Susitna-Watana Hydroelectric Project
(FERC No. 14241)

Ice Processes in the Susitna River Study
(Study 7.6)

Detailed Ice Observations
October 2013 – May 2014
Technical Memorandum

Prepared for

Alaska Energy Authority

SUSITNA-WATANA HYDRO

Clean, reliable energy for the next 100 years.

Prepared by

HDR Alaska, Inc.

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LIST OF ACRONYMS, ABBREVIATIONS, AND DEFINITIONS

Abbreviation	Definition
AEA	Alaska Energy Authority
ESS	Alaska Energy Authority station on the Susitna River for Surface water
FA	Focus Area (Aquatic Habitat)
FERC	Federal Energy Regulatory Commission
GIS	Geographic Information System
HDR	HDR, Inc.
HEC-RAS	Hydrologic Engineering Centers River Analysis System
ILP	Integrated Licensing Process
NEPA	National Environmental Policy Act
NWS	National Weather Service
PAD	Pre-Application Document
PRM	Project River Mile
Project	Susitna-Watana Hydroelectric Project
SNOTEL	National Water and Climate Center Snow Telemetry Data
USACE	U.S. Army Corps of Engineers
USGS	U.S. Geological Survey

ABSTRACT

This 2014 Spring Technical Memorandum describes all field activities and observations between October 16, 2013 and May 15, 2014 for the Ice Processes in the Susitna River Study. In general, freeze-up was characterized as being at or above long term averages for air temperatures during winter. The ice front progressed upstream from the mouth following the formation of an ice bridge at the mouth between November 8 and 12 and the front passed Talkeetna by November 25. Freeze-up progressed steadily through December 23 with dominant ice covers extending from PRM 4 to 122, PRM 129 to 143, 147.5 to 152.3, and from 183.7 to 222.3. Continued cold air temperatures extended these covers, allowing some to join together. Warm air temperatures in January resulted in some melting and opening of leads but the return of cold in February continued ice growth throughout the remainder of the winter and into spring. Open leads surveys were flown twice in 2014. One survey was conducted on February 20th and 21st to characterize the open leads at the mid-winter but prior to the low flows of the year. The lower and upper river were split into two flights due to the restrictions of daylight in February. The second survey was flown in the spring on April 2nd and represented the leads present at the end of freezing conditions (near the minimum flows of the year) prior to thawing temperatures and breakup. Leads were classified as thermal or velocity in origin and the location of each was identified as main channel or off channel/slough. Breakup was characterized by mild temperatures matching long term averages and less than normal snowpack. These factors contributed to a generally thermal melt-out of the ice cover with few jams and flooding events. Large jams occurred at FA-104 and FA-128 with ice pushed into overbank areas. However, a majority of the river experienced gradual melting and deteriorating of ice in place and the ice was flushed from most reachs of the main channel of the river between May 5 and 8.

1. INTRODUCTION

The Alaska Energy Authority (AEA) is preparing a License Application that will be submitted to the Federal Energy Regulatory Commission (FERC) for the Susitna-Watana Hydroelectric Project (Project) using the Integrated Licensing Process (ILP). The Project is located on the Susitna River, an approximately 300-mile-long river in the Southcentral region of Alaska. The Project's dam site, Watana Dam, would be located at Project River Mile (PRM) 187.2.

Project construction and operation as described in the Pre-application Document (PAD) would modify the flow and water temperature regimes of the Susitna River downstream of Watana Dam. The Project also has the potential to affect ice processes downstream of the Watana Dam site as the reservoir would remove the upstream source of ice from the downstream river reaches. The current ice processes that occur in the river (e.g., freeze up and breakup) likely had an effect on river geomorphology, fish and aquatic habitat, riparian vegetation, and potentially other resources (e.g., wildlife). The results of this study provide information that will serve as the basis for preparing Exhibit E of a license application (18 CFR 4.41) and for use in FERC's National Environmental Policy Act (NEPA) analysis for the Project license.

One of the objectives of the Ice Processes Study is to document ice cover conditions in the Susitna River from Cook Inlet (PRM 0) to the Oshetna River confluence at PRM 235.2. This report provides the results of the 2013/2014 Susitna River Ice Processes Study from October 2013 to May 2014. Field activities included aerial breakup and freeze up reconnaissance, mid- and late winter open-lead mapping, and time-lapse camera installation, maintenance, and review. Research activities included meteorological data compilation, time-lapse video creation, and data management and entry in a Global Information System (GIS) database. The results from these efforts will be used to characterize the Susitna River ice regime, identify spatial and temporal variations in ice processes, and provide information on the physical channel environment in the winter to other study disciplines. Some of the information (aerial reconnaissance) is similar to information collected during previous year's studies including work done in the 1980s. Collecting observations in a similar manner over a period of years will help define the year-to-year variability in the ice regime. Characterizing the existing ice regime and its variability due to climatic conditions will provide a basis for evaluating the impacts of the Project.

2. STUDY OBJECTIVES

As stated in the Revised Study Plan (RSP), the Ice Processes in the Susitna River Study (Study 7.6) will further the understanding of natural ice processes in the Susitna River and provide a method to model/predict pre-Project and post-Project ice processes in the Susitna River. The study will provide a basis for impact assessment, which will inform the development of any necessary protection, mitigation, and enhancement measures. The study also will provide ice processes input data for other resource studies with winter components (e.g., Fluvial

Geomorphology Modeling below Watana Dam Study [Study 6.6], Instream Flow Studies [Studies 8.5-8.6], Instream Flow Riparian [ISR Study 8.6], and Groundwater Study [Study 7.5]).

2.1. Study Goals and Objectives

The overall goals of the Ice Processes in the Susitna River Study (Study 7.6) are to understand existing ice processes in the Susitna River and to predict post-Project ice processes. The specific objectives are as follows:

- Document the timing, progression, and physical processes of freeze-up and break-up during 2012–2014 between tidewater and the Oshetna River confluence (PRM 235.2 [RM 233.4]), using historical data, aerial reconnaissance, stationary time-lapse cameras, and physical evidence.
- Determine the potential effect of various Project operational scenarios on ice processes downstream of Watana Dam using modeling and analytical methods.
    - Develop a modeling approach for quantitatively assessing ice processes in the Susitna River.
    - Calibrate the model based on existing conditions. Use the model to determine the extent of the open water reach downstream of Watana Dam during Project operations.
    - Use the model to determine the changes in timing and ice-cover progression and ice thickness and extent during Project operations.
- Develop detailed models and characterizations of ice processes at instream flow Focus Areas in order to provide physical data on winter habitat for the Fish and Aquatics Instream Flow Study (Study 8.5).
- Provide observational data of existing ice processes and modeling results of post-Project ice processes to the Fluvial Geomorphology Modeling below Watana Dam Study (Study 6.6), Groundwater Study (7.5), Instream Flow Studies (Studies 8.5-8.6), Fish and Aquatics Study (Studies 9.12), Riparian Vegetation Study Downstream of the Proposed Susitna-Watana Dam (Study 11.6), Recreation and Aesthetics Studies (12.5-12.7), and Socioeconomic and Transportation Study (Study 15.7).
- Research and summarize large river ice processes relevant to the Susitna River, analytical methods that have been used to assess impacts of projects on ice-covered rivers, and the known effects of existing hydropower operations in cold climates.

Thermal and ice modeling for the reservoir and the general thermal modeling for the river during the 5 months when ice is not present will be accomplished under the Water Quality Modeling Study (Study 5.6). The output from that work will be used in this river ice processes study. Likewise, open water flow routing will be performed under the Fish and Aquatics Instream Flow Study (Study 8.5), while ice-affected flow routing will be performed by this study.

3. STUDY AREA

The study area consists of the Susitna River between the mouth at Cook Inlet (PRM 0) and the Oshetna River confluence (PRM 235.2) as indicated in Figure 3.0-1. Observations were generally organized by river reach, with the Lower River extending from Cook Inlet to the upstream side of the confluence of the Chulitna, Talkeetna, and Susitna Rivers; the Middle River extending from the three rivers confluence up to the proposed Watana Dam site; and the Upper River extending from the proposed Watana Dam site to the Oshetna River confluence.

- Lower River: PRM 0 – PRM 102.4
- Middle River: PRM 102.4- PRM 187.1
- Upper River: PRM 187.1 – PRM 235.2

4. METHODS

This Technical Memorandum describes the components of the ice processes study which includes aerial observations of ice processes and time-lapse photography.

4.1. Aerial Reconnaissance

Aerial reconnaissance of freeze up progression, open leads, and breakup progression was completed on the Lower, Middle, and Upper River. Observations of these processes were completed by visual reconnaissance, photography, and video of the entire 235-mile study area. Ice processes field observation standards follow those of EM-1110-2-1612, Ice Engineering, developed by the U.S. Army Corps of Engineers (USACE 2002) and Michel (1971). Aerial reconnaissance flights included observations of the mainstem of the Susitna River and the mouths of major tributaries, including the Yentna, Chulitna, and Talkeetna Rivers. A Geodatabase of ice features was created and includes GPS-referenced photographs and video from each flight. Daily field summaries provide a narrative of ice processes over time. Open leads were systematically mapped using a GPS enabled iOS mapping application for use with the Apple iPad. Both downstream and upstream waypoints were collected for longer open leads, while for leads less than about 100 feet in length only a center point was located. Georeferenced photographs were taken of most leads mapped, as well as continuous video. Each lead was classified as thermal or velocity in origin based on the following criteria:

- Thermal leads were generally found in marginal areas outside of the main channel flow. These include bank toes, which may accumulate groundwater from the surrounding floodplain, the margins of gravel bars, side channels, and side sloughs where shallow upwelling water may occur. Thermal leads were distinguished by very shallow depth (often bare gravel), discoloration and staining of water (occasional), and uneven, rounded edges and beaded appearance. In addition, throughout the winter, thermal leads tended to grow larger, except during very cold periods when border ice might form.
- Velocity leads tend to be in the thalweg of main channel braids, have visible current, deeper water, occasionally broken ice accumulated along edges or at downstream end, and the margins were smoother and aligned with current. During cold periods, flowing frazil would accumulate at the downstream ends of velocity leads.

4.2. Time-Lapse Camera Monitoring

Time-lapse cameras monitored freeze up and breakup at locations corresponding to flow-routing model instrumentation, key ice processes, and fish habitat locations. Time-lapse cameras were set to take photos of a site at 15-minute intervals, all dark and night shots were removed, and the resulting images were compiled to create videos. Each site has videos created for both freeze up and breakup events. Each video was reviewed and a narration created to summarize key observations. The narrations for each site are found in Section 5.1.1.1and 5.1.2.1 for freeze up and Sections 5.3.1.1 and 5.3.2.1 for breakup. The narrations include the timing of ice cover advance and decay, the relative abundance of frazil ice visible in the channel during freeze up, the growth of border ice during freeze up from the shore, and the local interaction of ice with the floodplain. The locations of the time-lapse cameras for 2013 freeze up and 2014 breakup are listed below and in Table 4.2-1 and shown on Figure 4.2-1:

- PRM 13.9, Alexander Slough near Upper Tidal Influence
- PRM 29.8, Susitna Station at ESS20
- PRM 64.2, near Rustic Wilderness, Side Channel
- PRM 65.2, near Susitna Landing
- PRM 91.4, near Birch Creek
- PRM 104.3, Whiskers Slough near FA-104
- PRM 113.2, Slough 6 near FA-113
- PRM 115.4, Slough 6 near FA-115
- PRM 129.6, Slough 8A near FA-128
- PRM 132.2, Slough 9
- PRM 138.5, Slough 11 near FA-138
- PRM 142.2, near Indian River and FA-141
- PRM 145.7, Slough 21 near FA-144

4.3. Meteorological Data Collection

Daily meteorological data were obtained from the National Weather Service (NWS) station in Talkeetna between October 1, 2013 and June 1, 2014. A tabulation of freezing degree days and thawing degree days was kept; along with water temperature data from transect stations along the Lower and Middle River. SNOTEL data were collected during the same period at Susitna Valley High School, Tokositna Valley, and Point McKenzie. Data were collected at these same sites for the 2011/2012 and 2012/2013 Ice Processes Study.

5. RESULTS

Winter 2013/2014 was characterized by normal flows during early ice formation that continued to be near normal through fall and early winter as recorded by USGS gages at Tsusena (Figure 5.1-1), Gold Creek (Figure 5.1-2), and Sunshine (Figure 5.1-3). Temperatures during the winter were at or above historical averages at Talkeetna with generally higher than average temperatures during the month of January. Temperatures in late winter and spring were mild, similar to historical averages (Figure 5.1-4).

Overall, freeze-up was characterized by ice progression from downstream to upstream with few significant jamming or overbank events. Frazil flow was first observed in the Middle River at PRM 145.7 on October 23, 2013 when a field crew was installing time-lapse cameras. As temperatures dropped over the Basin, frazil ice production formed bridges with the earliest ice bridges being short, thick frazil ice bridges in Devils Canyon, which did not progress upstream. Again, ice cover in the Lower River was initiated by bridging in the lower 5 miles of the River which was similar to observed freeze-up in 2012. The Lower River ice cover progressed steadily to the Three Rivers confluence then slowed as it progressed farther upstream. Ice cover on the upper reaches of the Middle River and Upper River formed and progressed steadily upstream until the River was primarily ice covered by the end of December 2013. Figures 5.1-5 and 5.1-6 illustrate the ice front progression and ice bridge locations as observed over freeze-up in 2012 and 2013, respectively.

Breakup 2014 was characterized by mild temperatures and a gradual melt-out of the ice and snowpack in the Susitna Basin. Temperatures for late winter and spring followed historical averages at Talkeetna. The peak of breakup occurred the weekend of May 3, 2014 with mostly rotten ice cover flowing from the River with the only remaining ice cover observed at PRM 206-223 through May 8.

5.1. Freeze-up Observations

Freeze-up aerial reconnaissance of the 234-mile study reach began on November 6, 2013 following the first observed floating frazil ice and finished on December 23 when the ice cover progression approached its maximum extent. On November 6, frazil ice was observed flowing throughout the entire river except for the lower sections of the Lower River. Border ice was observed in early stages of growth with few constriction sites in the Middle and Upper River. Ice bridging locations were observed in the upper reaches of the Middle River and in few locations of the Upper River. Two short ice covers were present; one in the Middle River and one in the Upper River. Border ice continued to grow and frazil production appeared steady throughout the River. A bridge at the mouth was first observed on November 12 and the ice front progressed steadily upstream as shown in Figure 5.1-7. Bridging locations were observed, in addition to sections of ice cover, in the upper section of the Middle River and intermittently through the Upper River and continued to accumulate more ice. The flight on November 19 followed a sharp temperature drop which fueled frazil production and ice cover growth on the River. Heavy frazil production and movement downstream was observed throughout most open channels in all reaches of the River. The period of continued cold persisted through the end of November and the ice front passed Talkeetna by November 25. The month of December brought fluctuating temperatures but the Susitna River freeze-up progression neared its maximum extent by December 23. Continued cold weather and frazil deposition filled in most of the open reaches remaining.

5.1.1. Lower River Observations

November 6: Frazil ice was first observed at PRM 39.5 and was intermittent throughout the entire Lower River reach.

November 8: Frazil ice continued to move down the river and reached the Cook Inlet. Most of the river was covered with upwards of 50 percent surface concentration of frazil ice.

November 12: An ice bridge formed at the mouth of the river and the ice front had progressed to PRM 29.8 since the previous flight on November 8. The ice cover was formed from consolidated pans on the main channel while many side channels were open through the highly braided reach. Frazil continued to move into the Lower River and was observed through most open channel locations as shown in Figure 5.1-8. Border ice growth on the Lower River was isolated but present.

November 15: The ice front progressed 19 miles to PRM 48.8. Both mouths of the Yentna and Deshka Rivers were frozen with rough, consolidated frazil ice covers.

November 19: Cold air temperatures caused dense fog along open water sections on the Lower River making observations from the air difficult. Several ice bridges were observed on the main channel in this highly braided section with one continuous ice cover from PRM 72.2-74.6. Frazil was observed in most open water in the Lower River. The Talkeetna River was observed to be frozen at the confluence with the Susitna River.

November 21: Open leads were observed in the Lower River ice cover. Leads were primarily velocity in origin with several potentially thermally influenced leads in highly braided sections close to banks. A large open section of water was observed directly south of the airport near Talkeetna at PRM 99.

November 25: Ice cover stretched over the Lower River with open water designated as thermal or velocity leads with no other significant open sections. Overflow was observed in several locations. The mouth of the Chulitna River was frozen over at the confluence with the Susitna.

November 29: No significant changes were observed on the Lower River from the previous flight. Open leads remained present and frazil was observed in the open leads.

December 3: Open leads on the Lower River were generally similar to the last flight being long and narrow in the thalweg and short and narrow with apparent thermal input near banks in highly braided sections. Frazil was observed being produced in long and narrow open leads in thalweg of main channel.

December 12: Open leads on the Lower River were generally similar to the last flight being long and narrow in the thalweg and short and narrow with apparent thermal input near banks in highly braided sections. Frazil was observed being produced in long and narrow open leads in thalweg of main channel.

December 18: The Lower River continues to be ice covered with little sign of change from the previous flight.

December 23: The Lower River continues to be ice covered with little sign of change from the previous flight.

5.1.1.1. Lower River Time-Lapse Cameras

PRM 13.9, Alexander Slough near Upper Tidal Influence: The camera was installed on October 21, on the right bank, in a large cottonwood tree with a general upstream view. Floating frazil was first observed on November 7 at 9:00am, which was the first image of the day. Frazil concentration continued to increase over the next two days until the frazil ice stopped moving as observed in the first image of November 9 taken at 9:00am. River stage visibly increased over the next nine hours but no overflow was observed. By November 11 the entire channel was ice covered with a combination of consolidated frazil and thermally grown border ice. The site experienced small overflow events during the winter including December 5, January 3 and 31, and February 27. No other events were observed.

PRM 29.8, Susitna Station at ESS20: The camera was installed on October 16, on the left bank, in a birch tree on the same bluff that the USGS gage is located, roughly 50 feet above the river surface. The view was upstream towards the single, main channel. Low concentration of floating frazil was first observed on November 6 at 3:45pm. By November 7 surface frazil concentration sharply increased to 50 percent and continued to increase until observation of stopped ice flow at 12:00pm on November 12. The ice cover consolidated and no movement was observed following the cover formation. No overflow or stage increase were observed, likely due to the elevation difference between the camera site and the ice surface.

PRM 64.2, near Rustic Wilderness Side Channel: The camera was installed on October 21 on the right bank, on a small island in the highly braided section of Rustic Wilderness, farthest away from the mapped main channel. The camera view was across the main channel towards the left bank of the river. Floating frazil was first observed on November 6, with the first image of the day at 9:30am. A very gradual increase in frazil concentration between 5 percent and 25 percent surface concentration was observed through November 14 when frazil concentration decreased. During the afternoon of November 17, the channel nearest the camera froze over with a high thermal influence in conjunction with frazil accumulation. A stage rise and surface frazil concentration increase were observed at 5:00pm on November 18. The stage rise was assumed to have continued through the night and the channel became ice covered as the first image of the day on November 19 showed all channels covered. A small overflow was observed on November 25. No other events were observed.

PRM 65.2, near Susitna Landing: The camera was installed on October 16 on the left bank in a small birch tree with a general upstream view, nearest the mapped main channel. Frazil was first observed at low surface concentration on October 24, but was no longer visible during the late morning of October 25. Frazil begin flowing again on November 6 and surface concentration gradually increased from 5 percent to 40 percent between November 6 and 18. Frazil ice accumulated and a cover formed at 5:45pm on November 18. No further changes to the ice cover were observed.

