Susitna-Watana Hydroelectric Project
(FERC No. 14241)

2012 Instream Flow Planning Study
Summary Review of Susitna River Aquatic and Instream Flow Studies Conducted in the 1980s with Relevance to Proposed Susitna – Watana Dam Project – 2012: A Compendium of Technical Memoranda

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

Term	Definition
Accretion	1. Addition of flows to the total discharge of the stream channel, which may come from tributaries, springs, or seeps. 2. Increase of material such as silt, sand, gravel, water.
Active floodplain	The flat valley floor constructed by river during lateral channel migration and deposition of sediment under current climate conditions.
Adaptive management	A process whereby management decisions can be changed or adjusted based on additional biological, physical or socioeconomic information.
Adfluvial	Fish that spend a part of their life cycle in lakes and return to rivers and streams to spawn.
Adult	Sexually mature individuals of a species.
Age-0 juvenile	The description of an organism that, in its natal year, has developed the anatomical and physical traits characteristically similar to the mature life stage, but without the capability to reproduce.
Aggradation	1. Geologic process in which inorganic materials carried downstream are deposited in streambeds, floodplains, and other water bodies resulting in a rise in elevation in the bottom of the water body. 2. A state of channel disequilibrium, whereby the supply of sediment exceeds the transport capacity of the stream, resulting in deposition and storage of sediment in the active channel.
Anadromous	Fish that mature in salt water but migrate to fresh water to spawn.
Annual flow	The total volume of water passing a given point in one year. Usually expressed as a volume (such as acre-feet) but may be expressed as an equivalent constant discharge over the year, such as cubic feet per second.
Armoring	1. The formation of an erosion-resistant layer of relatively large particles on the surface of a streambed or stream bank that results from removal of finer particles by erosion, and which resists degradation by water currents. 2. The application of materials to reduce erosion. 3. The process of continually winnowing away smaller substrate material and leaving a veneer of larger ones.
Average daily flow	The long-term average annual flow divided by the number of days in the year usually expressed as an equivalent constant discharge such as cubic feet per second. In some settings, the value can be used to represent only the portion of the daily flow values in a defined period such as those that occur within a calendar month.
Bank	The sloping land bordering a stream channel that forms the usual boundaries of a channel. The bank has a steeper slope than the bottom of the channel and is usually steeper than the land surrounding the channel.
Bathymetric	Related to the measurement of water depth within a water body.
Bedload	Material moving on or near the streambed and frequently in contact with it.
Benthic	Associated with the bottom of a body of water.
Benthic macroinvertebrates	Animals without backbones, living in or on the sediments, a size large enough to be seen by the unaided eye, and which can be retained by a U.S. Standard No. 30 sieve (28 openings/inch, 0.595-mm openings). Also referred to as benthos, infauna, or macrobenthos.
Braid	Pattern of two or more interconnected channels typical of alluvial streams.
Breaching flow	The mainstem river flow that overtops the inlet elevation of a side channel.

Term	Definition
Calibration	The validation of specific measurement techniques and equipment, or the comparison between measurements. In the context of PHABSIM, calibration is the process of adjusting input variables to minimize the error between predicted and observed water surface elevations.
Capillary fringe	The subsurface layer in which groundwater seeps up from a water table by capillary action to fill soil pores.
Catch per unit effort (CPUE)	The quantity of fish caught (in number or in weight) with one standard unit of fishing effort. CPUE is often considered an index of fish biomass (or abundance). Sometimes referred to as catch rate. CPUE may be used as a measure of economic efficiency of fishing as well as an index of fish abundance.
Channel	A natural or artificial watercourse that continuously or intermittently contains water, with definite bed and banks that confine all but overbank streamflows.
Confidence interval	The computed interval with a given probability that the true value of the statistic – such as a mean, proportion, or rate – is contained within the interval.
Confinement	Ratio of valley width (VW) to channel width (CW). Confined channel VW:CW <2; Moderately confined channel VW:CW 2-4; Unconfined channel VW:CW >4.
Confluence	The junction of two or more streams.
Connectivity	Maintenance of lateral, longitudinal, and vertical pathways for biological, hydrological, and physical processes.
Cover	Structural features (e.g., boulders, log jams) or hydraulic characteristics (e.g., turbulence, depth) that provide shelter from currents, energetically efficient feeding stations, and/or visual isolation from competitors or predators.
Cross section	A plane across a stream channel perpendicular to the direction of water flow.
Cross-sectional area	The area of the stream's vertical cross section, perpendicular to flow.
Cubic feet per second (cfs)	A standard measure of the total amount of water passing by a particular location of a river, canal, pipe or tunnel during a one second interval. One cfs is equal to 7.4805 gallons per second, 28.31369 liters per second, 0.028 cubic meters per second, or 0.6463145 million gallons per day (mgd). Also called second-feet.
Current meter	Instrument used to measure the velocity of water flow in a stream, measured in units of length per unit of time, such as feet per second (fps).
Datum	A geometric plane of known or arbitrary elevation used as a point of reference to determine the elevation, or change of elevation, of another plane (see gage datum).
Decision support system (DSS)	Tools developed to evaluate alternative flow scenarios in support of water control decisions; can include matrices that array differences among alternative flow regimes by calculating values of indicator variables representing different habitat characteristics or processes of the riverine ecosystem.
Degradation	1. A decline in the viability of ecosystem functions and processes. 2. Geologic process by which streambeds and floodplains are lowered in elevation by the removal of material (also see down cutting).
Delta	A low, nearly flat accumulation of sediment deposited at the mouth of a river or stream, commonly triangular or fan-shaped.
Dendrochronology	The science of dating woody species (Fritts 1976).
Density	Number of individuals per unit area.
Deposition	The settlement or accumulation of material out of the water column and onto the streambed.
Depth	Water depth at the measuring point (station).

Term	Definition
Dewater	Remove or drain the water from a stream, pond or aquifer.
DIHAB	Direct Input Habitat model
Discharge	The rate of streamflow or the volume of water flowing at a location within a specified time interval. Usually expressed as cubic meters per second (cms) or cubic feet per second (cfs).
Dissolved oxygen (DO)	The amount of gaseous oxygen (O2) dissolved in the water column. Oxygen gets into water by diffusion from the surrounding air, by aeration (rapid movement), and as a waste product of photosynthesis. More than 5 parts oxygen per million parts water is considered healthy; below 3 parts oxygen per million is generally stressful to aquatic organisms.
Disturbance regime	Floodplain vegetation disturbance types found within the Susitna River Study Area corridor include: channel migration (erosion and depositional processes), ice processes (shearing impacts, flooding and freezing), herbivory (beaver, moose, and hare), wind, and, to an infrequent extent, fire. Floodplain soil disturbance is primarily ice shearing and sediment deposition.
Drainage area	The total land area draining to any point in a stream. Also called catchment area, watershed, and basin.
Ecosystem	Any complex of living organisms interacting with nonliving chemical and physical components that form and function as a natural environmental unit.
Electrofishing	A biological collection method that uses electric current to facilitate capturing fishes.
Embeddedness	The degree that larger particles (boulders, rubble, or gravel) are surrounded or covered by fine sediment. Usually measured in classes according to percent of coverage.
Emergent vegetation	An emergent plant is one which grows in water but which pierces the surface so that it is partially in air. Collectively, such plants are emergent vegetation.
Euphotic zone	Surface layer of an ocean, lake, or other body of water through which light can penetrate. Also known as the zone of photosynthesis.
FLIR	Forward looking infrared (FLIR) is an imaging technology that senses infrared radiation. Can be used for watershed temperature monitoring.
Flood	Any flow that exceeds the bankfull capacity of a stream or channel and flows out on the floodplain.
Floodplain	1. The area along waterways that is subject to periodic inundation by out-of-bank flows. 2. The area adjoining a water body that becomes inundated during periods of over-bank flooding and that is given rigorous legal definition in regulatory programs. 3. Land beyond a stream channel that forms the perimeter for the maximum probability flood. 4. A relatively flat strip of land bordering a stream that is formed by sediment deposition. 5. A deposit of alluvium that covers a valley flat from lateral erosion of meandering streams and rivers.
Floodplain vegetation − groundwater / surface water regime functional groups	Assemblages of plants that have established and developed under similar groundwater and surface water hydrologic regimes.
Flushing flow	A stream discharge with sufficient power to remove silt and sand from a gravel/cobble substrate but not enough power to remove gravels.
Focus Area	Areas selected for intensive investigation by multiple disciplines as part of the Instream Flow Study.
Fry	A recently hatched fish. Sometimes defined as a young juvenile salmonid with absorbed egg sac, less than 60 mm in length.

Term	Definition
Gaging station	A specific site on a stream where systematic observations of streamflow or other hydrologic data are obtained.
Geographic information system (GIS)	An integrated collection of computer software and data used to view and manage information about geographic places, analyze spatial relationships, and model spatial processes. A GIS provides a framework for gathering and organizing spatial data and related information so that it can be displayed and analyzed. In the simplest terms, GIS is the merging of cartography, statistical analysis, and database technology.
Geomorphic mapping	A map design technique that defines, delimits and locates landforms. It combines a description of surface relief and its origin, relative age, and the environmental conditions in which it formed. This type of mapping is used to locate and differentiate among relief forms related to geologic structure, internal dynamics of the lithosphere, and landforms shaped by external processes governed by the bio-climate environment.
Global positioning system (GPS)	A system of radio-emitting and -receiving satellites used for determining positions on the earth. The orbiting satellites transmit signals that allow a GPS receiver anywhere on earth to calculate its own location through trilateration. Developed and operated by the U.S. Department of Defense, the system is used in navigation, mapping, surveying, and other applications in which precise positioning is necessary.
Gradient	The rate of change of any characteristic, expressed per unit of length (see Slope). May also apply to longitudinal succession of biological communities.
Groundwater	In general, all subsurface water that is distinct from surface water; specifically, that part which is in the saturated zone of a defined aquifer.
Habitat guild	Groups of species that share common characteristics of microhabitat use and selection at various stages in their life histories.
Habitat suitability criteria (HSC)	A graph/mathematical equation describing the suitability for use of areas within a stream channel related to water depth, velocity and substrate by various species/lifestages of fish.
Habitat suitability index (HSI)	An HSI is a numerical index that represents the capacity of a given habitat to support a selected species. HSI model results represent the interactions of the habitat characteristics and how each habitat relates to a given species. The value is to serve as a basis for improved decision making and increased understanding of species-habitat relationships.
Hydraulic control	A horizontal or vertical constriction in the channel, such as the crest of a riffle, which creates a backwater effect.
Hydraulic head	A measure of energy or pressure, expressed in terms of the vertical height of a column of water that has the same pressure difference.
Hydraulic model	A computer model of a segment of river used to evaluate stream flow characteristics over a range of flows.
Hydrograph	A graph showing the variation in discharge over time.
IFG	Instream Flow Group
IFIM	Instream Flow Incremental Methodology
Incised	Lowering of the streambed by erosion that occurs when the energy of the water flowing through a stream reach exceeds that necessary to erode and transport the bed material.

Term	Definition
Incremental methodology	The process of developing an instream flow policy that incorporates multiple or variable rules to establish, through negotiation, flow-window requirements or guidelines to meet the needs of an aquatic ecosystem, given water supply or other constraints. It usually implies the determination of a habitat-discharge relation for comparing streamflow alternatives through time.
Instream flow	The rate of flow in a stream channel at any time of year.
Intergravel	Intergravel refers to the subsurface environment within the river bed.
Invertebrate	All animals without a vertebral column; for example, aquatic insects.
Isotopic dating	Direct dating using analyses of stable isotopes.
Large woody debris (LWD)	Pieces of wood larger than 10 feet long and 6 inches in diameter, in a stream channel. Minimum sizes vary according to stream size and region.
LiDAR	Light detection and ranging. An optical remote sensing technology that can measure the distance to a target, can be used to create a topographic map.
Life stage	An arbitrary age classification of an organism into categories relate to body morphology and reproductive potential, such as spawning, egg incubation, larva or fry, juvenile, and adult.
Macroinvertebrate	An invertebrate animal without a backbone that can be seen without magnification.
Main channel	Main Channel Habitat Types **Main Channel:** Single dominant main channel **Split Main Channel:** Less than 3 distributed dominant channels **Braided Main Channel:** Greater than 3 distributed dominant channels **Side Channel:** Channel that is turbid and connected to the active main channel but represents non-dominant proportion of flow **Tributary Mouth:** Clear water areas that exist where tributaries flow into the Susitna River main channel or side channel habitats
Mainstem	Mainstem refers to the primary river corridor, as contrasted to its tributaries. Mainstem habitats include the main channel, split main channels, side channels, tributary mouths, and off-channel habitats.
Manning’s n	A measure of channel roughness.
Mesohabitat	A discrete area of stream exhibiting relatively similar characteristics of depth, velocity, slope, substrate, and cover, and variances thereof (e.g., pools with maximum depth <5 ft, high gradient rimes, side channel backwaters).
Microhabitat	Small localized areas within a broader habitat type used by organisms for specific purposes or events, typically described by a combination of depth, velocity, substrate, or cover.
Non-native	Not indigenous to or naturally occurring in a given area. Presence is usually attributed to intentional or unintentional introduction by humans. Non-native species are also termed “exotic” species.
Nose velocity	The velocity at the approximate point vertically in the channel where a fish is located.

Term	Definition
Off-channel	Those bodies of water adjacent to the main channel that have surface water connections to the main river at some discharge levels. Off-channel Habitat Types **Side Slough:** Overflow channel contained in the floodplain, but disconnected from the main channel. Has clear water.[2] **Upland Slough:** Similar to a side slough, but contains a vegetated bar and is rarely overtopped by mainstem flow. Has clear water. [2] **Backwater:** Found along channel margins and generally within the influence of the active main channel. Water is not clear. **Beaver Complex**: Complex ponded water body created by beaver dams
Peak load	The greatest of all load demands on an interconnected electric transmission network occurring in a specified period of time.
Period of record	The length of time for which data for an environmental variable have been collected on a regular and continuous basis.
pH	A measure of the acidity or basicity of a solution. Pure water is said to be neutral, with a pH close to 7.0 at 25 °C (77 °F). Solutions with a pH less than 7 are said to be acidic, and solutions with a pH greater than 7 are said to be basic or alkaline.
PHABSIM	(pronounced P-HAB-SIM) The Physical HABitat SIMulation system; a set of software and methods that allows the computation of a relation between streamflow and physical habitat for various life stage of an aquatic organism or a recreational activity.
Physical habitat	Those abiotic factors such as depth, velocity, substrate, cover, temperature, water quality that make up some of an organism's living space.
Pool	Part of a stream with reduced velocity, often with water deeper than the surrounding areas, which is usable by fish for resting and cover.
Powerhouse	A structure that houses the turbines, generators, and associated control equipment.
PRM	Project River Mile(s) based on the digitized wetted width centerline of the main channel from 2012 Matanuska-Susitna Borough digital orthophotos. PRM 0.0 is established as mean lower low water of the Susitna River confluence at Cook Inlet.
Process domains	Define specific geographic areas in which various geomorphic processes govern habitat attributes and dynamics (Montgomery 1999).
Q	Hydrological abbreviation for discharge, usually presented as cfs (cubic feet per second) or cms (cubic meters per second). Flow (discharge at a cross-section).
Radiotelemetry	Involves the capture and placement of radio-tags in adult fish that allow for the remote tracking of movements of individual fish.
Ramping rate	The rate of change in discharge (typically inches per hour) below a hydroelectric facility that is fluctuating flow releases.
Recruitment	The number of new juvenile fish reaching a certain size/age class; connotes the process whereby juveniles survive and mature into adults.
Redd	The spawning ground or nest of various fishes.
Refugia	An area protected from disturbance and exposure to adverse environmental conditions where fish or other animals can find shelter from sudden flow surges, adverse water quality, or other short-duration disturbances.
Regime	The general pattern (magnitude and frequency) of flow or temperature events through time at a particular location (such as snowmelt regime, rainfall regime).

Term	Definition
Reservoir	A body of water, either natural or artificial, that is used to manipulate flow or store water for future use.
Restoration	To return a stream, river, or lake to its natural, predevelopment form and function. Restoration typically eliminates the human influence that degraded or destroyed riverine processes and characteristics.
Riffle	A fast water habitat with turbulent, shallow flow over submerged or partially submerged gravel and cobble substrates. Gradients are approximately 2 to less than 4%.
Riparian	Pertaining to anything connected with or adjacent to the bank of a stream or other body of water.
Riparian process domain	Define specific geographic areas in which various geomorphic processes govern floodplain habitat attributes and dynamics.
Riparian vegetation	Vegetation that is dependent upon an excess of moisture during a portion of the growing season on a site that is perceptively more moist than the surrounding area.
Riparian zone	A stream and all the vegetation on its banks that is influenced by the presence of the stream, including surface flow, hyporheic flow and microclimate.
River	A large stream that serves as the natural drainage channel for a relatively large catchment or drainage basin.
River corridor	A perennial, intermittent, or ephemeral stream and adjacent vegetative fringe. The corridor is the area occupied during high water and the land immediately adjacent, including riparian vegetation that shades the stream, provides input of organic debris, and protects banks from excessive erosion.
River mile (RM)	The distance of a point on a river measured in miles from the river's mouth along the low-water channel.
RJHAB	Resident Juvenile Habitat model
Scour	The localized removal of material from the streambed by flowing water. This is the opposite of fill.
Sediment	Solid material, both mineral and organic, that is in suspension in the current or deposited on the streambed.
Side channel	Lateral channel with an axis of flow roughly parallel to the mainstem, which is fed by water from the mainstem; a braid of a river with flow appreciably lower than the main channel. Side channel habitat may exist either in well-defined secondary (overflow) channels, or in poorly-defined watercourses flowing through partially submerged gravel bars and islands along the margins of the mainstem.
Sinuosity	The ratio of channel length between two points on a channel to the straight-line distance between the same two points. The amount of bending, winding and curving in a stream or river.
Slope	The inclination or gradient from the horizontal of a line or surface. The degree of inclination can be expressed as a ratio, such as 1:25, indicating one unit rise in 25 units of horizontal distance or as 0.04 height per length. Often expressed as a percentage and sometimes also expressed as feet (or inches) per mile.
Smolt	An adolescent salmon which has metamorphosed and which is found on its way downstream toward the sea.
Smoltification	The physiological changes anadromous salmonids and trout undergo in freshwater while migrating toward saltwater that allow them to live in the ocean.
Spawning	The depositing and fertilizing of eggs by fish and other aquatic life.

Term	Definition
Split channel	A river having numerous islands dividing the flow into two channels. The islands and banks are usually heavily vegetated and stable. The channels tend to be narrower and deeper and the floodplain narrower than for a braided system.
Stage	The distance of the water surface in a river above a known datum.
Stage of zero flow (SZF)	No discharge flowing through the cross-section if water stage is equal or lower than SZF. Usually SZF is the channel invert, the lowest point of the channel.
Stage-discharge relationship	The relation between the water-surface elevation, termed stage (gage height), and the volume of water flowing in a channel per unit time.
Stranding	Stranding refers to the beaching of fish and other aquatic organisms on low gradient channel bed as a result of declining river stage.
Streambed	The bottom of the stream channel; may be wet or dry.
Substrate	The material on the bottom of the stream channel, such as rocks or vegetation. Proposed substrate classification system for use in development of HSC/HIS curves for the Susitna-Watana Project. Code / Substrate Type / Size (Inches) / Size (mm) 1 Silt, Clay, or Organic <0.01 <0.1 2 Sand 0.01-0.10 0.1-2.0 3 Small Gravel 0.10-0.30 2.0-8.0 4 Medium Gravel 0.30-1.25 8.0-32 5 Large Gravel 1.25-2.50 32-64 6 Small Cobble 2.50-5.0 64-128 7 Large Cobble 5.0-10.0 128-256 8 Boulder >10.0 >256 9 Bedrock
Suitability	A generic term used in IFIM to indicate the relative quality of a range of environmental conditions for a target species.
Temporal variability	Pertaining to, or involving the nature of time, occurrence in time, and variability in occurrence over some increment in time (e.g., diurnally, daily, monthly, annually).
Thalweg	The deepest channel of a watercourse.
Time step	The interval over which elements in a time series are averaged.
Time-series analysis	Analysis of the pattern (frequency, duration, magnitude, and time) of time-varying events. These events may be discharge, habitat areas, stream temperature, population factors, economic indicators, power generation, and so forth.
Transferability	1. Applicability of a model (e.g., habitat suitability criteria) to settings or conditions that differ from the setting or conditions under which the model was developed. 2. Applicability of data obtained from a remote source (e.g., a meteorological station) for use at a location having different environmental attributes.
Trapping	Trapping is the isolation of fish and other aquatic organisms in pockets of water with no access to the free-flowing surface water as a result of declining river stage.
Tributary	A stream feeding, joining, or flowing into a larger stream (at any point along its course or into a lake). Synonyms: feeder stream, side stream.
Turbidity	A measure of the extent to which light passing through water is reduced due to suspended materials.
Varial zone	The area of river channel bed exposed to frequent inundation and dewatering caused by daily flow fluctuations associated with hydropower load-following operations.

Term	Definition
Velocity	The distance traveled by water in a stream channel divided by the time required to travel that distance.
Velocity adjustment factor (VAF)	$Q_{simulated}/Q_{trial}$, where Q_{trial} is the discharge computed by PHABSIM.
Vertical	A location along a transect across a river where microhabitat-related data are collected.
Weighted usable area (WUA)	The wetted area of a stream weighted by its suitability for use by aquatic organisms or recreational activity.
Wetted perimeter	The length of the wetted contact between a stream of flowing water and the stream bottom in a plane at right angles to the direction of flow.

1. INTRODUCTION

The construction and operation of the Susitna – Watana Hydroelectric Project (Project) (Federal Energy Regulatory Commission (FERC No. 14241) will affect Susitna River flows downstream of the dam; the degree of these effects will ultimately depend on final Project design and operating characteristics. 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 (AEA 2011). Determining the effects of Project operations on the different resources and processes is the focus of a series of studies that have been proposed by Alaska Energy Authority (AEA) as part of the FERC Integrated Licensing Process (ILP). Those studies have been described in detail within the Revised Study Plan (RSP) that was submitted by AEA to the FERC in December 2012.

The development of those study plans benefited from previous studies that were completed in the early 1980s in conjunction with the then proposed development of an earlier Susitna Hydroelectric Project (Susitna-Hydroelectric (Su-Hydro) Project (FERC No. 7114)). That project involved a two-dam configuration with a different proposed operational plan (see Section 2 below). Nevertheless, flow regulation was a paramount issue relative to effects on different resources (Perry and Trihey 1981) and therefore detailed studies were commissioned by the Alaska Power Authority (APA) with the majority conducted over a five year period (1981-1985). The extent and details of many of those studies were provided in the Draft Environmental Impact Statement (FERC 1984) along with companion appendices and attachments in the way of Alaska Department of Fish and Game (ADF&G) reports. A gap analysis conducted by HDR (2011) summarized some of the data and provided an initial listing of salient reports and data that warranted more detailed evaluations.

A more focused review of existing reports and data specific to the Su-Hydro Project proposed in the 1980s was initiated by AEA in 2012 that included the identification, acquisition, and compilation of study plans, reports, data, maps, drawings, photographs, and technical correspondence pertaining to the 1980s Su-Hydro Project. A substantial amount of this information had already been provided to and made available through the Alaska Resources Library and Information Services (ARLIS), and AEA has identified and is working with ARLIS in acquiring the majority of original files, documents, maps, drawings, and other information that had been archived in several locations in Alaska. These documents are in a variety of formats including textual, microfiche, and maps. The majority of these documents will be housed in the ARLIS library in Anchorage, Alaska (some are available online through the University of Alaska, Fairbanks library) and will be made available either electronically or by on-site review to interested parties, licensing participants, and Project team members. AEA has established the following link to the Su-Hydro documents via ARLIS http://www.susitna-watanahydro.org/type/documents/.

