Susitna-Watana Hydroelectric Project
(FERC No. 14241)

Fish and Aquatics Instream Flow Study
Study Plan Section 8.5

2014-2015 Study Implementation Report

Appendix A
2014 Instream Flow Winter Studies

Prepared for

Alaska Energy Authority

SUSITNA-WATANA HYDRO
Clean, reliable energy for the next 100 years.

Prepared by

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LIST OF ACRONYMS AND SCIENTIFIC LABELS

Abbreviation	Definition
AEA	Alaska Energy Authority
ARRI	Aquatic Restoration and Research Institute
°C	Degrees centigrade
cfs	Cubic feet per second
Cm	Centimeter
CPUE	Catch Per Unit Effort
FA	Focus Area
FDAML	Fish Distribution and Abundance in the Middle and Lower Susitna River
FERC	Federal Energy Regulatory Commission
GW	Groundwater
HSC	Habitat suitability criteria
HSI	Habitat suitability indices
IFS	Fish and Aquatics Instream Flow Study
ILP	Integrated Licensing Process
ISR	Initial Study Report
mg/L	Milligrams per liter
MW	Megawatts
NMFS	National Marine Fisheries Service
PRM	Project River Mile
Project	Susitna-Watana Hydroelectric Project, FERC No. 14242
QC	Quality Control
RSP	Revised Study Plan
SW	Surface Water
TM	Technical Memorandum

1. INTRODUCTION

The Fish and Aquatics Instream Flow Study (IFS), Section 8.5 of the Revised Study Plan (RSP) approved by the Federal Energy Regulatory Commission (FERC) for the Susitna-Watana Hydroelectric Project (FERC Project No. 14242), focuses on understanding important aquatic communities and associated habitats and the hydrologic, physical, and chemical processes in the Susitna River that directly influence those resources. Operation of the Susitna-Watana Hydroelectric Project (Project) will cause seasonal, daily, and hourly changes in Susitna River flows compared to existing conditions. The potential alteration in flows will influence downstream resources/processes, including fish and aquatic biota and their habitats, channel form and function including sediment transport, water quality, groundwater (GW)/surface water (SW) interactions, ice dynamics, and riparian and wildlife communities. The goal of the IFS (Study 8.5) and its component study efforts is to provide quantitative indices of existing aquatic habitats that enable a determination of the effects of alternative Project operational scenarios.

One element of the IFS (Study 8.5) pertains to the completion of winter studies designed to assess patterns of fish habitat use under winter conditions including under ice as well as in open-water leads influenced by GW inflow (RSP Section 8.5.4.5.1.2.1) (AEA 2012). Companion winter studies were also specified in the RSP as part of the Fish Distribution and Abundance in the Middle and Lower River Study (FDAML; Study 9.6) under the Fish Program (RSP Section 9.6.4.5) and under the GW Study (Study 7.5, RSP Section 7.5.4.7) (AEA 2012). The winter period is an ecologically important time for salmonids in that streamflows are typically at their lowest, relegating fish to areas suitable as overwintering habitats. The winter period is also the time when salmonid embryos are developing and alevins hatch and remain within the protective confines of the gravel until emergence occurs. Intergravel flow and GW upwelling are critical for egg incubation and emergent fry survival, while SW characteristics (e.g., temperature, depth, and velocity) can be important aspects of winter habitat for juvenile and adult fish. The winter studies, in conjunction with the Ice Processes Study (Study 7.6) are designed to provide data and information that will be used to first characterize existing conditions that occur during the winter period and then, via modeling and data analysis, evaluate how Project operations may influence those conditions and associated fish and fish habitats.

A summary of the development of this study, together with the Alaska Energy Authority's (AEA) implementation of it through the 2013 study season, appears in Part A, Section 1 of the Initial Study Report (ISR) filed with FERC in June 2014. As required under FERC's regulations for the Integrated Licensing Process (ILP), the ISR describes AEA's "overall progress in implementing the FERC-approved Study Plan and schedule and the data collected, including an explanation of any variance from the Study Plan and schedule" (18 CFR 5.15(c)(1)).

The RSP identified an initial pilot effort during winter 2012-2013 (i.e., February-April 2013), followed by an expanded effort during winter 2013-2014, and an additional winter survey effort as needed (AEA 2012). Detailed results of winter studies conducted during 2012-2013 and 2013-2014 were distributed independently by each resource group (i.e., IFS [Study 8.5], FDAML [Study 9.6], and GW [Study 7.5]) as part of the ISR and as Technical Memoranda (TM) and are listed below:

- ISR: Susitna-Watana Hydroelectric Project FERC No. 14241 (AEA 2014a)

  - IFS Study 8.5, Part C, Appendix L: *2012-2013 Instream Flow Winter Pilot Studies*, submitted to the FERC June 3, 2014 (R2 2014a)
  - FDAML Study 9.6, Part A, Appendix C: *2012-2013 Winter Sampling Report*, submitted to the FERC June 3, 2014 (R2 and LGL 2014a)
  - GW Study 7.5 Part A, Sections 4.8, 5.8, 6.8, and Part C, Section 7.8: Winter Groundwater / Surface-Water Interactions (AEA 2014a)
- TM: IFS Study 8.5, *2013-2014 Instream Flow Winter Studies,* submitted to the FERC September 17, 2014 (R2 2014b)
- TM: FDAML Study 9.6, *2013-2014 Winter Fish Study*, submitted to the FERC September 17, 2014 (R2 and LGL 2014b)
- TM: GW Study 7.5, *Preliminary Groundwater and Surface-Water Relationships in Lateral Aquatic Habitats within Focus Areas FA-128 (Slough 8A) and FA-138 (Gold Creek) in the Middle Susitna River*, submitted to the FERC September 30, 2014 (GWS and R2 2014)

Since filing the ISR in June 2014, AEA has continued to implement the FERC-approved Study Plan for IFS winter studies. For example,

- The results of 2013-2014 IFS winter studies were summarized in a TM distributed in September 2014 (R2 2014b).
- During September 2014, IFS winter studies instrumentation deployed during 2013-2014 ice-covered and open-water periods (i.e., September 2013 through September 2014) to continuously record water level and water quality (surface and intergravel temperature and intergravel dissolved oxygen) conditions was maintained and downloaded. Instrumentation was also reinstalled at existing sites and at new locations at this time to collect additional physical data in representative habitats and in areas of salmon spawning.
- On 17 October 2014, AEA held an ISR meeting that included a discussion on IFS winter studies (AEA 2014b).
- During September 2015, water level and water quality instrumentation deployed during 2014-2015 ice-covered and open-water periods (i.e., September 2014 through September 2015) were maintained and downloaded. Instruments at selected IFS winter studies sites were redeployed to record water level and water quality conditions during winter 2015-2016.

In furtherance of the next round of ISR meetings and FERC Director’s Study Determination, this report describes AEA’s overall progress in implementing the IFS winter studies since June 2014. Rather than a comprehensive reporting of all field work, data collection, and data analysis since the beginning of AEA’s study program, this report is intended to supplement and update the information presented in Part A of the ISR for IFS winter studies and the September 2014 TM (R2 2014b). It describes the methods and results of the subsequent effort and includes a discussion of the overall results achieved to date.

2. STUDY OBJECTIVES

IFS winter studies were initiated during the 2012-2013 winter period (i.e., February - April 2013) as a pilot effort to test the feasibility of using different instruments, methods, and approaches for winter data collection; results were reported in ISR Study 8.5, Part C, Appendix L (R2 2014a). The winter 2013-2014 efforts were then based on methods developed during the pilot effort and analyses completed as of July 2014 were reported in a September 2014 TM (R2 2014b). Additional winter 2013-2014 data were retrieved in September 2014 and analysis of these data are reported here to supplement the September 2014 TM (R2 2014b). The two primary objectives of the IFS winter studies are to 1) evaluate potential relationships between mainstem Susitna River stage and the quality and quantity of winter aquatic habitats that support embryonic, juvenile, and adult life stages of fish species; and 2) to record fish behavior and habitat utilization in support of Habitat Suitability Criteria (HSC)/Habitat Suitability Indices (HSI) development. Specific tasks of the IFS winter studies were as follows:

- Compare water level (stage) responses in representative habitat types relative to Susitna River main channel stage through the period of salmon egg incubation.
- Monitor surface and intergravel water temperatures in representative habitat types, at salmon spawning sites and in areas with and without GW influence, through the period of salmon egg incubation.
- Evaluate potential relationships between Susitna River stage and water temperature recorded in off-channel and main channel habitats.
- Monitor intergravel dissolved oxygen at two salmon spawning sites in off-channel habitats with GW influence.
- Describe juvenile and adult fish behavior in representative habitats during day and night conditions to discern potential patterns in habitat use.
- Obtain site-specific habitat utilization data for juvenile and adult fish species in support of HSC/HSI development.

IFS data collection during 2014-2015 consisted of stage and water quality (i.e., temperature and dissolved oxygen) monitoring in representative habitat types and at known salmon spawning locations through the periods of salmon egg incubation, ice-breakup and open-water (i.e., September 2014 through September 2015). No surveys of fish behavior and habitat utilization were conducted during winter 2014-2015. Data collected during 2014-2015 and recovered during September 2015 have not yet been analyzed and are not reported in this document.

3. STUDY AREA

IFS winter studies were conducted in the Middle River Segment of the Susitna River between the Three Rivers Confluence (Project River Mile [PRM] 102.4) and PRM 146. The winter 2012-2013 pilot effort was performed during February to April 2013 primarily in Focus Area (FA) FA-104 (Whiskers Slough), with some work in FA-128 (Slough 8A) (Figure 3-1 and Figure 3-2). During winter 2013-2014, IFS data collection primarily occurred within three Focus Areas: FA-

104 (Whisker Slough), FA-128 (Slough 8A), and FA-138 (Gold Creek); however, opportunistic sampling also occurred within FA-141 (Indian River) (Figure 3-1, Figure 3-2 and Figure 3-3). These Focus Areas were selected for the 2013-2014 study because they contain a diversity of habitat types with GW influence, they have documented fish utilization by multiple fish species and life stages, and they could be safely accessed during the winter. Continuous water level and water quality monitoring sites that operated during winter 2014-2015 were located in FA-104 (Whisker Slough), FA-128 (Slough 8A), FA-138 (Gold Creek), and FA-144 (Side Channel 21) (Figure 3-1, Figure 3-2, Figure 3-3 and Figure 3-4).

4. METHODS

The IFS winter studies were comprised of two primary components: 1) monitoring of water level, water quality, and ice conditions and 2) fish behavior and habitat use observations. Surface water level and surface and intergravel water quality were continuously monitored at various monitoring stations, while instantaneous measurements of depth, water quality and ice thickness were also recorded during field visits. Site specific observations of habitat utilization by fish species were recorded during electrofishing and underwater video surveys. Methods utilized during the 2013-2014 study were initially developed during the winter 2012–2013 pilot effort and are described in detail in R2 2014a and R2 2014b. Winter studies were coordinated with the study leads for IFS (Study 8.5), FDAML (Study 9.6), GW (Study 7.5), Geomorphology (Study 6.5), Baseline Water Quality (Study 5.5), and Ice Processes (Study 7.6).

The continuation of winter studies during 2014-2015 was specified in ISR Study 8.5 (IFS), Part C, Section 7.5.1 and ISR Study 9.6 (FDAML), Part C, Section 7.1 and primarily consisted of the second season of monitoring of water level and water quality conditions within selected Focus Areas. For this study, 25 continuous water level loggers and 108 water quality (surface and intergravel water temperature and intergravel dissolved oxygen loggers) instruments were again installed during September 2014 in representative habitats and in salmon spawning areas in FA-104 (Whiskers Slough), FA-128 (Slough 8A), and FA-138 (Gold Creek) (Table 4-1, Figure 3-1, Figure 3-2, and Figure 3-3). Instruments were also installed within side channel habitats in FA-144 (Slough 21) in areas with substantial GW influence and observed salmon spawning (Table 4-1 and Figure 3-4). Configuration and deployment of instrumentation followed methods previously described in R2 2014a and R2 2014b. No biological monitoring or sampling was completed during the 2014-2015 winter period. Water level and water quality loggers deployed during the winter 2014-2015 period were maintained and downloaded during September 2015. A total of 18 water level and 53 water quality instruments were also redeployed at select sites during this effort to collect additional data through winter 2015-2016 in the Susitna River main channel and in salmon spawning habitats of FA-104 (Whiskers Slough), FA-128 (Slough 8A), FA-138 (Gold Creek), FA-141 (Indian River) and FA-144 (Slough 21). Prominent spawning habitats and areas in which limited data have been collected were prioritized for 2015-2016 data collection.

5. RESULTS

Results of 2012-2013 and 2013-2014 IFS winter studies were reported in ISR Study 8.5, Part C, Appendix L (R2 2014a) and in a September 2014 TM (R2 2014b). Water level and water temperature data retrieved from IFS instruments during September 2014 represent late winter, ice-breakup and open water conditions (i.e., March - September 2014), but this information was collected too late to be included in the September 2014 TM. Therefore, the time series plots originally contained within that TM have been revised and are now presented in this report (Figure 5-1 through Figure 5-15). Continuous data collected during the 2014-2015 winter period were downloaded during September 2015 and additional time will be necessary to complete analysis of these data. Data associated with IFS winter studies have been compiled and were delivered as a comprehensive set (SIR Study 8.5, Table 5-1). Data associated with IFS winter fish captures have been consolidated within the HSC database and are discussed in SIR Study 8.5, Appendix D, *Habitat Suitability Criteria Development*, submitted to the FERC November 2015 (R2 2015), while FDAML winter fish results are summarized in AEA 2015.

The sections below describe the overall results and findings of the 2012-2013 and 2013-2014 winter studies, in terms of water surface elevations, measurements of water quality, and fish observations.

5.1. Water Surface Elevations

Water levels at main channel and various other continuous monitoring sites within FA-104 (Whiskers Slough), FA-128 (Slough 8A) and FA-138 (Gold Creek) varied widely over the 2012-2013 and 2013-2014 winter periods in response to ice formation and staging (Figure 5-1, Figure 5-2, and Figure 5-3) (R2 2014a; R2 2014b). In general, water levels declined during late September and October 2013 and several monitoring locations likely became dewatered prior to main channel staging in November and early December. Water levels at many sites increased markedly in response to main channel staging and/or ice jamming events. An ice jam downstream of FA-104 (Whiskers Slough) in November 2013 caused many habitats to become inundated by backwatered main channel flow, while a main channel ice jam near FA-128 (Slough 8A) was likely the cause for a side channel to become breached by main channel flow in January 2014. Most habitats experienced minor stage fluctuations during the ice-covered period (i.e., January – April 2014) just prior to break-up when streamflow and water levels at most sites increased substantially.

Water levels at side channel monitoring sites generally closely resembled main channel stage records, while water level conditions inside side slough, upland slough and tributary habitats were less responsive to main channel fluctuations (Figure 5-1, Figure 5-2, and Figure 5-3) (R2 2014a and R2 2014b). Though nearly all areas were either breached or backwatered by main channel streamflow during staging and/or ice break-up, the magnitude and duration of the stage response to these events was less in side slough, upland slough and tributary habitats relative to side channel sites. In addition, these areas were generally less susceptible to dewatering during winter than side channel areas, though this appeared to be dependent upon site-specific conditions (e.g., GW upwelling) (Figure 5-1, Figure 5-2, and Figure 5-3).

5.2. Water Quality

Water temperatures at each main channel monitoring site were approximately 6-8°C at the time of deployment in September 2013 and decreased during the fall to nearly 0°C at the time of ice freeze-up in November and December 2013 (Figure 5-4, Figure 5-9, and Figure 5-12) (R2 2014a, R2 2014b). Recorded values were negative at each site immediately prior to freeze-up when Susitna River flow was low and staging had not yet occurred. Main channel surface and intergravel temperatures were nearly 0°C during ice covered periods (e.g., January/February – April) in each season of study. In general, Whiskers Creek (104-WC-10) and Skull Creek (128-SC-05) tributary monitoring sites most closely resembled the main channel temperature regime during the winter studies as temperatures at each of these sites ranged between 0 to 1°C for ice-covered periods (e.g., Figure 5-7 and Figure 5-11). Surface water connectivity between side channels and the main channel varied among sites and throughout monitoring periods and the thermal characteristics of side channel habitats appeared to reflect these changes. Side channels in FA-104 (Whiskers Slough) were breached or backwatered by main channel flow in association with freeze-up and staging during November 2013, while Side Channel 8A was breached during January 2014 likely due to main channel ice jamming (Figure 5-4, Figure 5-5, Figure 5-6, Figure 5-8). Although surface and intergravel temperatures in side channels were typically below 1°C during breaching or backwater episodes, intergravel temperatures at some sites were nearly 4°C following such events (e.g., 104-WSL-30). Side slough and upland slough habitats were generally characterized by consistently warmer surface and intergravel temperatures (2–4°C) compared to other macrohabitat types. At several side slough and upland slough monitoring sites, water temperatures were the lowest (0–2°C) during November and December 2013 when main channel flow was low and freeze-up had not yet occurred.

Continuous intergravel dissolved oxygen data recorded at two sites during winter 2012-2013 and 2014-2015 seasons in FA-128 (Slough 8A) were similar. Median dissolved oxygen concentration was 5.21 mg/L at 128-SL8A-15 during March-April 2013 and 5.88 mg/L at 128-SL8A-40 during September 2013-March 2014 (R2 2014a; R2 2014b). With the exception of two periods, one in November 2013 and one in February 2014, dissolved oxygen concentrations were generally stable during each monitoring period and ranged from approximately 4.0 mg/L to 6.5 mg/L. During November 2013, concentrations were between 9–11 mg/L and approximately 7 mg/L during one week in February 2014. While it is not known whether Slough 8A was breached during November 2013, the elevated intergravel dissolved oxygen levels during February 2014 were coincident with an observed breach event within Slough 8A by main channel streamflow. Intergravel water temperatures at the Slough 8A monitoring sites tended to be stable at 2.7°C at 128-SL8A-15 and 4.5°C at 128-SL8A-40 during each measurement period and temperatures exhibited abrupt declines during periods coincident with apparent dissolved oxygen fluctuations. Intergravel dissolved oxygen at FA-138 (Gold Creek) Site 138-SL11-04 fluctuated between 7–10 mg/L during the September 2013 through April 2014 monitoring period with some temporary excursions to values less than 4 mg/L. The median dissolved oxygen concentration was 10.33 mg/L during the measurement period. Temperatures associated with dissolved oxygen recorded at Site 138-SL11-04 were stable and ranged between 6–7°C.