PRM 91.4, near Birch Creek: The camera was installed on October 21 at the exit of Birch Creek (slough) into the Susitna on the left bank with a general upstream view. Frazil was first observed on November 6 at 25 percent surface concentration but stopped in the morning of November 7. The channel froze over from thermally grown smooth border ice, with the cover complete on November 17. Numerous overflow events occur, with a persistent open lead present on the right bank of the main channel.

5.1.2. Middle River Observations

November 6: The Middle River generally showed flowing frazil at 50 to 75 percent concentration with a few constrictions but no ice bridges or covers below Devils Canyon. Bridging locations, including one notable ice cover, were present in Devils Canyon and just downstream of the dam site.

November 8: Lower reaches of the Middle River continued to see frazil transport with border ice visible in many areas. Heavy frazil production combined with border ice growth in specific areas began constricting the open channel and added to bridging in the upper reaches of the Middle River as shown in Figure 5.1-9.

November 12: Lower reaches of the Middle River were very similar to those of the Lower River except with an increase in border ice growth. The first ice bridge was encountered upstream of Portage Creek at PRM 152.8 and several small ice covers and ice bridges were observed through Devils Canyon. Open channel dominated between Devils Canyon and the dam site with a single ice bridge at PRM 183.7.

November 15: The Middle River continued to show signs of border ice growth with the main channel and few side channels open. Above Portage Creek, ice bridges and short ice covers present on the previous flight remained in place. Ice cover appeared lumpy from frazil pan accumulation as opposed to smooth in texture.

November 19: Observations on the iPad were collected only through PRM 136 at which time the cold temperatures rendered the device ineffective. The same was true for the video camera on the front of the aircraft. Still images and notes in field books were collected for the remainder of the flight. Heavy frazil flow and accumulation into frazil trains was observed through the Middle River with ice bridges and cover forming in Devils Canyon. Frazil was lighter upstream of Devils Canyon allowing anchor ice to be more visible. Border ice and anchor ice growth appeared increased from the previous flight through. An ice cover was present through the dam site canyon.

November 21: Heavy frazil ice dominated observations in the lower section of the Middle River with ice bridges and covers appearing upstream of Devils Canyon.

November 25: Reduction in frazil allowed for better observations of anchor ice formations present in many locations along the Middle River. The ice bridge cover on November 21 from PRM 163.2-164.3 had collapsed and only a bridge remained on November 25 at PRM 163.3. Nearly all other covers and bridges were the same as the previous flight.

November 29: The Middle River exhibited increased frazil from the previous flight, but bridging locations did not change from the previous flight. Devils Canyon showed more signs of jamming and releasing with shearwalls visibly increased in size.

December 3: Ice cover on the Middle River increased in the reach downstream of Devils Canyon. Open water in the Middle River was moving frazil downstream and anchor ice was visible through most open reaches as shown in Figure 5.1-10. Through Devils Canyon to the dam site, ice bridges and cover were similar in location and extents.

December 12: The ice front progressed only a few more miles upstream from observations on the previous flight and the ice cover upstream of FA 128 progressed a few miles as well. Ice covers and bridges in Devils Canyon were similar in length and location to the previous flight.

December 18: The ice front progressed to PRM 119.2 and the ice cover starting at FA128 extends up to PRM 148.5 which was an 8 mile extension from the previous flight. Devils Canyon continued to show signs of jamming and releasing with significant shearwalls and stranded ice present as shown in Figure 5.1-11. An ice cover remained intact through the dam site.

December 23: The ice front progressed to PRM 122.0 and the ice cover starting at FA128 has jammed and released, opening a section that was covered during the previous flight. Devils Canyon continues to show signs of jamming and releasing with significant shearwalls and stranded ice present. An ice cover remained intact through the dam site and has met the Upper River ice cover leaving the Susitna River ice-covered above PRM 185.5.

5.1.2.1. Middle River Time-lapse Cameras

PRM 104.3, Whiskers Slough near FA-104: The camera was installed on October 25 on the right bank while frazil was observed in the river. The camera view was upstream. Border ice begins growing on October 26 in conjunction with increased frazil flow but the frazil stopped and the border ice washed out on October 28. Continuous frazil flow resumed on November 5 and steadily increased from 25 percent to 75 percent surface concentration between November 5 and 21. During the night of November 21, the ice front passed the camera site and left remnants of a large freeze up jam with the ice cover remaining being very jumbled and rough in texture with notable stage rise observed. Following consolidation of ice, no further events were observed.

PRM 113.2, Slough 6 near FA-113: The camera was installed on October 25 on the left bank of the main channel on an island looking across the main channel towards the right bank. Frazil was observed in the river during installation, yet the frazil stopped on October 27. November 5 saw the return of frazil flow and the surface concentration continued to increase from 5 percent to 75 percent until November 23. During the afternoon of November 23, a sharp reduction in frazil concentration occurred; dropping from 75 percent to 10 percent surface concentration. Frazil concentration again gradually increased, from 10 to 50 percent, through the morning of December 3 at which time the stage began to rise and by 3:15pm the ice front was observed moving past the camera site. Within 1 hour and 45 minutes the ice front progressed past the site, leaving the channel ice covered, and the stage continued to rise causing minor flooding and overflow through 10:00am December 6. By December 6, the ice cover was consolidated and no further events were observed.

PRM 115.4, Slough 6 near FA-115: The camera was installed on October 23 on the right bank, just downstream from a slough entrance, and looking upstream at the main channel. Frazil was first observed on October 24 at a 10 percent surface concentration but ceased on October 27. November 5 was the return of frazil to the site at a 5 percent concentration and quickly jumped up to 25 percent on the morning of November 6 and persisted till November 14 when the surface concentration dropped to 10 percent. Between November 14 and 22 surface concentrations steadily increased from 10 to 75 percent, yet on the morning of November 23 a sharp reduction in frazil brought the surface concentration down to 10 percent. Frazil concentration fluctuated between 10 and 50 percent through December 12 and the first image of the day on the morning of December 13 revealed the channel to be ice covered. By the afternoon of December 13 the stage rise associated with the ice front passing the site stopped and the ice cover consolidated. There were two consolidation events associated with shifts in the ice cover; one shift in the ice cover on December 14 and a significant shift between 5:00pm and 5:15pm on December 16 that left the ice cover very broken and jumbled with an increase in ice surface elevation. No further events were observed.

PRM 129.6, Slough 8A near FA-128: The camera was installed on October 23 on the left bank of the main channel with a view generally upstream. A short-lived run of frazil at 25 percent surface concentration occurred between October 24 and 27 with continuous frazil flow resuming on November 5 at a 25 percent concentration. Between November 5 and 30 frazil concentration steadily increased to a maximum of 75 percent and during the afternoon of November 30 the ice front was observed moving past the camera site. In the time between 4:00pm and 4:15pm, the river went from flowing frazil to ice covered. Between 4:30 and 4:45 a stage rise was observed with ice consolidating during that time. Following the consolidation, no further events were observed.

PRM 132.2, Slough 9: The camera was installed on October 25 on the left bank with a view across and slightly upstream on the main channel. Frazil was present in the river during installation but ceased during the night of October 27. Frazil resumed on November 5 at a 10 percent surface concentration and jumped to 50 percent on the morning of November 6. The surface concentration remained at 50 percent until 5:00pm November 16 when the camera malfunctioned and stopped recording images.

PRM 138.5, Slough 11 near FA-138: No images were collected during freeze up due to equipment malfunction.

PRM 142.2, near Indian River and FA-141: The camera was installed on October 23 just upstream of the Indian River confluence on river right bank with a view across and slightly upstream on the main channel. Frazil was first observed between October 24 and 27 with surface concentration increasing from 10 to 25 percent but stopped on October 27. Frazil flow resumed on November 5 and increased in concentration from 10 percent to a maximum of 75 percent on November 10 and 11 and then began steadily reducing to below 5 percent surface concentration on November 14. Between November 14 and December 14 frazil concentration fluctuated between 10 and 75 percent and then during the night of December 14 the ice front passed the camera site with the first image of the day on December 15 showed the channel 100 percent covered. During the afternoon of December 21 the stage visibly increased and raised the ice surface elevation. An open lead began forming shortly after the stage increase in the main channel and remained open until February 9. A small open lead formed near the bank on December 28 and appeared to be thermal in origin. This open lead experienced several ice covers but seemed to always return to an open state. A cover formed on January 13 but opened on January 16 and again on February 9 but opened on February 28 and remained open. No other events were observed.

PRM 145.7, Slough 21 near FA-144: The camera was installed on October 23 on the left bank with a view across main channel and within one hour of installation frazil flow was first observed. Frazil stopped flowing during the night of October 28 and did not resume flowing until November 4. Surface frazil concentration fluctuated between 10 and 75 percent from November 4 until November 30 when an ice front progressed past the camera site. The ice cover was short-lived as it flushed out 60 minutes after forming. The open main channel fluctuated between 10 and 50 percent surface frazil concentration from November 30 to December 16. The morning of December revealed an ice cover and stage increase. The ice cover shifted and consolidated over the day and remained undisturbed until December 21 when the first image of the day showed a large stage rise resulting in a very jumbled and shifted ice cover. No further events were observed.

5.1.3. Upper River Observations

November 6: The Upper River was similar to the Middle River with 50 to 75 percent flowing frazil, several constrictions with frazil still moving and few bridging and cover locations.

November 8: Ice cover in the Upper River continues to grow and connect between bridging locations. Signs of one freeze up jam were observed near PRM 197.5.

November 12: Ice cover on the Upper River continued to grow with the most significant cover over 17 miles long. Signs of freeze up jams were present with very rough ice cover and several pressure ridges formed across the channel indicating jamming locations.

November 15: Ice bridges observed during the previous flight had grown into significant ice covers observed during this flight. Overall, the ice cover appeared rough from frazil accumulation with few areas appearing to have experienced freeze up jamming. Little frazil production and floating frazil were observed in open channels, although slightly more than in the Lower and Middle River.

November 19: Anchor ice and border ice growth as shown in Figure 5.1-12 continued on the Upper River and was present through most open water sections. A significant ice cover stretched from PRM 207 to 218.

November 21: The Upper River ice cover started around PRM 190 and continued to extend upstream with constant frazil production. Observation ended at PRM 210 as daylight was diminishing and the field team turned around.

November 25: The Upper River ice cover beginning at PRM 189 was still present but the field team did not observe the extent of the cover due to the short daylight and had to turn around at Watana Creek.

November 29: The Upper River ice cover beginning at PRM 189 was still present but again the team was not able to observe the extent of the cover due to short days and turned around at PRM 212. They commented that the cover extended as far as they could see, but no definite river mile was observed.

December 3: The ice cover on the Upper River was finally observed in its entirety as the team was unable to fly to the Oshetna River confluence since November 15. No observation of the rate of progression was able to be collected, but the cover extended over 30 miles of the river.

December 12: The Upper River was primarily ice covered. The cover had numerous open leads throughout and all appeared to be velocity in origin with defined down- and upstream ends. Upstream of Vee Canyon appeared to be continuously open, past the Oshetna confluence.

December 18: The Upper River remains primarily ice covered with little change from the previous flight.

December 23: The Upper River remains primarily ice covered with little change from the previous flight.

5.1.3.1. Upper River Time-Lapse Cameras

No time-lapse cameras were installed in the Upper River during the 2013/2014 winter field season due to lack of land access.

5.2. Open Lead Mapping

Two open lead mapping events occurred during late winter and early spring 2014; February 20-21 and April 2. Open leads from PRM 0-235.2 were mapped aerially and documented using GPS-enabled cameras. The limited daylight in February required two flights to complete the mapping with PRM 140 – 235.2 mapped on February 20 and PRM 0 – 187.2 mapped on February 21 providing for some overlap. The temperatures for Talkeetna during the February survey ranged from -23° C to a high of -7° C. In April, the temperatures (also recorded in Talkeetna) ranged from -12° C to a high of 5° C. Generally, long narrow velocity leads were observed in the thalweg in each reach of the river while shorter and narrower thermal leads were observed in the Lower and Middle River near gravel bars and braided sections. The Upper River was mostly ice covered athough there were thin velocity leads in the thalweg and some thermal input at the mouths of tributaries.

5.2.1. Lower River

Open leads in the Lower River during the February 21 and April 2 surveys included both those of velocity and thermal origin. In general, the velocity leads were either located in the main channel thalweg or on the outside of bends as shown in Figure 5.2-1. Several of these velocity leads could be characterized as elongated ‘holes’ caused by turbulence or upwelling water. Some of the side channels/sloughs were introducing warmer water, resulting in small thermal leads that would often blend into a velocity lead in the main channel. The thermal leads were either groundwater upwelling in the bottom of a side channel or slough, groundwater seepage off of bluffs/ river banks (Figure 5.2-2), from upland sources, or input from tributaries.

During the February 21 survey, 10 thermal leads and 41 velocity leads were mapped on the Lower River. Frazil ice was being generated and accumulating in many of the velocity leads.

On the April 2 survey, 12 thermal leads and 27 velocity leads were mapped. Many of the velocity leads identified during the February survey had narrowed and/or closed due to cold weather and dropping discharge in March. Rising temperatures in late March/early April allowed groundwater sources to widen areas of open water in side channels/sloughs and braided sections.

5.2.2. Middle River

The Middle River had a similar pattern of leads as the Lower River although there were more thermal leads coming from sloughs with groundwater origins. An example of these sloughs and beaver ponds can be seen at FA-104 (Whiskers Slough) as shown in Figure 5.2-3, FA-115 (Slough 6A), and FA-128 (Slough 8a). Some of the open velocity leads extended almost to the full channel width and these were often connected with sections of ice cover such that the reach was characterized as an intermittent open lead/reach. Several of these sections were quite long, sometimes extending for up to a mile in length. As with the Lower River, thermal leads running along a bank or side slough often combined with a velocity lead at its upper end.

On February 20-21 (there was coverage of PRM 140 – 187.2 on both days), 18 thermal leads, 45 velocity leads, and 5 velocity leads that were characterized as open channel sections were mapped. Frazil and anchor ice were observed in most of the velocity leads and open channel sections.

On April 2, 18 thermal leads were again mapped but the velocity leads and open channel sections had narrowed and frozen over to give a total of 27.

5.2.3. Upper River

In the Upper River almost all of the leads were velocity in origin as shown in Figure 5.2-4. Thermal input could be seen only at the mouths of tributaries which were mostly were frozen over. Groundwater contribution through seepage from upland sources showed up as small glaciated features flowing off the banks.

On February 20, only one thermal lead was mapped. Open channel or velocity leads accounted for 19 additional mapped features. The temperature in Talkeetna had dropped down to -23^{o} C the night before our survey and there was a lot of Frazil and anchor ice observed in the Upper River.

On April 2, again, only one thermal lead was mapped. Open channel or velocity leads continued to show a decrease in number from the February 20 survey due to cold temperatures with narrowing or total closure of many leads. A total of 8 leads or open channel features were mapped.

5.3. Breakup Observations

Breakup aerial reconnaissance of the 235-mile study reach began on April 14, 2014 (not long after the the last open lead mapping) and finished on May 8 when the main channel of the river was ice free. On April 14 the River showed initial signs of warmer temperatures with signs of melting including reduced snow cover on the ice and overflow downstream of open water sections. Gradual melting and deterioration of the ice cover continued through the end of April with mild temperatures and generally constant discharge and water levels observed. The flight on May 2 followed a week of warm weather in the basin and noticeably higher water levels were observed but no significant changes to ice cover were observed from the previous flight. Following the flight on May 2, ice conditions continued to deteriorate and breakup began in earnest. Inspection of the remote cameras at the ESS sites showed that the ice cover at Susitna Station began to breakup and pass downstream at approximately 10 PM on May 2 with a large run past the site (likely most of the Yentna and Lower River ice) passing between noon and 5 PM on May 3. The ice cover at Curry, PRM 124, broke up and passed downstream at 7-8 AM on May 3. The ice cover at Portage Creek broke up and passed downstream around 9-10 PM on May 2. An ice run passed by Fog Creek, ESS65 at PRM 176.4, around 5 PM on May 2, likely the same run that was witnessed just before at ESS80, PRM 225, during the May 2 flight. There was an ice jam that formed just below ESS40, upstream of FA104 - Whiskers Slough, at approximately 10AM on May 3, with a significant rise in water levels and some overbank flooding. This jam extended upstream from about PRM 105.5 to 108. The jam failed and passed downstream at approximately 5PM on May 4. The flights on May 5 and 8 revealed much of the ice had gone out on the River with the only significant cover present between PRM 206 and PRM 223. The May 8 flight traveled upstream of the Oshetna Confluence to assess ice cover in the upper reaches of the River. The upper reaches of the river appeared to have ice cover intact, but was open to the MacLaren River at PRM 265.

5.3.1. Lower River Observations

April 14: The mouth was open from tidal action but very few open leads were present in the main channel until PRM 65 near Susitna Landing. Numerous snow machine tracks and a few snow machines were spotted on the ice near Susitna Landing. Between Susitna Landing and Talkeetna the river was showing signs of melting with overflow present downstream of open leads. Many of the sloughs had open water due to the ice cover collapsing over the channels. This was the case for the Birch Creek area. At Talkeetna, a long and fairly wide open lead/open channel was present with ice chunks present in the downstream end, a sign of early-stage breakup. This open water section was along the river left bank and extended from the Three Rivers Confluence to directly south of the airport (PRM 101 to 99). The Talkeetna River was open upstream of the railroad bridge. The Chulitna River had several small and narrow open leads at the confluence with the Susitna but otherwise appeared to have a solid ice cover.

April 21: The mouth was open from tidal action to PRM 4. Leads were opening up in the main river channel; however they remain small and narrow in the main channel below PRM 65 near Susitna Landing. Many side channels and sloughs were showing signs of melting with water on the ice surface along the banks and following the thalweg. Between Susitna Landing, PRM 65, and Talkeetna, PRM 100, the river was showing signs of melting with overflow onto the ice surface downstream of open leads. The open leads had increased in length and connectivity and in some areas around the islands there were networks of braided thermal and velocity leads. At Talkeetna, just off the approach end of runway 36, the long and fairly wide open lead continued to extend to the confluence with the Chulitna. Both the width of the lead and amount of ice accumulated in the downstream end had increased from the previous flight. The Talkeetna River was open upstream of the railroad bridge but had not opened at the confluence with the Susitna. The water level in the Chulitna River was still low and several small and narrow open leads at the confluence persisted.

April 23: The mouth was open from tidal action to PRM 4. There were short open sections developing where the cover has locally moved downstream at PRM 8, 10.2, and 13.5. Above PRM 15 the cover was generally intact but it was visibly rotting. In the Delta Islands area, PRM 46, there were many thermal leads and open channels. The thalweg in most reaches shows some overflow and the cover was still depressed; meaning the flow can increase considerably prior to totally filling the thalweg channel. Open leads were widening and lengthening in the main channel between Susitna Landing, PRM 65, and Talkeetna, PRM 100. At Talkeetna, just off the approach end of runway 36, the wide open lead continued to increase in length as well as the amount of broken ice in the downstream end. The Talkeetna River remained open past the railroad bridge and only a short section of ice remained at its confluence with the Susitna. The water level in the Chulitna River was still low and there were several very small and narrow open leads at the confluence with the Susitna.

