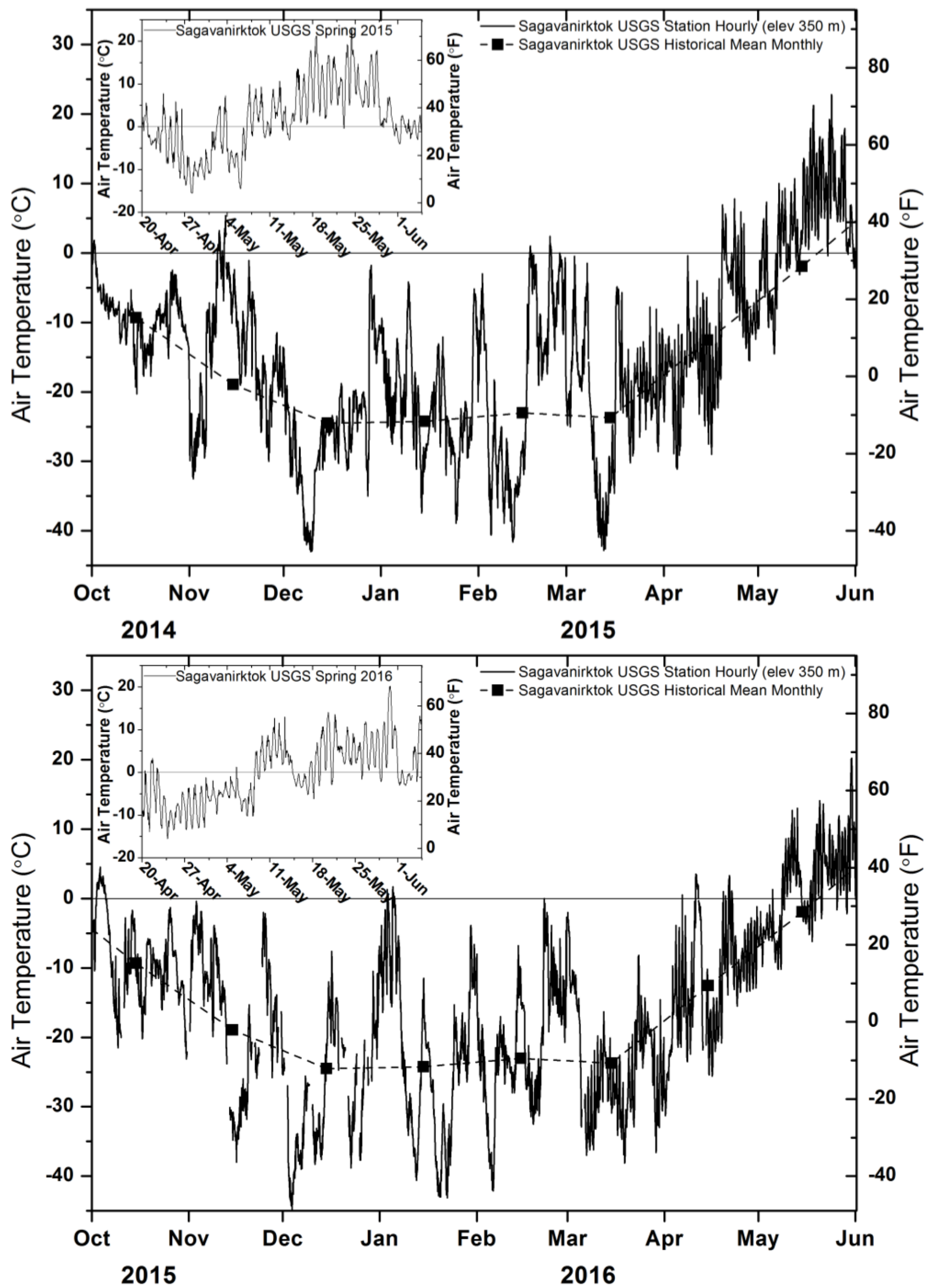


Figure 12. Hourly air temperature at USGS Sagavanirktok River station winter 2014–2015 and 2015–2016. Data courtesy of USGS (2016).

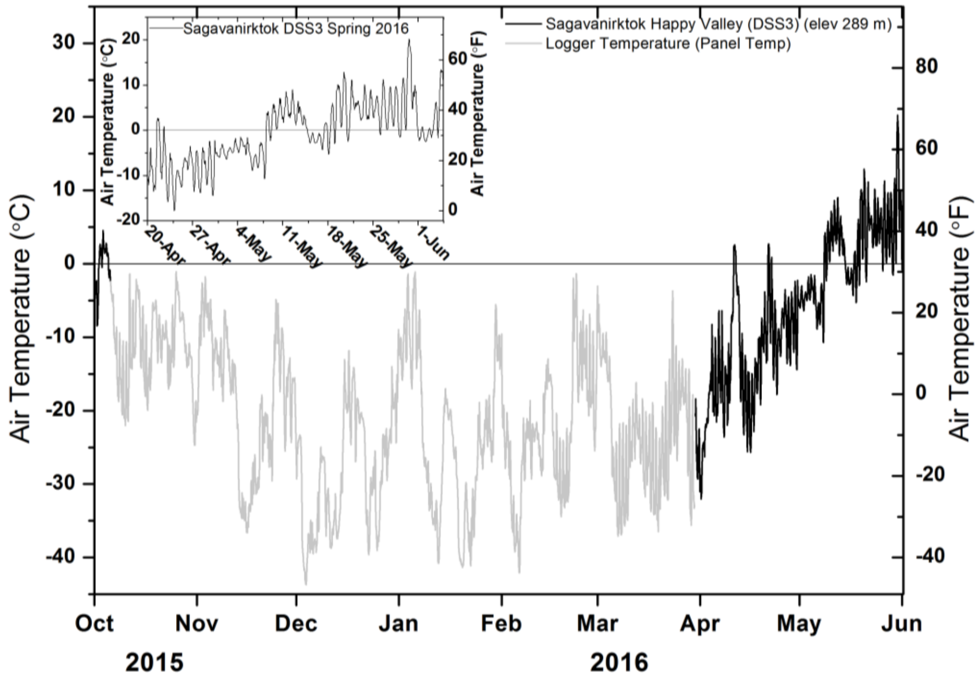


Figure 13. Hourly air temperature at Sagavanirktok River at Happy Valley (DSS3) station winter 2015–2016.

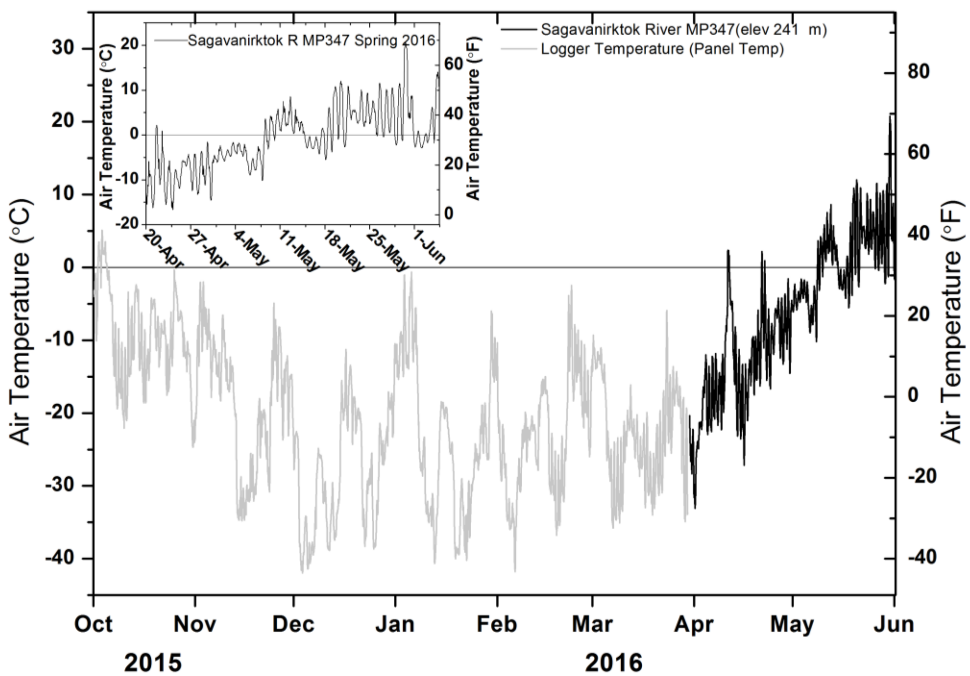


Figure 14. Hourly air temperature at Alyeska Sagavanirktok River near MP347 station winter 2015–2016.

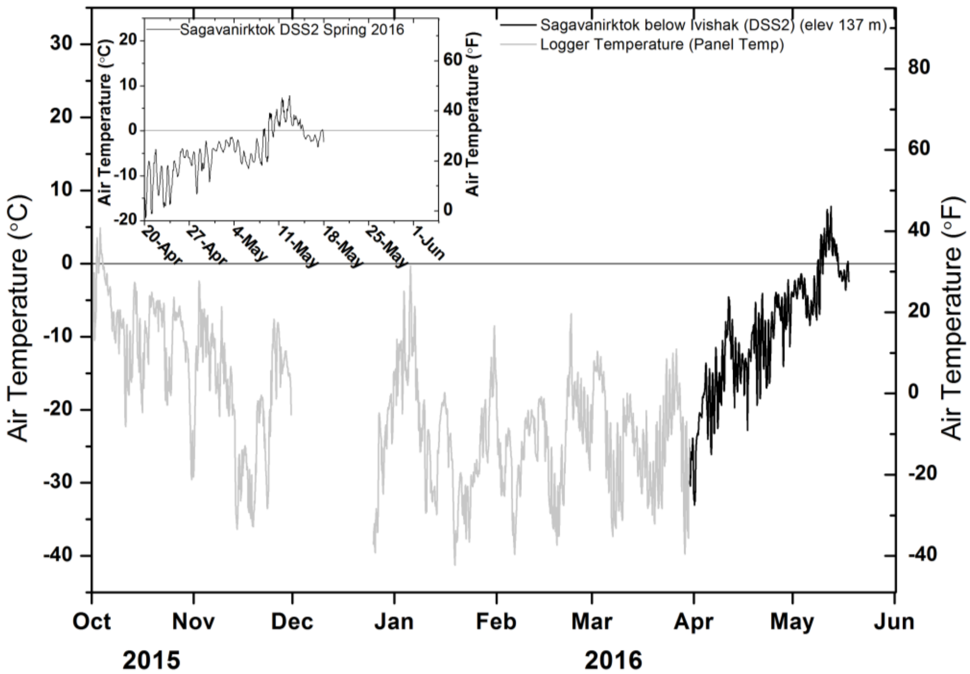


Figure 15. Hourly air temperature at Sagavanirktok River below Ivishak (DSS2) station winter 2015–2016. There was a problem with the temperature sensor after May 18, 2016. No data are available.

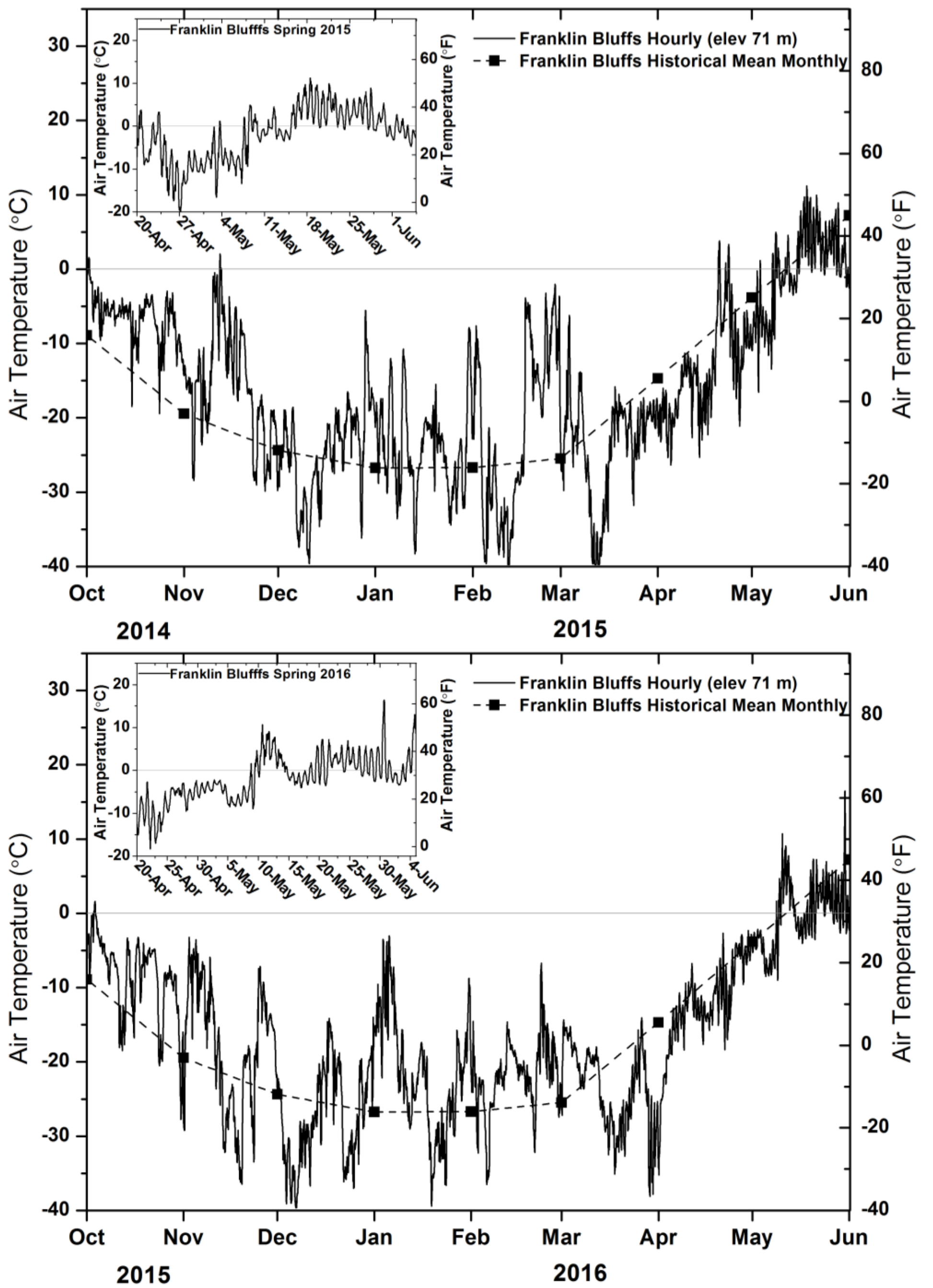


Figure 16. Hourly air temperature at Franklin Bluffs winter 2014–2015 and 2015–2016. Data courtesy of Kane (2014) and Arp and Stuefer (2016).

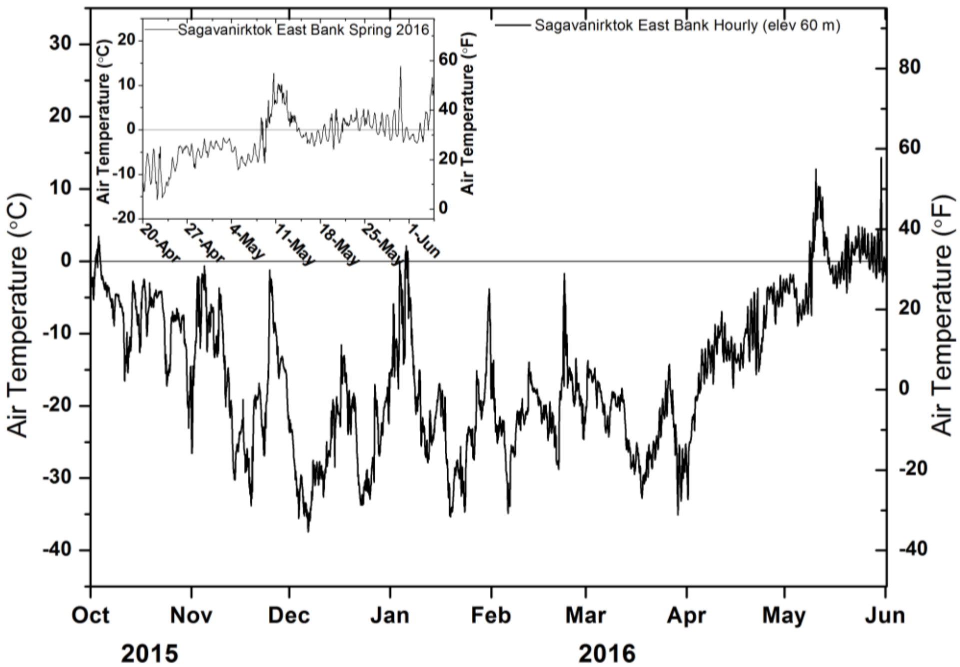


Figure 17. Hourly air temperature at Sagavanirktok River East Bank (DSS5) station winter 2015–2016.

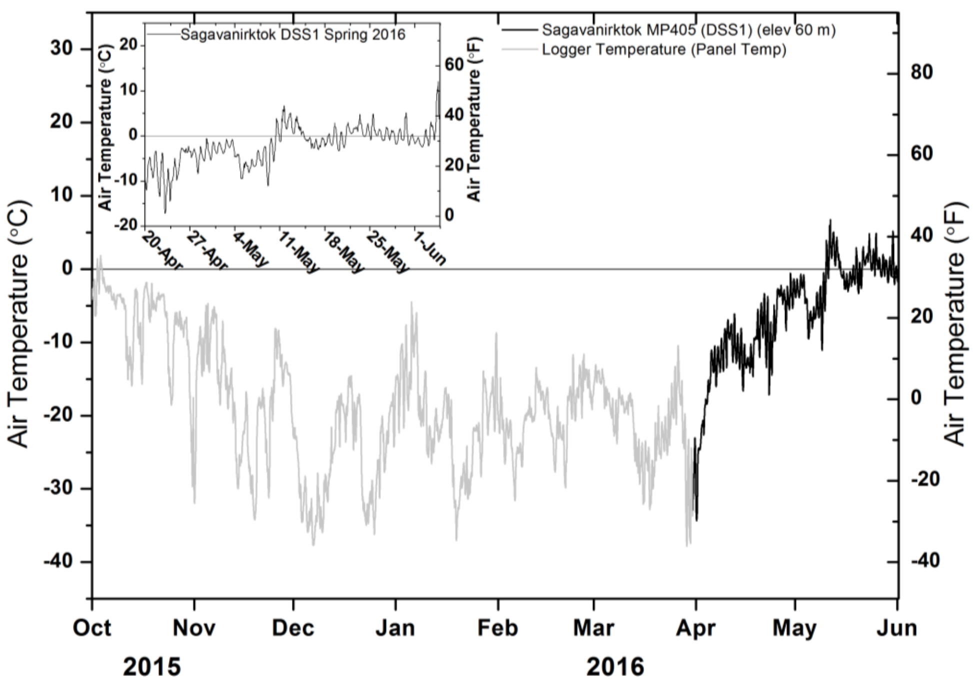


Figure 18. Hourly air temperature at Sagavanirktok River near MP405 (DSS1) station winter 2015–2016.

4.2 Wind Speed and Direction

Wind speed and direction are measured at the following stations within the Sagavanirktok River basin: Accomplishment Creek Met, Sagavanirktok River near MP318 (DSS4), Alyeska Sagavanirktok River Station 1 (near MP347, ASS1), Sagavanirktok River at Happy Valley (DSS3), Sagavanirktok River below the Ivishak (DSS2), Sagavanirktok River at East Bank (DSS5), and Sagavanirktok River at MP405 (DSS1). Wind roses (see Appendix A) were made for each station for (1) the period of record, (2) summer months (May 15 through September 15), and (3) winter months (September 16 through May 14). Table 4 is a summary of the wind conditions at each station.

Table 4. Summary of WRPLOT wind rose analysis for the period of record. Summer period is May 15 through September 15, and winter period is September 16 through May 14. See Appendix A for wind roses.

Station	Overall Average Hourly Wind Speed (m/s)	Summer Average Hourly Wind Speed (m/s)	Winter Average Hourly Wind Speed (m/s)	Overall Calm Winds (%)	Summer Calm Winds (%)	Winter Calm Winds (%)	Total Data Count (hr)	Missing Data (hr)
Sagavanirktok Rv. near Deadhorse (DSS1)	4.4	3.9	4.7	1.4	0.3	2.1	12073	828
Sagavanirktok Rv. near Ivishak Rv. (DSS2)	3.5	3.6	3.4	2.0	0.8	2.4	11590	2678
Sagavanirktok Rv. at Happy Valley (DSS3)	1.9	2.3	1.6	7.5	2.3	10.3	11302	1
Sagavanirktok Rv. near MP318 (DSS4)	1.7	1.8	1.5	5.7	4.1	7.3	5879	19
Sagavanirktok Rv. East Bank (DSS5)	2.6	3.5	4.7	2.6	1.0	3.7	13150	104
Franklin Bluffs Repeater	6.6	5.7	7.2	1.8	0.2	3.0	12954	176
Accomplishment Creek (ASM1)	3.0	2.5	3.2	4.1	4.3	4.1	92516	2563
Sagavanirktok Rv. Alyeska Station near MP347 (ASS1)	2.1	2.6	1.9	7.9	1.9	10.1	10340	502

At the southern stations along the Sagavanirktok River at MP318 (DSS4) and Happy Valley (DSS3), winds blow from the south in the winter and from the north in the summer, likely channeling up and down the valley bottom. At the Accomplishment Creek station in the Brooks

Range, winds are influenced by mountainous topography and blow from both the north-northeast and the east-southeast in the summer. In the winter, winds primarily blow from the east-southeast. Farther north on the coastal plain, near Franklin Bluffs at the Sagavanirktok River near MP405 (DSS1) and East Bank (DSS5) stations, winds blow from the east-northeast year-round, but in the winter months strong winds also blow from the southwest. At the East Bank station (DSS5), located at the base of Franklin Bluffs next to the river, winds blow from the north, channeling up the river valley. At the Franklin Bluffs Repeater, the highest wind speeds are from the northeast, with an average wind speed of 6.6 m/s (14.8 mph).

4.3 Annual Precipitation

Limited annual precipitation is available in the Arctic region. Several tipping buckets in or near the Sagavanirktok basin measure rainfall during the warm season, and winter measurements of snowpack conditions are sparse. Most of the Sagavanirktok basin falls within the mountainous region, and Atigun Pass is the only meteorological station in this region with long-term annual precipitation records.

Annual accumulated precipitation at the NRCS Wyoming gauge at Atigun Pass is shown in Table 5 (NRCS, 2016a). This gauge is located in the headwaters of the Sagavanirktok River, along the Dalton Highway. For the period of record (1983–2016), the highest recorded annual precipitation occurred in water year 1994. When precipitation data are examined based on season, 2014 had a total of ~530 mm of rainfall (the second highest on record, behind 1998), compared with the average of 412 mm. The winter of 1993–1994 had the highest accumulated solid precipitation (snow) on record (~254 mm, compared with an average of 175 mm). Based on the Atigun Pass station record, most of the annual precipitation in the mountains region of the watershed is liquid (summer rainfall). For 2016, annual precipitation for the water year is slightly below the average.

Table 5. Atigun Pass Wyoming gauge annual water year accumulated precipitation.

Water Year	Accumulated Precipitation October 1–September 30 (mm)	Accumulated Precipitation October 1–May 10 (mm)	Accumulated Precipitation May 10–September 30 (mm)
1983	592	150	442
1984	650	168	483
1985	511	114	396
1986	597	152	445
1987	653	185	467
1988	594	180	414
1989	648	196	452
1990	457	135	323
1991	485	178	307
1992	564	160	404
1993	742	231	511
1994	770	254	516
1995	721	185	536
1996	485	191	295
1997	640	152	488
1998	711	175	536
1999	625	137	488
2000	556	170	386
2001	546	165	381
2002	559	203	356
2003	714	224	490
2004	439	155	284
2005	495	196	300
2006	678	188	490
2007	478	165	312
2008	442	188	254
2009	559	231	328
2010	627	175	452
2011	594	188	406
2012	673	208	465
2013	439	130	310
2014	676	145	531
2015	467	140	328
2016	566	127	439
Average	587	175	412
Max	770 (1994)	254 (1994)	536 (1995,1998)
Min	439 (2013)	114 (1985)	254 (2008)
Median	593	175	427

Atigun Pass rainfall during summer 2015 was below average, with only 328 mm of precipitation. If summer and fall are dry, a storage deficit develops, which can affect the volume of runoff the following spring (Hinzman, 1990). Due to this storage deficit, an increased proportion of the spring meltwater recharges basin storage instead of contributing to runoff. Solid precipitation (snow) at Atigun Pass for winter 2015/2016 was also below average (127 mm, compared with an average of 175 mm).

4.4 Cold Season Precipitation

Kane et al. (2014) and Stuefer et al. (2014) attempted to quantify cold season precipitation by measuring end-of-winter snow density, depth, and snow water equivalents (SWEs) at selected locations within the Kuparuk, Sagavanirktok, and adjacent basins. The research teams found that the amount of SWE at winter's end varied little from the coastal plain to the continental divide in the Brooks Range (Homan and Kane, 2015; Kane et al., 2014). They also found spatial variation of snow depth and SWE at the scale of a few kilometers or less due to redistribution of snow (Kane et al., 2014).

In 2016, the UAF project team surveyed the historical snow survey sites previously established in the Sagavanirktok River watershed (Kane et al., 2014; Stuefer et al., 2014). Snow depth and SWE measurements were made at 32 locations (Table 6, Figure 19, and Figure 20) in mid-April, and represent end-of-winter snowpack conditions. Nearly half the sites are located in the mountains region of the basin. End-of-winter SWE measured in 2016 was compared with historical measurements for each snow survey site (Table 7). The comparison shows that average SWE for the Sagavanirktok basin is near normal or slightly below normal for winter 2015/2016. The NRCS also conducts snow surveys each month at Imnavait Creek in the foothills and at Atigun Pass in the mountains. The NRCS reported normal or slightly below normal snowpack conditions for the end of winter (April 2016) in the Arctic region (NRCS, 2016b).

Table 6. Snow survey results for spring 2016.

#	Station ID	Survey Date	Elevation (m)	Lat (dd)	Long (dd)	Snow Depth (cm)	Snow Depth (in.)	Snow Density (kg/m^3)	Snow Density ($Slug/ft^3$)	SWE (cm)	SWE (in.)
1	Atigun Pass	04/20/16	1469	68.13	-149.48	77	30	256	0.50	19.7	7.8
2	DBM1	04/18/16	1474	68.41	-148.14	37	15	280	0.54	10.5	4.1
3	DBM2	04/16/16	1478	68.64	-147.35	54	21	272	0.53	14.7	5.8
4	DBM4	04/19/16	431	69.22	-148.55	60	23	190	0.37	11.4	4.5
5	ECH1	04/16/16	868	69.10	-146.83	61	24	193	0.37	11.8	4.7
6	Franklin Bluffs	04/19/16	71	69.89	-148.77	16	6	266	0.52	4.2	1.7
7	FH1	04/18/16	548	68.87	-148.52	73	29	200	0.39	14.6	5.8
8	FH2	04/18/16	400	69.13	-147.92	65	25	224	0.43	14.5	5.7
9	FH3	04/18/16	524	69.23	-147.62	63	25	204	0.40	12.8	5.0
10	Galbraith	04/20/16	831	68.48	-148.50	30	12	286	0.56	8.6	3.4
11	Happy Valley	04/20/16	314	69.15	-148.84	63	25	229	0.44	14.4	5.7
12	IVI1	04/16/16	521	68.98	-147.23	29	11	305	0.59	8.9	3.5
13	IVI2	04/16/16	810	68.75	-146.82	48	19	175	0.34	8.4	3.3
14	LUP1	04/16/16	747	68.68	-148.04	51	20	231	0.45	11.8	4.7
15	MI1	04/19/16	48	70.00	-148.68	18	7	211	0.41	3.8	1.5
16	MI2	04/19/16	60	69.93	-148.77	23	9	189	0.37	4.3	1.7
17	MI3	04/19/16	90	69.80	-148.74	15	6	262	0.51	4.0	1.6
18	MI4	04/19/16	90	69.71	-148.72	26	10	342	0.66	8.8	3.5
19	MI5	04/19/16	140	69.61	-148.65	32	12	240	0.47	7.6	3.0
20	MI6	04/19/16	159	69.53	-148.60	40	16	239	0.46	9.7	3.8
21	MI7	04/20/16	175	69.49	-148.57	41	16	256	0.50	10.5	4.1
22	Oil Spill Hill	04/20/16	440	68.94	-148.87	54	21	214	0.42	11.6	4.6
23	RIB1	04/16/16	609	68.62	-148.15	29	11	290	0.56	8.3	3.3
24	RIB2	04/18/16	800	68.48	-147.84	23	9	231	0.45	5.3	2.1
25	RIB3	04/16/16	918	68.69	-147.48	52	20	236	0.46	12.2	4.8
26	SAG1	04/19/16	730	68.42	-148.96	0	0	No Snow		0.0	0.0
27	SAG2	04/19/16	868	68.26	-148.83	36	14	238	0.46	8.6	3.4
28	SAG3	04/16/16	830	68.45	-148.70	13	5	344	0.67	4.5	1.8
29	Sagwon	04/20/16	275	69.43	-148.69	40	16	237	0.46	9.5	3.8
30	SAV1	04/16/16	955	68.77	-147.43	62	24	207	0.40	12.8	5.0
31	UP1	04/19/16	194	69.23	-148.45	54	21	211	0.41	11.5	4.5
32	UP2	04/18/16	318	69.34	-147.85	56	22	206	0.40	11.5	4.5
Basin Average						42	17	241	0.47	9.7	3.8

Note: SWE – snow water equivalent

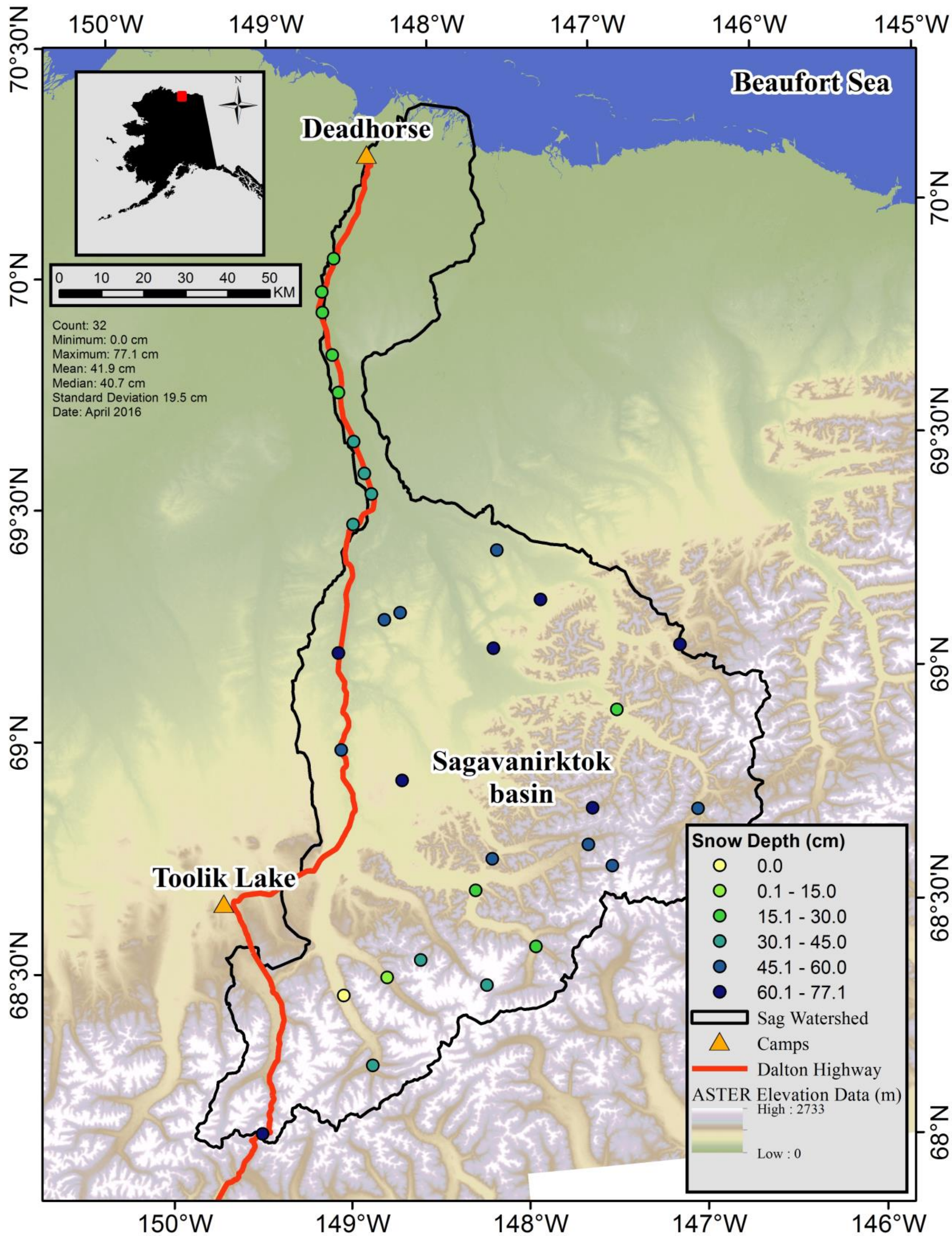


Figure 19. Snow depth at sites in the Sagavanirktok basin in April 2016.

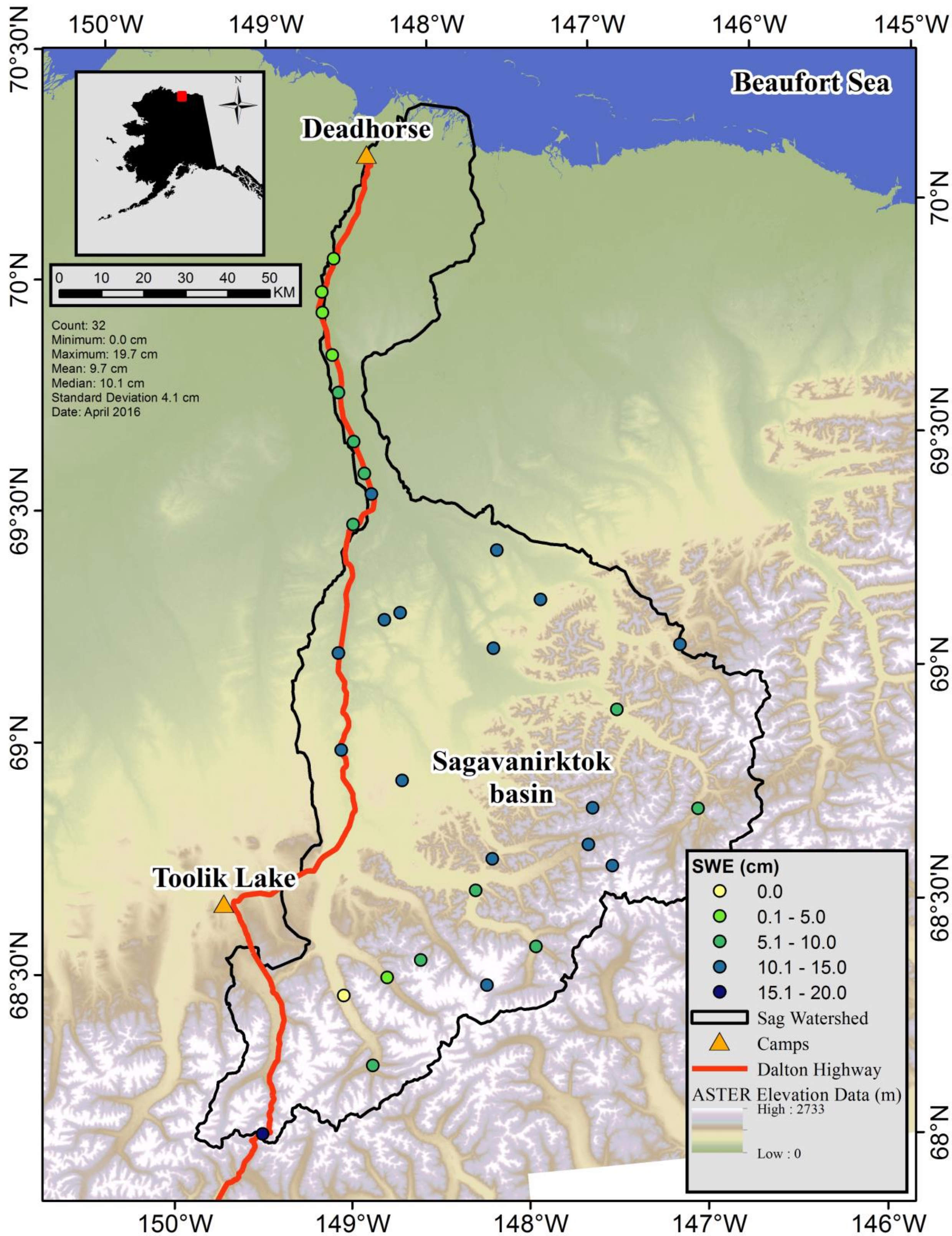


Figure 20. Snow water equivalent (SWE) at sites in the Sagavanirktok basin in April 2016.

Table 7. Comparison of 2016 snowpack to the historical record (Stuefer et al., 2011; Stuefer et al., 2012; Stuefer et al., 2014; Kane et al., 2006; Kane et al., 2012; Berezovskaya et al., 2007; Berezovskaya et al., 2008; Berezovskaya et al., 2009) in the Sagavanirktok basin. Locations are presented in Table 6.

#	Station ID	Period of Record	Number of Years	Average SWE		2016 SWE		Difference	
				(cm)	(in.)	(cm)	(in.)	(cm)	(in.)
2	DBM1	2007–10	4	13.7	5.4	10.5	4.1	-3.2	-1.3
3	DBM2	2007–10	4	11.8	4.6	14.7	5.8	2.9	1.1
4	DBM4	2007–10	4	9.7	3.8	11.4	4.5	1.7	0.7
5	ECH1	2006–10	5	12.8	5.0	11.8	4.7	-1.0	-0.4
6	Franklin Bluffs	2000–13	14	11.0	4.3	4.2	1.7	-6.8	-2.7
10	Galbraith	2010–13	4	11.6	4.6	8.6	3.4	-3.0	-1.2
11	Happy Valley	2000–13	14	21.5	8.5	14.4	5.7	-7.0	-2.8
12	IVI1	2006–10	5	5.8	2.3	8.9	3.5	3.1	1.2
13	IVI2	2006–10	5	9.4	3.7	8.4	3.3	-1.0	-0.4
14	LUP1	2006–10	5	8.0	3.2	11.8	4.7	3.8	1.5
15	MI1	2001–13	13	8.9	3.5	3.8	1.5	-5.1	-2.0
16	MI2	2001–13	13	9.4	3.7	4.3	1.7	-5.1	-2.0
17	MI3	2001–13	12 *	7.1	2.8	4.0	1.6	-3.1	-1.2
18	MI4	2001–13	12 *	10.0	3.9	8.8	3.5	-1.2	-0.5
19	MI5	2001–13	12 *	8.8	3.4	7.6	3.0	-1.1	-0.4
20	MI6	2001–13	12 *	13.6	5.4	9.7	3.8	-4.0	-1.6
21	MI7	2001–13	12 *	10.8	4.3	10.5	4.1	-0.4	-0.1
22	Oil Spill Hill	2010–13	4	11.7	4.6	11.6	4.6	-0.1	0.0
23	RIB1	2007–10	4	6.5	2.5	8.3	3.3	1.9	0.7
24	RIB2	2007–10	4	4.5	1.8	5.3	2.1	0.8	0.3
25	RIB3	2007–10	4	8.9	3.5	12.2	4.8	3.2	1.3
26	SAG1	2006–13	6 *	2.5	1.0	0.0	0.0	-2.5	-1.0
27	SAG2	2006–13	8	12.4	4.9	8.6	3.4	-3.7	-1.5
28	SAG3	2006–13	8	7.0	2.8	4.5	1.8	-2.5	-1.0
29	Sagwon	2000–13	14	7.2	2.8	9.5	3.8	2.3	0.9
30	SAV1	2006–10	5	10.1	4.0	12.8	5.0	2.7	1.1
31	UP1	2006–10	4 *	6.1	2.4	11.5	4.5	5.4	2.1
32	UP2	2006–10	5	10.0	3.9	11.5	4.5	1.5	0.6

Notes: * – Missing 1 or more years during surveyed record
SWE – snow water equivalent

4.5 Warm Season Precipitation

As mentioned previously, precipitation varies with location, most noticeably in summer. Rainfall greatly increases with elevation (southward). Since most of the Sagavanirktok River basin lies in the mountains and foothills regions (over 75% of basin area), rainfall data from these higher elevations need examination to better understand runoff and the water balance. Rainfall data in the region are available from the long-term stations at Atigun Pass in the mountains, Imnavait Creek in the foothills, and Franklin Bluffs in the coastal plain (NRCS, 2016a; Kane, 2014; Arp and Stuefer, 2016). Cumulative rainfall data for 2015 are not available at the newly installed stations within the Sagavanirktok River basin.

The long-term stations show that 2013 and 2014 were above-normal years for total rainfall. In 2015, the two stations in the foothills and mountains regions recorded normal and below normal rainfall, respectively, and the station on the coastal plain recorded above normal rainfall. June and July were very dry across the entire region, and August was wet. The NRCS Atigun Pass Wyoming gauge had below normal rainfall in 2015 (Figure 21), with approximately 328 mm (compared with 530 mm of rainfall in 2015). At the Imnavait Creek station (Figure 22), rainfall for 2012, 2013, and 2014 was above average at Imnavait Creek, and rainfall for 2015 was average. At Franklin Bluffs, 2014 was the third wettest year in 27 years of data (Figure 23). In 2015, rainfall at Franklin Bluffs was also above average, despite the dry early summer. A drier warm season can affect the next year's spring runoff, because during breakup, a higher percentage of meltwater can go into surface storage instead of runoff.

Rain events may occur during spring breakup that cause increases in runoff. In 2015, a rain event in the upper basin on May 28, when Imnavait Creek recorded 30 mm of rainfall (Arp and Stuefer, 2016), caused a small runoff peak to occur on May 29 in many area rivers. However, the larger spring breakup peak had already occurred: on May 15 at Imnavait Creek, on May 18 at Upper Kuparuk River (Arp and Stuefer 2016), and around May 20 at the lower Sagavanirktok River. In 2016, a small rain event occurred in the morning of May 22, when about 7 mm of rain fell in the headwaters at various stations (Figure 24). The rain event may have caused a slight increase in runoff, but the increase observed in the Sagavanirktok and Upper Kuparuk hydrographs (see Figure 43 in Section 4.7) at about this time was more likely due to the warming air temperatures after the freeze-back.

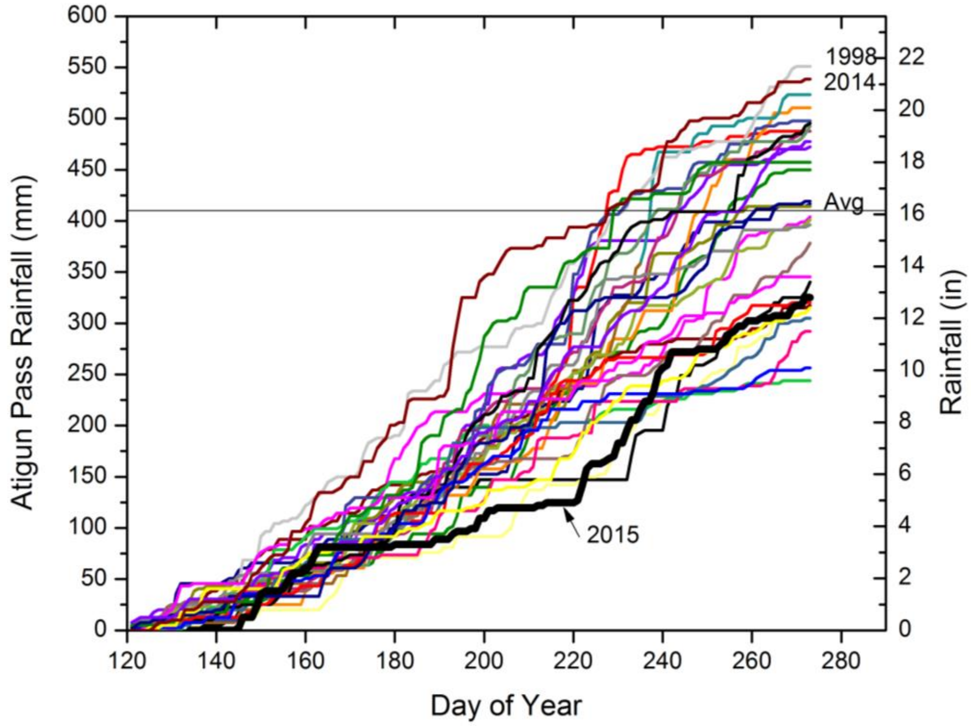


Figure 21. Accumulated rainfall at the Atigun Pass Wyoming gauge for the period of record (1983–2015). The wettest years were 1998 and 2014 (data courtesy NRCS, 2016a).

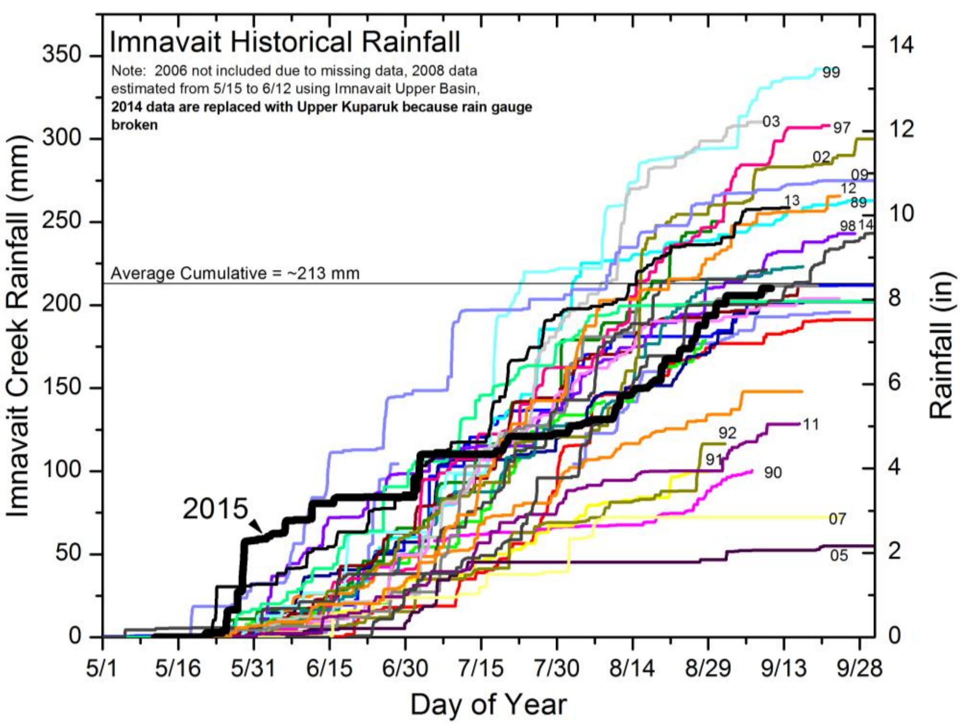


Figure 22. Imnavait Creek historical rainfall ($n = 29$). In 2014, data from the nearby Upper Kuparuk gauge are used in the plot. The wettest years were 1999, 2003, and 1997. The driest years were 2005 and 2007.

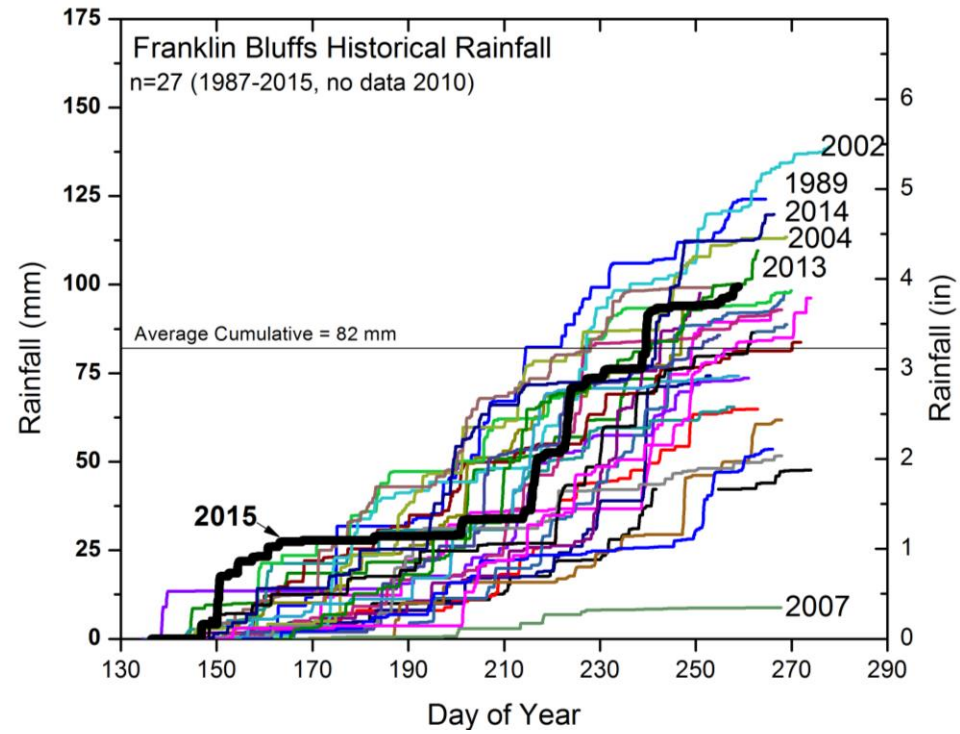


Figure 23. Historical rainfall at Franklin Bluffs (*n* = 26). The wettest years were 2002, 1989, and 2014. The driest year was 2007.

