Sagavanirktok River Spring Breakup Observations 2015

Final Report

H. Toniolo, E.K. Youcha, R.E. Gieck, T. Tschetter, M. Engram, and J. Keech

Prepared for the
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Water and Environmental Research Center
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Report INE/WERC 15.10

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Front cover photo:

Aerial view, looking south, of the Dalton Highway (left) and TAPS (right) in the vicinity of Deadhorse, Alaska, on May 22, 2015. Water overtopped the road in several places.

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ABSTRACT

Alaska's economy is strongly tied to oil production, with most of the petroleum coming from the Prudhoe Bay oil fields. Deadhorse, the furthest north oil town on the Alaska North Slope, provides support to the oil industry. The Dalton Highway is the only road that connects Deadhorse with other cities in Interior Alaska. The road is heavily used to move supplies to and from the oil fields.

In late March and early April 2015, the Dalton Highway near Deadhorse was affected by ice and winter overflow from the Sagavanirktok River, which caused the road's closure two times, for a total of eleven days (four and seven days, respectively). In mid-May, the Sagavanirktok River at several reaches flooded the Dalton from approximately milepost (MP) 394 to 414 (Deadhorse). The magnitude of this event, the first recorded since the road was built in 1976, was such that the Dalton was closed for nearly three weeks. During that time, a water station and several pressure transducers were installed to track water level changes on the river. Discharge measurements were performed, and water samples were collected to estimate suspended sediment concentration.

Water levels changed from approximately 1 m near MP414 to around 3 m at the East Bank station, located on the river's east bank (about MP392). Discharge measurements ranged from nearly 400 to 1560 m^3/s, with the maximum measurement roughly coinciding with the peak. Representative sediment sizes (D_{50}) ranged from 10 to 14 microns. Suspended sediment concentrations ranged from a few mg/L (clear water in early flooding stages) to approximately 4500 mg/L.

An analysis of cumulative runoff for two contiguous watersheds—the Putuligayuk and Kuparuk—indicates that 2014 was a record-breaking year in both watersheds. Additionally, an unseasonable spell of warm air temperatures was recorded during mid-February to early March. While specific conditions responsible for this unprecedented flood are difficult to pinpoint, runoff and the warm spell certainly contributed to the flood event.

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ACKNOWLEDGMENTS AND DISCLAIMER

The contents of this report reflect the views of the authors, who are responsible for the accuracy of the data presented herein. This research was funded by the Alaska Department of Transportation and Public Facilities (ADOT&PF). Earlier and ongoing work related to the hydrology of the Sagavanirktok River was funded by the Alaska Department of Natural Resources, National Science Foundation, U.S. Department of Energy, and U.S. Fish and Wildlife Service. The contents of the report do not necessarily reflect the views or policies of the ADOT&PF or any other project sponsor. This work does not constitute a standard, specification, or regulation. We thank Ken Irving, who assisted in field data collection efforts; Troy Hicks and Hagen Billy at ADOT&PF, who collected and processed all GPS survey data; and Franz Meyer and Olaniyi Ajadi, who contributed to the SAR analysis conducted by Melanie Engram. We also thank Doug Kane, Sveta Stuefer, and Chris Arp, faculty at the University of Alaska Fairbanks, Water and Environmental Research Center, for the use of their hydrometeorologic datasets (Franklin Bluffs, Upper Kuparuk, and Putuligayuk) in the analysis.

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, 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) (GEOID12AK) datum for all water level elevations.

ABBREVIATIONS, ACRONYMS, AND SYMBOLS

ADCP	acoustic Doppler current profiler
ADNR	Alaska Department of Natural Resources
ADOT&PF	Alaska Department of Transportation and Public Facilities
C	Celsius (°C)
cfs	cubic feet per second
cm	centimeter
cms	cubic meters per second
d	day
F	Fahrenheit (°F)
ft	feet
GPS	Global Positioning System
in.	inch
INE	Institute of Northern Engineering
km	kilometer
m	meter
mg/L	milligrams per liter, equivalent to ppm
mi	mile
mm	millimeter
NAVD	North American Vertical Datum
NRCS	Natural Resources Conservation Service
RTK	real-time kinematic
s	second
SAR	synthetic aperture radar
SBAS	satellite based augmentation system
SSC	suspended sediment concentration
SWE	snow water equivalent
TDR	time domain reflectometry
TSS	total suspended solids
UAF	University of Alaska Fairbanks
USF&WS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
WAAS	Wide Area Augmentation System
WERC	Water and Environmental Research Center

1 INTRODUCTION

The goal of this study was to monitor spring breakup conditions on the lower Sagavanirktok River near milepost (MP) 392 at the Dalton Highway (approximately 15 miles south of Prudhoe Bay) in May 2015. Widespread flooding during breakup was expected to occur due to a large buildup of aufeis near Franklin Bluffs. The aufeis deposit developed over the winter causing early overflow and temporary highway closures in late March and early April. We speculate that the increased baseflow during late winter months was due to very high rainfall the previous year and a higher than normal snowpack for 2 years prior (Stuefer et al., 2014; NRCS, 2014).

During May 2015, University of Alaska Fairbanks (UAF) personnel established a network of water level observation sites on the lower Sagavanirktok River and along the Dalton Highway from MP394.5 near Franklin Bluffs to MP414 near Prudhoe Bay. The observation sites consisted of water level recorders, which measure river stage (water levels) every 15 minutes. Additionally, river discharge was measured and water samples were taken. Table 1 presents a summary of site locations where data were collected, and Figure 1 is a map of the study area near the Dalton Highway.

To understand the extraordinary flooding that occurred in 2015, forcing the Alaska Department of Transportation and Public Facilities (ADOT&PF) to close the Dalton Highway for nearly 3 weeks, we examined not only river discharge and stage, but also antecedent meteorological conditions. Unfortunately, hydrometeorological data for the region are limited.

Kane et al. (2012) describe the history of long-term hydrometeorological data collection in the region. To summarize, in 1970, the U.S. Geological Survey (USGS) established the Putuligayuk River gauging station and, in 1971, began collecting streamflow data at the Kuparuk River near Deadhorse. From 1970 to1978, the USGS monitored the Sagavanirktok River near Sagwon Hills. In 1982, the USGS established a gauging station on the Sagavanirktok River near Pump Station 3, located above the confluence with the Ivishak River. In 1985, Kane et al. (2000) established a stream gauging and meteorological observation program in the headwaters of the Kuparuk basin. This meteorological observation network was expanded to the entire Kuparuk River basin in the late 1980s with the addition of stations in the middle and lower basins. In 2006, additional meteorological stations were installed in the Kuparuk and Sagavanirktok basins for road corridor studies (Kane et al., 2012).

Table 1. Site locations established during spring breakup on the Sagavanirktok in 2015.

Site Name	Latitude (NAD83)	Longitude (NAD83)	Elevation (m) (NAVD88, GEOID12A)	Elevation Error (m)	Description	Data Type
East Bank	69° 56' 46.32936" N	148° 40' 17.20520" W	61.597	0.007	East Bank station, Franklin Bluffs	Discharge, continuous water levels, discrete water levels
MP395.5 Alyeska Gate	69° 57' 44.22747" N	148° 43' 46.34186" W	56.216	0.006	HOBO3	Continuous water levels, discrete water levels
MP394.5	69° 57' 04.43886" N	148° 44' 15.21445" W	57.868	0.006	HOBO1	Discrete water levels
Spur Dike 6	69° 58' 20.94330" N	148° 42' 06.89200" W	54.211	0.006	HOBO8	Continuous water levels, discrete water levels
MP399	70° 00' 21.87288" N	148° 39' 49.41972" W	46.721	0.007	HOBO19	Continuous water levels, discrete water levels
MP402	70° 02' 40.40642" N	148° 36' 47.11188" W	38.063	0.009	HOBO20	Continuous water levels, discrete water levels
MP410	70° 09' 51.46276" N	148° 25' 53.21331" W	16.507	0.005	HOBO70	Discrete water levels
MP414	70° 11' 41.56194" N	148° 25' 30.70175" W	13.990	0.003	HOBO99	Continuous water levels, discrete water levels

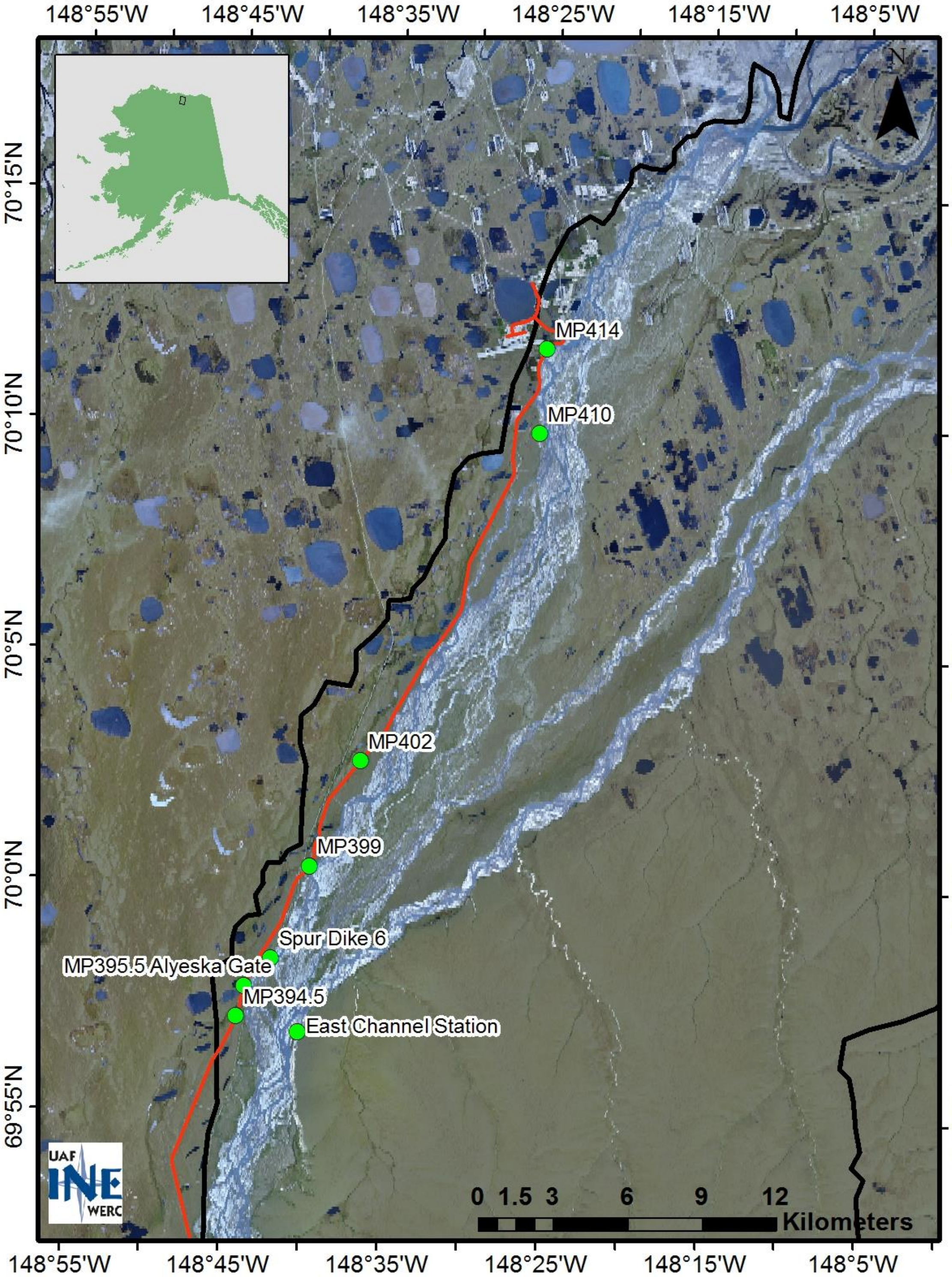


Figure 1. Water level observation network near Franklin Bluffs and Deadhorse. The red line indicates the location of the Dalton Highway; the black line indicates the Sagavanirktok watershed boundary.

Though there is a lack of complementary meteorological data for the Sagavanirktok River basin during recent years, data are available from stations in the Kuparuk basin, and we used them to examine the conditions that could produce such an unusual flood event. Additionally, we reviewed the region's long-term historical flow and weather data for information on the water budget of the arctic basins and the frequency of unusual flooding. Historical flow data from the Putuligayuk, Kuparuk, Upper Kuparuk, and Sagavanirktok Rivers (measured by USGS or the UAF Water and Environmental Research Center [WERC]) are presented.

2 STUDY AREA

The Sagavanirktok River originates in the Brooks Range and flows north to the Beaufort Sea near Deadhorse. The river flows through three distinct regions, previously defined by Kane et al. (2009) as the Coastal Plain, Foothill, and Mountain regions. Figure 2 is a regional map showing the major basins in the study area. In the Coastal Plain and Foothill regions, the Sagavanirktok River is constricted by the Kuparuk and Putuligayuk basins to the west and by Franklin Bluffs and the Kadleroshilik basin to the east. The Kuparuk River basin is adjacent to the Sagavanirktok River basin, but differs in that none of its basin lies in the Mountain region. In the Mountain region, the basin lies adjacent to the Itkillik River to the west and the Shaviovik River to the east. The upper part of the Sagavanirktok basin contains the Ivishak River and the Upper Sagavanirktok River. The basin is at least 250 km long, and the stream is over 300 km long. The basin has a low hydraulic gradient (Coastal Plain) near the Arctic Ocean and a high hydraulic gradient (Mountain) in the headwaters to the south. The basin area is approximately 13,500 km^2, most of which lies in the Brooks Range (>50%). Less than 20% of the basin area is located on the Coastal Plain (Figure 3).

Table 2 summarizes the Sagavanirktok River basin characteristics. The basin area above the USGS gauge site near Pump Station 3 is approximately 4100 km^2, and runoff is measured in the Sagavanirktok River before the confluence with the Ivishak River (Ivishak basin area ~5200 km^2). Upstream of the USGS gauge site, most of the basin lies in the Mountain region and a smaller percentage is within the Foothill region. The Sagavanirktok River area has an arctic climate, is underlain by continuous permafrost (Kane et al., 2012), and is vegetated with grasses, sedges, and shrubs (Homer et al., 2007). Some areas are barren (in the mountain region) (Homer et al., 2007), and the region is mostly treeless except for some areas along the major drainages (Kane et al., 2012).

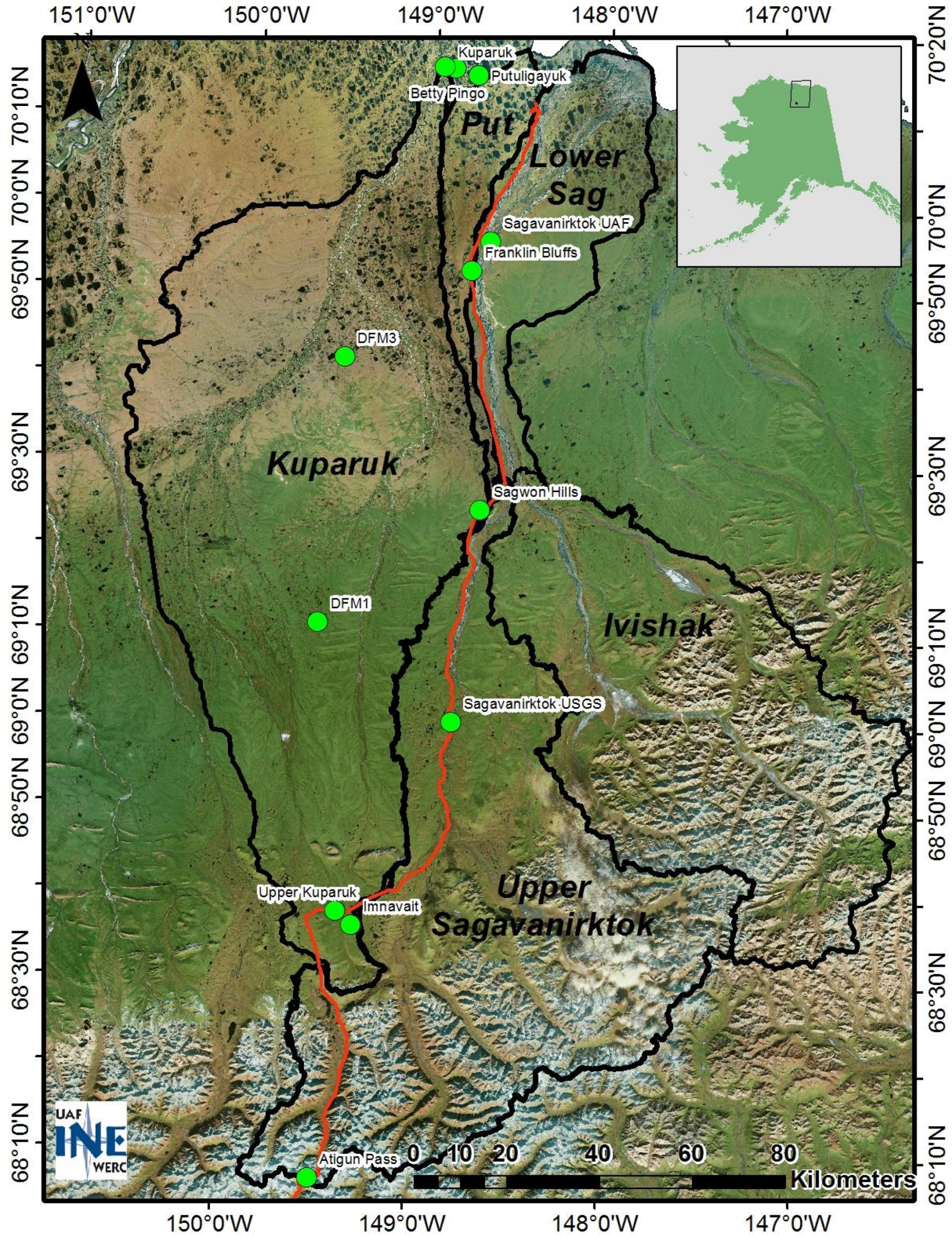


Figure 2. Study region showing UAF and USGS hydrometeorological stations (green dots), watershed boundaries, and the location of the Dalton Highway (red line).

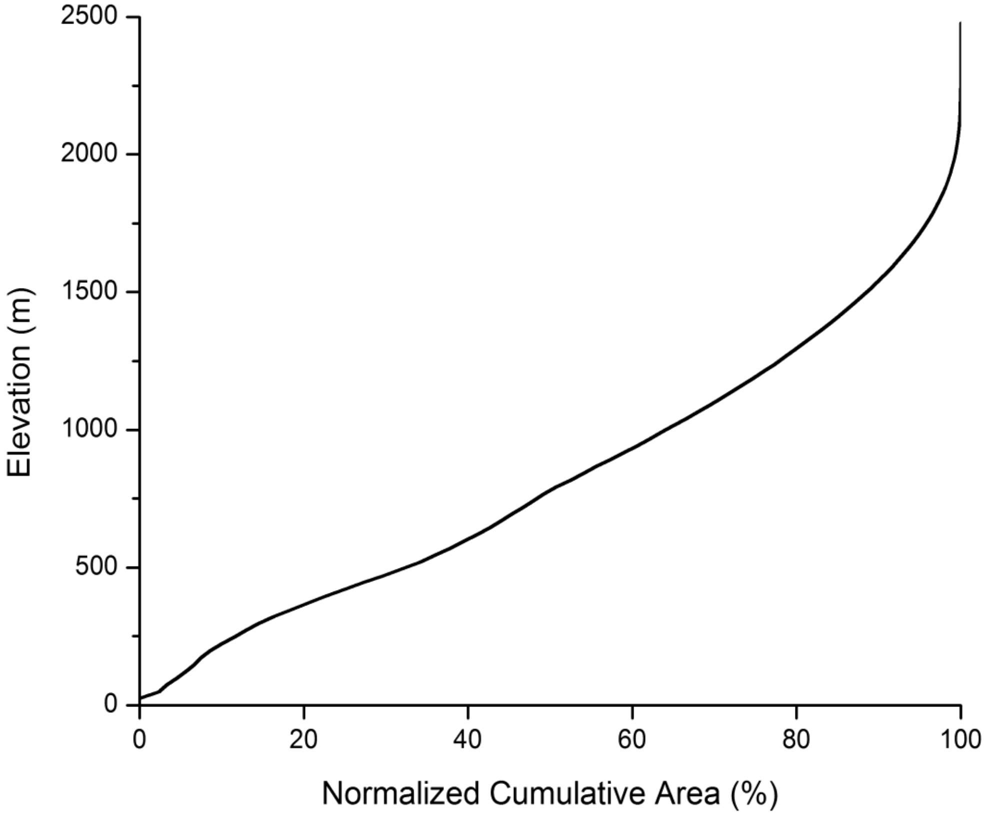


Figure 3. Hypsometric curve for the Sagavanirktok River basin. Over 50% of the basin is above 750 m (2460 ft).

Table 2. Characteristics of the Sagavanirktok River basin.

Basin Area (km²)	**13,500**
Aspect	north
Minimum Elevation (m)	0
Maximum Elevation (m)	2477
Mean Elevation (m)	784
Basin Area above 500 m (%)	70
Basin Area above 1000 m (%)	35
Basin Length (km)	250
Shrub (%)	43
Barren (%)	37
Sedge (%)	14
Other (%)	6

The active layer is the zone below the ground surface and above the permafrost table that thaws seasonally. It typically consists of a thin layer of organic soil, underlain by mineral soils (Kane et al., 2012). Hinzman et al. (1991) and Hinzman et al. (1998) describe an active layer 50 cm thick in the fall months and thicker in well-drained locations. Kane et al. (2012) describe the active layer as a storage zone of approximately a year's worth of annual precipitation, but a poor buffer to flooding and drought.

Permafrost acts as a hydraulic barrier between the suprapermafrost groundwater and the subpermafrost groundwater. However, Kane et al. (2013) found that in the eastern North Slope, taliks through the permafrost allowed subpermafrost groundwater to discharge through springs at the surface. Large aufeis formations are generally found downstream of these springs (Kane et al., 2013; Yoshikawa et al., 2007), but aufeis does not always form. Yoshikawa et al. (2007) describe the formation of river aufeis on the North Slope: in early winter, aufeis fills the river channel, and by late winter, the aufeis grows thicker and expands downstream. Additionally, late winter overflow can spread out into the floodplain and may not freeze at the surface. Yoshikawa et al. (2007) found that the size of the aufeis formation is sensitive to the source volume (discharge). Kane (1981) reports that aufeis growth occurs during warm spells, when pore pressures increase under the ice, causing ice to crack and water to flow onto the surface. Numerous springs are present in the Upper Sagavanirktok and Ivishak basins, and Kane et al. (2013) suggest that some springs on the North Slope may either be fed through subpermafrost groundwater, originating on the south side of the Brooks Range, or from water stored in near-surface taliks.

In addition to the UAF and USGS studies described in the Introduction, several hydrologic studies occurred in the 1980s and 1990s on the Sagavanirktok River near Prudhoe Bay in support of development of the Endicott causeway. Breakup measurements were made beginning in 1982 on the west channel. A daily discharge of 524 m^3/s in the west channel during peak flow (June 7, 1982) was reported by Woodward-Clyde (1982). LGL Alaska Research Associates (1983) reported that the west channel received approximately 49% of the flow during the spring breakup period, but this percentage increased as summer progressed (during periods of lower flows). In 1993, peak discharge at the west channel bridge near Prudhoe Bay was estimated to be 1,425 m^3/s on May 28, which was similar to the reported west channel peak flow in 1989.

3 METHODOLOGY AND EQUIPMENT

The goal of the breakup monitoring program in spring 2015 was to observe river stage, measure streamflow, and collect water samples where the river presents a single channel (approximately MP392 of the Dalton Highway). Typically, a stream stage–discharge relationship is developed, which involves installation of pressure transducers in the stream to acquire a continuous record of river stage, and measurements of discharge that can be related to the stage at the time of observations (equipment used listed in Table 3). However, because of extensive ice that had accumulated in the channel, the natural braided-river environment, the constantly changing channel geometry, and the limited time available for this study, a stream stage-discharge relationship was not developed.

Synthetic aperture radar imagery acquired by ADOT&PF was reviewed prior to spring breakup to better understand the extent of March/April overflow. In 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). In May, one permanent water level observation station was established on the east bank of the Sagavanirktok River (referred to as East Bank station) in an area that had relatively easy access by helicopter (on Franklin Bluffs), and seven temporary water level observation stations were installed on the west side of the river along the Dalton Highway. Vented pressure transducers and self-contained pressure sensors (HOBO) were used at the East Bank Station; a single HOBO was used at each station on the west side. Three time-lapse cameras were installed at the East Bank Station to document the breakup event and confirm water level data from pressure transducers. Additionally, wind speed and direction, barometric pressure, and air temperature were measured at the East Bank station to complement the hydrologic data. Benchmarks were established by ADOT&PF surveyors; the vertical datum is NAVD88 (GEOID12A). Accuracy information for each sensor is listed in Table 3. Water levels were recorded at 15-minute intervals and verified with level loop surveys of stage from the benchmarks.

Table 3. 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 Relative Humidity	HMP45C	± 3% at 20°C	
Met	Barometric Pressure	CS106	± 1.5 mb @ −40 to +60°C	
Hydro	Water Level	INW AquiStar 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	ADCP, shallow	RDI StreamPro		
Hydro	ADCP	RDI Rio Grande WHRZ1200		
Hydro	ADCP Software	WinRiver II		
Hydro	ADCP GPS Reference	Novatel Smart-V1 RTK/WAAS		
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		

3.1 Ice Elevations Prior to Breakup (GPS Surveys)

Altus real-time kinematic (RTK) GPS receivers (base and rover), controlled by a Carlson Surveyor Field PC running Carlson SurvCE software, were used to survey the Sagavanirktok River aufeis in April. The original plan was to conduct several river cross sections along a 2- to 3-mile river length, starting just south (upstream) of where the Sagavanirktok branches into east and west channels. Due to the lack of an established control at this location, random control points for the base station were established, with approximately 4 hours of static observations at each base location. While the specifications provided by the rental company for communication between the base and the rover receivers indicated a range of 1.5 to 2 miles, the actual range in the field was approximately 0.5 mile. The static data were post-processed, and the RTK data were adjusted accordingly. Post-processing was performed by Surveyors Exchange Company and ADOT&PF surveyors. Real elevations are reported as NAVD88 (GEOID12AK). The expected error for RTK data is 1 cm for the horizontal direction and 2 cm for the vertical direction (Altus Positioning Systems, 2011).

3.2 X-Band SAR Analysis

Satellite remote sensing is a useful tool during flood events, providing the areal extent of floodwater and a view of the surrounding landscape, less obtainable by ground observations. At high latitudes, synthetic aperture radar (SAR) is particularly useful, because as an active sensor it provides its own illumination in the microwave spectrum and can therefore image at night and through clouds. Historically, SAR has been used to monitor river ice during spring breakup. For several years, the National Weather Service used C-band, provided by the Alaska Satellite Facility, to help monitor river breakup on the Yukon, Koyukuk, Kuskokwim, and Sagavanirktok Rivers. River ice shows high backscatter (appears bright) in SAR imagery, while river water (if a smooth surface) directs microwaves away from the satellite due to specular reflection, resulting in liquid water appearing dark in a SAR image. Synthetic aperture radar has been widely used to detect flooding extent by comparing pre- and post-flood images (Duguay et al., 2015; Hall, 1996). Compiling different dates of SAR images in the RGB color bands helps with detection of change in the target that occurs between acquisition dates. Moreover, SAR can discriminate between floating or grounded ice, since it penetrates through ice and either reflects off liquid water beneath the ice (bright = floating ice) or penetrates the river-lake-bed substrate (dark = grounded ice).

After overflow from the Sagavanirktok River caused flooding on the Dalton Highway near MP400 in March 2015, ADOT&PF acquired SAR data (Table 4), recorded from early April to early May 2015, of the affected part of the highway. The SAR data were obtained from the TerraSAR-X (TSX) satellite, operated by DLR, the German space agency. X-band SAR has a relatively short wavelength (3.1 cm wavelength/9.6 Ghz) and is sensitive to small targets and any rough surface. The data have a very small pixel size (1.25 m) and thus a higher resolution than most other SAR data. The resolution of the X-band SAR scenes is high enough that small details on the landscape, such as a grid of seismic lines on the tundra, are visible in these images. Since

SAR instruments are active sensors, data acquisition from the TSX satellite must be planned. Data acquisition using SAR began after the Dalton Highway flooding had occurred; hence, there are no pre-flood images. The TSX images were compared with each other to detect change in overflow patterns, and SAR data were compared with optical data of the Sagavanirktok River.