Instantaneous measurements of SW temperature recorded during September 2014 indicated cooler water in side slough and upland slough habitats relative to the Susitna River main channel and side channel areas (Table 5-1). Following freeze-up, the inverse of this relationship was observed with slough habitats typically warmer than main channel and side channel areas (R2

2014a; R2 2014b). Although specific conductance values generally differed between main channel and off-channel habitats during winter, the degree and manner in which values differed was not consistent. In FA-104 (Whiskers Slough) and FA-128 (Slough 8A), specific conductance measured during February and March 2014 in main channel and side channel sites tended to be higher than off-channel and tributary areas, while conductance measured in FA-138 (Gold Creek) side sloughs was often equivalent to or higher than main channel sites (R2 2014b). Instantaneous measurements in side channel habitats indicated highly variable thermal and chemical conditions (i.e., specific conductance and dissolved oxygen), particularly in FA-138 (Gold Creek) in which multiple GW sources were apparent. At sites in which it was possible to measure, GW upwelling often reflected higher temperature and lower dissolved oxygen concentration than surface flow.

The majority of the main channel and side channel habitats were completely ice-covered during the studies, although open-water leads were present in certain locations (R2 2014a; R2 2014b). The open leads in main channel areas were likely related to high SW turbulence or velocity, while open water in side channel, side slough and upland sloughs were likely linked to warmer water temperatures as influenced by GW. During February and March 2014, ice thickness measurements at instantaneous water quality sites was generally greater than 3 feet in the main channel, and ranged from 0–2 feet at side channel sites, 0–1 foot in side sloughs, 0–2 feet at upland sloughs, and 0–1.5 feet in tributaries (R2 2014b).

5.3. Fish Observations

A total of 59 electrofishing surveys were conducted during the 2012-2013 and 2013-2014 winter data collection efforts in FA-104 (Whiskers Slough), FA-128 (Slough 8A), FA-138 (Gold Creek), and FA-141 (Indian River) (R2 2014a, R2 2014b), 21 of which were conducted at night. Fish species captured during day and night electrofishing surveys consisted of Chinook (*Oncorhynchus tshawytscha*), sockeye (*O. nerka*), chum (*O. keta*) and coho salmon (*O. kisutch*), rainbow trout (*O. mykiss*), Arctic grayling (*Thymallus arcticus*), Longnose sucker (*Catostomus catostomus*), lamprey (species undifferentiated), and sculpin (*Cottid sp.*). During an opportunistic survey of a main channel site in FA-141 (Indian River) in April 2014, one Chinook and three coho salmon were captured.

A total of 248 fish were captured during 29 daytime electrofishing surveys conducted between February–April 2014, while 659 fish were captured during 16 nighttime surveys. Overall, a total of 288 site specific HSC observations were recorded for eight fish species during the winter studies (Table 5-2). Most HSC observations were of coho salmon (120 observations), sockeye (68 observations), and chum (42 observations) though other observations were recorded for Chinook salmon, rainbow trout, Arctic grayling, longnose sucker and lamprey (Table 5-2).

Few fish were detected during underwater video surveys; no fish were observed at sites in FA-104 (Whiskers Creek) or FA-128 (Slough 8A) during February, March, and April 2014, and only a few juvenile salmon (unidentified 60-120 mm fork length) were observed during nighttime surveys at FA-138 (Gold Creek) at Site 138-SL11-22. As a result, no HSC observations were made based on underwater video surveys (R2 and LGL 2014a; R2 and LGL 2014b).

6. PRELIMINARY FINDINGS OF WINTER STUDIES RELATIVE TO PROJECT OPERATIONS

Winter is a critical period for various life stages of Susitna River fish species and aquatic habitat conditions can be severe. Susitna River areas that support spawning and egg incubation, juvenile fish rearing and adult holding are critical winter habitats that may be altered by proposed Project operations. In general, Project operations are anticipated to result in higher flows in the winter than under current conditions. Flows at the USGS Gold Creek gage station may range upwards to 7,000–9,000 cfs during the winter period (November–April) depending on Project operations, compared with existing winter flows that range from around 1,300–2,600 cfs (based on average monthly flows) during those months (Stream Flow Assessment TM submitted to the FERC March 1, 2013 [Tetra Tech 2013]). In addition, unlike current conditions in which the winter-time represents a stable, base-flow condition, the Project winter-time flows may vary both hourly and daily due to load-following demands.

The provision of higher flows in the winter will mean that, although some areas will be unaffected, other habitats that are normally dewatered and/or disconnected from the main channel may either remain continuously wetted by Susitna River flow (if wetted during lower load-following range), become periodically wetted if within the active range of load-following, or be inundated episodically in response to staging or ice jam events. It will also mean that some lateral habitats (side channels and side sloughs) that under current conditions are fed mostly by clear, stable, and comparatively warm GW flow would be subjected to daily/hourly flow increases from the much colder Susitna River. The frequency and magnitude of these flows into these areas will depend on the specific breaching conditions of each habitat feature, which can be determined through application of various hydrologic models including the Open-water Flow Routing Model (Study 8.5), SRH-2D hydraulic model (Study 6.6), and the River1D and River2D Ice Processes models (Study 7.6).

The objectives of the IFS winter studies were to evaluate potential relationships between mainstem Susitna River stage and the quality and quantity of winter aquatic habitats that support embryonic, juvenile, and adult life stages of fish species and to record fish behavior and habitat utilization in support of HSC/HSI development. This information, along with data, information, and modeling provided from other resource studies (e.g., Ice Processes [Study 7.6], GW [Study 7.5], Baseline Water Quality [Study 5.5], and FDAML [Study 9.6]) will be used for assessing potential impacts of winter-time Project operations on aquatic habitats and biota.

The results of the winter studies completed to date, along with information from the 1980s and from other more recent winter investigations provide useful insight regarding some of the potential effects of winter time Project operations on aquatic habitats.

6.1. Winter-time Project Operational Effects on Water Surface Elevations

Monitoring of water levels within different lateral habitats revealed a hierarchy of responses relative to stage changes in the mainstem channel of the Susitna River as follows: side channel stage response > side sloughs > upland sloughs. This hierarchy is consistent with what was found during the 1980s studies and is the inverse of the extent to which each of the habitats are influenced by GW, i.e., side channel < side sloughs < upland sloughs.

During the 2013-2014 monitoring period, changes in mainstem channel Susitna River stage were observed in all of the continuous monitoring sites within lateral habitats in FA-104 (Whiskers Creek), FA-128 (Slough 8A), and FA-138 (Gold Creek) (R2 2014b). Water level responses in side channel habitats were closely related to Susitna River main channel stage fluctuations. This was evident by the stage responses in Whiskers Side Channel (104-WSC-10), Side Channel 8A (128-SC8A-25), and Upper Side Channel 11 (138-USC11-09) that were synchronous with stage changes at respective main channel sites (104-MC-40, 128-MC-10, and 138-MC-50) (Figure 5-4, Figure 5-8 and Figure 5-12). Stage changes in side sloughs were less responsive to main channel water level fluctuations, particularly when side slough inlets were not breached by main channel streamflow. Water levels in tributary and upland slough habitats (e.g., 104-WC-10 and 104-SL3A-70) were the least affected by main channel stage changes reflecting water sources exogenous to the mainstem river. Hydrologic studies conducted during the 1980s similarly documented that side channels in the Middle Susitna River were generally more frequently breached by main channel streamflow relative to other habitat types (Quane et al. 1984). When not breached, side channel habitats were observed to be particularly susceptible during the 1980s winter studies to dewatering and freezing due to a general lack of GW upwelling compared to other off-channel habitats (e.g., side sloughs) (Vining et al. 1985).

Many of the 2013-2014 side channel and side slough monitoring sites became breached during the winter monitoring period, particularly during ice formation and main channel staging (November and December 2013) (R2 2014b). The duration of breaching events were typically short-term (e.g., 1-3 weeks) as main channel water levels receded relatively quickly within a month following ice jamming and staging events. An exception to this occurred in Side Channel 8A (Site 128-SC8A-25) in which breaching occurred in January 2014 and continued for the rest of the winter period. Similar breaching events in Slough 8A were reported in the 1980s in response to freeze-up events though the duration of such events was not documented (Labelle 1984). During the 1980s studies, breaching of side channel and side slough habitats reportedly occurred most frequently downstream of RM 130 (PRM 102 - PRM 134). Between Portage Creek (PRM 152) and Gold Creek (PRM 140), observed main channel staging was minor during the 1980s and few side channel and side slough breach events were recorded relative to the lower extent of the Middle Susitna (Labelle 1984).

Winter-time Project operations will result in higher flows than currently occur in the river and when load-following, these flows may fluctuate on an hourly basis as flow adjustments are made to meet energy demands (ISR Study 8.5, Part A, Section 5.4.1). Higher Susitna River discharge during winter periods will increase the frequency and magnitude that side channels and side sloughs are breached by cold main channel streamflow which would likely impact salmonid egg incubation (i.e., embryo development is directly related to water temperature; colder water will increase the incubation period) and possibly embryo survival. Application of the OWFRM/SRH-2D and River1D/River2D models for different Project operational scenarios will determine the extent to which this breaching will occur, and outputs from these models linked with the MODFLOW GW models will provide an indication of the extent to which GW fluxes may change within side channel and side sloughs. Hydrologic studies conducted in the 1980s determined that discharge in some of the non-breached side slough habitats was related to main channel stage via intergravel flow through islands and gravel bars, such that higher main channel stage resulted in higher side slough discharge (Harza-Ebasco and R&M 1984; Trihey & Associates and Entrix 1985). These riverine dominated sources of GW were found to vary directly in response to main channel stage changes; e.g., one-foot reductions in main channel stage resulted in changes between 0.3 to 0.6 cfs in non-breached side slough flows, depending on the slough (Harza-Ebasco and R&M 1984, Trihey & Associates and Entrix 1985).

Several side channel and side slough habitats that supported salmon spawning during September 2013 were observed to contain little surface flow and/or were dewatered and frozen during the 2013-2014 winter studies. Assuming higher winter baseflow conditions than what currently occur, those habitats may either remain continuously wetted or be subjected to periodic (in some cases daily) fluctuations in flow during load-following operations. In both cases, the majority of the source water would be from the Susitna River which during the winter time will be cold. Some tempering of water temperatures may occur depending on the quantity and residence time of flow entering via riverine GW. In some cases, winter-time Project operations may create additional spawning and incubation habitats via maintaining flows in areas currently dewatered during the winter. However, it is also possible that load-following operations would increase the risk of periodic dewatering/freezing and changes in surface and intergravel water temperatures that would negatively impact egg incubation. The extent of these types of effects, both positive (e.g., potential creation of spawning and incubation habitats) and negative (e.g., periodic dewatering/freezing and cold-water introduction) will be determined via the combined modeling efforts (SRH-2D, River2D, MODFLOW, 2D PHABSIM Fish Habitat Model) as noted above.

In terms of dewatering effects on incubation and embryo survival, studies have indicated that dewatering tolerance varies by developmental stage. Both Reiser and White (1983) and Becker et al. (1982) found that salmonid eggs could withstand several weeks (1 to 5 weeks) of dewatering provided they were maintained within a moist environment and temperatures remained above freezing. In contrast, salmonid alevins and pre-emergent fry were vulnerable to even short periods of dewatering (1 to 4 hours) (Becker et al. 1982; Reiser and White 1981). Fast and Stober (1984) observed that salmon alevins survived variable periods of dewatering (up to 48 hours), but that alevin survival declined with duration of dewatering, and the length of time that alevins tolerated dewatering declined with age from date of hatching. Individuals older than 30 days post-hatch experienced low survival (range: 0-18%) in response to two hours of dewatering (Fast and Stober 1983). The degree of mortality due to wintertime dewatering of eggs in redds within the Susitna River would likely vary widely depending on the extent of GW influence at the different redd locations. In areas where GW is prevalent, as may be the case in side sloughs and upland sloughs, temperatures may remain above freezing in the redd (due to warming of the intergravel environment from the warmer GW below the redd) during short-term periods of dewatering. In areas of no or little GW influence, any dewatering during the winter periods would likely result in 100 percent mortality of the eggs due to freezing.

6.2. Winter-time Project Operational Effects on Water Quality

Continuous surface and intergravel temperature data recorded at main channel and tributary monitoring sites were at or near 0°C for much of winter monitoring periods, indicating these areas were strongly influenced by SW with minimal GW input (R2 2014a; R2 2014b). In contrast, various side slough and upland slough habitats exhibited warmer (2-4°C) surface and intergravel water temperatures. Conditions at monitored side channel sites varied such that intergravel temperatures ranged from about 4°C at some sites (e.g., 104-WSC-30) to nearly 0°C at other sites (e.g., 104-WSC-10, 128-SC8A-25) (Figure 5-4, Figure 5-5, Figure 5-8). Researchers during the 1980s studies similarly identified a range of thermal conditions among Susitna River habitats. Although intergravel water temperature in most main channel and tributary habitats were believed to be dominated by near-0°C SW flow, the influence of localized upwelling was apparent. Intergravel temperatures recorded at main channel spawning locations exhibited GW influence and temperatures near 2-3°C during the ice-covered period (January - March) (Seagren and Wilkey 1985, Vining et al. 1985). Side channels were generally characterized during the 1980s studies as being thermally variable (<0-4°C) and particularly prone to dewatering and freezing due to the localized nature of GW upwelling in these habitats (Vining et al. 1985). In contrast, side slough and upland sloughs exhibited relatively warm (4°C) and stable intergravel temperatures due to the high contribution of GW to intergravel and surface flow (Vining et al. 1985).

Main channel surface flow was observed to breach and/or backwater side channel, side slough, upland slough and tributary habitats during IFS winter studies in association with ice formation, jamming or break-up events (R2 2014a; R2 2014b). During these episodes, surface and intergravel water temperature at affected sites typically declined to nearly 0°C. Exceptions to this response occurred at a few side slough and upland slough habitats that exhibited a strong GW influence and maintained comparatively warm (4°C) and stable intergravel temperatures (e.g., 104-SL3A-70, 138-SL11-04) (Figure 5-6, Figure 5-13). Side channel or side slough breaching events during winter were recognized during the 1980s studies as being potentially deleterious to salmon embryo development by causing a rapid and substantial decrease in intergravel temperature (Vining et al. 1985). Such a change may alter salmon egg incubation by prolonging development timing and could potentially cause egg mortality if it were to occur during the early stages of incubation prior to embryo development (Combs 1965; Bailey and Evans 1971; Velsen 1980; Hoffman et al. 1983).

In general, salmon embryos develop faster at warmer water temperatures, although the nature of this relationship varies with species. At 5°C constant temperature, incubation time (fertilization to hatching) was observed to range dramatically among coho (139 days), chum (161 days), sockeye and pink (173 days, each species) and Chinook (191 days) salmon (Murray and McPhail 1988; Quinn 2005). At 2°C, incubation time increased more than 60% for coho, sockeye and Chinook salmon (Murray and McPhail 1988; Quinn 2005). Extreme low water temperatures can limit salmon egg survival, although the effect on incubation success likely depends upon the timing of the onset of low temperature relative to developmental stage of the egg (Bjornn and Reiser 1991). Salmon eggs may tolerate near-0°C temperatures provided that the embryo matures past a critical development stage (i.e., gastrulation and epiboly) prior to the occurrence of the low temperatures (Combs 1965; Bailey and Evans 1971; Bjornn and Reiser 1991). For chum salmon eggs incubated at 3.5-4.0°C, this critical developmental stage would likely occur approximately 35-45 days after fertilization (Vining et al. 1985, Velsen 1987). The lower temperature threshold during initial egg development, below which egg survival would be compromised, is estimated to be approximately 2-3°C based on experimental evidence (Wangaard and Burger 1983; Velsen 1987). The lower water temperature at which 50 percent of embryos died was identified as 1°C for sockeye and coho, 2.5°C for chum, 3°C for Chinook and 3.5°C for even-year pink salmon (Beacham and Murray 1990).

Intergravel dissolved oxygen values recorded in Slough 8A (FA-128) during IFS winter studies were low (<6 mg/L) relative to SW conditions (>11 mg/L), while intergravel and surface values recorded in Slough 11 (FA-138 [Gold Creek]) were similar (R2 2014a; R2 2014b). These values are consistent with data collected during the 1980s; mean intergravel dissolved oxygen in April

1983 was 4.6 mg/L at FA-128 (Slough 8A) and 8.5 mg/L at FA-138 (Gold Creek) (Hoffman et al. 1983). The variation in dissolved oxygen concentration between sites may also reflect the variable sources of GW in the Susitna River and differing quality of such sources. During 1980s studies, the primary Susitna River GW source in side channel and side slough habitats was reported to be derived from lateral infiltration from the Susitna River main channel and the quality of such flow could vary depending upon the intergravel residence time of the subsurface flow (Trihey & Associates and Entrix 1985). Warm intergravel temperatures (3-5°C) and low dissolved oxygen concentrations are generally associated with older GW that has traveled longer subsurface distances and has experienced greater subsurface residence time (Durst 2001; Malcolm et al. 2005).

Although long-residence GW sources can provide a stable upwelling source relative to GW of shorter subsurface path, the chemical properties (i.e., low dissolved oxygen) of these water sources can be detrimental to salmon embryo survival (Bjornn and Reiser 1991; Quinn 2005). Uptake of dissolved oxygen by salmon embryos may depend on various factors in addition to dissolved oxygen concentration, including gravel permeability and hyporheic flow or exchange rates, such that reduced substrate porosity and flow can inhibit embryo development (Quinn 2005). Research with chum salmon embryos indicated that the amount of oxygen needed by the embryo increases with development time and that embryo sensitivity to hypoxia was greatest early in the incubation period (Alderdice et al. 1958; Bjornn and Reiser 1991; Salo 1991). Although acute mortality in salmon embryos occurs at low dissolved oxygen concentrations (2.0-2.5 mg/L), delayed or deformed development of the embryo and premature hatching can occur at levels above this critical minimum (Alderdice et al. 1958; Bjornn and Reiser 1991; Quinn 2005). However, strong upwelling conditions with high hyporheic exchange rates can potentially mitigate these negative effects (Quinn 2005).

