PART A - FIGURES

Susitna-Watana Hydroelectric Project (FERC No. 14241)

Groundwater Study (7.5)

Part A - Figures

Initial Study Report

Prepared for

Alaska Energy Authority

SUSITNA-WATANA HYDRO

Clean, reliable energy for the next 100 years.

Prepared by

Geo-Watersheds Scientific

June 2014

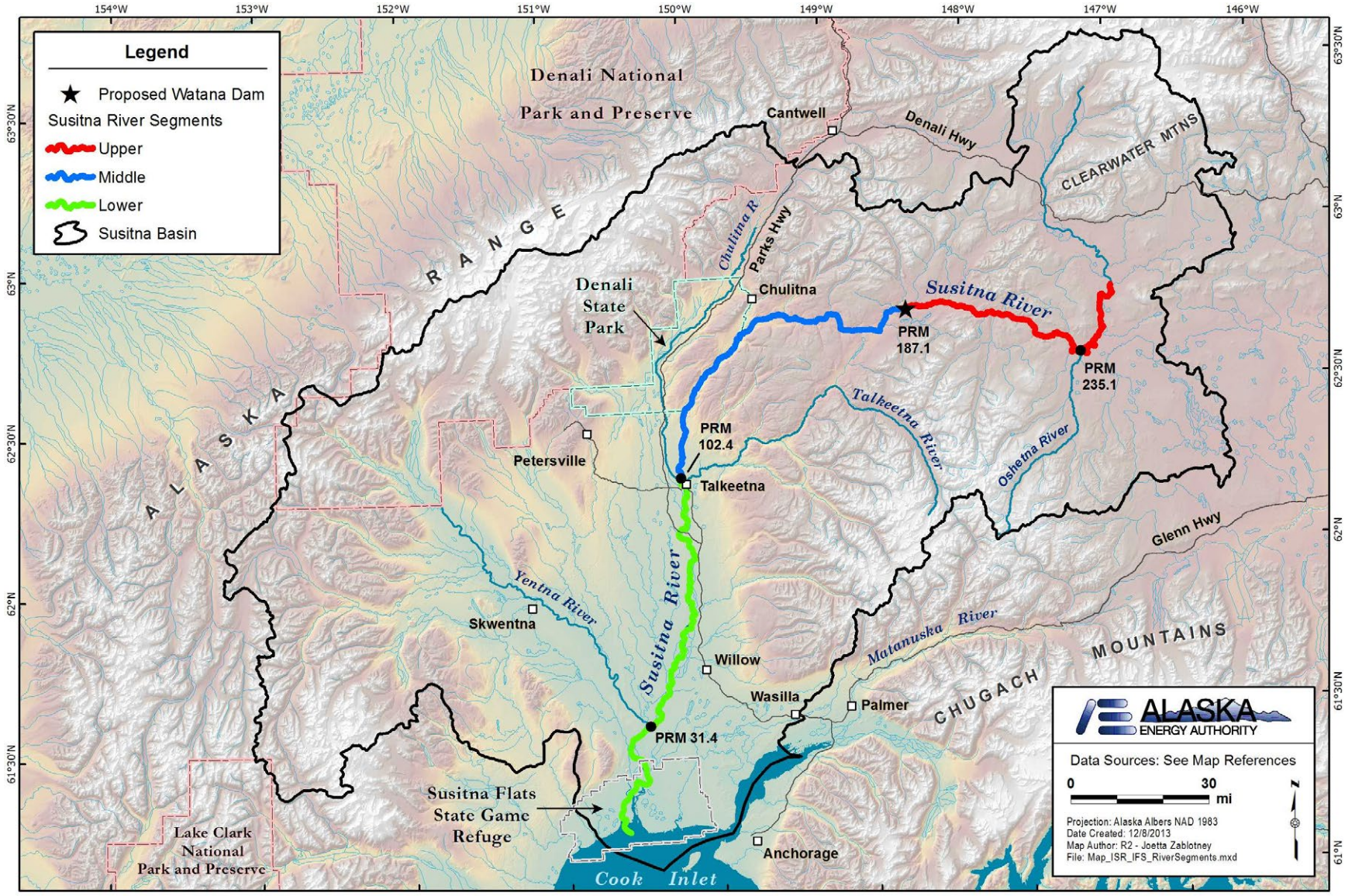

Figure 3-1. Susitna Watershed basin boundaries, showing the Project designation of upper, middle and lower river segments.

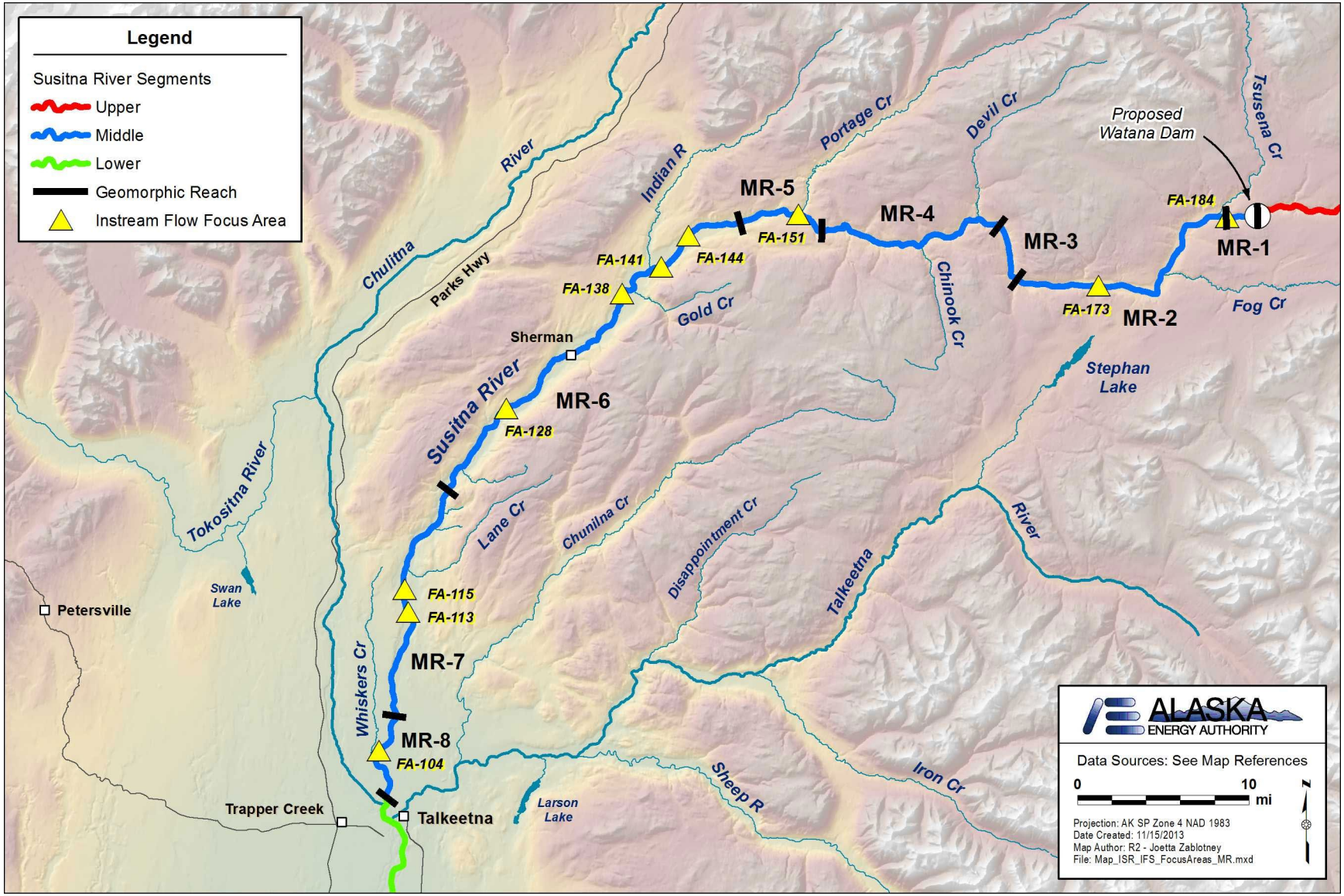

Figure 3-2. Susitna Watershed Middle River Segment, with geomorphic reaches and Focus Areas indicated.

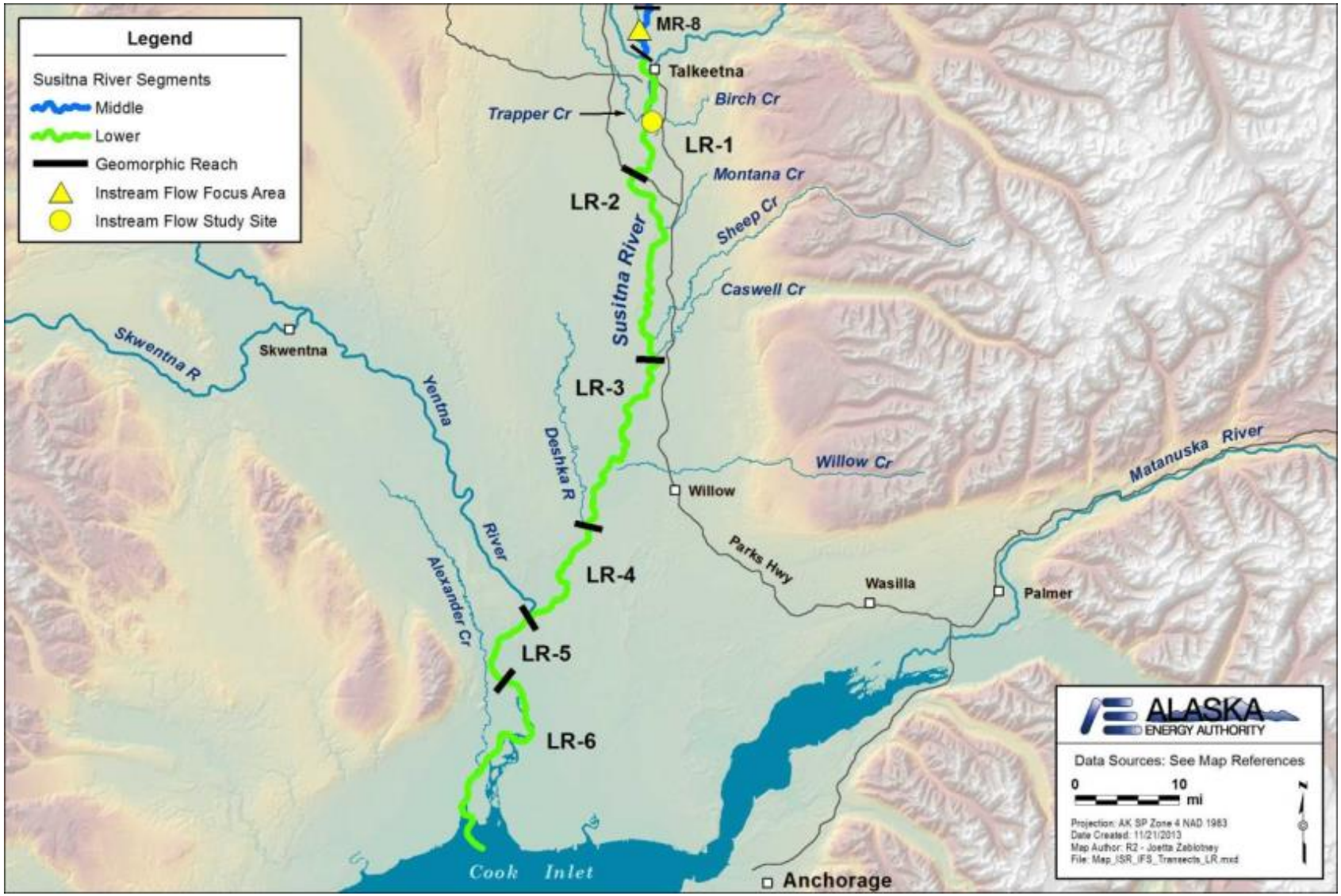

Figure 3-3. Susitna Watershed Lower River Segment, with geomorphic reaches indicated.

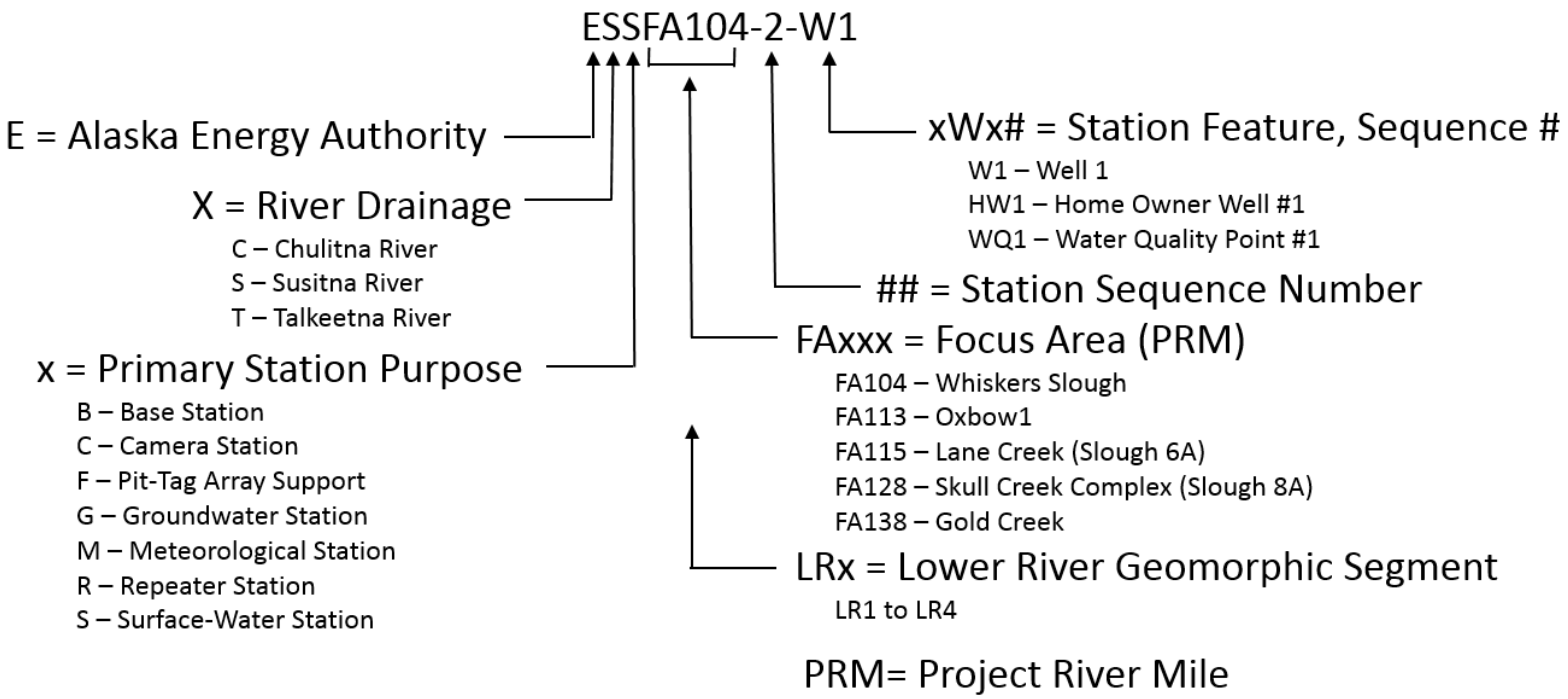

Figure 4.5-1. Data collection station short name convention used for continuously monitored stations.

Most stations collect data for multiple study objectives. This allows for improved efficiency of synoptic data collection, data collection standards and field logistics.

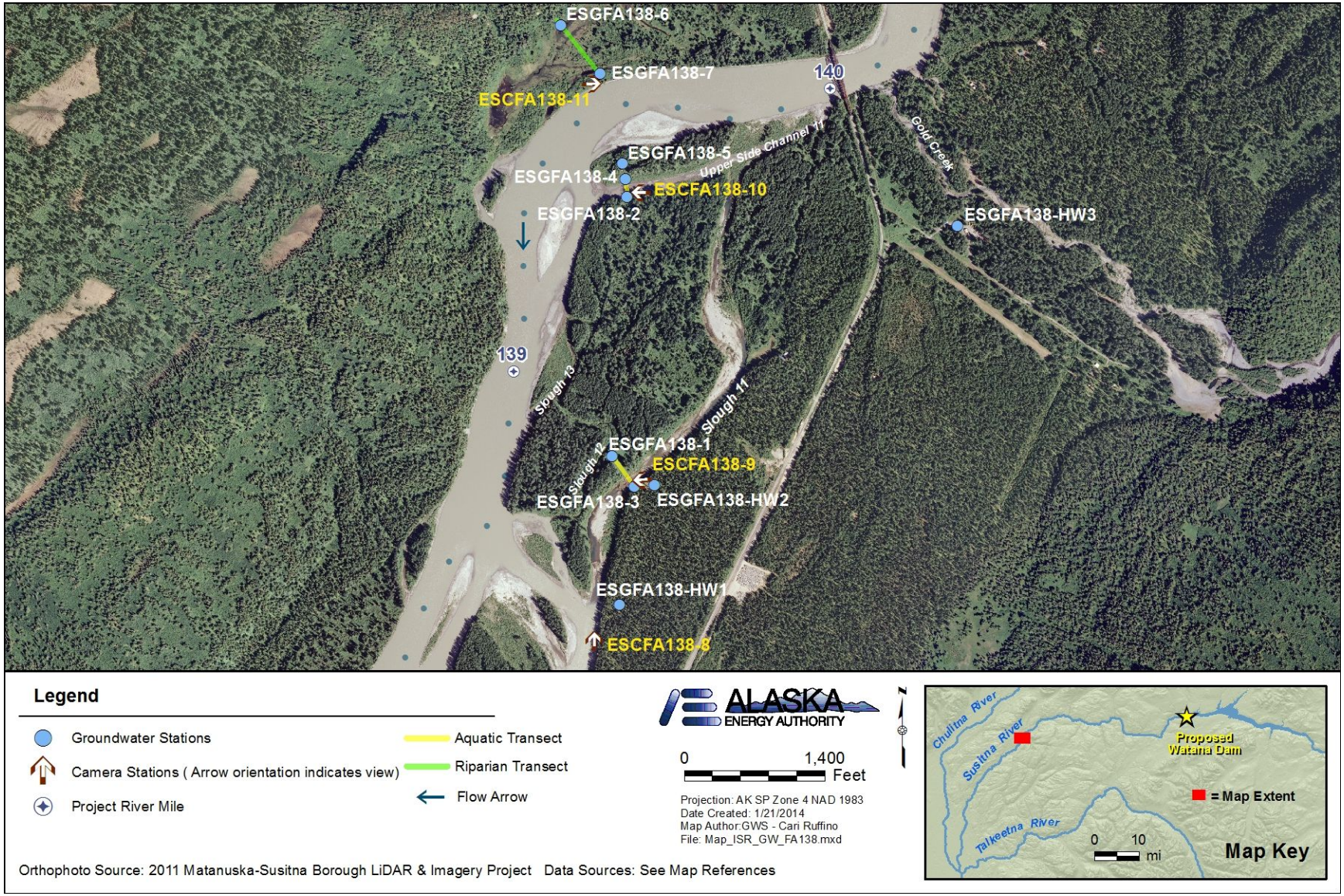

Figure 4.5-2. General location of FA-138 (Gold Creek) Focus Area, showing major data collection points and aquatic and riparian transects. Data from all stations and any manual data collection locations are used to understand and describe the hydrology and related processes at the Focus Area scale.

