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PART A - APPENDIX A: DETAILED ICE OBSERVATIONS AND LOWER RIVER HEC-RAS MODELING

PART A - APPENDIX B: 2013 ICE FIELD MEASUREMENTS

Susitna-Watana Hydroelectric Project
(FERC No. 14241)

Ice Processes in the Susitna River Study (7.6)

Part A - Appendix A
Detailed Ice Observations and Lower River HEC-RAS Modeling

Initial Study Report

Prepared for

Alaska Energy Authority

SUSITNA-WATANA HYDRO

Clean, reliable energy for the next 100 years.

Prepared by

HDR Alaska, Inc.

June 2014

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1.1.1. 2012 Lower River Observations

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April 19th: There were many thin, long open leads in this section of the river, but the river was still ice covered. The snow was melting and/or blowing off the bars in the lower quarter of this section. There were five small ice jams with large, angular ice slabs between PRM 57 (RM 53) and PRM 100 (RM 97).

April 23rd: The open leads were connecting together and forming long, narrow leads, some with small ice jams accumulating at the downstream ends. There was no significant difference at the Chulitna River confluence compared to April 19th, 2012 as there was only a long open lead in the Chulitna River that connects to another long open lead in the Susitna River. From PRM 0 (RM 0) to PRM 22 (RM 18) there was mainly ice, but there were a few thermal open leads and open water holes.

April 27th: There was more snow melt apparent on banks and bars compared to April 23rd, 2012. No significant change at the Chulitna River confluence and the open leads in that area were widening, but no jams were present. In the area of the river from the mouth to PRM 22 (RM 18), there was greater than 50% open water in many locations compared to very little open water on April 23rd, 2012. The bars in this area were generally melted.

April 30th: The confluence of the Chulitna and Susitna Rivers has a large ice jam that was causing some backwatering into a nearby slough. There was less snow and ice on the banks and bars compared to April 27th, 2012. Generally, this section was snow and ice free; however, between PRM 72 (RM 68) and PRM 90 (RM 86) there was more snow and ice compared to the rest of this section. Similar open water conditions exist from the mouth to PRM 22 (RM 18) as observed on April 27th, 2012. There was an ice floe from PRM 10 (RM 5) to PRM 15 (RM 10).

Figure 1.1-1. PRM 101.8 (RM 98)- A large ice jam at the confluence of the Susitna and Chulitna Rivers was back watering the side channel towards Billion Slough, April 30, 2012. Flow is from top to bottom in this photo.

May 2nd: The mainstem was generally ice free aside from a large ice floe near PRM 80 (RM 76). The mainstem Susitna River near the Parks Highway Bridge was generally ice free. The lowest reaches of this section were generally snow and ice free.

Figure 1.1-2. PRM 14.9 (RM 10)- Minimal mainstem and side channel ice present, May 2, 2012. Flow is from left to right in this photo.

May 4th: There were no large ice jams below the confluence of with the Talkeetna River to Rabideux Creek. Turbidity was still low in Birch Creek slough; however, the water was stained due to dissolved organics present in most of these lower river tributaries. Below Rabideux Creek to the mouth of the river, there were no large, mainstem ice jams. There were several stable side channel jams, but none caused any flooding or vegetation interaction.

May 9th: Very open with little to no ice observed on the mainstem or in side channels.

May 10th: Camera site at Birch Creek (PRM 91.4 [RM 88]): The upstream point of this island has very large woody debris mats from old ice-vegetation interactions. This debris pile was over 15 feet high. There were no signs of ice-vegetation interactions at this location this year.

Figure 1.1-3. Birch Creek Slough (PRM 92 [RM 88.6])- Large old woody debris pile on the upstream side of the island on May 10, 2012. No sign of ice-vegetation interactions this year.

Camera site at Rustic Wilderness (PRM 63.3 [RM 59]): Ice was melting on-site with signs of old ice-vegetation interaction; however there was no evidence of current ice-vegetation interactions. Water did flow through the slough between the two islands, but there was no sign of ice scouring.

Camera site at Susitna Station (PRM 29.7 [RM 25.6]): The camera was on the bluff above the river at Susitna Station at the old USGS station and there were no ice-vegetation or ice-sediment interactions. A higher-water mark was approximately four feet above the current water level.

Camera site Alexander Slough near upper tidal influence (PRM 13.9 [RM 9.5]): There was a freshly exposed bank on the point and some bank collapse leading to and from the point may be the result of water flow and ice scouring. No recent visible ice-vegetation interactions were observed.

1.1.2. 2013 Lower River Observations

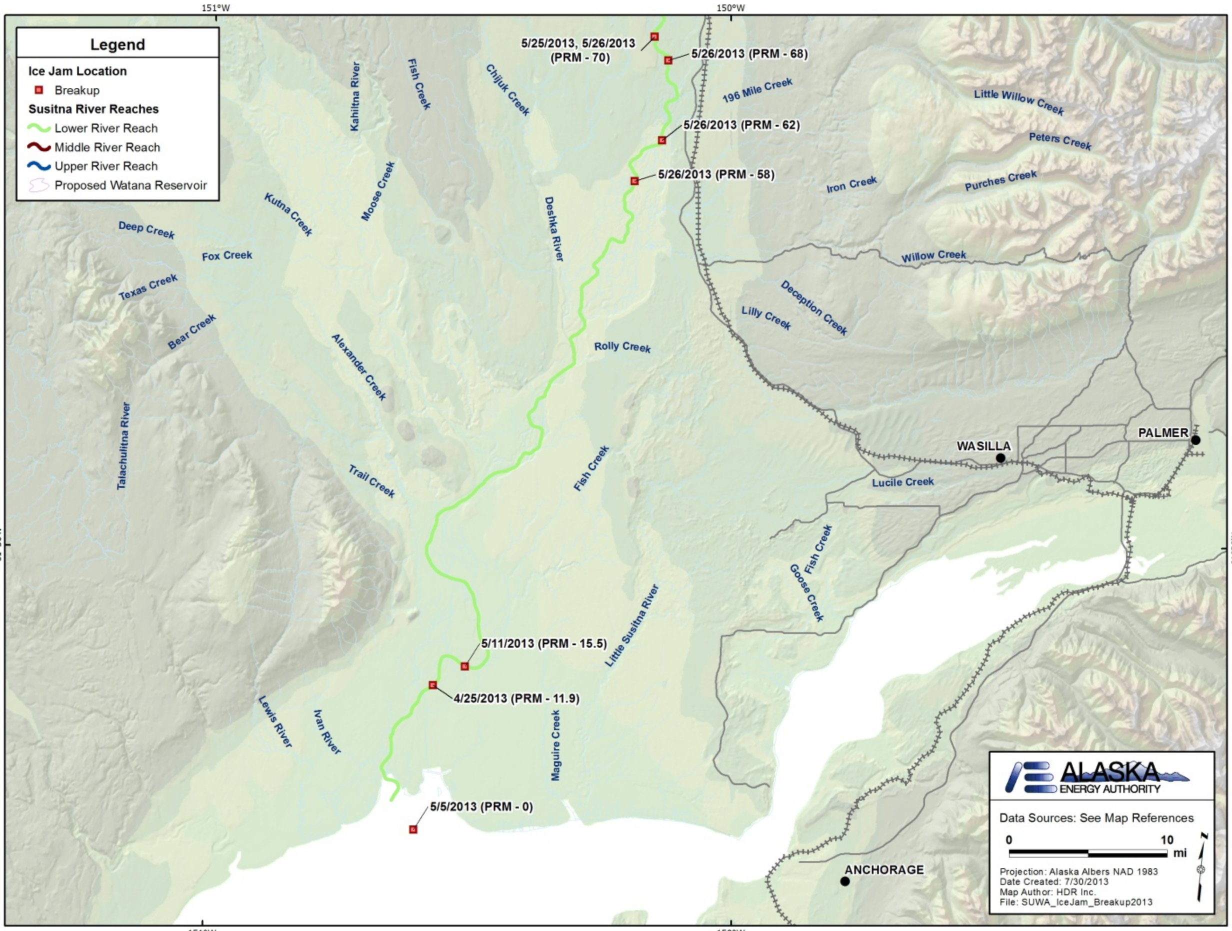

Figure 1.1-4. 2013 Significant Ice Jam Locations–Lower Susitna River

April 25th: The Lower River near the mouth was open from tidal action, along with the nearby tidal streams. The left channel of the Susitna River was mostly open through PRM 11.9 (RM 6.9), and the west channel discontinuously open through PRM 9.5 (RM 4.9). Within this area gravel bars were bare and there was very little snow along the banks. Upstream of Bell Island, snow cover on the banks and river channel became continuous with few open leads present. Alexander Slough and Creek (PRM 13.9 [RM 9.5]), Fish Creek (PRM 17.5 [RM 12.6]), Yentna River (PRM 31 [RM 27]), and the Deshka River (PRM 45 [RM 48]) were all ice covered. Further upriver, thermal leads began to open with more bare gravel exposed and higher apparent velocities. Sunshine Creek (PRM 88 [RM 84]) and Trapper Creek (PRM 93.5 [RM 90.2]) were open; along with many continuous thermal leads along the west bank of the main channel. Birch Creek slough was almost entirely open and flowing well. There were three open channels for the fir mile of the Chulitna River upstream of the confluence with the Susitna these channels became discontinuous further upstream.

May 5th: Open water at the mouth had not changed significantly from the previous observation, yet meltwater was beginning to pool on the ice surface in many places. Tributaries along the east side of the Susitna were mostly open with significant leads where they met the mainstem. In the last week, river stage had risen as much as a foot on the Lower River. The Talkeetna and Chulitna Rivers continued to open since the previous survey.

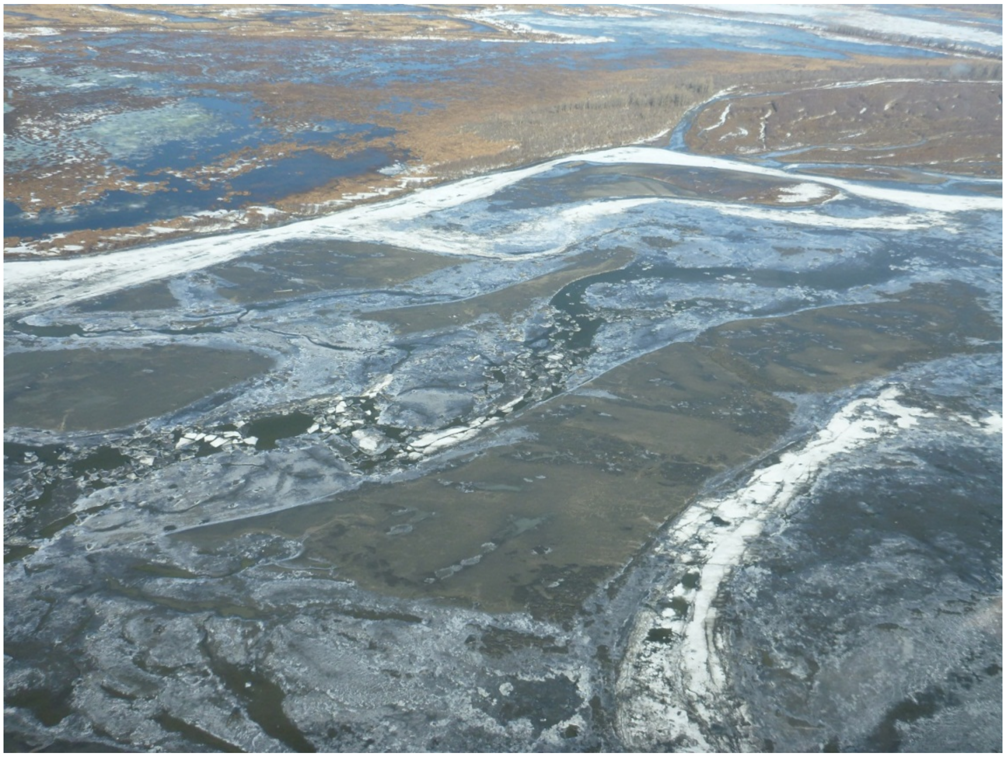

Figure 1.1-5. PRM 6 (RM 2.4)- Ice cover in the intertidal zone at the mouth of the Susitna River. May 5th, 2013.

May 7^th^: Ice conditions remained similar to the previous flight. The main channel of the Susitna River was largely ice covered upstream of PRM 15.8 (RM 11). Ice cover on Alexander Slough (PRM 13.9 [RM 9.5]) was mostly broken up in the lower 3 miles, with long open leads upstream for 5 miles. Kroto Slough was partially open and flowing into the main channel of the Yentna River at PRM 33 (RM 29). Rolly Creek (PRM 43 [RM 38.7]) had considerable amounts of dark brown overflow and was flowing into a long open lead on the mainstem of the Susitna. There was increasing overflow on the Deshka River (PRM 45 [RM 40.8]) with some open side channels. A large ice jam had formed at the mouth of the Talkeetna River (PRM 101 [RM 97.5]).

May 11^th^: The air temperature on the Lower and Middle Susitna River during the previous two nights was above freezing most of the night, and daytime temperatures had risen into the 50s. Upstream of Sunshine Bridge (PRM 88 [RM 84]), numerous open leads had opened in the main channel of the Susitna River. Most of the Susitna River had meltwater on the ice cover, and gravel bars downstream of Talkeetna were starting to appear from underneath the snow. The ice cover was clearly weakening and the river was slowly rising, but the vast majority of the snow had not melted. The ice jam at the mouth of the Talkeetna River that was present on May 7^th^ was broken up. There were ice jams forming at the confluence of the Chulitna and Susitna Rivers (PRM 102 [RM 98.2]). Temperatures remained below normal with highs in the mid-40s, which continued to slow the rate of melt and allow more of the ice cover to decay in place.

May 14th: On the Lower River, most of the ice had not moved in the main channel, yet more open water was beginning to appear at the edges of the ice and in side channels that were dry on May 11th, 2013. Alexander Slough and Creek (PRM 13 [RM 9.5]) were open upstream of an ice jam at the Susitna confluence. The northern channel on the Yentna River was beginning to break up, but the Deshka River (PRM 45 [RM 40.8]) was completely ice-free. Upstream of the Deshka, the mainstem was still mostly ice covered to Sunshine Bridge (PRM 88 [RM 84]); however, rising river levels had begun to flood side channels. Several large jams had formed around Sunshine Bridge but were not backing up water. The thalweg on the main channel was open upstream of Sunshine Bridge to Talkeetna. The Talkeetna and Chulitna Rivers were more broken up than on May 11th, 2013.

Figure 1.1-6. PRM 89.3 (RM 85.4) - Ice jam upstream of Sunshine Bridge, photo looking downstream. Ice became increasingly broken up upstream. May 14th, 2013.

May 15th: Numerous ice jams had cleared out that were present on May 14th between the mouth and PRM 31 (RM 27) near the Yentna confluence including the jam at Alexander Slough. The Yentna River was still ice covered. The Kashwitna River (PRM 65.1 [RM 60.7]) showed more signs of deteriorating ice and more open water but was still ice covered. The mainstem had over 50 percent ice cover up to Talkeetna. The Chulitna River (PRM 102 [RM 98.2]) continued to be ice covered at the confluence with the Susitna.

May 19th: Ice on the left most channel of the river finally gave out and the water level dropped from May 15th. There was an open lead that had formed from the mouth of Alexander Slough to tidewater and more fractures were present in the ice surface, indicating a progression of breakup. The northern channel of the Yentna River at the confluence was mostly clear of ice; while upstream of a jam at PRM 12.5 (RM 8) the Yentna was mostly open. The head of Kroto Slough had broken up and had dry gravel exposed. From the Yentna to the Deshka Rivers the main channel was about 50 percent open with unstable ice. From the Deshka River to Sunshine Bridge the river was mostly ice covered. Upstream of the bridge the main channel was about 75 percent open. The Talkeetna River remained unchanged and the jam on the Chulitna was still holding though the river continued to open up downstream of the jam.

May 23rd: The Susitna River had broken up from tidewater up to the Deshka River confluence (PRM 44.5) since the previous flight. The Yentna River and Deshka River were both mostly open. Extensive ice cover remained from the Deshka River confluence to an ice jam at PRM 85 (RM 80.6) near Sunshine, though the ice surface was covered in meltwater and appeared to be rotting. Upstream of the jam the main channel remained open through Whiskers Creek (PRM 104.9 [RM 101]). The Talkeetna River was fully open and the Chulitna River had numerous ice jams on the lower 5 miles, but no flooding.

May 25th: Ice and water movement was very dynamic, with ice jams giving way and reforming again downriver in short time periods. Large ice floes dominated the river channel. The Susitna River was open from the tidewater to PRM 50 (RM 46), just upstream of the Delta Islands. From PRM 50 (RM 46) to PRM 70 (RM 66) there were numerous ice jams and some ice coverage with water flooding islands. Upstream of PRM 75 (RM 70.5) the main channel was open, though some side channels and sloughs were still closed. The Chulitna River remained clogged with jams to 5 miles upstream from the confluence.

May 26th: Downstream of the Yentna River (PRM 31 [RM 27]) the main channel was open with only small chunks of ice present. Upstream of the Yentna River there was increasing shore and side channel ice, probably accumulating from upstream. Between PRM 52 (RM 47.4) and PRM 71 (RM 67), there were several large jams in the main channel, but no flooding. Upstream of PRM 71 (RM 67) the main channel was open. The isthmus between the Chulitna and Susitna Rivers was inundated with water and ice had been pushed 200 feet into the forest.

May 29th: The remaining jams on the Lower River had cleared except for minor shorefast ice. The river appeared to be flowing at bankfull but no significant overbank flow was visible. The Yentna and Deshka Rivers and Birch Creek were clear of ice and water had covered gravel bars but no islands were visibly flooded. The Talkeetna River was near bankfull and was flooding side channels near the town of Talkeetna.

1.1.3. 2012 Middle River Observations

April 11th: Some tributaries in the middle river, like Portage Creek, were beginning to open up. A thermal lead near Talkeetna Station at PRM 107.7 (RM 104) that was gaining water compared to a few days before. Many narrow and sinuous thermal leads were beginning to have more water in them compared to the last observation flight.

April 19th: Numerous small jams from PRM 137.5 (RM 134) to PRM 162.7 (RM 159) in this section of the river as compared to the previous observation flight. The upper half of this section had wide open leads and three ice bridges were identified in Devil Canyon. The open leads of the lower half of this section were generally long, narrow open leads.

Figure 1.1-7. PRM 140.4 (RM 137)- A small jam in a middle river velocity lead. Flow is from right to left in this photo. April 19, 2012.

April 23rd: Open leads melted and formed longer leads. Due to warmer daytime temperatures, less snow was observed on the banks and bars as compared to April 19th below PRM 123.6 (RM 120). There were fewer sections of ice cover than on previous trips. The ice jams were generally large, angular slabs of ice. There were many small ice jams from the mouth of Devil Canyon and the Gold Creek Alaska Railroad bridge. Three ice bridges were observed in the Devil Canyon stretch of this river section.

April 27th: The open lead through Devil Canyon was similar to that on April 23rd but there has been more melt on the edges and the thickness of the ice was decreasing. The water was browner than previous days. Open lead widths were nearly twice as wide as seen on April 23rd. Many more multiple-sized ice slabs in the ice jams between the mouth of Devil Canyon and the Gold Creek Alaska Railroad bridge. Below PRM 123.6 (RM 120), the mainstem leads were wider with more bank and bar melt than April 23rd.

April 30th: Three ice bridges were still present in Devil Canyon. The ice and snow covered areas of the river have decreased in number and size compared to what was observed on April 27th. The Portage Creek confluence was mainly ice-free. Many small, compact ice slab ice jams were present downstream of the Gold Creek Alaska Railroad bridge.

May 2nd: Near PRM 162.7 (RM 159), the slush ice accumulated along the shores of parts of the upper Devil Canyon. The ice slush had a ridged pattern that may be from wave action and/or flow dropping while the slush was still in a somewhat plastic and flowing state. There were some large ice jams in the middle river and it was evident that the river flow had dropped and stranded some of the ice that created the ice jams. There were minor ice/vegetation interactions observed. Only one ice bridge was observed in Devil Canyon and the ice jams were generally between PRM 123.6 (RM 120) and PRM 139.4 (RM 136).

Figure 1.1-8. PRM 139.4 (RM 136)- and Slough 11 after the ice jam collapsed and moved downstream, May 2nd, 2012.

May 4th: Below Devils Canyon, Portage Creek, Indian River, and Gold Creek were all open with shelf ice present. FA-144 (Slough 21) and Slough 17 (upstream from Indian River) were still partially ice covered. Slough 11, just downstream from the Alaska Railroad Bridge was open and a mainstem ice jam downstream was diverting flow into the upper end of the slough. This was the condition of most of the side channels and sloughs downstream (Slough 9, 8A, Moose Slough, and the oxbow below Curry) where remnant ice and ice jams were diverting flow into the upper end of the soughs or creating a backwater into the sloughs. There seem to be little to no ice interactions in this section of the river and water and ice were below the riparian vegetation as observed during this flight. At a confluence on the west side of the River between PRM 122.7 (RM 119) and PRM 134.3 (RM 131), an ice jam in the tributary ran into shelf ice on the mainstem of the Susitna River and created a large break (wrinkle) in the shelf ice.

May 9th: The middle river showed little evidence of ice-vegetation interactions. One of a few interactions was documented where slab ice was moved laterally toward the center of the island near PRM 132.4 (RM 129) and ice/vegetation/sediment interactions were observed. There were side channel ice jams in the middle river as well as stranded water in side channels as the mainstem water level dropped and left the side channels full of water and ice.

May 10th: At the confluence of Portage Creek and the Susitna River the water colors indicate the increased sediment being carried in the Susitna River on May 10th. Camera site at FA-151 (Portage Creek) was on the gravel point on the downstream side of the confluence. No ice-vegetation interaction was observed; however some sediment deposition was observed. The observed sediment deposition appears to be sediment that was carried in the ice and deposited when the ice melted in place.

Figure 1.1-9. (PRM 152.3 [RM 148.8])- The confluence of Portage Creek (flowing from the bottom of the photo) and the Susitna River (flowing from the left of the photo) showing the increased sediment being carried in the Susitna River. May 10, 2012.

Camera site Slough 9: Sediment deposition on the slough side of the island was observed. There was evidence of old ice-vegetation interaction on the downstream end of the island and there was no sign of recent ice-vegetation interaction. Facing upstream on the slough side of the island, thin willows and alders were bent due to ice and/or snow load but the vegetation was not scarred or damaged. The entire center of the island at this camera site was covered with dry leaves and snow deposited dust. Debris mats may indicate flowing water, but no scouring was observed at this site.

Camera site Curry: No ice reached the upper elevation of the island this year as the lower elevation of the island was covered by thick snow captured in the willows. There were cobbles on the upper level of the upstream end of this island as evidence of old deposition, but no evidence of any recent sediment deposition events was found.

