Susitna-Watana Hydroelectric Project
(FERC No. 14241)

Fish and Aquatics Instream Flow Study
(Study 8.5)

2013-2014 Instream Flow Winter Studies
Technical Memorandum

Prepared for

Alaska Energy Authority

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

Prepared by

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ACRONYMS AND SCIENTIFIC LABELS

Abbreviation	Definition
AEA	Alaska Energy Authority
ARIS	Adaptive Resolution Imaging Sonar
°C	Degrees centigrade
cfs	Cubic feet per second
Cm	Centimeter
FA	Focus Area
FDA	Fish Distribution and Abundance
FERC	Federal Energy Regulatory Commission
fps	Feet per second
mg/L	Milligrams per liter
HSC	Habitat suitability criteria
HSI	Habitat suitability indices
IFS	Instream Flow Study
ISR	Initial Study Report
MW	Megawatts
NTU	Nephelometric turbidity units
PRM	Project River Mile
RSP	Revised Study Plan
TM	Technical Memorandum

1. INTRODUCTION

1.1. Project Description

The Alaska Energy Authority (AEA) is preparing a License Application that will be submitted to the Federal Energy Regulatory Commission (FERC) for the Susitna-Watana Hydroelectric Project (Project) using the Integrated Licensing Process. The Project is located on the Susitna River, an approximately 300-mile long river in the Southcentral Region of Alaska. The Project's dam site will be located at Project River Mile (PRM) 187.1. As currently envisioned, the Project would include a large dam with an approximately 24,000-acre, 42-mile long reservoir. The Project construction and operation would have an effect on the flows downstream of the dam site, the degree of which will ultimately depend on final Project design and operations.

The Project may contain up to four turbines capable of generating 150-200 megawatts (MW) of power each such that the total power capacity could be 800 MW. The Project reservoir is expected to fill during the summer months (May – August), when runoff from snow melt and rainfall is greatest, to maximize power generation capability during the winter months (October – April) when energy demand is high. As a result, seasonal changes to Susitna River streamflow conditions during Project operations may include lower discharges during the summer reservoir refill period and higher discharges during the winter relative to current hydrologic conditions. In addition to these seasonal changes, the Project may be operated in a load-following mode to meet energy demands on an hourly basis. During load-following operations, the amount of water released from the reservoir would cycle daily according to energy demands such that higher volumes would be released during peak-load hours relative to off-peak hours. Seasonal and daily/hourly changes to Susitna River hydrology would influence downstream resources and processes, including resident and anadromous fish species and aquatic habitats. As a result, AEA developed and the FERC approved (FERC 2013) a detailed Instream Flow Study (IFS) plan (contained as Section 8.5 in the December 14, 2012 Revised Study Plan [RSP]; see AEA 2012) designed to evaluate the potential effects of Project operations.

One element of the IFS plan 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 groundwater inflow (RSP Section 8.5.4.5.1.2.1). Companion winter studies were also specified in the RSP as part of the Fish Distribution and Abundance (FDA) study under the Fish Program (RSP Section 9.6.4.5) and under the Groundwater (GW) Study (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 the ice-free period when emergence occurs. The winter studies, in conjunction with the Ice Processes Study (RSP Section 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. The RSP specified two separate field efforts for these studies including an initial pilot effort during the winter of 2012-2013 followed by an expanded effort during the winter of 2013-2014. The ISR specified continuation of winter studies in 2014-2015 in coordination with FDA and GW

(ISR Study 8.5, Section 7.5.1). This Technical Memorandum (TM) describes the methods applied, and data and information collected, as part of the IFS 2013-2014 winter studies. Results of the 2013-2014 winter studies for FDA are presented in a separate TM (AEA 2014b). The results of the 2012-2013 FDA winter studies were included as Appendix C of ISR Study 9.6 (AEA 2014); results of the 2012-2013 IFS winter studies were included as Appendix L of ISR Study 8.5 (AEA 2014). The results of those two studies provided information useful for developing the 2013-2014 expanded winter programs for FDA and IFS.

1.2. Study Background

The Susitna River is a large glacial river that exhibits large hydrologic changes at hourly, daily, and seasonal temporal scales. Susitna River discharge is typically the highest during the snowmelt period in spring and early summer (June – August) and large, short-term fluctuations in flow volumes often occur during summer in response to air temperature changes and precipitation events. Mean monthly Susitna River streamflow for June, July, and August during water years 1950 – 2010 ranged between 21,430 – 26,290 cfs (USGS Gold Creek gage #15292000) (Curran 2012). During the open-water period, Susitna River streamflow is fed primarily by surface and glacial runoff and water turbidity levels are high (> 200 nephelometric turbidity units [NTU]) due to suspended glacial silt. Susitna River discharge levels typically decline during September through November and are lowest during December through April when the channel is largely ice covered. Mean monthly Susitna River streamflow for December through April during water years 1950 – 2010 ranged between 1,303 – 1,893 cfs (USGS Gold Creek gage #15292000) (Curran 2012). Winter streamflow is fed primarily by groundwater and consequently discharge is stable and water turbidity is low (<10 NTU).

1.2.1. Ice Formation

Ice formation on the Susitna River occurs in an upstream direction from Cook Inlet and is typically initiated by frazil ice, which is fine ice particles suspended in the water column and formed in super cooled turbulent water (Labelle 1984, Brown et al. 2011). Jams of frazil ice form across the river channel and lead to the formation of solid river ice. Ice process surveys conducted in the Susitna River in the 1980s and in 2012 indicated the start of frazil ice generation occurred in the Upper Susitna River in mid-September and early October, while the upstream progression of solid river ice cover in the Middle Susitna River extended from mid-November through mid-January (Labelle 1984, Trihey & Associates and Entrix 1985, HDR 2014). As river ice forms, the river channel becomes occluded by solid ice which causes the river stage to increase upstream of the leading edge of ice cover. This process is termed staging. During 1980s studies, the level of staging was estimated to be greater than four feet in portions of the Middle Susitna River such that winter water surface levels were equivalent to summer water levels (Trihey 1982, Labelle 1984, HDR 2014). Average ice thickness in the Susitna River main channel at RM 120.6 (PRM 124.1) in winter ranged between 1.9 – 10.4 feet during the years 1980 – 1984 (Labelle 1984). Although nearly all of the Middle Susitna River is ice covered for portions of winter, open leads caused by water current (velocity lead) or warm water (thermal lead) derived from groundwater typically remain ice-free throughout winter. Many open leads mapped during ice surveys in the 1980s and in 2012 and 2013 were associated with side sloughs, upland sloughs, and tributary mouths with localized groundwater sources (Labelle 1984, HDR 2014).

1.2.2. Influence and Importance of Groundwater

Groundwater sources are an important aspect of Susitna River winter hydrology in terms of creating flow in habitats otherwise disconnected from the Susitna River main channel and maintaining ice-free areas via discharge of warmer water relative to surface flow. Groundwater influence was well documented during the 1980s studies, particularly in side channel, side slough, and upland slough habitats utilized by adult salmon for spawning and juvenile fish species for winter rearing (Trihey & Associates and Entrix 1985). Water temperatures of groundwater were observed to remain between 2.5° – 4.0°C through the winter period, whereas Susitna River main channel temperatures were typically measured to be near 0°C (Keklak and Quane 1985). The source of upwelling in Middle Susitna River habitats was attributed to three primary types of subsurface flow: 1) lateral hyporheic flow of surface streamflow from the Susitna River main channel, 2) subsurface flow from upland sources, and 3) hyporheic flow within the Susitna floodplain alluvium (Trihey & Associates and Entrix 1985). The primary groundwater source in Middle Susitna River side channel and side slough habitats was determined to be derived from lateral hyporheic flow from the Susitna River main channel. The 1980s studies further documented that changes in main channel stage could result in relatively rapid changes (several hours) in the amount of side slough flow (i.e., groundwater discharge) (Trihey 1982, Trihey & Associates and Entrix 1985). Increases in Susitna River stage can also affect groundwater-fed habitats via overtopping, or breaching of the inlets to side channels and side sloughs resulting in a mixing of both surface and groundwater. Breaching events documented by the 1980s studies during winter staging demonstrated that such events affected the amount of the flow and associated water quality characteristics, in particular, water temperature and dissolved oxygen. Breaching flows typically resulted in increased flows and water velocities within the channel that would result in concomitant reductions in both surface and intragravel water temperatures (Labelle 1984, Trihey & Associates and Entrix 1985).

Groundwater upwelling was considered to be the principal factor affecting salmon egg development and survival in the Middle Susitna River; groundwater helps to maintain stable water levels, provides warmer water relative to surface streamflow and promotes intergravel water exchange that is critical for maintenance of adequate water quality conditions for embryo development (Vining et al. 1985). Salmon embryos in habitats with unstable or insufficient groundwater discharge were more susceptible to mortality due to dewatering and freezing than in areas with stable groundwater flow (Vining et al. 1985). Intergravel water temperature is also a critical factor during salmon egg incubation, affecting the rate of embryo and alevin development and determining the solubility of oxygen in water (Bjornn and Reiser 1991, Quinn 2005). In general, embryos develop faster at warmer water temperatures, but this relationship varies with species. At 5°C, incubation time (fertilization to hatching) was observed to range dramatically among coho (*Oncorhynchus kisutch*) (139 days), chum (*O. keta*) (161 days), sockeye (*O. nerka*) and pink (*O. gorbuscha*) (173 days, each species) and Chinook (*O. tshawytscha*) (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). Although incubation may occur at near freezing temperatures, increased mortality can occur at low temperatures during the early stages of incubation (Burgner 1991, Salo 1991, Bjornn and Reiser 1991).

Groundwater discharge often contains low levels of dissolved oxygen as organic matter is processed by microbes within the subsurface environment (Allan and Castillo 2007). 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).

1.2.3. Salmonid Egg Incubation and Survival During the Winter

Conditions for salmon egg incubation varied considerably among macrohabitats during winter studies conducted during the 1980s. During those studies, hydrologic connectivity to the Susitna River main channel and presence of groundwater upwelling were considered to be primary factors that affected salmon egg incubation timing and success (Vining et al. 1985). Salmon embryos located in macrohabitats that were most directly affected by Susitna River main channel stage fluctuations and that lacked groundwater upwelling developed more slowly and were more susceptible to high embryo mortality than areas with groundwater influence (Vining et al. 1985). Embryo mortality was often due to dewatering and freezing as Susitna River stage declined during early winter (Vining et al. 1985). Main channel, side channel, and tributary mouth habitats were found to be most affected by Susitna River stage change, while side slough habitats were more influenced by groundwater flow (Hoffman et al. 1983, Vining et al. 1985). Although groundwater upwelling was present in the main channel, side channel, and tributary habitats, the resulting flows were overwhelmed by the larger, colder main channel surface flows (Vining et al. 1985). Intergravel water temperatures in main channel and tributary habitats typically were strongly affected by surface water and were near freezing during the winter, while the groundwater influenced temperatures in side sloughs were warmer and more stable (Hoffman et al. 1983; Seagren and Wilkey 1985; Vining et al. 1985). Intergravel temperatures in side channel habitats were often variable and more dependent on site-specific conditions (e.g., groundwater input and inlet breach elevation) that controlled the relative influence of groundwater and surface water sources (Vining et al. 1985). Intergravel dissolved oxygen concentrations in main channel, side channel, and tributary habitats were generally high (>8 mg/L) and reflected surface water concentrations (Hoffman et al. 1983, Vining et al. 1985). In contrast, intergravel dissolved oxygen concentrations in side sloughs were often low (<4 mg/L) and differed from measured surface water concentrations (Hoffman et al. 1983, Vining et al. 1985).

Salmon embryos in Middle Susitna River habitats were observed to hatch between January and April, though timing can vary between species and location (Hoffman et a. 1983, Wangaard and Burger 1983). After hatching, salmon alevins may remain in the gravel for one to three months, depending on intergravel conditions (Hoffman et a. 1983, Wangaard and Burger 1983). Initially after hatching, alevins are relatively immobile, but their ability to react to adverse conditions increases with the development of fins and absorption of the yolk sac. Fast and Stober (1984) found that Chinook, coho, chum and steelhead alevins all moved vertically downward up to 20 cm within artificial redds, which was the maximum possible in the experimental design, in response to favorable velocity, dissolved oxygen, and light conditions (Fast and Stober 1984). Similarly, upstream and downstream (horizontal) intergravel movement has been documented in separate laboratory experiments (Dill 1969, Fast and Stober 1983). In response to variable intergravel velocities (0.02 feet per second [fps] and 0.066 fps), pre-emergent salmonid alevins exhibited positive rheotaxis, while movement direction was random at zero velocity (Fast and Stober 1984). Intergravel movement by salmon alevins appears to be selective in terms of habitat conditions. Within tanks that were bifurcated to provide two choices of different dissolved oxygen concentrations (2 vs. 6 mg/L, 4 vs. 6 mg/L, and 6 vs. 10 mg/L), alevins of each species (Chinook, coho, chum, and steelhead) moved within the intergravel environment toward the water source of higher oxygen concentration (Fast and Stober 1984). Selective intergravel movement by alevins may be particularly critical during fluctuating streamflows and periods of redd dewatering.

The effects of complete redd dewatering has been previously investigated, with results indicating 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). However, Fast and Stober (1983) 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 the dewatering of eggs in redds within the Susitna River during the winter period would likely vary widely depending on the extent of groundwater influence at the different redd locations. In areas where groundwater 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 groundwater below the redd) during short-term periods of dewatering. In areas of no or little groundwater influence, any dewatering during the winter periods would likely result in 100 percent mortality of the eggs due to freezing.

Salmon alevins are generally light averse in the intergravel environment, though tolerance to light increases near the end of the alevin phase (Quinn 2005). Despite this increased light tolerance, most salmon fry emerge from the gravel at night (Heard 1964, Godin 1980, Quinn 2005). Following emergence, salmon fry fill their swim bladder to obtain neutral buoyancy, at which point the phase of intergravel residence is over and they become free-swimming. Habitat use by salmon fry immediately after emergence is not well known, though many fry are believed to retain close association with substrates near the redd site (Quinn 2005). During this period, salmon fry are sensitive to environmental conditions, including fluctuations in river stage. Fry stranding can occur during periods of declining river stage as fish become stranded on the substrate above the surface water stage. Previous studies of salmon stranding occurrence relative to river streamflow fluctuations determined that stranding was size selective among salmon fry and that individuals less than approximately 50 mm in length were particularly susceptible (Bauersfeld 1977, Bauersfeld 1978, R.W. Beck and Associates 1989, Olson 1990). A more detailed review of the effects of flow fluctuations on both fish and aquatic invertebrates, which are often termed pulse type flows, is found in Reiser et al. (2005).

1.2.4. Winter Habitat Conditions for Juvenile and Adult Fish

Winter habitat conditions in Alaskan Rivers can be severe for juvenile and adult fish species. Extreme low water temperature is a primary factor affecting overwintering fish, as reduced temperature can affect fish metabolism, feeding, diel behavior, swimming ability, and predator avoidance (Beamish 1978, Brown et al. 2011). Ice formation on the channel margins, substrate, and water surface can also affect fish habitat in terms of channel constriction and reduced habitat area, decreased light penetration into the water, and alteration of water quality conditions (e.g., dissolved oxygen concentration) (Prowse 2001). Suspended frazil ice can cause direct injury or mortality to fish by plugging or abrading gills, while anchor ice and ice dams can eliminate or modify aquatic habitat to the extent that it becomes unsuitable for fish (Brown et al. 1993, Brown et al. 2011).

Nearly all juvenile and adult fish species exhibit physiological and/or behavioral adjustments in response to seasonal changes in habitat conditions from summer to winter. During fall, many fish will move to winter habitats. Suitable winter habitats allow fish to minimize energy expenditure while providing a stable environment that is protected from environmental extremes (Brown et al. 2011). Winter habitat can be characterized by the presence of groundwater upwelling, structural complexity (e.g., large wood), coarse substrate, low current velocity, deep pools, and off-channel areas protected from more extreme main channel hydrologic conditions (Muhlfeld et al. 2001, Mitro and Zale 2002, Harper and Farag 2004, Brown et al. 2011). 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 too large to utilize interstitial habitats often seek deep pools in main channels (Reynolds 1997). In the Susitna River during the 1980s studies, juvenile coho salmon used groundwater-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 groundwater upwelling (Delaney et al. 1981, Stratton 1986). Adult rainbow trout (*Oncorhynchus mykiss*) and Arctic grayling (*Thymallus arcticus*) in the Susitna River migrated from spawning and feeding tributaries in late summer to main channel areas that were typically downstream and proximal to the spawning tributary, though some individuals exhibited long distance (> 20 miles) movements (Hoffman et al. 1983, Sundet and Pechek 1985, Sundet 1986). The specific habitat features of Susitna River holding areas used by adult resident species during 1980s winter telemetry studies were difficult to measure, though groundwater 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 commonly aggregate during winter, perhaps due in part to the reduced amount of habitat area in winter relative to summer (Cunjak and Power 1986). Although competitive interactions between individuals may otherwise limit large aggregations, reduced territorial aggression during winter is likely one mechanism by which aggregations occur (Reynolds 1997). In the Susitna River, radio telemetry during 1980s studies indicated that adult rainbow trout and Arctic grayling utilized the same main channel areas for winter habitat, while similar tracking data suggested aggregation of Arctic grayling and burbot (*Lota lota*) in the Middle Susitna River main channel habitats (Sundet and Wenger 1984, Sundet 1986). Arctic grayling distribution has similarly observed to be patchy in other Alaska rivers (West et al. 1992, Reynolds 1997). The same winter habitats are often used from year to year by fish species, which may indicate that stable environments are critical during the winter period (Reynolds 1997).

Diel behavior and activity patterns of fish species often change during winter in response to cold water temperature, ice formation, and low light conditions (Reeves et al. 2009, Valdimarsson and Metcalfe 2001). At low water temperatures particularly, salmon activity will often shift from diurnal in summer and fall to nocturnal during winter to minimize energy expenditure and reduce predation risk (Roni and Fayram 2000, Quinn 2005). Ice cover and light intensity may be mitigating factors based on studies examining the effect of ice cover on salmonid behavior during winter. Brown trout (*Salmo trutta*) that were primarily nocturnal during winter exhibited greater activity and foraging behavior in the presence of ice cover relative to its absence (Watz et al. 2013). Similarly, juvenile Atlantic salmon (*Salmo salar*) that were primarily nocturnal during winter exhibited greater activity levels during daytime in areas of ice cover relative to open-water (Linnansaari et al. 2008).

1.2.5. Summary

As noted above, winter instream flow conditions are an important component of fish habitat in the Susitna River, particularly with respect to egg incubation and juvenile and adult holding. Intergravel flow and groundwater upwelling are critical for egg incubation and emergent fry survival, while surface water characteristics (e.g., temperature, depth, and velocity) can be important aspects of winter habitat for juvenile and adult fish. Although groundwater has been observed to be an important aspect of aquatic habitat for many fish species and life stages in the Susitna River, the relationships between Susitna River streamflow, groundwater, and various other habitat criteria and indices relevant to winter conditions are not completely understood. The winter studies will result in an improved understanding of habitat conditions and utilization by fish species and life stages needed to evaluate overall effects of altered Susitna River streamflow on the quality and quantity of aquatic habitats. In terms of the IFS program, observations of winter conditions and fish habitat utilization will support development of Habitat Suitability Curve and Habitat Suitability Indices (HSC/HSI) for different fish species and life stages that will be used to develop fish habitat-flow relationships needed for assessing winter-time Project operational effects.

2. STUDY OBJECTIVES

The overall objectives of the 2013-2014 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. Specific tasks of the study 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 groundwater 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 groundwater influence.
- Describe juvenile and adult fish behavior in representative habitats during day and night conditions to discern potential patterns in behavior and habitat use.
- Record site-specific habitat utilization data for juvenile and adult fish species in support of HSC/HSI development.

3. STUDY AREA

The 2013-2014 IFS winter studies were conducted in the Middle River Segment of the Susitna River between the Three Rivers Confluence (PRM 102.4) and PRM 143. Data collection primarily occurred within three Focus Areas (FAs): FA-104 (Whisker Slough), FA-128 (Slough 8A), and FA-138 (Gold Creek); however, opportunistic sampling also occurred within FA-141 (Indian River) (Figure 1). These FAs were selected for the 2013-2014 study because they contain a diversity of habitat types with groundwater influence, they have documented fish utilization by multiple fish species and life stages, and they could be safely accessed during the winter. Candidate sampling locations within the study area were identified prior to sampling such that the relative data collection effort was similar among FA-104 (Whisker Slough), FA-128 (Slough 8A), and FA-138 (Gold Creek). However, adjustments to proposed sampling locations were made during each field effort based upon known fish distributions (e.g., spawning), logistical considerations (e.g., site access, ice cover), and site hazards and personal safety. Work was primarily based out of Talkeetna and Gold Creek camp, although temporary field camps were also used at FA-104 (Whiskers Slough), FA-128 (Slough 8A), and FA-138 (Gold Creek).