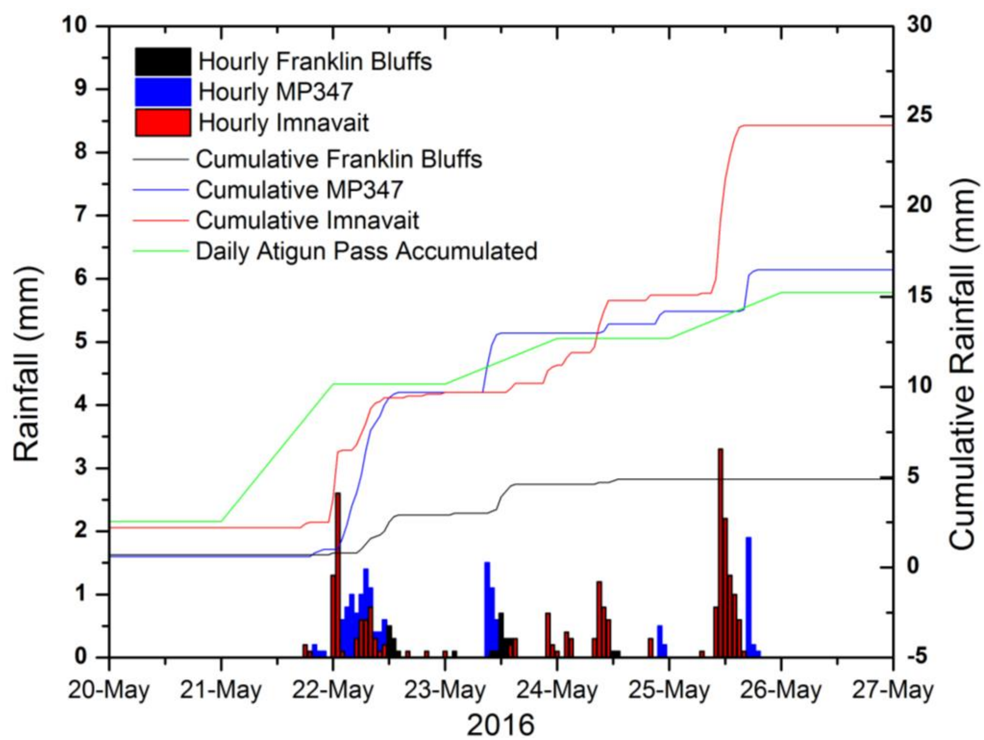


Figure 24. Hourly rainfall at Franklin Bluffs, Sagavanirktok River at MP347, and Imnavait Creek in late May 2016. Cumulative rainfall at the sites (including Atigun Pass) is also shown (Arp and Stuefer, 2016; NRCS, 2016a).

4.6 Aufeis Extent

In this section, the results of efforts to delineate the aufeis deposit on the Sagavanirktok River near Deadhorse and Franklin Bluffs are presented. In 2015, widespread flooding during spring breakup occurred due to extensive ice that had accumulated over the winter and a short breakup period. Significant damage to the Dalton Highway occurred, and during summer and fall, the road was rebuilt, up to 1.2 m (4 ft) higher in many places. In the winter of 2015/2016, efforts were taken to monitor the growth and extent of the aufeis formation with satellite imagery and field methods.

4.6.1 Historical Aufeis at Franklin Bluffs

Landsat satellite imagery (NIR band) was used to examine the Sagavanirktok aufeis extent near Franklin Bluffs in recent history. Figure 25 through Figure 27 show the aufeis extent from 2000 to 2016. Table 8 shows the calculated aufeis area. Figure 28 shows the number of years that aufeis forms at any particular location. During 2003, 2004, 2007, 2008, 2013, 2015, and 2016, aufeis formation extended well past Franklin Bluffs. Years 2010 and 2012 had the smallest extent of aufeis cover, and years 2015 and 2016 clearly had the largest extent of aufeis cover. These images show that the location and extent of aufeis vary from year to year, but areas of ice formation are persistent in the main stem of the Sagavanirktok River near Franklin Bluffs and near the dikes at MP395 (Figure 28). Dean (1984) observed similar aufeis distribution in 1972–1982 Landsat imagery of the lower Sagavanirktok River. Note that strands of aufeis occur frequently in active channels upstream of MP388, occur less frequently from MP389 to MP392, and occur both extensively and frequently from MP393 to MP396. The area of infrequent aufeis development from MP389 to MP392 is adjacent to a less steep portion of Franklin Bluffs. The lack of aufeis may be attributable to an increase in blown snow traversing the river. At this section of the river, the active floodplain is narrower in width than immediately upstream or downstream, suggesting the channel may be deeper here, thus less susceptible to aufeis formation (Harden et al., 1977). At approximately MP393, the active floodplain increases at the apex of the alluvial fan. This area is more susceptible to aufeis formation due to the decreased channel depth.

As mentioned in Section 3.1.3, the method used in this study may underestimate the extent of aufeis because this method does not include areas with fresh or windblown snow on top of aufeis. The method may also overestimate the extent of aufeis because it does not differentiate aufeis from river ice.

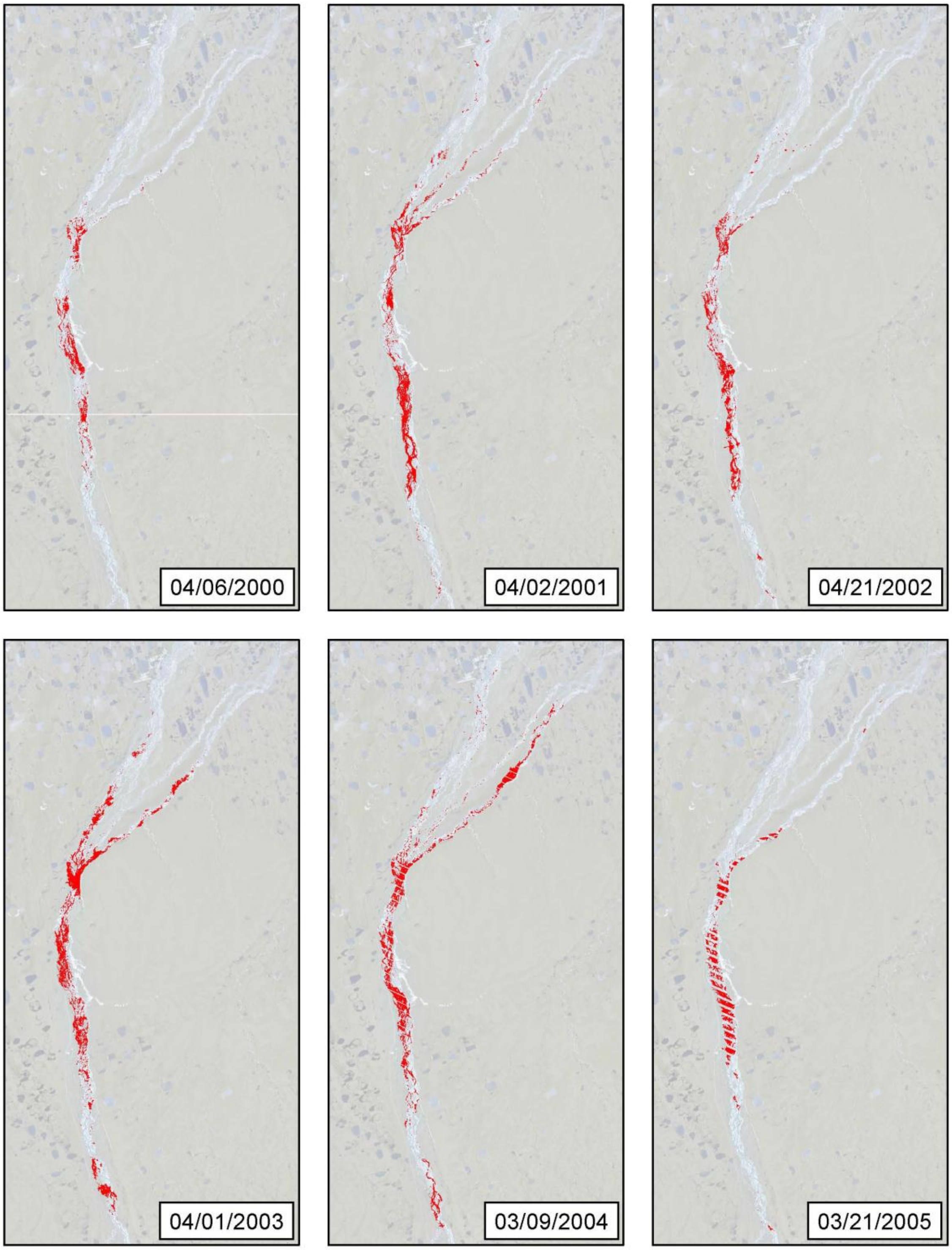


Figure 25. Landsat imagery of end-of-winter aufeis extent near Franklin Bluffs 2000–2005.

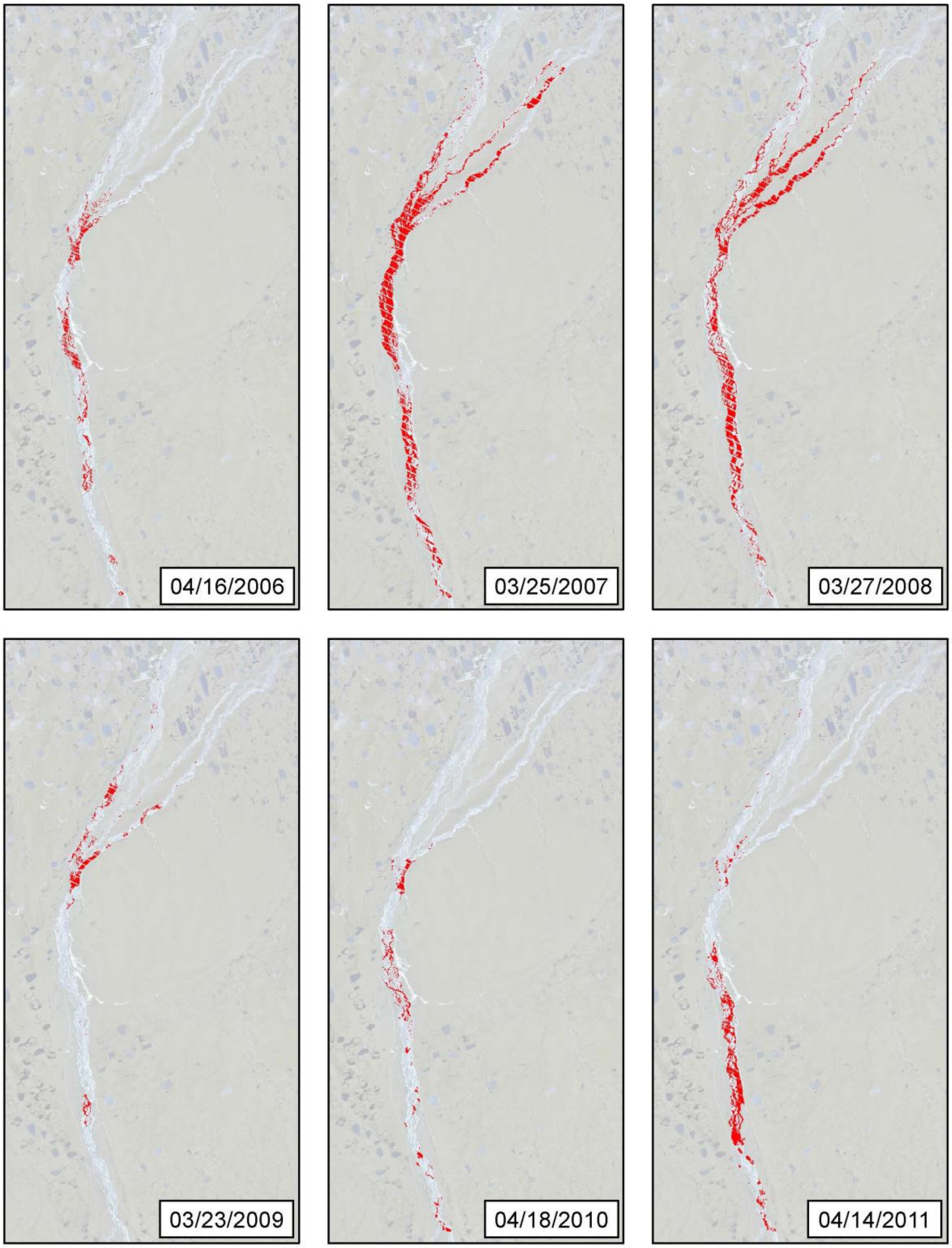


Figure 26. Landsat imagery of end-of-winter aufeis extent near Franklin Bluffs 2006–2011.

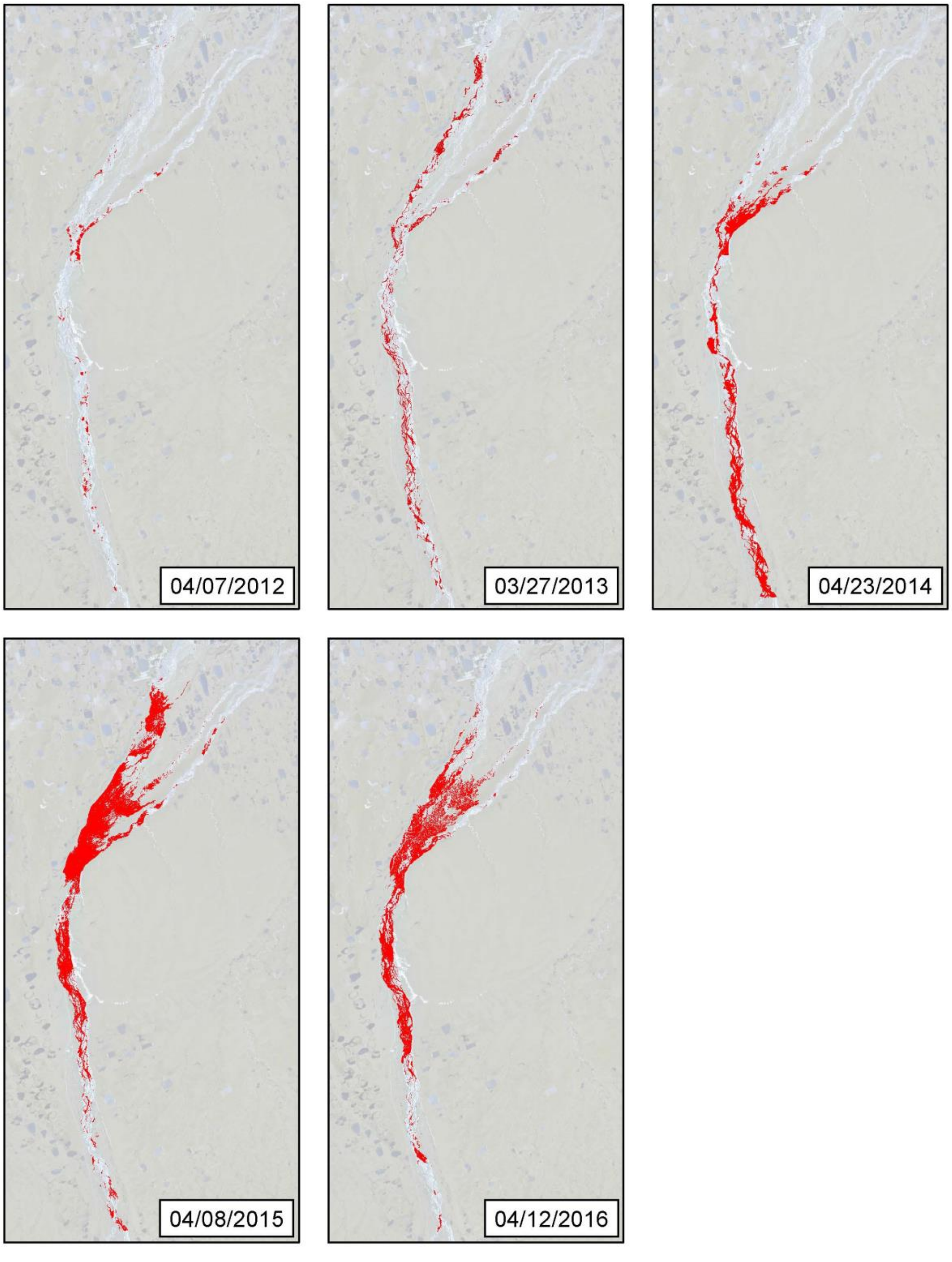


Figure 27. Landsat imagery of end-of-winter aufeis extent near Franklin Bluffs 2012–2016.

Table 8. Area of lower Sagavanirktok River aufeis based on Landsat imagery, 2000–2016.

Year	**Aufeis Area (km^2)**	**Rank**
2000	16.4	14
2001	33.1	9
2002	24.2	12
2003	43.9	7
2004	44.3	6
2005	29.5	10
2006	18.1	13
2007	73.5	3
2008	68.2	4
2009	13.7	15
2010	12.6	16
2011	29.3	11
2012	9.4	17
2013	33.3	8
2014	60.2	5
2015	116.7	1
2016	90.1	2

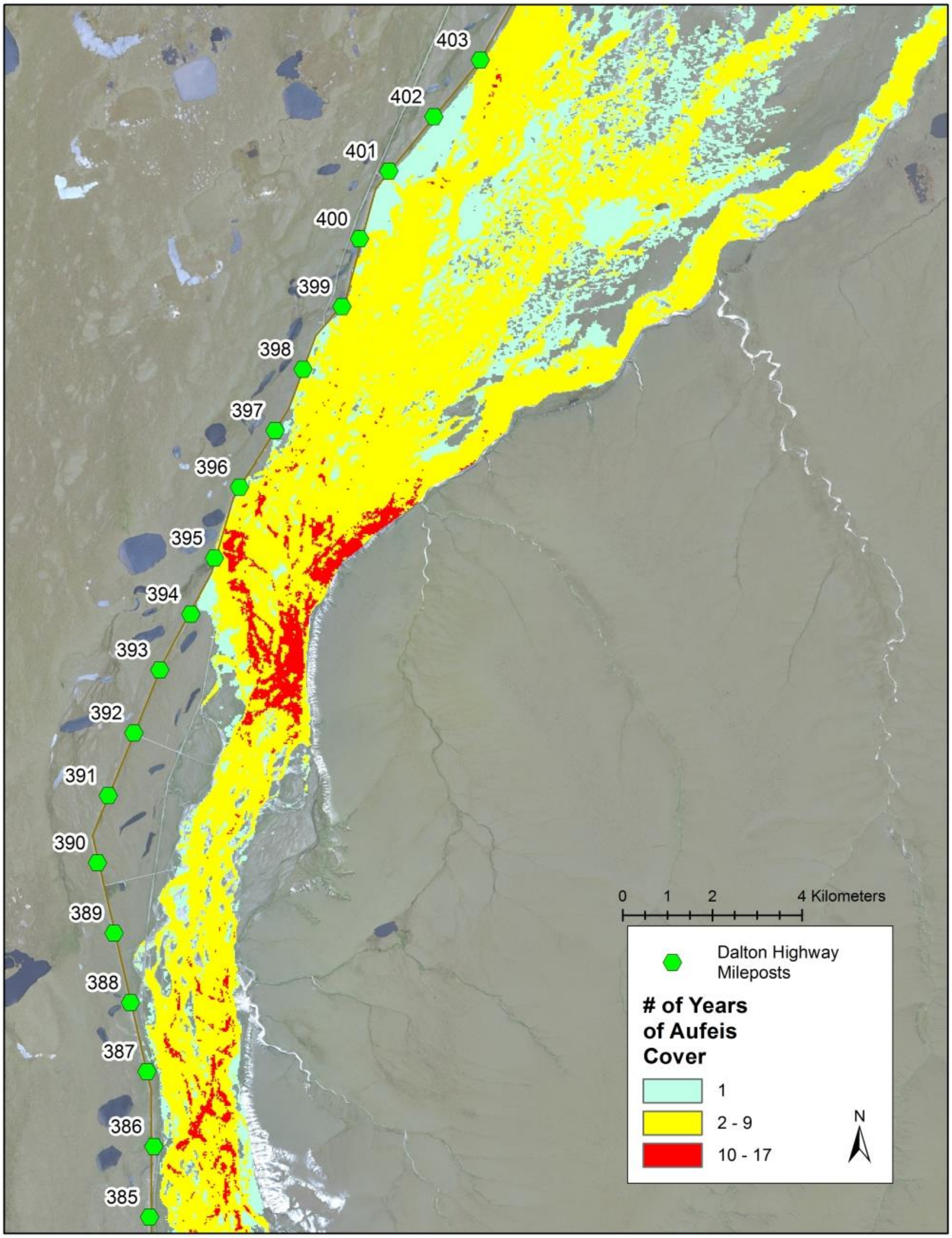


Figure 28. Frequency of aufeis occurrence near Franklin Bluffs (2000–2016, $n = 17$).

4.6.2 Delineating Ice Surface Elevation with GPS and Aerial Imagery

Two means were used to delineate the aufeis extent for 2016: (1) field GPS surveys of ice surface and (2) aerial imagery. As described in Section 3.1.1, in late February and early March and again in mid-April 2016, the elevation of the top of ice was surveyed with a differential GPS to define the slope and maximum height of the ice surface on the Sagavanirktok River near Franklin Bluffs (Figure 29). Over 10,000 ground and ice surface points were surveyed in multiple transects across both the river channel and the floodplain (Figure 30). A month later, on May 10, 2016, Fairbanks Fodar collected SfM imagery of the lower Sagavanirktok aufeis field to create a digital elevation model of the entire aufeis surface (as described in Section 3.1.2) (Figure 31). Landsat NIR imagery in late winter (Figure 32) was examined to delineate the lateral extent of aufeis, as described in Section 3.1.3. This section describes the results of the three datasets (GPS survey, SfM imagery, and Landsat NIR imagery) and how they were used to show change in the ice thickness and extent at Franklin Bluffs for 2016.

Figure 29. UAF researchers and ADOT&PF surveyors map elevation and thickness of aufeis formations on Sagavanirktok River near Franklin Bluffs on April 19, 2016.

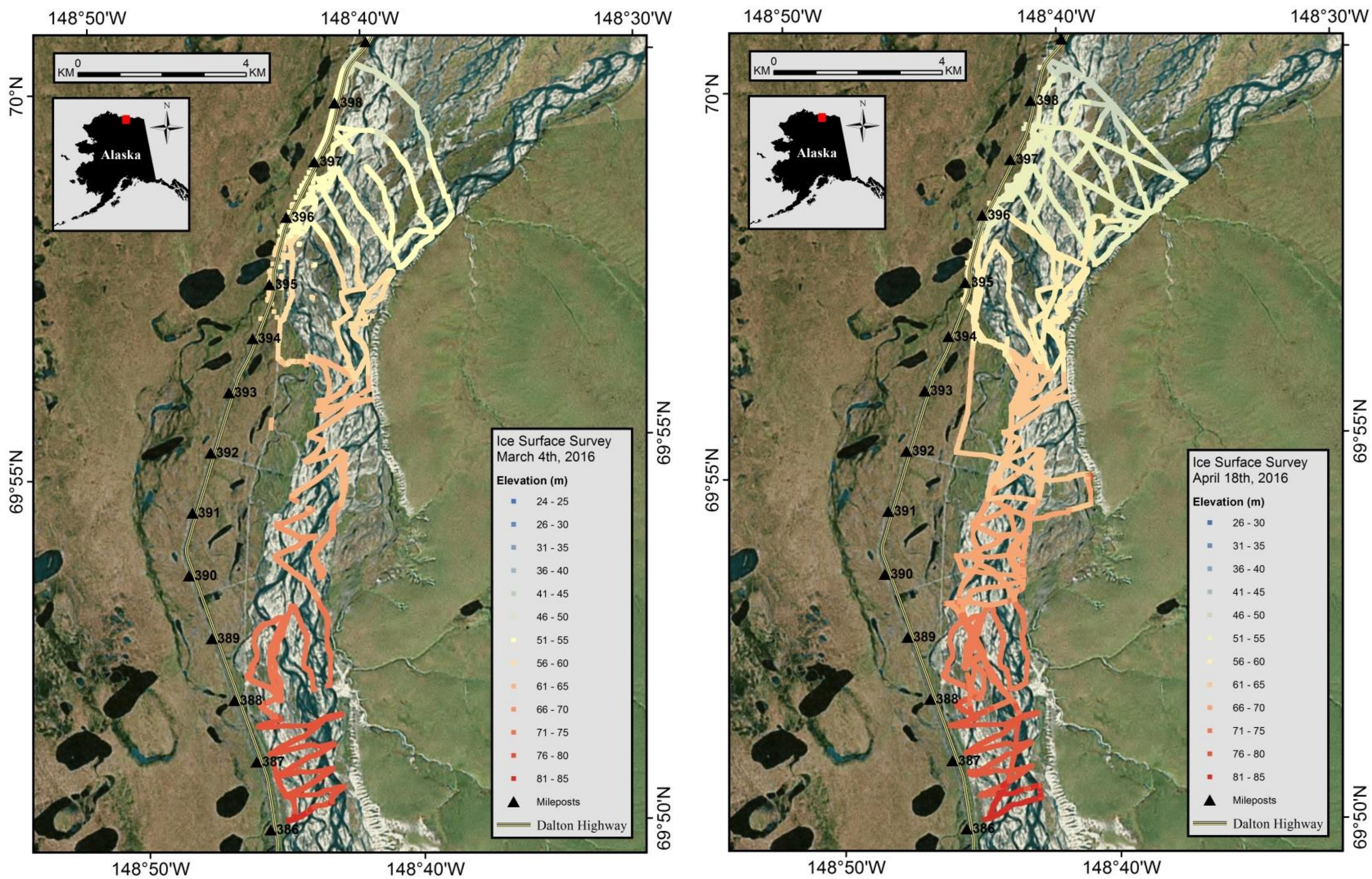


Figure 30. GPS surveys of ice surface elevation near Franklin Bluffs on March 4 and April 18, 2016 (vertical datum is NAVD88-GEOID12A).

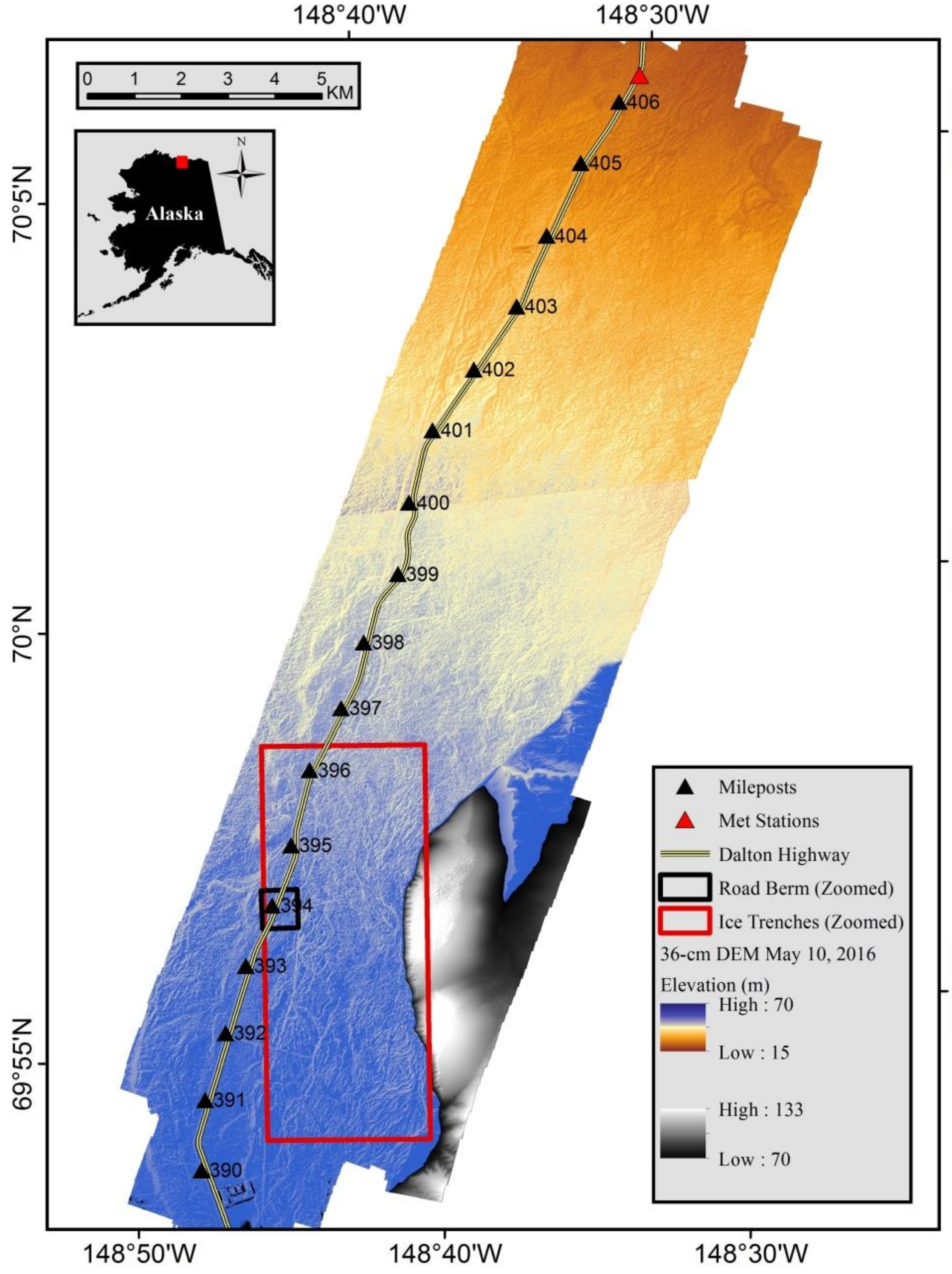


Figure 31. Digital elevation model (36 cm resolution) created from SfM (Fodar) imagery on May 10, 2016. The image shows the surface from 15 m to 133 m (above the WGS ellipsoid).

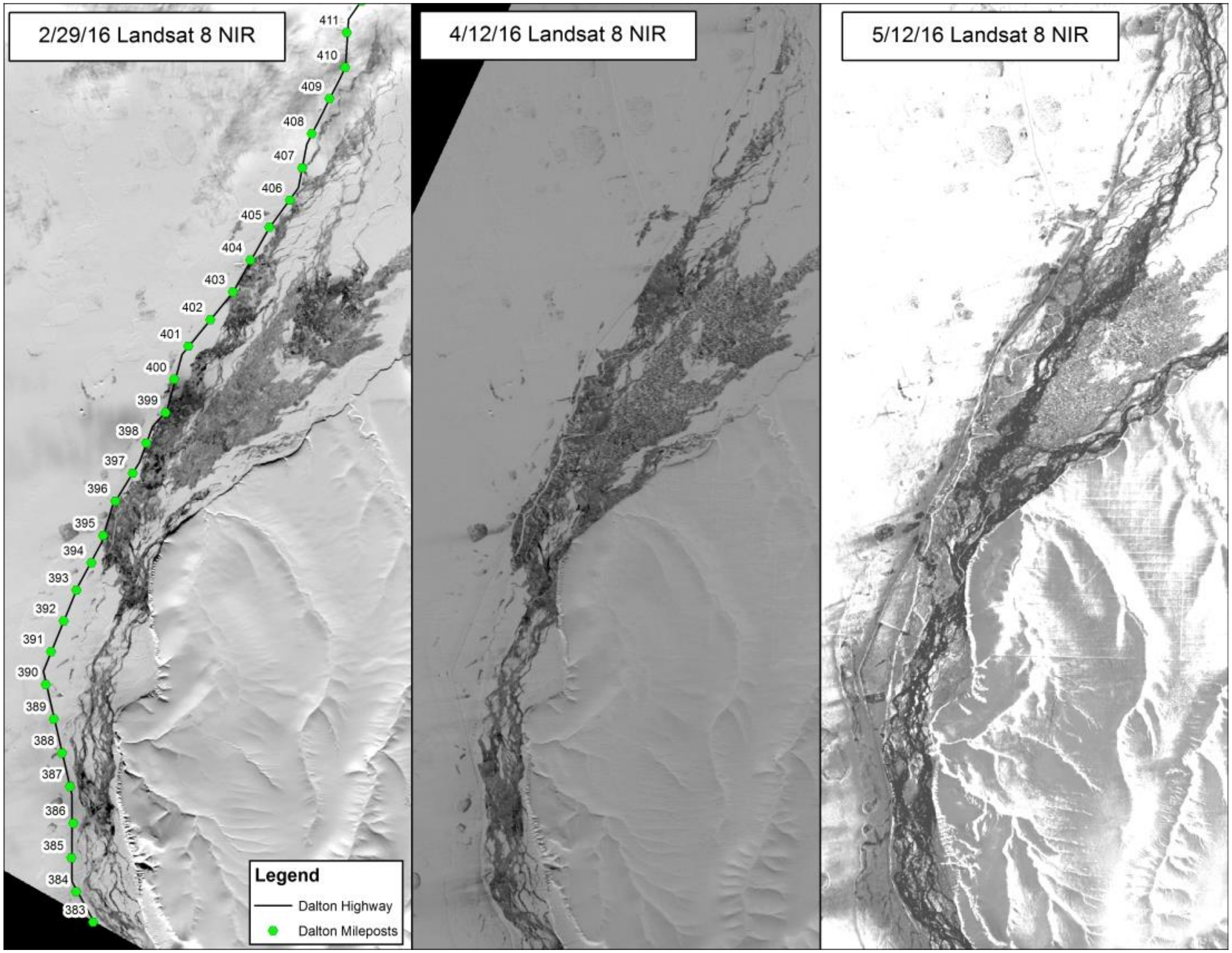


Figure 32. Landsat NIR imagery on February 29, April 12, and May 12, 2016, that was used to delineate lateral aufeis growth.

Figure 33 (a) shows the horizontal ice growth from Landsat imagery between late February and mid-May. Figure 33 (b, c) show ice elevation change between early March and mid-May. The elevation was recorded at a regular time interval during each GPS survey transect, however, survey points from the repeat transects were not co-located due to a small difference in the initial measurement point and, thus, could not be compared exactly. Several spatial interpolation techniques (kriging, inverse distance weighting, natural neighbor) were used to estimate aufeis surface elevation between the repeated transect lines for both surveys. When the interpolated surfaces from March to April were compared to investigate elevation change during that time, the interpolated elevation changes between the transect lines were significantly larger than the measured change at the transect lines. Because of these interpolation artifacts, only aufeis surface elevation change within 100 m of the transect line is presented in Figure 33 (b, c).

From early March to mid-April 2016, the aufeis thickness increased across almost the entire survey area. Aufeis thickness increased up to 1.9 m between MP384 and MP389. Aufeis thickness increased up to 2.2 m near the spur dikes between MP395 and MP396. The maximum observed thickness increase of 2.9 m occurred at the east bank across from MP397. From mid-April to May 10, aufeis growth rates decreased across the survey area. The area of maximum growth was on the east bank from MP393 to MP394, where up to 1 m of aufeis accumulated. Other significant accumulation occurred on the east bank downstream of MP394.

As mentioned previously, the Dalton Highway, between MP394 and MP401, was damaged by unprecedented flooding between March and May 2015. The highway was closed intermittently for weeks due to flooding. In an attempt to prevent such flooding in the future, the ADOT&PF built a temporary gravel berm in early 2016 on the east side of the road from MP394 to MP397. Over the winter of 2015/2016, ADOT&PF contractors dug ice trenches to facilitate the flow of water from the Sagavanirktok River toward the east channel (Figure 34). The material extracted from the river (ice and water) was deposited at the side of the trenches by the excavators. These deposits formed a compact ice berm near the trenches (Figure 35), with variable heights ranging from 1.2 to 1.8 m (4 to 6 ft). This berm directed the river flow to the east channel during breakup. Most of the berms were still present after nearly 2 weeks of breakup flows, which is a clear indication of lower flow in the river during the 2016 breakup. The SfM imagery from May 10 shows extensive aufeis on the eastern side of the highway at MP394 to MP396 (Figure 36).

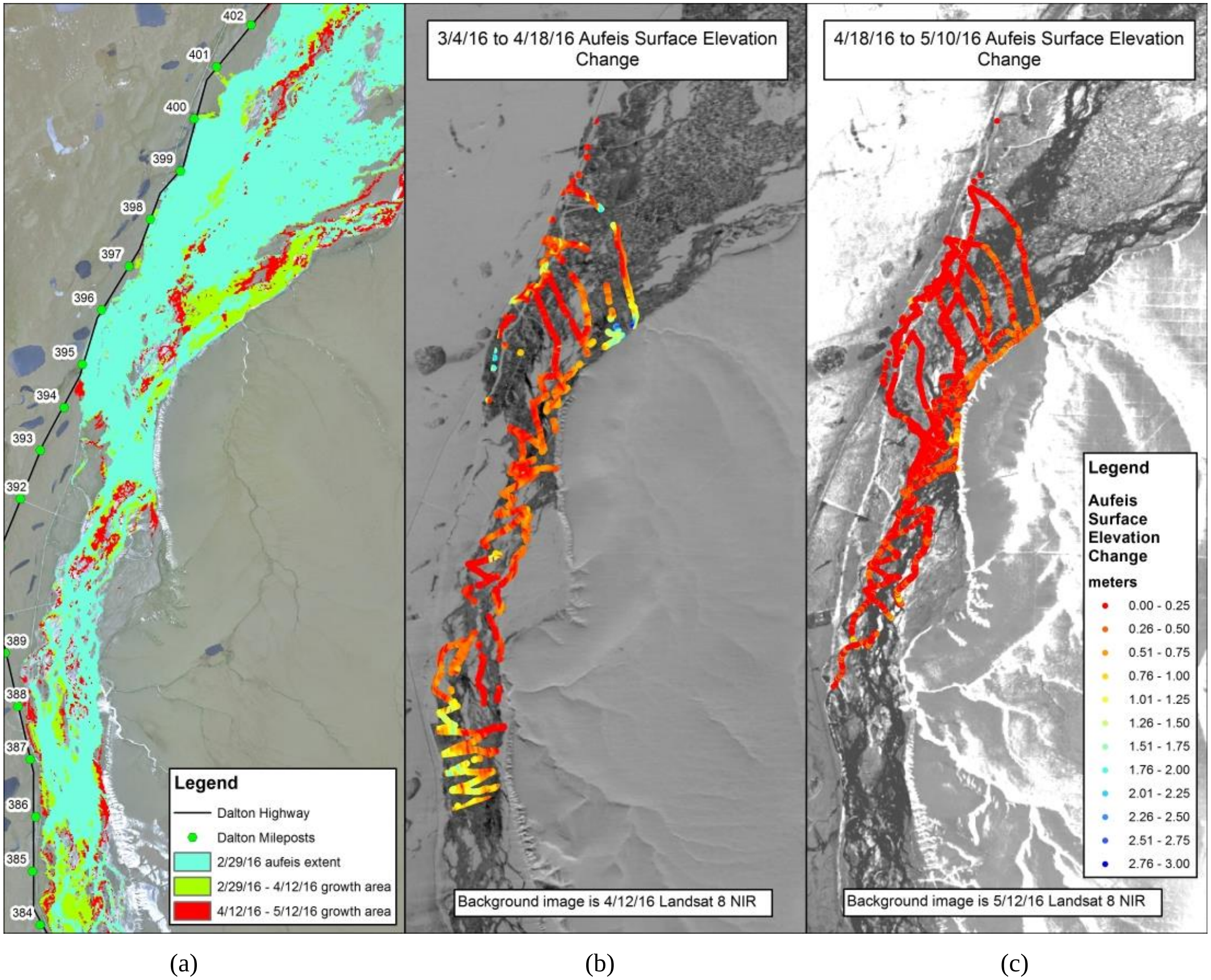


Figure 33. Winter 2016 ice conditions: (a) 2016 ice extent on February 29 (blue) and growth areas on April 12 (green), and May 12, 2016 (red) based on Landsat NIR imagery; (b) ice elevation change between March 4 (GPS survey) and April 18 (GPS survey); (c) ice elevation change between April 18 (GPS Survey) and May 10, 2016 (SfM). Vertical datum is NAV88 (GEOID12A).

Figure 34. Trench (open water) and ice berm (right side of trench) at Franklin Bluffs on April 17, 2016. The main goal was to improve flow conditions (trench); the secondary goal was to divert initial flow during breakup to the east channel (ice berm).

Figure 35. Trench (left) and ice berm (right) near Franklin Bluffs area on May 4, 2016.

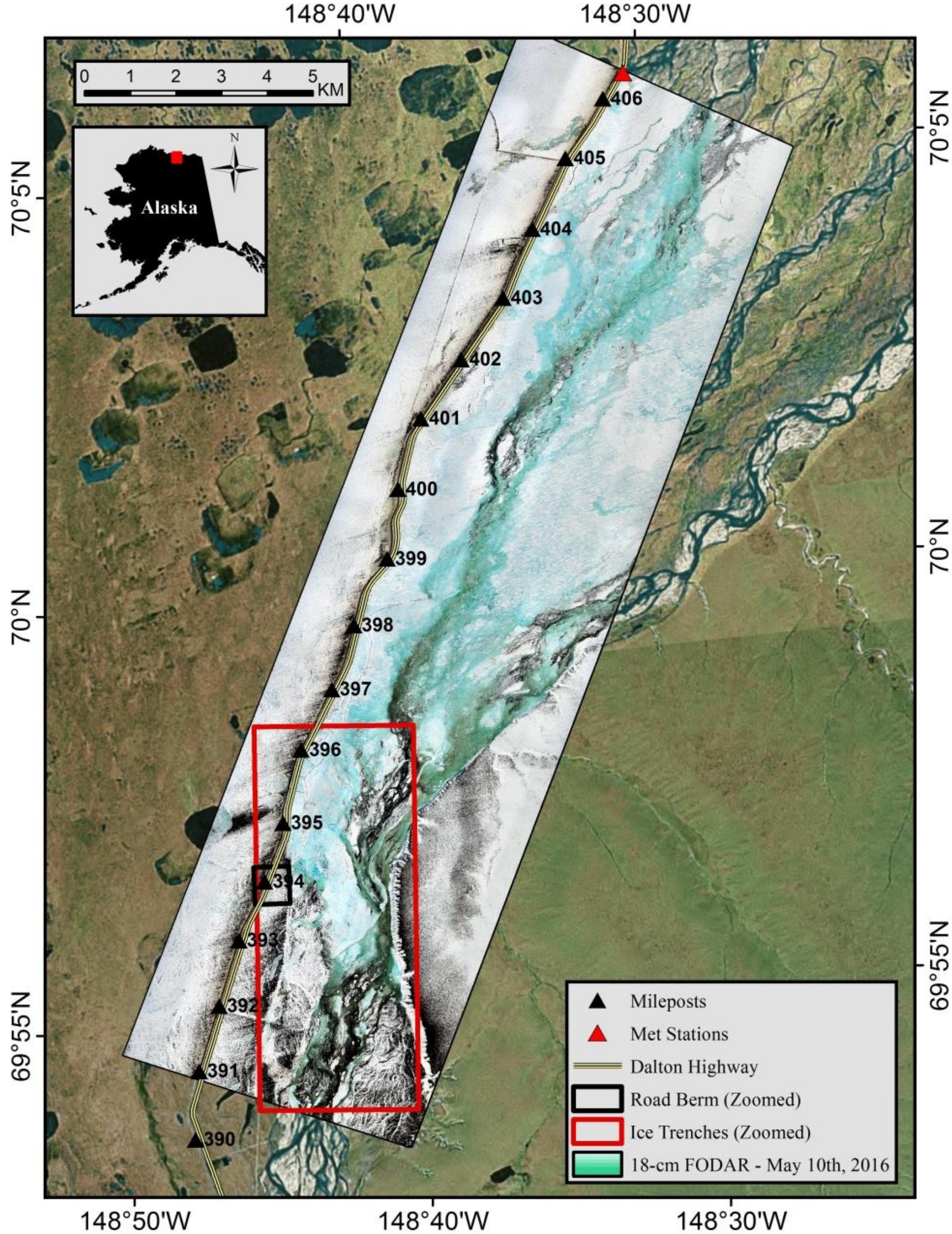


Figure 36. SfM (Fodar) imagery collected on May 10, 2016, near Franklin Bluffs, just prior to spring breakup.

In the SfM images (Figure 36 and Figure 37), the gravel berm transition at MP394 is visible, along with bulldozer markings from clearing drifted snow off the roadway. In 2016, with less aufeis extent than in 2015, the trenching efforts successfully diverted flowing water away from the highway to the east river channel and prevented overflow from flooding the Dalton Highway during the winter months. The highway remained open to traffic during breakup.

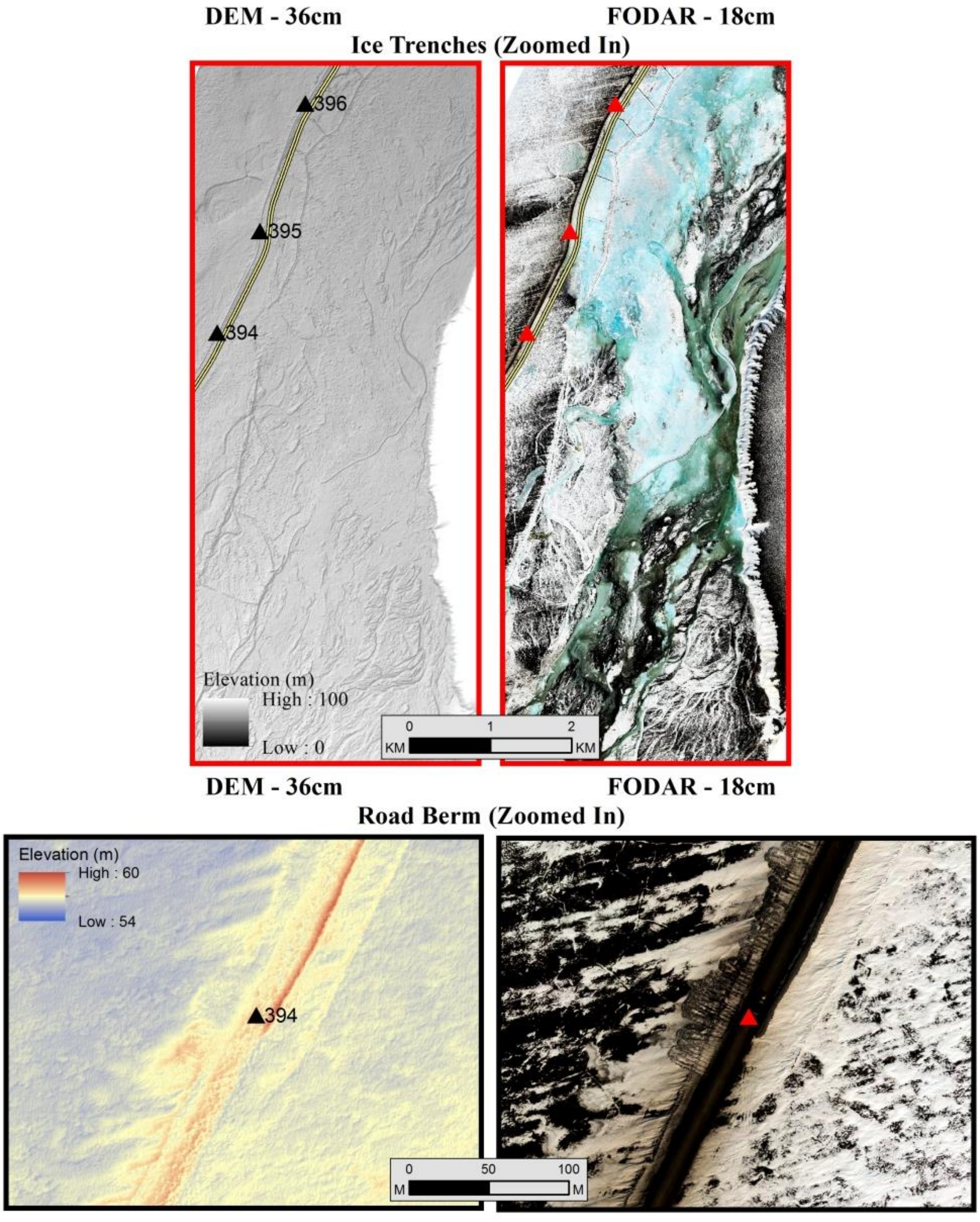


Figure 37. Digital elevation models (36 cm resolution) created from SfM (Fodar) imagery on May 10, 2016. The two inset plots show more detail: (top left) the Sagavanirktok River main channel at the East Bank station and (lower right) a close-up of the Dalton Highway. A temporary gravel berm was built by ADOT&PF contractors in the area where the highway was relatively low. Tracks are visible in the lower right panel.