1.1.4. 2013 Middle River Observations

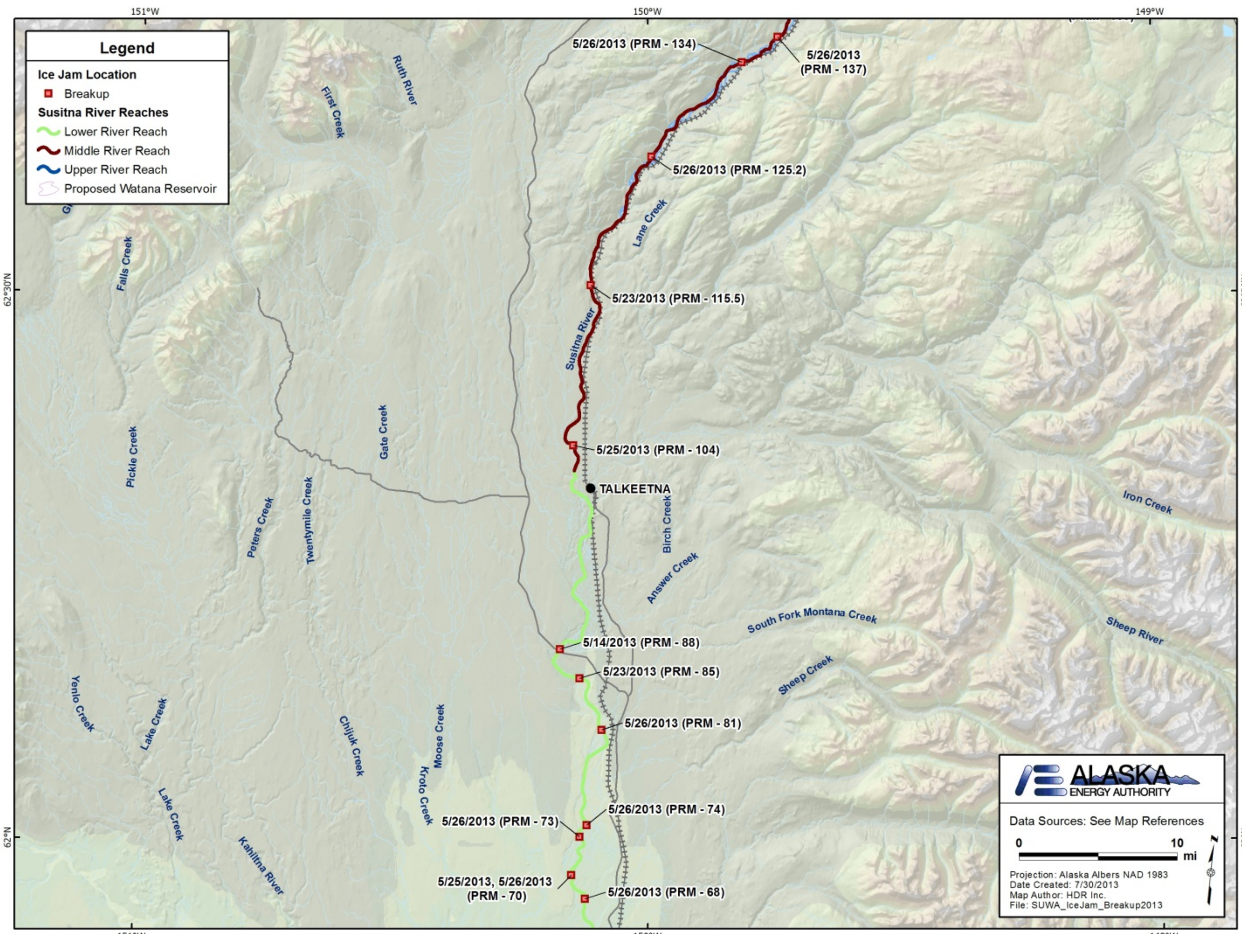

Figure 1.1-10. 2013 Significant Ice Jam Locations–Middle Susitna River

April 25th: Thermal and velocity leads showed signs of widening. The large leads were just upstream of FA-141 (Indian River) and just downstream of FA-151 (Portage Creek) where the ice had formed late in December and the leads appeared to encompass most of the main channel. However, both Portage Creek and Indian River were completely ice-covered. Bo leads and bridges were present in Devils Canyon.

May 5th: Open leads continued to expand; open water at sloughs and a slough mouth had increased significantly from April 25th. Portage Creek, Indian River, and Fog Creek remained mostly frozen. Devils Canyon was almost entirely open with the exception of a few ice bridges.

May 7th: Leads that were present on May 5th had continued to widen due to gradual melting below PRM 150 (RM 146.6), including those near Curry (PRM 124.2 [RM 120.7]) and at the mouth of the Indian River (PRM 143.2 [RM 137.7]). More extensive ice cover began at PRM 166 (RM 162.9) as open leads decreased in width and became more discontinuous and open channel flow was replaced with over-ice flow. Indian River was 75 percent open and large leads were present from Fog Creek through Tsusena Creek.

May 11th: Open leads continued to grow and there was a considerable amount of overflow. Thermal leads at side sloughs were extending further into the main channel. Indian River was mostly open.

May 14th: Upstream of the three-river confluence, the Susitna was approximately 50 percent ice covered and showed more signs of melt and ice degradation than on May 11th. Upstream of Devil Creek the Susitna was largely ice covered. Fog Creek was 50 percent open and Tsusena Creek was 10 percent open.

May 15th: An ice jam was present upstream of Slough 6A at PRM 115.1 (RM 111.6). The jam present at Curry Station (PRM 124.2 [RM 120.7]) was growing as more ice accumulated on the upstream side. Ice jams had formed at Slough 8A (PRM 129.5 [125.9]), PRM 130.3 (RM 126.7), Gold Creek Bridge (PRM 139.9 [RM 136.5]), near Indian River (PRM 143.2 [RM 139.7]) and at the mouth of Devils Canyon (PRM 153.7 [RM 150.1]). Portage Creek had more overflow present, showing signs of breakup.

Figure 1.1-11. FA-128 (Slough 8A) (PRM 127.9 [RM 124]) – Ice jams forming. May 15th, 2013

May 19th: The Middle River was about 75 percent ice covered with some mode progress from May 15th, 2013. Ice jams near FA-115 (Slough 6A had continued to accumulate ice without backing up much water. Upstream there were open leads to Gold Creek Bridge. There was one long jam before FA-151 (Portage Creek). The jam at the mouth of Devil Creek was gone. Fog and Tsusena Creeks were 70 percent and 15 percent open, respectively.

May 23rd: Stretches of intact ice cover with jams at the upstream ends remained from FA-104 (Whiskers Slough) through FA-115 (Slough 6A). Upstream the river was open to Devil Creek. Portage Creek was 80 percent open and numerous other tributaries had opened since May 19th. The Susitna River had opened up between Devils Canyon and Fog Creek. Upstream of Fog Creek there were several stretches of ice downstream of FA-184 (Watana Dam).

May 25th: A large jam formed just downstream of Whiskers Slough (PRM 104.9 [RM 101]) and was backing up water and ice and flooding the slough and mouth of Whiskers Creek. There were various ice jams along the Middle River up to Devils Canyon. Ice bridges remained at the mouth of Portage Creek. Fast, turbulent flow in Devils Canyon was breaking apart ice from the Upper River and leaving only slush and small chunks downstream. Few jams remain in the canyon. Ice was broken up and rapidly moving downstream upstream of Devils Canyon. Tsusena Creek continued to open and was at 20 percent during this survey.

Figure 1.1-12. (PRM 105.4 [RM 101.5]) - Ice jams at Whiskers Slough flooding the slough. May 25th, 2013.

May 26th: Several jams appeared to be forming and moving fairly rapidly along the Middle River. Whiskers Slough and Slough 8A were jammed, but the other study sloughs were clear. There were remnants of a large ice jam from PRM 103 (RM 99.3), near Whiskers Slough, up to PRM 113 (RM 109.4). There was another jam upstream of Curry Station (PRM 124.2 [RM 120.7]). An ice jam released in the afternoon from PRM 131 (RM 127.1) to PRM 134 (RM 130.7), near Slough 9, with signs of previous jams upstream as far as PRM 137 (RM 133.6). From Gold Creek Bridge to Devils Canyon there were some remains of previous jams. Devils Canyon was completely cleared of ice bridges that were present on May 25. From Devils Canyon to Fog Creek the river was clear. There was still some shelf ice from Fog Creek to Deadman Creek. Tsusena Creek had become 45 percent open upstream of a jam at the mouth.

May 29th: The main channel of the Middle River was completely open except for flowing ice, and water levels were around bankfull flood stage from snowmelt runoff. Ice was jammed near Whisker Slough in the east side channel and on islands and some ice was still present in the slough itself. Slough 6A (PRM 115.5 [RM 111.6]) was open except for a small ice flow at the mouth. There were a lot of stranded ice chunks on the shores of the main channel upstream and downstream of FA-115 (Slough 6A). There was ice damage to an island in the middle of the main channel near Curry (PRM 124.4 [RM 121]). There were numerous boulder piles 2-3 feet high on an island in FA-128 (Slough 8A) (PRM 127.9 [RM 124]). Trees had been uprooted and fallen into the river due to undercutting of the bank from high water. The head of the island had large ice blocks up in the vegetation but not into the tree line. Ice was pushed up again the tree in which the time-lapse camera was mounted. There was a large ice jam at Slough 9 (PRM 132.4 [RM 129]). Ice was at the base of trees and numerous trees had been knocked down. Islands upstream of the slough had been over run by debris and ice. There were large cobbles and boulders deposited in the middle of the island at Slough 11 (PRM 138.3 [RM 134.9]). The slough itself was overtopped with some ice crowding in from the main channel. High water and flowing ice continued to the dam site.

Figure 1.1-13. PRM 132.4 (RM 129) - Ice deposited in Slough 9. May 29th, 2013.

1.1.5. 2012 Upper River Observations

April 11th: The continued warm daily temperatures and intense sun caused velocity and thermal leads to continue to widen. There were many long open velocity leads that had localized overflow in the Upper River between PRM 221.9 (RM 220) and the Oshetna River confluence. Some tributaries in the upper river, like Fog Creek, were beginning to open up.

April 19th: Long, thin open leads were found throughout this section. The snow was melting on both the banks and the river and the open leads were widening as compared to the previous observation flight. There were a few small ice jams at the downstream ends of the larger open leads.

April 23rd: Many small jams with large, angular ice slabs were observed. The open leads have melted to connect and form long, narrow, thready leads. Melt water was observed on the ice with very little open water in that area of the river.

April 27th: Thermal leads were melting. There was increased bank and bar snow melt compared to the April 23rd observation flight. The ice jams were moving. The open leads were melting and were widening. The ice slabs in the ice jams were not as large or angular as those observed on April 23rd. The long, connected, narrow leads were generally twice as wide as they appeared during the April 23rd observation flight. There were almost twice as many observed ice jams as compared to April 23rd.

Figure 1.1-14. PRM 223.4 (RM 221.5) - Ice jam in Vee Canyon. April 27th, 2012.

April 30th: There were many shorter and wider jams present than observed on previous days and the mainstem was greater than 75% ice-free. There were stranded ice slabs on banks and bars along this section of the river. There were more snow and ice free banks and bars than seen on April 27th. There were fewer ice jams than were observed on previous flights.

May 2nd: Frazil ice was observed forming and flowing in the upper river. Similar to the rafted ice seen on April 30th, there was more rafted ice in the upper river on this day even though most of the channel was open. The grounded ice chunks were approximately 6 feet thick and the top surface of the ice was between 10 and 15 feet above the level of the river at that time. There were some ice jams in the upper river but mostly in side channels. There were chunks of ice stacked along the shelf ice in many areas along the shore in the upper river.

Figure 1.1-15. PRM 222.9 (RM 221) - Remnant ice slabs downstream of Vee Canyon. May 2nd, 2012.

May 4th: Stream flows were higher and ice cover considerably less than on the previous survey. Longitudinally, the river was over 90% ice free, with only occasional ice bridges and ice dams. Similarly the river cross-section was 80 to 90% ice free at most mainstem locations, however, ice cover remained within some side channels. Remnant river ice and ice dams were diverting flows within the channel or into side channels. Water and ice were well below the riparian vegetation lines in this section of the river as observed during this flight. Turbidity seemed to be decreasing as small areas of substrate were visible and shelf ice was observed near river edges where ice was still present. Continuous, clear flowing water was observed in all of the tributaries. Photographs for perspective of water flow and sedimentation segregation were made at a stop on the river left side gravel bar at the base of the foot bridge upstream of the canyon where the water was very turbid and very little ice remained (< 5% at the cross-section).

May 9th: The upper river was a red-brown color due to increased sediments and tannins. There were still a few large, dense, river-wide ice jams. The stranded ice pieces were beginning to show signs of melt as the ice was candling and rotting in place. There was evidence of previous ice/vegetation interactions, but very little occurred during this breakup season. At PRM 198.7 (RM 196), there was obvious ice-vegetation interaction with uprooted trees as well as bank undercutting due to water and ice flows. There was also a visible ice/vegetation/sediment interaction on the upstream side of the island at PRM 198.7 (RM 196) where an ice slab bulldozed the elevated point of that island. There still remained sections with mid-winter ice jams that have not broken up and wide, shallow sections above Watana Creek where the ice seemed to be anchored to the bottom of the river and had water flowing over it.

May 10th: FA-184 (Watana Dam) (PRM 186.8 [RM 184]): Ice-vegetation and ice-sediment interactions were observed at this location. There was both ice-vegetation and ice-sediment interactions on the upstream point of this island. There was some evidence of scouring, but no large material clearing was observed. Several old ice scars were observed at this site and two old ice scars were seen on large trees on the mainstem side of the island as evidence of old ice-vegetation interactions; however, no new ice scars were observed. Floating ice landed on the shore-edge of the island, but was not pushed to cause recent undercutting of the bank. There was white ice downstream on the island that was melting in place and showed no ice-vegetation or ice-sediment interactions.

Figure 1.1-16. PRM 181.2 (RM 184)- Time-lapse camera location. This photo documents both ice-vegetation and ice-sediment interactions on the upstream point of this island. Flow is from left to right. May 10th, 2012

1.1.6. 2013 Upper River Observations

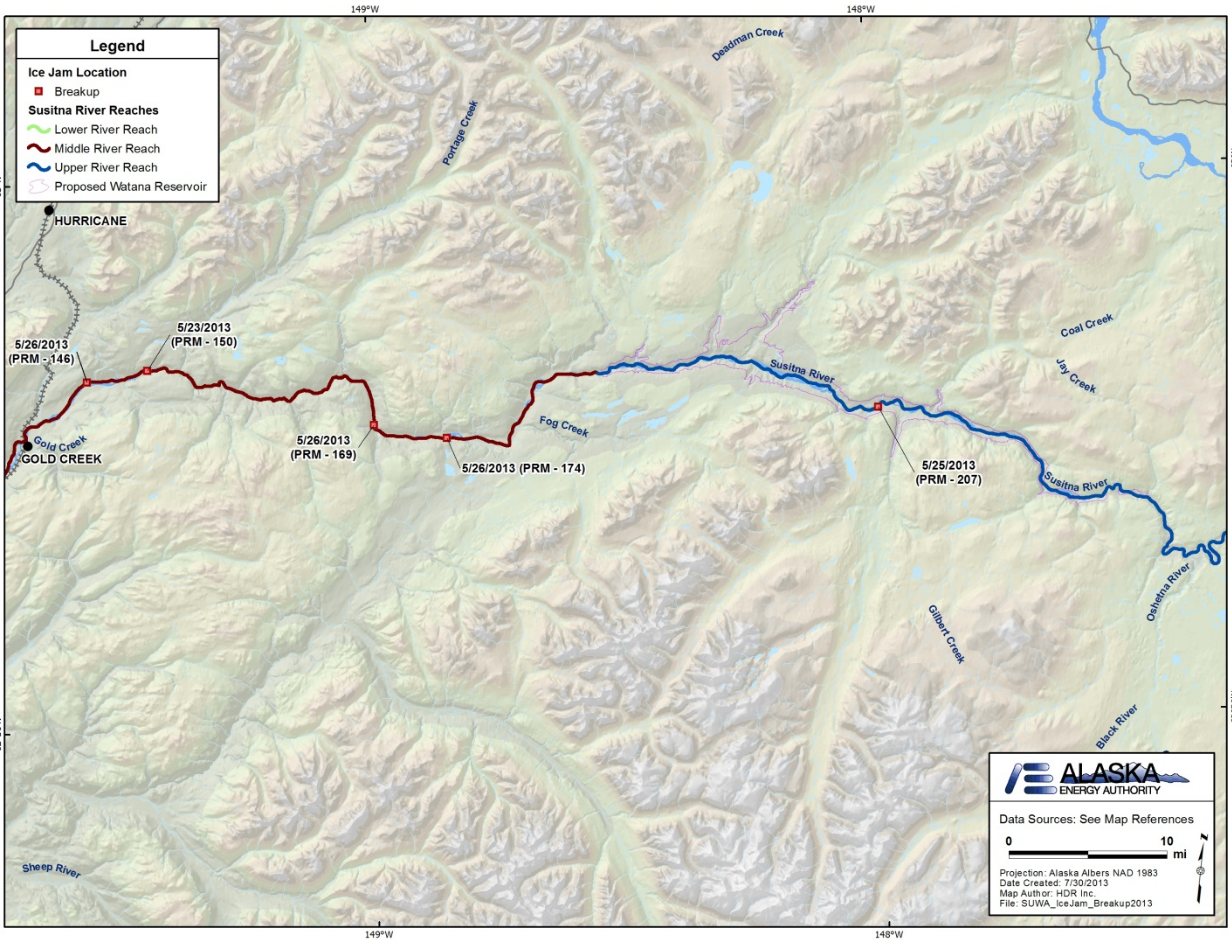

Figure 1.1-17. 2013 Significant Ice Jam Locations–Upper Susitna River.

April 25th: No survey of the Upper Susitna River.

May 5th: There was significant open water at the Kosina Creek confluence; however, the Oshetna River had not changed since January.

May 7th: The Upper River remained mostly ice covered without significant changes from the previous survey.

May 11th: Upstream of Devils Canyon the river was mostly ice covered with growing intermittent leads and some overflow.

May 14th: The Upper River was still largely ice covered. There were substantial open leads at the mouths of Kosina Creek, and at the Oshetna River, which had opened up since May 11.

May 15th: No survey upstream from FA-151 (Portage Creek).

May 19th: There was little change on the Upper River.

Figure 1.1-18. PRM 228 (RM 226) - Open lead on the upper river. May 19th, 2013.

May 23rd: On the Upper River, Watana Creek had opened completely, as had most of the lower 5 miles of the Oshetna River. Kosina Creek has continued to open up but there were many snow and ice bridges present.

May 25th: Ice was still present from FA-184 (Watana Dam) to Kosina Creek but was broken and jumbled. A massive ice jam extended several miles downstream of Vee Canyon.

Figure 1.1-19. PRM 196.8 (RM 194.1) - Broken but extensive ice cover. May 25th, 2013.

May 26th: All upper river tributaries were flowing strongly. There were still jams remaining with water flowing over the top of ice in some places. The jam at the mouth of Kosina Creek had broken up. Intact ice covered the river from PRM 213.8 (RM 211.6) to PRM 218.6 (RM 220.7) with a jam extending upstream to PRM 221 (RM 219).

May 29th: The main channel was clear of ice with remnants of shorefast ice and ice jams which surrounded the main channel and were in the trees on the banks. All Upper River tributaries downstream of the Oshetna River were clear and running high. Deadman and Kosina creeks were at high water with ice present on the banks. The remainder of the Upper River had large ice shelves and stranded ice in side channels and shores.

Figure 1.1-20. PRM 222 (RM 220.1) - Remnants of ice shelves and stranded ice on the Upper River. May 29th, 2013.

1.2. Time-Lapse Camera Monitoring

1.2.1. 2012 Lower River Time-Lapse Cameras

PRM 15.1 (RM 9.5), Alexander Slough near Upper Tidal Influence: This camera views the main river looking upstream from the right bank. Overflow was visible in tracks in the snow from the beginning of the image sequence (April 5th). The overflow went through daily freeze/thaw cycles until April 19th when a lead opened completely (though continuing to freeze at night until April 23rd). The near-shore ice began to break up April 23rd at 16:00. Ice in the near-shore channel alternately jammed up/flowed from April 24th until April 30th. At this time ice from the main channel was pushed to the near shore, which was on the outside of a sweeping bend (Figure 5.4-2). The ice went out completely on April 30th, with runs of broken ice on May 1st, 2nd, and 5th.

PRM 29.7 (RM 25.6), Susitna Station: Viewed from the left bank looking upstream, this image sequence ran from April 11th to May 9th. The river was completely ice covered on April 11th. Water was visible in the snow/ice near the left bank beginning on April 15th. A lead opened in the mid-channel on April 23rd and flowed freely on April 28th. Overflow near the left bank opened up to a lead on April 29th. The ice broke up completely on May 1st at approximately 16:00. Broken ice flowed downstream freely by May 5th. Only stranded ice was left to melt when the sequence ended on May 9th.

PRM 63.3 (RM 59), near Rustic Wilderness Side Channel: One camera at this site recorded images of two side channels near the right bank. This sequence includes images from April 5th through May 9th. Snow melt was fairly continuous and consistent from the beginning of the sequence. In the image there were two channels visible, a small gut in the foreground and a more sizable channel in the background. Overflow on top of the ice was fir visible on the foreground channel on April 24th, with overflow increasing during daily freeze/thaw cycles until a lead opened on April 29th. Flow continued (and diminished) until the channel was dry on May 3rd.

The larger channel in the background was open on April 5th, and the channel widened until the water level began to recede on May 3rd. The channel was fir ice free on April 28th until an ice run on May 2nd left large ice chunks stranded in the channel (Figure 5.4-3). The channel was almost dry by May 6th.

A second camera at this site recorded images of the main channel. The main channel was completely ice covered on April 5th. Overflow in the snow was fir visible in the afternoon of April 7th and increased until open water was visible beginning April 22nd. Daily freeze/thaw cycles closed the lead at night and opened it during the day until on April 25th the lead remained open. Ice began to break up and flow on April 27th in the evening. The water level dropped on May 2nd, stranding ice on the banks. The water level rose and ice began to flow again on May 5th. The channel was ice-free and flowing freely May 6th.

PRM 91.7 (RM 88.2), Birch Creek: This camera recorded images facing the mouth of a slough and side channel from April 5th through May 9th. There was an open lead in the side channel all winter. The lead began to widen on April 13th. The last of the ice went out on April 22nd. Occasional chunks of ice flowed by on April 26th; otherwise the channel was ice-free after April 22nd. By April 28th dry ground was appearing on the bank and by May 9th all that was left was some snow on the bank.

The second camera in this location recorded images of the main channel across two side channels from the left bank. Open water was visible in a hole in the foreground form the start of the images on April 9th. The channel continued to grow until it opened into a freely flowing channel on April 12th. A second channel opened up and joined the fir channel on April 24th. Bank ice receded or broke off and the channel grew continuously until it was ice-free on April 27th. Ice chunks could be seen flowing out in the main channel April 25th.

1.2.2. 2013 Lower River Time-Lapse Cameras

PRM 13.9 (RM9.5), Alexander Slough near Upper Tidal Influence: A lead opened and continued to grow on May 5th. The gradual in-place decay of the ice was disrupted by an abrupt breakup of the ice cover on May 22nd. Both river stage and water temperature increased rapidly at ESS15 (PRM 17.7 [RM 12.8]) near this time as well. By May 28th the entire slough was clear of ice with small ice floes continuing through May 30th.

PRM 29.7 (RM 25.6), Susitna Station (ESS20):

The first signs of ice cover deterioration were seen on May 6th toward the center of the channel in front of the USGS gage. A gradual in-place decay of the ice sheet continued through May 20th when a lead opened along the right bank. A lead down the middle of the channel opened on May 21st and the sheet moved downstream leaving the channel width entirely open on the morning of the 22nd. River stage increase was noticeable on the 25th and a significant loose ice run passed on the 26th. Light ice continued to pass as the water levels continued to increase through May 30th.

PRM 64.2 (RM 60), Rustic Wilderness Side Channel: An open lead began to form near the center of the channel on May 6th and appeared to re-freeze at night until May 13th when it remained open. The lead widened and water levels increased on May 24th with a second lead opening further across the channel (toward the left bank). The water levels increased significantly on May 26th and the entire ice cover was pushed downstream early on the 27th.

PRM 91.7 (RM 88.2), Birch Creek: On May 26th a visible rise in river stage occurred, with over-ice flow and ice flowing downstream. Minor flooding of islands in the channels occurred during this event. The staff gauge at PRM 98.4 (RM 95) shows a rise of over four feet during the night of May 25th. The ice present was flushed out and the river stage remained visibly constant at the increased stage for the remainder of the video.