4. METHODS

The 2013-2014 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. Data collection occurred during three trips in early 2014: February 3-16, March 4-16, and April 1-12. The 2013-2014 winter studies were coordinated with the study leads for IFS (Study 8.5), FDA (Study 9.6), Groundwater (Study 7.5), Geomorphology (Study 6.5), Water Quality (Study 5.5), and Ice Processes (Study 7.6). Methods utilized during the 2013-2014 study were initially developed during the 2012–2013 pilot winter study conducted at FA-104 (Whiskers Slough) and FA-128 (Slough 8A) (AEA 2014, Study 8.5 Appendix L).

4.1. Water Surface Elevations

Water level and selected water quality parameters (water temperature and dissolved oxygen) were continuously monitored during winter 2013-2014 at nine sites in FA-104 (Whiskers Slough), eight sites in FA-128 (Slough 8A), and seven sites in FA-138 (Gold Creek) (Figure 2,

Figure 3, and Figure 4). Continuous monitoring sites were established during the conclusion of the salmon spawning period in the Middle River Segment in September and early October 2013. Water level and water quality instruments were installed at representative macrohabitat types in each FA, which consisted of main channel, side channel, side slough, upland slough, and tributary habitats. Macrohabitat designations (e.g., side channel, side slough) used for the 2013-2014 winter studies were based on 2012 Middle River Segment remote line habitat mapping (HDR 2013). Continuous monitoring sites were comprised of areas with known or suspected groundwater upwelling, bank seepage and lateral intergravel flow from the main channel, mixing between upwelling and bank seepage, little apparent intergravel discharge, and areas where fish had been observed spawning. Salmon spawning was observed during fall 2013 near three sites in each of FA-104 (Whiskers Slough) (104-WESC-10, 104-WSL-20, and 104-WC-10) and FA-138 (138-SL11-04, 138-SL13-05, and 138-USC11-09) (Figure 2, Figure 4). In FA-128, five sites (128-SLA-20, 128-SC-05, 128-SC8A-25, 128-SL8A-15, and 128-SL8A-40) coincided with observed 2013 salmon spawning areas (Figure 3).

Water level at continuous monitoring sites was recorded using pressure transducers (Solinst Levelogger Model 3001) deployed at the substrate surface. Transducers were anchored with weights and attached to metal stakes driven into the substrate to prevent shifting during the deployment period. Pressure data recorded at each site were compensated with air barometric pressure data (Solinst Barologger Model 2001) recorded at each Focus Area (Figure 2, Figure 3 and Figure 4). Data collected during periods of low Susitna River streamflow in which pressure transducers appeared to become dewatered were eliminated from the affected stage records. To facilitate visual comparisons of stage between macrohabitat types, water level data were normalized to zero at the earliest common start time for transducers within each Focus Area. Stage records at each monitoring site in FA-104 (Whiskers Creek) was equalized to zero on October 1, 2013, while stage records at each site in FA-128 (Slough 8A) and FA-138 (Gold Creek) were set to zero on September 30, 2013. Aerial reconnaissance photo surveys of FA-104 (Whiskers Slough) performed by groundwater personnel during November 2013 were used to validate stage conditions among macrohabitats, including side channel and side slough inlet breach conditions that were apparent from continuous water level data.

Water level instruments accessible during winter were downloaded during March or April 2014. At salmon spawning locations, instruments were redeployed in March 2014 to collect additional data during the remaining salmon egg incubation period and spring ice breakup. Instruments at FA-104 (Whiskers Slough) salmon spawning sites were retrieved in June 2014, while most instruments at FA-128 (Slough 8A) and FA-138 (Gold Creek) will be retrieved during September 2014 (Table 1). At accessible non-spawning sites, instruments were removed prior to ice breakup to limit data loss and damage to equipment.

4.2. Water Quality

Surface and intergravel water temperatures and intergravel dissolved oxygen concentrations were continuously recorded during 2013-2014 IFS winter studies (Figure 2, Figure 3 and Figure 4). In each Focus Area, water temperature loggers (Hobo Tidbit v2) were deployed in surface water at the substrate and at three separate intergravel depths: 5 centimeters (cm) (2 in), 20 cm (7.9 in), and 35 cm (13.8 in) beneath the substrate surface. These depths reflect observed burial depth ranges of chum and sockeye eggs (Bigler and Levesque 1985; DeVries 1997). Surface and intergravel temperature loggers were attached to a stainless steel cable and inserted into the gravel at the appropriate depth using a steel installation device (*sensu* Zimmerman and Finn 2012). Water temperature loggers at salmon spawning sites that were accessible were downloaded during late winter 2014 and redeployed to record conditions through spring ice breakup and the period of salmon egg incubation (Table 1).

Intergravel dissolved oxygen concentrations were recorded with HOBO U26-001 loggers in two locations, one each within FA-128 (Slough 8A) and FA-138 (Gold Creek). The locations represented sites adjacent to observed 2013 salmon spawning areas (sites 128-SL8A-40 and 138-SL11-04) (Figure 3 and Figure 4). The loggers, which also recorded intergravel water temperature, were deployed approximately 20 cm below the substrate surface within a perforated PVC housing. Data from the loggers were downloaded during the field visits provided they were accessible; instantaneous measurements of dissolved oxygen and temperature were taken using a hand-held water quality meter (Hach HQ40D) at the same depths as the loggers (i.e., 20 cm below the substrate surface) for comparative purposes. Dissolved oxygen loggers were removed prior to spring breakup 2014 to avoid potential equipment loss (Table 1).

The relationship between main channel stage and surface and intergravel water temperature was evaluated in conjunction with water level for all monitoring sites. For each comparison, stage records were normalized to zero at the start of data collection to facilitate visual comparison. Stage records at each monitoring site in FA-104 (Whiskers Creek) was equalized to zero on October 1, 2013, while stage records at each site in FA-128 (Slough 8A) and FA-138 (Gold Creek) were set to zero on September 30, 2013.

Instantaneous measurements (spot measurements) of surface and groundwater quality were recorded during February, March, and April 2014 in each Focus Area at IFS monitoring sites, groundwater wells and sites associated with fish capture and observation (Figure 2, Figure 3, and Figure 4). Spot water quality data were recorded at two groundwater wells in each Focus Area (six wells total) (Figure 2, Figure 3 and Figure 4). These consisted of water temperature, specific conductance, and dissolved oxygen concentration recorded using a hand-held water quality meter (Hach HQ40D). Surface water quality at IFS sites was recorded at mid-column water depth. Measurements of groundwater quality were taken within each of the groundwater wells and at the two dissolved oxygen monitoring sites approximately 20 cm below the substrate surface. Instantaneous water quality data were used to characterize surface water quality in each Focus Area and to help discern qualitative differences in groundwater composition among habitats based on water temperature and specific conductance (Rosenberry and LaBaugh 2008).

Ice thickness and water depth were measured in association with water quality measurements at continuous and instantaneous monitoring sites. Hand and power augers were used to drill holes (2 – 10 inch) in the ice to access surface water and measure ice thickness. Ice and water depth measurements recorded were ice thickness, total water depth, and effective water depth, which is the depth from the bottom of ice cover to the substrate.

A total of 13 water samples (7 surface water and 6 groundwater) were collected for laboratory chemical analyses including nutrients (NO3, NO2, NH4, TKN, TP), total and dissolved metals, methyl mercury, chlorophyll-a, total and dissolved mercury, and total and dissolved organic carbon. Samples were collected in the field by R2 Resource Consultants following methods outlined by URS and transported to URS staff in Talkeetna or Anchorage for next day shipment to analytical laboratories. Field parameters of water quality were also measured in each Focus Area along longitudinal transects (100m) in sloughs or side channels adjacent to the groundwater wells. Temperature, specific conductance, and dissolved oxygen (DO) were measured at 10 m increments in open leads where available or through holes augered in the ice.

4.3. Fish Observations

Fish capture and observation efforts occurred in each Focus Area during February, March, and April 2014. Electrofishing methods were used in ice-free areas to capture fish and collect site-specific HSC/HSI data. Surveys were conducted using a backpack electrofisher (Smith Root LR-24) at 23 open-water sites in FA-104 (Whiskers Slough), FA-128 (Slough 8A), and FA-138 (Gold Creek). One site in FA-141 (Indian River) was opportunistically sampled during the April 2014 sampling effort. Paired day and night surveys were conducted at a subset of electrofishing sites (*n* = 11) to help evaluate potential differences in fish diel activity patterns. HSC/HSI data (e.g., water depth, water velocity, substrate size, and composition) were measured at the point of fish capture during electrofishing sampling. Water depth and velocity measurements were made using a wading rod and Price AA water velocity meter. Water temperature, dissolved oxygen, and specific conductance were recorded at the locations of fish observations using a hand-held water quality meter (Hach HQ40D).

Underwater fish observations in ice-covered areas within side slough and tributary habitats were recorded using underwater video during day and night periods. A total of five sites were surveyed by IFS staff in FA-104 (Whiskers Slough), FA-128 (Slough 8A), and FA-138 (Gold Creek). Observations were documented using an underwater video camera (Aqua-Vu MC2x) with a peripheral infrared light source (SeaViewer Model 42), each of which was equipped with a pole extension. White light sources were used as little as possible during night surveys to minimize the effect of visible light on fish behavior. At each site, multiple holes were drilled in the ice using an ice auger to accommodate the video and infrared light equipment. At each ice hole, an underwater survey was conducted for approximately four minutes by slowly rotating the camera 360° for two rotations with 30 second pauses at each 90° position (Carlson and Quinn 2005). Ice hole stations were surveyed sequentially in an upstream direction to minimize fish disturbance. Observed fish were enumerated by species and size class and HSC/HSI data were recorded, provided the target fish was observed maintaining a stationary position. As for the electrofishing surveys, the video surveys were performed during day and night to help evaluate potential behavioral differences in fish diel activity in the Susitna River during winter.

Underwater video was also used by FDA staff, in conjunction with Adaptive Resolution Imaging Sonar (ARIS) technology, during the 2013-2014 winter effort to monitor fish presence, movement and behavior (AEA 2014b).

4.4. Deviations from Study Plan

The 2013-2014 IFS winter studies methods were implemented as described in the Study Plan with no variances (see ISR Study 8.5, Section 4.5.1.10).

5. RESULTS

5.1. Water Surface Elevation

5.1.1. FA-104 (Whiskers Slough)

Water levels at various locations within FA-104 (Whiskers Slough) varied widely over the period of the winter studies in response to ice formation and staging. At main channel Site 104-MC-40 water levels declined during October and early November 2013 prior to solid river ice formation, and then increased markedly during main channel staging in late November 2014 (Figure 5). Short-term stage oscillations ranging from 0.5 – 4.0 feet were recorded during December 2013 through March 2014 and a large stage increase occurred in early May 2014 in association with spring ice breakup (USGS 2014) (Figure 5). Water levels at side channel sites 104-WSC-10 and 104-WESC-10 closely resembled the main channel stage record at Site 104-MC-40; stage recorders at each site appeared to be dewatered for short periods in November 2014 (Figure 5). At side channel sites 104-WSC-30 and 104-SL3B-10 stage recorders did not register short-term fluctuations during low stage periods in October 2013 and during January to March 2014 (Figure 5).

The inlets to each side channel site 104-WSC-30 and 104-SL3B-10 were not breached by Susitna River main channel streamflow following instrument installation in October 2013, though it was apparent from aerial surveys that each channel inlet was breached during the late November 2013 staging event in FA-104 (Whiskers Slough). It was not possible to determine whether the Whiskers Side Channel and Slough 3B inlets were breached during winter studies sampling in February, March, and April 2014. Stage records at side slough (Site 104-WSL-20), upland slough (Site 104-SL3A-70), and tributary (Site 104-WC-10) sites reflected large-scale stage changes (> 5 feet) that occurred at Site 104-MC-40 during fall ice formation and spring ice breakup. However, those sites were largely insensitive to small-scale stage changes (<1 foot) that were apparent in the Susitna River main channel during January to April 2014 (Figure 5). Aerial reconnaissance indicated that the Whiskers Slough inlet was breached and the Whiskers Creek site was backwatered by main channel streamflow during staging in November 2013.

5.1.2. FA-128 (Slough 8A)

In FA-128 (Slough 8A), Susitna River main channel water levels at Site 128-MC-10 declined during late September and October 2013 and likely became dewatered prior to main channel staging in early December (Figure 6). Following Susitna River main channel staging, the water level at Site 128-MC-10 continued to increase and peaked in early January 2014 and subsequently declined until the stage recorder was removed in April 2014 (Figure 6). The inlet to Side Channel 8A was not breached by Susitna River main channel flow during instrument installation in late September 2013; recorded stage at Site 128-SC8A-25 was stable relative to the main channel site (128-MC-10) during October to December 2013 (Figure 6). However, Susitna River main channel flow appeared to breach the Side Channel 8A inlet during a main channel freeze-up event in mid-January 2014, which caused a substantial rise in water level (4 – 8 feet) at Site 128-SC8A-25 (Figure 6). The subsequent stage record at 128-SC8A-25 during February to April 2014 resembles the recorded stage at main channel Site 128-MC-10 (Figure 6). Water level records at Side Slough 8A Site 128-SL8A-40 were generally steady through the period of record with the exception of a short-term increase in stage of approximately three feet that occurred in late February 2014 when Susitna River main channel flow breached the Slough 8A inlet (Figure 6). This breaching event was less evident at the lower Slough 8A Site (ESSFA128-1) because water levels at this site were affected by backwater from Side Channel 8A flow. Water levels in Slough A (128-SLA-20) were steady through the period of record and did not reflect stage fluctuations associated with the Side Channel 8A and Slough 8A breach events (Figure 6). Stage records in upland slough sites (128-US1-10, 128-US2-15) appeared independent of the main channel stage at Site 128-MC-10 until mid-January, at which point high flow volumes in Side Channel 8A affected water levels in each channel (Figure 6).

5.1.3. FA-138 (Gold Creek)

Water levels at FA-138 (Gold Creek) main channel Site 138-MC-50 decreased during late September and October 2013 and the channel was likely dewatered during the period of Susitna River main channel ice formation (late October to early December 2013) (Figure 6). Following the peak main channel stage in mid-December 2013 at Site 138-MC-50, water levels fluctuated between 0.5 to 3.0 feet between January to March 2013 (Figure 7). The stage in the Upper Side Channel 11 Site, Site 138-USC11-09, closely resembled that of main channel Site 138-MC-50 for most of the data period (Figure 7). Recorded water levels in Slough 11 were stable relative to the main channel and side channel sites, with the exception of the period of ice formation in mid-December (Figure 7).

5.2. Water Quality

5.2.1. FA-104 (Whiskers Slough)

Surface and intergravel water temperatures differed among habitat types at FA-104 (Whiskers Slough) during the 2013-2014 winter study based on data collected at nine continuous monitoring sites. In the Susitna River main channel (Site 104-MC-40), surface and intergravel temperatures were near 8°C during the September 2013 deployment and were very near 0°C during the period of ice cover in the main channel (December 2013 – April 2014) (Figure 8). In the lower portion of Whiskers Side Channel (Site 104-WSC-10), temperatures generally resembled that of the main channel site as surface and intergravel temperatures were both typically below 2°C during December 2013 through early March 2014 (Figure 8). At Site 104-WSC-30 in the upper extent of Whiskers Side Channel, surface and intergravel water temperatures were stable at approximately 4°C prior to the period of ice formation. Starting in late November 2013, water levels increased substantially in the main channel (Site 104-MC-40) and Whiskers Side Channel during which time temperatures at each gradient at Site 104-WSC-30 decreased to near 0°C (Figure 9). Following ice formation and apparent main channel water level decrease, intergravel temperature at Site 104-WSC-30 increased to between 2 – 4°C (Figure 9). At side channel sites 104-WESC-10 and 104-SL3B-10, water temperatures were generally cooler than the main channel site prior to ice formation and warmer following freeze-up. Water temperatures at these sites declined to near 0°C during the main channel stage increase in late November 2013 (Figure 9 and Figure 10). Surface and intergravel temperatures dropped below zero during a presumed period of dewatering in mid-November when water levels in the Susitna River main channel and Whiskers East Side Channel were low (Figure 10). Although the inlets to Whiskers Side Channel, Whiskers East Side Channel, and Slough 3B were breached by

Susitna River main channel flow during the November 2013 reconnaissance flight, it was not evident based on visual observations whether the inlets were breached during data collection periods in February, March, and April 2014.

At upland slough Site 104-SL3A-70, surface and intergravel temperatures were warm (>2°C) relative to the Susitna River main channel site (104-MC-40) and generally stable through the data collection period, with negligible temperature reduction during the ice formation period in late November 2014 (Figure 10). Whiskers Slough (Site 104-WSL-20) temperatures were cooler than the main channel site prior to freeze-up and warmer during December 2013 to February 2014 (Figure 10). Surface and intergravel water temperatures declined to near 0°C during the November 2013 freeze-up and May 2014 ice break-out periods, that coincided with high main channel stage (Figure 11). The Whiskers Slough inlet was breached by Susitna River main channel flow during the November 2013 reconnaissance flight but did not appear breached during February and March 2014 data collection efforts. Intergravel temperatures at the Whiskers Creek site (104-WC-10) tracked surface temperatures during the period of record and generally remained below 2°C throughout the period of ice cover (December 2013 – April 2014) (Figure 11).

Spot measurements of surface water temperature recorded in February and March 2014 at FA-104 (Whiskers Slough) indicated generally warmer surface water in side slough and upland slough habitats relative to the Susitna River main channel, which was consistent with data recorded at the continuous temperature monitoring sites (Figure 12). Specific conductance values at mainstem spot measurement sites were conversely higher than off-channel and tributary areas (Figure 12). Measurements within the groundwater wells found temperatures were warmer and conductance values intermediate to other sites (Figure 12). Exceptions to this general trend were at side channel Site 104-SL3B-10, which exhibited specific conductance and water temperatures unlike other side channel sites, and side slough Site 104-CFSL-10 where specific conductance was more similar to mainstem habitats than other side slough habitats (Figure 12). Groundwater upwelling measured at Site SL3A-11 exhibited similar temperature and conductivity values to those of surface water measurements at Site 104-SL3A-10, but substantially lower dissolved oxygen concentrations (Table 2). Specific conductance ranged from 125.3 – 265 µS/cm among main channel (Site 104-MC-50), Whiskers Side Channel (WSC), and Whiskers East Side Channel sites, 200.5 µS/cm at side slough Site CFSL-10, 90.9 µS/cm at side channel Site SL3B-10, 32.9 – 75.5 µS/cm at Whiskers Slough (WSL) sites, 32.3 – 35.7 µS/cm at Whiskers Creek (WC) sites, 92.0 µS/cm at Site 104-SL3A-70, and 124.0 µS/cm at groundwater well Site ESGFA104-10-W1 (Table 2 and Figure 12).

Ice cover in FA-104 (Whiskers Slough) was nearly complete in each macrohabitat during data collection efforts in February, March, and April 2014. Monitoring sites with open-water leads were 104-WSC-30, 104-SL3B-10, 104-CFSL-15, and 104-SL3A-10 (Table 2). During March 2014, ice thickness was 3.6 feet in the main channel, ranged from 0 – 2.2 feet among side channel sites, and ranged from 0 – 1.1 feet among side slough sites (Table 2).

5.2.2. FA-128 (Slough 8A)

Surface temperatures at FA-128 (Slough 8A) Site 128-MC-10 ranged from 0-6°C prior to main channel ice formation in September and October 2013, and then dropped below zero during a presumed period of instrument dewatering in November and December 2014 (Figure 13). During the period of ice cover, surface water temperatures at Site 128-MC-10 were near 0°C

(Figure 13). At Side Channel 8A monitoring Site 128-SC8A-25, surface and intergravel temperatures exhibited minimal vertical thermal gradient during September and October 2013 prior to Susitna River main channel ice formation, but varied during freeze-up in November 2013 (Figure 13). Surface and intergravel water temperature at Site 128-SC8A-25 declined to near 0 °C in mid-January coincident with the influx of Susitna River main channel flow into Side Channel 8A and abrupt increases in the Side Channel 8A stage (Figure 13). Water temperatures in Slough 8A were generally warmer (4°C intergravel temperature) and more stable through the data collection period than at monitoring sites in the main channel (128-MC-10) and Side Channel 8A (128-SC8A-25). However, short-term reductions in surface and intergravel temperature were evident in November 2013 and February 2014 (Figure 14). Similarly, surface and intergravel temperatures at Upland Slough 2 were warm (3-4°C) and stable with the exception of short-term declines in temperature coincident with transitory stage increases (Figure 15). At Upland Slough 1 and near the mouth of Skull Creek, surface and intergravel temperatures declined substantially during late November 2013 and remained low (<1°C) during December 2013 through March 2014 (Figure 15 and Figure 16). Surface and intergravel water temperatures at the Slough A monitoring site (128-SLA-20) declined below 1°C during the period of ice formation in November 2013 and increased to approximately 2°C in late December 2013 and January 2014 (Figure 16).

Intergravel dissolved oxygen measurements recorded at approximately 20 cm below the substrate surface at Site 128-SL8A-40 were generally stable at approximately 5.5 mg/L during September 2013 through March 2014, excepting periods during November 2013 (3 weeks) and February 2014 (1 week) when concentrations were elevated (Figure 17). Intergravel water temperatures at this site tended to be stable at nearly 4.5°C during most of the measurement period, but exhibited abrupt declines during periods coincident with apparent dissolved oxygen fluctuations (Figure 17). Dissolved oxygen and temperature fluctuations during February 2014 occurred during the Slough 8A inlet breach event observed during IFS data collection at FA-128 (Slough 8A).