As part of the 2012 effort, AEA also commissioned the targeted review of reports, data, and other information specific to the 1980s studies of fish, fish habitats, and instream flow-related assessments. These documents include 83 separate volumes containing descriptions of field studies and reports with tabular data, figures, and maps. The reports describe studies that were focused on a wide range of interrelated topics designed to provide information that would allow for an evaluation of the potential effects of the Su-Hydro Project operations on downstream fish and aquatic resources and habitats. These included studies focused on:

- Adult salmon passage in sloughs and side channels
- Adult salmon spawn timing and distribution
- Salmon Habitat Suitability Criteria
- Salmon spawning habitat evaluation
- Juvenile salmon abundance and distribution including winter studies
- Resident fish abundance, distribution, and life history
- Channel geometry investigations
- Groundwater upwelling detection; and
- Hydrological investigations and modeling of anadromous and resident fish habitat

That work has been completed and has resulted in the preparation of six Technical Memoranda (TMs) that summarize the salient fish and instream flow-related information from those studies. For convenience, and because of their interrelationships, the TMs have been compiled and are included together within this compendium document. The TMs are presented in the following order:

- Technical Memorandum – River Stratification and Study Site Selection Process: 1980s Studies and 2013-2014 Studies – discusses the study site selection process applied during the 1980s studies that allows for a comparison with the process proposed for the 2013-2014 studies.
- Technical Memorandum – Summary of Fish Distribution and Abundance Studies Conducted during the 1980s Su-Hydro Project – summarizes the methods used and study sites sampled for evaluating fish distributions in the Susitna River in the 1980s. This TM does not have a corollary section for the 2013-2014 studies since there are 12 separate fish related studies proposed for 2013-2014 (see RSP Sections 9.5 through 9.16).
- Technical Memorandum – Selection of Target Species and Development of Species Periodicity Information:1980s Studies and 2013-2014 Studies – summarizes the data and information that was collected in the 1980s that was used in identifying target species and developing species periodicities, and provides a general overview of the approach for developing this information in the 2013-2014 studies.
- Technical Memorandum – Development of Habitat Suitability Curves and Habitat Utilization Information: 1980s Studies and 2013-2014 Studies – describes methods used for collecting HSC data in the 1980s and provides a listing of HSC curves that were developed; the TM also provides an overview of the approach for developing this information in the 2013-2014 studies.
- Technical Memorandum – Review of Habitat Modeling Methods: 1980s Studies and 2013-2014 Studies – describes the different instream flow related methods that were applied during the 1980s studies and provides an overview of the approaches that will be applied in the 2013-2014 studies.

- Technical Memorandum – Biologically Relevant and Flow Dependent Physical Processes: 1980s Studies and 2013-2014 Studies – discusses various physical processes that were considered biologically relevant during the 1980s studies and that are linked to surface flow conditions; these processes are also briefly discussed relative to the 2013-2014 studies.

For convenience, all figures and tables, and a comprehensive listing of all references have been placed at the end of the compendium. The compendium includes three appendices:

- Appendix 1 – index of location names and river miles used in the compendium;
- Appendix 2 – a listing of all articles and reports cited in this compendium along with a hyperlink to the documents via ARLIS; and
- Appendix 3 – summary document that describes instream flow study sites and general modeling approaches used during the 1980s instream flow studies.

It should be noted that the TMs presented herein borrow extensively from the reports and documents that were prepared by the many scientists and researchers involved during the 1980s studies. This not only included borrowing from the text and narratives of the reports but in many cases, specific figures or tables that proved especially useful for explaining both methodologies as well as results. Throughout this process, special attention was placed on making sure that the paraphrasing and/or direct quoting or use of materials from these documents was properly cited. However, in spite of this, there may still be a few instances where such citations were missing or improperly assigned and for this we apologize to the respective authors.

2. BRIEF HISTORY OF THE 1980S SUSITNA PROJECT

The Susitna Hydroelectric project, as proposed in the 1980s consisted of a two – dam complex that was scheduled for completion over a 21 year period (Trihey and Associates, and Entrix (1985) in three stages. The two dams included an upper Watana Dam located at RM[1] 184 (PRM 187.5) that was to be constructed first (Stage 1), with a second dam, Devils Canyon Dam located at RM 152 about 32 miles downstream from Watana Dam that was to follow (Stage 2). Stage 3 was to involve raising the height of the Watana Dam, upgrading the four turbines and installing two additional units. At completion, the project would have had a total installed capacity of 1,880 MW (HDR 2009). Construction of the Watana Dam complex was to have occurred over an 8-9 year period commencing in 1985 with power generation to have begun in 1994. Construction of the Devils Canyon Dam was to commence immediately in sequence with the operation of the Watana Dam complex with initial site development beginning in 1994 with major construction occurring over a six year period leading to project operations in 2002 (FERC 1984).

Operationally, the Watana Dam was to be operated as a baseload facility until Devils Canyon operations commenced. At that time, Watana Dam operations were to shift to peak and reserve operation which would allow for daily and hourly changes in flow to meet daily power demands. The Devils Canyon Dam would then have been used as a re-regulating facility to smooth-out the rapid flow fluctuations resulting from operation of the Watana Dam and allow for more stable flow releases provided as part of baseload operations. Thus, the downstream flow releases from the Devils Canyon Dam would not have the daily flow fluctuations associated with peaking and load-following operations of the upper development. In addition, because the Devils Canyon Dam would create a reservoir that would inundate much of the river between the two dams, the instream flow and riparian study efforts in the 1980s focused on the effects of flow releases to the Susitna River downstream of the Devils Canyon Dam site, and the reach between the Devils Canyon Dam and Watana Dam sites was not really considered as part of the instream flow and fisheries studies.

The instream flow-related issues that were the focus of studies completed in the 1980s were more concerned with determining the effects of changes in the timing and magnitude of flows on the quantity and quality of fish habitats that would occur with the two dams as configured, rather than flow fluctuations. Indeed, under the two dam configuration, daily/hourly flow fluctuations would have been of little consequence to the Middle River resources below Devils Canyon. Nevertheless, many of the flow related resource issues that were of concern in the 1980s are similar to those raised for the newly proposed Susitna-Watana Hydroelectric Project (see Fish

[1] The Project River Mile (PRM) system for the Susitna River was developed to provide a consistent and accurate method of referencing features along the Susitna River. During the 1980s, researchers often referenced features by river mile without identifying the source map or reference system. If a feature is described by river mile (RM) or historic river mile (HRM), then the exact location of that feature has not been verified. The use of PRMs provides a common reference system and ensures that the location of the feature can be verified. The PRM was constructed by digitizing the wetted width centerline of the main channel from 2011 Matanuska-Susitna Borough digital orthophotos. Project River Mile 0.0 was established as mean low water of the Susitna River confluence at Cook Inlet. A centerline corresponding to the channel thalweg was digitized upstream to the river source at Susitna Glacier using data collected as part of the 2012 flow routing transect measurements. The resultant line is an ArcGIS route feature class in which linear referencing tools may be applied. The use of RM or HRM will continue when citing a 1980s study or where the location of the feature has not been verified. Features identified by PRM are associated with an ArcGIS data layer and process, and signifies that the location has been verified and reproduced.

and Aquatic Study Requests as posted at http://www.susitna-watanahydro.org/type/documents/). In the early 1980s, an initial set of issues and concerns regarding the Susitna Hydroelectric Project were identified as part of an organized survey of state and federal resource agencies and stakeholders. These concerns were summarized and discussed in Perry and Trihey (1981) and included comments that were separated into nine instream flow use categories including commercial, recreational, water quality, water rights, estuary, riparian vegetation, fish and wildlife, recreation and flow regime. Some of the comments and questions pertaining to fish and the aquatic ecosystem effects included:

- How would changes in flow regime, temperature, silt and water quality parameters affect spawning, movement, outmigration, egg development and seasonal habitat use?
- Would higher stream flow velocities associated with increased winter flows affect young-of-the-year that migrate into the mainstem from tributaries during winter months?
- What overwintering of juvenile and resident anadromous fish occurs in the main channel and how would it be affected?
- What will the effect be of reducing the sediment load and associated nutrients on downstream biota?
- Would the reduction of peak flows affect fishery utilization of side channels and backwater areas?
- What will the magnitude of flow change be under post-project conditions and how would this affect access (fish) to tributaries?
- Will the reduction in the seasonal variability of flow negatively impact the ability of the river to cleanse itself of debris?
- How will flows dampen in a downstream direction?
- What is the relationship of groundwater levels to surface flows in the Susitna River?
- What will the effect be of increased winter flows on icing?
- How would the changes in flow affect sediment transport, bedload transport, stream morphology and channel characteristics?

To address these questions, a series of studies were completed commencing in 1981 and extending through 1986. Table 2.1-1 provides a general listing of the types of instream flow and fish related studies that were completed as part of the Su-Hydro Project Fish and Aquatics Study Program. More details concerning these studies are provided in other sections of this TM Compendium, as well as in a synthesis document of 1980s fish data presented in R2 (2013a).

3. TECHNICAL MEMORANDUM – RIVER STRATIFICATION AND STUDY SITE SELECTION PROCESS: 1980S STUDIES AND 2013-2014 STUDIES

As in all complex riverine instream flow studies, one of the first and perhaps most important steps that occurs is the development of a study plan that spells out not only the study objectives but also the methods and techniques that will be used to accomplish the objectives. A fundamental part of that plan is typically devoted to specifying the locations/sites in which the studies will be conducted. For large river systems such as the Susitna River, this generally involves some form of stratification process in which the river is divided into reaches or segments based on similarity of physical, hydrologic, and morphologic conditions. This process, along with a habitat mapping component helps to determine both the number of study sites as well as their spatial distribution and is integral for being able to make inferences from measured to unmeasured sites. This TM describes the process that was used during the Su-Hydro 1980s studies and then how that process factored into the stratification and classification approach being proposed for the Susitna- Watana 2013-2014 studies.

3.1. Su-Hydro 1980s Studies – River Stratification, Classification and Site Selection

The stratification approach applied for the 1980s Su-Hydro studies involved dividing the Susitna River into segments, sub-reaches, and study sites based on hydrology, channel morphology, tributary input, macro- and mesohabitat features, and fish use. At the broadest scale, the Susitna River was divided into three segments following the historic river mile convention used at the time:

1. Upper River – Representing that portion of the watershed above the proposed Devils Canyon Dam (hereafter referred to as “Devils” Canyon) site at RM 152.
2. Middle River – Extending approximately 53.5 miles from RM 152 downstream through Devils Canyon to the Three Rivers Confluence at RM 98.5.
3. Lower River – Extending 98.5 miles downstream from the Three Rivers Confluence to Cook Inlet (RM 0).

These three breaks formed the first order level of stratification in the 1980s studies. It is important to note that even with a two dam configuration, as was proposed for the Su-Hydro Project (see above), the studies did not separate out a fourth segment that would have extended for about 32 miles from Devils Canyon to the proposed Watana Dam site at RM 184. This was presumably because the lower dam (Devils Canyon Dam) would represent the lowermost point of the affected upper reach so that the lower boundary of that reach was anchored at that location.

3.1.1. Middle River Stratification

For the Middle River, a second level of stratification was designated based on classifying riverine-related habitats of the Susitna River into six macro-habitat categories consisting of mainstem, side channel, side slough, upland slough, tributaries, and tributary mouths (Estes and Vincent-Lang 1984; Klinger and Trihey 1984). The distribution and frequency of these habitats varied longitudinally within the river depending in large part on its confinement by adjoining floodplain areas, size, and gradient. The habitat types were described by ADF&G with respect to mainstem flow influence in the *Susitna Hydroelectric Aquatic Studies Procedures Manual* (ADF&G 1984), also in Klinger and Trihey (1984) as follows, with additional clarification added here where considered appropriate:

- **Mainstem habitat** consisting of those portions of the Susitna River that normally convey stream flow throughout the year. Both single and multiple channel reaches are included in this habitat category. Groundwater and tributary inflows appear to be inconsequential contributors to the overall characteristics of mainstem habitat. Mainstem habitat is typically characterized by high water velocities and well-armored streambeds. Substrates generally consist of boulder- and cobble-size materials with interstitial spaces filled with a grout-like mixture of small gravels and glacial sands. Suspended sediment concentrations and turbidity are high during summer due to the influence of glacial meltwater. Stream flows recede in early fall and the mainstem clears appreciably in October. An ice cover forms on the river in late November or December.
- **Side channel habitat** consisting of those portions of the Susitna River that normally convey stream flow during the open-water season but become appreciably dewatered during periods of low flow. Side channel habitat may exist either in well-defined overflow channels, or in poorly defined water courses flowing through partially submerged gravel bars and islands along the margins of the mainstem river. Side channel streambed elevations are typically lower than the mean monthly water surface elevations of the mainstem Susitna River observed during June, July, and August. Side channel habitats are characterized by shallower depths, lower velocities, and smaller streambed materials than the adjacent habitat of the mainstem river.
- **Side slough habitat** located in spring- or tributary-fed overflow channels between the edge of the floodplain and the mainstem and side channels of the Susitna River and usually separated from the mainstem and side channels by well-vegetated bars. An exposed alluvial berm often separates the head of the slough from mainstem or side channel flows. The controlling streambed/streambank elevations at the upstream end of the side sloughs are slightly less than the water surface elevations of the mean monthly flows of the mainstem Susitna River observed for June, July, and August. At intermediate- and low-flow periods, the side sloughs convey clear water from small tributaries and/or upwelling groundwater (Estes et al. 1981). These clear water inflows are essential contributors to the existence of this habitat type. The water surface elevation of the Susitna River generally causes a backwater to extend well up into the slough from its lower end (Estes et al. 1981). Even though this substantial backwater exists, the sloughs function hydraulically very much like small stream systems and several hundred feet of the slough channel often conveys water independent of mainstem backwater effects. At high flows the water surface elevation of the mainstem river is sufficient to overtop the upper end of the slough (Estes et al. 1981). Surface water temperatures in the side sloughs during summer months are principally a function of air temperature, solar radiation, and the temperature of the local runoff.
- **Upland slough habitat** differs from the side slough habitat in that the upstream end of the slough is not interconnected with the surface waters of the mainstem Susitna River or its side channels at less than bankfull flows. The upstream end can be vegetated with

mature trees, although a morphologic signature of a converging inlet and gravel levee closure can still be discerned. These sloughs are characterized by the presence of beaver dams and an accumulation of silt covering the substrate resulting from the absence of mainstem scouring flows. They are not truly “upland” in the geomorphic sense, but the use of this nomenclature in the 1980s studies reflects the observation that the understanding of floodplain and channel forming processes was in the early stage in fisheries, where some variation in interpretation existed over what constituted a floodplain versus an upland terrace (e.g., see Williams 1978). Essentially, the main distinguishing characteristic between a “side” slough and an “upland” slough was the level of high flow at which each was engaged.

- **Tributary habitat** consists of the full complement of hydraulic and morphologic conditions that occur in the tributaries. Their seasonal stream flow, sediment, and thermal regimes reflect the integration of the hydrology, geology, and climate of the tributary drainage. The physical attributes of tributary habitat are not dependent on mainstem conditions.
- **Tributary mouth habitat** extends from the uppermost point in the tributary influenced by mainstem Susitna River or slough backwater effects to the downstream extent of the tributary plume that extends into the mainstem Susitna River or slough (Estes et al. 1981).

A schematic of these types of habitats as applied in the 1980s studies is depicted in Figure 3.1-1. These categories were also used by Trihey and Associates as part of instream flow modeling studies for the Middle river (Aaserude et al. 1985).

3.1.2. Lower River Stratification and Classification

Because of the increased channel complexity, a three tiered approach was used for stratification of the Lower River. This consisted of River Segment, Channel and Island Complexes, and Macrohabitat types (R&M Consultants et al. (R&M and Trihey & Associates 1985). In terms of River Segments, the Susitna River was divided into five segments based on river morphology and hydrology (R&M and Trihey & Associates 1985). These segments included breaks in river miles as follows: Segment 1: RM 98.5 to RM 78; Segment 2: RM 78 to RM 51; Segment 3: RM 51 to RM 42. 5; Segment 4: RM 42.5 to RM 28.5; and Segment V: RM 28.5 to RM 0 (see Figure 2.1 in R&M and Trihey & Associates 1985).

Within each River Segment, two primary classifications were made consisting of Mainstem Channel and Side Channel complexes with each of these further divided into the following sub-classifications:

- **Mainstem Channel** – subclassified into: 1: Mainstem river consisting of mainstem channel and main subchannels; and 2) Alluvial channel complexes consisting of areas of broad gravel islands with numerous subchannels that dewater as flows decrease; and
- **Side Channel Complexes** – subclassified into 1) Major side channels that were designated in the 1980s studies as channels overtopped at mainstem flows of 13, 900 cfs (the flow considered as the low winter flow during project operations (based on 1980s project design) (these channels may collect groundwater seepage and tributary flow); 2) Intermediate side channels that were distinguished based on the magnitude of the

mainstem flows in which the side channels dewater; and 3) Minor side channels that become dewatered over their entire length at flows of 36,600 cfs (the flow considered transitional natural flow and project operation flow during May and September (based on 1980s project design) (R&M and Trihey & Associates 1985).

With respect to habitat types, a slightly different classification procedure was used that consisted of eight general categories of which three (mainstem, side slough, and tributary mouth) were common with the Middle River categories. These categories were described in R&M et al. (1985) as follows:

- **"Mainstem habitats** consisting of the thalweg channel, major subchannels, major subchannels and alluvial island complexes". This habitat type was generally outside of areas that were generally considered as "representative areas" (R&M and Trihey & Associates 1985).
- **Primary side channels** consisting of "those channels which normally convey streamflow throughout the entire year" (R&M and Trihey & Associates 1985). These side channels exhibit characteristics similar to Middle river habitat types and are characterized by glacially induced turbid water, high water velocities and few mid-channel bars.
- **Turbid backwater habitats** consisting of nonbreached channels containing turbid water. These habitats have "non-vegetated upper thalwegs that are overtopped during periods of moderate to high mainstem discharge" and represent a "transitional habitat type between breached secondary side channel habitats and nonbreached Clearwater or side slough habitats" (R&M and Trihey & Associates 1985).
- **Clearwater habitats** consisting of "nonbreached channels containing clear water that dewater completely at a mainstem discharge of 13,900 cfs or higher. These channels have non-vegetated upper thalwegs that are overtopped during periods of moderate to high mainstem discharge. Groundwater and local surface runoff appear to supply water to these areas at mainstem flows above 13,900 cfs" (R&M and Trihey & Associates 1985)
- **Side slough habitats** consisting of clear water areas that are supplied via a mixture of groundwater (upwelling) and local surface runoff. These clear water areas exist up to mainstem flows of 13,900 cfs (R&M and Trihey & Associates 1985). Similar to the Middle river, the side sloughs have non-vegetated upper thalwegs that are overtopped at moderate to high mainstem discharges.
- **Tributary mouth habitats** consisting of "clear water habitat that exist between the downstream extent of a clear-water plume and upstream into the tributary, to the upper extent of the backwater influence. The surface area depends on the discharge of both the tributary and mainstem" (R&M and Trihey & Associates 1985).
- **Tributary habitats** consisting of areas upstream of the tributary mouth habitat. This habitat type was designated in the Lower River recognizing that tributary habitats may increase dramatically when tributary flows into nonbreached side channel (side slough) habitats and clear water tributary flows extend through the side channel to join the Susitna River (R&M and Trihey & Associates 1985).

During the 1981 and 1982 studies, side sloughs and side channels were distinguished primarily on their morphology. Side sloughs included (as noted above) an unvegetated berm at the head of the slough and were rarely overtopped. In contrast, a side channel conveyed mainstream flow during most of the year. During 1983 and following years, if a berm was overtopped and a channel conveyed mainstem flows it was then characterized as a side channel (Dugan et al. 1984). If the berm was not overtopped it was characterized as a side slough. Consequently, during the latter years of the 1980s Fish and Aquatic Program an area may have been characterized as a side channel during periods of high flows and a side slough during periods of lower flows[2].

3.1.3. Study and Sample Sites

Specific sites chosen for completion of the various studies by ADF&G between 1981 and 1985 varied from year to year and study to study. In general, sampling was relatively broad during 1981 and 1982, and more focused during 1983 to 1985. The 1981 Aquatic Habitat Studies were focused on 'Fishery Habitat' evaluations and 'Selected Habitat' evaluations (Estes et al. 1981). The Fishery Habitat evaluations collected point information on observed fish habitat use and general habitat evaluations (water quality, hydrology, and mapping). The Selected Habitat evaluations collected water quality, discharge, and mapping information at selected sloughs between Talkeetna and Devils Canyon.

A total of 5 river reaches were delineated and 8 to 13 representative study sites were selected in each, without consideration of proportional sampling or optimal allocation (e.g., see Cochran 1977). These included the following:

- Yentna Reach (Cook Inlet to Little Willow Creek; RM 0.0–50.5): 13 sites
- Sunshine Reach (Rustic Wilderness to Parks Highway Bridge; RM 58.1–83.5): 10 sites
- Talkeetna Reach (Parks Highway Bridge to Curry; RM 83.5–120.7): 11 sites
- Gold Creek Reach (Curry to Portage Creek; RM 120.7–148.8): 12 sites
- Impoundment Reach (Devils Canyon to Denali Highway; RM 151–281): 8 tributaries

With few exceptions, the sites sampled for aquatic habitat studies were the same as those sampled under resident and juvenile anadromous fish studies in 1981 and 1982. Selection of specific sampling sites was not based upon strict statistical sampling designs. Instead, sites were selected that were considered representative of each reach, and were based effectively on where fish were found. This basis was carried forward in subsequent years. For example, in 1982, habitat information was collected where spawning fish were located within the mainstem Susitna River downstream of Devils Canyon (tributary/mainstem confluence areas and sloughs were not sampled). Only spawning sites for chum salmon were observed in the mainstem, which led to the identification of eight mainstem spawning locations between Lane Creek (RM 113.6) to Devils Canyon.

Information on the distribution and abundance of juvenile and resident fish was also important to the Aquatics Study Program. Sampling for juvenile and resident fishes from November 1980 through mid October 1981 included a wide range of sites and sampling techniques. By June of 1981, the Aquatic Studies Program had settled on 39 areas, which they termed "habitat

[2] This naming convention is not being applied to the 2013/2014 studies. Rather, side sloughs will remain side sloughs even if breached via main channel flow.

locations," that were the focus of sampling during the open water period (Delaney et al. 1981). During the winter of 1980 to 1981, 29 of the habitat locations were sampled, plus an addition 48 "selected fish habitat sites" that were described as exploratory sampling. An understanding of habitat utilization by juvenile anadromous and resident fish was developed as part of more focused studies during 1982, 1983, and 1984. During 1982, 17 sites referred to as Designated Fish Habitat (DFH) sites were surveyed twice monthly from June through September during the open water season (Estes and Schmidt 1983). These sites were selected based upon four criteria (Estes and Schmidt 1983; ADF&G 1983):

1. Areas that will be affected by changes in discharge of the mainstem Susitna.
2. Sites identified from previous studies to have significant populations of resident and juvenile anadromous species.
3. Access to areas will not create severe logistics problems and limit the overall scope of the studies.
4. Sites selected represent a cross-section of critical areas available to resident and juvenile anadromous fish of the Susitna River.