1.2.3. 2012 Middle River Time-Lapse Cameras

PRM 102.7 (RM 99), Slough 1: The image sequence ran from April 6th through May 24th. Open water was visible from the beginning of the sequence in Slough 1 near the camera. A lead opened in the main channel on April 19th. Ice began to break up and move on April 27th. During the night of April 27th the water level rose by several feet, covering gravel bars that had been visible earlier in the day. The water level began dropping by the afternoon of the 28th. The remaining river ice went out early morning May 1st. The water level dropped continuously until 07:00, May 7th and then rose continuously until the sequence ended May 24th.

PRM 106.8 (RM 103), Talkeetna Station: The camera was on the left bank facing across the main channel and upstream. A small lead on the left bank was visible beginning April 6th. Water was visible on the ice at mid-channel on April 12th. A lead in the mid-channel opened and closed daily from April 17th until April 21st, when it opened for good. Ice jammed the center lead on April 25th and the near-shore lead on April 28th. Both jams broke sometime after 22:00 on April 30th. A small jam formed on the side channel upstream of the camera on May 1st. The jam broke May 3rd. The river flowed freely from this point on, with stranded ice melting by May 18th.

PRM 124.4 (RM 121) Curry Slough: This camera views the main channel from the left bank looking upstream across a side channel. The snow melt was continuous and consistent throughout this sequence. On April 9th, an open lead was visible again the left bank of the side channel. The lead widened and lengthened into a continuous channel on April 13th. A snow storm on May 1st obscured the camera's view. Broken ice can be seen flowing on May 6th. The channel was open and ice free (except for bank and bar snow) when the sequence ended May 9th.

PRM 132.4 (RM 129), Slough 9: Viewed from the left bank looking downstream, this sequence runs from April 9th through May 9th. Meltwater/overflow in a depression in the ice close to the camera melted through to running water on April 7th. Ice jammed downstream on April 19th, and at 16:00 on April 22nd the channel jammed completely with ice. The jam broke on April 25th at 16:00. A second jam occurred on April 26th and released on April 28th. A snow storm passed through May 1st. The large jam occurred on May 2nd and released on May 3rd, sending ice floes up onto the banks. Broken ice ran through on the morning of May 5th and when the sequence ended on May 9th the river was flowing freely with stranded ice from the jams on the banks.

PRM 144.4 (RM 141), FA-144 (Slough 21): An open lead was visible from the beginning of this image sequence, April 10th. The lead widened consistently from the beginning with no visible broken ice flowing. As snow melted and receded from the gravel bar, the surrounding brush sprang up and increasingly obscured the view until the sequence ended May 9th.

PRM 152.5 (RM 149), FA-151 (Portage Creek): This camera looks upstream across the mouth of Portage Creek. Small leads and depressions in the snow can be seen from the beginning of the image sequence in both Portage Creek and the Susitna River (April 11th). Water was visible in the snow/ice beginning April 13th. A lead in the Susitna River opened April 14thand went through daily freeze/thaw cycles until April 25th, when Portage Creek opened up. Broken ice runs occurred in the main channel April 26th to April 28th. Ice in the channel was gone by April 29th. A snow storm moved through on May 1st. The channel was ice-free (excepting bank ice) through May 9th.

PRM 186.8 (RM 184), FA-184 (Watana Dam: In this image sequence (viewed upstream from the right bank), a large puddle of melt water went through a daily freeze/thaw cycle, fir opening to the river on April 16th. A lead opened upstream of the site on April 22nd. The freeze/thaw cycle near-shore continued until April 23rd when a lead opened completely. On April 30th an ice jam formed in the main channel upstream and a lead opened from the main channel to the right side. The ice jam upstream broke on May 2nd and ice ran through May 3rd. The main drive of the jam occurred after dark on May 2nd, thus the floes that impacted the island were missed by the camera.

1.2.4. 2013 Middle River Time-lapse Cameras

PRM 104.9 (RM 101), FA-104 (Whiskers Slough): Helicopter access to the site was limited at the time of breakup and the images were not able to be recovered before the camera wrote over the key breakup photos. Other cameras and ESS station data showed that the ice cover went out on May 26th with an additional ice run on May 28th.

PRM 127.9 (RM 124), FA-128 (Slough 8A): The slough remained snow covered until an overflow event on May 24th spurred melting and breakup of the ice cover. On May 25th the river stage visibly raised causing further breakup of the ice cover. The stage recorder installed at PRM 124.2 (RM 120.7) had malfunctioned during the winter so stage variation was unknown. By 08:00 hours on May 28th most of the visible ice had cleared from the slough and a large ice floe passed the camera location at 14:00 hours. By May 29th all major ice floes were cleared from the slough.

PRM 132.4 (RM 129), Slough 9: This camera was lost during breakup flooding.

PRM 138.3 (RM 135), FA-138 (Slough 11): This view of the side slough along the left bank showed that is was open at the end of March and had a very gradual melting of the snow and ice cover starting through May 24th. The water levels increased on the 25th and ice began passing through the slough through the 27th.

PRM 144.4 (RM 141), FA-144 (Slough 21): This camera provided views of the side slough along the left bank which was open at the end of March. Snow gradually melted and the slough widened with the flow increasing on May 24th. An ice run pushed through the slough early on the 26th with a second larger ice run with increased water levels on May 28th.

PRM 186.8 (RM 184), FA-184 (Watana Dam) below Deadman Creek: This camera was lost during break-up flooding.

1.2.5. 2012 Upper River Time-Lapse Cameras

No time-lapse cameras were located on the Upper River during the 2012 breakup.

1.2.6. 2013 Upper River Time-Lapse Cameras

No time-lapse cameras were located on the Upper River during the 2013 breakup.

2. FREEZE-UP OBSERVATIONS

2.1. Aerial Reconnaissance

2.1.1. 2012 Lower River Observations

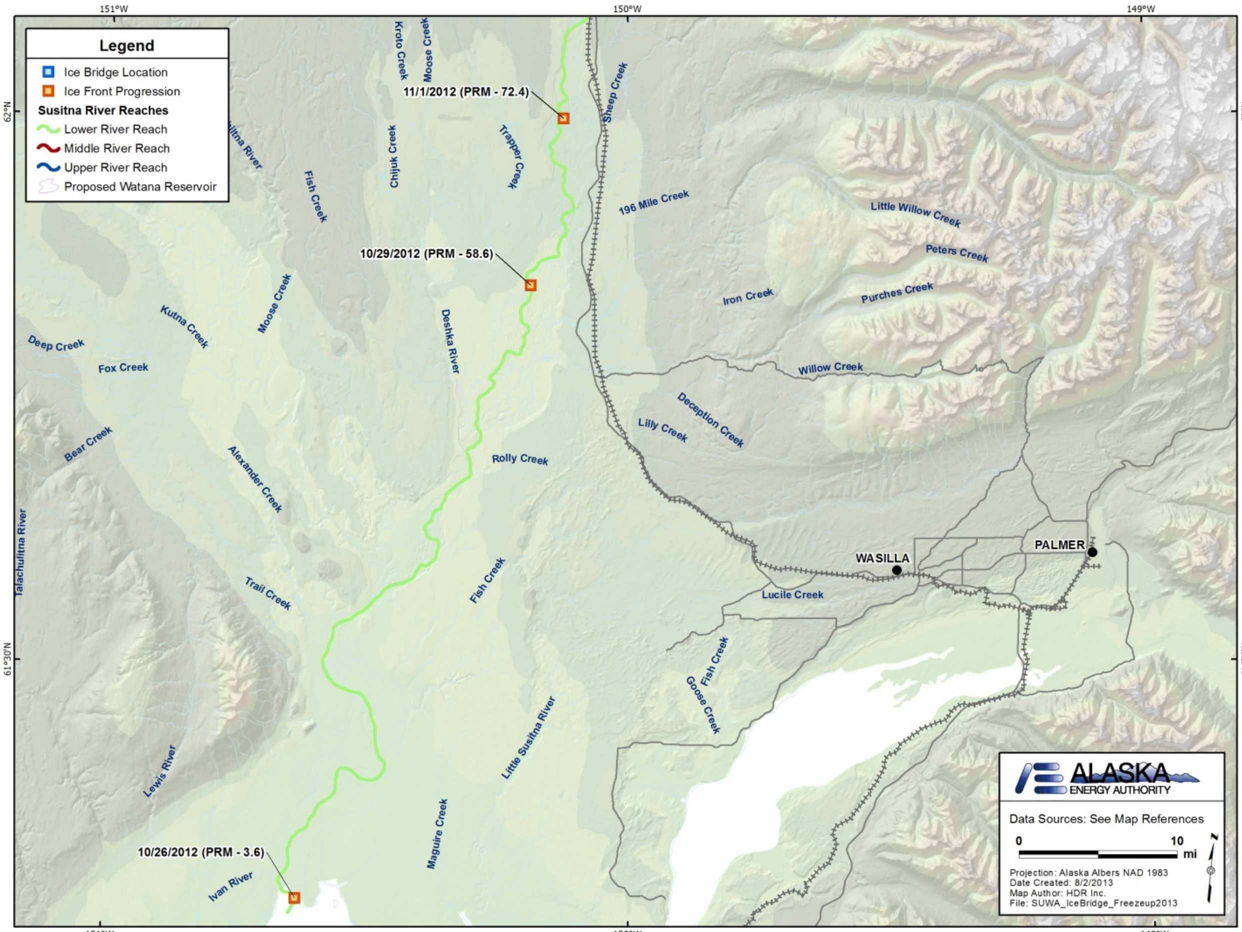

Figure 2.1-1. 2012 Ice Front Progression and Ice Bridge Locations–Lower Susitna River.

October 14th: Frazil ice appeared at Susitna Station (PRM 30.1 [RM 26]).

October 15th: Too much frazil ice near Deshka Landing (PRM 48.1 [RM 44]) to operate a jet boat.

October 17th: Frazil ice appeared at ESS10 below Flathorn Lake (PRM 14.9 [RM 10]).

October 23rd: Bridging appeared imminent at PRM 15.3 (RM 9) in afternoon. Pressure transducer readings at PRM 14.9 (RM 10) indicate ice cover progressed pa in the late evening. Pressure transducer reading at Susitna Station indicated ice cover progressed past on October 25th.

October 26th: Ice bridges were visible in west and east side channels at Big Island near Susitna mouth. The fir ice bridge extended from PRM 3.6 (RM 1) to PRM 9.6 (RM 5), and a second ice bridge extended from PRM 10.5 (RM 6) upstream. Open water was visible between the two bridges. An ice cover progressed upstream from the second ice bridge to PRM 24.1 (RM 20). A third ice bridge extended from PRM 25.8 (RM 21.5) past the Yentna confluence to PRM 36.8 (RM 33). On the Yenta, the ice cover extended about 3 miles upstream from the confluence.

October 29th: Ice cover extended from the mouth up to PRM 58.6 (RM 54). One additional ice bridge had formed in the Devil Canyon area.

Nov 1st: Ice cover extended up to PRM 72.4 (RM 68). ***Nov. 7th:*** Ice cover extended up to PRM 93.3 (RM 90).

Figure 2.1-2. PRM 88 (RM 84) - Parks Highway Bridge after ice cover progression. Note flooded gravel bars on both sides of the river. November 7th, 2013.

November 15th: Alexander Slough (PRM 15.1 [RM 9.5]) was mostly ice covered. Open leads persisted at Fish Creek (PRM 18 [RM 13.3]), Susitna Station (PRM 30 [RM 25.9]), and between the Yentna confluence and Delta Islands (PRM 32-46 [RM 28-41.7]), Willow Creek to Kashwitna Lake (PRM 54-58 [RM 49-53.3]), at Montana Creek (PRM 81 [RM 77]), and near Birch Creek Slough (PRM 92-96 [RM 88.6-92.6]). Heavy frazil was observed in thalweg velocity leads. The ice front progressed from PRM 93.3 (RM 90) to PRM 102 (RM 98.2) at an average of 1 mile per day.

November 20th: The Lower River was mostly frozen over with open leads persisting at Fish Creek (PRM 18 [RM 13.3]), Sheep Creek (PRM 86 [RM 81.8]), Sunshine Creek (PRM 88 [RM 84]), and at Susitna Station (PRM 30 [RM 25.9]). Birch Creek was completely frozen over.

November 28th: Open leads persisted at Susitna Station (PRM 30 [RM 25.9]), between the Yentna confluence and Delta Islands (PRM 32-46 [RM 28-41.7]), including the mouth of both the Yentna and Deshka Rivers, at Willow and Sheep Creek (PRM 53 [RM 47.8] and PRM 86 [RM 81.8]), and between Birch Creek to Talkeetna (PRM 92-102 [RM 88.6-98.2]). Frazil was visibly flowing in most open leads. Anchor ice accumulation created visible rapids downstream of Talkeetna.

December 3rd: Most open leads present on the Lower River during the November 28th survey showed signs of encroachment by border ice and frazil accumulation in velocity leads.

Figure 2.1-3. PRM 78 (RM 74.3) - Looking upstream. Velocity lead in main channel filling in from bottom with frazil ice. December 3rd, 2013.

December 19th: Open leads persisted along the Lower River with narrow leads present at the mouth of Deshka River (PRM 45 [RM 40.8]) and Birch Creek (PRM 92 [RM 88.6]).

January 9th: Freeze-up was mostly complete with the majority of ice-free areas designated as thermal or velocity open leads. Frazil ice was commonly seen in thalweg velocity leads and not in thermal leads near sloughs.

2.1.2. 2012 Middle River Observations

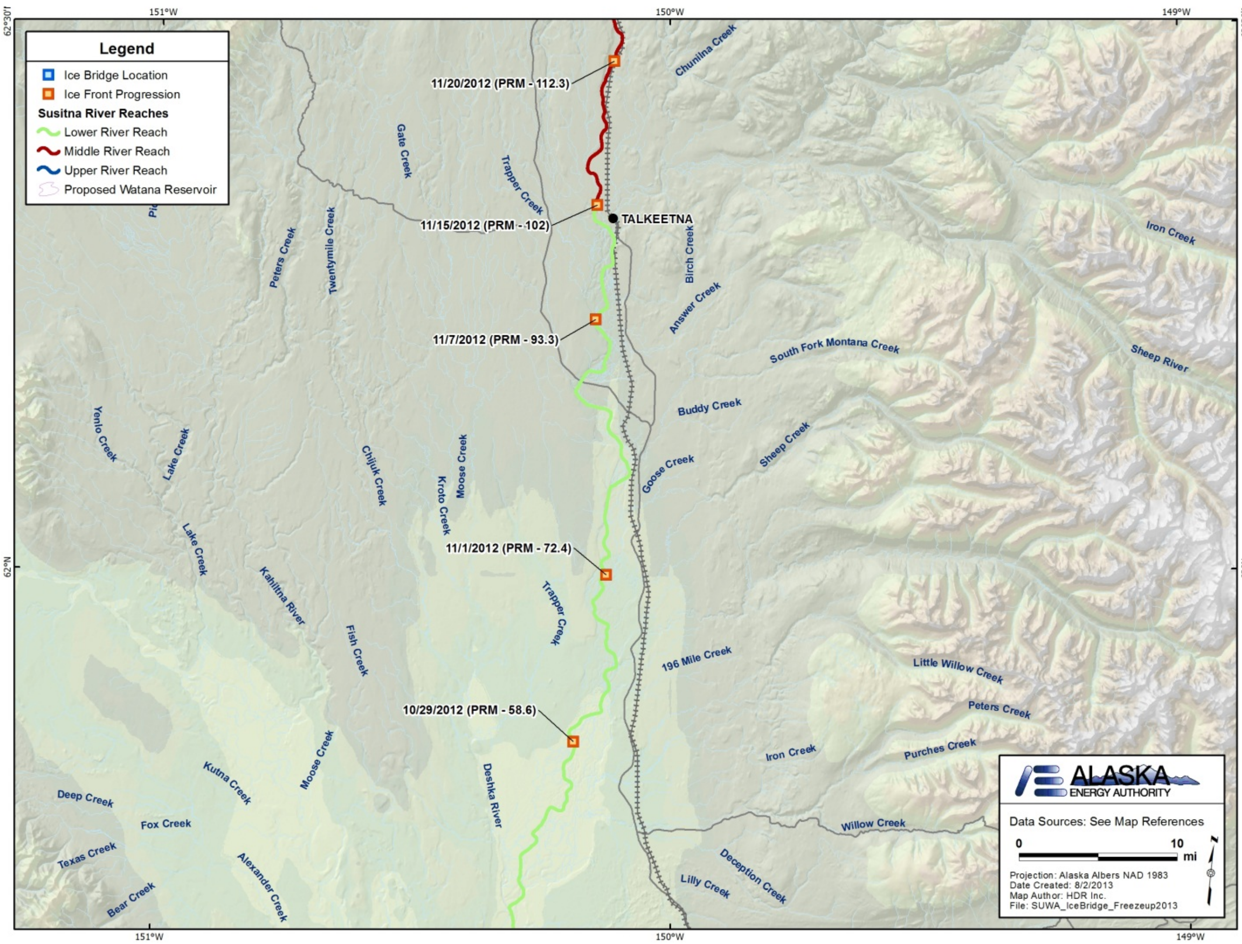

Figure 2.1-4. 2012 Ice Front Progression and Ice Bridge Locations–Middle Susitna River.

October 12th: Little frazil ice was seen at Curry Station (PRM 124.4 [RM 121]).

October 13th: Frazil ice appeared between Twister Creek and Curry Station (PRM 99.4 [RM 96] and PRM 131.4 [RM 128]).

October 16th and 17th: Frazil ice concentrations of 5-40% were observed at Talkeetna. No bridges were visible from PRM 186.8 (RM 184) downstream.

Figure 2.1-5. PRM 103.8 (RM 100) - Frazil ice pans flowing past on the Middle River. October 16th, 2012.

October 22nd: One short bridge formed in the Upper River just upstream of the Watana dam site (PRM 189.2 [RM 186.5]). In the Middle River, a short bridge formed at PRM 158.4 (RM 154.9), and two longer bridges formed over segments of Devil Canyon rapids. These bridges extended from PRM 153.8-154.7 (RM 150.2- 151), and from PRM 163-164.4 (RM 159.5-161). No bridges were visible in the main channel downstream of Devil Canyon on October 22nd. Anchor ice observed upstream of Devil Canyon.

Figure 2.1.2-6. PRM 154.7 (RM 151) - Ice bridge in Devil Canyon, flow is from bottom to top. October 22nd, 2012.

October 26th: Short ice bridges had formed in Devil Canyon at 154, 155, and 156, while the two longer bridges seen on October 22nd were unchanged.

Nov 1: Nine short ice bridges had formed in Devil Canyon and upstream. Devil Canyon ice cover was otherwise the same.

Nov. 7th: An ice cover formed in the south channel of Chulitna River, but two other channels of the Chulitna remained open. Two additional ice bridges formed just upstream of Portage Creek mouth.

November 15: Upstream of PRM 102 there was no continuous ice cover and frazil concentrations were significantly less than the previous flight. At the three rivers confluence, the Talkeetna River remained open, yet grow of anchor and border ice had narrowed the opening since the previous survey and the Chulitna River had low water levels and only one main channel braid remained open with little frazil visible. Ice cover was growing at FA-104 (Whiskers Slough) and at FA-115 (Slough 6A), Slough 9 (PRM 132.4 [RM 129]), and FA-144 (Slough 21). Additional ice bridges formed between FA-151 (Portage Creek) and the FA-184 (Watana Dam) with one notably large bridge spanning 1.4 miles (PRM 163-164.4 [RM 159.5-160.9]).

Figure 2.1-7. PRM 100-102 (RM 96.6-98.2) - Ice cover configuration and flooded channels at Talkeetna. November 15th, 2012.

November 20th: At the three rivers confluence, open leads were still present on the Talkeetna River with visible frazil flows and the open channel on the Chulitna was closed, leaving the river ice covered at the confluence. Ice cover extended to PRM 112.3 (RM 108.6), an average of 2 miles per day since November 15th. Slough 6A (PRM 115.5 [RM 112]), Curry Slough (PRM 124.4 [RM 121]), and Slough 8A (PRM 127.9 [RM 124]) were all between 50 percent and 75 percent ice covered.

November 28th: Open leads persisted at the confluence of the Talkeetna River, yet the Chulitna remained closed. Whiskers Slough (PRM 104.9 [RM 101]) and Slough 6A (PRM 115.5 [RM 112]) were both ice covered with few leads present. Continuous ice cover was disrupted by a significant continuous open lead between PRM 119 (RM 115.6) and Curry (PRM 124 [RM 120.5]) but continued again up to PRM 134 (RM 130.7), which resulted in an average of 2.7 miles per day progression. The mouth of Portage Creek (PRM 152.2 [RM 148.7]) was mostly ice covered with few open leads present. Ice bridges between FA-151 (Portage Creek) and FA-184 (Watana Dam) remained similar to past surveys. The mouths of Devil, Fog, and Tsusena Creeks (PRM 165, 179, 185 [RM 161.5, 176.3, 182.3], respectively) were all ice covered with no open leads present.

December 3rd: Both the Talkeetna River (PRM 101 [RM 97.4]) and Chulitna River (PRM 102 [RM 98.2]) had open leads present in the thalweg. The anchor ice rapids near Talkeetna persisted. Many of the sloughs in the Middle River had become ice covered without any open leads present, including Whiskers Slough (PRM 104.9 [RM 101]), Slough 6A (PRM 115.5 [RM

112]), Curry Slough (PRM 124.4 [RM 121]), Slough 8A (PRM 127.9 [RM 124]), and (Slough 21). Bo Sloughs 9 and 11 (PRM 132.4 and 138.3 [RM 129 and 135]) were mostly ice covered with small thermal leads visible. Ice cover extended to PRM 142 (RM 138.5) upstream of Gold Creek Bridge, an average of 1.6 miles per day. Portage Creek (PRM 152 [RM 148.5]) confluence was completely frozen. Bridging between FA-151 (Portage Creek) and the FA-184 (Watana Dam) remained similar to the observations of the November 15th survey. Heavy frazil concentrations were observed in the Middle River downstream of Devils Canyon, yet significantly lighter concentrations were present upstream of Devils Canyon. Two new bridges were present; one from PRM 172.1-173 (RM 169-170) and another from PRM 183.1-183.6 (RM 179.9-180.8).

December 19th: The Middle River presented intermittent open leads with overflow present at Four of July Creek at PRM 134.4 (RM 131.2). Ice cover progression extended to PRM 145 (RM 141.5). The main channel remained open between PRM 145 (RM 141.5) and FA-151 (Portage Creek) , where the same ice bridge formations remained from prior surveys.

January 9th: Open leads were present in both the Chulitna and Talkeetna Rivers upstream from their respective confluence with the Susitna River. Open water was more prevalent upstream from the Gold Creek Bridge (PRM 140 [RM 136.6]) as the river became narrower and the gradient increased. No visible frazil flow was observed in open sections of the Middle River, yet anchor ice in open leads was present in higher concentrations than the previous survey. Devils Canyon was open with little change in the ice bridges.