Spot water quality measurements measured in FA-128 (Slough 8A) during February and March 2014 indicated that side slough and upland slough habitats were generally warmer relative to main channel and side channel areas, but that specific conductance was not substantially different among habitats (Figure 18). Instantaneous surface water temperature measurements ranged from 0.1°C at main channel Site 128-MC-10, 0.1 – 1.1°C at Skull Side Channel (SSC) sites, 0.2 – 0.5°C at Side Channel 8A (SC8A) sites, 0.3 – 1.2°C among Slough 8A (SL8A) sites, 0.2°C at Upland Slough 1 (US1), 1.6°C at Upland Slough 2 (US2), 2.4 – 4.1°C at Upland Slough 3 (US3) sites, 0.3 – 2.1°C at Half Moon Slough (HMSL) sites, 1.1°C at the Skull Creek mouth (SC), and 1.2°C at Slough A (SLA) (Table 2). Specific conductance was lower in Slough 8A (SL8A), upland slough (US1, US2 and US3), and tributary (SC) sites relative to main channel and side channel habitats (Figure 18). Spot measurements of intergravel water (approximately 20 cm below substrate surface) measured at Site 128-SL8A-40 exhibited substantially higher temperatures (4.5°C), lower conductivities (58.6 µS/cm) and lower dissolved oxygen (4.01 mg/L) than surface waters at that site (1.2°C, 214.8 µS/cm, and 11.75 mg/L) (Table 2). Specific conductance measurements at FA-128 (Slough 8A) ranged from 284.1 µS/cm at main channel Site 128-MC-50, 260.0 – 268.0 µS/cm at side channel sites (SC8A and SSC sites), 207.9 – 263.0 µS/cm among Slough 8A (SL8A) surface water sites, 165.1 µS/cm at Slough A (SLA), 125.9 µS/cm at Upland Slough 1 (US1), 191.3 – 193.6 µS/cm at Upland Slough 2 and 3 (US2 and

US3) sites, 226.0 – 270.0 µS/cm at Half Moon Slough (HMSL) sites, and 162.9 µS/cm at the Skull Creek mouth (SC) (Table 2).

Ice coverage was nearly complete in FA-128 (Slough 8A) with the primary exceptions of Side Channel 8A and portions of Slough 8A and Skull Side Channel. Open leads at monitoring sites in Slough 8A (e.g., 128-SL8A-40) and Skull Side Channel (128-SSC-15) were likely thermal leads, while open-water in Side Channel 8A was the result of high water velocity. During February and March 2014, ice thickness was 3.2 feet in the main channel, 2.0 feet at Site 128-HMSC-01, 0.4 foot at Site 128-SL8A-15, ranged from 0 – 2.1 feet among upland slough sites, and was 1.5 feet in Skull Creek (Table 2).

5.2.3. FA-138 (Gold Creek)

Susitna River main channel water temperatures at FA-138 (Gold Creek) monitoring site 138-MC-50 declined from approximately 7°C in September 2013 to below zero in late October 2013 when surface water stage at the site was presumed to be zero (Figure 19). Following the dewater period at main channel site 138-MC-50, which was estimated to occur from late October to December 2013, surface and intergravel water temperature remained between 0-1°C (Figure 19). In Upper Side Channel 11 (Site 138-USC11-09), surface and intergravel water temperatures were warm (approximately 4°C) and stable during September and October 2013 relative to main channel temperatures (Figure 19). Beginning in November 2013, a thermal gradient was evident between surface and intergravel depths at Site 138-USC11-09, though all surface and intergravel temperatures exhibited a short-term decline in December 2013 that was coincident with transitory stage increases at main channel (Site 138-MC-50) and Upper Side Channel 11 (Site 138-USC11-09) sites (Figure 19). Surface water temperature records at the two monitoring sites near the outlet of Slough 11 (sites 138-SL11-04 and 138-SL11-06) similarly declined from 4°C in early October 2013 to between 1-2°C in November and remained generally stable at 2°C during the ice covered period (December 2013 – March 2014), excepting a short-term decline to near 0°C in mid-December (Figure 20). The surface temperature decline coincided with increases in water level in the main channel (Site 138-MC-50) and at Site 138-SL11-04. Intergravel water temperatures at Site 138-SL11-04 were stable at approximately 3.5°C through the monitoring period, while intergravel temperatures at Site 138-SL11-06 generally resembled surface water (Figure 20). At Slough 11 Site 138-SL11-20, surface and intergravel temperatures declined from 8°C in September 2013 to near 0°C during a short-term stage increase in December 2013 and fluctuated between approximately 1-2°C during January to March 2013 (Figure 21).

Intergravel dissolved oxygen at FA-138 (Gold Creek) Site 138-SL11-04 fluctuated generally between 7 – 10 mg/L during September 2013 through April 2014, although some recorded values were less than 4 mg/L (Figure 22). Intergravel temperatures at Site 138-SL11-04 were generally stable ranging between 6 – 7°C during the measurement period (Figure 22).

Spot water quality measurements at FA-138 (Gold Creek) during February and March 2014 indicated that surface water in side slough and upland slough habitats was generally warmer relative to main channel and side channel areas, but did not differ substantially in terms of specific conductance (Figure 23). Exceptions to this general trend occurred at most groundwater seepage measurement locations within side channel (138-USC11-12, 138-USC11-16, 138-LSC11-11 and 138-LSC11-12) and side slough (138-SL11-04) sites (Figure 23, Table 2). Spot surface water temperature measurements ranged from 0.2°C at main channel Site 138-MC-50, 0.2 – 0.8°C at Upper Side Channel 11 (USC11), Lower Side Channel 11 (LSC11), and Side Channel 14 (SC14) sites, 1.9°C at Side Channel 12 (138-SC12-05), 1.2 – 2.5°C among Slough 11 (SL11) sites, 0.1°C at Slough 12 (138-SL12-10), 1.6 – 2.2°C at Slough 13 (SL13) sites, and 0.3°C at Gold Creek (Table 2). Sites in Upper Side Channel 11 (USC11) and Lower Side Channel 11 (LSC11), which included several visible groundwater sources, were most variable in terms of temperature and specific conductance values among all macrohabitat types (Figure 23 and Table 2). Specific conductance of FA-138 (Gold Creek) surface water measurements ranged from 245.0 – 269.0 µS/cm at main channel (MC) sites, 203.9 – 324.0 µS/cm at Upper Side Channel 11 (USC11) sites, 261.0 – 275.0 µS/cm at Lower Side Channel 11 (USC11) sites, 261.0 – 264.0 µS/cm at Side Channel 12 and Side Channel 14 (SC12 and SC14) sites, 272.0 – 315.0 among Slough 11 (SL11) sites, 103.3 µS/cm at Slough 12 (Site 138-SL12-10), 202.6 – 256.0 µS/cm at Slough 13 (SL13) sites, 64.2 µS/cm at Slough 14 (Site 138-SL14-20), and 376.0 µS/cm at the Gold Creek mouth (GC) (Table 2).

Ice coverage in FA-138 (Gold Creek) was most consistent in the main channel, although open leads were present in each habitat type. During February and March 2014, ice thickness ranged from 0 – 1.5 feet at the main channel monitoring site, 0 – 2.5 feet among side channel sites, 0 – 0.5 foot among side slough sites, and 0 – 0.5 foot among upland slough sites (Table 2).

5.3. Fish Observations

A total of 45 electrofishing surveys were conducted during IFS data collection efforts in FA-104 (Whiskers Slough), FA-128 (Slough 8A), FA-138 (Gold Creek), and FA-141 (Indian River), of which 16 surveys were conducted at night (Table 3). Fish species captured during day and night electrofishing surveys consisted of Chinook, sockeye, chum and coho salmon, rainbow trout, Arctic grayling, Longnose sucker (*Catostomus catostomus*), and Arctic lamprey (*Lethenteron japonicum*); sculpin (*Cottid*) were also captured, though these individuals were not identified to species (Table 3). During the opportunistic survey of a main channel site in FA-141 (Indian River), one Chinook and three coho salmon were captured (Table 3). A total of 248 fish were captured during 28 daytime electrofishing surveys, while 659 fish were captured during 16 nighttime surveys (Table 3). Overall, a total of 262 site specific HSC observations were recorded for eight fish species during winter electrofishing surveys in February, March, and April 2014 (Table 4). Most HSC observations were of coho salmon (120 observations), sockeye (68 observations), and chum (42 observations) (Table 4).

Few fish were detected during winter underwater video surveys in each Focus Area. No fish were observed at underwater video sites in FA-104 (Whiskers Creek) or FA-128 (Slough 8A) during February, March, and April 2014. At FA-138 (Gold Creek), juvenile salmon (60 – 100 mm fork length) were observed during nighttime surveys at Site 138-SL11-22, though species could not be positively identified. No HSC observations were recorded in association with underwater video surveys conducted in 2014.

6. DISCUSSION AND CONCLUSION

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 substantially higher flows in the winter than under current conditions. Flows at the 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 (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 substantially both hourly and daily due to load-following demands.

The provision of higher flows in the winter-time will mean that areas/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) or be periodically wetted if within the active range of load following. It will also mean that lateral habitats (side channels and side sloughs) that under current conditions are fed mostly by clear, stable, and comparatively warm groundwater 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 would depend on the specific breaching conditions of each habitat feature.

The overall objective of the 2013-2014 winter study was 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. This information, along with data and information provided from other resource studies (Ice Processes, Groundwater, Water Quality, and Fish Distribution and Abundance) will be useful for assessing potential impacts of winter-time Project operations on aquatic habitats and biota.

The 2013-2014 winter study, which was an expansion of the initial Pilot study completed in 2012-2013 (AEA 2014, Study 8.5 Appendix L), was conducted at three Focus Areas: FA-104 (Whiskers Slough), FA-128 (Slough 8A), and FA-138 (Gold Creek). Each Focus Area was observed to support salmon spawning in 2013 and each contained a diversity of main channel and off-channel habitats.

6.1. Water Surface Elevation

Susitna River main channel stage was observed to affect each continuous monitoring site in FA-104 (Whiskers Creek), FA-128 (Slough 8A), and FA-138 (Gold Creek) during the 2013-2014 winter period. Not surprisingly, water levels in side channel habitats appeared to be most closely related to Susitna River main channel fluctuations than other habitat types. Water level stage at side channel sites in Whiskers Side Channel (104-WSC-10), Side Channel 8A (128-SC8A-25), and Upper Side Channel 11 (138-USC11-09) were closely related to stage at respective main channel sites (104-MC-40, 128-MC-10, and 138-MC-50). The water level stage at side slough sites was 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 change among macrohabitat types.

Hydrologic studies conducted during the 1980s observed a similar relationship between stage and discharge among macrohabitat types and noted that side channels in the Middle Susitna River were generally more frequently breached by main channel streamflow than other habitats (Quane et al. 1984). Although stage in side channel and side slough habitats become directly related to main channel streamflow and stage once the inlet is breached, discharge in non-breached side slough habitats was observed to be related to main channel streamflow via intergravel flow through islands and gravel bars (Harza-Ebasco and R&M 1984, Trihey & Associates and Entrix 1985). It was estimated that one-foot reductions in main channel stage resulted in changes of 0.3 – 0.6 cfs in non-breached side slough flow, depending on the slough (Harza-Ebasco and R&M 1984, Trihey & Associates and Entrix 1985).

During the 2013-2014 studies, the inlets to each side channel and side slough monitoring site were not breached by Susitna River main channel streamflow during instrument installation in September and October 2013, except the lower inlet to Whiskers Side Channel (Site 104-WSC-10). However, during Susitna River main channel staging events in each Focus Area, nearly each monitoring site was affected by high main channel stage via breached side channel or side slough inlets or due to backwater effects in tributary and upland slough habitats. The durations of breaching events in side channel and side sloughs were typically short-term as main channel water levels receded following staging events. As an exception to this, main channel Susitna River streamflow was diverted through Side Channel 8A (Site 128-SC8A-25) for the remainder of the winter sampling period following the January 2014 breach event. Similar breaching events at Slough 8A were observed during Susitna River freeze-up during the 1980s, though the duration of such events was not documented (Labelle 1984). During the 1980s studies, breaching of side channel and side slough habitats in the Middle Susitna River by main channel streamflow was noted to occur most frequently downstream of RM 130 (PRM 102 - PRM 134) (Labelle 1984). Between Portage Creek (PRM 152) and Gold Creek (PRM 140), 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).

As noted above, during Project operations, Susitna River streamflow and stage conditions will be altered relative to the existing conditions by reducing water levels during the open-water period and increasing discharge during winter. Higher Susitna River discharge during winter may increase the frequency and magnitude that side channel and side sloughs are breached by cold main channel streamflow and higher stage may alter the extent of groundwater upwelling in side channel and off-channel areas. In addition, the daily fluctuations in Susitna River flow could affect conditions in areas of salmon egg incubation in terms of stage changes that may result in periodic redd dewatering, as well as changes in temperature (i.e., prolonged egg incubation, potential freezing during dewatered periods). A better understanding of breaching flows (i.e., flows at which surface flows from the main channel Susitna River begin to enter side channel and off-channel habitats) and relationships between under-ice stage and main channel flows within each of the Focus Areas will be possible once the open-water and under ice 2-D hydraulic models are fully developed (AEA 2012, Sections 6.6 and 7.6). In addition, affects of Project operations on salmon spawning area, in terms of redd dewatering, freezing, channel inlet breaching, scour, and intergravel water quality (temperature and dissolved oxygen) will be evaluated as part of the effective spawning area analyses (AEA 2012, Section 8.5).

6.2. Water Quality

Main channel Susitna River intergravel water temperatures appeared to be strongly influenced by surface water at continuous monitoring sites with temperatures remaining near 0°C for much of the measurement period at each site. Among continuous monitoring sites in side slough and upland slough habitats, intergravel temperature were typically warm relative to main channel conditions (2 – 4°C), which likely indicates the strong influence of groundwater in these habitats.

Temperature profiles recorded at side channel monitoring sites suggested highly variable conditions among side channels in the three Focus Areas. Intergravel temperatures at Site 104-WSC-30 were near 4°C during January through March 2014, whereas other sites (104-WSC-10 and 128-SC8A-25) exhibited temperatures similar to main channel conditions. Intergravel temperature in each tributary site (104-WC-10 and 128-SC-05) reflected surface water temperature and was near 0°C for much of the winter period.

Researchers during the 1980s studies similarly identified off-channel areas with warmer water temperatures relative to the main channel (Keklak and Withrow 1985, Vining et al. 1985, Stratton 1986). Temperature data collected during 1984 – 1985 indicated that intergravel water temperature in the Susitna River main channel and tributaries were closely associated with surface water temperature, while surface and intergravel temperatures in side sloughs was generally warmer than the main channel due to groundwater input (Vining et al. 1985). Temperature variability among side channels was attributed to the complex nature of surface and groundwater interactions in these habitats (Vining et al. 1985); some side channels exhibited strong groundwater influence, although breaching by high Susitna River main channel streamflow can counteract this thermal effect (Vining et al. 1985).

In the 2013-2014 study, most of the monitoring sites affected by high main channel stage in November and December 2013, intergravel water temperature declined to between 0 – 1°C during a period in which the site was inundated by main channel streamflow. Exceptions to this trend occurred at side slough and upland slough habitats that were either not substantially affected by the increased main channel stage (e.g., Site 104-SL3A-70) or exhibited clear groundwater influence in terms of warm (4°C), stable intergravel temperature (e.g., Site 138-SL11-04). The variation in intergravel temperature response to main channel breaching of Slough 11 between sites 138-SL11-04, 138-SL11-06, and 138-SL11-20 may be an indication of the localized influence of groundwater and/or that multiple sources of groundwater may be present within a given habitat.

Studies in the 1980s indicated that the primary groundwater source in side channel and side slough habitats was derived from lateral infiltration from the Susitna River main channel. The studies further indicated that 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) are generally associated with older groundwater (e.g., longer subsurface path or residence time), which can provide a more stable upwelling source relative to groundwater of shorter subsurface path (Durst 2001, Malcolm et al. 2005).

During the 2013-2014 study, intergravel dissolved oxygen concentrations at Site 128-SL8A-40 ranged from approximately 5.5 – 11 mg/L during September 2013 through March 2014, while dissolved oxygen values at Slough 11 Site 138-SL11-04 ranged from approximately 4 – 11 mg/L. The minimum recorded dissolved oxygen values at each site reflect the presumed high influence of groundwater in Slough 8A and Slough 11. Studies conducted during the 1980s similarly recorded low intergravel dissolved oxygen values in groundwater-fed side sloughs (Vining et al. 1985). 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). Although the low dissolved oxygen concentrations recorded in side slough habitats may be below the ideal level for anadromous salmon egg incubation, the conditions present at these sites may be adequate for egg development depending on intergravel flow, substrate permeability, and water temperature (Vining et al. 1985, Bjornn and Reiser 1991, Quinn 2005).

Instantaneous measurements of surface water temperature and specific conductance during February – April 2014 supported the general trend indicated by continuous temperature data of warmer surface water in off-channel (i.e., side slough and upland slough) areas relative to main channel and side channel habitats. Although instantaneous water temperature was variable at many side channel sites, specific conductance within side channels typically reflects that of Susitna River main channel. At side channel sites in which specific conductance varies from that of the adjacent main channel (e.g., 138-USC11-12 and 138-USC11-16), surface water may reflect groundwater that is of a different source than the Susitna River main channel. Instantaneous measurements at side slough and upland slough habitats typically exhibited higher temperature and lower conductance values than main channel and side channel areas. However, exceptions to this trend were present in each Focus Area and may indicate that a portion of the groundwater source was derived from lateral subsurface flow from the Susitna River main channel.

Ice cover and thickness observations were recorded in each Focus Area during 2013-2014 IFS winter studies. As expected, ice cover and thickness was generally greater in FA-104 (Whiskers Slough) relative to FA-128 (Slough 8A) and FA-138 (Gold Creek), and in main channel and side channel habitats, in comparison to side slough and upland slough 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 was particularly evident in main channel and side channel habitats in which ice appeared to be thicker in areas not sampled. For additional information on Susitna River ice, refer to Ice Processes ISR Study 7.6 (AEA 2014).

6.3. Fish Observations

Fish presence was recorded during both day and night periods in open-water areas during electrofishing surveys (see also AEA 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 2013). Monitoring of fish activity and behavior during future day and nighttime winter surveys using underwater video, sonar and fish capture techniques will help elucidate potential winter behavioral patterns exhibited by fish species in the Susitna River.

A total of 262 HSC observations were recorded for eight species in FA-104 (Whiskers Slough), FA-128 (Slough 8A), FA-138 (Gold Creek), and FA-141 (Indian River). HSC/HSI curves for fish species will be developed to describe the response of fish to relatively short-term flow fluctuations (i.e., ramping).

7. PLANS FOR 2015

The 2014-2015 IFS winter studies represent the second complete year of studying the winter habitat conditions within the three Focus Areas (FA-104 [Whiskers Slough], FA-128 [Slough 8A], FA-138 [Gold Creek]), and in conjunction with data collected as part of the 2012-2013 Pilot winter studies, will provide information regarding the inter-annual variability of these conditions. These studies will be performed in conjunction with the winter studies to be performed by FDA and Groundwater resource disciplines.

The objectives of the 2014-2015 IFS winter studies remain the same as stated above and are 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. Specific tasks for the 2014-2015 work are identified in Section 2. The general approach of the 2014-2015 IFS winter study will be similar to the 2013-2014 effort (see Section 4), in terms of Focus Areas studied (FA-104 [Whiskers Slough], FA-128 [Slough 8A], and FA-138 [Gold Creek]) and the general level of effort. Specific tasks include:

- Continuous stage and water quality (temperature and dissolved oxygen) monitoring will occur at FA-104 (Whiskers Slough), FA-128 (Slough 8A), and FA-138 (Gold Creek) through the period of salmon egg incubation (September 2014 – April 2015) (Figure 1).
- Stage and water temperature data (surface and intergravel) will be continuously monitored at main channel and off-channel sites in each of FA-104 (Whiskers Slough), FA-128 (Slough 8A), and FA-138 (Gold Creek). Monitoring sites within each Focus Area will be distributed among habitat types, at locations of known salmon spawning, and at sites with and without groundwater influence.
- Intergravel dissolved oxygen will be continuously recorded at known salmon spawning locations.
- Fish observation and capture efforts will be performed at available habitat types in each of FA-104 (Whiskers Slough), FA-128 (Slough 8A), and FA-138 (Gold Creek); additional sites outside of these Focus Areas will be sampled based on observed fish distribution, site access, weather conditions, and personnel safety.
- Fish activity and behavior will be monitored using underwater video equipment to discern potential patterns in activity related to diurnal and seasonal periodicity and/or habitat (e.g., side channel, side slough).
- Site-specific habitat suitability criteria (HSC) for juvenile and adult fish will be recorded using electrofish capture methods in open-water areas and underwater video in ice covered habitats.
- Instantaneous surface water quality measurements (temperature, dissolved oxygen, specific conductance) and ice thickness data will be recorded in association with maintenance of continuous stage and water quality monitoring sites and fish observation and capture efforts.