Table 4. Acquisition details of X-band SAR data acquired over the Dalton Highway and Sagavanirktok River from TerraSAR-X (TSX) satellite. Data were processed in near real time.

Date 2015	Ascending/ Descending	Local Standard Time	θ	Polarization	Look Direction
8-Apr	descending	8:33:34	41°	HH	right
13-Apr	descending	8:42:06	35°	HH	right
15-Apr	descending	9:41:57	24°	HH	left
19-Apr	descending	8:33:32	41°	HH	right
21-Apr	ascending	18:52:44	24°	HH	right
24-Apr	descending	8:42:07	35°	HH	right
26-Apr	descending	9:41:59	24°	HH	left
26-Apr	ascending	19:01:19	31°	HH	right
2-May	ascending	18:52:44	24°	HH	right
5-May	descending	8:42:08	35°	HH	right
7-May	descending	9:42:01	24°	HH	left

3.3 Water Levels

In general, station locations were selected based on whether discharge and water levels could be safely and accurately measured during the spring flood event. Water level (also known as river stage) was measured continuously with pressure transducers, and discharge measurements were individual point measurements in time. Individual measurements of water levels were also collected with traditional surveying equipment. In addition to these measurements, hourly photographs from cameras at the stations helped us evaluate river water levels in more detail, observe ice conditions during breakup, and monitor the weather for field logistics.

Water levels were measured at the East Bank station with two AquiStar PT12 (SDI12) pressure transducers from Instrumentation Northwest, Inc. One or two HOBO U20 water level logger pressure transducers were available for backup at or near this station. The HOBO U20 water level loggers were placed at various sites along the Dalton Highway. Measurements of pressure were made every 15 minutes. The datalogger converted the pressure measurements to water depth. Non-vented pressure transducers were adjusted using barometric pressure data collected nearby. During post-processing, the water depths were converted to water level elevations (above the reference datum NAVD88/GEOID12AK).

Manual water level measurements were made with traditional level loop surveys. These discrete measurements of water level were used to adjust the continuous pressure transducer data to the datum and for verification purposes.

Time-lapse cameras located at the surface water station—Campbell Scientific CC640 and Wingscapes—took an image every hour to capture river stage and weather conditions. These station camera images were transmitted via radio telemetry to a base station in Deadhorse and to servers approximately each hour via radio telemetry; images from Wingscapes cameras not on the telemetry network were downloaded during site visits. These photos were helpful for observing what was happening to the river in near real time, and for reviewing and confirming river stage during post-processing of the pressure transducer data.

The vertical datum for water level elevations was NAVD88 (GEOID12AK), as previously mentioned. Differential GPS surveys were conducted by the ADOT&PF survey crew to determine the elevations of temporary benchmarks and reference points at each station and site. Leica GS14, GS15, and 1200 survey GPSs were used to conduct the survey (Hickman, 2015). All static GPS networked ties were done with a minimum of three stationary base stations and one rover. Multiple redundant measurements were made. Post-processing was done by ADOT&PF surveyors using Leica Geo Office software. Accuracies were estimated by assuming centering errors, measure-up errors, and software configured error estimates. All measurements were adjusted using least squares modeling. Results were an average error estimate for a position of 6 mm (3D error ellipse for one standard deviation). The positional quality of the various control points and the subsequent measurements made were about 0.5 cm across a project length of 30 km. Traditional level loop surveys were conducted to tie the water surface to the temporary benchmarks (with a known elevation).

Table 5 shows the accuracy specifications for the AquiStar and HOBO pressure transducers. Errors associated with the pressure transducer itself are generally less than 1 cm under ideal conditions. Additional errors associated with pressure transducer units may occur if a sensor is moving in the water because it has not been installed securely or because of barometric pressure errors during post-processing or vent tube constrictions.

Table 5. 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

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 to establish the temporary benchmarks for level loop surveys, and the reported errors are listed in Table 1.

3.4 Acoustic Doppler Current Profiler

Discharge measurements were made using the acoustic Doppler current profiler (ADCP) technique with a RDI Rio Grande 1200 kHz and RDI StreamPro. The Rio Grande is often used at the beginning of breakup and into peak flow, when water is deep. As water level drops, the StreamPro is used because it can measure in shallower water. Measurements are made by driving a 15-foot Jon boat with a 35 horsepower motor slowly across the river. The ADCP is mounted to the side of the boat. 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 and the right-to-left-bank directions when possible. However, due to ice conditions and other factors, this method was not possible, which is noted on the measurement summary. Each manual measurement is given a rating of good, fair, or poor, based on 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 extreme flooding conditions, the coefficient of variation or COV (standard deviation/average) for a given measurement was often greater than 5%, or transects were made in one direction only, or the percentage of unmeasured area was high; therefore, the measurement was given a lower rating (fair or poor).

3.5 Discharge Measurements

Both ADCP bottom tracking and ADCP GPS options were used as the reference 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 the Novatel Smart V1-2US-L1. Typically, a base station is set up and a RTK GPS is used, but satellite-based augmentation system (SBAS or WAAS) differential correction can also be used and is considered acceptable (Wagner and Mueller, 2011). The horizontal position accuracy of the RTK is 0.2 m and 1.2 m when using SBAS/WAAS with the Novatel units. Kane et al. (2012) discuss the methods and challenges associated with making discharge measurements using an ADCP. During spring breakup 2015, discharge measurements were made on the Sagavanirktok at various locations near Franklin Bluffs, as described in Table 6 and shown in Figure 4.

Table 6. Location of discharge measurements made during spring breakup 2015 on the Sagavanirktok River near Franklin Bluffs.

Measurement Number	Date	Location(s)	Comments
1	5/18/2015	At East Bank station, slightly downstream, east side of river	Most flow is on the east side of the channel, constricted by ADOT-built snow dikes
2	5/20/2015	0.5 km upstream of station in main channel	
3	5/22/2015	0.75 km upstream of station in main channel	
4	5/23/2015	0.75 km upstream of station in main channel	Based on field conditions, only a portion of discharge was measured

Measurement Number	Date	Location(s)	Comments
5	5/24/2015	0.75 km upstream of station in main channel	
6	5/27/2015	Two locations: 1) east channel, 1 km downstream of station; 2) west channel, 1.4 km NW of station	
7	5/28/2015	Two locations: 1) east channel, 1 km downstream of station; 2) west channel, 3.4 km north of station at north end of spur dikes	
8	5/30/2015	Two locations: 1) east channel, 0.75 km downstream of station; 2) west channel 3 km north of station at north end of spur dikes	

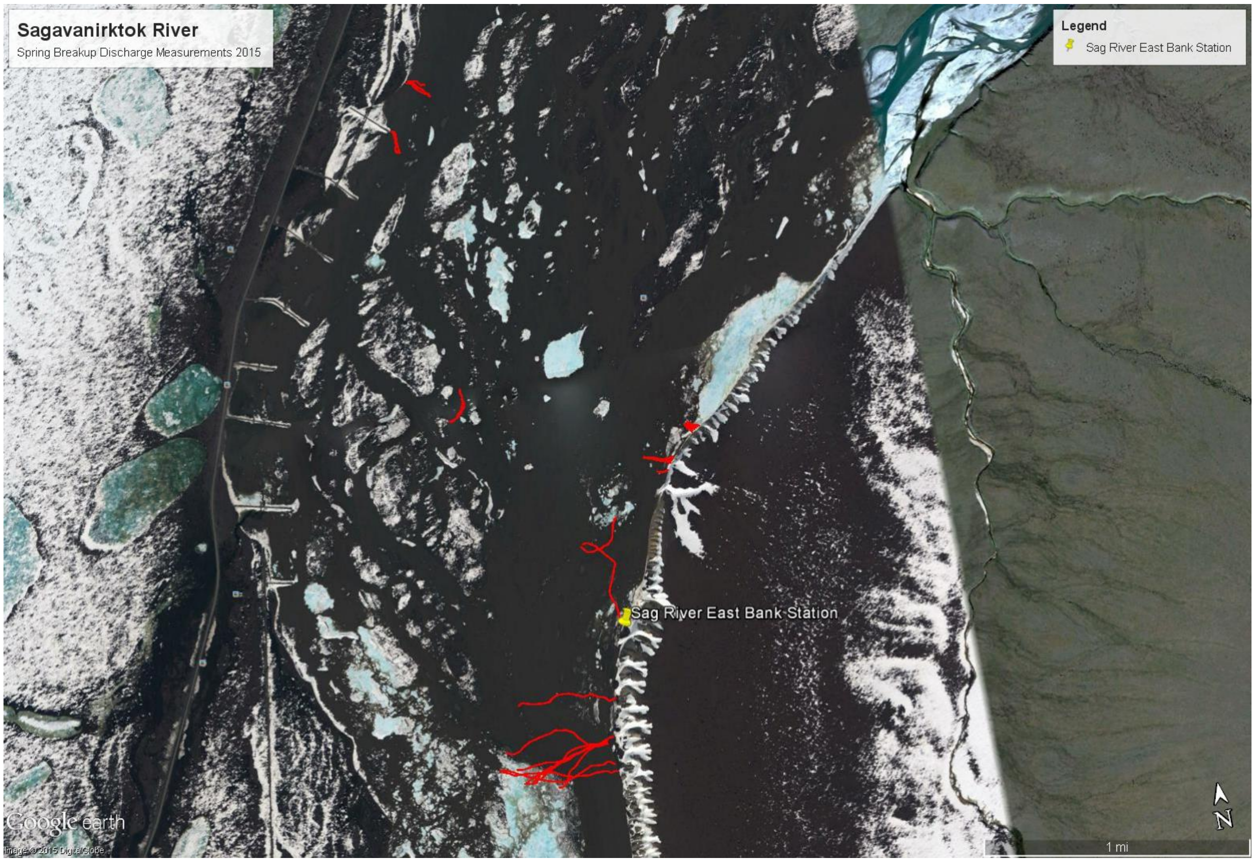


Figure 4. Locations of spring 2015 breakup flow measurement transects. This aerial photograph was taken in May 2009, but gives an idea of what the conditions are like during a typical breakup.

3.6 Suspended Sediments

Grab water samples were collected manually from the river on May 16, 18, and 19, 2015. 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 19 to May 25, and every 12 hours (3 A.M., 3 P.M.) from May 25 to June 1. During this period, additional (grab) water samples were collected manually when personnel were on site.

The suspended sediment concentration (SSC) was determined at 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.

4 RESULTS

In this chapter, hydrological and meteorological data collected on this and related projects that contribute to the understanding of the Sagavanirktok River flooding in 2015 are presented. A meteorological variable such as air temperature is useful when evaluating ice formation (river ice and aufeis) and the timing of snowmelt runoff. Precipitation (both snow and rain) is key to understanding the amount of water available in the annual water budget and the response runoff.

Selected data can be found in Appendices A, B, and C. Water level data and time-lapse photographs collected during this project can be found in Appendix D (on DVD).

4.1 Air Temperature

Mean monthly air temperature for the region was reviewed by Kane et al. (2014), who calculated mean monthly air temperature for the Kuparuk River basin region from approximately 20 meteorological stations that ranged from the Coastal Plain to the Brooks Range. To summarize their findings, in summer, air temperatures are the warmest in the Foothill region, less warm on the Coastal Plain, and on average, coolest in the Mountain region. During the cold season, the Coastal Plain region is the coldest, followed by the Foothill region, and the Mountain region is warmest. Generally, the air temperature decreases both with elevation and at higher latitudes. For all three regions, Kane et al. (2014) found that July has the warmest monthly air temperatures and January, February, and March have the coldest monthly air temperatures. Table 7 (reproduced from Kane et al., 2014) shows the average annual air temperatures for various longer-term stations in the region. The average annual air temperature at Franklin Bluffs for calendar year 2013 was -10.8°C; for 2014, it was -9.5°C.

Table 7. Average annual air temperature at stations in study area (from Kane et al., 2014).

Station Name	ID	Annual Average Air Temperature (°C)	Annual Average Air Temperature (°F)	No. of Complete Years in Record
Franklin Bluffs	FB	-10.5	13.2	24
Sagwon Hills	SH	-8.2	17.3	19
Upper Kuparuk	UK	-8.8	16.2	14
Imnavait	IB	-7.7	18.2	27
Green Cabin Lake (in Upper Kuparuk basin)	GCL	-6.2	20.9	14

The mean monthly air temperatures were reviewed for the Franklin Bluffs meteorological station to examine any unusual or extreme weather patterns for winter 2014–2015. The Franklin Bluffs station, located 22 miles south of Deadhorse, has been operated by UAF/WERC since 1986. Figure 5 shows the long-term mean monthly air temperature for the period of record (1986–present). Figure 6 shows the mean monthly air temperature for 2013–2015 and the historical mean monthly air temperature. The winters of 2013 and 2014 were warmer than the average historical monthly temperatures. Figure 7 shows the hourly air temperature for Franklin Bluffs for the winter of 2014–2015. Temperatures overall are warmer than average, and a warm period that lasted several weeks occurred beginning in mid-February 2015, with air temperatures varying between -18°C and -2°C (0–28°F).

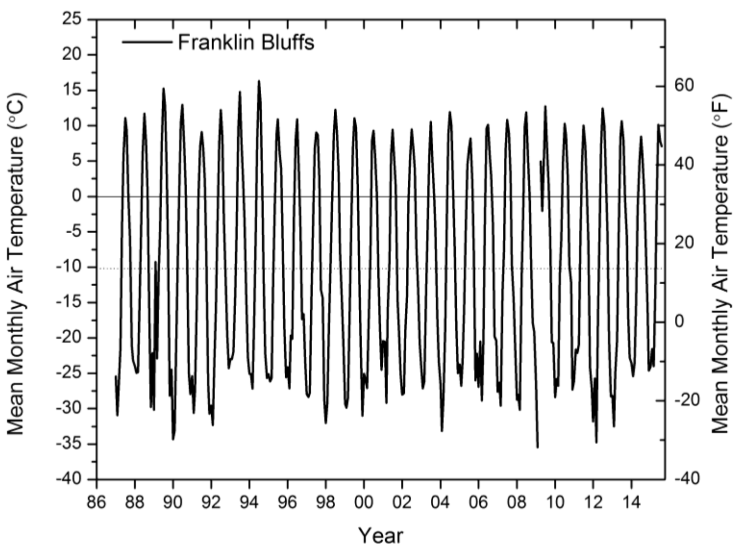


Figure 5. Mean monthly air temperature at Franklin Bluffs for the period of record (1986–2015). The solid horizontal line shows freezing, and the dotted horizontal line shows the mean air temperature for the station. Data courtesy of Kane (2014); Arp and Stuefer (2015).

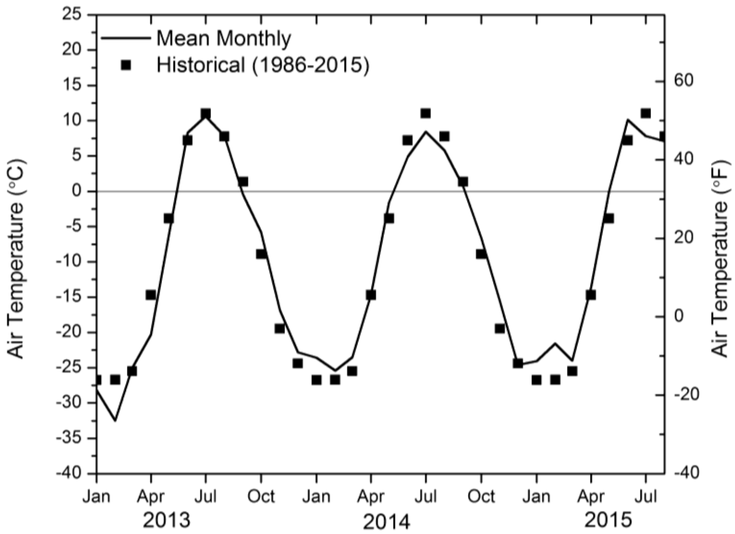


Figure 6. Franklin Bluffs mean monthly air temperature from 2014 to 2015 (solid line) is compared with the long-term historical monthly air temperature (squares). The months of January, February, and March are the coldest months of the year. At Franklin Bluffs, winter 2014 and winter 2015 were slightly warmer than average. Data courtesy of Kane (2014); Arp and Stuefer (2015).

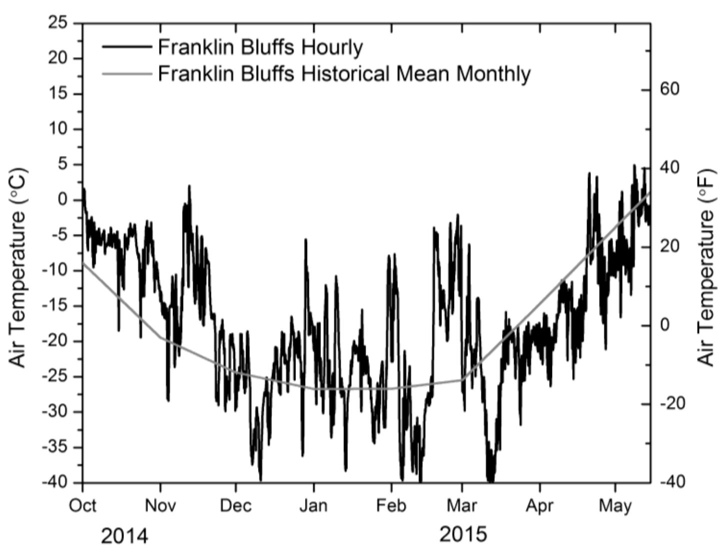


Figure 7. Hourly air temperature at Franklin Bluffs winter 2014–2015. A period of relative warmth occurred from mid-February through mid-March. Data courtesy of Kane (2014); Arp and Stuefer (2015).

4.2 Annual Precipitation

Precipitation data (both solid and liquid) were reviewed to obtain a better understanding of the hydrology of the region. Past hydrologic studies of the North Slope by UAF/WERC researchers were used to summarize the historical findings and current understandings of precipitation presented in this section. Up to 26 years of rainfall and snowpack, measurements at the 4 long-term meteorological stations in the Kuparuk River basin (Betty Pingo, Franklin Bluffs, Sagwon Hill, Imnavait Creek) are available (Kane et al., 2014). Beginning around 1985, rainfall precipitation was measured at meteorological stations using a tipping bucket rain gauge. Beginning around 2000, end-of-winter snow surveys were conducted in the Kuparuk River basin every April to determine the winter season's snow water equivalent (SWE). In 2006, the monitoring program was greatly expanded, with additional snow survey locations and meteorological stations in adjacent river basins (Kane et al., 2006a; Kane et al., 2006b; Kane et al., 2009).

Annual precipitation varies temporally and spatially over the North Slope. In the higher elevations (Brooks Range and Foothill region), annual precipitation is made up of approximately 33% snow and 67% rain (Kane et al., 2014). Annual precipitation generally increases from north to south (increases with elevation). Studies by UAF/WERC researchers have shown that rainfall increases with elevation, while SWE, on average, is fairly constant across the North Slope and the northern slopes of the Brooks Range (Kane et al., 2014; Homan and Kane, 2015). Along the coast, annual precipitation averages around 150 mm, and along the northern fringe of the Brooks Range, the average is ~300 mm (Kane et al., 2014).

Annual accumulated precipitation at the National Resource Conservation Service Wyoming gauge at Atigun Pass is shown in Table 8 (NRCS, 2015a). For the period of record (1983–2014), the highest recorded annual precipitation occurred in water years 1994 and 1995; each year had a total of 770 mm. When precipitation data are examined based on season, 2014 had a total of nearly 540 mm of rainfall (the second highest on record, behind 1998), compared with the average of 410 mm. The winter of 1993–1994 had the highest accumulated solid precipitation on record (~300 mm, compared with an average of 212 mm).

Kane et al. (2014) present the annual precipitation recorded at the four UAF/WERC long-term stations in the Kuparuk basin through 2013. Unfortunately, snowpack data were not collected by WERC in 2014 at any of the four sites. At Imnavait Creek in the Foothill region, the maximum annual precipitation occurred in 2003, and the second highest annual precipitation occurred in

2013, with very high snowpack both those years. At Sagwon Hill, which is located in the mid Kuparuk basin, maximum annual precipitation occurred in 2002; the second highest annual precipitation occurred in 1989. At Franklin Bluffs, maximum annual precipitation occurred in 1989; the second highest precipitation occurred in 1997. At Betty Pingo, maximum annual precipitation occurred in 1997; the second highest precipitation occurred in 2002.

Table 8. Atigun Pass Wyoming gauge annual water year accumulated precipitation in recent years.

Water Year	Accumulated Precipitation (mm)
2007	478
2008	442
2009	559
2010	627
2011	594
2012	673
2013	439
2014	676
Average	593

4.3 Cold Season Precipitation

Snow, which may contribute up to 50% of annual precipitation to the basin, is another component to consider when examining the basin's annual water budget. Kane et al. (2014) and Stuefer et al. (2014) attempted to quantify cold season precipitation during field campaigns by measuring snow density, depth, and SWE at selected locations within the Kuparuk River basin. For a number of years, their studies were expanded to 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 that there is spatial variation at the scale of a few kilometers or less due to redistribution of the snow and temporal variation in snow depth and SWE at the snow survey sites from year to year (Kane et al., 2014).

At 4 sites (Imnavait Creek, Sagwon Hills, Franklin Bluffs, and Betty Pingo), Kane et al. (2014) collected 20 years or more of end-of-winter snow depth and SWE. Unfortunately, snowpack data were not collected in 2014 by WERC. Both 2013 and 2014 are thought to be high snowpack years based on (1) reports of snow conditions from UAF field staff, (2) the April snow report by the National Resources Conservation Service (NRCS, 2014), and (3) volumetric runoff data from spring breakup on many rivers in the region (see Section 4.5.6).

For the period of record, the maximum recorded end-of-winter SWE was 22.9 cm at Franklin Bluffs in 1997. At Imnavait Creek, located in the headwaters of the Kuparuk, the maximum recorded end-of-winter SWE was 19.2 cm in 2013.

Generally, the overall average snowpack conditions are uniform on the North Slope from the Arctic Ocean to the continental divide in the Brooks Range. Kane et al. (2014) present a summary of SWE at each meteorological station in the WERC study areas from 2006 through 2013. During the short study period, the majority of stations (13 out of 20) had high SWE in 2011 or 2013. Based on NRCS snow reports (NRCS, 2014) and the very high observed cumulative runoff for many rivers that are monitored frequently during spring breakup, it is likely that the end-of-winter snowpack in 2014 was also higher than normal. Although UAF collected some snowpack data in the Kuparuk basin in 2015, final data are not available at this time. The NRCS reports average snowpack conditions for the end of winter in 2015 for the Arctic region (NRCS, 2015b).

4.4 Warm Season Precipitation

As mentioned previously, considerable variation occurs in rainfall, both temporally and spatially, and most of the variation occurs during the summer. Rainfall greatly increases with elevation (southward), and in the historical record (up to 26 years) of UAF/WERC stations, both dry and wet years have been observed.

Rainfall data at existing stations were examined to better understand the annual water balance and precipitation-runoff response for the Sagavanirktok River in recent years. Unfortunately, due to funding issues, few meteorological stations remain in the UAF/WERC network. Rainfall data in the region are still available from the long-term stations at Imnavait Creek in the south and Franklin Bluffs in the north (Kane, 2014; WERC/UAF, data retrieved September 2015). Additionally, some shorter-term stations from the ADOT&PF Umiat/Foothills study (Kane et al., 2014) have rainfall data from 2007–2014 (DFM1 South White Hills and DFM3 North White Hills). The stations in the White Hills were removed in the fall of 2014 due to decreased funding sources. All of these stations were located in the adjacent basin (Kuparuk), but are considered representative of rainfall in a north-to-south transect through the basin. One major component lacking in the understanding of flooding is rainfall data from a station at higher elevation that would be representative of the Mountain region, where much of the basin lies. Our only station in the mountains (DBM1 Accomplishment Creek) was removed in summer 2013. However, precipitation data are available from the long-term NRCS Wyoming gauge at Atigun Pass. In this report section, data on recent precipitation (2013 and 2014 seasons) are presented and compared with data on historical average precipitation.

The UAF/WERC stations show that 2013 and 2014 were above-normal years for total rainfall. At Franklin Bluffs, 2014 was the third wettest year in 26 years of data (Figure 8). At Imnavait Creek station, rainfall data were unavailable for 2014. Upper Kuparuk data are instead shown in the plot in Figure 9. Rainfall for 2012, 2013, and 2014 is above average. Although the period of record is short for the White Hills stations (Figure 10), both stations had high rainfall in 2013 and 2014, with the North White Hills station (DFM3) receiving the maximum rainfall in 2014. The NRCS Atigun Pass Wyoming gauge had above-normal rainfall in 2014, with approximately 540 mm of rainfall (Figure 11).

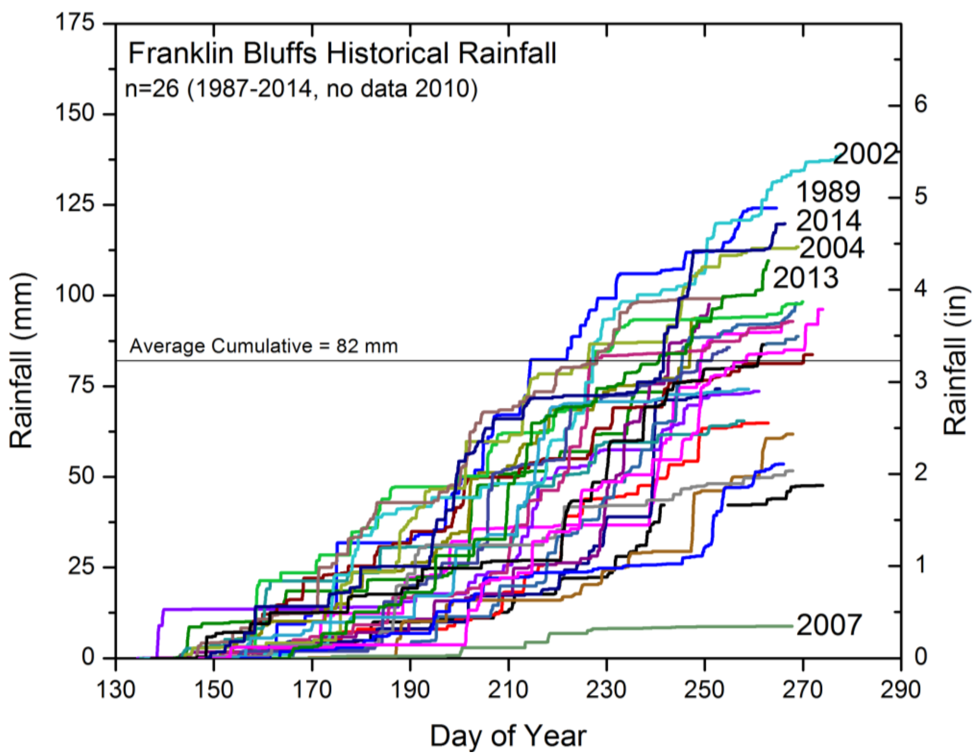


Figure 8. Historical rainfall at Franklin Bluffs (n = 26). The wettest years were 2002, 1989, and 2014. The driest year was 2007.