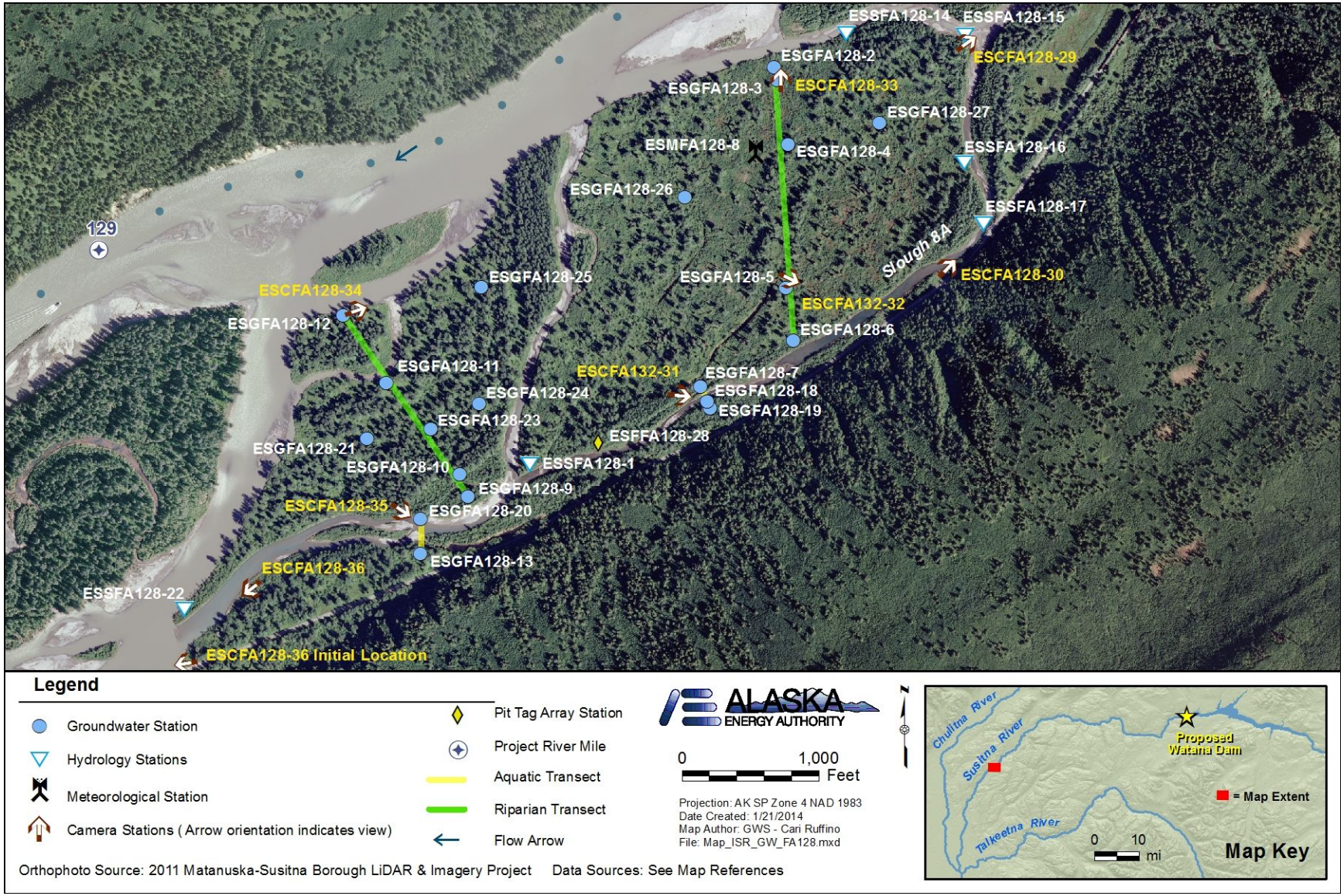

Figure 4.5-3. General location of FA-128 (Slough 8A) Focus Area, showing major data collection points and aquatic and riparian transects.
Data from all stations and any manual data collection locations are used to understand and describe the hydrology and related processes at the Focus Area scale.

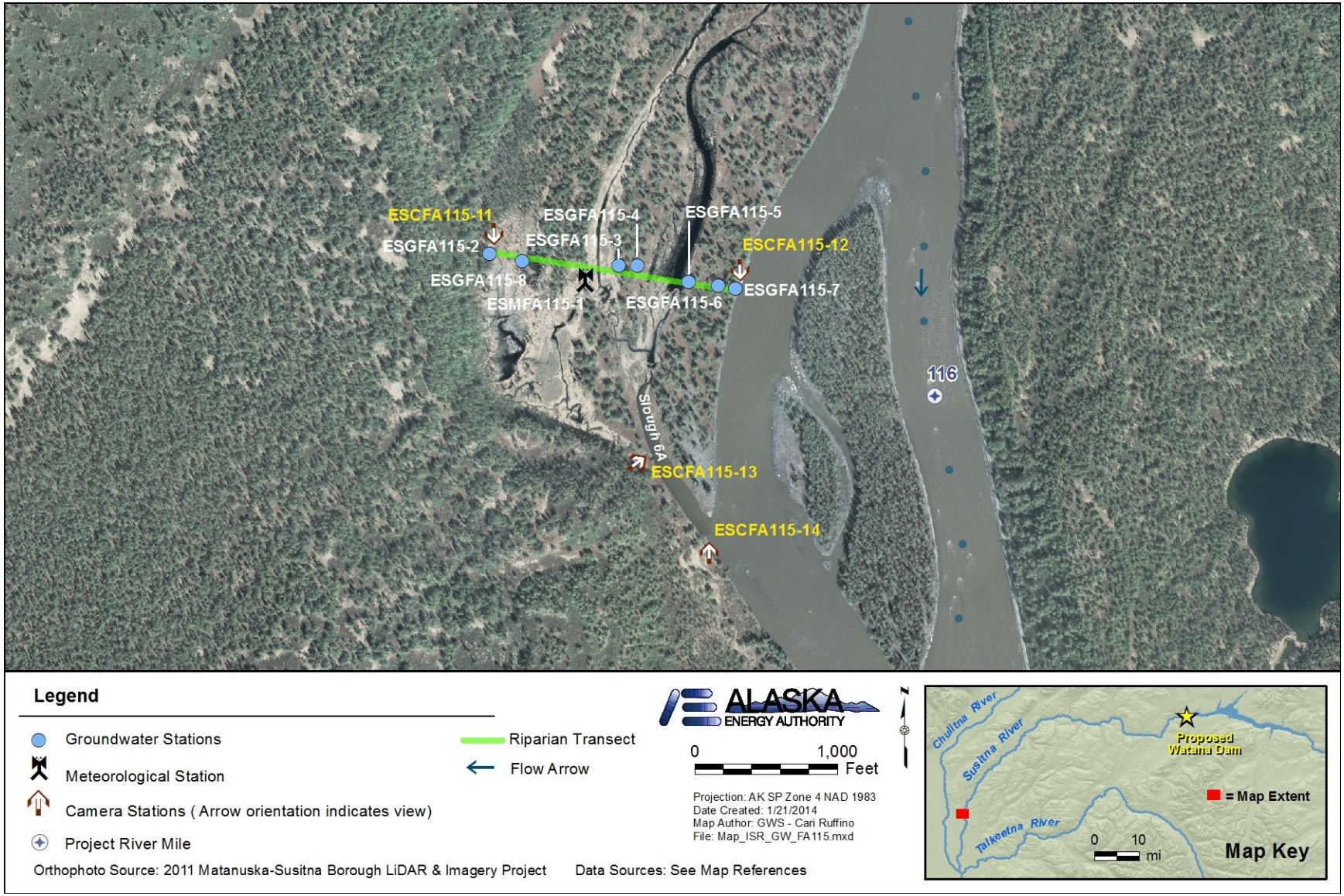

Figure 4.5-4. General location of FA-115 (Slough 6A) Focus Area, showing major data collection points and riparian transect.
Data from all stations and any manual data collection locations are used to understand and describe the hydrology and related processes at the Focus Area scale.

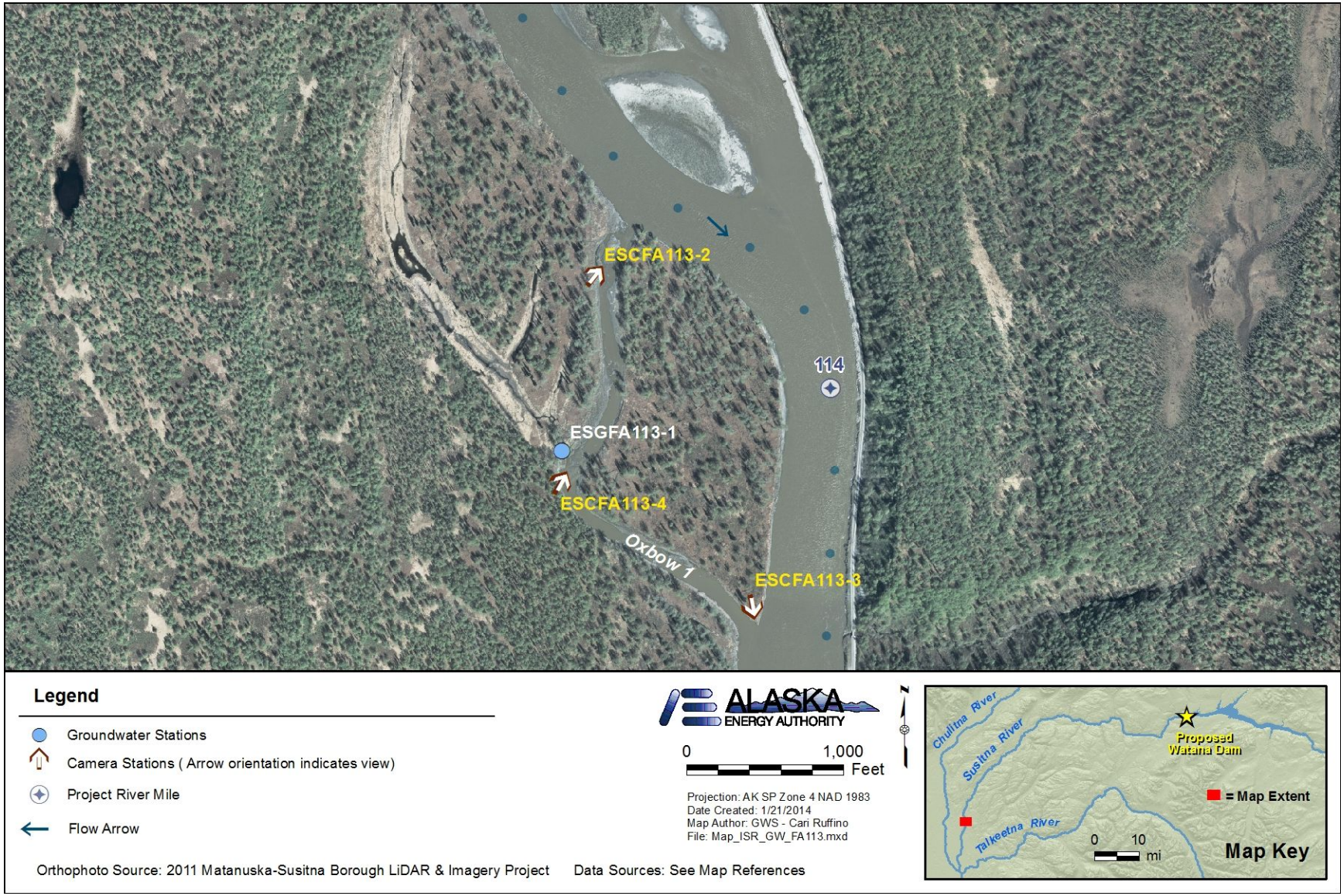

Figure 4.5-5. General location of FA-113 (Oxbow 1) Focus Area, showing major data collection points for supporting aquatic studies.
Data from all stations and any manual data collection locations are used to understand and describe the hydrology and related processes at the Focus Area scale.

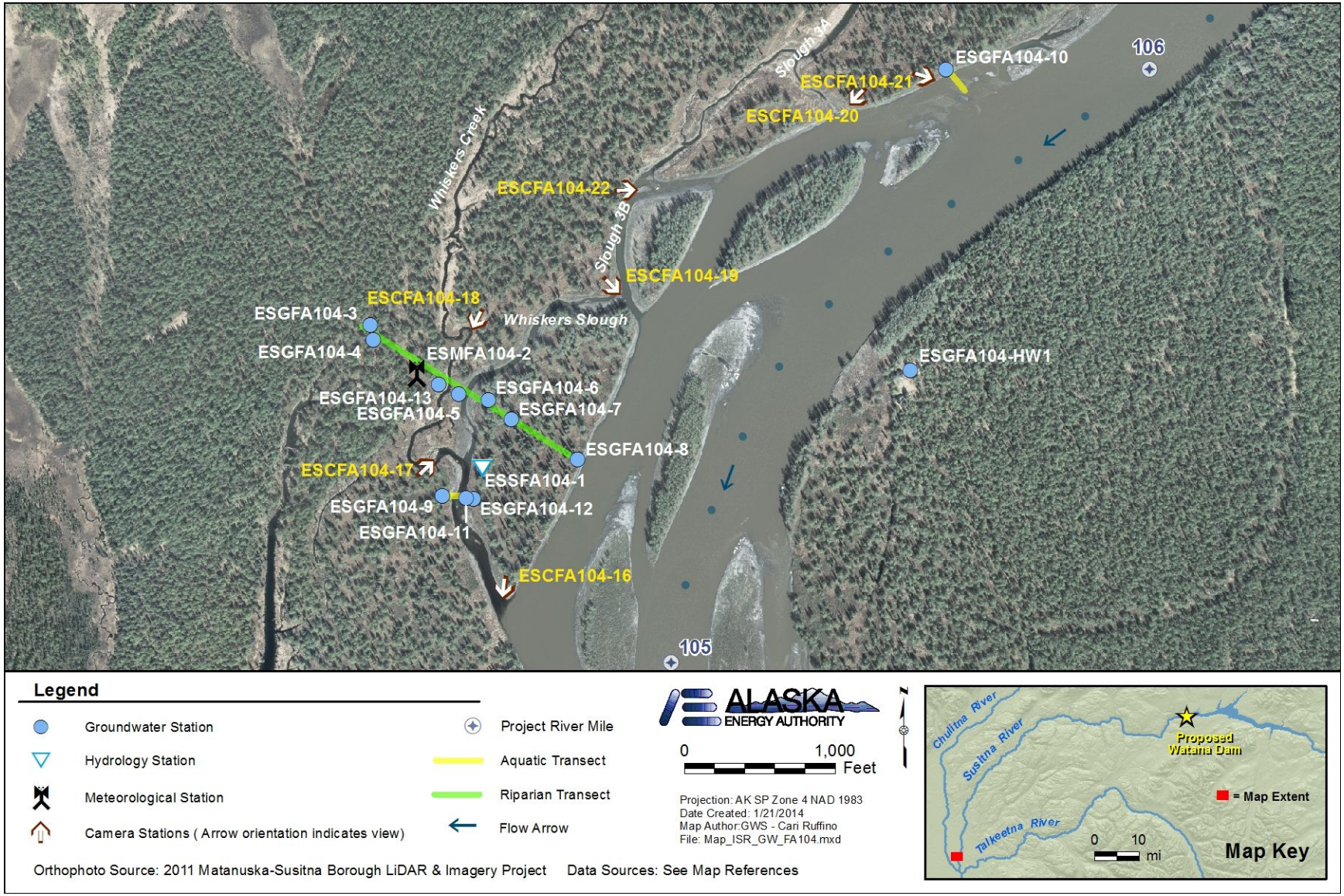

Figure 4.5-6. General location of FA-104 (Whiskers Slough) Focus Area, showing major data collection points and aquatic and riparian transects. Data from all stations and any manual data collection locations are used to understand and describe the hydrology and related processes at the Focus Area scale.

