Susitna-Watana Hydroelectric Project
(FERC No. 14241)

Fish and Aquatics Instream Flow Study
Study Plan Section 8.5

2014-2015 Study Implementation Report

Appendix E

Fish Habitat Modeling Data:
Surficial Substrate and Cover Characterization and Salmon Spawning Observations by Focus Area

Prepared for

Alaska Energy Authority

SUSITNA-WATANA HYDRO

Clean, reliable energy for the next 100 years.

Prepared by

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LIST OF ACRONYMS AND SCIENTIFIC LABELS

Abbreviation	Definition
2-D	2-Dimensional
AEA	Alaska Energy Authority
ARIS	Adaptive Resolution Imaging Sonar
FA	Focus Area
FDA	Fish Distribution and Abundance
FERC	Federal Energy Regulatory Commission
GIS	Geographic Information System
HSC	Habitat Suitability Criteria
HSI	Habitat Suitability Indices
IFS	Fish and Aquatics Instream Flow (Study 8.5)
ISR	Initial Study Report
LR	Lower Susitna River Segment, PRM 102.4 to PRM 0
MR	Middle Susitna River Segment, PRM 187.1 to PRM 102.4
PRM	Project River Mile
Project	Susitna-Watana Hydroelectric Project
QA/QC	Quality Assurance/Quality Control
RSP	Revised Study Plan
USGS	United States Geological Survey
VB	Visual Basic

1. INTRODUCTION

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

1.1 Focus Area Surficial Substrate Characterization

The focus of the IFS study has been on establishing a set of analytical tools/models based on the best available information and data that can be used to define Existing Conditions, i.e., without Project, and how these resources and processes will respond to alternative Project operational scenarios. As described in the FERC-approved Study Plan (AEA 2012), 2-Dimensional (2-D) hydraulic modeling will provide the greatest resolution for defining habitat-flow relationships and sediment transport relationships within the Susitna River. The physical parameters are modeled using 2-D hydraulic models, which are combined with Habitat Suitability Criteria (HSC) for the species of interest to calculate usable area of habitat. The habitat area calculations are made using geographic information system (GIS) tools to integrate hydraulic output data with other parameters such as groundwater, water quality, substrate, and cover. Data dependencies for the habitat modeling include output from hydraulic models for open-water and ice process simulations, data on channel morphology and substrate, groundwater data, water quality data, and biological information such as species periodicity, distribution and abundance, and HSC.

Because the flow dynamics of the Susitna River are complex, it was reasoned that concentrating study efforts across resource disciplines within specific locations would provide the best opportunity for understanding flow interactions and evaluating potential Project effects; therefore, major emphasis was placed on selecting those specific locations, termed Focus Areas (Initial Study Report [ISR] Study 8.5, Part A, Section 4.2). Ten Focus Areas (FA) were identified to describe MR habitats. These included FA-104 (Whiskers Slough), FA-113 (Oxbow 1), FA-115 (Slough 6A), FA-128 (Slough 8A), FA-138 (Gold Creek), FA-141 (Indian River), FA-144 (Slough 21), FA-151 (Portage Creek), FA-173 (Stephan Lake Complex), and FA-184 (Watana Dam) (*Adjustments to Middle River Focus Areas*, submitted to the FERC May 31, 2013 [R2 2013]). Bathymetric and hydraulic surveys of the first seven of the Focus Areas occurred in 2013, and the eighth one (FA-151 [Portage Creek]) was surveyed in 2014; all eight of the measured Focus Areas are located in the MR of the Susitna River below Devils Canyon. The two remaining Focus Areas are located above Devils Canyon and surficial substrates will be characterized when the bathymetry and hydraulic data are collected for those Focus Areas. Bathymetric and riparian elevation data were used to develop digital terrain models for each Focus Area. The digital terrain models allow 2-D modeling of hydraulic conditions during open-water and ice-cover periods (ISR Study 8.5, Part C, Appendix N: *Middle River Fish Habitat and Riverine Modeling: Proof of Concept* submitted to the FERC June 3, 2014 [R2 et al. 2014]). In addition to the elevation data used to develop the digital terrain models, fish habitat modeling requires the characterization of surficial substrates in each Focus Area. Surficial substrate characterization efforts were conducted during fall low flow periods (Table 1). Surficial substrate surveys were conducted following collection of bathymetric and hydraulic data to minimize any changes in surficial substrates associated with changes in beaver dams, or deposition or aggradation associated with spring break-up or high flow events. Surficial substrate surveys were coordinated with the different resource study leads to ensure that data necessary for developing the respective models were being collected. This memo summarizes surface substrate characterization efforts within the MR Focus Areas and outlines remaining efforts to support future use of the substrate information.

1.2 Cover GIS Layers by Focus Area

Similar to the characterization of surficial substrates, the type and distribution of features potentially used by fish for cover were characterized for each MR Focus Area below Devils Canyon and incorporated into modeled descriptions of potential fish habitat. Cover types consist of boulders, aquatic vegetation, overhanging vegetation, undercut banks, and small and large in-channel wood. Cover was characterized during the surficial substrate surveys; seven Focus Areas were surveyed in 2013 and one Focus Area was surveyed in 2014 (Table 1). Cover types have not been surveyed in the two remaining Focus Areas above Devils Canyon. To supplement the characterization of cover types during the field surveys, information on the size, type, and distribution of wood was provided by ISR Study 6.5 (Geomorphology), Part A, Appendix D: *Study Component 9: Large Woody Debris*, submitted to the FERC June 3, 2014 (Tetra Tech 2014). This memo presents additional information related to the characterization of physical cover attributes within MR Focus Areas.

1.3 Salmon Spawning Habitats

One objective of the IFS study plan is to quantify potential effects of Project operations on aquatic habitats in the MR of the Susitna River based on integrated hydraulic and biological modeling. Riverine modeling will be used to evaluate the effects of Project operations on the quality and quantity of aquatic habitat for target species and life stages. In particular, hydraulic and habitat modeling will quantify changes in potential salmon spawning habitat in response to hourly, daily, and seasonal changes in Susitna River flows associated with Project operations (ISR Study 8.5, Part C, Appendix N: *Middle River Fish Habitat and Riverine Modeling: Proof of Concept* [R2 et al. 2014]). Potential salmon spawning habitats are described as interactions of parameters such as depth, velocity, substrate, presence of upwelling/downwelling, and water temperature. The results of the habitat modeling efforts are expressed as weighted usable area under Existing Conditions and Project operations.

Weighted usable area represents potential habitat and does not predict the density or distribution of salmon redds. Total salmon escapement and antecedent flow conditions can affect the number and distribution of salmon redds. However, cell-by-cell comparisons of predicted spawning habitat (i.e., weighted able area) to observed salmon redds will help validate model predictions.

Salmon redds would not be expected to occur in cells that habitat modeling indicates are unsuitable for spawning within the flow associated with observed spawning activity. While not all cells containing high value weighted usable area are expected to correspond to observations of salmon redds, the preponderance of redd observations should correspond to cells with high value weighted usable area. Habitat modeling of Focus Areas is in progress and the results of aerial salmon spawning surveys conducted by IFS (Study 8.5) personnel in 2014 and other salmon spawning information within the MR Focus Areas below Devils Canyon will be used to evaluate habitat modeling results when available. This memo presents information on the distribution of salmon redds observed within each Focus Area in 2013 and 2014 and as reported in instream flow studies conducted in the 1980s.

1.4 Macrohabitats

Ten Focus Areas, each encompassing from 0.5 to 1.8 linear miles of the mainstem Susitna River, were selected to describe MR habitat conditions. Each Focus Area is the subject of intensive investigation by multiple resource disciplines including Water Quality (Study 5.6), Geomorphology (Study 6.5), Fluvial Geomorphology Modeling (Study 6.6), Groundwater (Study 7.5), Ice Processes (Study 7.6), Fish and Aquatics Instream Flow (Study 8.5) and Riparian Instream Flow (Study 8.6). Using 2-D mesh consisting of tens of thousands of elements per Focus Area, the effects of Project operations will be translated from main channel, reach scale effects to lateral habitats under Existing Conditions and alternate operational scenarios. Fish habitat modeling results associated with each element of the 2-D mesh will be summarized by flow condition for each Focus Area. In addition to summarizing habitat results by Focus Area, evaluation of Project effects can be summarized by macrohabitat type within each Focus Area. Characterization of macrohabitats within each Focus Area is provided by ISR Study 9.9 (Characterization and Mapping of Aquatic Habitats). This memo presents information on the use of macrohabitat characterizations as a supplementary method to evaluate Project effects.

2. STUDY AREA

The IFS program is focused on assessing flow-related effects of Project operations downstream of the proposed Watana Dam site (Project River Mile [PRM] 187.1). As established in the Study Plan (AEA 2012), the Susitna River is characterized by three segments: 1) Upper Segment that extends from the headwaters downstream to the proposed dam site (PRM 187.1); 2) Middle Segment Susitna River Segment (MR) that extends from PRM 187.1 downstream to the Three Rivers Confluence (Talkeetna River, Chulitna, and Susitna River) at PRM 102.4; and 3) Lower Susitna River Segment (LR) from PRM 102.4 to mouth (flows from the Deshka and Yentna River enter this segment). The 2-D hydraulic models portion of the IFS focuses on the MR which extends from PRM 187.1 downstream to the Three Rivers Confluence at PRM 102.4 (Figure 1). The development of the habitat-specific models is tailored around study sites in the MR Segment. Ten Focus Areas were established within this segment with the goal that data collection by all resource disciplines (i.e., fisheries, geomorphology, groundwater, riparian, ice processes, and water quality) would occur within the areas to provide an overall understanding of potential Project effects on basic physical, chemical, and ecological processes of the Susitna River (Figure 1). As of May 2015, bathymetry and hydraulics were measured for the eight Focus Areas below Devils Canyon and these Focus Areas are the subject of this memo. The two Focus Areas upstream of Devils Canyon (FA-173 [Stephan Lake Complex] and FA-184 [Watana Dam]) have not been surveyed.