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9. TABLES

Table 1. The period of data collection at continuous water level, water quality and barometric pressure monitoring sites in FA-104 (Whiskers Slough), FA-128 (Slough 8A) and FA-138 (Gold Creek) for 2013-2014 IFS winter studies.

Focus Area	Site	Instrument Type	Period of Record	Comment
104	104-BARO	Barometric	Sept 2013 - Current[1]	
	104-MC-40	Pressure transducer, Temperature	Sept 2013 - June 2014	
	104-MC-50	Pressure transducer	Feb 2014 - April 2014	
	104-SL3A-70	Pressure transducer, Temperature	Sept 2013 - April 2014	
	104-SL3B-10	Pressure transducer	Sept 2013 - Current[1]	
	104-SL3B-10	Temperature	Sept 2013 - March 2014	
	104-WC-10	Pressure transducer, Temperature	Sept 2013 - June 2014	2013 salmon spawn site
	104-WESC-10	Pressure transducer	Oct 2013 - June 2014	
	104-WESC-10	Temperature	Sept 2013 - March 2014	
	104-WESC2-12	Temperature	March 2014 - Current[1]	2013 salmon spawn site
	104-WSC-10	Pressure transducer	Sept 2013 - June 2014	2013 salmon spawn site
	104-WSC-10	Temperature	Sept 2013 - March 2014	2013 salmon spawn site
	104-WSC-30	Pressure transducer	Sept 2013 - June 2014	2012 salmon spawn site
	104-WSC-30	Temperature	Sept 2013 - Current[1]	2012 salmon spawn site
	104-WSL-20	Pressure transducer, Temperature	Sept 2013 - June 2014	2013 salmon spawn site
128	128-BARO	Barometric	Sept 2013 - Current[1]	
	128-MC-10	Pressure transducer	Sept 2013 - April 2014	
	128-MC-10	Temperature	Sept 2013 - Current[1]	
	128-SC-05	Temperature	Sept 2013 - March 2014	2013 salmon spawn site
	128-SC8A-24	Temperature	March 2014 - Current[1]	
	128-SC8A-25	Pressure transducer, Temperature	Sept 2013 - April 2014	2013 salmon spawn site
	128-SL8A-15	Temperature	Sept 2013 - Current[1]	2013 salmon spawn site
	ESSFA128-1[2]	Pressure transducer	Sept 2013 - March 2014	
	128-SL8A-40	Dissolved oxygen	Sept 2013 - March 2014	2013 salmon spawn site
	128-SL8A-40	Pressure transducer, Temperature	Sept 2013 - Current[1]	2013 salmon spawn site
	128-SLA-20	Pressure transducer, Temperature	Sept 2013 - Current[1]	2013 salmon spawn site
	128-US1-10	Pressure transducer, Temperature	Sept 2013 - March 2014	
	128-US2-15	Pressure transducer, Temperature	Sept 2013 - March 2014	
138	138-BARO	Barometric	Sept 2013 - Current[1]	
	138-MC-50	Pressure transducer	Sept 2013 - April 2014	
	138-MC-50	Temperature	Sept 2013 - March 2014	
	138-SL11-04	Dissolved oxygen	Sept 2013 - April 2014	2013 salmon spawn site
	138-SL11-04	Pressure transducer, Temperature	Sept 2013 - Current[1]	2013 salmon spawn site
	138-SL11-06	Temperature	Sept 2013 - Current[1]	2013 salmon spawn site
	138-SL11-20	Pressure transducer, Temperature	Sept 2013 - Current[1]	
	138-SL12-10	Pressure transducer, Temperature	Sept 2013 - Current[1]	Inaccessible during winter
	138-SL13-04	Pressure transducer	Feb 2014 - Current[1]	2013 salmon spawn site
	138-SL13-04	Temperature	March 2014 - Current[1]	2013 salmon spawn site
	138-SL13-05	Pressure transducer, Temperature	Sept 2013 - Current[1]	2013 salmon spawn site; Inaccessible in winter
	138-USC11-09	Pressure transducer, Temperature	Sept 2013 - Current[1]	2013 salmon spawn site

[1] Instruments are collecting data as of August 2014; approximate retrieval timing will be September 2014.

[2] The ESSFA128-1 station is operated and maintained as part of the Groundwater Study.

Table 2. Instantaneous measurements of surface and groundwater temperature, specific conductance, dissolved oxygen concentration, and ice thickness at sites in FA-104 (Whiskers Creek), FA-128 (Slough 8A), and FA-138 (Gold Creek) during February and March 2014. Surface water measurements were recorded at mid-column water depth and groundwater was measured approximately 20 cm below the substrate surface at intergravel and near the surface at groundwater wells and bank seep locations.

Site[1]	Water Body	Habitat Type[2]	Date	Water Temperature (°C)	Specific Conductance (µS/cm)	Dissolved Oxygen (mg/L)	Ice thickness (ft)
FA-104 (Whiskers Slough)							
104-MC-50	Main channel	MC	3/6/14	0.2	256.0	na	3.6
104-MC-50	Main channel	MC	2/7/14	0.1	227.0	na	3.5
104-WSC-30	Whiskers SC	SC	3/5/14	0.9	235.0	10.86	0
104-WSC-10	Whiskers SC	SC	3/6/14	1.0	125.3	6.53	1.0 - 4.0
104-WESC2-12	Whiskers East Side Channel	SC	3/7/14	0.9	237.0	11.06	0.1 – 0.4
104-WESC-20	Whiskers East Side Channel	SC	3/7/14	0.1	265.0	na	na
104-WESC-10	Whiskers East Side Channel	SC	3/7/14	0.2	264.0	na	2.2
104-SL3B-10	Slough 3B	SC	3/5/14	1.6	90.9	8.98	0
104-WSL-50	Whiskers Slough	SS	3/7/14	2.8	75.5	2.40	0.2 – 0.8
104-WSL-40	Whiskers Slough	SS	3/7/14	1.0	70.5	6.05	1.1
104-WSL-20	Whiskers Slough	SS	3/4/14	0.3	32.9	13.12	0.2
104-CFSL-15	Chicken Foot Slough	SS	3/5/14	1.7	200.5	6.63	0 – 0.3
104-WC-20	Whiskers Creek	TR	2/4/14	0.2	35.7	14.21	0.3
104-WC-10	Whiskers Creek	TR	3/5/14	0.6	32.3	13.21	na
104-SL3A-70	Slough 3A	US	3/7/14	0.6	96.3	7.74	na
104-SL3A-11*	Groundwater seep in Slough 3A	US*	3/5/14	1.0*	110.7*	0.21*	0
104-SL3A-10	Slough 3A	US	3/5/14	0.8	92.0	9.53	0
ESGFA104-9-W1*	Groundwater well	GW*	2/6/14	2.3	158.8	1.15	na
ESGFA104-10-W1*	Groundwater well	GW*	2/6/14	1.8*	124.0*	3.18*	na
FA-128 (Slough 8A)							
128-MC-10	Main channel	MC	2/15/14	0.1	284.1	na	3.2
128-SC8A-24	Side Channel 8A	SC	3/14/14	0.5	260.0	13.34	0
128-SC8A-35	Side Channel 8A	SC	3/13/14	0.2	268.0	na	0
128-SSC-14	Skull Side Channel	SC	3/16/14	0.1	264.0	na	0
128-SSC-15	Skull Side Channel open lead	SC	3/16/14	1.1	262.0	11.15	0
128-HMSC-01	Half Moon Side Channel	SC	3/16/14	0.3	270.0	na	2.0
128-SL8A-15	Slough 8A	SS	3/14/14	1.7	207.9	11.55	0.4
128-SL8A-40	Slough 8A	SS	3/16/14	1.2	214.8	11.75	0
128-SL8A-40*	Intergravel site in Slough 8A	SS*	3/16/14	4.5*	58.6*	4.01*	0
128-SL8A-40	Slough 8A	SS	2/15/14	0.3	263.0	12.94	0
128-SLA-20	Slough A	SS	3/14/14	1.2	165.1	12.63	0
128-US1-10	Upland Slough 1	US	3/15/14	0.2	125.9	na	2.1
128-US2-15	Upland Slough 2	US	3/13/14	1.6	193.6	9.76	0.6
128-US3-01	Upland Slough 3	US	3/15/14	2.4	191.5	11.50	0
128-US3-05	Upland Slough 3	US	3/13/14	4.1	191.3	6.91	0
128-HMSL-20	Half Moon Slough	US	3/14/14	2.1	226.0	6.84	1.4

Site[1]	Water Body	Habitat Type[2]	Date	Water Temperature (°C)	Specific Conductance (µS/cm)	Dissolved Oxygen (mg/L)	Ice thickness (ft)
128-SC-05	Skull Creek	TR	2/16/14	1.1	162.9	7.98	1.5
ESGFA128-13-W1*	Groundwater well	GW*	3/16/14	0.6*	269.0*	7.82*	na
ESGFA128-18-W1*	Groundwater well	GW*	3/16/14	3.0*	170.0*	4.86*	na
FA-138 (Gold Creek)							
138-MC-50	Main channel	MC	2/9/14	0.3	250.0	13.34	0 – 1.5
138-MC-50	Main channel	MC	3/9/14	0.2	269.0	na	0 – 1.5
138-MC-70	Main channel	MC	2/11/14	0.2	245.0	na	na
138-USC11-09	Upper Side Channel 11	SC	2/9/14	0.8	203.9	11.67	0.2
138-USC11-12*	Left bank seep; Upper SC 11	SC*	2/10/14	2.5*	135.2*	8.23*	0
138-USC11-16*	Right bank seep; Upper SC 11	SC*	2/10/14	3.3*	120.5*	6.69*	0
138-USC11-40	Upper Side Channel 11	SC	3/9/14	0.2	324.0	na	2.5
138-LSC11-11	Lower Side Channel 11	SC	2/10/14	0.8	261.0	12.62	0
138-LSC11-11*	Left bank seep; Lower SC 11	SC*	2/10/14	2.6*	114.4*	8.46*	0
138-LSC11-12*	Right bank seep; Lower SC 11	SC*	2/10/14	1.5*	288.0*	10.18*	0
138-LSC11-20	Lower Side Channel 11	SC	2/10/14	0.1	275.0	na	2.0
138-SC12-05	Side Channel 12	SC	3/12/14	1.9	264.0	10.41	0.2
138-SC14-25	Side Channel 14	SC	3/11/14	0.2	261.0	na	2.0
138-SL11-04*	Intergravel site in Slough 11	SS	3/12/14	3.3*	190.1*	10.00*	0
138-SL11-04	Slough 11	SS	3/12/14	2.5	272.0	11.33	0
138-SL11-10	Slough 11	SS	3/12/14	1.9	293.0	11.84	0
138-SL11-11*	Left bank seep; Slough 11	SS	3/12/14	1.1*	290.0*	9.70*	0
138-SL11-20	Slough 11	SS	3/10/14	1.3	296.0	11.82	0.5
138-SL11-50	Slough 11	SS	2/11/14	1.2	291.0	11.71	0
138-SL11-60	Slough 11	SS	3/10/14	2.1	315.0	12.02	0
138-SL12-10	Slough 12	US	2/9/14	0.1	103.3	na	na
138-SL13-04	Slough 13	US	3/12/14	2.2	256.0	7.16	0.5
138-SL13-15	Slough 13	US	3/12/14	1.6	202.6	7.98	0.2
138-US14-20	Seepage; Upland Slough 14	US	3/11/14	3.3	64.2	11.71	0
138-GC-05	Gold Creek	TR	2/11/14	0.3	376	13.65	na
ESGFA138-3-W1*	Groundwater well	GW*	3/12/14	2.2*	254*	9.84*	na
ESGFA138-4-W1*	Groundwater well	GW*	3/12/14	1.4*	185*	7.04*	na

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

[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 (HDR 2013).

na – Data are not available.

Table 3. Total number of fish captured by species and lifestage during daytime and nighttime electrofishing surveys conducted in FA-104 (Whiskers Slough), FA-128 (Slough 8A), FA-138 (Gold Creek), and FA-141 (Indian River) in February, March, and April 2014. Nighttime surveys are italicized.

				Capture totals, by species and lifestage[1]									
FA	Site	Survey Date	Habitat Type[2]	Chinook, Juvenile	Sockeye, Juvenile	Chum, Juvenile	Coho, Juvenile	Rainbow Trout, Juvenile	Grayling, Juvenile	Longnose sucker, Juvenile	Lamprey species, Juvenile	Sculpin species, Juvenile, Adult	Total Count
104	104-WSC-12	3-Apr	SC	0	0	0	0	0	0	1	0	0	1
	104-WSC-30	1-Apr	SC	0	0	0	0	0	0	0	0	0	0
	104-WESC-01	4-Apr	SC	0	0	0	0	0	0	0	0	0	0
	104-SL3B-01	*5-Mar*	*SC*	*2*	*0*	*0*	*21*	*0*	*1*	*0*	*0*	*24*	*48*
		7-Mar	SC	0	0	0	1	0	0	1	0	6	8
		1-Apr	SC	0	0	0	5	0	0	1	0	0	6
		2-Apr	*SC*	*0*	*0*	*0*	*15*	*0*	*0*	*0*	*0*	*0*	*15*
	104-SL3A-10	*5-Mar*	*US*	*0*	*0*	*0*	*28*	*0*	*0*	*0*	*0*	*2*	*30*
		7-Mar	US	0	0	0	4	0	0	0	0	1	5
		2-Apr	*US*	*0*	*0*	*0*	*16*	*1*	*0*	*0*	*0*	*0*	*17*
		4-Apr	US	0	0	0	3	0	0	0	0	0	3
	104-WC-25	*5-Feb*	*TR*	*0*	*0*	*0*	*2*	*1*	*0*	*0*	*0*	*4*	*7*
		3-Apr	TR	15	0	0	17	0	0	0	2	0	32
128	128-SSC-10	10-Apr	SC	0	3	0	0	0	0	0	0	0	3
	128-SC8A-05	12-Apr	SC	0	0	1	0	0	0	0	0	0	1
	128-SL8A-28	*11-Apr*	*SS*	*0*	*154*	*4*	*2*	*0*	*0*	*0*	*0*	*0*	*160*
	128-SL8A-30	14-Mar	SS	0	0	8	0	0	0	0	0	44	52
		14-Mar	*SS*	*0*	*2*	*4*	*0*	*0*	*0*	*0*	*0*	*36*	*42*
	128-SLA-01	12-Apr	US	*0*	*1*	*18*	*2*	*0*	*0*	*0*	*0*	*0*	*21*
	128-SLA-20	12-Apr	US	*5*	*4*	*0*	*8*	*0*	*0*	*0*	*0*	*0*	*17*
	128-US3-01	*14-Mar*	*US*	*0*	*2*	*1*	*2*	*2*	*0*	*0*	*0*	*0*	*7*
		15-Mar	US	0	0	2	2	0	0	0	0	0	4
		12-Apr	*US*	*0*	*6*	*0*	*3*	*0*	*0*	*0*	*0*	*0*	*9*
	128-HMSL-01	*10-Apr*	US	0	0	0	0	0	0	0	0	0	0
	128-HMSL-30	*10-Apr*	US	0	0	0	0	0	0	0	0	0	0

				Capture totals, by species and lifestage[1]									
FA	Site	Survey Date	Habitat Type[2]	Chinook, Juvenile	Sockeye, Juvenile	Chum, Juvenile	Coho, Juvenile	Rainbow Trout, Juvenile	Grayling, Juvenile	Longnose sucker, Juvenile	Lamprey species, Juvenile	Sculpin species, Juvenile, Adult	Total Count
138	138-MC-30	9-Apr	MC	1	0	0	1	0	0	0	0	0	2
	138-USC11-20	*10-Mar*	*SC*	*0*	*0*	*0*	*3*	*0*	*0*	*0*	*0*	*2*	*5*
		11-Mar	SC	0	0	3	1	2	0	0	0	3	9
	138-USC11-15	10-Feb	SC	0	0	0	0	0	0	0	0	0	0
		10-Feb	*SC*	*1*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*1*
	138-USC11-22	*7-Apr*	*SC*	*0*	*0*	*68*	*5*	*0*	*0*	*0*	*0*	*0*	*73*
		9-Apr	SC	0	0	44	0	0	0	0	0	0	44
	138-SL11-25	9-Feb	SS	0	1	0	0	0	0	0	0	23	24
		10-Feb	*SS*	*0*	*6*	*0*	*0*	*0*	*0*	*0*	*0*	*19*	*25*
		10-Mar	SS	0	1	0	0	0	0	0	0	29	30
		10-Mar	*SS*	*1*	*28*	*0*	*14*	*0*	*0*	*0*	*0*	*67*	*110*
		6-Apr	SS	0	0	0	2	0	0	0	0	0	2
		8-Apr	*SS*	*0*	*51*	*0*	*33*	*0*	*0*	*0*	*0*	*0*	*84*
	138-SL11-04	7-Apr	SS	0	1	0	0	0	0	0	0	0	1
	138-SL11-10	12-Mar	SS	0	0	0	0	0	0	0	0	2	2
		7-Apr	SS	0	1	0	0	0	0	0	0	0	1
	138-LSC11-10	10-Feb	SC	0	0	0	0	0	0	0	0	1	1
		10-Feb	*SC*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*4*	*4*
		7-Apr	SC	0	0	1	0	0	0	0	0	0	1
141	141-MC-30	9-Apr	MC	1	0	0	3	0	0	0	0	0	4
Total Count				26	261	154	193	6	1	3	2	267	911

[1] Juvenile lifestage represents fish less than 150 mm fork length for all species other than sculpin.

[2] SS = Side slough, SC = Side Channel, TR = Tributary, US = Upland Slough; habitat designations are based on 2012 Middle Susitna River remote line habitat mapping (HDR 2013).

Table 4. Total number of HSC observations recorded during electrofish sampling in February, March, and April 2014 by fish species and lifestage.

Species	Lifestage[1]	FA-104 (Whiskers Slough)	FA-128 (Slough 8A)	FA-138 (Gold Creek)	FA-141 (Indian River)	Total Count
Chinook salmon	Fry	13	0	0	1	14
	Juvenile	2	3	1	0	6
Sockeye salmon	Fry	1	30	4	0	35
	Juvenile	0	0	33	0	33
Chum salmon	Fry	0	17	25	0	42
Coho salmon	Fry	25	7	2	1	35
	Juvenile	47	7	32	2	88
Rainbow trout	Juvenile	2	0	2	0	4
Arctic grayling	Juvenile	1	0	0	0	1
Longnose sucker	Juvenile	2	0	0	0	2
Arctic lamprey	Juvenile	2	0	0	0	2
	Total Count	95	64	99	4	262

[1] Fry consist of fish less than 60 mm fork length; juvenile lifestage represents fish between 60 mm and 150 mm fork length.

10. FIGURES

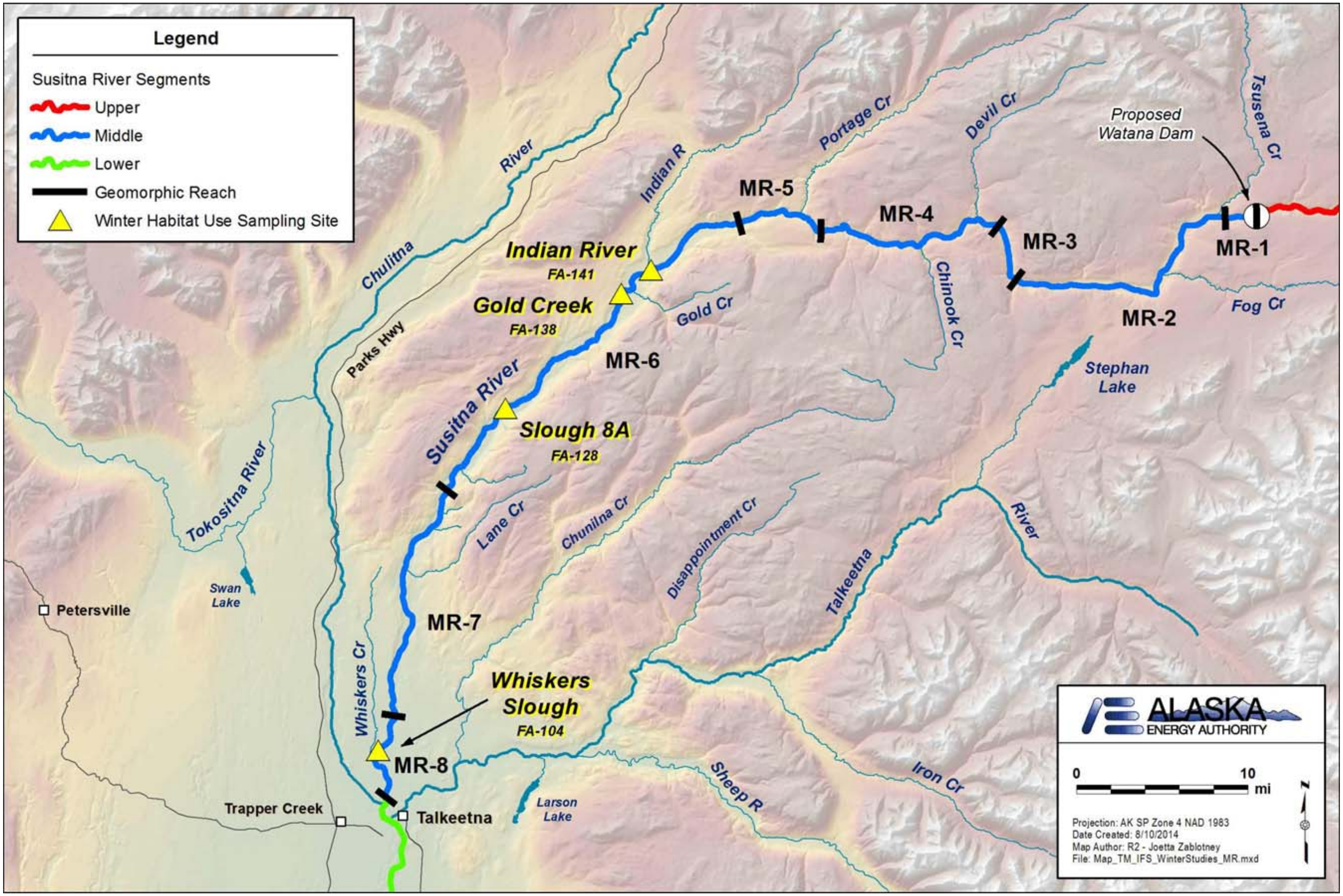

Figure 1. Location of Focus Areas used for 2013-2014 IFS winter data collection.