4.6.3 Ice Boreholes

Holes were bored in the Sagavanirktok River near Franklin Bluffs on two occasions during late winter 2016 to monitor the growth of aufeis. The boreholes were mostly located on the west side of the river channel (Figure 38), where they were easily accessible from the Dalton Highway. The first boreholes were drilled February 29 through March 4, 2016, and the thickness of the ice (from the streambed or ground surface to the top of the ice) was measured (Table 9). During the second trip (April 16 through 19), the original boreholes were located and re-measured, or re-drilled nearby if they could not be located. Several new bores drilled on the second trip were offset approximately 2 m from the original location because they could not be located due to a GPS discrepancy, except borehole 25, where the ice formation at the original location collapsed and the offset distance was greater by several meters. Due to this location discrepancy, the change in corresponding depth measurements may not reflect a change in ice accretion, but may only indicate variation in the underlying ground topography. Water was encountered under the ice near the MP405 station (DSS1) and near the spur dikes at MP396. Visual evidence and our results in Table 9 suggest that little or no subsequent vertical ice accumulation occurred at the borehole locations during the 1.5-month period in late winter.

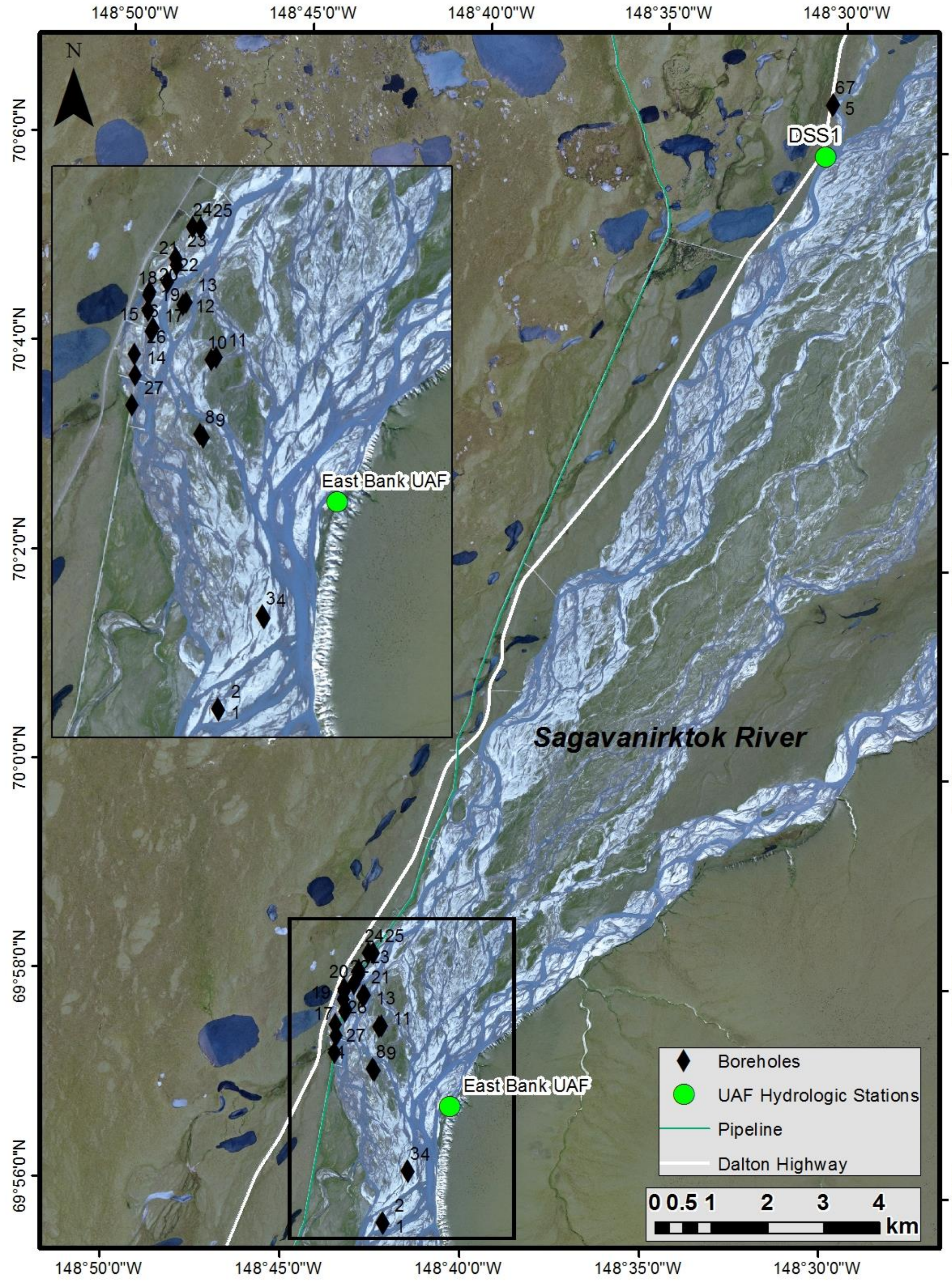


Figure 38. Locations of ice thickness measurements (borehole locations) in 2016. Number beside diamond indicates borehole number.

Table 9. Sagavanirktok River ice borehole locations and thickness.

Borehole Number	Northing (m)	Easting (m)	Depth1 (m) Feb 29 – Mar 4	Notes	Depth2 (m) Apr 16 – Apr 19	Notes
	Alaska State Plane Zone 4					
1	N1775310	E549737	1.03		1.00	Did not locate original bore, new bore
2	N1775324	E549731	0.29		0.18	Did not locate original bore, new bore
3	N1776272	E550130	0.24		0.71	Did not locate original bore, new bore
4	N1776247	E550142	0.39		0.76	Did not locate original bore, new bore
5	N1795554	E556747	0.35		n/a	Did not revisit location in April
6	N1795574	E556757	1.01	1st ice thickness 0.54 m Liquid water 0.09 m 2nd ice thickness 0.38 m	n/a	Did not revisit location in April
7	N1795574	E556757	0.35	1st ice thickness 0.23 m Liquid water 0.06 m 2nd ice thickness 0.06 m	n/a	Did not revisit location in April
8	N1778047	E549416	0.67		0.94	Did not locate original bore, new bore
9	N1778019	E549447	0.57		0.65	Did not locate original bore, new bore
10	N1778795	E549495	0.75		1.35	Did not locate original bore, new bore
11	N1778822	E549539	1.88		1.87	Did not locate original bore, new bore
12	N1779328	E549188	1.44		1.43	Found original bore
13	N1779349	E549212	0.75		0.75	Found original bore
14	N1778599	E548742	3.10		3.10	Found original bore
15	N1779043	E548885	2.24		2.24	Found original bore
16	N1779079	E548896	2.80	Approximately 0.02–0.05 m liquid water at bottom	2.77	Found original bore
17	N1779079	E548896	1.72		1.74	Found original bore

Borehole Number	Northing (m)	Easting (m)	Depth1 (m) Feb 29 – Mar 4	Notes	Depth2 (m) Apr 16 – Apr 19	Notes
	Alaska State Plane Zone 4					
18	N1779409	E548841	1.70	Approximately 0.10 m liquid water at bottom	1.63	Did not locate original bore, new bore
19	N1779257	E548839	1.14		1.14	Found original bore
20	N1779443	E548850	1.28	Approximately 0.06 m liquid water at bottom	1.25	Did not locate original bore, new bore
21	N1779718	E549097	0.87		0.86	Did not locate original bore, new bore
22	N1779546	E549017	0.54		0.59	Found original bore
23	N1779788	E549087	1.53		1.51	Found original bore
24	N1780105	E549247	1.23		1.23	Found original bore
25	N1780104	E549327	2.43	Ice thickness 0.73 m Void/liquid water 1.70 m	2.06	Did not locate original bore, new bore; Ice thickness 1.37 m; Void/liquid water 0.69 m
26	N1778813	E548724	2.06		2.08	Found original bore
27	N1778305	E548728	2.00		1.99	Found original bore

4.6.4 Ice Accumulation (SR50)

In winter 2016, sonic sensors (SR50) were installed to monitor ice growth and overflow at the Sagavanirktok River MP405 (DSS1), Sagavanirktok River East Bank station (DSS5), the end of spur dike 3 (approximately MP393), and MP387.5. The SR50 sensors measure the distance from a surface to the sensor. Data from sensors at MP393 and MP405 (DSS1) did not show any aufeis accumulation; diversion berms were built soon after the sensors were deployed, which kept overflow away from the sensors. Figure 39 shows overflow and aufeis at the SR50 sensor at MP387.5. Figure 40 shows the results of data from MP387.5 and the East Bank station. Results indicate up to 1 m of accumulation after the installation in early March at these two locations. Snow depth and precipitation accumulation at Prudhoe Bay NRCS station are also indicated in Figure 40 to show that snow accumulation was minimal. A few snow events appear in the record for both Prudhoe Bay NRCS and the East Bank station, but major accumulation at the two SR50 observation sites appears to be overflow or ice.

Figure 39. SR50 sensor at MP387.5 on May 3, 2016, recording overflow and growth of aufeis.

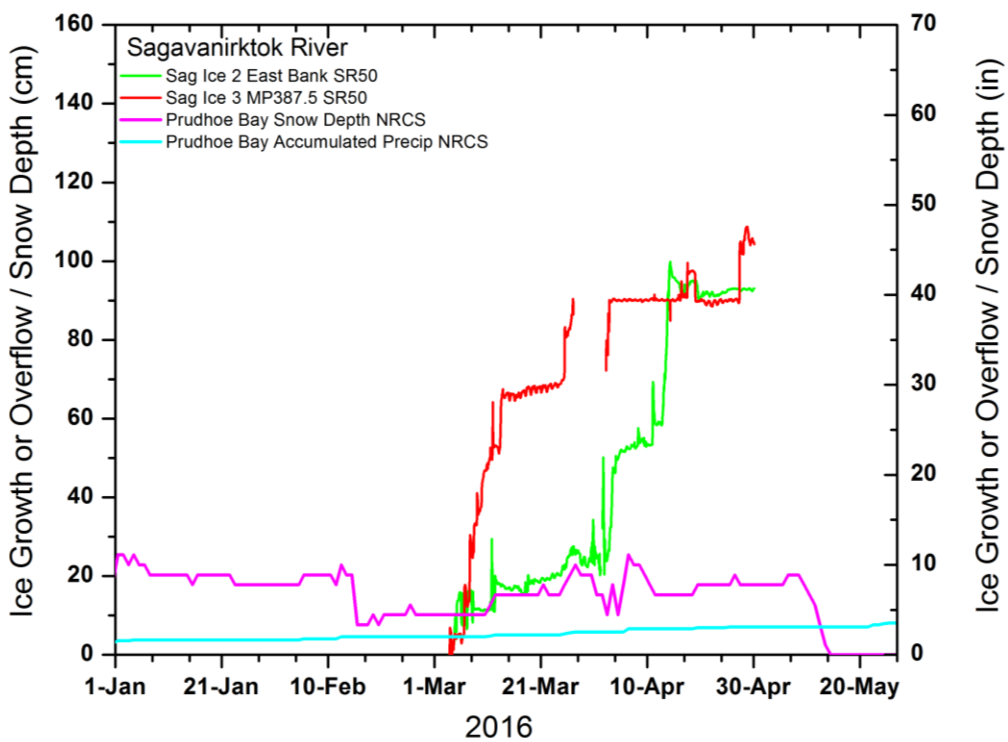


Figure 40. Ice or overflow at two sites on the Sagavanirktok River near Franklin Bluffs, 2016. Snow depth and precipitation at Prudhoe Bay are displayed for comparison.

4.6.5 Ice Thickness and Volume

Calculated ice thickness during 2015 and 2016 is shown in Figure 41. In 2015, a thick aufeis deposit formed near MP395 near Franklin Bluffs, where the river begins to widen and split into the east and west channels. Other areas of thick aufeis occurred on the west side of the west channel near MP398 and MP400. In 2016, aufeis again formed near the spur dikes at MP395 and near MP398. Other pronounced areas of thick aufeis formation were near MP405 and on the east side of the west channel near MP399 to MP400. In a comparison of 2015 with 2016, less aufeis was observed in 2016. Additionally, in 2016 aufeis thickness was more uniform in the west channel than in 2015, when the thick aufeis was concentrated on the west side of the river channel.

Ice thickness and volume were estimated for both 2015 and 2016 by comparing ice surface elevation with a digital elevation model, as described in Section 3.1.3. The ice volume on May 7, 2015, was estimated at 1.28×10^8 m^3 (Table 10). With information on final ice volume, the baseflow needed to develop that volume can be estimated. In order to make this estimation, two basic assumptions were made: (a) an assumed initial day of aufeis formation, and (b) the assumption that no water leaves the domain (i.e., all water is transformed into aufeis). The main limitations of these assumptions are that (a) the exact day of initial aufeis formation could be missed by days or even weeks, and that (b) it is highly improbable that all water flow is converted to ice. However, it could be argued that these errors partially balance (i.e., assuming a late start in the development of aufeis could be equilibrated by some fraction of the water leaving the domain). Thus, the calculation that follows should be considered a first and crude approximation.

Aufeis was first observed in the Sagavanirktok River channel around February 4, 2015, by APSC personnel during a reconnaissance flight. Thus, it is assumed that the aufeis formed during the 92 days between observation and the May LiDAR survey. If expansion of water as it freezes is accounted for, then an average baseflow of 16 m^3/s (565 ft^3/s) is needed to form the observed volume of aufeis. In 2016, the volume of ice on May 10 was estimated at 8.75×10^7 m^3, an order of magnitude less than in 2015. Aufeis began forming late in December 2015. If ice growth is assumed to have begun in late December 2015, then a baseflow of 8 m^3/s (283 ft^3/s) is needed to form the observed volume of aufeis.

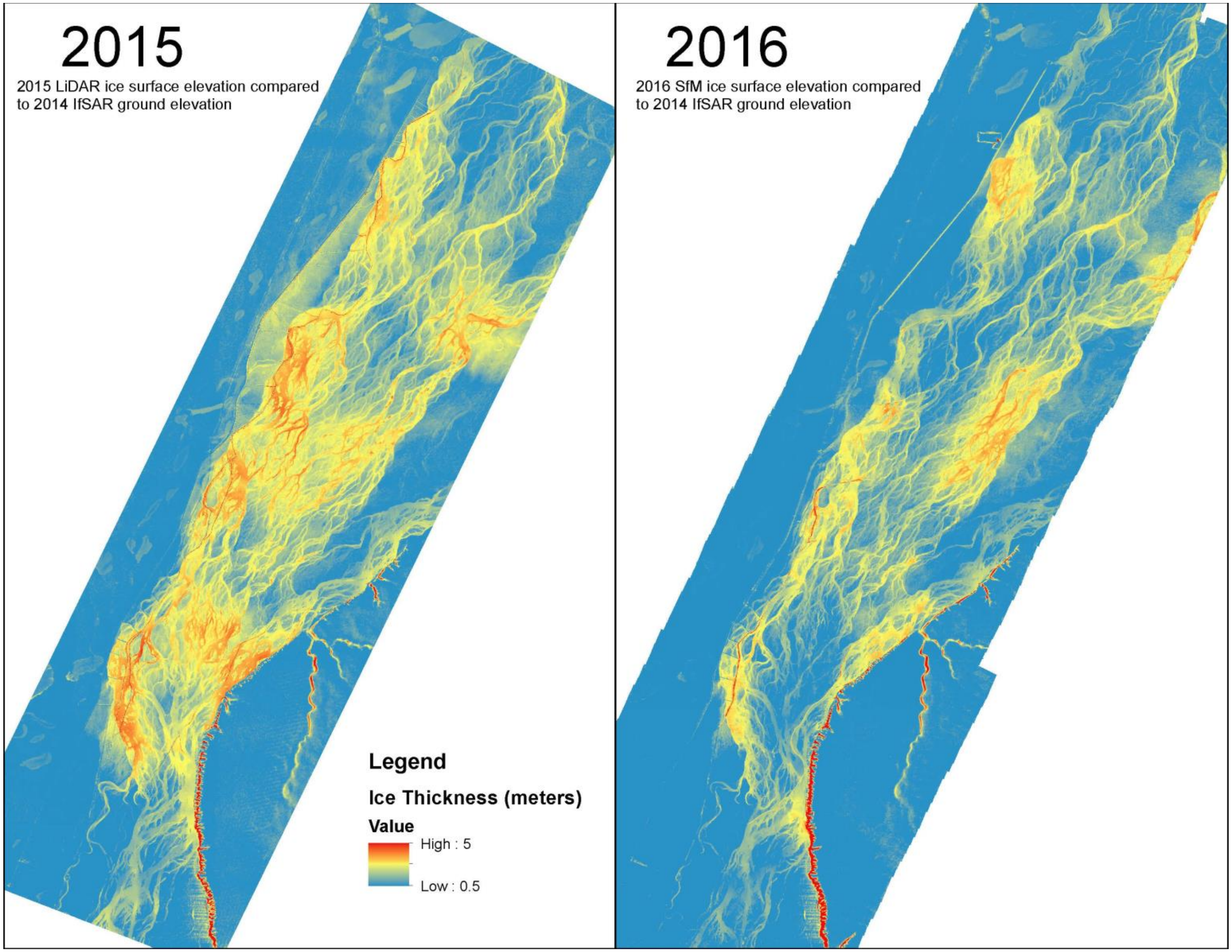


Figure 41. Ice surface elevation in 2015 and 2016 compared with ground elevation in 2014 at the Sagavanirktok River near Franklin Bluffs. The ice distribution is thicker and more spatially extensive in 2015 than in 2016.

Table 10. Ice volume near Franklin Bluffs.

Year	Ice Volume (m^3)	Days Aufeis Growth	Baseflow (m^3/s)	Baseflow (ft^3/s)
2015	1.28E+08	92	16	565
2016	8.75E+07	132	8	283

Even considering the intrinsic limitations of previous calculations, it can be argued that the approach provides a rough estimation of the amount of baseflow coming from the Ivishak and Sagavanirktok River basins that could form this aufeis. Baseflow in the upper Sagavanirktok River (above the confluence with the Ivishak) is measured occasionally in the winter by USGS; in the past decade, it has ranged from less than 1 m^3/s to 6 m^3/s (6 m^3/s was observed in 2015). Assuming that the Ivishak contributes at least the same amount of baseflow in forming the aufeis deposit, the baseflow estimate is of the same order of magnitude as the USGS measurements.

4.7 Surface Water Hydrology

Hydrology data were collected on the middle and lower reaches of the Sagavanirktok River during breakup 2016. In May, to document spring breakup, continuous water levels were collected at several new sites on the west side of the river channel near Franklin Bluffs and at four hydrometeorological stations (East Bank station [DSS5] near MP395, below Ivishak [DSS2], Happy Valley [DSS3], and near MP318 [DSS4]). Discharge measurements near each station were made during the breakup period between May 10 and May 30. To document the hydrologic activity more completely, cameras pointed at the river at each station were used. Water samples were collected for suspended sediment and water chemistry analysis (discussed in Section 4.8 and 4.9). The purpose of this section is to summarize the water level and discharge results of the spring runoff period in 2016.

In March and early May, continuous-recording (15-minute readings) water level sensors were installed in the Sagavanirktok River or along the Dalton Highway to determine the presence of water and record maximum water surface elevations. Figure 1 shows a map of these sensor locations. Three new water level sensors (HOBO models, without telemetry) were installed near MP398 and MP395, and ten new water level sensors (Campbell Scientific model CS451, with telemetry) were installed between MP387 and MP405. None of the three HOBO water level sensors installed in March recorded the presence of water prior to or during breakup; they were removed in late May. Manual level surveys of river stage were taken as frequently as possible during breakup at each hydrological observation station (East Bank [DSS5], below Ivishak [DSS2], Happy Valley [DSS3], and MP318 [DSS4]). Monitoring did not occur at the station near MP405 (DSS1) because water was not present and an extensive ice field was near the station. All water level elevation data collected at the hydrometeorological stations were surveyed to the temporary benchmarks established by ADOT&PF in 2015; these data are reported in NAVD88 (using the GEOID12A model). Continuous and discrete water level measurements for all the stations are presented in Figure 42.

Compared with 2015, spring breakup across the North Slope region in 2016 was mild. Breakup in 2016 occurred earlier than normal. Warm temperatures around May 9 or 10 initiated breakup throughout the southern part of the region. Measured runoff at the East Bank station was less than the previous year. Runoff measurements are presented in Figure 43, where for comparison, the results from Upper Kuparuk and Imnavait Creek (Arp and Stuefer, 2016), two small watersheds adjacent to the upper Sagavanirktok basin, are included. Maximum measured flow of 850 m^3/s (30,018 ft^3/s) on May 14 was observed at the Sagavanirktok River below the Ivishak (DSS2) (compared with the maximum measured 1560 m^3/s (55,090 ft^3/s) at the East Bank station on May 20, 2015). Temperatures cooled in the upper basin May 13–17, causing lower flows. Flows increased slightly by May 23, and then declined until June 4, when breakup was over. These lower breakup flows in 2016 are likely a result of (1) decreased annual precipitation in 2015/2016 (a drier summer in 2015 and/or a decreased 2015/2016 snowpack) and (2) a drop in air temperature for an extended period after runoff initiated.

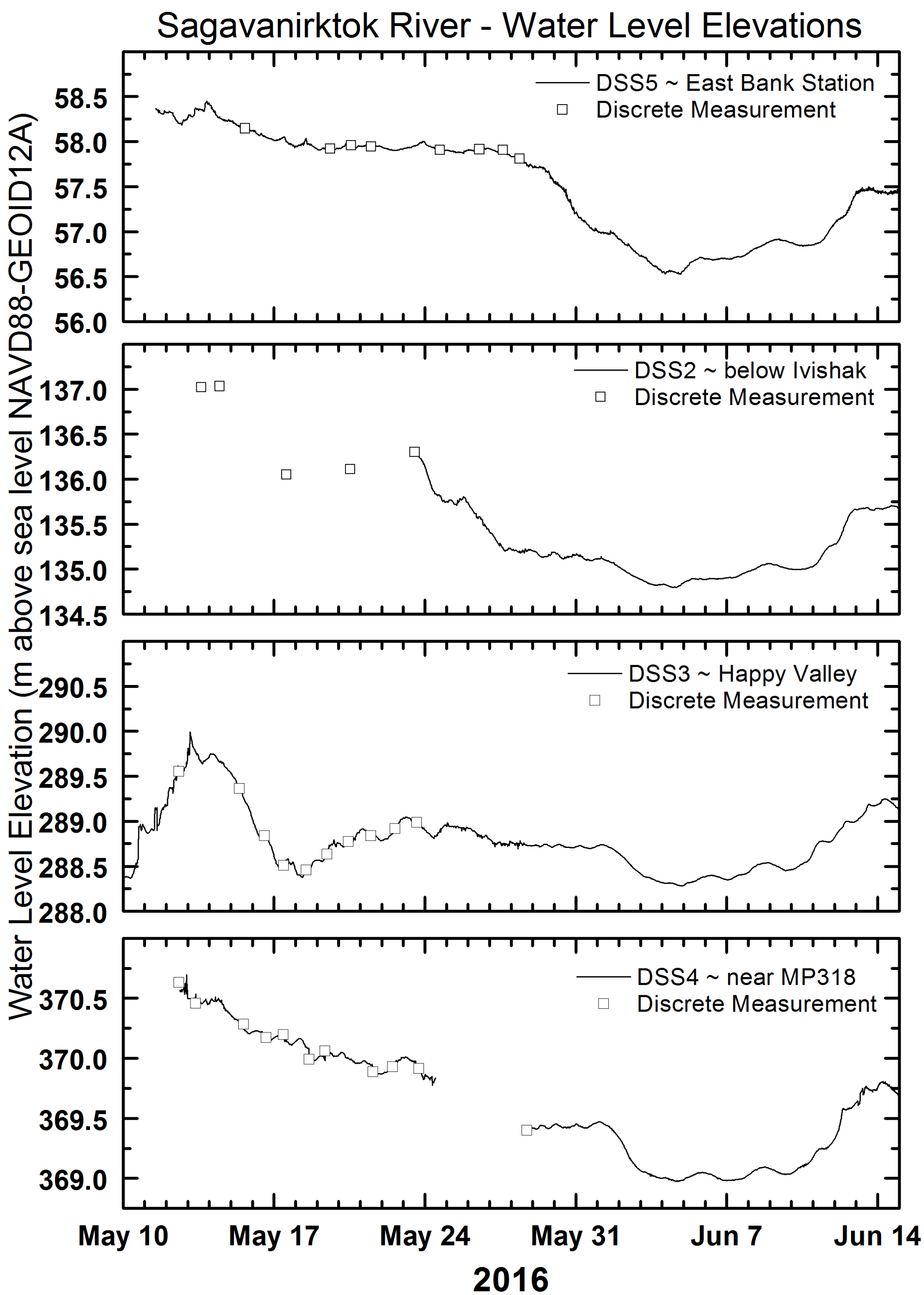
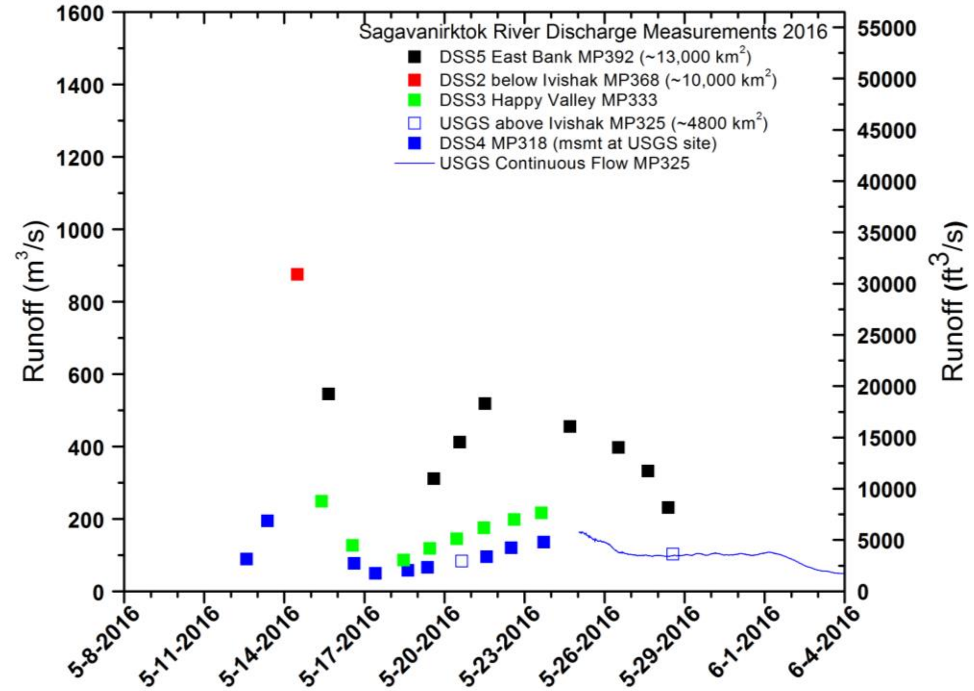


Figure 42. Water level elevations at four UAF stations on the Sagavanirktok River, spring 2016. Water levels were ice-affected and remained high through late May at the East Bank station (DSS5) near Franklin Bluffs and the DSS4 station near MP318.



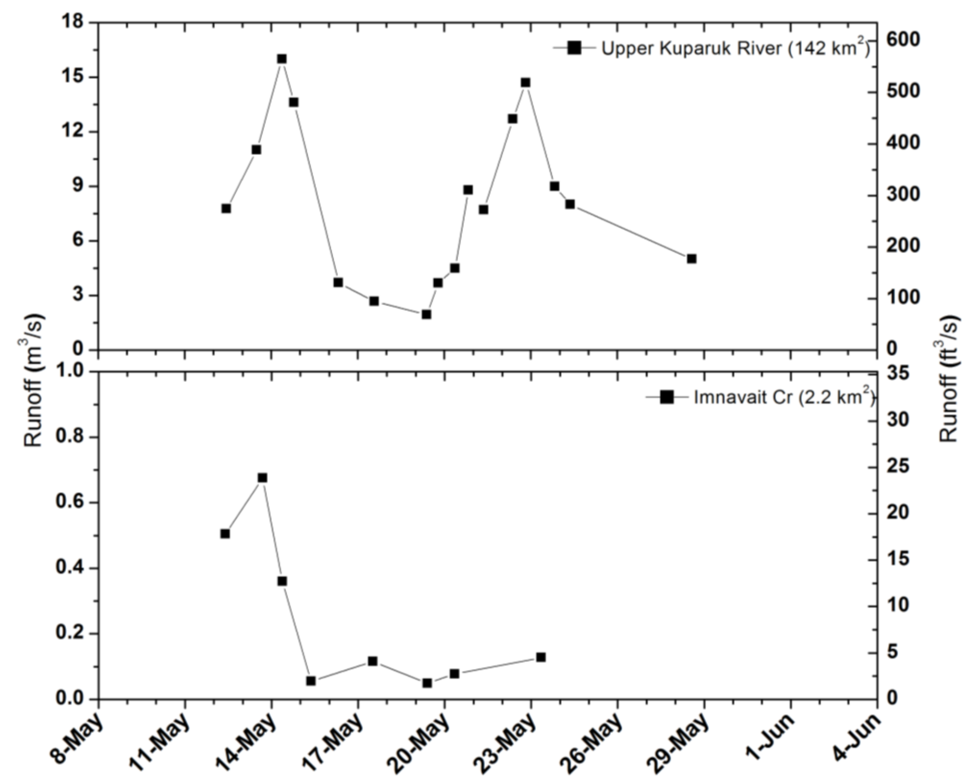


Figure 43. Flow measurements along the Sagavanirktok River for 2016. Upper Kuparuk and Imnavait Creek measurements show a similar trend of an early peak and a decrease in flow during the freeze-back (Arp and Stuefer, 2016).

Extensive ice covered the Sagavanirktok River channel and parts of the floodplain at UAF stations near MP318 (DSS4) (Figure 44) and closer to Deadhorse in the west channel, near MP405 (DSS1) (Figure 45). Initial flows during breakup reached the Sagavanirktok River near MP318 (DSS4) on May 10, 2016. The flow front reached the station below the Ivishak (DSS2) and the East Bank station (DSS5) on May 12, according to camera images. Peak flows in the Sagavanirktok River probably occurred on May 13 at both MP318 (DSS4) and Happy Valley (DSS3), and on May 14 at the station below the Ivishak (DSS2) and the East Bank station (DSS5). The peak flow dates in 2016 were approximately 6 days earlier than in 2015. In 2016, flows were initially high, but dropped due to a freeze-back, then increased slightly again. Breakup in 2016 was different from breakup in 2015. Temperatures remained warm throughout the basin for the entire breakup period in 2015, allowing meltwater to run off quickly.

Figure 44. Sagavanirktok River at MP318 (DSS4) on May 8, 2016; view facing upstream.

Figure 45. Extensive ice near the west channel of the Sagavanirktok River at MP405 (DSS1) on May 13, 2016. Black circle indicates the station location; view looking north.

The historical volumetric runoff at various North Slope rivers was examined in Toniolo et al (2015). The record-high volumetric runoff at the Putuligayuk and Kuparuk Rivers during spring breakup in 2013 and 2014 was attributed to high end-of-winter snowpack (Toniolo et al., 2015). Additionally, the Kuparuk in 2014 had record-high summer volumetric runoff due to a very wet summer. Looking at this from a water balance perspective, by fall of 2014, this basin storage surplus likely contributed to increased winter baseflow in the Sagavanirktok basin. Furthermore, this basin storage surplus in fall 2014, along with basin-wide warm air temperatures during May 2015, increased the magnitude of the peak flow during breakup of 2015. The spring 2016 volumetric runoff at the rivers reported in Toniolo et al. (2015) could not be analyzed because runoff data were not yet finalized.

4.7.1 Sagavanirktok River at MP318 (DSS4)

Due to extensive ice in the river channel, water levels at the Sagavanirktok River station near MP318 (DSS4) were initially high from May 12 through May 14 (Figure 46), with a maximum water level elevation on May 12 of 370.7 m (Figure 42, Table 11). After May 14, the water level began to decline, exposing gravel bars and stranded ice (Figure 47) until June 4, when it reached a minimum elevation of 369.0 m. Water levels were likely ice-affected through nearly all of breakup. Runoff was measured eight times (Table 12 and Figure 43), and peak flow likely occurred near May 13. Discharge measurements were made at the nearby USGS station (4 miles downstream) due to extensive braiding at the UAF station, and these measurements correlate well with the May 20 USGS measurement (Figure 43).

Figure 46. Sagavanirktok River at MP318 (DSS4) on May 13, 2016; view facing upstream.

Table 11. Water level elevations at the Sagavanirktok River DSS4 station.

Date/Time (AST)	Elevation (m, NAVD 88, GEOID12A)	Survey Crew	Notes
5/12/2016 0:00	370.63	JH, TT	Ice
5/13/2016 8:41	370.46	JH, TT	Ice
5/15/2016 13:03	370.28	JH, TT	Ice
5/16/2016 15:02	370.17	JH, TT	Ice
5/17/2016 8:20	370.20	JH, TT	Ice
5/18/2016 14:40	369.99	JH, TT	Ice
5/19/2016 8:45	370.06	JH, TT	Ice
5/21/2016 13:30	369.89	JH, TT	Ice
5/21/2016 13:30	369.89	JH, TT	Ice
5/22/2016 11:45	369.93	JH, TT	Ice
5/23/2016 17:20	369.92	JH, TT	
5/28/2016 17:15	369.40	JH, TT	
6/24/2016 13:45	369.94	JK, TT	
7/3/2016 15:00	369.72	JH, TT	
8/4/2016 12:00	369.40	JK, TT	
8/30/2016 13:30	369.40	JH, JK	

Figure 47. Sagavanirktok River near MP318 (DSS4) on May 23, 2016.

Table 12. ADCP discharge measurements on the Sagavanirktok River at MP318 (DSS4) during spring breakup 2016.

Date	Msmt. Number	Discharge (m^3/s)	Discharge (ft^3/s)	Coefficient of Variation (%)	Msmt. Rating	Reference	Notes
5/13/2016 12:00	5	195	6869	1	Good	BT	ICE, Measurement made 1 mile downstream DSS4
5/16/2016 14:33	6	77	2702	1	Good	WAAS/VTG	ICE, Measurement at USGS station, 4 miles downstream DSS4
5/17/2016 9:25	7	49	1737	2	Good	WAAS/VTG	ICE, Measurement at USGS station, 4 miles downstream DSS4
5/18/2016 14:54	8	58	2031	3	Good	WAAS/VTG	ICE, Measurement at USGS station, 4 miles downstream DSS4
5/19/2016 9:04	9	66	2331	1	Good	BT	ICE, Measurement at USGS station, 4 miles downstream DSS4
5/21/2016 13:40	10	96	3376	2	Good	WAAS/VTG	ICE, Measurement at USGS station, 4 miles downstream DSS4
5/22/2016 12:00	11	120	4227	2	Good	WAAS/VTG	ICE, Measurement at USGS station, 4 miles downstream DSS4
5/23/2016 15:22	12	135	4775	2	Good	WAAS/VTG	Measurement at USGS station, 4 miles downstream DSS4

4.7.2 Sagavanirktok River at Happy Valley (DSS3)

At the Sagavanirktok River station at Happy Valley (DSS3), water levels rose from 288.4 m on May 10 to a maximum of 290.0 m on May 13 (Figure 42 and Figure 48). Water levels were just below bankfull. Water levels then rapidly dropped 1.5 m through May 18, as the ice broke up and moved downstream (Figure 49). Beginning on May 18, the water levels began to rise while fluctuating diurnally until May 23 (Figure 50), and then remained steady for a week. By June 4, water levels at Happy Valley had dropped to a low of 288.3 m. Manual measurements of water level elevations are presented in Table 13. Runoff was measured eight times during breakup at the Happy Valley station (Table 14 and Figure 43), but measurements did not begin until May 15, which was probably after the peak flow. Discharge measurements at Happy Valley (DSS3) were similar to (but slightly higher than) the measurements at the USGS station (MP318/DSS4). Both sites are upstream of the confluence with the Ivishak River. Happy Valley is approximately 10 river miles downstream of the USGS gauge site and 14 river miles downstream of the gauge at MP318 (DSS4).

Figure 48. Sagavanirktok River at Happy Valley (DSS3) on May 13, 2016.

Figure 49. Sagavanirktok River at Happy Valley (DSS3) on May 15, 2016. Very little ice remained in the channel.

Figure 50. Sagavanirktok River at Happy Valley (DSS3) on May 23, 2016.

Table 13. Water level elevations at the Sagavanirktok River DSS3 station.

Date/Time (AST)	Elevation (m, NAVD 88, GEOID12A)	Survey Crew	Notes
5/12/2016 1:55	289.55	JH, TT	Ice
5/15/2016 9:30	289.36	JH, TT	Ice
5/16/2016 13:15	288.84	JH, TT	Ice
5/17/2016 10:45	288.51	JH, TT	Ice
5/18/2016 11:30	288.46	JH, TT	Ice
5/19/2016 11:00	288.63	JH, TT	Ice
5/20/2016 11:00	288.77	JH, TT	Ice
5/21/2016 11:45	288.84	JH, TT	Ice
5/22/2016 14:45	288.92	JH, TT	Ice
5/23/2016 15:15	288.99	JH, TT	
6/26/2016 15:00	289.20	JK, TT	
7/4/2016 12:00	288.95	JH, TT	
8/3/2016 12:30	288.79	JK, TT	
9/3/2016 13:00	288.77	JH, JK	

Table 14. ADCP discharge measurements on the Sagavanirktok River at Happy Valley (DSS3) during spring breakup 2016.

Date	Msmt. Number	Discharge (m^3/s)	Discharge (ft^3/s)	Coefficient of Variation (%)	Msmt. Rating	Reference	Notes
5/15/2016 10:52	4	248	8760	5, 2 and 2	Fair	RTK/VTG	Ice. Measured in 3 different channels
5/16/2016 11:00	5	126	4460	4 and 1	Good	BT/VTG	Ice. Measured in 2 different channels
5/18/2016 12:30	6	86	3040	3 and 1	Good	BT/VTG	Ice. Measured in 2 different channels
5/19/2016 11:30	7	118	4160	1 and 2	Good	BT/VTG	Ice. Measured in 2 different channels
5/20/2016 10:00	8	145	5125	2 and 1	Good	BT	Ice. Measured in 2 different channels
5/21/2016 11:30	9	175	7470	2 and 1	Good	BT/VTG	Ice. Measured in 2 different channels
5/22/2016 14:15	10	198	7000	1 and 1	Good	BT/VTG	Ice. Measured in 2 different channels
5/23/2016 13:00	11	216	7610	0 and 2	Good	BT/VTG	Ice. Measured in 2 different channels

Note: Msmt. = measurement

4.7.3 Sagavanirktok River Below the Ivishak River (DSS2)

At the Sagavanirktok River station below the Ivishak River confluence (DSS2), pressure transducers were installed and a runoff measurement was made on May 14. However, the pressure transducers were unstable until May 23, so data were deemed unusable prior to this date. Individual measurements of river stage are presented in Table 15. The first flow arrived at DSS2 on May 11 by 14:00 according to camera images. Water levels were initially high (~137.0 m) and were above bankfull from May 12 through 14 (see Figure 51), but dropped to a low of ~136.0 m on May 17 (Figure 42). Water level gradually increased to 136.3 m on May 23 and then declined to 134.8 m, exposing gravel bars (Figure 52), until June 4, the end of breakup. Runoff was only measured one time at this station (Table 16, Figure 43), on May 14 (Figure 53), and this measurement was the highest individual flow measured at any of the stations (850 m^3/s or 30,018 ft^3/s) for 2016. It is likely the peak flow occurred on May 14 at this station.

Table 15. Water level elevations at the Sagavanirktok River DSS2 station.

Date/Time (AST)	Elevation (m, NAVD 88, GEOID12A)	Survey Crew	Notes
5/13/2016 15:00	135.72	JH, TT	Ice
5/14/2016 11:45	135.73	JH, TT	Ice
5/17/2016 14:00	134.76	JH, TT	Ice
5/20/2016 13:15	135.48	JH, TT	Ice
5/23/2016 12:45	136.30	JH, TT	

Figure 51. Water levels briefly above bankfull at the Sagavanirktok River below the Ivishak River (DSS2). Photo taken on May 13, 2016.

Figure 52. Sagavanirktok River below the Ivishak River (DSS2) on May 25, 2016.

Table 16. ADCP discharge measurements on the Sagavanirktok River below the Ivishak River (DSS2) during spring breakup 2016.

Date	Msmt. Number	Discharge (m^3/s)	Discharge (ft^3/s)	Coefficient of Variation (%)	Msmt. Rating	Reference	Notes
5/14/2016 13:00	4	850	30018	3, 3, 3, 4, and 4	fair	BT/VTG	Measurement in 5 different channels

Figure 53. ADCP measurement on May 14, 2016, at the Sagavanirktok River below the Ivishak River (DSS2).

4.7.4 Sagavanirktok River at East Bank (DSS5) Near Franklin Bluffs

Farther north on the Sagavanirktok River, ADOT&PF constructed a continuous trench to improve water flow out of the system. The ice/water extracted from the river formed a large diversion berm. This ice berm diverted flow toward the east channel during breakup (Figure 54 and Figure 55). The UAF station on the East Bank of the Sagavanirktok River was established in 2015 during the breakup flooding. Continuous water levels are plotted in Figure 42, and surveys of stage for the period of record are presented in Table 17. In 2016, the river began flowing at the East Bank station on May 12, according to camera images. By May 13, when the highest water level elevations were recorded at the East Bank station along Franklin Bluffs, runoff partially overtopped the diversion berm near MP392 (Figure 56 and Figure 57). On May 14, the flow continued to overtop and degrade the diversion berm just above its constriction with Franklin Bluffs (Figure 58 and Figure 59).

Figure 54. Aufeis on the Sagavanirktok River at Franklin Bluffs and the easternmost trench and berm before significant meltwater inundated the area; view to the southeast. Photo taken on May 10, 2016.

Figure 55. This northward view shows aufeis on Sagavanirktok River at Franklin Bluffs and easternmost trench and berm in its initial condition on May 10, 2016. Note acute narrowing of trench and berm with the Bluffs at mid-photo.

Table 17. Water level elevations at the Sagavanirktok River East Bank station.

Date/Time (AST)	Elevation (m, NAVD 88, GEOID12A)	Survey Crew	Notes
5/11/2016 13:45	58.35	JK, HT	Ice
5/13/2016 15:27	58.35	JK, HT	Ice
5/14/2016 15:52	58.24	JK, HT	Ice
5/15/2016 15:45	58.15	JK, HT	Ice
5/16/2016 12:45	58.06	JK, HT	Ice
5/19/2016 14:34	57.92	JK, HT	Ice
5/20/2016 13:57	57.96	JK, HT	Ice
5/21/2016 12:30	57.94	JK, HT	Ice
5/24/2016 16:58	57.91	JK, HT	
5/26/2016 12:36	57.91	JK, HT	
5/27/2016 15:17	57.90	JK, HT	
5/28/2016 9:30	57.81	JK, HT	

Figure 56. In this east-facing view, Sagavanirktok River stage has risen dramatically and is overtopping the ice berm at its narrowest point with Franklin Bluffs on May 13, 2016.

Figure 57. View is south and shows the southwestern length of the ice berm above the narrowing—essentially intact and functioning to divert water to the east during high flow on the Sagavanirktok River near Franklin Bluffs on May 13, 2016. Note in the upper right of the photo that some water has made an “end run” around the southwestern terminus of the berm.

Figure 58. A south-facing view showing the Sagavanirktok River and Franklin Bluffs and the condition of the ice berm at its narrowest point during increased water stage on May 14, 2016.

Figure 59. This southeastern view depicts Sagavanirktok River overtopping and degrading the ice berm just above its constriction with Franklin Bluffs on May 14, 2016.

Water levels in the river channel began to drop slightly from May 14 to 17, as ice physically moved downstream and air temperatures dropped throughout the basin. The first discharge measurement of 545 m^3/s (19,245 ft^3/s) occurred on the afternoon of May 15, but peak flow probably occurred May 14 or in early morning May 15. A measurement of 850 m^3/s (30,018 ft^3/s) was made on May 14, approximately 25 miles upstream just below the confluence with the Ivishak (DSS2). On May 15, after the breakup peak flow, the southwestern length of the diversion berm was still intact and functioning, as shown in Figure 60.

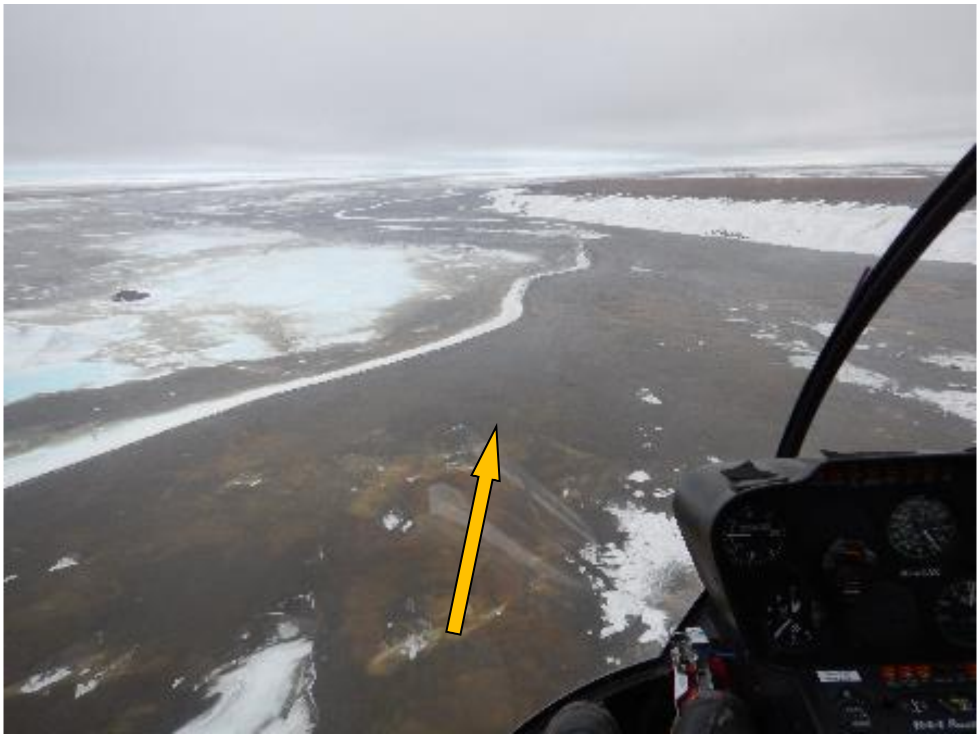


Figure 60. North-facing view of Sagavanirktok River and Franklin Bluffs on May 15, 2016. Cooler weather caused decreased melt input, and aufeis erosion and channel formation increased channel capacity.

Water levels remained relatively steady May 19 through 27, and flows increased slightly until May 23 (Figure 43, Figure 61, Figure 62). Beginning on May 27 (Figure 63), water levels receded through June 4, indicating the end of breakup. The southwestern length of the diversion berm remained intact and effective, funneling a large percentage of river water through the area during this mild breakup.

Figure 61. Slightly higher water levels on the Sagavanirktok River at Franklin Bluffs overtop the ice berm above its constriction on May 20, 2016. Gravel and aufeis are once more submerged. View is north.

Figure 62. Photo taken on May 23, 2016, looking north. Re-emerging gravel bars indicate that water level in the Sagavanirktok River at Franklin Bluffs is beginning to fall on May 23, 2016. UAF gauged river discharge upstream of the large breaches in the diversion berm. The green line depicts approximate measurement transect path.

Figure 63. North view showing the still intact southwestern length of the diversion berm on the Sagavanirktok River and Franklin Bluffs on May 27, 2016. Gravel bars are free of ice, and the river is becoming confined to normal channels.

In the main channel at East Bank station, the maximum water level was 58.45 m on May 13 (compared with the maximum of 59.52 m on May 18, 2015). By the end of breakup, water level had dropped 2 m from maximum elevation to a low of 56.55 m. All runoff measurements are presented in Table 18. Peak measured runoff (based on the May 14 measurement at DSS2) was approximately 50% of the 2015 peak measurement.

Table 18. ADCP discharge measurements during spring 2015 and 2016 on the Sagavanirktok River East Bank Station at Franklin Bluffs.

Date	Msmt. Number	Discharge (m^3/s)	Discharge (ft^3/s)	Coefficient of Variation (%)	Msmt. Rating	Reference	Notes
5/18/2015 14:50	1	1240	43790	N/A, only 1 transect	Poor	VTG	One R to L transect only
5/20/2015 12:50	2	1560	55090	4	Fair	RTK/VTG	
5/22/2015 12:30	3	1290	45450	5	Fair	RTK/VTG	
5/23/2015 10:00	4	1000e	35310e	N/A, estimated	Poor	WAAS and RTK/VTG	Estimated based on measured velocity, estimated width, estimated depth
5/24/2015 13:15	5	675	23835	10	Poor	WAAS and RTK/VTG	L to R transects only
5/27/2015 15:00	6	415	14655	2 (west) and 4 (east)	Fair	RTK/VTG	L to R transects only
5/28/2015 10:15	7	450	15890	15 (west) and 6 (east)	Poor	WAAS and RTK/VTG and BT	R to L transects only for west channel; no moving bed test
5/30/2015 14:00	8	1110	39200	6 (west) and 3 (east)	Poor	WAAS and RTK/VTG	Directional bias suspected; R to L transects only; and beam 3 misalignment
5/15/2016 15:45	9	545e	19245e	7	Poor	WAAS/VTG	Measurement made at MP380. Side channel estimated at 50 cm, (included in total discharge)
5/19/2016 14:34	10	311	10980	5	Fair	WAAS/VTG	
5/20/2016 13:57	11	412	14550	5	Fair	BT	
5/21/2016 12:30	12	465	16421	4	Good	WAAS/VTG	
5/24/2016 16:58	13	435	15362	3	Good	WAAS/VTG	
5/26/2016 12:36	14	378	13349	2	Good	WAAS/VTG	
5/27/2016 15:17	15	332	11725	2	Good	BT	
5/28/2016 9:30	16	198	6992	4	Good	WAAS/VTG	

Note: R – right; L – left; e – estimated discharge; Msmt. – measurement

Of the ten CS451 water level sensors installed in early May near the Dalton Highway (Figure 1), only three sensors recorded the presence of water during breakup. Pressure transducer #7 (just south of spur dike 4 near MP396) recorded water depths up to 1 m at the sensor during breakup, but these data were deemed unusable because the sensor was not stable. Pressure transducer #10 (pipeline access road near MP387.5) recorded water depths of 2–3 cm, but the post it was attached to was damaged by ice on May 7 (Figure 64). Pressure transducer #5 (near MP397.5) recorded shallow water depths (up to 14 cm) at various times during the breakup period.