Twelve of these sites were located in the Middle River (Whiskers Creek and Slough to Portage Creek Mouth) and five were located in the Lower River (Goose Creek and Side Channel to Birch Creek and Slough; Table 3.1-1; Figure 3.1-2).

Habitat zones were delineated within each DFH site based upon the influence of mainstem flow, tributary flow, and water velocity (Table 3.1-2; Figure 3.1-3). Because the zones were based upon flow characteristics, the size of the zones may have varied from survey to survey. As part of the statistical analysis the nine zones were aggregated into Hydraulic and Water Source Zones (Table 3.1-3). In addition to statistical tests to determine associations between fish species catch per unit effort and aggregate hydraulic and water source zones, tests were also run to examine correlations between catch per unit effort and habitat variables including water temperature, turbidity, and velocity (Schmidt and Bingham (1983, Appendix E). A large number of sites (275 mainstem sites and 55 tributary and other slough sites) called Selected Fish Habitat (SFH) sites were also sampled in 1982, but these sites were usually sampled less frequently (1 to 3 times) and more opportunistically than DFH sites.

During 1983 and 1984, studies were focused on obtaining information needed for developing instream flow models under the Anadromous Habitat (AH) component and sampling was coupled with obtaining additional distribution and abundance information desired for the Anadromous Juvenile (AJ) component (Schmidt et al. 1984, Suchanek et al. 1985). The instream flow models include Resident Juvenile Habitat (RJHAB) and Instream Flow Incremental Methodology (IFIM) models and Direct Input Habitat (DIHAB) models developed by Trihey and Associates (Hilliard et al. 1985) (more information concerning these models is provided in Section 8). As before, sites were selected based on where fish were found. During 1983, 32 sites (11 tributaries, 3 upland sloughs, 8 side slough/channel, 6 side channel, 4 side slough) were sampled in the reach from Talkeetna to Devils Canyon for fish distribution, and 13 sites were modeled by ADF&G with either the RJHAB (2 upland sloughs, 2 side channel/ sloughs, 1 side slough, 1 side channel) approach or IFG approach (3 side slough/channels, 1 side slough, 3 side channels) (see Appendix 3). The 13 modeled sites were chosen based upon observations of large numbers of spawning salmon or concentrations of juvenile salmon during 1981 and 1982 studies

(Dugan et al. 1984). They were also selected as being representative of the habitat types present between the Chulitna River and Devils Canyon likely to be affected by changes in mainstem flow from the proposed project (Dugan et al. 1984; Marshall et al. 1984).

Sampling in 1984 focused on main channel margins, side channels, side sloughs, and tributary mouth habitats in the Middle and Lower River segments between RM 147.1 and 35.2. During 1984, crews sampled three types of study sites:

- RJHAB sites (16 sites)
- IFG sites (6 sites)
- DIHAB sites (14 sites)
- Opportunistic sites (31 sites)

Opportunistic sites were sampled only once to expand the understanding of juvenile and resident fish distribution (Suchanek et al. 1985).

Instream flow modeling of spawning habitat was conducted for chum and sockeye salmon at mainstem margin, side channel, upland slough, and side slough habitat types. Modeled sites were considered to represent the range of spawning conditions for sloughs and side channels present in the mainstem between the Chulitna River and Devils Canyon. In addition, instream flow studies were performed to describe juvenile Chinook habitat-flow responses within mainstem margins, side channels, side sloughs, and upland sloughs of the middle river. The modeling studies relied effectively on the habitat classification, and manipulations thereof, for stratifying and extrapolating model results from sampled sites to larger study reaches (Steward et al. 1985; Ashton and Klinger-Kingsley 1985; and Klinger-Kingsley et al. 1985). The overall approach proposed for the extrapolation process was described in Aaserude et al. (1985) and consisted of methods for both single thread and multiple thread portions of the river (see Section 8). However, project funding was curtailed in 1985 and the approach was never implemented.

The 1983 open water studies for fish included 35 study sites (called Juvenile Anadromous Habitat Study or JAHS sites) in the lower Middle River while the 1984 studies included 20 sites in the Lower River (Table 3.1-4). Macro habitat types included in the study were those described above (i.e., tributary, upland slough, side slough, and mainstem side channel). Rationale for sites selected for study included (Dugan et al. 1984):

1. Sites where relatively large numbers of spawning adult salmon were recorded in 1982 (ADF&G 1982),
2. Sites where concentrations of rearing juvenile salmon were observed or collected in 1981 and 1982, and
3. Sites representing macrohabitat types associated with the Susitna River that are affected by changes in mainstem flow.

In addition to the combined AH and AJ sampling efforts, studies were implemented to better understand juvenile salmon outmigration and growth (Roth et al. 1984, Roth and Stratton 1985), resident fish distribution and abundance (Sundet and Pechek 1985), river productivity (Wilson 1985, Nieuwenhuyse 1985), and invertebrate food sources for Chinook salmon (Hansen and Richards 1985).

The 1983 and 1984 JAHS sites were sampled in a systematic fashion within grids delineated at each site (Dugan et al. 1984, Suchanek et al. 1985). As described in Dugan et al. (1984) and depicted in Figure 3.1-4:

> *"Each of the study sites was divided into one or more grids. Grids were located to keep water quality (temperature, turbidity) within the site as uniform as possible and to encompass a variety of depth, velocity, cover, and substrate types. Each grid consisted of a series of transects which intersected the channels of the study sites at right angles. There were one to three cells (6 ft. in width by 30 ft. in length = 300 sq. ft.) at every transect within the grid. An attempt was made to confine uniform habitat within each cell. Fish were usually sampled from a minimum of seven cells within each grid at each site.*
>
> *The cells were selected to represent the complete range of habitat types available within the grid. Fish density was estimated by electrofishing or beach seining the entire cell, attempting to capture all fish. Catch per unit effort (CPUE) was defined as the catch (number of fish) per cell."*

The analysis utilized the percent distribution of each salmon species among the four macrohabitat types sampled as the evaluation metric. Analysis of variance (ANOVA) techniques were used to discern factors affecting habitat use by the different juvenile salmon species. In addition to site and sampling period, the factors collected in each cell following fish sampling included mean water depth, mean water velocity, mean percent cover, water temperature, and turbidity. Depth, velocity, and cover measures were averaged over the entire site because the cells were not randomly distributed.

3.2. Susitna-Watana Hydroelectric Project 2013-2014 Studies: Stratification and Study Site Selection

Review of the process and methodologies applied in selecting study and sample sites during the 1980s Su-Hydro studies provided a good foundation of information that factored directly into development of the stratification and study site selection for the resource studies associated with the Susitna – Watana Project. That process was described in RSP Section 8.5 and restated with some modification in a Technical Memorandum provided to the FERC on March 1, 2013 (R2 2013b). For convenience, and for comparison with the 1980s studies, salient portions of the TM (R2 2013b) are presented below.

3.2.1. River Stratification and Classification

As noted in Section 3.1, during the 1980s studies and in consideration of the two-dam configuration, the Susitna River was characterized into three segments, an Upper segment that extended above the Devils Canyon Dam site (lower dam), a Middle segment extending from the lower dam site to the Three Rivers Confluence, and a Lower segment that extended down to Cook Inlet (see Section 3.1). The currently proposed Susitna – Watana Dam project entails a single dam configuration at the Watana Dam site at PRM 187.1. Therefore, although the river was again stratified into three segments, the segment start and end locations differ from those specified in the 1980s. In this case, the Upper River Segment represents that portion of the watershed above the Watana Dam site[3] at PRM 187.1 (RM 184), a Middle River Segment extending from PRM 187.1 downstream to the Three Rivers Confluence at PRM 102.4, and a Lower River Segment extending from the Three Rivers Confluence to Cook Inlet (PRM 0) (Figure 3.2-1),. From an instream flow perspective, the study area at issue with respect to the Susitna-Watana Project operations and flow regulation effects consists of the Middle and Lower River segments.

The Middle River Segment represents the section of river below the Project dam that is projected to experience the greatest effects of flow regulation caused by Project operations. Within this reach, the river flows from Watana Canyon into Devils Canyon, the narrowest and steepest gradient reach on the Susitna River. The Devils Canyon constriction creates extreme hydraulic conditions including deep plunge pools, drops, and high velocities. Downstream of Devils Canyon, the Susitna River widens but remains essentially a single main channel with stable islands, numerous side channels, and sloughs.

The Lower River Segment receives inflow from three other large river systems. An abrupt, large-scale change in channel form occurs where the Chulitna and Talkeetna rivers join the Susitna River near the town of Talkeetna in an area referred to as the Three Rivers Confluence. The annual flow of the Chulitna River is approximately the same as the Susitna River at the confluence, though the Chulitna contributes much more sediment than the Susitna. The Talkeetna River also supplies substantial flow rates and sediment volumes. Farther downriver, the Susitna River becomes notably more braided, characterized by unstable, shifting gravel bars and shallow subchannels. The Yentna River is a large tributary to the Lower Susitna River and supplies about 40 percent of the mean annual flow at the mouth of the Susitna River.

Contemporary geomorphic analysis of both the Middle River and Lower River segments confirmed the distinct variations in geomorphic attributes (e.g., channel gradient, confinement, channel planform types, and others) (see RSP Section 6.5) and resulted in the classification of the Middle River Segment into eight geomorphic reaches and the Lower River Segment into six geomorphic reaches (see Figures 8.5-11 and 8.5-12 of RSP Section 8.5,). These reaches were incorporated into a hierarchical stratification system that scales from relatively broad to more narrowly defined categories as follows:

Segment → Geomorphic Reach → Mainstem Habitat Type →

Main Channel Mesohabitat Types → Edge Habitat Types

The highest level category is termed Segment and refers to the Middle River Segment and the Lower River Segment. The Geomorphic Reach level is next and consists of the eight reaches (MR-1 through MR-8) for the Middle River Segment and six reaches (LR-1 through LR-6) for the Lower River Segment (see RSP Section 6.5.4.1.2.2 and RSP Section 8.5 Table 8.5 4). The geomorphic reach breaks were based in part on the following five factors: 1) Planform type (single channel, island/side channel, braided); 2) Confinement (approximate extent of floodplain, off-channel features); 3) Gradient; 4) Bed material / geology; and 5) Major river confluences.

This level is followed by Mainstem Habitat Types, which capture the same general categories applied during the 1980s studies but include additional sub-categories to provide a more refined delineation of habitat features (see RSP Section 8.5 Table 8.5 5). Major categories and sub-

[3] The Watana Dam site was the upper dam proposed as part of the Su-Hydro Project.

categories under this level include: 1) Main Channel Habitats consisting of Main Channel, Split Main Channel, Braided Main Channel, Side Channel; 2) Off-channel Habitats that include Side Slough, Upland Slough, Backwater and Beaver Complexes; and 3) Tributary Habitats that consist of the segment of the tributary influenced by mainstem flow. The next level in the hierarchy is Main Channel and Tributary Mesohabitats, which classifies habitats into categories of Cascades, Riffle, Pool, Run, and Glide. The mesohabitat level of classification is currently limited to the main channel and tributary mouths for which the ability to delineate these features is possible via aerial imagery and videography. Mesohabitat mapping in side channel and slough habitat types will require ground surveys, planned to begin in 2013. The last level in the classification is Edge Habitat and is intended to provide an estimate of the length of shoreline in contact with water within each habitat unit. The amount of edge habitat within a given habitat unit will provide an index of habitat complexity, i.e., more complex areas that consist of islands, side channels, etc. will contain more edge habitat than uniform, single channel areas.

Overall, the goal of the stratification step for the 2013-2014 studies was to define segments/reaches with effectively similar characteristics where, ideally, repeated replicate sampling would result in parameter estimates with similar statistical distributions. The stratification/classification system described above was designed to provide sufficient partitioning of sources of variation that can be evaluated through focused study efforts that target each of the habitat types, and from which inferences concerning habitat–flow responses in unmeasured sites can ultimately be drawn.

3.3. Selection of Study Areas/Study Sites

In general (as noted by Bovee 1982), there are three characteristic approaches to instream flow studies that pertain to site selection that were considered for application for the Susitna-Watana Project. These included representative sites/areas, critical sites/areas, and randomly selected sites/areas.

3.3.1. Representative Sites

Representative sites are those where professional judgment or numerically and/or qualitatively derived criteria are relied on to select one or more sites/areas that are considered representative of the stratum or larger river. Representative sites typically contain all habitat types of importance. In general, the representative site approach can be readily applied to simple, single thread channel reaches, where the attributes that are measured are extrapolated linearly based on stream length or area. In this case, the goal of stratification will be to identify river segments that are relatively homogenous in terms of mesohabitat mixes, and the methods used for stratification tend to be classification-based. This approach typically requires completing some form of mapping up front, and using the results to select sites that encompass the range of habitat conditions desired. The results of such habitat mapping were not available during the initial study site/area selection, but since then, the results of the habitat mapping have been completed and analyzed and are reported in R2 2013b.

3.3.2. Critical Sites

Critical sites are those where available knowledge indicates that either (i) a sizable fraction of the target fish population relies on that location, (ii) a particular habitat type(s) is (are) highly important biologically, or (iii) where a particular habitat type is well known to be influenced by flow changes in a characteristic way. For example, in the case of the Susitna River, historical fish studies repeatedly showed the importance of certain side slough, upland slough, and side channel areas for spawning and juvenile rearing. Critical sites or areas are typically selected assuming that potential Project effects to other areas are secondary in terms of implications to fish population structure, health, and size. This assumption can only really be tested if other sites are identified that are similar looking but were not deemed critical, and sampling is performed on those sites as well to confirm the critical nature of the sites that were identified as such.

3.3.3. Randomly Located Sites

Randomly located sites are those sites, areas, or measurement locations selected randomly from each defined stratum or habitat type, and replicate sites or cross-sections are sampled to estimate variance (e.g., Williams 1996; Payne et al. 2004). Site selection based on random sampling tends to involve statistical multivariate grouping or stratification approaches, such as cluster analysis or ordination techniques. The approach is the least subject to potential for bias, because it relies on distinct rules and algorithms. However, the approach becomes increasingly difficult to apply in site selection when the sites become more complex, such as is the case on the Susitna River. In addition, the number of sites will be contingent on the variability within the universal data set: the greater the number of clusters, the greater the potential number of sites. Strict random sampling is therefore not likely applicable for evaluating off-channel habitats and sloughs where the morphology of multiple channels varies substantially and in complex ways within and across sites.

3.3.4. Focus Areas and Study Sites – Middle River Segment

The concept of “intensive study areas” was introduced during a September Technical Workgroup Meeting (TWG) and discussed relative to sampling the Middle River Segment. This concept evolved from the realization that a prerequisite to determining the effects of Project development and operations on the Susitna River is the need to first develop an understanding of the basic physical, chemical and ecological processes of the river, their interrelationships, and their relationships with flow. Two general paths of investigation were considered, 1) process and resource specific and 2) process and resource interrelated. Under the first, process and resource specific, studies would focus on determining relationships of flow with specific resource areas (e.g., water quality, habitat, ice, groundwater) and at specific locations of the river without considering interdependencies of other resource areas at different locations. Under the second, process and resource interrelated, studies would be concentrated at specific locations of the river that would be investigated across resource disciplines with the goal of providing an overall understanding of interrelationships of river flow dynamics on the physical, chemical, and biological factors that influence fish habitat.

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 and therefore major emphasis was placed on selecting those areas, which were termed Focus Areas (FA). However, it was also reasoned that there will be a need to collect information and data from other locations to meet specific resource objectives. As a result, the study site/area selection process presented in the RSP (Section 8.5) pertaining to the Middle River Segment represented a combination of both approaches and resulted in the identification of ten FAs that are described in Table 3.3-1 and displayed in Figures 3.3-1 to 3.3-11.

Composition wise, the FAs contain *combinations* of different habitat types and features as characterized according to the hierarchical classification system noted above. The FA concept represents a combination of all three of the study site selection methods described above, inasmuch as (1) the areas would contain habitat types representative of other areas; (2) the areas would include certain habitat types repeatedly used by fish and therefore can be considered “critical areas,” and (3) sampling of certain habitat features or mesohabitat types within the areas would be best approached via random sampling. A comparative analysis of the habitat types present within each of the FAs compared to habitat types outside of FAs was completed and indicated that the ten FAs are generally representative of habitat types found in other portions of the river (see Section 3.1.1 of R2 2013b). Analysis of the FAs from the riparian perspective confirmed the representativeness of eight of the areas for analysis, with a further peer review resulting in selection of five FAs for final riparian investigation (see Section 3.1.2 of R2 2013).

In addition to the FAs in the Middle River, a number of other study sites have been identified that are specific to the goals and objectives of different resource investigations (see Fisheries (RSP Section 9.6, 9.8, and 9.9), Groundwater (RSP Section 7.5), Geomorphology (RSP Section 6.0), Ice Processes (RSP Section 7.6), and Water Quality (RSP Section 5.0).

3.3.5. Study Sites – Lower River Segment

Application of an FA approach to sampling the Lower River Segment was deemed unfeasible given the channel complexity, size, and inherent changing nature of the channel morphology. As a result, study areas were tentatively identified by AEA’s inter-disciplinary team including representatives from geomorphology, instream flow-fish, instream flow-riparian, and groundwater. One area was selected in each of the geomorphic reaches LR-1 and LR-2 to describe the mix of thalweg channel, major subchannels, alluvial island complexes, side channels and sloughs observed in aerial photos of the Lower River Segment channel. The area around Trapper Creek near PRM 94.5 was selected as representative of the habitat types in LR-1 (Figure 3.3-12), and the area around Caswell Creek near PRM 67 was selected as representative of habitat types in LR-2 (Figure 3.3-13). Study sites proposed for fish sampling, groundwater, and riparian studies are depicted in Figure 3.3-14 in 2013. The Susitna-Watana studies have been founded around an adaptive management framework such that the results from the 2013 studies for the Lower Susitna River Segment will provide a basis for assessing the need to perform further data collection and analysis in 2014.

4. TECHNICAL MEMORANDUM – SUMMARY OF FISH DISTRIBUTION AND ABUNDANCE STUDIES CONDUCTED DURING THE 1980S SU-HYDRO PROJECT

One of the primary objectives of the aquatic investigations completed for the 1980s Su-Hydro Project was to determine the distribution and abundance of both anadromous and resident fish species in the Susitna River. This information was considered essential for understanding how project operations may affect different species over space and time. As a result, a substantial effort was expended over a five year period (1981- 1985) conducting studies concerning the distribution and abundance of fish.

This TM summarizes salient information concerning those studies and includes a discussion of methods used, study sites sampled and general results on a species basis. The TM is complementary to the fish data synthesis document prepared by R2 (2013a) which should be referred to for more detailed information on the 1980s Su-Hydro fish studies.

4.1. Summary of Methods Used

Information on the distribution and abundance of anadromous and resident fish species in the Susitna River was collected using a variety of methods deployed at selected locations from the mouth of the river to the Oshetna River (RM 226.9) and within selected tributaries. Escapement and distribution of adult salmon during the 1980s Aquatic Studies Program was primarily based upon three sampling techniques:

- Fishwheels and sonar
- Spawning surveys
- Radio tracking

Floy spaghetti tags or Petersen disc tags were used to study fish movements and to estimate escapement using Peterson estimation techniques. Adult periodicity information is primarily available from fishwheels and Bendix sonar stationed at a number of locations in the mainstem Susitna River and in the Yentna River (Table 4.1-1). Stations were generally deployed in early- to mid-June and fished through early- to mid-August. Spawning surveys occurred annually by foot, raft, airplane, or helicopter. Radio tracking of adult Chinook (*Oncorhynchus tshawytscha*), coho (*O. kisutch*), and chum salmon (*O. keta*) occurred in 1981 and 1982 and was used to identify spawning and holding locations and better understand migration rates (ADF&G 1981, ADF&G 1982). The number of salmon tracked within a species and year was 18 or fewer fish (Table 4.1-2). Length information was obtained from a subsample of salmon captured at the fishwheels and scales removed to determine the age structure of returning adults and the age at ocean entry.

Sampling for juvenile salmon and resident fish included a wide range of sampling techniques that included beach seine, dip net, boat and backpack electrofishing, drift gill nets, set gill nets, minnow traps, trot lines, fyke/hoop nets, and hook and line. Effort expended by each gear type varied from year to year and by sampling site. Beach seines, minnow traps, trotlines, and boat and backpack electrofishing were the most commonly used gear for most sampling sites. Hook and line was the primary method for capturing Arctic grayling (*Thymallus arcticus*) in tributaries of the Upper Susitna River. Similar to adult salmon, captured resident fish were commonly tagged with Floy spaghetti or anchor tags to determine fish movements, growth, and estimation of population size. During 1984 and the winter of 1985-1986 juvenile Chinook and coho salmon were marked with cold brands or tagged with coded wire tags (CWT) to study tributary outmigration, overwintering habitat use, and population estimation (Schmidt et al. 1985, Stratton 1986). Radio tracking occurred on rainbow trout (*O. mykiss*), burbot (*Lota lota*) and Arctic grayling to identify spawning areas and movement patterns (Table 4.1-2). Fish sampling during winter primarily used trotlines and minnow traps, with occasional use of backpack electrofishing, gill nets, and fyke nets in open leads. Length information was obtained from a subsample of fish captured and scales removed to determine age structure.

Outmigration timing of juvenile salmon was monitored each year from 1982 to 1985 using incline plane traps (Schmidt et al. 1983, Roth et al. 1984, Roth and Stratton 1985, Roth et al. 1986). Traps were deployed shortly after ice-off (mid-May to mid-June) and fished until early- to mid-October (Table 4.1-3). Locations on the mainstem Susitna River included fixed traps near Flathorn Station (one or two traps at RM 22.4 and 24.6) and at Talkeetna Station (two traps at RM 103) and deployment of a mobile trap that sampled along a cross sectional transect at RM 25.4 near Flathorn.

4.2. Study Site Locations

In general, resident and juvenile (RJ) studies were broad-based during 1981 and 1982 with the widest geographic scale and sampling methods. Sampling in the Susitna River upstream of Devils Canyon (i.e., Reach 1) only occurred during 1981 and 1982, while sampling occurred downstream of Devils Canyon during 1981 through 1985. As the Aquatic Studies Program progressed, studies became more focused on acquiring specific information needs for habitat modeling and acquisition of specific biological data. In addition, the results of 1981 and 1982 sampling led to conclusions regarding fish distribution and hypotheses about habitat utilization that led to more intensive sampling at fewer sites with known fish use and a reliance on fewer sampling techniques that had demonstrated effective fish capture success within habitats and field conditions found in the river.

Sampling for juvenile and resident fish from November 1980 through mid October 1981 included a wide range of sites. By June of 1981, the Aquatic Studies Program had settled on 39 areas in the Lower and lower Middle Susitna River, which they termed “habitat locations”, that were the focus of sampling during the open water period (Delaney et al. 1981a, 1981b). During the winter of 1980 to 1981, 29 of the habitat locations were sampled, plus an addition 48 “selected fish habitat sites” that were described as exploratory sampling. An understanding of habitat utilization by juvenile anadromous and resident fish was developed as part of more focused studies during 1982, 1983, and 1984. During 1982, 17 sites referred to as Designated Fish Habitat (DFH) sites were surveyed twice monthly from June through September during the open water season (Estes and Schmidt 1983). Twelve sites were located in the Middle River (Whiskers Creek and Slough to Portage Creek Mouth) and five were located in the Lower River (Goose Creek and Side Channel to Birch Creek and Slough).