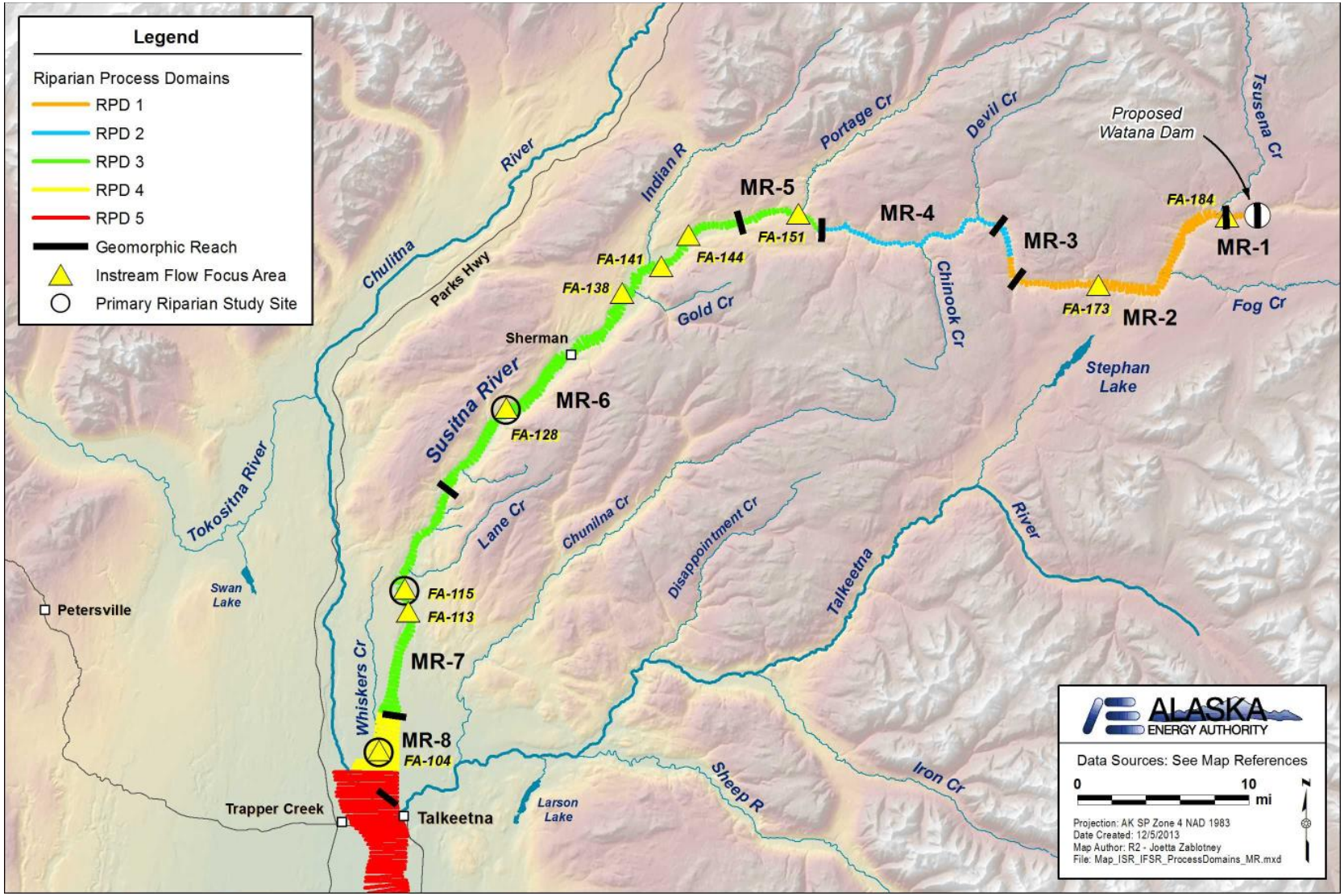

Figure 4.5-7. Riparian process domains on the Middle River with locations of associated Riparian IFS Focus Areas that have GW/SW data collection activities.

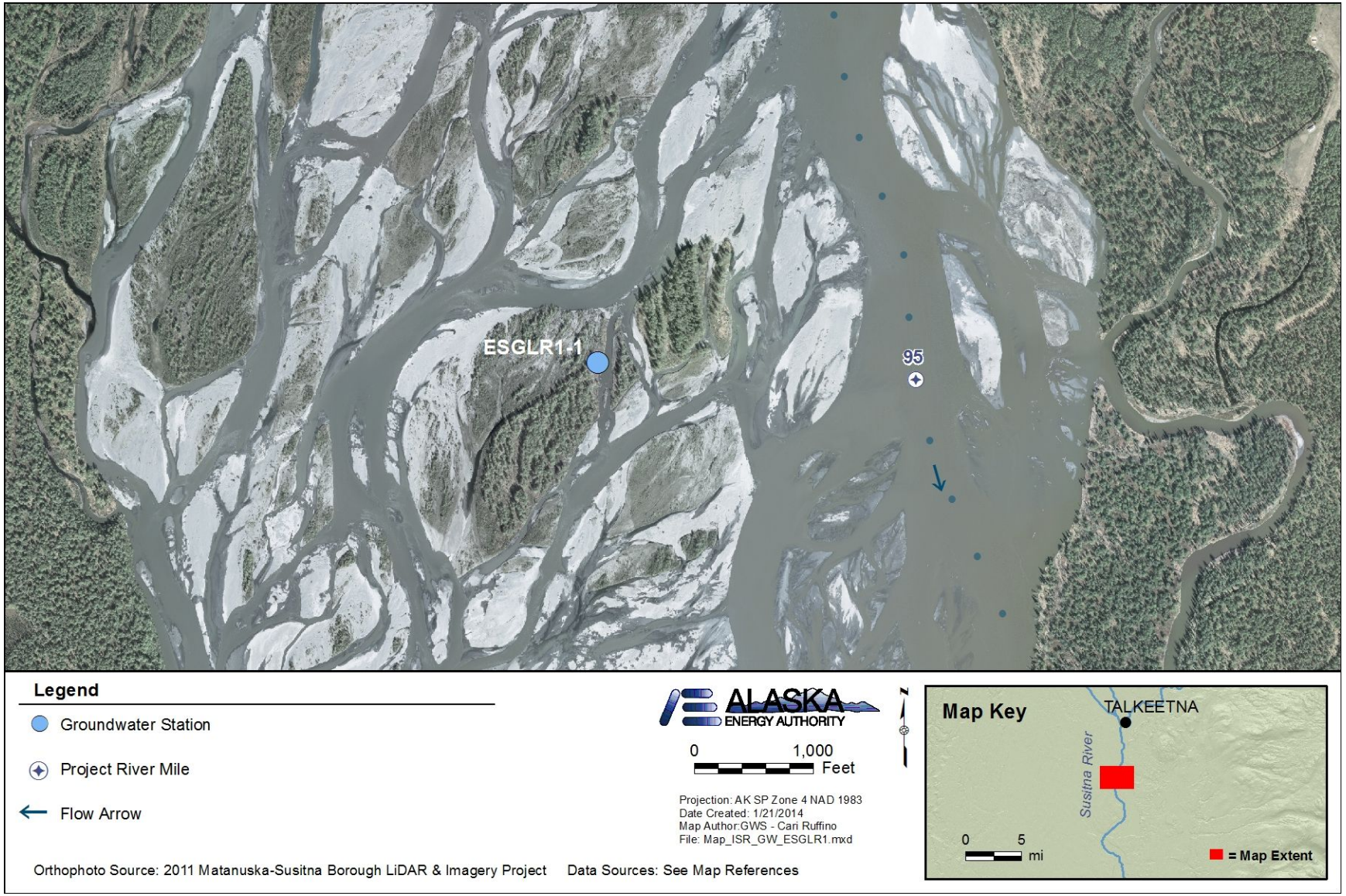

Figure 4.5-8. Location of station ESGLR1-1 in the Lower River geomorphic reach LR1. This station provides data for the Riparian Lower River transect studies.

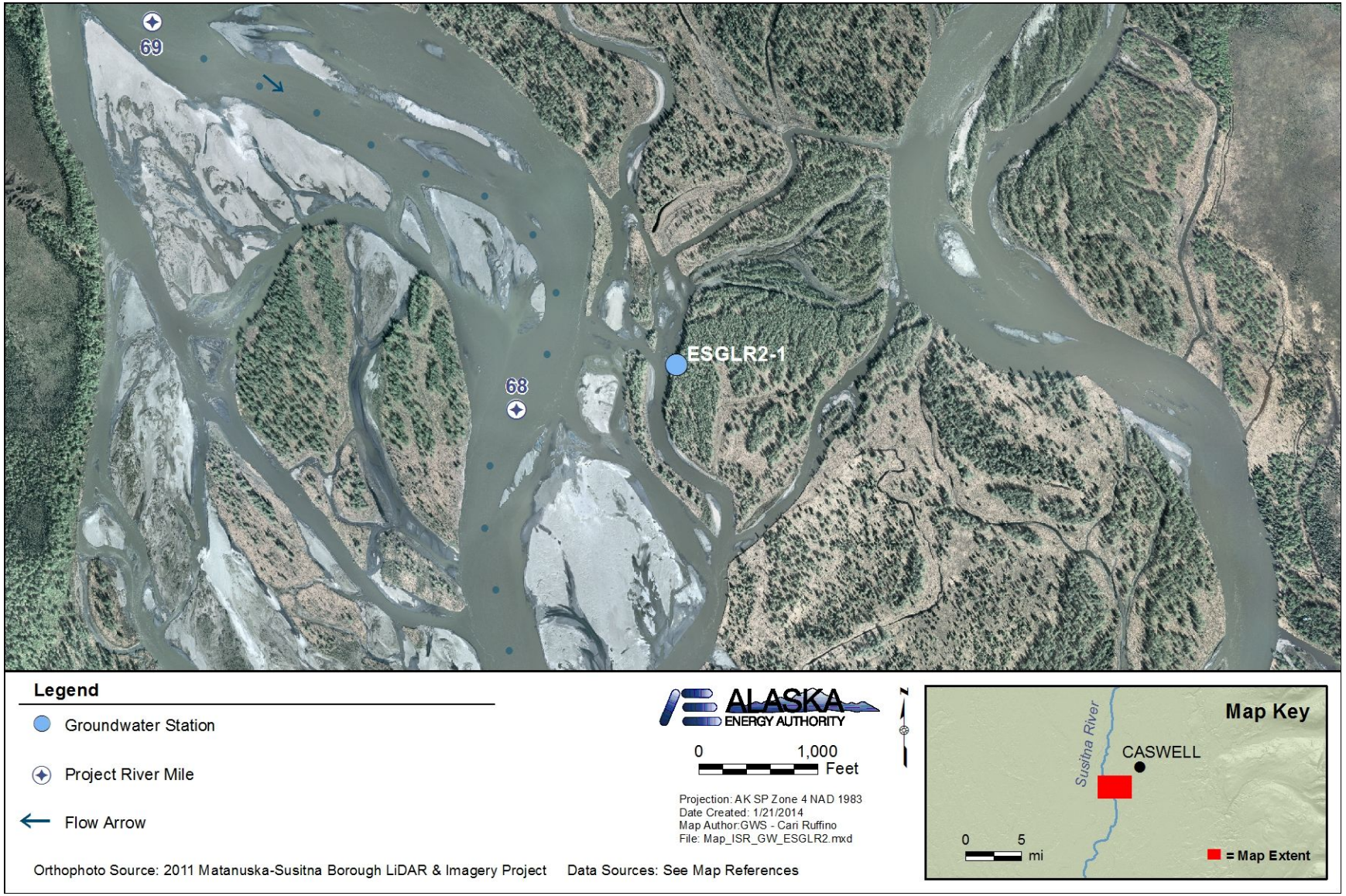

Figure 4.5-9. Location of station ESGLR2-1 in the Lower River geomorphic reach LR2. This station provides data for the riparian Lower River transect studies.

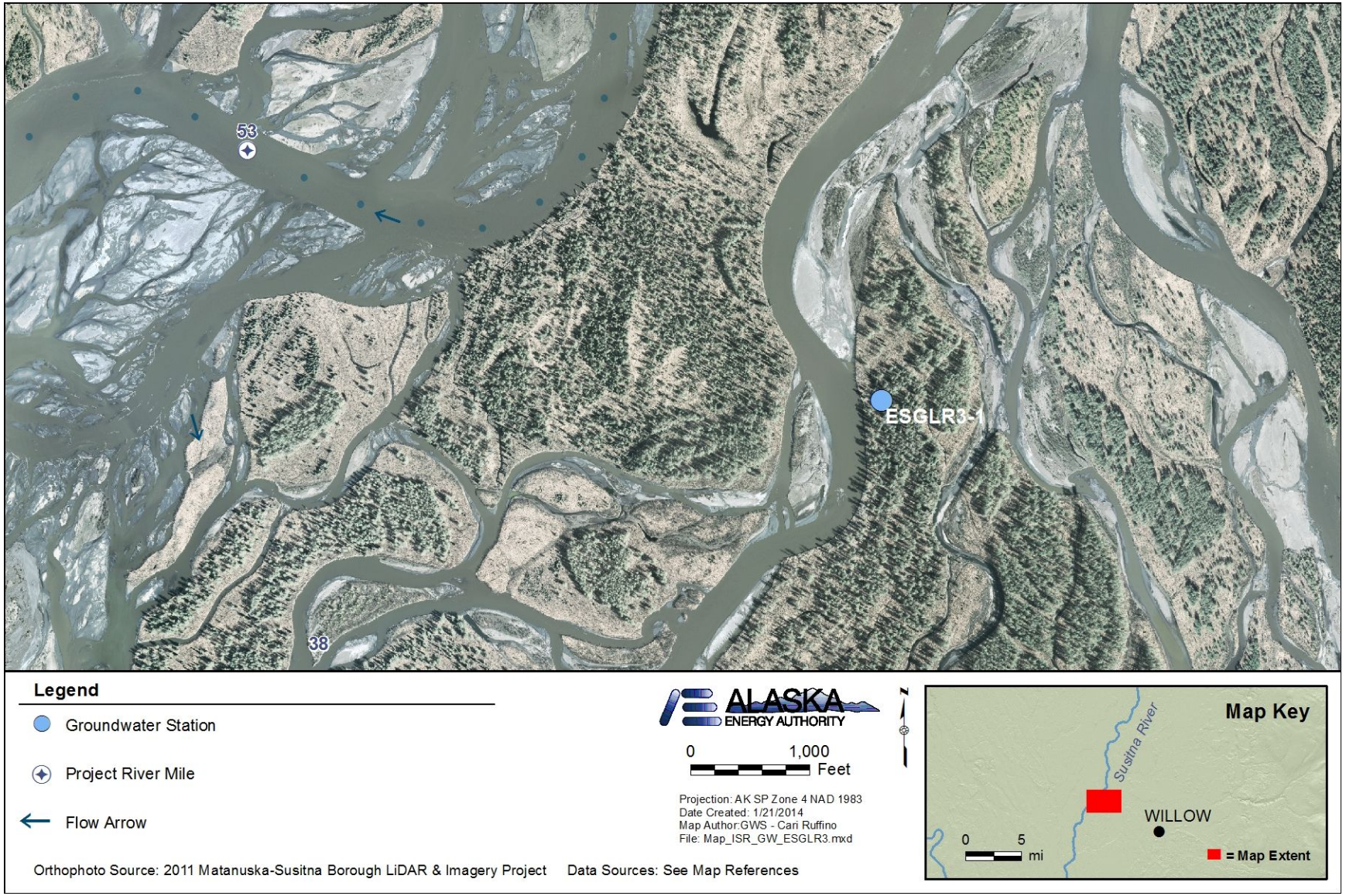

Figure 4.5-10. Location of station ESGLR3-1 in the Lower River geomorphic reach LR3. This station provides data for the riparian Lower River transect studies.

Figure 4.5-11. Location of station ESGLR4-1 and ESGLR4-2 in the Lower River geomorphic reach LR4. These stations provide data for the riparian Lower River transect studies.

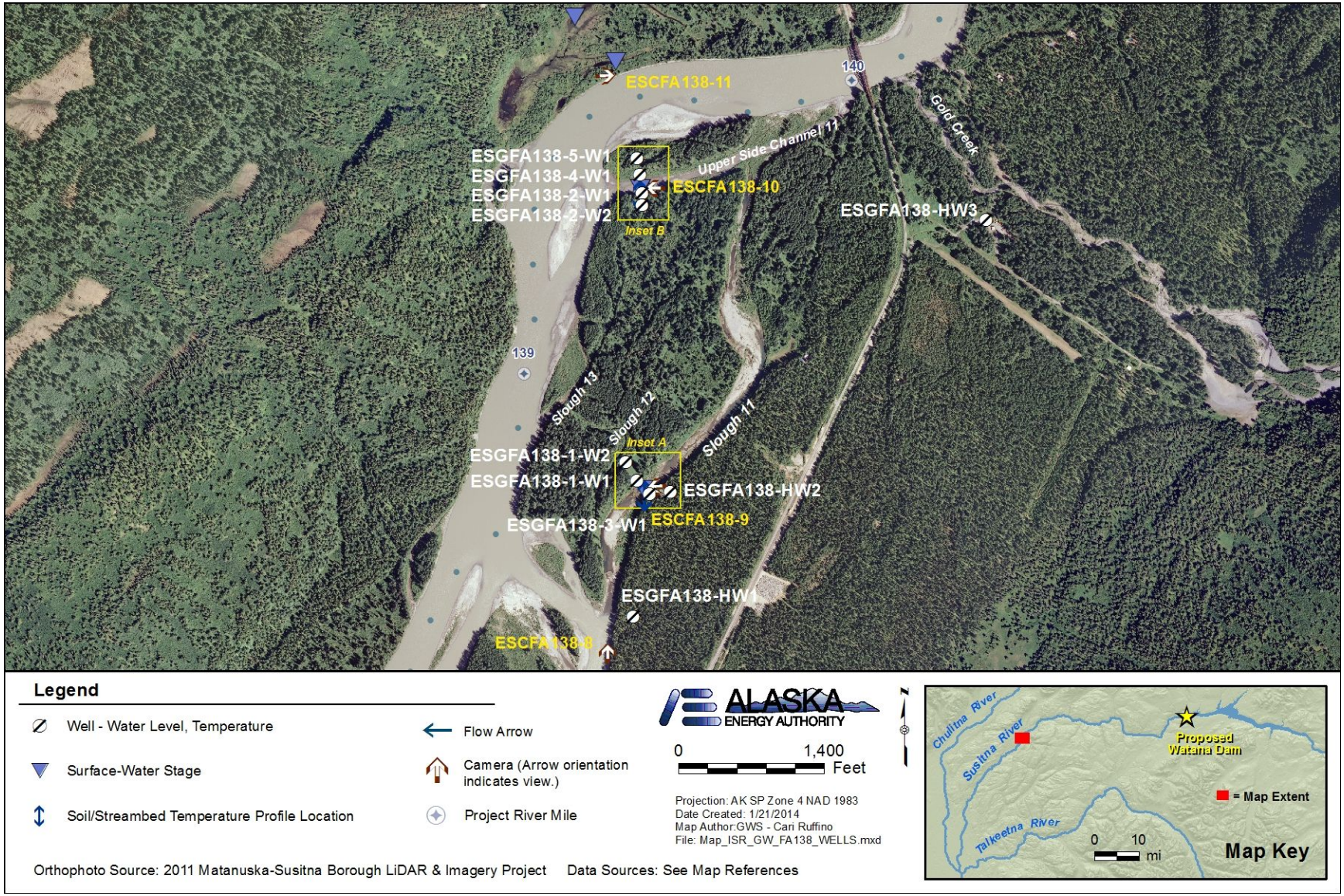

Figure 4.5-12. Well locations and continuously measured parameters at FA-138 (Gold Creek) Focus Area. Measured parameters include one or more of the following: groundwater level and temperature, surface water stage and temperature, streambed/soil temperature profile, and time-lapse photos (insets in Figure 4.5-13).

Figure 4.5-13. Inset A (left) and B (right) show locations of aquatic transect stations with continuously measured parameters at FA-138 (Gold Creek) Focus Area. These study sections are intended to improve the understanding of GW/SW interaction processes relevant to aquatic habitat evaluations.