Figure 64. Pressure transducer #10 attached to broken post observed on May 27, 2016.

4.7.5 Sagavanirktok River at MP405 (DSS1) West Channel

Water level elevations and runoff were not observed at the Sagavanirktok River near MP405 (DSS1) due to extensive ice in the west channel (Figure 45). It seems that the gravel berm around the material site located immediately upstream of the station created a shadow effect (i.e., an ice field, which extends downstream of the material site for several miles). Breakup water was pushed toward the central channel in the area. Figure 65 shows the ice conditions near the station on May 27, 2016.

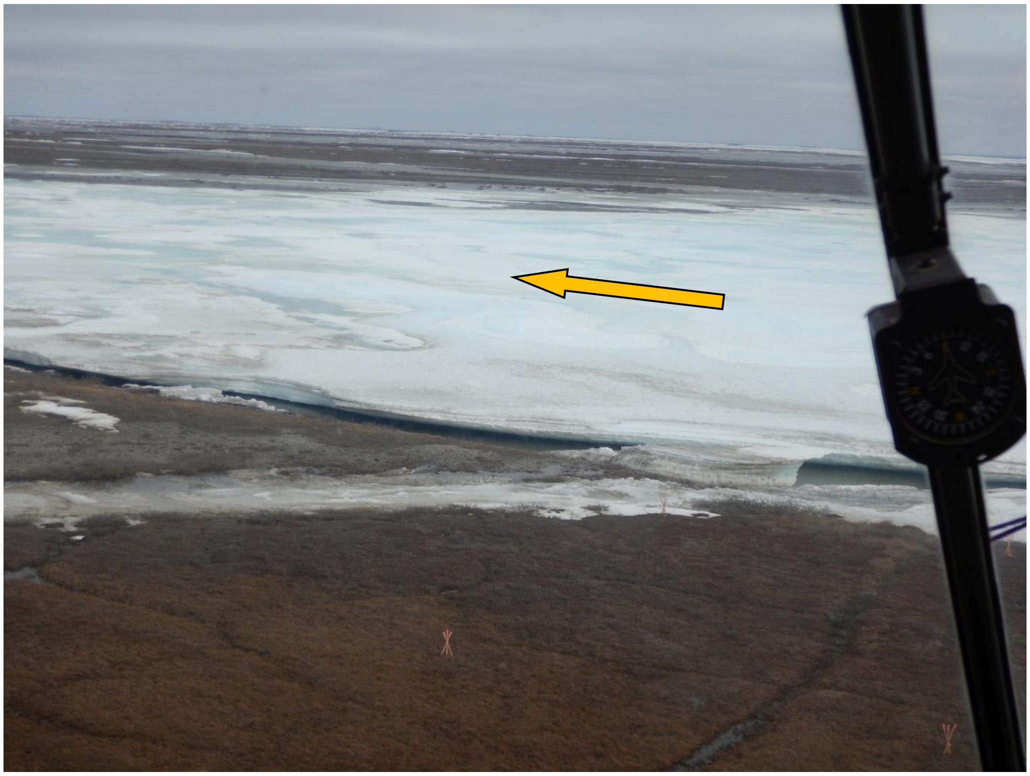


Figure 65. West channel of the Sagavanirktok River covered in ice on May 27, 2016. Open water is visible in the center of the picture. Location is downstream from the material site at MP405 (DSS1).

4.7.6 Additional Field Observations

In addition to the use of discharge measurements of the Upper Kuparuk and Imnavait Creek (Arp and Stuefer, 2016), the USGS data from the gauge site on the upper Sagavanirktok River were reviewed. The USGS measured spring runoff at its Sagavanirktok River station two times in 2016 (USGS, 2016). Figure 66 is a hydrograph for the Upper Sagavanirktok River station showing river discharge during the past decade (2006 through 2016), although spring data are uncertain. Runoff during spring may not be measured manually due to ice conditions; it is typically estimated or reported as backwater and may be reported as mean daily discharge. In 2016, the USGS measurements occurred after the breakup peak flow event on about May 14 (also shown in Figure 43), and estimated flow data were not yet available from USGS for breakup. Data are presented in a log scale to show winter baseflow measurements. The winters of 2013, 2014, and 2015 had the highest baseflow measurements recorded in the period shown in the figure. The increased baseflow in recent years is partially attributed to increased precipitation as discussed in Sections 4.3 through 4.5.

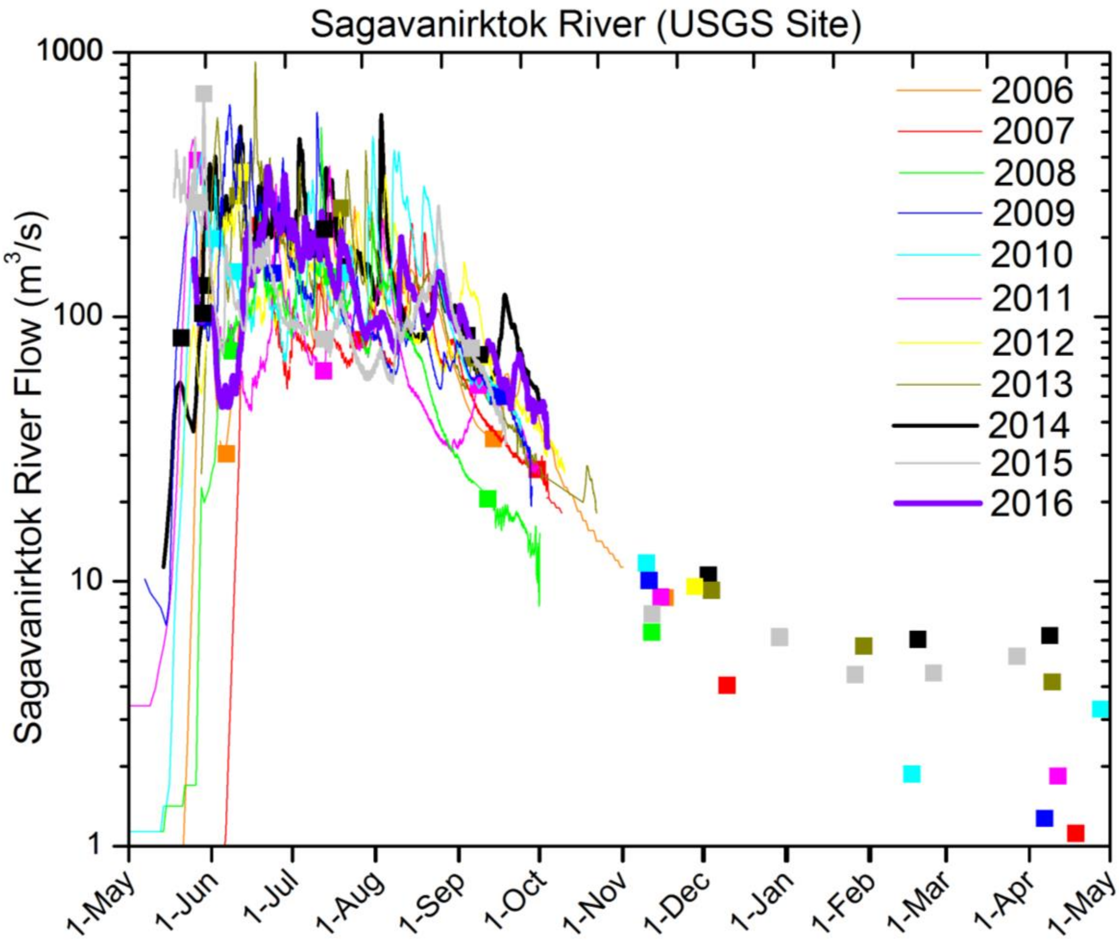


Figure 66. Upper Sagavanirktok River runoff, 2006 to 2016 (USGS, 2016), plotted on a logarithmic scale. The bold purple line indicates runoff for 2016. Individual measurements of runoff are plotted as squares.

4.8 Suspended Sediment

The results presented in this section provide insights on suspended sediment transport conditions during breakup.

Grain-size distributions for 31 selected samples from 3 different stations (DSS2, DSS3, and DSS4) are shown in Figure 67: DSS2 (n = 5), DSS3 (n = 9), DSS4 (n = 17). The average grain size, D_{50}, of each distribution ranged from 20 to 50 microns, which corresponds to silt-sized particles (ranging from medium to coarse silt).

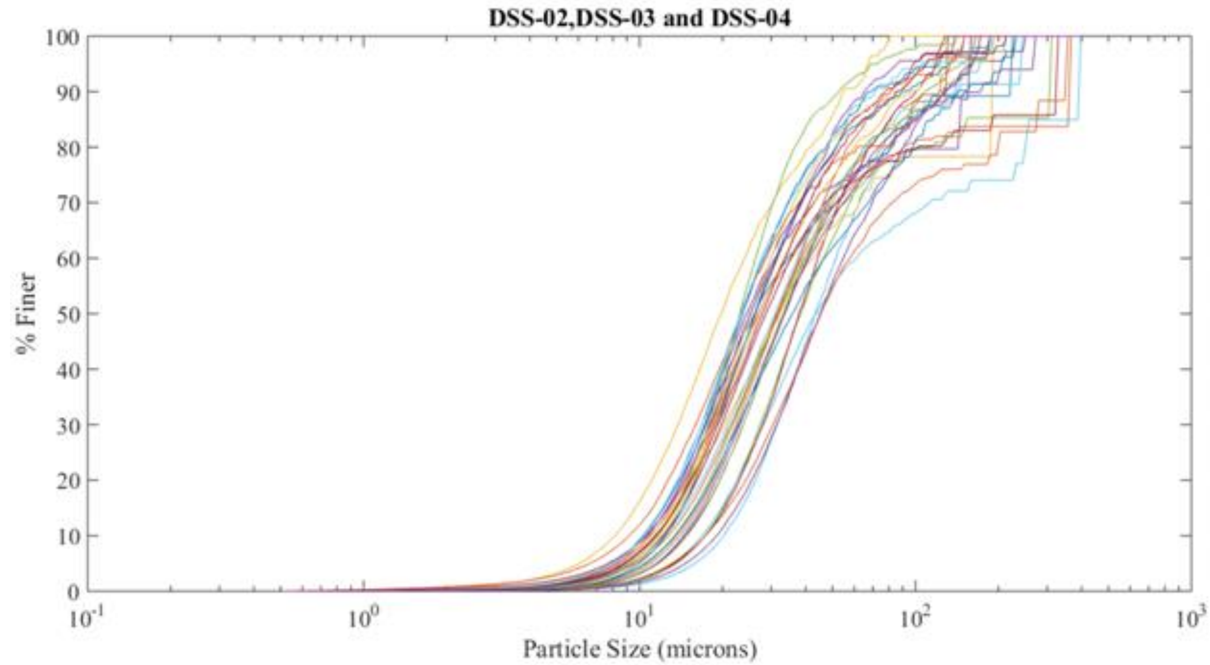


Figure 67. Grain-size distribution for 31 sediment samples.

Water levels and the temporal variation of suspended sediment concentration (SSC) are shown in Figure 68 and Figure 69. In general, the figures show that SSC reacts to relative changes in water levels. The plots indicate that the SSC values for spring breakup 2016 are significantly lower than the values reported for spring breakup 2015 (Toniolo et. al., 2015). The flows were lower in 2016 and breakup was slower; consequently, the flows had lower energy and sediment was not available (i.e., it was protected by ice).

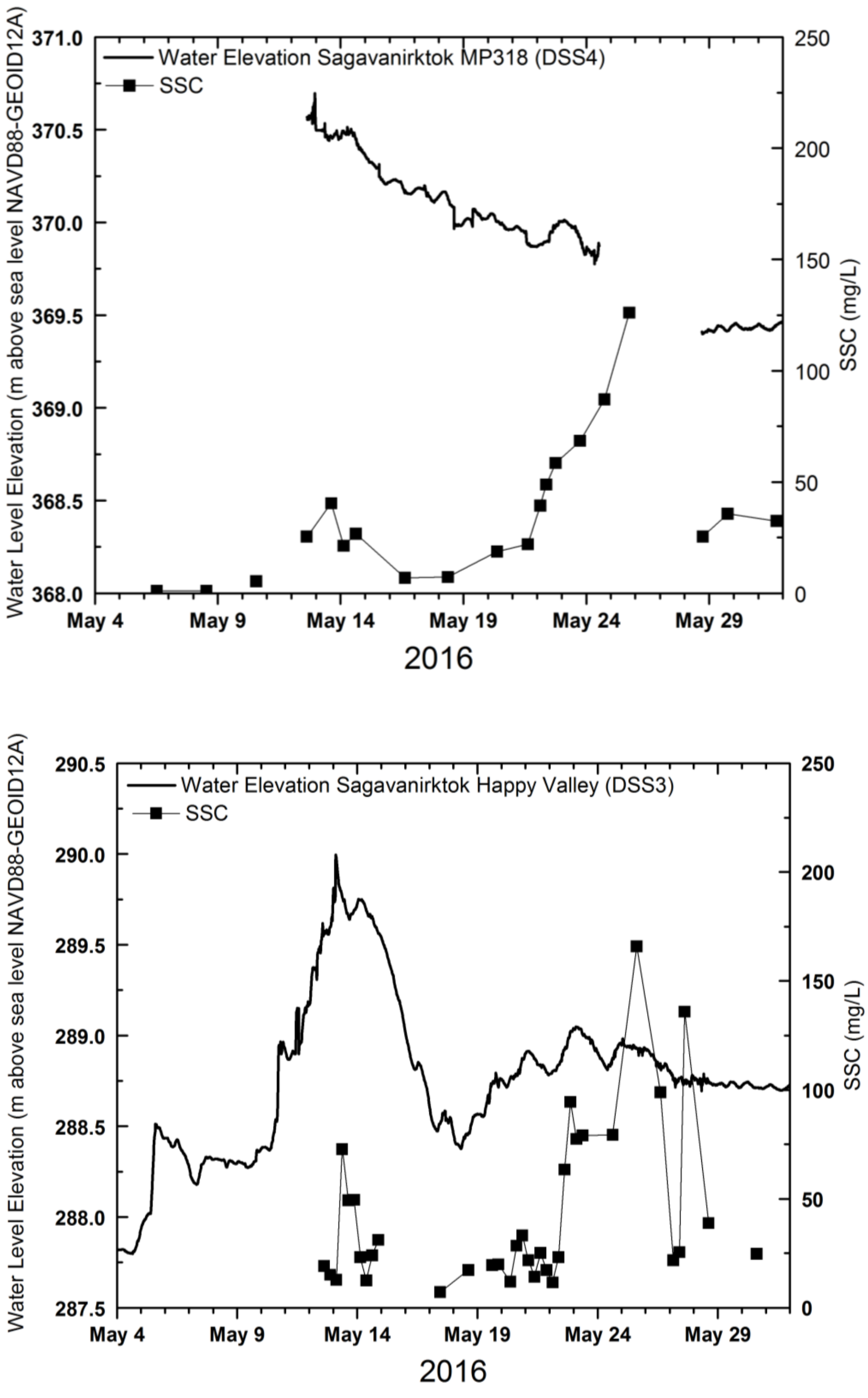


Figure 68. Suspended sediment concentration and water levels at stations on the Sagavanirktok River above the confluence with the Ivishak River.

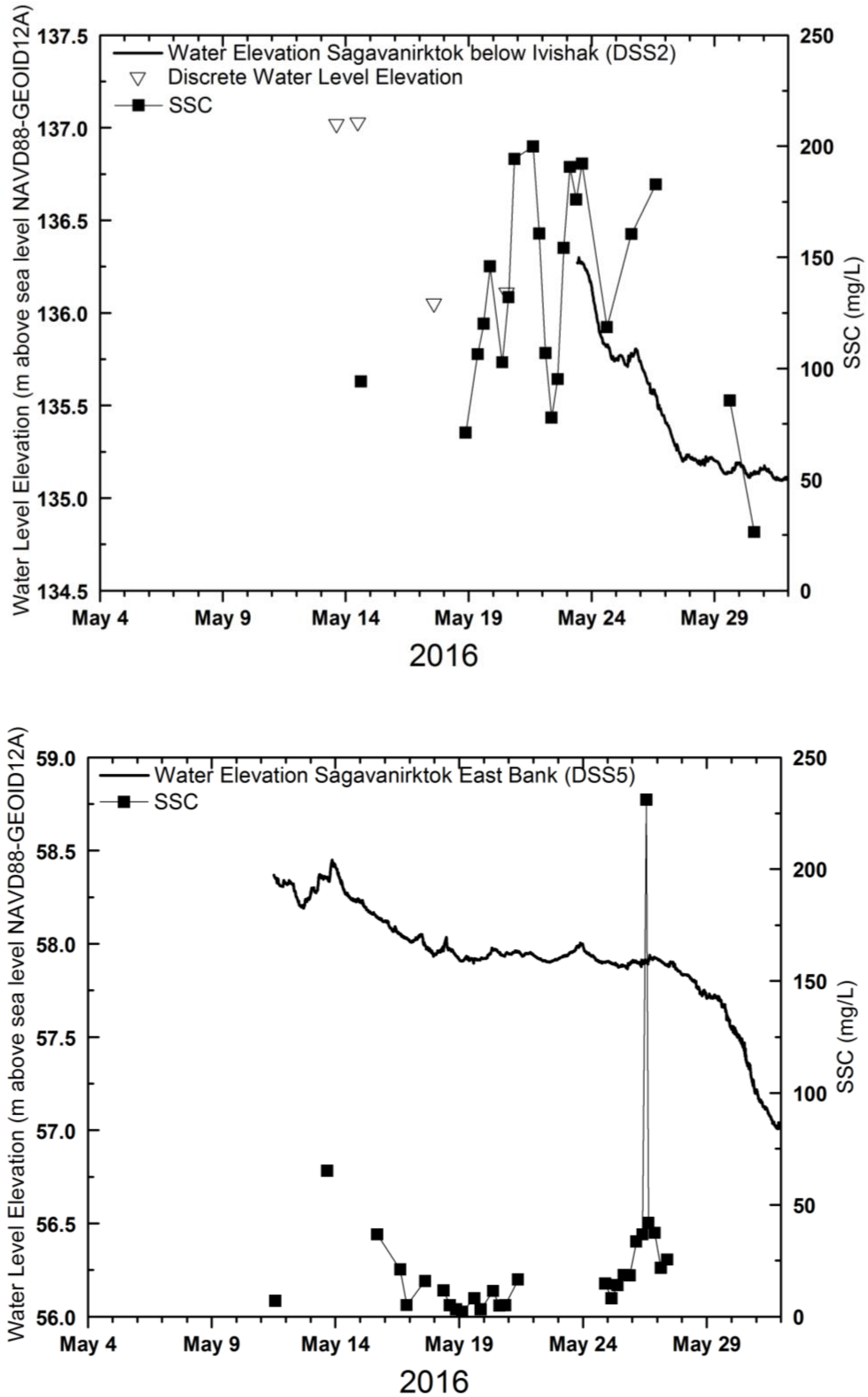


Figure 69. Suspended sediment concentration and water levels at stations on the Sagavanirktok River below the confluence with the Ivishak River.

4.9 Water Chemistry

We analyzed the water samples for concentrations of numerous trace elements, and simultaneously sampled possible contributing water sources between January and July 2016, including snow, glacial meltwater, and river water. Element concentrations of sample groups were strongly correlated with each other ($R^2 > 0.85$). Clear differences between the groups, however, were observed in their geochemical makeup (Figure 70). Snow, for example, has lower element concentrations than other groups.

Geochemical signatures calculated from the log-transformed data of all groups of samples (Figure 71) were likewise strongly correlated with each other ($R^2 > 0.9$), except ice core samples, which correlated weakly ($R^2 > 0.371$–0.646) with other groups (Table 19). The geochemical signature of the Sagavanirktok overflow that has formed large accumulations of ice in the floodplain is more similar to headwater overflow ($R^2 = 0.997$) than to any other contributor.

Our primary goal was to understand where the Sagavanirktok River overflow that forms the lower Sagavanirktok aufeis originates. Our mixing model with all sources included shows that Sagavanirktok overflow can be created using 51% headwater overflow + 40% river ice + 9% glacier water. This finding reaffirms the strong similarity between the Sagavanirktok and headwater overflow, and it indicates some differences between river ice and the overflow from the same area. The mixing model for the Sagavanirktok overflow was recalculated (1) ignoring headwater overflow, (2) ignoring river ice, (3) combining Ivishak overflow, Sagavanirktok overflow, and river ice, and then (4) combining headwater overflow and Sagavanirktok overflow samples but ignoring river ice (Table 20). Without the headwater overflow, the Sagavanirktok overflow mix was 88% river ice + 12% glacier water. Eliminating headwater overflow and river ice, the mix that emerges is 95.8% river water and 4.2% glacier water. Combining Sagavanirktok and headwater overflow yields 96.4% river water and 3.6% glacier water.

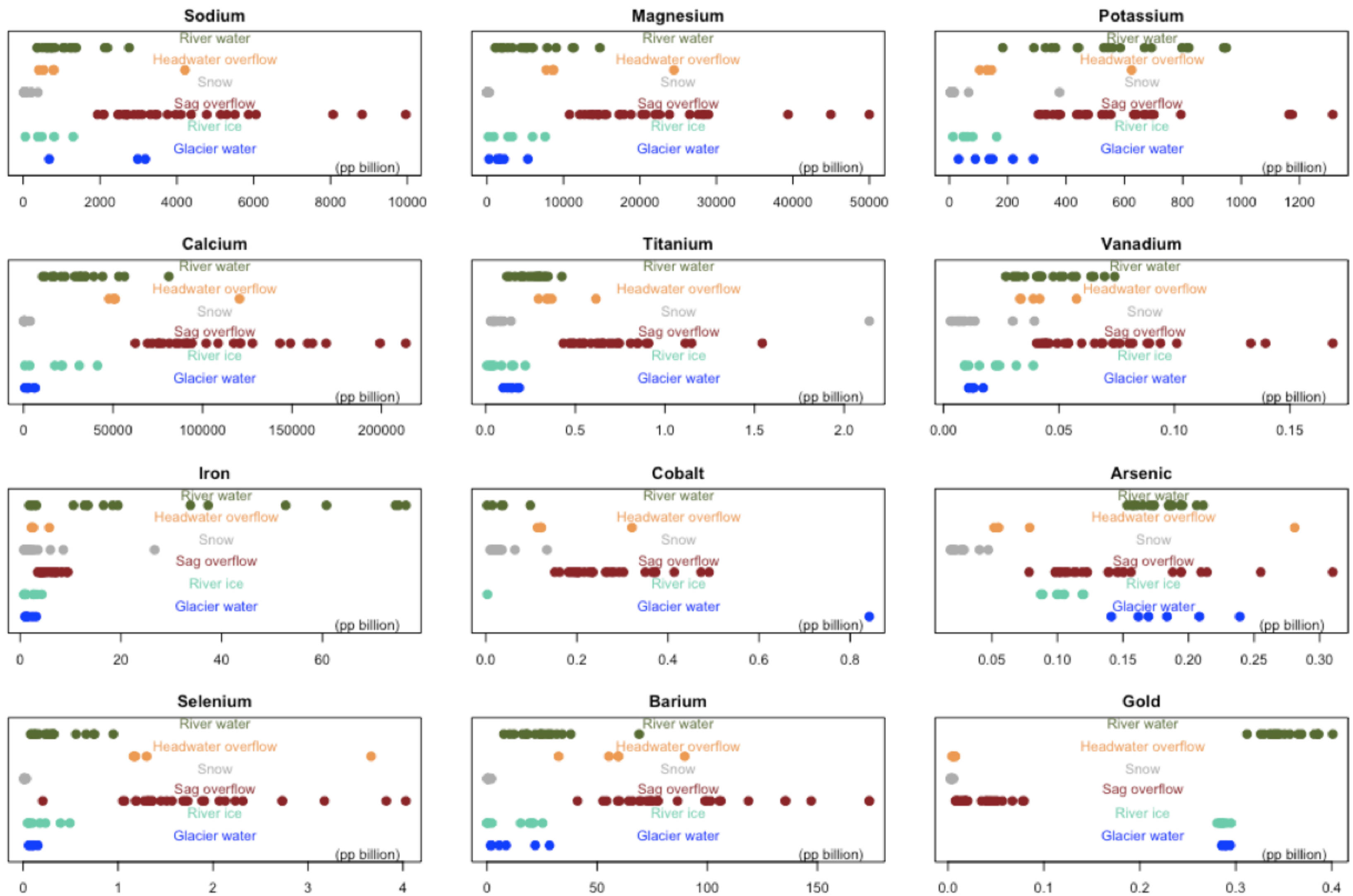


Figure 70. Concentrations (in parts per billion) of various elements in each sample (dots), by sample group. The map in Figure 8 shows where samples in each group were collected.

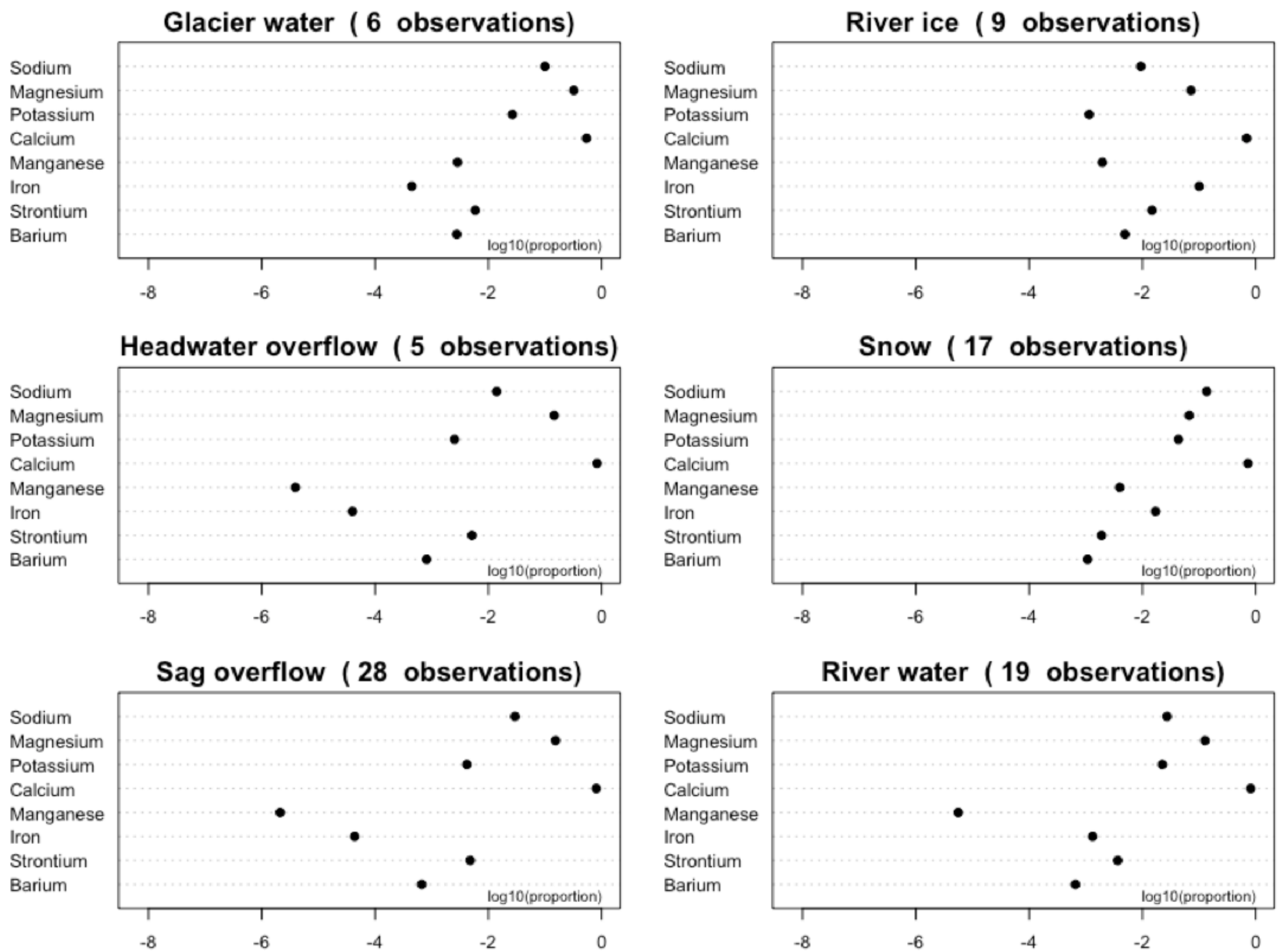


Figure 71. Geochemical signatures of each sample group. Signatures were calculated by determining the proportion of each element in each sample, applying a $\log_{10}(x)$ transform to those proportions, and then averaging by sample group. The log transform makes variations in the proportions of scarcer impurities apparent. Correlation among groups is highest between headwater overflow and Sagavanirktok overflow ($R^2 = 0.997$, Table 19), as indicated above by their nearly identical proportions of major trace elements.

Table 19. Correlations of geochemical signatures among groups. Italics indicate correlations exceeding 0.90, and bold italics indicate correlations exceeding 0.95.

	Glacier Water	Headwater Overflow	Sagavanirktok Overflow	River Ice	Snow	River Water
Glacier water	1	*0.936*	***0.957***	0.371	*0.900*	*0.927*
Headwater overflow	*0.936*	1	***0.997***	0.415	*0.911*	*0.921*
Sagavanirktok overflow	***0.957***	***0.997***	1	0.425	*0.922*	*0.939*
River ice	0.371	0.415	0.425	1	0.417	0.646
Snow	*0.900*	*0.911*	*0.922*	0.417	1	*0.917*
River water	*0.927*	*0.921*	*0.939*	0.646	*0.917*	1

Table 20. The average percentages of various elements in each sample group, including some combined groups (above double lines). Below the double lines are the mixing model equations derived to create combinations of overflow (left column), with various components removed (in parentheses).

Sample Type	Na	Mg	K	Ca	Mn	Fe	Sr	Ba
Glacier water	16.9	31.0	2.2	49.1	0.0	0.0	0.5	0.2
Snow	9.1	5.9	3.8	80.1	0.3	0.4	0.2	0.1
Sag overflow	3.0	15.7	0.4	80.4	0.0	0.0	0.5	0.1
River water	2.7	13.9	1.5	81.3	0.0	0.1	0.4	0.1
Headwater overflow	1.7	14.9	0.3	82.5	0.0	0.0	0.5	0.1
River ice	1.9	12.8	0.2	84.6	0.0	0.0	0.5	0.1
Sag overflow+Headwater overflow	2.9	15.6	0.4	80.5	0.0	0.0	0.5	0.1
Sag overflow+Headwater overflow+River ice	2.9	15.5	0.4	80.7	0.0	0.0	0.5	0.1
Sag overflow (no Headwater overflow)	3.0	15.7	0.4	80.4	0.0	0.0	0.5	0.1
0.120*Glacier+0.880*River ice	3.7	15.0	0.5	80.3	0.0	0.0	0.5	0.1
Sag overflow (no Headwater overflow or River ice)	3.0	15.7	0.4	80.4	0.0	0.0	0.5	0.1
0.042*Glacier+0.958*River water	3.3	14.6	1.5	80.0	0.0	0.1	0.4	0.1
Sag overflow+Headwater overflow (no River ice)	2.9	15.6	0.4	80.5	0.0	0.0	0.5	0.1
0.036*Glacier+0.964*River water	3.2	14.5	1.5	80.2	0.0	0.1	0.4	0.1
Sag overflow+Headwater overflow+River ice	2.9	15.5	0.4	80.7	0.0	0.0	0.5	0.1
0.032*Glacier+0.968*River water	3.2	14.4	1.5	80.3	0.0	0.1	0.4	0.1

River ice samples from the general area of the lower Sagavanirktok River aufeis could have formed as normal river ice early in the winter season or as overflow ice later in the season. Furthermore, changes in geochemistry during the freezing process could have rendered the overflow ice different from the overflow water forming it. Focus, therefore, was directed toward determining the composition of the Sagavanirktok overflow samples.

Winter overflow on the Sagavanirktok River is strikingly similar to that which occurs upstream in the mountains on the Ivishak and Sagavanirktok Rivers (Figure 71, Table 19). Previous work on aufeis in the region (Kane et al., 2013) suggests that the springs at the mountain front have deep groundwater sources, whereas some of the springs instead originate upstream and flow through river gravel before emerging downstream. Our sampling included several springs at the headwaters of the Ivishak and the Sagavanirktok River (headwater overflow), as well as extensive sampling on the lower Sagavanirktok River. Results show that the geochemical signatures (proportions) of overflow water samples from many upstream and downstream locations are nearly indistinguishable, indicating a common source. The difference between headwater overflow and Sagavanirktok overflow, however, is that Sagavanirktok overflow generally has higher trace element concentrations than headwater overflow, indicating that Sagavanirktok overflow has flowed farther through the substrate and accumulated more trace elements. Whether the water that traveled farther has flowed through taliks beneath the river channel or through groundwater channels beneath the permafrost is unknown.

Winter overflow on the Sagavanirktok and Ivishak Rivers is composed primarily of river water like that which flows during early summer, but with an additional glacial contribution. Because overflow was sampled during winter when glaciers are not melting, the glacial contribution likely began as glacier meltwater before recharging groundwater through rocky porous glacial deposits (till) and reemerging downslope as overflow (Kane et al., 2013).

In the future, the Sagavanirktok aufeis could be affected by reduced glacial contributions from diminishing glaciers. Aufeis in the Brooks Range and North Slope seems to be located downslope from glaciers. This relationship, though it has not been quantified yet, is manifest by the presence of both glaciers and aufeis in the eastern Brooks Range compared with the lack of glaciers and fewer aufeis formations in the western Brooks Range. Our results are somewhat consistent with this relationship, indicating that the overflow forming the aufeis is composed of a small fraction of glacier meltwater, and the remaining fraction is similar to river water. With glaciers in the Brooks Range shrinking (large ones) and disappearing (small ones), including those in the Sagavanirktok River watershed, it is possible that groundwater and aufeis associated with them will similarly diminish. This outcome depends, however, on whether glacial meltwater is recharging the groundwater or whether snowmelt and rain are recharging the groundwater. The large fraction of river water (sampled during and after snowmelt) in the overflow indicates that the overflow groundwater source is recharged primarily by precipitation, not glacier meltwater.

Data indicate that instead of existing glaciers being the source of groundwater, overflow, and aufeis, it is porous glacial deposits from the Pleistocene (Manley and Kaufman, 2002) that prevent permafrost from forming continuously and allow precipitation (as well as some glacier meltwater) to recharge groundwater in the mountains.

The Sagavanirktok River aufeis field near Franklin Bluffs will likely continue to form, affected by increasing winter river discharge. It is our opinion that recent highway flooding associated with aufeis is partly related to unusually warm winters forming larger than usual aufeis. Warming during the last century has deepened the active layer of soil, permitting greater water storage in the soil. The same warming delays the ground from freezing completely. The combined effect is more water and more unfrozen soil and taliks for water to flow through during winter. Thus, while it might seem counterintuitive, warm winters increase the flow of water and supply of overflow to produce larger accumulations of aufeis than in comparably cold winters.

5 CONCLUSIONS

In 2015, spring breakup on the Sagavanirktok River near Deadhorse was characterized by high flows that caused devastating damage to the Dalton Highway. Because of the damage, the highway was closed to traffic for nearly three weeks. During this unprecedented flood, infrastructure that supports the trans-Alaska pipeline was damaged, though the pipeline itself was not damaged. Emergency repairs were made to the affected infrastructure.

To be better prepared for the possibility of high flows in the Sagavanirktok River watershed during spring breakup 2016, ADOT&PF and APSC sought assistance with monitoring, recording, and analyzing breakup conditions along the Sagavanirktok River, where it parallels the Dalton Highway. Particular focus on aufeis accumulation and potential flooding was requested by the department. This report details our efforts in that regard.

An analysis of late-winter Landsat satellite imagery of aufeis extent near Franklin Bluffs for the past 17 years (2000–2016) indicates a continuous record of ice in the area between MP393 and MP396. In calculating aufeis extent over this 17-year period, we found that the highest value corresponds to 2015 (116.7 km^2); the second highest value corresponds to 2016 (90.1 km^2). Minimum values calculated corresponded to 2012 and 2010, with 9.4 km^2 and 12.6 km^2, respectively (Table 8). Ice elevations were surveyed, on repeated tracks, two times (late February and mid-April) using a GPS rover unit mounted on a PistenBully tracked vehicle. Noticeable changes were detected in both horizontal and vertical planes along the river near MP387.5. Ice thicknesses in a limited number of boreholes in the MP394 area were compared, but no significant changes were detected there. It appears that ADOT&PF's trenching activities in the area were partially responsible for the stability of ice thickness in the boreholes.

Ice volumes were calculated for 2015 and 2016, based on ground elevations from a 2014 survey. A LiDAR survey and a digital elevation model created from SfM imagery (Fodar) were used to obtain final ice elevations for 2015 and 2016, respectively. Results indicate a higher ice volume in 2015 than in 2016.

Rainfall was below normal in June and July and above normal in August. However, summer rainfall was average overall. Snow surveys were carried out along the entire watershed in mid-April to establish end-of-winter conditions in terms of snow water equivalent. Surveys of available historical information were performed. Results indicate that snow water equivalent conditions were normal or slightly below normal, with an average value of ~10 cm of water.

During 2016, air temperatures along the watershed were above freezing in early May, but dropped below freezing around mid-May and stayed cool to cold during the remainder of May. Due to the warm temperatures, breakup in 2016 occurred 6 days earlier than in 2015. However, the succeeding freeze-back reduced snowmelt, consequently reducing discharge. These temperature conditions were markedly different from the temperature conditions in 2015, when temperatures remained continuously above freezing (see Figures 10, 12, and 16 for a comparison of 2015 and 2016 air temperatures). Warm temperatures in 2015 allowed for a fast snowmelt and, as a result, high flows.

Twenty-five discharge measurements were performed during a 3-week period by the field crews at four gauging stations distributed along the Sagavanirktok River. During 5 days of this 3-week period, concurrent measurements were carried out upstream and downstream of the Ivishak. Thus, the discharge from the Ivishak River, as a first approximation, could be calculated as the difference between these simultaneous measurements. Maximum discharge (near peak) was around half of the maximum value measured during 2015.

A comparison of water levels at the East Bank Station (DSS5), which was installed during breakup 2015, indicates that maximum water level during 2016 was approximately 1 m below the maximum recorded in 2015. Suspended sediment concentrations during breakup were significantly lower in 2016 than in 2015; however, the characteristic grain sizes of suspended sediment were similar during breakup both years.

The water that forms the lower Sagavanirktok aufeis is geochemically similar to the water sampled in the river's headwaters. The only difference is a small contribution (4%) of glacier meltwater. Water, including both the precipitation source and the glacial source, emerges from the river's gravel substrate during winter. The glacial contribution has probably increased over the last 1.5 centuries as glacier mass has decreased, but this 4% contribution will eventually decline to zero if glaciers at the headwaters continue to shrink and/or disappear.

Finally, the ice berm that was formed when ADOT&PF carried out trenching activities diverted flow toward the east channel. Parts of the ice berm were still visible after 2 weeks of active flow. Thus, one could argue that ice berms are beneficial for protecting infrastructure, especially during a mild breakup such as that of 2016. However, during an abrupt breakup such as the one that occurred in 2015, berms would provide limited or no help.

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7 APPENDICES

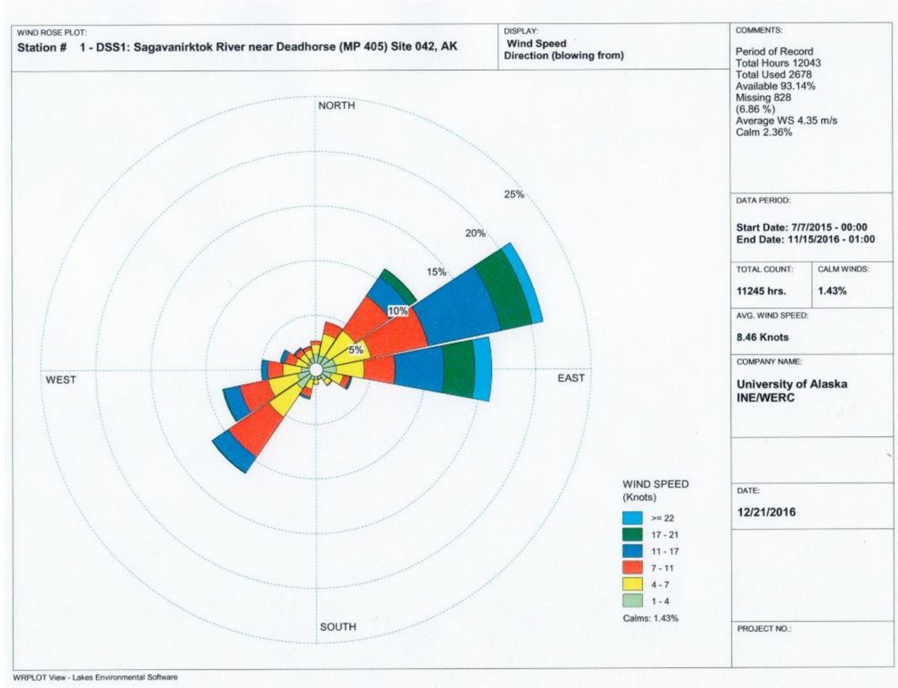
Appendix A – Wind Roses

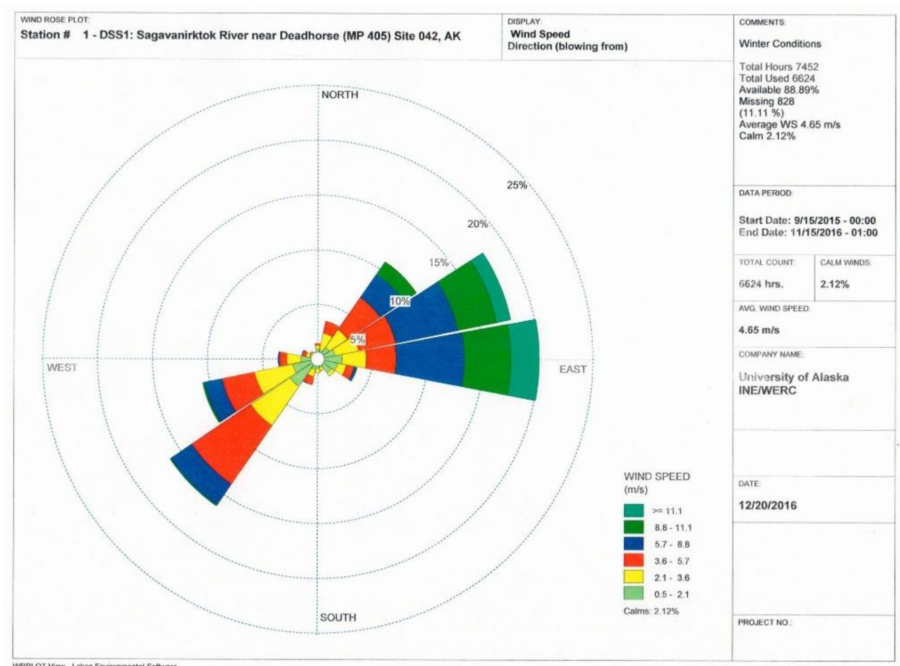
Appendix B – Discharge Measurement Summary Forms

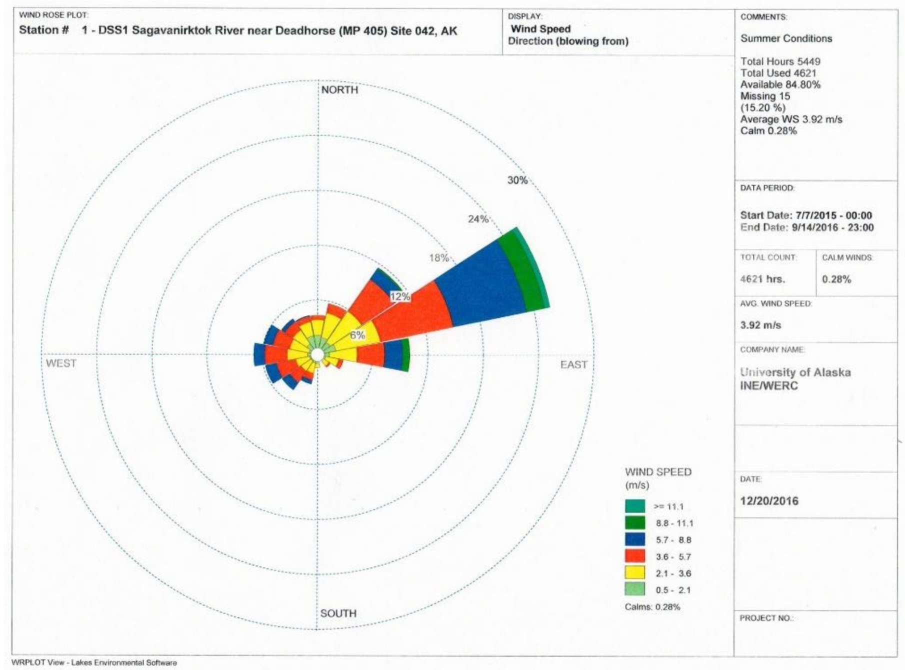
Appendix C – Data DVD

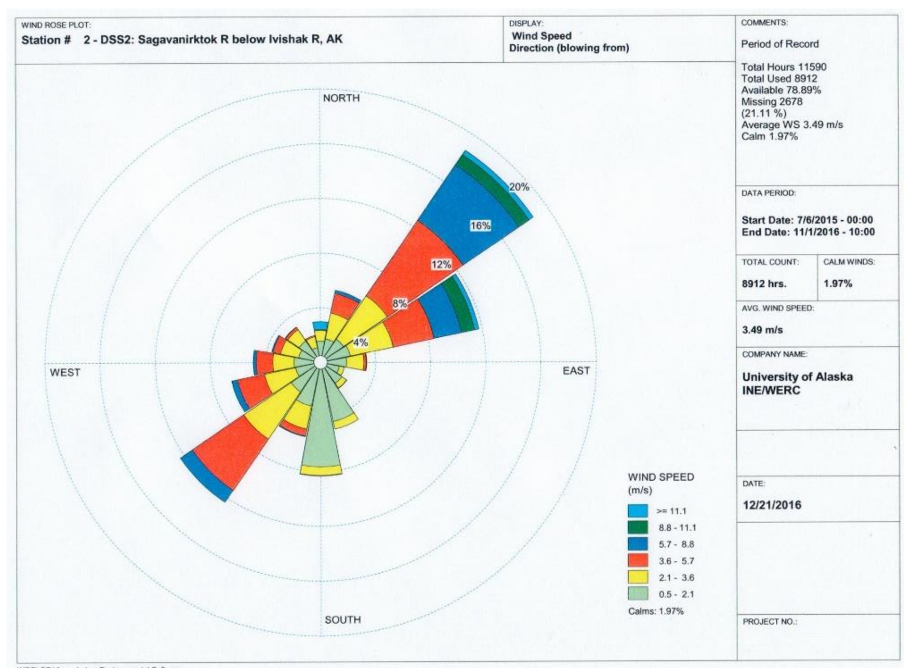
APPENDIX A

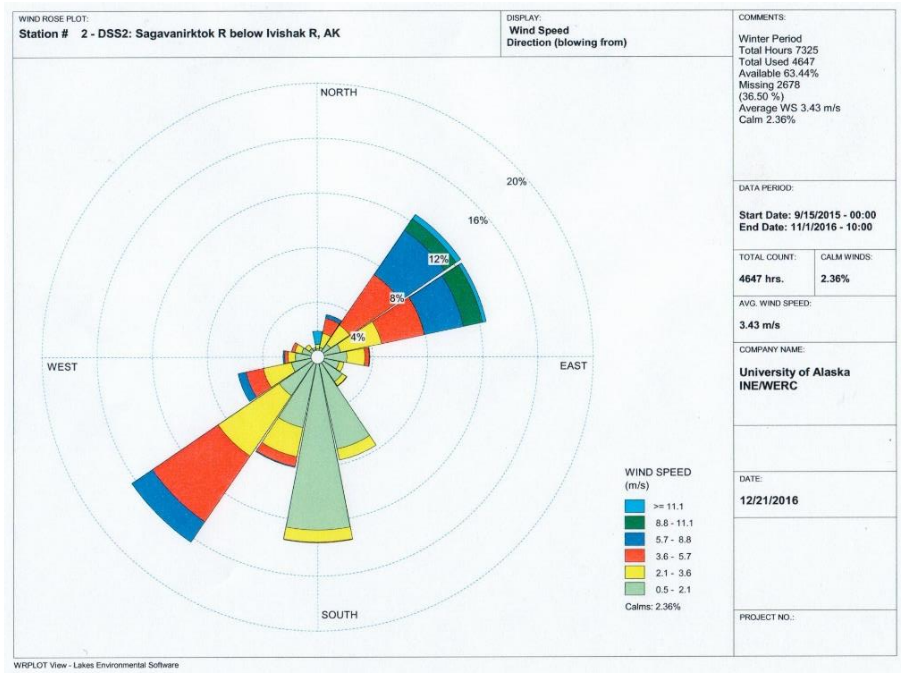
Wind Roses


WIND ROSE PLOT:
Station # 1 - DSS1: Sagavanirktok River near Deadhorse (MP 405) Site 042, AK
DISPLAY:
Wind Speed
Direction (blowing from)
COMMENTS:
Period of Record
Total Hours 12043
Total Used 2678
Available 93.14%
Missing 828
(6.86 %)
Average WS 4.35 m/s
Calm 2.36%
NORTH
SOUTH
EAST
WEST
25%
20%
15%
10%
5%
DATA PERIOD:
Start Date: 7/7/2015 - 00:00
End Date: 11/15/2016 - 01:00
TOTAL COUNT:
11245 hrs.
CALM WINDS:
1.43%
AVG. WIND SPEED:
8.46 Knots
COMPANY NAME:
University of Alaska
INE/WERC
WIND SPEED
(Knots)
>= 22
17 - 21
11 - 17
7 - 11
4 - 7
1 - 4
Calms: 1.43%
DATE:
12/21/2016
PROJECT NO.:
WRPLOT View - Lakes Environmental Software