April 25: The mouth was open from tidal action to PRM 5 where there was a short section of ice cover. The east channel was still covered in ice, but the main channel was open with remnant ice cover along the left bank. The intact ice cover begins at PRM 16.5 above Alexander Slough. The Yentna River was ice covered at the confluence of the Susitna River. Kroto Slough was open at its confluence with the Yentna due to thermal melt, but was still ice covered at the upstream confluence with the Susitna River. Through the Delta Islands, PRM 46, there was again a significant increase in the open interconnectivity of the thermal leads in off channel sections, which created braided flow channels that were discharging into to the main channel of the Susitna River. Open leads continued to widen and lengthen in the main channel between Susitna Landing, PRM 65, and Talkeetna, PRM 100. Sporadic short sections of open channel were beginning to appear. Ice had accumulated in the downstream ends of the open channels, but water levels upstream of the ice accumulation had not noticeably increased. At Talkeetna, off the approach end of runway 36, the wide open lead continued to increase in length to the point it was almost open channel in places. The amount of broken ice in the downstream end remained unchanged. The Talkeetna River still had not breached the confluence with the Susitna River, but was open upstream of the railroad bridge. The water level in the Chulitna River was still low, but the small and narrow open leads present on April 23 at the confluence with the Susitna had become larger.

April 28: The mouth was open and the short section of ice cover observed on April 25 was gone. The intact ice cover began at PRM 16.5 above Alexander Slough as shown in Figure 5.3-1. The Yentna River was still ice covered at the confluence of the Susitna River. Through the Delta Islands, PRM 46, there was again a significant increase in the open interconnectivity of the thermal leads in off channel sections, creating braided flow channels that were discharging into to the main channel of the Susitna River. Open leads continued to widen and lengthen in the main channel between Susitna Landing, PRM 65, and Talkeetna, PRM 100. Larger ice chunks were building up in the downstream ends of the open channels; water levels were starting to rise upstream of these developing jams. At Talkeetna, off the approach end of runway 36, the open lead had grown enough to be considered an open channel. The developing jam in the downstream end was larger and the water was rising all the way up to the Chulitna confluence. The Talkeetna River stage has increased yet still had a small section of ice separating it from the Susitna as shown in Figure 5.3-2. The water level in the Chulitna River was slightly higher and open leads at the confluence with the Susitna had become larger.

April 30: The mouth was open to PRM 16.5 above Alexander Slough. The Yentna River was still ice covered at the confluence of the Susitna River. Through the Delta Islands, PRM 46, there was again a significant increase in the open interconnectivity of the thermal leads in off channel sections, creating braided flow channels. Open leads continued to widen and lengthen in the main channel between Susitna Landing, PRM 65, and Talkeetna, PRM 100. Many sections had become open channels separated by accumulations of ice chunks. At Talkeetna, the open channel extended about a mile farther downstream to PRM 98. The Talkeetna River had breached the confluence with the Susitna and the channel was open upstream under the bridge. The open main channel of the Susitna now extended up to the Chulitna confluence.

May 2: The Susitna River was open from the mouth to approximately PRM 25. Sloughs and side channels were also open. The Yentna and Susitna confluence was still ice covered but the ice surface was showing signs of significant melt and rotting. In the Delta Islands area there were many thermal leads and open channels with some longer sections of open river. Open leads had widened and lengthened in the main channel between Susitna Landing, PRM 65, and Talkeetna, PRM 100, with significant open reaches from the Sunshine Bridge all the way to Talkeetna. The Talkeetna River was open past the railroad bridge. The water level in the Chulitna River had increased and there were several open leads and channels at the confluence with the Susitna.

May 5: The Lower River was open through the entire reach with shorefast ice in a few places and remnant chunks and brash along the banks. The Lower River had entered spring as many trees seemed to have budded out leaves over the weekend. USGS gage readings at Susitna Station as of May 7 indicated flows upwards of 80,000 CFS. Both the Chulitna and Talkeetna Rivers appeared open, and the Chulitna River had more shorefast ice on gravel bars.

May 8: The Lower River was open through the entire reach with remnant chunks and brash ice along the banks. USGS gage readings at Susitna Station as of May 9 indicate instantaneous flows of 82,600 CFS. Both the Chulitna and Talkeetna Rivers were open, and the Chulitna River had more ice chunks and brash on gravel bars.

5.3.1.1. Lower River Time-Lapse Cameras

PRM 13.9, Alexander Slough near Upper Tidal Influence: Evidence of tidal action was present at the site with visible stage rise occurring roughly one hour following high tide as measured at Port Mackenzie. Early April saw tides upwards of 32 feet above mean lower low water. This tidal action in combination with increasing solar radiation aided in weakening the ice cover which had no snow cover for insulation. Open water was first visible near shore to the camera on April 14 and continued to melt through April 17 when the first brash ice accumulated in the open water. As the water level subsided, corresponding to low tide, water velocity increased and cracks perpendicular to the current formed followed by a large shift in the cover early in the afternoon of April 17. The ice cover continued to shift and reconsolidate on April 18 and 19 and finally flushed out early in the evening of April 19. Ice floes from upstream passed the site with significant ice passage occurring on April 24, 29, May 1, 2, and 3. The ice runs on May 1 and 3 were the largest, which left ice stranded on the banks and bars and covered the entire channel with ice while it was passing the site. By May 4 all ice was clear of the site.

PRM 29.8, Susitna Station at ESS20: Snow covered the ice through most of April with signs of snow melting and pooling on top of the ice cover at several locations. Ponding of water was most notable April 16 over much of the ice cover across the entire channel. The ice cover remained intact and unmoved until the evening of May 2 when three quarters of the ice cover shifted and began to move downstream. By noon on May 3, the ice cover moved out of the site and large ice runs from upstream moved through the site. By the evening of May 3 most of the significant upstream ice had moved past the site with only small brash passing the site for the remainder of time the camera was in place.

PRM 64.2, near Rustic Wilderness Side Channel: Snow covered the ice through most of April with meltwater beginning to pool during the evening of April 16. Gradual melting of the snow cover continued through the end of April. April 30 brought the first view of open water. The far side of the channel, left bank of the river, began to open with visible brash movement. On May 2, a large accumulation of breakup debris covered the open channel, which increased the stage and caused the mid channel ice cover to to flush out. The channel nearest the camera opened only a few hours after the mid channel opened. The remnant ice cover was flushed out during the early afternoon of May 3. Brash and breakup debris accumulations covered between 50 and 100 percent of the channel for the remainder of May 3 and by the end of the following day the entire channel was open.

PRM 65.2, near Susitna Landing: The fist melting snow pooling on the ice cover was observed on April 7. The snow cover continued to gradually melt through the remainder of April. On April 23 a small hole formed in the ice and high velocity water was observed upwelling from the hole. By the end of the day on April 24 the near bank ice cover visibly weakened and a narrow open water section appeared. A large section of ice flushed from the site on the evening of April 29 and the remaining shorefast ice on the far right bank, flushed out by noon on May 1. A large ice floe moved through the site during the afternoon of May 2, stopped and began accumulating more ice and consolidating through the end of the day May 3. The first image of the day on May 4 revealed the channel clear of ice with remnant ice chunks stranded on the far bank.

PRM 91.4, near Birch Creek: The site experienced a gradual melt out and no jamming or accumulation of ice was observed at the site. No ice floes were captured in any of the images which were taken every 15 minutes. The main channel gradually opened with the first flowing water visible on April 5 and the entire channel was ice free on May 3. No ice floes, stage increases, accumulations, or other dynamic events were observed.

5.3.2. Middle River Observations

April 14: Sloughs and side channels were opening with long, narrow open leads. FA-104 and FA-128 both had significant open water in the sloughs, though only small open leads were present in the main channel. FA-128 had a long open lead in the slough running nearest the railroad (Slough 8A). This lead was open for a significant length of the focus area (over 3 miles). The main channel appeared to have collapsed in numerous areas, posing on-the-ice navigation hazards as low water levels were not supporting the ice covers. Above Portage Creek and through Devils Canyon the river presented remnants of many freeze up jams, overflow, and refreezing. Above Devils Canyon to the dam site had a fairly continuous ice cover with only few open leads in the main channel and sloughs. Ice conditions at the dam site appeared solid with remnants of overflow that had refrozen.

April 21: The Middle River presented more signs of melting with many of the sloughs and side channels opening with long, narrow open leads. There was more connectivity between the open leads and the ice cover showed visible signs of rotting. FA-104 (Whiskers Slough) and FA-128 (Slough 8A) both had significant open water in the sloughs, although open leads in the main channel remained small and narrow. Slough 8A, Upper Side Channel 8A, and Middle Side Channel 8A in FA-128 were almost entirely open. The main channel had collapsed in many places, resulting in narrow open sections following the thalweg. Above Portage Creek and through Devils Canyon the river was a combination of wide open leads and short ice covered sections with some reaches within the Canyon showing signs of significant opening. Shear walls in the canyon had begun to calve off into the center channel and ice accumulations were forming in the downstream end of open water sections. Devils Canyon to the dam site had a fairly continuous ice cover, however that cover was starting to be compromised with narrow open leads and overflow in the thalweg. The side channels and sloughs showed increased signs of opening. Ice conditions at the dam site were still solid but the thalweg had become more depressed with active flooding and overflow on the ice covered channel.

April 23: The Middle River continued to show more signs of melting with many of the sloughs and side channels continuing to open with long, narrow open leads. There was more connectivity between the open leads and the ice cover showed visible signs of rotting. Openings in the thalweg showed increased stage both directly through water level increase as well as an increase due to chucks of border ice accumulation at the downstream ends of the openings. FA-104 (Whiskers Slough) and FA-128 (Slough 8A) both had significant open water in the sloughs, with the open leads in the main channel becoming more pronounced. Slough 8A, Upper Side Channel 8A, and Middle Side Channel 8A in FA-128 were almost entirely open. Above Portage Creek and through Devils Canyon the river was a combination of wide open leads and short ice covered sections. Shear walls in the canyon continued to calve off into the channel. Above Devils Canyon there was a long reach of open channel with brash floating downstream. Between PRM 180 and the dam site there was a continuous ice cover, but narrow open leads and overflow were present in the thalweg through this reach.

April 25: Melting continued in the Middle River with sloughs and side channels continuing to open. Some of the long, narrow open leads identified during the previous flight had become sections of open channel. There was more connectivity between the open leads and open channels through sections of ice cover. Open channels at the thalweg continued to flow at increased stage. Border ice along the banks had broken off and was accumulating in the downstream end of open leads and channels. FA-104 (Whiskers Slough) and FA-128 (Slough 8A) both were open. Slough 8A, Upper Side Channel 8A, and Middle Side Channel 8A in FA-128 were entirely open but Lower Side Channel 8A remained ice covered as shown in Figure 5.3-3. Above Slough 8A the Susitna remained ice covered with open leads increasing in width. Through Devils Canyon, the river was mostly open. Most ice bridges had collapsed and remnant ice covers were rotting in place. Shear walls in the canyon continued to calve off; overall the channel had become wider. Above Devils Canyon, a long reach of open channel extended noticeably farther upstream than during the previous flight. Numerous ice chunks were moving downstream. The continuous ice cover started below the dam site, but narrow open leads and overflow in the thalweg channel increased since April 23. Water levels remained low in the upper reaches of the Middle River.

April 28: The Middle River stage showed signs of starting to rise. Most of the sloughs and side channels were completely open. Long, narrow open leads identified during the previous flight became sections of open channel. Much of the main channel was flowing at almost the open channel width with large sections of ice collapsed into the open water. Much of the border ice had broken off and accumulated in the downstream ends of open leads and channels. FA-104 (Whiskers Slough) and FA-128 (Slough 8A) both were open. The main channel of the Susitna was still ice covered at Slough 8A, although the ice cover had deteriorated. Open leads upstream of 8A were wider, transitioning to extended sections of open channel. Through Devils Canyon, the river was almost entirely open. Ice bridges had collapsed and overall the channel had become wider. Above Devils Canyon there was a long reach of open channel that extended farther upstream than the previous flight. Large ice chunks were moving downstream. There was still continuous ice cover through the dam site, but open leads and overflow had increased. There was an accumulation developing upstream of the dam site.

April 30: The sloughs and side channels of the lower reaches of the Middle River were completely open. Overflow overtopped the open channel in places which caused overflow onto the ice surface of the main channel. Deteriorated ice covered the Chulitna confluence. An open lead on along the right bank extended from the Chulitna confluence upstream to FA-104, Whiskers Slough which was open. The slough at FA-115 was open but had not breached the Susitna main channel. The main channel of the Susitna had open leads in FA-128 and the channel was open immediately upstream. A long and wide lead was open along the left bank at Gold Creek. Through lower Devils Canyon, the last remaining ice covered section had collapsed. Accumulated ice chunks appeared to be from shear walls calving and were clogging the channel. The upper portion of the lower canyon was completely open. The upper canyon has one small ice bridge remaining but the rest of the canyon was open and running fast. The channel above the canyon was open although shore fast ice remains along the banks. Much of the border ice had broken off and had accumulated in the downstream ends of open leads. The ice cover through the dam site was still intact but continued to deteriorate with overflow flooding the thalweg channel.

May 2: The Middle River had shown significant signs of melting and breakup with many of the sloughs and side channels opening up. There was more connectivity between open reaches and the ice cover showed more signs of rotting. While there were open sections through FA-104 (Whiskers Slough), this reach had very thick freeze-up jamming accumulations and the ice had remained in place for longer than many reaches. FA-128 (Slough 8A) has significant open water in the sloughs, with the open leads in the main channel becoming more pronounced. Slough 8A, Upper Side Channel 8A, and Middle Side Channel 8A in FA-128 were entirely open. Accumulations were forming at the upstream edges of the ice cover. Above Portage Creek and through Devils Canyon the river presented wide open leads and almost no ice covered sections remained. There were areas above Devils Canyon where little ice remained, even along the shoreline. There was a short accumulation at the dam site that extended from PRM 186.8 to 187.6.

May 5: The Middle River was primarily open with two significant ice accumulations and shear walls in several locations. The larger accumulations at FA-104 and FA-128 were forcing ice and water over banks and had inundated islands as shown in Figure 5.3-4. The accumulation at Whiskers Slough appeared to be held back by intact ice cover which has not weakened enough to move downstream. This was the same ice cover which was very thick from freeze up jamming. It showed signs of continued melt but continued to hold. A similar situation occurred at FA-128 with remnant ice holding back an accumulation upstream of the Focus Area. All side channels were open except for Lower Side Channel 8A which had an intact ice cover showing significant signs of melting and deterioration. Significant shear walls were present at FA-104, FA-128, FA-138, near the confluences of Gold Creek, Indian River, and Portage Creek, and just below the dam site.

May 8: The Middle River was open with shear walls in several locations. Water was now passing through open channels in the large accumulation at FA-104. Large shear walls upwards of 15 feet remained (Figure 5.3-5) but water levels had dropped and previously inundated islands were now high and dry. There was a similar situation at FA-128. Shear walls were present through the Focus Area, but the main channel and all side channels were open except for Lower Side Channel 8A which had an intact ice cover continuing to show significant signs of melting and deterioration.

5.3.2.1. Middle River Time-lapse Cameras

PRM 104.3, Whiskers Slough near FA-104: Snow covered the site and began melting with ponding visible on April 17. Ponding increased in depth and by the end of the day on April 23, the ponding meltwater appeared to begin flowing. Overflow upstream of the site is thought to have added to the flow observed. The flow over the ice cover eventually created an open channel section which began to accumulate brash at the downstream end on April 28. The stage began to rise on May 2 and the open channel continued to grow in width yet by the night of May 3 an ice accumulation covered the entire channel and did not move until May 7. Between 18:00 and 20:00 May 7, the accumulation was flushed out with several additional ice runs from upstream moving through the site. Only shorefast ice remained on the morning of May 8.

PRM 113.2, Slough 6 near FA-113: Meltwater from the snow cover began visibly ponding on the ice in the evening of April 19. The channel nearest to the right bank, farthest from the camera, appeared to be open on the morning of April 20 as brash seemed to be accumulating. Significant accumulation began in the far channel on April 24 and a stage rise was observed on April 28 which caused overflow to cover most of the ice. The far bank accumulation flushed out leaving the channel open on May 1. By this point the near bank remnant ice cover was showing increased stress fractures and signs of deterioration. The afternoon of May 2 brought a large ice run which flushed the remnant ice downstream but caused an accumulation which held till the evening when the far channel flushed out. The channel was open with remnant ice on shores and banks which was eventually carried downstream. The channel was clear of ice by the afternoon of May 5.

PRM 115.4, Slough 6 near FA-115: Freeze up 2013 left the main channel ice cover jumbled and collapsed at the thalweg. This depressed thalweg had meltwater from melting snow. Between April 15 and 25, the depressed thalweg experienced cycles of flowing overflow and ponding meltwater as temperatures fluctuated daily. By the evening of April 25, brash was observed accumulating in the open channel and the next morning the accumulation released and the open channel was flowing. The channel remained open until May 1 when a large ice run from upstream filled the channel and remained in place, covering the channel with ice. The following morning the remnant ice cover and brash accumulation showed signs of shifting and the entire channel was ice free from a single large flush as of 19:00 on May 2. A second smaller ice run accumulated in the channel in the morning of May 3, but by 10:00 the accumulation had moved out of the site. All ice was free of the channel with ice left only stranded on banks and bars by the end of the day May 3.

PRM 129.6, Slough 8A near FA-128: No images from this site were captured while the camera was deployed. It is unknown what type of malfunction occurred.

PRM 132.2, Slough 9: Snow covered the channel and the first ponding meltwater was observed on April 11. On April 12, the ponding water levels increased and flowing water was observed. The flowing water continued until the final image for the site was taken on April 15 at 13:15. Malfunction is suspected for the camera as no images were captured following April 15.

PRM 138.5, Slough 11 near FA-138: Snowmelt and ponding water was first observed on the snow-covered ice on April 18. The first observed ice movement occurred on April 26 as a brash accumulation began forming at the far right bank of the river. By April 30 the stage began to rise and overflow was visible at the mid-channel. The gradual melt out of ice was interrupted on May 3 when a large accumulation associated with high flow inundated the site. The image captured at 15:45 on May 3 revealed that upwards of 5 feet of brash ice accumulated at the site during a 15 minute time span. The accumulation began to wash out within the next 30 minutes and the site experienced two more ice run events similar to this before finally having all ice flushed from the site on May 7. Ice left stranded on the banks and bars (out of the channel) continued to melt in place.

PRM 142.2, near Indian River and FA-141: This camera malfunctioned during the morning of April 26. The camera continued to work beyond this day, but the timestamp was reset to January 1, 2012 at 06:00. This could occur due to a loss of power. Based on the known time that the camera was turned off on May 15, 2014 it was possible to detemine the actual timing of events recorded with timestamps that were in error. For this reason, the description following April 26 does not match the dates on the time lapse recording.

The ice cover had snow over the entire channel and the open thermal lead nearest the camera, on the right bank of the river, persisted as an open channel. Ponding water was first observed on April 15 at the mid channel and the amount of water increased to cause water to flow over the surface of the ice by April 18. Ice cover under the overflow deteriorated and an open channel remained. The first brash accumulation occurred on April 25 and the channel was completely filled by the early afternoon of the same day.

Over a period of two days, the stage increased and caused the weak ice cover to breakup and begin moving downstream on April 30. Ice runs moved through and briefly stopped on May 2 but the channel totally cleared late on May 3. The water level increased with ice deposited on the shore on May 5 about midday and a significant ice run passed by at 18:00. The channel stayed open after this with only minor passages of brash ice.