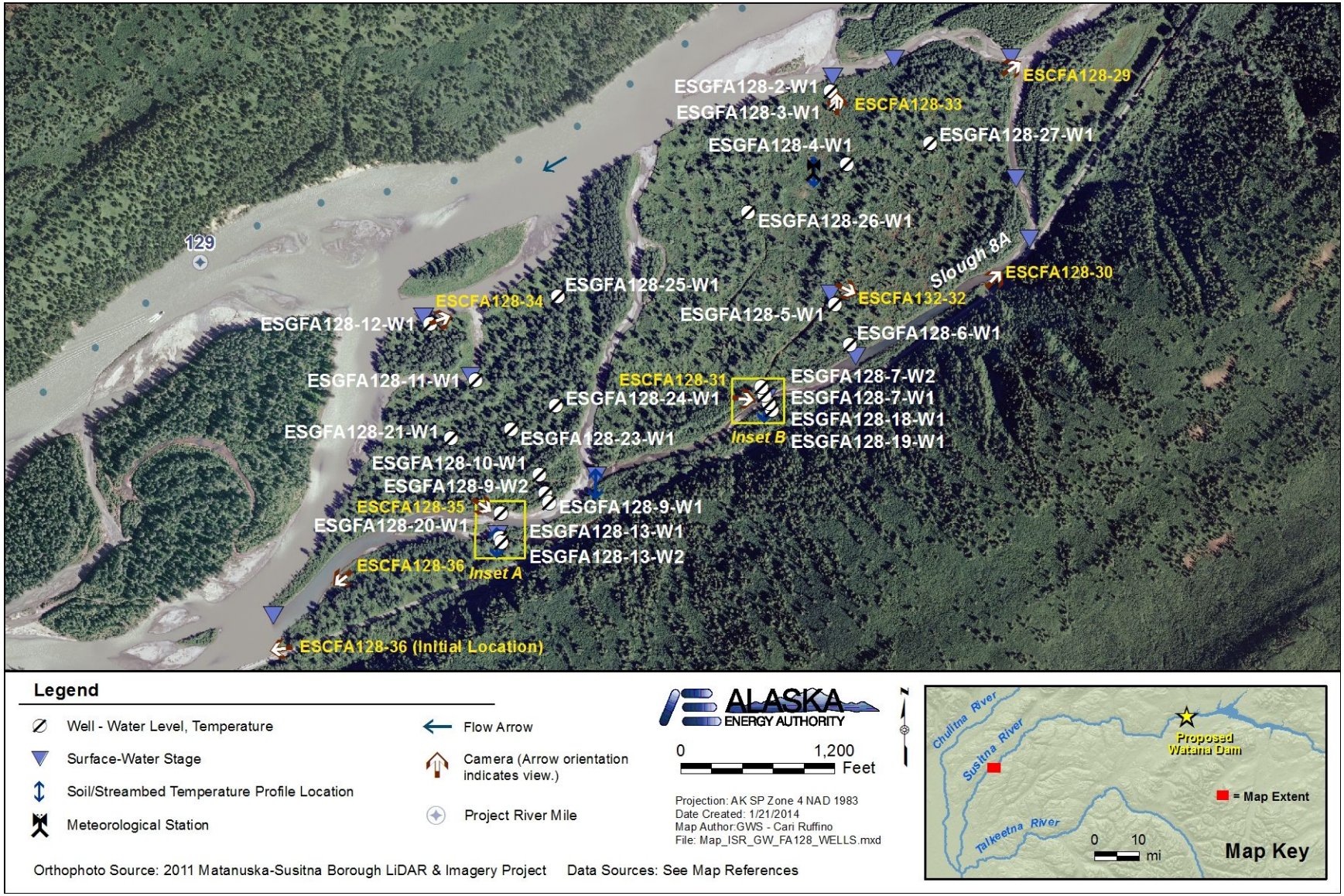

Figure 4.5-14. Well locations and continuously measured parameters at FA-128 (Slough 8A) Focus Area. Measured parameters include one or more of the following: groundwater level and temperature, surface water stage and temperature, streambed/soil temperature profile, and time-lapse photos (insets in Figure 4.5-15).

Figure 4.5-15. Inset A (left) and B (right) show locations of aquatic transect stations with continuously measured parameters at FA-128 (Slough 8A) Focus Area. These study sections are intended to improve the understanding of GW/SW interaction processes relevant to aquatic habitat evaluations.

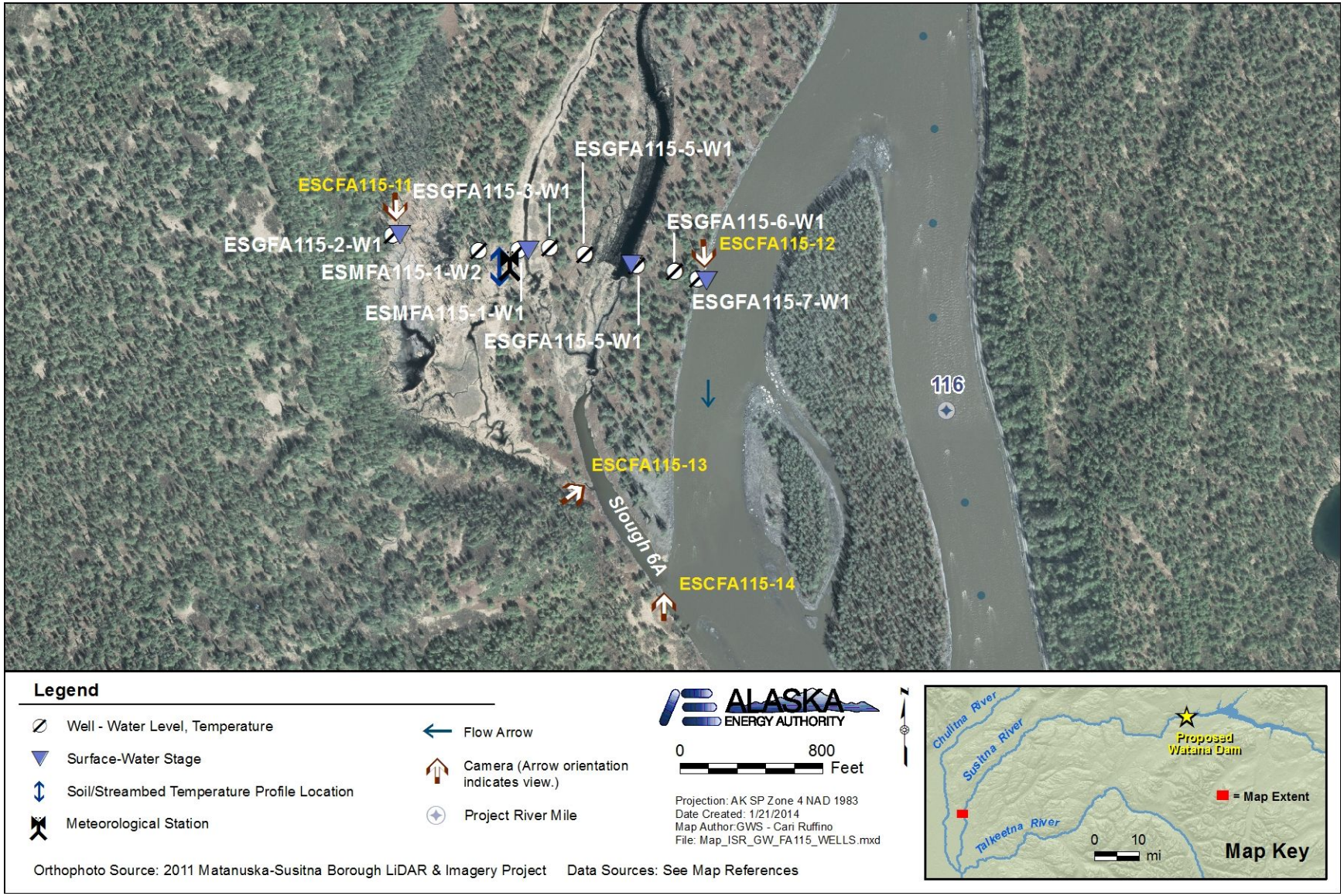

Figure 4.5-16. Well locations and continuously measured parameters at FA-115 (Slough 6A) Focus Area. Wells are used to obtain water levels and temperature. Surface water stage and temperature, streambed/soil temperature profile, and time-lapse camera locations are shown that record hydrologic and riparian features.

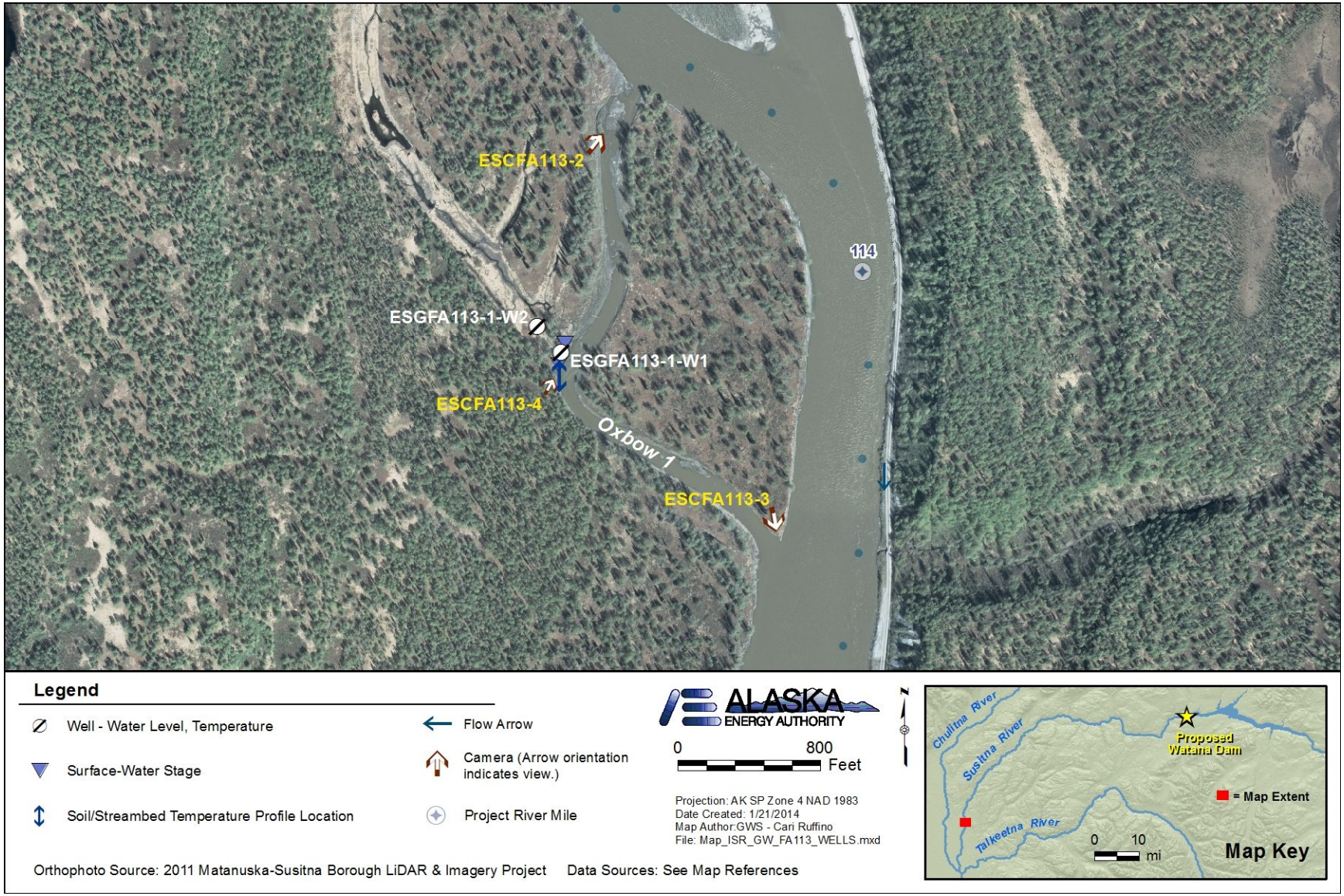

Figure 4.5-17. Well locations and continuously measured parameters at FA-113 (Oxbow 1) Focus Area. Wells are used to obtain groundwater levels and temperature. Surface water stage and temperature, streambed/soil temperature profile, and time-lapse camera locations are shown that record hydrologic and riparian features.

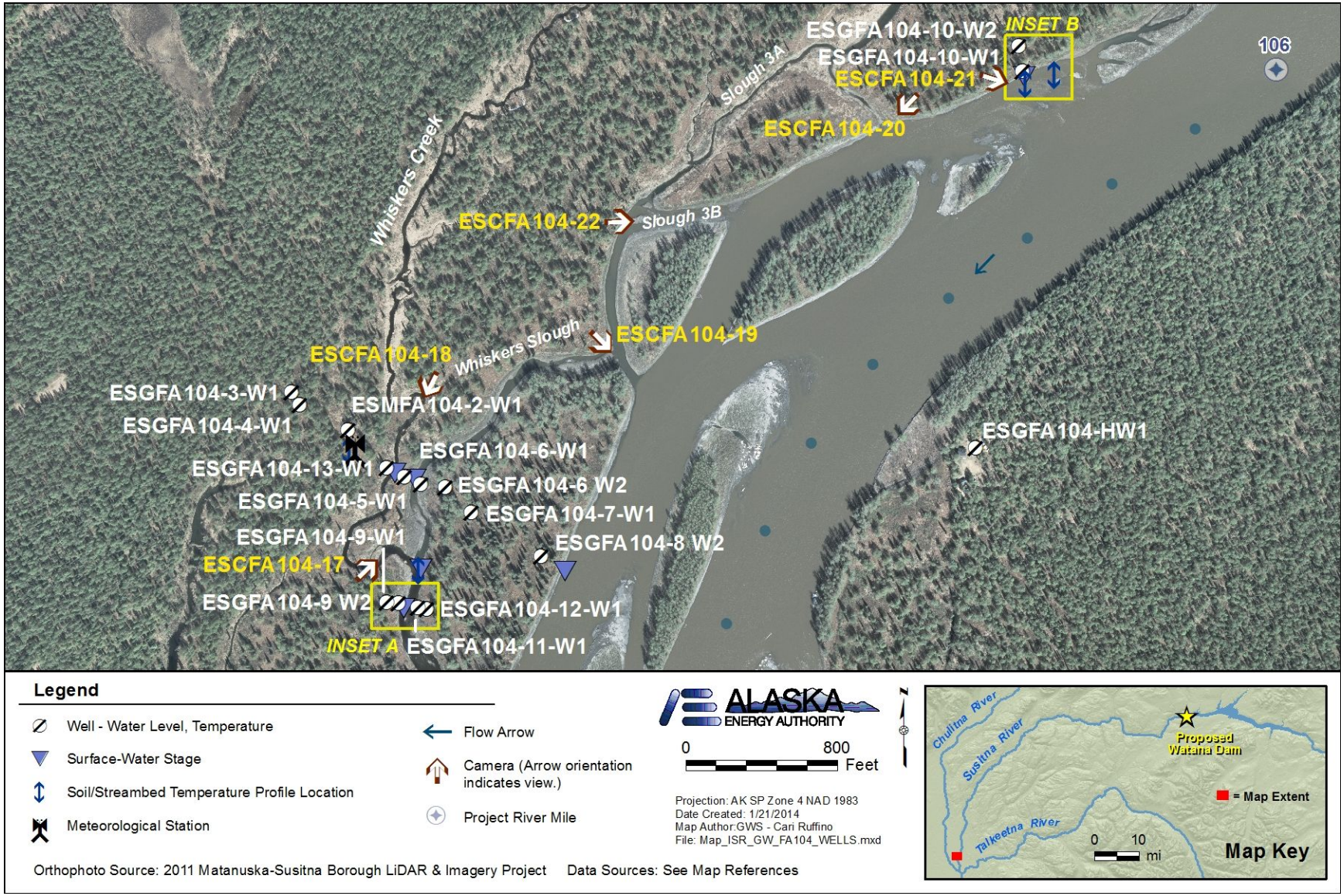

Figure 4.5-18. Well locations and continuously measured parameters at FA-104 (Whiskers Slough) Focus Area.
Wells are used to obtain groundwater levels and temperature. Surface water stage and temperature, streambed/soil temperature profile, and time-lapse camera locations are shown that record hydrologic and riparian features. Inset A (left) and B (right) of aquatic transect locations.

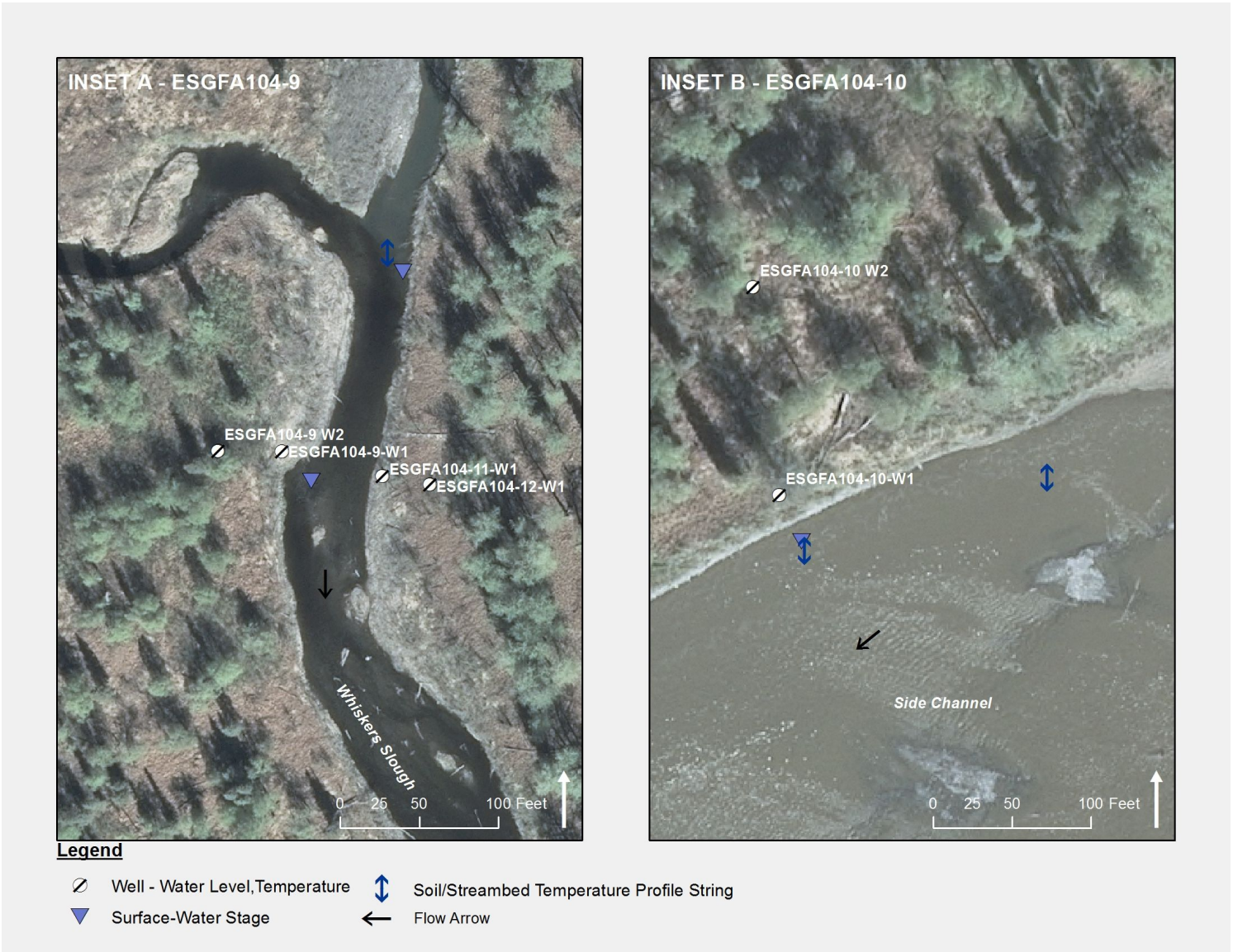

Figure 4.5-19. Inset A (left) and B (right) show locations of aquatic transects with continuously measured parameters at FA-104 (Whiskers Slough) Focus Area. These study sections are intended to improve the understanding of GW/SW interaction processes relevant to aquatic habitat evaluations.