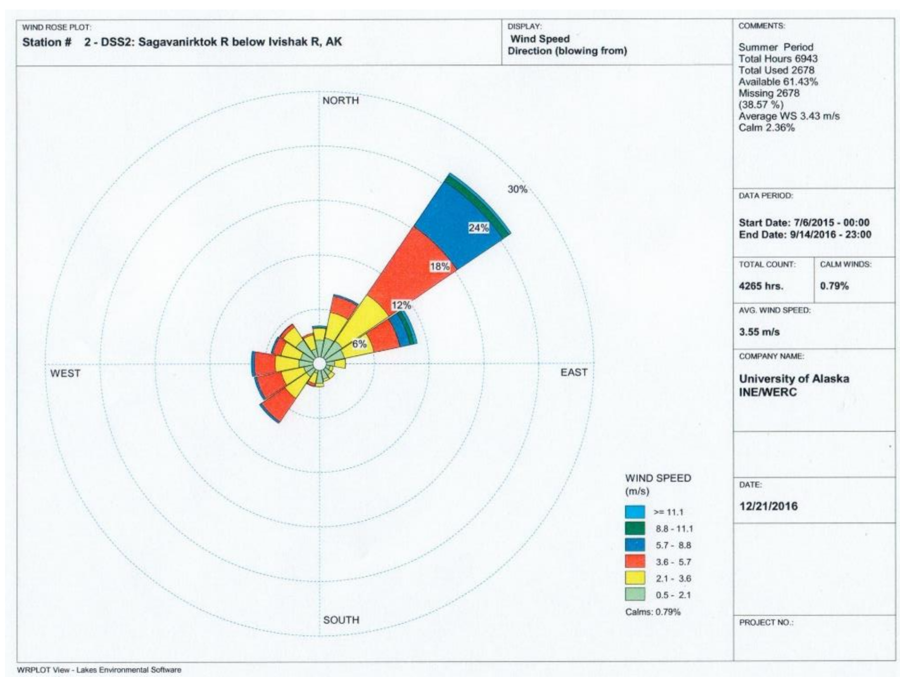

WIND ROSE PLOT:
Station # 1 - DSS1: Sagavanirktok River near Deadhorse (MP 405) Site 042, AK
DISPLAY:
Wind Speed
Direction (blowing from)
COMMENTS:
Winter Conditions
Total Hours 7452
Total Used 6624
Available 88.89%
Missing 828
(11.11 %)
Average WS 4.65 m/s
Calm 2.12%
NORTH
SOUTH
EAST
WEST
25%
20%
15%
10%
5%
DATA PERIOD:
Start Date: 9/15/2015 - 00:00
End Date: 11/15/2016 - 01:00
TOTAL COUNT:
6624 hrs.
CALM WINDS:
2.12%
AVG. WIND SPEED:
4.65 m/s
COMPANY NAME:
University of Alaska
INE/WERC
WIND SPEED
(m/s)
>= 11.1
8.8 - 11.1
5.7 - 8.8
3.6 - 5.7
2.1 - 3.6
0.5 - 2.1
Calms: 2.12%
DATE:
12/20/2016
PROJECT NO.:
WRPLOT View - Lakes Environmental Software


WIND ROSE PLOT:
Station # 1 - DSS1 Sagavanirktok River near Deadhorse (MP 405) Site 042, AK
DISPLAY:
Wind Speed
Direction (blowing from)
COMMENTS:
Summer Conditions
Total Hours 5449
Total Used 4621
Available 84.80%
Missing 15
(15.20 %)
Average WS 3.92 m/s
Calm 0.28%
DATA PERIOD:
Start Date: 7/7/2015 - 00:00
End Date: 9/14/2016 - 23:00
TOTAL COUNT:
4621 hrs.
CALM WINDS:
0.28%
AVG. WIND SPEED:
3.92 m/s
COMPANY NAME:
University of Alaska
INE/WERC
DATE:
12/20/2016
PROJECT NO.:
NORTH
SOUTH
EAST
WEST
30%
24%
18%
12%
6%
WIND SPEED
(m/s)
>= 11.1
8.8 - 11.1
5.7 - 8.8
3.6 - 5.7
2.1 - 3.6
0.5 - 2.1
Calms: 0.28%
WRPLOT View - Lakes Environmental Software

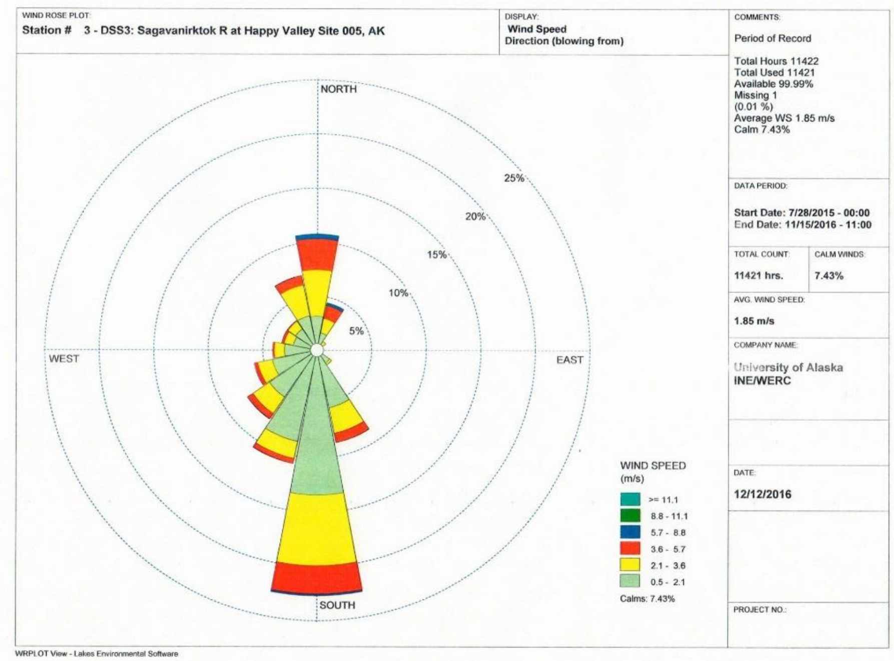

WIND ROSE PLOT:
Station # 2 - DSS2: Sagavanirktok R below Ivishak R, AK
DISPLAY:
Wind Speed
Direction (blowing from)
COMMENTS:
Period of Record
Total Hours 11590
Total Used 8912
Available 78.89%
Missing 2678
(21.11 %)
Average WS 3.49 m/s
Calm 1.97%
DATA PERIOD:
Start Date: 7/6/2015 - 00:00
End Date: 11/1/2016 - 10:00
TOTAL COUNT:
8912 hrs.
CALM WINDS:
1.97%
AVG. WIND SPEED:
3.49 m/s
COMPANY NAME:
University of Alaska
INE/WERC
DATE:
12/21/2016
PROJECT NO.:
NORTH
SOUTH
EAST
WEST
20%
16%
12%
8%
4%
WIND SPEED
(m/s)
>= 11.1
8.8 - 11.1
5.7 - 8.8
3.6 - 5.7
2.1 - 3.6
0.5 - 2.1
Calms: 1.97%
WRPLOT View - Lakes Environmental Software

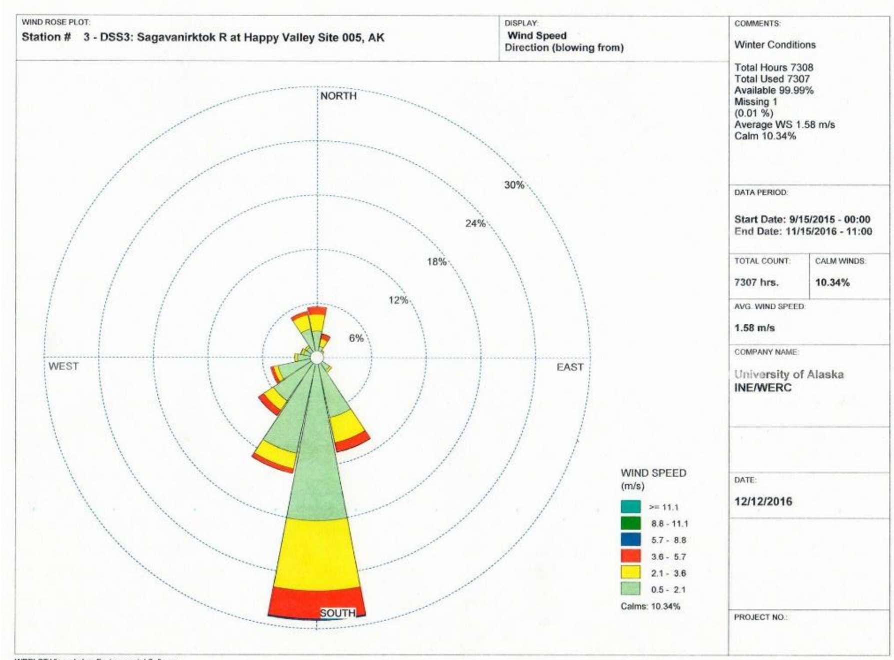


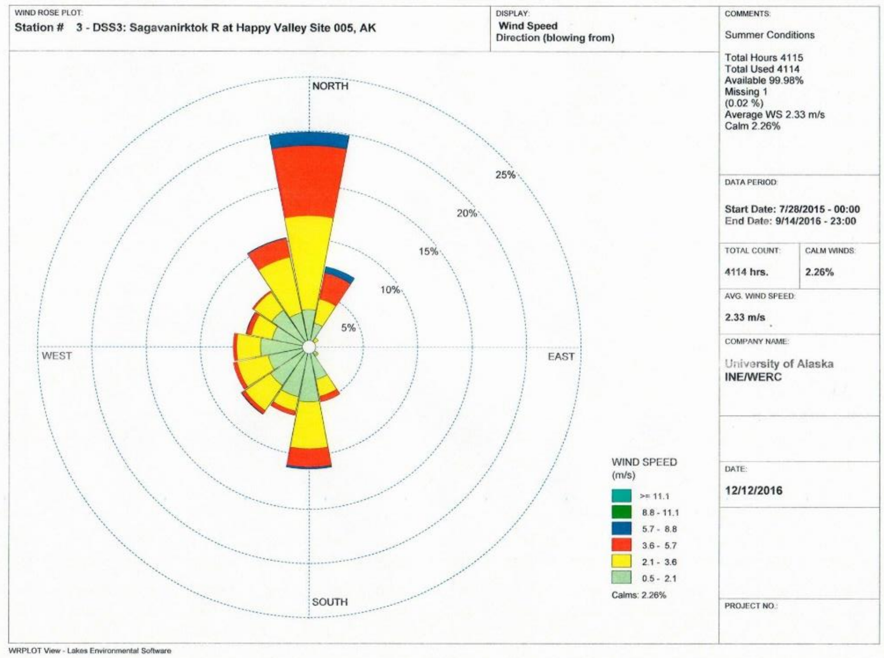
WIND ROSE PLOT:
Station # 2 - DSS2: Sagavanirktok R below Ivishak R, AK
DISPLAY:
Wind Speed
Direction (blowing from)
COMMENTS:
Winter Period
Total Hours 7325
Total Used 4647
Available 63.44%
Missing 2678
(36.50 %)
Average WS 3.43 m/s
Calm 2.36%
NORTH
SOUTH
WEST
EAST
20%
16%
12%
8%
4%
DATA PERIOD:
Start Date: 9/15/2015 - 00:00
End Date: 11/1/2016 - 10:00
TOTAL COUNT:
4647 hrs.
CALM WINDS:
2.36%
AVG. WIND SPEED:
3.43 m/s
COMPANY NAME:
University of Alaska
INE/WERC
WIND SPEED
(m/s)
>= 11.1
8.8 - 11.1
5.7 - 8.8
3.6 - 5.7
2.1 - 3.6
0.5 - 2.1
Calms: 2.36%
DATE:
12/21/2016
PROJECT NO.:
WRPLOT View - Lakes Environmental Software



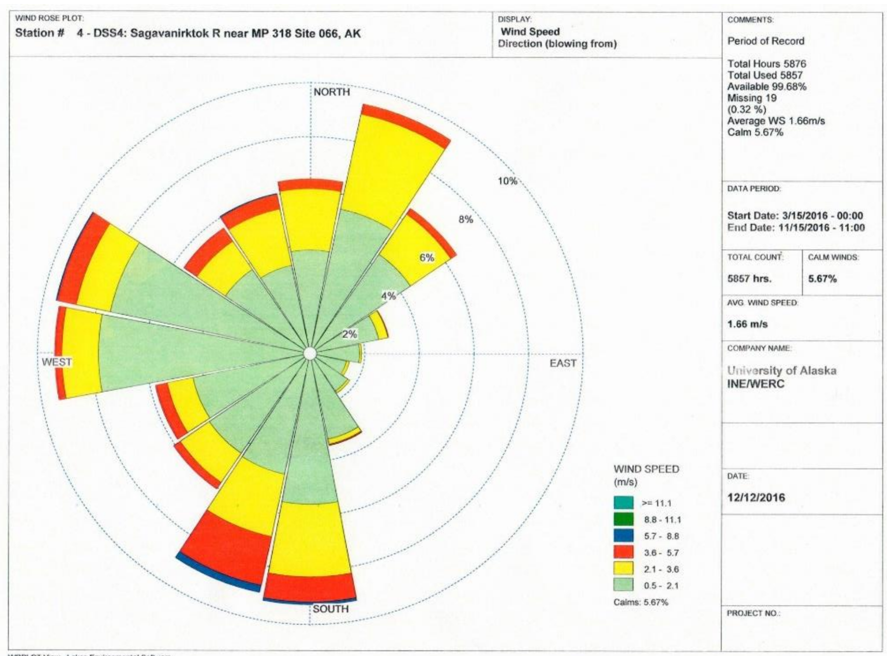
WIND ROSE PLOT:
Station # 2 - DSS2: Sagavanirktok R below Ivishak R, AK
DISPLAY:
Wind Speed
Direction (blowing from)
COMMENTS:
Summer Period
Total Hours 6943
Total Used 2678
Available 61.43%
Missing 2678
(38.57 %)
Average WS 3.43 m/s
Calm 2.36%
NORTH
SOUTH
WEST
EAST
30%
24%
18%
12%
6%
DATA PERIOD:
Start Date: 7/6/2015 - 00:00
End Date: 9/14/2016 - 23:00
TOTAL COUNT:
4265 hrs.
CALM WINDS:
0.79%
AVG. WIND SPEED:
3.55 m/s
COMPANY NAME:
University of Alaska
INE/WERC
WIND SPEED
(m/s)
>= 11.1
8.8 - 11.1
5.7 - 8.8
3.6 - 5.7
2.1 - 3.6
0.5 - 2.1
Calms: 0.79%
DATE:
12/21/2016
PROJECT NO.:
WRPLOT View - Lakes Environmental Software


WIND ROSE PLOT:
Station # 3 - DSS3: Sagavanirktok R at Happy Valley Site 005, AK
DISPLAY:
Wind Speed
Direction (blowing from)
COMMENTS:
Period of Record
Total Hours 11422
Total Used 11421
Available 99.99%
Missing 1
(0.01 %)
Average WS 1.85 m/s
Calm 7.43%
DATA PERIOD:
Start Date: 7/28/2015 - 00:00
End Date: 11/15/2016 - 11:00
TOTAL COUNT:
11421 hrs.
CALM WINDS:
7.43%
AVG. WIND SPEED:
1.85 m/s
COMPANY NAME:
University of Alaska
INE/WERC
DATE:
12/12/2016
PROJECT NO.:
NORTH
SOUTH
EAST
WEST
5%
10%
15%
20%
25%
WIND SPEED
(m/s)
>= 11.1
8.8 - 11.1
5.7 - 8.8
3.6 - 5.7
2.1 - 3.6
0.5 - 2.1
Calms: 7.43%
WRPLOT View - Lakes Environmental Software


WIND ROSE PLOT:
Station # 3 - DSS3: Sagavanirktok R at Happy Valley Site 005, AK
DISPLAY:
Wind Speed
Direction (blowing from)
COMMENTS:
Winter Conditions
Total Hours 7308
Total Used 7307
Available 99.99%
Missing 1
(0.01 %)
Average WS 1.58 m/s
Calm 10.34%
DATA PERIOD:
Start Date: 9/15/2015 - 00:00
End Date: 11/15/2016 - 11:00
TOTAL COUNT:
7307 hrs.
CALM WINDS:
10.34%
AVG. WIND SPEED:
1.58 m/s
COMPANY NAME:
University of Alaska
INE/WERC
DATE:
12/12/2016
PROJECT NO.:
NORTH
SOUTH
EAST
WEST
6%
12%
18%
24%
30%
WIND SPEED
(m/s)
>= 11.1
8.8 - 11.1
5.7 - 8.8
3.6 - 5.7
2.1 - 3.6
0.5 - 2.1
Calms: 10.34%
WRPLOT View - Lakes Environmental Software

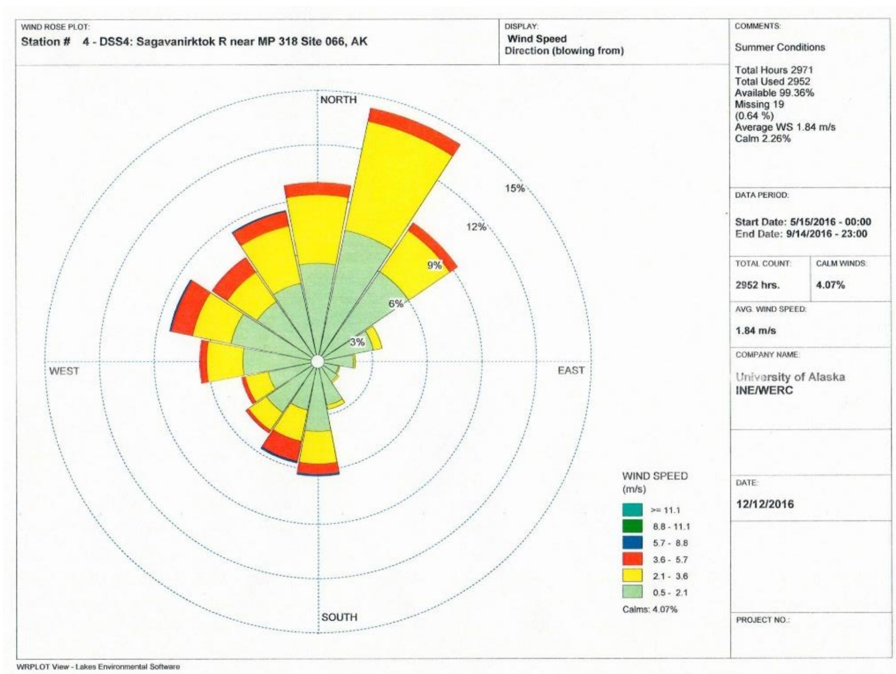


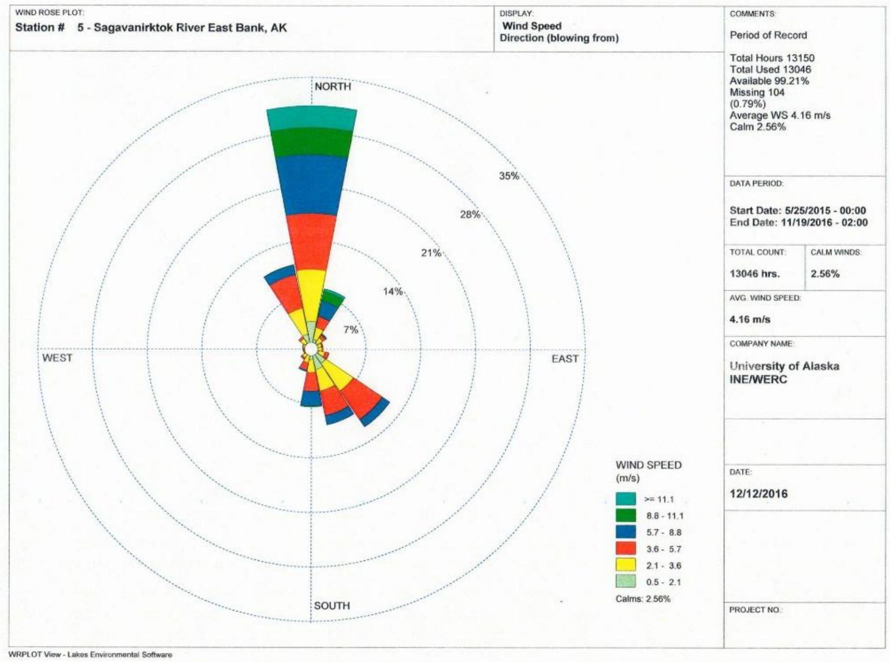
WIND ROSE PLOT:
Station # 3 - DSS3: Sagavanirktok R at Happy Valley Site 005, AK
DISPLAY:
Wind Speed
Direction (blowing from)
COMMENTS:
Summer Conditions
Total Hours 4115
Total Used 4114
Available 99.98%
Missing 1
(0.02 %)
Average WS 2.33 m/s
Calm 2.26%
NORTH
SOUTH
WEST
EAST
25%
20%
15%
10%
5%
DATA PERIOD:
Start Date: 7/28/2015 - 00:00
End Date: 9/14/2016 - 23:00
TOTAL COUNT:
4114 hrs.
CALM WINDS:
2.26%
AVG. WIND SPEED:
2.33 m/s
COMPANY NAME:
University of Alaska
INE/WERC
WIND SPEED
(m/s)
>= 11.1
8.8 - 11.1
5.7 - 8.8
3.6 - 5.7
2.1 - 3.6
0.5 - 2.1
Calms: 2.26%
DATE:
12/12/2016
PROJECT NO.:
WRPLOT View - Lakes Environmental Software



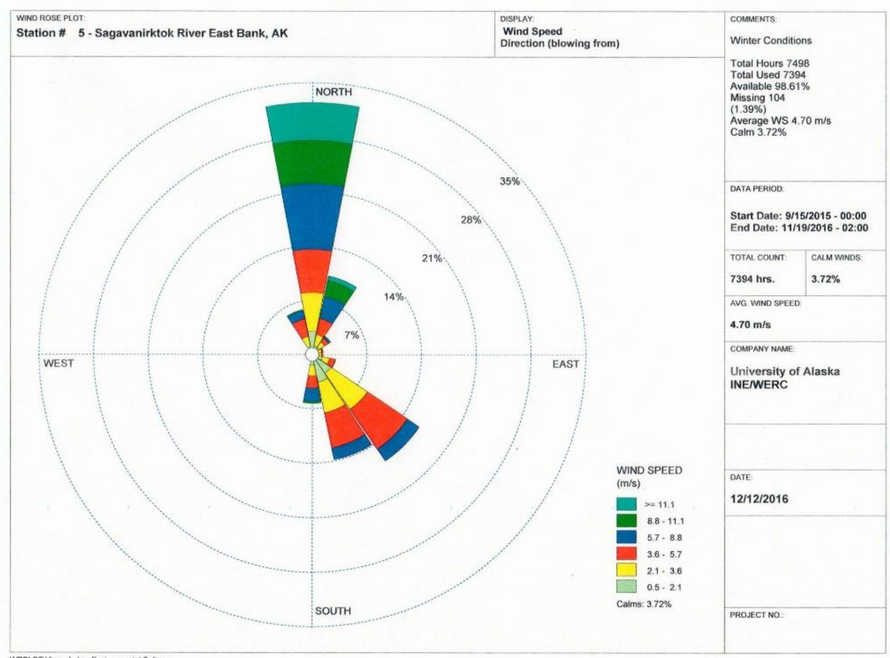
WIND ROSE PLOT:
Station # 4 - DSS4: Sagavanirktok R near MP 318 Site 066, AK
DISPLAY:
Wind Speed
Direction (blowing from)
COMMENTS:
Period of Record
Total Hours 5876
Total Used 5857
Available 99.68%
Missing 19
(0.32 %)
Average WS 1.66m/s
Calm 5.67%
NORTH
SOUTH
WEST
EAST
10%
8%
6%
4%
2%
DATA PERIOD:
Start Date: 3/15/2016 - 00:00
End Date: 11/15/2016 - 11:00
TOTAL COUNT:
5857 hrs.
CALM WINDS:
5.67%
AVG. WIND SPEED:
1.66 m/s
COMPANY NAME:
University of Alaska
INE/WERC
WIND SPEED
(m/s)
>= 11.1
8.8 - 11.1
5.7 - 8.8
3.6 - 5.7
2.1 - 3.6
0.5 - 2.1
Calms: 5.67%
DATE:
12/12/2016
PROJECT NO.:
WRPLOT View - Lakes Environmental Software


WIND ROSE PLOT:
Station # 4 - DSS4: Sagavanirktok R near MP 318 Site 066, AK
DISPLAY:
Wind Speed
Direction (blowing from)
COMMENTS:
Winter Conditions
Total Hours 2924
Total Used 2905
Available 99.35%
Missing 19
(0.65 %)
Average WS 1.48 m/s
Calm 7.25%
DATA PERIOD:
Start Date: 3/15/2016 - 00:00
End Date: 11/15/2016 - 11:00
TOTAL COUNT:
2905 hrs.
CALM WINDS:
7.25%
AVG. WIND SPEED:
1.48 m/s
COMPANY NAME:
University of Alaska
INE/WERC
DATE:
12/12/2016
PROJECT NO.:
NORTH
SOUTH
WEST
EAST
3%
6%
9%
12%
15%
WIND SPEED
(m/s)
>= 11.1
8.8 - 11.1
5.7 - 8.8
3.6 - 5.7
2.1 - 3.6
0.5 - 2.1
Calms: 7.25%
WRPLOT View - Lakes Environmental Software

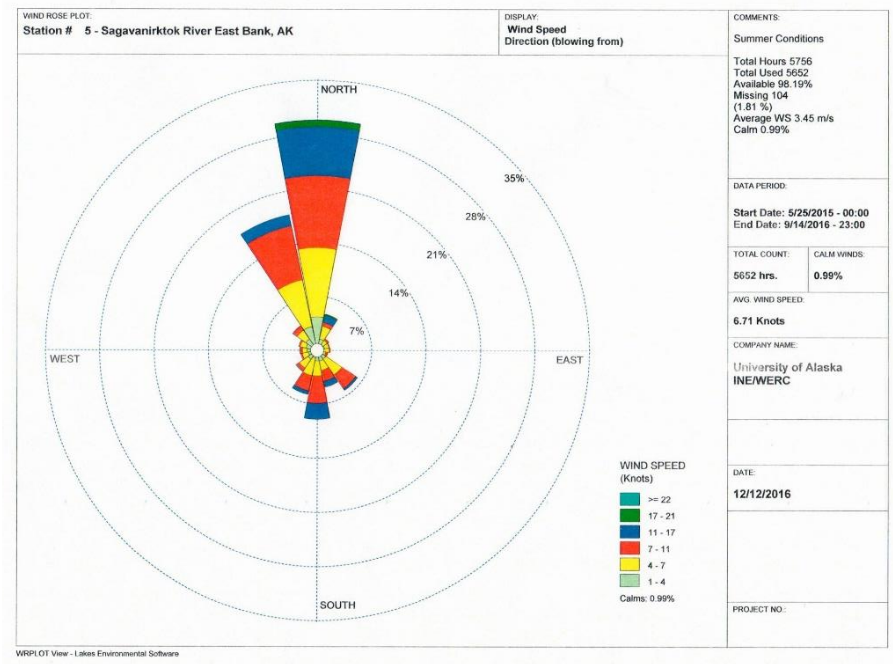

WIND ROSE PLOT:
Station # 4 - DSS4: Sagavanirktok R near MP 318 Site 066, AK
DISPLAY:
Wind Speed
Direction (blowing from)
COMMENTS:
Summer Conditions
Total Hours 2971
Total Used 2952
Available 99.36%
Missing 19
(0.64 %)
Average WS 1.84 m/s
Calm 2.26%
DATA PERIOD:
Start Date: 5/15/2016 - 00:00
End Date: 9/14/2016 - 23:00
TOTAL COUNT:
2952 hrs.
CALM WINDS:
4.07%
AVG. WIND SPEED:
1.84 m/s
COMPANY NAME:
University of Alaska
INE/WERC
DATE:
12/12/2016
PROJECT NO.:
NORTH
SOUTH
WEST
EAST
3%
6%
9%
12%
15%
WIND SPEED
(m/s)
>= 11.1
8.8 - 11.1
5.7 - 8.8
3.6 - 5.7
2.1 - 3.6
0.5 - 2.1
Calms: 4.07%
WRPLOT View - Lakes Environmental Software

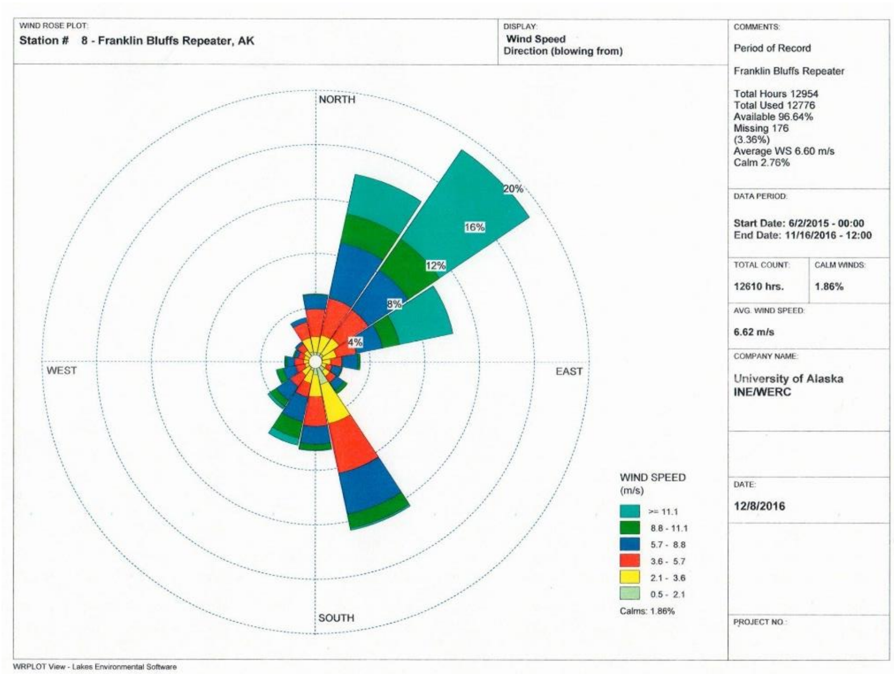


WIND ROSE PLOT:
Station # 5 - Sagavanirktok River East Bank, AK
DISPLAY:
Wind Speed
Direction (blowing from)
COMMENTS:
Period of Record
Total Hours 13150
Total Used 13046
Available 99.21%
Missing 104
(0.79%)
Average WS 4.16 m/s
Calm 2.56%
DATA PERIOD:
Start Date: 5/25/2015 - 00:00
End Date: 11/19/2016 - 02:00
TOTAL COUNT:
13046 hrs.
CALM WINDS:
2.56%
AVG. WIND SPEED:
4.16 m/s
COMPANY NAME:
University of Alaska
INE/WERC
DATE:
12/12/2016
PROJECT NO.:
NORTH
SOUTH
WEST
EAST
7%
14%
21%
28%
35%
WIND SPEED
(m/s)
>= 11.1
8.8 - 11.1
5.7 - 8.8
3.6 - 5.7
2.1 - 3.6
0.5 - 2.1
Calms: 2.56%
WRPLOT View - Lakes Environmental Software

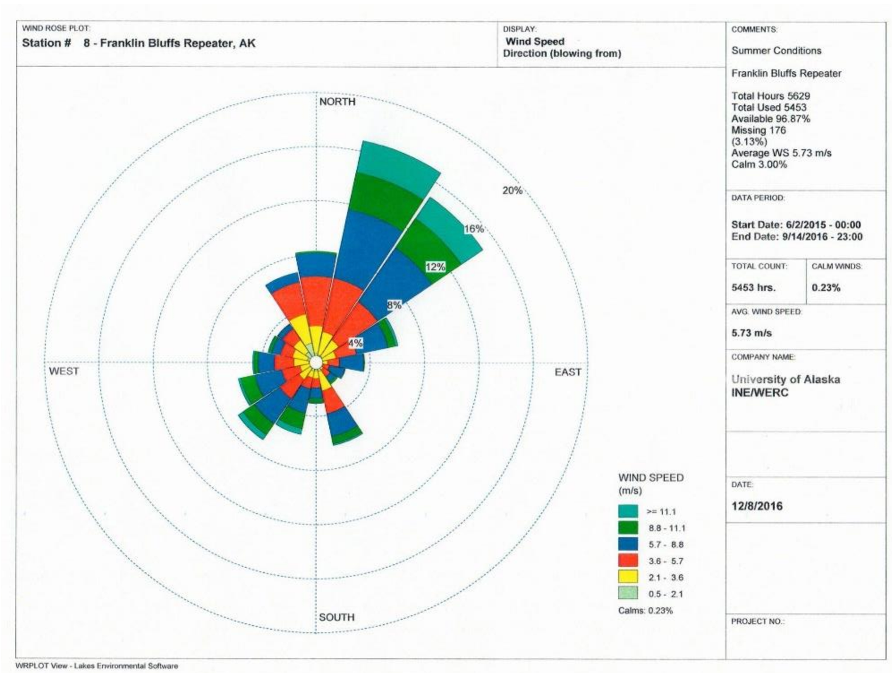


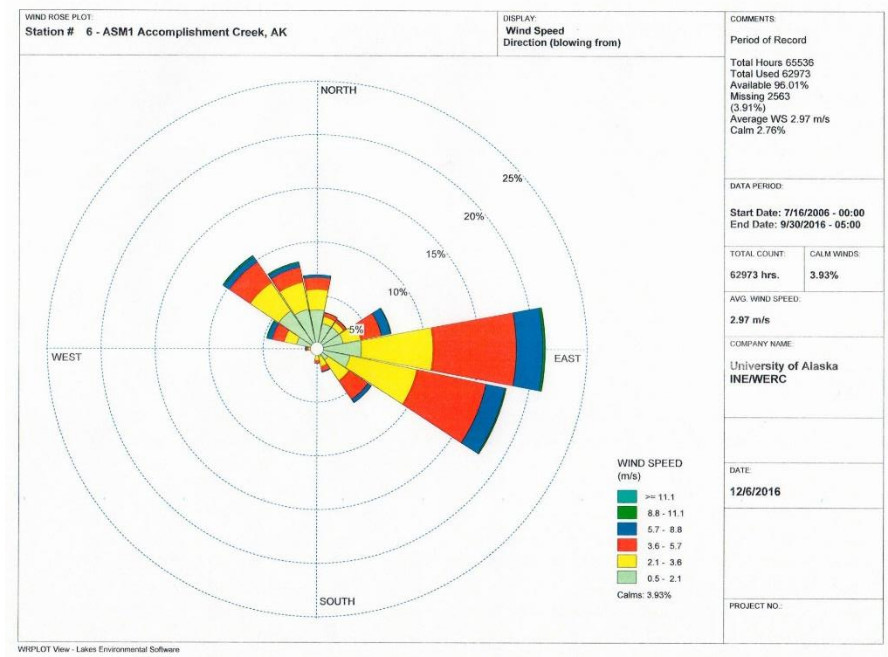
WIND ROSE PLOT:
Station # 5 - Sagavanirktok River East Bank, AK
DISPLAY:
Wind Speed
Direction (blowing from)
COMMENTS:
Winter Conditions
Total Hours 7498
Total Used 7394
Available 98.61%
Missing 104
(1.39%)
Average WS 4.70 m/s
Calm 3.72%
DATA PERIOD:
Start Date: 9/15/2015 - 00:00
End Date: 11/19/2016 - 02:00
TOTAL COUNT:
7394 hrs.
CALM WINDS:
3.72%
AVG. WIND SPEED:
4.70 m/s
COMPANY NAME:
University of Alaska
INE/WERC
DATE:
12/12/2016
PROJECT NO.:
NORTH
SOUTH
WEST
EAST
7%
14%
21%
28%
35%
WIND SPEED
(m/s)
>= 11.1
8.8 - 11.1
5.7 - 8.8
3.6 - 5.7
2.1 - 3.6
0.5 - 2.1
Calms: 3.72%
WRPLOT View - Lakes Environmental Software

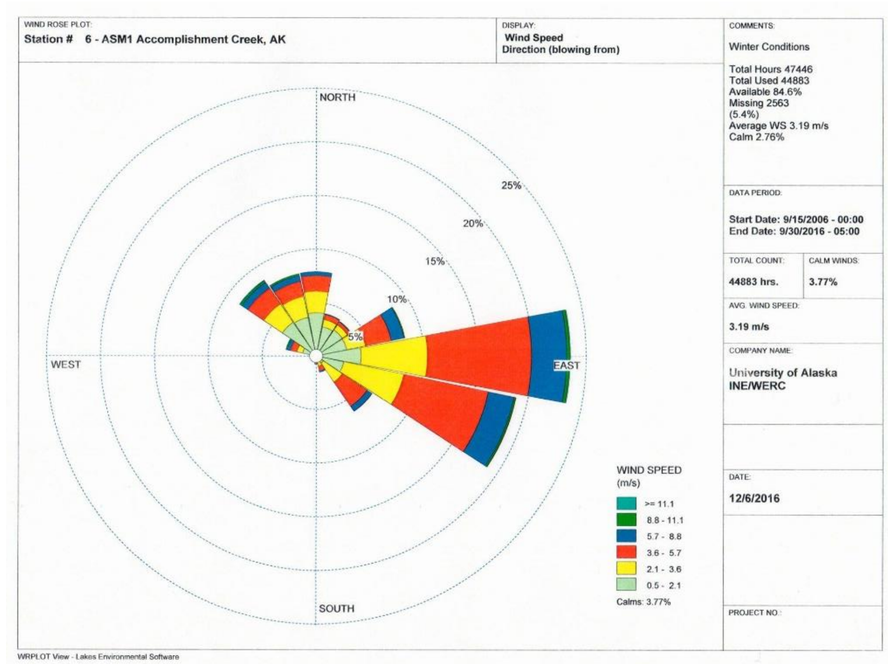

WIND ROSE PLOT:
Station # 5 - Sagavanirktok River East Bank, AK
DISPLAY:
Wind Speed
Direction (blowing from)
COMMENTS:
Summer Conditions
Total Hours 5756
Total Used 5652
Available 98.19%
Missing 104
(1.81 %)
Average WS 3.45 m/s
Calm 0.99%
DATA PERIOD:
Start Date: 5/25/2015 - 00:00
End Date: 9/14/2016 - 23:00
TOTAL COUNT:
5652 hrs.
CALM WINDS:
0.99%
AVG. WIND SPEED:
6.71 Knots
COMPANY NAME:
University of Alaska
INE/WERC
DATE:
12/12/2016
PROJECT NO.:
NORTH
SOUTH
EAST
WEST
35%
28%
21%
14%
7%
WIND SPEED
(Knots)
>= 22
17 - 21
11 - 17
7 - 11
4 - 7
1 - 4
Calms: 0.99%
WRPLOT View - Lakes Environmental Software

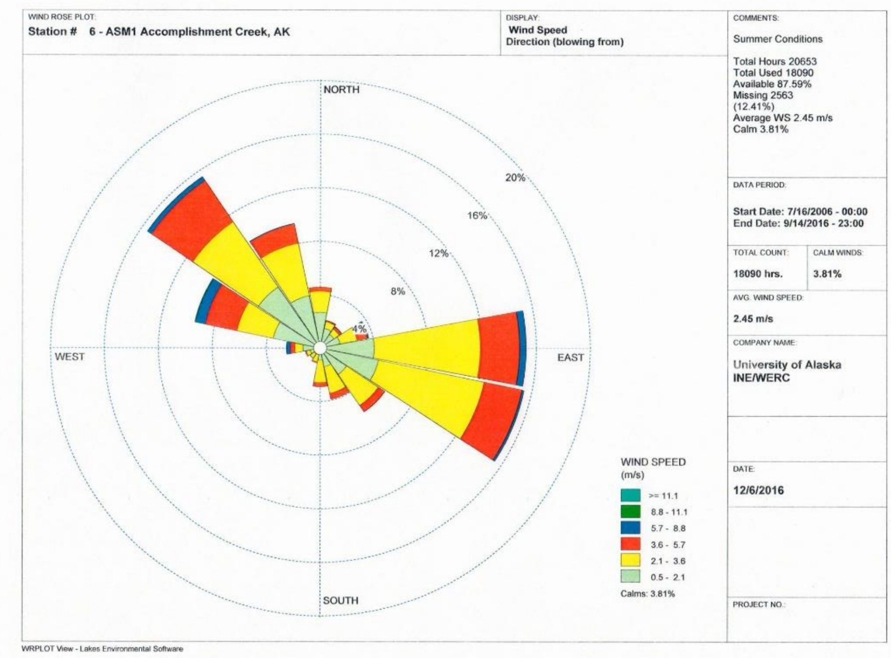

WIND ROSE PLOT:
Station # 8 - Franklin Bluffs Repeater, AK
DISPLAY:
Wind Speed
Direction (blowing from)
COMMENTS:
Period of Record
Franklin Bluffs Repeater
Total Hours 12954
Total Used 12776
Available 96.64%
Missing 176
(3.36%)
Average WS 6.60 m/s
Calm 2.76%
DATA PERIOD:
Start Date: 6/2/2015 - 00:00
End Date: 11/16/2016 - 12:00
TOTAL COUNT:
12610 hrs.
CALM WINDS:
1.86%
AVG. WIND SPEED:
6.62 m/s
COMPANY NAME:
University of Alaska
INE/WERC
DATE:
12/8/2016
PROJECT NO.:
NORTH
SOUTH
EAST
WEST
20%
16%
12%
8%
4%
WIND SPEED
(m/s)
>= 11.1
8.8 - 11.1
5.7 - 8.8
3.6 - 5.7
2.1 - 3.6
0.5 - 2.1
Calms: 1.86%
WRPLOT View - Lakes Environmental Software

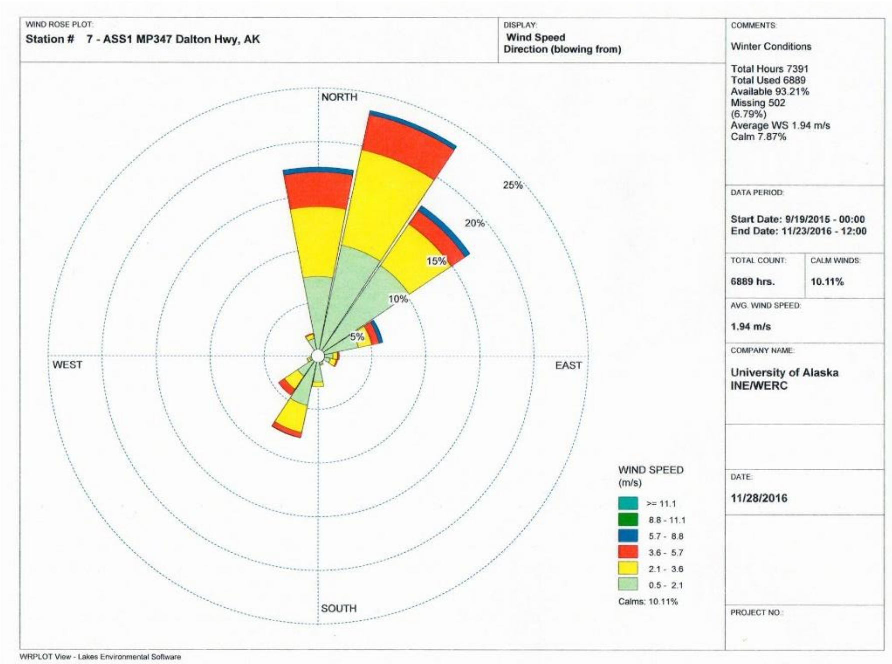

WIND ROSE PLOT:
Station # 8 - Franklin Bluffs Repeater, AK
DISPLAY:
Wind Speed
Direction (blowing from)
COMMENTS:
Winter Conditions
Franklin Bluffs Repeater
Total Hours 7501
Total Used 7325
Available 97.65%
Missing 176
(2.35%)
Average WS 7.24 m/s
Calm 3.00%
DATA PERIOD:
Start Date: 9/15/2015 - 00:00
End Date: 11/16/2016 - 12:00
TOTAL COUNT:
7325 hrs.
CALM WINDS:
3.00%
AVG. WIND SPEED:
7.24 m/s
COMPANY NAME:
University of Alaska
INE/WERC
DATE:
12/8/2016
PROJECT NO.:
NORTH
SOUTH
WEST
EAST
5%
10%
15%
20%
25%
WIND SPEED
(m/s)
>= 11.1
8.8 - 11.1
5.7 - 8.8
3.6 - 5.7
2.1 - 3.6
0.5 - 2.1
Calms: 3.00%
WRPLOT View - Lakes Environmental Software

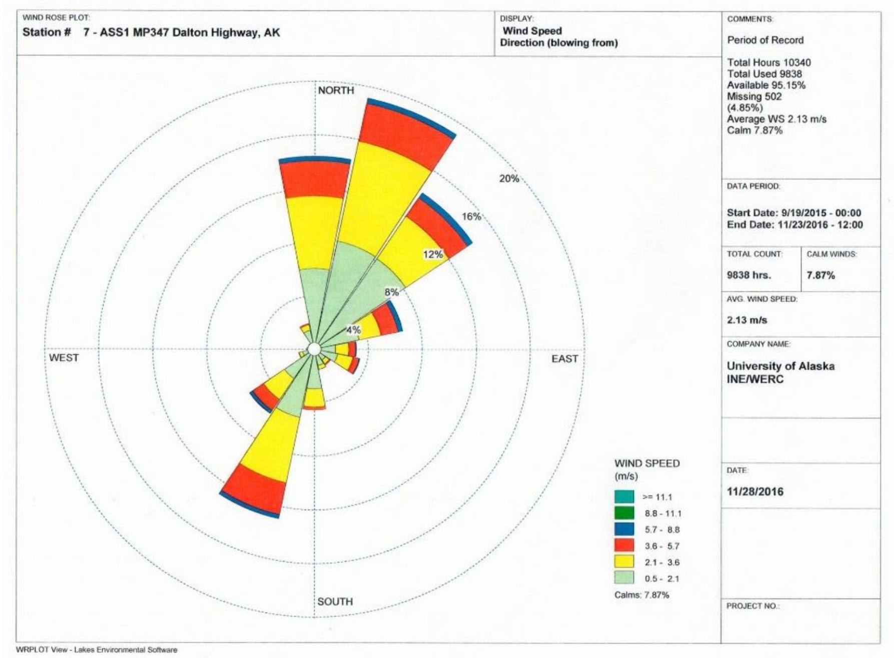

WIND ROSE PLOT:
Station # 8 - Franklin Bluffs Repeater, AK
DISPLAY:
Wind Speed
Direction (blowing from)
COMMENTS:
Summer Conditions
Franklin Bluffs Repeater
Total Hours 5629
Total Used 5453
Available 96.87%
Missing 176
(3.13%)
Average WS 5.73 m/s
Calm 3.00%
DATA PERIOD:
Start Date: 6/2/2015 - 00:00
End Date: 9/14/2016 - 23:00
TOTAL COUNT:
5453 hrs.
CALM WINDS:
0.23%
AVG. WIND SPEED:
5.73 m/s
COMPANY NAME:
University of Alaska
INE/WERC
DATE:
12/8/2016
PROJECT NO.:
NORTH
SOUTH
WEST
EAST
4%
8%
12%
16%
20%
WIND SPEED
(m/s)
>= 11.1
8.8 - 11.1
5.7 - 8.8
3.6 - 5.7
2.1 - 3.6
0.5 - 2.1
Calms: 0.23%
WRPLOT View - Lakes Environmental Software