PRM 145.7, Slough 21 near FA-144: Freeze up 2013 produced a very rough ice cover in this section. Snow covered the area and the first meltwater ponding was observed on April 19. The meltwater fluctuated in ponding depth until April 26 when a visible and sustained stage rise occurred. The ice surface elevation was not affected by this stage rise and so it was assumed that the flow observed was on the ice surface and not directly connected to main channel flow. A second stage increase was observed on May 2 and both the surface flow and ice surface elevations increased. Increased overflow on the ice surface was observed. During the night of May 2 the ice cover broke up as the first image of the day on May 3 revealed ice stranded on both banks but the main channel was ice free. Two additional ice runs passed the site but no further flooding or accumulations formed. The main channel was clear of ice with shorefast ice and sheerwalls upwards of 7 feet as of the evening of May 4.

5.3.3. Upper River Observations

April 14: Lower sections of the Upper River had significant signs of previous overflow but all surface water appeared to be refrozen. The ice cover appeared solid and continuous for a majority of this reach. Near the Oshetna confluence there were small open leads where the main channel ice cover had collapsed but no significant open water sections were observed.

April 21: From the dam site upstream, the Upper River had signs of overflow corresponding to the thalweg location. Open leads were present in Vee Canyon. The thalweg channel was generally sunken although it remains intact. Open leads were more frequent and ice had shown continued deterioration since the previous flight. There were short sections where open leads with large ice chunks in the downstream ends had refrozen. Near the Oshetna confluence, there were numerous small open leads and holes where the main channel ice cover had collapsed. The confluence with the Oshetna River was not open.

April 23: There were sections of open water immediately above the dam site up to about PRM 190, then intermittent open leads up to PRM 200. Vee Canyon was primarily open with short sections where ice remained intact. Where there was an intact ice cover, the thalweg channel was generally sunken with overflow on the ice surface as shown in Figure 5.3-6. Near the Oshetna confluence there were numerous small open leads where the main channel ice cover had collapsed. The confluence with the Oshetna River was not open but there were short sections of the OshetnaRiver ice cover that were beginning to open.

April 25: Immediately above the dam site there were extended sections of open water that generally were wider at the downstream ends and narrowed to thin open leads in their upstream ends. Ice accumulations were often the only remaining interruption between the open sections. Where the river remained ice covered, overflow in the thalweg channels had increased to almost bankfull depth, and in places overflow spilled onto the remaining ice surface. Vee Canyon was primarily open with short sections of intact ice. Near the Oshetna River confluence, there were numerous sections of open channel connected with remnant ice cover. Ice cover in the thalweg channel had collapsed with fast moving overflow running down the channel. The confluence with the Oshetna was not yet open, but the main channel of the Oshetna was a combination of open holes and collapsed channel.

April 28: Immediately above the dam site the open water sections were similar to the previous flight with similar accumulations interrupting open sections. Where the river remained ice covered, overflow in the thalweg channels had increased to bankfull depth and in places spilled out onto the ice surface. Near the Oshetna confluence there were numerous sections of open channels interrupted by remnant ice cover. Ice cover in the thalweg channel had collapsed with fast moving overflow running down the channel. At the Oshetna confluence, overflow was running into the main channel of the Susitna from the Oshetna and accumulations were developing on the Oshetna.

April 30: Immediately above the dam site, the extended sections of open water identified on April 28 were longer, wider, and more frequent. Ice accumulations were often the only remaining interruption between the open sections. Where the river remained ice covered, overflow in the thalweg channels was at bankfull depth. Vee Canyon was open; however, a large accumulation of ice had developed mid-canyon. Nearing the Oshetna confluence there were numerous sections of open channel separated by remnant ice cover. At the Oshetna confluence, overflow was running into the main channel of the Susitna from the Oshetna similar to the previous flight.

May 2: There were many sections of open water immediately above the dam site which continued as intermittent open leads up to PRM 200. Where the cover was still intact, it was showing significant signs of rotting with overflow and shorter open leads corresponding to the thalweg. There was an accumulation downstream of Vee Canyon but the canyon itself was open. Near the Oshetna confluence there was evidence of a recent jam and failure with large ice chunks pushed onto both banks but below the vegetation line as shown in Figure 5.3-7. The confluence with the Oshetna was open.

May 5: Open water was dominant above the dam site to PRM 200, where an intermittent remnant ice cover, showing significant deterioration and melting, began. The ice cover had numerous open leads and open channels throughout and appeared to be shorefast on gravel bars. Several small accumulations were present above the remnant ice covers with the largest accumulations present below the mouth of Kosina Creek and at PRM 222. The accumulation at PRM 222 appears to be remnant debris from the accumulation at Vee Canyon (PRM 225) observed on May 2. A significant shear wall was present through Vee Canyon. Near the Oshetna confluence, the remnant evidence of a jam failure was still present.

May 8: Open water was dominant above the dam site to PRM 200 and remained similar to the observations from the previous flight. The ice cover at PRM 200 was about a mile long and held back a small accumulation. A larger ice cover was present from PRM 206-223. The ice cover had numerous open leads and open channels throughout and appeared to be shorefast on gravel bars. The confluence with the Oshetna was open.

5.3.3.1. Upper River Time-Lapse Cameras

No time-lapse cameras were installed in the Upper River during the 2013/2014 winter field season due to ongoing negotiations regarding land access permits.

5.4. Meteorological Data Collection

NWS air temperature data collected at Talkeetna was at or above long term averages for the 2013/2014 winter with January being upwards of 17 degrees Fahrenheit warmer on average than the long term records. Spring brought mild temperatures that stayed close to the long term averages.

Snowpack and snow water equivalent were at or below long term averages as measured at Point Mackenzie, Susitna Valley High School, and Tokositna Valley. Tokositna Valley snow water equivalents were up to 3 inches less for the 2013/2014 season cumulative measurements than cumulative long term averages. The low snowpack and snow water equivalent led to the low observed discharge in the Susitna River during spring breakup. Details of meteorological data can be found in Appendix A. Stage and temperature records at the ESS stations can be found in Appendix B.

6. LITERATURE CITED

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7. TABLES

Table 4.2-1. Time-Lapse Camera Information

Station/Location	Project River Mile	Condition
Alexander Slough near Upper Tidal Influence	13.9	Removed 5/8/2014
Susitna Station	29.8	Removed 5/8/2014
Rustic Wilderness, Side Channel	64.2	Removed 5/8/2014
Susitna Landing	65.2	Removed 5/8/2014
Birch Creek	91.7	Removed 5/8/2014
Whiskers Slough – FA-104	104.3	Removed 5/15/2014
Slough 6 – FA-113	113.2	Removed 5/15/2014
Slough 6A – FA-115	115.4	Removed 5/15/2014
Slough 8A – FA-128	129.6	Removed 5/15/2014
Slough 9	132.2	Removed 5/15/2014
Slough 11 – FA-138	138.5	Removed 5/15/2014
Indian River – FA-141	142.2	Removed 5/15/2014
Slough 21 – FA-144	145.7	Removed 5/15/2014

8. FIGURES

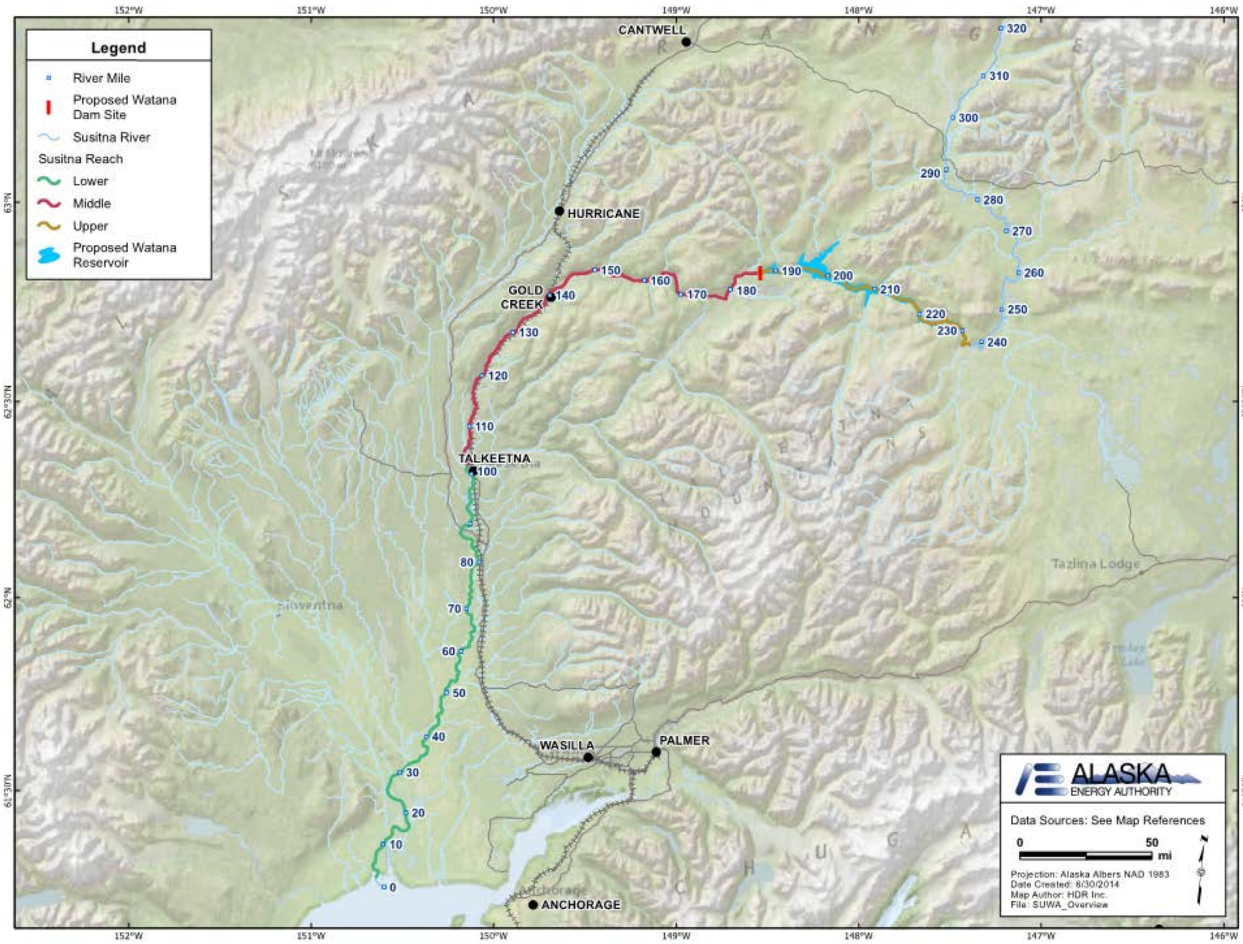


Figure 3.1-1.Map of Ice Processes Study Area

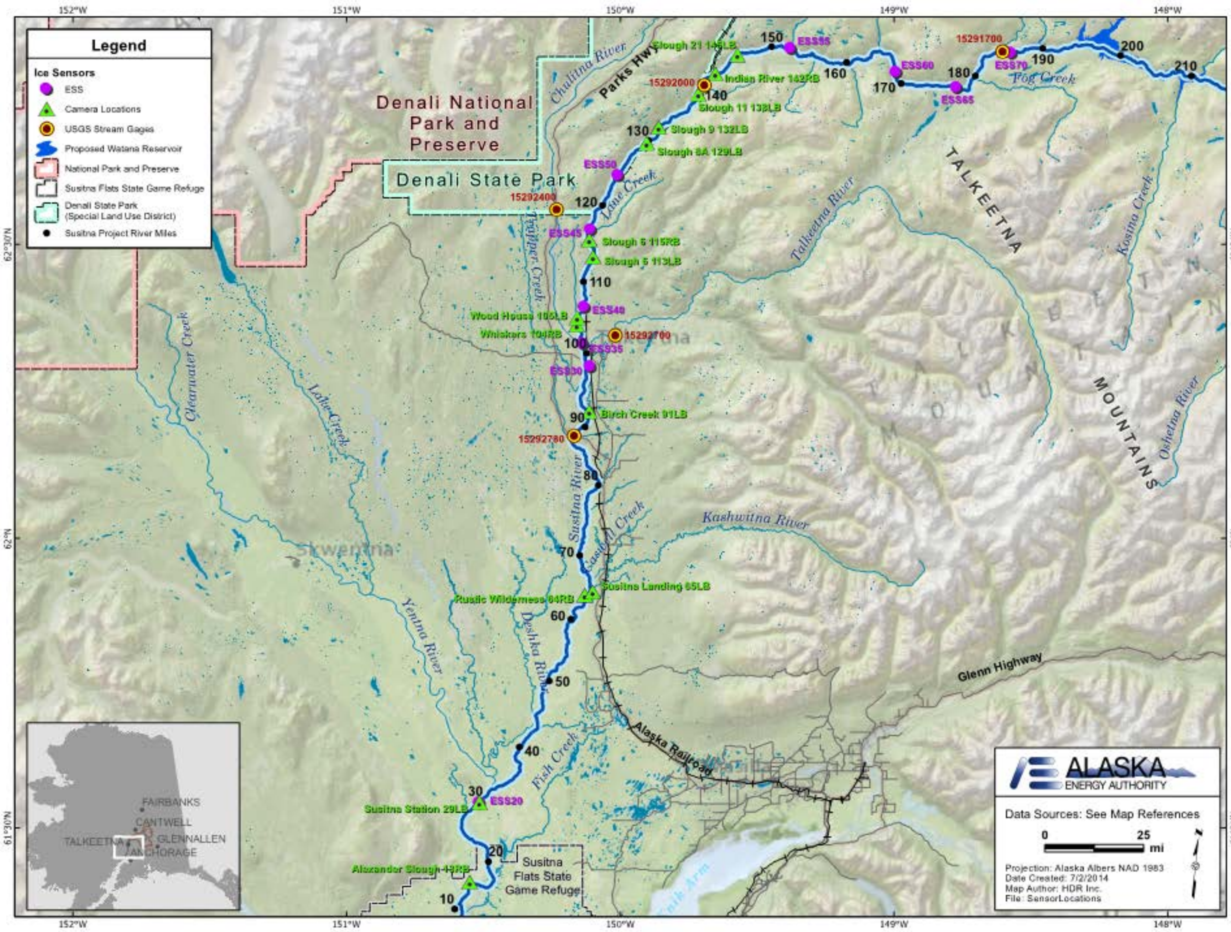


Figure 4.2-1. Map of Time-Lapse Camera Locations and Pressure Transducers

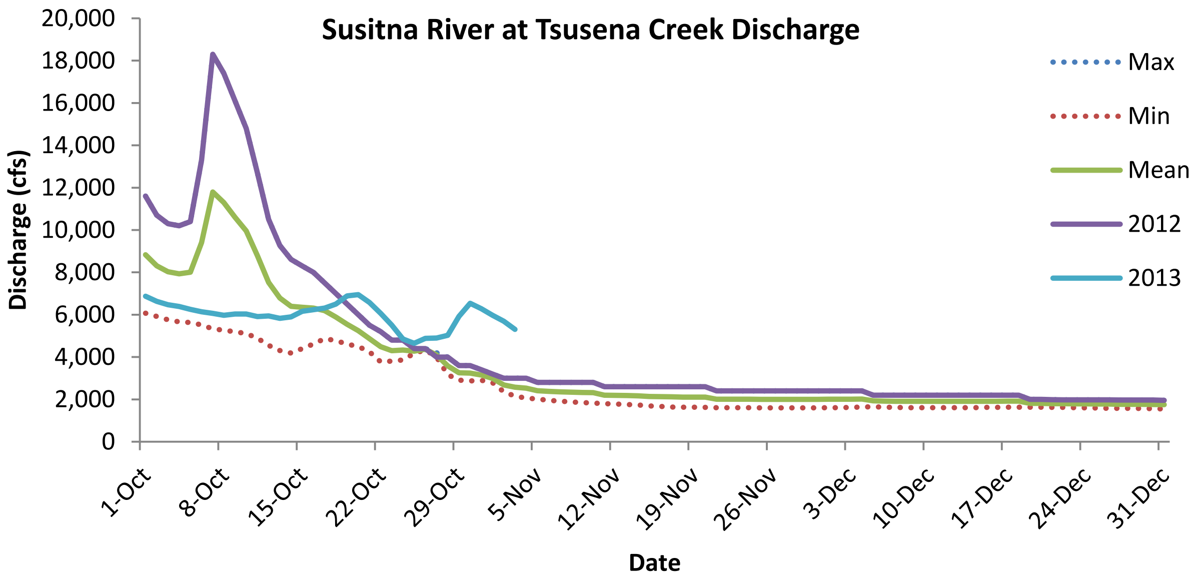


Figure 5.1 - 1. Susitna River at Tsusena Creek USGS Gage, #152917000. Note: 2012 Discharge was Maximum discharge for period of record