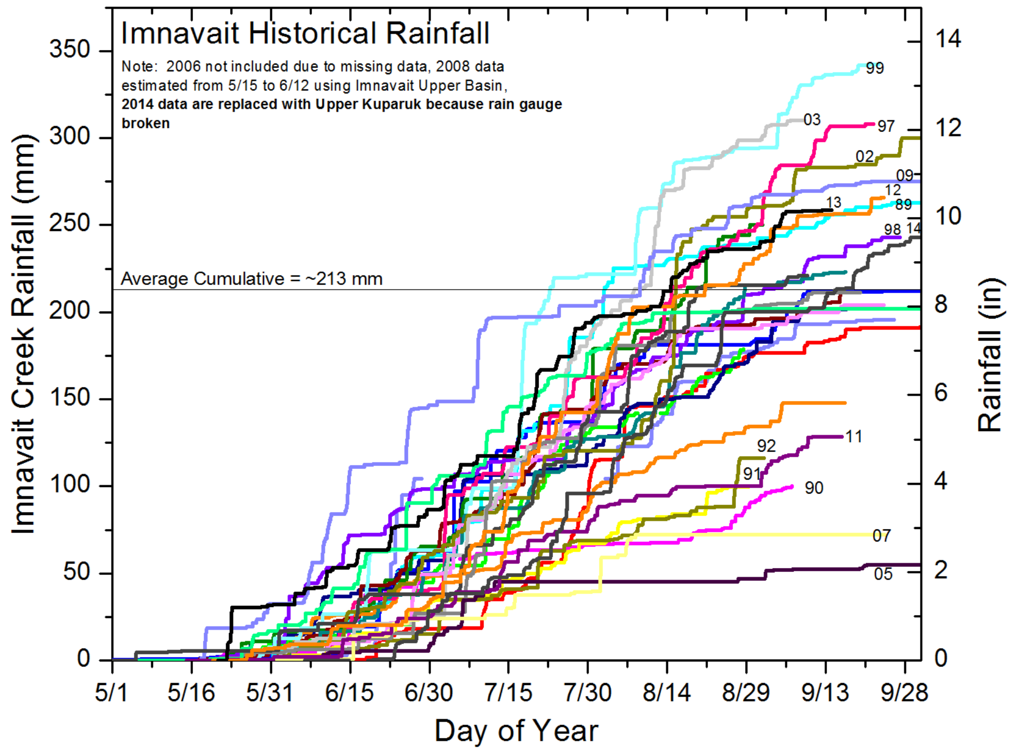


Figure 9. Imnavait Creek historical rainfall (*n* = 29). In 2014, data from the nearby Upper Kuparuk gauge are used in the plot. The wettest years were 1999, 2003, and 1997. The driest years were 2005 and 2007.

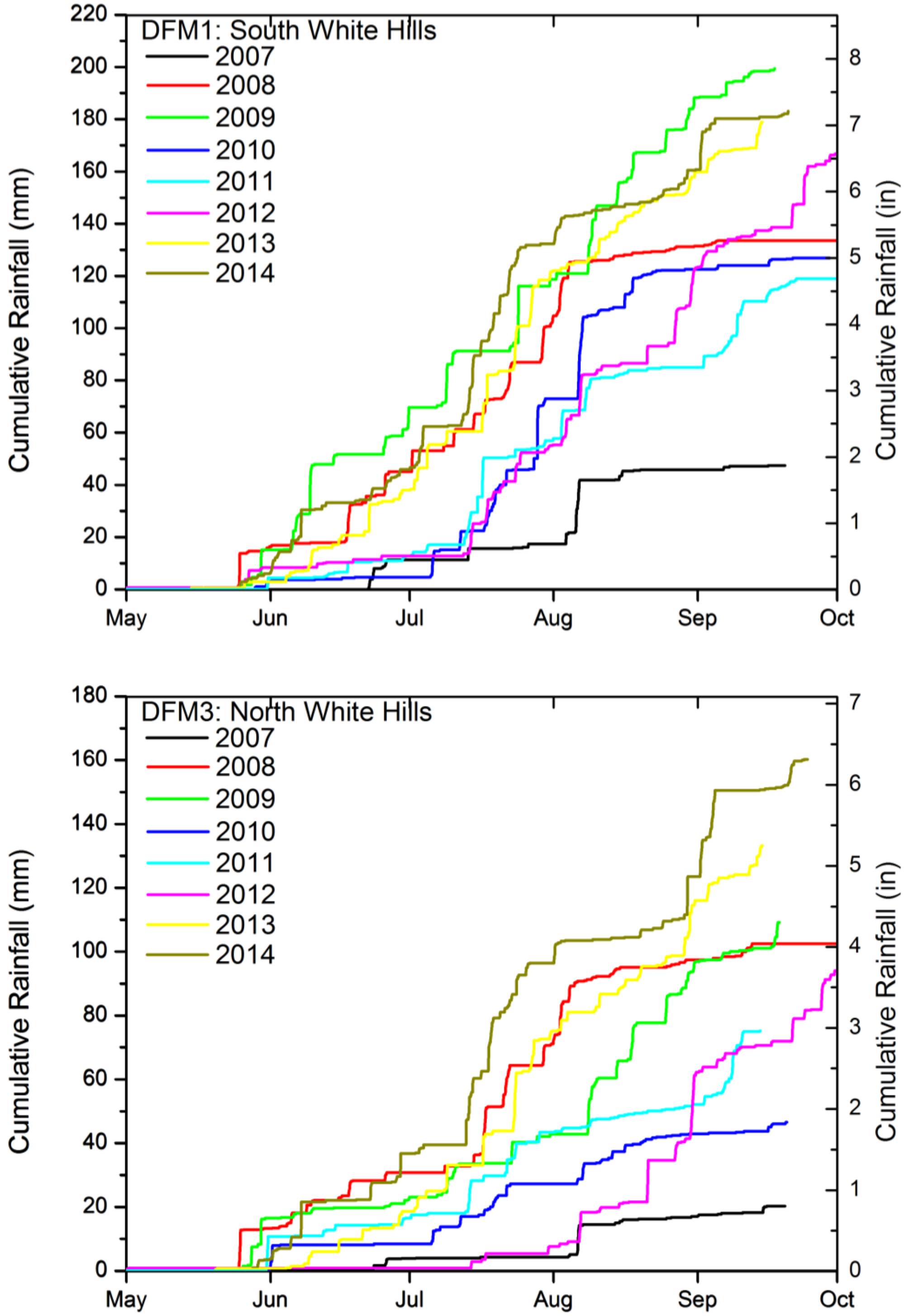


Figure 10. Rainfall at (a) DFM1, South White Hills and (b) DFM3, North White Hills for period of record (2007–2014).

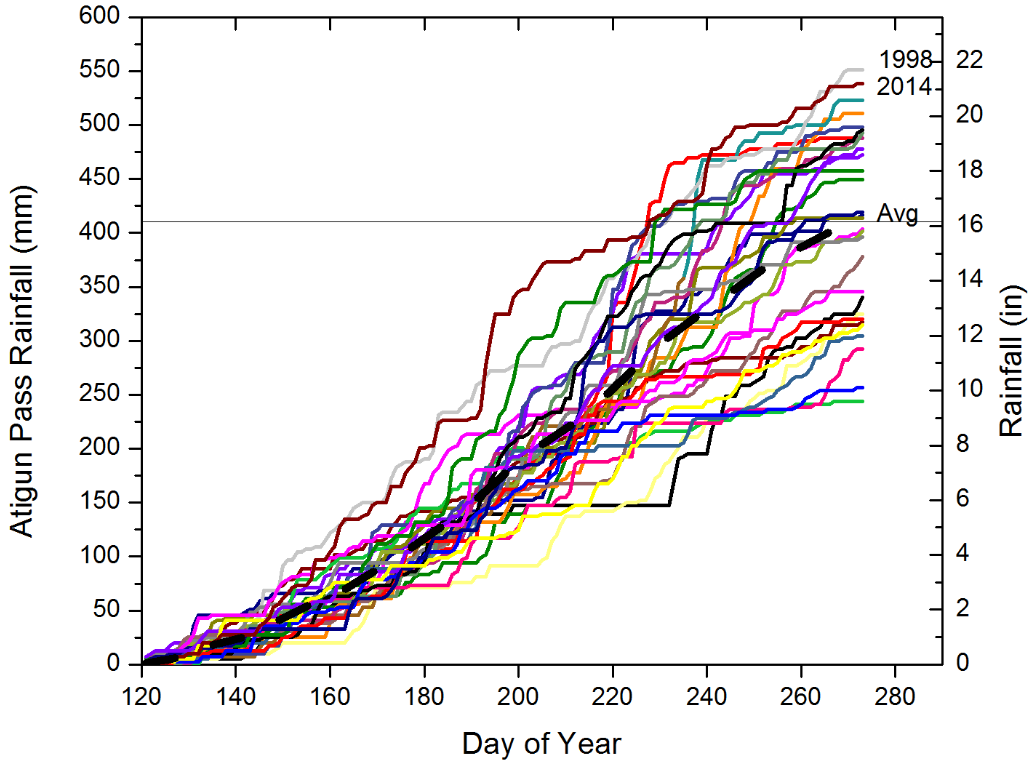


Figure 11. Accumulated rainfall at the Atigun Pass Wyoming gauge for the period of record (1983–2014). The wettest years were 1998 and 2014 (data courtesy NRCS, 2015a).

4.5 Surface Water Hydrology

Hydrology data were collected on the Sagavanirktok River between Franklin Bluffs and Deadhorse during breakup 2015. The intent was to collect some data on an initial trip in April; however, it was not possible to measure any runoff (under ice or in ice-free areas) due to road construction activities and safety considerations. An ice elevation survey was conducted near Franklin Bluffs, and photographs were taken. On the May trip, to document spring breakup, water levels were collected with portable non-vented pressure transducers (HOBOs) at seven sites on the west side of the river and with vented pressure transducers at the East Bank station on the east side of the river. One portable pressure transducer was lost during breakup, and another yielded bad data due to movement of the sensor. Point discharge measurements near the station were made eight times during the breakup period between May 15 and May 30. To document the hydrologic activity more completely, we used cameras, pointed at the river at the station. The purpose of this section is to summarize the water level and discharge results of the spring runoff period for 2015.

4.5.1 Ice Elevations

On April 14 and 15, 2015, the elevation of the top of ice was surveyed with a GPS to get an idea of the slope and maximum height of the ice surface on the Sagavanirktok River. Three hundred points were surveyed near Franklin Bluffs, with the majority of points collected on the downstream end, near MP394.5.

The first area surveyed was the southernmost, as plotted on the drawing in Figure 12. Unfortunately, it was soon discovered that the rover range was severely limited due to radio malfunction at the base station. A second problem occurred when, due to cold temperatures, the base station battery died before 4 hours of static observations were collected. Battery failure was viewed as a lesser problem, since 2 hours is the minimum collection period for standard static observation, and well beyond 2 hours had been reached, just not the goal of 4 hours. Because of impaired base station radio telemetry and limited time, concentration was directed at the cross-sectioning effort farther north at the separation of the river channels and the beginning of aufeis encroachment on the highway.

Figure 12 and Figure 13 show the location of each point surveyed. Data were processed by ADOT&PF as explained in Section 3.1 (using the GEOID12AK model to get orthometric elevation). The data were then kriged to create a contour plot of the top of ice elevation (Figure 14). On the downstream survey, data show a mound in the center with the ice sloping to both the northwest (toward the west channel) and the northeast (toward the east channel).

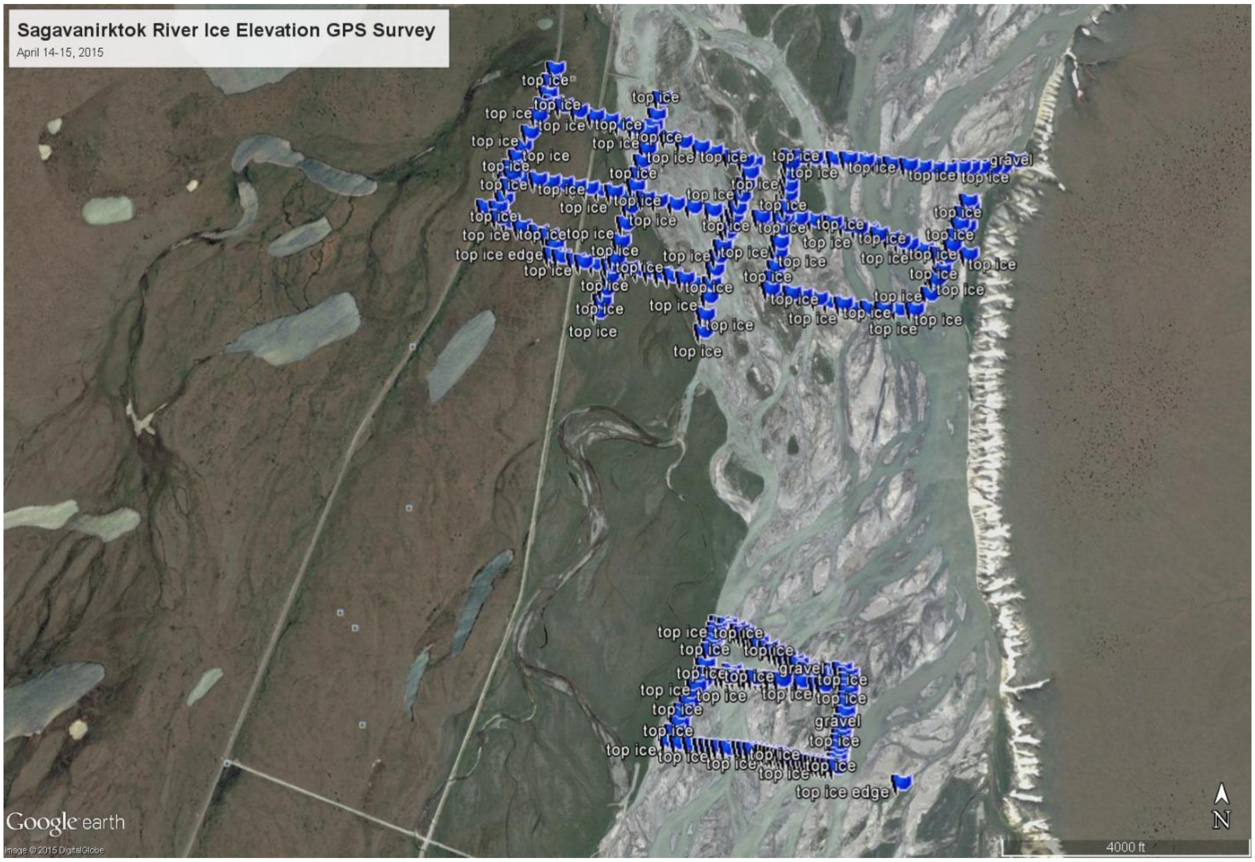


Figure 12. Locations of points surveyed with a GPS to map ice elevation near Franklin Bluffs.

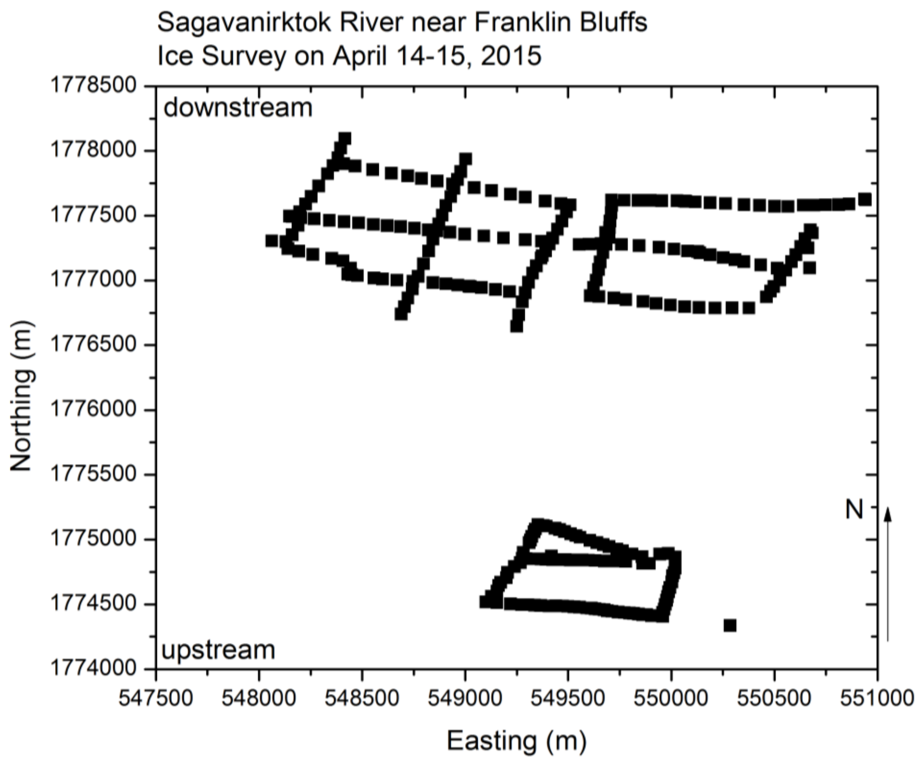


Figure 13. Ice survey locations in northing and easting coordinates (Alaska State Plane Zone 4).

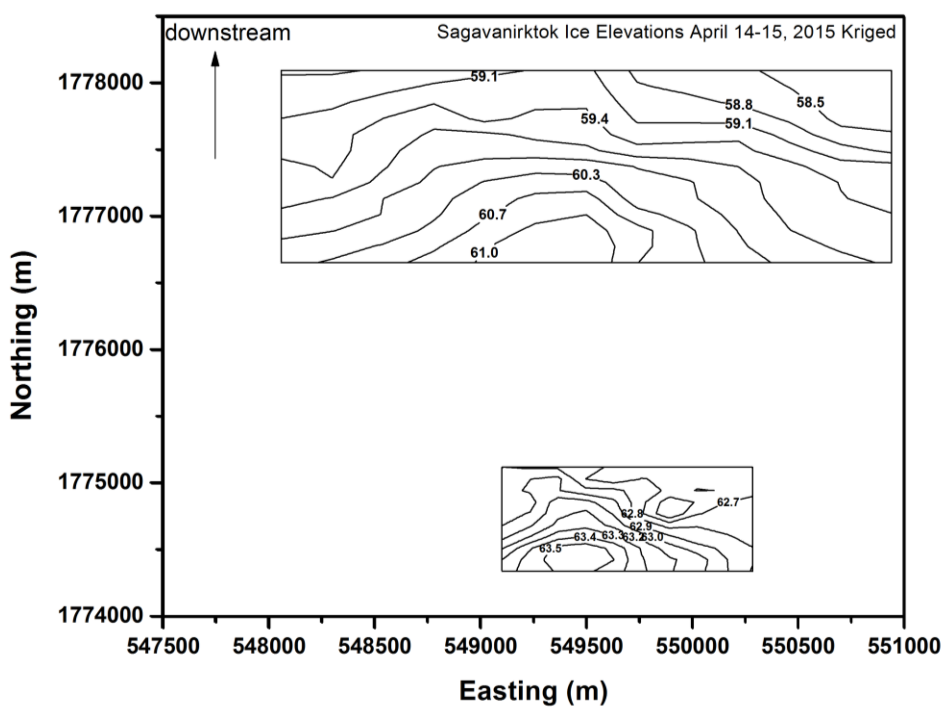
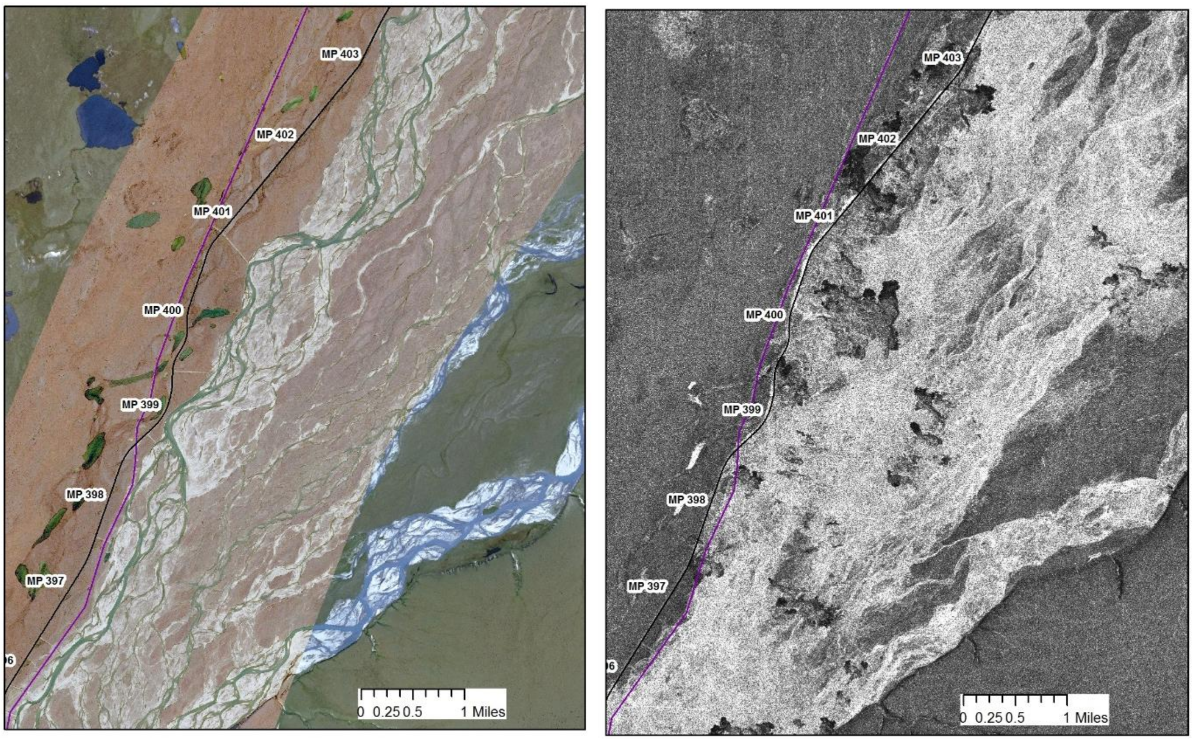


Figure 14. Results of the GPS survey to map ice elevations. Kriged data show a higher elevation mound in the middle and ice slopes to the northwest and northeast.

4.5.2 X-Band SAR Analysis

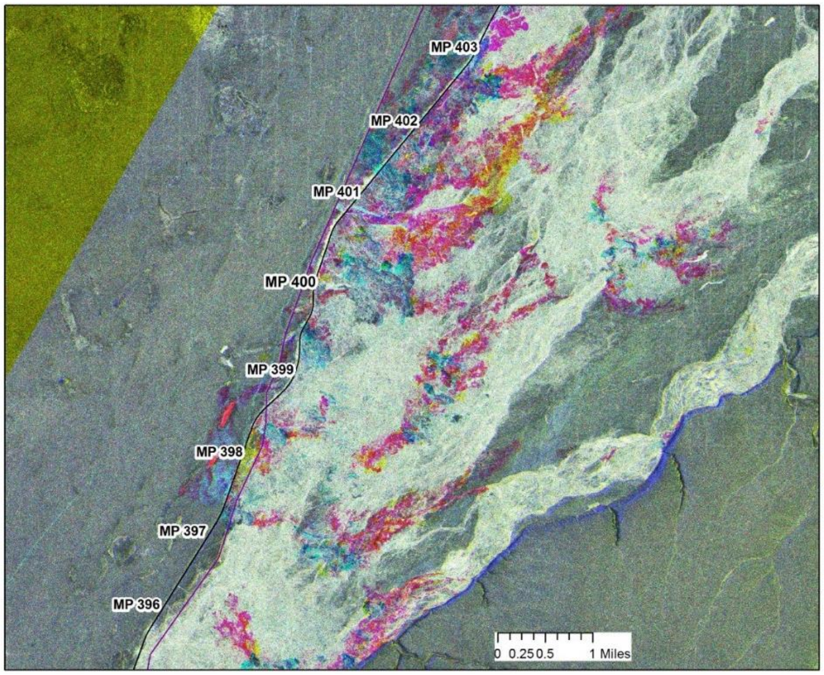
The earliest SAR acquisition on April 8, 2015 (Figure 15b), showed liquid water (dark) flowing on top of river ice, water on the Dalton Highway, and water to the west of the highway. Subsequent dates showed growth in the extent of these wet areas, with new wet areas emerging on top of the river ice.



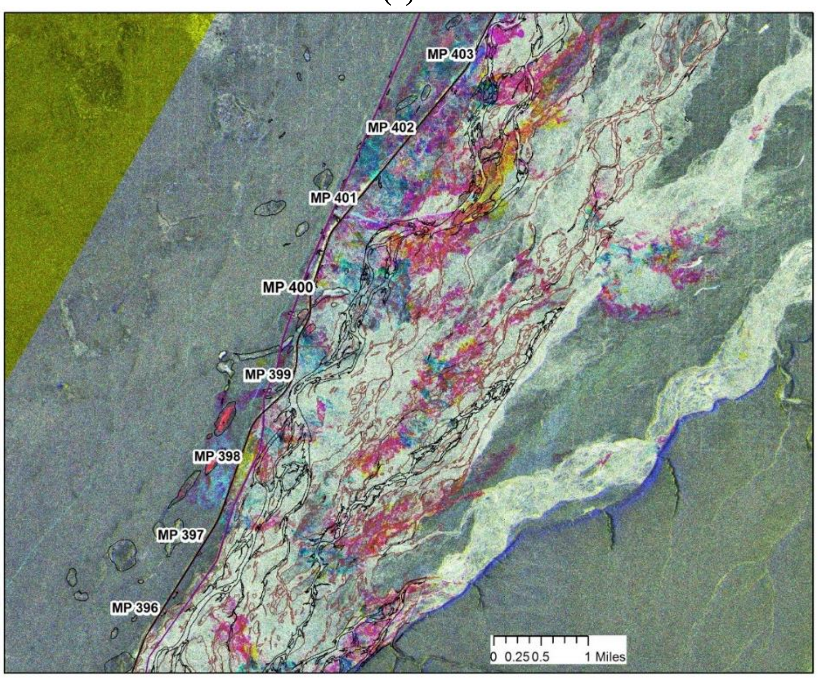
(a) (b)

Figure 15. Optical image (a) a narrow strip from SPOT6 shows river channel in 2014, with brown land and green water overlying optical Best Data Layer from Geographic Information Network of Alaska, compared with (b) TerraSAR-X image from April 8, 2015. Overflow appears as dark areas in SAR image (b); river ice shows as white. Dalton Highway is black line with milepost labels (ADOT&PF shapefile), and Trans-Alaska Pipeline is purple line (AK DNR shapefile).

A comparison of three early April 2015 dates of SAR in a false-color RGB composite (Figure 16a) shows a progression of overflow near the Trans-Alaska Pipeline (TAP) and the Dalton Highway near MP401 to MP403. A comparison of three SAR images from late April in an RGB color composite (Figure 17a) shows overflow patterns forming and water flowing downstream farther from the highway. Channels that had been constructed near the highway to remove water from the road appear bright in the late April composite (Figure 17a) due to snow piled next to the narrow channels of water.

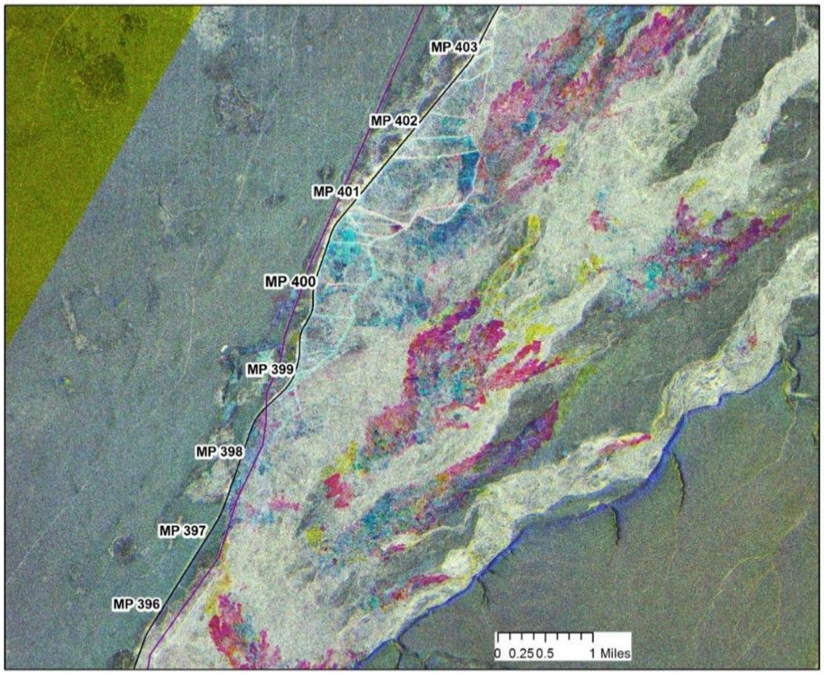


(a)

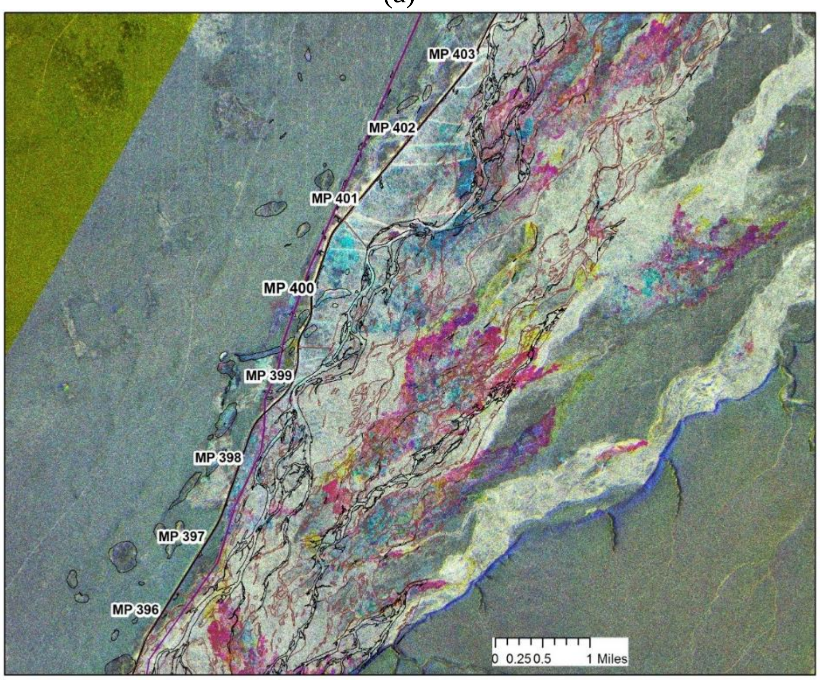


(b)

Figure 16. (a) A false-color composite with April 8, 2015, SAR as red band, April 13, 2015, SAR as green band, and April 15, 2015, SAR as blue band. Overflow on April 8 is cyan, overflow on April 13 is magenta, and overflow on April 15 is yellow. (b) Same image with overlay of river water channels derived from 2014 SPOT6 image (black) and gravel channels (brown) for spatial comparison of overflow and riverbed.