2.1.3. 2012 Upper River Observations

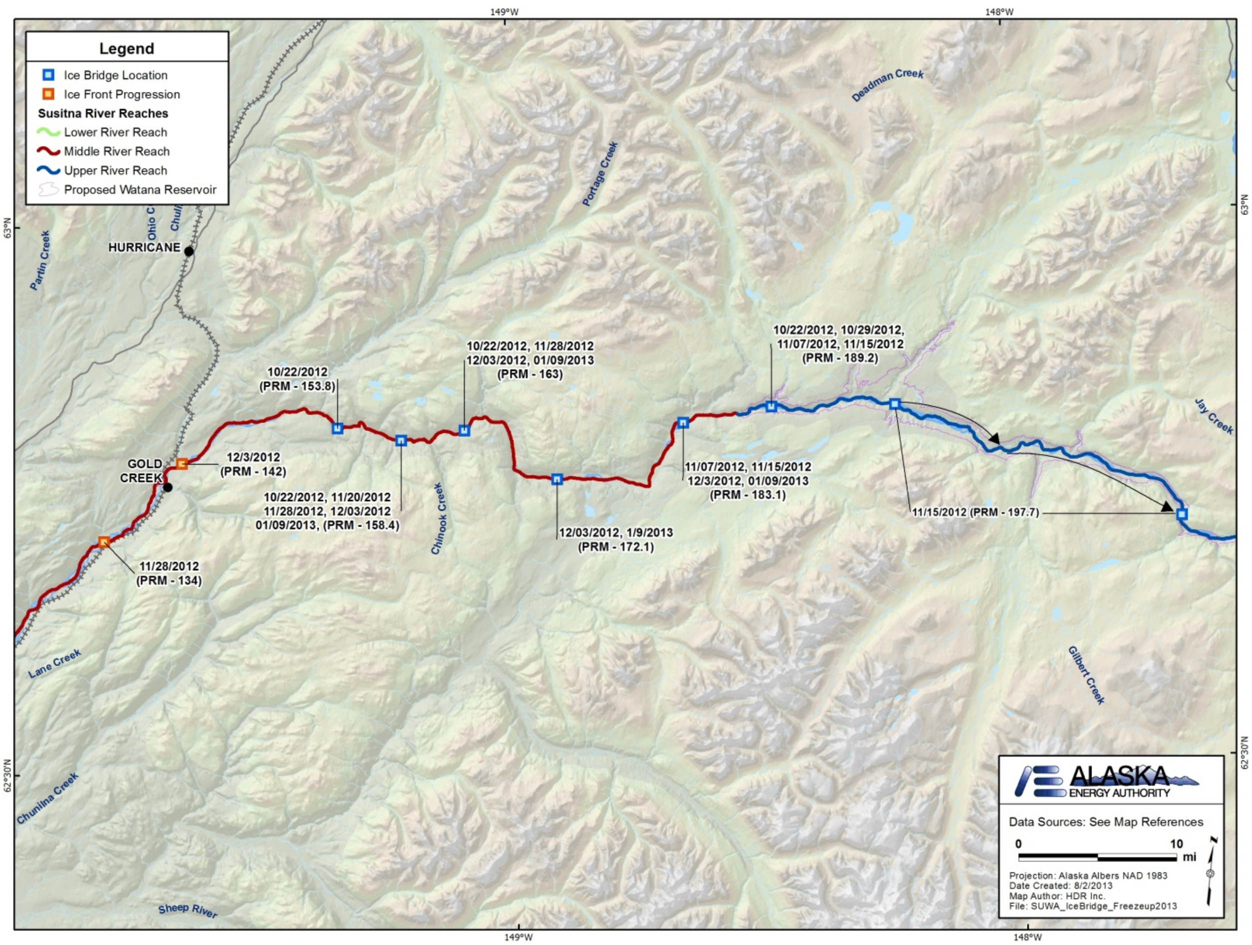

Figure 2.1-8. 2012 Ice Front Progression and Ice Bridge Locations–Upper Susitna River.

October 12th: Frazil ice appeared in the river between FA-151 (Portage Creek) and ESS80 (PRM 224.8 [RM 223]).

October 26th: The same short bridge was seen in the Upper River at PRM 189.2 (RM 186.5).

Nov 1st: A short bridge formed at PRM 224.8 (RM 223).

Nov. 7th: The ice bridge at PRM 224.8 (RM 223) had broken.

November 15th: New ice cover between PRM 195-218 (RM 192.3-215.9) had formed rapidly since the previous survey. Ice loading from an apparent ice jam breakout on the Oshetna River (PRM 235 [RM 233.4]) could have aided the growth of the ice cover at PRM 218 (RM 215.9). This extensive ice cover could have contributed to the low frazil concentrations observed in the Middle River.

Figure 2.1-9. RM 235 (RM 233.4) - Oshetna River confluence and apparent ice-jam breakout flood (brown water coming from Oshetna River). November 15th, 2012.

November 20th: One new ice bridge had formed at PRM 188.4 (RM 185.6) near Deadman Creek, yet no other notable changes occurred to ice bridges in the Upper River.

November 28th: The ice bridge present at Deadman Creek (PRM 189 [RM 186.2]) on November 20th caused ice cover to progress upstream to the extensive ice cover fir observed on November 15th at PRM 195 (RM 192.3), leaving continuous ice cover between PRM 189-223 (RM 186.2-221.1). The Oshetna River (PRM 235 [RM 233.4]) remained open despite cold temperatures on the Upper River.

December 3rd: Watana, Kosina, and Goose Creeks (PRM 197, 209, 233 [RM 194.3, 206.7, 231.6], respectively) were all ice covered, leaving only the Oshetna River (PRM 235 [RM 233.4]) open.

December 19th: The Upper River remained mostly frozen with continuous ice cover between PRM 189-223 (RM 186.2-221.1) with all tributaries completely frozen.

January 9th: Open leads persisted intermittently between the dam site and Oshetna confluence. Many of the mainstem open leads had visible anchor ice, especially near the canyon upstream of Watana Creek (PRM 197 [RM 194.3]). There was no visible frazil ice in any open lead. Small open leads were visible at the confluence of most of the small tributaries. The Susitna River had intermittent open leads downstream of the Oshetna River confluence and this trend seemed to continue upstream of the confluence.

Figure 2.1-10. PRM 217 (RM 214.9) - Anchor ice. January 9th, 2012.

2.2. 2012 Freeze-Up Time-Lapse Camera Monitoring

2.2.1. Lower River Time-Lapse Cameras

PRM 15.1 (RM 10.4), Alexander Slough near Upstream Tidal Influence: The recording began on October 23rd, 2012. On October 23rd, pan ice was covering about 95 percent of the river surface near the shore and 50 percent in the main channel. The next day, October 24th, the pan ice had solidified across the entire channel, except for an open lead near shore. The entire channel was covered by the morning of October 25th and remained covered for the remainder of the monitoring period. The first snow fall appeared on November 9th. There was slight overflow visible on the near shore on November 11th. Snow falls occurred on November 14th and December 8th through December 10th. There was slight overflow visible near the shore on December 13th. A snow fall on December 25th was followed by the ice surface melting due to above-freezing air temperatures starting on December 27th. A snow fall event on January 11th, 2013 was followed by slight overflow on the channel nearest the camera on January 12th and the entire river on January 13th. The recording ended January 18th.

PRM 29.8 (RM 25.7), Susitna Station: The recording began on September 10th, 2012. The daily low air temperature dropped consistently below freezing starting October 12th and the water temperature followed with a rapid decline from 40°F to 32°F over the next week. Frazil and small pan ice was visible October 14th and 15th, 2012, and then the river cleared of all visible ice until the morning of October 17th. Small (less than 1 foot diameter) pans of ice were visible channel-wide on October 17th, covering less than 50 percent of the water surface. The density of the ice pans (still approximately 1 foot in diameter individually) increased by filling in the channel from the near shore out. Shore ice developed at the toe of the bluff on October 19th, while pan ice flowed river-wide. Approximately 95 percent of the river surface was covered by October 22nd and the ice on the far side of the river continued to flow. The river level rose approximately 4.5 feet (sensor data) between October 25th and October 26th. The daily high air temperature remained below freezing for most days beginning October 27th. The channel froze completely on October 26th; though an open lead on the far side of the channel remained until November 9th. The river remained frozen until the recording ended on January 18th.

PRM 64.2 (RM 62), near Rustic Wilderness Side Channel: Moving ice chunks (1-10 feet across and covering approximately 25 percent of the river channel) were seen in the river and shore ice had already formed on the near bank when the recording began on October 19th, 2012. The shore ice width, and the size and density of the pan ice increased through October 30th, with the main channel ice slowing to a stop on October 31st. A channel of open water (approximately 30 feet wide) remained open between the shore ice and the remainder of the main channel (which was now stationary ice chunks). Ice chunks began flowing in the open channel November 5th and began backing up in the open channel on November 9th. The channel froze over completely by the end of the day November 9th. Overflow developed close to the near shore on November 10th and 11th. After a snowfall on January 13th, a small area of overflow developed over the area of the last open channel and remained unchanged until the end of the recording on January 18th.

PRM 91.7 (RM 88.2), Birch Creek: The recording began on October 19th, 2012; snow was visible on the ground and there was no ice visible in the side channel. Ice began to form along the shores of the side channel on October 22nd and advanced and retreated daily until ice clogged the small side channels on October 31st. The channel froze over (except for one small patch of open water) on November 3rd. Water in the channel backed up and rose on November 7th, and then mostly froze over (there was still a small area of open water). There was overflow on the ice on November 11th. The open area froze across November 21st. Overflow developed on January 14th and subsequently froze solid. The recording ended January 18th.

2.2.2. Middle River Time-Lapse Cameras

PRM 104.9 (RM 101), Whiskers Slough – Aquatic Habitat Focus Area 104: Shore ice was visible and pan ice (approximately 80 percent density) was flowing in the slough and main channel from the beginning of the recording on October 26th through the evening of November 16th. By fir light on November 17th the slough had jammed with ice and remained frozen. It appeared that the main channel froze over later in the same day. Small areas of overflow developed after snow falls from December 10th to 13th. A lead appeared downstream of the slough near the bank and remained open, widening to 3 or 4 feet, until the recording ended on January 18th.

PRM 116.7, Slough 6A – Aquatic Habitat Focus Area 115 (ESS45): The recording began on July 27th, 2012. The daily low air temperature dropped consistently below freezing starting October 17th and the water temperature declined from 41°F on October 9th to 32°F by October 12th. The daily high temperature dropped consistently to freezing or below starting October 31st. Frazil ice and shore ice on the near shore were visible on October 13th. The slush ice increased in size to pan ice and increased in quantity to covering approximately 90 percent of the channel by October 20th. The river continued to flow with fairly consistent large sheets until November 9th, when the sheets were replaced with slush ice. The slush ice began forming chunks on November 11th and water levels rose approximately 1 foot (this approximation was made from camera images) and then dropped the next day. The ice chunks began to fill the channel by November 19th. On November 21st, the river rose approximately 6 feet and ice formed from the far shore toward the near shore, leaving only a small center channel. Late on November 22nd, significant overflow developed over the near shore ice as the center channel jammed up. By November 23rd, the river was frozen over. A center lead opened on November 27th and remained open until the end of the recording on January 15th.

PRM 127.9, Slough 8A – Aquatic Habitat Focus Area 128: The slough was completely ice covered and the main channel was flowing with ice at the beginning of the recording on October 23rd, 2012. Snow fell on November 9th, overflow formed on the slough November 11th and the main channel almost completely cleared of flowing ice. On the morning of November 22nd, the river (and slough) level dropped approximately 1 foot back to the original level of October 23rd. On the morning of November 23rd, the ice in the main channel stopped flowing and the water level rose in the slough. Ice chunks clogged the slough at this time, though a small area of open water remained until it froze over on December 8th. A lead appeared to open in the main channel (difficult to see in the images) on January 4th. It appeared to close again by the end of the recording on January 18th.

PRM 132.4, Slough 9: This data from this card was found to be corrupt and no images from freeze-up could be retrieved.

PRM 138.3, Slough 11 – Aquatic Habitat Focus Area 138: The recording began on October 23rd, 2012 and both the slough and the main river channel were flowing with most of the surface covered in frazil ice and some cohesive pans of ice ranging in size from 5 feet to 20 feet. On November 1st, the ice on the surface of the slough stopped moving. The main channel continued to flow with what appeared to be slush ice and pan ice. The water level in the slough rose approximately 2 feet and flowed over the ice surface on November 4th and November 5th. The water level dropped back to its original level on November 7th. After a snow fall on November 14th, the slough was completely frozen over. On November 16th, a small patch of open water opened (and remained open) in the slough on the near side. The open water appeared to be less than 1 foot wide and at lea 10 feet long (its full length was not visible in the captured images). During the night of November 30th and December 1st, the slough rose about 2.5 feet and flowed over the ice surface. This coincided with the flow of ice in the main channel coming to a stop. Though the depth of snow varied, the ice surface appeared to remain consistent from December 1st through the end of the recording on January 18th.

PRM 144.4, Slough 21 – Aquatic Habitat Focus Area 144: The recording began on October 17th. The camera was positioned on a narrow section of an island looking upstream with two sloughs (one on each side of the island) visible in the frame. The slough on the right hand side of the image had some shore ice and no visible flow. It was frozen over by October 31st. The camera was repositioned on November 18th and the slough on the right was no longer visible. At the beginning of the video, some shore ice had formed and slush ice flowed in the slough on the left side of the image. On the morning of October 23rd, the slough clogged with ice upstream of the camera site, leaving some open water below. The open water gradually froze over completely by November 5th. On November 10th the channel partially opened up (approximately 25 percent) and dropped in level by about 1 foot. The channel froze over again by November 12th. On December 5th the channel opened again at the same location until December 8th. On December 9th, the water level rose and the entire slough overflowed to the gravel bars toward the main channel and to the right side of the image. Beginning December 16th, more surface ice became visible, but it was not clear if this was the result of overflow or snow being blown away. A major overflow event on December 22nd and 23rd created a skating rink-like surface from the main channel across the slough and over the island bar into the next slough to the right. This level appeared to remain constant until the image was obscured by snow on January 13th.

PRM 152.2, Portage Creek – Aquatic Habitat Focus Area 151 (ESS55): The recording began on August 9th, 2012. The daily low air temperature dropped consistently below freezing starting October 11th and the water temperature dropped from 40°F to 32°F between October 10th and 14th. The daily high air temperature remained below freezing for most days beginning October 17th. Chunks of ice flowing in the channel were fir visible on the afternoon of October 12th, 2012. Bank ice began to form by the morning of October 13th. Chunks and pans of ice (approximately 3- to 10-feet in diameter) flowed consistently on the far half of the channel. Slush ice appeared in the near side of the channel on October 18th and shore ice grew rapidly, extending approximately 40 feet into the channel by October 23rd. On November 9th, a drop in the river level fractured the shore ice and the edge retreated to within 30 feet of the shore. The edge advanced into the river again on November 14th in conjunction with a rise in water level and remained there until the river level began to rise again on December 4th. The river continued to rise until December 9th, overtopping the shore ice shelf, refreezing, and constricting the river to a narrow open channel on the far bank. The river level rose again on December 28th, overflowing the shore ice and refreezing a smooth layer. The edge of ice on the channel visible at the far side of the river bridges to the far shore on January 8th, leaving an open lead downstream that remained until the video ended on January 15th.

PRM 185.8, Below Deadman Creek near Dam Site – Aquatic Habitat Focus Area 184 (ESS70): The recording began on August 7th, 2012. Slush ice and shore ice were fir visible on the morning of October 12th. Slush and small chunks were visible covering approximately 75 percent of the river. By October 21st slush and pan ice filled approximately 90 percent of the channel and the shore ice began advancing into the main channel, reaching approximately 20 feet into the channel by October 24th. On November 2nd, the river level dropped about 1 foot, and the main channel ice floes stopped, most likely due to an ice bridge formation upstream. The river flowed with mainly slush ice and the shore ice continued growing outward again from November 3rd, reaching approximately 40 feet into the channel by November 7th. On November 9th, the river began to rise and overflowed the shore ice. At noon on November 10th, the river had risen about 2 feet and the center channel had filled with ice that had stopped flowing. By November 10th, the river flowed over the ice and opened a channel in the middle of the river again. It appears the water height sensor became inoperable at this time. On the morning of November 11th, the river was once again open and had dropped, leaving a shelf of shore ice approximately 20 feet wide. The river flowed mostly clear until November 17th, when slush was again visible. Shore ice began to advance into the river and choked off the entire main channel, except for a narrow channel on the far side. The river rose slightly and overflowed the ice on November 30th, December 5th, December 10th, and December 14th. Between December 14th and December 20th, the river became frozen over its entire width, yet the freeze-over was not observed due to corrupt image files. Overflow appeared on the near shore on December 22nd and spread across the river by December 25th. The recording ended on January 15th.

2.2.3. Upper River Time-Lapse Cameras

There were no time-lapse cameras present in the Upper River during 2012 freeze-up.

3. OPEN LEAD MAPPING

3.1. Lower River Mapping

March 21, 2012: The River was mostly frozen over. There was a lot of snow (3-6 feet) on top of ice that appeared to be less than one foot thick in areas where it could be observed on the ground near shallow open leads. The thermal leads were often at the toe of banks or adjacent to mid-channel bars. Some thermal leads appeared as a narrow and sinuous or threaded pattern. Many side channels and sloughs had evidence of thermal open water areas. Velocity leads were uncommon downstream of Talkeetna. Open water leads most commonly seen were thermal leads. The leads were generally thin and braided in side channels and sloughs. Human and moose activity were apparent on the river as snowmachine and moose tracks were observed crossing the river and using the river for a transportation corridor.

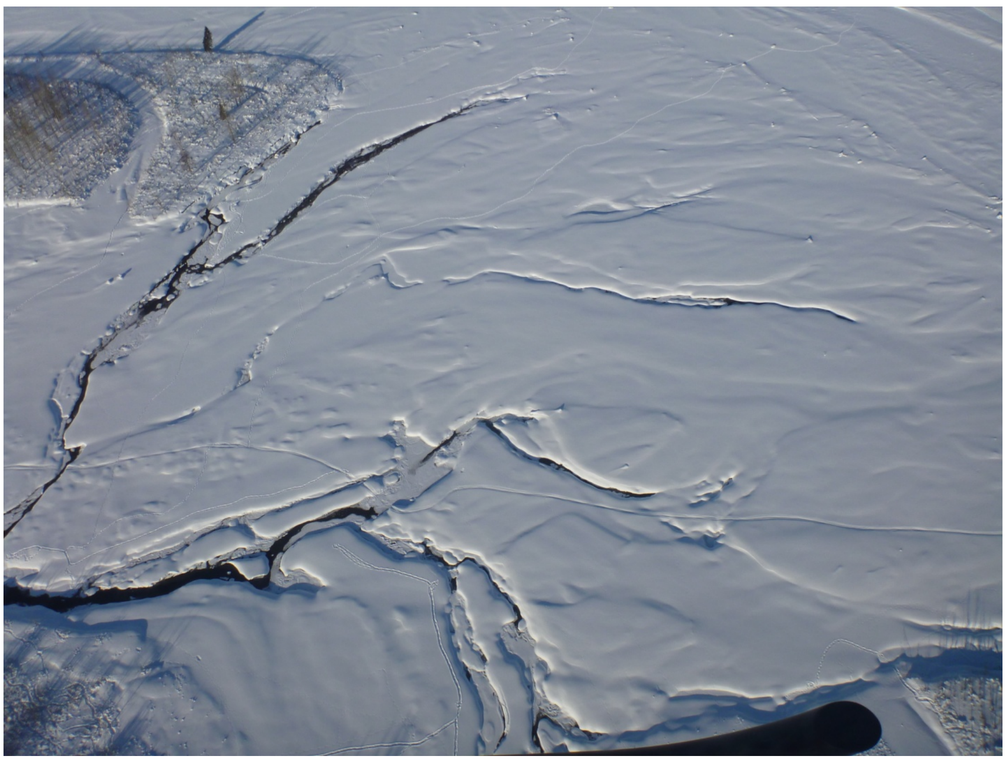

Figure 3.1-1. PRM 49 (RM54) - Photo of threaded pattern of open water thermal leads on the Susitna River. Flow is from right to left in this photo. March 21st, 2012.

March 12, 2013: Downstream of the Yentna River confluence the Susitna River was mostly ice covered outside of thermal leads in Alexander Slough and Creek. The frequency of leads increased upstream of the Yentna with several velocity leads in the main channel and numerous thermal leads in side channels and sloughs. The greatest concentration of velocity leads on the lower river was in the Talkeetna area. There were few open leads between the mouth of the Susitna River and the Yentna River confluence, with the exception of the Alexander Slough area, which had numerous thermal leads. There were a few short velocity leads in the main channel that had persisted since ice cover formed in October, and a few short thermal leads associated with the bank toe or side channels. The number of open leads increased around the Yentna River confluence, with several velocity leads in the main channel along the confluence area. Upstream of the confluence, through the Delta Islands reach, the left-bank main braids had numerous small thermal leads, while the right-bank main braid had numerous velocity leads and a few thermal leads at the margins of gravel bars. A long side channel on the left-bank of the braid plain from Little Willow Creek to 197½ Mile Creek (PRM 54 to PRM 64) had numerous thermal leads, while the main channel braid along the right-bank bank had numerous short velocity leads. A larger velocity lead with broken ice occupied the main channel thalweg at PRM 81.5. Long thermal leads occurred in the Sunshine Slough complex, Birch Creek Slough complex, and Trapper Creek confluence area. The Talkeetna area had the greatest concentration of velocity leads in the Lower River. These were also the widest velocity leads. These leads formed shortly after freeze-up had progressed past Talkeetna and slowly decreased in length over the course of the winter as frazil and anchor ice accumulated in them.

Figure 3.1-2. PRM 89 (RM 85.3) – Thermal lead in Sunshine Slough. March 12th, 2013.

3.2. Middle River Mapping:

March 22, 2012: The River was mostly covered with snow and there were no snow machine tracks on the river. Most of the open leads in the middle river were thermally derived and were located at the edge of the bank or in side channels and sloughs areas. The ice in these areas was observed to be generally less than one foot thick at the edges of thermal lead areas. Approximately 40% of the leads had a thin layer of clear ice and had small open water sections. As seen on the 21st of March, some thermal leads had a thread-like pattern. Velocity leads were uncommon downstream of Devil Canyon and prevalent through Devils Canyon. The shelf ice was quite thick through parts of Devils Canyon and in some places appeared to be more than 10 feet thick (later surveys confirmed this).

Figure 3.2-1. PRM 149.4 (RM146) - Thermal lead on river right and a velocity lead on river left near Susitna. Note that flow is from top to bottom in this photo and river right and river left are with respect to flow. March 22nd, 2012.

March 12, 2013: Downstream of Devils Canyon most sloughs had open thermal leads and the mouths of most tributaries were open. There were intermittent velocity leads along the main channel downstream of the canyon and long stretches of open water within the canyon. Upstream of Devils Canyon there were fewer velocity leads. Most thermal leads were concentrated in side sloughs and upland sloughs. Whiskers Slough and Whiskers Creek entrance had extensive thermal leads, along with Slough 1, Slough 6A, Slough 8A, Slough 9, Slough 11, and Slough 21. Tributary mouths were associated with open leads, including Lane Creek, Indian River, and Portage Creek. All other sloughs and tributary mouths were ice covered. There were intermittent velocity leads throughout the main channel downstream of Devils Canyon and long stretches of open water over the rapids in Devils Canyon. Upstream of Devil Canyon there were a few velocity leads and thermal leads associated with the Fog and Tsusena Creek confluences, but overall fewer open leads than in the Middle River downstream of Devil Canyon.