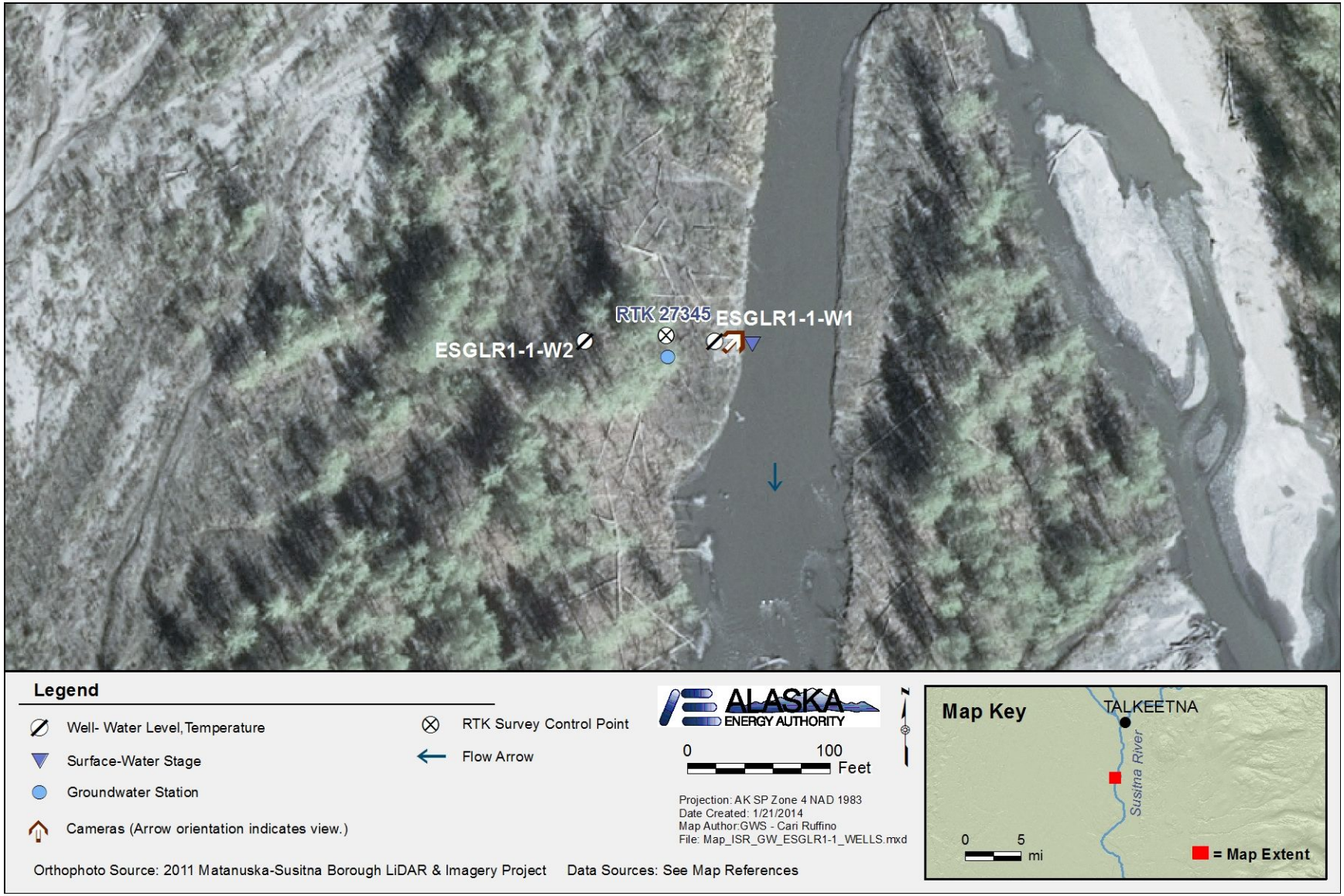

Figure 4.5-20. Well locations and continuously measured parameters at Lower River Transect Groundwater Station ESGLR1-1.
Wells are used to obtain groundwater levels and temperature. Surface water stage and temperature, streambed/soil temperature profile, and time-lapse camera locations are shown that record hydrologic and riparian features and processes important to study objectives.

Figure 4.5-21. Well locations and continuously measured parameters at Lower River Transect Groundwater Station ESGLR2-1.
Wells are used to obtain groundwater levels and temperature. Surface water stage and temperature, streambed/soil temperature profile, and time-lapse camera locations are shown that record hydrologic and riparian features and processes important to study objectives.

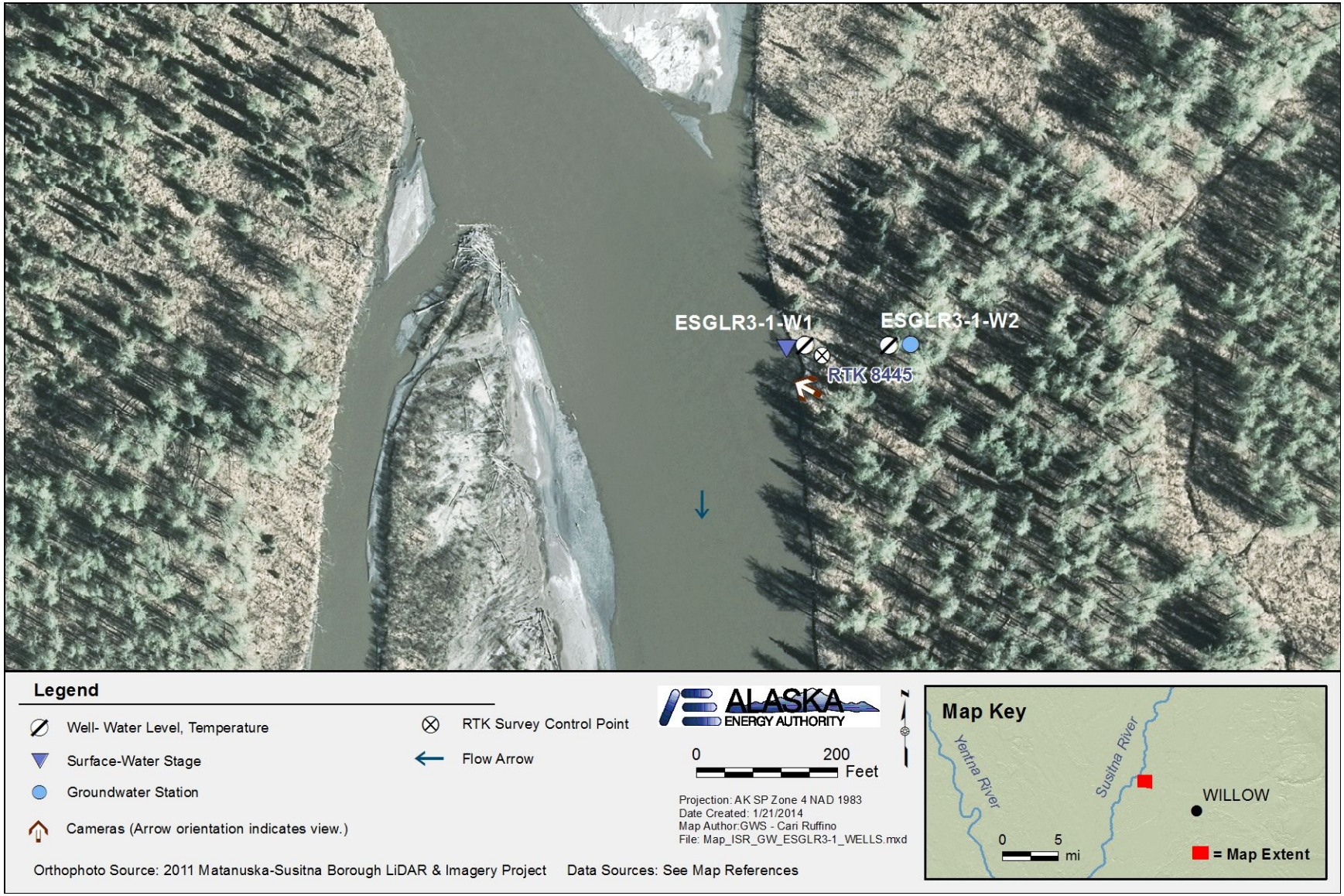

Figure 4.5-22. Well location and continuously measured parameters at Lower River Transect Groundwater Station ESGLR3-1.
Wells are used to obtain groundwater levels and temperature. Surface water stage and temperature, streambed/soil temperature profile, and time-lapse camera locations are shown that record hydrologic and riparian features and processes important to study objectives.

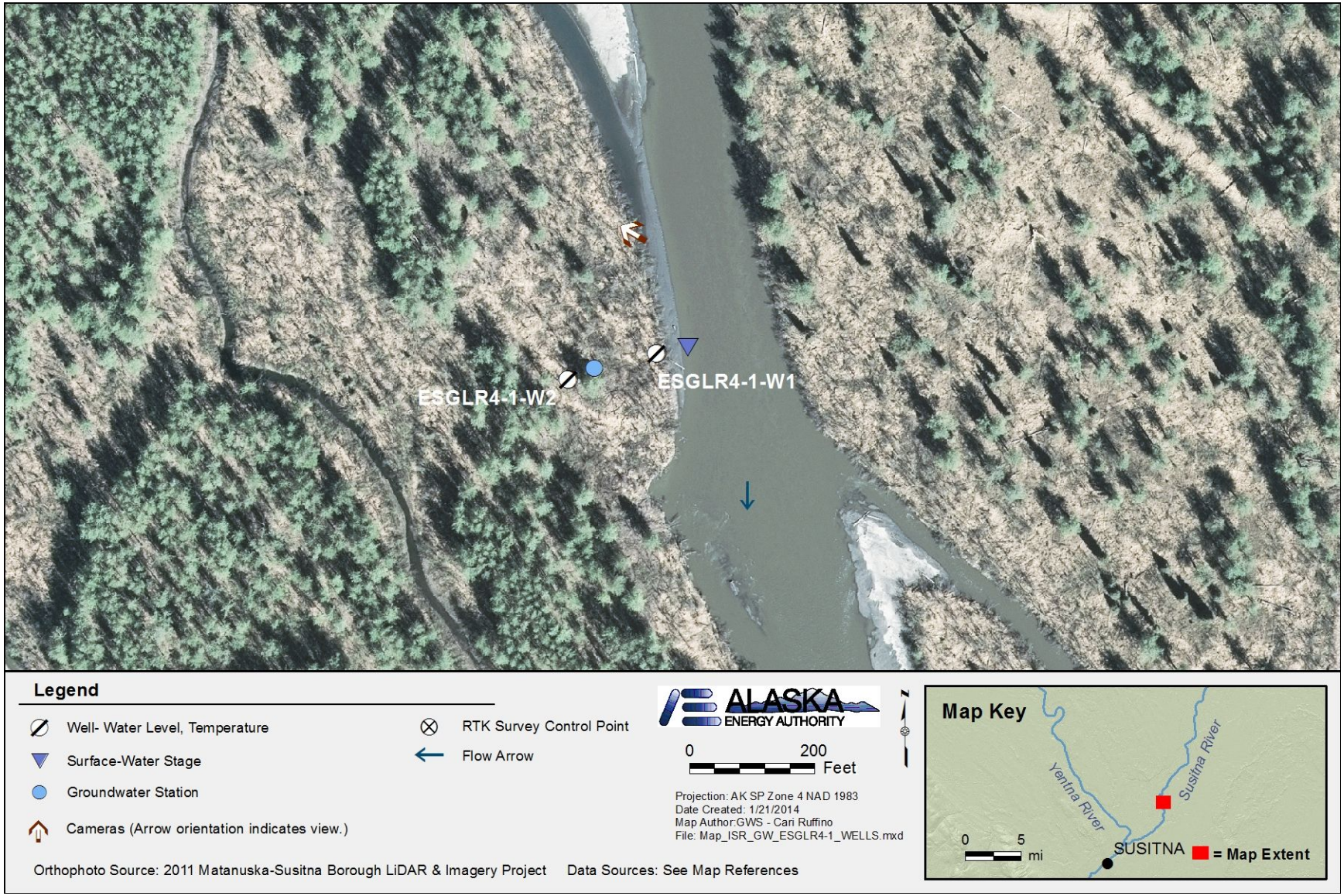

Figure 4.5-23. Well locations and continuously measured parameters at Lower River Transect Groundwater Station ESGLR4-1.
Wells are used to obtain groundwater levels and temperature. Surface water stage and temperature, streambed/soil temperature profile, and time-lapse camera locations are shown that record hydrologic and riparian features and processes important to study objectives.

Figure 4.5-24. Well locations and continuously measured parameters at Lower River Transect Groundwater Station ESGLR4-2.
Wells are used to obtain groundwater levels and temperature. Surface water stage and temperature, streambed/soil temperature profile, and time-lapse camera locations are shown that record hydrologic and riparian features and processes important to study objectives.

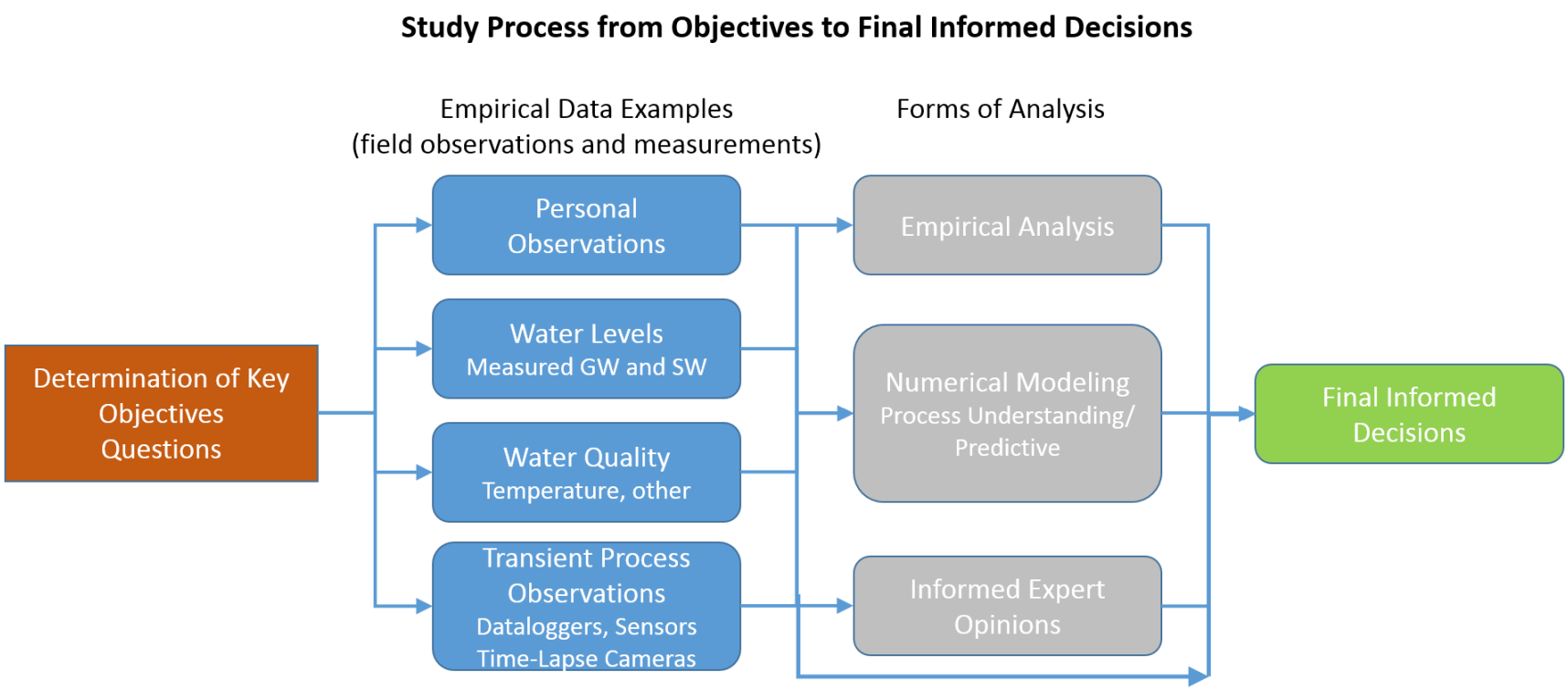

Figure 4.5-25. Process of using empirical data, observations, numerical modeling and concluding analysis to evaluation hydrology processes and interactions.

Figure 4.6-1. Image from FA-104 (Whiskers Slough), surface-water station ESSFA104-1.
In many of the study area locations, flooding is an annual event with ice jam flooding producing the highest water levels. Ice jam scars on trees were used to determine the past high flood elevations. The station was installed on the Cottonwood tree about 3 feet above the highest observed ice scars in trees in the general area

a) b)

Figure 4.6-2. A typical groundwater data station. a) tree used as mounting with radio antenna, solar panel, datalogger enclosure (white box mounted to tree, ESGFA128-12) and battery enclosure (gray box on the ground at base of tree) b) shows the complex wiring inside the white enclosure (ESGFA138-1) required to collect and transmit multi-sensor data such as streambed temperature profile strings and water quality sensors.