3. METHODS

3.1 Focus Area Surficial Substrate Characterization

During 2013 and 2014, physical and hydraulic data collection within the MR Segment included measurement of hydraulic boundary conditions, stage and discharge measurements, bathymetric surveys, velocity mapping, roughness (channel substrate), and cover determinations at eight Focus Areas: FA-104 (Whiskers Slough), FA-113 (Oxbow 1), FA-115 (Slough 6A), FA-128 (Slough 8A), FA-138 (Gold Creek), FA-141 (Indian River), FA-144 (Slough 21), and FA-151 (Portage Creek). A description of the sampling methods utilized to characterize channel substrate within each of the eight sampled Focus Areas is presented below.

In late September 2013, IFS biologists from R2 Resource Consultants (R2) and Miller Ecological Services worked with Fluvial Geomorphology modelers (ISR Study 6.5 and 6.6) to record size classifications of surficial substrate at the lower seven Focus Areas in the MR below Devils Canyon (Table 1). Bathymetry and hydraulic data were collected at FA-151 (Portage Creek) in 2014 and surficial substrate was characterized on September 25, 2014. Surficial substrate assessment was conducted by two teams of two people by wading in shallow water areas under low flow conditions. Surveys were scheduled in late September when night-time air temperatures dropped below freezing and turbidity due to glacial meltwater was reduced. Main channel substrate in deep mid-channel areas was recorded along transects by probing with a long rod over the side of a jet boat. Transects were repeated at regular intervals at a frequency dependent on channel and substrate complexity in each Focus Area. The combined data collection of shoreline crews and boat crews resulted in a complete substrate survey of each Focus Area.

The same substrate categories as used for the HSC data collection were applied during the surveys. Substrate size (dominant, subdominant, and percent composition) within the Focus Area was characterized in accordance with a Wentworth grain size scale modified to reflect English units (Table 2). As described in the ISR Study 8.5, Part A, Section 4.5.2, substrate composition was simplified to include only two gravel size classes (small and large). Field personnel found it impracticable to attempt to accurately differentiate gravel composition into three size classes in turbid water conditions. Using two size classifications to describe gravel is consistent with substrate classifications used on numerous other HSC/Habitat Suitability Indices (HSI) curve development studies, and it was not anticipated to impact HSC/HSI curve development. Visual calibration of the size classes was made prior to the data collection by having each observer estimate substrate size classes within a given area and then measuring the substrate using a gravelometer (Potyondy and Bunte 2002). This calibration procedure was repeated periodically each day by all observers at each Focus Area.

The substrate categories were recorded on enlarged, laminated aerial photographs as polygons or point values on cross-sections. Photographs of field data sheets were taken after each field day as a backup copy of the field data. These polygons were then translated into a GIS layer for use in aquatic habitat modeling. Recent aerial photos were used as field maps to record substrate polygons, but in some cases there were discrepancies between the photos and channel shapes observed on the ground. For instance, laminated aerial field photos used to record the surficial substrate polygons at FA-151 (Portage Creek) were developed using 2011 images. Surficial substrates at FA-151 (Portage Creek) were recorded in September 2014, and while key features and the general shape of the Portage Creek delta remained consistent, some minor change was observed in the width and shape of small distributor channels. The GIS layer containing the substrate polygons was overlaid onto a base map of 2013 aerial photos for Quality Assurance/Quality Control (QA/QC) and presentation purposes. In some cases, the shape of the polygons recorded in September 2014 did not follow the shape of the channels observed in the underlying photos. For fish habitat modeling purposes, the substrate polygons should match the bathymetry of FA-151 (Portage Creek) observed and measured in 2014. Measurements of the channel bathymetry at FA-151 (Portage Creek) were collected in summer 2014 but were not yet available as of May 2015. Prior to finalizing the surficial substrate GIS layers, the shape of the substrate polygons should be compared to the bathymetry used to describe each Focus Area.

3.2 Cover GIS Layers by Focus Area

Coordinated surveys were performed by IFS (Study 8.5) and Geomorphology (Studies 6.5 and 6.6) staff during September 2013 and September 2014 to record physical cover attributes and characterize surficial substrate at eight Focus Areas in the MR below Devils Canyon (Table 1). For the purposes of the fish habitat modeling, cover habitat was characterized as: boulders, aquatic vegetation, overhanging vegetation, undercut bank and woody debris (Table 3). Cover features were identified during the 2013 and 2014 field surveys and mapped on enlarged, laminated aerial photographs as polygons. All cover within the active channel (i.e., below ordinary high water) was mapped such that features not wetted at the surveyed flow conditions would function as cover habitat at modeled higher flow conditions. Cover polygons mapped during the field surveys were digitized and geo-referenced into a GIS layer for use in the 2-D habitat modeling analysis.

Field maps used to record cover attributes consisted of 2011 or 2012 aerial orthographic photos and in some cases channel features on the field maps did not correspond with conditions encountered during the 2013 and 2014 field surveys. Following each survey, cover recorded on field maps was reviewed and compared to high resolution 2013 orthographic imagery of the Susitna River to reconcile potential differences in channel features between field photo maps and the more recent imagery. While the location of some beaver ponds and small changes in some macrohabitat features were observed, key features and channel morphology of the mainstem Susitna River remained consistent between 2011 and 2014.

Mapped cover features, in conjunction with other physical habitat data (e.g., substrate), were digitized using channel morphology measured during 2013 and 2014 channel profile surveys. Channel profile surveys were performed in 2013 within Focus Areas downstream of Devils Canyon, with the exception of FA-151 (Portage Creek) for which bathymetric data were collected in 2014 (Study 8.5, see AEA 2014).

To supplement the characterization of cover types during the field surveys, information on the size, type, and distribution of wood was provided by ISR Study 6.5 (Geomorphology), Part A, Appendix D: *Study Component 9: Large Woody Debris* (Tetra Tech 2014). As part of the large woody debris study, 2012 or 2013 aerial photos were used as a base to digitize large woody debris. Individual logs with a minimum length of 20 feet were digitized, and log jams were digitized as polygons. Results of the aerial photograph mapping of large woody debris were field verified during surveys conducted in 2013. To ensure consistency between studies, the study lead for the large woody debris survey participated in the substrate and cover characterizations of the seven Focus Areas surveyed in 2013.

Woody debris interacts with other natural processes (i.e., climate, hydrology, and erosion) to promote food production and create microhabitats suitable for virtually all species of juvenile salmonids at some point during their maturation. Large wood provides current breaks providing velocity shelter and summer and winter rearing habitat and winter refugia for juvenile salmonids. Spawning sites for adult salmonids often form in the presence of woody debris. The results of the large woody debris study (ISR Study 6.5 [Geomorphology], Part A, Appendix D: *Study Component 9: Large Woody Debris* [Tetra Tech 2014]) provided digitized locations of individual large wood pieces and log jams within each Focus Area below Devils Canyon, but the influence of large wood as fish cover extends beyond the footprint of the pieces of wood. For fish habitat modeling purposes, cover was assumed to be present within a one meter buffer around the footprint of the wood.

3.3 Salmon Spawning Habitats

The distribution of salmon spawning in the Middle Segment of the Susitna River Focus Areas has been recorded both during the current Project licensing effort and in association with studies conducted during the 1980s. Spatial mapping of salmon spawning activity in the Middle Susitna River has been completed in association with the following efforts: 1) 2014 IFS (Study 8.5) aerial spawning surveys, 2) IFS (Study 8.5) HSC sampling (AEA 2014), and 3) Salmon Escapement (Study 9.7) radio telemetry surveys (AEA 2014; *Adult Salmon Distribution and Habitat Utilization Study*, submitted to the FERC March 1, 2013 [LGL 2013]; *2014 Implementation and Preliminary Results*, submitted to the FERC September 30, 2014 [LGL 2014]) and 4) 1980s studies of the Middle Susitna River.

3.3.1 2014 Aerial Spawning Surveys

Aerial surveys to map areas of salmon redds and salmon spawning activity were conducted by helicopter within Focus Areas downstream of Devils Canyon in 2014. Surveys were performed during low flow conditions in September when salmon were actively spawning. The aerial surveys were performed by biologists with multiple years of experience conducting aerial salmon surveys in large, glacial river systems. Aerial surveys concentrated on the Focus Areas and covered the extent of all wetted main channel (i.e., main channel, side channel and tributary mouth) and off-channel (i.e., side slough and upland slough) habitat within each Focus Area. Aerial spawning surveys were conducted on September 10 and September 26 during the estimated peak of chum and sockeye salmon spawning (ISR Study 8.5, Part A, Appendix H, *Periodicity Tables*, submitted to FERC June 3, 2014 [R2 2014]). Susitna River discharge at the United States Geological Survey (USGS) Gold Creek Gage (No. 15292000) was approximately 16,000 cfs for the September 10 flight and 13,500 cfs during the September 26 survey (USGS 2015). Water clarity in the main channel Susitna River was estimated from the air to be approximately 3 feet for the September 10 flight and 2.5 feet for the September 26 survey. Salmon spawning areas mapped during the September 2014 aerial surveys were digitized into GIS layers for use during habitat model validation.