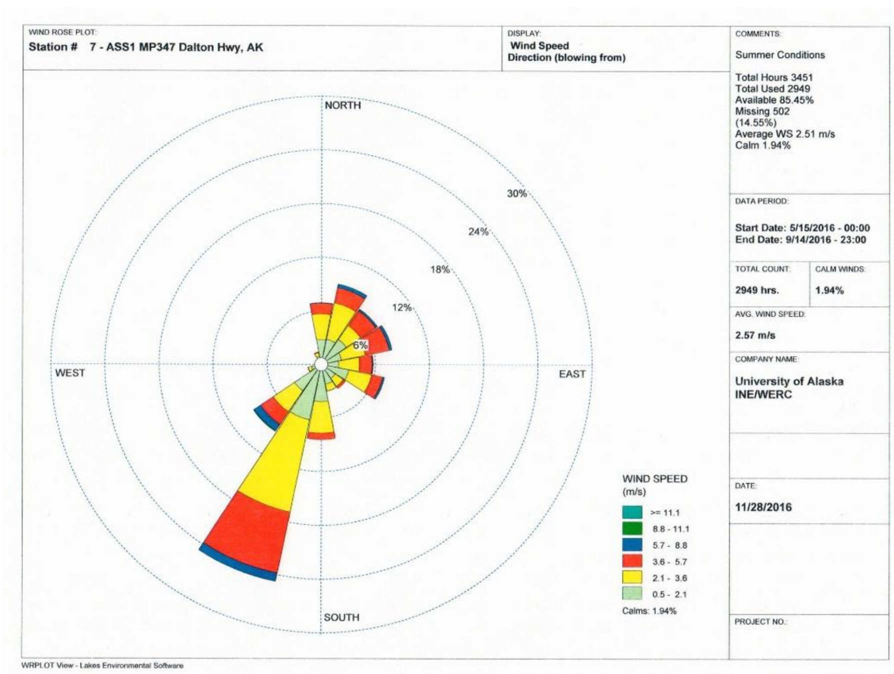

WIND ROSE PLOT:
Station # 6 - ASM1 Accomplishment Creek, AK
DISPLAY:
Wind Speed
Direction (blowing from)
COMMENTS:
Period of Record
Total Hours 65536
Total Used 62973
Available 96.01%
Missing 2563
(3.91%)
Average WS 2.97 m/s
Calm 2.76%
DATA PERIOD:
Start Date: 7/16/2006 - 00:00
End Date: 9/30/2016 - 05:00
TOTAL COUNT:
62973 hrs.
CALM WINDS:
3.93%
AVG. WIND SPEED:
2.97 m/s
COMPANY NAME:
University of Alaska
INE/WERC
DATE:
12/6/2016
PROJECT NO.:
NORTH
SOUTH
EAST
WEST
5%
10%
15%
20%
25%
WIND SPEED
(m/s)
>= 11.1
8.8 - 11.1
5.7 - 8.8
3.6 - 5.7
2.1 - 3.6
0.5 - 2.1
Calms: 3.93%
WRPLOT View - Lakes Environmental Software


WIND ROSE PLOT:
Station # 6 - ASM1 Accomplishment Creek, AK
DISPLAY:
Wind Speed
Direction (blowing from)
COMMENTS:
Winter Conditions
Total Hours 47446
Total Used 44883
Available 84.6%
Missing 2563
(5.4%)
Average WS 3.19 m/s
Calm 2.76%
DATA PERIOD:
Start Date: 9/15/2006 - 00:00
End Date: 9/30/2016 - 05:00
TOTAL COUNT:
44883 hrs.
CALM WINDS:
3.77%
AVG. WIND SPEED:
3.19 m/s
COMPANY NAME:
University of Alaska
INE/WERC
DATE:
12/6/2016
PROJECT NO.:
NORTH
SOUTH
EAST
WEST
5%
10%
15%
20%
25%
WIND SPEED
(m/s)
>= 11.1
8.8 - 11.1
5.7 - 8.8
3.6 - 5.7
2.1 - 3.6
0.5 - 2.1
Calms: 3.77%
WRPLOT View - Lakes Environmental Software


WIND ROSE PLOT:
Station # 6 - ASM1 Accomplishment Creek, AK
DISPLAY:
Wind Speed
Direction (blowing from)
COMMENTS:
Summer Conditions
Total Hours 20653
Total Used 18090
Available 87.59%
Missing 2563
(12.41%)
Average WS 2.45 m/s
Calm 3.81%
NORTH
SOUTH
WEST
EAST
4%
8%
12%
16%
20%
DATA PERIOD:
Start Date: 7/16/2006 - 00:00
End Date: 9/14/2016 - 23:00
TOTAL COUNT:
18090 hrs.
CALM WINDS:
3.81%
AVG. WIND SPEED:
2.45 m/s
COMPANY NAME:
University of Alaska
INE/WERC
DATE:
12/6/2016
PROJECT NO.:
WIND SPEED
(m/s)
>= 11.1
8.8 - 11.1
5.7 - 8.8
3.6 - 5.7
2.1 - 3.6
0.5 - 2.1
Calms: 3.81%
WRPLOT View - Lakes Environmental Software


WIND ROSE PLOT:
Station # 7 - ASS1 MP347 Dalton Hwy, AK
DISPLAY:
Wind Speed
Direction (blowing from)
COMMENTS:
Winter Conditions
Total Hours 7391
Total Used 6889
Available 93.21%
Missing 502
(6.79%)
Average WS 1.94 m/s
Calm 7.87%
NORTH
SOUTH
WEST
EAST
5%
10%
15%
20%
25%
DATA PERIOD:
Start Date: 9/19/2015 - 00:00
End Date: 11/23/2016 - 12:00
TOTAL COUNT:
6889 hrs.
CALM WINDS:
10.11%
AVG. WIND SPEED:
1.94 m/s
COMPANY NAME:
University of Alaska
INE/WERC
DATE:
11/28/2016
PROJECT NO.:
WIND SPEED
(m/s)
>= 11.1
8.8 - 11.1
5.7 - 8.8
3.6 - 5.7
2.1 - 3.6
0.5 - 2.1
Calms: 10.11%
WRPLOT View - Lakes Environmental Software


WIND ROSE PLOT:
Station # 7 - ASS1 MP347 Dalton Highway, AK
DISPLAY:
Wind Speed
Direction (blowing from)
COMMENTS:
Period of Record
Total Hours 10340
Total Used 9838
Available 95.15%
Missing 502
(4.85%)
Average WS 2.13 m/s
Calm 7.87%
DATA PERIOD:
Start Date: 9/19/2015 - 00:00
End Date: 11/23/2016 - 12:00
TOTAL COUNT:
9838 hrs.
CALM WINDS:
7.87%
AVG. WIND SPEED:
2.13 m/s
COMPANY NAME:
University of Alaska
INE/WERC
DATE:
11/28/2016
PROJECT NO.:
NORTH
SOUTH
EAST
WEST
20%
16%
12%
8%
4%
WIND SPEED
(m/s)
>= 11.1
8.8 - 11.1
5.7 - 8.8
3.6 - 5.7
2.1 - 3.6
0.5 - 2.1
Calms: 7.87%
WRPLOT View - Lakes Environmental Software


WIND ROSE PLOT:
Station # 7 - ASS1 MP347 Dalton Hwy, AK
DISPLAY:
Wind Speed
Direction (blowing from)
COMMENTS:
Summer Conditions
Total Hours 3451
Total Used 2949
Available 85.45%
Missing 502
(14.55%)
Average WS 2.51 m/s
Calm 1.94%
DATA PERIOD:
Start Date: 5/15/2016 - 00:00
End Date: 9/14/2016 - 23:00
TOTAL COUNT:
2949 hrs.
CALM WINDS:
1.94%
AVG. WIND SPEED:
2.57 m/s
COMPANY NAME:
University of Alaska
INE/WERC
DATE:
11/28/2016
PROJECT NO.:
NORTH
SOUTH
EAST
WEST
30%
24%
18%
12%
6%
WIND SPEED
(m/s)
>= 11.1
8.8 - 11.1
5.7 - 8.8
3.6 - 5.7
2.1 - 3.6
0.5 - 2.1
Calms: 1.94%
WRPLOT View - Lakes Environmental Software

APPENDIX B

Summary of Discharge Measurement Forms

DSS4 (Sagavanirktok River at MP318)

USGS Sagavanirktok River Gauge (Near Pump Station 3)

DSS3 (Sagavanirktok River at Happy Valley)

DSS2 (Sagavanirktok River Below the Ivishak River)

DSS5 (Sagavanirktok River at East Bank Near Franklin Bluffs)

Station Number: DSS4 Meas. No: 5
Station Name: DSS4 Date: 05/13/2016

Party: DB/JH/TT	Width: 158.3 m	Processed by: DAV
Boat/Motor: 12' cataraft w/10 hp motor	Area: 160.0 m²	Mean Velocity: 1.22 m/s
Gauge Height: 370.63 m	G.H.Change: 0.000 m	Discharge: 194 m³/s

Area Method: Mean Flow	ADCP Depth: 0.091 m	Index Vel.: 0.00 m/s	Rating No.: 1
Nav. Method: Bottom Track	Shore Ens.:10	Adj. Mean Vel: 0.00 m/s	Qm Rating: U
MagVar Method: Model (18.6°)	Bottom Est: Power (0.1667)	Rated Area: 0.000 m²	Diff.: 0.000%
Depth: Composite (BT)	Top Est: Power (0.1667)	Control1: Unspecified	
Discharge Method: None		Control2: Unspecified	
% Correction: 0.00		Control3: Unspecified	

Screening Thresholds:		ADCP:	
BT 3-Beam Solution: YES	Max. Vel.: 3.42 m/s	Type/Freq.: RiverPro/RioPro / 1200 kHz	
WT 3-Beam Solution: YES	Max. Depth: 1.39 m	Serial #: 1129	Firmware: 56.03
BT Error Vel.: 1.00 m/s	Mean Depth: 1.01 m	Bin Size: 2 cm	Blank: 10 cm
WT Error Vel.: 10.00 m/s	% Meas.: 66.28	BT Mode: Auto	BT Pings: Dyn
BT Up Vel.: 10.00 m/s	Water Temp.: 0.2 °C	WT Mode: Auto	WT Pings: Dyn
WT Up Vel.: 10.00 m/s	ADCP Temp.: 0.1 °C	WZ : 5	
Use Weighted Mean Depth: YES			

Performed Diag. Test: YES
Performed Moving Bed Test: YES
Performed Compass Calibration: YES Evaluation: YES
Meas. Location: 1 mile DS of DSS4

Project Name:dss4_20160513_q194.5cms
Software: 2.17

Tr.#		Edge Distance		#Ens.	Discharge						Width	Area	Time		Mean Vel.		% Bad	
		L	R		Top	Middle	Bottom	Left	Right	Total			Start	End	Boat	Water	Ens.	Bins
000	R	1.22	1.52	465	42.0	127	22.1	0.039	0.102	191	158.1	161.3	14:46	14:51	0.60	1.18	0	0
001	L	1.22	4.57	396	42.9	128	23.3	0.037	0.153	194	157.3	158.1	14:52	14:56	0.65	1.23	0	0
002	R	1.52	4.57	374	43.3	129	22.5	0.110	0.155	196	159.8	159.8	14:56	15:00	0.70	1.22	0	0
003	L	1.52	4.57	345	42.1	129	22.3	0.090	0.065	194	157.6	160.6	15:00	15:04	0.75	1.21	0	0
004	R	1.22	4.57	405	44.1	131	22.7	0.057	0.078	198	158.3	157.6	15:04	15:08	0.67	1.25	0	0
005	L	1.22	4.57	333	42.0	129	22.7	0.093	0.123	194	158.6	162.5	15:08	15:12	0.75	1.20	0	0
Mean		1.32	4.06	386	42.7	129	22.6	0.071	0.113	194	158.3	160.0	**Total**	00:25	0.69	1.22	0	0
SDev		0.16	1.24	48	0.863	1.52	0.422	0.031	0.038	2.29	0.9	1.9			0.06	0.03		
SD/M		0.12	0.31	0.12	0.02	0.01	0.02	0.43	0.33	0.01	0.01	0.01			0.08	0.02		

Remarks: Q with River Pro 194.5 cms using BT with 1% error, no GPS data.

Station Number: USGS gauge
Station Name: USGS gauge

Meas. No: 6
Date: 05/16/2016

Party: DB/JH/TT	Width: 91.2 m	Processed by: DAV
Boat/Motor: 12' cataraft w/10 hp motor	Area: 107.1 m²	Mean Velocity: 0.715 m/s
Gauge Height: 370.17 m	G.H.Change: 0.000 m	Discharge: 76.5 m³/s

Area Method: Mean Flow	ADCP Depth: 0.091 m	Index Vel.: 0.00 m/s	Rating No.: 1
Nav. Method: DGPS	Shore Ens.:10	Adj. Mean Vel: 0.00 m/s	Qm Rating: U
MagVar Method: Model (18.6°)	Bottom Est: Power (0.1667)	Rated Area: 0.000 m²	Diff.: 0.000%
Depth: Composite (BT)	Top Est: Power (0.1667)	Control1: Unspecified	
		Control2: Unspecified	
		Control3: Unspecified	

Screening Thresholds:		ADCP:	
BT 3-Beam Solution: YES	Max. Vel.: 2.05 m/s	Type/Freq.: RiverPro/RioPro / 1200 kHz	
WT 3-Beam Solution: YES	Max. Depth: 2.12 m	Serial #: 1129	Firmware: 56.03
BT Error Vel.: 1.00 m/s	Mean Depth: 1.17 m	Bin Size: 2 cm	Blank: 10 cm
WT Error Vel.: 10.00 m/s	% Meas.: 72.72	BT Mode: Auto	BT Pings: Dyn
BT Up Vel.: 10.00 m/s	Water Temp.: 0.2 °C	WT Mode: Auto	WT Pings: Dyn
WT Up Vel.: 10.00 m/s	ADCP Temp.: 0.1 °C	WZ : 5	
Use Weighted Mean Depth: YES			

Performed Diag. Test: YES
Performed Moving Bed Test: YES
Performed Compass Calibration: YES   Evaluation: YES
Meas. Location: USGS gauge, 4 miles downstream of DSS4

Project Name: usgs_gauge_20150516_q76.5cms
Software: 2.17

Tr.#		Edge Distance		#Ens.	Discharge						Width	Area	Time		Mean Vel.		% Bad	
		L	R		Top	Middle	Bottom	Left	Right	Total			Start	End	Boat	Water	Ens.	Bins
000	L	5.49	7.62	260	11.5	56.0	9.16	0.193	0.194	77.0	90.9	107.2	14:33	14:35	0.53	0.72	0	11
001	R	5.49	7.62	221	11.4	55.3	8.60	0.151	0.151	75.6	92.4	108.9	14:36	14:38	0.59	0.69	0	5
002	L	5.49	8.23	243	11.5	55.9	9.49	0.158	0.084	77.2	91.1	105.8	14:38	14:41	0.53	0.73	4	7
003	R	4.57	8.23	233	11.6	56.4	9.27	0.203	0.354	77.8	90.8	107.7	14:41	14:43	0.56	0.72	0	4
004	L	4.57	9.14	247	11.4	54.9	8.78	0.167	0.195	75.4	90.8	106.0	14:43	14:46	0.52	0.71	1	7
005	R	5.49	9.14	232	11.3	55.4	9.07	0.270	0.078	76.1	91.1	107.1	14:46	14:48	0.56	0.71	2	4
Mean		5.18	8.33	239	11.4	55.7	9.06	0.190	0.176	76.5	91.2	107.1	**Total**	00:15	0.55	0.71	1	7
SDev		0.47	0.69	14	0.115	0.539	0.327	0.044	0.101	0.961	0.6	1.1			0.03	0.01		
SD/M		0.09	0.08	0.06	0.01	0.01	0.04	0.23	0.57	0.01	0.01	0.01			0.05	0.02		

Remarks: Q with River Pro 76.5 cms using VTG with 1% error, 75 cms using BT with 1% error.

Station Number: USGS gauge | Meas. No: 7
Station Name: USGS gauge | Date: 05/17/2016

Party: DB/JH/TT
Boat/Motor: 12' cataraft w/10 hp motor
Gauge Height: 370.20 m

Width: 81.5 m
Area: 95.0 m²
G.H.Change: 0.000 m

Processed by: DAV
Mean Velocity: 0.518 m/s
Discharge: 49.2 m³/s

Area Method: Mean Flow
Nav. Method: DGPS
MagVar Method: Model (18.6°)
Depth: Composite (BT)

ADCP Depth: 0.091 m
Shore Ens.:10
Bottom Est: Power (0.1667)
Top Est: Power (0.1667)

Index Vel.: 0.00 m/s | Rating No.: 1
Adj. Mean Vel: 0.00 m/s | Qm Rating: U
Rated Area: 0.000 m² | Diff.: 0.000%
Control1: Unspecified
Control2: Unspecified
Control3: Unspecified

Screening Thresholds:
BT 3-Beam Solution: YES
WT 3-Beam Solution: YES
BT Error Vel.: 1.00 m/s
WT Error Vel.: 10.00 m/s
BT Up Vel.: 10.00 m/s
WT Up Vel.: 10.00 m/s
Use Weighted Mean Depth: YES

Max. Vel.: 3.06 m/s
Max. Depth: 2.37 m
Mean Depth: 1.17 m
% Meas.: 72.63
Water Temp.: 0.2 °C
ADCP Temp.: 0.1 °C

ADCP:
Type/Freq.: RiverPro/RioPro / 1200 kHz
Serial #: 1129 | Firmware: 56.03
Bin Size: 2 cm | Blank: 10 cm
BT Mode: Auto | BT Pings: Dyn
WT Mode: Auto | WT Pings: Dyn
WZ : 5

Performed Diag. Test: YES
Performed Moving Bed Test: YES
Performed Compass Calibration: YES Evaluation: YES
Meas. Location: at gauge, 4 miles downstream of DSS4

Project Name: usgs_gauge_20150517_q49.2cms
Software: 2.17

Tr.#		Edge Distance		#Ens.	Discharge						Width	Area	Time		Mean Vel.		% Bad	
		L	R		Top	Middle	Bottom	Left	Right	Total			Start	End	Boat	Water	Ens.	Bins
000	L	1.52	6.40	238	8.09	35.2	5.74	0.037	-0.008	49.1	77.8	89.9	09:25	09:28	0.53	0.55	8	12
001	R	2.44	6.40	194	7.70	34.6	5.52	0.048	-0.053	47.8	81.6	92.2	09:28	09:30	0.64	0.52	3	10
002	L	2.44	7.32	243	7.76	36.3	5.91	0.058	0.155	50.1	80.8	95.7	09:30	09:33	0.55	0.52	10	13
003	R	2.13	7.32	178	7.49	35.8	5.68	0.028	0.135	49.1	83.1	97.5	09:33	09:34	0.70	0.50	1	6
004	L	2.13	8.23	218	7.57	35.2	5.55	0.026	0.062	48.4	83.4	96.6	09:35	09:37	0.60	0.50	2	11
005	R	1.83	8.23	189	7.53	35.8	5.65	0.027	0.063	49.1	83.1	96.9	09:37	09:39	0.65	0.51	0	6
006	L	1.83	7.32	214	7.50	36.8	6.03	0.019	0.066	50.4	80.4	95.8	09:39	09:41	0.62	0.53	4	11
007	R	2.13	7.32	195	7.55	36.2	5.73	0.042	0.043	49.6	82.2	95.4	09:41	09:43	0.62	0.52	0	7
Mean		2.06	7.32	208	7.65	35.7	5.73	0.036	0.058	49.2	81.5	95.0	**Total**	00:18	0.61	0.52	3	9
SDev		0.32	0.69	24	0.202	0.711	0.172	0.013	0.068	0.857	1.9	2.6			0.06	0.01		
SD/M		0.15	0.09	0.11	0.03	0.02	0.03	0.37	1.17	0.02	0.02	0.03			0.09	0.03		

Remarks: Q with River Pro 49.2 cms using VTG with 2% error, 48.2 cms using BT with 1% error.

Station Number: USGS gauge
Station Name: USGS gauge

Meas. No: 8
Date: 05/18/2016

Party: DB/JH/TT
Boat/Motor: 12' cataraft w/10 hp motor
Gauge Height: 369.99 m

Width: 84.8 m
Area: 92.2 m²
G.H.Change: 0.000 m

Processed by: DAV
Mean Velocity: 0.624 m/s
Discharge: 57.5 m³/s

Area Method: Mean Flow
Nav. Method: DGPS
MagVar Method: Model (18.6°)
Depth: Composite (BT)

ADCP Depth: 0.091 m
Shore Ens.:10
Bottom Est: Power (0.1667)
Top Est: Power (0.1667)

Index Vel.: 0.00 m/s
Adj. Mean Vel: 0.00 m/s
Rated Area: 0.000 m²
Control1: Unspecified
Control2: Unspecified
Control3: Unspecified

Rating No.: 1
Qm Rating: U
Diff.: 0.000%

Screening Thresholds:
BT 3-Beam Solution: YES
WT 3-Beam Solution: YES
BT Error Vel.: 1.00 m/s
WT Error Vel.: 10.00 m/s
BT Up Vel.: 10.00 m/s
WT Up Vel.: 10.00 m/s
Use Weighted Mean Depth: YES

Max. Vel.: 2.96 m/s
Max. Depth: 2.28 m
Mean Depth: 1.09 m
% Meas.: 71.66
Water Temp.: 0.6 °C
ADCP Temp.: 0.8 °C

ADCP:
Type/Freq.: RiverPro/RioPro / 1200 kHz
Serial #: 1129 Firmware: 56.03
Bin Size: 2 cm Blank: 10 cm
BT Mode: Auto BT Pings: Dyn
WT Mode: Auto WT Pings: Dyn
WZ : 5

Performed Diag. Test: YES
Performed Moving Bed Test: YES
Performed Compass Calibration: YES Evaluation: YES
Meas. Location: at gauge, 4 miles downstream of DSS4

Project Name: usgs_gauge_20150518_q57.5cms
Software: 2.17

Tr.#		Edge Distance		#Ens.	Discharge						Width	Area	Time		Mean Vel.		% Bad	
		L	R		Top	Middle	Bottom	Left	Right	Total			Start	End	Boat	Water	Ens.	Bins
000	R	6.40	8.23	257	8.58	40.8	6.84	0.366	0.094	56.6	82.5	91.9	14:54	14:57	0.49	0.62	3	6
001	L	6.40	9.14	208	9.37	42.8	7.17	0.269	0.122	59.8	83.0	91.1	14:57	14:59	0.61	0.66	0	8
002	R	4.57	9.14	210	8.87	40.4	6.58	0.200	0.119	56.1	85.7	92.3	14:59	15:01	0.59	0.61	0	4
003	L	4.57	9.14	226	9.41	41.9	7.24	0.325	0.207	59.1	85.6	92.4	15:01	15:04	0.57	0.64	3	9
004	R	4.57	9.14	234	9.10	41.7	6.51	0.251	0.152	57.7	86.7	93.7	15:04	15:06	0.53	0.62	0	3
005	L	4.57	9.14	197	8.86	39.7	6.89	0.239	0.042	55.7	85.3	91.7	15:06	15:08	0.63	0.61	1	5
Mean		5.18	8.99	222	9.03	41.2	6.87	0.275	0.123	57.5	84.8	92.2	**Total**	00:14	0.57	0.62	1	6
SDev		0.94	0.37	22	0.322	1.16	0.297	0.061	0.055	1.65	1.7	0.9			0.05	0.02		
SD/M		0.18	0.04	0.10	0.04	0.03	0.04	0.22	0.45	0.03	0.02	0.01			0.09	0.03		

Remarks: Q with River Pro 57.5 cms using VTG with 3% error, 56.4 cms using BT with 2% error.

Station Number: USGS gauge
Station Name: USGS gauge

Meas. No: 9
Date: 05/19/2016

Party: DB/JH/TT
Boat/Motor: 12' cataraft w/10 hp motor
Gauge Height: 370.06 m

Width: 83.4 m
Area: 94.9 m²
G.H.Change: 0.000 m

Processed by: DAV
Mean Velocity: 0.696 m/s
Discharge: 66.1 m³/s

Area Method: Mean Flow
Nav. Method: Bottom Track
MagVar Method: Model (18.6°)
Depth: Composite (BT)
Discharge Method: None
% Correction: 0.00

ADCP Depth: 0.091 m
Shore Ens.:10
Bottom Est: Power (0.1667)
Top Est: Power (0.1667)

Index Vel.: 0.00 m/s
Adj. Mean Vel: 0.00 m/s
Rated Area: 0.000 m²
Control1: Unspecified
Control2: Unspecified
Control3: Unspecified

Rating No.: 1
Qm Rating: U
Diff.: 0.000%

Screening Thresholds:
BT 3-Beam Solution: YES
WT 3-Beam Solution: YES
BT Error Vel.: 1.00 m/s
WT Error Vel.: 10.00 m/s
BT Up Vel.: 10.00 m/s
WT Up Vel.: 10.00 m/s
Use Weighted Mean Depth: YES

Max. Vel.: 2.40 m/s
Max. Depth: 2.17 m
Mean Depth: 1.14 m
% Meas.: 72.33
Water Temp.: 0.3 °C
ADCP Temp.: 0.6 °C

ADCP:
Type/Freq.: RiverPro/RioPro / 1200 kHz
Serial #: 1129 Firmware: 56.03
Bin Size: 2 cm Blank: 10 cm
BT Mode: Auto BT Pings: Dyn
WT Mode: Auto WT Pings: Dyn
WZ : 5

Performed Diag. Test: YES
Performed Moving Bed Test: YES
Performed Compass Calibration: YES Evaluation: YES
Meas. Location: at gauge, 4 miles downstream of DSS4

Project Name: usgs_gauge_20150519_q66cms
Software: 2.17

Tr.#		Edge Distance		#Ens.	Discharge						Width	Area	Time		Mean Vel.		% Bad	
		L	R		Top	Middle	Bottom	Left	Right	Total			Start	End	Boat	Water	Ens.	Bins
000	R	1.52	10.1	264	10.4	47.9	7.90	0.034	-0.180	66.0	82.4	94.6	09:04	09:07	0.47	0.70	2	3
001	L	1.52	9.14	233	10.5	48.0	7.86	0.028	0.233	66.6	83.7	95.4	09:07	09:09	0.54	0.70	1	3
002	R	2.44	9.14	222	10.1	47.8	7.64	0.065	0.072	65.7	83.6	95.0	09:09	09:12	0.54	0.69	5	3
003	L	2.44	10.1	214	10.4	47.8	7.95	0.065	-0.173	66.0	83.7	95.0	09:12	09:14	0.57	0.69	4	4
004	R	2.13	10.1	213	10.2	47.6	7.55	0.018	0.185	65.6	83.7	95.3	09:14	09:16	0.55	0.69	1	1
005	L	2.13	10.1	211	10.4	47.6	8.20	0.049	0.158	66.4	83.2	94.2	09:16	09:19	0.58	0.70	1	3
Mean		2.03	9.75	226	10.3	47.8	7.85	0.043	0.049	66.1	83.4	94.9	**Total**	00:14	0.54	0.70	2	3
SDev		0.42	0.47	20	0.133	0.136	0.229	0.020	0.182	0.379	0.5	0.4			0.04	0.01		
SD/M		0.20	0.05	0.09	0.01	0.00	0.03	0.46	3.71	0.01	0.01	0.00			0.07	0.01		

Remarks: Q with River Pro 65.9 cms using VTG with 7% error, 66.1 cms using BT with 1% error.

Station Number: USGS gauge
Station Name: USGS gauge

Meas. No: 10
Date: 05/21/2016

Party: DB/JH/TT
Boat/Motor: 12' cataraft w/10 hp motor
Gauge Height: 369.89 m

Width: 89.3 m
Area: 101.3 m²
G.H.Change: 0.000 m

Processed by: DAV
Mean Velocity: 0.944 m/s
Discharge: 95.6 m³/s

Area Method: Mean Flow
Nav. Method: DGPS
MagVar Method: Model (18.6°)
Depth: Composite (BT)

ADCP Depth: 0.091 m
Shore Ens.:10
Bottom Est: Power (0.1667)
Top Est: Power (0.1667)

Index Vel.: 0.00 m/s
Adj. Mean Vel: 0.00 m/s
Rated Area: 0.000 m²
Control1: Unspecified
Control2: Unspecified
Control3: Unspecified

Rating No.: 1
Qm Rating: U
Diff.: 0.000%

Screening Thresholds:
BT 3-Beam Solution: YES
WT 3-Beam Solution: YES
BT Error Vel.: 1.00 m/s
WT Error Vel.: 10.00 m/s
BT Up Vel.: 10.00 m/s
WT Up Vel.: 10.00 m/s
Use Weighted Mean Depth: YES

Max. Vel.: 2.08 m/s
Max. Depth: 2.31 m
Mean Depth: 1.13 m
% Meas.: 72.09
Water Temp.: 0.3 °C
ADCP Temp.: 0.4 °C

ADCP:
Type/Freq.: RiverPro/RioPro / 1200 kHz
Serial #: 1129 Firmware: 56.03
Bin Size: 2 cm Blank: 10 cm
BT Mode: Auto BT Pings: Dyn
WT Mode: Auto WT Pings: Dyn
WZ : 5

Performed Diag. Test: YES
Performed Moving Bed Test: YES
Performed Compass Calibration: YES Evaluation: YES
Meas. Location: at gauge , 4 miles downstream of DSS4

Project Name: usgs_gauge_20150521_q95.6cms
Software: 2.17

Tr.#		Edge Distance		#Ens.	Discharge						Width	Area	Time		Mean Vel.		% Bad	
		L	R		Top	Middle	Bottom	Left	Right	Total			Start	End	Boat	Water	Ens.	Bins
000	R	6.10	8.23	267	14.4	67.9	11.6	0.444	0.272	94.7	88.8	102.0	13:40	13:42	0.47	0.93	2	0
001	L	6.10	10.1	260	14.7	70.0	11.5	0.482	0.341	97.1	89.2	100.6	13:43	13:45	0.47	0.96	1	1
002	R	5.49	10.1	264	14.5	67.2	11.6	0.317	0.295	93.8	88.8	99.3	13:46	13:48	0.45	0.94	0	0
003	L	5.49	10.1	222	14.5	71.0	11.3	0.375	0.388	97.6	90.2	103.7	13:49	13:51	0.54	0.94	0	1
004	R	5.49	10.1	243	14.7	69.6	11.5	0.358	0.360	96.6	89.2	100.7	13:51	13:54	0.49	0.96	0	0
005	L	5.49	10.1	239	14.0	67.6	11.3	0.311	0.357	93.5	89.7	101.6	13:54	13:56	0.52	0.92	0	0
Mean		5.69	9.75	249	14.5	68.9	11.5	0.381	0.335	95.6	89.3	101.3	**Total**	00:16	0.49	0.94	1	0
SDev		0.32	0.75	18	0.257	1.52	0.143	0.069	0.044	1.76	0.5	1.5			0.03	0.02		
SD/M		0.06	0.08	0.07	0.02	0.02	0.01	0.18	0.13	0.02	0.01	0.01			0.07	0.02		

Remarks: Q with River Pro 95.6 cms using VTG with 2% error, 96 cms using BT with 1% error.

Station Number: USGS gauge
Station Name: USGS gauge

Meas. No: 11
Date: 05/22/2016

Party: DB/JH/TT	Width: 91.3 m	Processed by: DAV
Boat/Motor: 12' cataraft w/10 hp motor	Area: 111.2 m²	Mean Velocity: 1.08 m/s
Gauge Height: 369.93 m	G.H.Change: 0.000 m	Discharge: 120 m³/s

Area Method: Mean Flow	ADCP Depth: 0.091 m	Index Vel.: 0.00 m/s	Rating No.: 1
Nav. Method: DGPS	Shore Ens.:10	Adj. Mean Vel: 0.00 m/s	Qm Rating: U
MagVar Method: Model (18.6°)	Bottom Est: Power (0.1667)	Rated Area: 0.000 m²	Diff.: 0.000%
Depth: Composite (BT)	Top Est: Power (0.1667)	Control1: Unspecified	
		Control2: Unspecified	
		Control3: Unspecified	

Screening Thresholds:		ADCP:	
BT 3-Beam Solution: YES	Max. Vel.: 2.42 m/s	Type/Freq.: RiverPro/RioPro / 1200 kHz	
WT 3-Beam Solution: YES	Max. Depth: 2.39 m	Serial #: 1129	Firmware: 56.03
BT Error Vel.: 1.00 m/s	Mean Depth: 1.22 m	Bin Size: 2 cm	Blank: 10 cm
WT Error Vel.: 10.00 m/s	% Meas.: 73.40	BT Mode: Auto	BT Pings: Dyn
BT Up Vel.: 10.00 m/s	Water Temp.: 0.7 °C	WT Mode: Auto	WT Pings: Dyn
WT Up Vel.: 10.00 m/s	ADCP Temp.: 0.6 °C	WZ : 5	
Use Weighted Mean Depth: YES			

Performed Diag. Test: YES
Performed Moving Bed Test: YES
Performed Compass Calibration: YES   Evaluation: YES
Meas. Location: at gauge , 4 miles downstream of DSS4

Project Name: usgs_gauge_20150522_q119.7cms
Software: 2.17

Tr.#		Edge Distance		#Ens.	Discharge						Width	Area	Time		Mean Vel.		% Bad	
		L	R		Top	Middle	Bottom	Left	Right	Total			Start	End	Boat	Water	Ens.	Bins
000	R	4.57	8.23	236	17.2	88.0	13.8	0.226	0.233	119	90.2	110.7	12:00	12:02	0.56	1.08	1	0
001	L	4.57	8.23	210	17.1	86.6	13.8	0.280	0.209	118	90.7	111.8	12:02	12:04	0.61	1.06	1	0
002	R	5.49	8.23	236	17.3	88.6	14.2	0.202	0.210	121	91.5	111.7	12:05	12:07	0.55	1.08	1	0
003	L	5.49	8.23	202	16.8	85.4	13.6	0.219	0.211	116	91.1	111.0	12:07	12:09	0.63	1.05	0	0
004	R	5.49	8.23	221	17.6	88.5	14.5	0.201	0.219	121	91.8	111.1	12:09	12:12	0.57	1.09	0	0
005	L	5.49	8.23	203	17.8	89.8	14.7	0.179	0.198	123	92.5	110.8	12:12	12:14	0.63	1.11	0	0
Mean		5.18	8.23	218	17.3	87.8	14.1	0.218	0.213	120	91.3	111.2	**Total**	00:14	0.59	1.08	0	0
SDev		0.47	0.00	16	0.364	1.58	0.440	0.035	0.012	2.31	0.8	0.4			0.04	0.02		
SD/M		0.09	0.00	0.07	0.02	0.02	0.03	0.16	0.06	0.02	0.01	0.00			0.06	0.02		

Remarks: Q with River Pro 119.7 cms using VTG with 2% error, 119.1 cms using BT with 1% error.

Station Number: USGS gauge
Station Name: USGS gauge

Meas. No: 12
Date: 05/23/2016

Party: DB/JH/TT
Boat/Motor: 12' cataraft w/10 hp motor
Gauge Height: 369.92 m

Width: 94.5 m
Area: 115.9 m²
G.H.Change: 0.000 m

Processed by: DAV
Mean Velocity: 1.17 m/s
Discharge: 135 m³/s

Area Method: Mean Flow
Nav. Method: DGPS
MagVar Method: Model (18.6°)
Depth: Composite (BT)

ADCP Depth: 0.091 m
Shore Ens.:10
Bottom Est: Power (0.1667)
Top Est: Power (0.1667)

Index Vel.: 0.00 m/s
Adj. Mean Vel: 0.00 m/s
Rated Area: 0.000 m²
Control1: Unspecified
Control2: Unspecified
Control3: Unspecified

Rating No.: 1
Qm Rating: U
Diff.: 0.000%

Screening Thresholds:
BT 3-Beam Solution: YES
WT 3-Beam Solution: YES
BT Error Vel.: 1.00 m/s
WT Error Vel.: 10.00 m/s
BT Up Vel.: 10.00 m/s
WT Up Vel.: 10.00 m/s
Use Weighted Mean Depth: YES

Max. Vel.: 2.73 m/s
Max. Depth: 2.48 m
Mean Depth: 1.23 m
% Meas.: 73.56
Water Temp.: 1.7 °C
ADCP Temp.: 0.8 °C

ADCP:
Type/Freq.: RiverPro/RioPro / 1200 kHz
Serial #: 1129 Firmware: 56.03
Bin Size: 2 cm Blank: 10 cm
BT Mode: Auto BT Pings: Dyn
WT Mode: Auto WT Pings: Dyn
WZ : 5

Performed Diag. Test: YES
Performed Moving Bed Test: YES
Performed Compass Calibration: YES Evaluation: YES
Meas. Location: at gauge, 4 miles downstream of DSS4

Project Name: usgs_gauge_20150523_q135.2cms
Software: 2.17

Tr.#		Edge Distance		#Ens.	Discharge						Width	Area	Time		Mean Vel.		% Bad	
		L	R		Top	Middle	Bottom	Left	Right	Total			Start	End	Boat	Water	Ens.	Bins
000	R	5.49	10.1	242	19.3	103	16.5	0.459	0.349	140	94.6	116.2	15:22	15:24	0.59	1.20	2	0
001	L	5.49	10.1	195	18.5	97.3	16.1	0.435	0.279	133	94.0	115.8	15:24	15:27	0.65	1.15	0	0
002	R	5.49	10.1	201	19.0	100	15.8	0.368	0.242	136	94.2	115.5	15:27	15:29	0.65	1.17	0	0
003	L	5.49	10.1	188	18.5	96.1	17.0	0.417	0.253	132	94.3	115.4	15:29	15:31	0.66	1.15	0	0
004	R	5.49	10.1	199	18.7	99.3	15.4	0.302	0.286	134	94.9	116.9	15:31	15:33	0.66	1.15	1	0
005	L	5.49	10.1	214	19.3	101	16.7	0.334	0.188	137	95.2	116.1	15:33	15:35	0.61	1.18	0	0
006	R	5.49	10.1	195	18.7	99.0	16.0	0.362	0.244	134	94.5	115.5	15:35	15:38	0.65	1.16	0	0
Mean		5.49	10.1	204	18.9	99.4	16.2	0.382	0.263	135	94.5	115.9	**Total**	00:15	0.64	1.17	0	0
SDev		0.00	0.00	18	0.340	2.30	0.556	0.057	0.050	2.64	0.4	0.5			0.03	0.02		
SD/M		0.00	0.00	0.09	0.02	0.02	0.03	0.15	0.19	0.02	0.00	0.00			0.04	0.02		

Remarks: Q with River Pro 135.2 cms using VTG with 2% error, 136.1 cms using BT with 1% error.

Station Number: DSS3 | Meas. No: 4
Station Name: DSS3 Channel 1 | Date: 05/15/2016

Party: DB/JH/TT	Width: 19.9 m	Processed by: DAV
Boat/Motor: 12' cataraft w/10 hp motor	Area: 13.6 m²	Mean Velocity: 0.354 m/s
Gauge Height: 289.36 m	G.H.Change: 0.000 m	Discharge: 4.76 m³/s

Area Method: Mean Flow	ADCP Depth: 0.091 m	Index Vel.: 0.00 m/s	Rating No.: 1
Nav. Method: DGPS	Shore Ens.:10	Adj. Mean Vel: 0.00 m/s	Qm Rating: U
MagVar Method: Model (18.6°)	Bottom Est: Power (0.1667)	Rated Area: 0.000 m²	Diff.: 0.000%
Depth: Composite (BT)	Top Est: Power (0.1667)	Control1: Unspecified	
		Control2: Unspecified	
		Control3: Unspecified	

Screening Thresholds:		ADCP:	
BT 3-Beam Solution: YES	Max. Vel.: 1.55 m/s	Type/Freq.: RiverPro/RioPro / 1200 kHz	
WT 3-Beam Solution: YES	Max. Depth: 1.14 m	Serial #: 1129	Firmware: 56.03
BT Error Vel.: 1.00 m/s	Mean Depth: 0.683 m	Bin Size: 2 cm	Blank: 10 cm
WT Error Vel.: 10.00 m/s	% Meas.: 60.41	BT Mode: Auto	BT Pings: Dyn
BT Up Vel.: 10.00 m/s	Water Temp.: 0.3 °C	WT Mode: Auto	WT Pings: Dyn
WT Up Vel.: 10.00 m/s	ADCP Temp.: 0.2 °C	WZ : 5	
Use Weighted Mean Depth: YES			

Performed Diag. Test: YES
Performed Moving Bed Test: NO
Performed Compass Calibration: NO   Evaluation: NO
Meas. Location: at gauge

Project Name: dss3_20160515_ch1_q4.8cms
Software: 2.17

Tr.#		Edge Distance		#Ens.	Discharge						Width	Area	Time		Mean Vel.		% Bad	
		L	R		Top	Middle	Bottom	Left	Right	Total			Start	End	Boat	Water	Ens.	Bins
000	R	1.22	3.66	175	1.60	2.66	0.490	0.058	0.053	4.86	19.8	11.5	11:22	11:24	0.21	0.42	0	0
001	L	1.22	3.05	109	1.57	2.69	0.466	0.066	-0.052	4.73	19.9	12.8	11:24	11:25	0.31	0.37	2	0
002	*R*	*1.52*	*3.05*	*137*	*1.31*	*2.57*	*0.455*	*0.055*	*-0.035*	*4.36*	*20.1*	*14.0*	*11:25*	*11:26*	*0.24*	*0.31*	*0*	*0*
003	L	1.52	3.05	106	1.47	2.91	0.478	0.053	-0.085	4.83	20.5	14.0	11:26	11:27	0.31	0.35	3	0
004	*R*	*1.52*	*3.05*	*122*	*1.26*	*2.78*	*0.504*	*0.059*	*-0.105*	*4.50*	*19.6*	*14.2*	*11:28*	*11:29*	*0.26*	*0.32*	*0*	*0*
005	*L*	*1.52*	*3.05*	*104*	*1.50*	*3.18*	*0.578*	*0.059*	*-0.006*	*5.32*	*20.4*	*13.7*	*11:29*	*11:30*	*0.32*	*0.39*	*5*	*0*
006	R	1.22	3.05	125	1.15	2.85	0.549	0.068	-0.063	4.55	20.3	15.1	11:30	11:31	0.28	0.30	0	0
007	L	1.22	3.05	123	1.27	2.99	0.518	0.065	-0.015	4.83	18.6	12.2	11:31	11:32	0.31	0.40	4	0
008	R	1.22	3.05	118	1.12	2.96	0.601	0.068	0.058	4.81	19.9	15.5	11:33	11:34	0.29	0.31	0	0
009	L	1.22	3.05	96	1.23	3.07	0.485	0.076	-0.021	4.84	19.5	12.6	11:34	11:35	0.33	0.39	0	0
010	R	1.22	3.05	136	1.12	2.80	0.552	0.077	0.018	4.56	20.2	14.6	11:35	11:37	0.27	0.31	1	0
011	L	1.22	3.05	95	1.25	3.07	0.587	0.049	0.030	4.98	19.2	12.7	11:37	11:38	0.33	0.39	0	1
Mean		1.32	3.10	120	1.32	2.88	0.522	0.063	-0.019	4.76	19.9	13.6	**Total**	00:15	0.29	0.35	1	0
SDev		0.15	0.18	22	0.171	0.187	0.050	0.009	0.052	0.252	0.5	1.2			0.04	0.04		
SD/M		0.11	0.06	0.18	0.13	0.07	0.10	0.14	2.82	0.05	0.03	0.09			0.13	0.12		

Remarks: Q with River Pro 4.8 cms using VTG with 5% error, 4.8 cms using BT with 4% error. Total Q from 3 channels 248 cms.

Discharge for transects in *italics* have a total Q more than 5% from the mean.

Station Number: DSS3 | Meas. No: 4
Name: DSS3 Channel 2 | Date: 05/15/2016

Party: DB/JH/TT
Boat/Motor: 12' cataraft w/10 hp motor
Gauge Height: 289.36 m

Width: 57.8 m
Area: 49.7 m²
G.H.Change: 0.000 m

Processed by: DAV
Mean Velocity: 0.487 m/s
Discharge: 24.2 m³/s

Area Method: Mean Flow
Nav. Method: DGPS
MagVar Method: Model (18.6°)
Depth: Composite (BT)

ADCP Depth: 0.091 m
Shore Ens.:10
Bottom Est: Power (0.1667)
Top Est: Power (0.1667)

Index Vel.: 0.00 m/s | Rating No.: 1
Adj. Mean Vel: 0.00 m/s | Qm Rating: U
Rated Area: 0.000 m² | Diff.: 0.000%
Control1: Unspecified
Control2: Unspecified
Control3: Unspecified

Screening Thresholds:
BT 3-Beam Solution: YES
WT 3-Beam Solution: YES
BT Error Vel.: 1.00 m/s
WT Error Vel.: 10.00 m/s
BT Up Vel.: 10.00 m/s
WT Up Vel.: 10.00 m/s
Use Weighted Mean Depth: YES

Max. Vel.: 1.97 m/s
Max. Depth: 1.27 m
Mean Depth: 0.861 m
% Meas.: 63.87
Water Temp.: 0.2 °C
ADCP Temp.: 0.1 °C

ADCP:
Type/Freq.: RiverPro/RioPro / 1200 kHz
Serial #: 1129 | Firmware: 56.03
Bin Size: 2 cm | Blank: 10 cm
BT Mode: Auto | BT Pings: Dyn
WT Mode: Auto | WT Pings: Dyn
WZ : 5

Performed Diag. Test: YES
Performed Moving Bed Test: YES
Performed Compass Calibration: NO   Evaluation: NO
Meas. Location: at gauge

Project Name: dss3_20160515_ch2_q24.2cms
Software: 2.17

Tr.#		Edge Distance		#Ens.	Discharge						Width	Area	Time		Mean Vel.		% Bad	
		L	R		Top	Middle	Bottom	Left	Right	Total			Start	End	Boat	Water	Ens.	Bins
000	R	1.83	6.10	195	6.37	14.7	2.69	-0.018	0.186	24.0	63.5	51.1	10:52	10:54	0.54	0.47	1	1
001	L	1.83	3.66	213	6.37	15.3	2.71	-0.012	0.085	24.4	60.5	50.0	10:54	10:56	0.49	0.49	0	1
002	R	1.52	3.66	197	6.11	14.6	2.60	-0.017	0.076	23.4	59.1	49.4	10:56	10:58	0.52	0.47	1	1
003	L	1.52	1.52	228	6.27	15.7	2.71	-0.008	0.020	24.7	55.5	48.8	10:58	11:00	0.45	0.51	0	1
004	R	1.83	1.52	199	6.25	15.8	2.78	-0.031	0.029	24.8	57.7	50.2	11:00	11:02	0.52	0.49	1	0
005	L	1.83	1.22	221	5.59	15.5	2.56	-0.016	0.015	23.6	55.1	49.6	11:02	11:04	0.45	0.48	0	1
006	R	2.13	1.22	221	5.91	16.1	2.48	-0.028	0.018	24.5	56.3	49.5	11:05	11:07	0.45	0.49	2	0
007	L	2.13	1.22	217	5.61	15.9	2.60	0.027	0.016	24.1	54.8	48.8	11:07	11:09	0.45	0.49	1	1
Mean		1.83	2.51	211	6.06	15.5	2.64	-0.013	0.056	24.2	57.8	49.7	**Total**	00:17	0.48	0.49	1	1
SDev		0.23	1.79	13	0.320	0.539	0.100	0.018	0.060	0.509	3.1	0.7			0.04	0.01		
SD/M		0.13	0.71	0.06	0.05	0.03	0.04	1.38	1.07	0.02	0.05	0.02			0.08	0.03		

Remarks: Q with River Pro 24.2 cms using VTG with 2% error, 24 cms using BT with 2% error. Total Q from 3 channels 248 cms.

Station Number: DSS3
Station Name: DSS3 Channel 3

Meas. No: 4
Date: 05/15/2016

Party: DB/JH/TT	Width: 100.1 m	Processed by: DAV
Boat/Motor: 12' cataraft w/10 hp motor	Area: 130.1 m²	Mean Velocity: 1.69 m/s
Gauge Height: 289.36 m	G.H.Change: 0.000 m	Discharge: 219 m³/s

Area Method: Mean Flow	ADCP Depth: 0.091 m	Index Vel.: 0.00 m/s	Rating No.: 1
Nav. Method: DGPS	Shore Ens.:10	Adj. Mean Vel: 0.00 m/s	Qm Rating: U
MagVar Method: Model (18.6°)	Bottom Est: Power (0.1667)	Rated Area: 0.000 m²	Diff.: 0.000%
Depth: Composite (BT)	Top Est: Power (0.1667)	Control1: Unspecified	
		Control2: Unspecified	
		Control3: Unspecified	

Screening Thresholds:		ADCP:	
BT 3-Beam Solution: YES	Max. Vel.: 3.91 m/s	Type/Freq.: RiverPro/RioPro / 1200 kHz	
WT 3-Beam Solution: YES	Max. Depth: 1.76 m	Serial #: 1129	Firmware: 56.03
BT Error Vel.: 1.00 m/s	Mean Depth: 1.30 m	Bin Size: 2 cm	Blank: 10 cm
WT Error Vel.: 10.00 m/s	% Meas.: 72.27	BT Mode: Auto	BT Pings: Dyn
BT Up Vel.: 10.00 m/s	Water Temp.: 0.3 °C	WT Mode: Auto	WT Pings: Dyn
WT Up Vel.: 10.00 m/s	ADCP Temp.: 0.0 °C	WZ : 5	
Use Weighted Mean Depth: YES			

Performed Diag. Test: YES
Performed Moving Bed Test: YES
Performed Compass Calibration: YES   Evaluation: YES
Meas. Location: at gauge

Project Name: dss3_201605_ch3_q219cms
Software: 2.17

Tr.#		Edge Distance		#Ens.	Discharge						Width	Area	Time		Mean Vel.		% Bad	
		L	R		Top	Middle	Bottom	Left	Right	Total			Start	End	Boat	Water	Ens.	Bins
000	L	1.52	0.61	268	36.7	161	25.4	0.144	-0.010	223	100.3	131.6	09:59	10:02	0.58	1.70	0	0
001	R	1.22	0.61	260	36.2	156	22.9	0.096	0.003	215	100.0	128.9	10:02	10:05	0.63	1.67	0	0
002	L	1.22	0.61	245	36.3	158	25.1	0.069	-0.010	220	99.3	129.7	10:05	10:08	0.64	1.69	0	0
003	R	1.22	0.61	271	36.3	156	23.2	0.054	0.004	216	100.7	130.5	10:08	10:11	0.59	1.65	0	0
004	L	1.22	0.61	239	37.2	161	24.2	0.057	0.008	223	100.2	129.9	10:11	10:14	0.64	1.71	0	0
Mean		1.28	0.61	256	36.6	158	24.2	0.084	-0.001	219	100.1	130.1	**Total**	00:14	0.62	1.69	0	0
SDev		0.14	0.00	14	0.405	2.49	1.11	0.037	0.008	3.70	0.5	1.0			0.03	0.02		
SD/M		0.11	0.00	0.06	0.01	0.02	0.05	0.45	8.43	0.02	0.00	0.01			0.04	0.01		

Remarks: Q with River Pro 219 cms using VTG with 2% error, 221 cms using BT with 1% error. Total Q from 3 channels 248 cms.