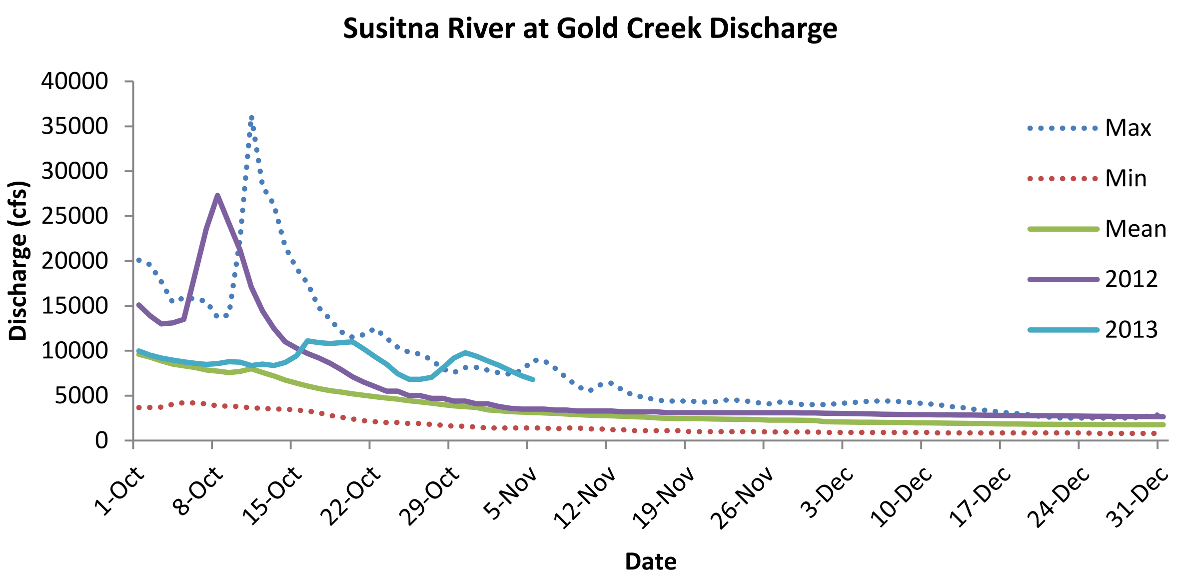


Figure 5.1 - 2. Susitna River at Gold Creek USGS Gage, #15292400

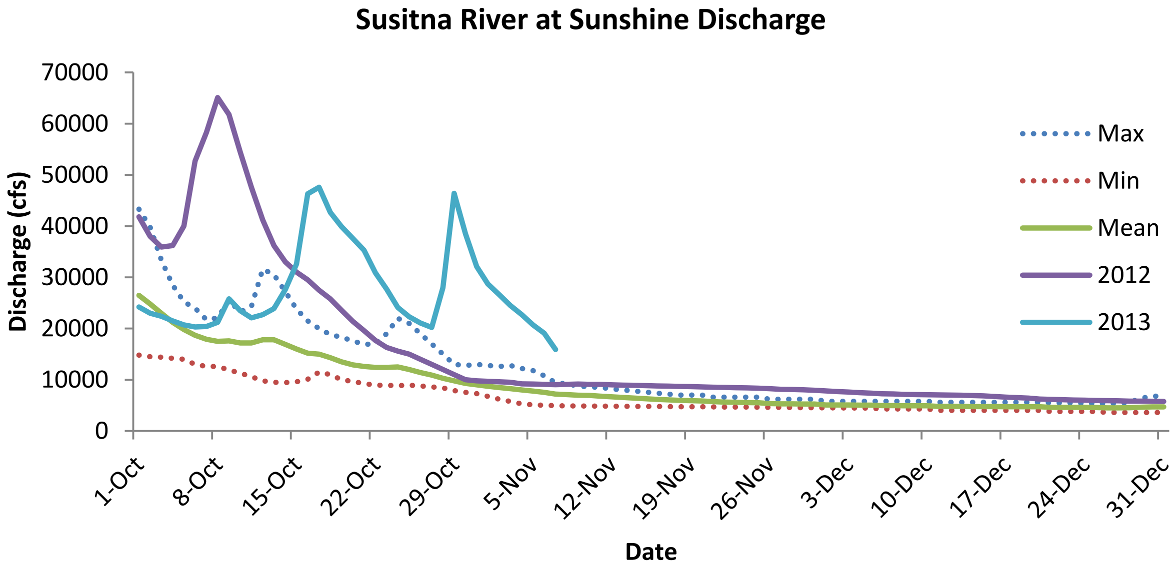


Figure 5.1 - 3. Susitna River at Sunshine USGS Gage, # 15292480

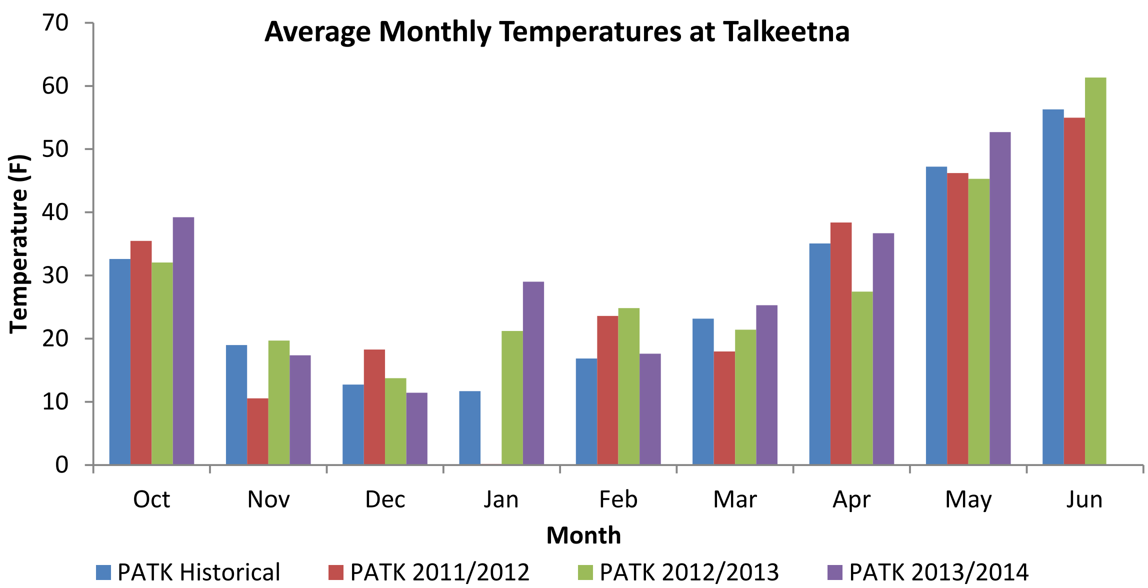


Figure 5.1 - 4. Average Monthly Temperatures at Talkeetna

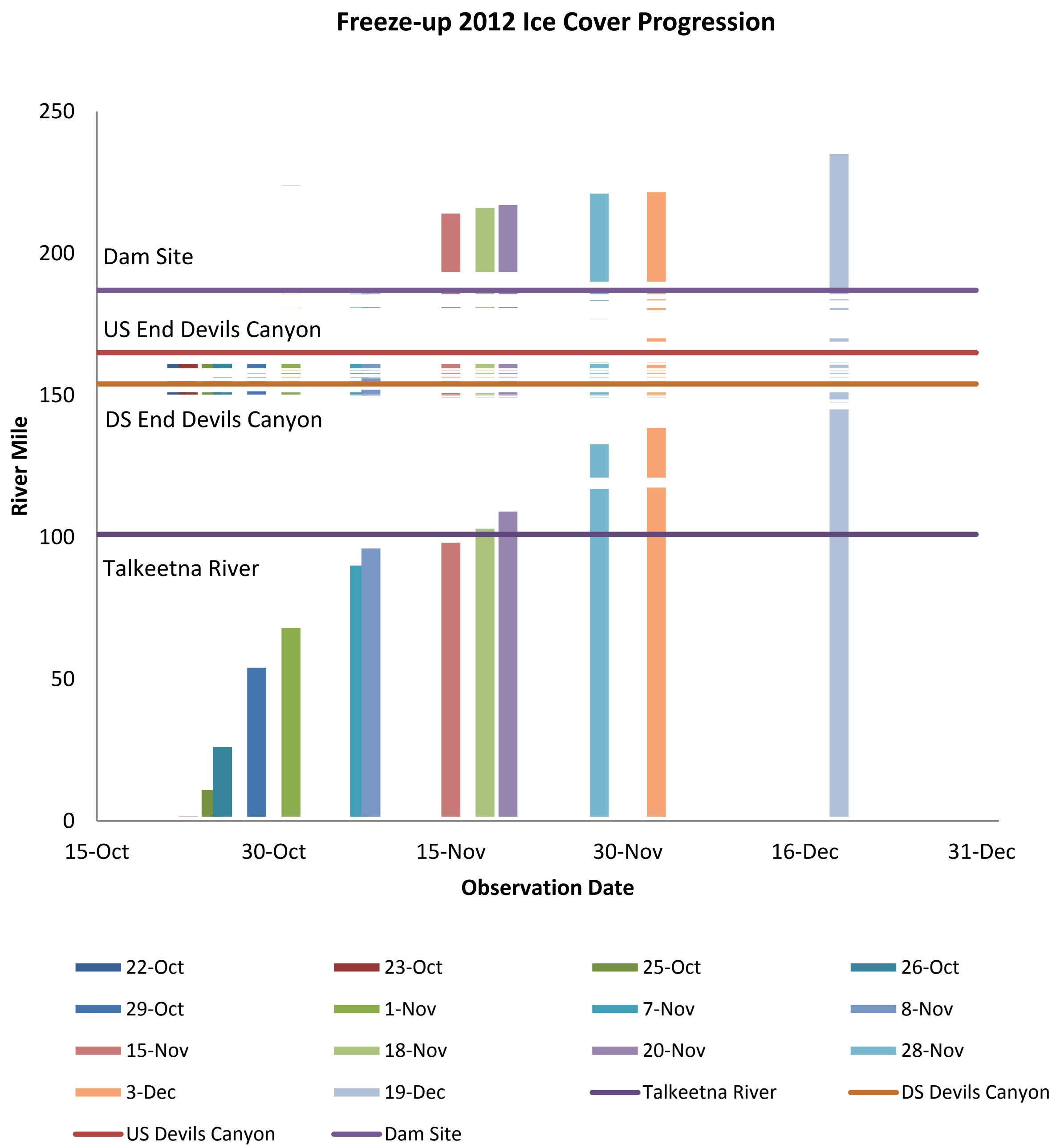


Figure 5.1 - 5. Ice Front Progression and Ice Bridge Locations – Freeze-up 2012

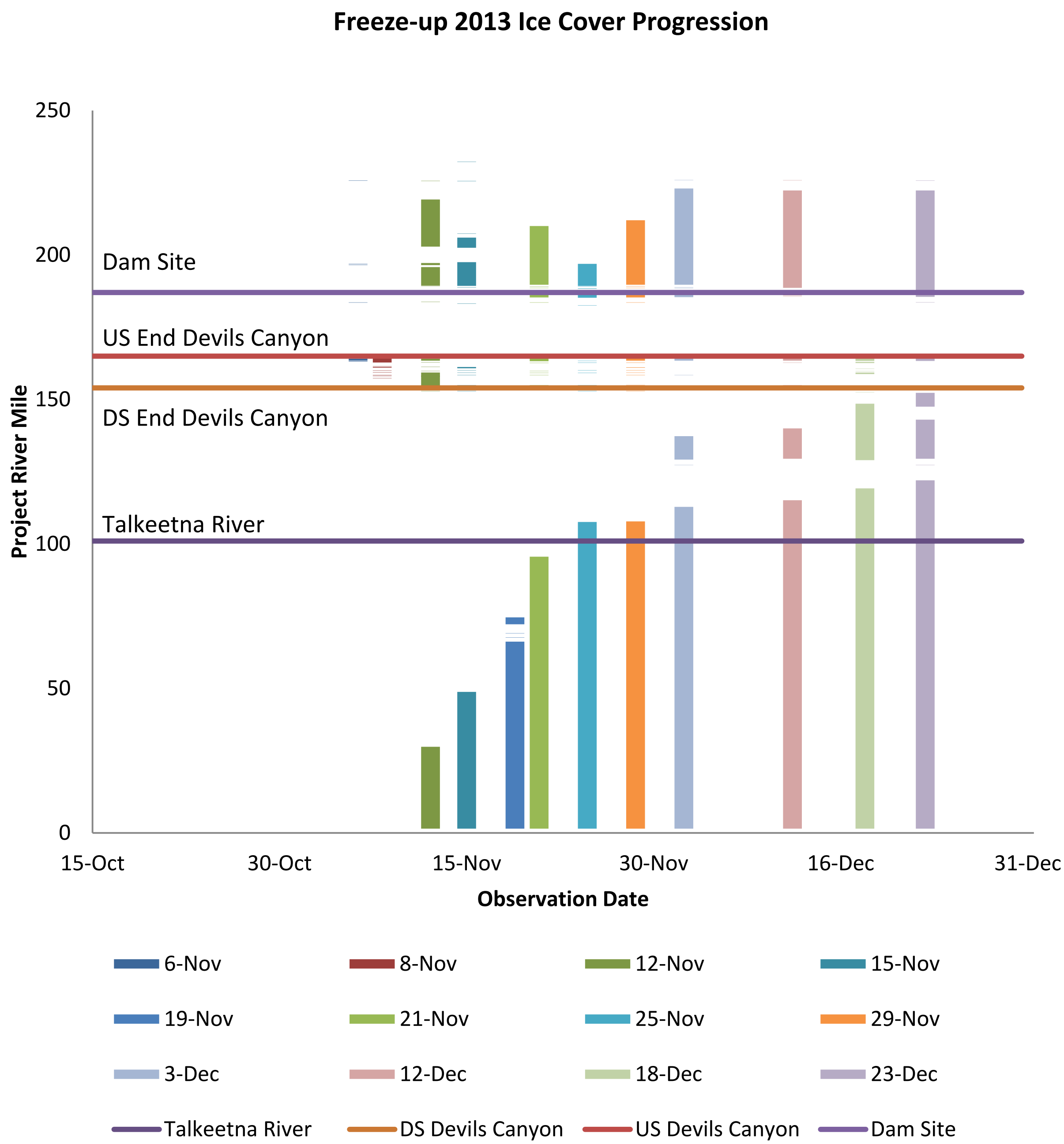


Figure 5.1 - 6. Ice Front Progression and Ice Bridge Locations – Freeze-up 2013

Figure 5.1 - 7. Ice bridge formed near the mouth of the Susitna river on November 12, 2013

Figure 5.1 - 8. Frazil ice moving through the Delta Islands area

Figure 5.1 - 9.Heavy frazil and border ice growth on Middle River on Novermber 8, 2013

Figure 5.1 - 10. Anchor ice deposits on the bed on December 3, 2013

Figure 5.1 - 11. Shear walls and frazil jams in Devils Canyon on December 18, 2013

Figure 5.1 - 12. Anchor ice and border ice growth on the Upper River on November 19, 2013

Figure 5.2 - 1. Open velocity lead follwoign thalweg in Lower River on February 21, 2014

Figure 5.2 - 2. Open thermal lead following edge of island on February 21, 2014

Figure 5.2 - 3. Thermal lead along right bank at FA-104 on February 21, 2014

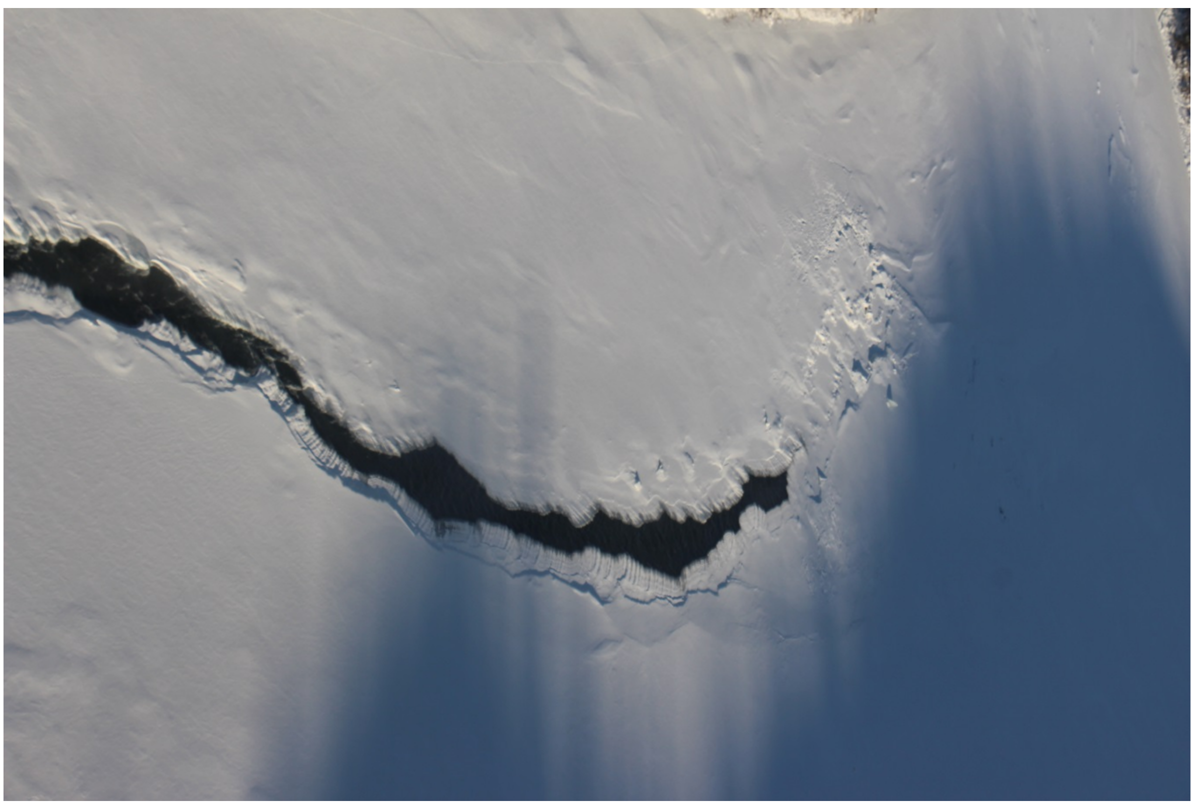


Figure 5.2 - 4. Open velocity lead in the Upper River on February 20, 2014

Figure 5.3 - 1. Downstream edge of ice cover in Lower River on April 28, 2014

Figure 5.3 - 2. Mouth of the Talkeetna river on April 28, 2014

Figure 5.3 - 3. FA-128 showing Slough 8A open on April 25, 2014

Figure 5.3 - 4. Ice jam and overbank flooding upstream of FA-128 on May 5, 2014

Figure 5.3 - 5. Shear walls upstream of FA-104 on May 8, 2014

Figure 5.3 - 6. Flooded ice surface at thalweg, Upper River on April 23, 2014

Figure 5.3 - 7. Evidence of previous jam at mouth of the Oshetna River on May 2, 2014

APPENDIX A: METEOROLOGICAL DATA FOR THE SUSITNA BASIN

Appendix A-1
Susitna Weather Station Data Tables

OCTOBER 2013						
Date	PATK Historical Ave Temp (°F) Near PRM100	PATK 2012 Ave Temp (°F) Near PRM100	PATK 2013 Ave Temp (°F) Near PRM100	ESM1 Watana Met Station 2013 Ave Temp (°F) Near PRM186.5	ESM2 Cantwell Met Station 2013 Ave Temp (°F)	ESM3 Gold Creek Met Station 2013 Ave Temp (°F) Near PRM140
1-Oct	40	31	44		39	
2-Oct	40	38	41		37	
3-Oct	40	40	43	39	36	40
4-Oct	39	44	43	40	35	44
5-Oct	39	47	39	39	37	39
6-Oct	39	45	41	34	33	37
7-Oct	38	43	40	33	36	38
8-Oct	37	41	38	32	33	38
9-Oct	36	44	38	34	35	35
10-Oct	36	43	33	33	33	36
11-Oct	35	41	37	29	25	34
12-Oct	35	35	40	34	32	36
13-Oct	34	34	44	38	35	38
14-Oct	34	34	39	38	34	39
15-Oct	33	32	42	33	32	38
16-Oct	33	27	41	34	34	36
17-Oct	32	27	44	37	36	38
18-Oct	31	23	44	38	32	41
19-Oct	31	33	42	37	36	40
20-Oct	31	32	41	37	36	39
21-Oct	30	31	39	34	32	39
22-Oct	30	18	38	29	26	34
23-Oct	29	18	32	31	27	34
24-Oct	28	34	30	24	16	28
25-Oct	27	29	37	26	17	32
26-Oct	27	22	31	33	29	34
27-Oct	26	21	37	29	22	29
28-Oct	27	20	39	31	27	35
29-Oct	26	17	43	37	35	36
30-Oct	25	25	42	35	25	39
31-Oct	25	27	35	34	26	37

Highlight indicates an aerial reconnaissance or field event.

Appendix A-1
Susitna Weather Station Data Tables (continued)

NOVEMBER 2013						
Date	PATK Historical Ave Temp (°F) Near PRM100	PATK 2012 Ave Temp (°F) Near PRM100	PATK 2013 Ave Temp (°F) Near PRM100	ESM1 Watana Met Station 2013 Ave Temp (°F) Near PRM186.5	ESM2 Cantwell Met Station 2013 Ave Temp (°F)	ESM3 Gold Creek Met Station 2013 Ave Temp (°F) Near PRM140
1-Nov	25	23	36	34	32	35
2-Nov	25	28	34	30	31	34
3-Nov	25	29	36	28	28	33
4-Nov	24	23	37	27	22	33
5-Nov	24	20	33	26	19	32
6-Nov	23	22	30	25	23	29
7-Nov	22	20	24	14	7	18
8-Nov	20	11	19	11	5	21
9-Nov	20	25	21	8	6	12
10-Nov	21	30	26	14	11	22
11-Nov	21	29	27	20	18	26
12-Nov	21	27	15	18	19	21
13-Nov	18	21	14	5	-6	4
14-Nov	17	25	21	12	10	17
15-Nov	18	26	21	18	17	20
16-Nov	18	26	14	13	4	19
17-Nov	17	20	-1	8	9	5
18-Nov	17	15	-1	2	-9	-5
19-Nov	16	16	-8	-5	-18	-8
20-Nov	17	13	-5	-14	-23	-10
21-Nov	17	8	2	-17	-28	-13
22-Nov	18	12	19	-7	-22	1
23-Nov	18	11	22	13	5	24
24-Nov	16	7	22	13	5	18
25-Nov	15	13	24	16	5	23
26-Nov	16	10	19	18	10	21
27-Nov	16	12	27	20	11	22
28-Nov	17	18	14	21	19	27
29-Nov	17	25	-14	3	4	4
30-Nov	13	28	-7	-4	-13	-13

Highlight indicates an aerial reconnaissance or field event.