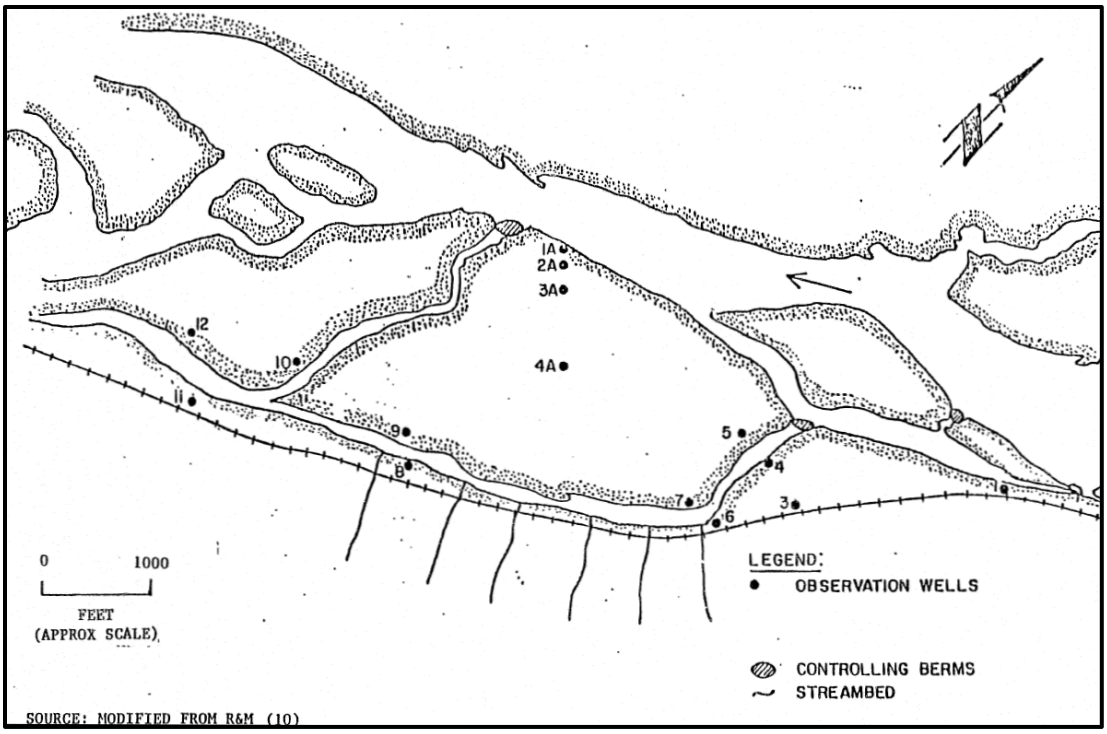

Figure 5.1-1 Example of 1980s reference map for slough hydrology studies in FA-128 (Slough 8A). Some of the old wells have been found and are being used for water level measurements (Figure from Harza-Ebasco Susitna Joint Venture, 1984).

Figure 5.2-1. October 31, 2013 aerial observations of the groundwater recharge zone for FA-144 (Slough 21), which is just downstream of the power line cut visible on the right-hand side of the image. The watershed areas upgradient of the Slough 11 serve as a collection area for snowmelt and rainfall, which partially contributes to the groundwater recharge in the slough.

Figure 5.3-1. October 3, 2013 flow conditions at the high pool elevation for the proposed reservoir operations, looking downstream at the left bank. The white helicopter helmet on the bank is marking the approximate high pool elevation line.

Figure 5.3-2. October 3, 2013 proposed high pool elevation, looking upstream at the left bank. Armored bank conditions are a result of fall and spring ice processes.

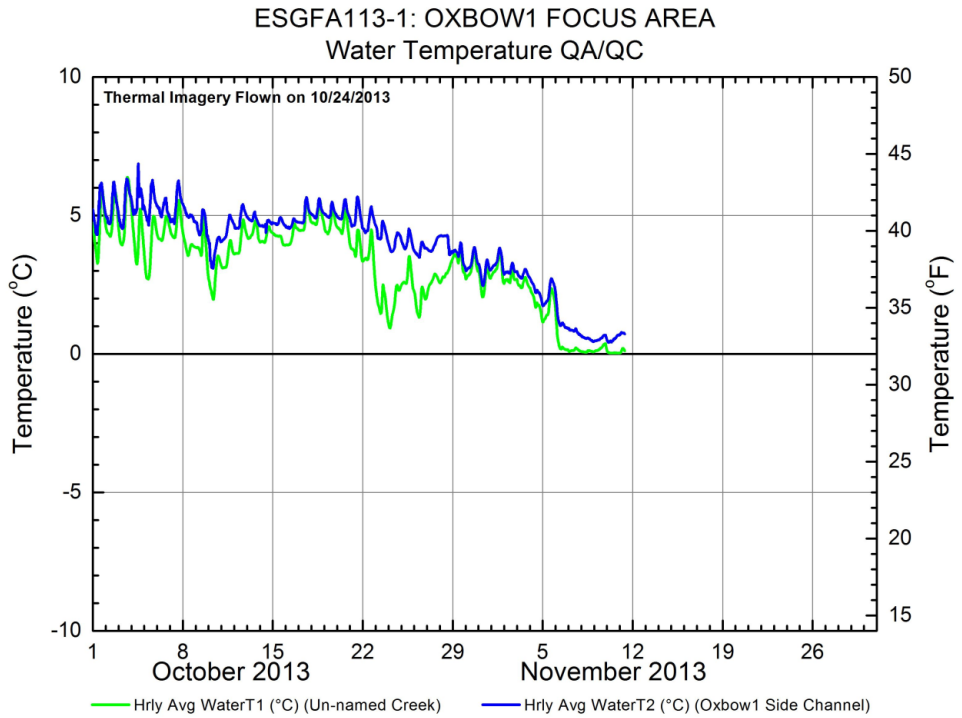

Figure 5.4-1. Example of water quality data processed to support Water Quality Study's Thermal Infrared (TIR) imagery in the FA-113 (Oxbow 1) Focus Area. Surface-water temperature data from different water bodies were processed for the imagery data collection period.

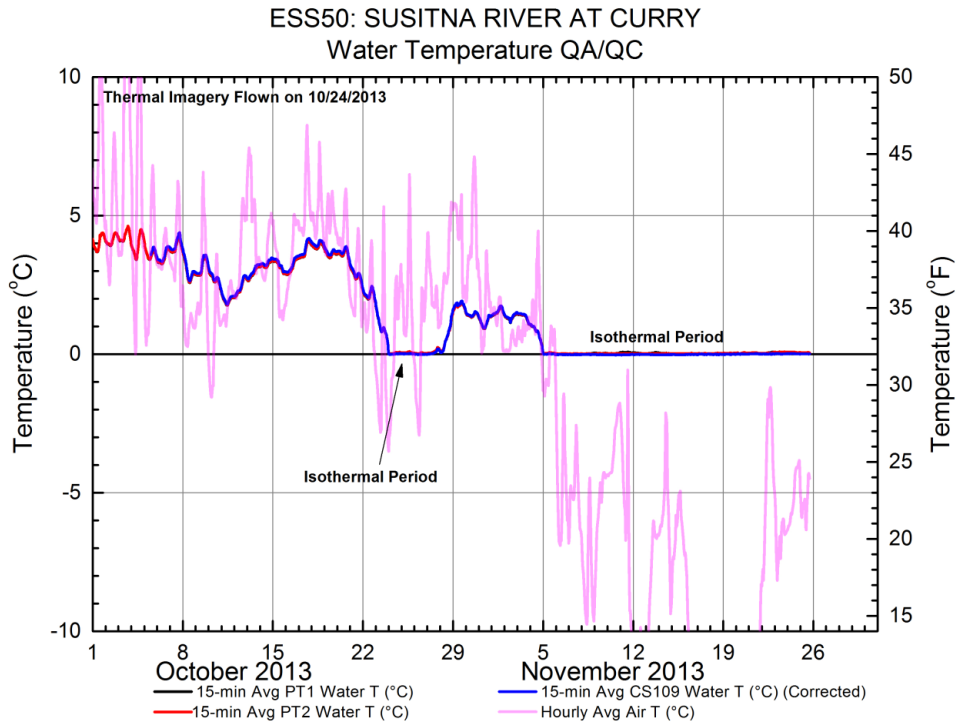

Figure 5.4-2. Example of water quality data processed to support Water Quality Study's Thermal Infrared (TIR) imagery in the Curry area at hydrology station ESS50.

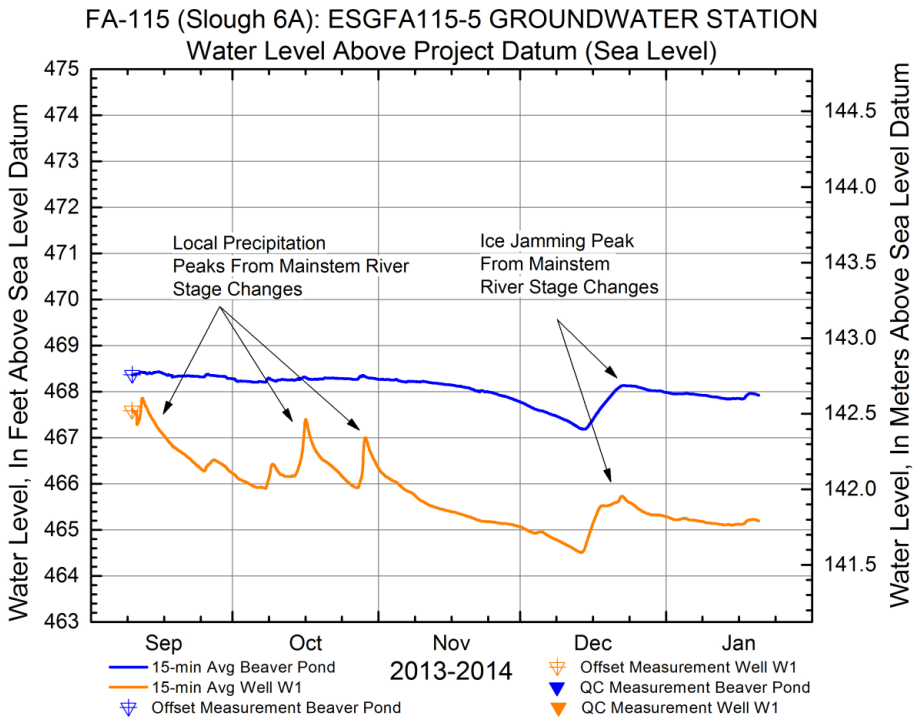

Figure 5.5-1. Example of groundwater and surface water level changes in the Riparian Transect in FA-115 (Slough 6A) from groundwater station ESGFA115-5. The relative changes in water surface elevations will be used to help develop a better understanding of the groundwater level dependency on mainstem river stage levels.

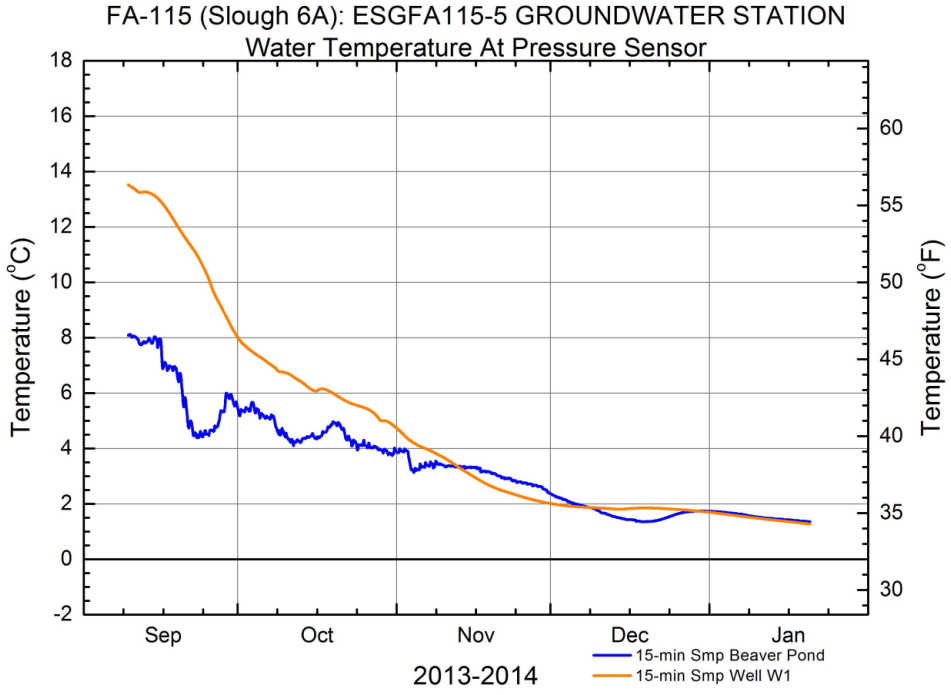

Figure 5.5-2. Example of groundwater and surface temperature changes in the Riparian Transect in FA-115 (Slough 6A) from groundwater station ESGFA115-5. The relative changes in temperature will be used to help develop a better understanding of the GW/SW interactions.

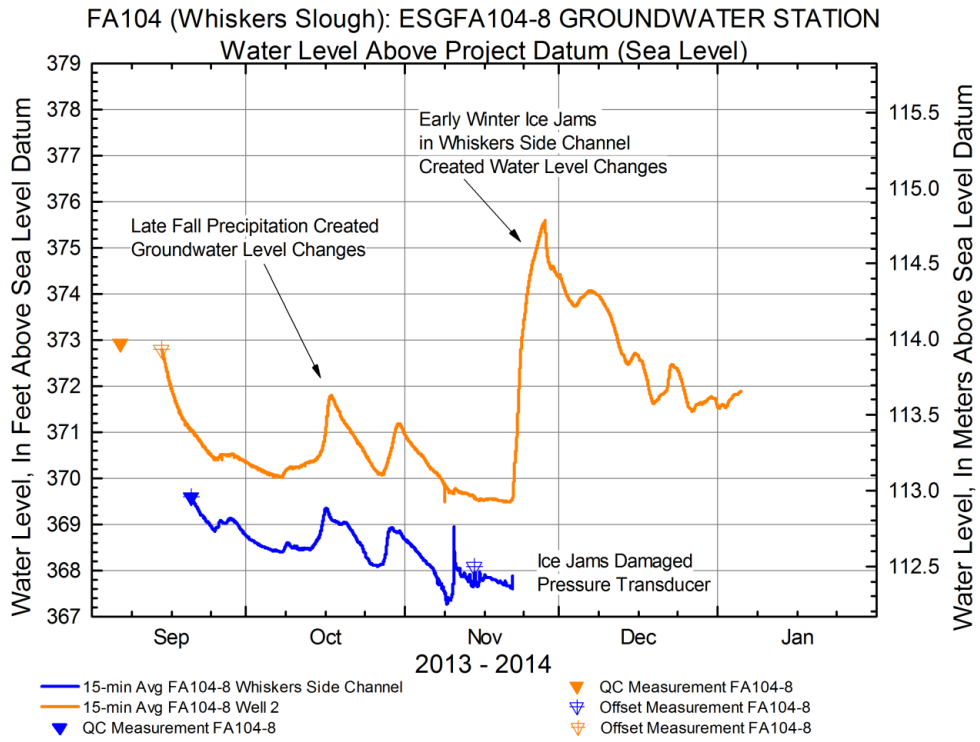

Figure 5.5-3. Example of groundwater level changes in the Riparian Transect in FA-104 (Whiskers Slough) from groundwater station ESGFA104-8. The early peaks were associated with late fall precipitation peaks and the larger peak in November is associated with early winter ice jamming on the mainstem of the Susitna River.

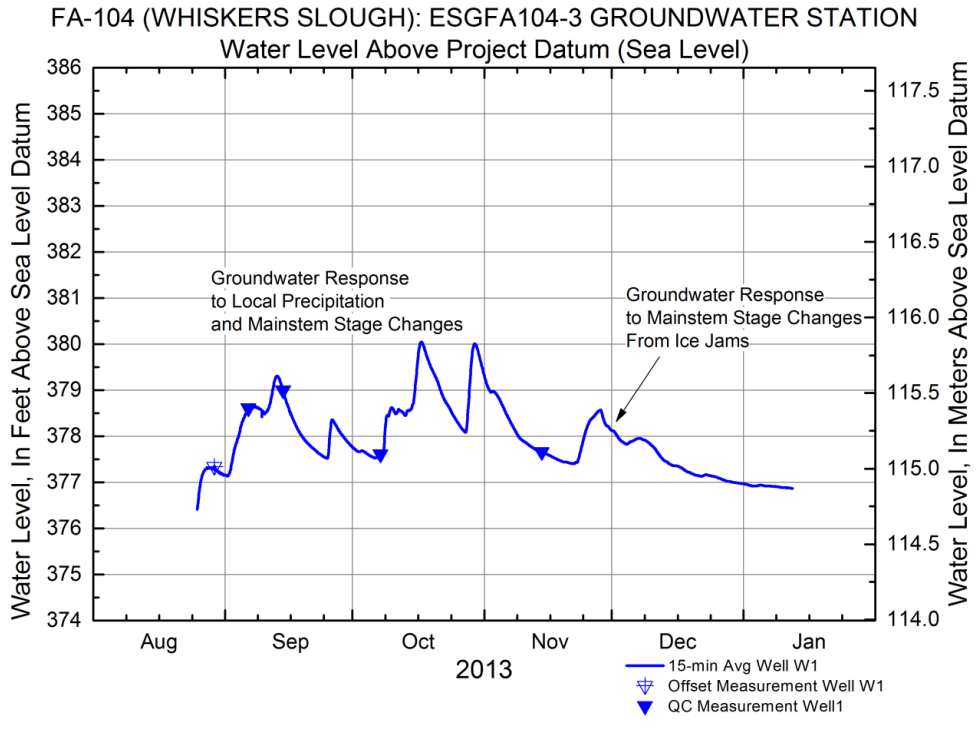

Figure 5.5-4. Example of groundwater level changes in the Riparian Transect in FA-104 (Whiskers Slough) from groundwater station ESGFA104-3. This station is at the upper end of the transect, furthest from the Susitna River.