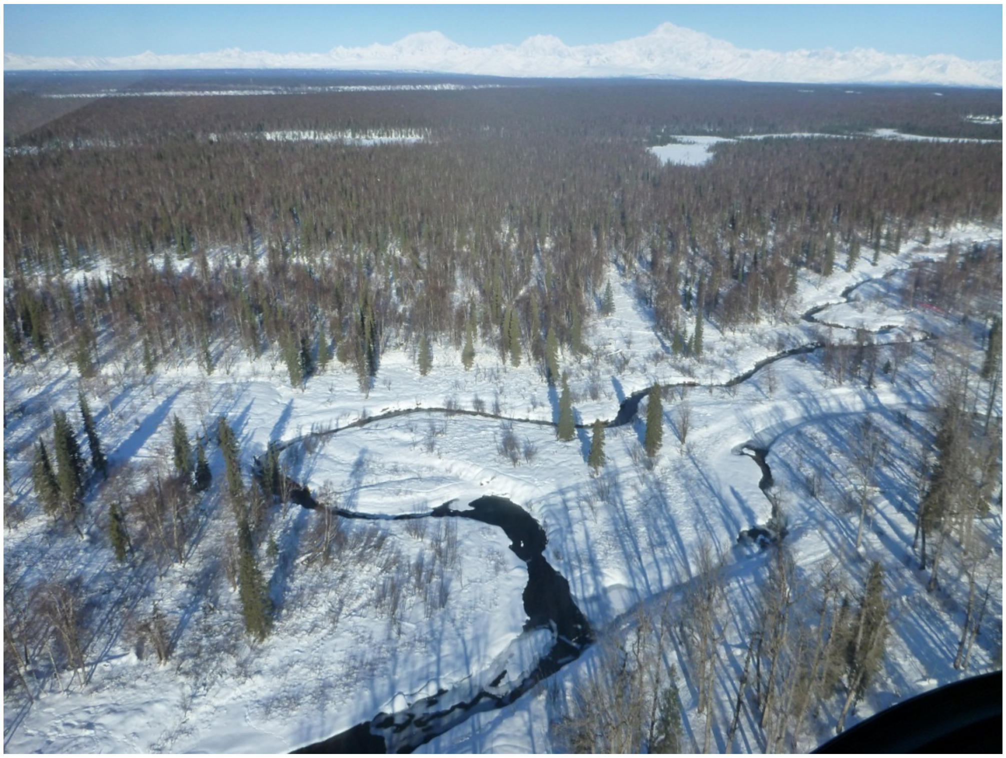

Figure 3.2-2. PRM 105.5 (RM 101.6) - Thermal leads in Whiskers Creek where it joins Whiskers Slough. March 12th, 2013.

3.3. Upper River Mapping:

April 4, 2013: The River was mostly covered with snow and there were fewer velocity leads in this section of the upper river than there were in the middle and lower river sections on previous days. The velocity leads in the upper river were generally smaller than velocity leads in the lower sections, with the exception of the long velocity lead downstream of PRM 184.7 (RM 182). There were fewer thermal leads in the upper river compared to the middle and Lower River on previous flights, and they were mostly located at the toes of banks through this section of river. Between approximately PRM 208.3 (RM 206) and PRM 214.3 (RM 212) there was a section of river where there was evidence of an old river-wide ice jam.

Figure 3.3-1. PRM 184.7 (RM 182) - A long velocity lead on the Susitna River. Flow is from bottom to top in this photo. April 4th, 2012.

March 12, 2013: There were fewer open leads in the upper river. Velocity leads were present downstream of Deadman Creek and the Oshetna River and thermal leads appeared at confluences. The Upper River had fewer leads than the middle or lower segments. There were multiple velocity leads just downstream of Deadman Creek in Vee Canyon, and around the Oshetna River confluence. Open leads in this reach were mainly associated with creek confluences; it was likely that leads in these areas originated both from turbulent flow and thermal input associated with tributary deltas. Seeps along the river banks were apparent, but instead of thermal leads, they appeared as large icings just above river level rather than upwelling in the channel.

Figure 3.3-2. PRM 236 (RM 234.7) - Velocity leads at the Oshetna River confluence. March 12th, 2013.

4. LOWER RIVER HEC-RAS MODELING

4.1. Discharge and Temperature Data

Two sections of the Lower River were modeled under steady state conditions using the US Army Corps of Engineers HEC-RAS model (Hydrological Engineering Center – River Analysis System); near Sunshine (PRM 80-86) and at Susitna Station (PRM 30). In order to assess the large natural variation in discharge that occurs during freeze-up on the Susitna River, the reconstructed discharge data for the USGS gages at Susitna Station and Sunshine as described by Curran 2012 was utilized for the period of 1950 to 2010. Table 4.1.1 below shows the range of dates of actual and reconstructed discharge data for these gages as well as the USGS gage at Gold Creek.

Table 4.1-1 USGS gage records for Susitna Station and Sunshine

Gage name	USGS number	Observed data	Reconstructed data
Susitna River at Susitna Station	USGS 15294350	1974-1993, 2013-present	1950-1974, 1993-2010
Susitna River at Sunshine	USGS 15292780	1981-1986, 2011-present	1950-1981, 1986-2010
Susitna River at Gold Creek	USGS 15292000	1949-1996, 2001-present	1996-2001

Daily air temperature records for the Talkeetna Airport were used to determine the beginning of the freeze-up period for each year. Based on historic ice cover observations in 1980-1985, 2012, and 2013, the river ice cover reaches Talkeetna (freezes over at Talkeetna) after the accumulation of approximately 175 freezing degree days (degrees F) following the onset of subfreezing air temperatures. The beginning of the freeze-up period can occur as early as October 5th or as late as December 11th each year resulting in a wide range of discharge in the Susitna River during the freeze-up period. Figure 4.1-1 shows the discharge at the USGS Susitna River at Susitna Station gage (USGS 15294350) on both the date of the beginning of the freeze-up period (diamonds) and the date when the ice cover had progressed to Talkeetna (circles) for Water Year 1950-2010. Similarly, Figure 4.1-2 shows the discharge at the USGS Susitna River at Sunshine gage (USGS 15292780) and Figure 4.1-3 shows the discharge at the USGS Susitna River at Gold Creek (USGS 15292000). The figures show the natural variability in discharge during the freeze-up period.

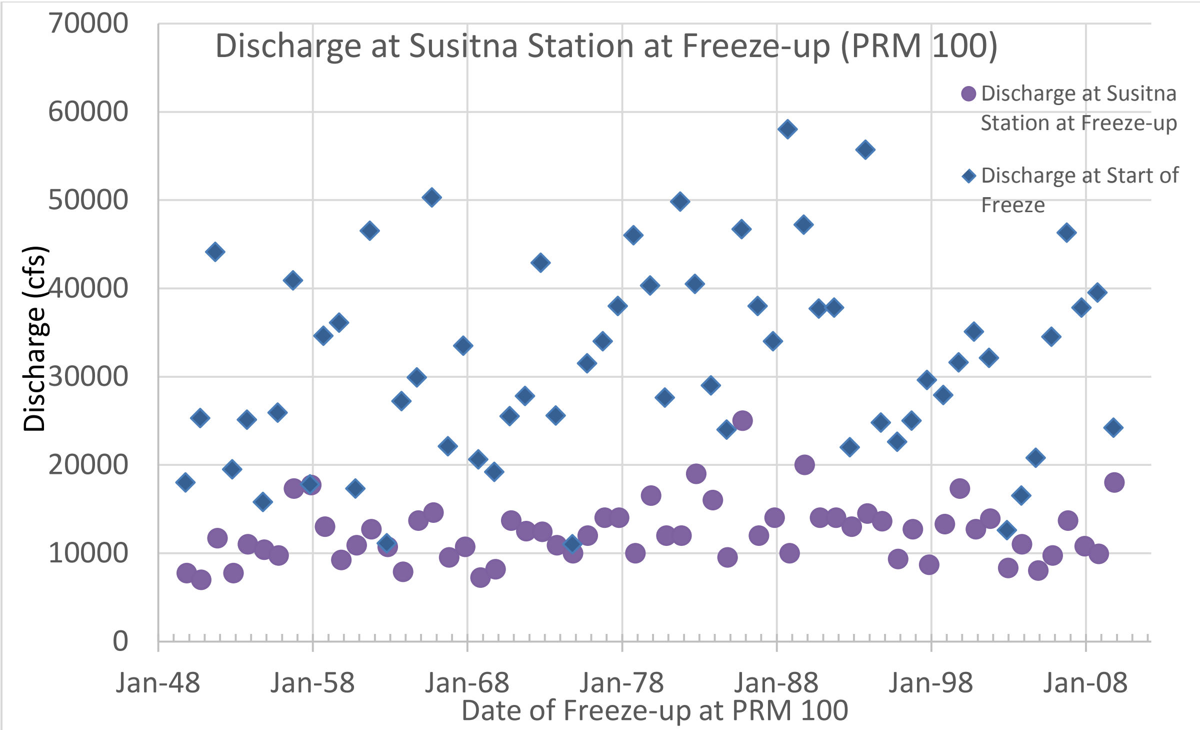

Figure 4.1-1. Discharge at the USGS Susitna River at Susitna Station gage at the start of the freeze-up period (diamonds) and when the ice cover reaches PRM 100 (circles).

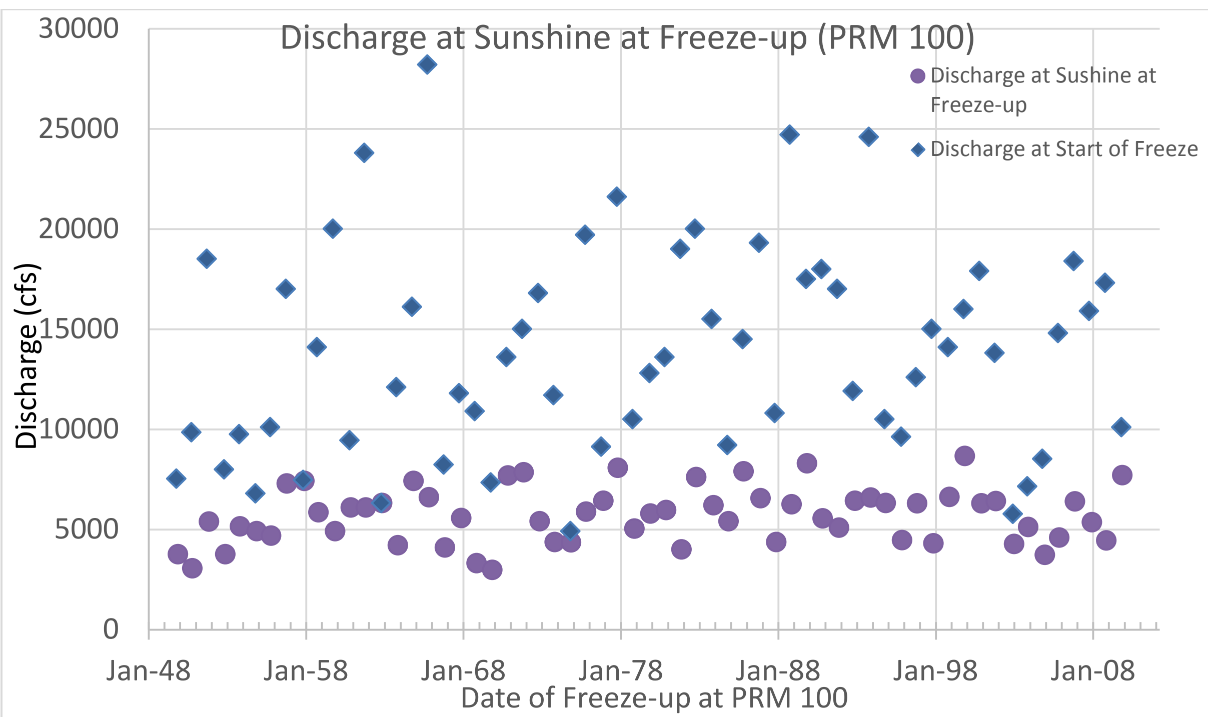

Figure 4.1-2. Discharge at the USGS Susitna River at Sunshine gage at the start of the freeze-up period (diamonds) and when the ice cover reaches PRM 100 (circles).

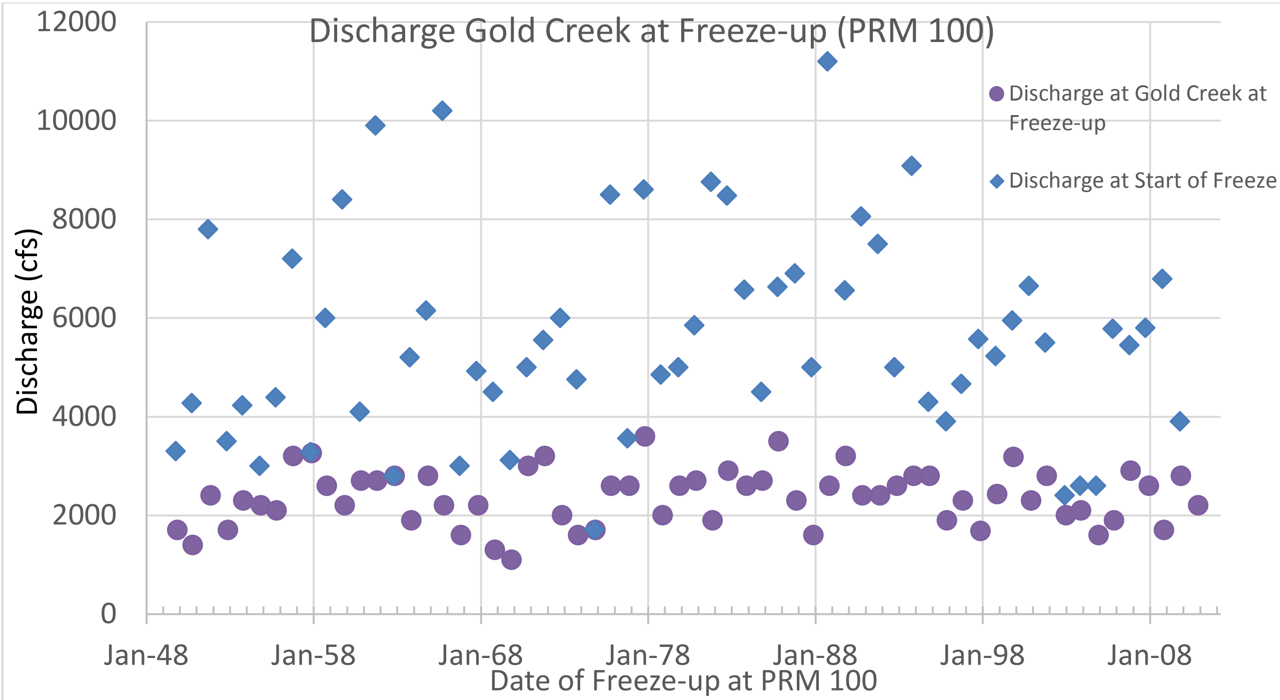

Figure 4.1-3. Discharge at the USGS Susitna River at Gold Creek gage at the start of the freeze-up period (diamonds) and when the ice cover reaches PRM 100 (circles).

4.2. HEC-RAS Modeling at Sunshine

At the beginning of the freeze-up period, the river at Sunshine is flowing open with some minor amounts of frazil ice flowing unimpeded downstream. The natural discharge under these conditions (based on the reconstructed data for 1950–2010) ranges from 5,000 to 28,000 cfs. By the time the freeze-up is completed at Sunshine, the river is covered with a static ice surface formed of accumulated frazil pans and slush. The side channels are fairly smooth and freeze over first while the main channel is slightly rougher, considered to be more of a freeze-up jam accumulation. The discharge recedes during the freeze-up process and when the ice cover reaches Talkeetna, the discharge naturally ranges from 3,000 to 8,000 cfs at Sunshine. HEC-RAS was used to simulate these flow conditions as well as the impacts of both ice cover formation and the proposed increase in winter discharge levels associated with project operation.

Figure 4.2-1 shows a profile plot of the modeled water levels depicting the range of natural conditions at the beginning of freeze-up, simulated as open water at a range of discharge from 5,000 to 28,000 cfs. The results indicate a stage (for a representative cross-section about midway through the modeled Sunshine reach) of 243.8 to 250.2 ft. at the beginning of freeze-up, corresponding to a discharge of 5,000 to 28,000 cfs at Sunshine.

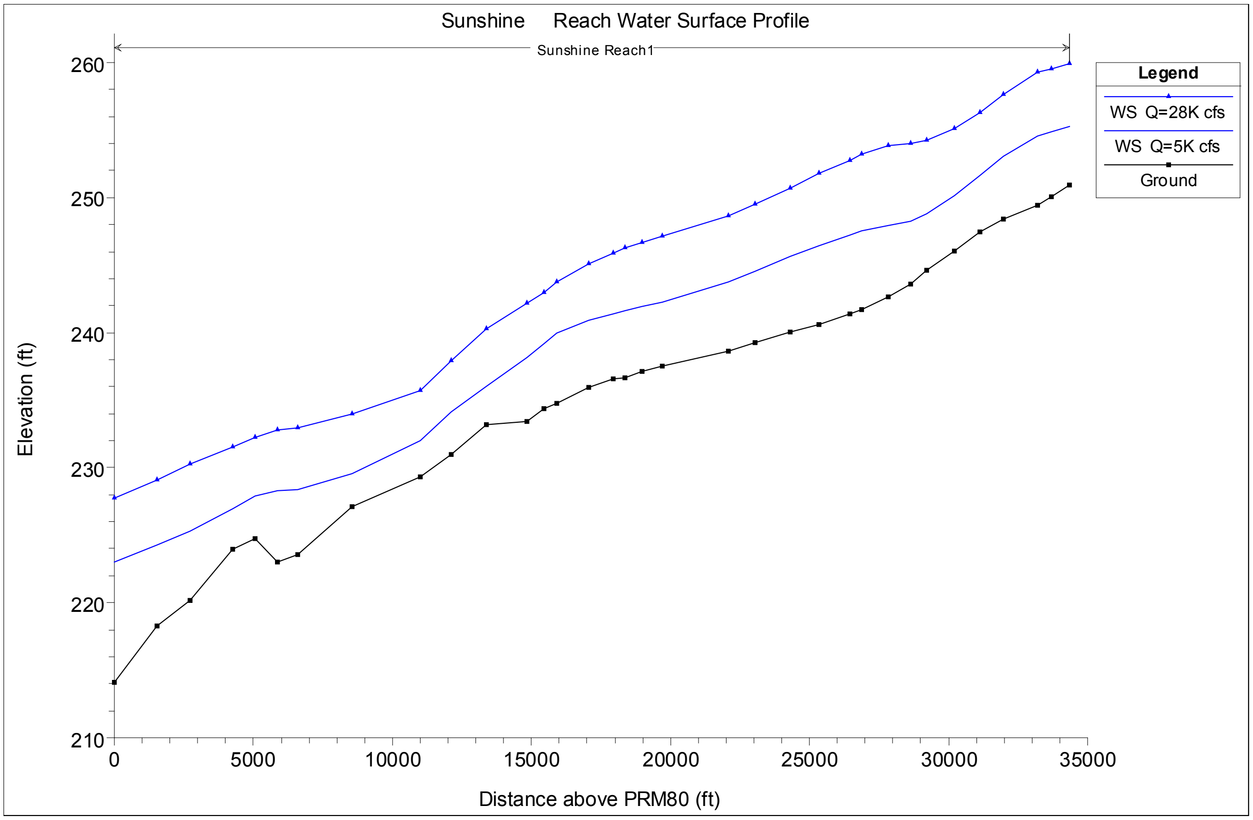

Figure 4.2-1. HEC-RAS profile plot of the modeled reach near Sunshine at the start of the freeze-up period at discharge levels of 5,000 and 28,000 cfs.

The range of natural ice conditions at the completion of the freeze-up period was simulated using HEC-RAS and assuming ice jammed conditions at a range of discharge from 3,000 to 8,000 cfs. Figure 4.2-2 shows these results that indicate a stage of 246.2 to 249.1 ft., corresponding to a discharge of 3,000 to 8,000 cfs at Sunshine with an ice cover thickness ranging from 2.7 to 3.7 ft. thick, respectively.

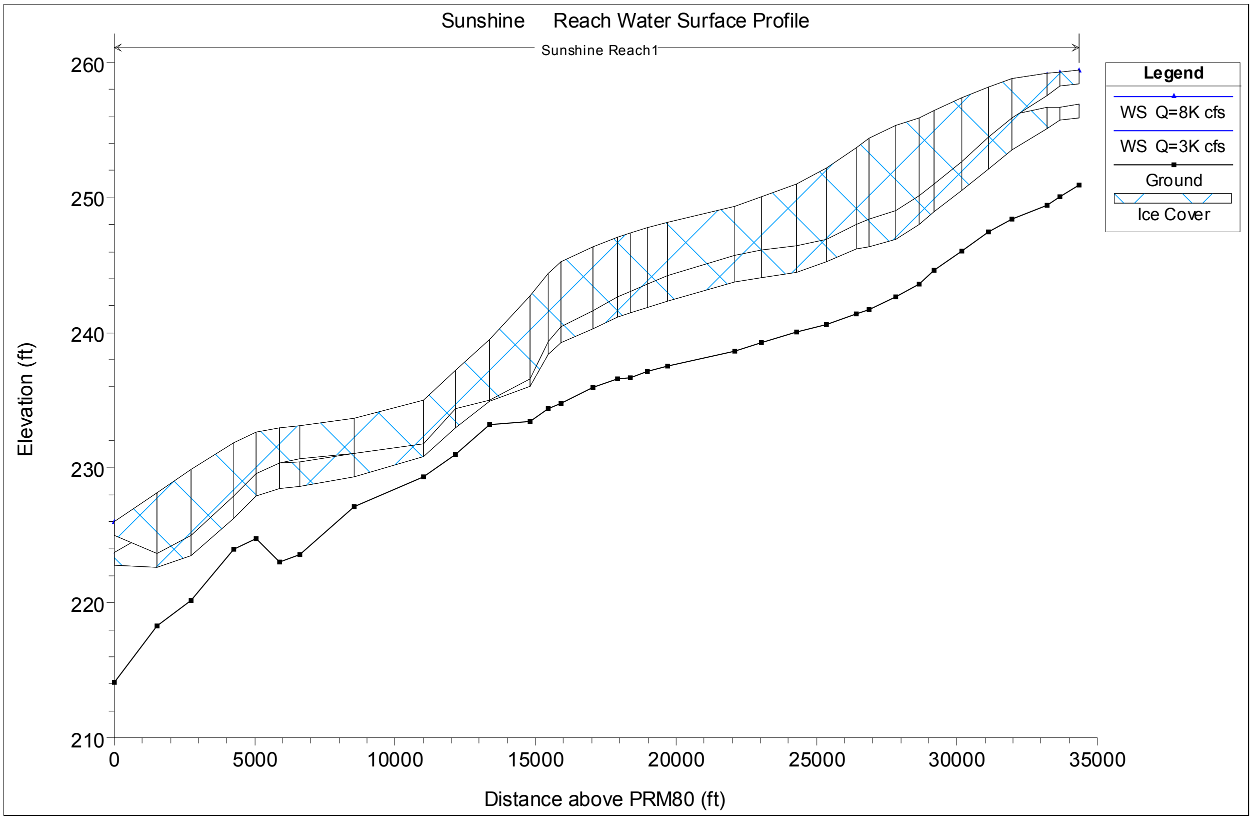

Figure 4.2-2. HEC-RAS profile plot of the modeled reach near Sunshine at the completion of the freeze-up period at discharge levels of 3,000 and 8,000 cfs with an ice jam.

Finally, additional ice jammed conditions were modeled to simulate the effects of increased winter project flows at discharges of 10,000 and 12,000 cfs (all discharge levels at Sunshine). Figure 4.2-3 provides plots of the HEC-RAS output for these conditions. Increasing the modeled discharge to 10,000 and 12,000 cfs results in a stage of 249.8 and 250.4 ft. with ice cover thicknesses of 4.0 and 4.2 ft., respectively. These levels are approximately 1.3 ft over the natural range of water levels once an ice cover is established at the end of the freeze-up period and about equal to the natural range of water levels at the beginning of the freeze-up period. All elevations reported are ft above mean sea level (NAVD88).