Appendix A-1
Susitna Weather Station Data Tables (continued)

DECEMBER 2013						
Date	PATK Historical Ave Temp (°F) Near PRM100	PATK 2012 Ave Temp (°F) Near PRM100	PATK 2013 Ave Temp (°F) Near PRM100	ESM1 Watana Met Station 2013 Ave Temp (°F) Near PRM186.5	ESM2 Cantwell Met Station 2013 Ave Temp (°F)	ESM3 Gold Creek Met Station 2013 Ave Temp (°F) Near PRM140
1-Dec	12	18	-2	-9	-23	-1
2-Dec	11	9	-2	-5	-21	-1
3-Dec	12	16	3	3	-15	0
4-Dec	11	6	11	8	0	7
5-Dec	12	-4	23	13	1	9
6-Dec	11	3	31	26	17	25
7-Dec	10	-6	34	25	22	32
8-Dec	12	10	33	26	25	32
9-Dec	14	21	30	26	21	30
10-Dec	14	26	27	17	12	25
11-Dec	14	25	26	13	11	22
12-Dec	16	23	15	5	-11	11
13-Dec	14	24	7	7	7	15
14-Dec	12	21	21	7	5	12
15-Dec	11	-4	12	10	7	17
16-Dec	12	5	-10	5	-3	4
17-Dec	11	-13	-19	-9	-18	-13
18-Dec	13	-3	-20	-14	-33	-19
19-Dec	16	2	12	-7	-30	-5
20-Dec	16	17	19	5	-8	14
21-Dec	13	14	25	8	-1	17
22-Dec	13	8	28	15	7	26
23-Dec	15	7	18	18	16	26
24-Dec	13	8	-8	2	-4	6
25-Dec	13	24	-8	-7	-33	-5
26-Dec	14	26	-10	-9	-37	2
27-Dec	12	28	-13	-13	-39	-4
28-Dec	12	17	17	-3	-32	4
29-Dec	13	32	21	9	-3	21
30-Dec	10	35	19	7	-2	13
31-Dec	11	32	16	7	-7	14

Highlight indicates an aerial reconnaissance or field event.

Appendix A-1
Susitna Weather Station Data Tables (continued)

JANUARY 2014						
Date	PATK Historical Ave Temp (°F) Near PRM100	PATK 2012 Ave Temp (°F) Near PRM100	PATK 2013 Ave Temp (°F) Near PRM100	ESM1 Watana Met Station 2013 Ave Temp (°F) Near PRM186.5	ESM2 Cantwell Met Station 2013 Ave Temp (°F)	ESM3 Gold Creek Met Station 2013 Ave Temp (°F) Near PRM140
1-Jan	13	34	30	11	-4	23
2-Jan	13	30	29	19	9	28
3-Jan	12	32	28	19	10	24
4-Jan	11	31	29	19	10	26
5-Jan	13	29	32	20	10	26
6-Jan	11	33	34	24	18	31
7-Jan	10	29	32	24	12	28
8-Jan	9	17	27	17	18	24
9-Jan	9	8	28	19	16	22
10-Jan	9	19	24	18	14	23
11-Jan	11	24	18	10	2	17
12-Jan	11	27	8	-1	-2	5
13-Jan	12	32	12	0	-2	9
14-Jan	10	34	23	4	-10	13
15-Jan	10	31	27	18	9	24
16-Jan	12	20	30	20	3	27
17-Jan	12	16	34	23	16	30
18-Jan	12	9	35	34	26	34
19-Jan	13	14	33	29	21	32
20-Jan	14	25	34	23	9	29
21-Jan	13	25	35	27	5	28
22-Jan	14	26	36	30	14	33
23-Jan	12	29	37	32	19	33
24-Jan	9	27	39	35	32	35
25-Jan	9	21	39	34	36	34
26-Jan	11	3	37	35	30	37
27-Jan	12	-11	38	36	23	35
28-Jan	14	1	34	34	9	31
29-Jan	12	4	26	29	13	27
30-Jan	14	15	22	22	22	18
31-Jan	17	27	14	9	0	8

Highlight indicates an aerial reconnaissance or field event.

Appendix A-1
Susitna Weather Station Data Tables (continued)

FEBRUARY 2014						
Date	PATK Historical Ave Temp (°F) Near PRM100	PATK 2012 Ave Temp (°F) Near PRM100	PATK 2013 Ave Temp (°F) Near PRM100	ESM1 Watana Met Station 2013 Ave Temp (°F) Near PRM186.5	ESM2 Cantwell Met Station 2013 Ave Temp (°F)	ESM3 Gold Creek Met Station 2013 Ave Temp (°F) Near PRM140
1-Feb	16	25	9	4	-10	3
2-Feb	14	27	10	9	-13	7
3-Feb	13	33	25	12	-12	20
4-Feb	12	31	24	14	-14	23
5-Feb	13	30	15	8	-14	18
6-Feb	17	23	7	1	-18	2
7-Feb	17	21	20	4	-13	7
8-Feb	17	24	19	6	-16	18
9-Feb	16	28	13	2	-21	11
10-Feb	16	33	17	-6	-26	7
11-Feb	18	30	6	-5	-29	8
12-Feb	17	18	1	-6	-29	2
13-Feb	16	25	3	-9	-21	4
14-Feb	16	29	12	-2	-13	6
15-Feb	16	31	20	5	-12	11
16-Feb	14	13	13	7	3	15
17-Feb	16	20	20	7	-8	12
18-Feb	17	23	17	7	-10	14
19-Feb	18	6	20	8	-7	15
20-Feb	16	20	12	8	-13	13
21-Feb	17	23	4	4	-9	-3
22-Feb	18	21	18	0	-17	1
23-Feb	18	19	23	8	-16	17
24-Feb	19	24	18	9	-16	21
25-Feb	20	26	17	7	-17	9
26-Feb	21	29	28	10	-14	12
27-Feb	21	29	38	22	-7	31
28-Feb	19	31	38	27	4	36
29-Feb	20	27				

Highlight indicates an aerial reconnaissance or field event.

Appendix A-1
Susitna Weather Station Data Tables (continued)

MARCH 2014						
Date	PATK Historical Ave Temp (°F) Near PRM100	PATK 2012 Ave Temp (°F) Near PRM100	PATK 2013 Ave Temp (°F) Near PRM100	ESM1 Watana Met Station 2013 Ave Temp (°F) Near PRM186.5	ESM2 Cantwell Met Station 2013 Ave Temp (°F)	ESM3 Gold Creek Met Station 2013 Ave Temp (°F) Near PRM140
1-Mar	18	23	28	28	13	33
2-Mar	19	26	25	22	4	30
3-Mar	19	19	22	18	0	28
4-Mar	19	26	25	13	-2	20
5-Mar	20	29	25	14	7	22
6-Mar	21	23	20	17	10	24
7-Mar	21	32	10	14	7	13
8-Mar	22	31	19	8	-10	11
9-Mar	21	34	15	4	-13	17
10-Mar	21	33	20	3	-14	1
11-Mar	22	24	35	15	6	24
12-Mar	21	29	34	31	31	35
13-Mar	21	23	30	25	23	28
14-Mar	20	18	39	29	24	35
15-Mar	21	22	26	32	26	39
16-Mar	22	19	12	11	14	17
17-Mar	22	12	24	6	4	8
18-Mar	23	11	27	16	6	24
19-Mar	24	19	26	19	13	24
20-Mar	25	11	29	18	11	22
21-Mar	26	6	26	13	1	18
22-Mar	25	18	26	14	0	17
23-Mar	25	22	27	13	1	20
24-Mar	26	18	27	18	4	27
25-Mar	28	23	33	20	6	28
26-Mar	28	7	29	23	8	31
27-Mar	28	-2	27	21	7	24
28-Mar	28	15	23	16	5	20
29-Mar	27	28	23	15	4	20
30-Mar	28	32	24	15	5	20
31-Mar	28	35	26	17	7	21

Highlight indicates an aerial reconnaissance or field event.

Appendix A-1
Susitna Weather Station Data Tables (continued)

APRIL 2014						
Date	PATK Historical Ave Temp (°F) Near PRM100	PATK 2012 Ave Temp (°F) Near PRM100	PATK 2013 Ave Temp (°F) Near PRM100	ESM1 Watana Met Station 2013 Ave Temp (°F) Near PRM186.5	ESM2 Cantwell Met Station 2013 Ave Temp (°F)	ESM3 Gold Creek Met Station 2013 Ave Temp (°F) Near PRM140
1-Apr	29	30	29	17	9	21
2-Apr	30	28	26	18	11	23
3-Apr	31	34	26	19	10	21
4-Apr	31	31	32	17	10	22
5-Apr	31	27	36	21	14	29
6-Apr	32	19	37	24	19	34
7-Apr	32	21	36	28	27	33
8-Apr	33	14	30	26	22	32
9-Apr	33	19	22	15	18	23
10-Apr	32	8	22	8	9	16
11-Apr	32	8	25	10	3	20
12-Apr	33	15	31	15	8	23
13-Apr	33	23	34	21	16	28
14-Apr	34	24	37	30	27	34
15-Apr	34	29	36	29	27	37
16-Apr	35	27	39	32	32	32
17-Apr	35	29	39	33	35	37
18-Apr	36	31	41	33	32	37
19-Apr	36	33	39	34	34	38
20-Apr	36	35	43	34	32	38
21-Apr	37	32	44	38	33	40
22-Apr	38	33	41	36	34	38
23-Apr	38	37	40	35	34	38
24-Apr	38	39	40	35	36	39
25-Apr	39	36	41	36	36	38
26-Apr	40	31	42	33	35	36
27-Apr	40	34	43	37	34	40
28-Apr	41	32	44	37	34	41
29-Apr	41	32	42	38	37	40
30-Apr	41	34	45	40	39	41

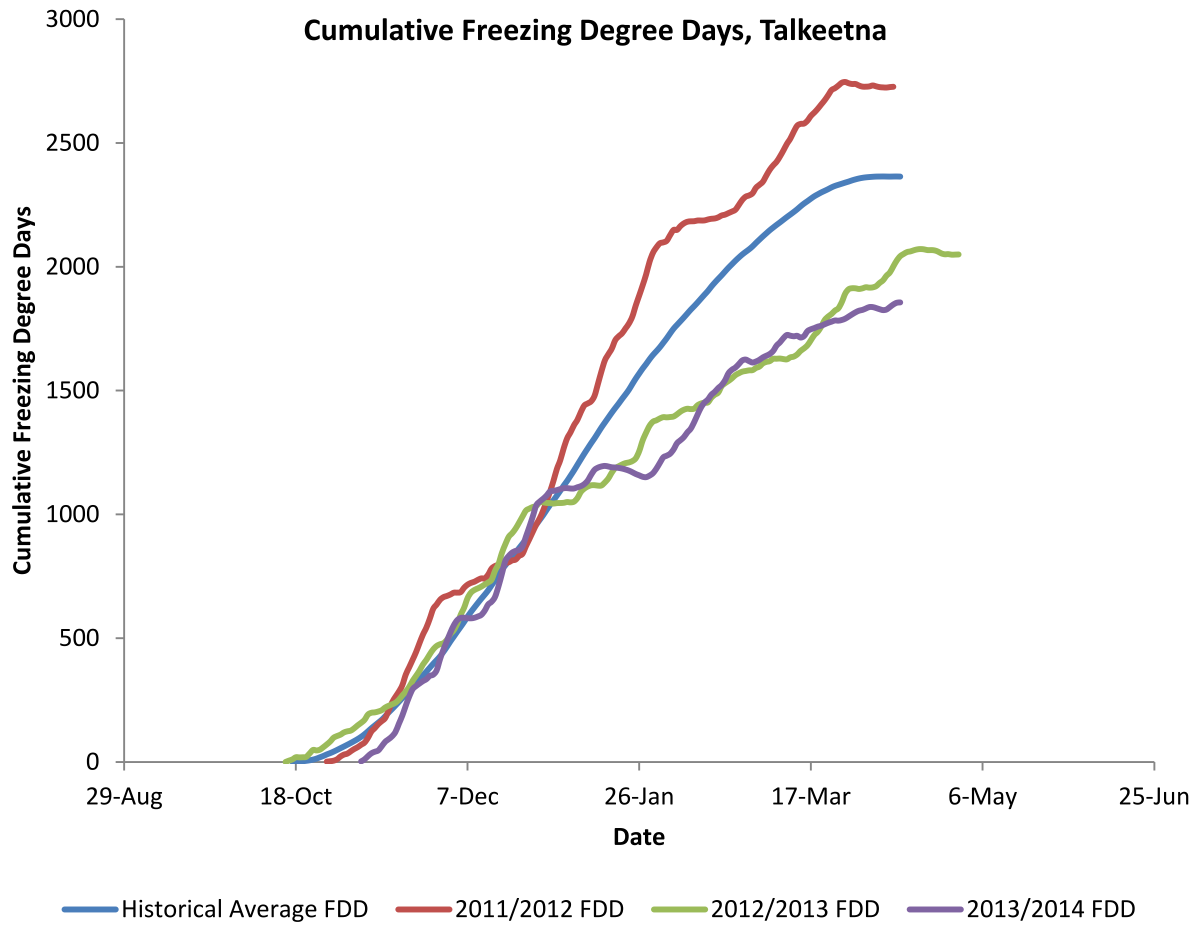
Highlight indicates an aerial reconnaissance or field event.

Appendix A-1
Susitna Weather Station Data Tables (continued)

MAY 2014						
Date	PATK Historical Ave Temp (°F) Near PRM100	PATK 2012 Ave Temp (°F) Near PRM100	PATK 2013 Ave Temp (°F) Near PRM100	ESM1 Watana Met Station 2013 Ave Temp (°F) Near PRM186.5	ESM2 Cantwell Met Station 2013 Ave Temp (°F)	ESM3 Gold Creek Met Station 2013 Ave Temp (°F) Near PRM140
1-May	42	35	48	41	38	42
2-May	42	38	59	43	41	46
3-May	42	34	56	48	45	49
4-May	42	36	53	51	46	47
5-May	42	39	53	50	45	45
6-May	43	38	49	48	44	45
7-May	44	37	44	39	41	40
8-May	44	40	46	39	42	42
9-May	44	44	50	44	44	44
10-May	44	48	56	45	45	47
11-May	45	48	55	46	42	50
12-May	46	51	54	47	43	51
13-May	46	45	54	51	47	50
14-May	46	41	57	48	46	48
15-May	47	40	54	47	45	53
16-May	47	39	57	51	48	51
17-May	47	36	61	53	53	54
18-May	47	33	57	53	52	56
19-May	48	34	49	41	44	49
20-May	49	38	50	39	42	46
21-May	50	42	52	42	43	49
22-May	50	46	55	44	43	49
23-May	50	49	53	46	44	51
24-May	51	52	55	48	46	51
25-May	52	56	53	50	47	52
26-May	52	56	52	45	46	48
27-May	52	58	50	50	51	53
28-May	52	64	49	43	47	46
29-May	53	66	51	45	48	47
30-May	53	64	51	48	52	50
31-May	52	60	48	49	50	49

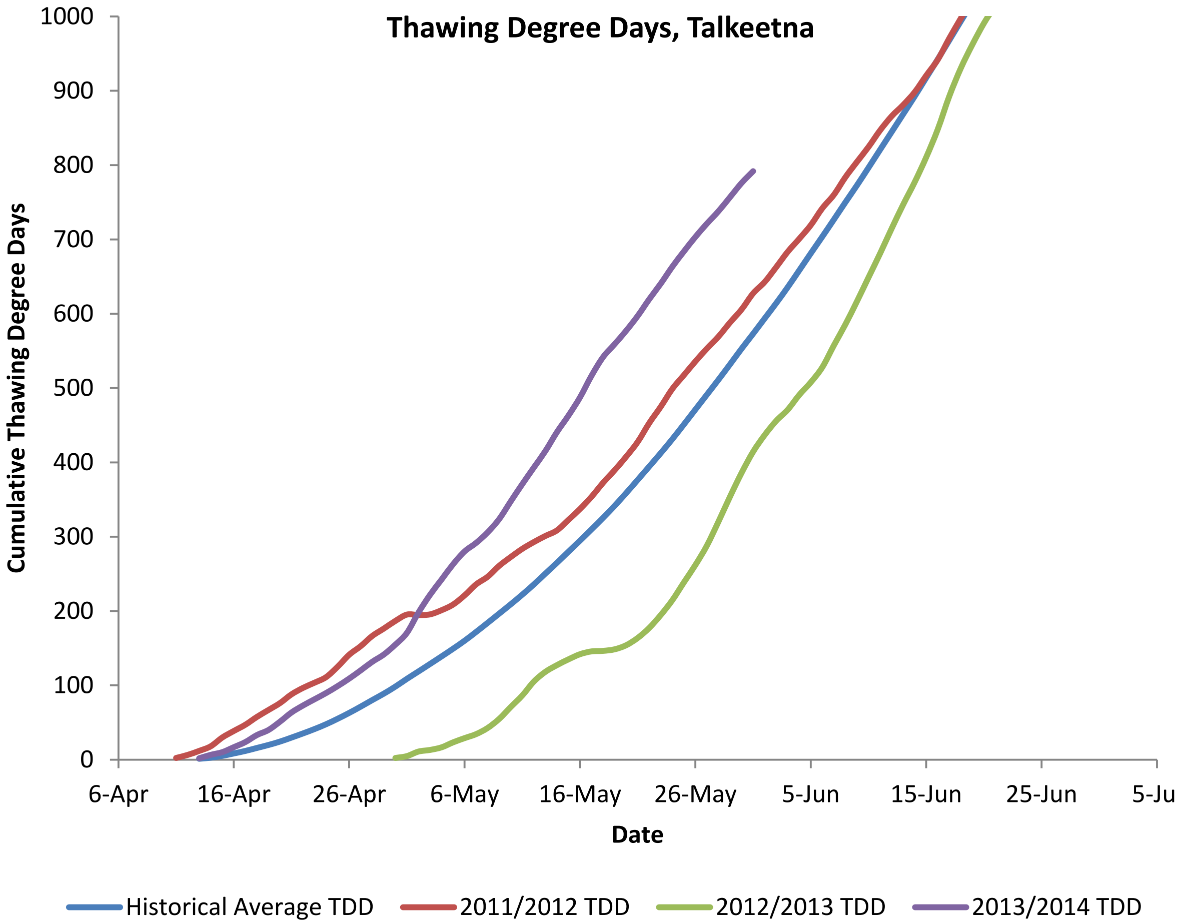
Highlight indicates an aerial reconnaissance or field event.