During 1983 and 1984, studies were focused on obtaining information needed for developing instream flow models under the AH component and sampling was coupled with obtaining additional distribution and abundance information desired for the AJ component (Schmidt et al. 1984, Suchanek et al. 1985). The 1983 open water studies included 35 study sites (called

Juvenile Anadromous Habitat Study or JAHS sites) in the lower Middle River while the 1984 studies included 20 sites in the Lower River.

4.2.1. Upper River Study Sites

Fish distribution abundance surveys were conducted in the Upper Susitna River during 1981 and 1982. In addition, aerial Chinook salmon spawning surveys were conducted by helicopter in selected tributaries and tributary mouths each year from 1981 to 1985. During 1981 surveys were conducted in five tributaries of the Upper Susitna River: Watana Creek (RM 190.4), Kosina Creek (RM 202.4), Jay Creek (RM 203.9), Goose Creek (RM 224.9), and the Oshetna River (Delaney et al. 1981c). Each stream was surveyed in up to five segments (0 to 500 ft, 1000 to 1500 ft, 2000 to 2500 ft, 2500 to 3000 ft, 4000 to 4500ft). The lower segments also included sampling in the Clearwater areas of the mainstem influenced by the tributary outflow. Gillnet and hook and line surveys also occurred at Sally Lake, which drains to Watana Creek, and hook and line surveys occurred in Deadman Lake. Delaney et al. (1981) indicated that Arctic grayling were captured in the Tyone River (RM 346.6), but details regarding the location, gear, or numbers captured were not reported.

During 1982, tributary surveys in the Upper Susitna River were focused on understanding the distribution and abundance of Arctic grayling in areas that would be inundated by the proposed reservoir and surveys were conducted over greater distances: Watana Creek (TRM 4.0 to 6.0; East Fork TRM 8.5 to 9.8, West Fork TRM 8.5 to 10.6), Kosina Creek (TRM 0.0 to 4.5), Jay Creek (TRM 0.0 to 3.8), Goose Creek (TRM 0.0 to 1.2), and the Oshetna River (TRM 0.0 to 2.2; Sautner and Stratton 1983).

Mainstem sampling other than the tributary mouths, only occurred during 1982 at seven mainstem slough areas: Site No. 1 (RM 191.5), Site No. 2 (RM 191.5), Watana Creek Slough (RM 194.1), Site No. 3 (RM 197.8), Site No. 3A (RM 201.6), Site No, 4 (RM 201.2), and Site No. 5 (Lower Jay Creek Slough, RM 208.1; Sautner and Stratton 1983). In addition, Sally Lake was surveyed during 1982.

4.2.2. Middle River Study Sites

During 1981 and 1982, the Middle Susitna River segment upstream of the proposed Devils Canyon Dam at RM 152 (upper Middle Susitna River) was considered part of the Upper River and reported along with other Upper Susitna River tributaries in Delaney et al. (1981) and Sautner and Stratton (1983). Tributaries surveyed by Delaney et al. (1981) during 1981 included up to five sections in Fog Creek (RM 173.9), Tsusena Creek (RM 178.9), and Deadman Creek (RM 183.4). During 1982 survey distances were Fog Creek TRM 0.0 to 1.3, Tsusena Creek TRM 0.0 to 0.4, and Deadman Creek TRM 0.0 to 2.7. In addition, Cheechako Creek (RM 152.4), Chinook Creek (RM 157.0), and Devil Creek (RM 161.4) were sampled during 1982. No mainstem sites were surveyed in the upper Middle Susitna River during 1981.

Sampling occurred in the lower Middle Susitna River from the Three Rivers Confluence to the proposed Devils Canyon Dam during each of the years 1981 to 1985 to discern the distribution and relative abundance of adult anadromous spawning fish (AA studies) and resident and juvenile anadromous fish (RJ studies). Spawning surveys were conducted at Chinook salmon index streams from mid-July through mid-August (ADF&G 1981, ADF&G 1983b, Barrett et al. 1984, Barrett et al. 1985, Thompson 1986). For other salmon species all known slough, side channel, and tributary streams known to be used by adult salmon in the Middle River downstream of Devils Canyon on a weekly basis, generally started in late July to early August and ended in mid-October.

The RJ studies component sampled 17 habitat locations during 1981, 13 DFH sites during 1982, 35 JAHS sites during 1983, 24 sites during 1984, and 20 sites in 1985 (Table 4.2-1). Many of the sites were sampled during 1984 and 1985 primarily to mark (cold brand) or tag (coded wire tag) juvenile Chinook or coho salmon that could potentially be recaptured at incline plane traps located farther downstream, or were specifically sampled for resident fish. In addition to the habitat locations and DFH sites sampled in 1981 and 1982, respectively, a relatively large number of sites called selected fish habitat (SFH) sites were sampled opportunistically 3 or fewer times over the open water season. During 1981 the SFH sites were sampled primarily by minnow trap and trotline (Delaney et al. 1981c) while during 1982 these sites were primarily sampled using boat electrofishing gear (Figure 4.2-1).

During 1984 six lakes with outlets that drain to the lower Middle River Segment were sampled to determine if rainbow trout were present and whether they use the mainstem Susitna River (Sundet and Pechek 1985). These included four lakes that drain into Fourth of July Creek, Miami Lake that drains into the Indian River at TRM 4.5, and one unnamed lake that drains into Portage Creek at TRM 2.3.

4.2.3. Lower River Study Sites

A relatively large number of habitat location sites (22) were sampled in the Lower Susitna River for juvenile and resident fish during 1981 (Table 4.2-2; Delaney et al. 1981a, b). Sampling effort in the Lower Susitna River was somewhat lower in 1982 compared to 1981, with 12 DFH sites sampled twice per month in the open water period from RM 74.8 (Goose 2 Side Channel) to RM 91.6 (Trapper Creek Side Channel; Schmidt et al. (1983). However, similar to the Middle Susitna River numerous SFH sites were sampled usually one to three times over the open water period, which did contribute to the understanding of fish distribution (Figure 4.2-1). During 1983 resident and juvenile salmon sampling was focused on the Middle Susitna River and no sites were sampled in the Lower Susitna River. Sampling occurred at 20 JAHS sites in the Lower Susitna River during 1984 and no sites were sampled during 1985.

Sampling specifically for eulachon and Bering cisco occurred during 1982 and 1983 (ADF&G 1983b, Barrett et al. 1984, Vincent-Lang and Queral (1984). From May 16 through June 9, 1981, ADF&G (1983) used set gillnets at two sites in Susitna River estuary between RM 4.0 and RM 4.5 and dip nets and boat electrofishing gear between RM 4.5 and the Kashwitna River confluence at RM 61. From May 10 through June 9, 1983, set gillnets were deployed at three sites between RM 2.3 to RM 4.5 (Barrett et al. 1984). Similar to 1982, dipnets and electrofishing occurred between RM 4.5 and RM 60 during 1983. The gillnet sampling was used to better understand run timing while the dipnet and electrofishing was used to identify spawning areas and better understand the extent of upstream migration by spawning eulachon. Vincent-Lang and Queral (1984) selected 20 sites between RM 20.0 and RM 36.5 identified by ADF&G (1983) as eulachon spawning locations for characterizing spawning habitat between May 23 and May 26, 1983. Measurements included depth, velocity, substrate composition, and water quality.

4.3. Results

4.3.1. Upper River Studies

Because Susitna-Watana Project flow related effects will not occur above the Watana Dam, the contemporary instream flow studies (IFS) proposed for 2013-2014 will not be modeling or sampling in the Upper River (see RSP 8.5). Nevertheless, the Upper Susitna River may be a source of fish that move downstream and use habitat potentially affected by the proposed Project. Consequently, an understanding of the fish populations present in the Upper Susitna River is important.

The only anadromous fish known to pass all three of the riffle barriers within Devils Canyon is Chinook salmon. The Upper Susitna River fish community has relatively low diversity compared to the Susitna River downstream of Devils Canyon (Table 4.3-1). The Upper Susitna River is dominated by Arctic grayling in tributary streams (Delaney et al. 1981c, Sautner and Stratton 1983). The resident fish community also includes burbot, Dolly Varden (*Salvelinus malma*), round whitefish (*Prosopium cylindraceum*), humpback whitefish (*Coregonus pidschian*), longnose sucker (*Catostomus catostomus*), and sculpin (*Cottus* spp.). However, their distribution and abundance in the mainstem Susitna River is poorly understood because few surveys have been conducted. Lake trout are also present in some of the lakes draining to the Upper Susitna River, but relatively few of the lakes have been surveyed (e.g., Sally Lake and Deadman Lake). During 1981 and 1982 eight tributaries and tributary mouths were surveyed, as well as Sally Lake and Deadman Lake. The 1982 sampling in tributaries was focused primarily on developing abundance estimates for Arctic grayling using mark recapture methods and angling.

4.3.1.1. Chinook Salmon

The distribution of Chinook salmon (*O. tshawytscha*) in the Upper Susitna River is uncertain because relatively few surveys have occurred and their abundance is low. However, Chinook salmon appear to be present to at least the Oshetna River during some years (Figure 4.3-1). Surveys conducted by Buckwalter (2011) during 2003 and 2011 resulted in the collection of Chinook juveniles in the Oshetna River (2003 only) and adults (2011) and juveniles (2003) in Kosina Creek (Table 4.3-2Table 4.3-). Surveys conducted during 2012 by helicopter resulted in the observation of 16 adult Chinook salmon in Kosina Creek (HDR 2013).

4.3.1.2. Arctic Grayling

Arctic grayling (*Thymallus arcticus*) were captured in all of the tributaries sampled (Figure 4.3-2). Delaney et al. (1981c) reported the capture of 3,313 Arctic grayling during 1981, and Sautner and Stratton (1983) reported the capture of 4,367 Arctic grayling during 1982. Hook and line was a very successful capture method in tributary streams during 1981 and 1982 with a median catch rate of 6.0 fish per hour and a maximum rate of 23.2 fish per hour.

During 1981, catch rates by anglers were highest for Kosina and Jay creeks (Figure 4.3-2). Angler catch rates increased from May (6.1 fish per hour) to July (8.1 fish per hour) and then declined in August (4.5 fish per hour) and September (4.0 fish per hour). A Chi-square analysis on the number of fish captured by angling indicated there were significant differences in catch between the tributaries.

For many sites and sampling periods, hook and line catch rates were somewhat higher in 1982 compared to 1981. During 1982, hook and line catch rates were highest for the Oshetna River (11.1 fish per hour) and Kosina Creek (10.4 fish per hour; Figure 4.3-2). Catch rates were highest in July (12.8 fish per hour) and August (13.4 fish per hour).

Observations of spent Arctic grayling with frayed fins during late May and early June suggested that most spawning had already been completed; however two ripe males were collected on May 22 (Delaney et al. 1981c). Based upon this information and experience from other areas, Delaney et al. (1981c) suggested that Arctic grayling spawning likely occurs during late-April to mid-May. Arctic grayling fry and Age 1+ were observed in the slough near Jay Creek. Fry were 20 to 22 mm in June, 24 to 45 mm in July, and 47 to 60 mm in September. Age 1 Arctic grayling were 54 mm in May, 75 to 95 mm in June, and 84 to 98 mm in July.

In 1981, Floy tags were attached to 2,511 Arctic grayling and 268 tagged fish were recaptured (Delaney et al. 1981c). In 1982, 3,560 Arctic grayling were tagged and 350 tagged fish were recaptured (Stratton 1983). Population sizes were estimated using the Schnabel method from the mark-recapture data with a total upper Middle and Upper Susitna River estimate of 10,279 fish with a 95 percent confidence interval of 9,194 to 11,654 fish (Table 4.3-3Table 4.3-). Total Arctic grayling population size during 1982 was 16,346 fish (Sautner and Stratton (1983). In the Upper Susitna River, Arctic grayling abundance was highest in Kosina Creek and lowest in Goose Creek. Tagged Arctic grayling moved around considerably (Delaney et al. 1981c, Sautner and Stratton 1983). In 1981, 243 fish were recaptured within the same tributary in which they were tagged. Of these fish, 50 moved up to 2 miles downstream and 69 fish moved up to 12 miles upstream. Approximately half (124 fish) of the recaptured tagged fish remained at the tagging location, and nine percent were recaptured in a tributary or tributary mouth different from the tagging location. The longest movement was 34.5 miles from Goose Creek to Watana Creek. During 1982, Arctic grayling tagged in tributaries made movements of up to 30.2 miles, and similar to 1981, a substantial proportion of the recaptured fish (12.0 percent) were recaptured in a different stream than tagged (Sautner and Stratton 1983).

In 1982, relatively few Arctic grayling were captured at mainstem sites (Sautner and Stratton 1983). Among the seven mainstem slough sites that were sampled, only 21 Arctic grayling and, and all were captured at the Watana Creek Slough. Sampling in Sally Lake resulted in the capture of 42 Arctic grayling.

4.3.1.3. Dolly Varden

Dolly Varden (*Salvelinus malma*) were present in the Upper Susitna River (Delaney et al. 1981c, Sautner and Stratton 1983), but relatively uncommon compared to Arctic grayling. No Dolly Varden were captured in the Upper Susitna River during 1981. Sautner and Stratton (1983) captured a total 16 Dolly Varden at five of the upper Middle and Upper tributaries sampled during 1982 and three of the tributaries, Watana, Jay creeks, and upper Deadman creeks, were in the Upper Susitna River. All of the Dolly Varden captured during 1982 in the Upper Susitna River were small (120 to 205 mm) and considered stunted.

4.3.1.4. Burbot

Burbot (*Lota lota*) were present throughout the mainstem Upper Susitna River to at least the Oshetna River (Delaney et al. 1981c, Sautner and Stratton 1983). Delaney et al. (1981) captured 88 burbot immediately upstream or downstream from the mouth of tributaries. During 1981, CPUE was not reported by each period and site. However, the overall monthly CPUE ranged from 0.5 burbot per trotline-day in June to 1.0 burbot per trotline-day in September. Most burbot were captured near the mouth of Jay Creek (32 fish) and Watana Creek (24 fish) during 1981 (Figure 4.3-3). Sautner and Stratton (1983) sampled at seven locations within the mainstem during 1982 and captured 135 burbot by trotline. Overall monthly CPUE ranged from 0.6 (July and September) to 0.8 (June) fish per trotline-day. For individual sites and periods, CPUE ranged from zero (Mainstem Site 2 in September) to 3.5 fish per trotline-day (Watana Creek mouth in May; Figure 4.3-3). Burbot appeared to move little within the Upper Susitna River, or they may have returned to feeding territories. Floy tags were attached to 23 and 69 burbot in 1981 and 1982, respectively. Four of the burbot tagged during 1981 and three of burbot tagged during 1982 were recaptured during 1982 at the location of tagging (Sautner and Stratton (1983). Based upon observation of spent burbot and observations by anglers in Paxson Lake, Delaney et al. (1981c) suggested that burbot probably spawned during March in the Upper Susitna River.

4.3.1.5. Round Whitefish

Round whitefish (*Prosopium cylindraceum*) were present in the Upper Susitna River (Delaney et al. 1981c, Sautner and Stratton 1983). Delaney et al. (1981) captured a total of 80 round whitefish immediately upstream or downstream of tributary mouths. Gillnets were effective at capturing adult round whitefish (33 fish), and beach seining and electrofishing captured 47 juvenile round whitefish at the mouth of Jay Creek. Jay and Kosina creeks accounted for 39.4 and 27.3 percent of the adult round fish captured. None of the 17 floy-tagged round whitefish were recaptured. During the studies by Sautner and Stratton (1983), five adult round whitefish were captured at the Watana Creek Slough during July and August and in prespawning condition.

4.3.1.6. Humpback Whitefish

Humpback whitefish (*Coregonus pidschian*) were present in the Upper Susitna River in low numbers. During 1981, one humpback whitefish (347 mm in length) was captured at the mouth of Kosina Creek (Delaney et al. 1981c), and in 1982, a single humpback whitefish was captured at RM 208.1 (Sautner and Stratton (1983). Delaney et al. 1981c also reported that humpback whitefish were present in lakes Susitna and Louise. These lakes are headwater lakes to the Tyrone River, which enters the Susitna River near RM 246.5.

4.3.1.7. Longnose Sucker

Longnose suckers (*Catostomus catostomus*) were present throughout the mainstem Upper Susitna River to at least the Oshetna River (Delaney et al. 1981c, Sautner and Stratton 1983). Delaney et al. (1981) captured 168 longnose suckers immediately upstream or downstream from the mouth of all surveyed tributaries except Fog and Tsusena creeks. Gillnets were effective at capturing adult round whitefish (144 fish). Beach seines, electrofishing, and minnow traps captured 24 juvenile longnose suckers. The Watana Creek and Jay Creek sites accounted for

52.1 and 19.4 percent of the adult longnose suckers captured. However, catch rates were highest in Watana Creek (12.5 fish per net-day) and the Oshetna River (4.0 fish per net-day).

During 1982, longnose suckers were captured by gillnets at four of the seven mainstem slough sites (Sautner and Stratton 1983). Similar to 1981, the highest catch occurred near Watana Creek (80.3 percent of all captured suckers). The highest catch observed was in July, when 21 longnose suckers were captured near the mouth of Watana Creek. Longnose suckers were in spawning condition in May and early-June, but all were spent in late-June.

Tags were attached to 97 and 50 longnose suckers in 1981 and 1982, respectively (Sautner and Stratton 1983). One of the fish tagged in 1981 was recaptured during 1981, and two were recaptured in 1982. Two fish tagged in 1982 were subsequently recaptured. All recaptures occurred at the tagging location.

4.3.1.8. Sculpin

In 1981, slimy sculpin (*Cottus congnatus*) were captured in minnow traps within all tributaries sampled in the Upper Susitna River except Jay Creek (Delaney et al. 1981c). Catch rates were highest in Fog Creek (8 per trap-day), Tsusena Creek (9 per trap-day), and the Oshetna River (10 per trap-day). Length of captured sculpins ranged from 37 to 95 mm.

4.3.1.9. Lake Trout

Sampling for lake trout (*Salvelinus namaycush*) occurred in Sally Lake in 1981 and 1982 and in Deadman Lake in 1981 (Delaney et al. 1981c, Sautner and Stratton 1983). Sally Lake is a 63 acre lake with a maximum depth of 27 feet and mean depth of 11.6 feet (Sautner and Stratton 1983). The southern end of the lake is shallow (average depth of about 4 feet) and has substantial aquatic vegetation.

In 1981, sampling in Sally Lake was primarily by gillnet with some angling, and only angling was attempted at Deadman Lake. Lake trout were captured in both Sally Lake (32 fish, 2 by angling) and Deadman Lake (3 fish, all by angling). Lake trout in Sally Lake were captured in less than 6 feet of water and within 100 feet of shore. The length of lake trout in Sally Lake ranged from 305 to 508 mm with a mean of 410 mm. Most scales removed from Lake Trout were unreadable. Consequently, no age information was obtained. In 1982, sampling in Sally Lake resulted in the capture of 32 lake trout (Sautner and Stratton 1983), and fish sizes ranged from 260 to 490 mm with an average length of 419 mm.

4.3.2. Middle River Studies

4.3.2.1. Upper Middle Susitna River

The fish community in the upper Middle Susitna River was found to be similar to the Upper Susitna River (Table 4.3-1Table 4.3-). The distribution of Chinook salmon in the upper Middle Susitna River is uncertain because relatively few surveys have occurred and their abundance is low. Aerial surveys conducted from 1982 to 1985 were the first to document passage of Chinook salmon through Devils Canyon and spawning within, or near the mouth of, several tributaries in the upper Middle Susitna River including Cheechako Creek, Chinook Creek, Devil Creek, and Fog Creek (ADF&G 1983c, Barrett et al. 1984, Barrett et al. 1985, Thompson et al. 1986; Table 4.3-4). Surveys conducted by Buckwalter (2011) during 2003 and 2011 resulted in the observations of Chinook adults in Fog Creek (2003 only) and collection of juveniles during 2003 and 2011. Juvenile Chinook salmon were also collected in Tsusena Creek during 2003 (Table 4.3-2).

4.3.2.1.1. Arctic Grayling

Arctic grayling were captured in Fog Creek and Tsusena Creek in both 1981 and 1982 (Delaney et al. 1981c, Sautner and Stratton (1983). Mark-recapture population estimates suggested substantially more Arctic grayling were present in Tsusena Creek (1,000 fish) compared to Fog Creek (176 fish) during 1981 (Table 4.3-3). Insufficient marks and/or recaptures occurred during 1982 to develop estimates in Fog and Tsusena creeks (Sautner and Stratton 1983). Average catch rates were 6.1 fish per angler-hour in Tsusena Creek and 0.4 fish per angler-hour in Fog Creek during 1982. Sautner and Stratton (1983) indicated that Arctic grayling were captured in Cheechako and Devil creeks during 1982, but catch rates were not reported. Arctic grayling were not captured in Chinook Creek.

4.3.2.1.2. Dolly Varden

Dolly Varden were present in the Upper Susitna River (Delaney et al. 1981c, Sautner and Stratton 1983), but relatively uncommon compared to Arctic grayling. Delaney et al. (1981) captured one Dolly Varden (235 mm length) at the mouth of Fog Creek. Sautner and Stratton (1983) captured a total of 16 Dolly Varden at five of the tributaries sampled during 1982 and two of them, Cheechako and Devil, were in the upper Middle Susitna River. All of the Dolly Varden captured during 1982 in the Upper Susitna River were small (120 to 205 mm) and considered stunted.

4.3.2.1.3. Burbot

Burbot were captured by trotline near the mouth of Fog Creek during May (2 fish) and Tsusena Creek (2 fish during June 1981 (Delaney et al. 1981c). Round whitefish (3 fish over 4 days of effort) were captured near the mouth of Tsusena Creek by gillnet during 1981, but none were captured near of the mouths of Fog Creek and Deadman Creek with 3 or 4 gillnet-days of effort, respectively (Delaney et al. 1981c). Capture of longnose sucker was also low during 1981, with 3 captured near the mouth of Deadman Creek and none captured near Fog and Tsusena creeks. Sculpin were capture in all tributaries sample during 1981 in the upper Middle Susitna River. No sampling occurred in the mainstem of the upper Middle Susitna River during 1982 (Sautner and Stratton 1983).

4.3.2.2. Lower Middle River

The lower Middle River (from Devils Canyon downstream to Three Rivers Confluence) has a relatively diverse community of anadromous and resident fish species compared to the river upstream of Devils Canyon (Table 4.3-1). In addition to the seven fish species found upstream of Devils Canyon, there are four more anadromous salmon species, rainbow trout, three-spine stickleback (*Gasterosteus aculeatus*), and Arctic lamprey (*Lethenteron japonicum*) present in the lower Middle River.

4.3.2.2.1. Chinook Salmon

Chinook salmon are one of the most important sport fish in the Susitna River drainage and present in most of the larger tributary streams of the lower Middle River (Figure 4.3-1). Chinook salmon spawn exclusively in tributary streams (Thompson et al. 1986, Barrett 1985, Barrett 1984, Barrett 1983; Figure 4.3-4). Consequently, the mainstem Susitna River primarily provides a migration corridor and holding habitat for adult Chinook salmon. Apportionment of Chinook salmon among the major Susitna River subbasins based on peak spawning surveys has been somewhat confounded by inconsistent surveys, in part because poor visibility and partly due to annual differences in surveying priorities. Nevertheless, major patterns in the distribution of Chinook salmon spawning during the late 1970s and early 1980s are discernible based upon data summarized in Jennings (1985). Within the Middle River, Portage Creek and Indian River account for nearly all Chinook salmon spawning (Figure 4.3-5). These two tributaries in combination with other Middle River tributaries typically account for about 5 percent of the Chinook salmon spawning in the Susitna River. Fourth of July Creek and Whiskers Creek account for minor amounts of spawning, generally with no more than about 2.5 percent of the spawning in the Middle River (Figure 4.3-6).