3.3.2 IFS-HSC Spawning Surveys

IFS HSC (Study 8.5) sampling was conducted during 2012, 2013 and 2014 to record site-specific habitat utilization data for juvenile and adult life stages present in the MR and LR. As part of HSC sampling, IFS staff recorded the location (i.e., latitude and longitude) and spatial extent of adult salmon spawning during ground surveys of spawning areas. HSC sample sites were randomly selected among representative habitats in each Focus Area, though some supplemental spawning sites were targeted on an opportunistic basis (Study 8.5, AEA 2014). HSC surveys were conducted in all habitat types, however, salmon spawning was generally documented in clear water habitats in which spawning activity could be visually verified (e.g., side slough, upland slough, tributary mouths). Mapped spawning areas were digitized into GIS layers. The location of salmon redds and spawning activity recorded during HSC surveys does not represent an independent data set to validate habitat modeling results since microhabitat conditions associated with each redd measurements were used to develop habitat modeling criteria. However, recorded salmon redds and spawning activity can be used to check whether the integration of hydraulic modeling and HSC results in high weighted usable area values that are associated with salmon spawning and redd observations.

3.3.3 1980s Salmon Spawning Surveys

During the 1980s, salmon spawning was monitored in main channel, off-channel and tributary habitats of the Middle Susitna River as part of escapement and spawning distribution studies. Spawning surveys conducted during 1980-1985 covered the entirety of Middle Susitna River main channel and off-channel habitats and the lower extents of most tributaries using a variety of methods. Clear water in off-channel areas (i.e., side sloughs and upland sloughs) and tributaries allowed surveyors to visually identify salmon spawning activity, while in turbid habitats (i.e., main channel and side channels) other techniques such as gill nets, side scan sonar, electrofishing, egg deposition pumps and radio telemetry were needed in addition to visual methods to identify salmon spawning (ADF&G 1981; ADF&G 1984; Barrett et al. 1983; Barrett et al. 1985; Thompson et al. 1986).

In general, salmon spawning distribution was well tabulated by habitat type (e.g., main channel or tributary) or site (e.g., Whiskers Slough) for the 1980-1985 period. However, the spatial extent of spawning areas was not comprehensively mapped and/or published with 1980s studies results. Consequently, the location of spawning is not known for all habitats known to have supported salmon spawning during the 1980s. Spawning areas mapped during the 1980s represent primary spawning sites (i.e., one or more salmon species observed spawning during one or more survey years) within mainstem habitats (i.e., main channel, side channel, tributary mouth, side slough and upland slough) (ADF&G 1983, ADF&G 1984, Vincent-Lang et al. 1984, Barrett et al. 1985, Seagren and Wilkey 1985). Salmon spawning areas were mapped within six MR Focus Areas: FA-104 (Whiskers Slough), FA-113 (Oxbow 1), FA-128 (Slough 8A), FA-138 (Gold Creek), FA-141 (Indian River), and FA-144 (Slough 21). Salmon spawning areas mapped during the 1980s were digitized into GIS layers to compare historic spawning areas with current model predictions of potential spawning habitats and to compare 1980s salmon spawning locations with more recent observations of salmon redds and spawning activity.

3.3.4 Salmon Escapement Surveys 2012-2014

Radio telemetry surveys were conducted by Fish Distribution and Abundance (FDA) (Studies 9.5 and 9.6) personnel during 2012, 2013, and 2014 to track the migration and spawning destination of radio-tagged adult salmon (AEA 2014; LGL 2013; LGL 2014). The destinations of tagged fish were determined by monitoring fish movement and location during mobile aerial (fixed-wing and helicopter) and boat/ground telemetry surveys and using fixed-position receiver stations. Fish location and movement were tracked in main channel, off-channel and tributary habitats of the LR and MR, though it was not always possible to determine the precise location or spawning status of tagged fish in turbid habitats (e.g., main channel and side channel habitats) due to difficulty with visual identification of fish presence or activity. Helicopter telemetry surveys comprehensively covered the MR mainstem habitat (i.e., main channel and off-channel) to identify potential salmon spawners, while boat and ground surveys targeted potential spawning areas (Study 9.7, AEA 2014). In general, the resolution of the tagged fish position was approximately 1,000 feet during helicopter telemetry surveys and between 6 – 32 feet during boat and ground tracking surveys (Study 9.7, AEA 2014). Final spawning destinations of radio tagged fish were determined based on the position of the tagged fish over multiple mobile telemetry surveys; for example, detection of a tagged individual at the same location over multiple surveys was the basis for determination of final spawning destination for many tagged fish (Study 9.7, AEA 2014). Spatial data associated with mobile telemetry surveys may be useful for habitat model validation, particularly where high-resolution spawning locations were recorded. As of May 2015, spatial data associated with Salmon Escapement (Study 9.7) radio telemetry surveys have not been digitized into GIS layers compatible for use in salmon spawning habitat modeling validation.

3.4 Macrohabitats

Characterization of macrohabitats within each Focus Area is provided by ISR Study 9.9 (Characterization and Mapping of Aquatic Habitats) as lines identifying each macrohabitat. For fish habitat modeling purposes, macrohabitat lines were expanded to polygons described as a GIS coverage layer for each Focus Area. Macrohabitat line types were expanded to cover all areas within each Focus Area expected to be inundated during project operations (i.e., zone of influence). Separations between main channel and side channel macrohabitat areas were identified as the side channel invert during a reference flow range of 12,000 to 16,000 cfs measured at the USGS gage Susitna River at Gold Creek (No. 15292000).

4. RESULTS

4.1 Focus Area Surficial Substrate Characterization

Substrate maps showing geo-referenced polygons of substrate composition for each surveyed Focus Area are presented in Figure 2 through Figure 9. For display purposes, the figures show the distribution of coarse and fine substrate within each Focus Area; however, the dominant and subdominant particle size and the percent composition of each substrate polygon are used for aquatic habitat modeling. A small section of the lower end of each Focus Area is enlarged in Figures 2 through 9 to display the data used for habitat modeling.

4.2 Cover GIS Layers by Focus Area

Maps showing geo-referenced polygons of cover composition for each surveyed Focus Area are presented in Figure 10 through Figure 17. Fish cover habitat was characterized as: boulders, aquatic vegetation, overhanging vegetation, undercut bank and woody debris. Aquatic vegetation is a cover type that consists of both submergent and emergent vegetation. Some of the gravel and sand bars that are frequently inundated have sparse emergent vegetation such as willow and alder seedlings and saplings. Inundation of this vegetation will provide cover to fish such as juvenile salmonids. Gravel bars and riparian areas that have not been exposed to the scouring effects of spring break up or high flow events become colonized by more mature vegetation including trees and shrubs. These trees and shrubs were characterized as overhanging vegetation and will represent aquatic cover when those areas become inundated.

4.3 Salmon Spawning Habitats

4.3.1 2014 Aerial Spawning Surveys

Spawning areas identified during each September 2014 aerial survey were mapped and digitized into GIS layers of observed spawning activity. Salmon redds were enumerated and mapped in FA-104 (Whiskers Slough), FA-128 (Slough 8A), FA-138 (Gold Creek), FA-141 (Indian River) and FA-144 (Slough 21) during each September 2014 aerial survey (Figure 18 through Figure 23). No evidence of spawning activity was apparent in FA-113 (Oxbow 1), FA-115 (Slough 6A) or FA-151 (Portage Creek) during either aerial spawning survey conducted in September 2014. The vast majority of salmon spawning areas observed during the September 2014 aerial surveys were located in side channel and side slough macrohabitats. A main channel spawning area documented during the surveys was located in FA-141 (Indian River) on the north bank of the main channel immediately upstream and downstream of the Indian River confluence (Figure 22). In general, the distribution of salmon spawning recorded during the 2014 aerial survey was similar to observed 1980s spawning, though beaver activity may have limited adult salmon passage to some habitat. Beaver dams in Slough 11 (FA-138 [Gold Creek] and Slough 21 (FA-144 [Slough 21] in 2013-2014 appeared to affect salmon spawning in these habitats that were historically utilized for spawning (Figure 21 and Figure 23).

4.3.2 IFS-HSC Spawning Surveys

Locations of salmon spawning activity observed within Focus Areas during the HSC surveys are identified in Figure 18 through Figure 23. Salmon spawning areas were documented in the MR of the Susitna River during 2013 and 2014 HSC sampling in FA-104 (Whiskers Slough), FA-113 (Oxbow 1), FA-128 (Slough 8A), FA-138 (Gold Creek), FA-141 (Indian River), and FA-144 (Slough 21).

4.3.3 1980s Salmon Spawning Surveys

Salmon spawning areas mapped in the 1980s in areas of the Susitna River now encompassed by Focus Areas were digitized into GIS layers (Figure 18 through Figure 23). The distribution of salmon spawning recorded during the 1980s was generally similar to salmon spawning area observed in 2013-2014. At a broad scale, results during each period indicated that tributary and slough (side slough and upland slough) habitats were primary spawning areas for salmon species, while main channel and side channel habitats were considered secondary or incidental spawning areas (Figure 24, Figure 25 and Figure 26). At a finer scale, discrete areas of salmon spawning mapped within each Focus Area during 2013 and 2014 closely resemble the spatial extent of spawning mapped during 1980s surveys. Although some differences in spawning distribution are apparent between recent and 1980s spawning surveys, some discrepancies are attributable to changes in habitat accessibility and/or channel configuration. For example, salmon access and use of spawning areas documented in Slough 11 (FA-138 [Gold Creek]; Figure 21) and Slough 21 (FA-144 [Slough 21]; Figure 23) during the 1980s may have been hindered by the presence of large beaver dams near the outlets of each channel.