(a)



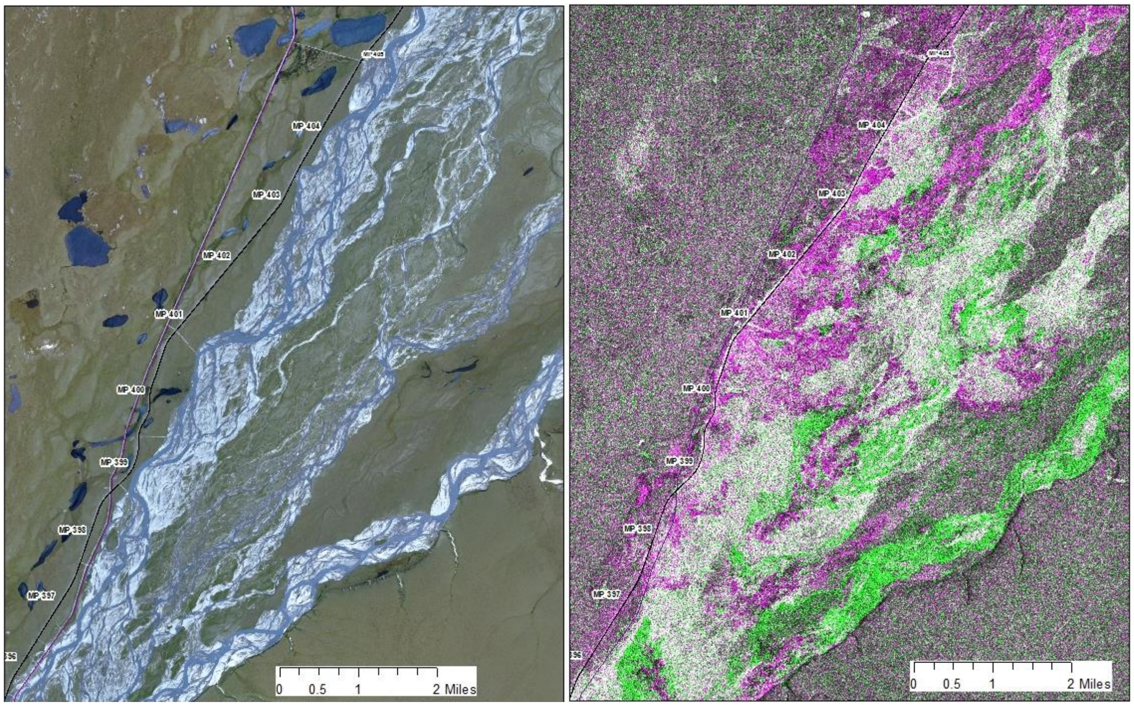
(b)

Figure 17. (a) A false-color composite, with April 19, 2015, SAR as red band, April 24, 2015, SAR as green band, and April 26, 2015, SAR as blue band. Overflow on April 19 is cyan, overflow on April 24 is magenta, and overflow on April 26 is yellow. (b) Same image with overlay of river water channels derived from 2014 SPOT 6 image (black) and gravel channels (brown) for spatial comparison of overflow and riverbed. Flood abatement activity by ADOT&PF is visible from MP339 to MP403 (thick white lines).

To compare the TSX image with the outline of the river, the extent of the Sagavanirktok River braided channels were extracted from the September 8, 2014, SPOT 6 image using an unsupervised classification to 12 categories. These 12 categories were reclassified to 3: water, riverbed/gravel, and surrounding land. The river channel outline from 2014 was superimposed onto the SAR images (Figure 16b and Figure 17b) to determine if there was a spatial correlation between the river channels from 2014 and the areas of overflow on the SAR image. No relationship between overflow in the TSX composite images and the river channels could be detected. Overflow patterns sometimes followed a similar route as the riverbed, and sometimes the overflow emerged on top of river ice in areas above islands, gravel, or mud flats between channels of the river.

The river ice in the TSX images was examined and compared with the spatial extent of the river channels from 2014 SPOT 6 images to find areas where river ice was completely frozen to the riverbed (which should appear darker in SAR) and areas where liquid water was under the river ice (which would appear brighter in SAR). We could not discern grounded versus floating ice regimes from these images.

A comparison of an early image (April 13, 2015) with a late image (May 5, 2015) using a false-color composite image, with May 5 as red band, April 13 as green band, and May 5 as blue band near MP400, shows overflow predominately on the west channel of the Sagavanirktok River close to (and over) the highway in the early April image, and overflow predominately on the east channel in the later image. Comparison of this early/late SAR RGB composite with an optical image from circa 2009 (Figure 18a) shows that ice and water in the spring 2015 SAR images are not confined to the extent of the river channels (Figure 18b). Further comparisons can be found in Appendix A.



(a) (b)

Figure 18. (a) Optical SPOT mosaic (circa 2009) image of Sagavanirktok River at MP400 from Geographic Information Network of Alaska, compared with (b) a false-color composite created using a later X-band SAR image (May 5, 2015) in red and blue bands, with an early SAR image (April 13, 2015) in the green band. Liquid water on April 13, 2015, is magenta, while liquid water on May 5, 2015, is green, showing the water flow in the west channel in April, but changing to the east channel in May. White is ice on both dates.

Additional change detection near Prudhoe Bay using SAR imagery was completed by researchers at the UAF Earth and Planetary Remote Sensing Group (Ajadi and Meyer, 2015, personal communication). Results are presented in Figure 19. Ajadi and Meyer described their approach as follows:

> *The approach is composed of two steps: (1) data enhancement and filtering, and (2) the creation of a multiscale change detection map. In the data enhancement and filtering step, a ratio image was formed by dividing the SAR image by a reference acquisition to suppress stationary image information and enhance change signatures. The generated ratio image was further log-transformed to create near-Gaussian data and to convert the originally multiplicative noise into additive noise. A subsequent fast nonlocal mean filter was applied to reduce image noise while preserving most of the image details. The filtered log-ratio image was then inserted into a multiscale change detection algorithm composed of (1) a multiscale decomposition of the input image using a two-dimensional discrete stationary wavelet transform (2D-SWT); (2) a multiresolution classification (adaptive scale selection) into "change" and "no-change" areas; and (3) a scale-driven fusion of the classification results.*

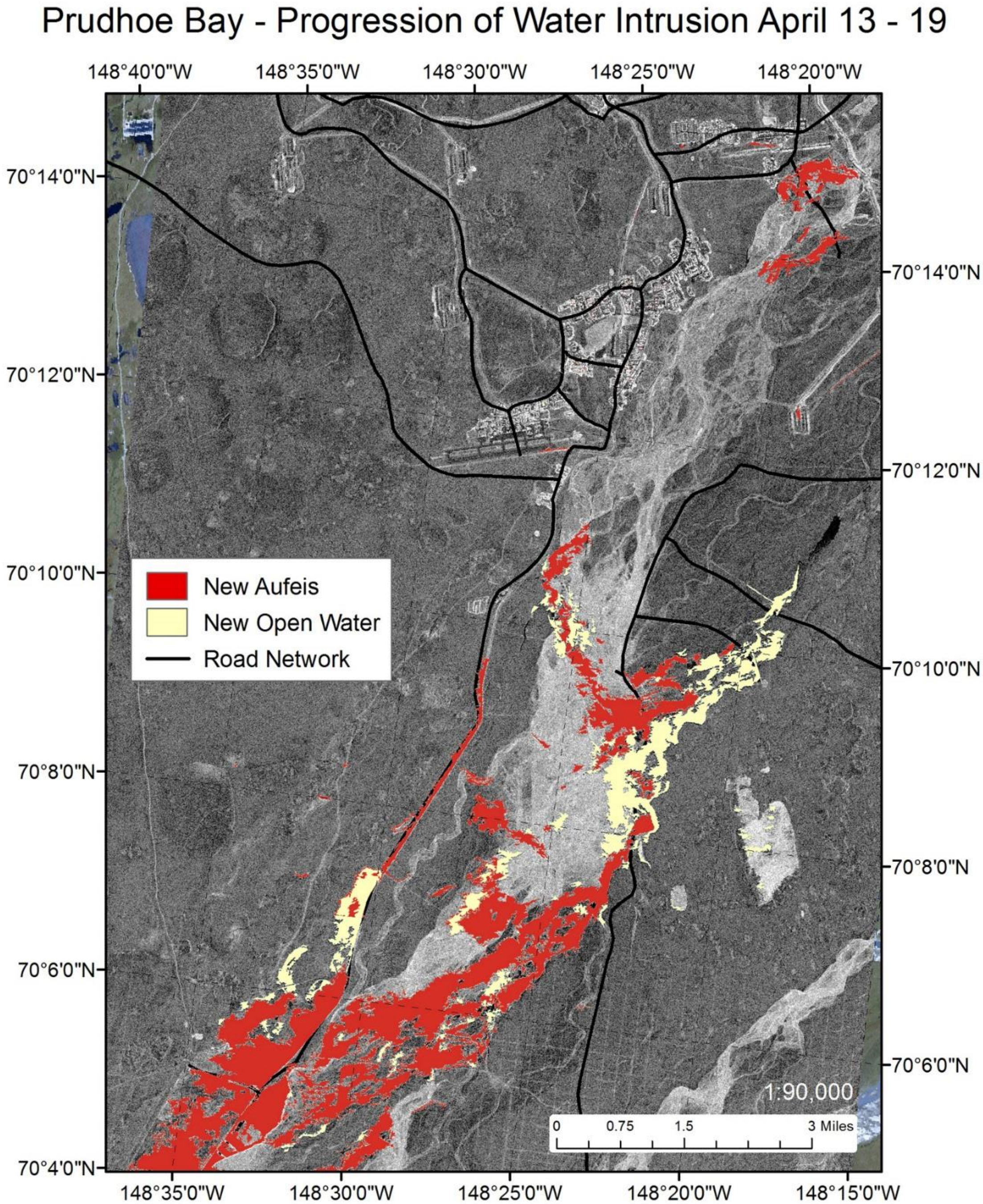


Figure 19. Change detection map showing the progression of water intrusion in Prudhoe Bay (created and provided by Ajadi and Meyer [2015, personal communication]). The red color represents new aufeis, and the cream color represents areas of open water intrusion to the surface.

In summary, SAR was useful for detecting the location of liquid water during this overflow event. While X-band data are useful for high-resolution imagery, managers could consider using

C-band SAR for greater ice penetration and for comparison with archived C-band imagery over the Sagavanirktok River. We recommend trying VV polarization or dual-polarized (HH and HV, or VV and HV) options to better delineate different types of ice. RADARSAT-2 has these capabilities (Canadian Space Agency).

4.5.3 Water Levels

In this section, the results of water levels collected at five sites on the west side of the Sagavanirktok River and one site on the east side of the river are presented. Manual level surveys of river stage were taken as frequently as possible at the sites, daily at the East Bank station near Franklin Bluffs and at least one time at the HOBO sites (Table 9 through Table 15). Continuous recording (15-minute readings) pressure transducers were installed in the river or along the road to document maximum water surface elevations. All elevation data were surveyed to the temporary benchmarks established by ADOT&PF and are reported in NAVD88 (using the GEOID12AK model).

As the initial front reached the station near Franklin Bluffs on May 16, water began flowing over the ice. Much of the flow was confined to the east side of the main channel. Until May 18, the snow dikes that were constructed by ADOT&PF diverted most of the flow toward the east channel. Water levels in the river channel (recorded at the East Bank station) were at their maximum elevations through May 20, the date at which peak flow likely occurred based on field measurements of discharge (Figure 20). After the peak, water levels rapidly declined because ice no longer remained in the channel. Flows continued to decrease until May 29, when a rain event occurred causing flows and stages to increase briefly. In the main channel (on the east side of the river at Franklin Bluffs), maximum water level was 59.52 m on May 18. After the river receded (from the rain event on May 29–30), water levels had dropped 3 m from maximum elevation to a low of 56.56 m on June 7.

On the west side of the river, in the west channel (downstream from the East Bank station), water levels remained high until May 24 at Spur Dike 6 (near MP396) as shown in Figure 21. On the Dalton Highway, water levels rose over the road near the Alyeska Gate and MP395.5 (Figure 22). Farther downstream, along the Dalton Highway, water levels gradually rose as the snow dikes began to fail. At MP399, where the road is close to the Sagavanirktok River west channel, water levels reached their maximum of 47.23 m on May 20 (Figure 23) and declined dramatically on May 25 as discharge decreased. At MP402, at least one-quarter mile from the west channel, water levels also gradually rose to a maximum of 38.01 m on May 26, and immediately after the peak, declined by nearly 1 m (Figure 24).

Farther downstream, closer to Deadhorse, water levels were monitored in the Sagavanirktok River channel near MP414 and at the erosion control barbs. Water levels began rising by May 18 and reached a peak of over 11.2 m on May 20 (Figure 25). By May 25, water levels had dropped by over 1 m from the peak.

Table 9. Water level elevations at the Sagavanirktok River East Bank station.

Date/Time (AST)	Elevation (m, NAVD 88, GEOID12AK)	Survey Crew	Notes
5/16/2015 10:56	59.093	UAF-JK	
5/17/2015 15:12	59.401	UAF-JK	
5/18/2015 10:20	59.478	UAF-JK	
5/18/2015 12:23	59.353	UAF-JK	
5/18/2015 16:38	59.253	UAF-JK	
5/19/2015 14:12	59.255	UAF-JK	
5/20/2015 13:44	58.996	UAF-JK	
5/21/2015 13:35	58.750	UAF-JK	
5/22/2015 13:30	58.656	UAF-JK	
5/22/2015 14:07	58.687	UAF-JK	
5/23/2015 11:49	58.310	UAF-JK	
5/24/2015 15:12	57.964	UAF-JK	
5/26/2015 13:19	57.793	UAF-JK	
5/27/2015 16:38	57.470	UAF-JK	PTs not in main channel
5/28/2015 11:35	57.348	UAF-JK	PTs not in main channel
5/29/2015 15:41	57.301	UAF-JK	
5/30/2015 15:52	57.571	UAF-JK	
5/31/2015 14:32	57.211	UAF-JK	
6/1/2015 10:31	56.980	UAF-JK	
6/2/2015 11:59	56.787	UAF-JK	

Table 10. Water level elevations at HOBO3-Alyeska Gate-MP395.

Date/Time (AST)	Elevation (m, NAVD 88, GEOID12AK)	Survey Crew
5/21/2015 15:00	56.22934	UAF-JK

Table 11. Water level elevations at HOBO8-Spur Dike 6 in the Sagavanirktok River.

Date/Time (AST)	Elevation (m, NAVD 88, GEOID12AK)	Survey Crew
5/16/2015 14:40	53.6161	ADOT
5/26/2015 9:19	53.3291	UAF-JK

Table 12. Water level elevations at HOBO19-MP399.

Date/Time (AST)	Elevation (m, NAVD 88, GEOID12AK)	Survey Crew
5/16/2015 15:47	46.73598	ADOT
5/17/2015 12:00	46.97668	ADOT
5/21/2015 15:34	47.18668	UAF-JK
5/26/2015 8:23	46.70368	UAF-JK

Table 13. Water level elevations at HOBO20-MP402.

Date/Time (AST)	Elevation (m, NAVD 88, GEOID12AK)	Survey Crew
5/17/2015 10:00	37.701	ADOT-TH
5/26/2015 8:55	37.9628	UAF-JK
5/29/2015 14:40	37.2588	UAF-JK

Table 14. Water level elevations at HOBO70-MP410.

Date/Time (AST)	Elevation (m, NAVD 88, GEOID12AK)	Survey Crew
5/22/2015 16:06	15.80	UAF-JK
5/26/2015 15:45	15.75	UAF-JK
5/31/2015 15:08	15.81	UAF-JK
6/2/2015 11:59	15.67	UAF-JK

Table 15. Water level elevations at HOBO99-MP414.

Date/Time (AST)	Elevation (m, NAVD 88, GEOID12AK)	Survey Crew
5/18/2015 8:16	10.75	UAF-JK
5/19/2015 9:25	11.08	UAF-JK
5/20/2015 15:37	11.18	UAF-JK
5/22/2015 8:17	10.80	UAF-JK
5/24/2015 17:05	10.68	UAF-JK
5/25/2015 18:57	9.89	UAF-JK

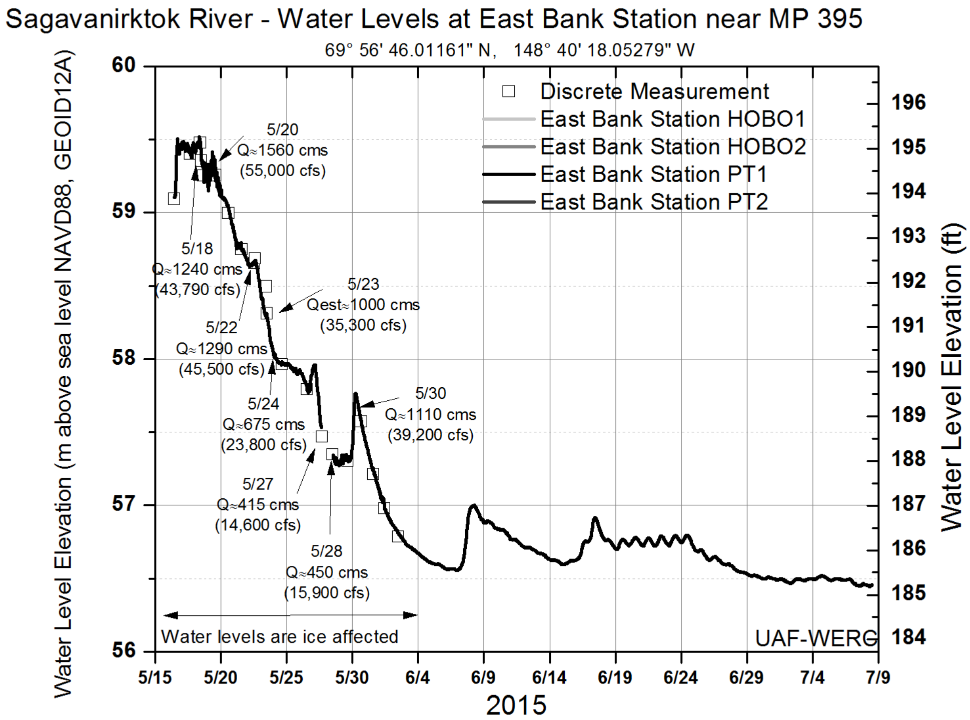


Figure 20. Water levels in the Sagavanirktok River at the East Bank station, near Franklin Bluffs. Measurements of approximate river discharge are also displayed on the plot.

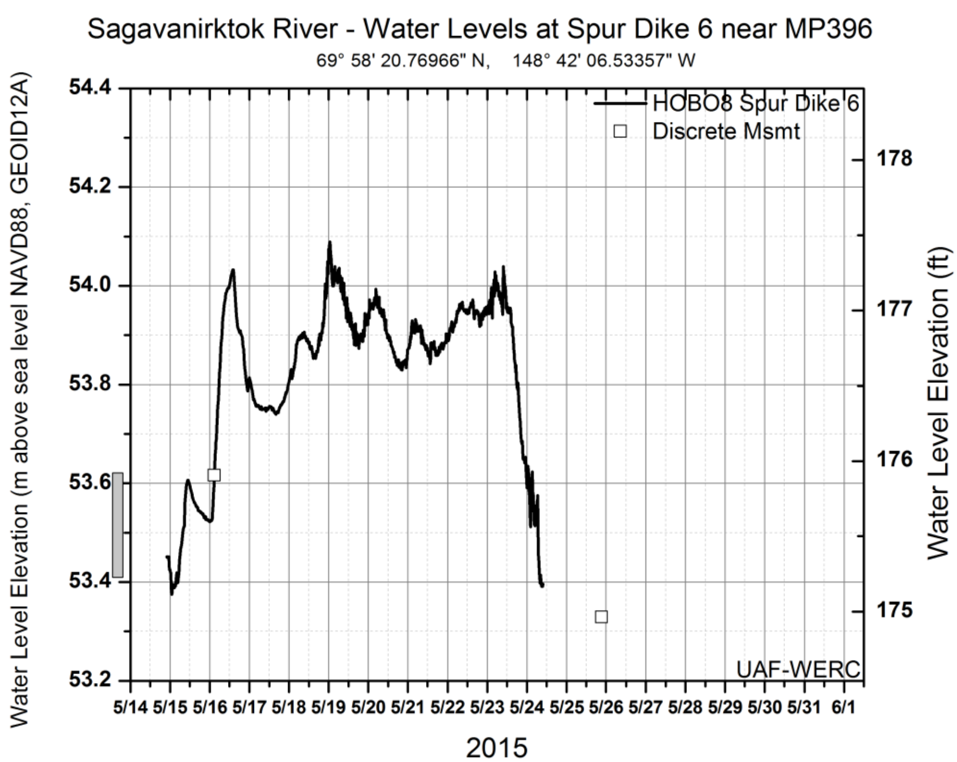


Figure 21. Water levels in the Sagavanirktok River at Spur Dike 6 near MP396.

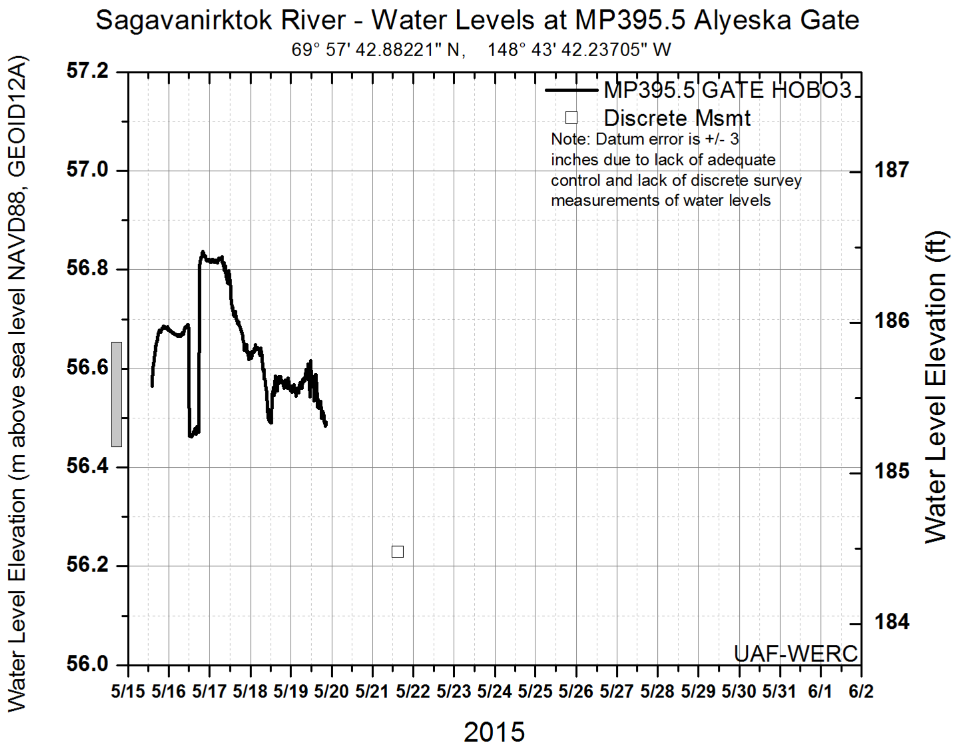


Figure 22. Water levels on the Dalton Highway near MP395.5 (Alyeska gate).

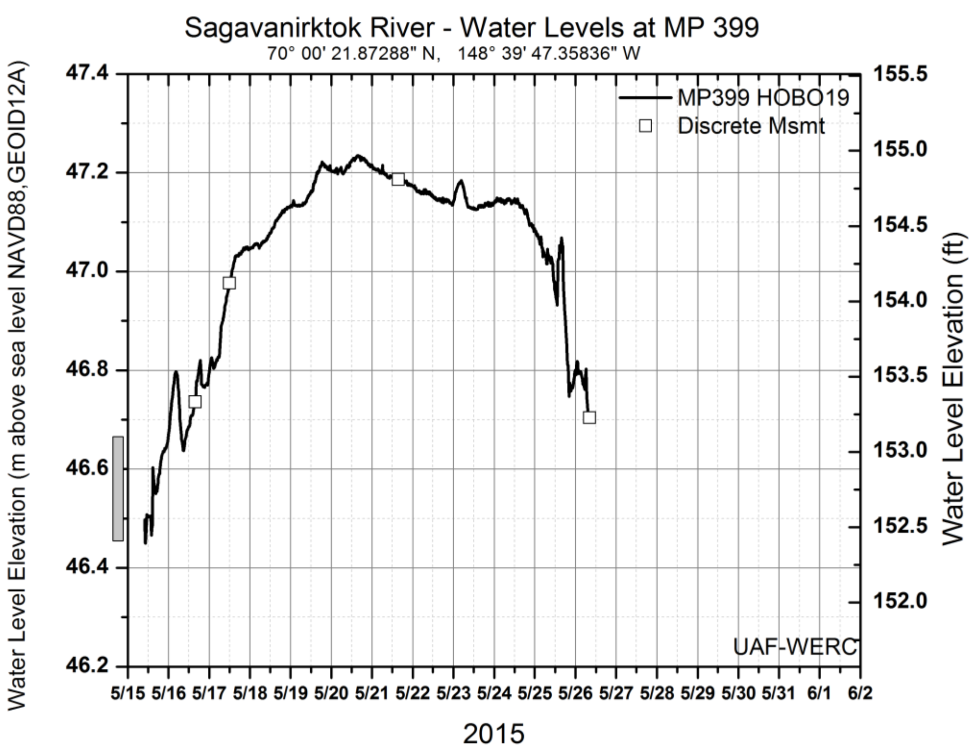


Figure 23. Water levels on the Dalton Highway near MP399.

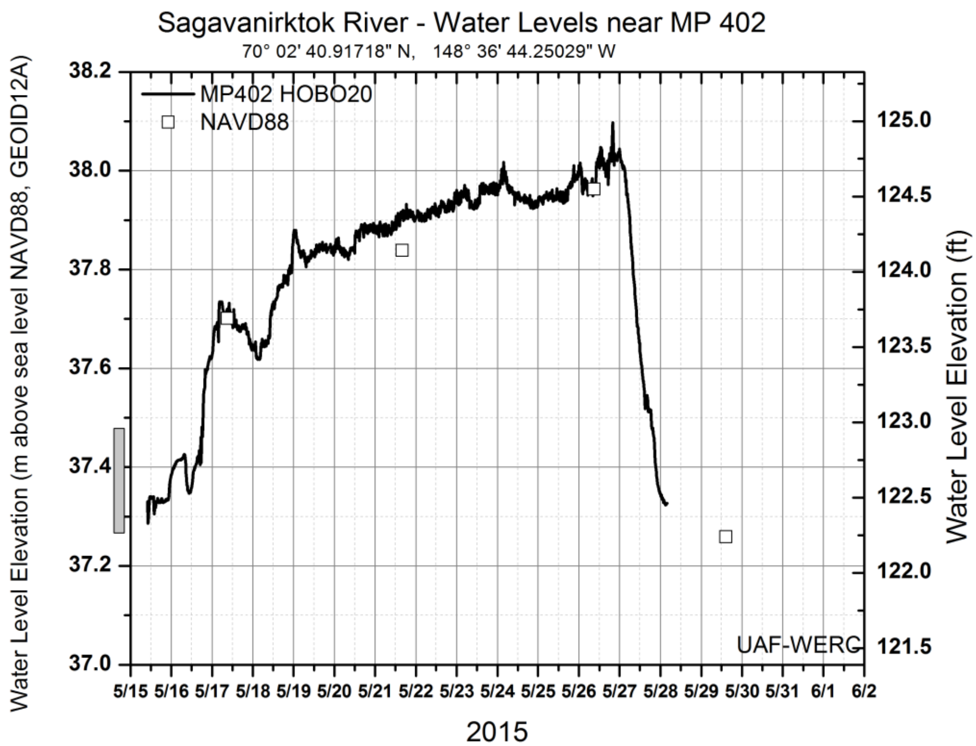


Figure 24. Water levels on the Dalton Highway near MP402.