Of the five salmon species returning to the Susitna River, Chinook salmon account for the fewest number of fish but have been the most important sport fish (Jennings 1985). Long term escapement trend data from 1974 to 2009 is available for a number of index streams in the Susitna River Basin monitored by ADF&G, but between stream comparisons are unreliable because of different survey methods (weirs, foot, or aerial; Fair et al. 2010). Most index streams are tributaries to the mainstem in the Lower River or tributaries in the Chulitna and Talkeetna subbasins (Fair et al. 2010). No index streams are located in the Middle Susitna River.

Total peak counts of Chinook salmon spawning in Middle River tributaries between 1981 and 1985 ranged from 1,121 to 7,180 fish with a median of 4,179 fish (Jennings 1985, Thompson et al. 1986). As described above, generally over 90 percent of the Chinook salmon returns to the Middle Susitna River have spawned in Indian or Portage creeks. Peak spawner counts from 1976 to 1984 ranged from 114 to 1,456 fish (median 479.5 fish) in Indian Creek and 140 to 5,446 fish (median 680.5 fish) in Portage Creek (Jennings 1985).

ADF&G used mark recapture techniques to estimate escapement to fishwheel stations during the early 1980s (Figure 4.3-7). From 1982 to 1985, total escapement to Talkeetna Station ranged from 10,900 to 24,591 fish (median 14,400 fish), but was considered an overestimate because many Chinook salmon tagged at Talkeetna Station were found to have spawned in tributaries downstream of Talkeetna Station (Jennings 1985).

Juvenile Chinook salmon exhibited very little freshwater life history diversity during studies conducted in the 1980s. Scale samples from adult Chinook salmon collected at fishwheels indicated that nearly all Chinook salmon that survive to adulthood exhibit a stream-type life history pattern and outmigrate to the ocean as yearlings (ADF&G 1981, ADF&G 1983c, Barrett et al. 1984, Barrett et al. 1985, Thompson et al. 1986). A small percentage of returning adult Chinook salmon outmigrated as fry.

Roth and Stratton (1985) suggested Chinook salmon juveniles have three patterns of distribution following emergence in tributary streams. One group rears and overwinters in the natal tributary, and then outmigrates at Age 1+. Another group rears in the natal tributary during part of the first summer, migrates to the mainstem for overwintering and additional rearing and eventually outmigration to the ocean, again at Age 1+. The third group migrates to the lower Susitna River as fry. Roth and Stratton (1985) were uncertain what the relative proportion of Chinook production used the three behavior patterns.

During 1980s studies, the bulk of Chinook salmon fry outmigrated from Indian and Portage creeks by mid-August and redistributed into sloughs and side channels of the Middle Susitna River or migrated to the Lower River (Roth and Stratton 1985, Roth et al. 1986; Figure 4.3-8). Outmigrant trapping occurred at Talkeetna Station (RM 103) during open water periods from 1982 to 1985 and demonstrated Chinook salmon fry were migrating downstream to the Lower Susitna River throughout the time traps were operating (Schmidt et al. 1983, Roth et al. 1984, Roth and Stratton 1985, Roth et al. 1986; Figure 4.3-9). Based on timing of movements, Roth and Stratton (1986) suggested that some Chinook salmon fry from the Middle Susitna River either overwinter in the Lower Susitna River downstream of Flathorn Station or outmigrate to the ocean as fry, but are unsuccessful, as demonstrated by the low prevalence of Age 0 outmigrant characteristics in adult scales.

The capture of a small number of Age 1+ Chinook salmon juveniles in the Indian River during winter sampling indicated that some Chinook salmon fry remain in natal tributaries throughout their first year of life (Stratton 1986). During 1984, sampling in the Indian River failed to capture any Chinook salmon Age 1+ fish during July, but were successful during May and June, indicating that Age 1+ Chinook salmon juveniles emigrated from tributary streams shortly after ice-out (Roth and Stratton 1985). The cumulative frequency of Age 1+ Chinook salmon juveniles catch at the Talkeetna Station reached 90 percent by early July in 1985 and by late-July at the Flathorn Station (Roth et al. 1986; Figure 4.3-10). Consequently, most outmigrating Chinook salmon Age 1+ smolts are generally in estuarine or nearshore waters by mid-summer.

4.3.2.2.2. Sockeye Salmon

During the 1980s, sockeye salmon (*O. nerka*) entered the Susitna River in two runs (Jennings 1985); the first run was the smaller of the two with a run size generally of less than 15,000 fish (Jennings 1985, Thompson et al. 1986). The second run was substantially larger with total escapement estimates ranging from approximately 340,000 to 606,000 fish (ADF&G 1981, Barrett et al.1983, Barrett et al. 1984, Barrett et al. 1985, Thompson et al. 1986; Figure 4.3-11).

Historically, sockeye salmon spawning in the lower Middle Susitna River was a relatively small component to the total Susitna River run with peak spawner counts from 1981 to 1985 ranging from 555 to 1,241 sockeye salmon (Jennings 1985, Thompson et al. 1986). Nevertheless, the use of the middle river is important because these fish exhibit a life history pattern that is not dependent upon lakes for juvenile rearing. While juvenile lake rearing is the norm for most sockeye salmon populations, “river-type” and “ocean-type” life history patterns have also been identified, particularly in glacial rivers (Gustafson and Winans 1999), such as the Susitna River and several of its major tributaries.

Sockeye salmon are widely distributed in the Susitna River downstream of Devils Canyon according to ADF&G’s Anadromous Waters Catalog (Figure 4.3-12Figure 4.3-), but are especially prevalent in tributaries with accessible lake rearing habitat (Yanusz et al. 2011b). Sockeye Salmon in the lower Middle Susitna River spawn almost exclusively in side sloughs (Sautner et al. 1984). Sockeye salmon spawning was observed within 24 sloughs of the lower Middle Susitna River from 1981 to 1985 (Jennings 1985, Thompson et al. 1986). There are no accessible juvenile rearing lakes with associated spawning areas accessible to sockeye salmon in the Middle Susitna River. On rare occasions during the 1980s spawning surveys, one or two pairs of sockeye were observed spawning along the edge of the main channel, tributaries, or in side channels (ADF&G 1981, ADF&G 1983c, Barrett et al. 1984, Barrett et al. 1985, Thompson et al. 1986). Sockeye salmon primarily spawned in Sloughs 11, 8A, and 21 (Figure 4.3-13). Some sloughs were used for spawning by sockeye salmon in all years while others were only intermittently used.

Although sockeye salmon spawning was rarely observed within tributaries of the Middle Susitna River, Roth and Stratton (1985) reported the capture of sockeye salmon fry in the Indian River during July and August 1984 and Yanusz et al. (2011a) reported the terminal location of one radio-tagged sockeye salmon in the Indian River and one in Portage Creek during 2007. No adult sockeye salmon were observed in tributaries to the Middle Susitna River during 1981 through 1983. Barrett et al. (1985) observed one sockeye salmon adult in Indian River and 12 in Portage Creek during 1984, but suspected most were milling; only one pair of sockeye salmon were spawning. During 1985, Thompson et al. (1986) observed two adult sockeye salmon in the Indian River, but no spawning activity.

4.3.2.2.3. Chum Salmon

Chum salmon (*O. keta*) have been the most abundant anadromous salmon returning to the Susitna River Basin with the exception of even-year pink salmon runs. Chum salmon have been an important component to the commercial salmon fishery with an average of 478,000 caught in the UCI Management Area during 1966 to 2006 (Merizon et al. 2010). Chum salmon also have contributed to the sport fishery with an average of 2,893 captured during 1998 to 2007 (Merizon et al. 2010).

Based upon sonar counts to the Yentna River plus the Peterson estimates to the Sunshine Station, minimum chum salmon returns to the Susitna River averaged 440,751 fish (range 276,577 to 791,466) from 1981 through 1985[4] (ADF&G 1981, ADF&G 1983c, Barrett et al. 1984, Barrett et al. 1985, Thompson et al. 1986; Figure 4.3-14). These counts were considered minimums because sonar counts at the Yentna River station underestimated the total returns (Jennings 1985). The average returns to the Talkeetna Station during a similar time period was 54,640 chum salmon, but this was probably an overestimate since chum salmon have been documented entering the Middle Susitna River and then migrating back downstream to spawn in Lower River habitats. The Talkeetna Station was not operated during 1985. Average returns to Curry Station were 21,993 fish (range 13,068 to 29,413) from 1981 to 1985. The returns to Curry Station were likely reasonable estimates of the returns to the Middle Susitna River because all of the known primary spawning areas are upstream of Curry Station.

Chum salmon are widely distributed in the Susitna River downstream of Devils Canyon according to ADF&G's Anadromous Waters Catalog (Figure 4.3-15). Merizon et al. (2010) radio-tagged 239 chum salmon at Flathorn during 2009 and assigned a spawning location to 210 of the tagged fish. Chum salmon were strongly oriented toward the east or west banks.

[4] No estimate was available for the Yentna River during 1985 and the estimate at the downstream Flathorn Station was 56,800 fish lower than the Sunshine estimate. Consequently, the minimum chum run size for 1985 was estimated using the Sunshine estimate plus the four-year average at the Yentna Station from 1981 to 1984.

Consequently, fish captured and tagged on the west side of the river primarily entered the Yentna River, while those captured on the east side tended to migrate up the Susitna River. Ten (4.8 percent) of the 210 chum salmon tagged at Flathorn and assigned a spawning location were assigned as spawning in the Middle Susitna River and none entered tributaries (Figure 4.3-16; Merizon et al. 2010).

Spawning surveys were conducted each year from 1981 to 1985, but the level of intensity varied from year to year. Chum salmon spawn primarily in clearwater tributary and side slough habitat within the Middle Susitna River (Figure 4.3-4). Indian River and Portage Creek account for the majority of tributary spawning in the Middle Susitna River while Sloughs 11, 8A, and 21 account for the majority of slough spawning (Figure 4.3-17). During 1984 Barrett et al. (1985) identified 36 non-slough spawning areas in the mainstem of the Middle Susitna River. Peak counts in these areas ranged from 1 to 131 (RM 136.1) chum salmon. During 1985, with relatively poor viewing conditions, Thompson et al. (1986) identified three mainstem spawning areas with 13 to 17 peak chum salmon counts.

While there is some uncertainty regarding the precise proportional distribution of chum salmon among the different Susitna River spawning areas due to annual variations, the tributaries associated with the Lower Susitna River are the major chum salmon production areas with lower amounts of production from side sloughs, and occasional production from mainstem channels and side-channels. Based upon the radiotracking conducted by Merizon et al. (2010), and the studies conducted during the 1980s, the Middle Susitna River mainstem channels, sloughs, and tributaries account for a small, but significant portion of the total river chum salmon production.

All chum salmon outmigrate to marine waters during their first year of life. Based upon the catch of fry at incline plane traps, Roth et al. (1986) and Roth and Stratton (1985) concluded that about 95 percent of chum salmon fry from the Middle Susitna River emigrated to the Lower Susitna River by mid-July. During the period while present in the Middle Susitna River during 1983, chum fry were predominately observed in side sloughs (59%) and, tributaries (34%), but were also observed occasionally in side channels (4%) and upland sloughs (3%; Dugan et al. 1984; Figure 4.3-18Figure 4.3-). However, most side channels were not sampled until early July (e.g., side channels 10, 10A and Slough 22) and only one upland slough was sampled more than once (Slough 6A; Figure 4.3-19). Consequently, chum use of these habitat types may be somewhat higher than depicted in Figure 4.3-18.

4.3.2.2.4. Coho Salmon

Historically, coho salmon (*O. kisutch)* have been the least abundant anadromous salmon returning to the Susitna River Basin. Coho salmon have been an important component to the commercial salmon fishery with an average of 313,000 caught in the UCI Management Area during 1966 to 2006 (Merizon et al. 2010). Next to Chinook salmon, coho salmon have been the second highest contributor to the sport fishery with an average of 40,767 captured during 1998 to 2007 (Merizon et al. 2010).

Based upon sonar counts to the Yentna River plus the Peterson estimates to the Sunshine Station, minimum coho salmon returns to the Susitna River have averaged 61,986 fish (range 24,038 to 112,874) from 1981 through 1985 (ADF&G 1981, ADF&G 1983c, Barrett et al. 1984, Barrett et al. 1985, Thompson et al. (1986). These were considered minimums, because sonar counts at the Yentna River station underestimated the total returns to the Yentna River (Jennings 1985). The average returns to the Talkeetna Station from 1981 to 1984 was 5,666 coho salmon (Figure 4.3-20), but this was probably an overestimate, because radio-tracking studies and traditional tag recaptures have indicated that coho salmon enter the Middle Susitna River and then migrate back downstream to spawn. The Talkeetna Station fishwheel was not operated during 1985. Average returns to Curry Station were 1,613 fish (range 761 to 2,438) from 1981 to 1985. The returns to Curry Station were likely underestimates of the returns to the Middle River based on milling behavior described previously and the fact that one of the known primary spawning areas, Whiskers Creek, is downstream of Curry Station.

Coho salmon are widely distributed downstream of Devils Canyon according to ADF&G's Anadromous Waters Catalog (Figure 4.3-21). However, the terminal location of 275 radio-tagged salmon during 2009 suggests the Middle Susitna River accounts for about 2 percent of the Susitna River basin coho salmon production (Merizon et al. 2010; Figure 4.3-22). Coho salmon spawn almost exclusively in clearwater tributary streams (Sautner 1984; Figure 4.3-4). During 1984 Barrett et al. (1985) identified one non-slough spawning area with two coho salmon along the edge of the mainstem of the Middle Susitna River. However, that was the only observation of non-tributary spawning of coho salmon in the middle river from 1981 through 1985.

Similar to Chinook salmon, coho salmon demonstrate three behavioral patterns following emergence in tributaries (Roth and Stratton 1985). One group rears and overwinters in the natal tributary, and then outmigrates at Age 1+ or 2+. Another group rears in the natal tributary during part of the first summer but eventually migrates to the mainstem. Overwintering can occur in tributaries, sloughs, beaver ponds or other areas. The third group migrates to the lower Susitna River as fry.

The 1983 field work at JAHS sites by Dugan et al. (1984) indicated coho salmon juveniles had relative high density distribution (51 percent) in tributaries (Figure 4.3-23), followed by upland sloughs (35.3 percent). Side channels (4.0 percent) and side sloughs (9.8 percent) were infrequently used by coho salmon. Overall catch rates for the JAHS sites in 1983 are depicted in Figure 4.3-24. Relatively high catch rates for coho juveniles occurred at Chase Creek, Slough 6A, and Whiskers Creek.

4.3.2.2.5. Pink Salmon

Pink salmon (*O. gorbuscha*) have a strict two-year life history. Consequently, even and odd year populations are genetically distinct stocks. During even years pink salmon are often the most abundant anadromous salmon returning to the Susitna River Basin. Based upon sonar counts to the Yentna River plus the Peterson estimates to the Sunshine Station, minimum pink salmon returns to the Susitna River averaged 546,888 fish (range 85,554 to 1,386,321) from 1981 through 1985 (ADF&G 1981, ADF&G 1983c, Barrett et al. 1984, Barrett et al. 1985, Thompson et al. (1986). These were considered minimums, because sonar counts at the Yentna River station underestimated the total returns to the Yentna River (Jennings 1985). The average returns to the Talkeetna Station fishwheel from 1981 to 1984 was 65,684 pink salmon (Figure 4.3-25), but this was probably an overestimate because traditional tag recaptures have indicated pink salmon have entered the Middle Susitna River and then migrated back downstream to spawn. The Talkeetna Station was not operated during 1985. Average returns to Curry Station were 22,437 fish (range 1,041 to 58,835) from 1981 to 1985.

Pink salmon are found in the mainstem Susitna River downstream of Devils Canyon and many of tributary rivers and streams (Figure 4.3-26). Pink salmon spawn primarily in clearwater tributary streams with small numbers observed in side channels or side sloughs (Sautner 1984; Figure 4.3-4). Barrett et al. (1985) and Thompson et al. (1986) conducted intensive surveys in 1984 and 1985 and found pink salmon spawning in tributaries of the Lower and Middle Susitna River and concluded that pink salmon did not spawn in main channel habitat. Indian River (RM 138.6), Portage Creek (RM 148.9), 4th of July Creek (RM 131.1), and Lane Creek (RM 113.6) accounted for the majority of the pink salmon tributary spawning in the Middle Susitna River (Figure 4.3-27). Pink salmon holding or spawning occurred in a number of sloughs within the Middle Susitna River. Habitat use was not consistent from year to year. Barrett et al. (1984) identified 17 sloughs that pink salmon occupied, but only ten of the sloughs were used for spawning. Barrett et al. (1985) identified Sloughs 8A, 11, and 20 as the most important for pink salmon spawning. In contrast, during 1985 Thompson et al. (1986) observed pink salmon in seven sloughs and a peak dead fish count of 5 fish in Slough 16. During 1985, pink salmon were only observed in one (Slough 20) of the three sloughs considered important during 1984. Use of sloughs for spawning by pink salmon in the Middle Susitna River may in part depend upon run strength, which is typically larger during even years.

Most pink salmon fry emerge from the gravel and outmigrate prior to complete ice breakup. Consequently, there is little information on habitat use. Very few pink salmon fry were captured as part of juvenile anadromous salmon studies during the 1980s.

4.3.2.2.6. Rainbow Trout

Rainbow trout (*O. mykiss*) are widely distributed in the Middle Susitna River and its tributaries downstream of Devils Canyon. During 1982, rainbow trout were widely distributed at the 17 DFH sites (Schmidt et al. 1983); Figure 4.3-28Figure 4.3-). Rainbow trout were captured at all DFH sites except Whitefish Slough. Rainbow trout catch was frequently higher and more consistent at DFH sites associated with tributary streams (Lane Creek and Slough 8, 4th of July Creek, Whiskers Creek and Slough) and clearwater sloughs (e.g., Slough 6A and Slough 8A). Similar use of these tributaries and tributary mouths were observed during 1983 by Sundet and Wenger (1984).

Adult rainbow trout utilize clearwater tributary habitats to spawn following ice break-up each spring (Schmidt et al. 1983). After spawning, adults primarily hold and feed during the open water period in tributary and tributary mouth habitats, although some utilization of clearwater side slough habitat was observed during the 1980s (Schmidt et al. 1983). Holding and feeding areas during the open water period were closely associated with Chinook, chum and pink salmon spawning areas where it was suspected rainbow trout were feeding on salmon eggs (Sundet and Pechek 1985). Juvenile rainbow trout generally utilize natal clearwater tributaries as nursery habitats (Schmidt et al. 1983). Some juveniles also rear in the mainstem and sloughs, but the use of these habitats appears to be limited (Schmidt et al. 1983, Sundet and Wenger 1984). Movement from spawning or feeding tributaries to overwintering habitat is commonly in a downstream direction (Sundet and Pechek 1985). Many adults overwinter relatively close (i.e., <4 miles) to spawning tributaries, while others exhibit long-distance migrations that typically range from 10 to 20 miles downstream but can extend over 76 miles (Schmidt et al. 1983, Sundet 1986).

Rainbow trout were also documented in lakes within the Susitna River basin. A total of 390 fish were captured in six lakes surveyed in 1984, comprising 86 percent of the total fish catch (Sundet and Pechek 1985). Lakes in which rainbow trout were abundant in 1984 include those that flow into Fourth of July and Portage creeks (Sundet and Pechek 1985).

4.3.2.2.7. Arctic Grayling

In the Middle Susitna River, Arctic grayling primarily use mainstem habitats for overwintering and tributaries for spawning and rearing (Schmidt et al. 1983, Sundet and Wenger 1984). Upstream of Talkeetna, Arctic grayling move into tributaries to spawn in May and early June (Schmidt et al. 1983, Sundet and Wenger 1984). During 1982, Arctic grayling were captured at 15 of the 17 DFH sites (Figure 4.3-29). Arctic grayling catch was highest at tributary mouths of Indian River, Portage Creek, Lane Creek, 4th of July Creek, and Whiskers Creek and Slough.

After spawning, many adult grayling either remain within spawning tributaries or move to other nearby tributaries to feed during summer (Delaney et al. 1981b, Schmidt et al. 1983, Sundet and Pechek 1985). Arctic grayling also use tributary mouth, side slough and main channel habitats during the open water season, though fish captured in these areas were typically of smaller size than grayling in tributaries which may suggest that small individuals are displaced from tributaries by larger, older fish (Schmidt et al. 1983, Sundet and Wenger 1984). During late summer, most adult grayling disperse from tributaries to mainstem winter holding habitats typically located in areas proximal to spawning tributaries, though winter movements of 10 to 35 miles were observed by tagged grayling (Sundet and Pechek 1985, Sundet 1986). Juvenile Arctic grayling typically reside within their natal tributaries for at least one year, though some age-0+ grayling were observed to move to tributary mouth habitats during late summer (Schmidt et al. 1983).

4.3.2.2.8. Dolly Varden

Adult Dolly Varden are thought to primarily reside within tributary habitats during the open water season (Schmidt et al. 1983). Movement into tributaries occurred in June and July during 1980s studies, coincident with the timing of upstream spawning migrations of adult Chinook salmon (Delaney et al. 1981b, Schmidt et al. 1983). During late September and October adult Dolly Varden are believed to spawn in the upstream extents of clear tributaries (Delaney et al. 1981b, Schmidt et al. 1983, Sautner and Stratton 1984).

Juvenile Dolly Varden in the Susitna Basin primarily utilize natal tributaries as summer and winter nursery habitat (Delaney et al. 1981b, Sautner and Stratton 1983, Sundet and Wenger 1984). During winter, some juvenile Dolly Varden move downstream within natal tributaries (Schmidt et al. 1983).

In the Middle Susitna River downstream of Devils Canyon, Dolly Varden are found primarily in the upper reaches of tributaries and at tributary mouths (Schmidt et al. 1983, Sundet and Wenger 1984) but also in the mainstem for overwintering (Sundet and Wenger 1984). Spawning and juvenile rearing areas are suspected to be in tributaries (Schmidt et al. 1983).

Surveys conducted in 1982 captured low numbers of Dolly Varden (28 fish) at nine (53%) of the 17 DFH sites sampled (Figure 4.3-30; Schmidt et al. 1983). Total Dolly Varden catch was greatest at the Lane Creek and Slough 8 site (8 fish). Surveys conducted during 1981 and 1983 had their highest catch of Dolly Varden at the mouth of Portage Creek and Indian River (Delaney et al. 1981b, Sundet and Wenger 1984).

4.3.2.2.9. Burbot

Burbot were present throughout the mainstem of the Middle Susitna River during the 1980s (Delaney et al. 1981b) and may be present in many of the larger tributaries such as the Talkeetna, Chulitna, Yentna, and Deshka Rivers. However, surveys targeted for burbot have not been conducted in many Susitna River tributaries. During 1982, burbot were captured at all DFH sites surveyed in the Middle Susitna River (Figure 4.3-31Figure 4.3-, Schmidt et al. 1983). Sundet and Wenger (1984) concluded from surveys conducted during 1981-1983 that few burbot spawn in the Middle River downstream of Devils Canyon because relatively few juvenile were observed upstream of the Three Rivers Confluences and fewer adult burbot were captured upstream of the confluence compared to downstream (Delaney et al. 1981b, Schmidt et al. 1983,). Spawning areas used by burbot in the Middle Susitna River are unknown, but Sundet and Wenger (1984) hypothesized that it occurred at sloughs and backwaters with ground water and identified Slough 9 as one potential location due to the higher numbers of juveniles and adults found at that location. In addition, Sundet and Pechek (1985) hypothesized that ice processes may disrupt burbot spawning in the Middle Segment. They observed anchor ice breaking away from substrate and floating to the surface in open water areas of the Middle Segment, which they suspected might adversely affect burbot spawning success.