The degree and extent of lateral GW infiltration from the Susitna River to side channel and off-channel habitats may be affected by increased main channel streamflow and stage as part of proposed Project operations during winter (see Section 6.1). Higher main channel stage levels during winter may increase the quantity and quality of GW discharge to off-channel habitats. This possible effect may be most evident during late fall and early winter prior to freeze-up when Susitna River flow is typically low and main channel staging has not yet occurred. At some side slough habitats characterized by warm (4°C) intergravel temperature (e.g., 128-SL8A-40, 138-SL13-05), surface and intergravel temperatures appear to decline during this period of extremely low main channel flow and stage (e.g., November 2013) possibly due to low lateral GW infiltration rates (Figure 5-9, Figure 5-15). Consistently higher Susitna River flow during the winter period may create more stable GW sources in some of these off-channel habitats. In addition, if the quantity of GW discharge is increased, the rate of intergravel dissolved oxygen exchange may also be increased, which may improve incubation conditions in areas of low dissolved oxygen concentration (e.g., Slough 8A) (Vining et al 1985).

Instantaneous measurements of SW temperature and specific conductance during IFS winter studies supported the general trend indicated by continuous temperature data of warmer SW in off-channel (i.e., side slough and upland slough) areas relative to main channel and side channel habitats (R2 2014a; R2 2014b). Although instantaneous water temperature was variable at many side channel sites, specific conductance within side channels typically reflected that of Susitna River main channel. At side channel sites in which specific conductance varied from that of the adjacent main channel (e.g., 138-USC11-12 and 138-USC11-16), surface flow may represent water that is of a different source than the Susitna River main channel (R2 2014a; R2 2014b). Instantaneous measurements at side slough and upland slough habitats typically exhibited higher temperature and lower conductance values than main channel and side channel areas. Exceptions to this trend were present in each Focus Area and may indicate that a portion of the GW source was derived from lateral subsurface flow from the Susitna River main channel.

Ice cover and thickness observations were recorded in each IFS winter studies Focus Area. Ice cover and thickness was generally greater in main channel areas of FA-104 (Whiskers Slough; 3.6 feet) relative to FA-128 (Slough 8A; 3.2 feet) and FA-138 (Gold Creek; 1.5 feet), and in main channel (1.5-3.6 feet) and side channel (0-2.5 feet) habitats compared to side slough (0-1.1 feet) and upland slough (0-2.1 feet) areas. Although ice measurements were recorded in each macrohabitat, sample locations were associated with existing (i.e., continuous monitoring sites) or opportunistic sites (i.e., spot measurements) and thus may not completely reflect the variation in ice conditions. This perceived bias was particularly evident in main channel and side channel habitats in which ice appeared to be thicker in areas not sampled. Additional information on Susitna River ice conditions is found in Ice Processes ISR Study 7.6 (AEA 2014a) and SIR Study 7.6 (AEA 2015).

6.3. Winter-time Fish Observations

The relative distribution of juvenile salmon captured during winter studies indicated that fish were associated with tributary and off-channel habitats. Although more IFS winter electrofish surveys were conducted in side channels (n=18) relative to side sloughs (n=12), upland sloughs (n=11), main channel (n=2) and tributary (n=2) habitat types, the majority of fish were captured in side slough habitats (R2 2014a; R2 2014b). Fish capture surveys associated with FDAML (Study 9.6) winter studies similarly indicated that relative abundance of juvenile salmon was greater in tributary and off-channel habitats relative to side channels based on minnow trap, fyke net and electrofish sampling catch per unit effort (CPUE) (R2 and LGL 2014b). Juvenile coho salmon were the most abundant fish species and were captured in all habitat types during FDAML winter sampling. Juvenile coho were observed most consistently and typically in greatest abundance in tributary and side slough habitats. Among the three Focus Areas sampled during winter 2013-2014, Chinook salmon were most closely associated with tributary and side slough habitats, though capture rates were low in FA-128 (Slough 8A) and FA-138 (Gold Creek) (R2 and LGL 2014b). Although few juvenile chum and sockeye salmon were captured during FDAML winter sampling, observed chum were typically located near spawning areas in side channels and side sloughs, while sockeye were typically found in side slough habitats. Main channel habitats were not sampled on a consistent basis due to physical limitations in these areas; limited availability of open-water in main channels precluded electrofishing sampling, while extensive, thick (2-4 feet) ice cover conditions made large-scale deployment of minnow traps impractical.

Suitable winter habitats for fish in riverine environments allow fish to minimize energy expenditure while providing a stable environment protected from physical extremes (Cunjak 1996; Brown et al. 2011). Such habitats are generally located in deep portions of the main channel and side channels and in off-channel areas that provide protection from main channel flow and/or ice accumulation (Hartman 1965; Brown and Mackay 1995; Cunjak 1996; Jakober et al. 1998). Comparison of salmonid abundance among macrohabitats in interior rivers located in British Columbia during winter indicated that utilization of side channel and off-channel habitats was greater than main channel areas (Swales et al. 1986). Off-channel habitats, such as side sloughs and beaver ponds, are particularly important for juvenile coho salmon by providing refuge from extreme winter conditions (Bustard and Narver 1975; Peterson 1982; Swales et al. 1986). During the 1980s studies in the Susitna River, juvenile coho salmon used GW-fed side sloughs and upland sloughs for winter habitat, in addition to natal tributaries, while primary winter habitats for juvenile Chinook consisted of side slough and side channel areas with GW upwelling (Delaney et al. 1981; Stratton 1986). Adult rainbow trout and Arctic grayling migrated from spawning and feeding tributaries in late summer to main channel areas that were typically downstream and proximal to the spawning tributary, although some individuals exhibited long distance (>20 miles) movements (Hoffman et al. 1983; Sundet and Pechek 1985; Sundet 1986).

Winter fish sampling was conducted by the Aquatic Restoration and Research Institute (ARRI) and National Marine Fisheries Service (NMFS) in the Susitna and Talkeetna rivers during the 2012-2013 and 2013-2014 winter seasons to assess winter sampling methods, describe fish distribution, and test for associations between coho salmon abundance and physical habitat characteristics (Davis et al. 2013; Davis et al. 2015). Sampling occurred at eight side channel, side slough, upland slough and tributary mouth sites during the winter 2012-2013 season and at nine side slough, upland slough and tributary mouth sites during winter 2013-2014. Fish species captured during the two winter sampling periods consisted primarily of Chinook and coho salmon, although various other species were recorded in small numbers. During the ice-covered period (January, February, and/or March), capture totals of juvenile coho salmon were highest in side slough and upland sloughs relative to side channel and tributary mouth habitats, while Chinook were most abundant in side channel and tributary mouth habitats between the two sampling seasons.

Microhabitat utilization (HSC) data by juvenile and adult fish species were recorded during IFS winter studies in FA-104 (Whiskers Slough), FA-128 (Slough 8A), FA-138 (Gold Creek), and FA-141 (Indian River). A total of 288 HSC observations were recorded during 59 electrofishing surveys. Electrofish sampling was used for fish habitat utilization surveys because it provided a more direct and effective means of recording fish habitat use compared to passive trapping methods (e.g., minnow trapping), which can introduce capture biases related to fish size and sampling area (Bryant 2000). Extensive use of minnow traps in Alaska has indicated that the effective capture radius can be at least 6.6 feet (2 meters) and the presence of current may increase the extent of this range downstream, depending on flow and site-specific conditions (Bryant 2000). Consequently, the use of baited minnow traps to evaluate potential associations between fish distribution and physical habitat is often inappropriate, particularly in complex and varied habitats and at sites proximal to multiple habitat types (e.g., tributary mouths). In such situations, it cannot be reliably ascertained whether the captured fish was attracted from outside the sampled habitat or which physical characteristics may have influenced fish abundance. Winter IFS habitat utilization data will be used to develop site-specific HSC/HSI curves for relevant fish species and life stages to help evaluate how Project operations may affect aquatic habitat conditions in the Susitna River (SIR Study 8.5, Appendix D [R2 2015]).

The microhabitat characteristics of winter habitat and suitability of these features for fish vary among species and life stages, but in general consist of low velocity areas with physical attributes that provide refuge from predators and environmental extremes (Brown et al. 2011). Specific features that often characterize winter habitat include low current velocity, deep pools, off-channel areas, GW upwelling, structural complexity (e.g., large wood) and coarse substrate (Muhlfeld et al. 2001; Mitro and Zale 2002; Harper and Farag 2004; Brown et al. 2011). During fall and winter, habitat preferences of juvenile salmonids often shift to areas with greater depth and lower velocity relative to habitats used during summer, presumably for refuge from high current velocities (Bustard and Narver 1975; Allen 2000; Baltz et al. 1991). These habitats are frequently located in off-channel areas that are protected from main channel flow fluctuations and ice movement and are often influenced by GW upwelling (Peterson 1982; Swales and Levings 1989; Reynolds 1997). Groundwater upwelling provides thermal refuge from frazil and anchor ice and extreme low temperatures that may otherwise freeze surface flow (Brown and Mackay 1995; Reynolds 1997; Harper and Farag 2004). Juvenile salmonids in various winter settings have been observed to conceal themselves within the interstitial spaces in coarse substrate (Meyer and Gregory 2000; Muhlfeld et al. 2001; Brown et al. 2011). Adult fish may also use interstitial habitats in large substrates (e.g., rip rap), but those too large to utilize these areas often seek deep pools in main channels (Swales et al. 1986; Reynolds 1997). The specific habitat features of Susitna River holding areas used by adult resident species during the 1980s winter telemetry studies were difficult to measure, although GW upwelling, overhead cover (depth and/or ice cover), lack of frazil and/or anchor ice, and low water velocity appeared to be common characteristics of known holding habitats (Schmidt et al. 1983; Sundet and Pechek 1985).

Fish presence was recorded during both day and night periods in open-water areas during electrofish surveys (R2 2014a; R2 2014b; R2 and LGL 2014a; R2 and LGL 2014b). Diel differences in fish behavior are common among fish species, particularly during winter, but information specific to the Susitna River is sparse. In general, when day length is short and water temperatures are low, fish activity often shifts from diurnal to nocturnal periods, such that individuals become inactive and/or hide during the day to minimize energy expenditure and reduce predation risk (Roni and Fayram 2000; Quinn 2005; Reeves et al. 2009). The presence of ice cover, however, may mitigate such behavioral shifts. During a winter study of the effect of ice cover on fish behavior, greater fish activity and foraging was observed in the presence of ice cover relative to its absence (Watz et al. 2013). High numbers of fish captured during IFS and FDAML night surveys relative to daytime sampling likely indicates that nocturnal activity is common among fish species in the Middle River Segment of the Susitna River during the winter (R2 and LGL 2014a; R2 and LGL 2014b). Sonar monitoring for continuous 24-hour periods in FA-104 (Whiskers Slough) and FA-138 (Gold Creek) during winter 2013-2014 indicated a relatively high level of fish movement during periods of dawn and dusk relative to nighttime and daytime periods (R2 and LGL 2014a; R2 and LGL 2014b).

7. CONCLUSION

The IFS winter studies were comprised of two primary components: 1) monitoring of water level, water quality, and ice conditions and 2) fish behavior and habitat use observations. The RSP identified an initial pilot effort during winter 2012-2013 (i.e., February - April 2013), followed by an expanded effort during winter 2013-2014, and an additional winter survey effort as needed (AEA 2012). Each IFS winter studies component was addressed during the initial pilot winter effort (February - April 2013) and during winter 2013-2014. Analysis and reporting is complete for data collected through September 2014. Additional continuous water level and water quality monitoring was completed during the 2014-2015 ice-covered and open-water periods (i.e., September 2014 through September 2015) and has been reinitiated for winter 2015-2016. As a result, a robust set of water level and water quality data have been and are continuing to be collected that can be used as part of the modeling efforts noted above. However, fish behavior and habitat use surveys were not performed during winter 2014-2015 and are not proposed for winter 2015-2016. Because Project operational effects on flows will likely have some of the greatest effects during the winter period, it will be important to understand the distribution, behavior, and habitat use of fish under current winter conditions from which to draw conclusions regarding Project induced effects. Therefore, an additional winter period of IFS data collection, consisting of both study components (i.e., water quality monitoring and fish surveys), is needed to complete the objectives of this study component.

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9. TABLES

Table 4-1. Continuous surface water stage (i.e., pressure and barometric transducers), surface and intergravel water temperature and intergravel dissolved oxygen monitoring sites maintained in association with IFS winter studies during each winter of 2012-2013, 2013-2014 and 2014-2015 with the periods of record for each site and instrument type.

Focus Area	Monitoring Site	Instrument Type	Period of Record
FA-104	104-BARO	Barometric transducer	Feb 2013 – Sept 2014; Sept 2014 – Sept 2015
	104-CFSL-10	Temperature	Feb 2013 – Apr 2013
	104-CFSL-15	Pressure transducer	July 2014 – Sept 2015[3]
	104-MC-40	Pressure transducer	Sept 2013 – June 2014; Sept 2014 – Sept 2015[3]
	104-MC-40	Temperature	Sept 2013 – June 2014[1]; Sept 2014 – Sept 2015[3]
	104-MC-50	Pressure transducer	Feb 2013 – April 2013; Feb 2014 – April 2014
	104-MC-50	Temperature	Feb 2013 – April 2013
	104-SL3A-20	Pressure transducer	Sept 2014 – Sept 2015[3]
	104-SL3A-20	Temperature	Sept 2014 – Sept 2015[3]
	104-SL3A-70	Pressure transducer	Feb 2013 – April 2014
	104-SL3A-70	Temperature	Feb 2013 – April 2014
	104-SL3B-08	Pressure transducer	Sept 2014 – Sept 2015[3]
	104-SL3B-08	Temperature	Sept 2014 – Sept 2015[3]
	104-SL3B-08	Dissolved oxygen	Sept 2014 – April 2015[3]
	104-SL3B-10	Pressure transducer	Feb 2013 – April 2013; Sept 2013 – Sept 2014
	104-SL3B-10	Temperature	Feb 2013 – April 2013; Sept 2013 – March 2014
	104-SL3B-10	Dissolved oxygen	Feb 2013 – April 2013[2]
	104-WC-10	Pressure transducer	Feb 2013 – April 2013; Sept 2013 – June 2014
	104-WC-10	Temperature	Feb 2013 – April 2013; Sept 2013 – June 2014
	104-WC-11	Pressure transducer	Sept 2014 – Sept 2015[3]
	104-WC-11	Temperature	Sept 2014 – Sept 2015[3]
	104-WESC-10	Pressure transducer	Oct 2013 – June 2014; July 2014 – Sept 2014
	104-WESC-10	Temperature	Sept 2013 – March 2014
	104-WESC2-12	Pressure transducer	Sept 2014 – Sept 2015[3]
	104-WESC2-12	Temperature	Mar 2014 – *Not relocated*; Sept 2014 – Sept 2015[3]
	104-WSC-10	Pressure transducer	Feb 2013 – April 2013 [2]; Sept 2013 – June 2014
	104-WSC-10	Temperature	Feb 2013 – April 2013; Sept 2013 – March 2014
	104-WSC-30	Pressure transducer	Feb 2013 – April 2013; Sept 2013 – June 2014; Sept 2014 – Sept 2015[3]
	104-WSC-30	Temperature	Feb 2013 – Sept 2014; Sept 2014 – Sept 2015[3]
	104-WSL-20	Pressure transducer	Feb 2013 – Apr 2013; Sept 2013 – June 2014; Sept 2014 – Sept 2015[3]
	104-WSL-20	Temperature	Feb 2013 – Apr 2013; Sept 2013 – June 2014; Sept 2014 – Sept 2015[3]
	104-WSL-35	Temperature	Sept 2014 – Sept 2015[3]
	104-WSL-35	Dissolved oxygen	Sept 2014 – April 2015[3]

Focus Area	Monitoring Site	Instrument Type	Period of Record
	104-WSL-40	Pressure transducer	Feb 2013 – Apr 2013; Sept 2014 – Sept 2015[3]
	104-WSL-40	Temperature	Feb 2013 – Apr 2013
FA-128	128-BARO1	Barometric transducer	March 2013 – Aug 2013
	128-BARO2	Barometric transducer	Sept 2013 – Sept 2014
	128-MC-09	Pressure transducer	Sept 2014 – Sept 2015[3]
	128-MC-09	Temperature	Sept 2014 – Sept 2015[3]
	128-MC-10	Pressure transducer	Sept 2013 – Mar 2014
	128-MC-10	Temperature	Sept 2013 – *Not Relocated*[1]
	128-SC8A-15	Pressure transducer	Sept 2014 – Sept 2015[3]
	128-SC8A-15	Temperature	Sept 2014 – Sept 2015[3]
	128-SC8A-15	Dissolved oxygen	Sept 2014 – *Not Relocated*[1]
	128-SC8A-24	Temperature	Mar 2014 – June 2015[3]
	128-SC8A-25	Pressure transducer	Sept 2013 – April 2014
	128-SC8A-25	Temperature	Sept 2013 – April 2014
	128-SC8A-45	Pressure transducer	Sept 2014 – Sept 2015[3]
	128-SC8A-45	Temperature	Sept 2014 – Sept 2015[3]
	128-SC8A-45	Dissolved oxygen	Sept 2014 – April 2015[3]
	128-SL8A-15	Pressure transducer	March 2013 – Aug 2013; Sept 2014 – Sept 2015[3]
	128-SL8A-15	Temperature	Sept 2013 – Sept 2014; Sept 2014 – Sept 2015[3]
	128-SC8A-15	Dissolved oxygen	March 2013 – April 2013
	128-SL8A-40	Pressure transducer	Sept 2013 – Sept 2014; Sept 2014 – Sept 2015[3]
	128-SL8A-40	Temperature	Sept 2013 – Sept 2014; Sept 2014 – Sept 2015[3]
	128-SL8A-40	Dissolved oxygen	Sept 2013 – March 2014
	128-HMSL-05	Pressure transducer	July 2014 – Sept 2014; Sept 2014 – Sept 2015[3]
	128-HMSC-01	Temperature	Sept 2014 – Sept 2015[3]
	128-SSC-18	Pressure transducer	Sept 2014 – Sept 2015[3]
	128-SSC-18	Temperature	Sept 2014 – Sept 2015[3]
	128-SC-05	Temperature	Sept 2013 – March 2014
	128-SC-06	Pressure transducer	Sept 2014 – Sept 2015[3]
	128-SC-06	Temperature	Sept 2014 – Sept 2015[3]
	128-SLA-20	Pressure transducer	Sept 2013 – Sept 2014
	128-SLA-20	Temperature	Sept 2013 – Sept 2014
	128-US1-10	Pressure transducer	Sept 2013 – March 2014
	128-US1-10	Temperature	Sept 2013 – March 2014
	128-US2-10	Pressure transducer	March 2013 – Aug 2013
	128-US2-15	Pressure transducer	Sept 2013 – March 2014; March 2014 – May 2015[3]
	128-US2-15	Temperature	Sept 2013 – March 2014