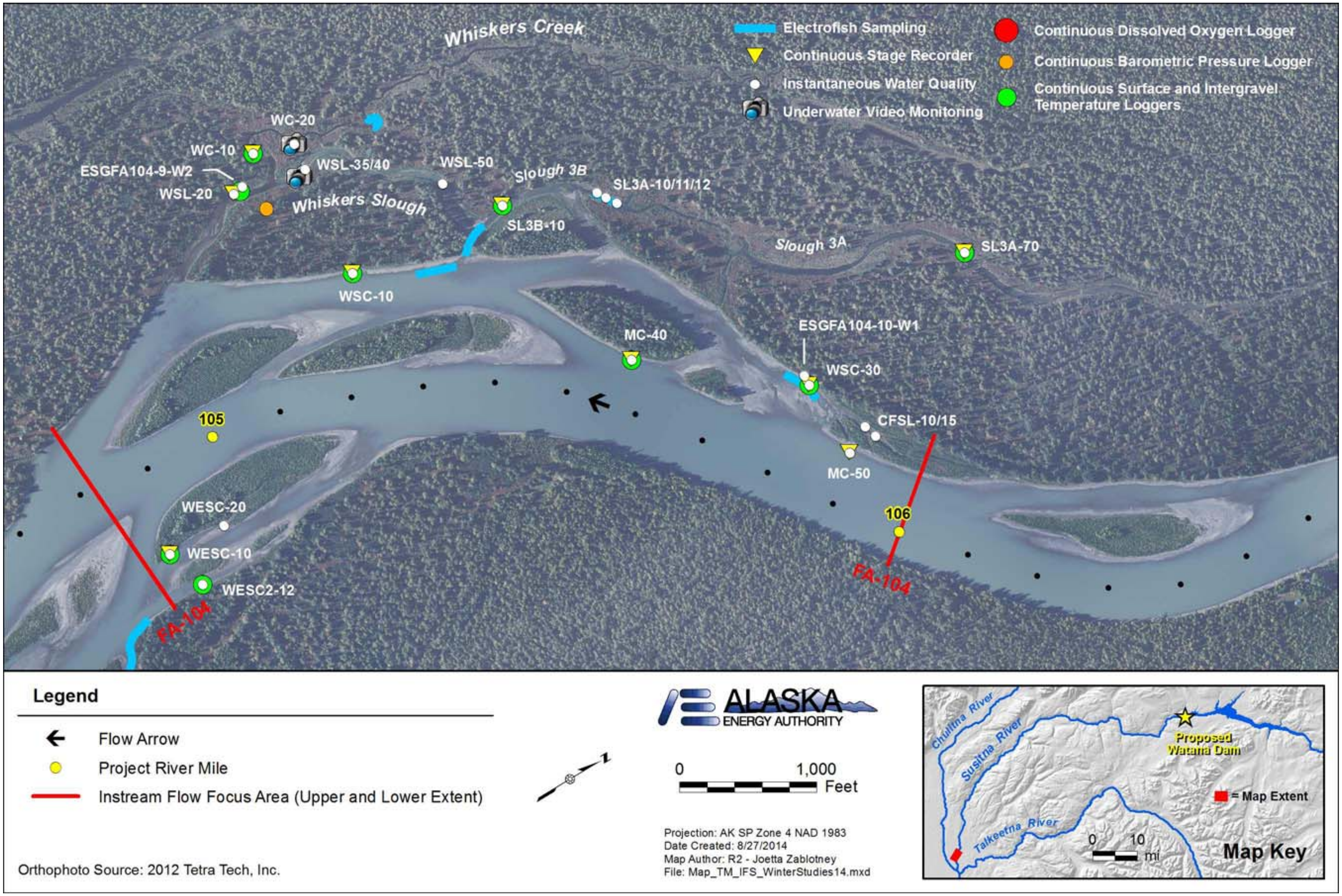

Figure 2. Locations of 2013-2014 winter sites for continuous and instantaneous water quality monitoring, water level monitoring, and fish sampling in FA-104 (Whiskers Slough).

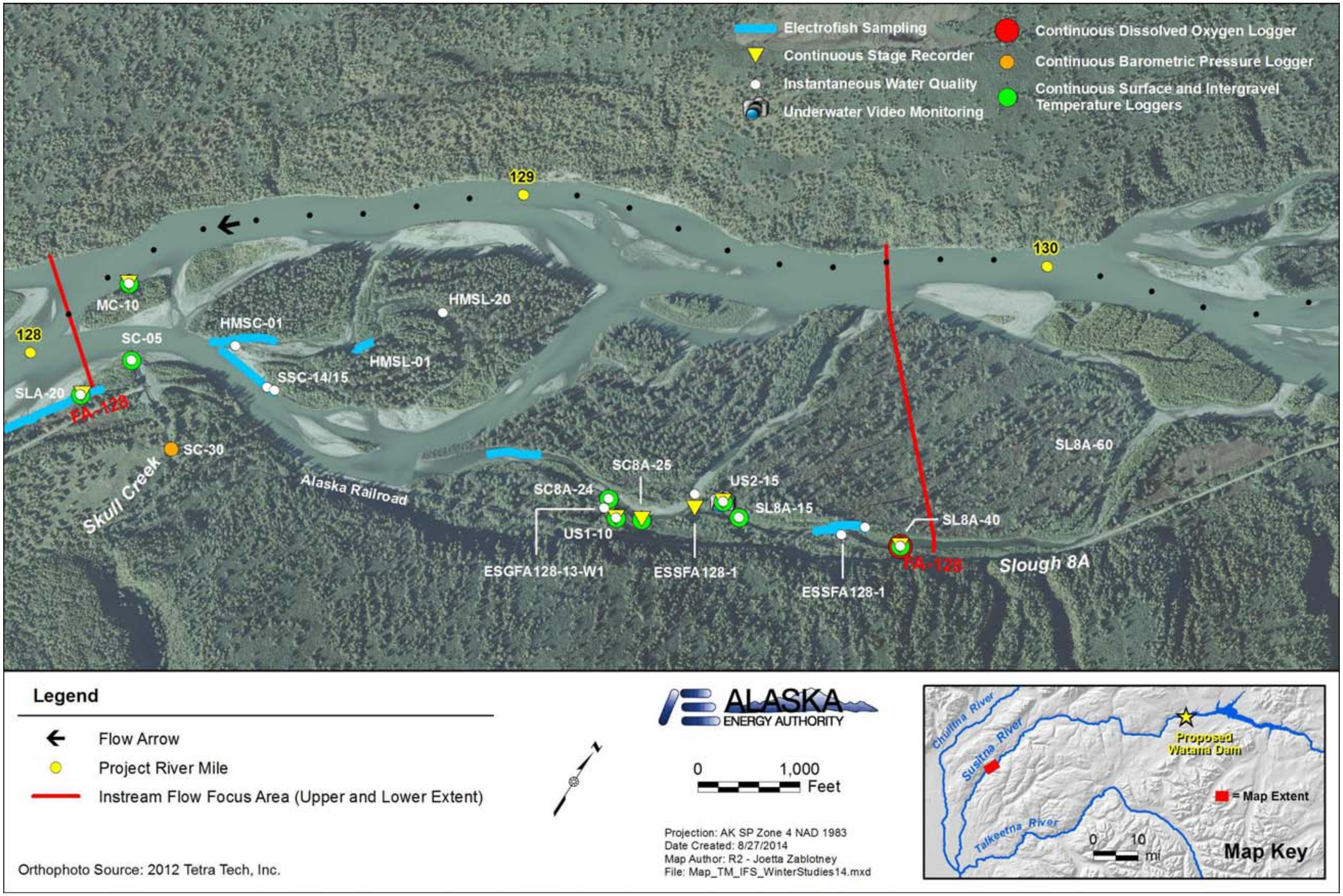

Figure 3. Locations of 2013-2014 winter sites for continuous and instantaneous water quality monitoring, water level monitoring, and fish sampling in FA-128 (Slough 8A).

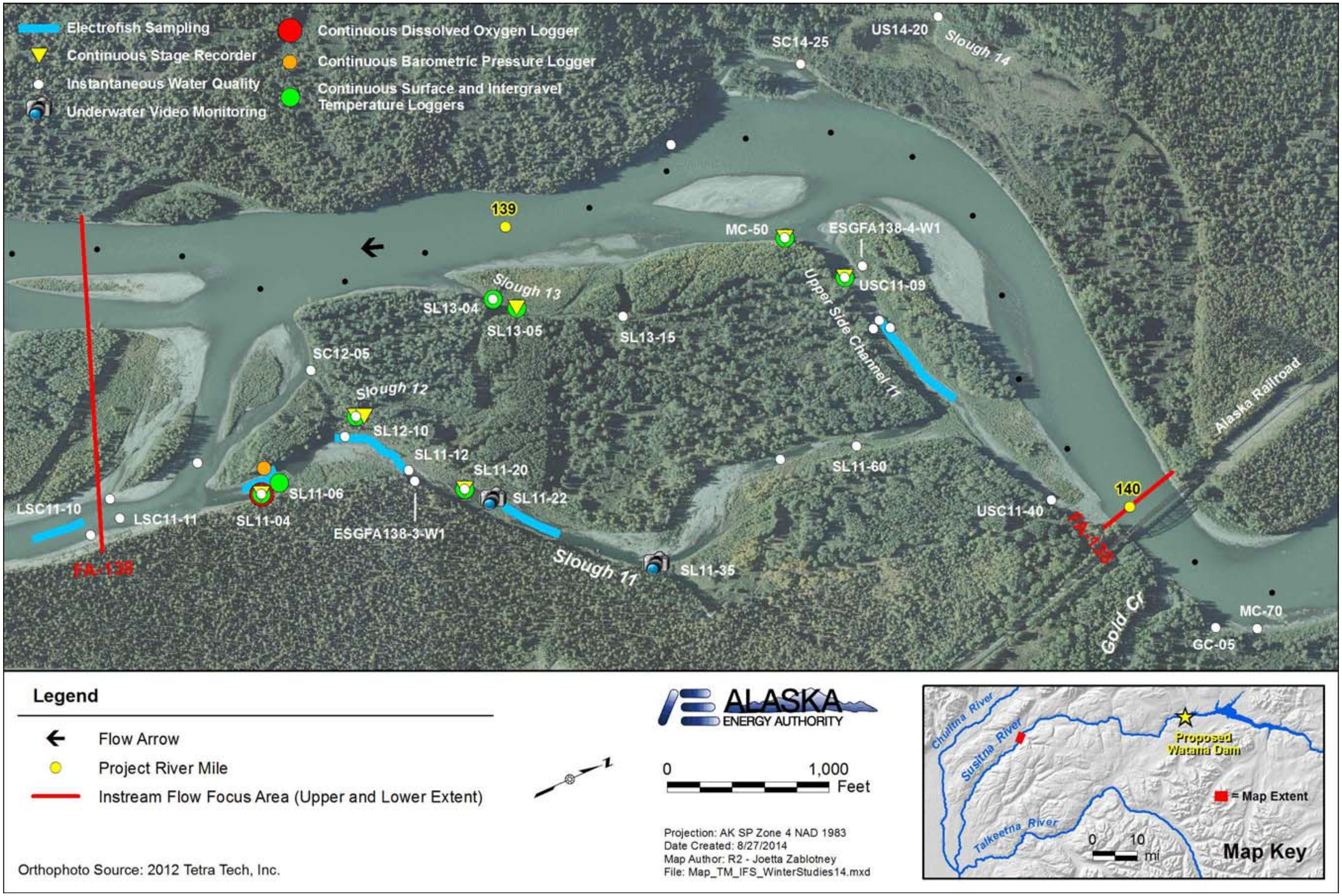

Figure 4. Locations of 2013-2014 winter sites for continuous and instantaneous water quality monitoring, water level monitoring, and fish sampling in FA-138 (Gold Creek).

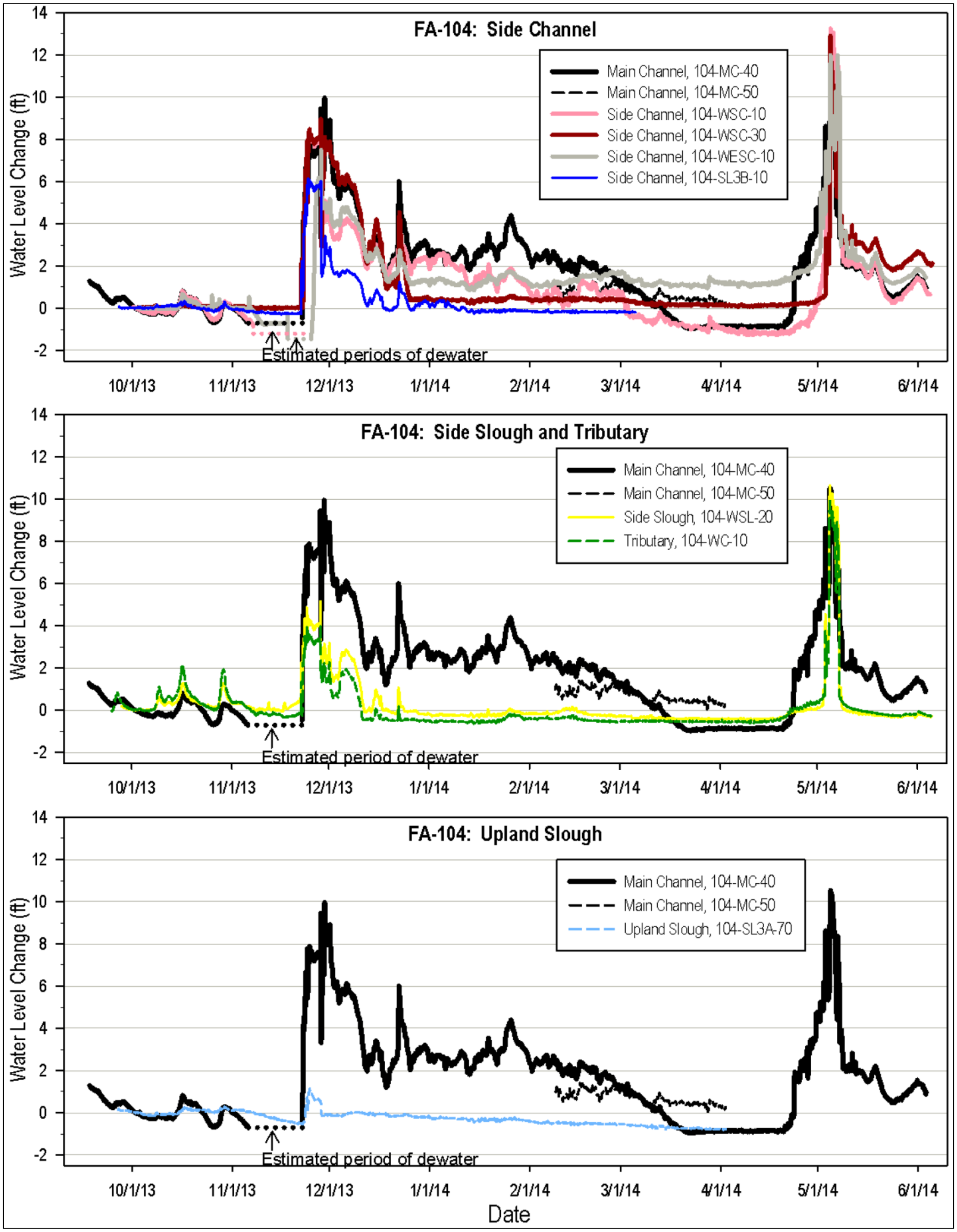

Figure 5. Comparison of change in normalized water surface elevation among continuous monitoring sites in FA-104 (Whiskers Slough) during September 2013 through June 2014. Elevations were normalized to zero on October 1, 2013.

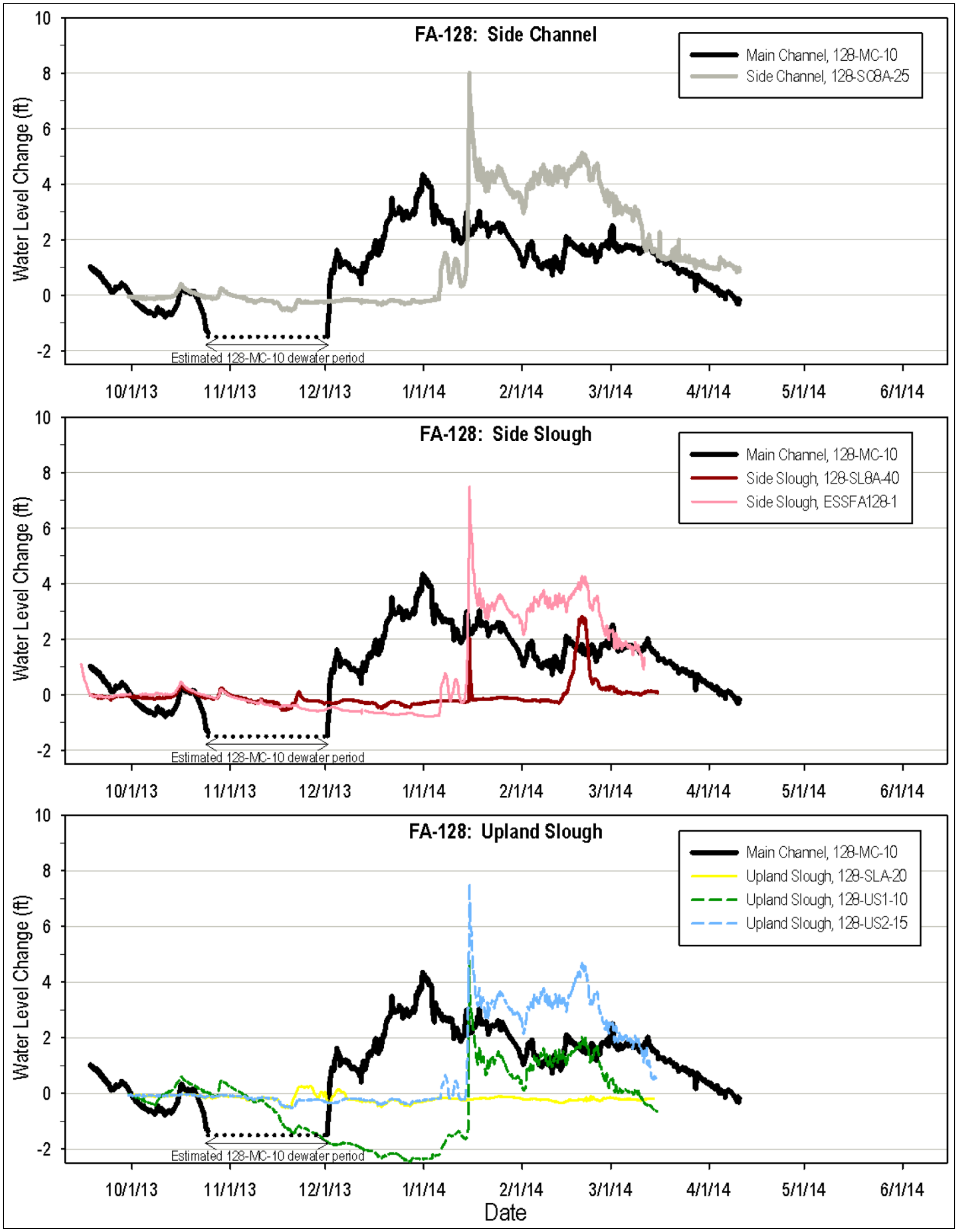

Figure 6. Comparison of change in normalized water surface elevation among continuous monitoring sites in FA-128 (Slough 8A) during September 2013 through April 2014. Elevations were normalized to zero on September 30, 2013.