4.3.2.2.10. Round Whitefish

Round whitefish were present throughout the mainstem of the Middle Susitna River during the 1980s (Delaney et al. 1981b). Furthermore, abundance is higher upstream of the Three Rivers Confluence compared to downstream (Schmidt et al. 1983). During the open water season, adult round whitefish primarily use tributary, tributary mouth and slough habitats of the Susitna River for feeding (Schmidt et al. 1983, Sundet and Wenger 1984). Many adult whitefish move into large, clear tributaries in the Middle Segment of the Susitna River in June and return to mainstem habitats in August and September (Schmidt et al. 1983, Sundet and Wenger 1984). Use of mainstem habitats was also documented for spawning, juvenile rearing, and as a migration corridor (Sundet and Wenger 1984).

Spawning occurs in the mainstem and at tributary mouths (Schmidt et al. 1983, Sundet and Wenger 1984). During 1981 through 1983, nine spawning areas were identified upstream of Talkeetna. Mainstem sites were: RM 100.8, 102.0, 102.6, 114.0, 142.0 and 147.0 (Sundet and Wenger 1984). Round white fish also spawn in tributary mouths, such as Lane Creek, Indian River and Portage Creek (Sundet and Wenger 1984). Juvenile round whitefish rear mainly in the mainstem and sloughs (Schmidt et al. 1983, Sundet and Wenger 1984). Overwintering areas used by round whitefish have not been identified (Schmidt et al. 1983).

During the 1982 surveys, round whitefish were captured at all sites by a variety of gear types (Figure 4.3-32). Round whitefish catch was highest mouths of Portage Creek, Indian River, Fourth of July Creek, and at Slough 9. Catch at JAHS sites during 1983 were not substantially different. Relatively high catch rates were reported for Indian River, Portage Creek, Slough 8A, and Jack Long Creek (Sundet and Wenger 1984). The highest catch rates (actual rates not reported) for adult round whitefish during 1983 were between RM 147.0 to 148.0 (Sundet and Wenger 1984).

4.3.2.2.11. Humpback Whitefish

Humpback whitefish are less common than round whitefish in the Susitna River. They are distributed throughout the Middle Susitna River mainstem downstream of Devils Canyon, but at relatively low abundance (Delaney et al. 1981b, Schmidt et al. 1983, Sundet and Wenger 1984). Relative abundance is lower upstream of the Three Rivers Confluence compared to downstream (Schmidt et al. 1983), which may in part be due to humpback whitefish typically being an anadromous species (Morrow 1980). During 1982, humpback whitefish were occasionally captured in low numbers at DFH sites surveyed in the Middle River Segment (Figure 4.3-33). During 1983 most juvenile humpback whitefish were captured by downstream migrant traps and most adults were captured by fishwheel (Sundet and Wenger 1984). Sundet and Wenger (1984) reported that gillnets, hoop nets, and boat electrofishing captured a few humpback whitefish at JAHS sites including: Slough 8A (36 fish), Slough 6A (14 fish), and Slough 22 (9 juveniles).

4.3.2.2.12. Longnose Sucker

Longnose suckers are common throughout the Susitna River including the Middle River Segment (Delaney et al. 1981b, 1981c; Schmidt et al. 1983). However, longnose sucker abundance appears to be somewhat lower in the Middle Segment compared to the Lower River (Sundet and Wenger 1984). In the Middle Susitna River downstream of Devils Canyon, longnose suckers were primarily associated with tributary and slough mouths, although the mainstem was also used throughout the open-water season (Schmidt et al. 1983, Sundet and Wenger 1984). Longnose sucker were found in all 12 DFH sites sampled in the Middle Segment during 1982 (Figure 4.3-34; Schmidt et al. 1983). Boat electrofishing surveys during 1983 were not substantially different with longnose suckers observed to be most abundant in Slough 8A, Lane Creek, Fourth of July Creek, a mainstem site between RM 147.0-RM 148.0, and Portage Creek (Sundet and Wenger 1984).

4.3.2.2.13. Threespine Stickleback

The distribution and abundance of threespine stickleback (*Gasterosteus aculeatus*) appears to be quite variable from year to year (Sundet and Wenger 1984). Delaney et al. (1981b) observed threespine sticklebacks as far upstream as RM 146.9, but Schmidt et al. (1983) found them as far as RM 101.2 (Whiskers Creek and Slough; Figure 4.3-35) during 1982, and Sundet and Wenger (1984) observed them at RM 112.3. Threespine sticklebacks can be very numerous at a sited some years, but absent during others. For example, Sundet and Wenger (1984) reported several thousand sticklebacks were observed in Slough 6A during 1981, but none during 1982, and 77 during 1983. Sundet and Wenger (1984) hypothesized that annual population dynamics and year-class strength could explain the variability and that 1981 was a strong year-class for spawners because few (32 fish) young-of the year were captured by inclined plane traps during 1982, while over 1,400 sticklebacks (88% of those captured) were young-of-the year during 1983. Sundet and Wenger (1984) concluded that 1982 was a relatively week year class for spawners, and 1983 was intermediate.

4.3.2.2.14. Sculpin

Sculpin appear to be present throughout the fishbearing waters of the Susitna Basin including the Middle River Segment. Sculpin were only identified to family (Cottidae) during fishery studies conducted during the 1980s (ADF&G 1981, ADF&G 1982), but slimy sculpin (*Cottus congnatus*) was considered the primary species observed (Delaney et al. 1981b). During 1982, all sculpin catch was recording as cottid but reported as slimy sculpin (ADF&G 1982, Schmidt et al. 1983). During some years (e.g., 1983; Sundet and Wenger 1984) catch summaries and discussion of sculpin were not reported.

Sculpin were considered relatively sedentary with limited movement (Delaney et 1981b, Schmidt et al. 1983). While sculpin were observed at nearly all sites, relative abundance tended to be somewhat higher at areas with water contributed from a clearwater tributary (Delaney et al 1981b). During 1982, sculpin were captured at all DFH sites in the Middle River Segment (Schmidt et al. 1983; Figure 4.3-36Figure 4.3-). During 1981, sculpin were observed at all habitat locations sampled in the Middle River Segment, but not during all periods (Delaney et al. 1981b)

4.3.2.2.15. Arctic Lamprey

Arctic lamprey (*Lethenteron japonicum*) are present, but uncommon in the Middle Susitna River Segment (Delaney.et al. 1981b, Schmidt et al. 1983, Sundet and Wenger 1984). During 1981, Delaney et al. (1981) captured Arctic lamprey ammocoetes at Whiskers Creek using minnow traps in early July and late August. During 1982, Schmidt et al. (1983) reported observations of Arctic lamprey ammocoetes at Whiskers Creek and Slough and Gash Creek (RM 111.6). During 1983, Sundet and Wenger captured 25 Arctic lamprey at Chase Creek (RM 106.9).

4.3.2.3. Lower Susitna River

4.3.2.3.1. Chinook Salmon

Production of Chinook salmon from the Susitna River basin primarily occurs in tributaries to the lower river segment (Fair et al. 2010), with substantial juvenile rearing in lateral habitats associated with the mainstem (Suchanek et al. 1985). Most index streams surveyed by ADF&G were tributaries to the mainstem in the Lower River or tributaries in the Chulitna and Talkeetna subbasins (Fair et al. 2010). No index streams are located in the Middle Susitna River. The Deshka River (RM 40.6) has the highest escapement of all tributaries with a median of 35,548 fish (Figure 4.3-37). ADF&G installed a counting weir in the Deshka River prior to the 1995 season to improve the accuracy of salmon escapement counts (Fair et al. (2010). All other index streams generally have fewer than 5,000 fish spawning during peak surveys (Figure 4.3-38). From 1982 to 1985, total escapement (point estimates) to Sunshine Station ranged from 52,900 to 185,700 fish with a median 103,614 (ADF&G 1983c, Barrett et al. 1984, Barrett et al. 1985, Thompson et al. 1986).

Suchanek et al. (1985) sampled 20 JAHS sites in the Lower Susitna River during the 1984 open water season (Table 4.2-2). They observed that Chinook juveniles, primarily fry, had the highest density at tributary mouths (average of 1.5 fish per cell sampled), moderate density at side channels (0.8 fish per cell), and low density at side sloughs (0.1 fish per cell). Relatively little upland slough habitat is present in the Lower Susitna River and none were sampled during 1984. Their observations generally confirmed the patterns of macrohabitat use reported by Dugan et al. (1984) for the lower Middle Susitna River. They also observed that turbidity had a substantial influence on habitat use by juvenile Chinook salmon. They concluded that areas with moderate levels of turbidity (100 to 150 NTU) had the highest density of Chinook juveniles (Figure 4.3-

39). Suchanek et al. (1985) concluded that side channels influenced by the Talkeetna River plume were the most important rearing areas for Chinook salmon juveniles because of its effect on turbidity levels.

4.3.2.3.2. Sockeye Salmon

Tributaries to the Lower Susitna River plus the Chulitna and Talkeetna rivers are the major producers of sockeye salmon in the drainage. Based upon terminal locations of radio-tagged adults, Yanusz et al. (2011a, 2011b), observed over 97 percent of the returning sockeye salmon used these spawning areas. Fried (1994, as cited in Fair 2009) used sonar and fishwheel counts data to estimate that between 41 and 59 percent of the sockeye salmon entering the Susitna River between 1981 and 1985 spawned in the Yentna River drainage. During the two years (i.e., 1984 and 1985) when Peterson estimates were available from both the Sunshine Station and Flathorn/Susitna Stations, data indicated that 21 to 30 percent of sockeye salmon spawned upstream of Sunshine Station (Barrett et al. 1985,Thompson 1986). While there was some uncertainty regarding the precise proportional distribution of sockeye salmon among the different Susitna River subwatersheds (Fair 2009), the tributaries associated with the Lower Susitna River were the major sockeye salmon production areas. In addition to the Yentna River, other Lower River spawning areas included lakes in the Fish Creek drainage (RM 7.0), Alexander Lake (Alexander Cree drainage, RM 10.1), Whitsol Lake (Kroto Slough drainage RM 35.2), Trapper and Neil Lakes (Deshka River drainage, RM 40), and Fish Lake (Birch Creek drainage, RM 89.3). Spawning surveys conducted in the Lower Susitna River indicated that sockeye salmon did not spawn in the main channel, tributary stream mouths or associated sloughs (ADF&G 1981, ADF&G 1983c, Barrett et al. 1985).

Yanusz et al. (2007, 2011a, 2011b) radio-tagged 75 sockeye salmon captured by fishwheels at Sunshine during 2006, 311 during 2007, and 253 during 2008. Sockeye salmon were also radio-tagged at the Yentna Station. Tracking of tagged fish confirmed the historic data that indicated sockeye salmon spawn primarily in Susitna River tributaries (Figure 4.3-40). Within the Susitna River tributaries, spawning occurred in the main channel, sloughs, or in lake systems (inlets, outlets, and beaches). It is of interest that during 2007 and 2008, more than half of the fish radio-tagged at Sunshine were returning to the Larson Lake system in the Talkeetna River drainage (Yanusz et al. 2011a, 2011b). Also during 2007 and 2008, approximately 2.6 percent and 1.8 percent, respectively, of the fish tagged at Sunshine spawned in habitats associated with the mainstem river. During 2007, 17 fish tagged at Sunshine were not assigned a spawning location (Yanusz et al. 2011b). These included seven fish last recorded below the Talkeetna River mouth, one fish that moved downstream below the tagging location, one fish that was recorded in an off-channel area, four fish (possibly two others) that were captured in the sport fishery, two fish that moved downstream, and one fish that returned to Cook Inlet. Thus, the terminal locations depicted in Figure 4.3-40 do not necessarily indicate final spawning locations for tagged fish.

4.3.2.3.3. Chum Salmon

As discussed previously, minimum chum salmon returns to the Susitna River averaged 440,751 fish (range 276,577 to 791,466) from 1981 through 1985[5] based upon sonar counts to the Yentna River plus the Peterson estimates to the Sunshine Station (ADF&G 1981, ADF&G 1983c, Barrett et al. 1984, Barrett et al. 1985, Thompson et al. 1986; Figure 4.3-14). Based upon the terminal location of radio-tagged fish tracked by Merizon et al. (2010), the majority of the Susitna River Basin chum salmon production is from tributaries to the lower river including the Yentna River (47%), Talkeetna River (13%), Deshka River (5%), and Chulitna River (4%; Figure 4.3-16). However, a small but significant portion also use lateral habitats adjacent to the mainstem within lower river and the smaller tributaries (Barrett et al. 1985, Thompson et al. 1986, Merizon et al. 2010). During 1984 Barrett et al. (1985) documented chum spawning in twelve non-slough and five slough habitats in the mainstem of the Lower River upstream of the Yentna River. Not all of these locations were used in 1985. For example, 795 chum were observed to spawn in the Trapper Creek side channel during 1984, but none were reported observed during 1985 (Barrett et al. 1985, Thompson et al. 1986).

Similar to the middle river, during the early 1980s nearly all chum salmon fry passed the Flathorn Station incline plane trap by mid- to late-July. During 1984, chum catch rates at JAHS sites were highest between Island Side Channel (RM 63.2) and Sucker Side Channel (RM 84.5; Suchanek et al. 1985). Catch rates were also highest at side channels (0.6 fish per cell), moderate at tributary mouths (0.1 fish per cell), and low at sloughs (0.01 fish per cell). However, Suchanek et al. (1985) noted that few surveys occurred at sloughs during the period that most chum could be present. Chum fry catch rates were highest in side channels with low turbidity (Figure 4.3-41).

4.3.2.3.4. Coho Salmon

Based upon sonar counts to the Yentna River plus the Peterson estimates to the Sunshine Station, minimum coho salmon returns to the Susitna River averaged 61,986 fish (range 24,038 to 112,874) from 1981 through 1985 (ADF&G 1981, ADF&G 1983c, Barrett et al. 1984, Barrett et al. 1985, Thompson et al. 1986). Similar to the middle river, nearly all coho spawning is in clearwater tributary habitat. Based upon the terminal location of radio-tagged fish tracked by Merizon et al. (2010), the majority of fish spawn in tributaries of the Lower Susitna River including the Yentna River (47%), Chulitna River (17%), Talkeetna River (7%) and Deshka River (7%; Figure 4.3-22). During 1982, spawning surveys conducted at 811 sites in the Lower Susitna River did not identify any coho salmon spawning in the main channel (ADF&G 1983c). However, in 1984, Barrett et al. (1985) identified two non-slough (RM 87.5 and RM 90.3, 200 to 400 fish) and one slough (RM 57, 10 to 20 fish) spawning areas in the mainstem of the Lower Susitna River. No coho salmon spawning was observed in main channel of the Lower Susitna River during 1981 to 1983, and the lower river was not surveyed during 1985.

Similar to the middle river during 1983, surveys at JAHS sites during 1984 suggested coho juveniles in the Lower Susitna River predominately reared in tributary mouths (observed at all 4

[5] No estimate was available for the Yentna River during 1985 and the estimate at the downstream Flathorn Station was 56,800 fish lower than the Sunshine estimate. Consequently, the minimum chum run size for 1985 was estimated using the Sunshine estimate plus the four-year average at the Yentna Station from 1981 to 1984.

sites), and to a lesser extent at side channels (5 of 16 sites), and side sloughs (2 of 14 sites) during the open water period (Suchanek et al. 1985). There are few upland sloughs in the Lower Susitna River and none were sampled during 1984. JAHS sites with relatively high catch rates of coho salmon included Caswell Creek mouth, Birch Slough, and Beaver Dam Slough (Figure 4.3-42).

4.3.2.3.5. Pink Salmon

Based upon sonar counts to the Yentna River plus the Peterson estimates to the Sunshine Station, minimum pink salmon returns to the Susitna River averaged 546,888 fish (range 85,554 to 1,386,321) from 1981 through 1985 (ADF&G 1981, ADF&G 1983c, Barrett et al. 1984, Barrett et al. 1985, Thompson et al. (1986), and most of these returns are to tributaries draining to the Lower Susitna River (Figure 4.3-25Figure 4.3-). ADF&G has operated a counting weir at TRM 7.0 on the Deshka River (RM 40.6) since 1995. The weir was built and operated for counting Chinook salmon. In recent years, the counting operation ceased prior to the completion of the pink salmon run. Consequently, recent pink salmon escapement counts to the Deshka River were underestimates. Nevertheless, the available information suggests the Deshka River has been an important spawning tributary in the lower river for pink salmon with escapement estimates of up to 1.2 million fish (Figure 4.3-43).

In the Lower Susitna River most pink salmon spawned in Birch Creek, Willow Creek, and Sunshine Creek. During 1984, Barrett et al. (1985) identified both Birch Creek (5 percent of peak survey counts) and Birch Creek Slough (59 percent of peak survey counts) as important spawning locations in the Lower River. Birch Creek Slough was the only slough habitat in the Lower River with significant pink salmon spawning during 1984. In contrast, during 1985, Thompson et al. (1986) identified Birch Creek as a spawning area that accounted for 55 percent of the peak survey counts in the Lower Susitna River. Most of the pink salmon counted in Birch Creek Slough were live, up to 9,917 fish, while 222 or fewer pink salmon were dead. Thus, it is possible that Birch Creek Slough provided holding habitat for fish spawning in Birch Creek, with little to no spawning in the slough.

During 2012, ADF&G began a mark-recapture study to identify major spawning locations of pink salmon throughout the Susitna River drainage (Cleary et al. *in prep*). Pink salmon are also recorded incidentally at the Yentna River sonar site, which is operated primarily for sockeye salmon and not considered to provide complete estimates of other species (Westerman and Willette 2011). There are no pink salmon escapement goals in the Susitna River drainage (Fair et al. 2010).

Similar to the Middle Susitna River, little is known about the distribution and abundance of pink salmon fry in the Lower River because nearly all fry outmigrate prior to ice-out. Few pink fry were captured as part of 1980s juvenile salmon distribution and abundance studies.

4.3.2.3.6. Rainbow Trout

Rainbow trout are present throughout the Lower Susitna River and likely in most of the clearwater tributaries draining to the mainstem. However, their relative abundance in the mainstem appears to be somewhat less in the Lower River and more variable compared to the Middle Segment downstream of Devils Canyon (Delaney et al. 1981b, Schmidt et al. 1983). Comparison of seasonal catch rates, Floy tag recoveries, and radiotracking of rainbow trout suggest that many rainbow trout spawn and rear within clearwater tributaries and overwinter within the mainstem Susitna River (Delaney et al. 1981b, Schmidt et al. 1983, Sundet and Wenger 1984, Sundet and Pechek 1985). For larger tributaries, such as the Deshka River, Sundet and Pechek (1985) suggested some rainbow trout may overwinter within the tributary, while others overwinter in the mainstem. During 1982 Schmidt et al. (1983) captured rainbow trout at four of the five DFH sites sampled in the Lower River Segment, with the highest numbers in Birch Creek and Slough and Sunshine Creek and Side Channel (Figure 4.3-28Figure 4.3-). During 1981 Delaney et al. (1981) reported catch of rainbow trout were more consistent and relatively higher at Anderson Creek, Alexander Creek, and Deshka River sampling sites.

4.3.2.3.7. Arctic Grayling

Arctic grayling are present, usually near tributary mouths, but relatively uncommon in the Lower Susitna River Segment compared to the Middle Segment. Jennings (1985) and Schmidt et al. (1983) reported that Arctic grayling likely overwinter in the mainstem Susitna River, but spawn and rear in tributary streams. During 1982, Schmidt et al. (1983) captured Arctic grayling at four of the five DFH sites surveyed, but not during all survey periods, and the number captured were 6 fish or fewer. During September 1981, Delaney et al. (1981b) captured relatively high numbers of Arctic grayling at the Kashwitna River (RM 61.0), Montana Creek (RM 77.0), and Birch Creek Slough (RM 88.4).

4.3.2.3.8. Dolly Varden

Dolly Varden are present, but relatively uncommon in the mainstem of the Lower Susitna River Segment. Spawning and rearing areas was suspected to primarily be in tributaries with some use of the mainstem for overwintering (Schmidt et al. 1983). During 1982, Dolly Varden were captured in low numbers (1 or 2 fish) at two of the five DFH sites sampled in the Lower River, Sunshine Creek and Side Channel and Birch Creek and Slough (Figure 4.3-30). During 1981, Delaney et al. (1981b) captured Dolly Varden at 8 to 20 percent of the habitat locations surveyed during each two-week period in the Lower Susitna River. During both years capture of Dolly Varden in the mainstem was usually associated with a nearby tributary mouth (Delaney et al. 1981b, Schmidt et al 1983).

4.3.2.3.9. Burbot

Burbot are relatively common in the Lower Susitna River and its larger tributaries such as the Yentna, Deshka, Talkeetna, and Chulitna rivers and Alexander Creek. Winter radiotracking by Sundet (1966) documented use of the Deshka River by burbot. Surveys by Delaney et al. (1981b) documented burbot in the Deshka River and Alexander Creek. Burbot were captured at all five of the DFH sites sampled in the Lower Susitna River during 1982 (Figure 4.3-31) and Schmidt et al. (1983) reported that patterns of distribution were similar to surveys conducted in the 1981.

4.3.2.3.10. Round Whitefish

Round whitefish are present throughout the mainstem of the Lower Susitna River Segment, but appear to be less abundant than in the Middle Segment (Jennings 1985). During 1982, round whitefish were captured at each of the five DFH sites surveyed in the Lower River, but generally in low numbers (Schmidt et al. 1983; Figure 4.3-32Figure 4.3-). The highest number of round whitefish captured in the Lower River was at Goose Creek 2 and Side Channel. In contrast, the highest gillnet catch rate for round whitefish during 1981 was at the mouth of Sunshine Creek (Delaney et al. 1981b), but survey results are difficult to compare between years. Schmidt et al. (1983) reported that substantially more round whitefish were captured during 1982 because of greater effort with boat electrofishing.

4.3.2.3.11. Humpback Whitefish

Humpback whitefish are found throughout the mainstem of the Lower Susitna River and more abundant than the Middle River Segment (Jennings 1985). However, catch rates during 1981 and 1982 were highly variable from site to site and period to period, suggesting humpback whitefish is, in general, a relatively uncommon species. During 1982, humpback whitefish were captured at three of the five DFH sites surveyed, but not during every period (Schmidt et al. 1983; Figure 4.3-33). During 1981, humpback whitefish were captured at 10 to 30 percent of the sites sampled during each two-week period in the Lower River Segment from June through September, except late July when no humpback whitefish were captured (Delaney et al. 1981b).

4.3.2.3.12. Longnose Sucker

Longnose sucker are commonly found throughout the mainstem of the Lower Susitna River and generally more abundant than the Middle River Segment downstream of Devils Canyon (Schmidt et al. 1983, Jennings 1985). During 1982, longnose suckers were captured at all five of the DFH sites surveyed (Figure 4.3-34) with relatively high catch reported for Goose Creek 2 and Side Channel, Rabideaux Creek and Slough, and Sunshine Creek and Slough (Schmidt et al 1983). During 1981, longnose sucker were captured at 11 to 50 percent of the sites sampled during each two-week period in the Lower River Segment from June through September (Delaney et al. 1981b). Areas noted for longnose sucker catch in the Lower River Segment during 1981 include the Deshka River and Cache Creek Slough, Kroto Slough, and Sheep Creek (Delaney et al. 1981b). Schmidt et al. (1983) suggested that increased catch of longnose sucker near tributary mouths during spring were the result of spawning congregations.