Focus Area	Monitoring Site	Instrument Type	Period of Record
FA-138	138-BARO	Barometric transducer	Sept 2013 – Sept 2014; Sept 2014 – Sept 2015[3]
	138-MC-20	Pressure transducer	Sept 2014 – Sept 2015[3]
	138-MC-20	Temperature	Sept 2014 – Sept 2015[3]
	138-MC-50	Pressure transducer	Sept 2013 – April 2014
	138-MC-50	Temperature	Sept 2013 – Feb 2014
	138-SL11-04	Pressure transducer	Sept 2013 – Sept 2014; Sept 2014 – Sept 2015[3]
	138-SL11-04	Temperature	Sept 2013 – Sept 2014; Sept 2014 – Sept 2015[3]
	138-SL11-04	Dissolved oxygen	Sept 2013 – April 2014
	138-SL11-06	Temperature	Sept 2013 – Mar 2014; Mar 2014 – *Not Relocated* [1]
	138-SL11-08	Pressure transducer	Sept 2014 – Sept 2015[3]
	138-SL11-08	Temperature	Sept 2014 – Sept 2015[3]
	138-SL11-20	Pressure transducer	Sept 2013 – Sept 2014
	138-SL11-20	Temperature	Sept 2013 – Sept 2014 [1]
	138-SL11-55	Pressure transducer	July 2014 – Sept 2015[3]
	138-SL11-55	Temperature	Sept 2014 – Sept 2015[3]
	138-SL11-55	Dissolved oxygen	Sept 2014 – April 2015[3]
	138-SL12-10	Pressure transducer	Sept 2013 – Sept 2014
	138-SL12-10	Temperature	Sept 2013 – Sept 2014
	138-SL13-04	Pressure transducer	Feb 2014 – Sept 2014; Sept 2014 – Sept 2015[3]
	138-SL13-04	Temperature	March 2014 – Sept 2014; Sept 2014 – Sept 2015[3]
	138-SL13-04	Dissolved oxygen	Sept 2014 – April 2015
	138-SL13-05	Pressure transducer	Sept 2013 – Sept 2014
	138-SL13-05	Temperature	Sept 2013 – Sept 2014
	138-USC11-09	Pressure transducer	Sept 2013 – Sept 2014
	138-USC11-09	Temperature	Sept 2013 – Sept 2014
	138-USC11-25	Pressure transducer	July 2014 – Sept 2015[3]
	138-USC11-25	Temperature	Sept 2014 – Sept 2015[3]
	138-USC11-25	Dissolved oxygen	Sept 2014 – Sept 2015[3]
FA-144	144-SC21-20	Pressure transducer	July 2013 – Sept 2015[3]
	144-SC21-60	Pressure transducer	July 2013 – Sept 2015[3]
	144-SC21-60	Temperature	Sept 2014 – Sept 2015[3]

Notes:

1 One or more instruments could not be relocated during data retrieval efforts due to high flow conditions and/or loss of the instrument.

2 Data from instrument could either not be retrieved or appeared erroneous and were not reported.

3 Data were retrieved in September 2015 and are not summarized in this report.

Table 5-1. Instantaneous measurements of surface water and groundwater temperature, specific conductance, and dissolved oxygen concentration in FA-104 (Whiskers Creek), FA-128 (Slough 8A), FA-138 (Gold Creek) and FA-144 (Slough 21) during September 2014. Surface water measurements were recorded at mid-column water depth and groundwater was measured approximately 20 cm below the substrate surface at intergravel sites and near the surface at bank seep locations.[1]

Site[1]	Water Body	Habitat Type[2]	Date	Water Temperature (°C)	Specific Conductance (µS/cm)	Dissolved Oxygen (mg/L)
FA-104 (Whiskers Slough)						
104-MC-40	Main channel	MC	9/10/14	9.7	150.2	12.51
104-WESC2-12	Whiskers East Side Channel	SC	9/8/14	8.1	185.5	8.70
104-WSC-30	Whiskers Side Channel	SC	9/11/14	9.5	151.5	12.62
104-SL3B-08	Slough 3B	SC	9/8/14	6.4	101.3	8.91
104-CFSL-15	Chicken Foot Slough	SS	9/11/14	7.9	199.6	3.90
104-WSL-20	Whiskers Slough	SS	9/9/14	9.3	33.7	11.07
104-WSL-35	Whiskers Slough	SS	9/10/14	9.3	80.6	8.92
104-WSL-35*	Whiskers Slough intergravel site*	SS-GW*	9/10/14	6.6*	52.1*	4.51*
104-WSL-40	Whiskers Slough	SS	9/9/14	5.9	77.5	5.01
104-SL3A-20	Slough 3A	US	9/8/14	6.6	102.4	8.79
104-WC-11	Whiskers Creek	TR	9/9/14	8.2	31.7	11.77
FA-128 (Slough 8A)						
128-MC-09	Main channel	MC	9/11/14	9.7	155.7	11.99
128-SSC-18	Skull Side Channel	SC	9/15/14	11.2	160.9	11.33
128-HMSC-01	Half Moon Side Channel	SC	9/13/14	10.3	166.8	11.40
128-SC8A-15	Side Channel 8A	SC	9/14/14	10.2	169.3	11.51
128-SC8A-15*	Side Channel 8A intergravel site*	SC-GW*	9/14/14	5.2*	248.0*	4.32*
128-SC8A-45	Side Channel 8A	SC	9/14/14	9.6	173.2	11.80
128-SC8A-45*	Side Channel 8A intergravel site*	SC-GW*	9/14/14	9.9*	195.9*	10.70*
128-SL8A-15	Slough 8A	SS	9/14/14	7.9	130.6	10.55
128-SL8A-15*	Slough 8A intergravel site*	SS-GW*	9/14/14	5.5*	123.9*	4.05*
128-SL8A-40	Slough 8A	SS	9/14/14	9.7	117.0	10.25
128-SL8A-40*	Slough 8A intergravel site*	SS-GW*	9/14/14	7.3*	49.2*	7.10*
128-HMSL-05	Half Moon Slough	US	9/15/14	11.8	190.8	7.12
128-SC-06	Skull Creek	TR	9/13/14	9.7	103.3	11.42
FA-138 (Gold Creek)						
138-MC-20	Main channel	MC	9/11/14	9.9	163.7	12.39
138-SL11-04	Slough 11	SS	9/12/14	6.5	277.0	10.04
138-SL11-08	Slough 11	SS	9/12/14	7.5	291.0	10.25
138-SL11-08*	Slough 11 intergravel site*	SS-GW*	9/12/14	7.1*	121.5*	3.68*
138-SL11-55	Slough 11	SS	9/13/14	6.3	243.0	11.42
138-SL11-55*	Slough 11 intergravel site*	SS-GW*	9/13/14	6.0*	250.0*	9.91*
138-SL13-04	Slough 13	US	9/12/14	7.2	259.0	10.33
138-SL13-04*	Slough 13 intergravel site*	US-GW*	9/12/14	5.3*	257.0*	6.43*
138-USC11-25	Upper Side Channel 11	SC	9/13/14	9.3	174.5	11.58

Site[1]	Water Body	Habitat Type[2]	Date	Water Temperature (°C)	Specific Conductance (μS/cm)	Dissolved Oxygen (mg/L)
138-USC11-25*	Upper Side Channel 11 intergravel site*	SC-GW*	9/13/14	5.0*	225.0*	8.39*
138-USC11-25	Upper Side Channel 11, north bank seep*	SC-GW*	9/13/14	7.4*	236.0*	7.55*
FA-144 (Slough 21)						
144-SC21-20	Side Channel 21	SC	9/15/14	9.2	163.1	10.92
144-SC21-60	Side Channel 21	SC	9/15/14	5.4	185.9	8.03
144-SC21-60	Side Channel 21 intergravel site*	SC-GW*	9/15/14	4.7*	90.3*	7.26*

Notes:

1 Asterisks (*) indicate measurements of groundwater at intergravel dissolved oxygen monitoring sites (approximately 20 cm below the substrate surface) or bank seepage locations.

2 MC = Main Channel, SC = Side Channel, SS = Side slough, US = Upland Slough TR = Tributary, GW = Groundwater monitoring well; habitat designations are based on 2012 Middle Susitna River remote line habitat mapping (*Middle Susitna River Segment Remote Line Habitat Mapping* TM submitted to the FERC January 31, 2013 [HDR 2013]).

Table 5-2. Total number of HSC observations recorded during each winter season of 2012-2013 and 2013-2014 and used in HSC comparisons of seasonal habitat utilization by fish species and life stage in the Susitna River (see R2 2015).

Winter Season	Species	Lifestage[1]	FA-104 (Whiskers Slough)	FA-128 Slough 8A)	FA-138 (Gold Creek)	FA-141 (Indian River)	Non-Focus Areas	Total
2012-2013	Chinook salmon	Fry	1	2	0	0	0	**3**
		Juvenile	13	10	0	0	0	**23**
	Coho salmon	Fry	2	0	0	0	0	**2**
		Juvenile	1	0	0	0	0	**1**
2013-2014	Chinook salmon	Fry	13	0	0	1	0	**14**
		Juvenile	2	2	1	0	0	**5**
	Sockeye salmon	Fry	1	29	4	0	1	**35**
		Juvenile	0	0	33	0	0	**33**
	Chum salmon	Fry	0	13	24	0	5	**42**
	Coho salmon	Fry	25	4	2	1	2	**34**
		Juvenile	47	6	32	2	0	**87**
	Rainbow trout	Juvenile	2	0	2	0	0	**4**
	Arctic grayling	Juvenile	1	0	0	0	0	**1**
	Longnose sucker	Fry	2	0	0	0	0	**2**
	Lamprey (undifferentiated)	Juvenile	2	0	0	0	0	**2**
2012-2013 Total			**17**	**12**	**0**	**0**	**0**	**29**
2013-2014 Total			**95**	**54**	**98**	**4**	**8**	**259**
Cumulative Total			**112**	**66**	**98**	**4**	**8**	**288**

Notes:

1 Fry consist of fish less than 60 mm fork length; juvenile life stage represents fish between 60 mm and 150 mm fork length.

10. FIGURES

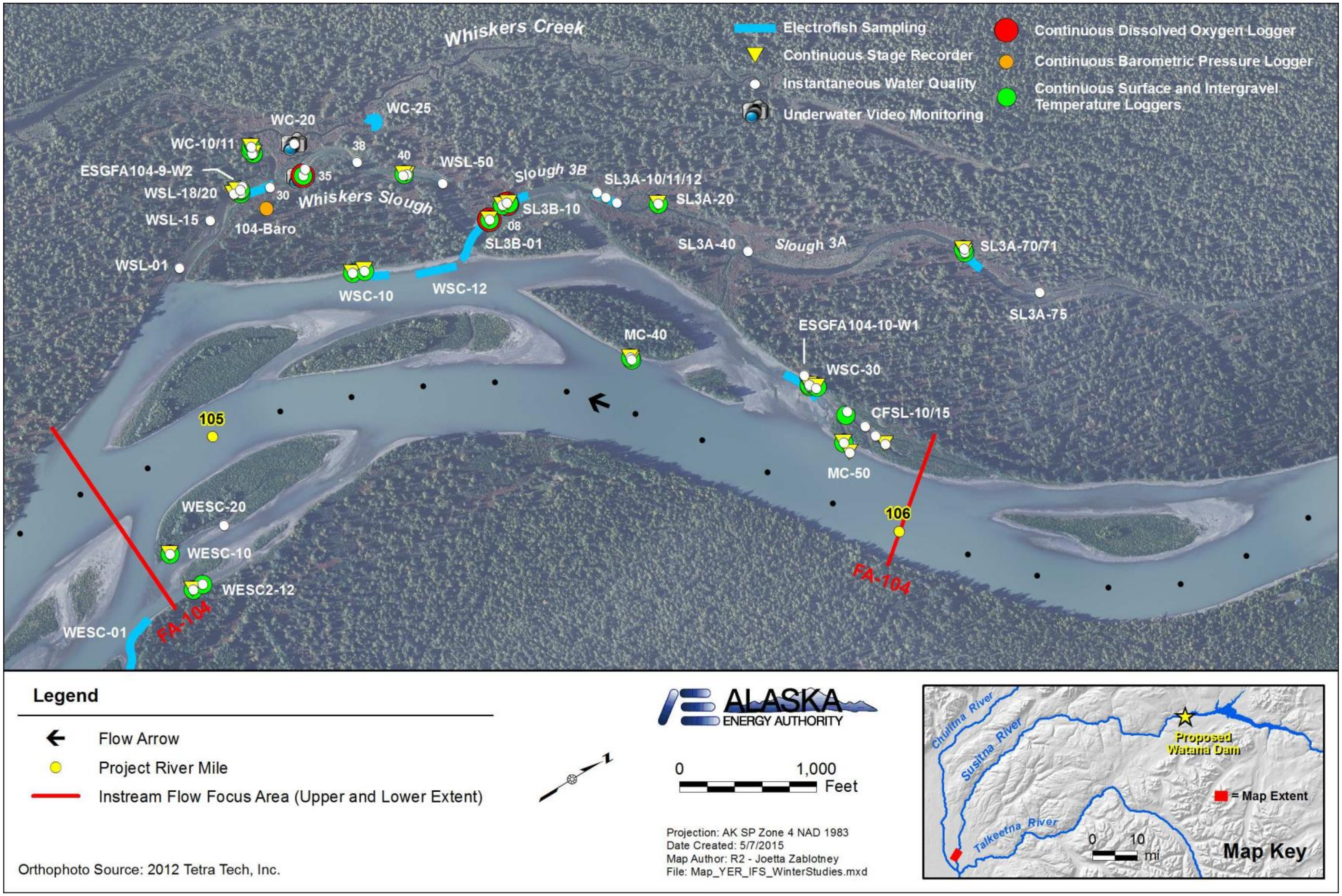

Figure 3-1. Locations of IFS winter studies sites used for continuous and instantaneous water quality monitoring, water level monitoring, and fish sampling in FA-104 (Whiskers Slough) during the winter seasons of 2012-2013 and 2013-2014 and continuous water quality and water level monitoring during 2014-2015.

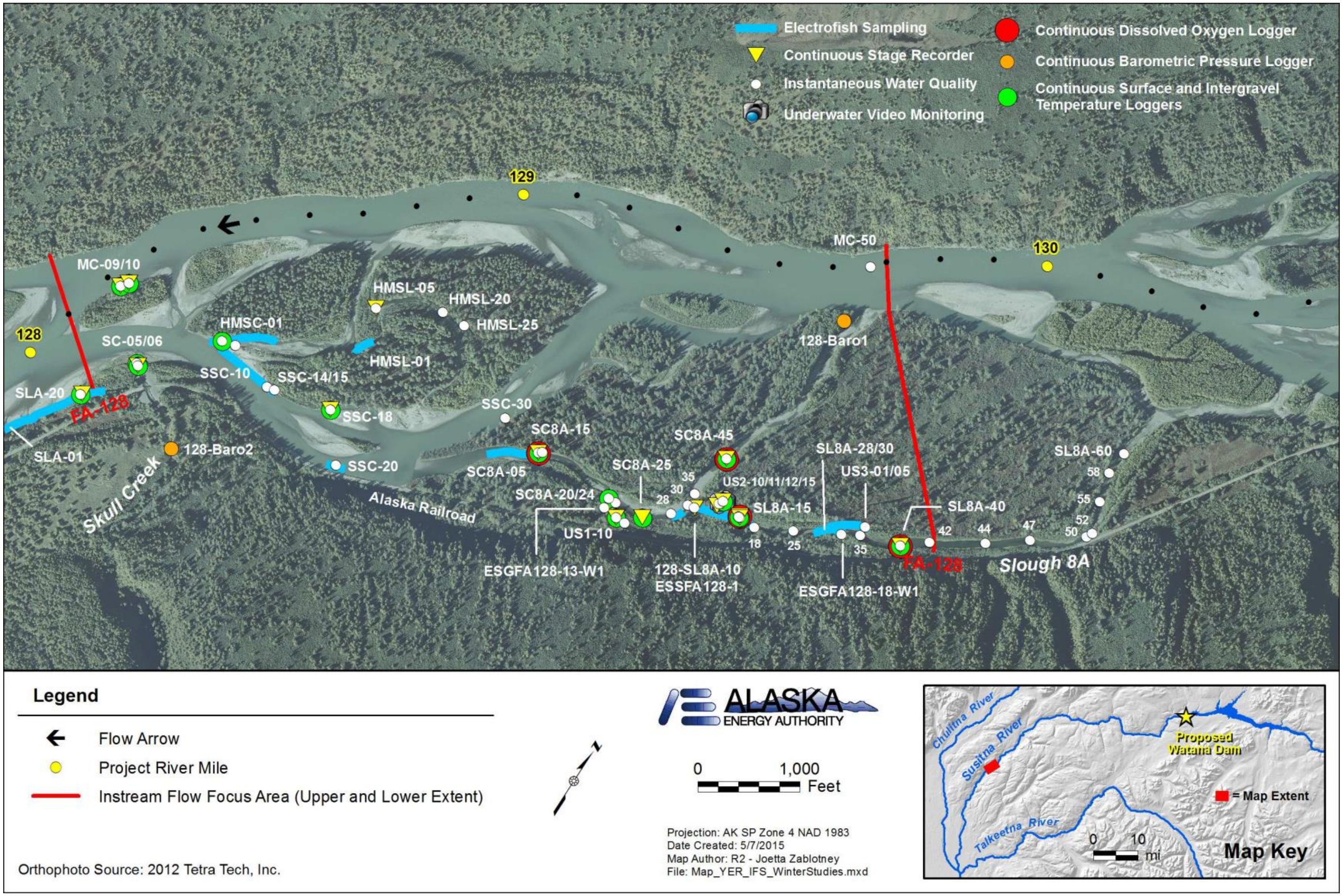

Figure 3-2. Locations of IFS winter studies sites used for continuous and instantaneous water quality monitoring, water level monitoring, and fish sampling in FA-128 (Slough 8A) during the winter seasons of 2012-2013 and 2013-2014 and continuous water quality and water level monitoring during 2014-2015.