Station Number: DSS3 | Meas. No: 5
Station Name: DSS3 Channel 1&2 | Date: 05/16/2016

Party: DB/JH/TT
Boat/Motor: 12' cataraft w/10 hp motor
Gauge Height: 288.84 m

Width: 115.7 m
Area: 65.5 m²
G.H.Change: 0.000 m

Processed by: DAV
Mean Velocity: 0.183 m/s
Discharge: 11.9 m³/s

Area Method: Mean Flow
Nav. Method: Bottom Track
MagVar Method: Model (18.6°)
Depth: Composite (BT)
Discharge Method: None
% Correction: 0.00

ADCP Depth: 0.091 m
Shore Ens.:10
Bottom Est: Power (0.1667)
Top Est: Power (0.1667)

Index Vel.: 0.00 m/s
Adj. Mean Vel: 0.00 m/s
Rated Area: 0.000 m²
Control1: Unspecified
Control2: Unspecified
Control3: Unspecified

Rating No.: 1
Qm Rating: U
Diff.: 0.000%

Screening Thresholds:
BT 3-Beam Solution: YES
WT 3-Beam Solution: YES
BT Error Vel.: 1.00 m/s
WT Error Vel.: 10.00 m/s
BT Up Vel.: 10.00 m/s
WT Up Vel.: 10.00 m/s
Use Weighted Mean Depth: YES

Max. Vel.: 2.85 m/s
Max. Depth: 1.35 m
Mean Depth: 0.566 m
% Meas.: 49.82
Water Temp.: 0.3 °C
ADCP Temp.: 0.1 °C

ADCP:
Type/Freq.: RiverPro/RioPro / 1200 kHz
Serial #: 1129 | Firmware: 56.03
Bin Size: 2 cm | Blank: 10 cm
BT Mode: Auto | BT Pings: Dyn
WT Mode: Auto | WT Pings: Dyn
WZ : 5

Performed Diag. Test: YES
Performed Moving Bed Test: NO
Performed Compass Calibration: NO Evaluation: NO
Meas. Location: at gauge

Project Name: dss3_20160515_ch1&2_q11.9cms
Software: 2.17

Tr.#		Edge Distance		#Ens.	Discharge						Width	Area	Time		Mean Vel.		% Bad	
		L	R		Top	Middle	Bottom	Left	Right	Total			Start	End	Boat	Water	Ens.	Bins
000	R	4.57	1.22	333	4.74	5.55	1.15	0.040	0.021	11.5	118.3	63.2	11:17	11:20	0.61	0.18	3	4
001	L	4.57	1.22	308	5.15	5.86	1.24	0.063	0.024	12.3	114.3	59.9	11:20	11:23	0.69	0.21	2	3
002	R	1.83	1.22	360	4.48	5.91	1.09	0.021	0.019	11.5	117.5	69.8	11:23	11:27	0.61	0.17	1	3
003	L	2.44	0.91	304	4.61	6.41	1.21	0.029	0.009	12.3	112.8	69.0	11:27	11:30	0.71	0.18	1	3
Mean		3.35	1.14	326	4.75	5.93	1.17	0.038	0.018	11.9	115.7	65.5	**Total**	00:13	0.65	0.18	2	3
SDev		1.43	0.15	26	0.291	0.355	0.068	0.018	0.007	0.458	2.6	4.8			0.05	0.02		
SD/M		0.43	0.13	0.08	0.06	0.06	0.06	0.48	0.36	0.04	0.02	0.07			0.08	0.09		

Remarks: Q with River Pro 11.9 cms using BT with 4% error, bad GPS data. Total Q from 3 channels 126.3 cms.

Station Number: DSS3
Station Name: DSS3 Channel 3

Meas. No: 5
Date: 05/16/2016

Party: DB/JH/TT
Boat/Motor: 12' cataraft w/10 hp motor
Gauge Height: 288.84 m

Width: 93.7 m
Area: 77.2 m²
G.H.Change: 0.000 m

Processed by: DAV
Mean Velocity: 1.48 m/s
Discharge: 114 m³/s

Area Method: Mean Flow
Nav. Method: DGPS
MagVar Method: Model (18.6°)
Depth: Composite (BT)

ADCP Depth: 0.091 m
Shore Ens.:10
Bottom Est: Power (0.1667)
Top Est: Power (0.1667)

Index Vel.: 0.00 m/s
Adj. Mean Vel: 0.00 m/s
Rated Area: 0.000 m²
Control1: Unspecified
Control2: Unspecified
Control3: Unspecified

Rating No.: 1
Qm Rating: U
Diff.: 0.000%

Screening Thresholds:
BT 3-Beam Solution: YES
WT 3-Beam Solution: YES
BT Error Vel.: 1.00 m/s
WT Error Vel.: 10.00 m/s
BT Up Vel.: 10.00 m/s
WT Up Vel.: 10.00 m/s
Use Weighted Mean Depth: YES

Max. Vel.: 3.35 m/s
Max. Depth: 1.45 m
Mean Depth: 0.824 m
% Meas.: 60.11
Water Temp.: 0.4 °C
ADCP Temp.: 0.0 °C

ADCP:
Type/Freq.: RiverPro/RioPro / 1200 kHz
Serial #: 1129 Firmware: 56.03
Bin Size: 2 cm Blank: 10 cm
BT Mode: Auto BT Pings: Dyn
WT Mode: Auto WT Pings: Dyn
WZ : 5

Performed Diag. Test: YES
Performed Moving Bed Test: YES
Performed Compass Calibration: YES Evaluation: YES
Meas. Location: at gauge

Project Name: dss3_20160516_ch3_q114.4cms
Software: 2.17

Tr.#		Edge Distance		#Ens.	Discharge						Width	Area	Time		Mean Vel.		% Bad	
		L	R		Top	Middle	Bottom	Left	Right	Total			Start	End	Boat	Water	Ens.	Bins
000	L	2.13	4.57	260	29.3	68.5	16.1	0.280	0.246	114	94.0	77.7	10:21	10:24	0.55	1.47	0	0
001	R	2.13	4.57	256	29.8	70.1	15.5	0.256	0.222	116	92.9	76.5	10:24	10:26	0.57	1.51	1	0
002	L	2.13	4.57	287	28.4	67.9	15.1	0.274	0.316	112	92.5	77.0	10:27	10:30	0.50	1.46	0	0
003	R	2.13	4.57	258	29.0	68.1	16.2	0.255	0.272	114	92.8	77.3	10:30	10:33	0.56	1.47	1	0
004	L	2.13	6.10	248	28.8	68.0	15.5	0.292	0.287	113	95.4	77.9	10:33	10:35	0.57	1.45	0	0
005	R	1.83	6.10	259	30.0	69.9	16.6	0.210	0.445	117	94.4	76.8	10:35	10:38	0.56	1.53	0	0
Mean		2.08	5.08	261	29.2	68.7	15.8	0.261	0.298	114	93.7	77.2	**Total**	00:17	0.55	1.48	0	0
SDev		0.12	0.79	13	0.619	0.983	0.535	0.029	0.079	1.89	1.2	0.5			0.03	0.03		
SD/M		0.06	0.15	0.05	0.02	0.01	0.03	0.11	0.27	0.02	0.01	0.01			0.05	0.02		

Remarks: Q with River Pro 114.4 cms using VTG with 2% error, 114 cms using BT with 1% error. Total Q from 3 channels 126.3 cms.

Station Number: DSS3
Station Name: DSS3 Channel 1&2

Meas. No: 6
Date: 05/18/2016

Party: DB/JH/TT
Boat/Motor: 12' cataraft w/10 hp motor
Gauge Height: 288.46 m

Width: 104.7 m
Area: 58.7 m²
G.H.Change: 0.000 m

Processed by: DAV
Mean Velocity: 0.109 m/s
Discharge: 6.34 m³/s

Area Method: Mean Flow
Nav. Method: Bottom Track
MagVar Method: Model (18.6°)
Depth: Composite (BT)
Discharge Method: None
% Correction: 0.00

ADCP Depth: 0.091 m
Shore Ens.:10
Bottom Est: Power (0.1667)
Top Est: Power (0.1667)

Index Vel.: 0.00 m/s
Adj. Mean Vel: 0.00 m/s
Rated Area: 0.000 m²
Control1: Unspecified
Control2: Unspecified
Control3: Unspecified

Rating No.: 1
Qm Rating: U
Diff.: 0.000%

Screening Thresholds:
BT 3-Beam Solution: YES
WT 3-Beam Solution: YES
BT Error Vel.: 1.00 m/s
WT Error Vel.: 10.00 m/s
BT Up Vel.: 10.00 m/s
WT Up Vel.: 10.00 m/s
Use Weighted Mean Depth: YES

Max. Vel.: 2.23 m/s
Max. Depth: 1.07 m
Mean Depth: 0.561 m
% Meas.: 49.73
Water Temp.: 2.0 °C
ADCP Temp.: 1.5 °C

ADCP:
Type/Freq.: RiverPro/RioPro / 1200 kHz
Serial #: 1129 Firmware: 56.03
Bin Size: 2 cm Blank: 10 cm
BT Mode: Auto BT Pings: Dyn
WT Mode: Auto WT Pings: Dyn
WZ : 5

Performed Diag. Test: YES
Performed Moving Bed Test: NO
Performed Compass Calibration: NO Evaluation: NO
Meas. Location: at gauge

Project Name: dss3_20160518_ch1&2_q6.3cms
Software: 2.17

Tr.#		Edge Distance		#Ens.	Discharge						Width	Area	Time		Mean Vel.		% Bad	
		L	R		Top	Middle	Bottom	Left	Right	Total			Start	End	Boat	Water	Ens.	Bins
000	R	2.44	2.44	392	2.60	2.97	0.654	0.020	0.039	6.29	111.1	59.1	12:48	12:52	0.58	0.11	1	2
001	L	2.44	1.83	292	2.40	3.15	0.602	-0.086	0.034	6.10	93.3	52.1	12:52	12:54	0.77	0.12	1	2
002	R	2.44	1.83	329	2.60	3.10	0.599	0.007	0.032	6.34	115.0	65.5	12:55	12:58	0.69	0.10	0	2
003	L	2.44	1.52	313	2.58	3.38	0.661	-0.018	0.019	6.62	99.4	58.2	12:58	13:01	0.72	0.11	0	2
Mean		2.44	1.91	331	2.54	3.15	0.629	-0.019	0.031	6.34	104.7	58.7	**Total**	00:12	0.69	0.11	1	2
SDev		0.00	0.38	43	0.097	0.167	0.033	0.047	0.009	0.213	10.1	5.5			0.08	0.01		
SD/M		0.00	0.20	0.13	0.04	0.05	0.05	2.45	0.27	0.03	0.10	0.09			0.11	0.08		

Remarks: Q with River Pro 6.3 cms using BT with 3% error, bad GPS data. Total Q from 3 channels 86 cms.

Station Number: DSS3 | Meas. No: 6
Station Name: DSS3 Channel 3 | Date: 05/18/2016

Party: DB/JH/TT | Width: 89.9 m | Processed by: DAV
Boat/Motor: 12' cataraft w/10 hp motor | Area: 63.4 m² | Mean Velocity: 1.26 m/s
Gauge Height: 288.46 m | G.H.Change: 0.000 m | Discharge: 79.7 m³/s

Area Method: Mean Flow
Nav. Method: DGPS
MagVar Method: Model (18.6°)
Depth: Composite (BT)

ADCP Depth: 0.091 m
Shore Ens.:10
Bottom Est: Power (0.1667)
Top Est: Power (0.1667)

Index Vel.: 0.00 m/s | Rating No.: 1
Adj. Mean Vel: 0.00 m/s | Qm Rating: U
Rated Area: 0.000 m² | Diff.: 0.000%
Control1: Unspecified
Control2: Unspecified
Control3: Unspecified

Screening Thresholds:
BT 3-Beam Solution: YES
WT 3-Beam Solution: YES
BT Error Vel.: 1.00 m/s
WT Error Vel.: 10.00 m/s
BT Up Vel.: 10.00 m/s
WT Up Vel.: 10.00 m/s
Use Weighted Mean Depth: YES

Max. Vel.: 3.44 m/s
Max. Depth: 1.19 m
Mean Depth: 0.706 m
% Meas.: 56.33
Water Temp.: 1.9 °C
ADCP Temp.: 0.9 °C

ADCP:
Type/Freq.: RiverPro/RioPro / 1200 kHz
Serial #: 1129 | Firmware: 56.03
Bin Size: 2 cm | Blank: 10 cm
BT Mode: Auto | BT Pings: Dyn
WT Mode: Auto | WT Pings: Dyn
WZ : 5

Performed Diag. Test: YES
Performed Moving Bed Test: YES
Performed Compass Calibration: YES   Evaluation: YES
Meas. Location: at gauge

Project Name: dss3_20160518_ch3_q79.7cms
Software: 2.17

Tr.#		Edge Distance		#Ens.	Discharge						Width	Area	Time		Mean Vel.		% Bad	
		L	R		Top	Middle	Bottom	Left	Right	Total			Start	End	Boat	Water	Ens.	Bins
000	L	2.44	6.40	262	23.2	44.3	10.7	0.275	0.394	78.9	89.6	63.2	12:12	12:15	0.55	1.25	0	0
001	R	1.83	6.40	249	23.5	44.6	11.0	0.170	0.414	79.7	90.1	63.3	12:15	12:17	0.57	1.26	0	0
002	L	1.83	6.40	287	22.7	43.9	10.7	0.241	0.489	78.0	88.8	63.0	12:18	12:21	0.50	1.24	0	0
003	R	1.83	6.40	333	23.2	45.0	10.8	0.167	0.498	79.6	89.0	63.1	12:21	12:24	0.43	1.26	0	1
004	L	1.83	6.40	275	24.5	46.7	11.2	0.179	0.363	83.0	91.6	64.1	12:24	12:27	0.54	1.29	0	1
005	R	1.83	6.40	270	23.0	44.7	10.5	0.192	0.466	78.9	90.2	64.0	12:27	12:30	0.53	1.23	0	0
Mean		1.93	6.40	279	23.3	44.9	10.8	0.204	0.437	79.7	89.9	63.4	**Total**	00:17	0.52	1.26	0	0
SDev		0.25	0.00	29	0.615	0.990	0.244	0.044	0.055	1.72	1.0	0.5			0.05	0.02		
SD/M		0.13	0.00	0.10	0.03	0.02	0.02	0.22	0.13	0.02	0.01	0.01			0.09	0.02		

Remarks: Q with River Pro 79.7 cms using VTG with 2% error, 79.6 cms using BT with 1% error. Total Q from 3 channels 86 cms.

Station Number: DSS3
Station Name: DSS3 Channel 1&2

Meas. No: 7
Date: 05/19/2016

Party: DB/JH/TT	Width: 111.0 m	Processed by: DAV
Boat/Motor: 12' cataraft w/10 hp motor	Area: 74.0 m²	Mean Velocity: 0.146 m/s
Gauge Height: 288.63 m	G.H.Change: 0.000 m	Discharge: 10.7 m³/s

Area Method: Mean Flow	ADCP Depth: 0.091 m	Index Vel.: 0.00 m/s	Rating No.: 1
Nav. Method: Bottom Track	Shore Ens.:10	Adj. Mean Vel: 0.00 m/s	Qm Rating: U
MagVar Method: Model (18.6°)	Bottom Est: Power (0.1667)	Rated Area: 0.000 m²	Diff.: 0.000%
Depth: Composite (BT)	Top Est: Power (0.1667)	Control1: Unspecified	
Discharge Method: None		Control2: Unspecified	
% Correction: 0.00		Control3: Unspecified	

Screening Thresholds:		ADCP:	
BT 3-Beam Solution: YES	Max. Vel.: 1.97 m/s	Type/Freq.: RiverPro/RioPro / 1200 kHz	
WT 3-Beam Solution: YES	Max. Depth: 1.20 m	Serial #: 1129	Firmware: 56.03
BT Error Vel.: 1.00 m/s	Mean Depth: 0.667 m	Bin Size: 2 cm	Blank: 10 cm
WT Error Vel.: 10.00 m/s	% Meas.: 56.52	BT Mode: Auto	BT Pings: Dyn
BT Up Vel.: 10.00 m/s	Water Temp.: 2.1 °C	WT Mode: Auto	WT Pings: Dyn
WT Up Vel.: 10.00 m/s	ADCP Temp.: 1.4 °C	WZ : 5	
Use Weighted Mean Depth: YES			

Performed Diag. Test: YES
Performed Moving Bed Test: NO
Performed Compass Calibration: NO Evaluation: NO
Meas. Location: at gauge

Project Name: dss3_20160519_ch1&2_q10.7cms
Software: 2.17

Tr.#		Edge Distance		#Ens.	Discharge						Width	Area	Time		Mean Vel.		% Bad	
		L	R		Top	Middle	Bottom	Left	Right	Total			Start	End	Boat	Water	Ens.	Bins
000	L	2.13	1.52	342	3.68	6.09	1.01	0.036	0.035	10.9	108.1	69.4	11:40	11:43	0.68	0.16	0	2
001	R	1.52	1.52	347	3.49	6.25	1.05	0.009	0.027	10.8	116.2	81.5	11:43	11:46	0.68	0.13	0	1
003	R	1.22	1.22	368	3.63	5.96	0.993	0.006	0.052	10.6	116.0	73.5	11:50	11:53	0.62	0.14	0	1
004	L	1.22	1.22	333	3.53	5.96	1.09	0.013	0.017	10.6	103.5	71.5	11:54	11:57	0.74	0.15	1	1
Mean		1.52	1.37	347	3.58	6.07	1.03	0.016	0.033	10.7	111.0	74.0	**Total**	00:17	0.68	0.15	0	1
SDev		0.43	0.18	15	0.088	0.140	0.041	0.014	0.015	0.128	6.2	5.3			0.05	0.01		
SD/M		0.28	0.13	0.04	0.02	0.02	0.04	0.85	0.45	0.01	0.06	0.07			0.07	0.07		

Remarks: Q with River Pro 10.7 cms using BT with 1% error, bad GPS data. Total Q from 3 channels 117.8 cms.

Station Number: DSS3 | Meas. No: 7
Station Name: DSS3 Channel 3 | Date: 05/19/2016

Party: DB/JH/TT	Width: 93.7 m	Processed by: DAV
Boat/Motor: 12' cataraft w/10 hp motor	Area: 76.9 m²	Mean Velocity: 1.40 m/s
Gauge Height: 288.63 m	G.H.Change: 0.000 m	Discharge: 107 m³/s

Area Method: Mean Flow	ADCP Depth: 0.091 m	Index Vel.: 0.00 m/s	Rating No.: 1
Nav. Method: DGPS	Shore Ens.:10	Adj. Mean Vel: 0.00 m/s	Qm Rating: U
MagVar Method: Model (18.6°)	Bottom Est: Power (0.1667)	Rated Area: 0.000 m²	Diff.: 0.000%
Depth: Composite (BT)	Top Est: Power (0.1667)	Control1: Unspecified	
		Control2: Unspecified	
		Control3: Unspecified	

Screening Thresholds:		ADCP:	
BT 3-Beam Solution: YES	Max. Vel.: 2.98 m/s	Type/Freq.: RiverPro/RioPro / 1200 kHz	
WT 3-Beam Solution: YES	Max. Depth: 1.35 m	Serial #: 1129	Firmware: 56.03
BT Error Vel.: 1.00 m/s	Mean Depth: 0.821 m	Bin Size: 2 cm	Blank: 10 cm
WT Error Vel.: 10.00 m/s	% Meas.: 59.61	BT Mode: Auto	BT Pings: Dyn
BT Up Vel.: 10.00 m/s	Water Temp.: 1.2 °C	WT Mode: Auto	WT Pings: Dyn
WT Up Vel.: 10.00 m/s	ADCP Temp.: 0.9 °C	WZ : 5	
Use Weighted Mean Depth: YES			

Performed Diag. Test: YES
Performed Moving Bed Test: YES
Performed Compass Calibration: YES Evaluation: YES
Meas. Location: at gauge

Project Name: dss3_20160519_ch3_q107.1cms
Software: 2.17

Tr.#		Edge Distance		#Ens.	Discharge						Width	Area	Time		Mean Vel.		% Bad	
		L	R		Top	Middle	Bottom	Left	Right	Total			Start	End	Boat	Water	Ens.	Bins
000	R	1.83	4.57	210	27.7	64.5	14.9	0.221	0.424	108	90.2	74.3	11:05	11:07	0.69	1.45	0	0
001	L	1.83	3.05	211	27.5	63.9	14.9	0.256	0.174	107	90.7	75.2	11:09	11:11	0.69	1.42	0	0
002	R	1.83	3.05	215	27.7	63.2	15.2	0.213	0.188	106	90.8	75.0	11:11	11:13	0.67	1.42	0	0
003	L	1.83	3.05	204	28.5	65.1	14.9	0.261	0.278	109	104.8	85.8	11:13	11:15	0.82	1.27	0	0
004	R	1.83	3.05	226	27.8	62.2	14.7	0.184	0.206	105	91.7	74.3	11:16	11:18	0.66	1.42	0	0
Mean		1.83	3.35	213	27.8	63.8	14.9	0.227	0.254	107	93.7	76.9	**Total**	00:12	0.70	1.40	0	0
SDev		0.00	0.68	8	0.405	1.11	0.154	0.032	0.103	1.46	6.3	5.0			0.07	0.07		
SD/M		0.00	0.20	0.04	0.01	0.02	0.01	0.14	0.41	0.01	0.07	0.06			0.09	0.05		

Remarks: Q with River Pro 107.1 cms using VTG with 1% error, 107.6 cms using BT with 2% error. Total Q from 3 channels 117.8 cms.

Station Number: DSS3
Station Name: DSS3 Channel 1&2

Meas. No: 8
Date: 05/20/2016

Party: DB/JH/TT
Boat/Motor: 12' cataraft w/10 hp motor
Gauge Height: 288.77 m

Width: 114.9 m
Area: 83.3 m²
G.H.Change: 0.000 m

Processed by: DAV
Mean Velocity: 0.253 m/s
Discharge: 21.1 m³/s

Area Method: Mean Flow
Nav. Method: Bottom Track
MagVar Method: Model (18.6°)
Depth: Composite (BT)
Discharge Method: None
% Correction: 0.00

ADCP Depth: 0.091 m
Shore Ens.:10
Bottom Est: Power (0.1667)
Top Est: Power (0.1667)

Index Vel.: 0.00 m/s
Adj. Mean Vel: 0.00 m/s
Rated Area: 0.000 m²
Control1: Unspecified
Control2: Unspecified
Control3: Unspecified

Rating No.: 1
Qm Rating: U
Diff.: 0.000%

Screening Thresholds:
BT 3-Beam Solution: YES
WT 3-Beam Solution: YES
BT Error Vel.: 1.00 m/s
WT Error Vel.: 10.00 m/s
BT Up Vel.: 10.00 m/s
WT Up Vel.: 10.00 m/s
Use Weighted Mean Depth: YES

Max. Vel.: 1.28 m/s
Max. Depth: 1.48 m
Mean Depth: 0.725 m
% Meas.: 60.34
Water Temp.: 1.7 °C
ADCP Temp.: 1.4 °C

ADCP:
Type/Freq.: RiverPro/RioPro / 1200 kHz
Serial #: 1129 Firmware: 56.03
Bin Size: 6 cm Blank: 10 cm
BT Mode: Auto BT Pings: Dyn
WT Mode: Auto WT Pings: Dyn
WZ : 5

Performed Diag. Test: YES
Performed Moving Bed Test: NO
Performed Compass Calibration: NO Evaluation: NO
Meas. Location: at gauge

Project Name: dss3_20160520_ch1&2_q21.1cms
Software: 2.17

Tr.#		Edge Distance		#Ens.	Discharge						Width	Area	Time		Mean Vel.		% Bad	
		L	R		Top	Middle	Bottom	Left	Right	Total			Start	End	Boat	Water	Ens.	Bins
000	L	1.52	0.91	333	6.42	13.0	2.05	0.030	0.013	21.6	113.8	82.4	10:20	10:23	0.70	0.26	1	1
001	R	1.22	0.91	369	6.50	12.6	2.04	0.032	0.013	21.2	117.2	82.2	10:23	10:27	0.62	0.26	0	2
002	L	1.22	1.22	318	5.99	12.7	1.97	0.025	0.020	20.7	112.0	85.8	10:27	10:30	0.75	0.24	0	1
003	R	1.22	1.22	401	6.34	12.5	1.95	0.008	0.018	20.8	116.6	82.7	10:30	10:34	0.58	0.25	0	2
Mean		1.30	1.07	355	6.31	12.7	2.00	0.024	0.016	21.1	114.9	83.3	**Total**	00:13	0.66	0.25	0	2
SDev		0.15	0.18	37	0.222	0.233	0.053	0.011	0.004	0.380	2.4	1.7			0.08	0.01		
SD/M		0.12	0.17	0.10	0.04	0.02	0.03	0.46	0.22	0.02	0.02	0.02			0.11	0.04		

Remarks: Q with River Pro 21.1 cms using BT with 2% error, bad GPS data. Total Q from 3 channels 145.1 cms.

Station Number: DSS3
Station Name: DSS3 Channel 3

Meas. No: 8
Date: 05/20/2016

Party: DB/JH/TT
Boat/Motor: 12' cataraft w/10 hp motor
Gauge Height: 288.77 m

Width: 92.1 m
Area: 82.5 m²
G.H.Change: 0.000 m

Processed by: DAV
Mean Velocity: 1.50 m/s
Discharge: 124 m³/s

Area Method: Mean Flow
Nav. Method: Bottom Track
MagVar Method: Model (18.6°)
Depth: Composite (BT)
Discharge Method: None
% Correction: 0.00

ADCP Depth: 0.091 m
Shore Ens.:10
Bottom Est: Power (0.1667)
Top Est: Power (0.1667)

Index Vel.: 0.00 m/s
Adj. Mean Vel: 0.00 m/s
Rated Area: 0.000 m²
Control1: Unspecified
Control2: Unspecified
Control3: Unspecified

Rating No.: 1
Qm Rating: U
Diff.: 0.000%

Screening Thresholds:
BT 3-Beam Solution: YES
WT 3-Beam Solution: YES
BT Error Vel.: 1.00 m/s
WT Error Vel.: 10.00 m/s
BT Up Vel.: 10.00 m/s
WT Up Vel.: 10.00 m/s
Use Weighted Mean Depth: YES

Max. Vel.: 3.04 m/s
Max. Depth: 1.43 m
Mean Depth: 0.896 m
% Meas.: 62.35
Water Temp.: 1.5 °C
ADCP Temp.: 1.1 °C

ADCP:
Type/Freq.: RiverPro/RioPro / 1200 kHz
Serial #: 1129 Firmware: 56.03
Bin Size: 2 cm Blank: 10 cm
BT Mode: Auto BT Pings: Dyn
WT Mode: Auto WT Pings: Dyn
WZ : 5

Performed Diag. Test: YES
Performed Moving Bed Test: YES
Performed Compass Calibration: YES Evaluation: YES
Meas. Location: at gauge

Project Name: dss3_20160520_ch3_q124cms
Software: 2.17

Tr.#		Edge Distance		#Ens.	Discharge						Width	Area	Time		Mean Vel.		% Bad	
		L	R		Top	Middle	Bottom	Left	Right	Total			Start	End	Boat	Water	Ens.	Bins
000	R	1.52	3.35	219	29.8	77.8	16.9	0.126	0.153	125	92.1	82.6	09:53	09:56	0.65	1.51	0	0
001	L	1.52	3.35	204	29.4	76.1	16.4	0.166	0.130	122	92.6	82.7	09:56	09:58	0.69	1.48	0	0
002	R	1.52	3.35	215	29.8	77.4	16.0	0.134	0.140	123	92.0	81.9	09:58	10:00	0.65	1.51	0	0
003	L	1.52	3.35	230	30.4	77.8	17.0	0.119	0.148	125	93.1	83.2	10:00	10:03	0.61	1.51	0	1
004	R	1.52	3.35	221	29.2	76.7	16.4	0.174	0.171	123	91.1	82.1	10:03	10:05	0.64	1.50	0	0
005	L	1.52	3.35	201	29.8	77.7	17.1	0.172	0.141	125	91.4	82.4	10:05	10:08	0.69	1.52	0	0
Mean		1.52	3.35	215	29.7	77.3	16.6	0.149	0.147	124	92.1	82.5	**Total**	00:14	0.65	1.50	0	0
SDev		0.00	0.00	11	0.394	0.693	0.450	0.025	0.014	1.32	0.7	0.5			0.03	0.01		
SD/M		0.00	0.00	0.05	0.01	0.01	0.03	0.17	0.10	0.01	0.01	0.01			0.05	0.01		

Remarks: Q with River Pro 124 cms using BT with 1% error, bad GPS data. Total Q from 3 channels 145.1 cms.

Station Number: DSS3
Station Name: DSS3 Channel 1&2

Meas. No: 9
Date: 05/21/2016

Party: DB/JH/TT
Boat/Motor: 12' cataraft w/10 hp motor
Gauge Height: 288.84 m

Width: 117.9 m
Area: 95.0 m²
G.H.Change: 0.000 m

Processed by: DAV
Mean Velocity: 0.393 m/s
Discharge: 37.4 m³/s

Area Method: Mean Flow
Nav. Method: Bottom Track
MagVar Method: Model (18.6°)
Depth: Composite (BT)
Discharge Method: None
% Correction: 0.00

ADCP Depth: 0.091 m
Shore Ens.:10
Bottom Est: Power (0.1667)
Top Est: Power (0.1667)

Index Vel.: 0.00 m/s
Adj. Mean Vel: 0.00 m/s
Rated Area: 0.000 m²
Control1: Unspecified
Control2: Unspecified
Control3: Unspecified

Rating No.: 1
Qm Rating: U
Diff.: 0.000%

Screening Thresholds:
BT 3-Beam Solution: YES
WT 3-Beam Solution: YES
BT Error Vel.: 1.00 m/s
WT Error Vel.: 10.00 m/s
BT Up Vel.: 10.00 m/s
WT Up Vel.: 10.00 m/s
Use Weighted Mean Depth: YES

Max. Vel.: 1.63 m/s
Max. Depth: 1.27 m
Mean Depth: 0.805 m
% Meas.: 62.78
Water Temp.: 1.1 °C
ADCP Temp.: 0.9 °C

ADCP:
Type/Freq.: RiverPro/RioPro / 1200 kHz
Serial #: 1129 Firmware: 56.03
Bin Size: 2 cm Blank: 10 cm
BT Mode: Auto BT Pings: Dyn
WT Mode: Auto WT Pings: Dyn
WZ : 5

Performed Diag. Test: YES
Performed Moving Bed Test: YES
Performed Compass Calibration: NO Evaluation: NO
Meas. Location: at gauge

Project Name: dss3_20160521_ch1&2_q37.4cms
Software: 2.17

Tr.#		Edge Distance		#Ens.	Discharge						Width	Area	Time		Mean Vel.		% Bad	
		L	R		Top	Middle	Bottom	Left	Right	Total			Start	End	Boat	Water	Ens.	Bins
000	L	2.44	1.22	355	10.3	24.1	3.55	0.112	0.011	38.0	118.7	96.8	11:40	11:43	0.63	0.39	1	3
001	R	1.52	1.22	367	10.3	23.4	3.51	0.049	-0.024	37.3	117.9	94.0	11:43	11:47	0.61	0.40	0	3
002	L	1.52	0.91	339	10.4	23.6	3.67	0.045	0.001	37.7	117.6	95.5	11:47	11:50	0.66	0.39	1	3
003	R	1.22	0.91	384	10.2	22.8	3.50	0.035	0.013	36.5	117.6	93.7	11:50	11:53	0.59	0.39	1	3
Mean		1.68	1.07	361	10.3	23.5	3.56	0.060	0.000	37.4	117.9	95.0	**Total**	00:13	0.62	0.39	1	3
SDev		0.53	0.18	19	0.089	0.548	0.079	0.035	0.017	0.676	0.5	1.4			0.03	0.00		
SD/M		0.31	0.17	0.05	0.01	0.02	0.02	0.58	67.99	0.02	0.00	0.02			0.05	0.01		

Remarks: Q with River Pro 35.6 cms using VTG with 7% error, 37.4 cms using BT with 2% error. Total Q from 3 channels 174.2 cms

Station Number: DSS3 | Meas. No: 9
Station Name: DSS3 Channel 3 | Date: 05/21/2016

Party: DB/JH/TT
Boat/Motor: 12' cataraft w/10 hp motor
Gauge Height: 288.84 m

Width: 92.8 m
Area: 86.2 m²
G.H.Change: 0.000 m

Processed by: DAV
Mean Velocity: 1.59 m/s
Discharge: 137 m³/s

Area Method: Mean Flow
Nav. Method: DGPS
MagVar Method: Model (18.6°)
Depth: Composite (BT)

ADCP Depth: 0.091 m
Shore Ens.:10
Bottom Est: Power (0.1667)
Top Est: Power (0.1667)

Index Vel.: 0.00 m/s
Adj. Mean Vel: 0.00 m/s
Rated Area: 0.000 m²
Control1: Unspecified
Control2: Unspecified
Control3: Unspecified

Rating No.: 1
Qm Rating: U
Diff.: 0.000%

Screening Thresholds:
BT 3-Beam Solution: YES
WT 3-Beam Solution: YES
BT Error Vel.: 1.00 m/s
WT Error Vel.: 10.00 m/s
BT Up Vel.: 10.00 m/s
WT Up Vel.: 10.00 m/s
Use Weighted Mean Depth: YES

Max. Vel.: 3.17 m/s
Max. Depth: 1.46 m
Mean Depth: 0.928 m
% Meas.: 62.56
Water Temp.: 1.4 °C
ADCP Temp.: 0.9 °C

ADCP:
Type/Freq.: RiverPro/RioPro / 1200 kHz
Serial #: 1129 | Firmware: 56.03
Bin Size: 2 cm | Blank: 10 cm
BT Mode: Auto | BT Pings: Dyn
WT Mode: Auto | WT Pings: Dyn
WZ : 5

Performed Diag. Test: YES
Performed Moving Bed Test: YES
Performed Compass Calibration: YES   Evaluation: YES
Meas. Location: at gauge

Project Name: dss3_20160521_ch3_q136.8cms
Software: 2.17

Tr.#		Edge Distance		#Ens.	Discharge						Width	Area	Time		Mean Vel.		% Bad	
		L	R		Top	Middle	Bottom	Left	Right	Total			Start	End	Boat	Water	Ens.	Bins
000	R	1.22	3.05	214	31.8	85.5	18.3	0.125	0.184	136	92.0	85.8	11:06	11:09	0.64	1.58	0	0
001	L	1.22	3.05	198	32.1	85.0	18.9	0.178	0.174	136	92.8	86.1	11:09	11:11	0.70	1.58	0	0
002	R	1.52	3.05	236	32.5	86.7	19.2	0.195	0.191	139	92.9	86.4	11:11	11:14	0.60	1.61	0	0
003	L	1.52	3.05	194	32.1	85.1	18.8	0.185	0.196	136	93.5	86.6	11:14	11:16	0.72	1.57	0	0
004	R	1.52	3.05	231	31.7	85.9	18.6	0.159	0.169	137	93.1	86.6	11:16	11:18	0.60	1.58	0	0
005	L	1.52	3.05	220	32.2	85.0	19.1	0.179	0.195	137	92.8	85.7	11:18	11:21	0.65	1.60	0	0
Mean		1.42	3.05	215	32.0	85.6	18.8	0.170	0.185	137	92.8	86.2	**Total**	00:14	0.65	1.59	0	0
SDev		0.16	0.00	17	0.283	0.670	0.341	0.025	0.011	1.02	0.5	0.4			0.05	0.01		
SD/M		0.11	0.00	0.08	0.01	0.01	0.02	0.15	0.06	0.01	0.01	0.00			0.08	0.01		

Remarks: Q with River Pro 136.8 cms using VTG with 1% error, 138.7 cms using BT with 1% error. Total Q from 3 channels 174.2 cms.

Station Number: DSS3
Station Name: DSS3 Channel 1&2

Meas. No: 10
Date: 05/22/2016

Party: DB/JH/TT
Boat/Motor: 12' cataraft w/10 hp motor
Gauge Height: 288.92 m

Width: 121.0 m
Area: 109.0 m²
G.H.Change: 0.000 m

Processed by: DAV
Mean Velocity: 0.443 m/s
Discharge: 48.2 m³/s

Area Method: Mean Flow
Nav. Method: Bottom Track
MagVar Method: Model (18.6°)
Depth: Composite (BT)
Discharge Method: None
% Correction: 0.00

ADCP Depth: 0.091 m
Shore Ens.:10
Bottom Est: Power (0.1667)
Top Est: Power (0.1667)

Index Vel.: 0.00 m/s
Adj. Mean Vel: 0.00 m/s
Rated Area: 0.000 m²
Control1: Unspecified
Control2: Unspecified
Control3: Unspecified

Rating No.: 1
Qm Rating: U
Diff.: 0.000%

Screening Thresholds:
BT 3-Beam Solution: YES
WT 3-Beam Solution: YES
BT Error Vel.: 1.00 m/s
WT Error Vel.: 10.00 m/s
BT Up Vel.: 10.00 m/s
WT Up Vel.: 10.00 m/s
Use Weighted Mean Depth: YES

Max. Vel.: 2.34 m/s
Max. Depth: 1.32 m
Mean Depth: 0.900 m
% Meas.: 66.32
Water Temp.: 2.1 °C
ADCP Temp.: 1.4 °C

ADCP:
Type/Freq.: RiverPro/RioPro / 1200 kHz
Serial #: 1129 Firmware: 56.03
Bin Size: 2 cm Blank: 10 cm
BT Mode: Auto BT Pings: Dyn
WT Mode: Auto WT Pings: Dyn
WZ : 5

Performed Diag. Test: YES
Performed Moving Bed Test: YES
Performed Compass Calibration: NO Evaluation: NO
Meas. Location: at gauge

Project Name: dss3_20160522_ch1&2_q48.2cms
Software: 2.17

Tr.#		Edge Distance		#Ens.	Discharge						Width	Area	Time		Mean Vel.		% Bad	
		L	R		Top	Middle	Bottom	Left	Right	Total			Start	End	Boat	Water	Ens.	Bins
000	L	2.74	0.61	267	11.9	32.3	4.24	0.177	-0.004	48.6	120.5	108.8	14:35	14:37	0.80	0.45	0	0
001	R	2.44	0.61	327	11.8	30.8	4.27	0.108	-0.004	46.9	121.3	107.0	14:37	14:40	0.68	0.44	0	0
002	L	2.44	0.61	262	11.8	32.4	4.33	0.118	0.004	48.6	120.8	109.6	14:40	14:43	0.82	0.44	0	1
003	R	2.44	0.61	321	11.8	32.0	4.36	0.107	-0.002	48.2	121.2	109.4	14:43	14:46	0.68	0.44	0	1
004	L	2.44	0.61	286	11.8	32.5	4.26	0.148	0.003	48.7	120.6	109.3	14:46	14:49	0.75	0.45	0	1
005	R	2.44	0.61	327	11.8	31.9	4.43	0.118	0.005	48.2	121.6	109.7	14:49	14:52	0.67	0.44	1	0
Mean		2.49	0.61	298	11.8	32.0	4.31	0.129	0.000	48.2	121.0	109.0	**Total**	00:17	0.74	0.44	0	0
SDev		0.12	0.00	30	0.038	0.625	0.075	0.028	0.004	0.667	0.4	1.0			0.07	0.00		
SD/M		0.05	0.00	0.10	0.00	0.02	0.02	0.21	12.39	0.01	0.00	0.01			0.09	0.01		

Remarks: Q with River Pro 46.8 cms using VTG with 6% error, 48.2 cms using BT with 1% error. Total Q from 3 channels 198.2 cms.

Station Number: DSS3
Station Name: DSS3 Channel 3

Meas. No: 10
Date: 05/22/2016

Party: DB/JH/TT
Boat/Motor: 12' cataraft w/10 hp motor
Gauge Height: 288.92 m

Width: 92.4 m
Area: 90.5 m²
G.H.Change: 0.000 m

Processed by: DAV
Mean Velocity: 1.66 m/s
Discharge: 150 m³/s

Area Method: Mean Flow
Nav. Method: DGPS
MagVar Method: Model (18.6°)
Depth: Composite (BT)

ADCP Depth: 0.091 m
Shore Ens.:10
Bottom Est: Power (0.1667)
Top Est: Power (0.1667)

Index Vel.: 0.00 m/s
Adj. Mean Vel: 0.00 m/s
Rated Area: 0.000 m²
Control1: Unspecified
Control2: Unspecified
Control3: Unspecified

Rating No.: 1
Qm Rating: U
Diff.: 0.000%

Screening Thresholds:
BT 3-Beam Solution: YES
WT 3-Beam Solution: YES
BT Error Vel.: 1.00 m/s
WT Error Vel.: 10.00 m/s
BT Up Vel.: 10.00 m/s
WT Up Vel.: 10.00 m/s
Use Weighted Mean Depth: YES

Max. Vel.: 3.32 m/s
Max. Depth: 1.53 m
Mean Depth: 0.980 m
% Meas.: 64.38
Water Temp.: 1.4 °C
ADCP Temp.: 0.9 °C

ADCP:
Type/Freq.: RiverPro/RioPro / 1200 kHz
Serial #: 1129 Firmware: 56.03
Bin Size: 2 cm Blank: 10 cm
BT Mode: Auto BT Pings: Dyn
WT Mode: Auto WT Pings: Dyn
WZ : 5

Performed Diag. Test: YES
Performed Moving Bed Test: YES
Performed Compass Calibration: YES Evaluation: YES
Meas. Location: at gauge

Project Name: dss3_20160522_ch3_q150cms
Software: 2.17

Tr.#		Edge Distance		#Ens.	Discharge						Width	Area	Time		Mean Vel.		% Bad	
		L	R		Top	Middle	Bottom	Left	Right	Total			Start	End	Boat	Water	Ens.	Bins
000	R	1.52	2.74	219	33.1	94.9	19.7	0.186	0.131	148	92.6	90.4	13:55	13:58	0.65	1.64	0	0
001	L	1.52	2.74	202	33.5	95.9	20.0	0.158	0.119	150	93.5	90.8	13:58	14:00	0.69	1.65	0	0
002	R	1.52	2.74	192	32.7	95.8	19.4	0.167	0.124	148	91.6	89.8	14:00	14:02	0.69	1.65	2	0
003	L	1.52	2.74	188	33.2	96.4	20.3	0.148	0.173	150	92.7	90.4	14:02	14:04	0.73	1.66	0	0
004	R	1.52	2.74	205	33.1	97.3	19.8	0.172	0.179	151	91.8	90.5	14:05	14:07	0.65	1.66	1	0
005	L	1.52	2.74	208	33.6	99.0	20.2	0.179	0.169	153	92.2	90.9	14:07	14:09	0.66	1.68	0	0
Mean		1.52	2.74	202	33.2	96.5	19.9	0.168	0.149	150	92.4	90.5	**Total**	00:14	0.68	1.66	0	0
SDev		0.00	0.00	11	0.320	1.44	0.326	0.014	0.027	1.87	0.7	0.4			0.03	0.02		
SD/M		0.00	0.00	0.06	0.01	0.01	0.02	0.08	0.18	0.01	0.01	0.00			0.05	0.01		

Remarks: Q with River Pro 150 cms using VTG with 1% error, 151.9 cms using BT with 1% error. Total Q from 3 channels 198.2 cms.

Station Number: DSS3 | Meas. No: 11
Station Name: DSS3 Channel 1&2 | Date: 05/23/2016

Party: DB/JH/TT
Boat/Motor: 12' cataraft w/10 hp motor
Gauge Height: 288.99 m
Width: 120.8 m
Area: 107.4 m²
G.H.Change: 0.000 m
Processed by: DAV
Mean Velocity: 0.426 m/s
Discharge: 45.8 m³/s

Area Method: Mean Flow
Nav. Method: Bottom Track
MagVar Method: Model (18.6°)
Depth: Composite (BT)
Discharge Method: None
% Correction: 0.00
ADCP Depth: 0.091 m
Shore Ens.:10
Bottom Est: Power (0.1667)
Top Est: Power (0.1667)
Index Vel.: 0.00 m/s
Adj. Mean Vel: 0.00 m/s
Rated Area: 0.000 m²
Control1: Unspecified
Control2: Unspecified
Control3: Unspecified
Rating No.: 1
Qm Rating: U
Diff.: 0.000%

Screening Thresholds:
BT 3-Beam Solution: YES
WT 3-Beam Solution: YES
BT Error Vel.: 1.00 m/s
WT Error Vel.: 10.00 m/s
BT Up Vel.: 10.00 m/s
WT Up Vel.: 10.00 m/s
Use Weighted Mean Depth: YES

Max. Vel.: 2.82 m/s
Max. Depth: 1.37 m
Mean Depth: 0.889 m
% Meas.: 65.91
Water Temp.: 2.9 °C
ADCP Temp.: 1.8 °C

ADCP:
Type/Freq.: RiverPro/RioPro / 1200 kHz
Serial #: 1129 | Firmware: 56.03
Bin Size: 6 cm | Blank: 10 cm
BT Mode: Auto | BT Pings: Dyn
WT Mode: Auto | WT Pings: Dyn
WZ : 5

Performed Diag. Test: YES
Performed Moving Bed Test: YES
Performed Compass Calibration: NO Evaluation: NO
Meas. Location: at gauge

Project Name: dss3_20160523_ch1&2_q45.8cms
Software: 2.17

Tr.#		Edge Distance		#Ens.	Discharge						Width	Area	Time		Mean Vel.		% Bad	
		L	R		Top	Middle	Bottom	Left	Right	Total			Start	End	Boat	Water	Ens.	Bins
000	L	3.05	0.61	291	11.5	30.4	4.12	0.132	-0.019	46.1	122.0	107.9	13:20	13:22	0.75	0.43	0	1
001	R	2.44	0.61	280	11.2	30.1	4.17	0.123	-0.001	45.6	121.0	107.2	13:22	13:25	0.77	0.42	0	0
002	L	2.44	0.61	268	11.3	30.4	4.13	0.117	-0.003	45.9	120.5	107.9	13:25	13:27	0.81	0.43	0	0
003	R	2.13	0.61	284	11.3	30.1	4.25	0.094	-0.004	45.7	120.4	107.4	13:28	13:30	0.77	0.43	0	0
004	L	2.13	0.61	269	11.2	29.9	4.24	0.102	0.004	45.5	119.9	107.4	13:30	13:33	0.80	0.42	0	1
005	R	2.13	0.61	281	11.4	30.1	4.23	0.074	0.001	45.8	120.7	106.4	13:33	13:35	0.78	0.43	0	1
Mean		2.39	0.61	278	11.3	30.2	4.19	0.107	-0.004	45.8	120.8	107.4	**Total**	00:15	0.78	0.43	0	1
SDev		0.36	0.00	9	0.116	0.176	0.061	0.021	0.008	0.228	0.7	0.6			0.02	0.00		
SD/M		0.15	0.00	0.03	0.01	0.01	0.01	0.20	2.19	0.00	0.01	0.01			0.03	0.00		

Remarks: Q with River Pro 45.8 cms using BT with 0% error, bad GPS data. Total Q from 3 channels 215.5 cms.