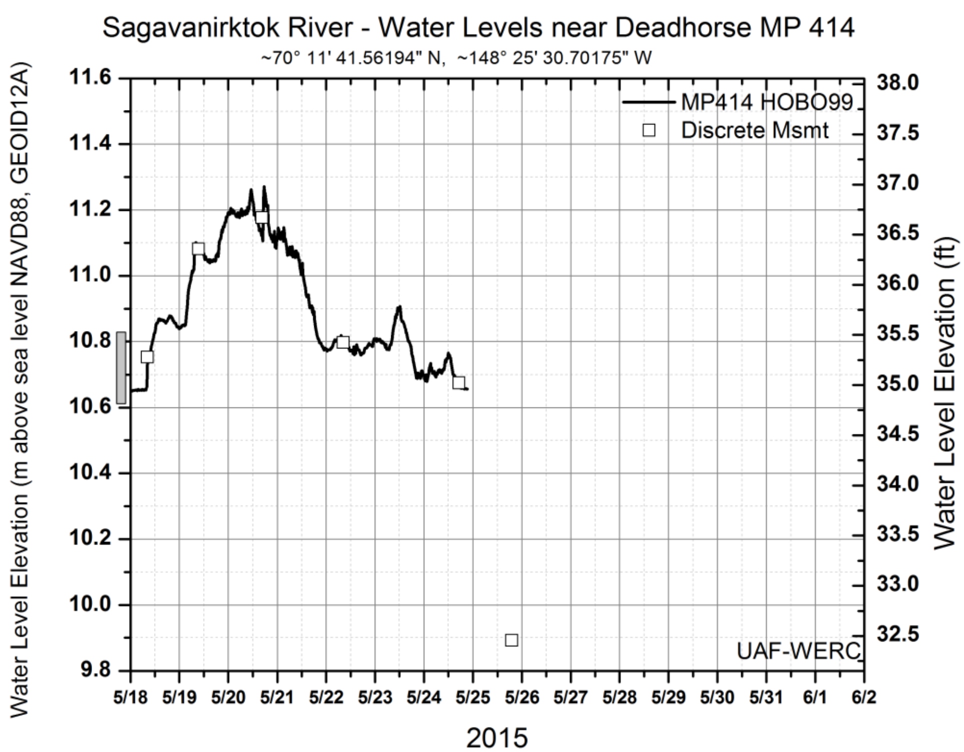


Figure 25. Water levels in the Sagavanirktok River near Deadhorse, MP414.

4.5.4 Discharge Measurements

Individual measurements of discharge were made with an ADCP when safe to do so. Measurements at this location of the Sagavanirktok River are challenging due to the river's natural braiding as the main channel divides into the east and west channels. Because of the vast amount of ice that had accumulated in the channels, the runoff tended to be over bankfull as it spread over the ice. Additionally, measurements had to be conducted when conditions were safe to have a boat in the water (i.e., low amounts of ice and debris). Measurements were made on eight days between May 15 and June 1. All measurements were made using a 15-foot aluminum Jon boat with a 35 HP jet motor and a side-mounted ADCP. Early measurements were made with the Rio Grande 1200 kHz, and later measurements were made with a StreamPro. An RTK or WAAS GPS (VTG as the GPS reference) was used with the ADCP to measure river velocity. At least 90% of the runoff was typically measured, except on May 23, when only 20% of the runoff was measured (the rest was estimated based on channel width and velocity from measurements the previous day). Various factors such as technical difficulties and river conditions led to measurement coefficient of variation (COV) of 2–15% and measurement ratings of fair to poor. Figure 4 shows the locations of all transects made during breakup. Table 16 summarizes the discharge measurements.

Table 16. ADCP discharge measurements during spring 2015 on the Sagavanirktok River.

Date	Msmt. Number	Discharge (m^3/s)	Discharge (ft^3/s)	Percent of Channel Measured (%)	Coefficient of Variation (%)	Msmt. Rating	Reference	Notes
5/18/2015 14:50	1	1240	43790	90	N/A, only 1 transect	Poor	VTG	One R to L transect only
5/20/2015 12:50	2	1560	55090	90	4	Fair	RTK/VTG	
5/22/2015 12:30	3	1290	45450	90	5	Fair	RTK/VTG	
5/23/2015 10:00	4	1000e	35310e	20	N/A, estimated	Poor	WAAS and RTK/VTG	
5/24/2015 13:15	5	675	23835	95	10	Poor	WAAS and RTK/VTG	L to R transects only
5/27/2015 15:00	6	415	14655	95	2 (west) and 4 (east)	Fair	RTK/VTG	L to R transects only
5/28/2015 10:15	7	450	15890	95	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	95	6 (west) and 3 (east)	Poor	WAAS and RTK/VTG	Directional bias suspected; R to L transects only; and beam 3 misalignment

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

Pictures were taken at the measurement reach each day (Figure 26 through Figure 34). Additional photographs can be found in Appendix B. Around May 20, 2015, the peak flow for spring breakup was over 1600 cms (56,500 cfs). Flows decreased through the next week, until a rainfall event on May 29 caused flows to increase for a brief period.

Figure 26. Measurement reach looking north on May 18, 2015. The Franklin Bluffs are on the right. Most of the flow is on the east (right) side of the channel, partially contained by a failing snow dike. Water is flowing over ice to the left (west) of the snow dike.

Figure 27. Measurement reach on May 20, 2015, facing southwest, with Franklin Bluffs in the distance. The photograph shows water flowing over the Dalton Highway near the spur dikes. Water levels are very high, and water continues to flow over the ice on the western side of the river.

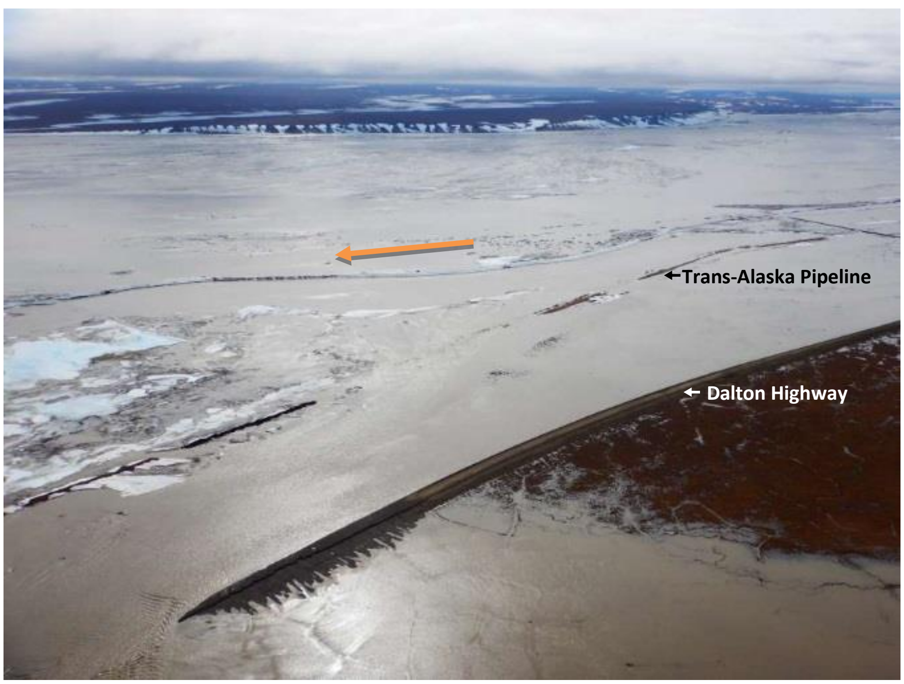


Figure 28. Measurement reach on May 22, 2015, facing southwest. Franklin Bluffs are visible in the distance. The linear and curvilinear forms in the photo are from top to bottom: a snow dike, the buried pipeline, and the Dalton Highway. The road prism was breached and completely washed out at the bottom left of the photo.

Figure 29. Measurement reach on May 23, 2015, facing south. Franklin Bluffs are visible at the top left of the photograph.

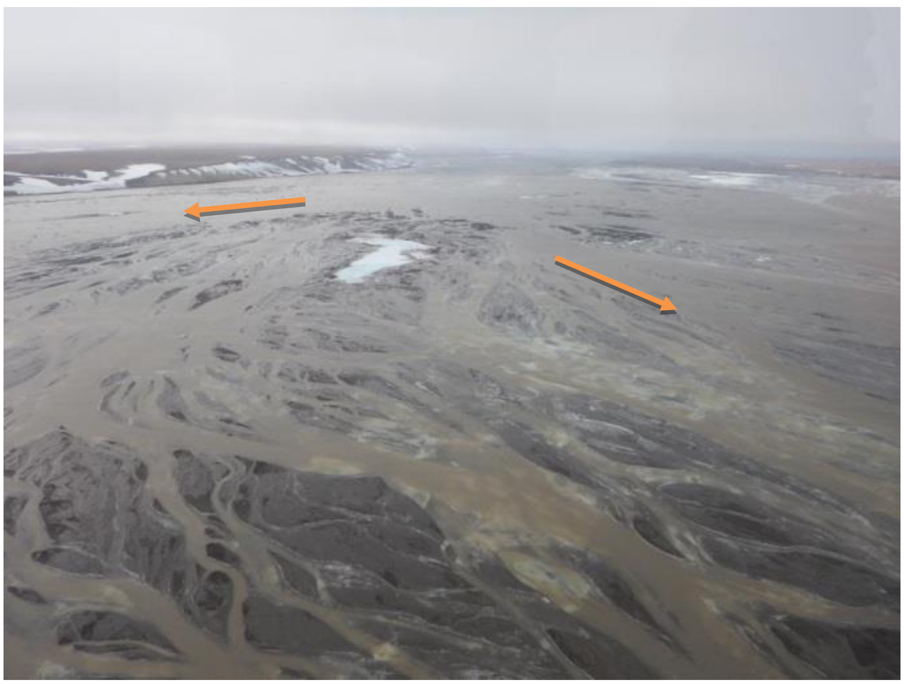


Figure 30. Measurement reach on May 24, 2015. Photograph is taken facing south, and Franklin Bluffs are visible at the top left. Water levels have declined, and gravel bars are becoming visible, defining the bifurcation.

Figure 31. Measurement reach on May 27, 2015, facing south. Franklin Bluffs are at the left. Water levels have receded, and stranded ice is observed on gravel bars.

Figure 32. Measurement reach on May 28, 2015, near the west channel facing south. Franklin Bluffs are visible toward the top center of the photograph. Extensive ice remains in the west channel.

Figure 33. Measurement reach on May 29, 2015, facing south (upstream). Franklin Bluffs are visible at the left. Water levels have increased in response to rain. This channel is the East Fork.

Figure 34. Measurement reach on May 30, 2015, facing southwest. Franklin Bluffs are in the distance. Water levels and flows increased in response to rainfall.

Individual water level peaks from the UAF East Bank site were coupled with the corresponding peaks reported by the USGS gauging station near Pump Station 3. Four distinctive peaks were identified, and the travel time between stations was calculated. Figure 35 shows the travel time as a function of upstream discharge (USGS data). The plot indicates that big flood waves move faster than small flood waves in the river system.

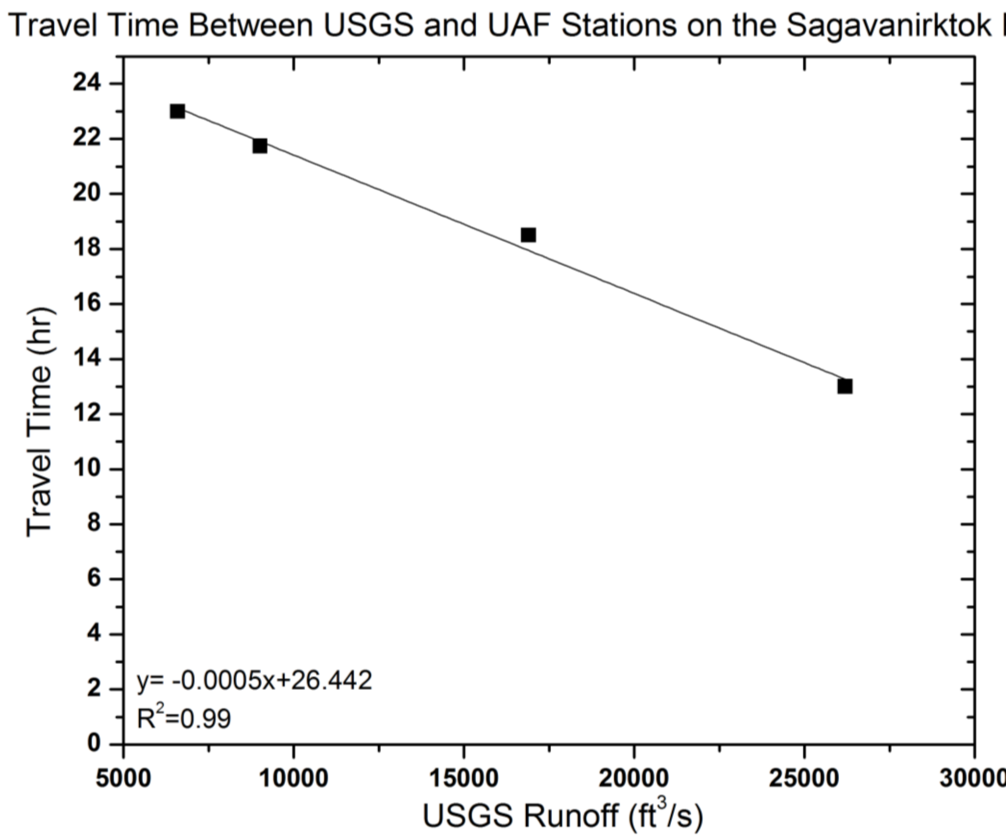


Figure 35. Travel time as a function of river discharge (USGS, 2015).

4.5.5 Additional Field Observations

Runoff at several other rivers within or near the study region was also measured by UAF and the USGS. This section presents runoff measurements on the Upper Sagavanirktok (USGS), the Upper Kuparuk (UAF, funded by U.S. Fish and Wildlife Service [USF&WS]), the Kuparuk at Prudhoe Bay (USGS), and the Putuligayuk at Prudhoe Bay (UAF, funded by USF&WS). Since 1985, runoff data have been collected on Imnavait Creek (UAF, funded by the National Science Foundation). These data can be used to compare long-term runoff records with the flooding observed on the Sagavanirktok River in spring 2015 to see if similar conditions occurred on other rivers.

The Upper Sagavanirktok River originates in the Brooks Range and flows north into the Arctic Ocean near Deadhorse. The basin area at the USGS gauge site is 4100 km^2 (the entire basin is approximately 14,000 km^2), and runoff is measured in the Sagavanirktok before the confluence with the Ivishak River. Above the gauge site, most of the basin lies in the Mountain region; a smaller percentage of the basin area is within the Foothill region. Figure 36 presents hydrographs for the Upper Sagavanirktok River from 2007 through 2015 (in a log scale), although spring runoff data are uncertain. Data are presented in a log scale to show that in 2014, the river did not enter baseflow recession due to the amount of rainfall received all summer long. 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. Even though rainfall events may produce higher flows than breakup flows, spring flows tend to produce higher river stages (PND, 2005). Because cumulative spring runoff is unavailable for the Upper Sagavanirktok site, it is not possible to complete a spring water balance. The timing and magnitude of the highest flow events on the Upper Sagavanirktok correlate well with observations on the lower part of the river (example: May 29 and 30, 2015, rain event).

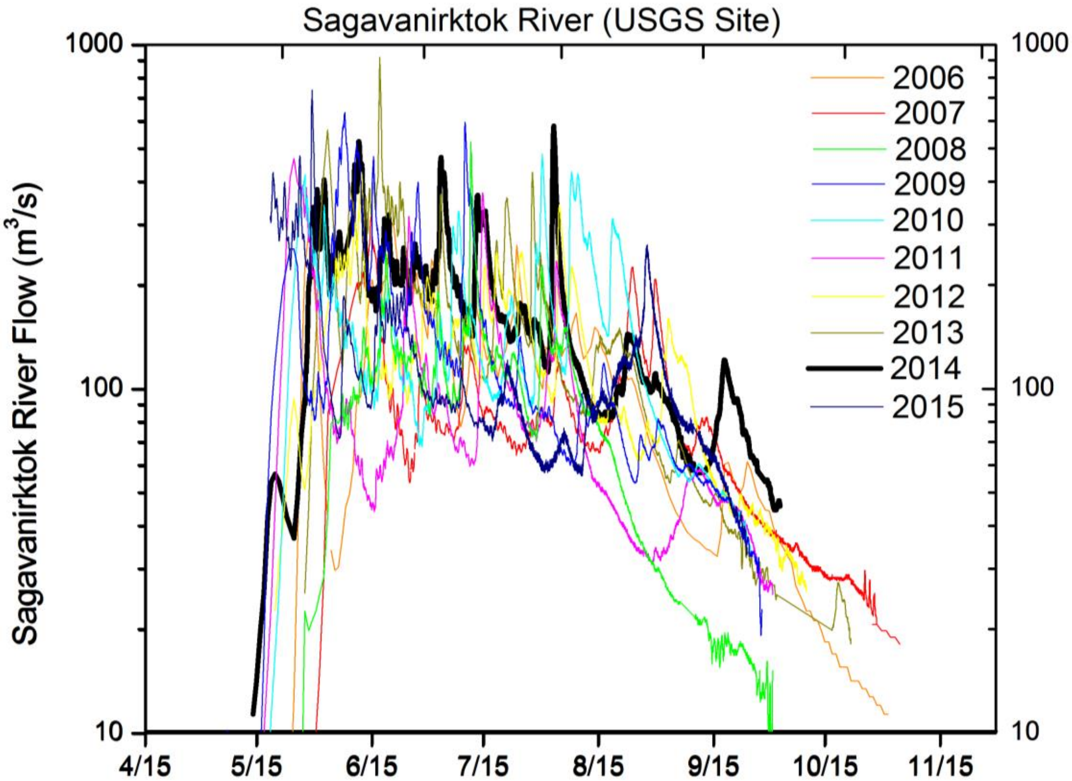


Figure 36. Upper Sagavanirktok River runoff, 2006 to 2015 (USGS, 2015), plotted on a logarithmic scale. Runoff for 2014 is the bold black line; the hydrograph shows no baseflow recession for 2014, indicating basin storage is full.

The Upper Kuparuk River (142 km^2 above the gauge site) is a small basin that originates in the foothills of the Brooks Range; it is the headwaters of the Kuparuk River basin. It is adjacent to and west of the Upper Sagavanirktok basin. Runoff in the Upper Kuparuk River is measured by UAF at the Dalton Highway crossing, just northeast of Toolik Field Station. Runoff is manually measured twice daily during the spring runoff period to capture discharge when the channel is ice-affected, and once or twice per summer to verify and improve the station rating curve. Runoff for the Upper Kuparuk from 2007 to 2014 is presented in Figure 37; the runoff for 2015 is presented in Figure 38. Annual peak flow may be due to snowmelt runoff or summer runoff. Floods of record will always be rainfall-generated (Kane et al., 2008). The timing of both spring and summer peak flow events on the Upper Kuparuk correlates well not only with other nearby small gauged basins (such as the Atigun and Oksrukuyik Rivers that used to be gauged by the USGS), but also with the nearby Itkillik and Sagavanirktok Rivers. The summer floods of 1999 and 2002 were the largest floods that occurred during the 19-year period of record. In 2011, the largest snowmelt runoff event on record occurred, but unfortunately, the peak discharge was not measured. In 2013, another high runoff event occurred during the snowmelt period, which correlates well with the higher snowpack observed by Stuefer et al. (2014). Additionally, the timing of the 2013 peak correlates with that of other nearby rivers (the Upper Sagavanirktok, Itkillik, Anaktuvuk, and Chandler Rivers).

In both 2013 and 2014, the peak flow for breakup was higher than the previous years; however, in 2014 the cumulative volume of flow during spring runoff was very high, nearly double the average. Additionally, the cumulative summer flows were higher than average due to the rainy summer. These data are further shown in Section 4.5.6. In 2015, upon arrival at the Upper Kuparuk, field staff reported a thick aufeis deposit in the floodplain at the gauge site (2 ft thick above the cut bank). The Upper Kuparuk snowmelt runoff for 2015 (Figure 38) was quicker than usual. Peak flow occurred on the night of May 18, approximately a day and a half before the estimated peak flow on the Sagavanirktok River near Deadhorse, and likely within a day of the spring peak flow for the upper Sagavanirktok (USGS gauge site).

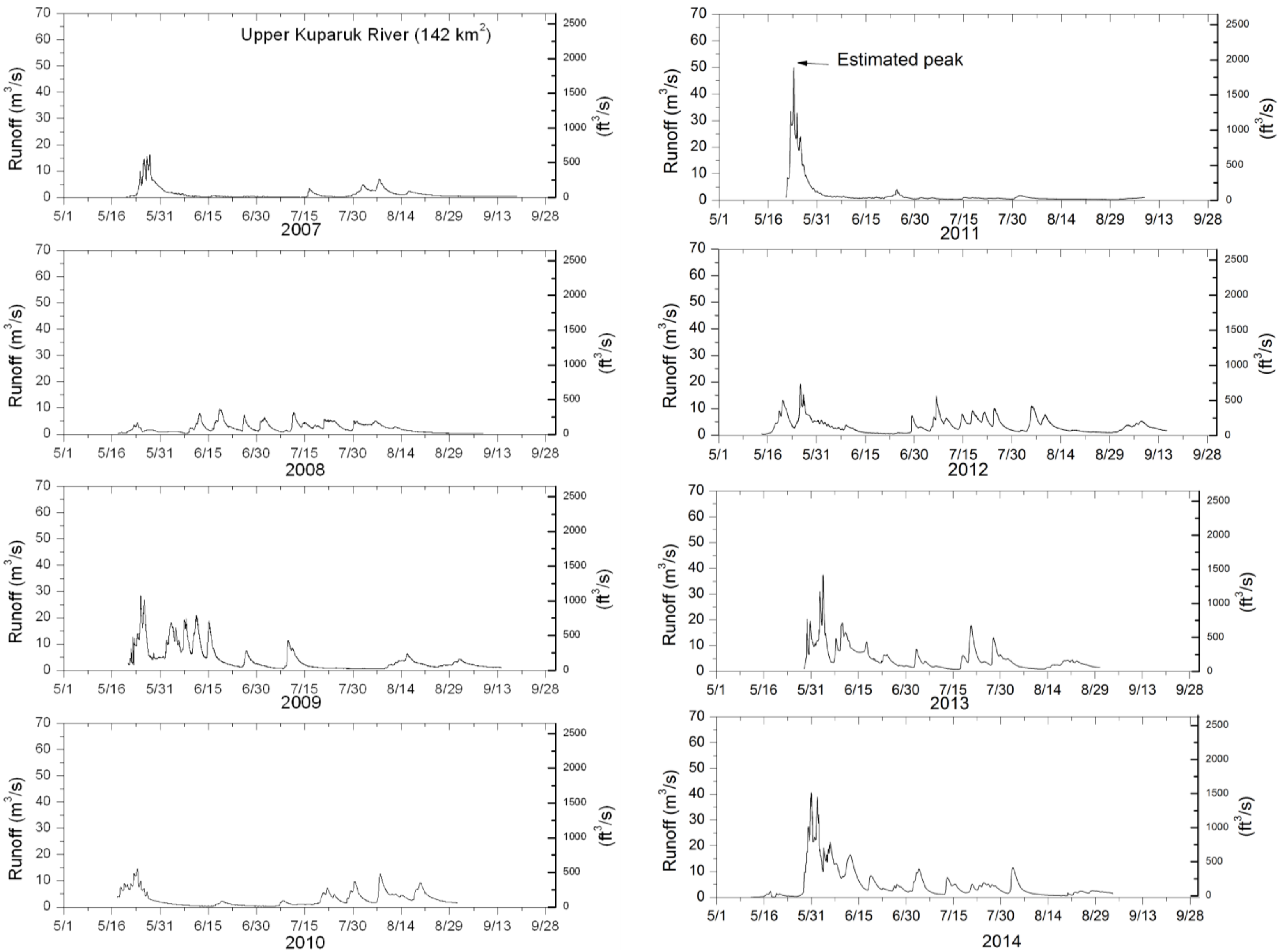


Figure 37. Upper Kuparuk River hydrographs, 2007–2014. The peak flow for spring 2011 is estimated. Data courtesy Kane (2015).

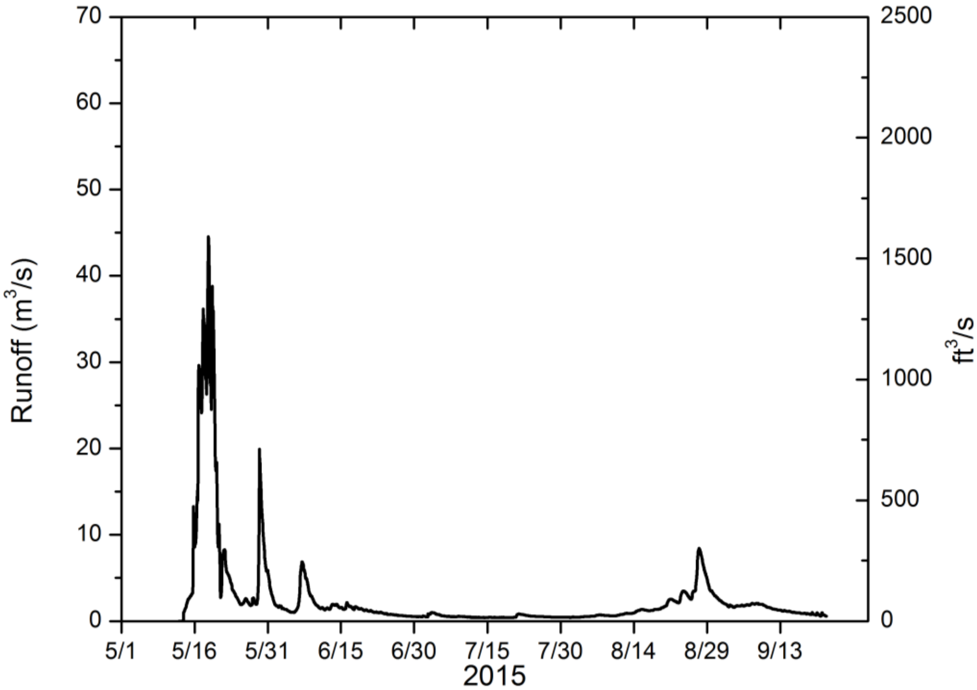


Figure 38. Upper Kuparuk hydrograph for 2015. Data courtesy Arp and Stuefer (2015).

The Kuparuk River originates in the foothills of the Brooks Range and flows north through the coastal plain to the Arctic Ocean. It is a medium-gradient basin of relatively large size (8100 km^2). Approximately 62% of the basin area is within the Foothill region, and 38% is within the Coastal Plain region. Runoff is measured by the USGS near Prudhoe Bay. This data (2007 through 2014) are presented in Figure 39. Since runoff observations began in 1971, the largest runoff event (in terms of total volume and annual peak flow) has always occurred during snowmelt runoff. For the early part of snowmelt runoff, the runoff presented in Figure 39 may be estimated (or reported as mean daily values) if the channel is still ice-affected. Peak snowmelt runoff on the Kuparuk was highest in 2013 during the 7-year study period (based on 15-minute-interval data) and occurred sometime between June 3 and 5, similar to nearby rivers (Kane et al., 2014). Additionally, the cumulative flow for breakup in 2013 was the second highest on record. In 2014, although the magnitude of breakup flow was not unusually high, cumulative flow tied with 2013 for the second highest volume of water on record. Additionally, due to a rainy summer in 2014, the cumulative flow for that year's entire warm season is the highest on record (discussed in Section 4.5.6). Provisional data are also presented for 2015 (USGS, 2015). Unfortunately, the record begins on May 23, when the river was already entering recession (Figure 40). .