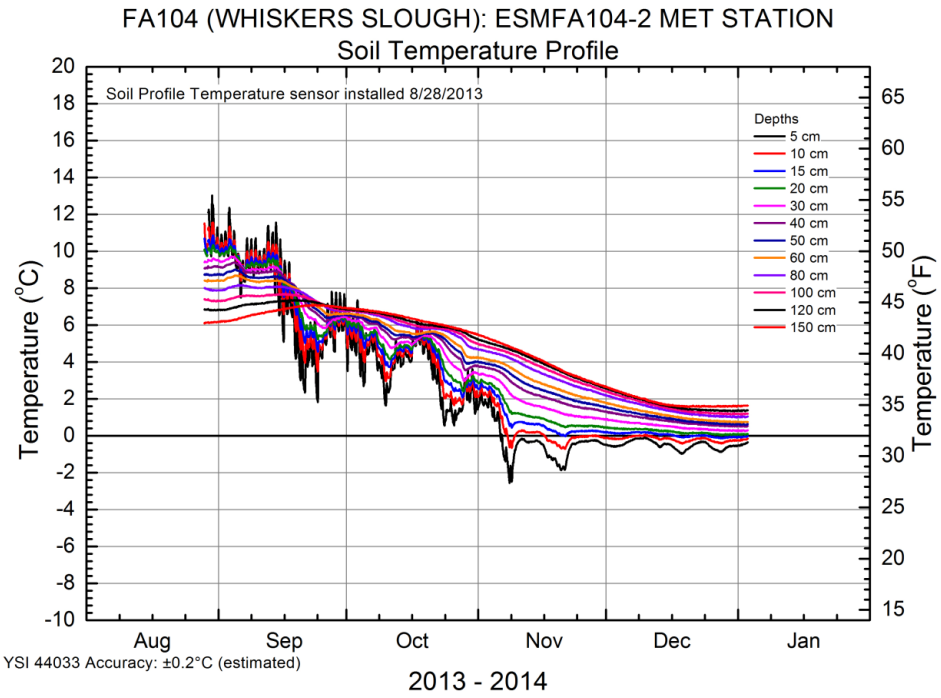

Figure 5.5-5. Example of soil temperature conditions in the Riparian Transect in FA-104 (Whiskers Slough) from meteorological station ESMFA104-2. This station is near the middle of the Riparian Transect. The soil temperature information is critical to the characterization of moisture movement between the land surface and groundwater.

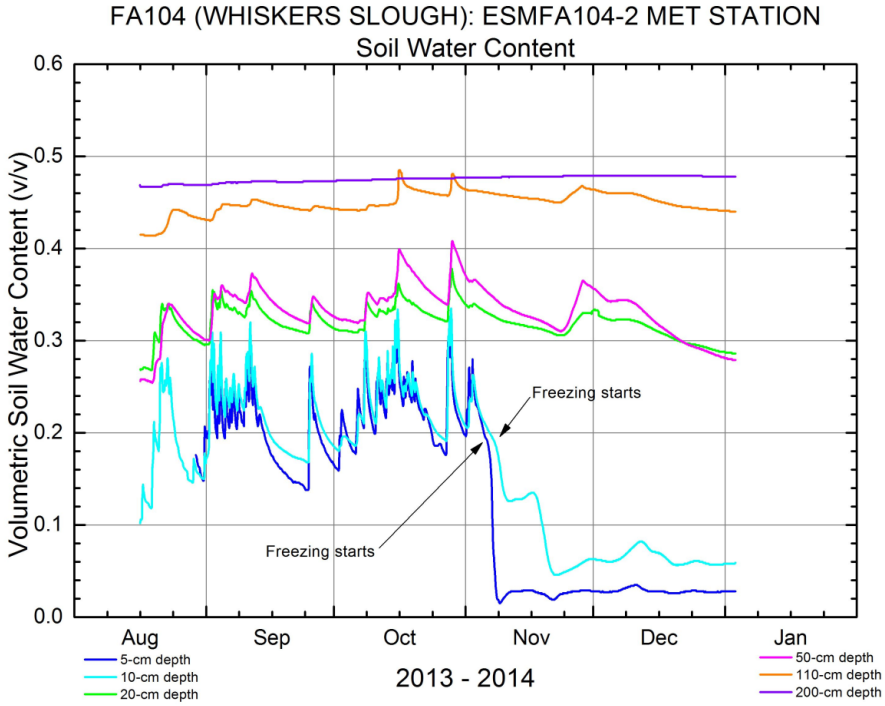

Figure 5.5-6. Example of soil moisture conditions in the Riparian Transect in FA-104 (Whiskers Slough) from meteorological station ESMFA104-2. Data is indicating soil moisture infiltration and freezing events.

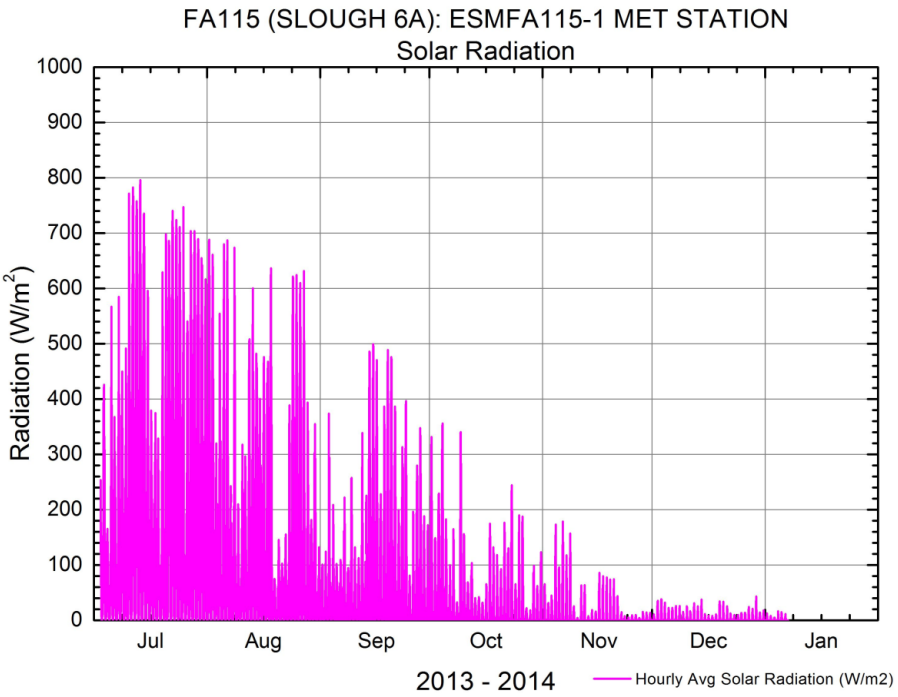

Figure 5.5-7. Example of solar radiation variation in the Riparian Transect in FA-115 (Slough 6A) from meteorological station ESMFA115-1. This station is near the middle of the Riparian Transect. The radiation data is being collected to help support evapotransportation (ET) analysis.

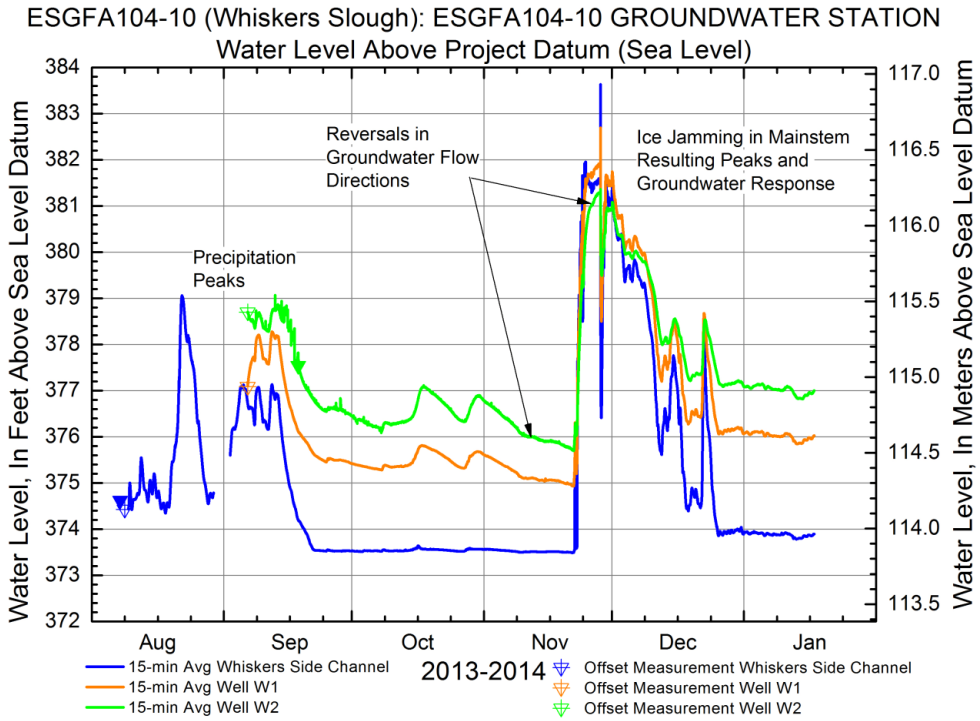

Figure 5.6-1. Example of groundwater and surface water measurements in the Aquatic Transect in FA-104 (Whiskers Slough) from groundwater station ESGFA104-10. The station is located at upstream end of Whiskers Side Channel. Surface-water gage levels are measured in the side channel and also in two wells on the right bank side (facing downstream).

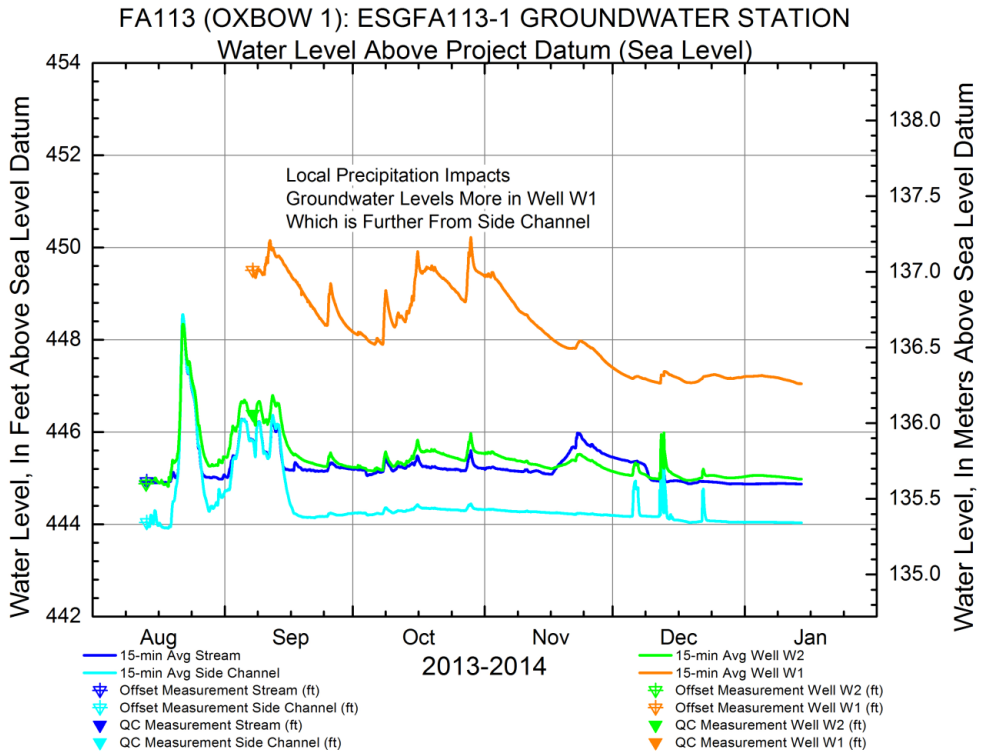

Figure 5.6-2. Example of groundwater and surface-water interactions in the Aquatic Transect in FA-113 (Oxbow 1) from groundwater station ESGFA113-1. This station has two groundwater wells, measurements in an unnamed stream flowing into the side channel and measurements in the side channel.

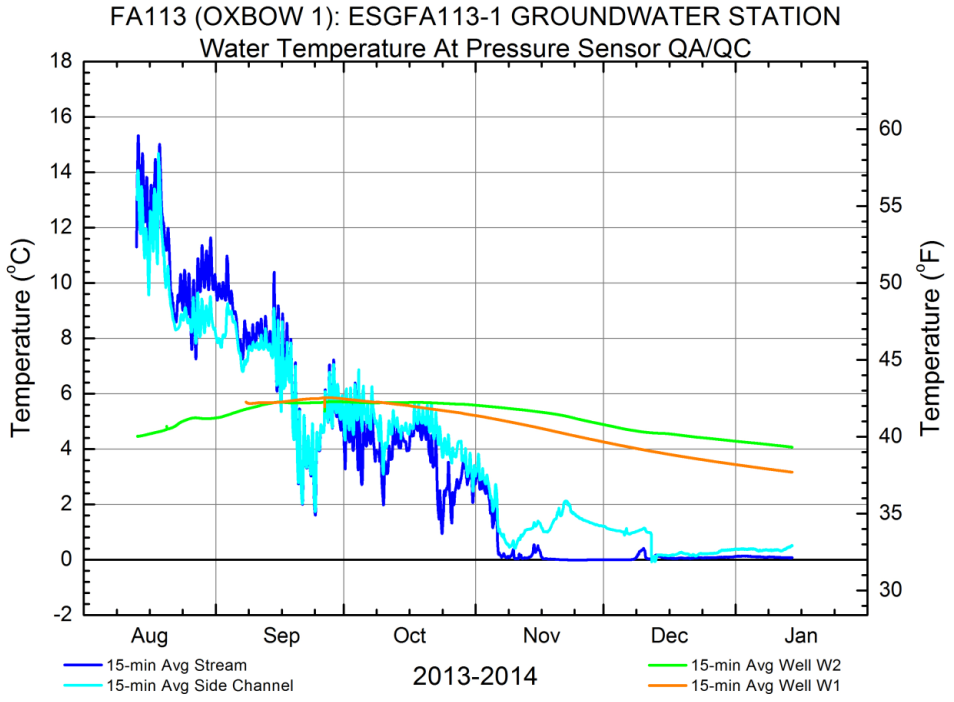

Figure 5.7-1. Example of water temperature in groundwater and surface water in the Aquatic Transect in FA-113 (Oxbow 1) from groundwater station ESGFA113-1.

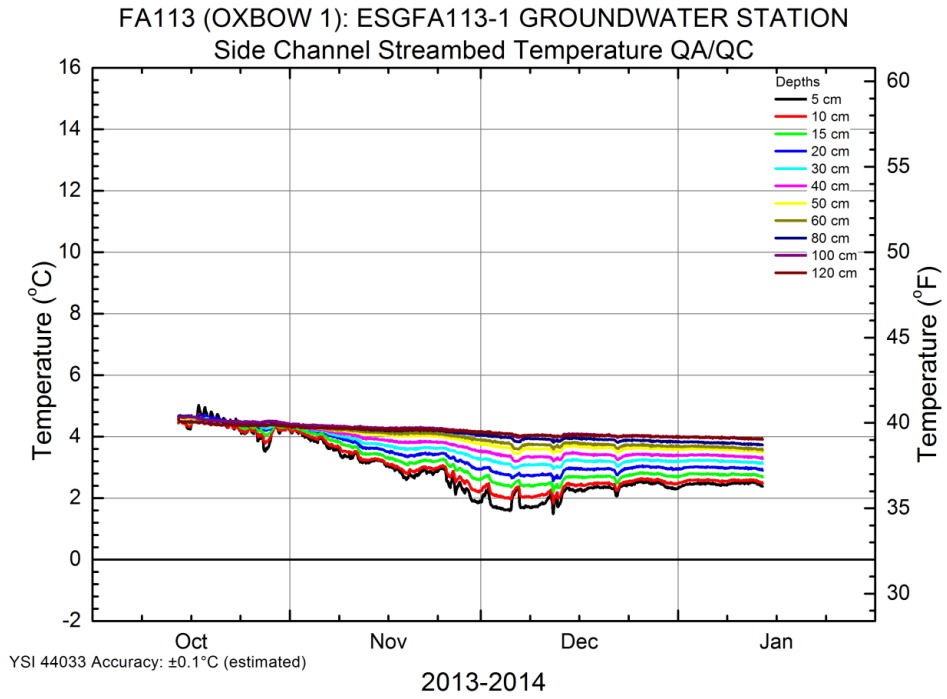

Figure 5.7-2. Example of streambed temperature measurements in the Aquatic Transect in FA-113 (Oxbow 1) from groundwater station ESGFA113-1.

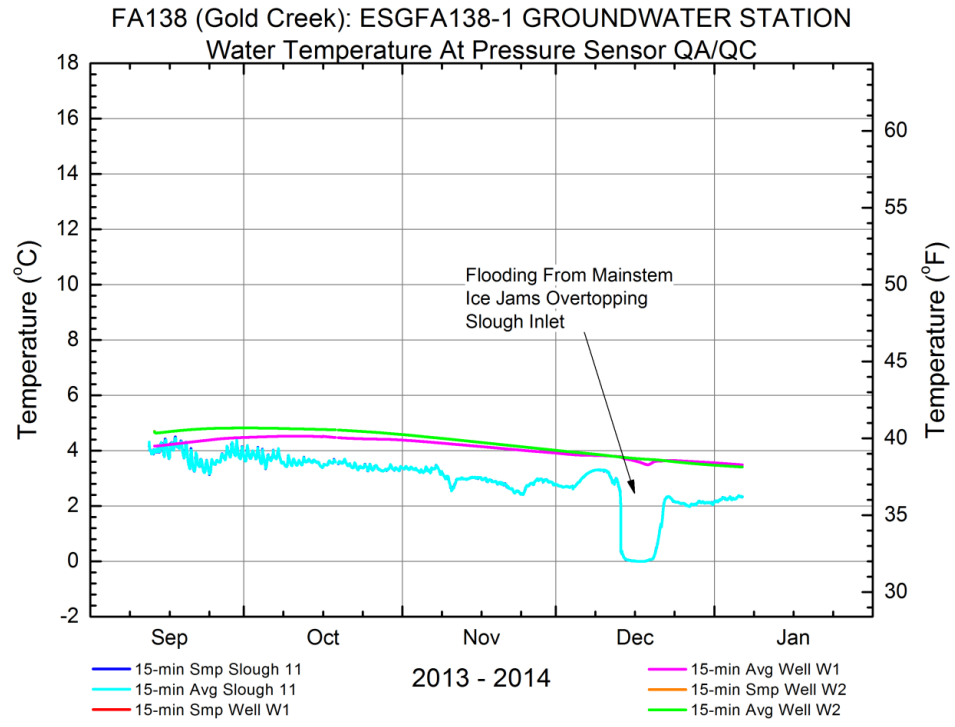

Figure 5.7-3. Example of groundwater and surface water temperature at the Aquatic Transect in FA-138 (Slough 11) from groundwater station ESGFA138-1. Slough 11 was relatively warm until early winter ice jams on the mainstem caused overflow of colder water to go down the channel in the middle of December.