4.3.2.3.13. Threespine Stickleback

Threespine sticklebacks are commonly found in the mainstem of the Lower Susitna River and substantially more abundant than the Middle Segment downstream of Devils Canyon (Schmidt et al. 1983, Jennings 1985). During 1982, threespine sticklebacks were captured at all five of the DFH sites surveyed in the Lower Susitna River (Figure 4.3-35) with the highest catch occurring at Whitefish Slough. Adult threespine sticklebacks were observed migrating upstream to spawn during late May and early June 1982 (Schmidt et al. 1983). Subsequently, catch rates of adults were relatively high over the early July spawning period, young of the year were observed during late July and early August in similar areas, and catch rates of young of year threespine sticklebacks increased during late August and September at incline plane traps (Schmidt et al. 1983). Jennings (1985) concluded that threespine stickleback likely spawned at tributary and slough mouths.

4.3.2.3.14. Sculpin

Similar to the Middle Susitna River Segment, sculpin (primarily slimy sculpin) are abundant throughout the mainstem of the Lower Susitna River. Schmidt et al. (1983) captured sculpin at all five of the DFH sites surveyed during 1982 (Figure 4.3-36). Delaney et al. (1981b). Similarly, Delaney et al. (1981b) captured sculpin at 42 to 76 of the habitat location sites surveyed during 1981. Sites influenced by clear water tributaries typically had higher catch rates of sculpin during 1981 and the highest minnow trap catch rate was noted for Birch Creek.

4.3.2.3.15. Arctic Lamprey

Arctic lamprey are present in low numbers within the Lower Susitna River. Delaney et al. (1981b) captured 30 Arctic lamprey were during 1981in the Lower River with the highest catch rate occurring at Little Willow Creek (RM 50.5) during early September. Schmidt et al. (1983) captured 32 Arctic lamprey at DFH sites in Lower River during 1982 of which 30 were captured at Birch Creek and Slough.

4.3.2.3.16. Eulachon

Adult eulachon (*Thaleichthys pacificus*) have been observed in the Lower Susitna River up to RM 50.5, but are more common downstream of the Yentna River near RM 29. Eulachon are an anadromous fish with two runs that enter the river during late May to early June (Vincent-Lang and Queral 1984). ADF&G (1984) identified 61 spawning areas used by eulachon during 1983 with about 70 percent of the areas occurring between RM 12.0 and RM 27.0. ADF&G (1984) also reported that eulachon were observed to spawn in the Yentna River during 1982 and 1983, but the amount of river used for spawning was not determined. ADF&G (1984) reported that first run eulachon population size during 1982 and 1983 was approximately several hundred thousand fish and the second run was about an order of magnitude higher.

4.3.2.3.17. Bering Cisco

Bering cisco (*Coregonus laurettae*) were collected incidentally to other studies during the 1980s (Barrett et al. 1984). Consequently, information regarding Bering cisco distribution is relatively imprecise, and abundance is largely unknown. Adult Bering cisco are apparently present in the Lower Susitna River up to the Three Rivers Confluence during spawning runs (Jennings 1985). However, ADF&G (1984) reported a few Bering cisco are sometimes captured at the Talkeetna and Curry fishwheels at RM 103 and 120, respectively, and a single Bering Cisco was captured at Fourth of July Creek during 1983. Bering cisco are an anadromous species that enters the Susitna River in August with spawning completed by the third week of October (Barrett et al. 1984).

4.3.2.3.18. Ninespine Stickleback

Ninespine sticklebacks (*Pungitius pungitius*) are rare within the Lower Susitna River. Ninespine stickleback were not captured during surveys conducted during 1981 to 1983. During 1984, Sundet and Pechek (1985) captured 50 ninespine sticklebacks on August 5 near RM 57.2 and 10 were captured by an outmigrant trap at RM 22.4.

4.3.2.3.19. Northern Pike

The northern pike (*Esox lucius*) is an invasive species within the Susitna River drainage, which were illegally transplanted into several lakes of the Yentna River in the 1950s (Delaney et al. 1981b). During the 1980s Aquatic Studies Program five northern pike were captured: one in Kroto Slough (RM 36.2), one at the Yenta Station fishwheel, and three at the Flathorn Station fishwheel (RM 22.4). Since the 1980s, the range of northern pike in the Susitna River basin has expanded greatly. Ivey et al. (2009) reported northern pike have been documented in Lower River tributaries as far upstream as Rabideaux Creek (RM 83.1) and the suspected distribution extends to tributaries up to the Three Rivers Confluence. There is little information specific to the mainstem of the Susitna River regarding northern pike spawning, juvenile emergence, or juvenile rearing. Telemetry studies suggest that adult northern pike do not migrate significant distances within the Susitna Basin. A 1996 study found that over the course of one year, only one out of 18 radio-tagged northern pike moved a distance greater than 10 km and many moved less than 1 km (Rutz 1999).

5. TECHNICAL MEMORANDUM – SELECTION OF TARGET SPECIES AND DEVELOPMENT OF SPECIES PERIODICITY INFORMATION FOR THE SUSITNA RIVER

Defining the species of interest (i.e., target species) and then developing an understanding of the timing of different life stage functions for each of the species is an important aspect of instream flow studies. Fish species have evolved their life history strategies around the climatic and hydrologic patterns of a given riverine system. Such strategies are directed toward increasing population viability by synching important life stage functions during periods of time affording the greatest opportunities for the success of that lifestage. Thus, the timing of different life stage functions (e.g., migration, spawning, egg incubation, fry and juvenile rearing, smoltification, etc.) will differ by species generally, and even for a given species will vary both within (depending upon local climatological and hydrologic conditions) and between watersheds. Understanding the timing and duration of these life stage functions as they exist under an unregulated flow regime is important for being able to evaluate potential changes that may occur following construction and operation of a hydroelectric project.

Both the 1980s Su-Hydro studies and the Susitna-Watana studies proposed for 2013-2014 recognized the importance of defining target species and their life stage periodicities for evaluating potential project effects. This TM summarizes the studies completed in the 1980s that served to identify target species and the periodicities of their life stages, and then provides summary information concerning the proposed methods for completing this as part of the 2013-2014 studies. Unlike the fish summary information presented above that discusses fish distributions on a reach basis, the target species and life stage information for the 1980s studies was deemed best presented by species for each river reach.

5.1. Su-Hydro 1980s Studies

Based on information provided by Jennings (1985) and Delaney et al. (1981), the Susitna River basin historically supported at least 20 fish species (Table 4.3-1), of which, with the exception of northern pike, all were considered to be endemic to the basin. Fish species richness within the Susitna Basin was generally highest in the Lower reach and lowest in the Upper reach and the upper Middle reach section upstream of Devils Canyon (River Mile [RM 150 – RM 162]). Steep channel gradients and high water velocities within Devils Canyon obstructed upstream passage for many fish species.

5.1.1. Target Species Selection

Aquatic studies conducted in the Susitna River during the 1980s identified the periodicity of habitat utilization of various fish species. Pacific salmon species (Chinook, sockeye, chum, coho and pink salmon) were a primary focus of the 1980s studies and can be considered the primary target species for many of those studies, although some studies specifically targeted other species including other anadromous fish (e.g., eulachon), and resident species (see Section 4). Thus, there was no single species that was designated as the target species for the instream flow studies. Rather, the studies were designed to develop a general understanding of river use by all species of fish. Certain species were however studied more intensely than others, a factor of their importance relative to sport and commercial fisheries as well as the degree to which their habitats may be directly influenced by the Susitna Project. For example, as more information was obtained concerning the habitat utilization of adult salmon, in particular spawning habitats, more emphasis shifted to certain salmon species, in particular, sockeye and chum salmon. Both of these species were found to utilize clear water lateral habitats that were hydraulically connected to the main channel of the Susitna River for spawning (keying in on groundwater upwelling areas) and because these habitats could be affected by the regulation of flows in the Susitna River, understanding the responses of these habitats to mainstem flows was important. The other salmon species including primarily Chinook and coho were found to spawn primarily in other main rivers tributary to the lower Susitna River including the Yentna and Chulitna, as well as smaller tributaries that enter directly to the river. However, studies of juvenile fish habitat use indicated that the main channel as well as side channel, side slough and other lateral habitats were frequently utilized by all species of salmon and therefore understanding how those habitats functioned and were influenced by main channel flows was a central focus of many of those studies.

Determining potential effects of the proposed operations of the Su-Hydro Project on different species and lifestages of fish and their habitats in the Susitna River was never completed due to funding cuts and project cancellation. The types of information and data that had been collected at the end of the five years of study, suggest that the flow-effects evaluation may have ultimately been more macro-habitat based rather than focused on one or more target species.

5.1.2. Species Periodicities

Periodicities of juvenile and adult salmon habitat utilization in the Middle and Lower River were described during 1980s studies (see Section 4), and the more recent fisheries studies conducted in the Susitna River during the 2000s (e.g., Merizon etc.) have provided supplemental information. The periodicities of other fish species were also described during the 1980s studies. However, the sampling methods employed then were not always well-suited for identifying and monitoring the complex life history patterns exhibited by resident fish species. Some of the species other than Pacific salmon for which periodicity information was described included: rainbow trout, Arctic grayling, burbot, round whitefish, humpback whitefish, longnose sucker, Dolly Varden, Bering cisco, and eulachon. Although some information is available for most resident and anadromous non-salmonids in each of the three reaches delineated during the 1980s studies (Upper, Middle and Lower), most data pertain to the Middle and Lower reaches downstream of Devils Canyon (RM 152). In general, insufficient information was collected during the 1980s studies to describe the periodicities of Arctic lamprey, Lake trout, Northern pike, threespine stickleback, ninespine stickleback, and various sculpin species present in the Susitna Basin. Information relating to periodicity of fish habitat use in the Upper Segment is sparse relative to that of the Middle and Lower segments.

To the extent possible, the timing of use by macro-habitat type (main channel, side channel, side slough, upland slough, tributary mouth and tributary; see Section 4) was provided by species and life stage for each Segment (Upper, Middle, Lower) based on studies conducted in the Susitna River. Habitat utilization data for some species and/or life stages in the Susitna River is sparse; in these cases, the available information for this TM was consolidated among Susitna River Segments and/or was supplemented by data not specific to the Susitna Basin (e.g., Morrow 1980).

Adult salmon migration timing in the Susitna River was identified during the 1980s based primarily on fish capture data at stationary fishwheels, which were operated in the main channel at Curry (RM 120), Talkeetna (RM 103), Sunshine (RM 80), Susitna (RM 25.7), and Flathorn (RM 22) stations (e.g., Barrett et al. 1985). Spawning distribution and timing was determined from visual observation of salmon spawning locations recorded during foot, boat and aerial surveys. Data from fishwheel operation and spawning distribution studies during the 2000s by Yanusz et al. (2007, 2011b) and Merizon et al. (2010) provide additional information regarding adult salmon migration timing and spawning distribution. Salmon spawning surveys during the 1980s were conducted in main channel, off-channel and tributary habitats with varying intensity among Susitna River tributaries and mainstem areas between the Upper and Lower segments.

The periodicity of habitat use for adult freshwater resident and non-salmonid anadromous species (i.e., Bering cisco and eulachon) was determined based primarily on 1980s studies to identify juvenile and resident fish distribution and abundance in the Middle and Lower segments (e.g., Schmidt et al. 1983). These studies utilized a variety of methods to capture juvenile and resident fish species (see Section 4). Migration timing of adult resident and non-salmonid anadromous species was based on fishwheel data in the Middle and Lower segments and on information from summer and winter radio telemetry and capture-mark-recapture studies designed to track patterns of fish movement and habitat use. Utilization of the Upper Segment by resident fish species was derived from summer sampling of the impoundment area in 1982. Information not available from Susitna River 1980s aquatic studies was obtained from literature sources relating to fish populations in Alaska or regions with comparable climate.

The periodicity of egg incubation and development for all fish species is based on adult spawn timing, available information regarding egg development time from fertilization to emergence, and observations of fry emergence. Egg development and incubation studies were performed for sockeye and chum salmon during winter in the Susitna River and/or simulated environments during the 1980s, but site-specific egg development and fry emergence timing is less well documented for other species. Consequently, data from similar regions and temperature regimes were used to help estimate the period of egg incubation and development. Documented timing of fry emergence in late winter or early spring also was used to identify the end of the egg incubation period and start of fry emergence.

Juvenile fry and smolt movement timing for all species was estimated during the 1980s based primarily on capture at stationary downstream migrant traps operated in the Susitna River main channel at Talkeetna (RM 103) and Flathorn (RM 22) stations. Fish capture data from 1980s summer and winter sampling were used to supplement outmigrant trap data and to identity habitat utilization of anadromous and resident fish species. Capture sites visited during the 1980s and 2000s were located in all major meso-habitats between Susitna River RM 233.4 and RM 7.1.

5.1.2.1. Chinook Salmon

The known distribution of Chinook salmon in the Susitna Basin extends from Oshetna Creek (RM 233.4) to Cook Inlet at RM 0.0 (Jennings 1985, Thompson et al. 1986, Buckwalter 2011). Estimated total adult Chinook salmon escapement in the Susitna Basin during 1976 – 1984 ranged from 10,453 to 77,937 based on peak counts of spawning survey reaches (Jennings 1985). During the same period, Chinook salmon escapement to the Lower Susitna was consistently highest among Susitna River subbasins (Jennings 1985). Chinook escapement to the Lower

Susitna subbasin ranged from 43 to 58 percent of the total basin escapement during 1981 – 1984, while the proportion of Middle Susitna subbasin escapement ranged from 7 to 11 percent of the total escapement during the same period (Jennings 1985).

Juvenile Chinook salmon in the Susitna River typically exhibit one of three freshwater life history patterns. One group of Chinook fry rear in their natal tributary for nearly one year prior to emigrating to the ocean as age 1+ smolts, while a second group of Chinook disperse from natal tributaries throughout the spring and summer to Susitna River main channel, side channel and slough habitats in the Middle and Lower segments (Roth and Stratton 1985, Stratton 1986). Winter studies during the 1980s suggest that most Chinook fry utilize the Lower Susitna as winter nursery habitat (Stratton 1986). A third freshwater life history pattern, in which juvenile Chinook emigrate to the ocean as age 0+ smolts, was either exhibited by very few juvenile Chinook during the 1980s or was subject to high ocean mortality based on adult scale analyses (Barrett et al. 1985, Roth and Stratton 1985, Suchanek et al. 1985). Age analysis of adult Chinook scales in 1985 indicated that 5% of fish sampled had emigrated as age 0+ smolts (Thompson et al. 1986).

5.1.2.1.1. Upper Segment

The upstream extent of documented adult Chinook salmon presence in the Upper Susitna River is Kosina Creek (RM 206.8), while juvenile Chinook have been identified as far upstream as the Oshetna River (RM 233.4) (Buckwater 2011, AEA unpublished data). Few observations of adult Chinook salmon have been recorded in the Upper River and as a result, the timing of migration and spawning is not well defined. Active Chinook spawning was observed in Kosina Creek during late July, which suggests that the periods of adult Chinook migration and spawning in this segment may be similar to that described for Chinook in the Middle Susitna River (Table 5.1-1) (Buckwalter 2011). If so, the timing and duration of egg incubation and fry emergence would also likely be comparable to the period described for the Middle Segment (Table 5.1-1).

Chinook fry were documented in Kosina Creek (RM 206.8) in 2003 and 2011 and in the Oshetna River (RM 233.4) in 2003 (Buckwalter 2011). No Chinook salmon were identified in any Upper River tributaries sampled during impoundment studies in 1982 (Deadman, Watana, Kosina and Jay Creeks) or in Watana Creek (RM 194.1) or Deadman Creek (RM 186.7) during aerial spawning surveys conducted in 1984 (Sautner and Stratton 1983, Barrett et al. 1985). The periodicity of juvenile Chinook salmon rearing and migration are poorly defined in the Upper River due to a paucity of data pertaining to juvenile Chinook presence and movement. It is unclear whether juvenile Chinook captured in 2003 and 2011 in the Upper River were age 0+ and/or age 1+ (Buckwalter 2011). Periodicity of juvenile Chinook rearing and migration are considered undefined until additional data are available.

5.1.2.1.2. Middle Segment

Adult Chinook salmon typically entered the Middle Susitna River during upstream spawning migrations in early June of each year, with most movement occurring late June and early July (Table 5.1-1). Adult Chinook primarily utilized main channel habitats for migration to access spawning sites, which were distributed nearly exclusively in tributary habitat (ADF&G 1983a, Jennings 1985, Thompson et al. 1986). Upstream migration into Middle Susitna River tributaries was delayed from that of main channel migration and occurred from in mid-June through early

August (Jennings 1985, Trihey & Associates and Entrix 1985). Most tributary migration occurred during July (Table 5.1-1) (Jennings 1985).

The spawning period for Chinook salmon in the Middle Segment during the 1980s was early July through late August, with the majority of spawning activity occurring between late July and mid-August (Table 5.1-1) (Barrett et al. 1985, Jennings 1985, Thompson et al. 1986). Chinook spawning occurred almost entirely in tributaries in the Middle Susitna, with occasional use of habitat at tributary mouths (ADF&G 1983a, Jennings 1985, Thompson et al. 1986). Spawning was observed at Cheechako Creek (RM 152.4) and Chinook Creek (RM 157) tributary mouths in 1982 but was not documented at similar habitats elsewhere in the Susitna Basin (ADF&G 1983a, Barrett et al. 1985, Thompson et al. 1986). Chinook spawning was not documented in main channel habitats during 1981 – 1985; however, surveys conducted during 1983 – 1985 did not specifically target Chinook salmon (ADF&G 1983a, Barrett et al. 1984, Jennings 1985, Thompson et al. 1986). The primary spawning tributaries during the 1980s were Indian River and Portage Creek; annual peak index counts of live Chinook during 1981 – 1985 in these streams accounted for over 90 percent of total annual peak index counts among Middle Susitna tributaries (Jennings 1985, Thompson et al. 1986).

Chinook salmon egg incubation extends from the start of spawning in early July through juvenile fry emergence, though egg development and the timing of fry emergence in this segment is not well defined due to limited availability of winter sampling data. Chinook fry emergence began prior to the start of outmigrant trap seasonal operation in mid-May 1983 and 1985, though ice cover precluded trap operation prior to this point (Schmidt et al. 1983, Roth et al. 1986). Salmon egg incubation time depends on water temperature and approximate time necessary for Chinook egg development from the point of fertilization to fry emergence can range from 316 days at water temperatures of 2° C to 191 days at 5° C (Murray and McPhail 1988, Quinn 2005). Based on these data and approximate timing of Chinook emergence in similar areas, emergence in the Susitna River is estimated to begin in early March (Table 5.1-1) (Scott and Crossman 1973, Jennings 1985). Small size of juvenile Chinook captured during May and June suggests that Chinook emergence may continue until early May or later (Roth and Stratton 1985). The small size (35 mm) of some age-0+ Chinook captured at outmigrant traps in June and July of 1981, 1982 and 1983, supports the possibility that emergence may continue through May or beyond (Table 5.1-1) (Jennings 1985).

Age 0+ Chinook salmon fry movement from natal tributaries was observed to peak at the start of tributary sampling in June and continued through September in 1981, 1984, and 1985 (Delaney et al. 1981a, Roth and Stratton 1985, Roth et al. 1986). These data, in conjunction with early June presence of age 0+ Chinook in the mainstem Susitna River, indicate that the period of age 0+ fry migration from tributaries occurs from early May through mid-September, with most movement in late May and July (Table 5.1-1) (Roth et al. 1984, Roth et al. 1986). Chinook that remained in the Middle Segment primarily occupied tributary and side channel habitats during the summer and side channels and side sloughs during winter (Figure 5.1-1) (Dugan et al. 1984). Age 0+ Chinook that emigrated from the Middle Susitna River moved downstream to the Lower River from early May through late September, and peak movement occurred in July and early August (Table 5.1-1) (Roth et al. 1984, Roth and Stratton 1985, Roth et al. 1986). These downstream migrant age 0+ Chinook either selected winter nursery habitats in the Lower Susitna or immigrated to estuarine habitats; the relative proportion of fish that demonstrated each life history was not clear based on 1980s studies (Roth and Stratton 1985).

Age 1+ Chinook salmon utilized side channels and side sloughs as primary nursery habitats during winter in the Middle Susitna, and tributary mouths, main channels, and upland sloughs as secondary habitats. Based on winter capture data, emigration of age 1+ Chinook from natal tributaries and mainstem nursery areas began in early winter and was mostly completed by July (Table 5.1-1) (Stratton 1986, Roth et al. 1986). Catch records at the Talkeetna Station outmigrant trap (RM 103) indicated that age 1+ Chinook emigration from mainstem areas started prior to the late May start of trap operation in 1984 and 1985 (Roth and Stratton 1985, Roth et al. 1986). Outmigration data during 1983 – 1985 indicate age 1+ Chinook emigration from Middle Susitna mainstem areas occurred from early May through mid-August, with most movement between late May and early July (Table 5.1-1) (Roth et al. 1984, Roth and Stratton 1985, Roth et al. 1986).

5.1.2.1.3. Lower River

Adult Chinook salmon entered the Lower Susitna River in late May and upstream migration to tributary spawning sites continued through the spawn period in late August (Table 5.1-1) (Barrett et al. 1984, Thompson et al. 1986). The peak of migration in the Lower River occurred during the latter part of June (Barrett et al. 1984, Thompson et al. 1986). Susitna River fishwheels were not operational prior to late May during the 1980s studies, so Chinook movement patterns prior to this time are not well documented. The timing of upstream migration into tributaries is not well documented in the Lower Susitna; however, based on main channel movement timing and initiation of spawning in tributaries, tributary migration is estimated to occur from mid-June through August (Table 5.1-1).

Chinook salmon spawning in the Lower Susitna River occurred entirely in tributary habitat with no observed use of mainstem, side channel or slough habitats (Barrett et al. 1985, Thompson et al. 1986). The Chinook spawn period in 1984 and 1985 in tributaries took place from early July through late August, with the peak of spawning during the last three weeks of July (Table 5.1-1) (Barrett et al. 1985, Thompson et al. 1986). Primary Chinook spawning tributaries in the Lower Susitna River included the Yentna River (RM 28), Alexander Creek (RM 10.1), Deshka River (RM 40.6), Willow Creek (RM 49.1), Montana Creek (RM 77.0), Talkeetna River (RM 97.1) and Chulitna River (RM 98.5) (Jennings 1985). Chinook escapement in the Deshka River accounted for at least 60 percent of the total annual Lower Susitna escapement in each year during 1982 – 1984 (Jennings 1985).

The start of Chinook salmon egg incubation in the Lower Susitna River was coincident with the start of spawning in early July and is presumed to be similar to estimated incubation and emergence timing in the Middle Segment (Table 5.1-1) (Schmidt and Bingham 1983, Jennings 1985). Chinook fry emergence was estimated to occur during March, April though the small size of juvenile Chinook captured in May and June indicate that the period may extend to early May or later (Table 5.1-1) (Jennings 1985, Roth and Stratton 1985).

Dispersal of age 0+ Chinook salmon from natal tributaries in the Lower River was not well defined during 1980s studies. Age 0+ Chinook fry were captured at main channel outmigrant traps in early June during 1984 and 1985, which suggests that timing of tributary migrations began in mid-May (Table 5.1-1) (Roth and Stratton 1985, Roth et al. 1986). Weir catch on the Deshka River (RM 40.6) indicated that age 0+ Chinook movement peaked during July and continued through September (Delaney et al. 1981a, Roth and Stratton 1985). Age 0+ Chinook migrated through the Lower Susitna main channel from late May through September, with peak movement during late July and early August (Table 5.1-1) (Roth and Stratton 1985, Roth et al. 1986). Many of the age 0+ Chinook captured at outmigrant traps at Flathorn Station (RM 22) were believed to emigrate to the ocean in their first year because few age 0+ fish were captured downstream of this trap during 1984 site sampling efforts (Roth and Stratton 1985, Suchanek et al. 1985).