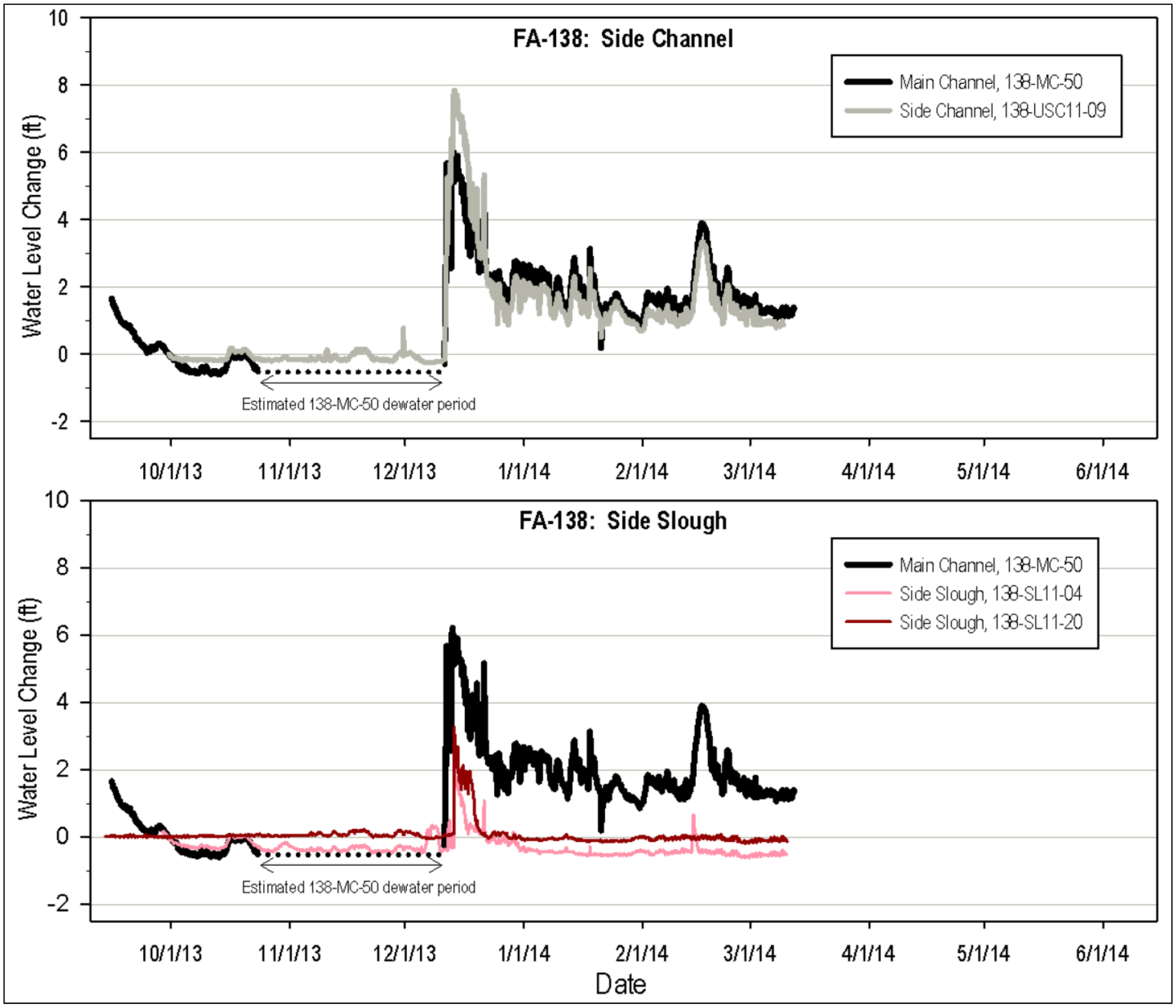

Figure 7. Comparison of change in normalized water surface elevation among continuous monitoring sites in FA-138 (Gold Creek) during September 2013 through April 2014. Elevations were normalized to zero on September 30, 2013.

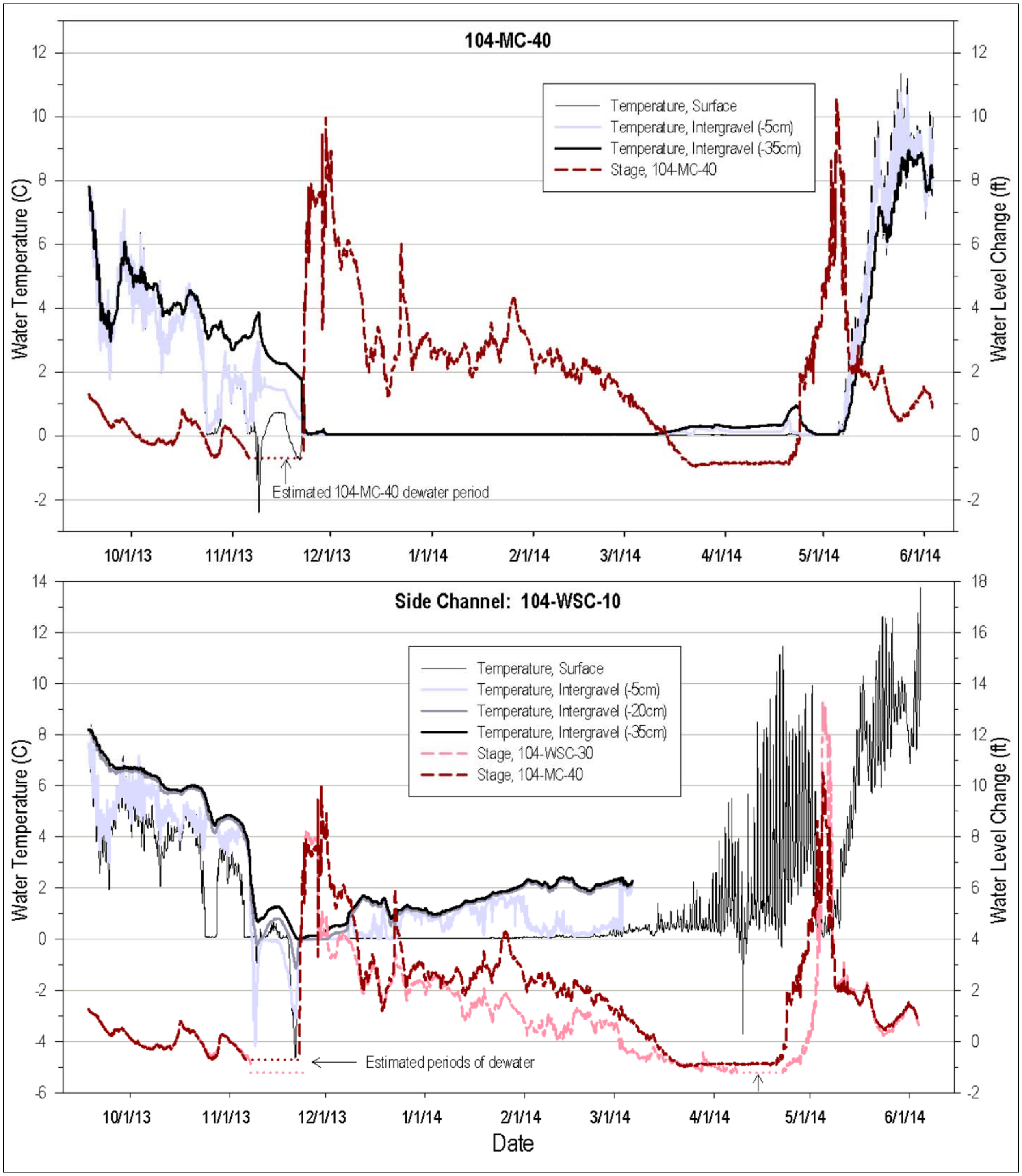

Figure 8. Water temperature recorded above the substrate surface and at intergravel depths of 5 cm (2 in), 20 cm (7.9 in), and 35 cm (13.8 in) relative to normalized water surface elevation at Susitna River main channel (104-MC-40) and Whiskers Side Channel (104-WSC-10) continuous monitoring sites in FA-104 (Whiskers Slough) during September 2013 - June 2014. Water elevations were normalized to zero on October 1, 2013.

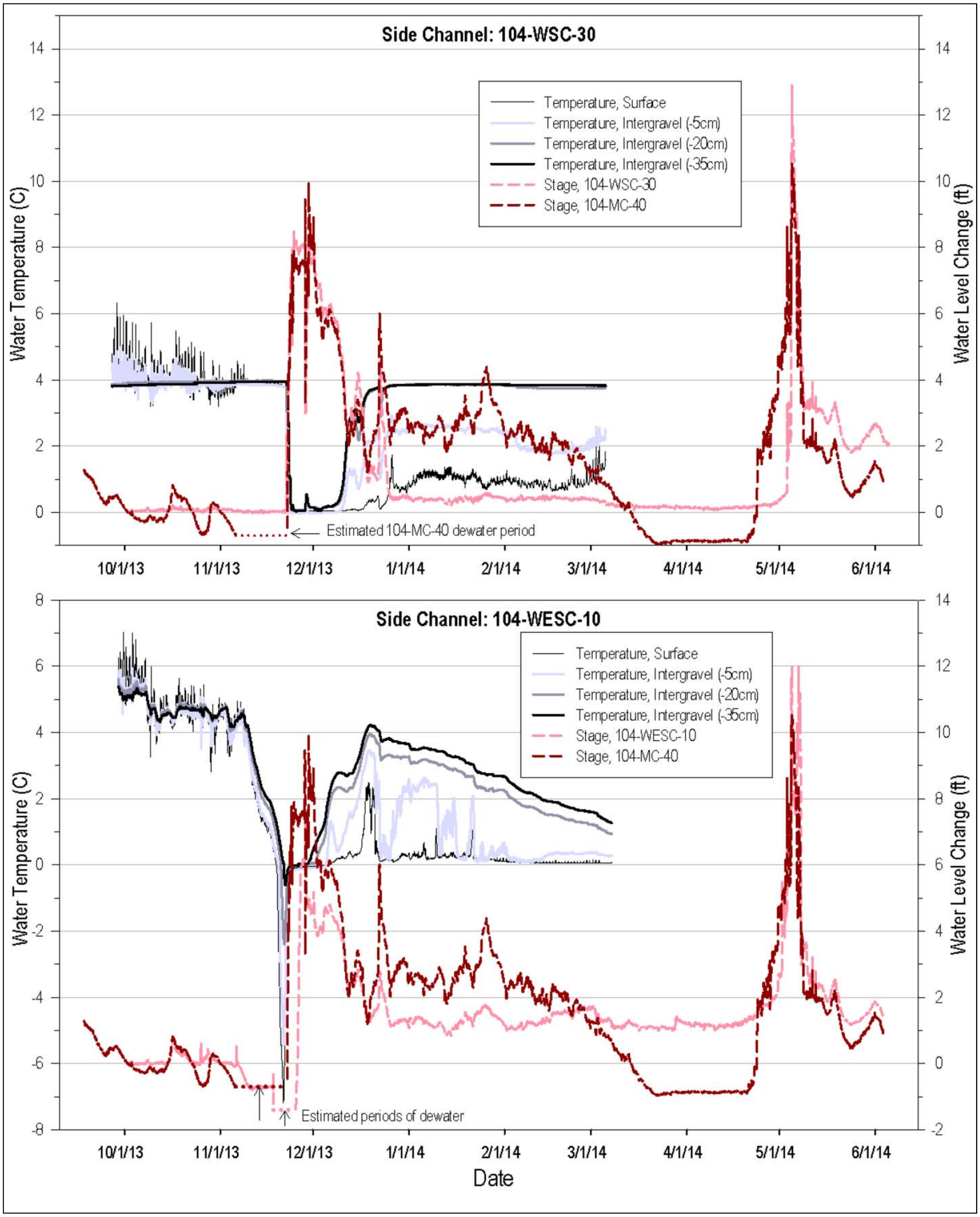

Figure 9. Water temperature recorded above the substrate surface and at intergravel depths of 5 cm (2 in), 20 cm (7.9 in), and 35 cm (13.8 in) relative to normalized water surface elevation at Whiskers Side Channel (104-WSC-30) and Whiskers East Side Channel (104-WESC-10) continuous monitoring sites in FA-104 (Whiskers Slough) during September 2013 - June 2014. Water elevations were normalized to zero on October 1, 2013.

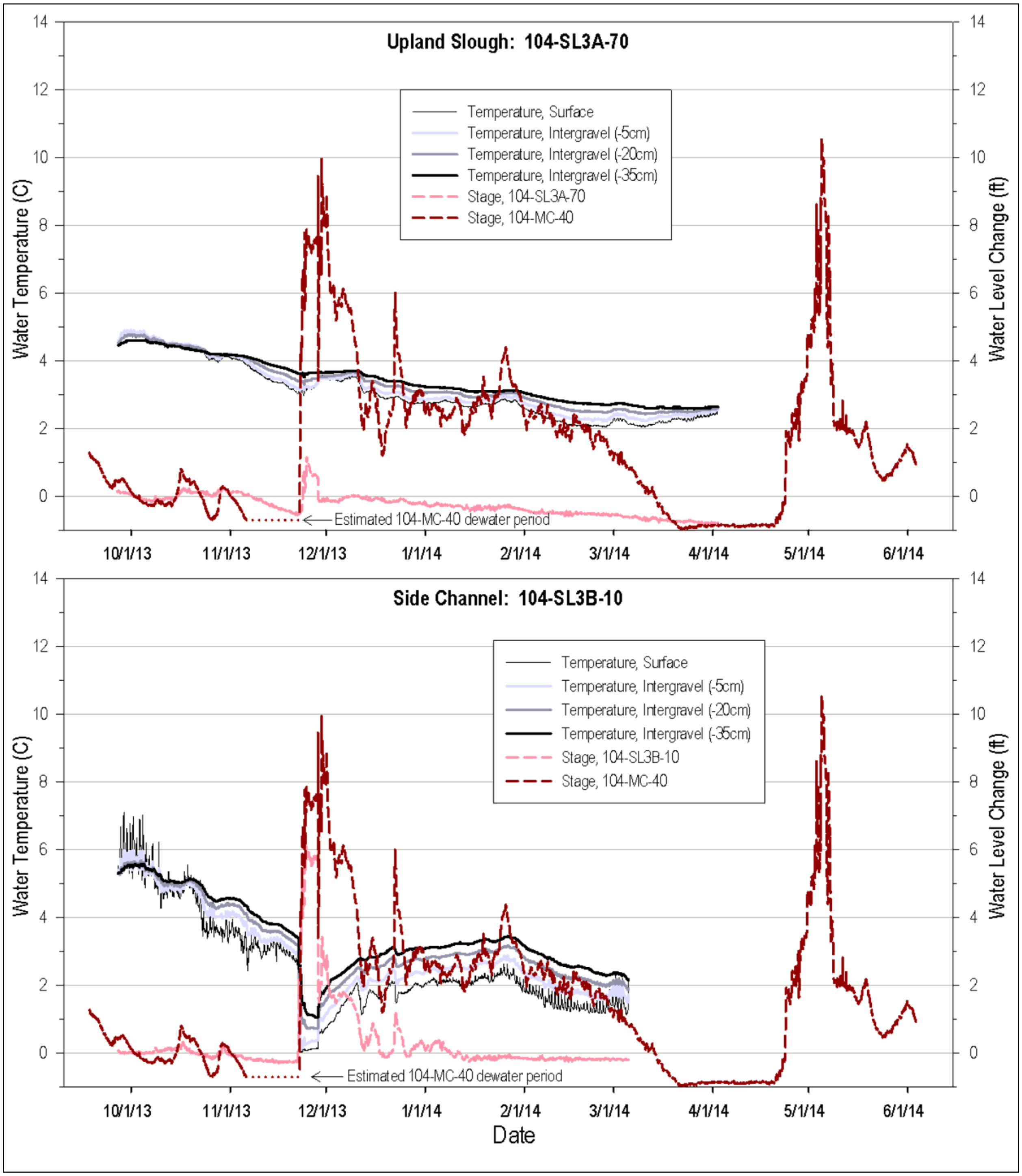

Figure 10. Water temperature recorded above the substrate surface and at intergravel depths of 5 cm (2 in), 20 cm (7.9 in), and 35 cm (13.8 in) relative to normalized water surface elevation at upland slough (104-SL3A-70) and side channel (104-SL3B-10) continuous monitoring sites in FA-104 (Whiskers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

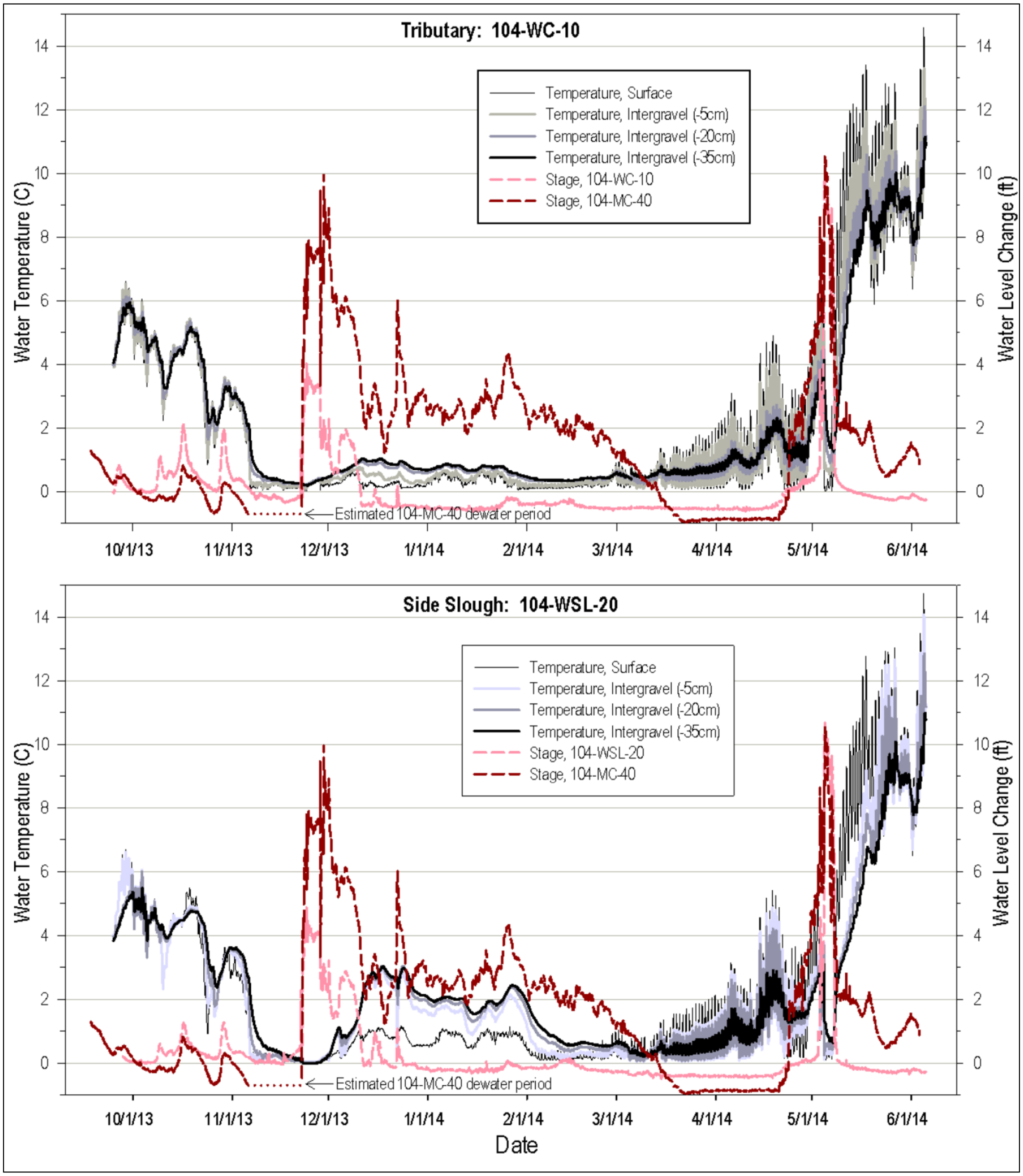

Figure 11. Water temperature recorded above the substrate surface and at intergravel depths of 5 cm (2 in), 20 cm (7.9 in), and 35 cm (13.8 in) relative to normalized water surface elevation at Whiskers Creek (104-WC-10) and Whiskers Slough (104-WSL-20) continuous monitoring sites in FA-104 (Whiskers Slough) during September 2013 - June 2014. Water elevations were normalized to zero on October 1, 2013.