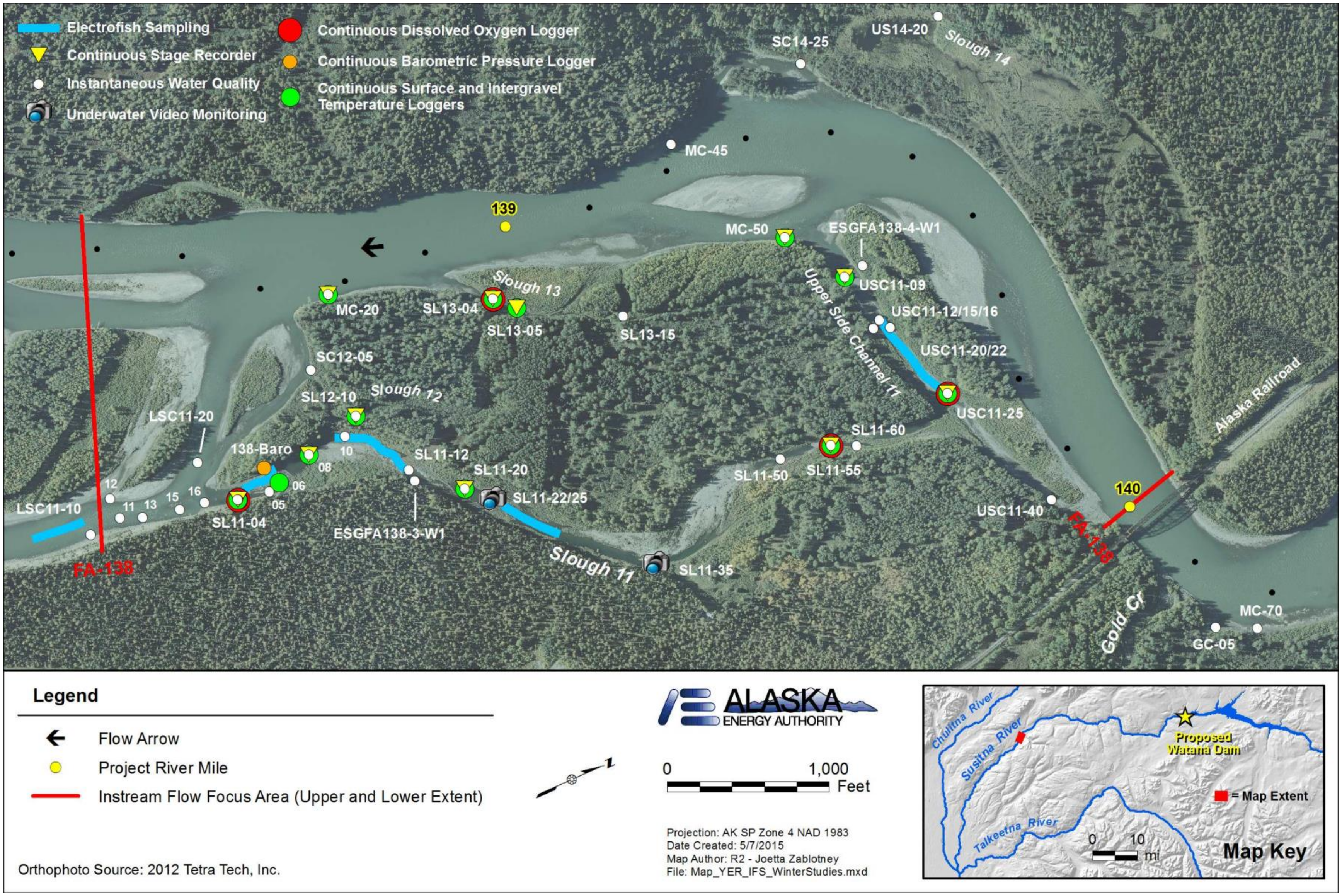

Figure 3-3. Locations of IFS winter studies sites used for continuous and instantaneous water quality monitoring, water level monitoring, and fish sampling in FA-138 (Gold Creek) during winter 2013-2014 and continuous water quality and water level monitoring during 2014-2015.

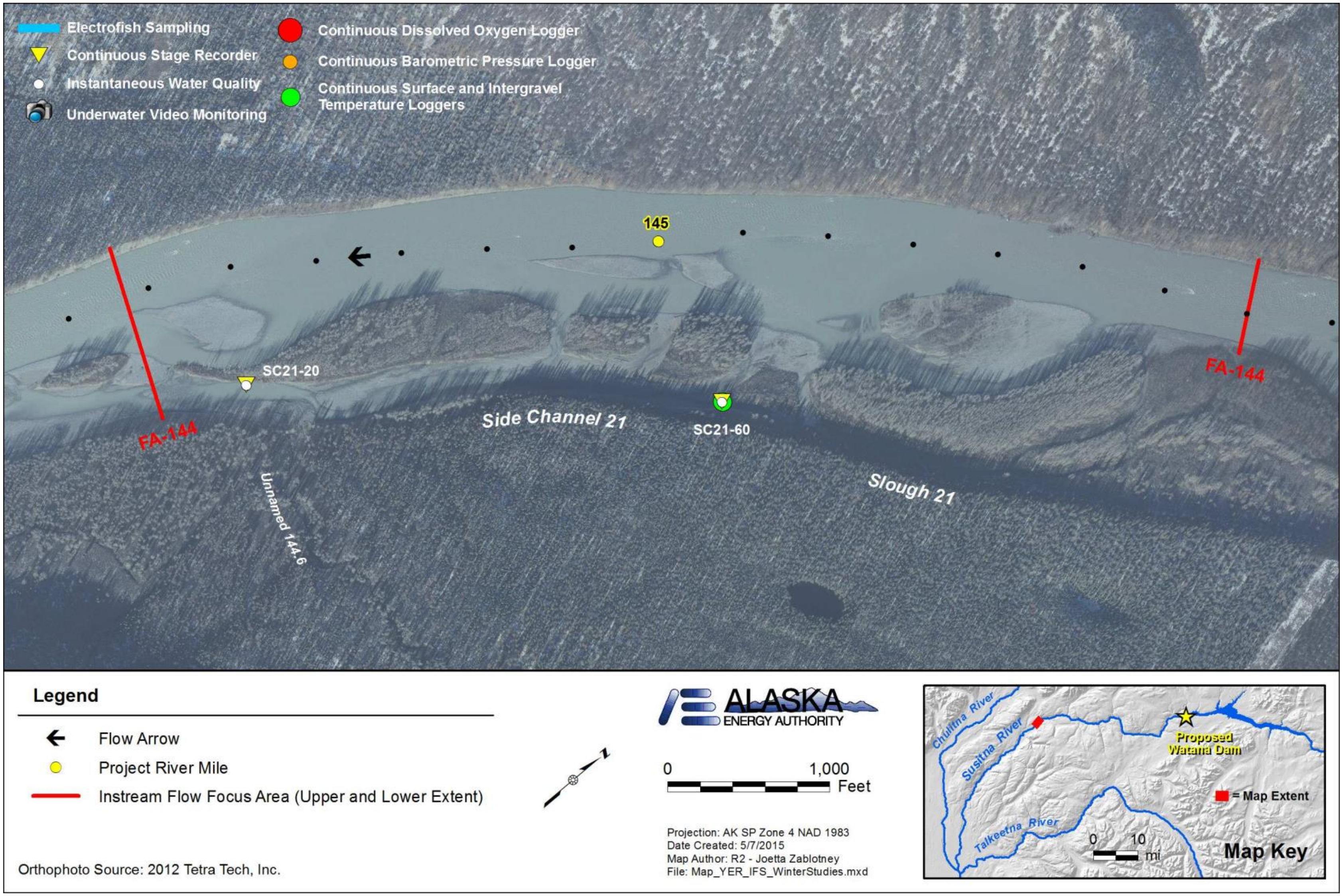

Figure 3-4. Locations of IFS winter studies sites used for continuous and instantaneous water quality monitoring and water level monitoring in FA-144 (Slough 21) during the winter season of 2014-2015.

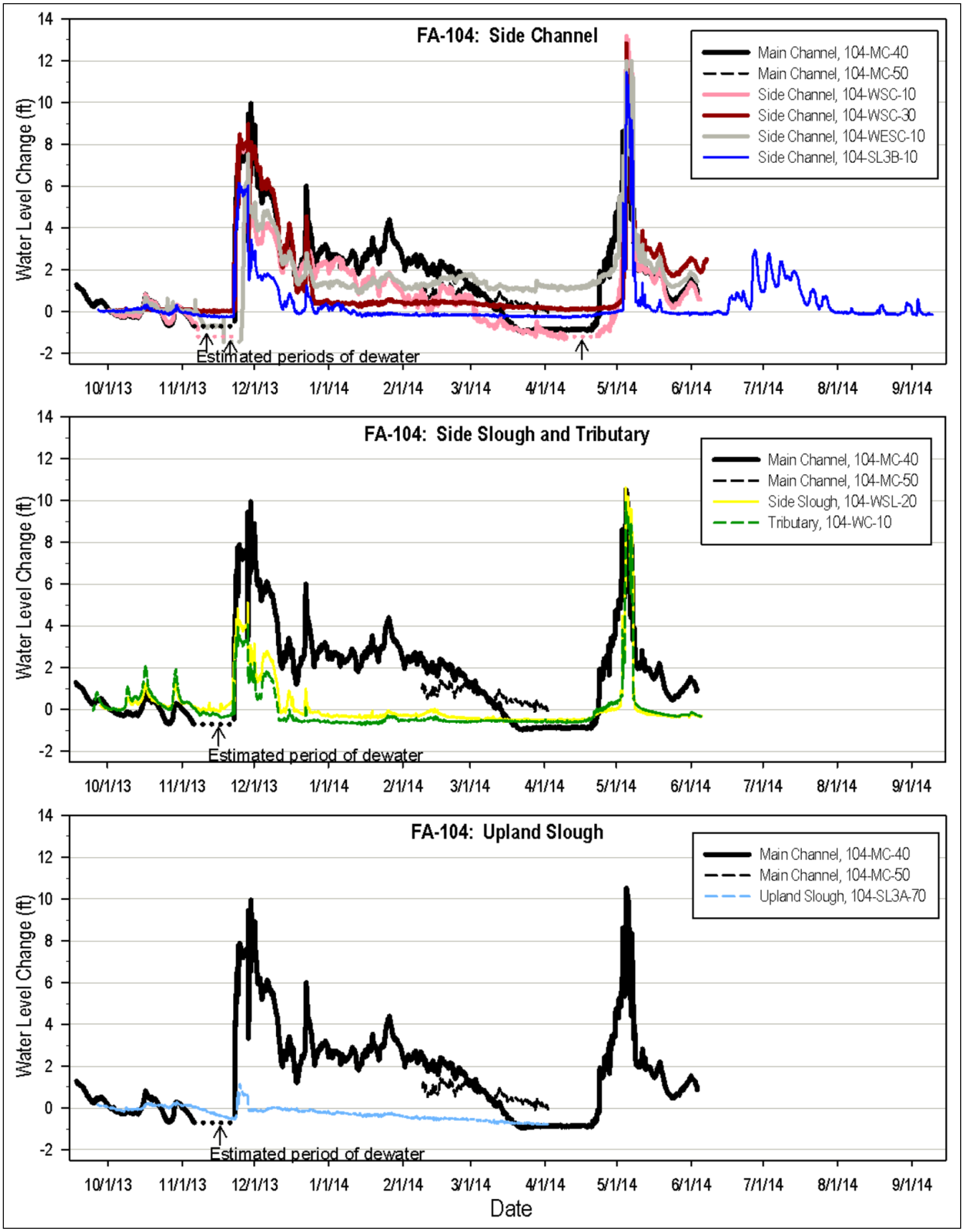

Figure 5-1. Comparison of change in normalized water surface elevation among continuous monitoring sites in FA-104 (Whiskers Slough) relative to the main channel site (104-MC-40) during September 2013 through September 2014. Elevations were normalized to zero on October 1, 2013.

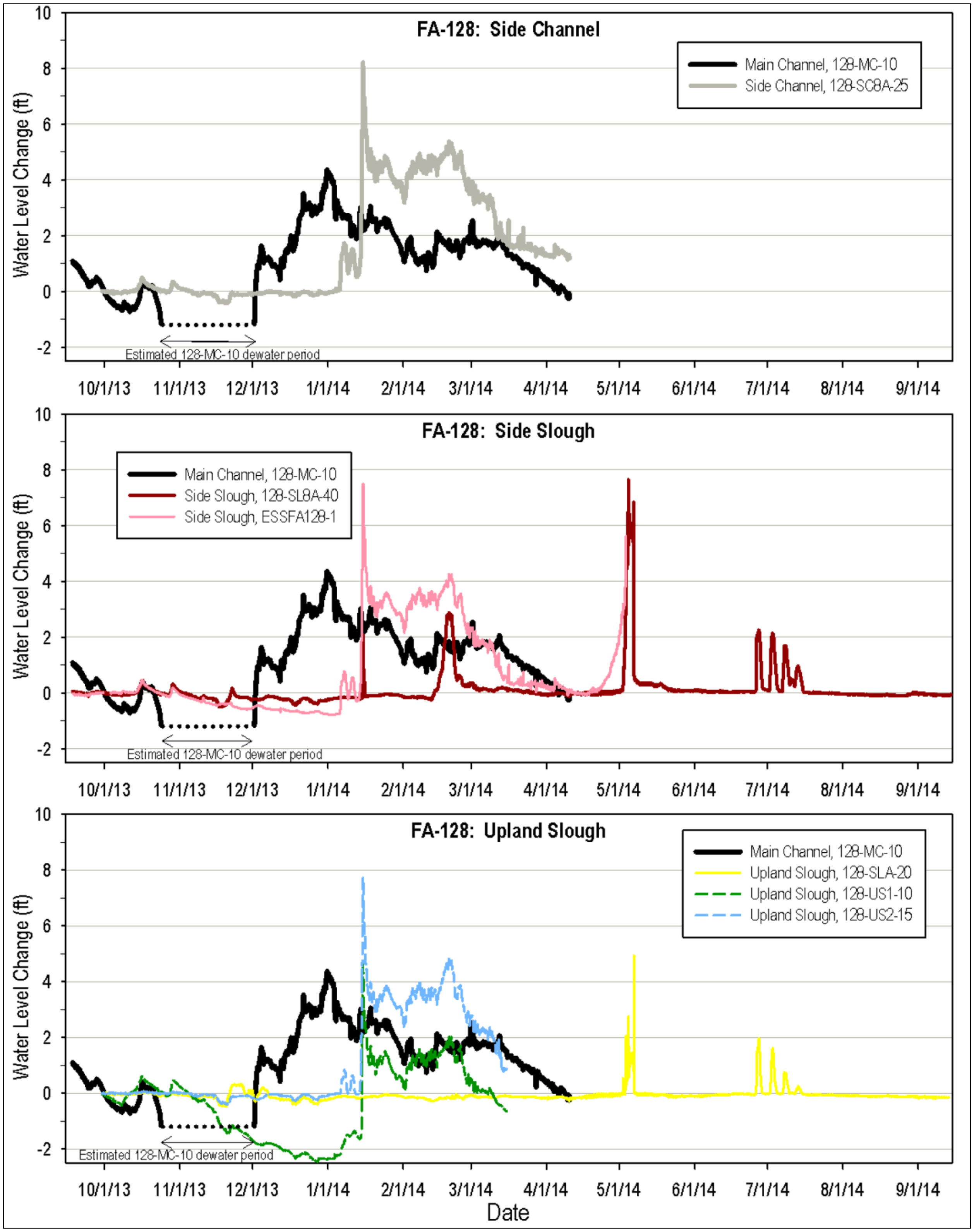

Figure 5-2. Comparison of change in normalized water surface elevation among continuous monitoring sites in FA-128 (Slough 8A) relative to the main channel site (128-MC-10) during September 2013 through September 2014. Elevations were normalized to zero on September 30, 2013.