Appendix A-2
Winter 2013/2014 Freezing Degree Days



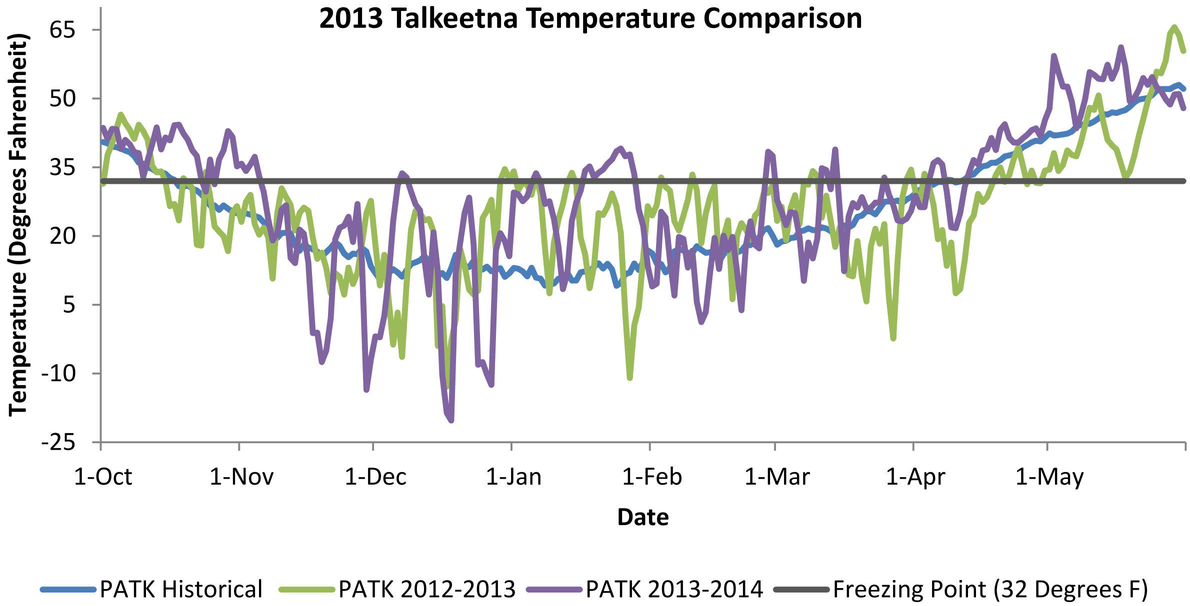
Winter 2013 to Spring 2014 Cumulative Freezing Degree Days at Talkeetna compared to previous two years and long-term average. Plot created from National Weather Service data from Talkeetna Airport weather station.

Appendix A-3
Spring 2014 Thawing Degree Days

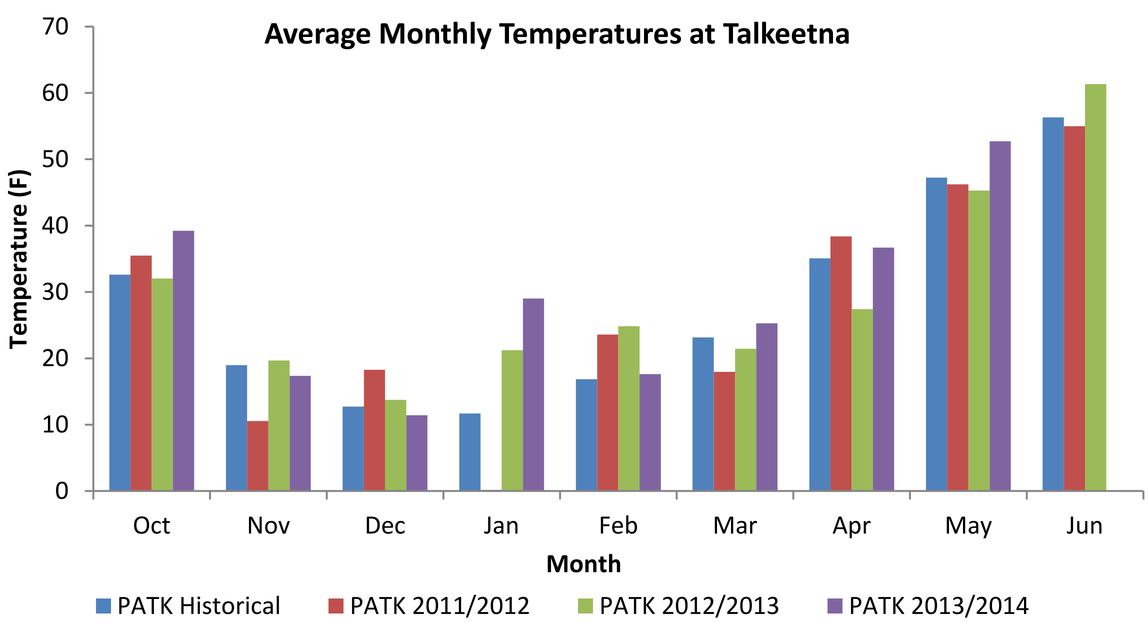


Spring 2014 Cumulative Thawing Degree Days at Talkeetna compared to previous two years and long-term average. Plot created from National Weather Service data from Talkeetna Airport weather station.

Appendix A-4
Temperature Comparison

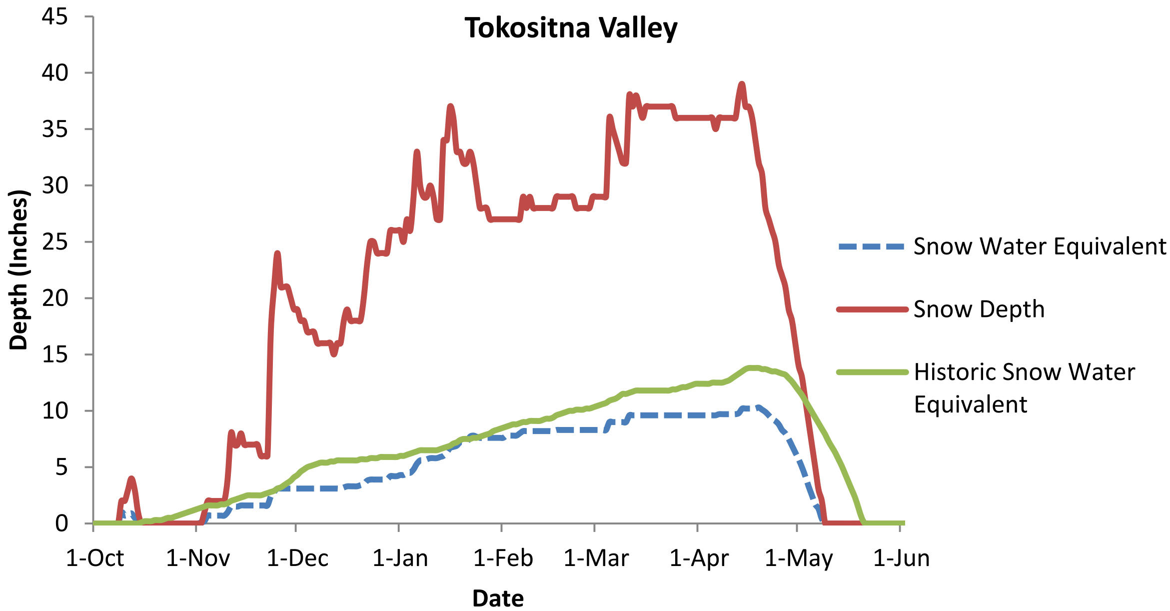


Winter 2013 to Spring 2014 temperature at Talkeetna compared to the previous year and long-term average. Plot created from National Weather Service data from Talkeetna Airport weather station.

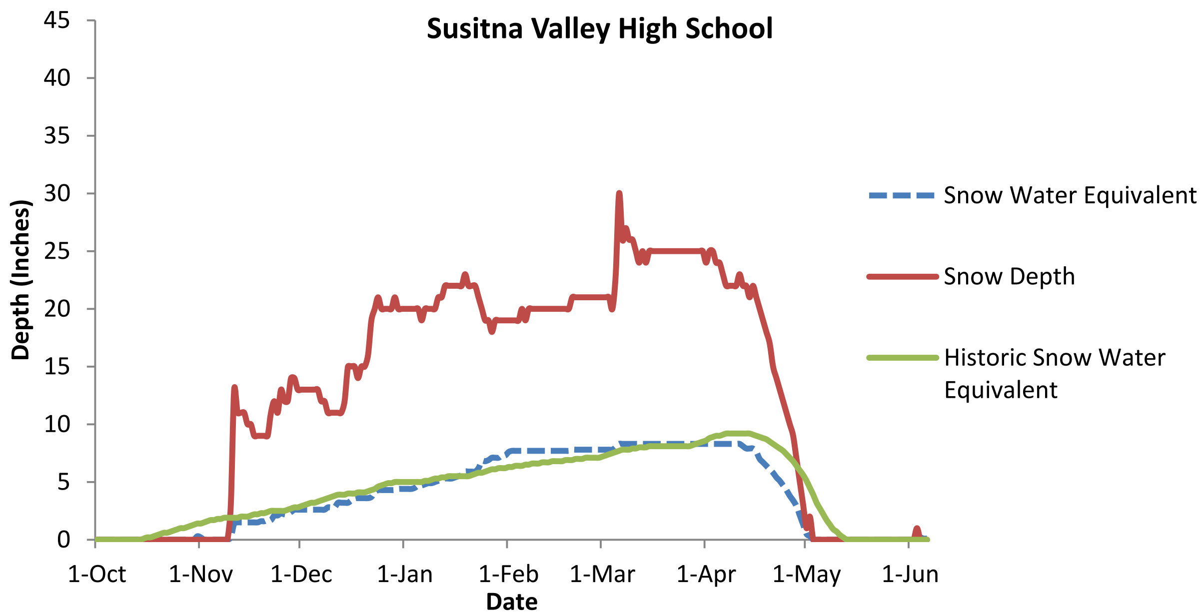


Winter 2013 to Spring 2014 comparison of average monthly temperatures at Talkeetna between the previous two years and long-term average. Plot created from National Weather Service data from Talkeetna Airport weather station.

Appendix A-5
Susitna Basin Snow Depth Measurements

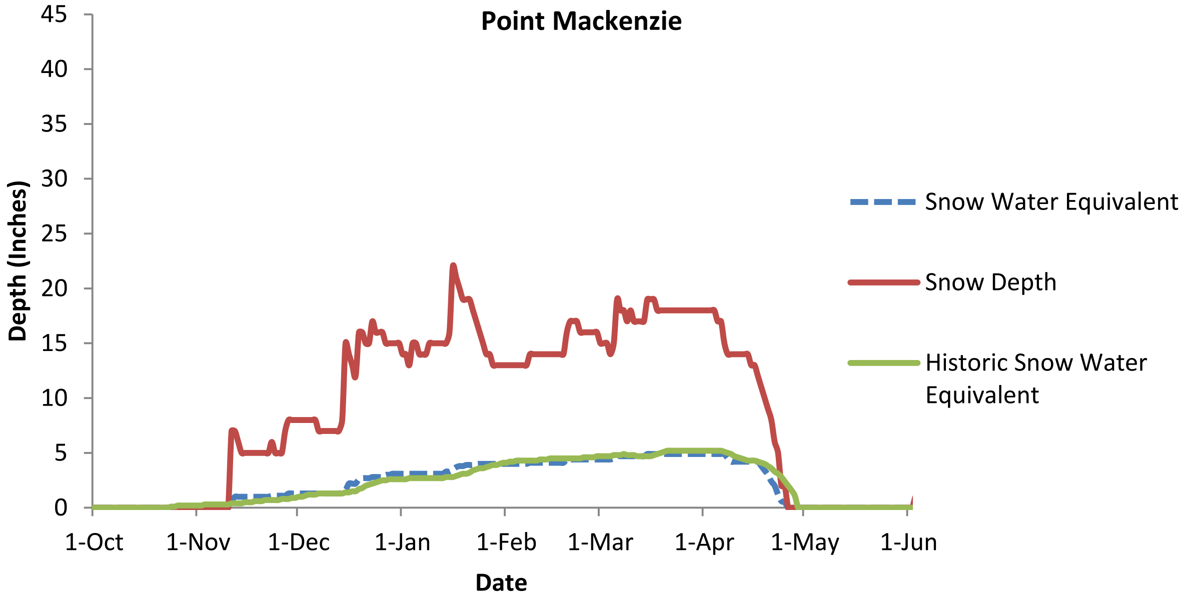


Tokositna Valley SNOTEL Site Daily Measurements of Snow Depth and Snow Water Equivalent, 2013-2014. Data collected by the NRCS.



Susitna Valley High SNOTEL Site Daily Measurements of Snow Depth and Snow Water Equivalent, 2013-2014. Data collected by the NRCS.

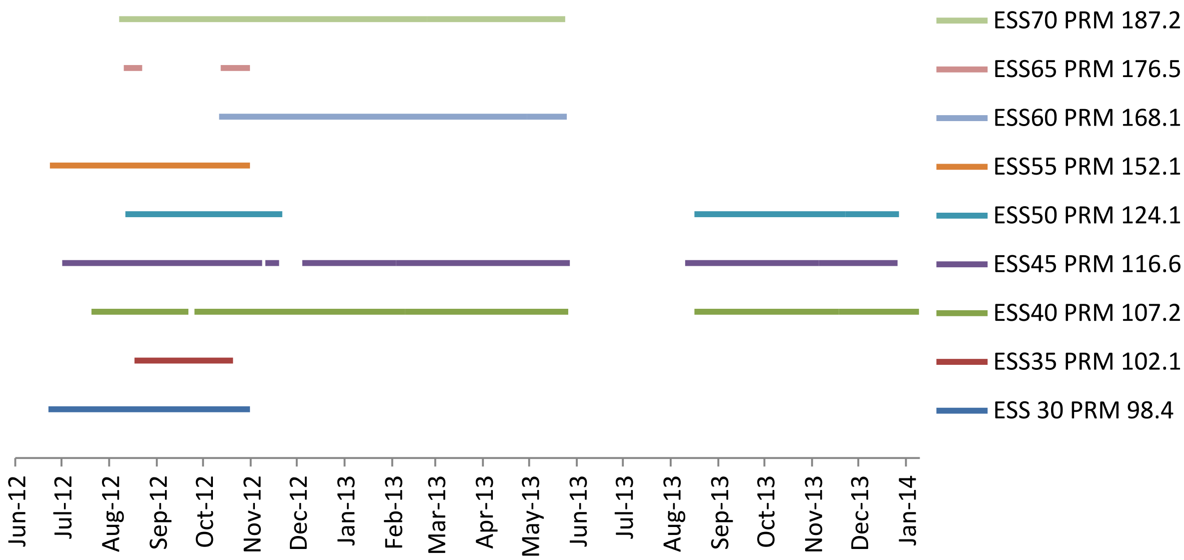
Appendix A-5
Susitna Basin Snow Depth Measurements (continued)



Point MacKenzie SNOTEL Site Daily Measurements of Snow Depth and Snow Water Equivalent, 2013-2014. Data collected by the NRCS.

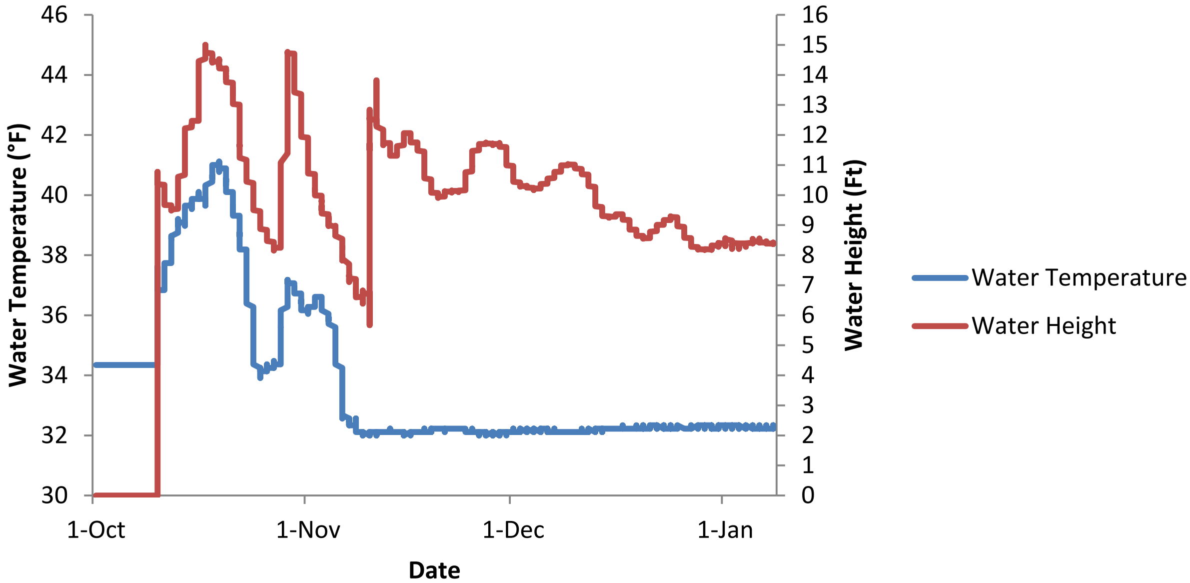
APPENDIX B: SUSITNA RIVER SURFACE WATER STATION DATA

Appendix B-1
Surface Water Stations (ESS Stations) Period of Record

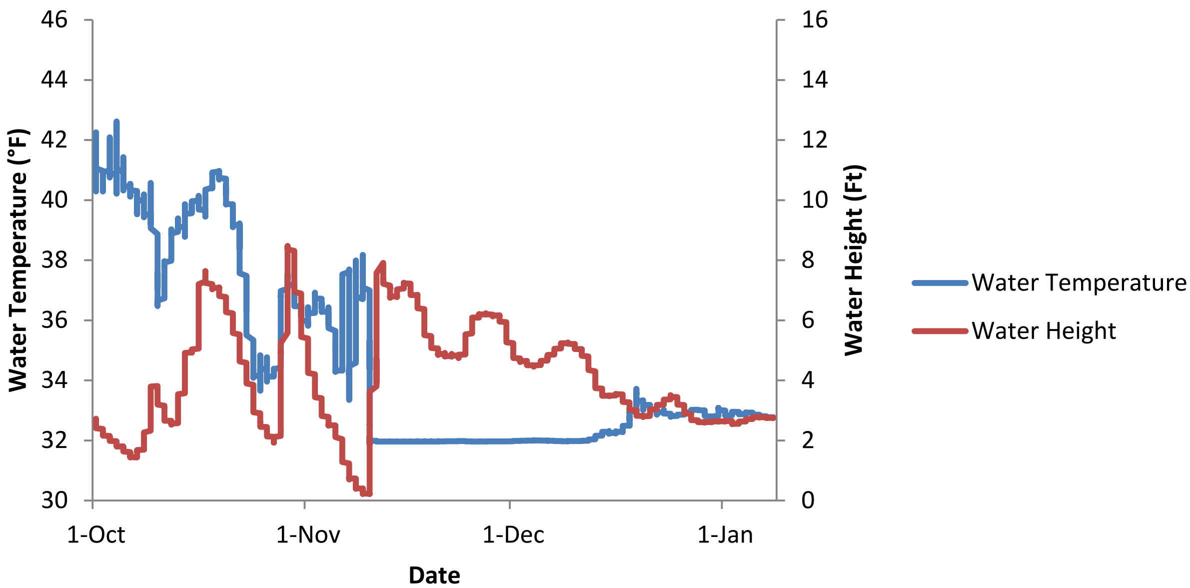


Period of Record of all ESS stations in the Susitna River basin as deployed between June 2012 and January 2014. Data is sparse for several stations.