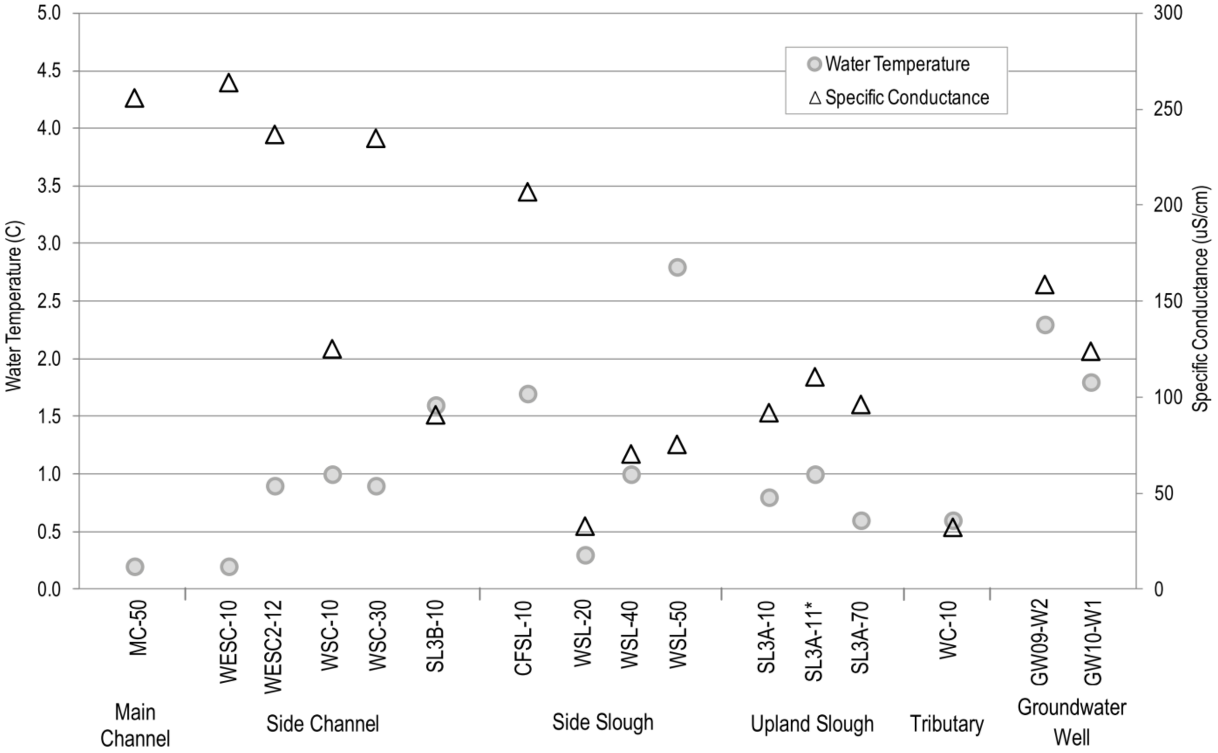

Figure 12. Instantaneous measurements of surface water temperature and specific conductance recorded at sites in FA-104 (Whiskers Slough) during February and March 2014, by macrohabitat type.

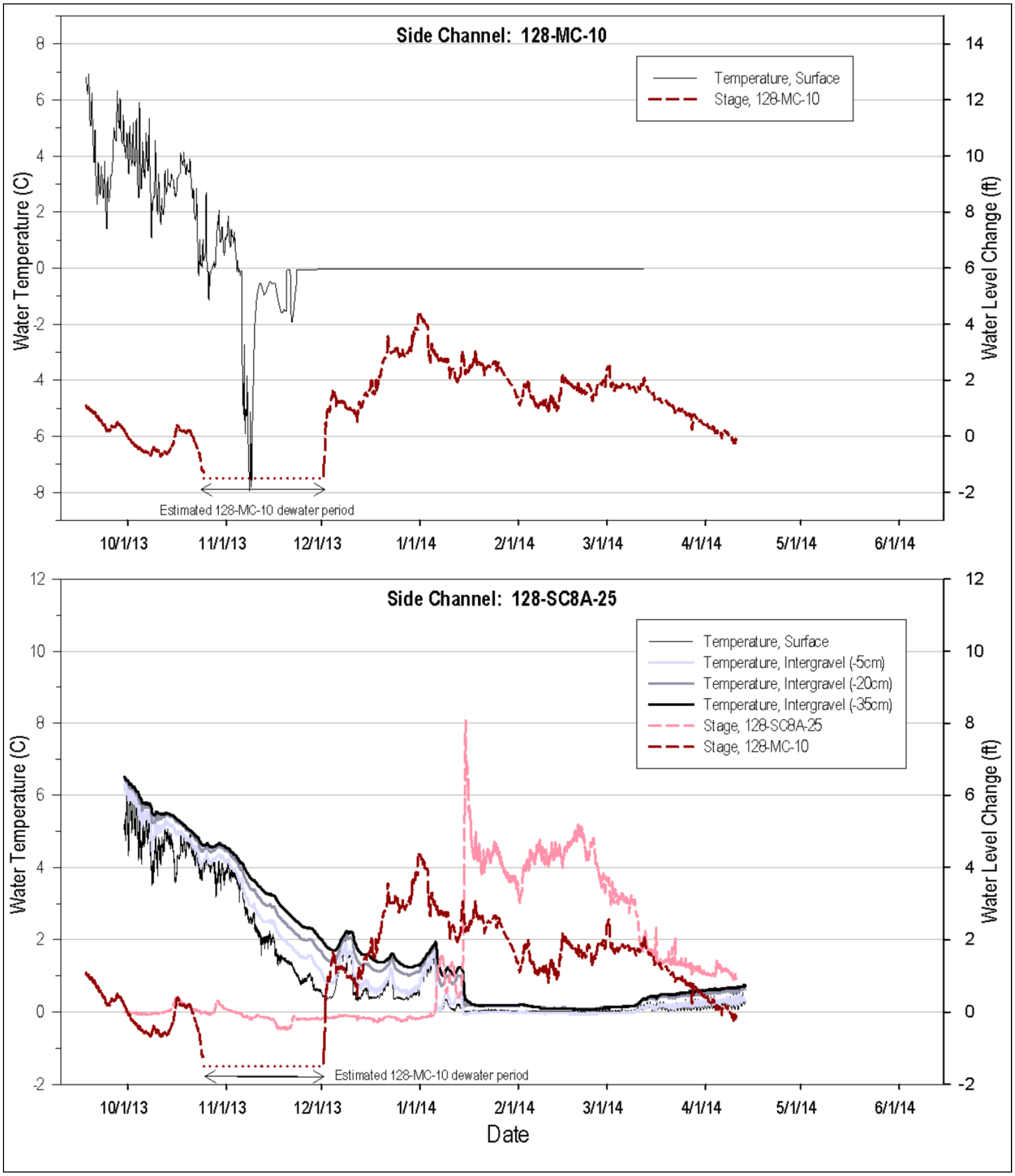

Figure 13. Water temperature recorded above the substrate surface and at intergravel depths of 5 cm (2 in), 20 cm (7.9 in), and 35 cm (13.8 in) relative to normalized water surface elevation at Susitna River main channel (128-MC-10) and Side Channel 8A (128-SC8A-25) continuous monitoring sites in FA-128 (Slough 8A) during September 2013 - April 2014. Water elevations were normalized to zero on September 30, 2013.

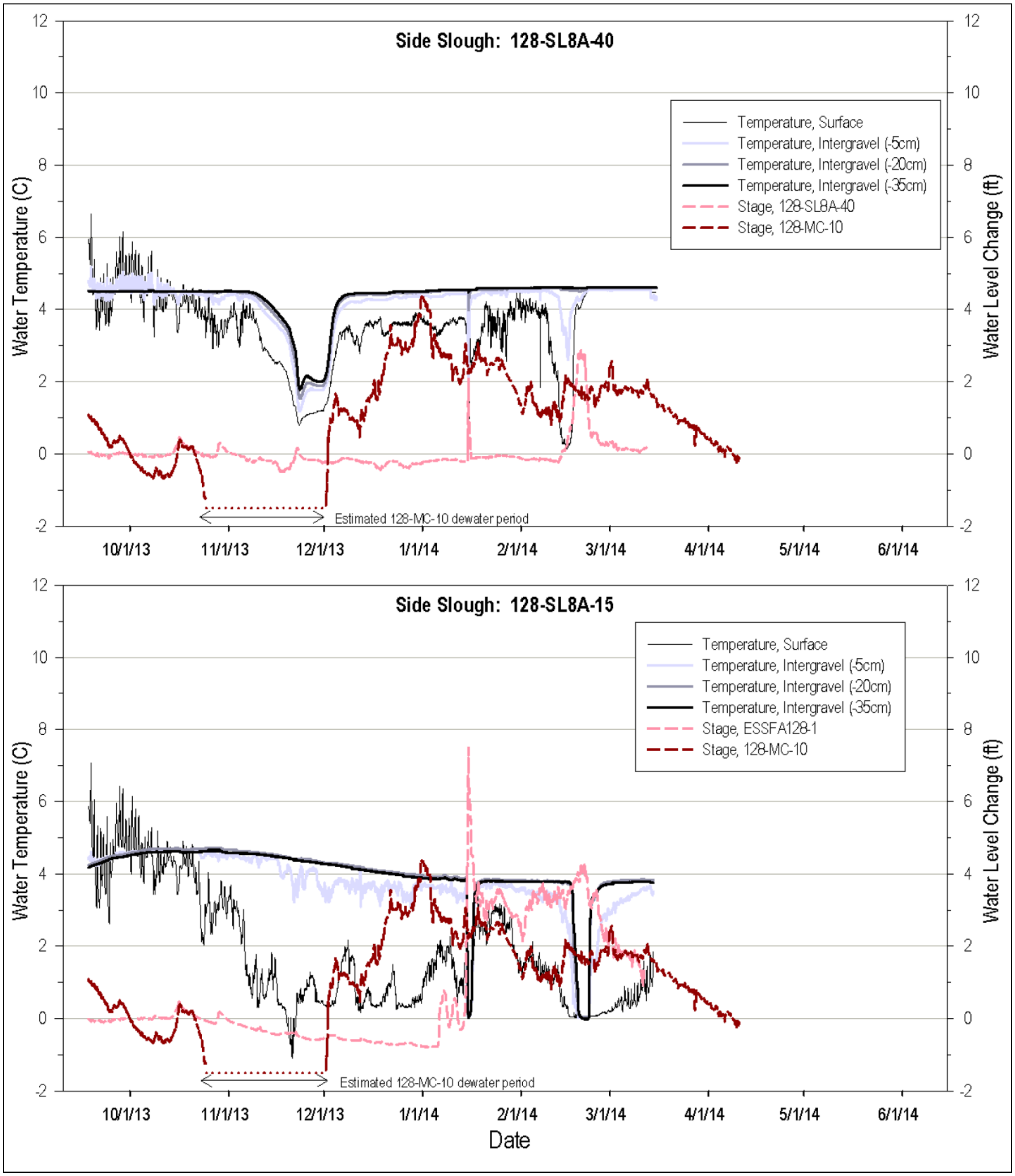

Figure 14. Water temperature recorded above the substrate surface and at intergravel depths of 5 cm (2 in), 20 cm (7.9 in), and 35 cm (13.8 in) relative to normalized water surface elevation at Slough 8A (128-SL8A-40 and 128-SL8A-15) continuous monitoring sites in FA-128 (Slough 8A) during September 2013 - April 2014. Water elevations were normalized to zero on September 30, 2013.

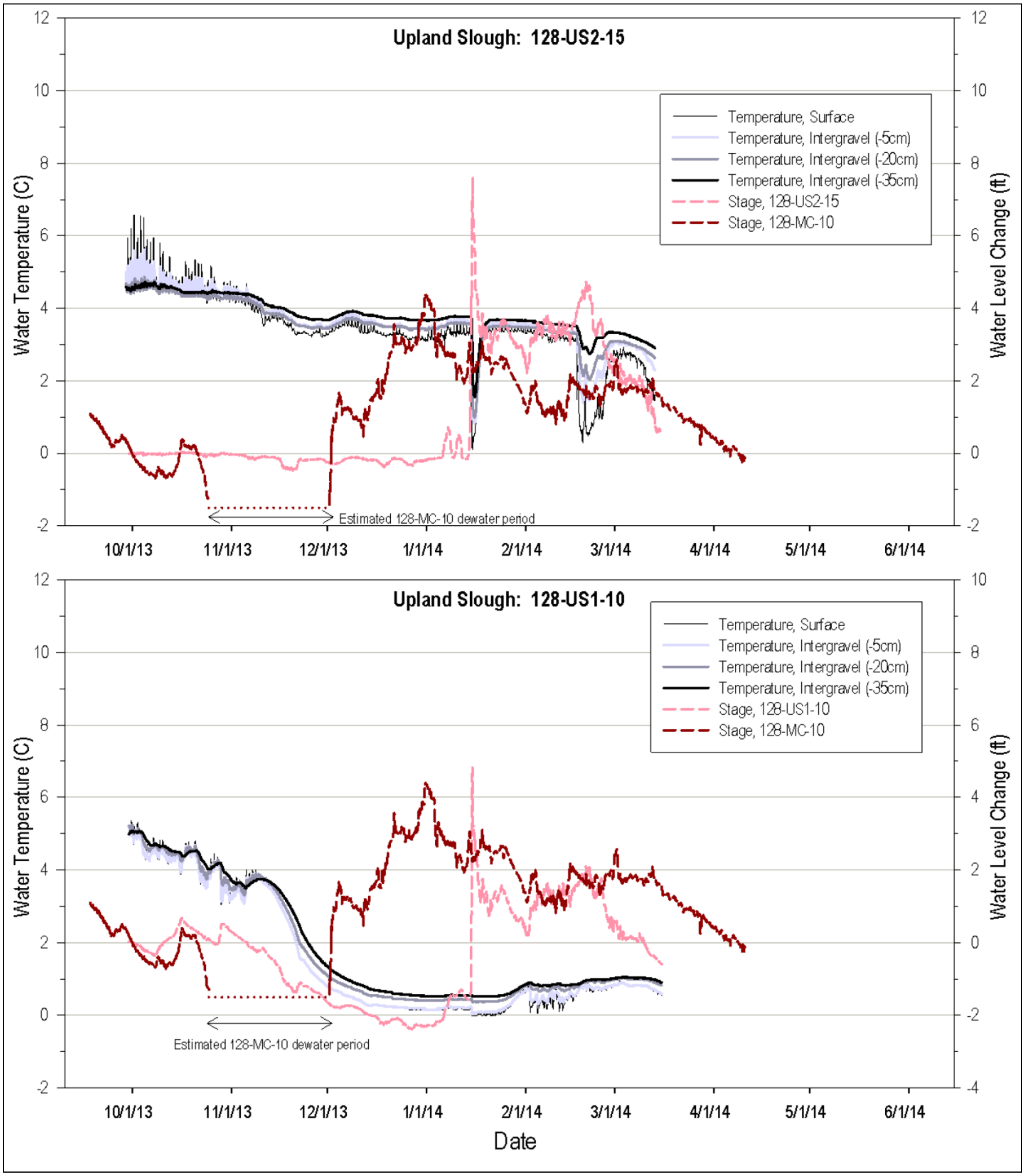

Figure 15. Water temperature recorded above the substrate surface and at intergravel depths of 5 cm (2 in), 20 cm (7.9 in), and 35 cm (13.8 in) relative to normalized water surface elevation at Upland Slough 2 (128-US2-15) and Upland Slough 1 (128-US1-10) continuous monitoring sites in FA-128 (Slough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

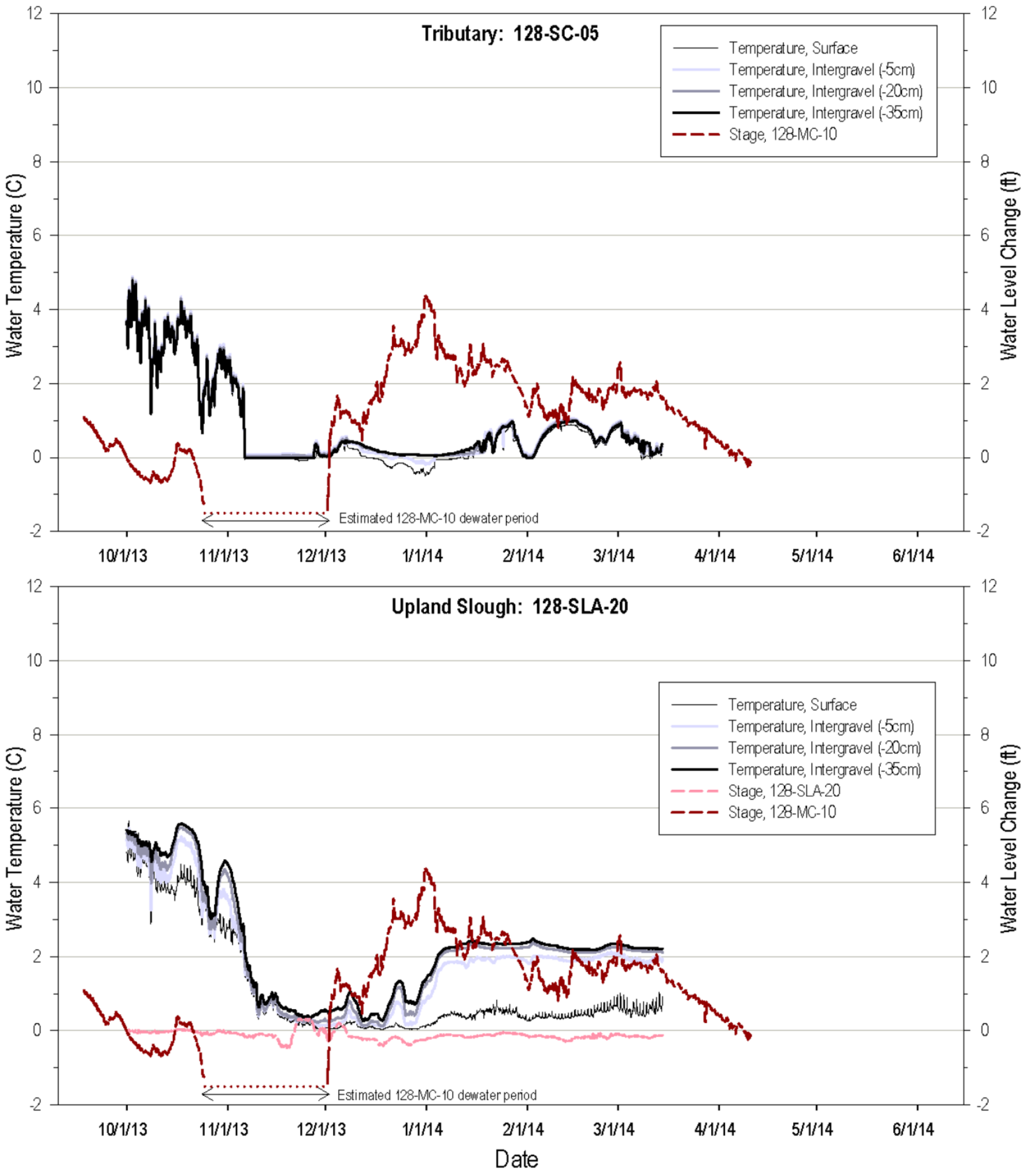

Figure 16. Water temperature recorded above the substrate surface and at intergravel depths of 5 cm (2 in), 20 cm (7.9 in), and 35 cm (13.8 in) relative to normalized water surface elevation at Skull Creek (128-SC-05) and Slough A (128-SLA-20) continuous monitoring sites in FA-128 (Slough 8A) during September 2013 - April 2014. Elevations were normalized to zero on September 30, 2013.

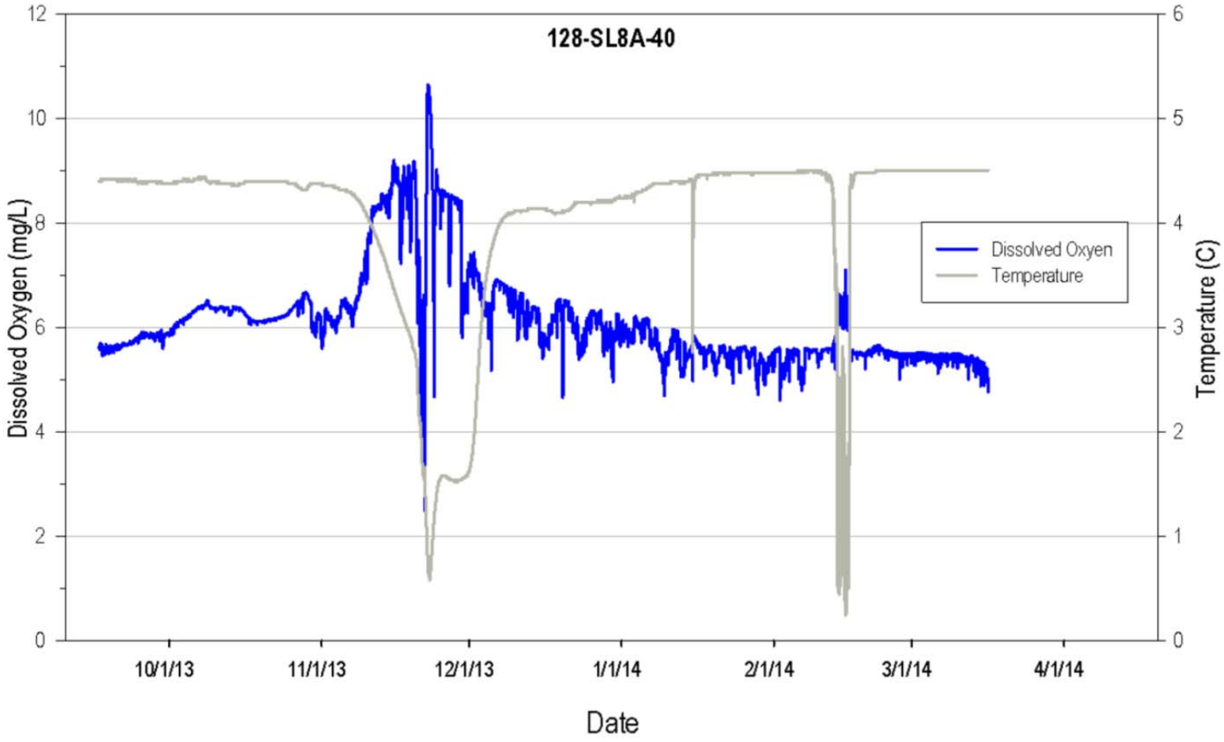

Figure 17. Continuous intergravel dissolved oxygen concentration and water temperature data recorded approximately 20 cm (7.9 in) below the substrate surface at in FA-128 (Slough 8A; Site SL8A-40) and during September 2013 - April 2014.