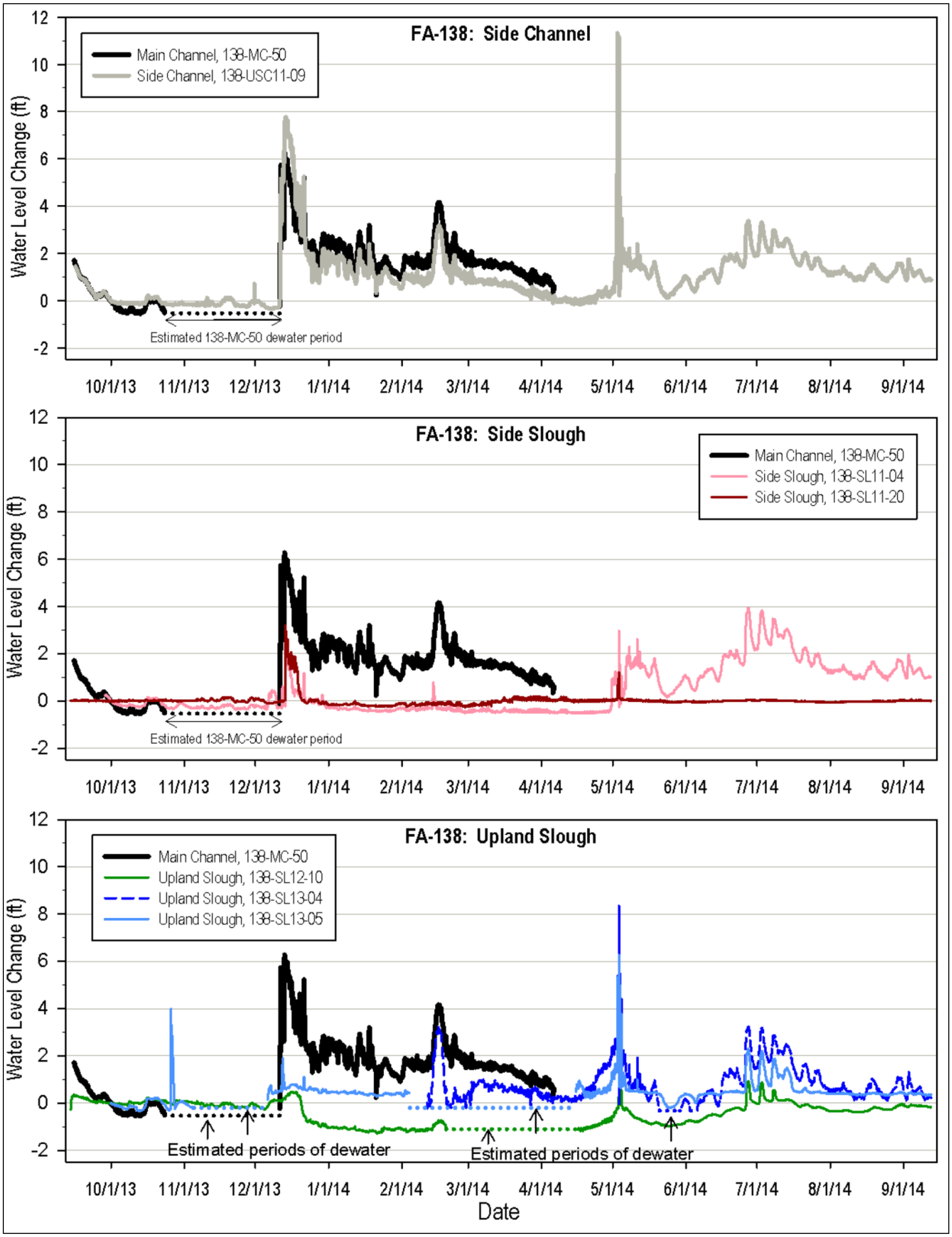

Figure 5-3. Comparison of change in normalized water surface elevation among continuous monitoring sites in FA-138 (Gold Creek) relative to the main channel site (138-MC-50) during September 2013 through September 2014. Elevations were normalized to zero on September 30, 2013.

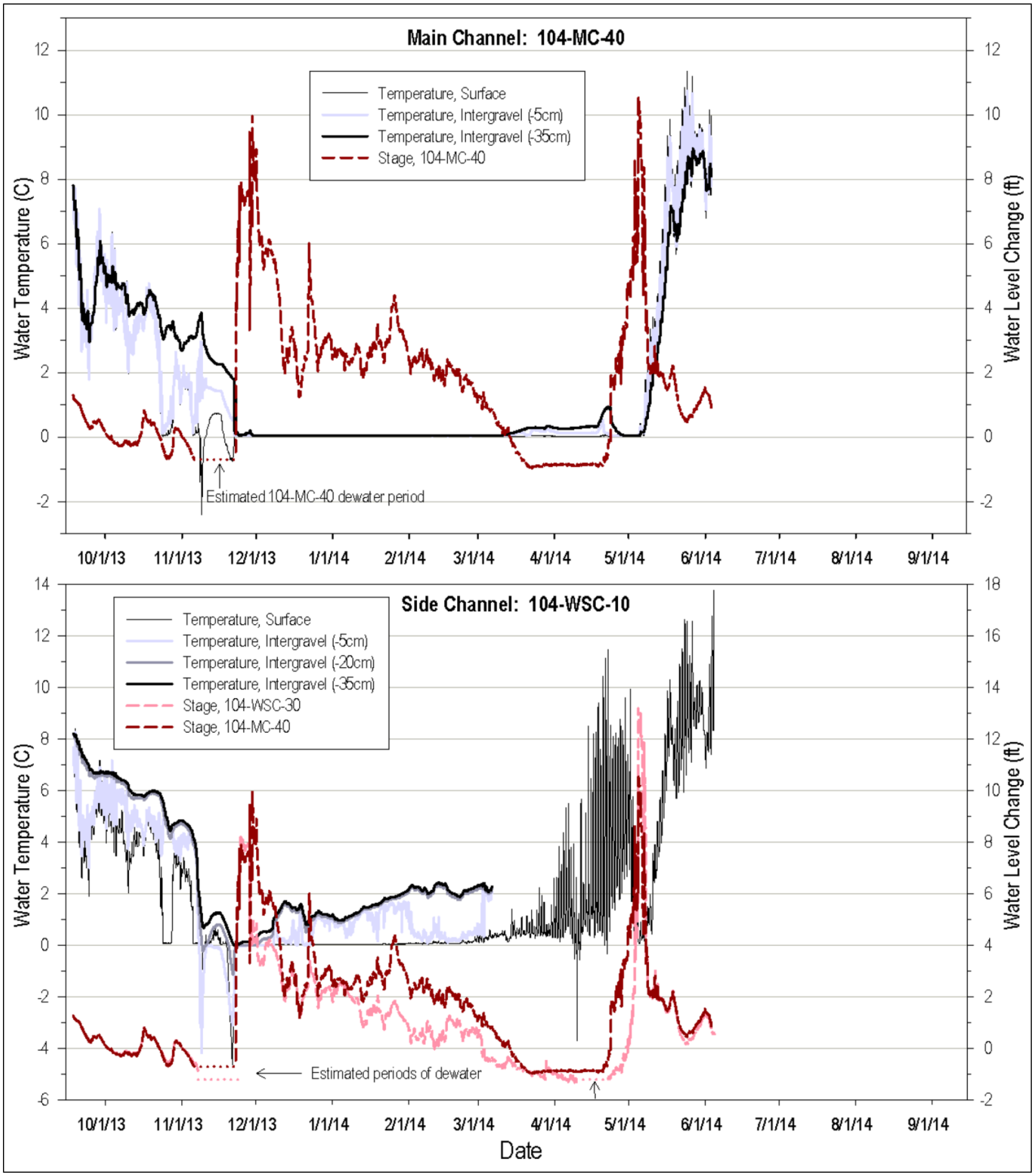

Figure 5-4. Water temperature recorded above the substrate surface and at intergravel depths of 5 cm (2 in), 20 cm (7.9 in), and 35 cm (13.8 in) at Susitna River main channel (104-MC-40) and Whiskers Side Channel (104-WSC-10) continuous monitoring sites in FA-104 (Whiskers Slough) relative to normalized water surface elevation recorded at the site and the main channel site (104-MC-40) during September 2013 – September 2014. Water elevations were normalized to zero on October 1, 2013.

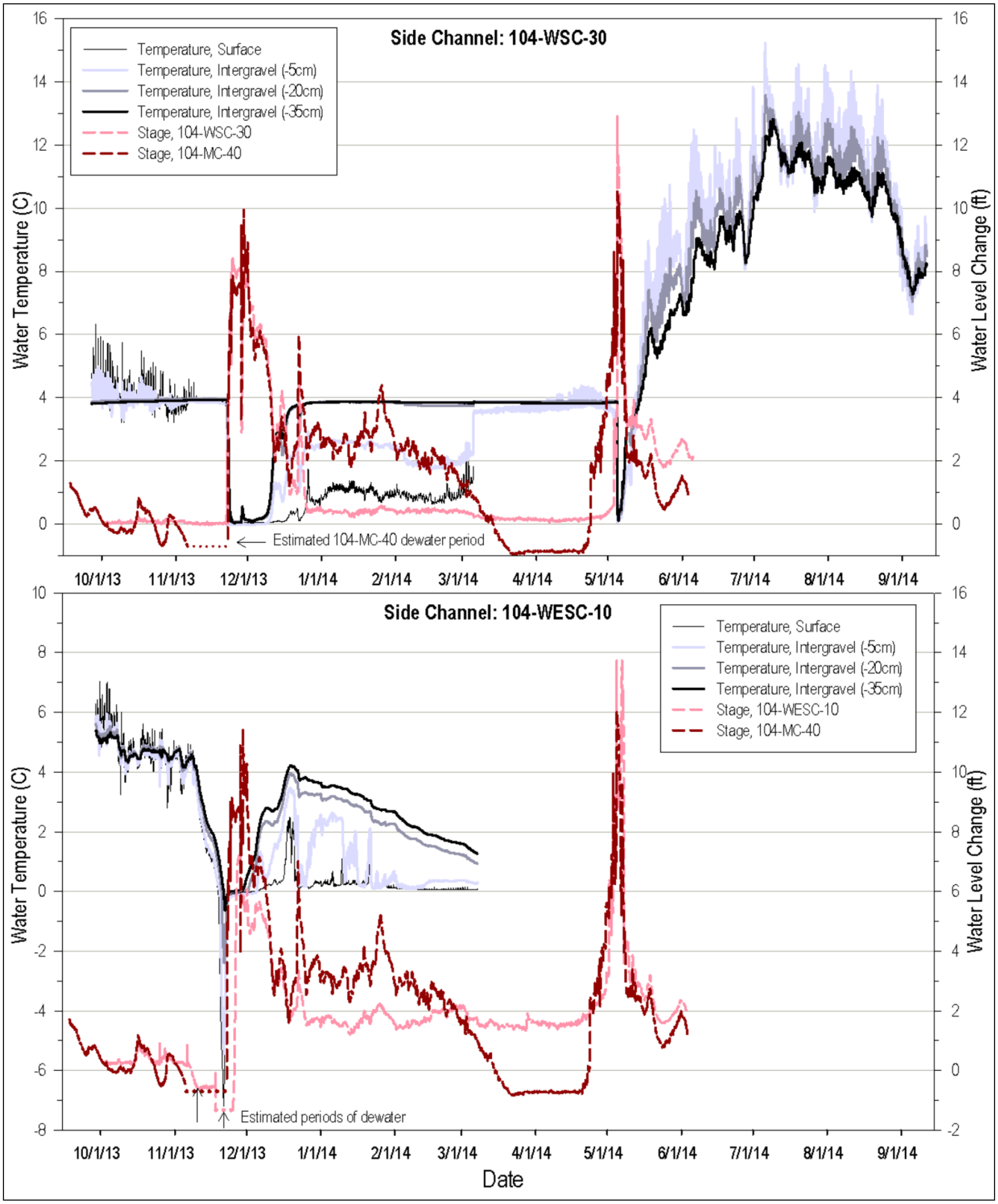

Figure 5-5. Water temperature recorded above the substrate surface and at intergravel depths of 5 cm (2 in), 20 cm (7.9 in), and 35 cm (13.8 in) at Whiskers Side Channel (104-WSC-30) and Whiskers East Side Channel (104-WESC-10) continuous monitoring sites in FA-104 (Whiskers Slough) relative to normalized water surface elevation recorded at each site and the main channel site (104-MC-40) during September 2013 – September 2014. Water elevations were normalized to zero on October 1, 2013.

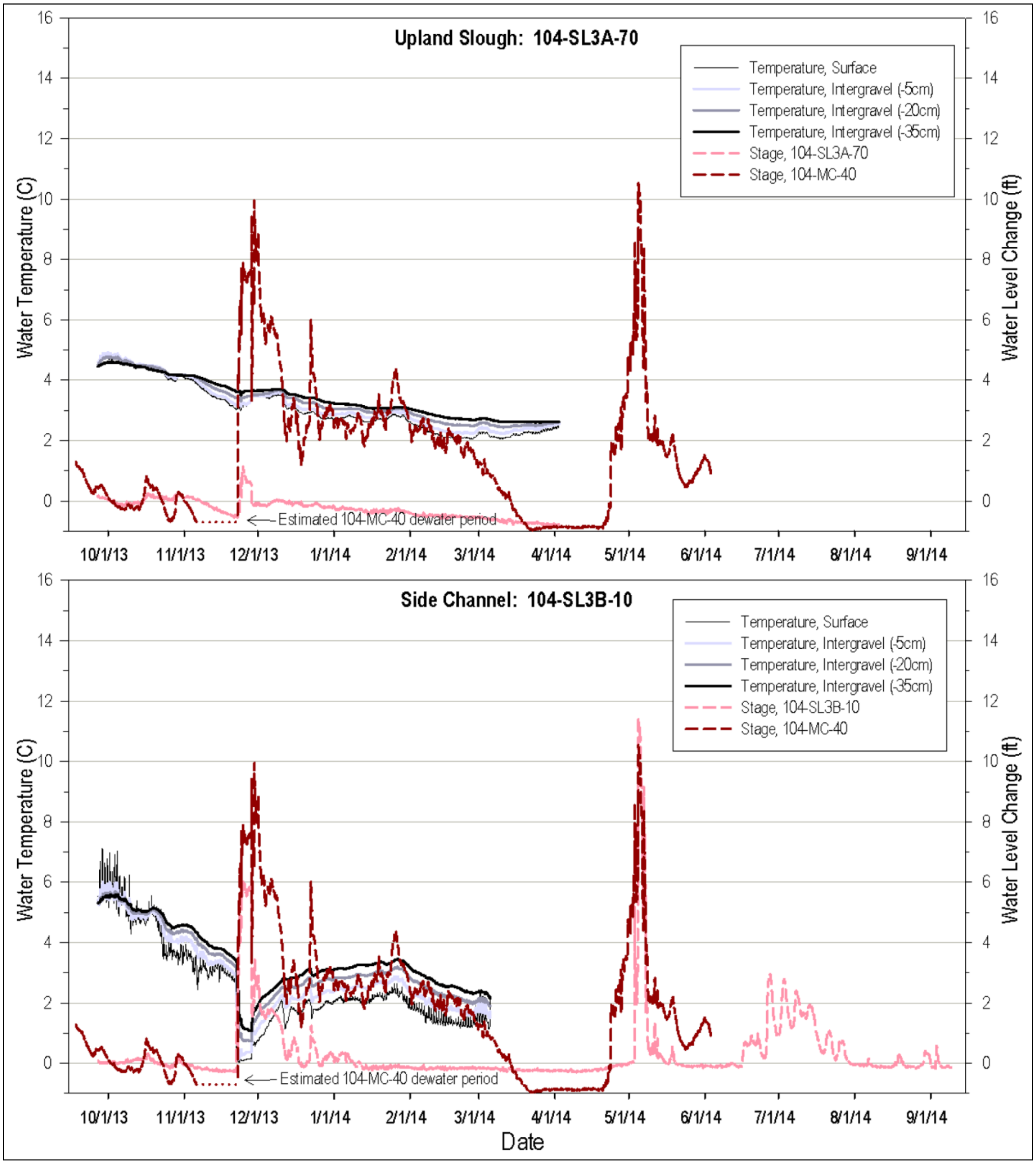

Figure 5-6. Water temperature recorded above the substrate surface and at intergravel depths of 5 cm (2 in), 20 cm (7.9 in), and 35 cm (13.8 in) at upland slough (104-SL3A-70) and side channel (104-SL3B-10) continuous monitoring sites in FA-104 (Whiskers Slough) relative to normalized water surface elevation recorded at each site and the main channel site (104-MC-40) during September 2013 – September 2014. Water elevations were normalized to zero on October 1, 2013.

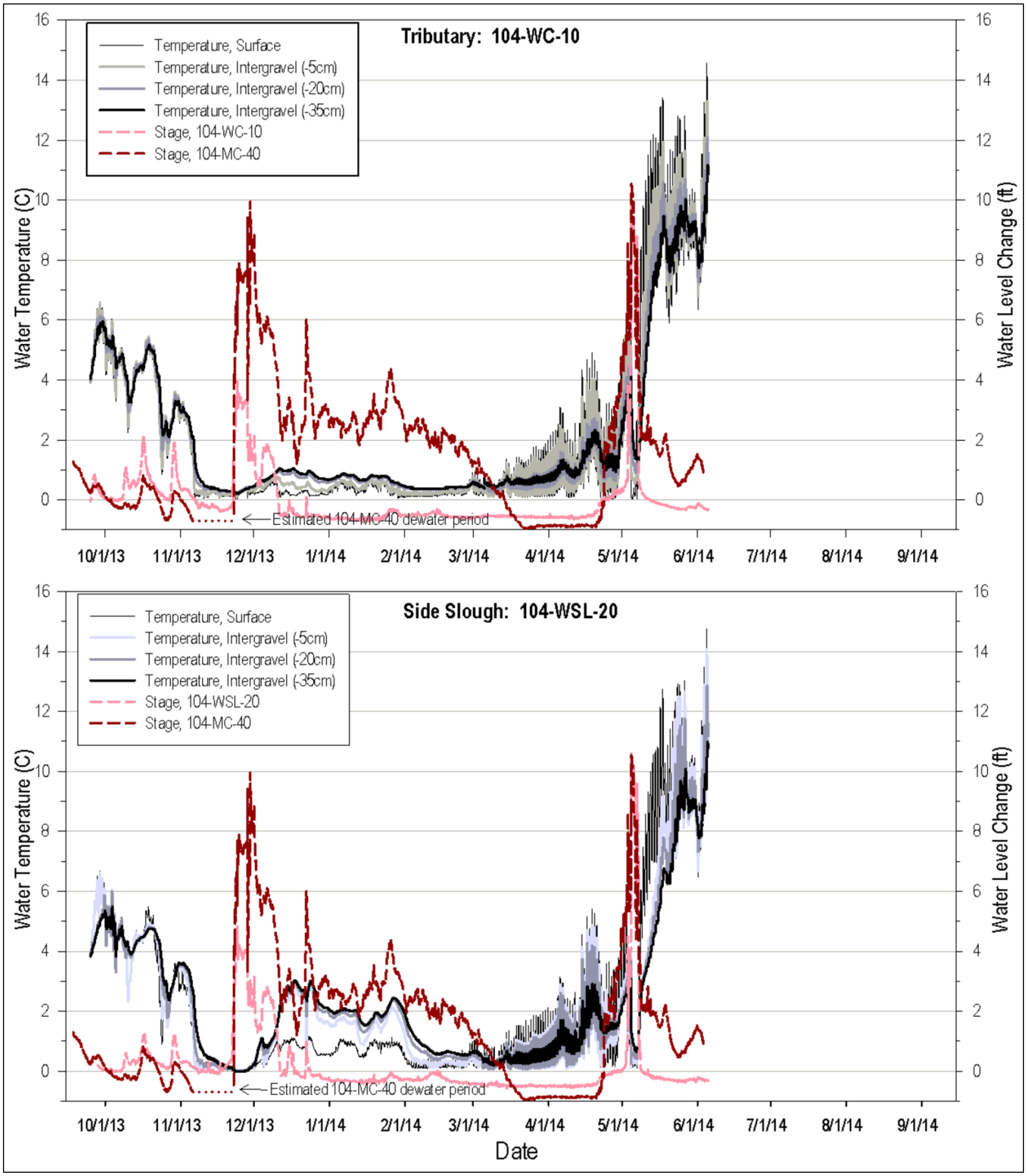

Figure 5-7. Water temperature recorded above the substrate surface and at intergravel depths of 5 cm (2 in), 20 cm (7.9 in), and 35 cm (13.8 in) at Whiskers Creek (104-WC-10) and Whiskers Slough (104-WSL-20) continuous monitoring sites in FA-104 (Whiskers Slough) relative to normalized water surface elevation recorded at each site and the main channel site (104-MC-40) during September 2013 – September 2014. Water elevations were normalized to zero on October 1, 2013.