4.3.4 Salmon Escapement Surveys

Results of both the 1980s and current fish studies have shown that the majority (~95%) of Chinook salmon (*Oncorhynchus tshawytscha*) use the major tributary systems that enter the LR (LGL 2014) with 5% using tributary systems in the MR downstream of Devils Canyon. Likewise for sockeye salmon (*O. nerka*), 95.5% use tributaries in the LR with about 80% headed to the Yentna River; only about 0.5% use the MR of the Susitna River. Most coho salmon (*O. kisutch*) use tributaries in the LR and only 2.5 - 5% use tributaries in the MR. About 92-96% of chum salmon (*O. keta*) use tributaries and lateral habitats to the LR, and 4-8% use the MR with about half using tributaries and half were using off-channel habitats to the mainstem river (ISR Study 9.7 [Salmon Escapement]). The following discussion is based on radio-tagging information developed from adult salmon that were captured and radio-tagged in the MR and tracked to final destinations in the MR.

The spawning destinations of adult salmon captured and radio-tagged in the MR of the Susitna River (Figure 8, Figure 9 and Figure 10) and tracked to final positions within the segment were primarily distributed in tributary habitats, though the apparent spawning distribution differed among species (Study 9.7; LGL 2013; AEA 2014). In particular, sockeye salmon radio-tagged in the MR appeared to use tributaries less than other salmon species and were detected in side channel, side slough and upland slough habitats in greater proportions than other salmon (Figure 24 and Figure 25) (LGL 2013; AEA 2014). Less than ten percent of all adult salmon captured and radio-tagged in 2012-2013 in the MR with designated MR spawning destinations had final designations within the main channel (Figure 24 and Figure 25) (LGL 2013; AEA 2014). During 2014, the proportion of radio-tagged Chinook salmon spawning destinations designated within main channel habitats was approximately 2% among fish tagged and tracked within the Middle Susitna River (LGL 2014).

Main channel spawning was not visually confirmed during radio tracking surveys due to turbid water conditions (LGL 2014). Adaptive Resolution Imaging Sonar (ARIS) was used in 2013 to assess the effectiveness of sonar technology to identify salmon spawning locations in turbid water (AEA 2014). Adult salmon were observed at seven sites in July 2013, though the observed fish could not be differentiated between Chinook salmon and chum salmon. Chinook spawning activity, distinguished by observed nest-guarding behavior, was identified at one site (Indian River delta). Chum salmon spawning activity was observed at one site during surveys conducted in July and August 2013 (AEA 2014).

4.4 Macrohabitats

An example of macrohabitat polygons developed for MR Focus Area FA-128 (Slough 8A) is presented in Figure 27. Macrohabitat polygons will be developed for each Focus Area using the macrohabitat line types as the basis for expanding the line to polygon areas.

5. NEXT STEPS

The IFS Study (Study 8.5) will establish a set of analytical tools/models that can be used to define Existing Conditions, i.e., without Project, and how riverine resources and processes will respond to alternative Project operational scenarios. Physical parameters measured at MR Focus Areas are modeled using 2-D hydraulic models (SRH-2D and River2D), which are combined with HSC data for the species of interest to calculate usable area of habitat. The habitat area calculations are made using GIS tools to combine hydraulic output data or other parameters such as groundwater, water quality, substrate, and cover with HSC. Data dependencies for the habitat modeling include output from hydraulic models for open-water and ice process simulations, data on channel morphology and substrate, groundwater data, water quality data, and biological information such as species periodicity, distribution and abundance, and HSC/HSI.

In addition to the GIS component, a visual basic (VB) model was developed for a more efficient computational approach. GIS is used to spatially join the physical parameters into a single data file with all parameters needed for the habitat analysis. The result of the spatially-joined parameters is a single geo-referenced data file that can be used in the VB model. The 2-D habitat model relies on several physical process models or physical data sets as part of the analysis. These data sets include hydraulic data, substrate data, cover data, and groundwater data. This memo described the development of surficial substrate and cover data that will be incorporated into the aquatic habitat predictions. Observations of salmon redds and spawning activity within Focus Areas have been compiled to provide a check on habitat predictions and macrohabitat polygons have been developed to assist in analysis of habitat modeling results.

Input data have been collected to model the eight MR Focus Areas below Devils Canyon, but habitat modeling has only been conducted at FA-128 (Slough 8A) (ISR Study 8.5, Part C, Appendix N: *Middle River Fish Habitat and Riverine Modeling: Proof of Concept* [R2 et al. 2014]). Data collection of the two MR Focus Areas above Devils Canyon and modeling of all MR Focus Areas will be completed and reported in the Updated Study Report. Next steps pertaining to specific habitat model inputs are described in the following sections.

5.1 Focus Area Surficial Substrate Characterization

- Complete substrate mapping at the two Focus Areas above Devils Canyon (FA-173 [Stephan Lake Complex] and FA-184 [Watana Dam]).
- Compare substrate polygons to bathymetry mapping: Prior to finalizing the surficial substrate GIS layers, the shape of the substrate polygons should be compared to the bathymetry used to describe each Focus Area to align polygon boundaries with bed elevations and ensure that the entire channel area included in the 2-D habitat modeling is covered by the substrate mapping.

- Complete quality control checks of substrate mapping: Use substrate characterization data collected during the geomorphology (Study 6.5) and HSC fish utilization surveys (Study 8.5) to confirm the Focus Area substrate mapping. Resolve conflicting substrate calls with other study leads and make any necessary corrections to substrate mapping coverage.

5.2 Cover GIS Layers by Focus Area

- Complete cover mapping for FA-173 (Stephan Lake Complex) and FA-184 (Watana Dam).

5.3 Salmon Spawning Habitats

- The compilation of observed salmon spawning activity and redds will be used to evaluate the results of the salmon spawning habitat models. The results of the 2014 aerial spawning surveys that mapped salmon spawning locations in Focus Areas downstream of Devils Canyon will be used to validate the results of the Focus Area salmon spawning habitat models. Spatial data collected at spawning areas during 2013-2014 HSC licensing studies will also be useful for model evaluations, while data collected during 1980s studies may complement the more recently collected data.

5.4 Macrohabitats

- Complete macrohabitat polygons for all MR Focus Areas.

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7. TABLES

Table 1. Description of Middle River Segment Focus Areas and date sampled as part of substrate and cover characterization mapping.

Focus Area ID	Common Name	Location (PRM)	Length (Miles)	Sample Date (2013 or 2014)
FA-104	Whiskers Slough	104.8-106.0	1.2	September 19, 2013
FA-113	Oxbow I	113.6-115.3	1.7	September 18, 2013
FA-115	Slough 6A	115.3-116.5	1.2	September 17, 2013
FA-128	Slough 8A	128.1-129.7	1.6	September 21, 2013
FA-138	Gold Creek	138.5-140.0	1.5	September 20, 2013
FA-141	Indian River	141.8-143.4	1.6	September 22, 2013
FA-144	Slough 21	144.4-145.7	1.3	September 23, 2013
FA-151	Portage Creek	151.8-152.3	0.5	September 25, 2014
FA-173	Stephan Lake Complex	173.6-175.4	1.8	Not Sampled
FA-184	Watana Dam	184.7-185.7	1.0	Not Sampled

Table 2. Substrate classification system used in Focus Area substrate characterization within the Middle River Segment of the Susitna River (adapted from Wentworth 1922).

Substrate Code	Substrate Type	Size (Decimal Inches)	Size (mm)
1	Fines	<0.01	<1
2	Sand	0.05-0.1	1-2
3	Small Gravel	0.1-0.6	2-16
4	Large Gravel	0.6-2.5	16-64
5	Small Cobble	2.5-5.0	64-128
6	Large Cobble	5.0-10.0	128-256
7	Boulder	>10.0	>256
8	Bedrock		

Table 3. Classification system used to identify and map cover habitat features during 2013 and 2014 surveys in Middle River Segment Focus Areas.

Cover Code	Cover Type	Description
AV	Aquatic Vegetation	Small vegetation (e.g., grasses and shrubs)
BO	Boulder	Surficial substrate greater than 10 inches (256 mm) in diameter
OV	Overhanging Vegetation	Large vegetation (e.g., mature trees) overhanging the active channel
UCB	Undercut Bank	Eroded stream bank with
WD	Woody Debris	Large wood (> 4 inch diameter and > 10 feet long)