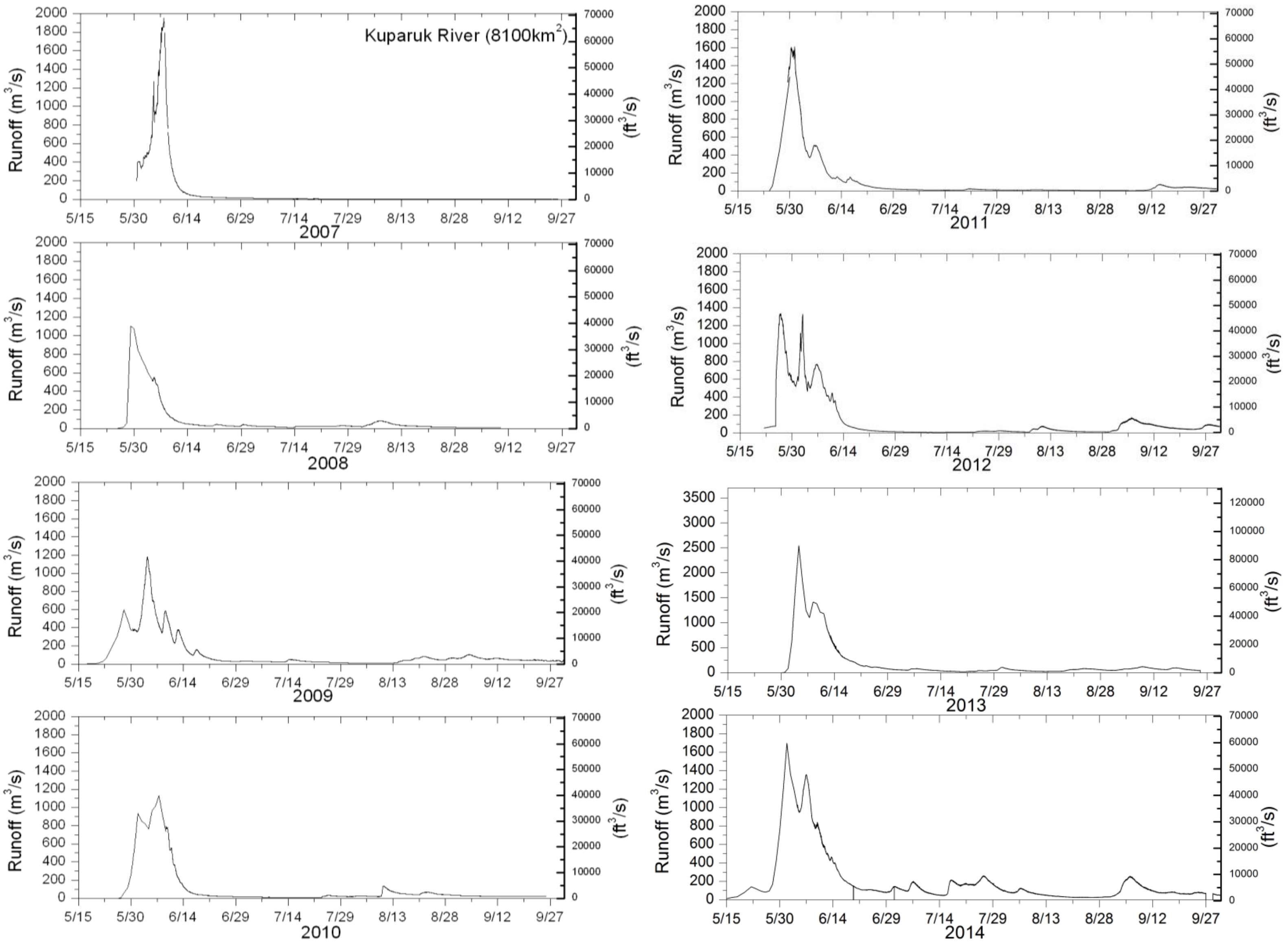


Figure 39. Kuparuk River (at Prudhoe Bay) hydrographs, 2007 to 2013 (USGS, 2015). Note that early data during spring runoff may be estimated due to ice in the channel. Also, note the change in the *y*-axis scale for 2013.

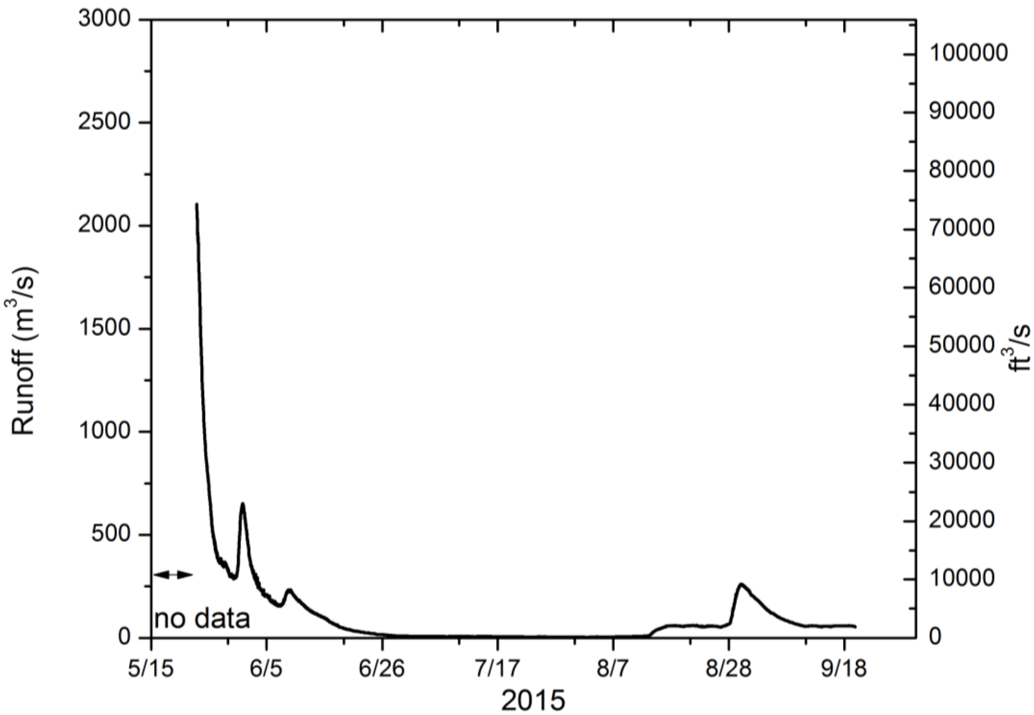


Figure 40. Kuparuk River at Deadhorse hydrograph for 2015 (provisional; USGS, 2015). Data were not available for the early part of breakup, and it is thought that the peak occurred prior to the first available data on the morning of May 23. Note the change in *y*-axis scale from the previous figure.

The Putuligayuk River (471 km^2) is a low-gradient basin contained entirely within the coastal plain and constrained by the Kuparuk to the west and the Sagavanirktok to the east. Snowmelt runoff is the major runoff event of the year, because what little precipitation that occurs during summer goes into deficit storage in the numerous lakes and wetlands within the basin (Kane et al., 2014). Figure 41 presents hydrographs for the Putuligayuk River for the past 8 years. The Putuligayuk is measured twice daily by UAF/WERC during snowmelt runoff and once or twice during the summer months during low flow conditions. The years 2007 and 2008 had lower magnitudes and lower total volumes of runoff. In 2010, the highest peak runoff was recorded for the period of record; however, the total volume of runoff was similar to 2011. Although 2013 and 2014 did not have very high peak flows, the cumulative flow was the highest on record. This topic is discussed further in Section 4.5.6. Additionally, in 2014, the Putuligayuk River had a higher than usual summer baseflow due to the high amount of rainfall over the summer. Unfortunately, runoff could not be measured in spring 2015 due to widespread flooding and road closures in the Deadhorse area. Stage was recorded, however, and the peak flow occurred on May 24 (Figure 42), more than a week earlier than normal (similar to the Kuparuk River at

Deadhorse). Runoff data were not yet available at the time of publication, but based on the rating curve, it is estimated that peak flow was around 112 m^3/s (Gieck, 2015, personal communication).

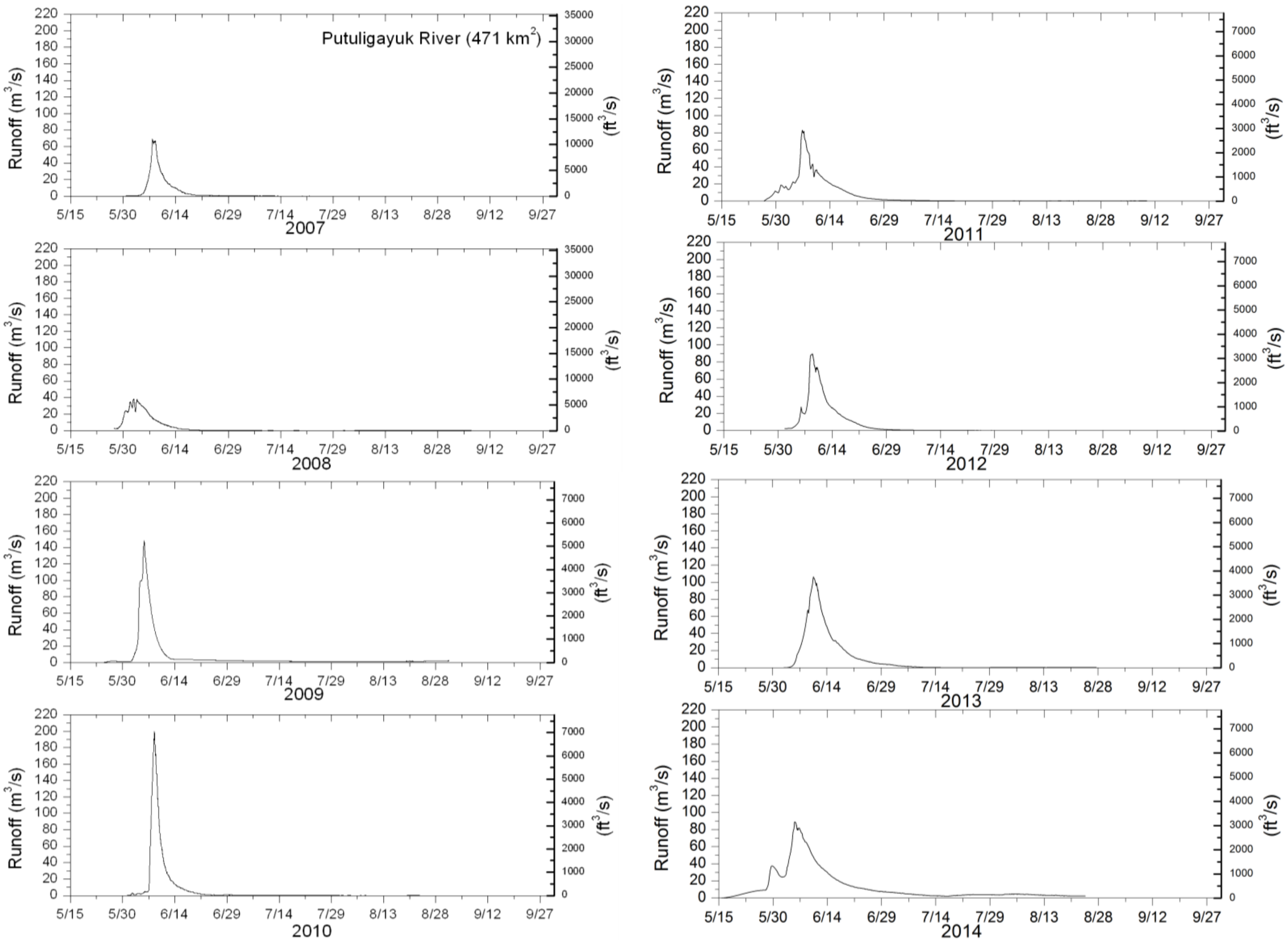


Figure 41. Putuligayuk River hydrographs, 2007–2014. Although peak flows were not very high, both 2013 and 2014 had the highest recorded volumetric flow during breakup, and summer of 2014 had significantly higher than normal volumetric flow.

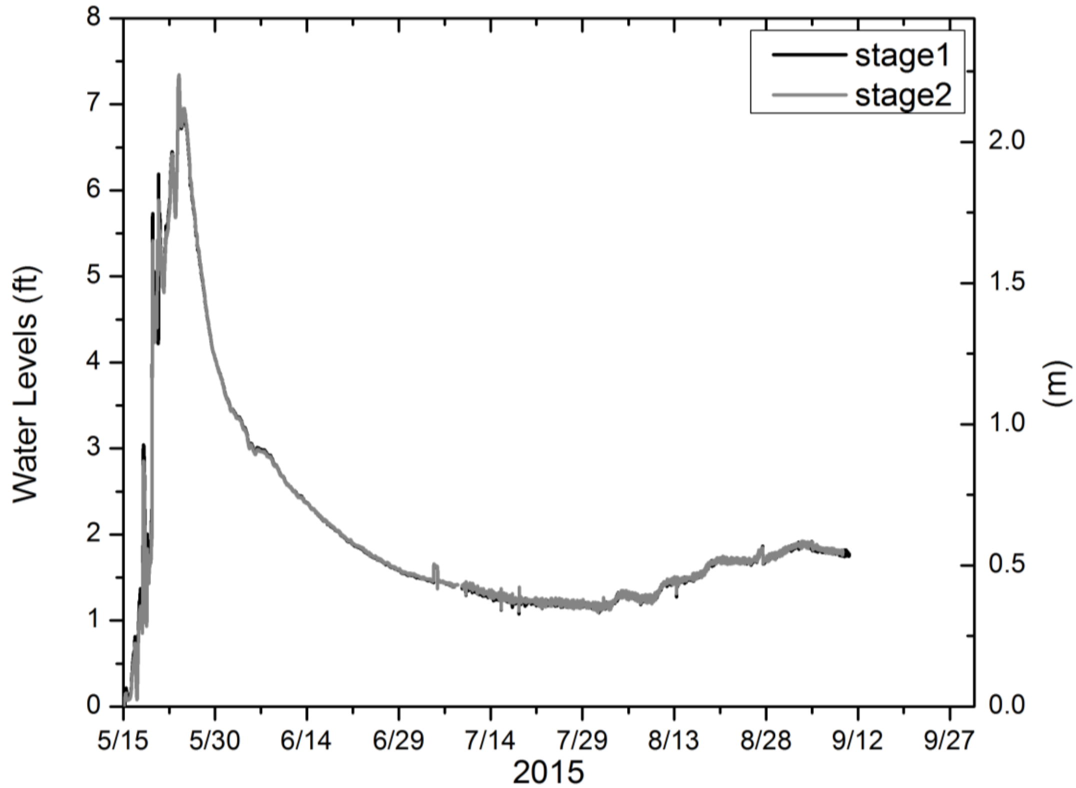


Figure 42. Water levels in 2015 for the Putuligayuk River. Runoff data were not yet available. The peak occurred on May 24, more than a week earlier than normal.

4.5.6 Cumulative Volumetric Warm Season Runoff

The annual cumulative runoff (total volume of water leaving the watershed) in rivers in the region was calculated to examine the water budget for the basin. The water balance is defined as

$$(P_{snow}+P_{rain}) - (R_{snow}+R_{rain}) - ET - \Delta S = \eta \quad (1)$$

where *P* is precipitation, *R is* runoff, *ET* is evapotranspiration, Δ*S* is change in storage, and η is the closure error (Kane et al., 2004). The storage term for basins on the North Slope includes water in the active layer and lakes, ponds, and aufeis. Subpermafrost groundwater is usually not important in North Slope watersheds; however, the Sagavanirktok River may be an exception. Springs in the headwater drainage of the Sagavanirktok River are thought to be of subpermafrost origin (Kane et al., 2013). The USGS makes winter baseflow measurements on the Sagavanirktok River above the confluence with the Ivishak. This winter runoff is either from subpermafrost groundwater or from water stored in the shallow subsurface along the river in unfrozen taliks (Kane et al., 2013).

In this section of the report, the water balance components are examined for whether any were unusual in the Sagavanirktok or adjacent basins in recent years, which could explain some of the recent flooding observed. The focus is on the water balance components that may be easily measured in the hydrometeorological network (such as precipitation and runoff). Evapotranspiration data are not readily available. Another important factor to consider is change in basin storage, such as a change in active layer thickness, subpermafrost groundwater, or shrinking/draining lakes from climate change and permafrost degradation. A detailed analysis, however, is beyond the scope of this report.

Precipitation data pertinent to this study are presented in Sections 4.2 through 4.4; they show that above-normal snow and rain occurred in 2013 and 2014—two years in a row. A way to understand the total quantity of water leaving the basin is to calculate the cumulative flow over the warm season (the *R* term in the water balance). This calculation provides additional clues about the amount of snowpack and rainfall entering and leaving the watershed each year, particularly if it is assumed that the change in storage is negligible. Only the warm season volumetric flow (spring breakup through mid to late September) was examined due to the lack of late fall or early winter runoff data.

The nearby Putuligayuk basin had record-high volumetric runoff during spring breakup in 2014. The plot in Figure 43 shows a steeper slope than normal after breakup and into fall that year, indicating higher than normal flows during summer. The Putuligayuk typically shows little response to summer rain events, as indicated in Figure 43 by a flat slope in cumulative flow during summer months. The highest total volumetric runoff during the period of record (31 years) occurred in 2014 because of both a high snowmelt runoff period and a higher than normal summer runoff period. The average total volume of water leaving the watershed is 98 mm, but in 2014, the total volume was approximately 237 mm, more than double the average.

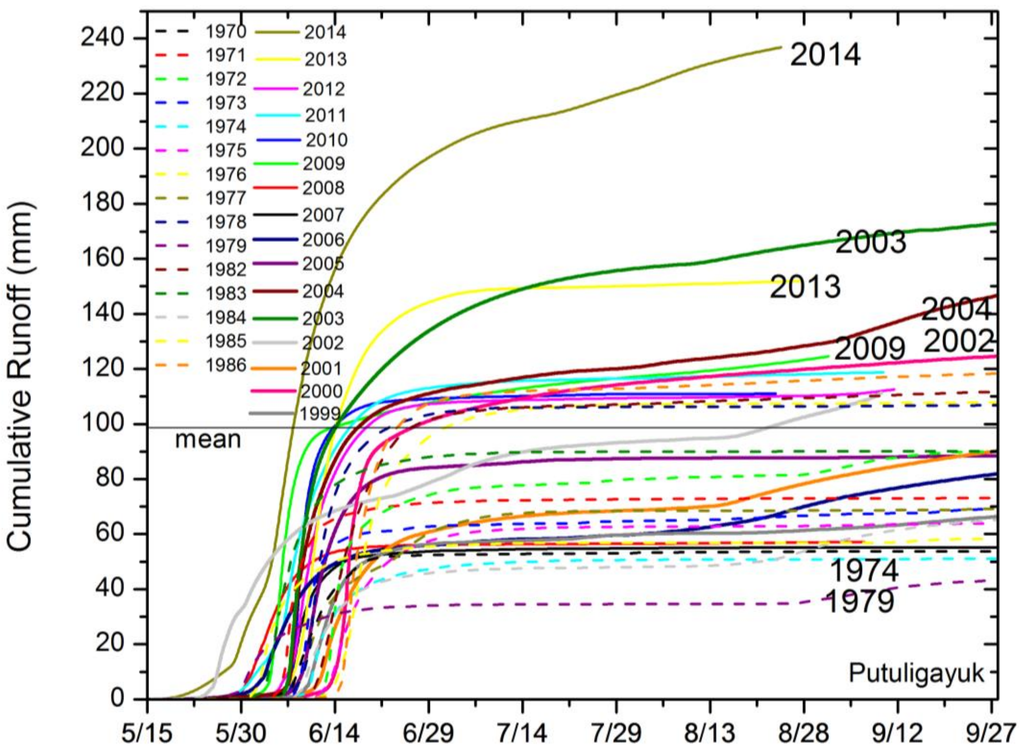


Figure 43. Cumulative runoff at the Putuligayuk basin, 1970 through 2014. The year 2014 was the highest on record for the total volume of water leaving the watershed.

In the Kuparuk River basin (near Deadhorse), both 2013 and 2014 had high volumetric runoff during spring breakup, as shown in Figure 44. In 2014, cumulative runoff continued to increase through the summer because of numerous rain events, and the highest (volumetric) runoff for the historical record occurred that year. The total volume of water leaving the watershed in 2014 was approximately 276 mm, compared with the average of 150 mm.

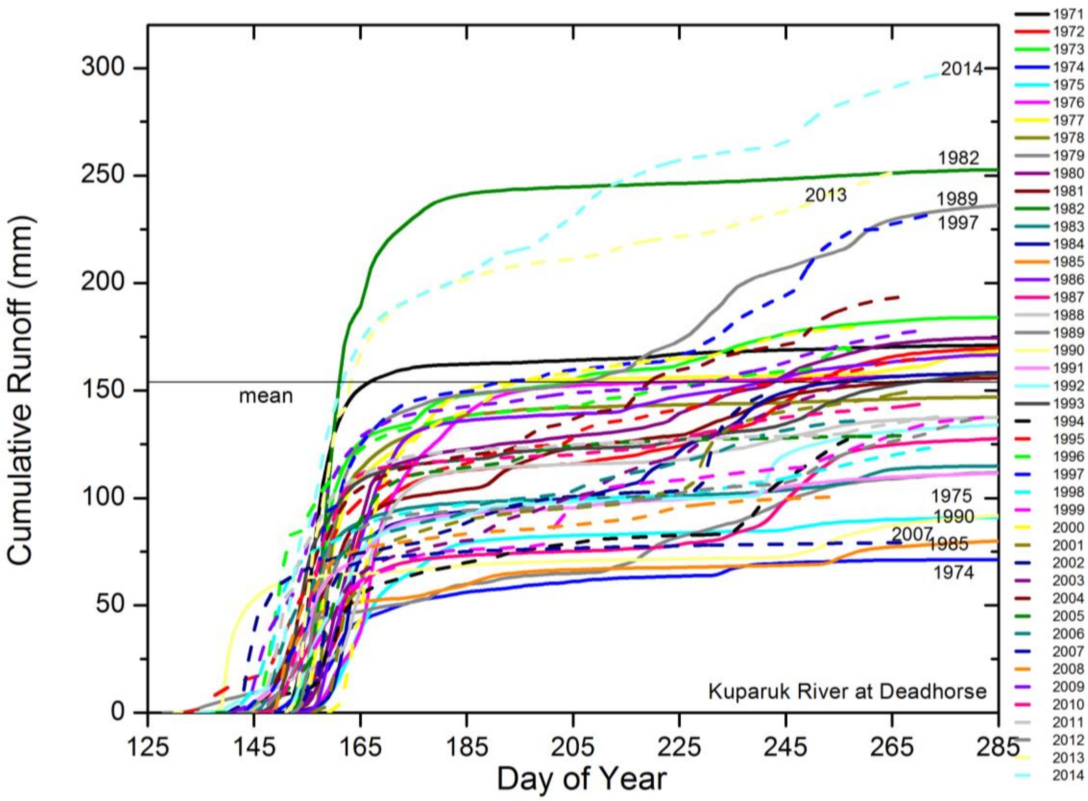


Figure 44. Cumulative runoff at Kuparuk River at Deadhorse (USGS), 1971–2014. The year 2014 was the highest on record for total volume of water leaving the watershed. Complementary meteorological data (such as precipitation) are available from UAF/WERC studies beginning in the mid-1980s.

The water budget and cumulative runoff were examined for the Upper Kuparuk, a smaller watershed located in the foothills of the Brooks Range, adjacent to the Upper Sagavanirktok basin. Again, 2014 had the highest total volume of water on record exiting the watershed (*n* = 19 years) due to high snowpack and a wet summer. The total volume of water leaving the basin was 325 mm, compared with an average of 214 mm.

Runoff data for the USGS Sagavanirkok River station (located above the confluence with the Ivishak) were reviewed, but a volumetric analysis could not be conducted due to the quality of data during spring breakup (data are often not available or are estimated, ice-affected, backwater; rating curve invalid). Continuous flow data are needed to calculate volumetric runoff. Either the rating curve must be valid, or frequent individual measurements of discharge are needed (at least daily) during ice-affected conditions. Often, manual flow measurements are not made until after conditions are safe or ice is no longer in the channel, which may not occur until after spring flooding. One note of interest is that the manual winter measurements (December through early April) of runoff made by USGS in the winters of 2013–2014 and 2014–2015 were the highest on record (*n* = 27 years of late winter measurements). Any winter runoff is from subsurface contribution. The increased winter flow in recent years is likely a result of the increased precipitation observed in 2013 and 2014.

Based on the above analysis, along with the available precipitation data, it is clear that both 2013 and 2014 were extreme years in terms of the total volume of water entering and leaving the watershed during the warm season. This surplus of water continued to flow during the winter months in the Sagavanirktok River basin, and possibly other basins that do not completely freeze. All rivers with good continuous flow data (Putuligayuk, Kuparuk, Upper Kuparuk) had record-high volumes of runoff during spring breakup in both 2013 and 2014.

4.5.7 Suspended Sediment

In this section of the report, the results related to suspended sediment concentration are presented, providing insights on the suspended sediment transport conditions during breakup.

On May 28, 2015, at the East Bank station, the side channel containing the automated sampling port became hydraulically isolated from the river's main channel as floodwater receded. On May 30, the sampling port was moved to an adjacent flowing channel, but again became isolated on May 31. Samples that were not representative of the main flow were identified and discarded. Suspended sediment concentration (SSC) values for the remaining water samples were obtained in the lab. The SSC and water levels are shown in Figure 45. The sample collected on May 16 was of clear water, obtained in the early stage of breakup (i.e., water moving on top of ice). Figure 45 shows the maximum SSC on May 22. Discharge measurements were also correlated to SSC. Figure 46 indicates high sediment loads after discharge peaked on May 20. The overall relationship between discharge and SSC is counterclockwise, which is relatively unusual for rivers during breakup (Tananaev, 2015). Grain-size distributions for selected samples are shown in Figure 47. The average grain size, $D_{50,}$ of each distribution ranged from 10 to 14 microns, which corresponds to silt-sized particles, indicating a narrow variation in terms of sediment particles in suspension.

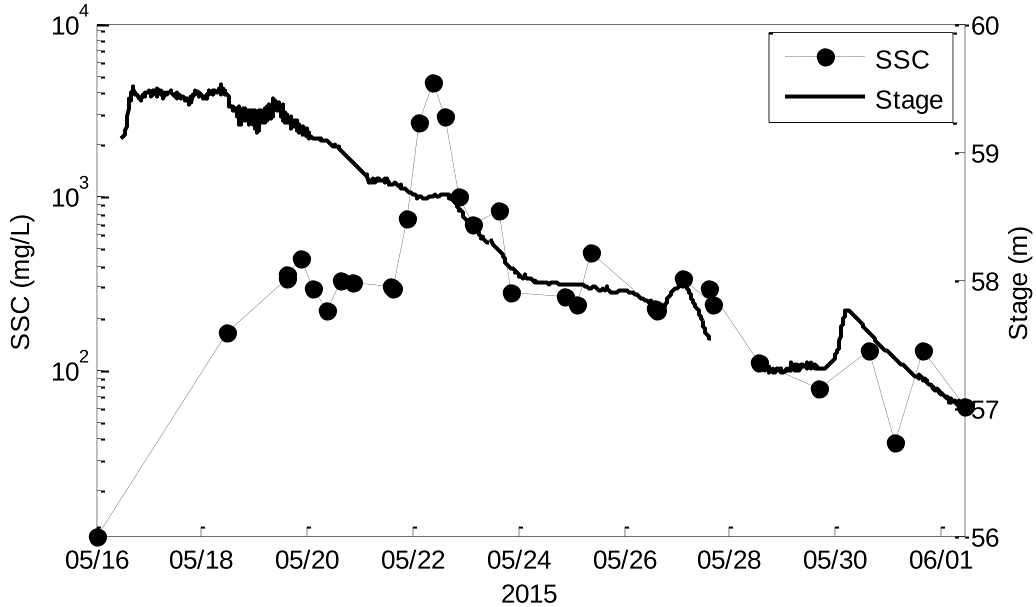


Figure 45. Suspended sediment concentration and river stage.