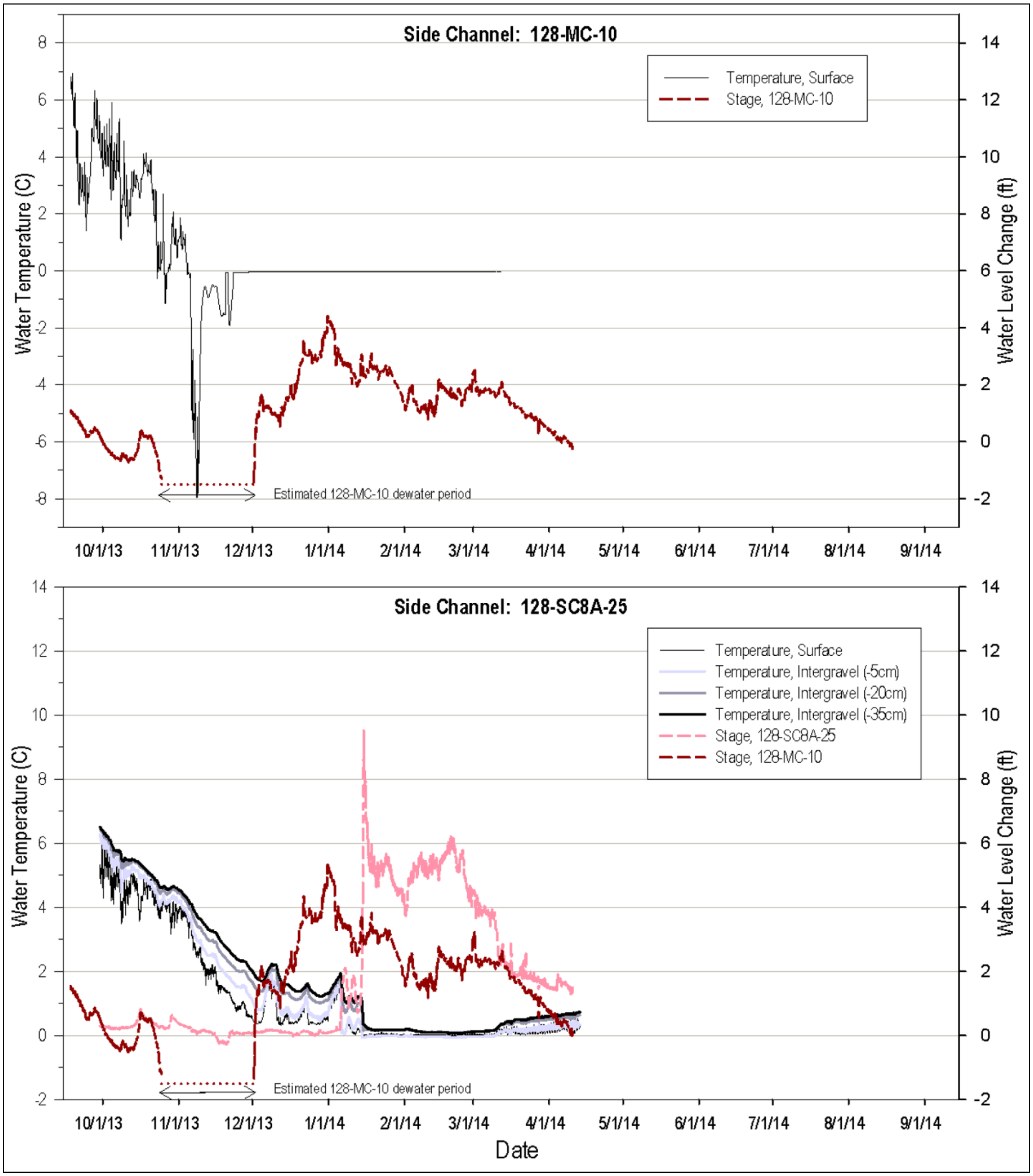

Figure 5-8. Water temperature recorded above the substrate surface and at intergravel depths of 5 cm (2 in), 20 cm (7.9 in), and 35 cm (13.8 in) at Susitna River main channel (128-MC-10) and Side Channel 8A (128-SC8A-25) continuous monitoring sites in FA-128 (Slough 8A) relative to normalized water surface elevation recorded at the site and the main channel site (128-MC-10) during September 2013 – September 2014. Water elevations were normalized to zero on September 30, 2013.

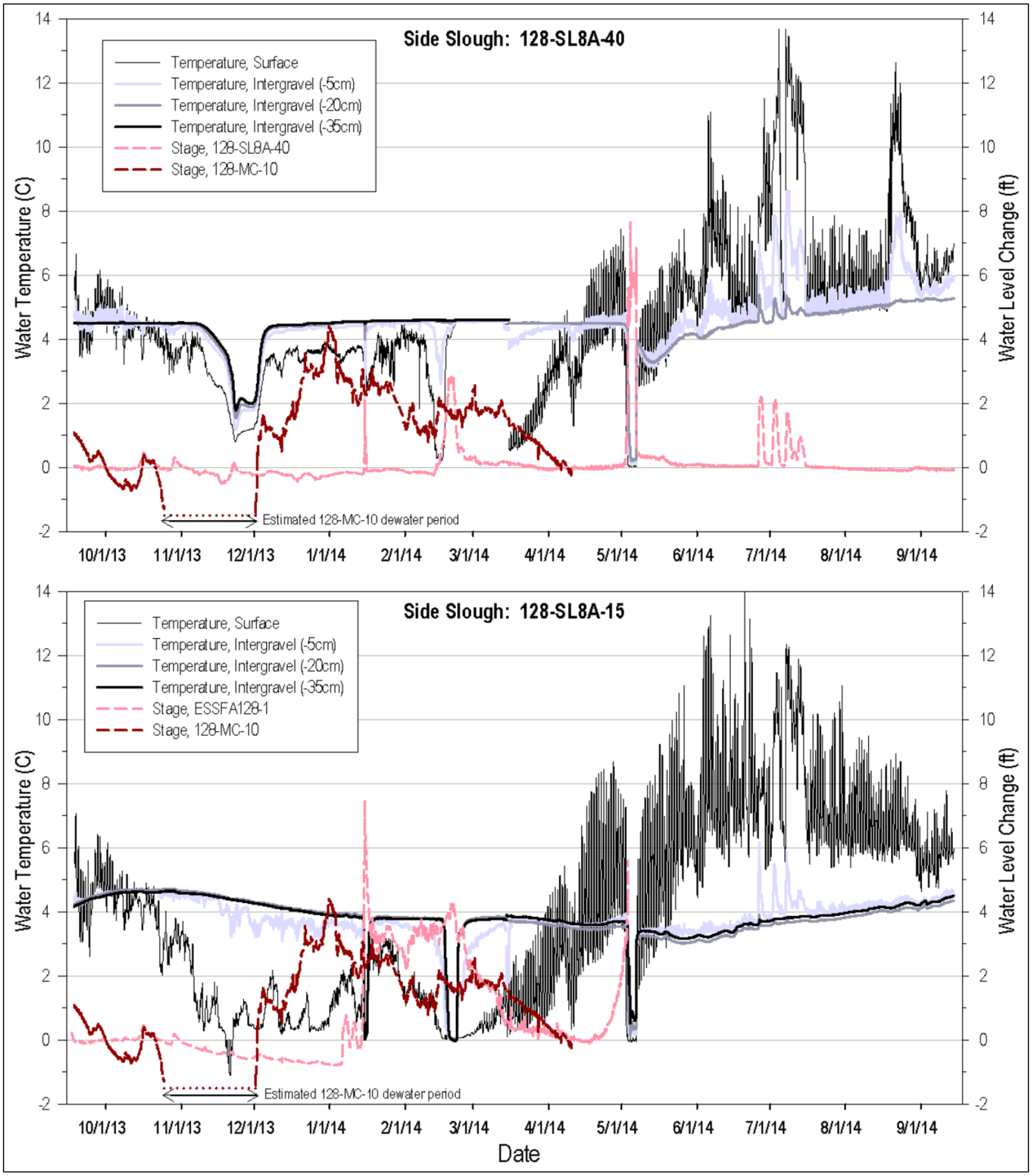

Figure 5-9. Water temperature recorded above the substrate surface and at intergravel depths of 5 cm (2 in), 20 cm (7.9 in), and 35 cm (13.8 in) at Slough 8A (128-SL8A-40 and 128-SL8A-15) continuous monitoring sites in FA-128 (Slough 8A) relative to normalized water surface elevation recorded at each site and the Susitna River main channel site (128-MC-10) during September 2013 – September 2014. Water elevations were normalized to zero on September 30, 2013.

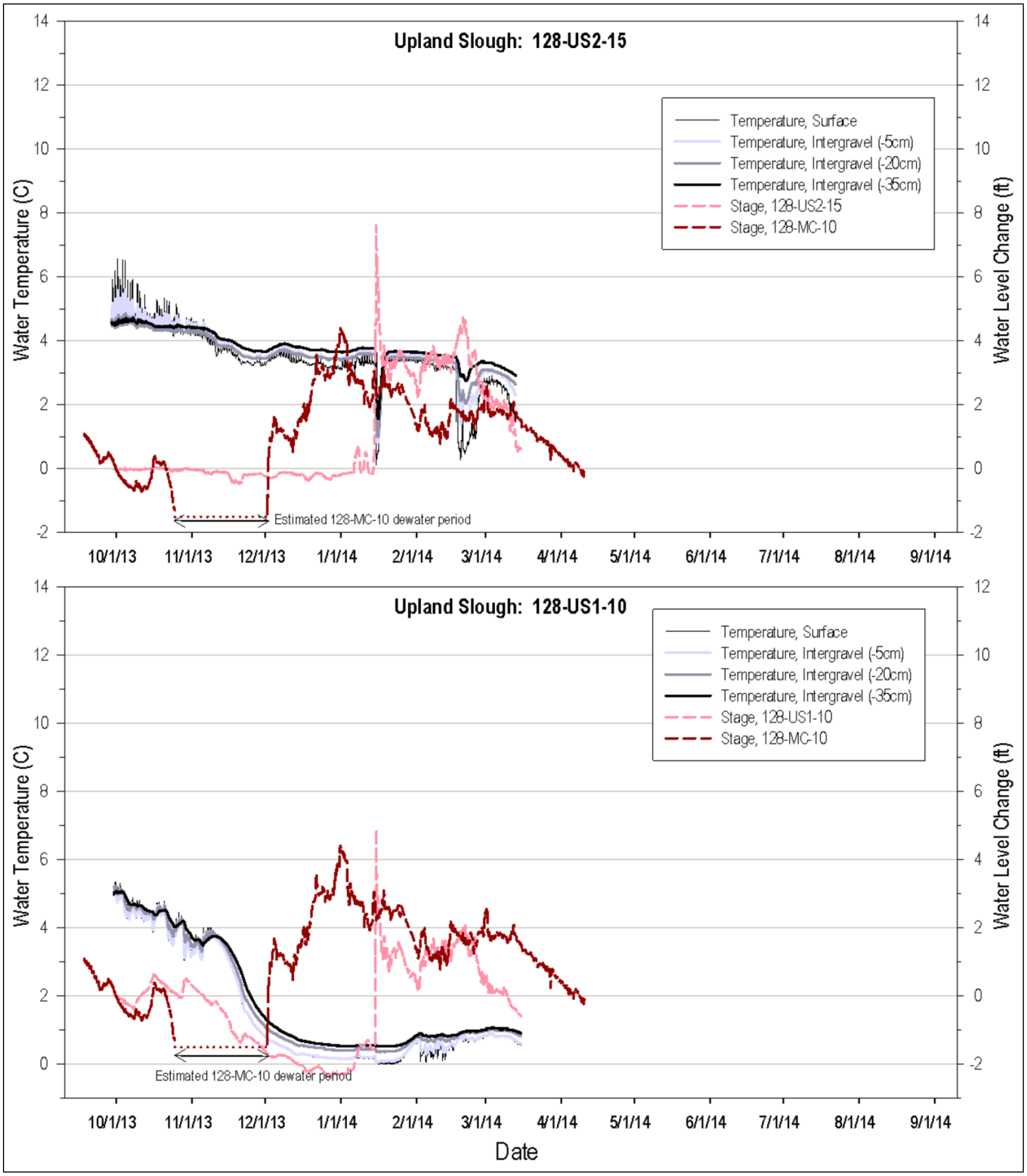

Figure 5-10. Water temperature recorded above the substrate surface and at intergravel depths of 5 cm (2 in), 20 cm (7.9 in), and 35 cm (13.8 in) at Upland Slough 2 (128-US2-15) and Upland Slough 1 (128-US1-10) continuous monitoring sites in FA-128 (Slough 8A) relative to normalized water surface elevation recorded at each site and the Susitna River main channel site (128-MC-10) during September 2013 – September 2014. Water elevations were normalized to zero on September 30, 2013.

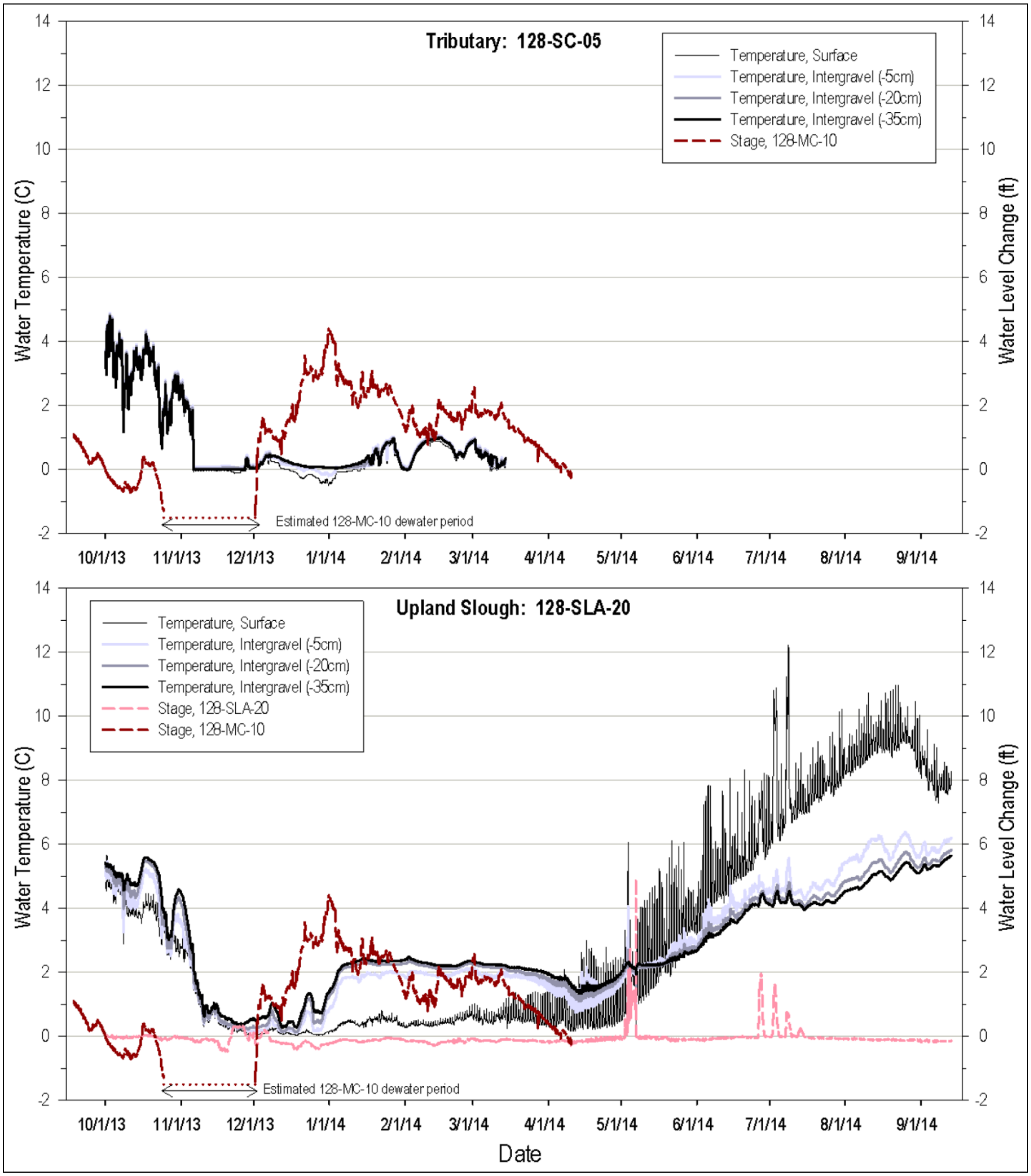

Figure 5-11. Water temperature recorded above the substrate surface and at intergravel depths of 5 cm (2 in), 20 cm (7.9 in), and 35 cm (13.8 in) at Skull Creek (128-SC-05) and Slough A (128-SLA-20) continuous monitoring sites in FA-128 (Slough 8A) relative to normalized water surface elevation recorded at each site and the Susitna River main channel site (128-MC-10) during September 2013 – September 2014. Water elevations were normalized to zero on September 30, 2013.