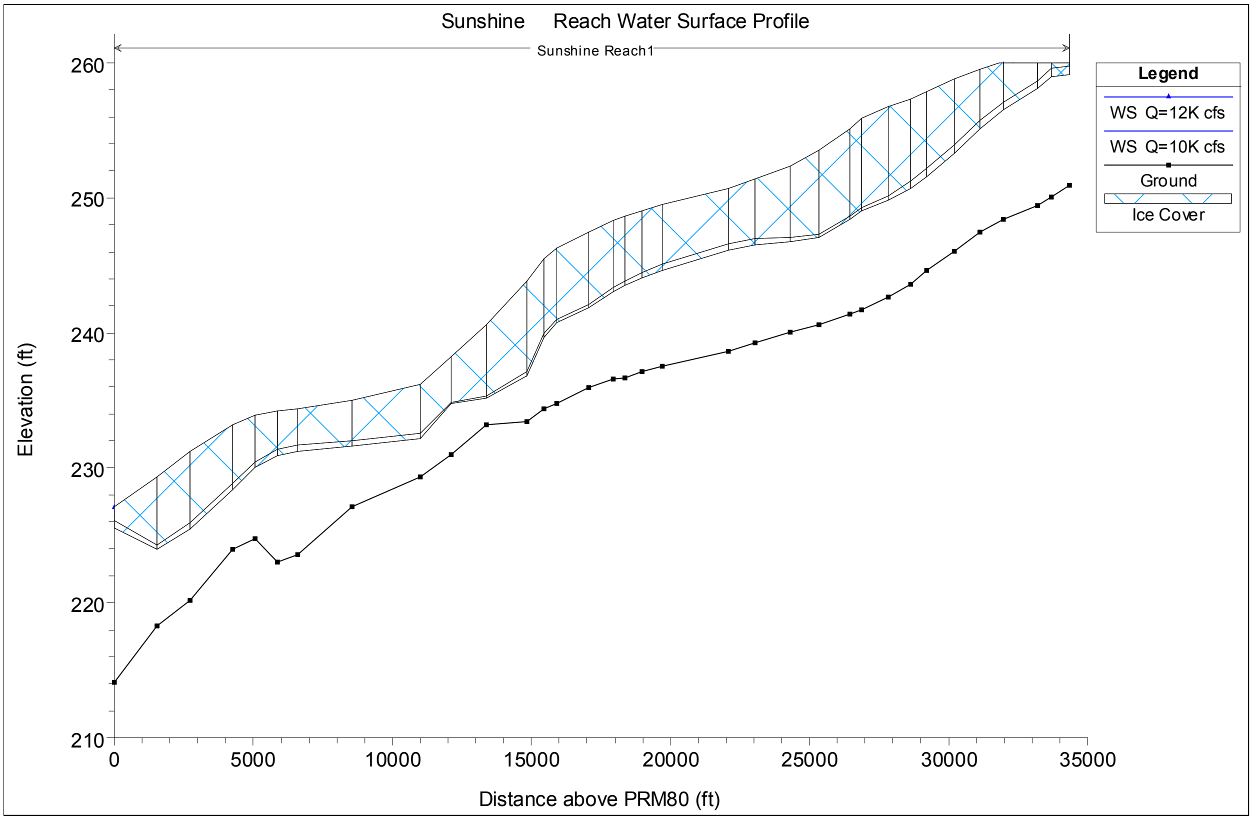

Figure 4.2-3. HEC-RAS profile plot of the modeled reach near Sunshine at the completion of the freeze-up period at discharge levels of 10,000 and 12,000 cfs with an ice jam.

4.3. HEC-RAS Modeling at Susitna Station

A similar modeling effort was conducted to simulate conditions at Susitna Station at PRM 30 (RM 25.9). At the beginning of the freeze-up period at Susitna Station, the river is flowing open with some minor amounts of frazil ice with natural discharge ranging (based on the reconstructed data for 1950–2010) from 11,000 to 58,000 cfs. By the time the freeze-up is completed at Susitna Station, the river is also covered with a static ice surface formed of accumulated frazil pans and slush, typical of a smooth freeze-up jam accumulation. The discharge recedes during the freeze-up process and by the time that the ice cover reaches Talkeetna, naturally ranges from 6,950 to 25,000 cfs. HEC-RAS was used to simulate these flow conditions as well as the impacts of both ice cover formation and the proposed increase in winter discharge levels associated with project operation.

Figure 4.3-1 shows the modeled results for the current range of natural conditions at the beginning of freeze-up, simulated as open water at a range of discharge from 11,000 to 58,000 cfs. The model results indicate a stage (at the USGS gage site) of 32.7 to 39.0 ft. at the beginning of freeze-up, corresponding to a discharge of 11,000 to 58,000 cfs, respectively at Susitna Station.

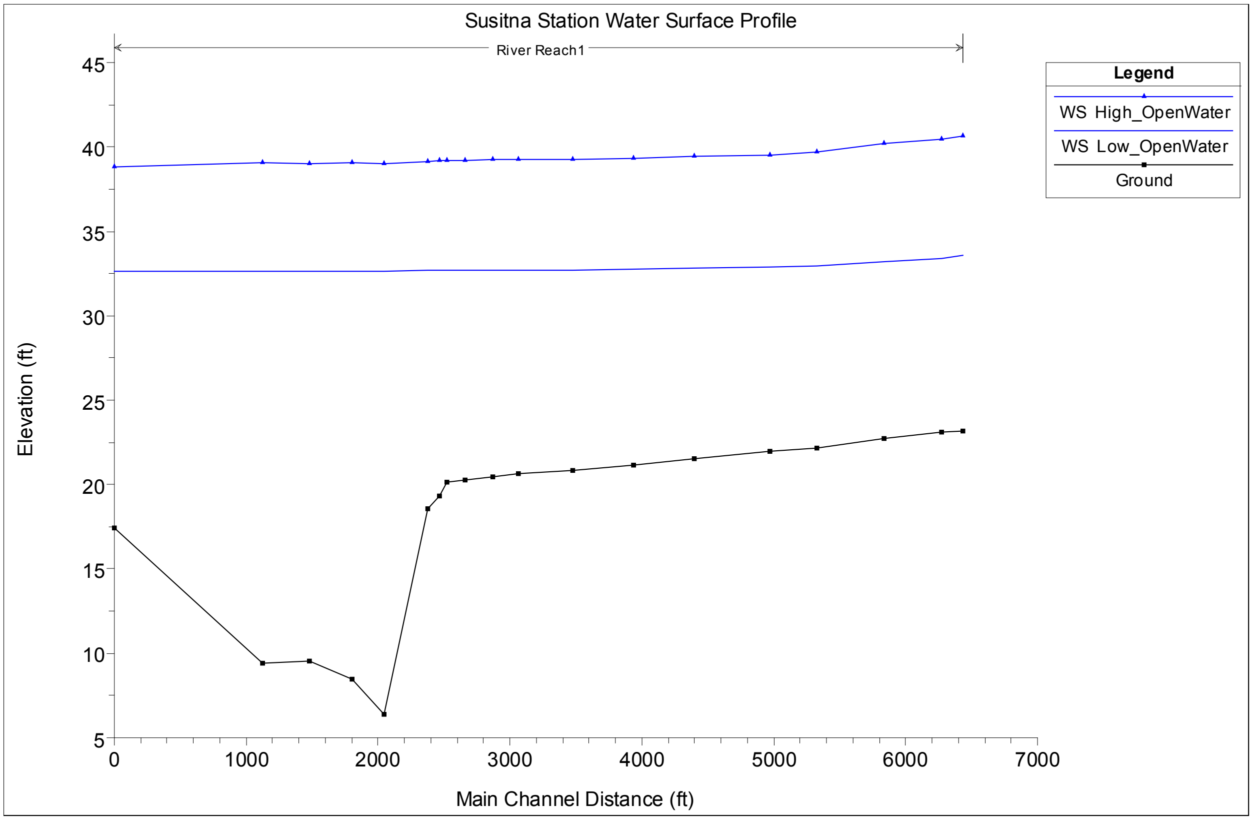

Figure 4.3-1. HEC-RAS profile plot of the modeled reach at Susitna Station at the start of the freeze-up period at discharge levels of 11,000 and 58,000 cfs.

Figure 4.3-2 shows the range of natural ice conditions at the completion of the freeze-up period and was simulated as ice jammed conditions at a range of discharge from 7,000 to 25,000 cfs. Following freeze-up and establishment of an ice cover, the results indicate a stage of 31.4 to 38.7 ft., corresponding to a discharge of 7,000 to 25,000 cfs at Susitna Station with an ice cover.

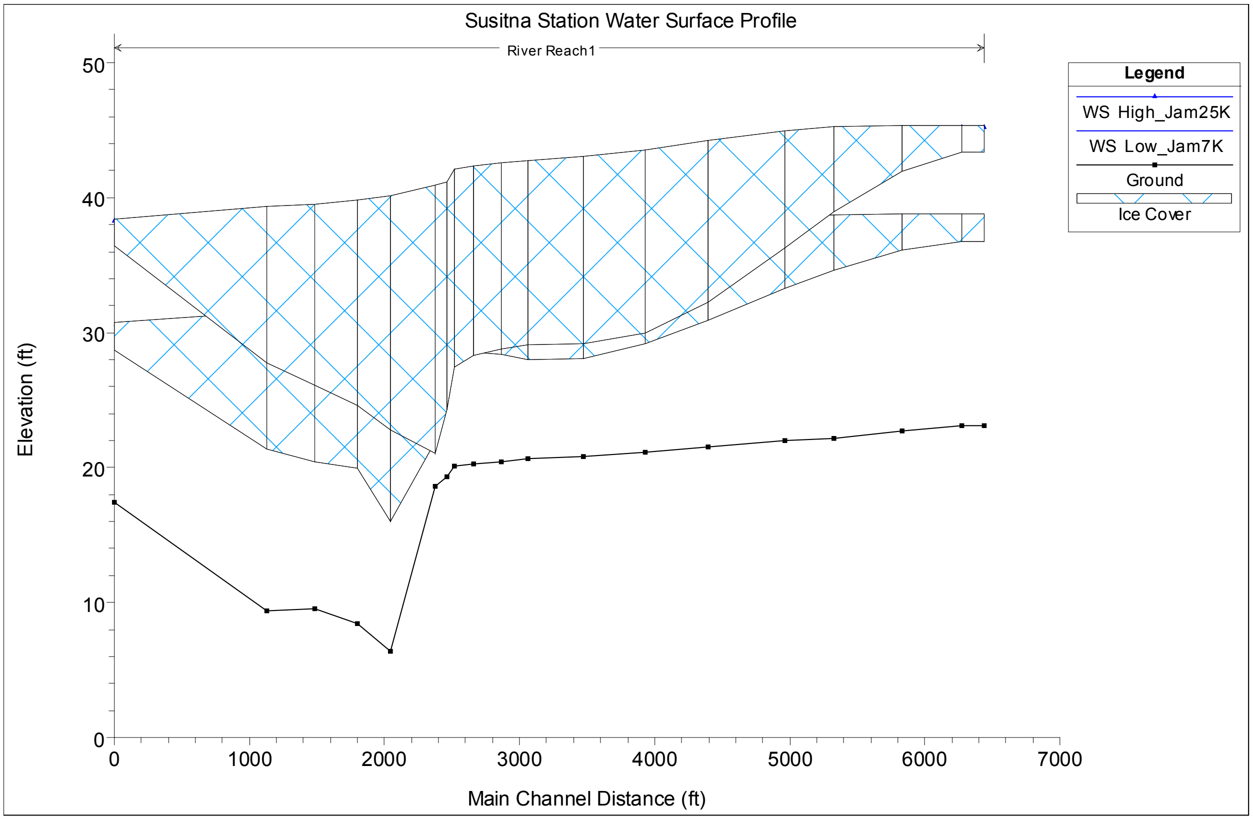

Figure 4.3-2. HEC-RAS profile plot of the modeled reach at Susitna Station at the completion of the freeze-up period at discharge levels of 7,000 to 25,000 cfs.

Finally, additional ice jammed conditions were modeled to simulate the effects of increased winter project flows at discharges of 30,000 and 35,000 cfs (all discharge levels at Susitna Station). Figure 4.3-3 shows the results of this modeling and that increasing the modeled discharge to 30,000 and 35,000 cfs results in a stage of 40.0 and 41.1 ft., respectively. Elevations are ft above mean sea level (NAVD88).

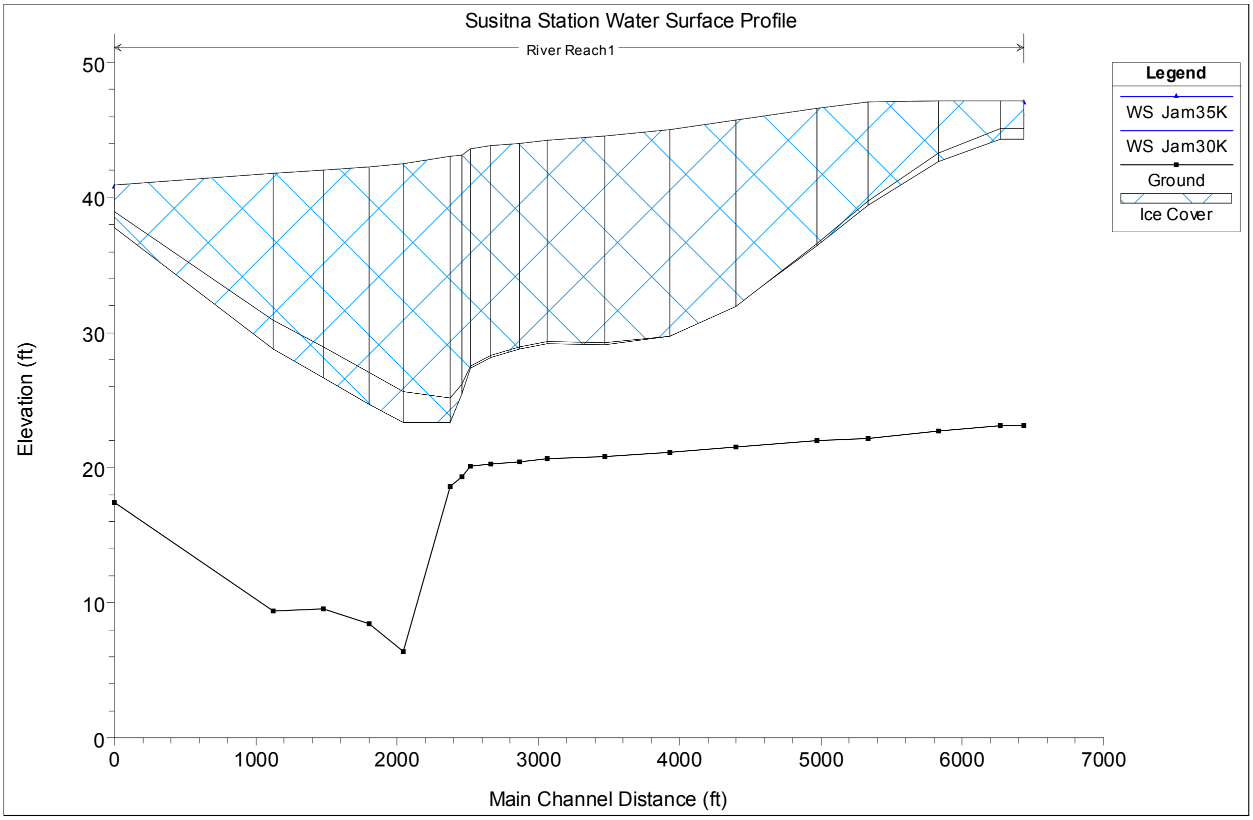

Figure 4.3-3. HEC-RAS profile plot of the modeled reach at Susitna Station at the completion of the freeze-up period at discharge levels of 30,000 to 35,000 cfs.

The short modeling length of this HEC-RAS simulation reach coupled with the deep hole located just downstream of the USGS gage site results in ice jam thicknesses that appear overly large. In reality, this deep hole continually fills with frazil ice all winter leading to the very thick frazil accumulations refered to in Appendix B.

The USGS gage at Susitna Station also corresponds to the location of ESS20; both stage recording stations providing direct observations of the stage increase due to the progression of the ice cover through this reach. The USGS gage at Susitna Station reports a stage reading referenced to a vertical datum that is approximately 28.2 ft above mean sea level (NAVD88) while ESS20 reports elevations referenced to mean sea level (as in the HEC-RAS plots above). As a check on the accuracy of the HEC-RAS models of this reach, the hydrograph of ESS20 for the freeze-up period in 2012 is presented in Figure 4.3-4. The figure shows that the 2012 freeze-up period actually exceeded the natural range of discharge over 1950-2010 for both the beginning of the freeze-up period (Q = 62,000 cfs) and when the freeze-up was complete at Talkeetna (Q = 33,000 cfs). The stage at the beginning of freeze-up was 39.3 ft., just above that shown in Figure 4.3-1 for a Q of 58,000 cfs. Also, after the ice cover progressed past ESS20, with a rise in stage of 4.8 ft., the resulting stage with an ice jam/cover at Q = 33,000 cfs was 41.1 ft. This is the same stage as was simulated at the site with a q of 35,000 cfs and an ice jam. Finally, Figure 4.3-4 shows the gradual drop of the stage as winter progresses with the stage in late December at 36 ft., or approximately 5 ft. lower than the stage when the ice cover progresses through this reach (late December Q of 9,000 cfs).

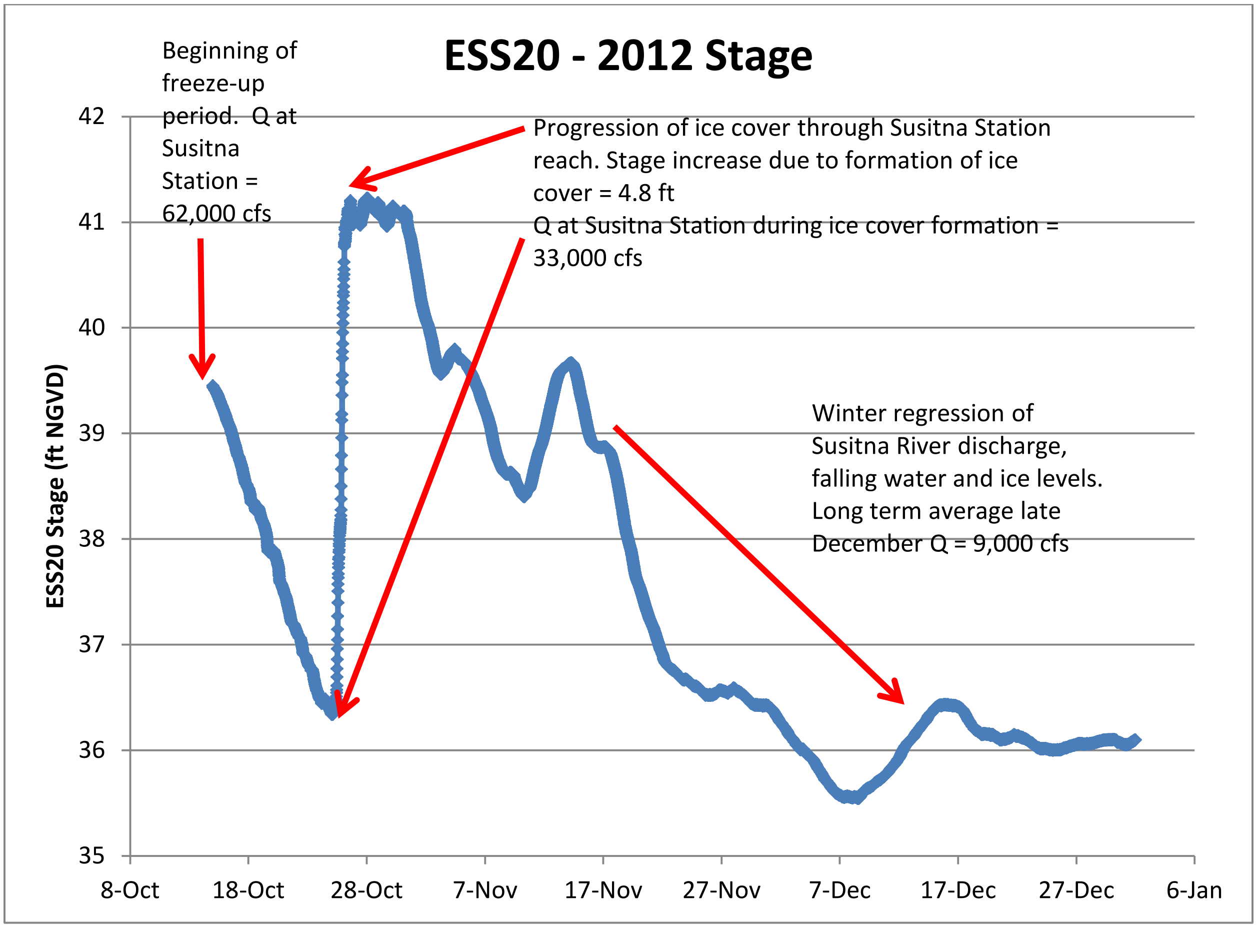

Figure 4.3-4. Hydrograph of ESS20 during the freeze-up period in 2012 with discharge at various times annotated.

Susitna-Watana Hydroelectric Project
(FERC No. 14241)

Ice Processes in the Susitna River Study (7.6)

Part A - Appendix B
2013 Ice Field Measurements

Initial Study Report

Prepared for

Alaska Energy Authority

SUSITNA-WATANA HYDRO

Clean, reliable energy for the next 100 years.

Prepared by

HDR Alaska, Inc.

June 2014

CONTENTS

TABLES

FIGURES

1. INTRODUCTION

The Ice Processes Team collected ice thickness and elevation measurements as well as discharge data on the Susitna River in support of the Ice Processes on the Susitna River Study (Study 7.6) during the winter of 2012-2013. This baseline study is part of the feasibility study for the Susitna-Watana hydroelectric project funded by the Alaska Energy Authority (AEA). This Appendix B describes the methods used to characterize the ice cover along the Susitna River and the results of the surveys.

2. STUDY OBJECTIVES

The objective of the work carried out during the winter of 2012-2013 was to provide information on the existing state of the ice cover and to help calibrate a predictive model of ice processes that is being developed for the Middle River. In support of this task the following parameters were measured at ten locations corresponding to the telemetered ESS stations installed in 2012 by the Fish and Aquatics Instream Flow Study (Study 8.5):

- Ice thickness, including the depth of frazil ice where present
- Elevation of the ice and water surfaces
- Snow depth
- Discharge, collected at three of these ten ESS stations

The ESS stations are those located at the PRM listed below:

- PRM 30.1 (RM 26) – Susitna River at Susitna Station (ESS20)
- PRM 99.4 (RM 96) – Susitna River near Twister Creek (ESS30)
- PRM 101.8 (RM 98) – Susitna River near Chulitna River (ESS35)
- PRM 106.8 (RM 103) – Susitna River above Whiskers Creek (ESS40)
- PRM 116.7 (RM 113) – Susitna River below Lane Creek (ESS45)
- PRM 124.4 (RM 121) – Susitna River at Curry (ESS50)
- PRM 152.5 (RM 149) – Susitna River below Portage Creek (ESS55)
- PRM 168.3 (RM 165) – Susitna River near Devil Creek (ESS60)
- PRM 179.2 (RM 176.5) – Susitna River near Fog Creek (ESS65)
- PRM 186.8 (RM 184) – Susitna River below Deadman Creek (ESS70)

3. STUDY AREA

Field measurements were collected by two Ice Processes teams; HDR Alaska, Inc. and Brailey Hydrologic. The ten study sites listed above on the mainstem of the Susitna River, spanned from Susitna Station (ESS20) (PRM 30.1 [RM 26])to just downstream of Deadman Creek (ESS70) (PRM 186.8 [RM 184]). Two stations were located on the Lower River and eight on the Middle River. The USGS conducted discharge measurements at three sites not visited by either Ice Processes field team. These are long term discharge measurement locations associated with gaging stations (one located on the Lower River, and two on the Middle River). A summary of the dates of thickness, elevation, and discharge measurements by the HDR Alaska, Inc. field team is provided in Table 3.1-1.

4. METHODS

HDR Alaska, Inc. field teams conducted two thickness and elevation measurement campaigns in late January and early- to mid-March using helicopter support to access sites. Brailey Hydrologic collected ice thickness, elevation, and discharge data during January and April field events, while USGS collected discharge at several sites in January and March.

4.1. Elevation

Ice and water surface elevations were tied into the project datum using temporary benchmarks (TBM's) installed by Geovera in 2012 (Figure 4.1-1). At each measurement site, a safe transect was located near a TBM and marked out in the snow, then the field team located 5 to 10 areas of changing topography to create a picture of ice conditions across the transect. The field team dug down to the ice surface and used an 8-inch gas-powered auger to drill through the ice cover. Using the TBM at a known elevation, the group used a survey level and rod to calculate the elevations of the snow, ice, and water surfaces at each auger hole (Figure 4.1-2). A GPS waypoint was taken with each elevation measurement to locate the auger holes along the transect.