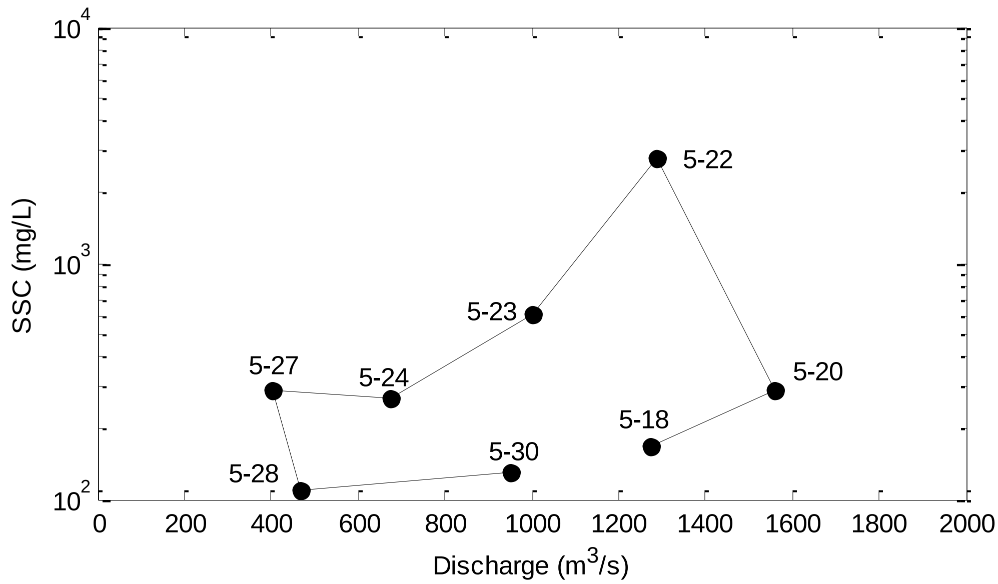


Figure 46. Suspended sediment concentration versus discharge. Date of measurement (in May 2015) is labeled for each point. The measurement on May 30 corresponds to a rainfall event.

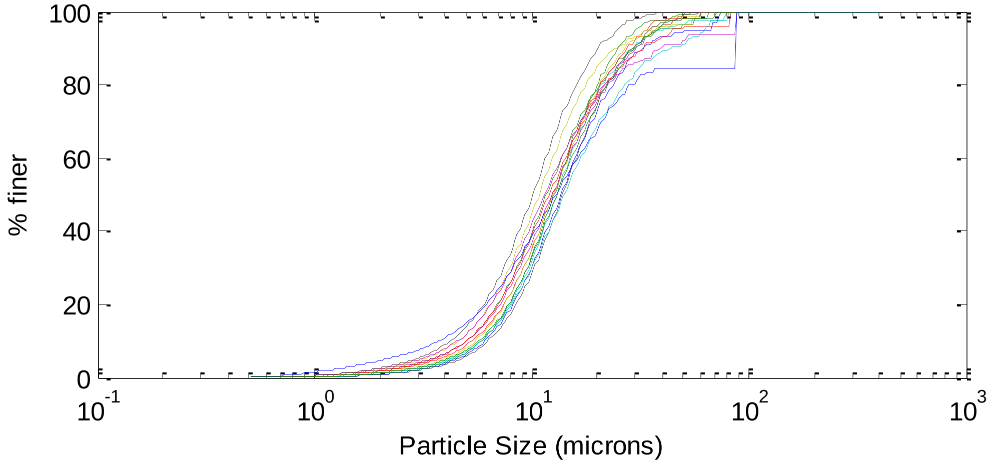


Figure 47. Particle-size distribution for 15 sediment samples.

5 CONCLUSIONS

Alaska's economy is strongly tied to oil production, with most of the petroleum coming from the Prudhoe Bay oil fields. Deadhorse, the furthest north oil town on the Alaska North Slope, provides support to the oil industry. The Dalton Highway, built in 1976, is the only road that connects Deadhorse with other cities in Interior Alaska. The road is heavily used to move supplies to and from the oil fields.

Before the spring 2015 breakup, the road was impassable at times due to winter overflow from the Sagavanirktok River. Specifically, the road was closed during the periods March 30–April 2 and April 5–12, 2015.

ADOT&PF field crews and contractors worked promptly to reopen the Dalton and divert water from the road. In addition, ADOT&PF acquired SAR data from early April to early May 2015 of the affected part of the highway. The SAR data were obtained from the TerraSAR-X (TSX) satellite, operated by DLR, the German space agency. The analysis conducted on the images was useful for detecting the location of liquid water during this overflow event. Should similar events occur in the future, we recommend trying VV polarization or dual-polarized (HH and HV, or VV and HV) options to better delineate different types of ice. RADARSAT-2 has these capabilities (Canadian Space Agency).

Field staff from UAF performed a limited GPS survey of ice elevations in the area where the stream splits into two channels (east and west channels). The goal of this task was to identify any slope towards the west (i.e., in the direction of the road). However, the collected data did not provide any conclusive evidence of such slope. In fact, ice elevations in that area seemed to follow the natural slope of the area (see Figure 14). The graph in Figure 14 shows relatively high ground in the middle of the river, which diverts the flows into the west and east channels).

To monitor the river conditions during breakup, UAF staff spent three weeks in the field. As part of this monitoring task, a hydrologic observation station was installed on the east river bank (about MP392). This station was capable of tracking water level changes, reporting data in near real time during the unprecedented flood event, which caused the highway's closure for nearly three weeks (May 17–June 5). Water levels reported from the station were critical to the personnel dealing with the emergency in Deadhorse. In addition, several pressure transducers were deployed along the road and on the river (west channel). Even though field conditions were unfavorable for gauging measurements, field staff measured the river discharge eight times. Water samples were also collected during that period. Suspended sediment concentrations were calculated from these samples.

Water levels changed from approximately 1 m near MP414 to around 3 m at the East Bank station (about MP392). Discharge measurements ranged from nearly 400 to 1560 m^3/s, with the maximum measurement roughly coinciding with the peak, which occurred on May 20, 2015. Representative sediment sizes (D_{50}) ranged from 10 to 14 microns (i.e., silt-sized particles), indicating a narrow variation in terms of sediment particles in suspension. Suspended sediment concentrations ranged from a few mg/L (clear water in early flooding stages) to approximately 4500 mg/L on May 22, 2015.

Assuming an equal discharge distribution between the east and west channels, which relatively coincides with discharge measurements performed by UAF during breakup and is in the order of magnitude of previously published percentages (Veldman and Ferrell, 2002), the corresponding return period for this flood would be about 5 years, according to a study on flood frequency performed by PND in 2003 (PND, 2005).

An analysis of cumulative runoff for the Putuligayuk and Kuparuk Rivers, along with available precipitation data, showed that both 2013 and 2014 were extreme years in terms of the total volume of water entering and leaving the watershed during the warm season. Additionally, a spell of warm air temperatures was recorded during mid-February to early March. The surplus of water and the warm temperatures could have played an important role in the extensive aufeis formed along the Dalton Highway.

We recommend the establishment of a hydrometeorological monitoring program along the entire watershed to collect basic data. With this data, road managers will be better able to predict breakup conditions.

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7 APPENDICES

Appendix A – SAR Imagery

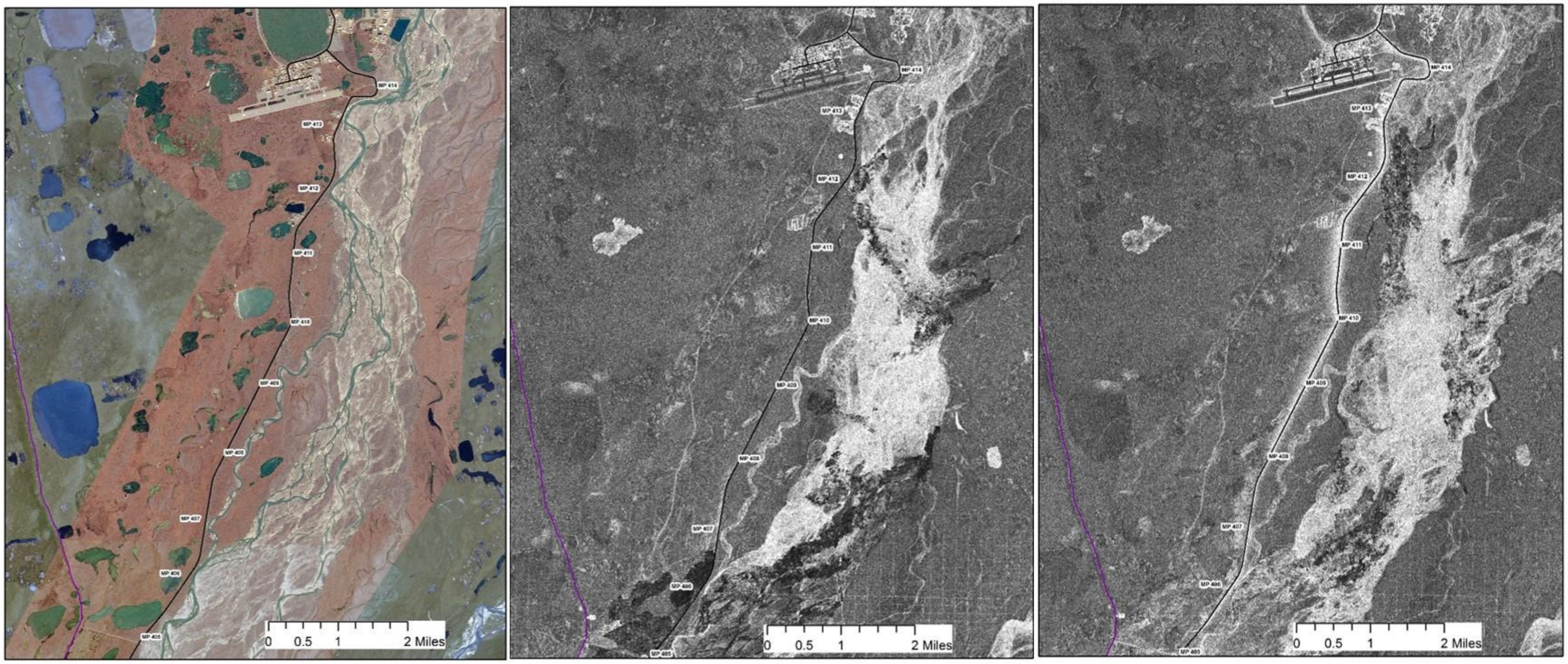
Appendix B – Photographs

Appendix C – Discharge Measurement Summaries

Appendix D – Data DVD

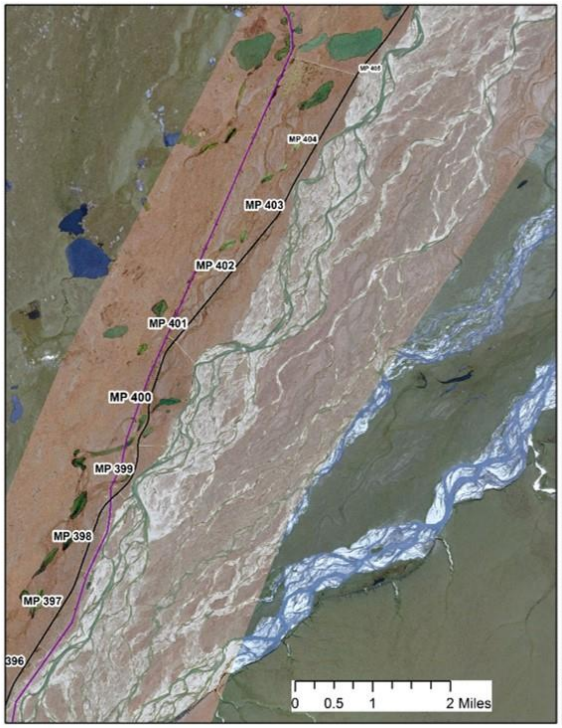
Appendix A – SAR Imagery

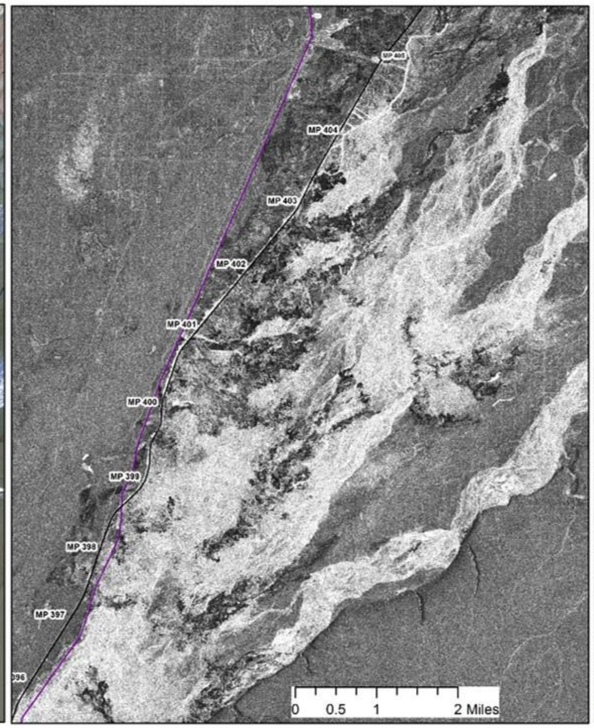
North view, from MP405 – MP415

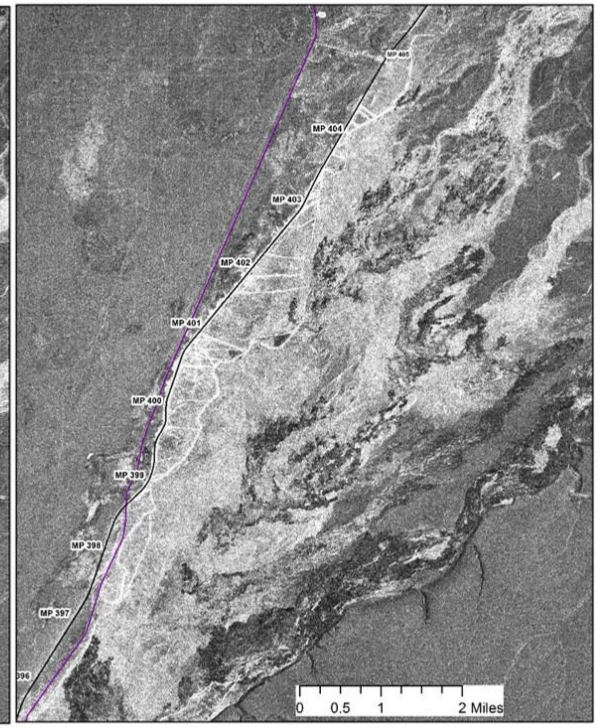


SPOT6 – September 2014	TSX – April 8, 2015	TSX – May 5, 2015

Mid view, from MP397 – MP405

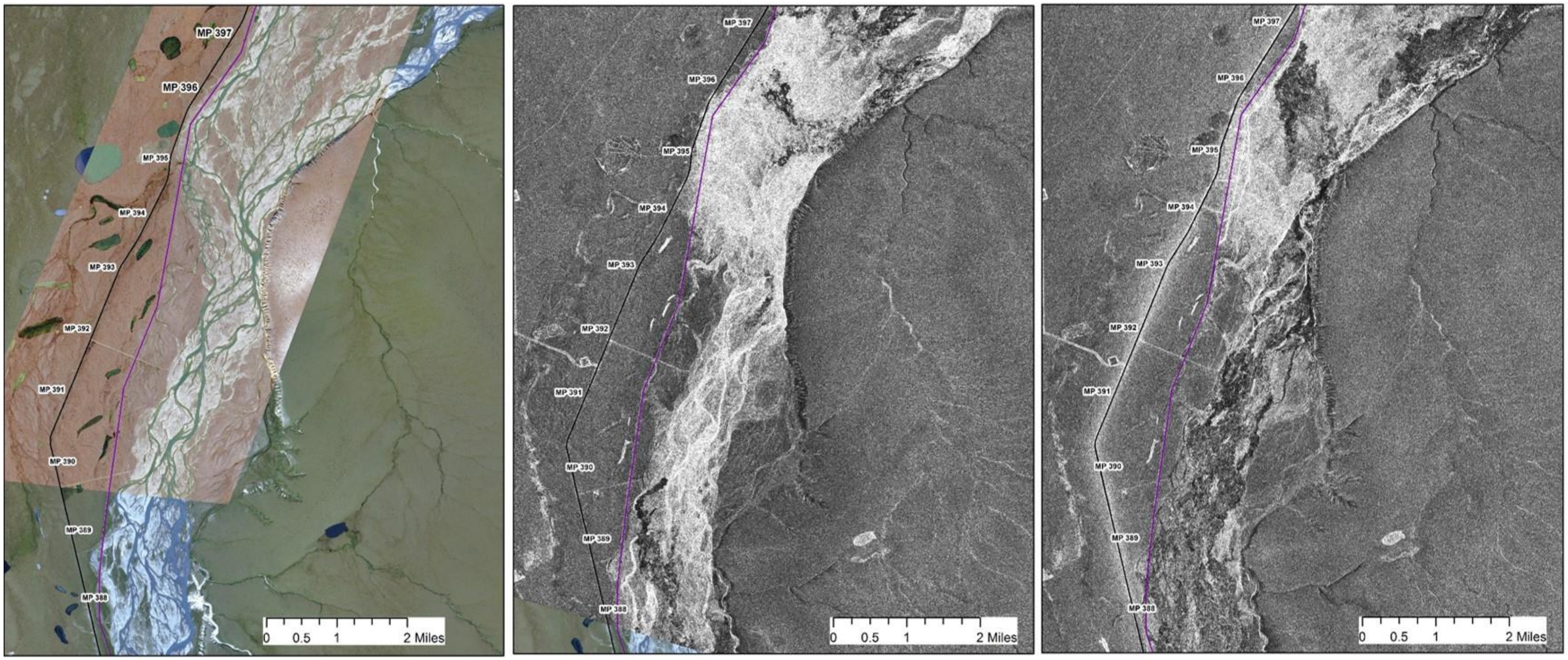






SPOT6 – September 2014 TSX – April 8, 2015 TSX – May 5, 2015

South view, from MP 388 – MP 397



SPOT6 – September 2014 | TSX – April 8, 2015 | TSX – May 5, 2015

Appendix B – Photographs

Figure B.1. Photo taken May 19, 2015, near Dalton Highway MP414. View is south and shows accumulated floodwater west of the Dalton over-topping the road surface at right, flowing across tundra in mid-ground, and cutting through a protective gravel berm as the water returns to an active channel of the Sagavanirktok River at the far left of photo.

Figure B.2. Photo taken May 20, 2015, near Dalton Highway MP414, view south.
Dark material is permafrost.

Figure B.3. Photo taken May 22, 2015, near Dalton Highway MP414, view south. This photo was taken several feet to the right of Figure B.2. Note the extensive removal of permafrost in center of photo and continued erosion at the waterfall face. The difference in elevation from tundra surface to the active river channel is approximately 9–12 ft (3–4 m) in this area.

Figure B.4. Photo taken May 17, 2015, near Dalton Highway MP400. View is south and shows the highway on the left and the buried pipeline on the right, converging to intersection. Aufeis is extensive, including area between road and pipeline. Some water is flowing on the ice, and the road is beginning to flood. A Sagavanirktok River channel is at far left, and Franklin Bluffs are seen in the distance, on the horizon.

Figure B.5. Photo taken May 18, 2015, near Dalton Highway MP400, view south. Photo shows water levels rising and inundation of tundra west (right) of the pipeline. A Sagavanirktok River channel is at far left, and Franklin Bluffs are seen in the distance, upper left of center.

Figure B.6. Photo taken May 19, 2015, near Dalton Highway MP400, view south. Continued high water west (right) of the road and pipeline. A Sagavanirktok River channel is at far left, and Franklin Bluffs appear near the horizon, upper center of photo.

Figure B.7. Photo taken May 20, 2015, near Dalton Highway MP400, view south. Continued high water west (right) of the road and pipeline. Note completely submerged sections of road in this area. A Sagavanirktok River channel is at far left, and Franklin Bluffs are seen in the distance, upper left of center.

Figure B.8. Photo taken May 21, 2015, near Dalton Highway MP400, view south. Water levels are falling, but extensive areas remain submerged. A Sagavanirktok River channel is at far left, and Franklin Bluffs are seen in the distance, upper left of center.

Figure B.9. Photo taken May 27, 2015, near Dalton Highway MP400, view south. Water levels have dropped appreciably, and tundra west of the pipeline (far right) is no longer flooded. Road damage is easily discernable in this photo. A Sagavanirktok River channel is at far left, and Franklin Bluffs are seen on the horizon, upper center.

Figure B.10. Photo taken May 31, 2015, near Dalton Highway MP400, view south. Tundra between road and pipeline is emerging as water levels continue to fall. The aufeis between the road and pipeline is completely gone, but much remains east (left) of the road. Road repair work has begun. A Sagavanirktok River channel is at far left, and Franklin Bluffs are seen on the horizon, upper left of center.

Figure B.11. Photo taken May 15, 2015 at Dalton Highway MP395.5. View is northeast and shows the extensive buildup of aufeis—several feet thick at this location—evidenced by the partially buried Alyeska access gate. Franklin Bluffs can be seen in the background.

Figure B.12. Photo taken May 17, 2015 at Dalton Highway MP395.5, view east. Water is flowing on top of aufeis. One of the diversionary snow dikes in the river channel can be discerned along the far edge of the ice flat and the base of the Franklin Bluffs.

Figure B.13. Photo taken May 21, 2015 at Dalton Highway MP395.5, view east. Photo shows access road rendered impassable until repair. Water levels are falling, and although most of the ice has melted in the foreground, a considerable amount remains in the area beyond the gate.

Figure B.14. Photo taken May 17, 2015, near Dalton Highway MP395. View is south and photo shows water at left flowing over aufeis accumulation 1–2 ft higher than the road surface. Water continues across road and begins erosion of the west (right) shoulder. Road material is still frozen at this time. This location is the southernmost occurrence of flooding across the road.

Figure B.15. Photo taken May 21, 2015, near Dalton Highway MP395, view south. While some ice remains under the water on the left, the road has been eroded down to the underlying tundra. Note the bent delineator, above and right of photo center; this is the left-most delineator in Figure B.14. This delineator was hit by large mobile ice transported in the current by sliding on top of the aufeis.

Figure B.16. Photo taken May 26, 2015, near Dalton Highway MP395, view south. Water has stilled and cleared, revealing the depth of damage to the road. Bent delineator noted in Figure B.15 was the location of a water-measuring instrument that broke free during ice collision and was subsequently buried in deposited gravel west of the road. Unfortunately, the instrument was not recoverable.

Figure B.17. Photo taken May 17, 2015, near Dalton Highway MP395. View is southeast and shows the initial flooding of the road in this area. This location is the southernmost incidence of flooding during this event. Compare with Figure B.14, which shows a ground view as seen from the road surface at left edge of this photo. Note vehicles still using road. Franklin Bluffs are in the distance.

Figure B.18. Photo taken May 18, 2015, near Dalton Highway MP395, view southeast. Water is nearing peak, submerging aufeis at left of photo. Franklin Bluffs appear at upper left.

Figure B.19. Photo taken May 19, 2015, near Dalton Highway MP395, view southeast. Aufeis at left is mostly covered. Franklin Bluffs seen in distance at left.

Figure B.20. Photo taken May 20, 2015, near Dalton Highway MP395, view southeast. Even though water levels are high, the aufeis is still visible at left. Franklin Bluffs seen in the distance.

Figure B.21. Photo taken May 21, 2015, near Dalton Highway MP395, view southeast. Much aufeis at left is exposed, and water levels are falling. Eroded channels across road are clearly visible. Franklin Bluffs seen in upper left.

Figure B.22. Photo taken May 16, 2015, near bifurcation of the Sagavanirktok River. View is north. Photo shows a large amount of water being directed to the East Fork by a diversionary snow dike with extensive aufeis beyond. Dark linear streak near horizon is Dalton Highway. Franklin Bluffs are east (far right).

Figure B.23. Photo taken May 18, 2015, near bifurcation of the Sagavanirktok River, View is north. Franklin Bluffs and the diversionary snow dike noted in Figure B.22 can be seen at right. The snow dike is failing, and water covers much of the aufeis seen in Figure B.22.

Figure B.24. Photo taken May 21, 2015, near bifurcation of the Sagavanirktok River. View is north. Though failing, snow dikes continue to divert water to the East Fork. Water levels have dropped from peak, and stranded ice can be seen between the right-most snow dike and Franklin Bluffs at right (near arrowhead). This stranded ice was adjacent to the gauging station installed by UAF during this event.

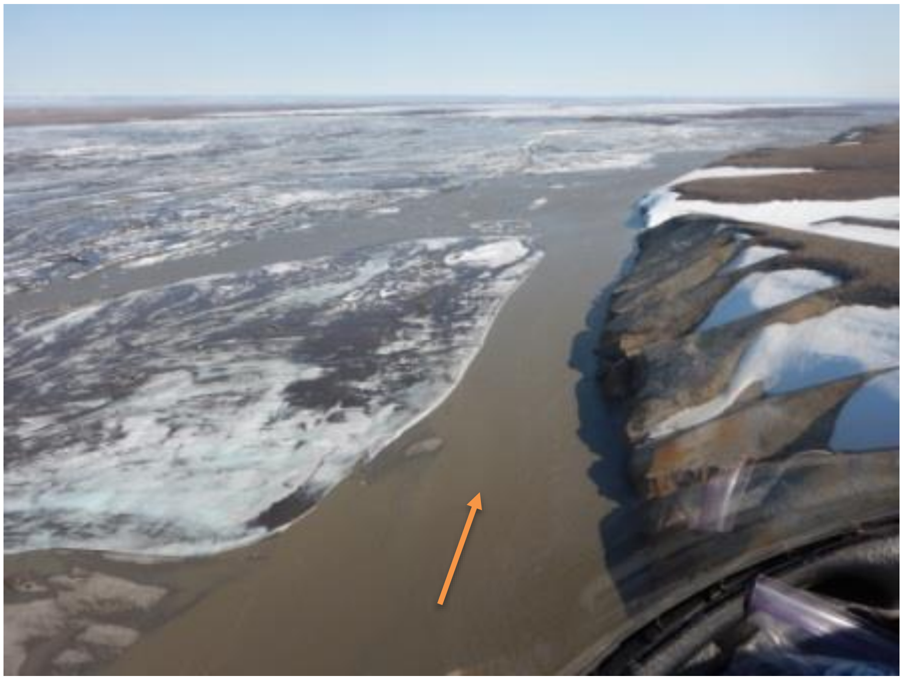


Figure B.25. Photo taken May 21, 2015, near bifurcation of the Sagavanirktok River. View is north. Franklin Bluffs are at right, and definite channels are appearing. Aufeis remains on many gravel bars. This is the main channel of the East Fork.

Figure B.26. Photo taken May 27, 2015, near bifurcation of the Sagavanirktok River. View is north. This photo, taken closer to Franklin Bluffs, seen at right, shows water levels receding and gravel bars appearing. Snow dikes are all but gone, and some aufeis remains in the middle distance.

Appendix C – Discharge Measurement Summaries

(in order of date)

Station Number: Meas. No: 0
Station Name: Sagavanirktok River Main Station Date: 05/18/2015

Party: JK/HT/KI	Width: 607.0 m	Processed by: DAV
Boat/Motor: 15' Alweld 40hp jet	Area: 791.1 m²	Mean Velocity: 1.57 m/s
Gage Height: 0.000 m	G.H.Change: 0.000 m	Discharge: 1,240 m³/s

Area Method: Avg. Course	ADCP Depth: 0.250 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 (19.5°)	Bottom Est: Power (0.1667)	Rated Area: 0.000 m²	Diff.: 0.000%
Depth: Composite	Top Est: Power (0.1667)	Control1: Unspecified	
		Control2: Unspecified	
		Control3: Unspecified	

Screening Thresholds:		ADCP:	
BT 3-Beam Solution: YES	Max. Vel.: 4.12 m/s	Type/Freq.: Rio Grande / 1200 kHz	
WT 3-Beam Solution: YES	Max. Depth: 1.66 m	Serial #: 12558	Firmware: 10.16
BT Error Vel.: 0.10 m/s	Mean Depth: 1.30 m	Bin Size: 10 cm	Blank: 25 cm
WT Error Vel.: 1.07 m/s	% Meas.: 40.17	BT Mode: 7	BT Pings: 1
BT Up Vel.: 0.30 m/s	Water Temp.: None	WT Mode: 12	WT Pings: 1
WT Up Vel.: 7.00 m/s	ADCP Temp.: 1.6 °C	WV : 626	WO : 7, 4
Use Weighted Mean Depth: YES			

Performed Diag. Test: YES
Filename Prefix:Project Name: sag_main_station20150518q124
Performed Moving Bed Test: NO
Software: 2.15
Performed Compass Calibration: YES Evaluation: YES
Meas. Location: 69 56.794N,148 40.280W

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	23.0	25.0	486	584	498	143	16.4	-2.30	1239	607.0	791.1	14:47	14:55	1.46	1.57	3	0
Mean		23.0	25.0	486	584	498	143	16.4	-2.30	1239	607.0	791.1	**Total**	00:07	1.46	1.57	3	0
SDev																		
SD/M																		

Remarks: Q with RioGrande 1240cms using VTG with 13 bad ens. and 1 transect (second transect incomplete due to hazardous floating ice conditions), 1280cms using BT with 175 bad ens.