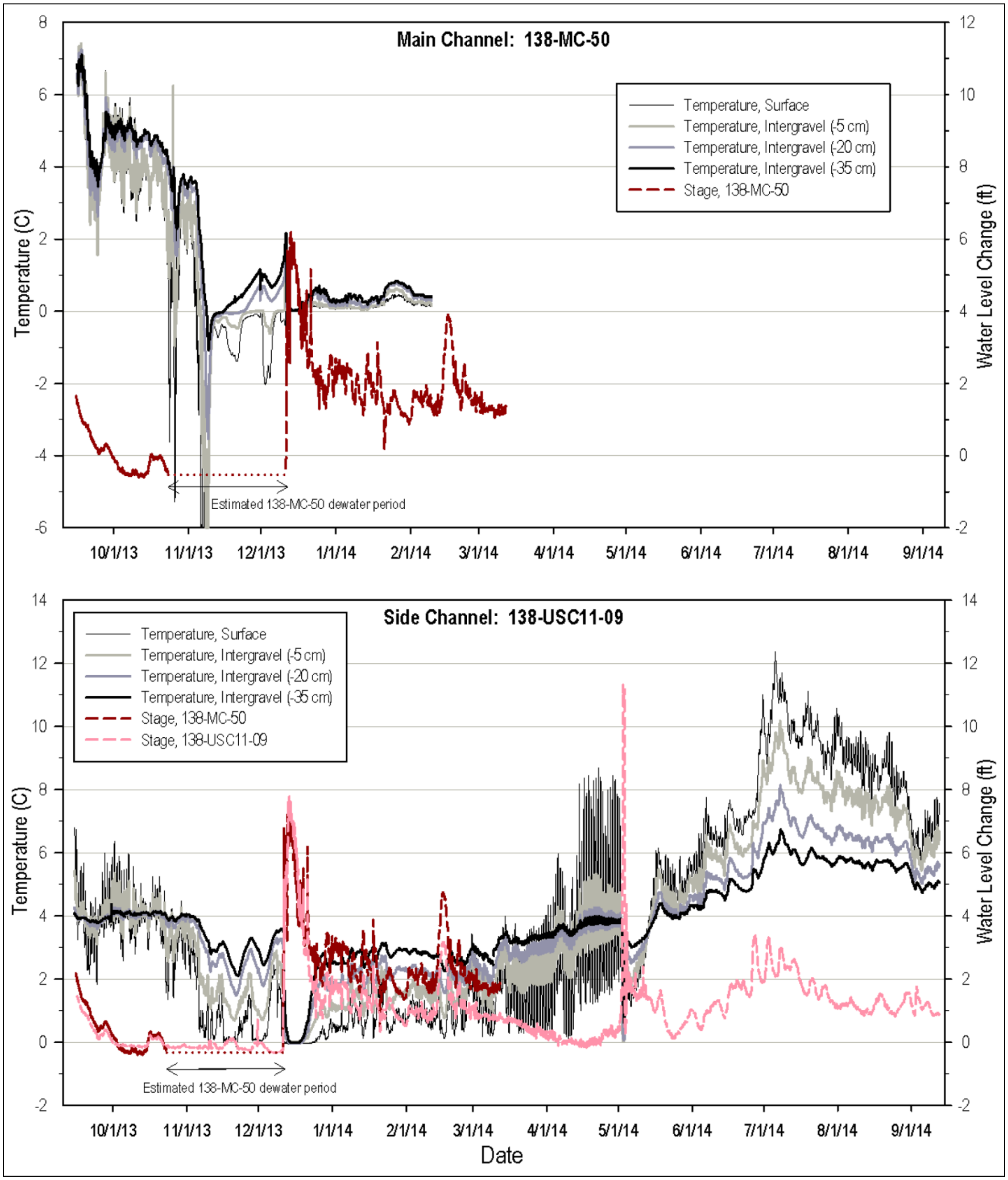

Figure 5-12. Water temperature recorded above the substrate surface and at intergravel depths of 5 cm (2 in), 20 cm (7.9 in), and 35 cm (13.8 in) at Susitna River main channel (138-MC-50) and Upper Side Channel 11 (138-USC11-09) continuous monitoring sites in FA-138 (Gold Creek) relative to normalized water surface elevation recorded at the site and the main channel site (138-MC-50) during September 2013 – September 2014. Water elevations were normalized to zero on September 30, 2013.

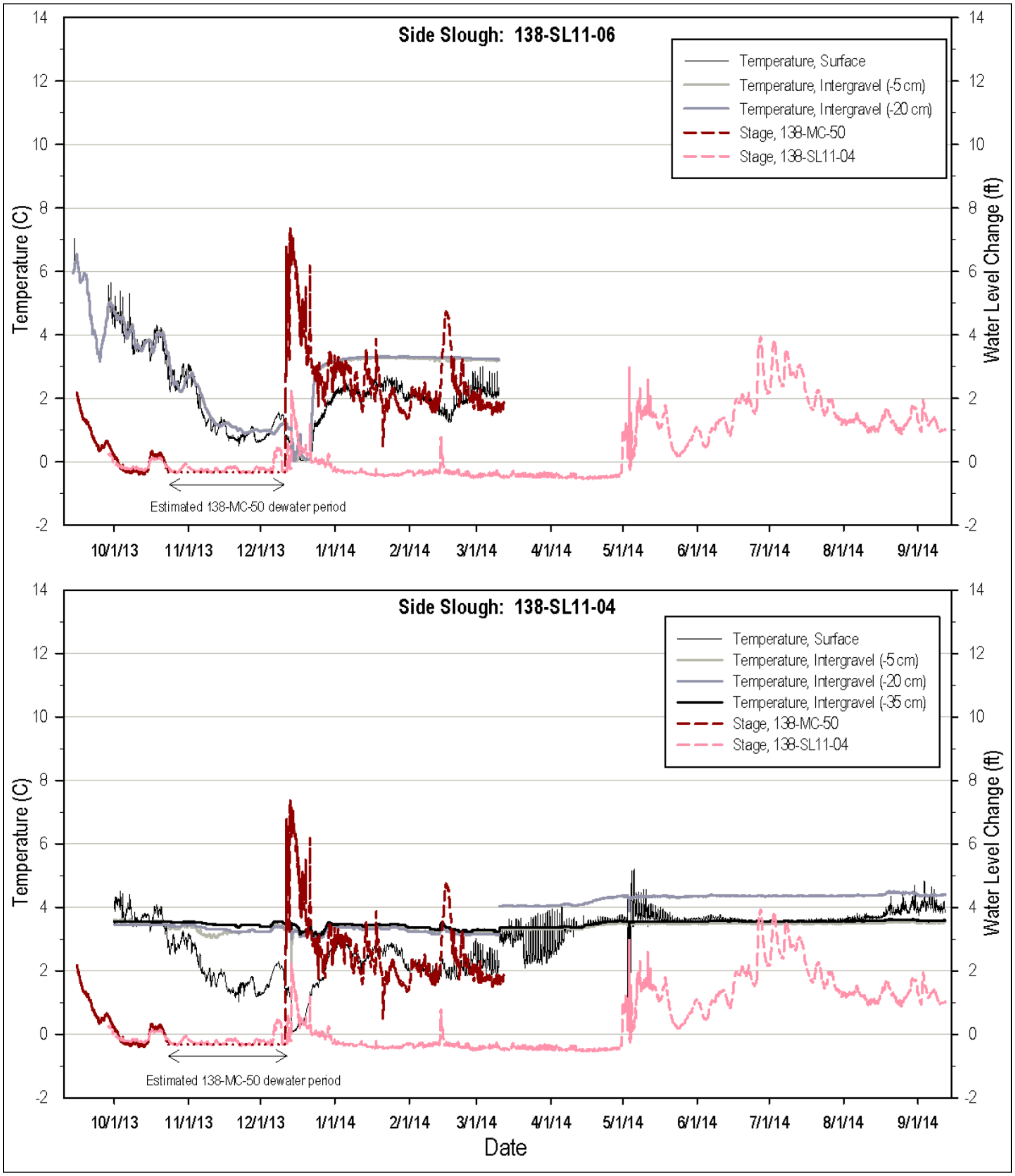

Figure 5-13. Water temperature recorded above the substrate surface and at intergravel depths of 5 cm (2 in), 20 cm (7.9 in), and 35 cm (13.8 in) at Slough 11 (138-SL11-06 and 138-SL11-04) continuous monitoring sites in FA-138 (Gold Creek) relative to normalized water surface elevation recorded at Site 138-SL11-04 and the Susitna River main channel site (138-MC-50) during September 2013 – September 2014. Water elevations were normalized to zero on September 30, 2013.

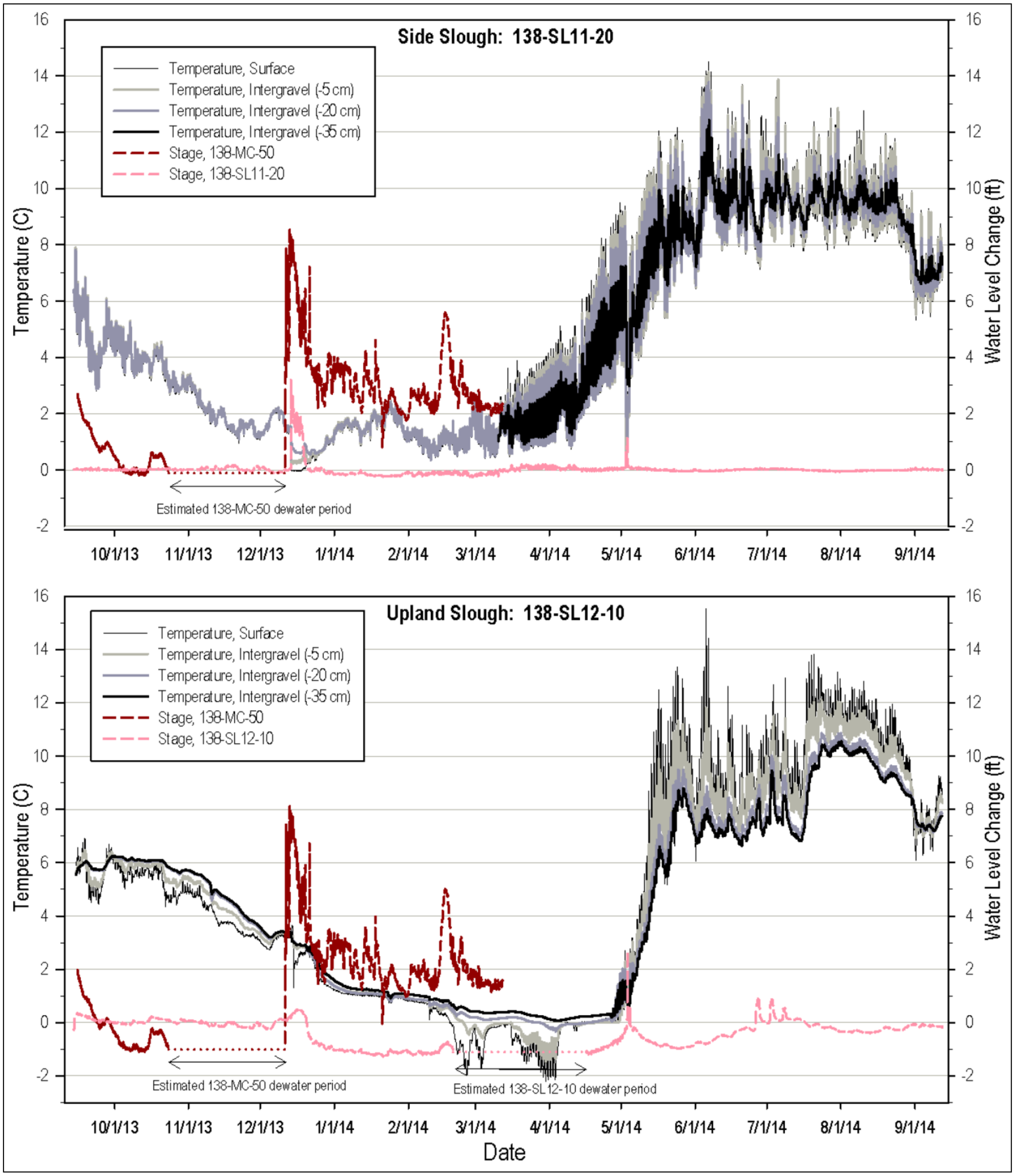

Figure 5-14. Water temperature recorded above the substrate surface and at intergravel depths of 5 cm (2 in), 20 cm (7.9 in), and 35 cm (13.8 in) at Slough 11 (138-SL11-20) and Slough 12 (138-SL12-10) continuous monitoring sites in FA-138 (Gold Creek) relative to normalized water surface elevation recorded at each site and the Susitna River main channel site (138-MC-50) during September 2013 – September 2014. Water elevations were normalized to zero on September 30, 2013.

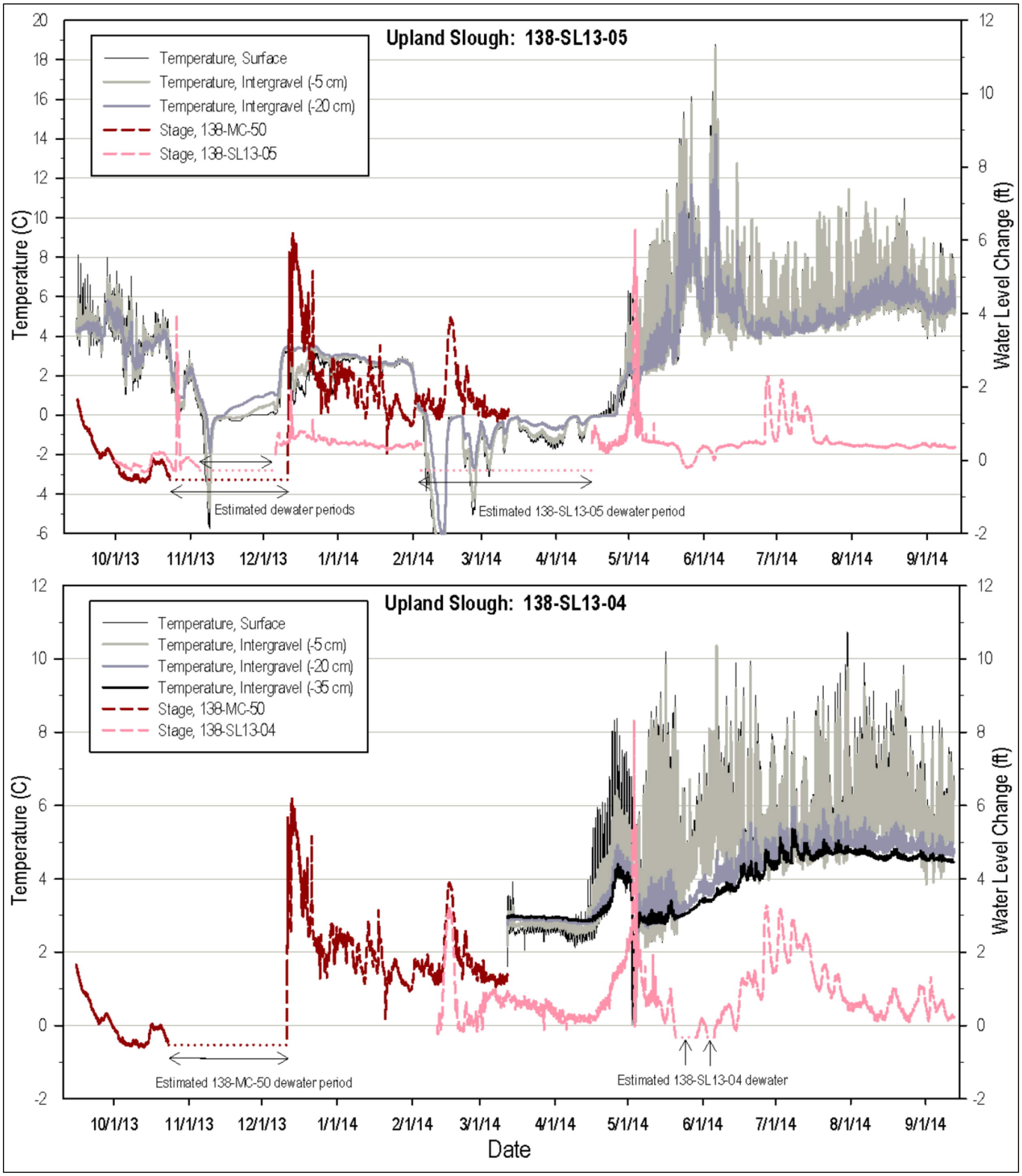

Figure 5-15. Water temperature recorded above the substrate surface and at intergravel depths of 5 cm (2 in), 20 cm (7.9 in), and 35 cm (13.8 in) at Slough 13 (138-SL13-04 and 138-SL13-05) continuous monitoring sites in FA-138 (Gold Creek) relative to normalized water surface elevation recorded at each site and the Susitna River main channel site (138-MC-50) during September 2013 – September 2014. Water elevations were normalized to zero on September 30, 2013.