8. FIGURES

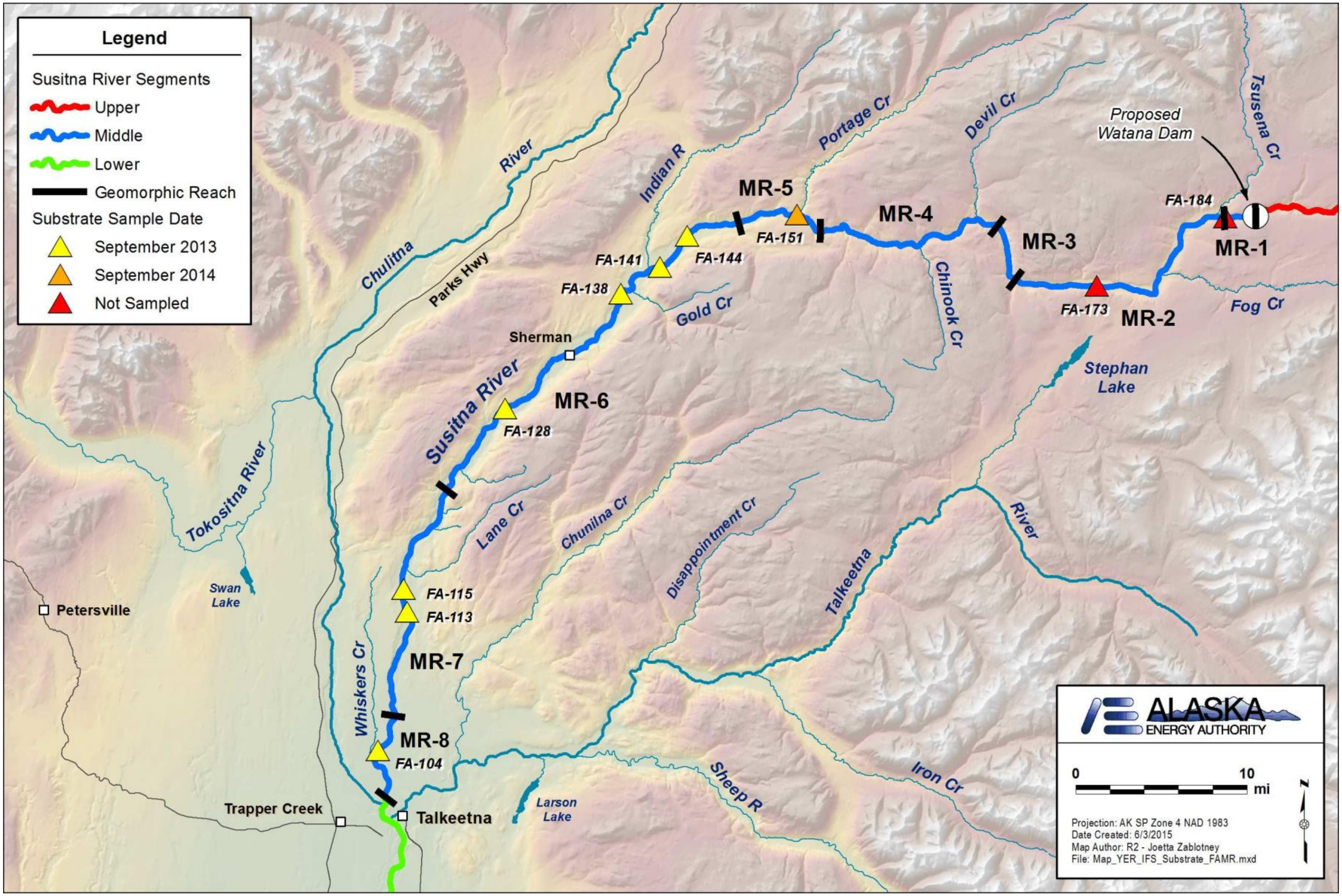

Figure 1. Map of the Middle River Segment of the Susitna River depicting the eight Geomorphic Reaches, locations of the ten Focus Areas and eight Focus Areas sampled during 2013 and 2014. No Focus Areas were located in MR-3 and MR-4 due to safety issues related to sampling within or proximal to Devils Canyon.

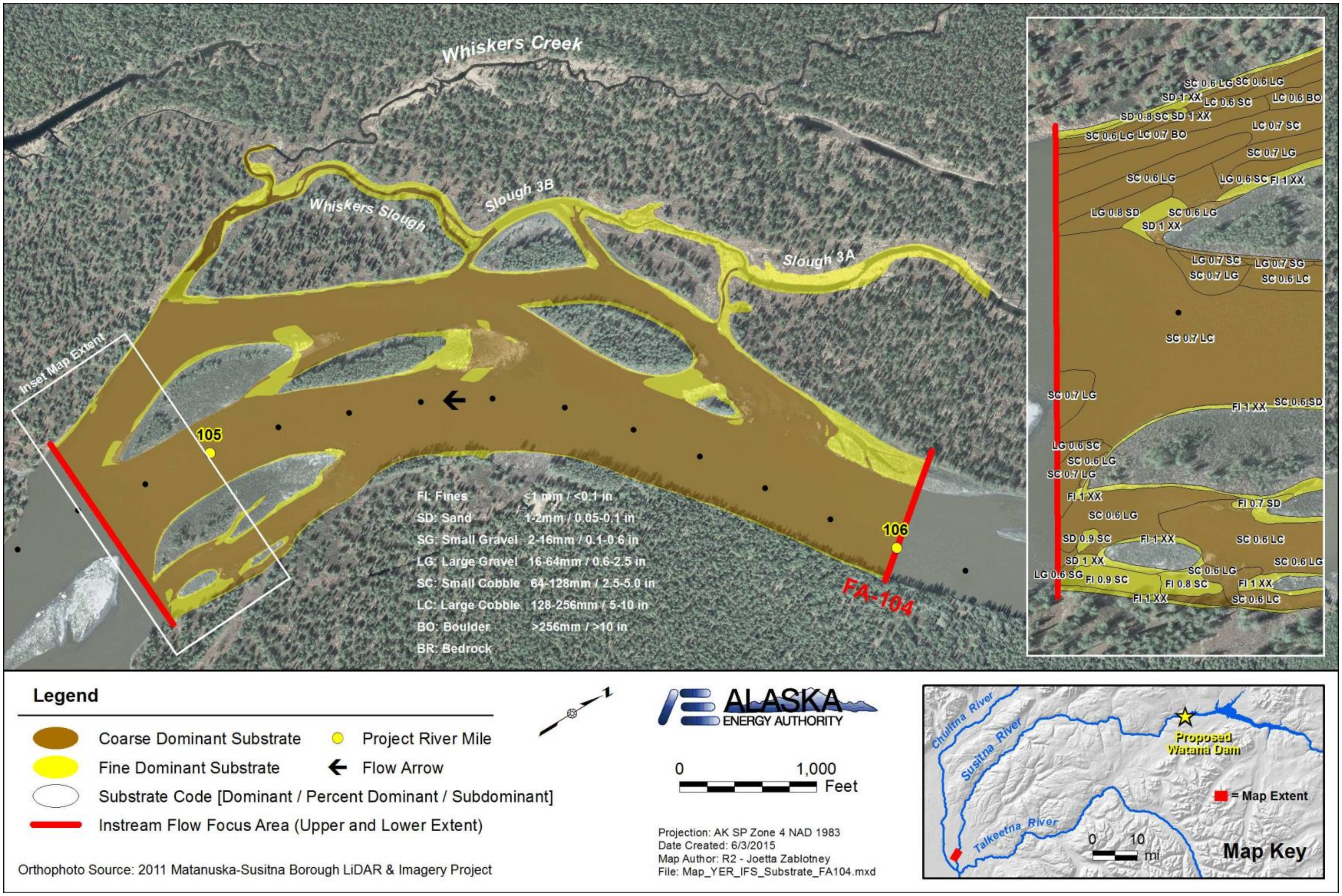

Figure 2. Substrate characterization mapping in FA-104 (Whiskers Slough) on September 19, 2013. For display purposes, the figure shows the distribution of coarse and fine substrate within the Focus Area; however, the dominant and subdominant particle size and the percent composition of each substrate polygon is used for habitat modeling purposes (see enlargement of the lower end of the Focus Area).