4.2. Ice Thickness

Ice thickness was measured at each auger hole using a "plunger pole," a 6-foot-long wooden dowel with gradations along the side and an 8-inch-diameter perforated plastic disk attached to one end. The disk was inserted into the auger hole and hooked on the underside of the ice. Total ice thickness was measured using the gradations along the dowel. Extensive frazil ice was frequently found beneath the surface ice but could not be measured using the plunger pole as it offered little perceptible resistance and often exceeded 6 feet in depth. Instead, a Price AA velocity meter attached to an extendable ice rod was used to locate the boundary between stagnant frazil ice and the flowing water below.

During the HDR field trip in January to ESS30 (PRM 99.4 [RM 96]), the HDR field crew used a Kovacs ice auger kit, a series of meter-long auger bits that are powered by a handheld drill. The auger blades on the end cut a 5-centimeter hole. The HDR field crew found it was not possible to detect frazil ice without a hole large enough for a Price AA velocity meter and discontinued the use of the Kovacs drill. Frazil ice thicknesses were not measured at ESS30.

4.3. Discharge

At sites ESS20 (PRM 30.1 [RM 26]), ESS40 (PRM 106.8 [RM 103]), and ESS55 (PRM 152.5 [RM 149]) a discharge measurement was completed using a Price AA velocity meter and an extendable ice rod. As many as 30 auger holes were drilled along these transects to locate and measure areas of highest discharge. The velocity meter was used to locate the effective depth and to measure the distance from the substrate to the bottom of the surface ice or frazil ice at each vertical measurement point on the transect. Field teams from Brailey Hydrologic and USGS performed discharge measurements using a similar methodology.

5. RESULTS

5.1. Cross Sectional Geometry

Measurement transects for the ice thickness and elevation surveys varied widely in character; from wide, shallow channels on the Lower River and certain portions of the Middle River, to deeper channels constrained by canyon walls. Consequently, the ice thickness and its topography varied as well. ESS20 (PRM 30.1 [RM 26]) and ESS55 (PRM 152.5 [RM 149]) had a relatively flat ice surface and a water surface elevation near, or above, the ice elevation. ESS45 (PRM 116.7 [RM 113]) and ESS50 (PRM 124.4 [RM 121]) also had relatively smooth topography but showed some slumping in the surface ice over sections of the channel with the most flow. At the other transects, pressure ridges and cracks along the ice surface indicate some movement within the cover.

The most consistent aspect between stations was the presence of frazil ice beneath the ice surface. The thickness of the frazil ice layer differed drastically between stations as well as across each measurement transect (Table 5.1-1), but it was present in large enough amounts at each site to have an effect on the under-ice hydraulics. At many of the sites visited, the flow beneath the ice surface was separated into two channels by frazil ice alone. These sites were

ESS20 (PRM 30.1 [RM 26]) (Figure 5.1-1), ESS35 (PRM 101.8 [RM 98]) (Figure 5.1-2), ESS45 (PRM 116.7 [RM 113]) (Figure 5.1-4, Figure 5.1-5), ESS55 (PRM 152.5 [RM 149]) (Figure 5.1-7, Figure 5.1-8), ESS65 (PRM 179.2 [RM176.5]) (Figure 5.1-11, Figure 5.1-12), and ESS70 (PRM 186.8 [RM 184]) (Figure 5.1-13, Figure 5.1-14). At ESS35 (PRM 101.8 [RM 98]) and ESS60 (PRM 168.3 [RM 165]) there were isolated side channels that seemed to be controlled by substrate topography as well as surface ice (Figure 5.1-2, Figure 5.1-9, and Figure 5.1-10). Only ESS40 (PRM 106.8 [RM 103]) and ESS50 (PRM 124.4 [RM121]) were flowing entirely in one channel beneath the ice, and even these sites were constrained by frazil ice (Figure 5.1-3, Figure 5.1-6, and Figure 5.1-7).

At many sites, the bulk of the flow was not found in the middle of the river transect; instead, there were deposits of stagnant frazil ice in the deepest sections of the river, diverting flow to the sides of the channel. ESS50 (PRM 124.4 [RM121]) was the only station at which the flow remained in the center of the channel.

5.2. Discharge Results

Stream discharge measurements were conducted by HDR Alaska, Inc. and Brailey Hydrologic and spanned from late January through early April. In January and March, the USGS collected discharge measurements at Tsusena Creek (PRM 185 [RM 182.3]), Gold Creek (PRM 140 [RM 136.6]), and Sunshine (PRM 88 [RM 84]), as part of long term discharge measurements at their gaging stations which were not visited by either Ice Processes field team. The Ice Processes field teams coordinated their field events to avoid replication of efforts at the various study sites. Instantaneous discharge measurements conducted by all the teams are summarized in Table 5.1-2.

During the January field event, Brailey Hydrologic measured discharge at FA-104 (Whiskers Slough) (ESS40). On January 25, 2013 the HDR field team attempted to measure discharge at Susitna Station (ESS20) (PRM 30.1 [RM 26]) using a Sontek M9 Acoustic Doppler Current Profiler (ADCP) due to depths greater than 30 feet during summer measurements at the station. They were unable to complete the measurement due to equipment malfunctions caused by temperatures around 10 degrees Fahrenheit and layers of frazil ice more than 8 feet thick beneath much of the cross section.

During HDR's work from March 4–9, 2013, the team conducted discharge measurements at ESS55 (PRM 152.5 [RM 149]) and ESS40 (PRM 106.8 [RM 103]) in conjunction with ice thickness and elevation measurements. The HDR team returned to ESS20 (PRM 30.1 [RM 26]) on March 13 with an extendable ice rod and found the average frazil ice thickness to be over 10 feet and as much as 27 feet in places. Brailey Hydrologic collected discharge measurements at additional ESS stations from April 2–6, 2013.

The March and April measurements appear to have been within the late winter low flow period as measured discharge was higher during the January event than during the March/April event at the four stations that were measured during both field events (Table 5.1-1). Unit runoff values decreased an average of about 27.5 percent from January to the March/April field event. Data developed in support of the discharge measurements by HDR Alaska, Inc. for this ISR is available for download at http://gis.suhydro.org/reports/isr/.

During both field events the unit runoff values (computed by dividing discharge by the total drainage area above the measurement transect) generally increased when moving downstream (Figure 5.1-15). There are, however, some exceptions in both events. In January, the sole discharge measurement collected by Brailey Hydrologic was lower than the USGS measurement taken 33 miles upstream just two days prior. It is unlikely that a large portion of the flow was missed during the measurement by Brailey Hydrologic, or that there was such a considerable drop in discharge over the 2 days between measurements. This discrepancy may be explained by the inherent difficulty in capturing discharge under ice cover on such a large river.

A similar discrepancy appears in the March/April event in which each HDR Alaska discharge measurement had a lower unit runoff than the upstream measurement collected by USGS or

Brailey Hydrologic. Some of this could be explained by the time elapsed between the measurements. HDR Alaska collected discharge measurements in early- to mid-March, compared to USGS in late-March, and Brailey Hydrologic in early April. The USGS measurements during this event have the highest unit runoff values of all, despite having been collected nearly 2 weeks prior to the Brailey Hydrologic measurements.

6. TABLES

Table 3.1-1. Summary of Ice Thickness and Elevation Measurements Conducted by HDR Alaska

Station	PRM (RM)	Measurements	Date
Susitna Station (ESS20)	30.1 (26)	Thickness, elevation, IQ	January 25 and March 1, 2013
Susitna River near Twister Creek (ESS30)	99.4 (96)	Thickness, elevation	January 21, 2013
Upstream of Chulitna River (ESS35)	101.8 (98)	Thickness, elevation	March 9, 2013
Whiskers Creek (ESS40)	106.8 (103)	Thickness, elevation, IQ	March 7, 2013
Lane Creek (ESS45)	116.7 (113)	Thickness, elevation	March 9, 2013
Curry (ESS50)	124.4 (121)	Thickness, elevation	March 6, 2013
Portage Creek (ESS55)	152.5 (149)	Thickness, elevation, IQ	March 6, 2013
Devil Creek (ESS60)	168.3 (165)	Thickness, elevation	March 8 2013
Fog Creek (ESS65)	179.2 (176.5)	Thickness, elevation	March 8, 2013
Deadman Creek (ESS70)	186.8 (184)	Thickness, elevation	March 8, 2013

*IQ = Instantaneous discharge

Table 5.1-1. Summary of Ice and Frazil Ice Thickness at HDR Alaska Visited Sites

Station	Ice Thickness (ft)			Frazil Thickness (ft)		
	Minimum	Maximum	Mean	Minimum	Maximum	Mean
ESS20	2.9	3.5	3.3	0.0	27.0	10.7
ESS30	2.6	3.8	3.3	-	-	-
ESS35	1.9	4.5	3.1	0.0	7.7	1.0
ESS40	2.4	6.0	3.7	0.0	8.1	2.5
ESS45	1.5	3.3	2.5	0.0	6.9	2.6
ESS50	2.4	4.5	3.9	0.0	9.5	5.1
ESS55	1.2	6.3	3.3	0.0	10.3	3.3
ESS60	0.7	4.0	2.5	0.0	4.4	0.8
ESS65	1.4	5.4	3.6	0.0	6.9	1.2
ESS70	3.5	8	4.4	0.0	7.5	2.7

*Frazil ice thickness was not measured at ESS30

Table 5.1-2. Summary of Winter Discharge Measurements

Station	Project River Mile (River Mile)	Drainage Area (square miles)	Date	Discharge	Unit Hydrograph
Susitna Station (ESS20)	30.1 (26)	19400	1/25/13 3/13/13	– 5200	– 0.27
Sunshine	88 (84)	11100	1/24/13 3/25/13	4860 3480	0.44 0.31
Whiskers Creek (ESS40)	106.8 (103)	6264	1/26/13 3/7/13	1850 1430	0.30 0.23
Lane Creek (ESS45)	116.7 (113)	6242	4/2/13	1510	0.24
Curry (ESS50)	124.4 (121)	6205	4/3/13	1320	0.21
Gold Creek	140 (136.6)	6106	1/24/13 3/25/13	2120 1510	0.35 0.25
Portage Creek (ESS55)	152.5 (149)	5942	3/6/13	1120	0.19
Devil Creek (ESS60)	168.3 (165)	5570	4/6/13	1360	0.24
Fog Creek (ESS65)	179.2 (176.5)	5519	4/5/13	1230	0.22
Tsusena Creek	185 (182.3)	5135	1/24/13 3/25/13	1580 1130	0.31 0.22
Deadman Creek (ESS70)	186.8 (184)	5131	4/4/13	1130	0.22

* Measurements at Sunshine, Gold Creek, and Tsusena Creek were conducted by USGS as part of long term discharge measurements at gage stations.

7. FIGURES

Figure 4.1-1. Locating TBM2 at ESS50 (PRM 124.4 [RM 121]) (HDR Alaska).

Figure 4.1-2. Surveying ice elevation at ESS40 (PRM 106.8 [RM 103]) (HDR Alaska).

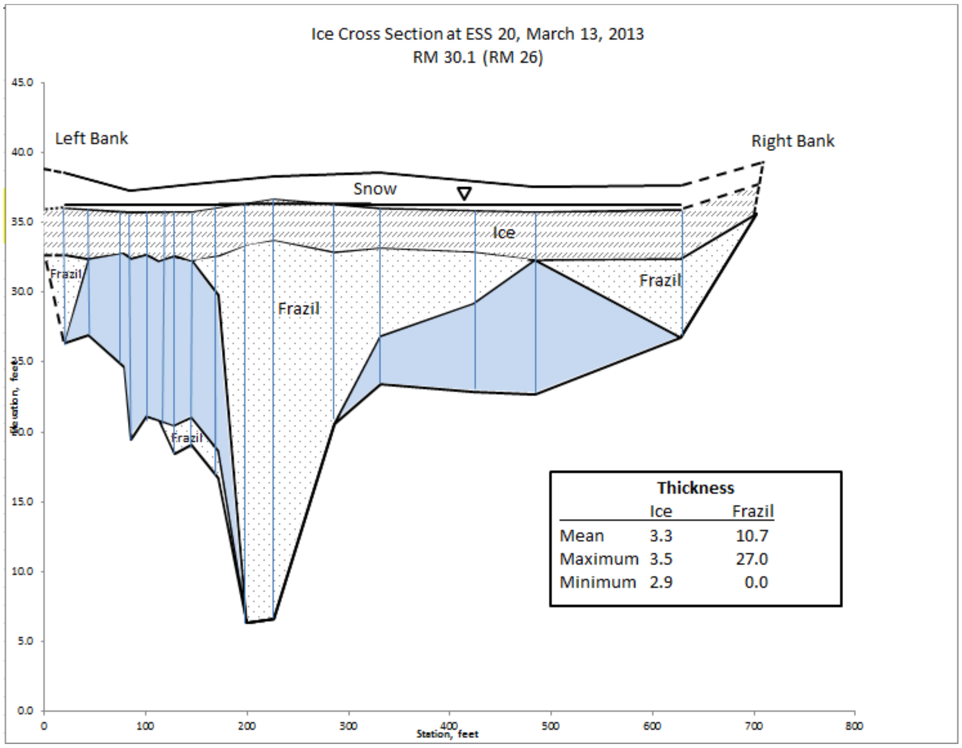

Figure 5.1-1. Cross Sectional Diagram of ESS20. HDR Alaska.

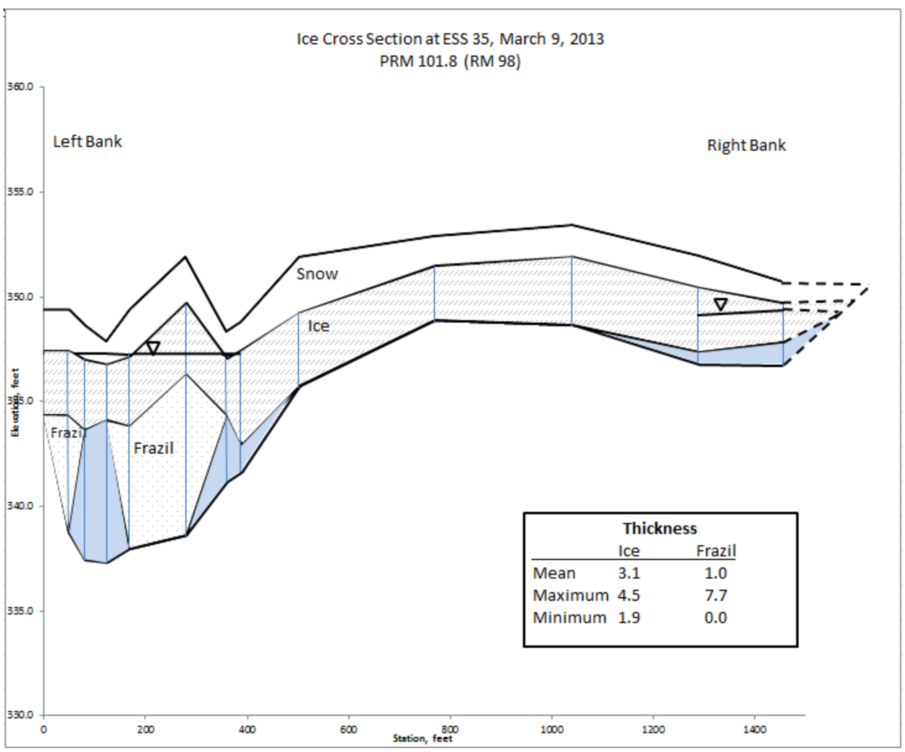

Figure 5.1-2. Cross Sectional Diagram of ESS35. HDR Alaska.

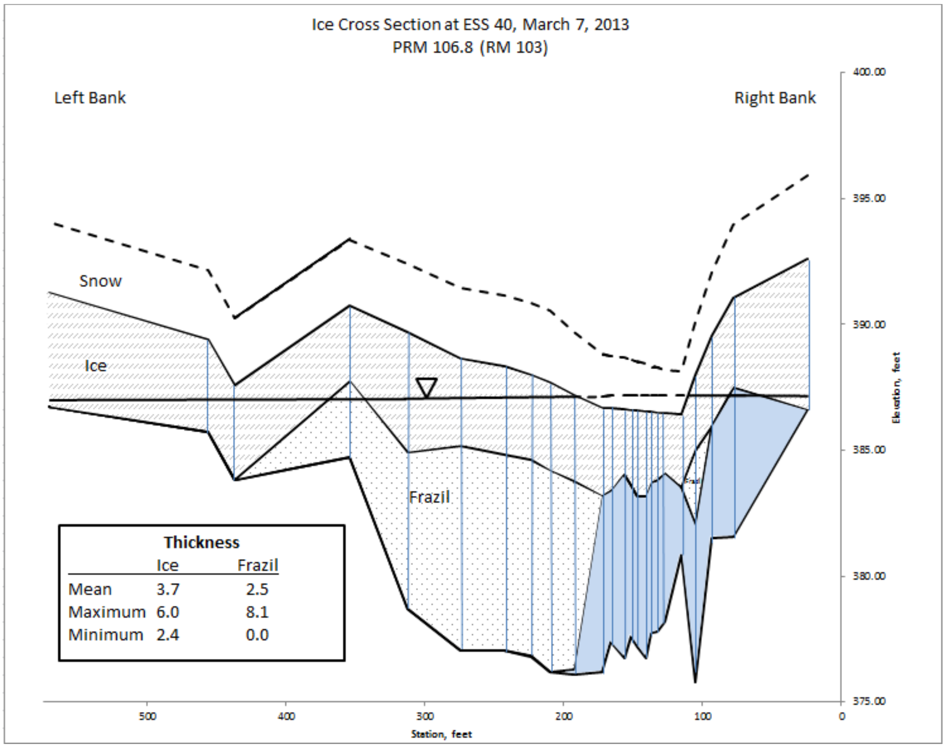

Figure 5.1-3. Cross Sectional Diagram of ESS40. HDR Alaska.

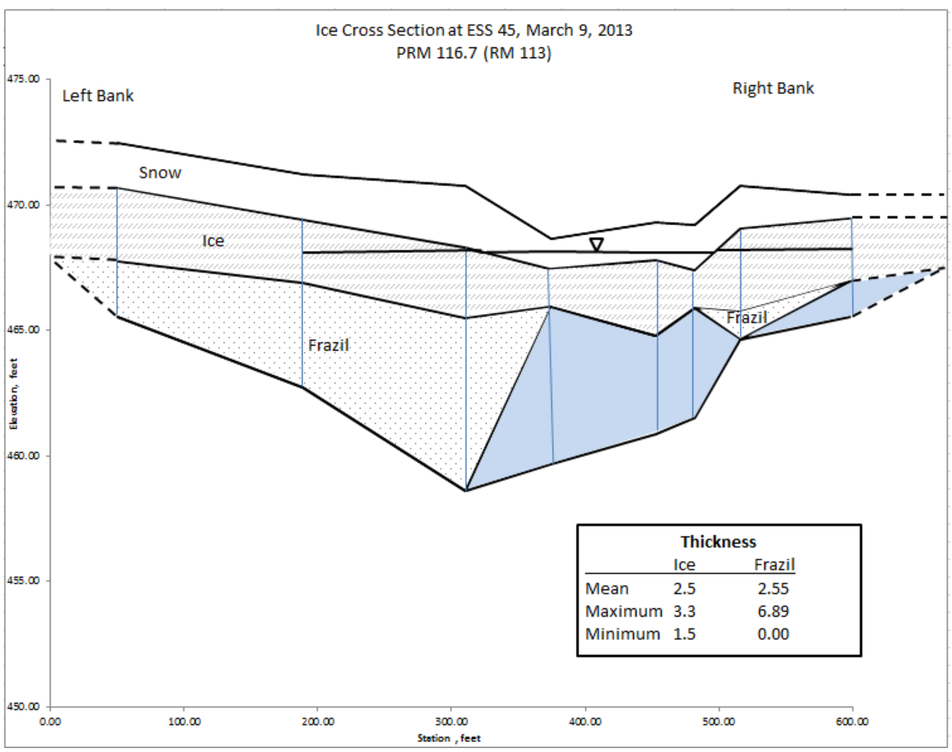

Figure 5.1-4. Cross Sectional Diagram of ESS45. HDR Alaska.

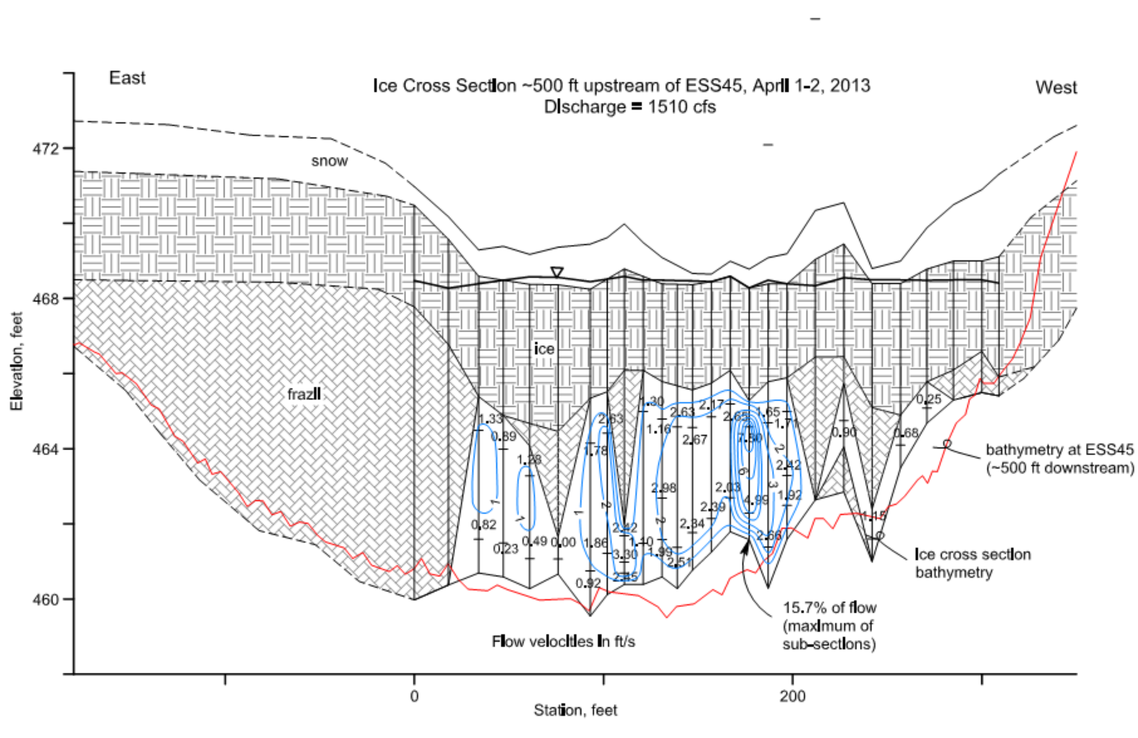

Figure 5.1-5. Cross Sectional Diagram of ESS45. Brailey Hydrologic.