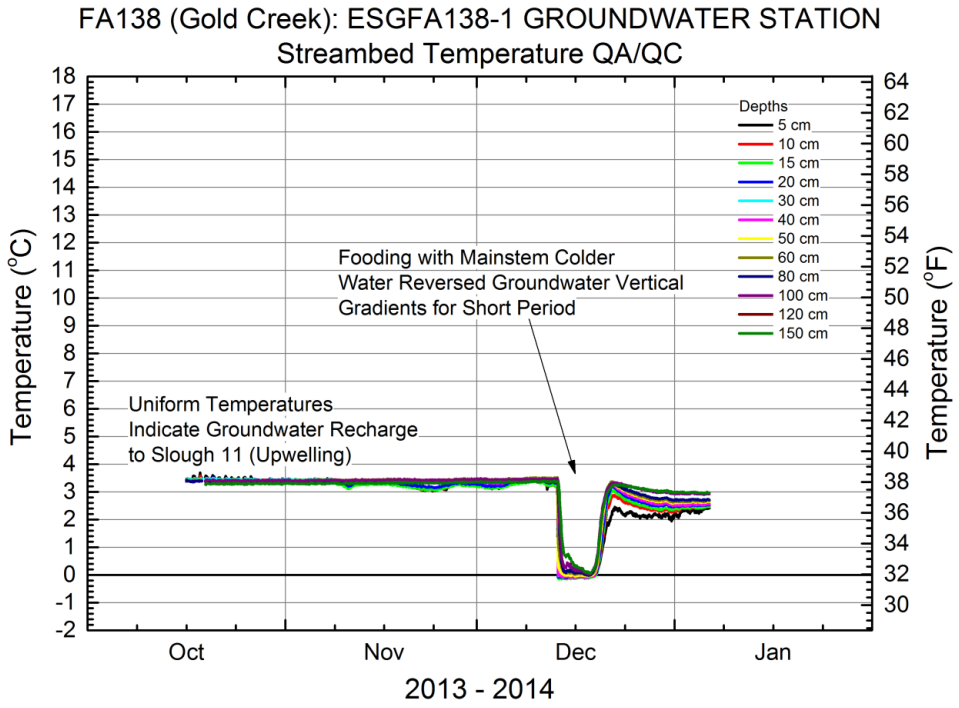

Figure 5.7-4. Example of streambed temperature measurements in the Aquatic Transect in FA-138 (Slough 11) from groundwater station ESGFA138-1. The temporary drop in temperatures during December was from over topping cold water flows from the mainstem due to winter ice jamming.

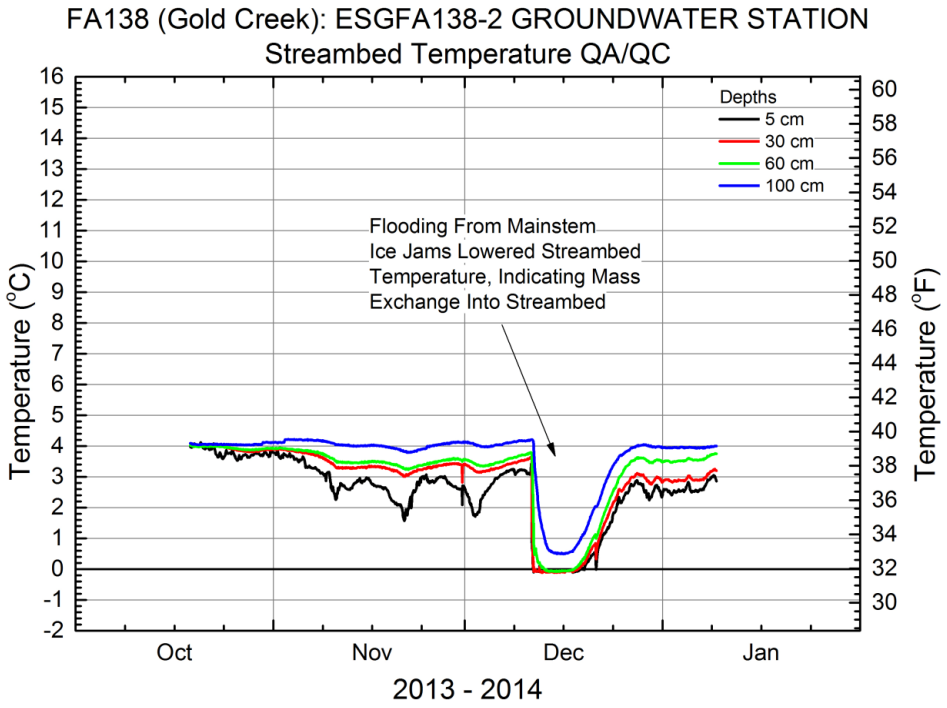

Figure 5.7-5. Example of selected streambed temperature measurements in the Aquatic Transect in FA-138 (Gold Creek) from groundwater station ESGFA138-2. The streambed temperatures are measured in Upper Side Channel 11.

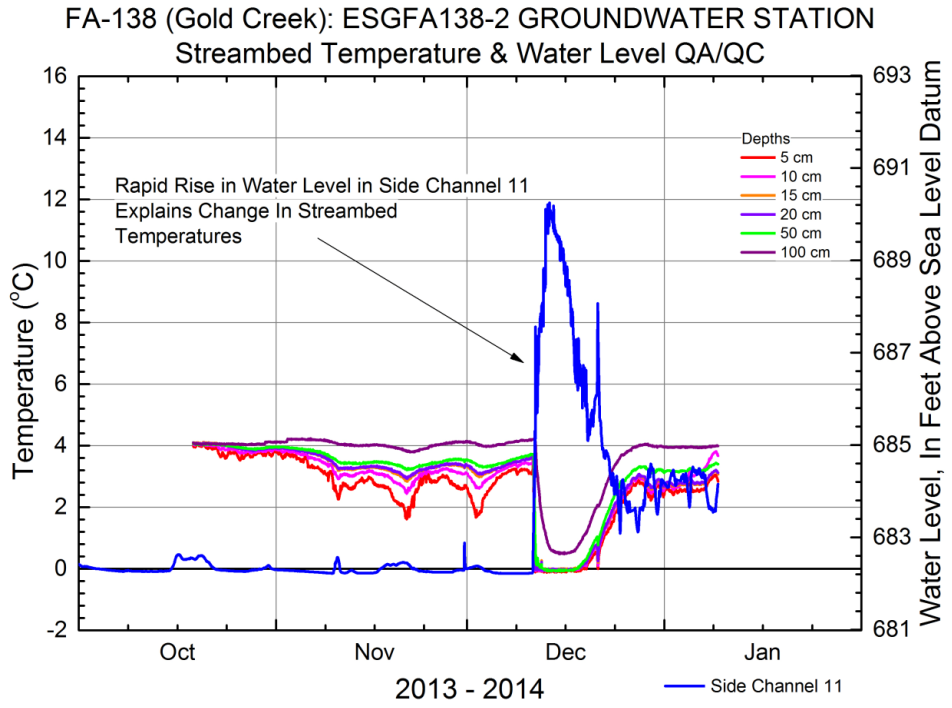

Figure 5.7-6. Example of streambed temperature measurement and the water level in Upper Side Channel 11 in the Aquatic Transect in FA-138 (Gold Creek) from groundwater station ESGFA138-2. The drop in streambed water temperature is correlated with the rapid change in water levels due ice jamming in the mainstem Susitna River.

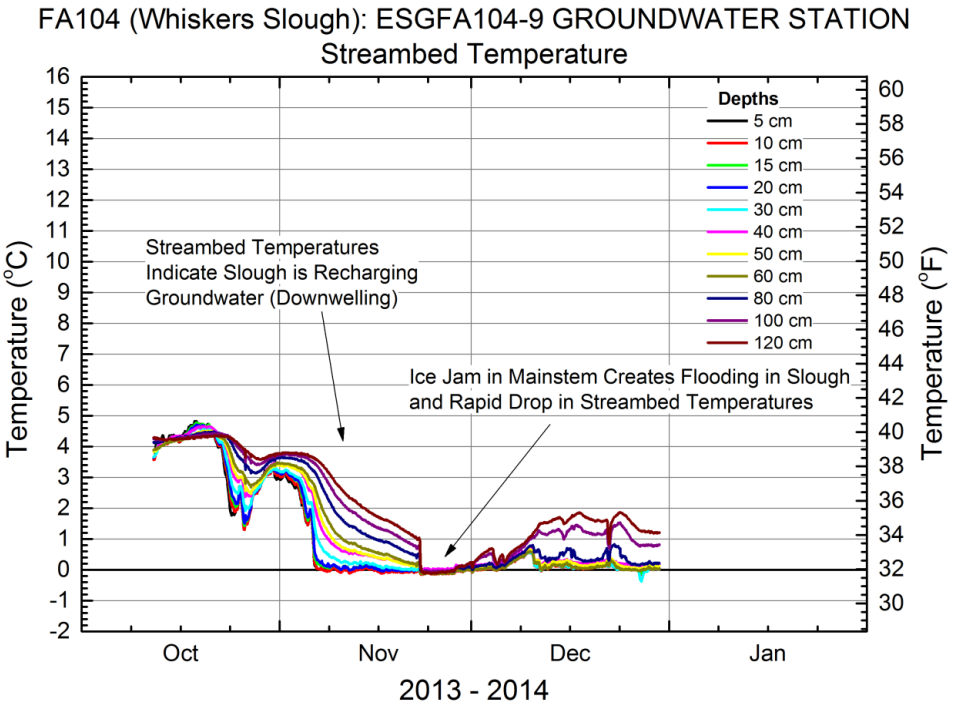

Figure 5.7-7. Example of streambed temperature measurement in the Aquatic Transect in FA-104 (Whiskers Slough) from groundwater station ESGFA104-9. This station is located at the lower end of Whiskers Slough.

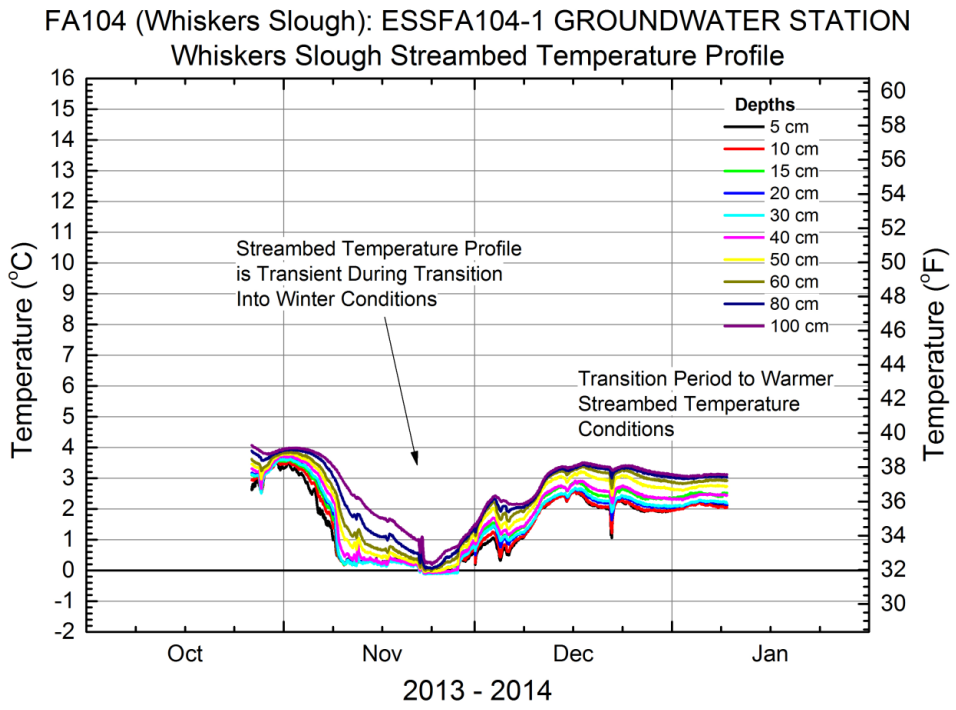

Figure 5.7-8. Example of streambed temperature measurement in the Aquatic Transect in FA-104 (Whiskers Slough) from surface-water station ESSFA104-1. This station is located in the middle of Whiskers Slough, near the confluence with Whiskers Creek.

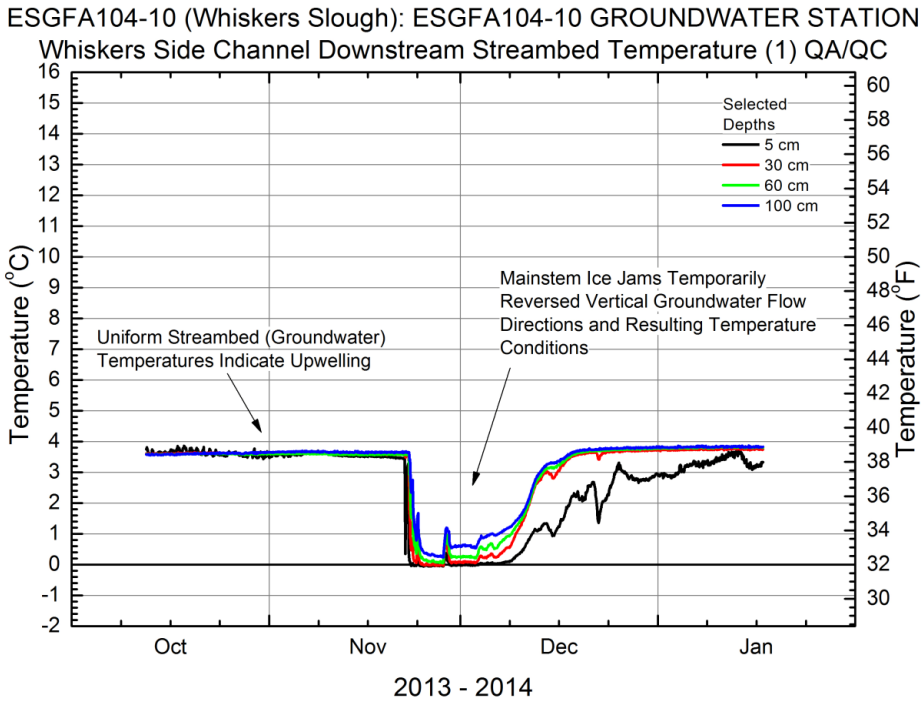

Figure 5.7-9. Example of streambed temperature measurement in the Aquatic Transect in FA-104 (Whiskers Slough) from groundwater station ESGFA104-10. This is the downstream streambed profile. This station is located at the upstream end of Whiskers Side Channel.

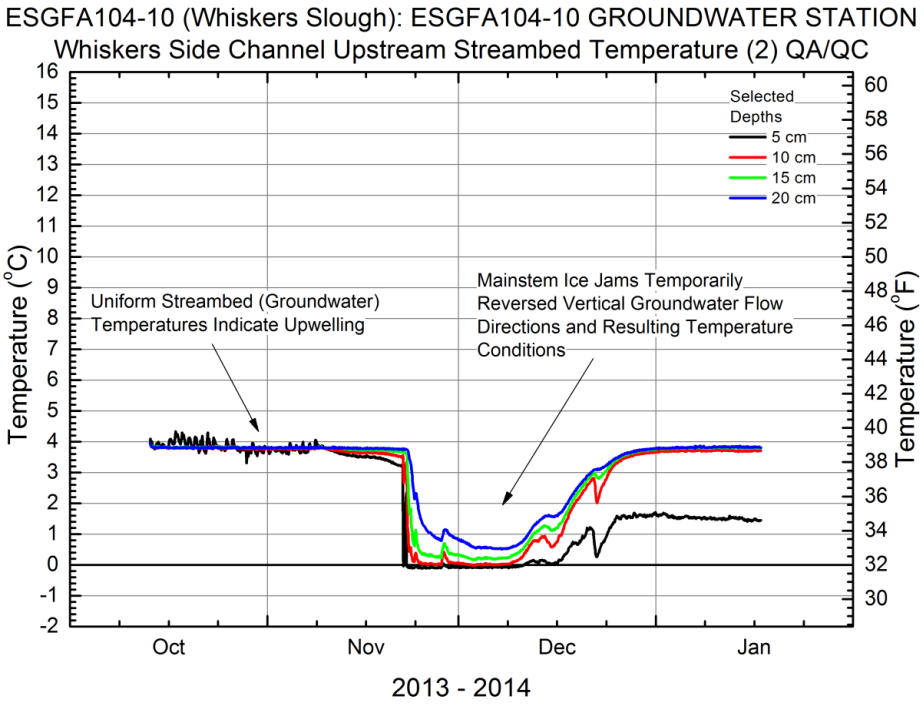

Figure 5.7-10. Example of streambed temperature measurement in the Aquatic Transect in FA-104 (Whiskers Slough) from groundwater station ESGFA104-10. This is the upstream streambed profile sensor at the station (Figure 4.5-19). This station is located at the upstream end of Whiskers Side Channel.

Figure 5.7-11. Example of uses for time-lapse images in FA-128 (Slough 8A) from surface-water station ESGFA128-1. This station is located at the confluence of Slough 8A and a side channel. Images also detect fish presence in the clear slough water.

Figure 5.7-12. Example of uses for time-lapse images in FA-128 (Slough 8A) from surface-water station ESGFA128-1. This station is located at the confluence of Slough 8A and a side channel. Images also detect wildlife presence at the interface of clear slough water and turbid water that is coming from mainstem into the side channel.

Figure 5.8-10. Example of slough conditions in FA-104 (Whiskers Slough) from camera station ESCFA104-22. The image was taken at 15:15 on November 21, 2013. Ice cover was developed over the slough and recent temperature had been well below freezing.

Figure 5.8-11. Example of slough conditions in FA-104 (Whiskers Slough) from camera station ESCFA104-22. The image was taken at 11:00 on November 22, 2013. Ice cover was developed over the slough and recent temperature had been well below freezing.

Figure 5.8-12. Example of slough conditions in FA-104 (Whiskers Slough) from camera station ESCFA104-22. The image was taken at 13:15 on November 23, 2013. Ice cover was developed over the slough and recent temperature had been well below freezing.

Figure 5.9-1. Example of a home owner well that has had a self-logging pressure transducer added, which record water level and temperature. This well is in FA-138 (Gold Creek) Focus Areas and adjacent to Slough 11. It is groundwater station ESGFA138-HW3. Data is only accessible during site visits.