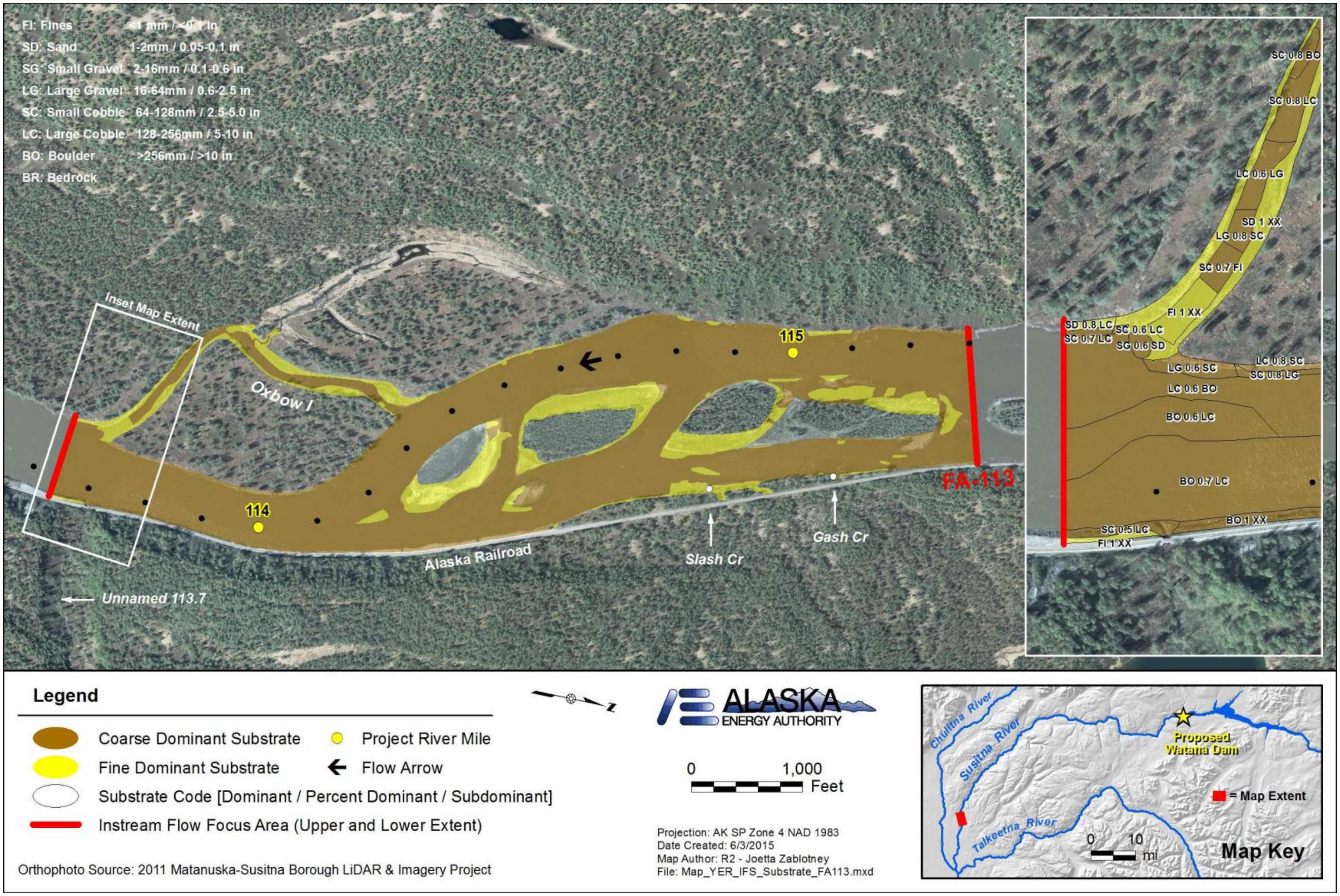

Figure 3. Substrate characterization mapping in FA-113 (Oxbow 1) on September 18, 2013. For display purposes, the figure shows the distribution of coarse and fine substrate within the Focus Area; however, the dominant and subdominant particle size and the percent composition of each substrate polygon is used for habitat modeling purposes (see enlargement of the lower end of the Focus Area).

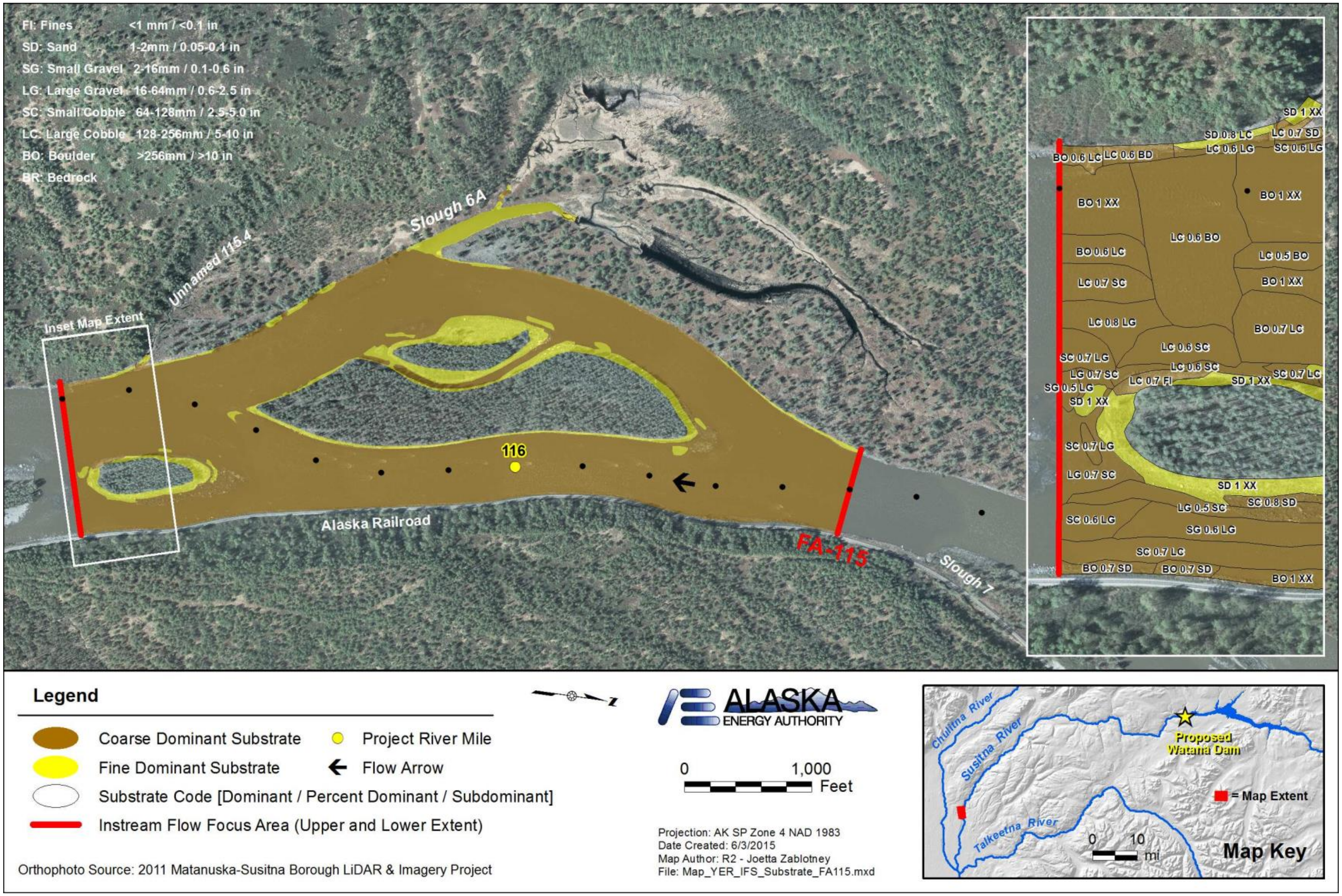

Figure 4. Substrate characterization mapping in FA-115 (Slough 6A) on September 17, 2013. For display purposes, the figure shows the distribution of coarse and fine substrate within the Focus Area; however, the dominant and subdominant particle size and the percent composition of each substrate polygon is used for habitat modeling purposes (see enlargement of the lower end of the Focus Area).

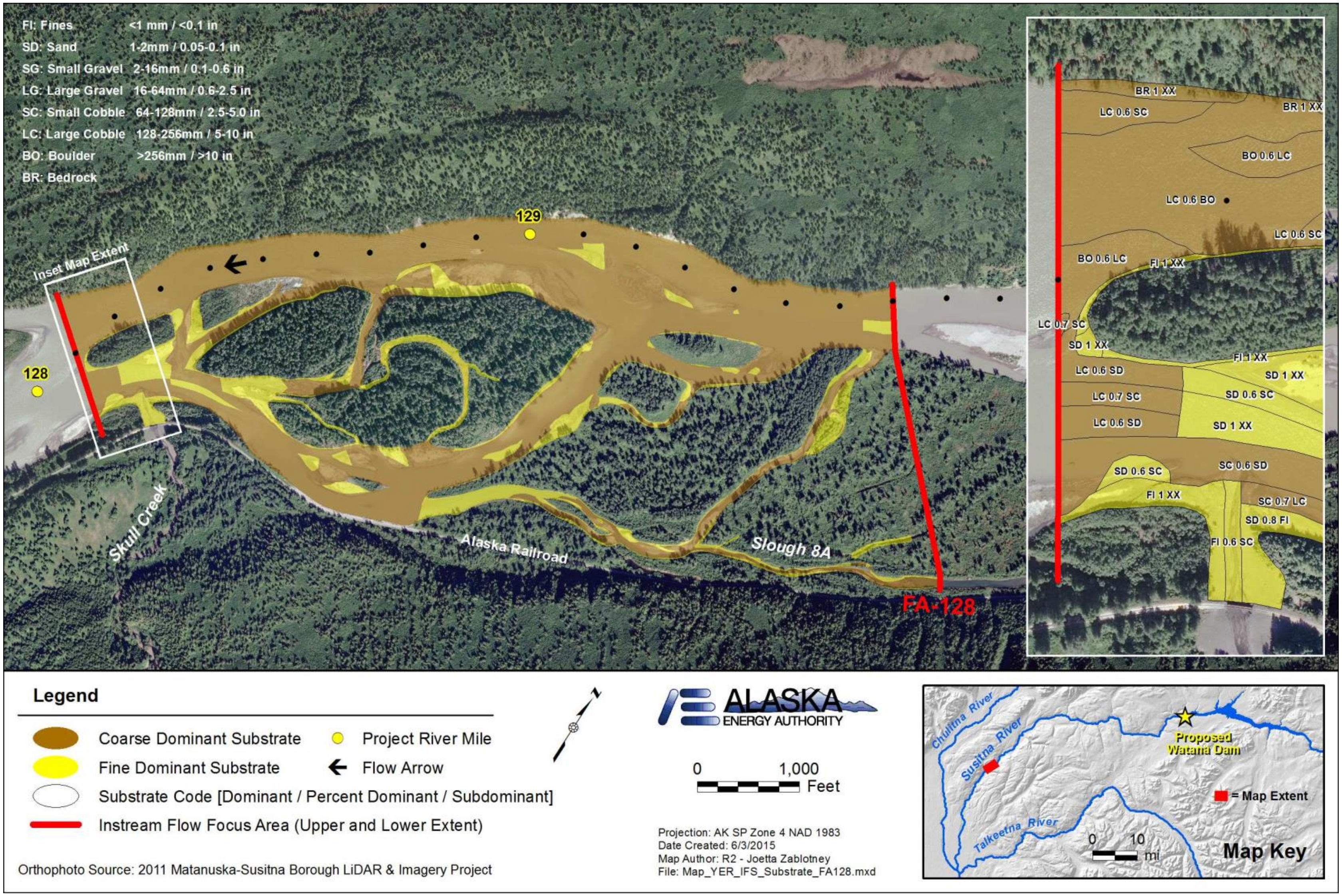

Figure 5. Substrate characterization mapping in FA-128 (Slough 8A) on September 21, 2013. For display purposes, the figure shows the distribution of coarse and fine substrate within the Focus Area; however, the dominant and subdominant particle size and the percent composition of each substrate polygon is used for habitat modeling purposes (see enlargement of the lower end of the Focus Area).