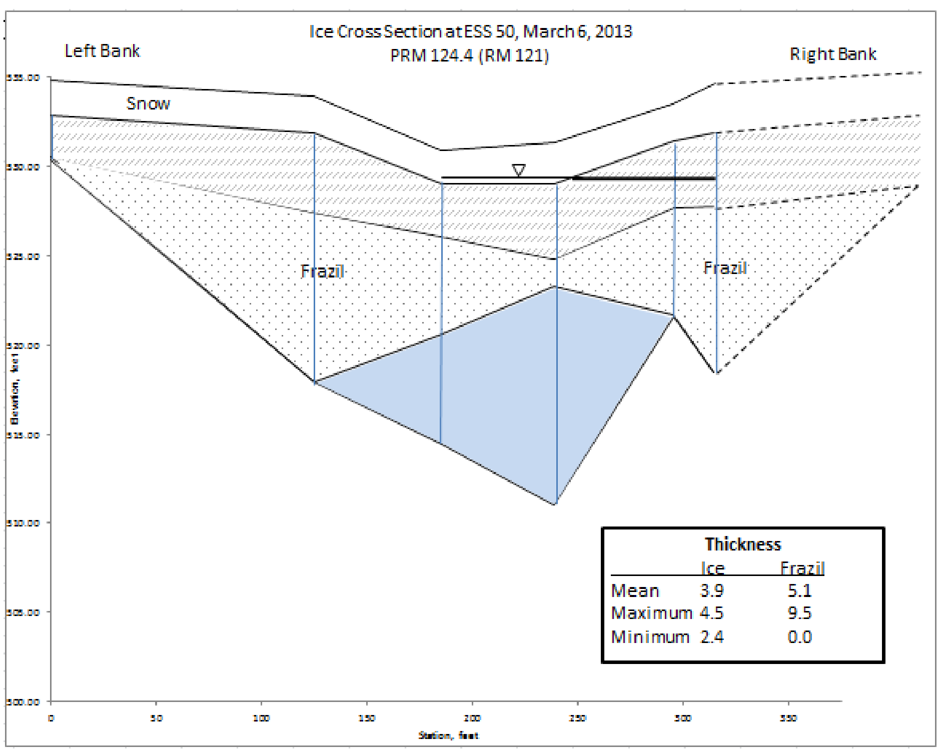

Figure 5.1-6. Cross Sectional Diagram of ESS50. HDR Alaska.

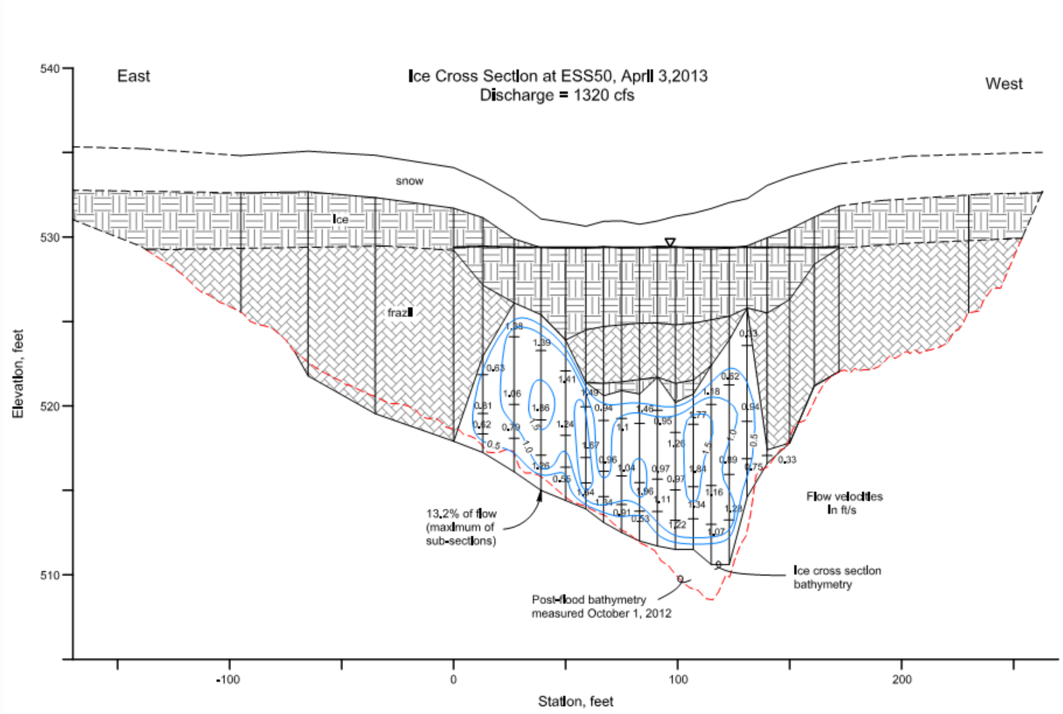

Figure 5.1-7. Cross Sectional Diagram of ESS50. Brailey Hydrologic.

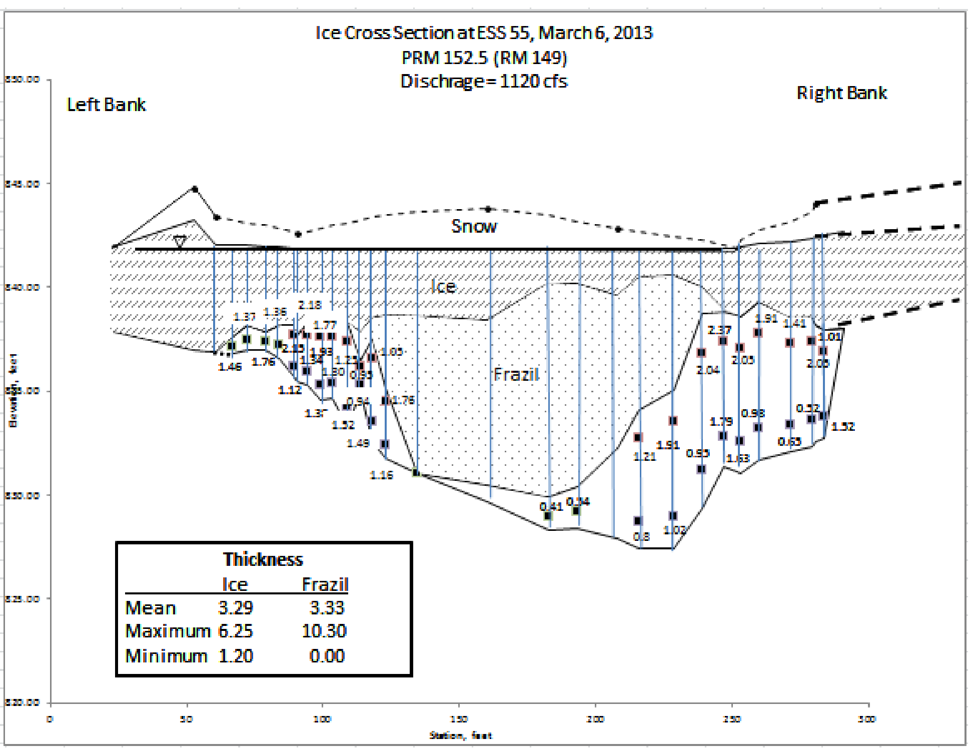

Figure 5.1-8. Cross Sectional Diagram of ESS55. HDR Alaska.

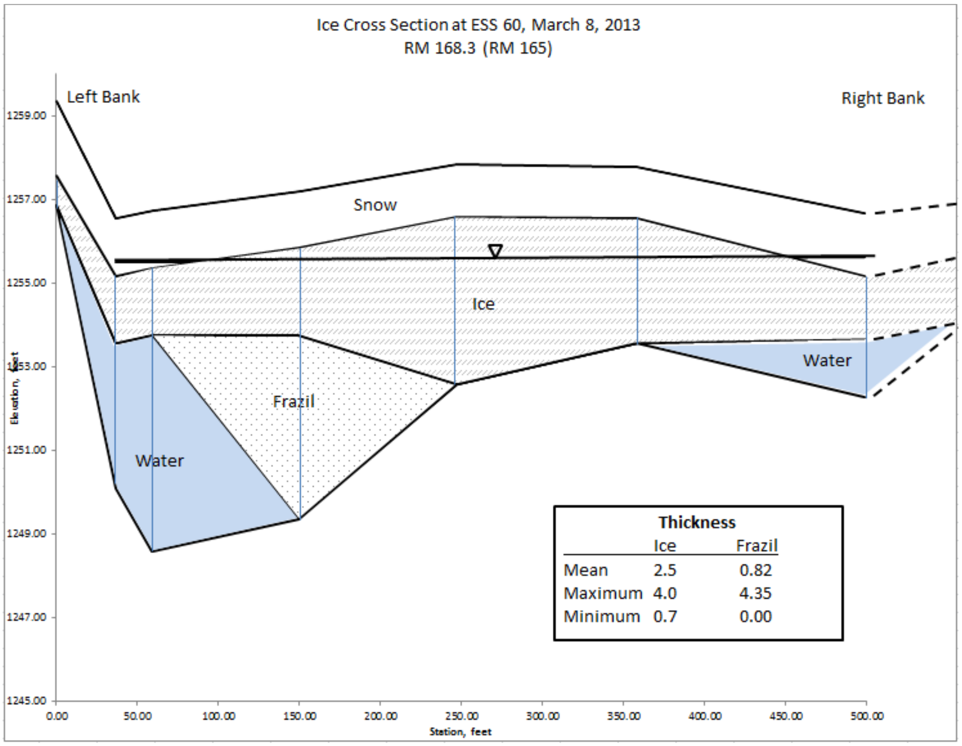

Figure 5.1-9. Cross Sectional Diagram of ESS60. HDR Alaska.

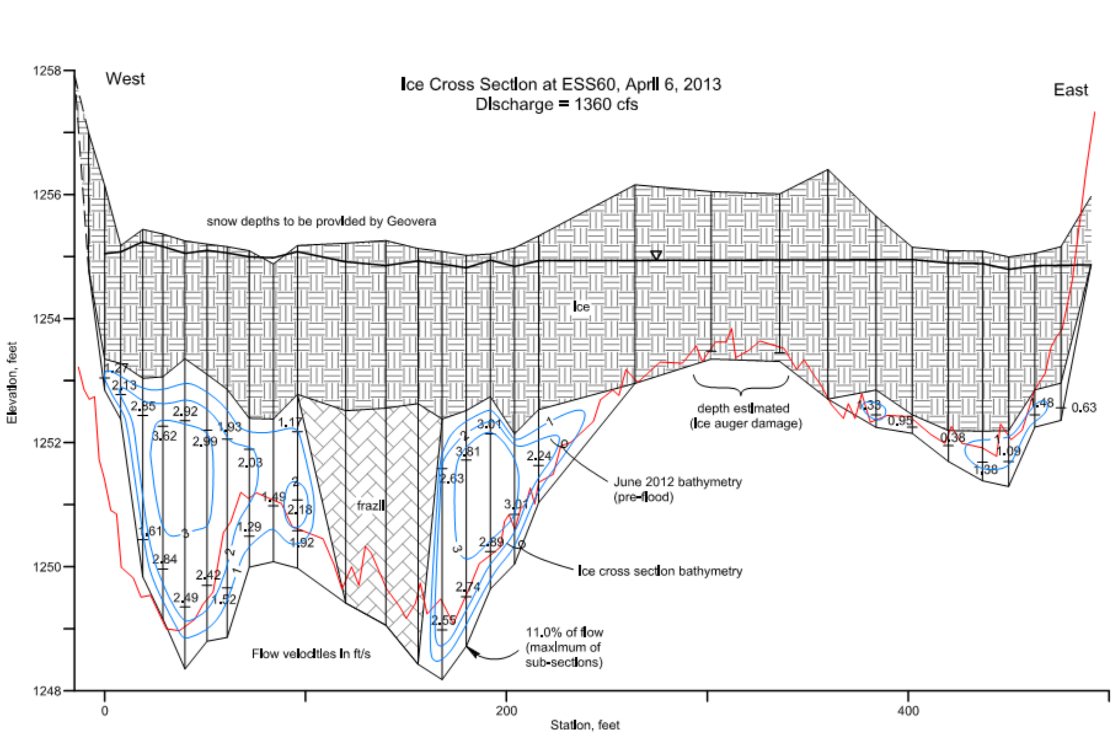

Figure 5.1-10. Cross Sectional Diagram of ESS60. Brailey Hydrologic.

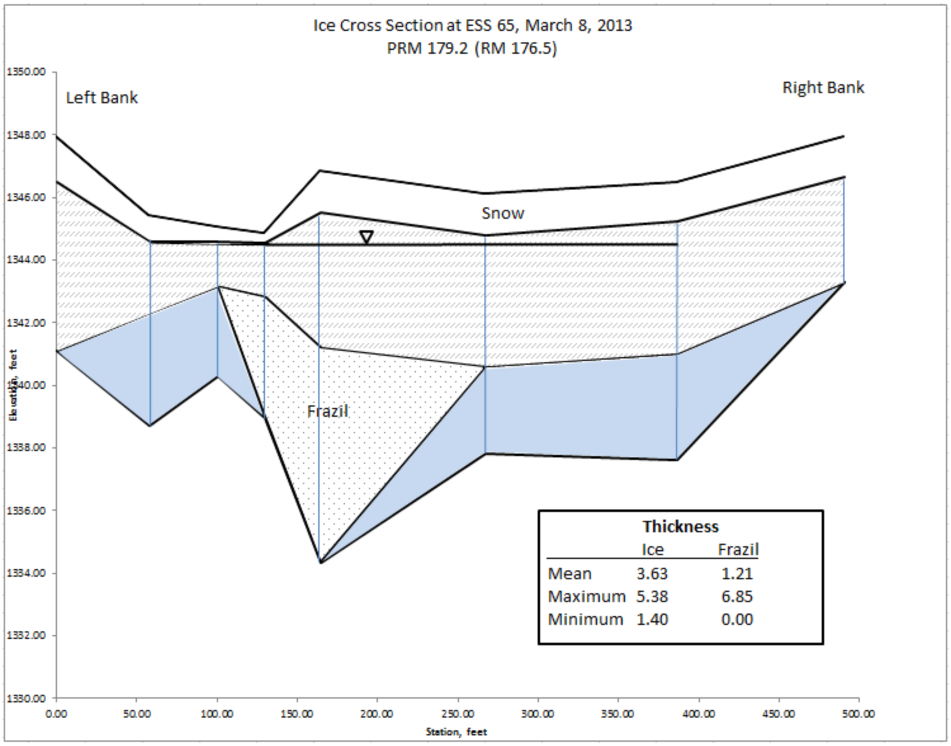

Figure 5.1-11. Cross Sectional Diagram of ESS65. HDR Alaska.

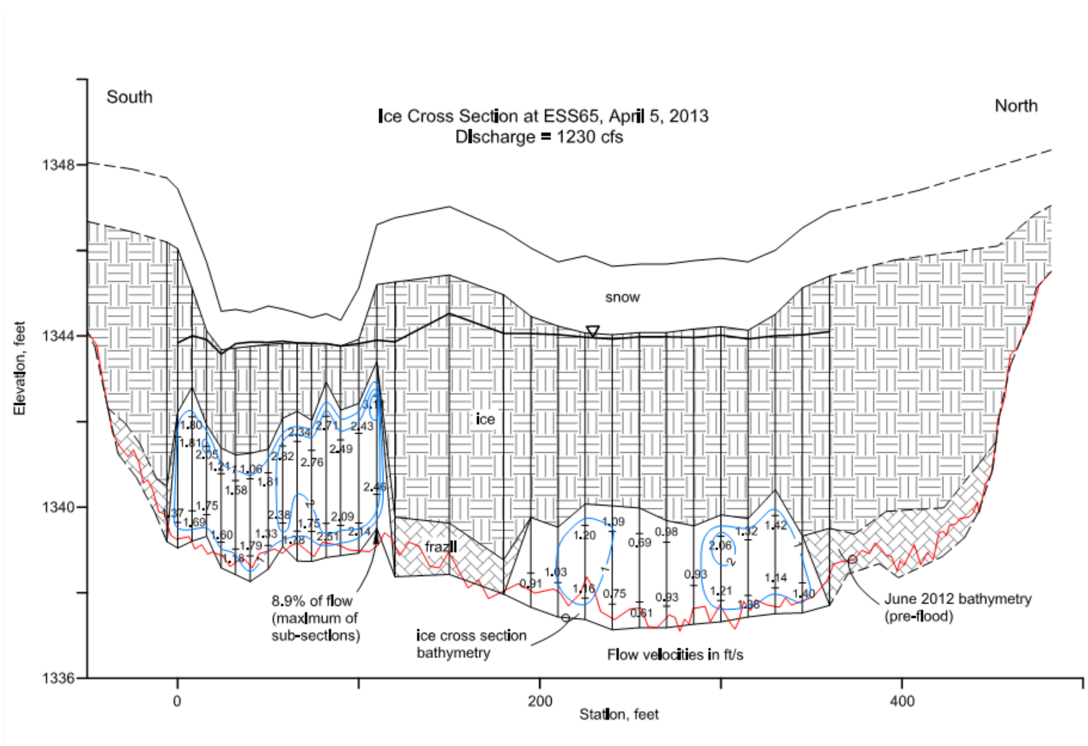

Figure 5.1-12: Cross Sectional Diagram of ESS65. Brailey Hydrologic.

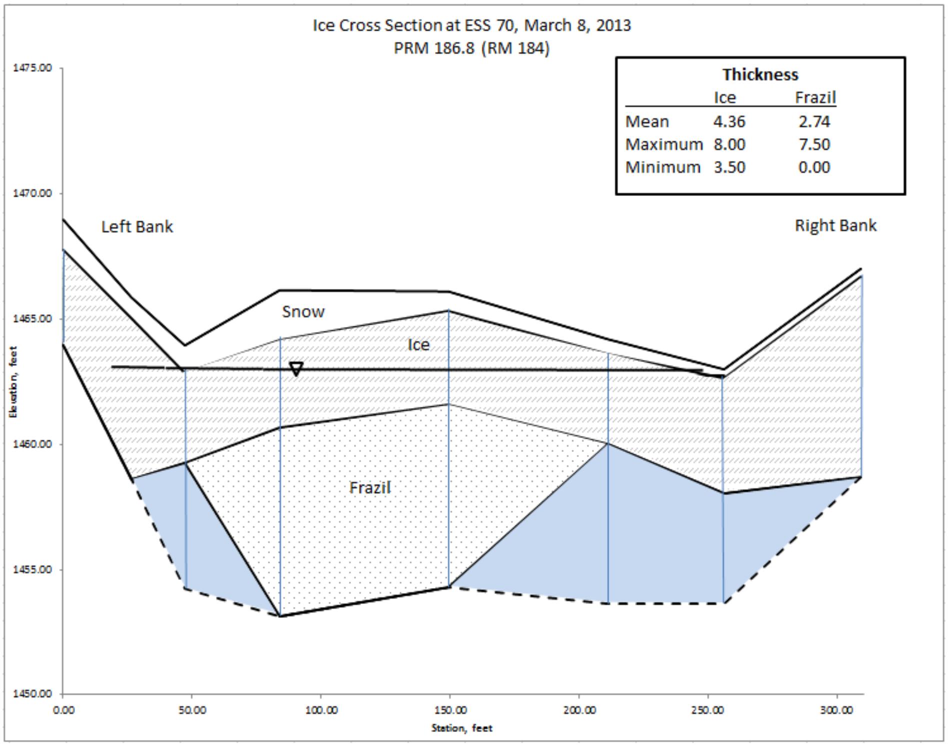

Figure 5.1-13. Cross Sectional Diagram of ESS70. HDR Alaska.

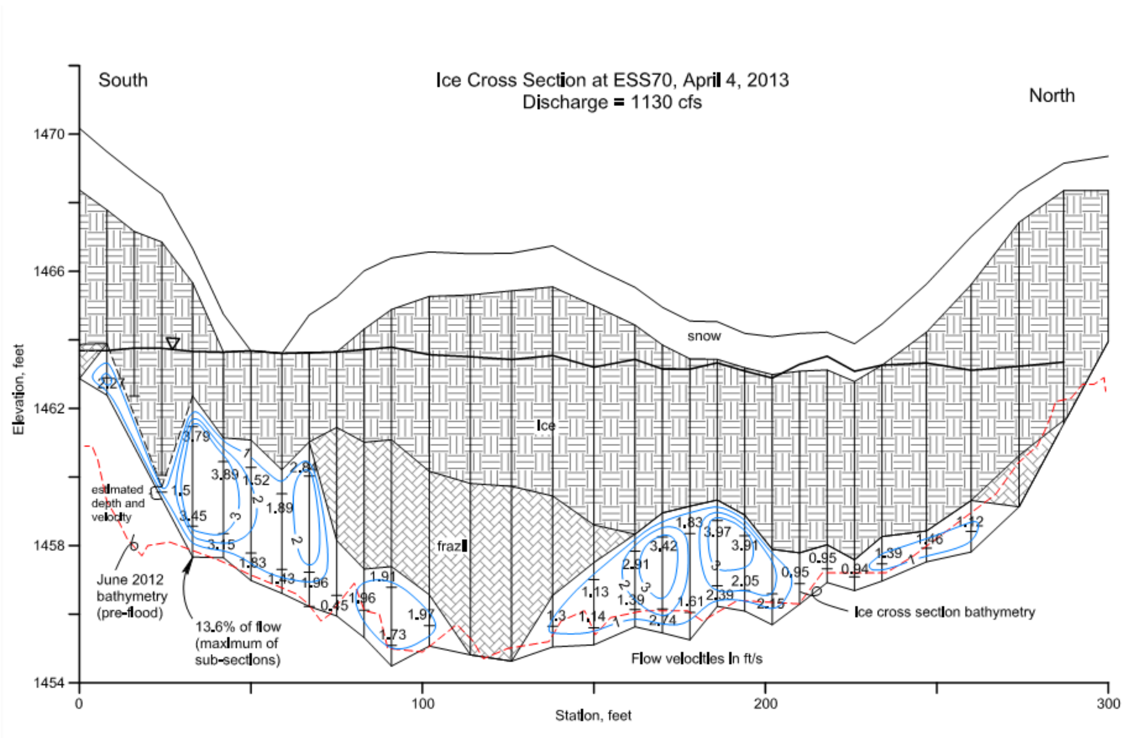

Figure 5.1-14. Cross Sectional Diagram of ESS70. Brailey Hydrologic.

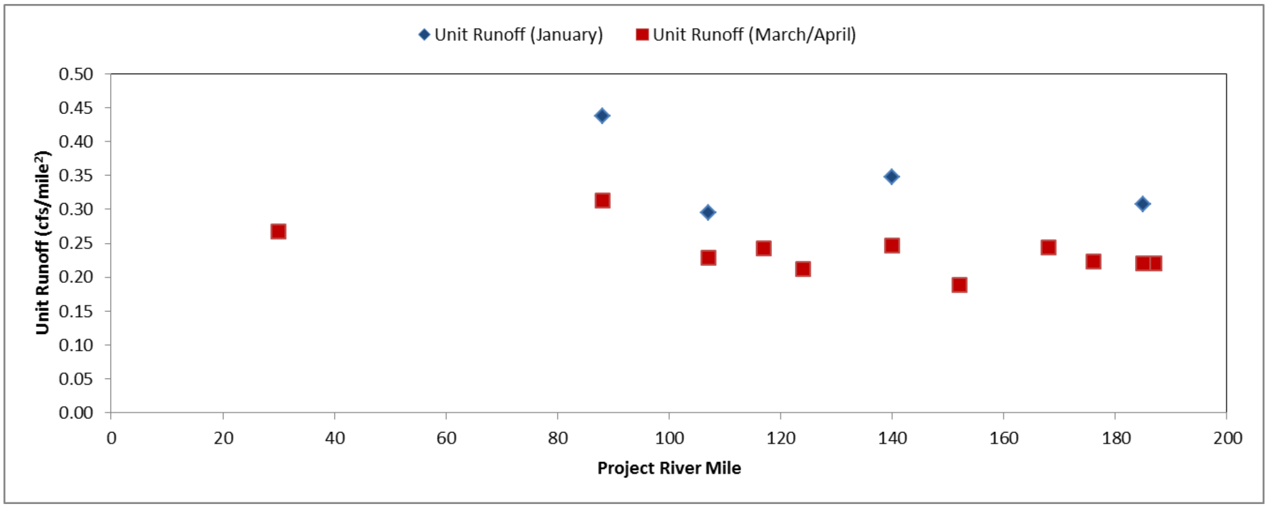

Figure 5.1-15. Unit Runoff Plotted Against Project River Mile for the January and March/April Field Events