Station Number: Meas. No:

Station Name: Sagavanirktok River Main Station Date: 05/20/2015

Party: JK/HT
Boat/Motor: 15' Alweld 40hp jet
Gage Height: 0.000 m

Width: 663.5 m
Area: 1015.2 m²
G.H.Change: 0.000 m

Processed by: DAV
Mean Velocity: 1.55 m/s
Discharge: 1,560 m³/s

Area Method: Avg. Course
Nav. Method: DGPS
MagVar Method: Model (19.5°)
Depth: Composite

ADCP Depth: 0.250 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: 2-Ice Anchor
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.: 0.10 m/s
WT Error Vel.: 1.07 m/s*
BT Up Vel.: 0.30 m/s*
WT Up Vel.: 5.00 m/s
Use Weighted Mean Depth: YES

Max. Vel.: 5.26 m/s
Max. Depth: 4.15 m
Mean Depth: 1.53 m
% Meas.: 49.67
Water Temp.: None
ADCP Temp.: 1.2 °C

ADCP:
Type/Freq.: Rio Grande / 1200 kHz
Serial #: 12558 Firmware: 10.16
Bin Size: 5 cm Blank: 25 cm
BT Mode: 7 BT Pings: 1
WT Mode: 12 WT Pings: 1
WV : 624 WO : 4, 4

Performed Diag. Test: YES
Performed Moving Bed Test: NO
Performed Compass Calibration: NO* Evaluation: NO*
Meas. Location:Meas. Location: 69 56.567N,148 40.530W

Filename Prefix:Project Name: sag-main-station-may-20-2015
Software: 2.15

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	18.0	21.0	592	622	742	131	16.4	8.09	1520	626.0	924.5	12:42	12:53	1.07	1.64	6	16
001	L	18.0	21.0	735	619	809	152	10.7	12.9	1603	700.9	1106.0	12:56	13:09	0.98	1.45	3	16
Mean		18.0	21.0	663	621	776	141	13.6	10.5	1562	663.5	1015.2	**Total**	00:26	1.03	1.55	4	16
SDev		0.00	0.00	101	2.53	47.4	14.9	4.04	3.41	59.2	52.9	128.4			0.07	0.14		
SD/M		0.00	0.00	0.15	0.00	0.06	0.11	0.30	0.32	0.04	0.08	0.13			0.06	0.09		

Remarks: Q with RioGrande 1560cms using VTG (2 transects) with 4% error and 37 bad ens., 1585cms using BT with 5% error and 192 ens.

*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 for the entire period).

* - value not consistent for all transects

Station Number: Meas. No:

Station Name: Sagavanirktok River Main Station Date: 05/22/2015

Party: JK/HT
Boat/Motor: 15' Alweld 40hp jet
Gage Height: 0.000 m

Width: 750.3 m
Area: 1086.2 m²
G.H.Change: 0.000 m

Processed by: DAV
Mean Velocity: 1.19 m/s
Discharge: 1,290 m³/s

Area Method: Avg. Course
Nav. Method: DGPS
MagVar Method: Model (19.4°)
Depth: Composite

ADCP Depth: 0.250 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.: 0.10 m/s
WT Error Vel.: 1.07 m/s
BT Up Vel.: 0.30 m/s
WT Up Vel.: 3.00 m/s
Use Weighted Mean Depth: YES

Max. Vel.: 3.17 m/s
Max. Depth: 3.48 m
Mean Depth: 1.45 m
% Meas.: 44.78
Water Temp.: None
ADCP Temp.: 1.1 °C

ADCP:
Type/Freq.: Rio Grande / 1200 kHz
Serial #: 12558 Firmware: 10.16
Bin Size: 9 cm Blank: 25 cm
BT Mode: 7 BT Pings: 1
WT Mode: 12 WT Pings: 1
WV : 469 WO : 8, 4

Performed Diag. Test: YES
Performed Moving Bed Test: YES
Performed Compass Calibration: NO* Evaluation: NO*
Meas. Location: 69 56.353N,148 40.646W,

Filename Prefix:Project Name: sag-main-station-may-22-2015
Software: 2.15

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	21.0	25.0	568	513	534	131	7.98	51.8	1237	751.7	1037.1	12:28	12:37	1.36	1.19	1	0
001	L	11.0	17.0	633	539	618	140	4.55	34.8	1337	748.9	1135.4	12:37	12:48	1.22	1.18	7	0
Mean		16.0	21.0	600	526	576	135	6.27	43.3	1287	750.3	1086.2	**Total**	00:19	1.29	1.19	4	0
SDev		7.07	5.66	46	18.8	59.6	6.22	2.42	12.0	70.3	2.0	69.5			0.10	0.01		
SD/M		0.44	0.27	0.08	0.04	0.10	0.05	0.39	0.28	0.05	0.00	0.06			0.08	0.01		

Remarks: Q with RioGrande 1290cms with 5% error and 42 bad ens. using VTG, 1310cms with 7% error and 324 bad ens. using BT, 2 transects.

*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 for the entire period).

Station Number:
Station Name: Sagavanirktok River Main Station

Meas. No:
Date: 05/23/2015

Party: JK/RTK
Boat/Motor: 15' Alweld 40hp jet
Gage Height: 0.000 m

Width: 98.5 m
Area: 132.4 m²
G.H.Change: 0.000 m

Processed by: DAV
Mean Velocity: 1.69 m/s
Discharge: 219 m³/s

Area Method: Avg. Course
Nav. Method: Bottom Track
MagVar Method: Model (19.5°)
Depth: Composite
Discharge Method: None
% Correction: 0.00

ADCP Depth: 0.250 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.: 0.10 m/s
WT Error Vel.: 1.07 m/s*
BT Up Vel.: 0.30 m/s*
WT Up Vel.: 3.00 m/s
Use Weighted Mean Depth: YES

Max. Vel.: 4.03 m/s
Max. Depth: 3.16 m
Mean Depth: 1.57 m
% Meas.: 52.70
Water Temp.: None
ADCP Temp.: 1.2 °C

ADCP:
Type/Freq.: Rio Grande / 1200 kHz
Serial #: 12558 Firmware: 10.16
Bin Size: 5 cm Blank: 25 cm
BT Mode: 7 BT Pings: 1
WT Mode: 12 WT Pings: 1
WV : 347 WO : 4, 4

Performed Diag. Test: YES
Performed Moving Bed Test: NO
Performed Compass Calibration: NO* Evaluation: NO*
Meas. Location: 69 56.331N,148 40.631W

Filename Prefix:Project Name: sag-main-station-may-23-2015
Software: 2.15

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	R	7.00	20.0	204	62.4	115	18.2	4.65	26.4	226	86.5	151.4	10:08	10:11	0.54	1.50	61	1
002	*R*	*0.00*	*3.00*	*155*	*61.9*	*122*	*18.2*	*0.000*	*2.13*	*204*	*49.5*	*101.5*	*10:19*	*10:22*	*0.57*	*2.01*	*52*	*1*
003	R	*125*	*3.00*	*157*	*23.3*	*109*	*12.7*	*79.9*	*0.639*	*225*	*159.3*	*144.4*	*10:25*	*10:28*	*0.60*	*1.56*	*62*	*1*
Mean		44.0	8.67	172	49.2	115	16.4	28.2	9.72	219	98.5	132.4	**Total**	00:19	0.57	1.69	58	1
SDev		70.2	9.81	28	22.5	6.63	3.18	44.9	14.4	12.5	55.9	27.0			0.03	0.28		
SD/M		1.60	1.13	0.16	0.46	0.06	0.19	1.59	1.49	0.06	0.57	0.20			0.05	0.17		

Remarks: Q with StreamPro 213cms using VTG with 6% error and 53 bad ens., 219cms using BT with 6% error and 162 bad ens. Only 3 right starting transects were measured, not sure about directional bias. Due to high winds and fast moving floating ice only part of the channel could be measured. To estimate the flow we compared the measured q to the one measured the previous day at the same location (20150522). Q estimated 1000cms.

*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 for the entire period).

* - value not consistent for all transects
Discharge for transects in *italics* have a total Q more than 5% from the mean

Station Number: Meas. No:

Station Name: Sagavanirktok River Main Station Date: 05/24/2015

Party: JK/HT	Width: 746.2 m	Processed by: DAV
Boat/Motor: 15' Alweld 40hp jet	Area: 830.7 m²	Mean Velocity: 0.811 m/s
Gage Height: 0.000 m	G.H.Change: 0.000 m	Discharge: 674 m³/s

Area Method: Avg. Course	ADCP Depth: 0.150 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 (19.4°)	Bottom Est: Power (0.1667)	Rated Area: 0.000 m²	Diff.: 0.000%
Depth: Composite	Top Est: Power (0.1667)	Control1: Unspecified	
		Control2: Unspecified	
		Control3: Unspecified	

Screening Thresholds:		ADCP:	
BT 3-Beam Solution: YES	Max. Vel.: 3.80 m/s	Type/Freq.: StreamPro / 2000 kHz*	
WT 3-Beam Solution: YES	Max. Depth: 3.20 m	Serial #: 1180	Firmware: 31.12*
BT Error Vel.: 0.10 m/s	Mean Depth: 1.11 m	Bin Size: 10 cm*	Blank: 3 cm
WT Error Vel.: 10.00 m/s*	% Meas.: 66.76	BT Mode: 10	BT Pings: 2
BT Up Vel.: 10.00 m/s*	Water Temp.: None	WT Mode: 12*	WT Pings: 6*
WT Up Vel.: 10.00 m/s*	ADCP Temp.: 2.8 °C	WV : 170	WO : 1, 4
Use Weighted Mean Depth: YES			

Performed Diag. Test: YES

Performed Moving Bed Test: NO

Performed Compass Calibration: NO* Evaluation: NO*

Meas. Location: 69 56.789N,148 40.334W

Filename Prefix:Project Name: sag-main-station-second-file

Software: 2.15

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	*R*	*200*	*3.00*	*411*	*125*	*489*	*78.7*	*22.1*	*2.81*	*718*	*761.4*	*903.3*	*13:00*	*13:09*	*1.04*	*0.80*	*7*	*0*
000	*R*	*250*	*4.00*	*376*	*107*	*382*	*84.5*	*22.6*	*4.19*	*600*	*745.8*	*749.4*	*14:05*	*14:13*	*1.15*	*0.80*	*14*	*5*
001	R	*145*	*4.00*	*346*	*121*	*479*	*79.0*	*21.7*	*3.39*	*704*	*731.5*	*839.4*	*14:16*	*14:23*	*1.45*	*0.84*	*14*	*4*
Mean		198	3.67	377	118	450	80.8	22.1	3.46	674	746.2	830.7	**Total**	01:23	1.21	0.81	12	3
SDev		52.5	0.58	33	9.70	59.4	3.28	0.456	0.695	64.7	15.0	77.3			0.21	0.02		
SD/M		0.26	0.16	0.09	0.08	0.13	0.04	0.02	0.20	0.10	0.02	0.09			0.17	0.03		

Remarks: Q with StreamPro 674cms using VTG with 10% error and 28 bad ens., 215cms using BT with 86% error and 101 bad ens. Only right starting transects were measured, not sure about 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 for the entire period).

* - value not consistent for all transects

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

Station Number: | Meas. No:
Station Name: Sagavanirktok River East Channel | Date:05/27/2015

Party: JK/HT
Boat/Motor: 15' Alweld 40hp jet
Gage Height: 0.000 m

Width: 92.3 m
Area: 125.4 m²
G.H.Change: 0.000 m

Processed by: DAV
Mean Velocity: 1.52 m/s
Discharge: 190 m³/s

Area Method: Avg. Course
Nav. Method: DGPS
MagVar Method: Model (19.5°)
Depth: Composite

ADCP Depth: 0.250 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.: 0.10 m/s
WT Error Vel.: 0.30 m/s
BT Up Vel.: 0.30 m/s
WT Up Vel.: 0.50 m/s
Use Weighted Mean Depth: YES

Max. Vel.: 3.02 m/s
Max. Depth: 2.40 m
Mean Depth: 1.36 m
% Meas.: 56.34
Water Temp.: None
ADCP Temp.: 4.6 °C

ADCP:
Type/Freq.: StreamPro / 2000 kHz
Serial #: 1180 | Firmware: 31.12
Bin Size: 9 cm | Blank: 3 cm
BT Mode: 10 | BT Pings: 2
WT Mode: 12 | WT Pings: 6

Performed Diag. Test: YES
Performed Performed Moving Bed Test: NO
Performed Compass Calibration: NO* Evaluation: NO*
Meas. Location:Meas. Location: 69 56.821N,148 40.232W

Filename Prefix:Project Name: sag-main-station-may-27-2015
Software: 2.15

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	10.0	8.00	105	49.5	98.3	21.6	4.84	8.08	182	90.9	112.9	15:48	15:50	0.61	1.62	16	5
001	L	10.0	5.00	93	57.2	110	20.7	4.93	3.46	196	90.6	132.9	15:53	15:55	0.74	1.48	12	6
002	L	15.0	5.00	106	46.1	113	20.9	8.17	3.66	192	95.2	130.5	15:57	15:59	0.78	1.47	17	1
Mean		11.7	6.00	101	50.9	107	21.1	5.98	5.07	190	92.3	125.4	**Total**	00:11	0.71	1.52	15	4
SDev		2.89	1.73	7	5.66	7.83	0.480	1.90	2.61	7.05	2.6	10.9			0.09	0.08		
SD/M		0.25	0.29	0.07	0.11	0.07	0.02	0.32	0.52	0.04	0.03	0.09			0.13	0.05		

Remarks: Q with StreamPro 190cms using VTG with 4% error and 18 bad ens., 245cms using BT with 23% error and 87 bad ens. Only 3 starting transects were measured, not sure about directional bias. Total Q W+E channels + a small channel that was estimated 20cms =414cms.

*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 for the entire period).

Station Number: | Meas. No:
Station Name: Sagavanirktok River West Channel | Date: 05/27/2015

Party: JK/HT	Width: 222.9 m	Processed by: DAV
Boat/Motor: 15' Alweld 40hp jet	Area: 223.4 m²	Mean Velocity: 0.913 m/s
Gage Height: 0.000 m	G.H.Change: 0.000 m	Discharge: 204 m³/s

Area Method: Avg. Course	ADCP Depth: 0.150 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 (19.5°)	Bottom Est: Power (0.1667)	Rated Area: 0.000 m²	Diff.: 0.000%
Depth: Composite	Top Est: Power (0.1667)	Control1: Unspecified	
		Control2: Unspecified	
		Control3: Unspecified	

Screening Thresholds:		ADCP:	
BT 3-Beam Solution: YES	Max. Vel.: 2.69 m/s	Type/Freq.: StreamPro / 2000 kHz	
WT 3-Beam Solution: YES	Max. Depth: 1.78 m	Serial #: 1180	Firmware: 31.12
BT Error Vel.: 0.10 m/s	Mean Depth: 1.00 m	Bin Size: 9 cm	Blank: 3 cm
WT Error Vel.: 0.30 m/s	% Meas.: 51.21	BT Mode: 10	BT Pings: 2
BT Up Vel.: 0.30 m/s	Water Temp.: None	WT Mode: 12	WT Pings: 6
WT Up Vel.: 3.00 m/s	ADCP Temp.: 6.2 °C		
Use Weighted Mean Depth: YES			

Performed Diag. Test: YES
Performed Moving Bed Test: NO
Performed Compass Calibration: NO* Evaluation: NO*
Location: 69 57.560N,148 41.614W

Filename Prefix:Project Name: sag_west20150527
Software: 2.15

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	8.00	5.00	263	61.9	108	32.1	1.42	3.34	207	225.2	224.8	14:56	15:02	0.71	0.92	0	1
003	L	10.0	5.00	280	62.1	101	32.3	1.81	3.99	201	220.6	221.9	15:04	15:10	0.70	0.91	1	5
Mean		9.00	5.00	271	62.0	104	32.2	1.62	3.66	204	222.9	223.4	**Total**	00:13	0.70	0.91	1	3
SDev		1.41	0.00	12	0.171	5.24	0.151	0.276	0.456	4.19	3.2	2.1			0.00	0.01		
SD/M		0.16	0.00	0.04	0.00	0.05	0.00	0.17	0.12	0.02	0.01	0.01			0.01	0.01		

Remarks: Q with StreamPro 204cms using VTG with 2% error and 3 bad ens., 201cms using BT with 3% error and 23 bad ens. Only 2 left starting transects were measured, not sure about directional bias.Total Q W+E channels + a small channel that was estimated 20cms =414cms.

*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 for the entire period).

Station Number: Meas. No:

Station Name: Sagavanirktok River East Channel Date: 05/28/2015

Party: JK/HT	Width: 87.7 m	Processed by: DAV
Boat/Motor: 15' Alweld 40hp jet	Area: 118.5 m²	Mean Velocity: 1.77 m/s
Gage Height: 0.000 m	G.H.Change: 0.000 m	Discharge: 209 m³/s

Area Method: Avg. Course	ADCP Depth: 0.250 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 (19.5°)	Bottom Est: Power (0.1667)	Rated Area: 0.000 m²	Diff.: 0.000%
Depth: Composite	Top Est: Power (0.1667)	Control1: Unspecified	
		Control2: Unspecified	
		Control3: Unspecified	

Screening Thresholds:		ADCP:	
BT 3-Beam Solution: YES	Max. Vel.: 3.50 m/s	Type/Freq.: StreamPro / 2000 kHz	
WT 3-Beam Solution: YES	Max. Depth: 2.09 m	Serial #: 1180	Firmware: 31.12
BT Error Vel.: 0.10 m/s	Mean Depth: 1.35 m	Bin Size: 9 cm	Blank: 3 cm
WT Error Vel.: 0.30 m/s	% Meas.: 58.46	BT Mode: 10	BT Pings: 2
BT Up Vel.: 0.30 m/s	Water Temp.: None	WT Mode: 12	WT Pings: 6
WT Up Vel.: 3.00 m/s	ADCP Temp.: 7.3 °C		
Use Weighted Mean Depth: YES			

Performed Diag. Test: YES

Performed Moving Bed Test: YES

Performed Compass Calibration: NO* Evaluation: NO*

Meas. Location: 69 57.415N,148 39.356W

Filename Prefix:Project Name: sag-main-station-may-28-2015

Software: 2.15

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	8.00	5.00	109	54.5	112	26.2	4.17	3.28	201	89.2	115.0	10:13	10:16	0.57	1.74	6	8
001	R	10.0	8.00	68	51.2	132	22.7	4.61	7.29	218	86.3	122.0	10:18	10:19	0.79	1.79	1	2
Mean		9.00	6.50	88	52.9	122	24.5	4.39	5.28	209	87.7	118.5	**Total**	00:05	0.68	1.77	4	5
SDev		1.41	2.12	29	2.32	14.2	2.46	0.312	2.83	12.6	2.1	5.0			0.16	0.03		
SD/M		0.16	0.33	0.33	0.04	0.12	0.10	0.07	0.54	0.06	0.02	0.04			0.23	0.02		

Remarks: Q with StreamPro 210cms using VTG with 6% error and 1 bad ens., 227cms using BT with 4% error and 6 bad ens. Only 2 transects were measured. Total Q E+W channel = 453cms.

*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 for the entire period).

Station Number:

Station Name: Sagavanirktok River West Channel

Meas. No:

Date: 05/28/2015

Party: JK/HT
Boat/Motor: 15' Alweld 40hp jet
Gage Height: 0.000 m

Width: 179.8 m
Area: 147.8 m²
G.H.Change: 0.000 m

Processed by: DAV
Mean Velocity: 1.64 m/s
Discharge: 243 m³/s

Area Method: Avg. Course
Nav. Method: DGPS
MagVar Method: Model (19.5°)
Depth: Composite

ADCP Depth: 0.250 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.: 0.10 m/s
WT Error Vel.: 0.30 m/s
BT Up Vel.: 0.30 m/s
WT Up Vel.: 3.00 m/s
Use Weighted Mean Depth: YES

Max. Vel.: 2.94 m/s
Max. Depth: 1.53 m
Mean Depth: 0.821 m
% Meas.: 39.11
Water Temp.: None
ADCP Temp.: 6.8 °C

ADCP:
Type/Freq.: StreamPro / 2000 kHz
Serial #: 1180 Firmware: 31.12
Bin Size: 9 cm Blank: 3 cm
BT Mode: 10 BT Pings: 2
WT Mode: 12 WT Pings: 6

Performed Diag. Test: YES
Performed Moving Bed Test: YES
Performed Compass Calibration: NO* Evaluation: NO*
Meas. Location: 69 58.648N,148 41.221W

Filename Prefix:Project Name: sag-main-station-may-28-2015
Software: 2.15

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
004	*R*	*17.0*	*13.0*	*145*	*93.3*	*80.9*	*32.9*	*7.39*	*3.32*	*218*	*172.9*	*138.6*	*10:43*	*10:46*	*0.84*	*1.57*	*19*	*1*
006	*R*	*15.0*	*13.0*	*125*	*108*	*109*	*36.7*	*7.04*	*7.03*	*268*	*186.8*	*157.1*	*10:51*	*10:54*	*1.02*	*1.71*	*10*	*1*
Mean		**16.0**	**13.0**	**135**	**101**	**95.0**	**34.8**	**7.22**	**5.18**	**243**	**179.8**	**147.8**	**Total**	**00:11**	**0.93**	**1.64**	**14**	**1**
SDev		**1.41**	**0.00**	**14**	**10.3**	**19.9**	**2.69**	**0.245**	**2.63**	**35.3**	**9.8**	**13.1**			**0.12**	**0.09**		
SD/M		**0.09**	**0.00**	**0.10**	**0.10**	**0.21**	**0.08**	**0.03**	**0.51**	**0.15**	**0.05**	**0.09**			**0.13**	**0.06**		

Remarks: Q with StreamPro 243cms using VTG with 15% error and 12 bad ens., 244cms using BT with 3% error and 27 bad ens. Only right starting transects were measured. Total Q E+W channel = 453cms.

*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 for the entire period).

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

Station Number: Meas. No:

Station Name: Sagavanirktok River East Channel Date: 05/30/2015

Party: JK/HT	Width: 194.6 m	Processed by: DAV
Boat/Motor: 15' Alweld 40hp jet	Area: 291.8 m²	Mean Velocity: 2.14 m/s
Gage Height: 0.000 m	G.H.Change: 0.000 m	Discharge: 624 m³/s

Area Method: Avg. Course	ADCP Depth: 0.400 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 (19.5°)	Bottom Est: Power (0.1667)	Rated Area: 0.000 m²	Diff.: 0.000%
Depth: Composite	Top Est: Power (0.1667)	Control1: Unspecified	
		Control2: Unspecified	
		Control3: Unspecified	

Screening Thresholds:		ADCP:	
BT 3-Beam Solution: YES	Max. Vel.: 4.49 m/s	Type/Freq.: StreamPro / 2000 kHz	
WT 3-Beam Solution: YES	Max. Depth: 2.19 m	Serial #: 1180	Firmware: 31.12
BT Error Vel.: 0.10 m/s	Mean Depth: 1.50 m	Bin Size: 12 cm	Blank: 3 cm
WT Error Vel.: 0.30 m/s	% Meas.: 49.84	BT Mode: 10	BT Pings: 2
BT Up Vel.: 0.30 m/s	Water Temp.: None	WT Mode: 12	WT Pings: 6
WT Up Vel.: 4.00 m/s	ADCP Temp.: 5.2 °C		
Use Weighted Mean Depth: YES			

Performed Diag. Test: YES

Performed Moving Bed Test: NO

Performed Compass Calibration: NO* Evaluation: NO*

Meas. Location: 69 57.275N,148 39.612W

Filename Prefix:Project Name: sag-east-2-may-30-2015

Software: 2.15

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	R	12.0	7.00	120	227	321	72.0	17.9	8.66	646	192.1	288.8	15:05	15:08	1.19	2.24	0	1
003	R	13.0	8.00	119	216	304	64.3	19.1	9.84	614	196.1	291.1	15:12	15:15	1.18	2.11	0	2
004	R	9.00	5.00	117	219	307	66.9	12.9	5.10	612	195.4	295.5	15:16	15:19	1.26	2.07	0	2
Mean		11.3	6.67	118	221	311	67.7	16.7	7.87	624	194.6	291.8	**Total**	00:13	1.21	2.14	0	2
SDev		2.08	1.53	2	5.51	8.85	3.90	3.30	2.46	19.4	2.1	3.4			0.04	0.09		
SD/M		0.18	0.23	0.01	0.02	0.03	0.06	0.20	0.31	0.03	0.01	0.01			0.04	0.04		

Remarks: Q with StreamPro 624cms using VTG with 3% error and 0 bad ens., 177cms using BT with 27% error and 51 bad ens. ONLY right starting transects were used, not sure about directional bias. Total Q E+W channel = 1110cms.

*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 for the entire period).

Station Number: Meas. No:

Station Name: Sagavanirktok River West Channel Date: 05/30/2015

Party: JK/HT	Width: 185.8 m	Processed by: DAV
Boat/Motor: 15' Alweld 40hp jet	Area: 249.0 m²	Mean Velocity: 1.97 m/s
Gage Height: 0.000 m	G.H.Change: 0.000 m	Discharge: 486 m³/s

Area Method: Avg. Course	ADCP Depth: 0.250 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 (19.4°)	Bottom Est: Power (0.1667)	Rated Area: 0.000 m²	Diff.: 0.000%
Depth: Composite	Top Est: Power (0.1667)	Control1: Unspecified	
		Control2: Unspecified	
		Control3: Unspecified	

Screening Thresholds:		ADCP:	
BT 3-Beam Solution: YES	Max. Vel.: 4.30 m/s	Type/Freq.: StreamPro / 2000 kHz	
WT 3-Beam Solution: YES	Max. Depth: 4.17 m	Serial #: 1180	Firmware: 31.12
BT Error Vel.: 0.10 m/s	Mean Depth: 1.34 m	Bin Size: 13 cm	Blank: 3 cm
WT Error Vel.: 0.30 m/s	% Meas.: 52.41	BT Mode: 10	BT Pings: 2
BT Up Vel.: 0.30 m/s	Water Temp.: None	WT Mode: 12	WT Pings: 6
WT Up Vel.: 4.00 m/s	ADCP Temp.: 5.3 °C		
Use Weighted Mean Depth: YES			

Performed Diag. Test: YES

Performed Moving Bed Test: YES

Performed Compass Calibration: NO* Evaluation: NO*

Meas. Location: 69 58.479N,148 41.632W

Filename Prefix:Project Name: sag-main-station-may-30-2015

Software: 2.15

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	*R*	*9.00*	*41.0*	*110*	*104*	*257*	*63.0*	*12.9*	*18.4*	*455*	*186.3*	*275.3*	*13:41*	*13:43*	*1.09*	*1.65*	*15*	*6*
002	*R*	*12.0*	*32.0*	*99*	*132*	*275*	*71.5*	*23.6*	*11.0*	*513*	*186.1*	*235.6*	*13:45*	*13:47*	*1.31*	*2.18*	*35*	*12*
003	R	*11.0*	*36.0*	*87*	*133*	*232*	*89.9*	*22.2*	*12.2*	*489*	*184.9*	*236.2*	*13:48*	*13:50*	*1.43*	*2.07*	*24*	*13*
Mean		10.7	36.3	98	123	254	74.8	19.6	13.9	486	185.8	249.0	**Total**	00:09	1.28	1.97	25	10
SDev		1.53	4.51	12	16.4	21.6	13.7	5.81	3.95	29.2	0.8	22.7			0.18	0.28		
SD/M		0.14	0.12	0.12	0.13	0.08	0.18	0.30	0.28	0.06	0.00	0.09			0.14	0.14		

Remarks: Q with StreamPro 486cms with 6% error and 21 bad ens. using VTG, 322cms using BT with 17% error and 56 bad ens. ONLY right starting transects were used, not sure about directional bias. Total Q E+W channel = 1110cms.

*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 for the entire period).

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

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