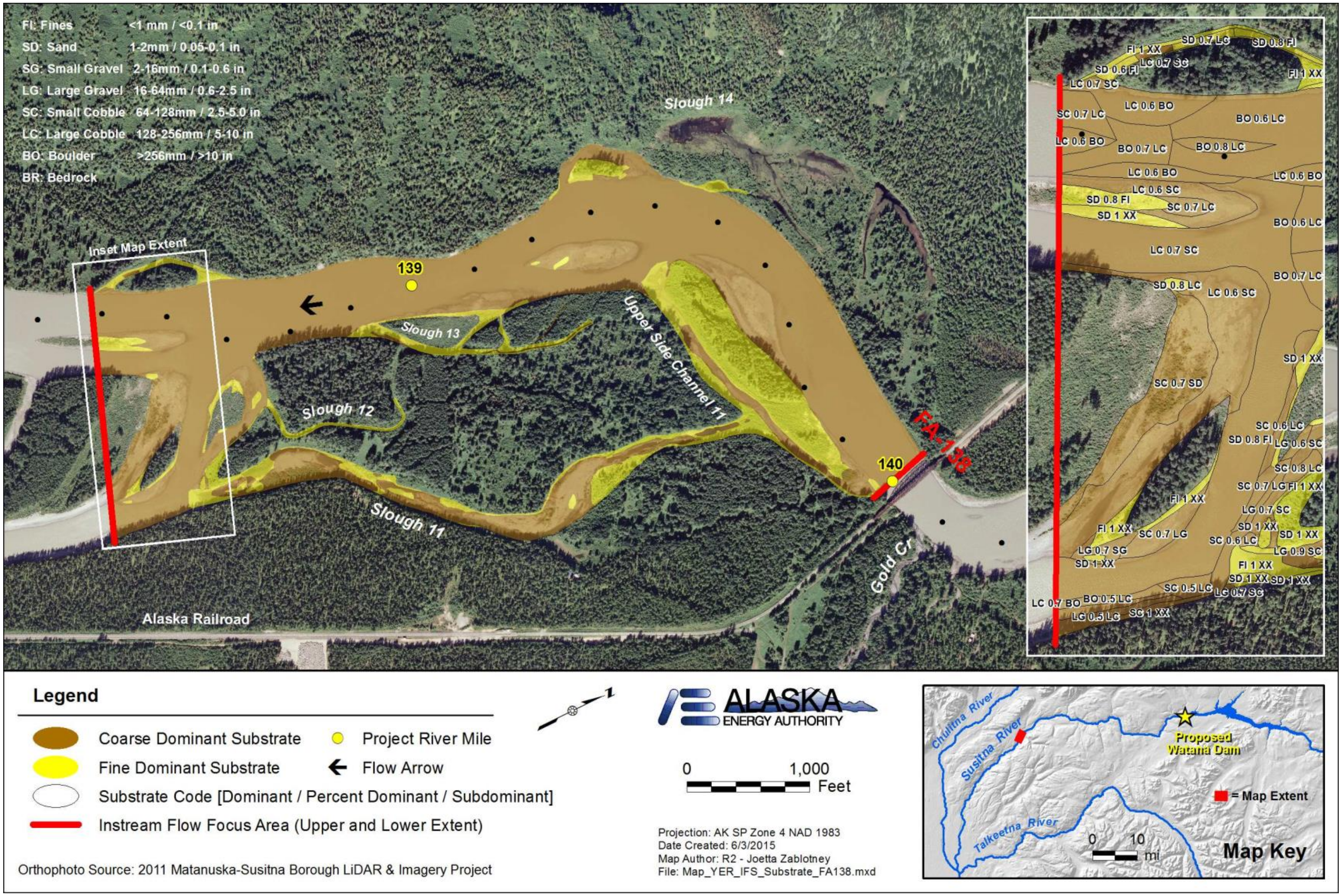

Figure 6. Substrate characterization mapping in FA-138 (Gold Creek) on September 20, 2013. For display purposes, the figure shows the distribution of coarse and fine substrate within the Focus Area; however, the dominant and subdominant particle size and the percent composition of each substrate polygon is used for habitat modeling purposes (see enlargement of the lower end of the Focus Area).

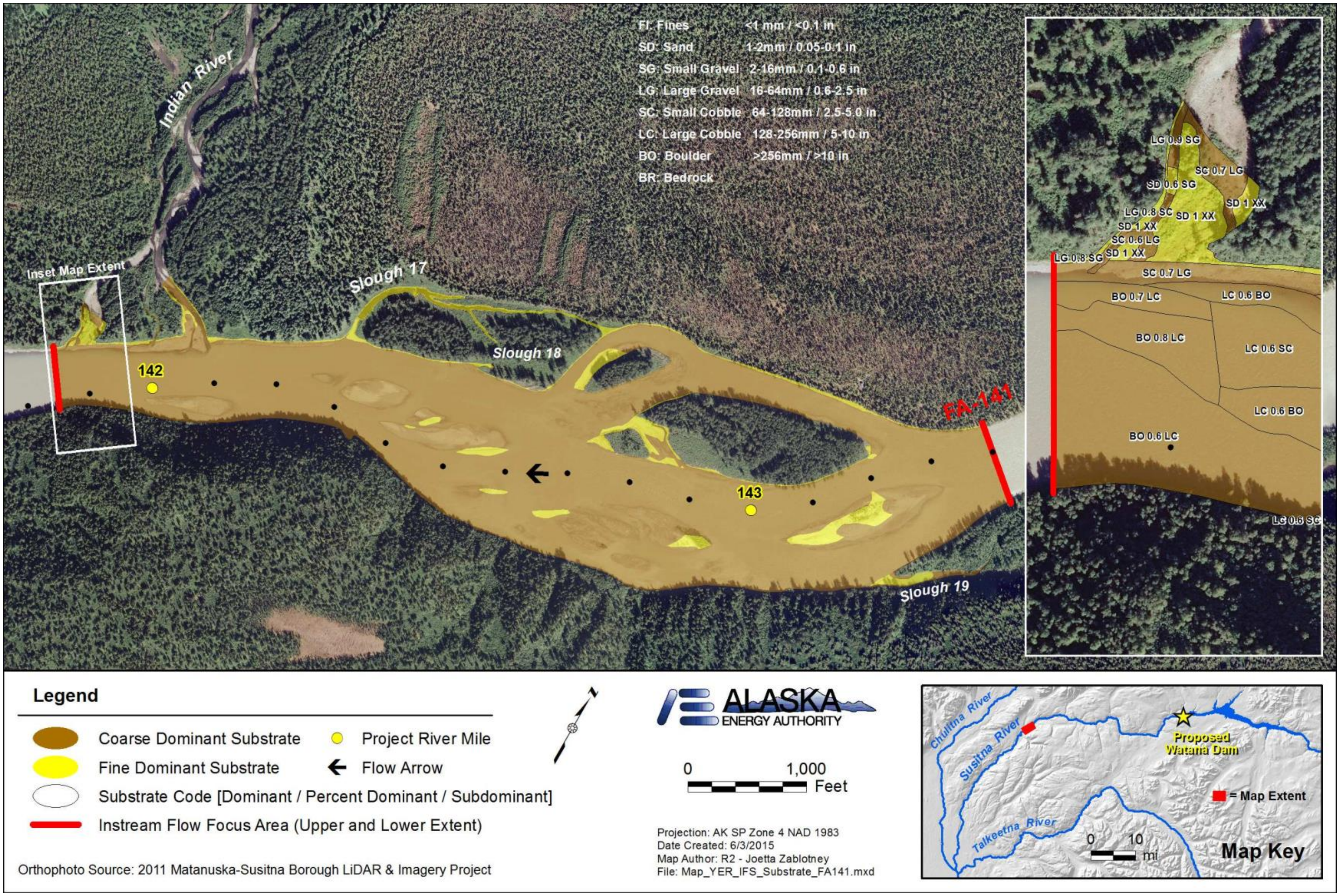

Figure 7. Substrate characterization mapping in FA-141 (Indian River) on September 22, 2013. For display purposes, the figure shows the distribution of coarse and fine substrate within the Focus Area; however, the dominant and subdominant particle size and the percent composition of each substrate polygon is used for habitat modeling purposes (see enlargement of the lower end of the Focus Area).

Figure 8. Substrate characterization mapping in FA-144 (Slough 21) on September 23, 2013. For display purposes, the figure shows the distribution of coarse and fine substrate within the Focus Area; however, the dominant and subdominant particle size and the percent composition of each substrate polygon is used for habitat modeling purposes (see enlargement of the lower end of the Focus Area).