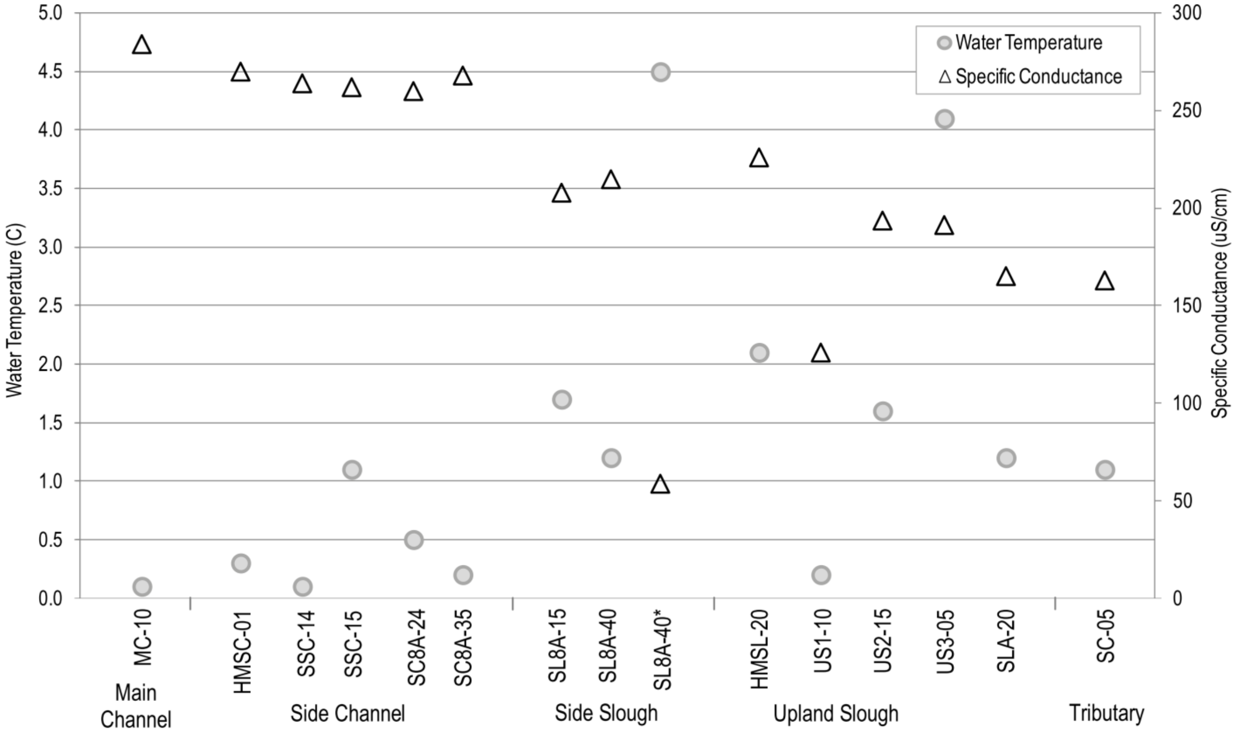

Figure 18. Instantaneous measurements of surface water temperature and specific conductance recorded at sites in FA-128 (Slough 8A) during February and March 2014, by macrohabitat type.

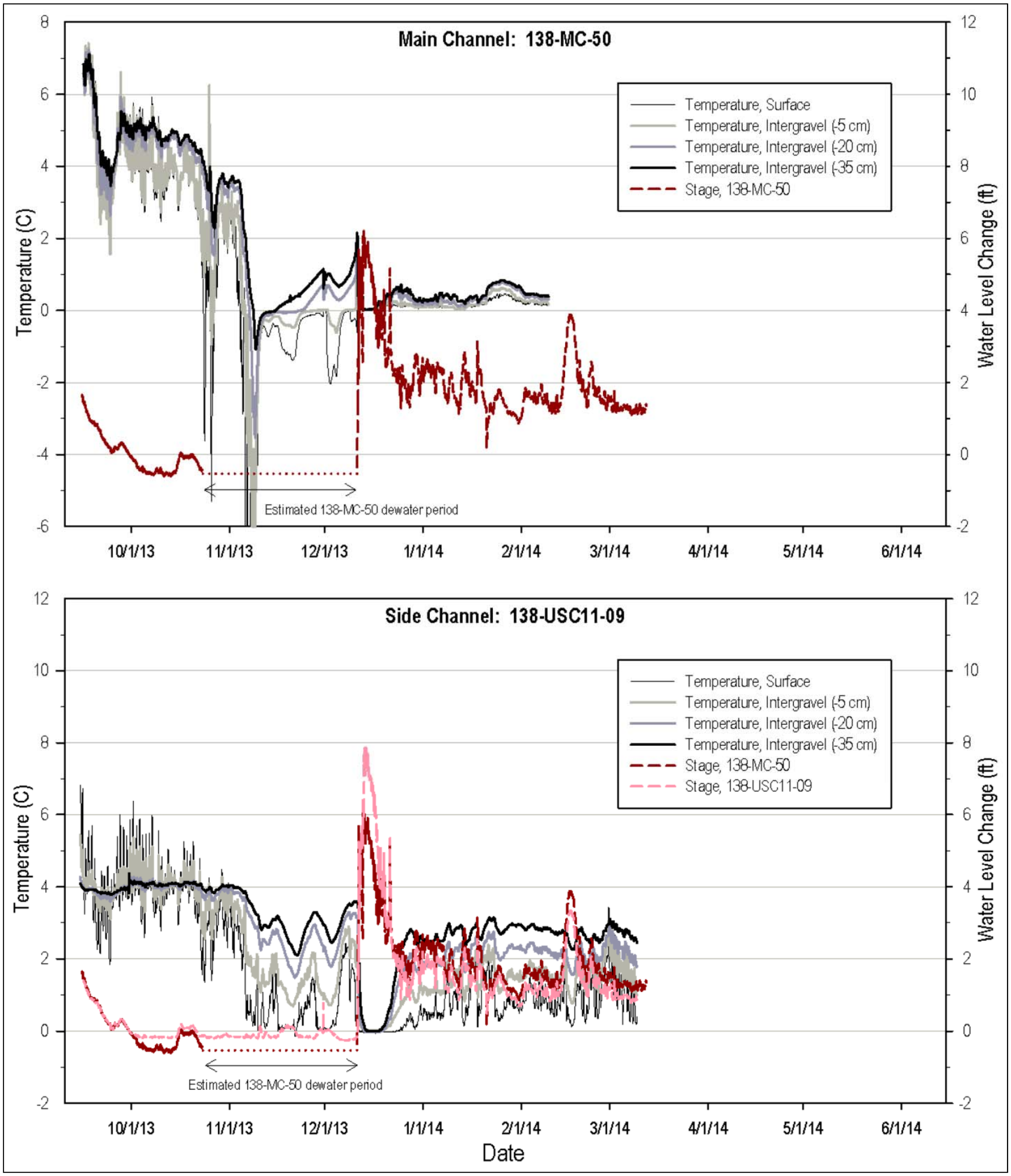

Figure 19. Water temperature recorded above the substrate surface and at intergravel depths of 5 cm (2 in), 20 cm (7.9 in), and 35 cm (13.8 in) relative to normalized water surface elevation at Susitna River main channel (138-MC-10) and Upper Side Channel 11 (138-USC11-09) continuous monitoring sites in FA-138 (Gold Creek) during September 2013 - March 2014. Water elevations were normalized to zero on September 30, 2013.

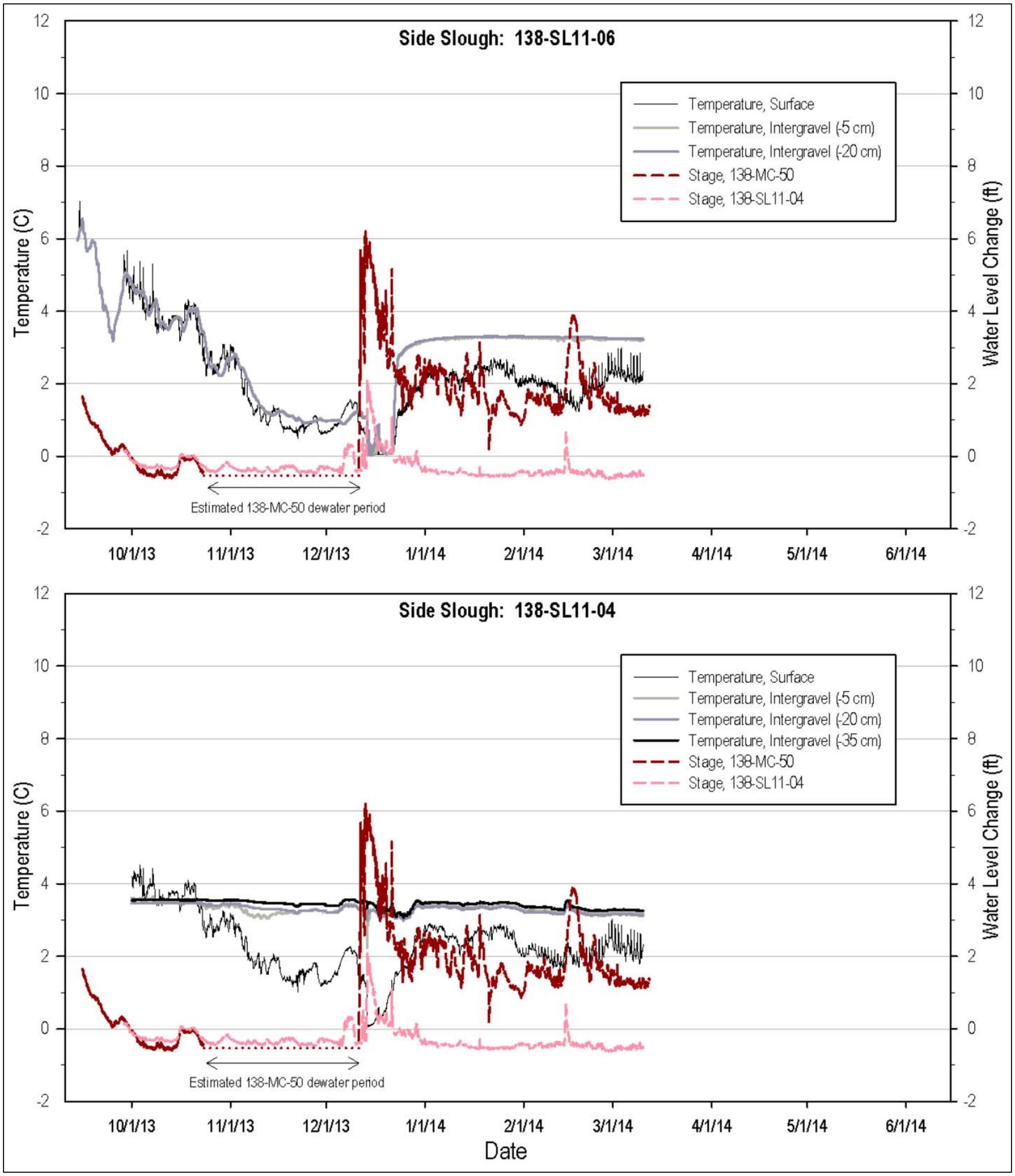

Figure 20. Water temperature recorded above the substrate surface and at intergravel depths of 5 cm (2 in), 20 cm (7.9 in), and 35 cm (13.8 in) relative to normalized water surface elevation at Slough 11 (138-SL11-06 and 138-SL11-04) continuous monitoring sites in FA-138 (Gold Creek) during September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

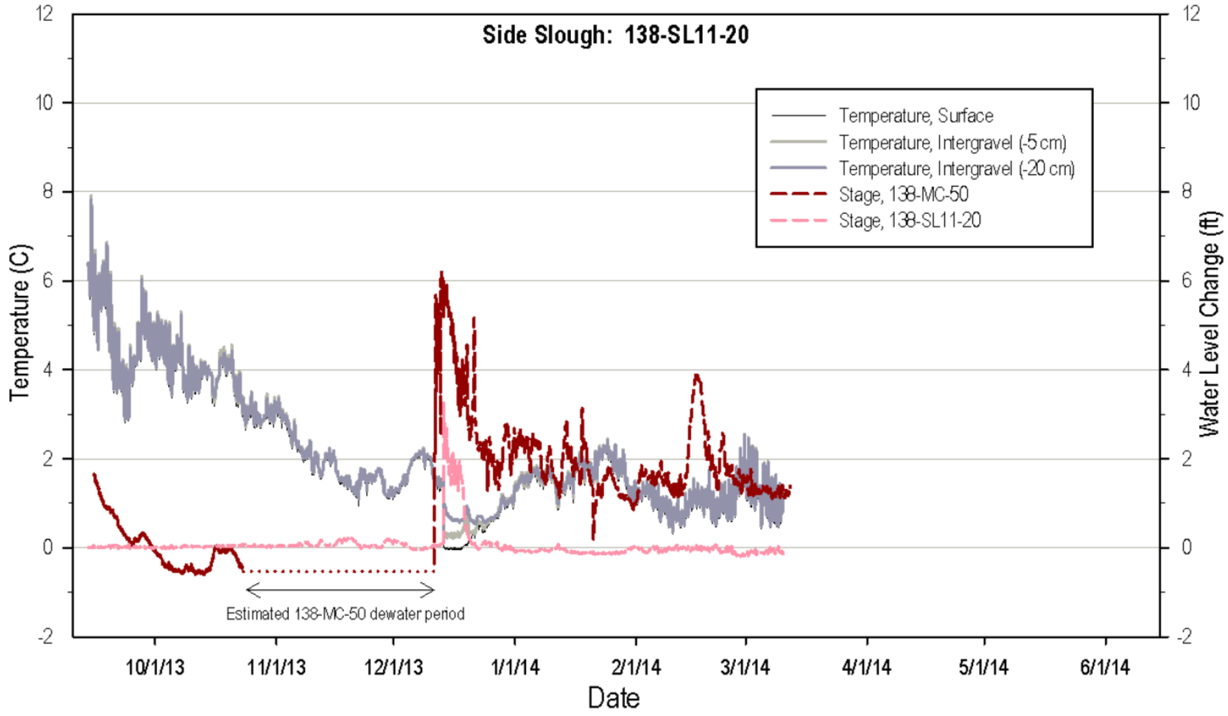

Figure 21. Water temperature recorded above the substrate surface and at intergravel depths of 5 cm (2 in), 20 cm (7.9 in), and 35 cm (13.8 in) relative to normalized water surface elevation at Slough 11 continuous monitoring site 138-SL11-20 in FA-138 (Gold Creek) during September 2013 - March 2014. Elevations were normalized to zero on September 30, 2013.

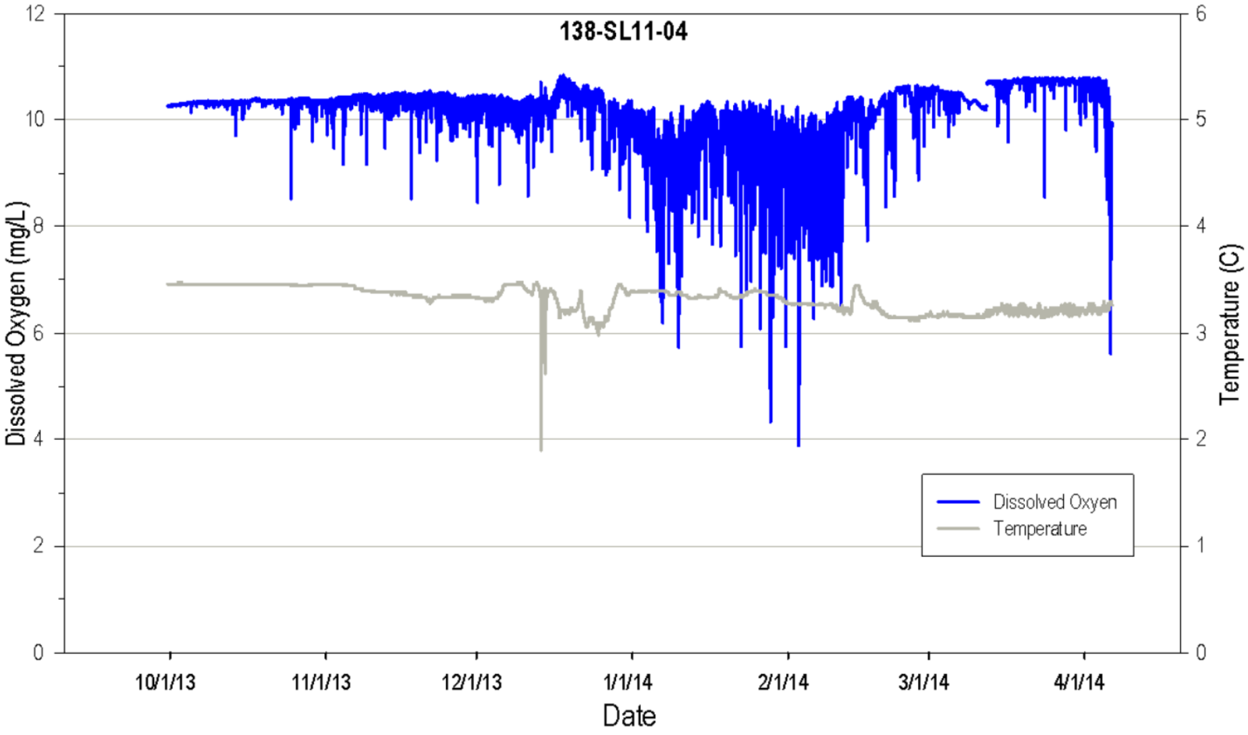

Figure 22. Continuous intergravel dissolved oxygen concentration and water temperature data recorded approximately 20 cm (7.9 in) below the substrate surface at FA-138 (Gold Creek; Site 138-SL11-04) during September 2013 - April 2014.

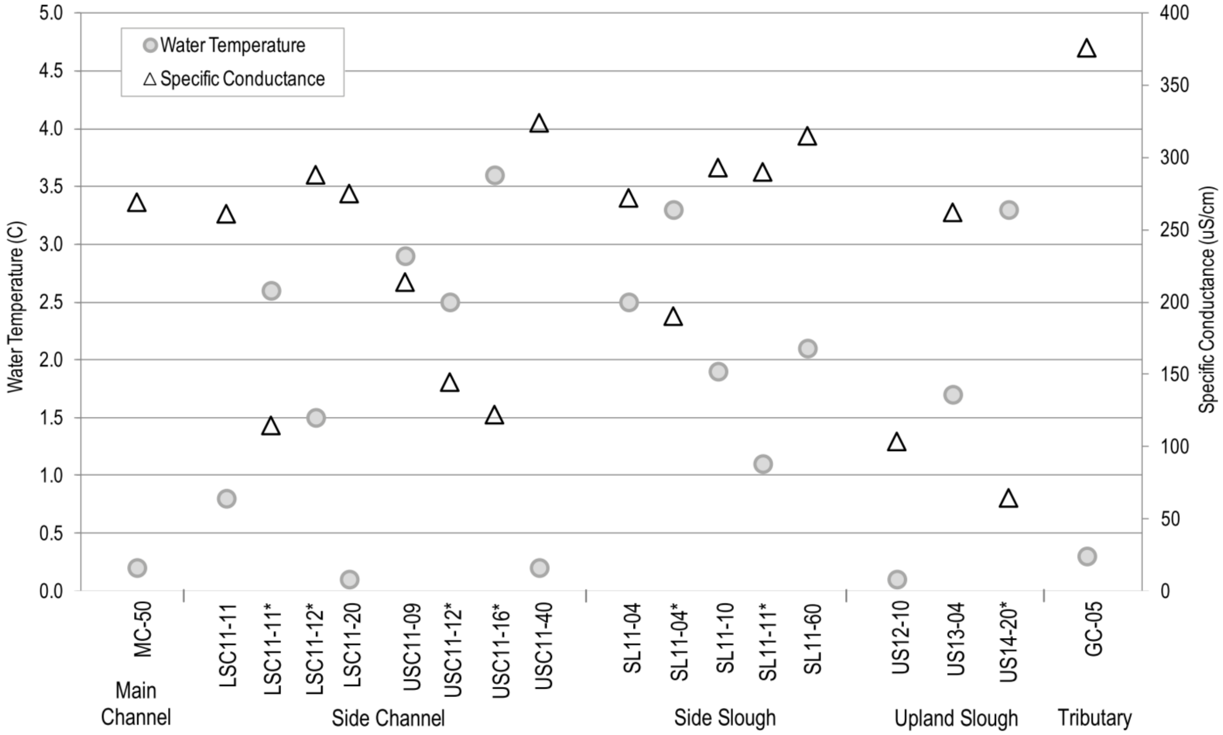

Figure 23. Instantaneous measurements of surface water temperature and specific conductance recorded at sites in FA-138 (Gold Creek) during February and March 2014, by macrohabitat type.