Appendix B-2
Surface Water Temperature (°F) and Preliminary Stream Stage for the Susitna River during Freeze up 2013

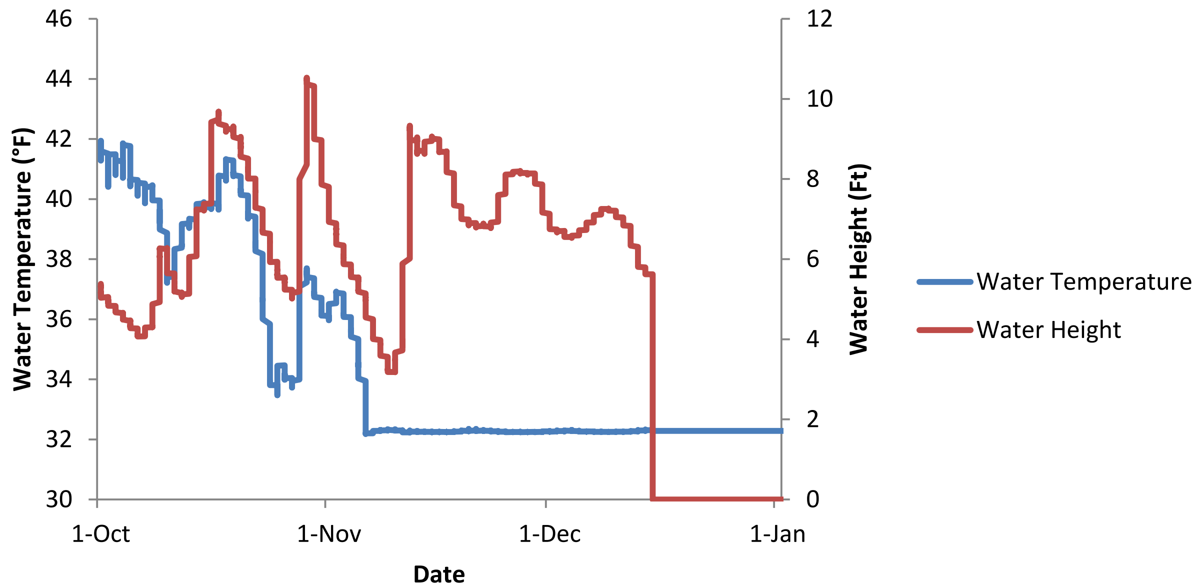


PRM 15.8 – Flathorn Lake (ESS10)

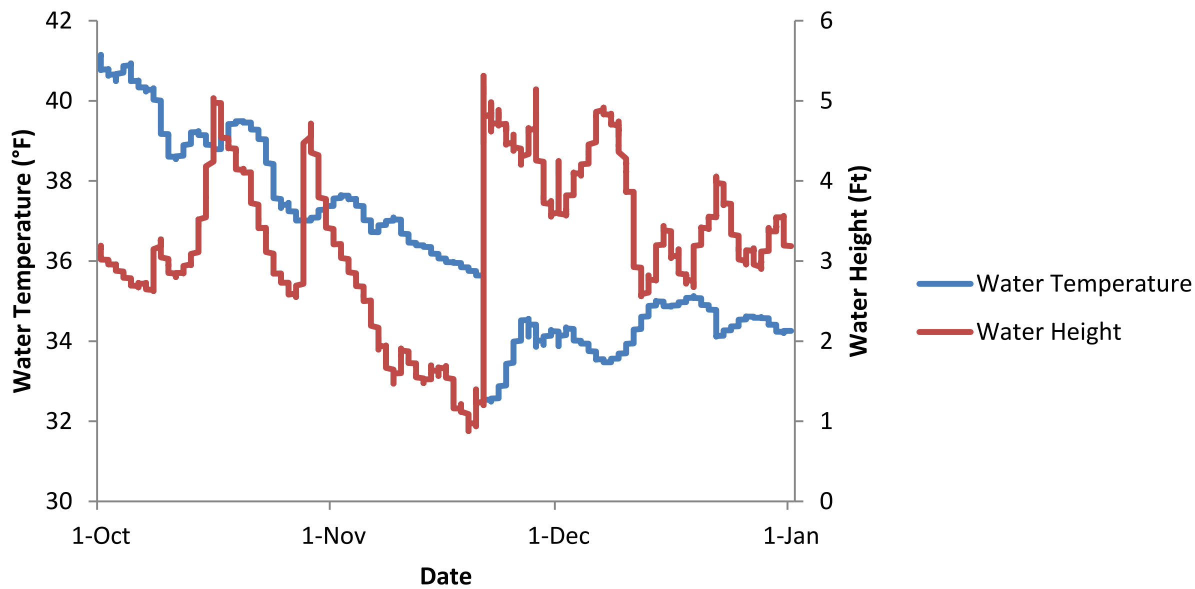


PRM 17.7 – Susitna River near Dinglishna Hill (ESS15)

Appendix B-2
Surface Water Temperature (°F) and Preliminary Recorded Stream Stage for the Susitna River Freeze up 2013 (Continued)



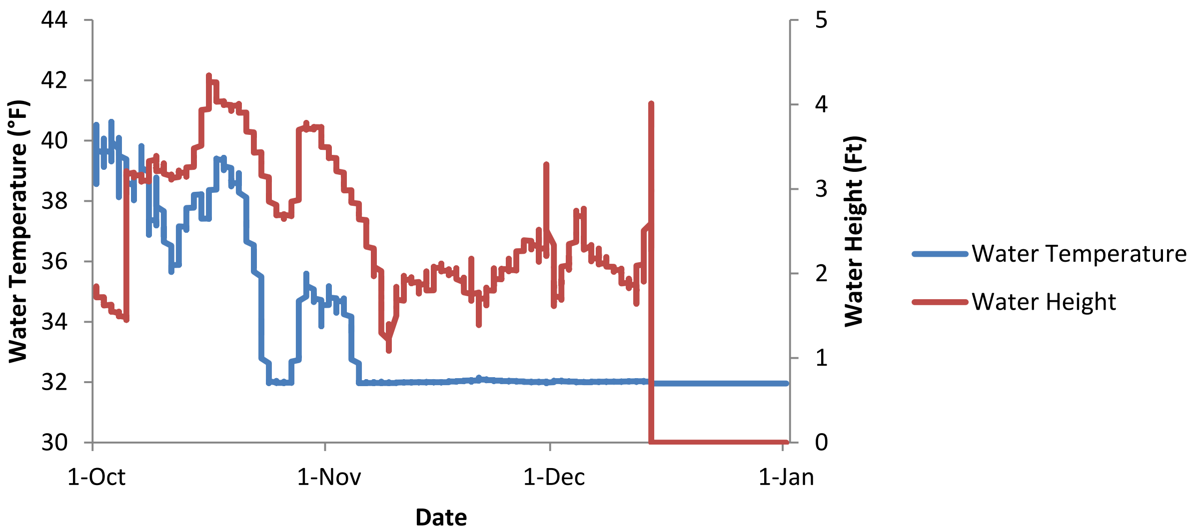
PRM 29.8, Susitna Station (ESS20)



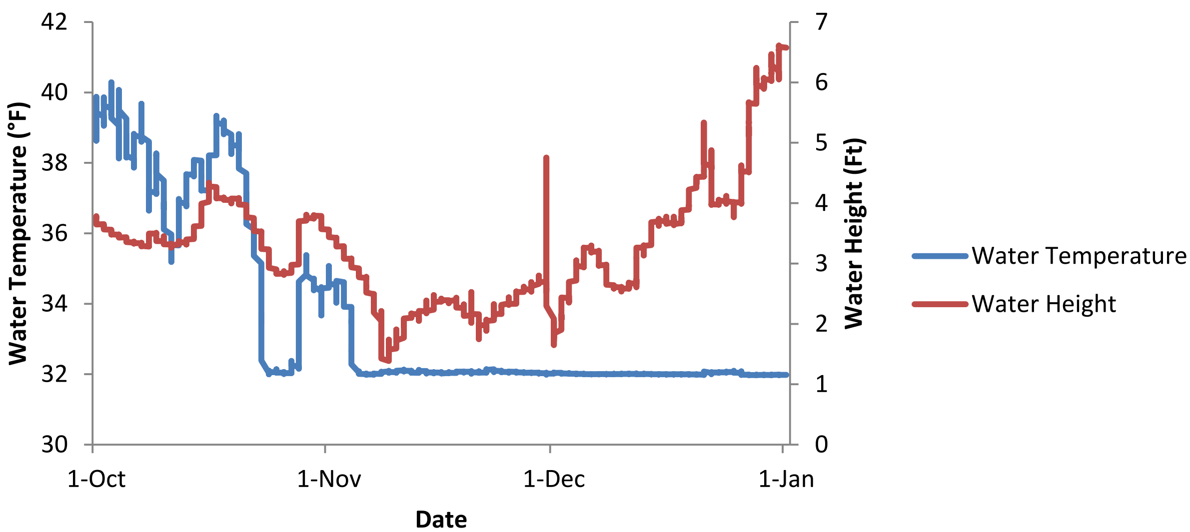
PRM 98.4 – Twister Creek (ESS30)

Appendix B-2
Surface Water Temperature (°F) and Preliminary Recorded Stream Stage for the Susitna River Freeze up 2013 (Continued)

PRM 101.8 – Chulitna River (ESS35). No Data; Sensors at the station malfunctioned during the May 2013 breakup.



PRM 116.7, Downstream of Lane Creek near Slough 6A – FA-115 (ESS45).



PRM 124.2, Curry Slough (ESS50)

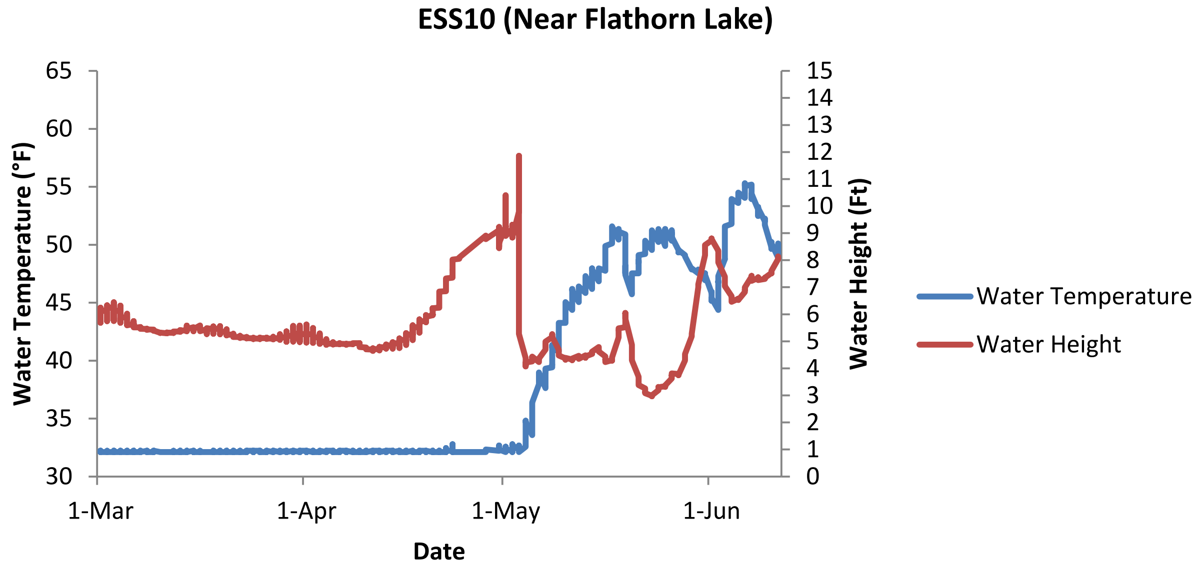
Appendix B-2
Surface Water Temperature (°F) and Preliminary Recorded Stream Stage for the Susitna River Freeze up 2013 (Continued)

PRM 152.2, Portage Creek – FA-151 (ESS55). No Data; Sensors at the station malfunctioned during the May 2013 breakup.

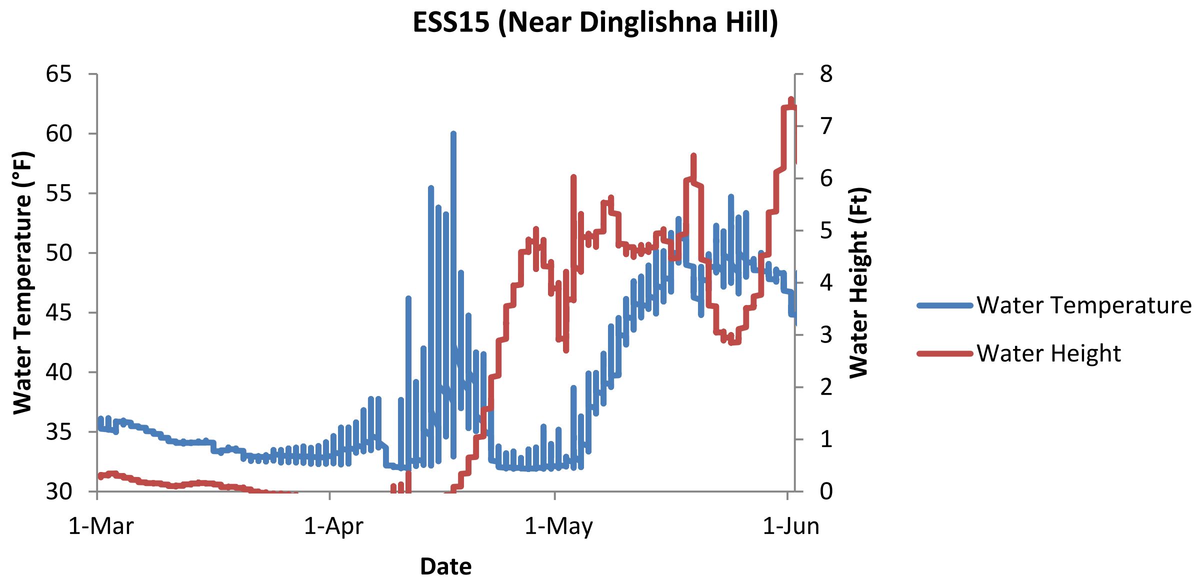
PRM 168.2, Devil Creek (ESS60). No Data; Sensors at the station malfunctioned during the May 2013 breakup.

PRM 176.4, Fog Creek – FA-173 (ESS65). No Data; Sensors at the station malfunctioned during the 2012 freeze up.

Appendix B-3
Surface Water Temperature (°F) and Preliminary Recorded Stream Stage for the Susitna River Breakup 2014



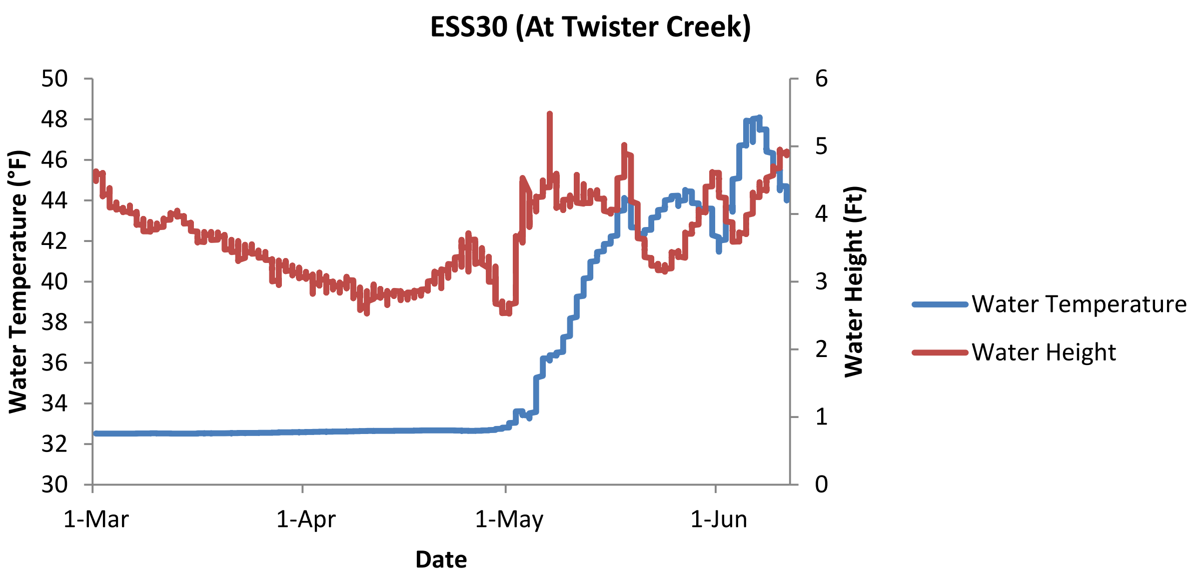
PRM 15.8 – Flathorn Lake (ESS10)



PRM 17.7 – Susitna River near Dinglishna Hill (ESS15)

Appendix B-3
Surface Water Temperature (°F) and Preliminary Recorded Stream Stage for the Susitna River Breakup 2014 (Continued)

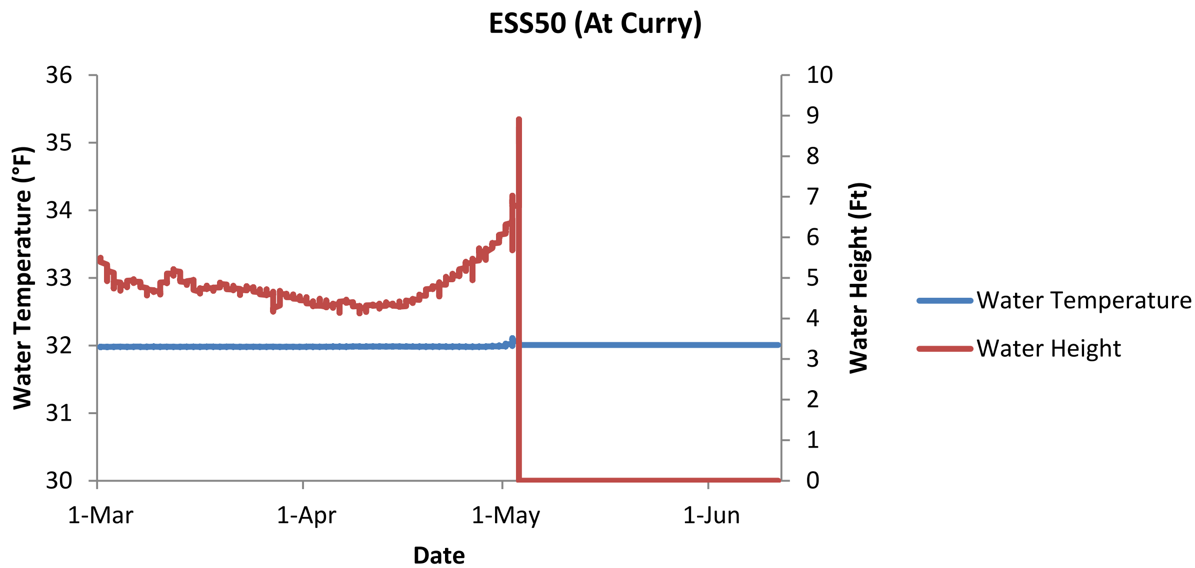
PRM 29.8, Susitna Station (ESS20); Sensors malfunctioned in mid-December.



PRM 98.4 – Twister Creek (ESS30)

PRM 116.7, Downstream of Lane Creek near Slough 6A – FA-115 (ESS45): Sensors at the station malfunctioned during the May 2013 breakup.

Appendix B-3
Surface Water Temperature (°F) and Preliminary Recorded Stream Stage for the Susitna River Breakup 2014 (Continued)



PRM 124.2, Curry Slough (ESS50): Water temperature sensor at the station malfunctioned during the winter 2013; the water height sensor appears to have malfunctioned on May 3rd, during breakup.

PRM 152.2, Portage Creek – FA-151 (ESS55): Sensors at the station malfunctioned during the May 2013 breakup.

PRM 168.2, Devil Creek (ESS60): No data recorded past 11/4/2013.

PRM 176.4, Fog Creek –FA-173 (ESS65): Sensors at the station malfunctioned during the May 2013 breakup.