Station Number: DSS3
Station Name: DSS3 Channel 3

Meas. No: 11
Date: 05/23/2016

Party: DB/JH/TT
Boat/Motor: 12' cataraft w/10 hp motor
Gauge Height: 288.99 m

Width: 95.6 m
Area: 108.4 m²
G.H.Change: 0.000 m

Processed by: DAV
Mean Velocity: 1.57 m/s
Discharge: 170 m³/s

Area Method: Mean Flow
Nav. Method: DGPS
MagVar Method: Model (18.6°)
Depth: Composite (BT)

ADCP Depth: 0.091 m
Shore Ens.:10
Bottom Est: Power (0.1667)
Top Est: Power (0.1667)

Index Vel.: 0.00 m/s
Adj. Mean Vel: 0.00 m/s
Rated Area: 0.000 m²
Control1: Unspecified
Control2: Unspecified
Control3: Unspecified

Rating No.: 1
Qm Rating: U
Diff.: 0.000%

Screening Thresholds:
BT 3-Beam Solution: YES
WT 3-Beam Solution: YES
BT Error Vel.: 1.00 m/s
WT Error Vel.: 10.00 m/s
BT Up Vel.: 10.00 m/s
WT Up Vel.: 10.00 m/s
Use Weighted Mean Depth: YES

Max. Vel.: 3.97 m/s
Max. Depth: 1.67 m
Mean Depth: 1.13 m
% Meas.: 70.19
Water Temp.: 0.9 °C
ADCP Temp.: 1.5 °C

ADCP:
Type/Freq.: RiverPro/RioPro / 1200 kHz
Serial #: 1129 Firmware: 56.03
Bin Size: 2 cm Blank: 10 cm
BT Mode: Auto BT Pings: Dyn
WT Mode: Auto WT Pings: Dyn
WZ : 5

Performed Diag. Test: YES
Performed Moving Bed Test: YES
Performed Compass Calibration: YES Evaluation: YES
Meas. Location: at gauge

Project Name: dss3_20160523_ch3_q169.7cms
Software: 2.17

Tr.#		Edge Distance		#Ens.	Discharge						Width	Area	Time		Mean Vel.		% Bad	
		L	R		Top	Middle	Bottom	Left	Right	Total			Start	End	Boat	Water	Ens.	Bins
000	L	1.52	1.22	243	32.5	115	18.7	0.148	0.058	166	91.0	101.9	12:40	12:42	0.64	1.63	0	0
001	R	1.22	1.22	244	31.8	118	19.0	0.054	0.076	169	96.6	108.7	12:43	12:45	0.63	1.55	0	0
002	L	1.22	1.22	245	31.6	120	18.6	0.033	0.052	170	95.7	108.8	12:45	12:48	0.60	1.57	0	0
003	R	1.22	1.22	254	30.7	118	18.5	0.026	0.066	167	97.2	111.6	12:48	12:51	0.60	1.50	0	0
004	L	1.22	1.22	244	31.7	120	18.8	0.035	0.075	171	96.4	109.3	12:51	12:53	0.61	1.56	0	0
005	R	1.22	1.22	258	32.1	123	18.7	0.049	0.073	174	96.5	109.8	12:54	12:56	0.59	1.58	0	0
Mean		1.27	1.22	248	31.7	119	18.7	0.058	0.067	170	95.6	108.4	**Total**	00:16	0.61	1.57	0	0
SDev		0.12	0.00	6	0.623	2.74	0.187	0.046	0.010	2.71	2.3	3.4			0.02	0.04		
SD/M		0.10	0.00	0.03	0.02	0.02	0.01	0.79	0.15	0.02	0.02	0.03			0.03	0.03		

Remarks: Q with River Pro 169.7 cms using VTG with 2% error, 173.2 cms using BT with 1% error. Total Q from 3 channels 215.5 cms.

Station Number: DSS2 Meas. No: 4
Station Name: DSS2 Channel 1 Date: 05/14/2016

Party: DB/JH/TT	Width: 32.6 m	Processed by: DAV
Boat/Motor: 12' cataraft w/10 hp motor	Area: 33.9 m²	Mean Velocity: 1.42 m/s
Gauge Height: 135.73 m	G.H.Change: 0.000 m	Discharge: 46.5 m³/s

Area Method: Mean Flow	ADCP Depth: 0.091 m	Index Vel.: 0.00 m/s	Rating No.: 1
Nav. Method: Bottom Track	Shore Ens.:10	Adj. Mean Vel: 0.00 m/s	Qm Rating: U
MagVar Method: Model (18.8°)	Bottom Est: Power (0.1667)	Rated Area: 0.000 m²	Diff.: 0.000%
Depth: Composite (BT)	Top Est: Power (0.1667)	Control1: Unspecified	
Discharge Method: None		Control2: Unspecified	
% Correction: 0.00		Control3: Unspecified	

Screening Thresholds:		ADCP:	
BT 3-Beam Solution: YES	Max. Vel.: 3.57 m/s	Type/Freq.: RiverPro/RioPro / 1200 kHz	
WT 3-Beam Solution: YES	Max. Depth: 2.81 m	Serial #: 1129	Firmware: 56.03
BT Error Vel.: 1.00 m/s	Mean Depth: 1.03 m	Bin Size: 2 cm	Blank: 10 cm
WT Error Vel.: 10.00 m/s	% Meas.: 64.05	BT Mode: Auto	BT Pings: Dyn
BT Up Vel.: 10.00 m/s	Water Temp.: 0.5 °C	WT Mode: Auto	WT Pings: Dyn
WT Up Vel.: 10.00 m/s	ADCP Temp.: 0.3 °C	WZ : 5	
Use Weighted Mean Depth: YES			

Performed Diag. Test: YES
Performed Moving Bed Test: NO
Performed Compass Calibration: NO Evaluation: NO
Meas. Location: at gauge

Project Name: dss2_20160514_ch1_q45cms
Software: 2.17

Tr.#		Edge Distance		#Ens.	Discharge						Width	Area	Time		Mean Vel.		% Bad	
		L	R		Top	Middle	Bottom	Left	Right	Total			Start	End	Boat	Water	Ens.	Bins
005	L	1.83	2.44	133	6.20	34.3	7.51	-0.176	0.083	47.9	37.9	48.4	14:40	14:42	0.45	0.99	24	0
006	R	1.83	2.44	153	5.77	35.3	7.63	-0.084	0.100	48.7	35.0	45.8	14:42	14:44	0.39	1.06	8	0
008	R	1.22	2.44	163	11.1	28.0	6.64	-0.332	0.119	45.5	31.1	29.2	14:47	14:49	0.58	1.56	2	1
009	L	1.22	2.44	132	12.2	27.3	7.11	-0.236	0.146	46.6	33.8	28.9	14:49	14:50	0.71	1.61	1	2
010	R	1.22	2.44	152	9.90	28.5	6.77	-0.423	0.184	44.9	29.4	28.3	14:50	14:52	0.60	1.59	1	0
011	L	1.22	2.44	123	10.3	28.6	7.01	-0.331	0.179	45.7	32.2	32.9	14:52	14:54	0.71	1.39	0	2
012	R	1.22	2.44	157	10.2	28.1	7.55	-0.171	0.172	45.9	29.2	28.2	14:54	14:56	0.53	1.63	1	1
013	L	1.22	2.44	112	11.0	28.2	7.74	-0.345	0.174	46.8	31.9	29.9	14:56	14:57	0.79	1.57	4	2
Mean		1.37	2.44	140	9.59	29.8	7.24	-0.262	0.145	46.5	32.6	33.9	**Total**	00:16	0.60	1.42	5	1
SDev		0.28	0.00	18	2.34	3.12	0.419	0.114	0.039	1.27	2.9	8.3			0.14	0.26		
SD/M		0.21	0.00	0.13	0.24	0.10	0.06	0.43	0.27	0.03	0.09	0.24			0.23	0.18		

Remarks: Q with River Pro 45 cms using VTG with 6% error, 46.5 cms using BT with 3% error. Total Q from 5 channels 850 cms.

Station Number: DSS2 | Meas. No: 4
Station Name: DSS2 Channel 2 | Date: 05/14/2016

Party: DB/JH/TT
Boat/Motor: 12' cataraft w/10 hp motor
Gauge Height: 135.73 m

Width: 73.7 m
Area: 80.7 m²
G.H.Change: 0.000 m

Processed by: DAV
Mean Velocity: 0.780 m/s
Discharge: 62.9 m³/s

Area Method: Mean Flow
Nav. Method: DGPS
MagVar Method: Model (18.8°)
Depth: Composite (BT)

ADCP Depth: 0.091 m
Shore Ens.:10
Bottom Est: Power (0.1667)
Top Est: Power (0.1667)

Index Vel.: 0.00 m/s | Rating No.: 1
Adj. Mean Vel: 0.00 m/s | Qm Rating: U
Rated Area: 0.000 m² | Diff.: 0.000%
Control1: Unspecified
Control2: Unspecified
Control3: Unspecified

Screening Thresholds:
BT 3-Beam Solution: YES
WT 3-Beam Solution: YES
BT Error Vel.: 1.00 m/s
WT Error Vel.: 10.00 m/s
BT Up Vel.: 10.00 m/s
WT Up Vel.: 10.00 m/s
Use Weighted Mean Depth: YES

Max. Vel.: 2.61 m/s
Max. Depth: 1.49 m
Mean Depth: 1.10 m
% Meas.: 72.12
Water Temp.: 0.3 °C
ADCP Temp.: 0.2 °C

ADCP:
Type/Freq.: RiverPro/RioPro / 1200 kHz
Serial #: 1129 | Firmware: 56.03
Bin Size: 2 cm | Blank: 10 cm
BT Mode: Auto | BT Pings: Dyn
WT Mode: Auto | WT Pings: Dyn
WZ : 5

Performed Diag. Test: YES
Performed Moving Bed Test: NO
Performed Compass Calibration: NO   Evaluation: NO
Meas. Location: at gauge

Project Name: dss2_20160514_ch2_q65cms
Software: 2.17

Tr.#		Edge Distance		#Ens.	Discharge						Width	Area	Time		Mean Vel.		% Bad	
		L	R		Top	Middle	Bottom	Left	Right	Total			Start	End	Boat	Water	Ens.	Bins
000	R	0.91	6.10	205	11.7	46.1	5.77	0.007	0.167	63.7	72.9	80.3	14:00	14:02	0.56	0.79	0	0
001	L	0.91	4.57	181	11.5	45.2	5.60	-0.017	0.092	62.4	74.1	82.1	14:02	14:04	0.64	0.76	0	0
002	*R*	*0.91*	*4.57*	*166*	*11.2*	*42.7*	*5.58*	*0.031*	*0.069*	*59.5*	*73.3*	*81.2*	*14:04*	*14:06*	*0.72*	*0.73*	*1*	*0*
003	L	0.91	4.57	183	12.1	46.8	5.95	0.032	0.069	64.9	74.2	81.6	14:07	14:08	0.64	0.80	0	0
004	R	0.91	4.57	189	12.0	45.9	5.77	0.056	0.058	63.8	74.1	81.1	14:09	14:10	0.65	0.79	0	0
005	L	0.91	4.57	211	12.2	45.8	5.79	0.020	0.051	63.8	73.9	79.9	14:11	14:13	0.57	0.80	0	0
006	R	0.91	4.57	180	11.7	45.6	5.42	0.024	0.064	62.9	73.7	79.7	14:13	14:15	0.71	0.79	1	0
007	L	0.91	4.57	198	11.5	44.9	5.75	0.014	0.055	62.3	73.1	79.7	14:15	14:17	0.60	0.78	1	0
Mean		0.91	4.76	189	11.7	45.4	5.70	0.021	0.078	62.9	73.7	80.7	**Total**	00:17	0.64	0.78	0	0
SDev		0.00	0.54	15	0.344	1.24	0.164	0.021	0.038	1.64	0.5	0.9			0.06	0.02		
SD/M		0.00	0.11	0.08	0.03	0.03	0.03	1.02	0.49	0.03	0.01	0.01			0.09	0.03		

Remarks: Q with River Pro 63 cms using VTG with 3% error, 65 cms using BT with 2% error. Total Q from 5 channels 850 cms

Discharge for transects in *italics* have a total Q more than 5% from the mean.

Station Number: DSS2 Meas. No: 4
Station Name: DSS2 Channel 3 Date: 05/14/2016

Party: DB/JH/TT
Boat/Motor: 12' cataraft w/10 hp motor
Gauge Height: 135.73 m

Width: 499.3 m
Area: 355.7 m²
G.H.Change: 0.000 m

Processed by: DAV
Mean Velocity: 1.60 m/s
Discharge: 568 m³/s

Area Method: Mean Flow
Nav. Method: DGPS
MagVar Method: Model (18.8°)
Depth: Composite (BT)

ADCP Depth: 0.091 m
Shore Ens.:10
Bottom Est: Power (0.1667)
Top Est: Power (0.1667)

Index Vel.: 0.00 m/s Rating No.: 1
Adj. Mean Vel: 0.00 m/s Qm Rating: U
Rated Area: 0.000 m² Diff.: 0.000%
Control1: Unspecified
Control2: Unspecified
Control3: Unspecified

Screening Thresholds:
BT 3-Beam Solution: YES
WT 3-Beam Solution: YES
BT Error Vel.: 1.00 m/s
WT Error Vel.: 10.00 m/s
BT Up Vel.: 10.00 m/s
WT Up Vel.: 10.00 m/s
Use Weighted Mean Depth: YES

Max. Vel.: 7.49 m/s
Max. Depth: 1.22 m
Mean Depth: 0.712 m
% Meas.: 56.24
Water Temp.: 0.1 °C
ADCP Temp.: 0.1 °C

ADCP:
Type/Freq.: RiverPro/RioPro / 1200 kHz
Serial #: 1129 Firmware: 56.03
Bin Size: 2 cm Blank: 10 cm
BT Mode: Auto BT Pings: Dyn
WT Mode: Auto WT Pings: Dyn
WZ : 5

Performed Diag. Test: YES
Performed Moving Bed Test: NO
Performed Compass Calibration: YES Evaluation: YES
Meas. Location: at gauge

Project Name: dss2_20160514_ch3_q568cms
Software: 2.17

Tr.#		Edge Distance		#Ens.	Discharge						Width	Area	Time		Mean Vel.		% Bad	
		L	R		Top	Middle	Bottom	Left	Right	Total			Start	End	Boat	Water	Ens.	Bins
000	L	12.2	15.2	911	168	310	74.0	0.377	-0.968	552	497.2	347.4	11:22	11:32	0.96	1.59	1	0
001	R	15.2	15.2	838	173	327	78.9	-0.017	-0.631	578	500.9	358.0	11:32	11:41	1.04	1.61	1	0
002	L	15.2	15.2	753	170	310	76.5	-0.071	0.866	558	495.9	344.8	11:41	11:49	1.11	1.62	0	0
003	R	15.2	15.2	782	169	331	83.1	-0.080	1.06	585	503.3	372.8	11:49	11:57	1.11	1.57	1	0
Mean		14.5	15.2	821	170	319	78.1	0.052	0.082	568	499.3	355.7	**Total**	00:34	1.06	1.60	1	0
SDev		1.52	0.00	70	1.98	11.0	3.91	0.218	1.03	15.7	3.4	12.7			0.07	0.02		
SD/M		0.11	0.00	0.08	0.01	0.03	0.05	4.18	12.56	0.03	0.01	0.04			0.07	0.01		

Remarks: Q with River Pro 568 cms using VTG with 3% error, 592 cms using BT with 2% error. Total Q from 5 channels 850 cms.

Station Number: DSS2 Meas. No: 4

Station Name: DSS2 Channel 4 Date: 05/14/2016

Party: DB/JH/TT	Width: 112.7 m	Processed by: DAV
Boat/Motor: 12' cataraft w/10 hp motor	Area: 82.2 m²	Mean Velocity: 0.587 m/s
Gauge Height: 135.73 m	G.H.Change: 0.000 m	Discharge: 48.3 m³/s

Area Method: Mean Flow	ADCP Depth: 0.091 m	Index Vel.: 0.00 m/s	Rating No.: 1
Nav. Method: DGPS	Shore Ens.:10	Adj. Mean Vel: 0.00 m/s	Qm Rating: U
MagVar Method: Model (18.8°)	Bottom Est: Power (0.1667)	Rated Area: 0.000 m²	Diff.: 0.000%
Depth: Composite (BT)	Top Est: Power (0.1667)	Control1: Unspecified	
		Control2: Unspecified	
		Control3: Unspecified	

Screening Thresholds:		ADCP:	
BT 3-Beam Solution: YES	Max. Vel.: 4.05 m/s	Type/Freq.: RiverPro/RioPro / 1200 kHz	
WT 3-Beam Solution: YES	Max. Depth: 80.2 m	Serial #: 1129	Firmware: 56.03
BT Error Vel.: 1.00 m/s	Mean Depth: 0.730 m	Bin Size: 6 cm	Blank: 10 cm
WT Error Vel.: 10.00 m/s	% Meas.: 65.55	BT Mode: Auto	BT Pings: Dyn
BT Up Vel.: 10.00 m/s	Water Temp.: 0.4 °C	WT Mode: Auto	WT Pings: Dyn
WT Up Vel.: 10.00 m/s	ADCP Temp.: 0.2 °C	WZ : 5	
Use Weighted Mean Depth: YES			

Performed Diag. Test: YES

Performed Moving Bed Test: NO

Performed Compass Calibration: NO Evaluation: NO

Meas. Location: at gauge

Project Name: dss2_20160514_ch4_q48cms

Software: 2.17

Tr.#		Edge Distance		#Ens.	Discharge						Width	Area	Time		Mean Vel.		% Bad	
		L	R		Top	Middle	Bottom	Left	Right	Total			Start	End	Boat	Water	Ens.	Bins
000	R	3.05	15.2	283	10.3	32.2	5.13	0.343	0.146	48.1	112.6	82.6	13:21	13:24	0.59	0.58	0	4
001	L	3.05	15.2	224	10.7	31.9	5.10	0.334	-0.007	48.1	112.5	82.1	13:24	13:26	0.79	0.58	0	3
002	R	3.05	15.2	272	10.6	31.0	5.24	0.319	0.410	47.6	115.2	84.4	13:26	13:29	0.62	0.56	6	3
003	L	3.05	15.2	229	11.7	33.3	5.72	0.247	0.248	51.1	112.0	82.9	13:30	13:32	0.77	0.62	1	3
004	R	3.05	15.2	263	10.5	30.0	5.35	0.257	0.372	46.5	112.3	81.6	13:32	13:35	0.63	0.57	0	3
005	L	3.05	15.2	251	11.3	32.8	5.96	0.214	-0.243	50.1	113.0	83.2	13:35	13:38	0.70	0.60	3	3
006	R	3.05	15.2	266	10.8	30.0	5.45	0.314	-0.397	46.1	112.4	80.0	13:38	13:41	0.64	0.58	2	4
007	L	3.05	15.2	224	10.6	32.2	5.30	0.280	0.415	48.8	111.8	81.1	13:41	13:43	0.76	0.60	0	3
Mean		3.05	15.2	251	10.8	31.7	5.40	0.289	0.118	48.3	112.7	82.2	**Total**	00:21	0.69	0.59	2	3
SDev		0.00	0.00	23	0.450	1.23	0.297	0.046	0.309	1.70	1.1	1.4			0.08	0.02		
SD/M		0.00	0.00	0.09	0.04	0.04	0.06	0.16	2.62	0.04	0.01	0.02			0.11	0.03		

Remarks: Q with River Pro 48 cms using VTG with 4% error, 51 cms using BT with 2% error. Total Q from 5 channels 850 cms

Discharge for transects in *italics* have a total Q more than 5% from the mean.

Station Number: DSS2 | Meas. No: 4
Station Name: DSS2 Channel 5 | Date: 05/14/2016

Party: DB/JH/TT
Boat/Motor: 12' cataraft w/10 hp motor
Gauge Height: 135.73 m

Width: 73.5 m
Area: 72.5 m²
G.H.Change: 0.000 m

Processed by: DAV
Mean Velocity: 1.72 m/s
Discharge: 124 m³/s

Area Method: Mean Flow
Nav. Method: DGPS
MagVar Method: None (18.8°)
Depth: Composite (BT)

ADCP Depth: 0.091 m
Shore Ens.:10
Bottom Est: Power (0.1667)
Top Est: Power (0.1667)

Index Vel.: 0.00 m/s | Rating No.: 1
Adj. Mean Vel: 0.00 m/s | Qm Rating: U
Rated Area: 0.000 m² | Diff.: 0.000%
Control1: Unspecified
Control2: Unspecified
Control3: Unspecified

Screening Thresholds:
BT 3-Beam Solution: YES
WT 3-Beam Solution: YES
BT Error Vel.: 1.00 m/s
WT Error Vel.: 10.00 m/s
BT Up Vel.: 10.00 m/s
WT Up Vel.: 10.00 m/s
Use Weighted Mean Depth: YES

Max. Vel.: 4.78 m/s
Max. Depth: 1.62 m
Mean Depth: 0.986 m
% Meas.: 67.58
Water Temp.: 0.1 °C
ADCP Temp.: 0.2 °C

ADCP:
Type/Freq.: RiverPro/RioPro / 1200 kHz
Serial #: 1129 | Firmware: 56.03
Bin Size: 6 cm | Blank: 10 cm
BT Mode: Auto | BT Pings: Dyn
WT Mode: Auto | WT Pings: Dyn
WZ : 5

Performed Diag. Test: YES
Performed Moving Bed Test: NO
Performed Compass Calibration: NO   Evaluation: NO
Meas. Location: at gauge

Project Name: dss2_20160515_ch5_q125cms
Software: 2.17

Tr.#		Edge Distance		#Ens.	Discharge						Width	Area	Time		Mean Vel.		% Bad	
		L	R		Top	Middle	Bottom	Left	Right	Total			Start	End	Boat	Water	Ens.	Bins
000	*R*	*3.05*	*3.05*	*213*	*26.1*	*90.0*	*16.8*	*0.184*	*0.332*	*133*	*72.7*	*71.9*	*12:40*	*12:42*	*0.58*	*1.86*	*0*	*0*
001	L	*3.05*	*3.05*	*204*	*25.1*	*86.5*	*15.2*	*0.175*	*0.114*	*127*	*75.2*	*73.7*	*12:42*	*12:45*	*0.65*	*1.73*	*0*	*0*
002	R	*3.05*	*3.05*	*208*	*23.6*	*80.3*	*14.3*	*0.143*	*0.193*	*119*	*74.1*	*73.1*	*12:45*	*12:47*	*0.60*	*1.62*	*0*	*0*
003	L	*3.05*	*3.05*	*169*	*24.2*	*84.8*	*15.7*	*0.126*	*0.279*	*125*	*73.0*	*72.9*	*12:47*	*12:49*	*0.69*	*1.72*	*0*	*0*
004	R	*3.05*	*3.05*	*194*	*24.7*	*84.1*	*15.5*	*0.136*	*0.284*	*125*	*73.3*	*72.1*	*12:49*	*12:51*	*0.58*	*1.73*	*1*	*0*
005	L	*3.05*	*3.05*	*173*	*24.4*	*85.7*	*15.9*	*0.200*	*0.189*	*126*	*71.5*	*71.0*	*12:51*	*12:53*	*0.59*	*1.78*	*1*	*0*
007	L	*3.05*	*3.05*	*185*	*24.2*	*82.3*	*16.2*	*0.159*	*0.320*	*123*	*74.7*	*73.0*	*12:56*	*12:58*	*0.62*	*1.69*	*0*	*0*
008	*R*	*3.05*	*3.05*	*195*	*23.3*	*79.1*	*14.5*	*0.083*	*0.249*	*117*	*73.7*	*72.5*	*12:59*	*13:01*	*0.65*	*1.62*	*2*	*0*
Mean		3.05	3.05	192	24.4	84.1	15.5	0.151	0.245	124	73.5	72.5	**Total**	00:20	0.62	1.72	0	0
SDev		0.00	0.00	16	0.862	3.51	0.832	0.037	0.075	5.06	1.2	0.8			0.04	0.08		
SD/M		0.00	0.00	0.08	0.04	0.04	0.05	0.25	0.30	0.04	0.02	0.01			0.06	0.05		

Remarks: Q with River Pro 125 cms using VTG with 4% error, 129 cms using BT with 2% error. Total Q from 5 channels 850 cms.

Discharge for transects in *italics* have a total Q more than 5% from the mean.

Station Number: Sag MP380
Station Name: Sag MP380

Meas. No: 9
Date: 05/15/2016

Party: HT/JK
Boat/Motor: 12' zodiac/10 hp Honda
Gauge Height: 58.15 m

Width: 330.1 m
Area: 282.8 m²
G.H.Change: 0.000 m

Processed by: DAV
Mean Velocity: 1.74 m/s
Discharge: 493 m³/s

Area Method: Mean Flow
Nav. Method: DGPS
MagVar Method: None (18.8°)
Depth: Composite (BT)

ADCP Depth: 0.200 m
Shore Ens.:10
Bottom Est: Power (0.1667)
Top Est: Power (0.1667)

Index Vel.: 0.00 m/s
Adj. Mean Vel: 0.00 m/s
Rated Area: 0.000 m²
Control1: Unspecified
Control2: Unspecified
Control3: Unspecified

Rating No.: 1
Qm Rating: U
Diff.: 0.000%

Screening Thresholds:
BT 3-Beam Solution: YES
WT 3-Beam Solution: YES
BT Error Vel.: 1.00 m/s
WT Error Vel.: 10.00 m/s
BT Up Vel.: 10.00 m/s
WT Up Vel.: 10.00 m/s
Use Weighted Mean Depth: YES

Max. Vel.: 5.12 m/s
Max. Depth: 1.63 m
Mean Depth: 0.860 m
% Meas.: 42.40
Water Temp.: None
ADCP Temp.: 0.9 °C

ADCP:
Type/Freq.: RiverPro/RioPro / 1200 kHz
Serial #: 12813 Firmware: 56.03
Bin Size: 6 cm Blank: 10 cm
BT Mode: Auto BT Pings: Dyn
WT Mode: Auto WT Pings: Dyn
WZ : 5

Performed Diag. Test: YES
Performed Moving Bed Test: YES
Performed Compass Calibration: YES Evaluation: YES
Meas. Location: MP380

Project Name: sagmp380_20160515q545cms
Software: 2.17

Tr.#		Edge Distance		#Ens.	Discharge						Width	Area	Time		Mean Vel.		% Bad	
		L	R		Top	Middle	Bottom	Left	Right	Total			Start	End	Boat	Water	Ens.	Bins
000	L	12.0	130	864	120	238	51.7	2.97	105	518	315.6	291.6	13:36	13:46	0.54	1.77	3	0
001	R	5.00	144	508	119	181	44.0	3.88	122	469	344.6	274.0	13:47	13:52	0.78	1.71	4	1
Mean		8.50	137	686	119	209	47.9	3.42	114	493	330.1	282.8	**Total**	00:15	0.66	1.74	3	1
SDev		4.95	9.90	252	1.23	40.1	5.44	0.643	11.9	34.2	20.4	12.5			0.17	0.04		
SD/M		0.58	0.07	0.37	0.01	0.19	0.11	0.19	0.10	0.07	0.06	0.04			0.26	0.03		

Remarks: Q with RioPro 494 cms using VTG with 7% error, 497 cms using BT with 7% error. Total Q 545 cms (495 + 50 cms estimated from a small stream).

Station Number: DSS5
Station Name: DSS5

Meas. No: 10
Date: 05/19/2016

Party: HT/JK	Width: 323.1 m	Processed by: DAV
Boat/Motor: Helo	Area: 244.3 m²	Mean Velocity: 1.29 m/s
Gauge Height: 57.92 m	G.H.Change: 0.000 m	Discharge: 311 m³/s

Area Method: Mean Flow	ADCP Depth: 0.060 m	Index Vel.: 0.00 m/s	Rating No.: 1
Nav. Method: DGPS	Shore Ens.:10	Adj. Mean Vel: 0.00 m/s	Qm Rating: U
MagVar Method: Model (18.8°)	Bottom Est: Power (0.1667)	Rated Area: 0.000 m²	Diff.: 0.000%
Depth: Composite (BT)	Top Est: Power (0.1667)	Control1: Unspecified	
		Control2: Unspecified	
		Control3: Unspecified	

Screening Thresholds:		ADCP:	
BT 3-Beam Solution: YES	Max. Vel.: 7.67 m/s	Type/Freq.: RiverPro/RioPro / 1200 kHz*	
WT 3-Beam Solution: YES	Max. Depth: 1.95 m	Serial #: 12813	Firmware: 56.03*
BT Error Vel.: 0.10 m/s*	Mean Depth: 0.772 m	Bin Size: 6 cm	Blank: 10 cm
WT Error Vel.: 10.00 m/s	% Meas.: 64.69	BT Mode: Auto	BT Pings: Dyn
BT Up Vel.: 10.00 m/s	Water Temp.: None	WT Mode: Auto	WT Pings: Dyn
WT Up Vel.: 10.00 m/s	ADCP Temp.: 1.7 °C	WZ : 5	
Use Weighted Mean Depth: YES			

Performed Diag. Test: YES
Performed Moving Bed Test: NO
Performed Compass Calibration: YES Evaluation: YES

Project Name: sageast20160519q311cms
Software: 2.17

Meas. Location: Sag East Bank

Tr.#		Edge Distance		#Ens.	Discharge						Width	Area	Time		Mean Vel.		% Bad	
		L	R		Top	Middle	Bottom	Left	Right	Total			Start	End	Boat	Water	Ens.	Bins
002	L	7.00	5.00	1591	85.0	194	34.5	7.73	1.90	323	358.7	224.4	12:50	13:05	0.68	1.44	6	1
001	R	7.00	5.00	805	60.1	209	27.7	1.20	1.57	300	287.5	264.2	13:12	13:19	0.78	1.13	0	0
Mean		7.00	5.00	1198	72.6	201	31.1	4.47	1.73	311	323.1	244.3	**Total**	00:29	0.73	1.29	3	0
SDev		0.00	0.00	556	17.6	11.0	4.82	4.62	0.231	16.3	50.4	28.1			0.07	0.21		
SD/M		0.00	0.00	0.46	0.24	0.05	0.15	1.03	0.13	0.05	0.16	0.11			0.10	0.17		

Remarks: Q with RioPro 311 cms using VTG with 5% error, 318 cms using BT with 2% error.

Station Number: DSS5

Station Name: DSS5

Meas. No: 11

Date: 05/20/2016

Party: HT/JK	Width: 282.6 m	Processed by: DAV
Boat/Motor: Helo	Area: 280.0 m²	Mean Velocity: 1.47 m/s
Gauge Height: 57.96 m	G.H.Change: 0.000 m	Discharge: 412 m³/s

Area Method: Mean Flow	ADCP Depth: 0.060 m	Index Vel.: 0.00 m/s	Rating No.: 1
Nav. Method: Bottom Track	Shore Ens.:10	Adj. Mean Vel: 0.00 m/s	Qm Rating: U
MagVar Method: Model (18.8°)	Bottom Est: Power (0.1667)	Rated Area: 0.000 m²	Diff.: 0.000%
Depth: Composite (BT)	Top Est: Power (0.1667)	Control1: Unspecified	
Discharge Method: None		Control2: Unspecified	
% Correction: 0.00		Control3: Unspecified	

Screening Thresholds:		ADCP:	
BT 3-Beam Solution: YES	Max. Vel.: 3.44 m/s	Type/Freq.: RiverPro/RioPro / 1200 kHz	
WT 3-Beam Solution: YES	Max. Depth: 1.53 m	Serial #: 12813	Firmware: 56.03
BT Error Vel.: 1.00 m/s	Mean Depth: 0.991 m	Bin Size: 6 cm	Blank: 10 cm
WT Error Vel.: 10.00 m/s	% Meas.: 68.36	BT Mode: Auto	BT Pings: Dyn
BT Up Vel.: 10.00 m/s	Water Temp.: None	WT Mode: Auto	WT Pings: Dyn
WT Up Vel.: 10.00 m/s	ADCP Temp.: 1.6 °C	WZ : 5	
Use Weighted Mean Depth: YES			

Performed Diag. Test: YES

Performed Moving Bed Test: NO

Performed Compass Calibration: NO* Evaluation: NO*

Project Name: sageast20160520q412cms

Software: 2.17

Meas. Location: Sag East Bank

Tr.#		Edge Distance		#Ens.	Discharge						Width	Area	Time		Mean Vel.		% Bad	
		L	R		Top	Middle	Bottom	Left	Right	Total			Start	End	Boat	Water	Ens.	Bins
002	R	5.00	15.0	369	70.3	261	42.5	2.52	15.1	392	293.2	288.6	12:48	12:51	1.62	1.36	11	0
003	L	7.00	7.00	344	77.5	299	43.7	3.40	7.18	431	281.4	276.2	12:52	12:55	1.70	1.56	0	0
004	R	5.00	7.00	275	74.0	285	48.0	2.18	4.88	414	273.2	275.1	12:57	13:00	1.85	1.51	5	0
Mean		5.67	9.67	329	73.9	282	44.8	2.70	9.05	412	282.6	280.0	**Total**	00:12	1.72	1.47	5	0
SDev		1.15	4.62	49	3.63	19.1	2.88	0.632	5.36	19.6	10.1	7.5			0.12	0.11		
SD/M		0.20	0.48	0.15	0.05	0.07	0.06	0.23	0.59	0.05	0.04	0.03			0.07	0.07		

Remarks: Q with RioPro 357 cms using VTG with 13% error, 412 cms using BT with 5% error. Use BT; VTG has strong directional bias.

*Compass calibration and evaluation were not necessary because the instrument's compass was previously calibrated and evaluated at this location (the instrument was in place).

Station Number: DSS5
Station Name: DSS5

Meas. No: 12
Date: 05/21/2016

Party: HT/JK	Width: 301.4 m	Processed by: DAV
Boat/Motor: Helo	Area: 322.4 m²	Mean Velocity: 1.44 m/s
Gauge Height: 57.94 m	G.H.Change: 0.000 m	Discharge: 465 m³/s

Area Method: Mean Flow	ADCP Depth: 0.060 m	Index Vel.: 0.00 m/s	Rating No.: 1
Nav. Method: DGPS	Shore Ens.:10	Adj. Mean Vel: 0.00 m/s	Qm Rating: U
MagVar Method: Model (18.8°)	Bottom Est: Power (0.1667)	Rated Area: 0.000 m²	Diff.: 0.000%
Depth: Composite (BT)	Top Est: Power (0.1667)	Control1: 2-Ice Anchor	
		Control2: Unspecified	
		Control3: Unspecified	

Screening Thresholds:		ADCP:	
BT 3-Beam Solution: YES	Max. Vel.: 7.65 m/s	Type/Freq.: RiverPro/RioPro / 1200 kHz	
WT 3-Beam Solution: YES	Max. Depth: 1.79 m	Serial #: 12813	Firmware: 56.03
BT Error Vel.: 1.00 m/s	Mean Depth: 1.07 m	Bin Size: 6 cm	Blank: 10 cm
WT Error Vel.: 10.00 m/s	% Meas.: 72.05	BT Mode: Auto	BT Pings: Dyn
BT Up Vel.: 10.00 m/s	Water Temp.: None	WT Mode: Auto	WT Pings: Dyn
WT Up Vel.: 10.00 m/s	ADCP Temp.: 1.3 °C	WZ : 5	
Use Weighted Mean Depth: YES			

Performed Diag. Test: YES
Performed Moving Bed Test: YES
Performed Compass Calibration: NO* Evaluation: NO*

Project Name: sageast20160521q465cms
Software: 2.17

Meas. Location: Sag East Bank

Tr.#		Edge Distance		#Ens.	Discharge						Width	Area	Time		Mean Vel.		% Bad	
		L	R		Top	Middle	Bottom	Left	Right	Total			Start	End	Boat	Water	Ens.	Bins
001	L	10.0	5.00	578	76.8	323	32.9	2.37	3.94	439	305.2	314.0	10:18	10:24	1.09	1.40	3	0
002	R	7.00	5.00	516	78.2	336	49.0	2.78	2.84	469	299.8	326.3	10:26	10:32	1.27	1.44	0	0
003	L	7.00	5.00	635	79.3	343	49.5	2.76	4.40	479	297.2	324.3	10:33	10:39	0.99	1.48	0	0
004	R	5.00	7.00	602	80.0	339	50.3	1.90	3.16	475	303.3	325.2	10:41	10:47	1.21	1.46	0	0
Mean		7.25	5.50	582	78.6	335	45.4	2.45	3.59	465	301.4	322.4	**Total**	00:29	1.14	1.44	1	0
SDev		2.06	1.00	50	1.39	8.53	8.36	0.412	0.713	17.9	3.6	5.7			0.13	0.03		
SD/M		0.28	0.18	0.09	0.02	0.03	0.18	0.17	0.20	0.04	0.01	0.02			0.11	0.02		

Remarks: Q with RioPro 465 cms using VTG with 4% error, 518 cms using BT with 2% error.

*Compass calibration and evaluation were not necessary because the instrument's compass was previously calibrated and evaluated at this location (the instrument was in place).

Station Number: DSS5
Station Name: DSS5

Meas. No: 13
Date: 05/24/2016

Party: HT/JK	Width: 308.8 m	Processed by: DAV
Boat/Motor: Helo	Area: 281.7 m²	Mean Velocity: 1.56 m/s
Gauge Height: 57.91 m	G.H.Change: 0.000 m	Discharge: 435 m³/s

Area Method: Mean Flow	ADCP Depth: 0.060 m	Index Vel.: 0.00 m/s	Rating No.: 1
Nav. Method: DGPS	Shore Ens.:10	Adj. Mean Vel: 0.00 m/s	Qm Rating: U
MagVar Method: Model (18.8°)	Bottom Est: Power (0.1667)	Rated Area: 0.000 m²	Diff.: 0.000%
Depth: Composite (BT)	Top Est: Power (0.1667)	Control1: Unspecified	
		Control2: Unspecified	
		Control3: Unspecified	

Screening Thresholds:		ADCP:	
BT 3-Beam Solution: YES	Max. Vel.: 4.45 m/s	Type/Freq.: RiverPro/RioPro / 1200 kHz	
WT 3-Beam Solution: YES	Max. Depth: 2.08 m	Serial #: 12813	Firmware: 56.03
BT Error Vel.: 1.00 m/s	Mean Depth: 0.916 m	Bin Size: 6 cm	Blank: 10 cm
WT Error Vel.: 10.00 m/s	% Meas.: 69.89	BT Mode: Auto	BT Pings: Dyn
BT Up Vel.: 10.00 m/s	Water Temp.: None	WT Mode: Auto	WT Pings: Dyn
WT Up Vel.: 10.00 m/s	ADCP Temp.: 1.5 °C	WZ : 5	
Use Weighted Mean Depth: YES			

Performed Diag. Test: YES
Performed Moving Bed Test: YES
Performed Compass Calibration: NO* Evaluation: NO*

Project Name: sageast20160524q435cms
Software: 2.17

Meas. Location: Sag East Bank

Tr.#		Edge Distance		#Ens.	Discharge						Width	Area	Time		Mean Vel.		% Bad	
		L	R		Top	Middle	Bottom	Left	Right	Total			Start	End	Boat	Water	Ens.	Bins
000	R	5.00	5.00	667	77.2	304	51.5	0.363	2.54	436	291.8	289.9	15:36	15:42	0.97	1.50	4	0
001	L	7.00	5.00	480	78.2	313	50.4	4.84	2.15	448	283.0	253.5	15:45	15:50	1.29	1.77	0	0
002	R	4.00	7.00	503	69.1	295	48.9	4.60	3.11	421	351.6	301.6	15:53	15:57	1.31	1.40	0	1
Mean		5.33	5.67	550	74.8	304	50.3	3.27	2.60	435	308.8	281.7	**Total**	00:21	1.19	1.56	2	0
SDev		1.53	1.15	102	4.99	8.90	1.28	2.52	0.481	13.9	37.4	25.1			0.19	0.19		
SD/M		0.29	0.20	0.19	0.07	0.03	0.03	0.77	0.19	0.03	0.12	0.09			0.16	0.12		

Remarks: Q with RioPro 435 cms using VTG with 3% error, 455 cms using BT with 1% error.

*Compass calibration and evaluation were not necessary because the instrument's compass was previously calibrated and evaluated at this location (the instrument was in place).

Station Number: DSS5
Station Name: DSS5

Meas. No: 14
Date: 05/26/2016

Party: HT/JK	Width: 263.7 m	Processed by: DAV
Boat/Motor: Helo	Area: 264.1 m²	Mean Velocity: 1.46 m/s
Gauge Height: 57.91 m	G.H.Change: 0.000 m	Discharge: 378 m³/s

Area Method: Mean Flow	ADCP Depth: 0.060 m	Index Vel.: 0.00 m/s	Rating No.: 1
Nav. Method: DGPS	Shore Ens.:10	Adj. Mean Vel: 0.00 m/s	Qm Rating: U
MagVar Method: Model (18.8°)	Bottom Est: Power (0.1667)	Rated Area: 0.000 m²	Diff.: 0.000%
Depth: Composite (BT)	Top Est: Power (0.1667)	Control1: 14-Shore Ice	
		Control2: Unspecified	
		Control3: Unspecified	

Screening Thresholds:		ADCP:	
BT 3-Beam Solution: YES	Max. Vel.: 4.25 m/s	Type/Freq.: RiverPro/RioPro / 1200 kHz	
WT 3-Beam Solution: YES	Max. Depth: 2.39 m	Serial #: 12813	Firmware: 56.03
BT Error Vel.: 1.00 m/s	Mean Depth: 0.998 m	Bin Size: 6 cm	Blank: 10 cm
WT Error Vel.: 10.00 m/s	% Meas.: 70.57	BT Mode: Auto	BT Pings: Dyn
BT Up Vel.: 10.00 m/s	Water Temp.: None	WT Mode: Auto	WT Pings: Dyn
WT Up Vel.: 10.00 m/s	ADCP Temp.: 1.4 °C	WZ : 5	
Use Weighted Mean Depth: YES			

Performed Diag. Test: YES
Performed Moving Bed Test: YES
Performed Compass Calibration: NO* Evaluation: NO*

Project Name: sageast20160526q378cms
Software: 2.17

Meas. Location: Sag East Bank

Tr.#		Edge Distance		#Ens.	Discharge						Width	Area	Time		Mean Vel.		% Bad	
		L	R		Top	Middle	Bottom	Left	Right	Total			Start	End	Boat	Water	Ens.	Bins
000	L	5.00	7.00	387	63.8	263	43.3	1.54	2.38	374	230.6	228.3	11:36	11:40	1.26	1.64	1	0
001	R	5.00	7.00	360	58.7	264	43.6	1.72	1.94	370	292.5	309.9	11:43	11:47	1.51	1.19	0	0
002	L	3.00	5.00	435	68.6	263	44.1	0.515	1.31	377	246.8	224.8	11:47	11:52	1.19	1.68	0	0
003	R	3.00	7.00	325	66.3	276	45.0	0.878	0.894	389	284.7	293.6	11:54	11:57	1.51	1.33	0	0
Mean		4.00	6.50	376	64.3	267	44.0	1.16	1.63	378	263.7	264.1	**Total**	00:20	1.37	1.46	0	0
SDev		1.15	1.00	46	4.22	6.49	0.721	0.562	0.658	8.23	29.7	43.9			0.17	0.24		
SD/M		0.29	0.15	0.12	0.07	0.02	0.02	0.48	0.40	0.02	0.11	0.17			0.12	0.16		

Remarks: Q with RioPro 378 cms using VTG with 2% error, 397 cms using BT with 1% error.

*Compass calibration and evaluation were not necessary because the instrument's compass was previously calibrated and evaluated at this location (the instrument was in place).

Station Number: DSS5
Station Name: DSS5

Meas. No: 15
Date: 05/27/2016

Party: HT/JK	Width: 304.7 m	Processed by: DAV
Boat/Motor: Helo	Area: 241.2 m²	Mean Velocity: 1.41 m/s
Gauge Height: 57.90 m	G.H.Change: 0.000 m	Discharge: 332 m³/s

Area Method: Mean Flow	ADCP Depth: 0.060 m	Index Vel.: 0.00 m/s	Rating No.: 1
Nav. Method: Bottom Track	Shore Ens.:10	Adj. Mean Vel: 0.00 m/s	Qm Rating: U
MagVar Method: Model (18.8°)	Bottom Est: Power (0.1667)	Rated Area: 0.000 m²	Diff.: 0.000%
Depth: Composite (BT)	Top Est: Power (0.1667)	Control1: Unspecified	
Discharge Method: None		Control2: Unspecified	
% Correction: 0.00		Control3: Unspecified	

Screening Thresholds:		ADCP:	
BT 3-Beam Solution: YES	Max. Vel.: 4.26 m/s	Type/Freq.: RiverPro/RioPro / 1200 kHz	
WT 3-Beam Solution: YES	Max. Depth: 2.70 m	Serial #: 12813	Firmware: 56.03
BT Error Vel.: 1.00 m/s	Mean Depth: 0.788 m	Bin Size: 6 cm	Blank: 10 cm
WT Error Vel.: 10.00 m/s	% Meas.: 67.99	BT Mode: Auto	BT Pings: Dyn
BT Up Vel.: 10.00 m/s	Water Temp.: None	WT Mode: Auto	WT Pings: Dyn
WT Up Vel.: 10.00 m/s	ADCP Temp.: 1.9 °C	WZ : 5	
Use Weighted Mean Depth: YES			

Performed Diag. Test: YES
Performed Moving Bed Test: YES
Performed Compass Calibration: NO* Evaluation: NO*

Project Name: sageast20160527q332cms
Software: 2.17

Meas. Location: Sag East Bank

Tr.#		Edge Distance		#Ens.	Discharge						Width	Area	Time		Mean Vel.		% Bad	
		L	R		Top	Middle	Bottom	Left	Right	Total			Start	End	Boat	Water	Ens.	Bins
000	L	5.00	3.00	624	72.3	225	37.9	1.44	1.29	338	284.9	192.5	16:22	16:29	1.00	1.75	0	1
001	R	5.00	5.00	642	59.0	235	40.2	1.88	2.16	338	313.9	288.2	16:31	16:37	1.04	1.17	2	1
002	L	3.00	3.00	649	68.1	219	38.8	0.994	0.828	327	304.3	216.7	16:37	16:43	1.01	1.51	2	1
003	R	5.00	3.00	546	57.6	229	37.2	1.65	0.648	326	318.6	280.8	16:44	16:49	1.16	1.16	1	1
004	L	2.00	2.00	618	69.5	222	39.0	0.567	0.495	332	301.5	227.7	16:50	16:56	1.05	1.46	1	2
Mean		4.00	3.20	615	65.3	226	38.6	1.31	1.08	332	304.7	241.2	**Total**	00:33	1.05	1.41	1	1
SDev		1.41	1.10	41	6.58	6.24	1.14	0.526	0.671	5.65	13.0	41.6			0.06	0.25		
SD/M		0.35	0.34	0.07	0.10	0.03	0.03	0.40	0.62	0.02	0.04	0.17			0.06	0.18		

Remarks: Q with RioPro 307 cms using VTG with 8% error, 332 cms using BT with 2% error.

*Compass calibration and evaluation were not necessary because the instrument's compass was previously calibrated and evaluated at this location (the instrument was in place).

Station Number: DSS5
Station Name: DSS5

Meas. No: 16
Date: 05/28/2016

Party: HT/JK	Width: 113.8 m	Processed by: DAV
Boat/Motor: Helo	Area: 131.1 m²	Mean Velocity: 1.51 m/s
Gauge Height: 57.81 m	G.H.Change: 0.000 m	Discharge: 198 m³/s

Area Method: Mean Flow	ADCP Depth: 0.060 m	Index Vel.: 0.00 m/s	Rating No.: 1
Nav. Method: DGPS	Shore Ens.:10	Adj. Mean Vel: 0.00 m/s	Qm Rating: U
MagVar Method: Model (18.8°)	Bottom Est: Power (0.1667)	Rated Area: 0.000 m²	Diff.: 0.000%
Depth: Composite (BT)	Top Est: Power (0.1667)	Control1: Unspecified	
		Control2: Unspecified	
		Control3: Unspecified	

Screening Thresholds:		ADCP:	
BT 3-Beam Solution: YES	Max. Vel.: 6.38 m/s	Type/Freq.: RiverPro/RioPro / 1200 kHz	
WT 3-Beam Solution: YES	Max. Depth: 2.02 m	Serial #: 12813	Firmware: 56.03
BT Error Vel.: 1.00 m/s	Mean Depth: 1.15 m	Bin Size: 6 cm	Blank: 10 cm
WT Error Vel.: 10.00 m/s	% Meas.: 69.48	BT Mode: Auto	BT Pings: Dyn
BT Up Vel.: 10.00 m/s	Water Temp.: None	WT Mode: Auto	WT Pings: Dyn
WT Up Vel.: 10.00 m/s	ADCP Temp.: 1.5 °C	WZ : 5	
Use Weighted Mean Depth: YES			

Performed Diag. Test: YES
Performed Moving Bed Test: YES
Performed Compass Calibration: NO* Evaluation: NO*

Project Name: sageast20160528q198cms
Software: 2.17

Meas. Location: Sag East Bank

Tr.#		Edge Distance		#Ens.	Discharge						Width	Area	Time		Mean Vel.		% Bad	
		L	R		Top	Middle	Bottom	Left	Right	Total			Start	End	Boat	Water	Ens.	Bins
001	L	10.0	5.00	247	32.3	144	22.0	6.17	2.61	207	113.9	130.5	08:50	08:52	0.81	1.58	0	1
002	R	3.00	5.00	170	32.6	139	24.1	1.68	3.52	201	114.0	129.1	08:54	08:56	1.03	1.55	0	1
003	L	3.00	10.0	168	29.1	130	22.3	1.77	4.87	188	116.2	133.8	08:56	08:58	1.11	1.41	0	0
004	R	5.00	2.00	148	30.2	138	25.4	2.87	0.383	197	111.0	131.1	08:58	09:00	1.18	1.50	0	1
Mean		5.25	5.50	183	31.1	138	23.4	3.12	2.84	198	113.8	131.1	**Total**	00:10	1.03	1.51	0	1
SDev		3.30	3.32	44	1.71	5.43	1.59	2.10	1.88	7.67	2.1	2.0			0.16	0.08		
SD/M		0.63	0.60	0.24	0.06	0.04	0.07	0.67	0.66	0.04	0.02	0.02			0.16	0.05		

Remarks: Q with RioPro 198 cms using VTG with 4% error, 213 cms using BT with 1% error.

*Compass calibration and evaluation were not necessary because the instrument's compass was previously calibrated and evaluated at this location (the instrument was in place).

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