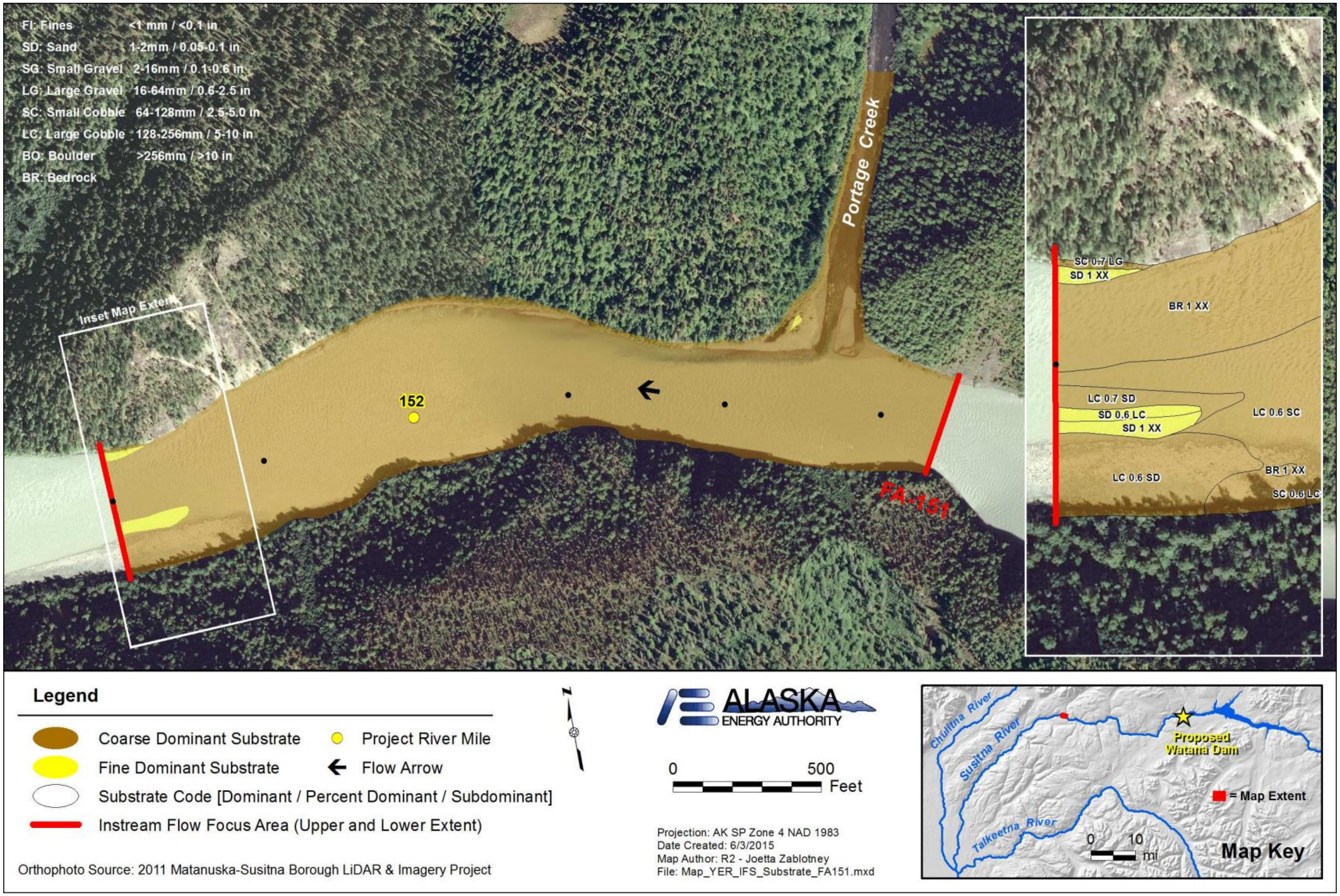

Figure 9. Substrate characterization mapping in FA-151 (Portage Creek) on September 25, 2014. For display purposes, the figure shows the distribution of coarse and fine substrate within the Focus Area; however, the dominant and subdominant particle size and the percent composition of each substrate polygon is used for habitat modeling purposes (see enlargement of the lower end of the Focus Area).

FIGURE INCLUDED IN FILE 08.5_IFS_ISR_SIR_App_E_FishHabitatModelingData_2_of_2

Figure 10. Cover polygons in FA-104 (Whiskers Slough) mapped during September 2013 habitat surveys.

FIGURE INCLUDED IN FILE 08.5_IFS_ISR_SIR_App_E_FishHabitatModelingData_2_of_2

Figure 11. Cover polygons in FA-113 (Oxbow I) mapped during September 2013 habitat surveys.

FIGURE INCLUDED IN FILE 08.5_IFS_ISR_SIR_App_E_FishHabitatModelingData_2_of_2

Figure 12. Cover polygons in FA-115 (Slough 6A) mapped during September 2013 habitat surveys.

FIGURE INCLUDED IN FILE 08.5_IFS_ISR_SIR_App_E_FishHabitatModelingData_2_of_2

Figure 13. Cover polygons in FA-128 (Slough 8A) mapped during September 2013 habitat surveys.

FIGURE INCLUDED IN FILE 08.5_IFS_ISR_SIR_App_E_FishHabitatModelingData_2_of_2

Figure 14. Cover polygons in FA-138 (Gold Creek) mapped during September 2013 habitat surveys.

FIGURE INCLUDED IN FILE 08.5_IFS_ISR_SIR_App_E_FishHabitatModelingData_2_of_2

Figure 15. Cover polygons in FA-141 (Indian River) mapped during September 2013 habitat surveys.

FIGURE INCLUDED IN FILE 08.5_IFS_ISR_SIR_App_E_FishHabitatModelingData_2_of_2

Figure 16. Cover polygons in FA-144 (Slough 21) mapped during September 2013 habitat surveys.

FIGURE INCLUDED IN FILE 08.5_IFS_ISR_SIR_App_E_FishHabitatModelingData_2_of_2

Figure 17. Cover polygons in FA-151 (Portage Creek) mapped during September 2014 habitat surveys.

FIGURE INCLUDED IN FILE 08.5_IFS_ISR_SIR_App_E_FishHabitatModelingData_2_of_2

Figure 18. Salmon spawning areas mapped within FA-104 (Whiskers Slough) during 2013 and 2014 IFS aerial and ground spawning surveys and in association with 1981-1984 monitoring efforts in the Middle River Segment of the Susitna River.

FIGURE INCLUDED IN FILE 08.5_IFS_ISR_SIR_App_E_FishHabitatModelingData_2_of_2

Figure 19. Salmon spawning areas mapped within FA-113 (Oxbow 1) during 2013 and 2014 IFS aerial and ground spawning surveys and in association with 1981-1984 monitoring efforts in the Middle River Segment of the Susitna River.

FIGURE INCLUDED IN FILE 08.5_IFS_ISR_SIR_App_E_FishHabitatModelingData_2_of_2

Figure 20. Salmon spawning areas mapped within FA-128 (Slough 8A) during 2013 and 2014 IFS aerial and ground spawning surveys and in association with 1981-1984 monitoring efforts in the Middle River Segment of the Susitna River.

FIGURE INCLUDED IN FILE 08.5_IFS_ISR_SIR_App_E_FishHabitatModelingData_2_of_2

Figure 21. Salmon spawning areas mapped within FA-138 (Gold Creek) during 2013 and 2014 IFS aerial and ground spawning surveys and in association with 1981-1984 monitoring efforts in the Middle River Segment of the Susitna River.

FIGURE INCLUDED IN FILE 08.5_IFS_ISR_SIR_App_E_FishHabitatModelingData_2_of_2

Figure 22. Salmon spawning areas mapped within FA-141 (Indian River) during 2013 and 2014 IFS aerial and ground spawning surveys and in association with 1981-1984 monitoring efforts in the Middle River Segment of the Susitna River.

FIGURE INCLUDED IN FILE 08.5_IFS_ISR_SIR_App_E_FishHabitatModelingData_2_of_2

Figure 23. Salmon spawning areas mapped within FA-144 (Slough 21) during 2013 and 2014 IFS aerial and ground spawning surveys and in association with 1981-1984 monitoring efforts in the Middle River Segment of the Susitna River.

FIGURE INCLUDED IN FILE 08.5_IFS_ISR_SIR_App_E_FishHabitatModelingData_2_of_2

Figure 24. Destinations of radio tagged adult salmon spawners among habitats in 2012 based on fish radio tagged in the Middle River Segment of the Susitna River and determined to have Middle River Segment spawning destinations during radio telemetry surveys; main channel spawners consist of tagged fish with assigned spawning destinations upstream of Lane Creek. Tagged fish whose destination could not be conclusively determined are not included in this figure. Source: LGL 2013.

FIGURE INCLUDED IN FILE 08.5_IFS_ISR_SIR_App_E_FishHabitatModelingData_2_of_2

Figure 25. Destinations of radio tagged adult salmon spawners among habitats in 2013 based on fish radio tagged in the Middle River Segment of the Susitna River and determined to have Middle River Segment spawning destinations during radio telemetry surveys; main channel spawners consist of tagged fish with assigned spawning destinations upstream of Lane Creek. Tagged fish whose destination could not be conclusively determined are not included in this figure. Source: AEA 2014 (Study 9.7).

FIGURE INCLUDED IN FILE 08.5_IFS_ISR_SIR_App_E_FishHabitatModelingData_2_of_2

Figure 26. Relative distribution and average escapement of adult salmon species among macrohabitat types in the Middle River Segment of the Susitna River during 1981-1984. Large arrows indicate primary spawning habitat and thinner arrows represent secondary and incidental spawning habitats. Source: Figure adapted from Sautner et al. 1984; abundance data are from Barrett et al. 1985.

FIGURE INCLUDED IN FILE 08.5_IFS_ISR_SIR_App_E_FishHabitatModelingData_2_of_2

Figure 27. Macrohabitat polygons for FA-128 (Slough 8A).