Age 1+ Chinook salmon movement was not well documented for the Lower Susitna, but appears to be similar to that of the Middle Segment based on available information. Migration of age 1+ Chinook from natal tributaries started in January and continued through July (Stratton 1986); catch records from Lower Susitna tributaries indicated age 1+ Chinook were absent as of August, but timing of peak movement is unclear due to sparse data (Table 5.1-1) (Schmidt et al. 1983). Age 1+ migration from mainstem habitats appeared to start prior to the late May start of trapping at the Flathorn Station (RM 22) in 1984 and 1985, and is assumed to have begun in early May (Table 5.1-1). Catch at this trap indicates that movement age 1+ movement continued through the end of August and peaked during late June and early July (Roth and Stratton 1985, Roth et al. 1986).

5.1.2.2. Sockeye Salmon

Sockeye salmon were distinguished during 1980s studies in terms of first and second runs based on adult migration timing and spawning location (Jennings 1985, Thompson et al. 1986). First run sockeye adult spawning and juvenile rearing occurred within the Fish Creek system in the Talkeetna River Basin (RM 97.2) and in the Fish Lake system located within the Yentna River (RM 30.1) during the 1980s (Thompson et al. 1986). Second run sockeye spawning and rearing occurred within Susitna River mainstem and tributary habitats in the Middle and Lower segments and were distributed from Devils Canyon (RM 150) to Cook Inlet (Barrett et al. 1985, Jennings 1985, Thompson et al. 1986, Yanusz et al. 2007).

The first run of sockeye salmon was substantially smaller than the second run and was known during the 1980s to only spawn within tributaries of the Talkeetna (RM 97.2) and Yentna (RM 30.1) rivers (Jennings 1985, Thompson et al. 1986). Total escapement in 1985 for first run sockeye in the Susitna Basin was 11,750 (Thompson et al. 1986). Estimated escapement of second run of sockeye salmon was 407,600 for the entire Susitna Basin, 120,800 at the Sunshine Station fishwheel (RM 80) and 2,800 at the Curry Station fishwheel (RM 120) (Thompson et al. 1986). In 1984, estimated total basin escapement of second run sockeye was 605,800 and the proportional abundance at Sunshine (RM 80) and Curry (RM 120) stations was similar to that observed in 1985 (Barrett et al. 1985). Based on estimated escapements at sampling stations in 1984 and 1985, most second run sockeye within the Susitna Basin utilize tributaries downstream of Sunshine Station (RM 80) (Barrett et al. 1985, Thompson et al. 1986).

Juvenile sockeye salmon in the Susitna River typically reside in freshwater nursery habitats for one year prior to emigrating as age-1+ smolts, though adult scale analysis during the 1980s and in 2008 indicate a portion emigrate as age-0+ or age-2+ smolts (Barrett et al. 1984, Barrett et al. 1985, Thompson et al. 1986, Yanusz et al. 2011b). In the Middle Segment, a substantial portion of age-0+ sockeye salmon fry redistribute from natal areas during the open water season to nursery habitats in the Lower River, though some remain within the Middle Segment through winter (Dugan et al. 1984, Roth and Stratton 1985, Roth et al. 1986). A portion of the Susitna River sockeye emigrate to marine areas during the first year as age-0+, though the relative proportion of juvenile sockeye salmon that exhibit this early life history type was believed to be small based on the small proportion (less than 10 percent) of adult sockeye scales with this pattern (Barrett et al. 1985, Thompson et al. 1986, Roth et al. 1986).

5.1.2.2.1. Middle Segment

Adult sockeye salmon in the Middle Segment, which are comprised of second run stock, typically began upstream migration during the 1980s in early July with peak movement during late July and early August (Table 5.1-2) (Jennings 1985, Thompson et al. 1986). Minimal holding or milling behavior was observed by adult sockeye salmon, so observed main channel migration timing at Curry (RM 120) and Talkeetna (RM 103) stations is likely similar to upstream movements into side slough spawning sites (ADF&G 1983a). Adult sockeye in the Middle Segment utilize main channel and side channel areas to access primary spawning areas in side sloughs (Jennings 1985).

Nearly all sockeye spawning in the Middle Segment occurred within side sloughs, though active spawning in the mainstem and occasional use of tributaries was observed (Jennings 1985, Thompson et al. 1986). Sockeye salmon spawning in side sloughs occurred from early August through early October and peaked during the month of September (Jennings 1985, Thompson et al. 1986). Mainstem spawning in 1983 and 1984 was observed during mid- and late September, while the few observations of adult sockeye spawning in tributaries occurred in early September (Table 5.1-2) (Barrett et al. 1984, Barrett et al. 1985). Primary spawning sloughs in the Middle Segment during the 1980s were Slough 21 (RM 141.1), Slough 11 (RM 135.3), and Slough 8A (RM 125.1) (Jennings 1985).

Sockeye egg incubation in the Middle Segment is initiated at the start of spawning in early August and is estimated to continue through May based on observations of sockeye egg development during winter 1982 (Table 5.1-2) (Schmidt and Estes 1983, Jennings 1985, Roth and Stratton 1985). Emergence timing for sockeye in side slough habitats is estimated to occur from late March through May, though timing is likely variable among sites due to differences in intergravel incubation conditions (e.g., water temperature and dissolved oxygen levels) (Table 5.1-2) (Schmidt and Estes 1983, Wangaard and Burger 1983, Jennings 1985). The duration of incubation at two Middle Segment sites, Slough 11 (RM 135.3) and Slough 21 (RM 141.1), was approximately 130-140 days and sockeye fry emergence was either initiated or completed at these two sites by late April (Schmidt and Estes 1983). The wide size range of juvenile sockeye salmon fry captured at outmigrant traps and Lower River sampling sites may indicate that emergence continues over a long period (Roth and Stratton 1985).

Age-0+ juvenile sockeye salmon in the Middle Segment primarily utilize natal side sloughs and upland sloughs for nursery habitat (Figure 5.1-1) (Schmidt et al. 1983, Dugan et al. 1984). Juvenile sockeye capture data following breaching events in side sloughs in 1983 suggested that age-0+ sockeye dispersed from breached side sloughs and redistributed to upland slough areas during late summer (Dugan et al. 1984). Use of main channel, side channel, tributary and tributary mouth habitats by juvenile sockeye in the Middle Segment was low during 1980s studies (Dugan et al. 1984). Juvenile sockeye use of main channel and side channel areas was highest in backwatered areas with low water velocity (Dugan et al. 1984). Most age-0+ sockeye from the Middle Segment disperse downstream during the open water season to either reside in Lower River nursery habitats for the winter or emigrate to marine areas as age-0+ smolts (Roth and Stratton 1985, Suchanek et al. 1985, Roth et al. 1986). Dispersal of age-0+ sockeye from natal habitats was typically underway prior to the start of mainstem outmigrant trapping at Talkeetna Station (RM 13), but likely began in early May, peaked in late June and July and declined in September (Table 5.1-2) (Roth and Stratton 1985, Roth et al. 1986). High juvenile sockeye use was observed in Side Slough 11 (RM 135.3) and upland Slough 6A (RM 112.3) during summer 1983 (Dugan et al. 1984).

Age-1+ sockeye salmon typically began emigration from the Middle Segment prior to mainstem outmigrant trap seasonal operation during the 1980s studies, but fyke net traps operated in Lower River side channels suggest that downstream movement may have begun in early April (Table 5.1-2) (Bigler and Levesque 1985). Age-1+ migration peaked during late May and early June and was completed by early or late July among sampling years in the 1980s (Table 5.1-2) (Schmidt et al. 1983, Roth et al. 1984, Roth and Stratton 1985). Based on the low number of age-1+ sockeye captured at outmigrant traps, it was hypothesized that most juvenile sockeye salmon from the Middle Segment dispersed to the Lower River prior to winter (Roth et al. 1984, Roth and Stratton 1985).

5.1.2.2.2. Lower River

First and second runs of adult sockeye utilize the Lower River of the Susitna River for migration (Thompson et al. 1986). Migration of first run sockeye in the Lower River in 1984 occurred during late May and June and appeared to peak in early June (Table 5.1-2) (Thompson et al. 1986). First run sockeye spawn exclusively in the Talkeetna and Yentna basins, so Lower River use by this stock is for passage only (Barrett et al. 1985, Thompson et al. 1986). Second run adult sockeye salmon migration occurs from early July through September with most movement during late July and early August (Table 5.1-2) (Barrett et al. 1985, Thompson et al. 1986).

Second run sockeye spawn almost entirely within Lower River tributaries (Barrett et al. 1985, Thompson et al. 1986, Yanusz et al. 2007, 2011b). No spawning was observed in main channel, side slough, or tributary mouth habitats in 1984, though approximately 4 percent of adult sockeye radio tagged in 2006 utilized mainstem areas for spawning (Barrett et al. 1985, Yanusz et al. 2007). Second run sockeye spawn timing in the Lower River is estimated to occur from late July through September and peak during August, though data are sparse for spawning tributaries (Table 5.1-2) (Barrett et al. 1985, Thompson et al. 1986). Principal second run spawning basins in the Lower River are the Talkeetna (RM 97.2) and Yentna (RM 30.1) rivers (Barrett et al. 1985, Thompson et al. 1986, Yanusz et al. 2011b).

Sockeye egg incubation and fry emergence timing in mainstem areas of the Lower River are likely similar to the period described in the Middle Segment (Table 5.1-2), though timing in Lower River tributaries is not well defined. Egg incubation occurs from the start of spawning in early August through May based on observations of sockeye egg development during winter 1982 (Table 5.1-2) (Schmidt and Estes 1983, Jennings 1985, Roth and Stratton 1985). Emergence timing for sockeye in side slough habitats is estimated to occur from late March through May, though timing can be dependent on site-specific intergravel incubation conditions such as water temperature and dissolved oxygen levels (Table 5.1-2) (Schmidt and Estes 1983, Wangaard and Burger 1983, Jennings 1985). Based on wide size ranges of juvenile sockeye salmon fry captured at outmigrant traps and Lower River sampling sites, the emergence period may continue over a long period (Roth and Stratton 1985).

The majority of juvenile sockeye salmon in the Lower River use lacustrine nursery habitats during freshwater residence, though a portion use areas associated with the mainstem Susitna River (Suchanek et al. 1985). Age-0+ dispersal from natal areas to Lower River nursery habitats occurred concurrently with movements in the Middle Segment, from early May through September, though most movement was during late June, July and early August based on outmigrant trap data at Talkeetna (RM 103) and Flathorn (RM 22) stations (Table 5.1-2) (Roth and Stratton 1985, Suchanek et al. 1985). Low age-0+ sockeye abundance within the Lower River mainstem areas soon after ice breakup was attributed to the general lack of mainstem adult spawning habitat, while higher abundance during late June was likely a result of juvenile sockeye redistribution from the Middle Segment (Suchanek et al. 1985). Juvenile sockeye abundance in the Lower River was highest in tributary mouth habitats, though capture rates were variable among these areas (Suchanek et al. 1985). Relative to tributary mouths, sockeye use was low in main channel and side channels and minimal in side sloughs (Suchanek et al. 1985). Highest capture rates of sockeye salmon were among habitats with low turbidity levels (75 – 125 NTU) (Suchanek et al. 1985). Juvenile sockeye abundance declined in breached side channels with increasing main channel discharge, either due to elevated turbidity or current velocity levels caused by breaching (Suchanek et al. 1985). Juvenile sockeye salmon abundance in the Lower River was generally highest at Beaver Dam Slough and Side Channel (RM 86.3) and at Rolly Creek mouth (39.0) among sampled sites (see Section 4) (Suchanek et al. 1985).

Age-1+ sockeye salmon emigration from Lower River habitats began in early April, based on fyke net trapping data from Lower River side channels, and continued through mid- or late July at the Flathorn Station (RM 22) outmigrant trap (Bigler and Levesque 1985, Roth and Stratton 1985). In 1984, most age-1+ sockeye migrated during late May and June (Table 5.1-4) (Roth and Stratton 1985).

5.1.2.3. Chum Salmon

Chum salmon are distributed in the Susitna Basin from Devils Canyon (RM 150) downstream to Cook Inlet (Jennings 1985, Thompson et al. 1986). Among Pacific salmon species, chum salmon are the most abundant salmon species returning to the Susitna River, except during high even-year pink salmon runs. The average combined annual chum salmon escapement in the Yentna Basin and Susitna Basin upstream of RM 80 during 1981-1984 was 452,200; annual escapement was not estimated for the Susitna Basin downstream of RM 80 during 1981-1983, excepting the Yentna Basin (Jennings 1985). Escapement during 1981-1984 for the Middle Segment, upstream of RM 103, was 54,600 (Jennings 1985). During 1980s studies, chum spawning primarily occurred in the Talkeetna River Basin, whereas in 2009 radio telemetry data indicated a larger chum escapement in the Yentna Basin (Barrett et al. 1985, Merizon et al. 2010). Approximately 4 percent of tagged chum in 2009 spawned in the Middle Segment and 14 percent used the Lower River and associated tributaries for spawning, excluding the Chulitna, Talkeetna, and Yentna Rivers (Merizon et al. 2010).

5.1.2.3.1. Middle River

Adult chum salmon migration in the Middle River of the Susitna River typically began in mid-July during 1980s studies and peaked during September in mainstem and tributary habitats (Table 5.1-3) (Jennings 1985, Thompson et al. 1986). Timing of entry into spawning tributaries by adult chum can be delayed for a week or more as fish hold near the mouth of the tributary, based on radio tag studies in the early 1980s (ADF&G 1981, ADF&G 1983a). Chum salmon utilize a range of mainstem and tributary habitat to access Middle Segment spawning areas located in tributary, side slough, side channel and main channel habitats (Jennings 1985).

Adult chum salmon primarily spawned in tributary and side slough habitats during the 1980s, though some spawning occurred in mainstem habitats (Jennings 1985, Thompson et al. 1986). Less than 10 percent of observed chum spawning during 1981-1984 occurred in mainstem habitats in the Middle Segment (Jennings 1985). Spawn timing was observed to differ among side slough, tributary and mainstem habitats (Jennings 1985). The tributary spawning period was from early August through September and peaked in late August and early September (Table 5.1-3) (Barrett et al. 1985, Jennings 1985, Thompson et al. 1986). In side slough habitats, chum spawning occurred from early August through mid-October, with peak activity occurring during September (Table 5.1-3) (Barrett et al. 1985, Jennings 1985, Thompson et al. 1986). Mainstem spawning occurred from early September through early October, though most chum spawned during early September (Table 5.1-3) (Barrett et al. 1985, Jennings 1985, Thompson et al. 1986). Portage Creek (RM 148.9), Indian River (RM 138.6) and 4th of July Creek (RM 131.1) were the primary chum spawning tributaries during the 1980s, while sloughs 21 (RM 141.1), 11 (RM 135.3), and 8A (RM 125.1) were principal side sloughs used for spawning (Jennings 1985).

Incubation of chum salmon eggs began at the start of spawning in each habitat type: early August in tributary and side sloughs, and early September in main channel areas (Table 5.1-3) (Barrett et al. 1985, Jennings 1985, Thompson et al. 1986). Egg incubation conditions among these habitats differ considerably, particularly in terms of water temperature, and such differences can affect egg development timing (Wangaard and Burger 1983, Vining et al. 1985). Intergravel water temperatures in tributary and main channel are strongly influenced by surface streamflow, which suggests that incubation temperatures are high during fall and near freezing during winter (Vining et al. 1985). In contrast, intergravel water temperatures in side slough habitats are typically higher relative to tributary and main channel areas during winter due to the influence of thermally stable groundwater upwelling (Vining et al. 1985). Timing of chum fry emergence in tributary and main channel areas is estimated to begin in early March, approximately two weeks later than the estimated start of emergence in side slough areas, based on evaluation of chum egg incubation and development in variable temperature regimes (Table 5.1-3) (Wangaard and Burger 1983, Vining et al. 1985). The duration of chum emergence periods among habitats are not well defined due to sampling difficulty during this time, however, based on the small size of juvenile chum captured at downstream traps in late May, it is assumed that emergence in tributary and main channel areas extends through mid-May (Table 5.1-3) (Bigler and Levesque 1985, Roth and Stratton 1985).

Juvenile chum salmon emigrate from the natal habitats to marine areas as age-0+ smolts, though some may feed within nursery habitats for one to three months prior to or during migration (Morrow 1980, ADF&G 1983c, Jennings 1985). Primary nursery habitats for age-0+ chum generally corresponded with areas highly utilized by adult chum spawners (i.e., tributary and side slough) (Figure 5.1-1); areas with the highest juvenile density also supported the highest spawning density (Jennings 1985, Dugan et al. 1984). Tributary mouths and side channels were also occupied by juvenile chum, though their use was low relative to side slough and tributary areas (Figure 5.1-1) (Schmidt et al. 1983). Downstream migration of juvenile chum began prior to the start of outmigrant trap seasonal operation in mid- and late May 1983 and 1985, and fyke trap data collected in the Lower River suggest an early May start of juvenile chum movement (Dugan et al. 1984, Roth et al. 1986). Based on these capture data, age-0+ chum movement in the Middle Segment is estimated to occur from early May through mid-August and peak during late May and June, though peak timing was variable during the 1980s and correlated with Susitna River discharge levels (Table 5.1-3) (Roth et al. 1984, Dugan et al. 1984, Roth et al. 1986). The vast majority (> 95 percent) of juvenile chum movement was completed by mid-July during 1980s studies (Jennings 1985, Roth et al. 1986).

5.1.2.3.2. Lower River

Adult chum salmon spawning migration in the Lower River of the Susitna River during the 1980s began in early July, peaked during late July and early August and continued through the end of spawning in early October (Table 5.1-3) (Barrett et al. 1985, Thompson et al. 1986). Timing of entry into Lower River tributaries is likely delayed approximately one to two week from mainstem movement based on observations of adult chum behavior during radio telemetry studies in the 1980s (Table 5.1-3) (ADF&G 1981, ADF&G 1983a). Adult chum passage occurs in a variety of Lower River mainstem habitats to access tributary, tributary mouth, side slough, side channel and main channel spawning areas (Barrett et al. 1985, Thompson et al. 1986).

In the Lower River, adult chum spawned in tributaries, tributary mouths, side channel, side slough, and main channel habitats and spawn timing appeared to differ among habitats during 1980s studies (Barrett et al. 1985, Thompson et al. 1986). Spawning in tributary and tributary mouth habitats occurred from mid-July through September and peaked during late July and early August (Table 5.1-3) (Barrett et al. 1985). Among main channel, side channel and side slough habitats, chum spawning started in late August, peaked in early September and was completed in early October (Table 5.1-3). Tributaries and tributary mouths were primary spawning areas for chum in the Lower River during 1984; high utilization of Lower River side channels by juvenile chum during 1984 possibly indicated high spawning use, though this could not be verified during spawn surveys (Barrett et al. 1985, Suchanek et al. 1985). In 2009, similar proportions of tagged adult chum used mainstem (i.e., tributary mouth, side channel, side slough, and main channel) habitats for spawning relative to tributaries (Merizon et al. 2010). The presence of groundwater upwelling was noted at most main channel, side channel and side slough spawning sites (Barrett et al. 1985). The Yentna and Talkeetna Rivers were primary spawning tributaries for chum salmon in the Lower River, while Birch Creek Slough (RM 88.4) was an important side slough (Barrett et al. 1985).

The periods of chum egg incubation and fry emergence is considered to be similar to that of the Middle River, though utilization of spawning habitat is distinct between segments. Egg incubation began in early August in tributary and tributary mouth sites and in early September at main channel, side channel and side slough areas (Table 5.1-3). Specific information on egg development and intergravel incubation conditions are lacking for spawning sites in the Lower River (see Section 3.4.1), but the duration of incubation and timing of fry emergence is assumed to resemble Middle Segment timing. Timing of chum fry emergence in tributary and mainstem areas is estimated to begin in early March and extend through mid-May, based on capture timing at fyke net trap operated on Lower River side channels and the size of chum captured at outmigrant traps in late May (Table 5.1-3) (Bigler and Levesque 1985, Roth and Stratton 1985).

Prior to emigration, age 0+ juvenile chum salmon in the Lower River were widely distributed among habitat types during late spring and early summer, though the highest densities were captured in side channel and tributary mouth habitats (Suchanek et al. 1985). Juvenile chum distribution reflected that of adult chum spawning; low use of side slough habitats relative to tributary mouths by chum fry was an indication of the low number of side sloughs in the Lower River used for chum spawning (Suchanek et al. 1985). Side channel use by juvenile chum may have been an indication of adult chum spawning in such habitats, however, the prevalence of spawning in Lower River side channels could not be assessed due to insufficient sampling coverage (Suchanek et al. 1985). The period of age-0+ chum salmon emigration from the Lower River is similar to that described for the Middle Segment; age-0+ chum emigration from the Lower River is estimated to occur from early May through mid-August and peak during late May and June (Table 5.1-3) (Bigler and Levesque 1985, Roth and Stratton 1985, Roth et al. 1986). Emigration started prior to outmigrant trap seasonal operation, but fyke net trapping on Lower River side channels suggest an early or mid-May start of movement (Bigler and Levesque 1985). During downstream migration, juvenile chum primarily utilized side channel habitats and use of side channels mostly occurred prior to high turbidity levels, which are typically elevated from June to August (Suchanek et al. 1985). Age-0+ chum capture was highest in habitats of low turbidity (less than 50 NTU) and lowest in areas with turbidity values greater than 200 NTU (Suchanek at al. 1985). Use of tributary mouths by emigrant chum was low relative to side channel areas (Suchanek et al. 1985).

5.1.2.4. Coho Salmon

Coho salmon distribution in Susitna River Basin extends from Portage Creek (RM 148.9) downstream to Cook Inlet (Jennings 1985, Thompson et al. 1986). Average combined escapement for coho salmon in the Yentna Basin and Susitna Basin upstream of RM 80 during 1981-1984 was 61,400; annual escapement was not estimated for the Susitna Basin downstream of RM 80 during 1981-1983, excepting the Yentna Basin (Jennings 1985). During 1981-1984, average escapement at the Talkeetna Station (RM 103) fishwheel was 5,700, while averaged escapement estimates at the Sunshine Station (RM 80) and Yentna River Station (RM 28.0, TRM 4.0) were 43,900 and 19,600 fish, respectively, during the same time period (Jennings 1985). Total coho salmon escapement in the Susitna Basin was estimated to be 663,000 in 2002 (Willette et al. 2003).

Most juvenile coho salmon in the Susitna Basin reside in nursery habitats for 1 or 2 years prior to emigrating as age-1+ and age-2+ smolts to marine areas, based on scale analysis of returning adults (Barrett et al. 1984, Barrett et al. 1985). The proportions of coho that emigrate as age-1+ and age-2+ varied among years during the 1980s, though approximately equal proportions of adults exhibited each life history (Barrett et al. 1984, Barrett et al. 1985). A small portion (< 5 percent) of juvenile coho emigrated as age-3+ smolts (Barrett et al. 1984, Barrett et al. 1985).

5.1.2.4.1. Middle River

Upstream spawning migration of adult coho salmon into the Middle River of the Susitna River typically began in late July and continued through early October based on studies conducted in during the 1980s, with peak movement during early and mid-August (Table 5.1-4) (Jennings 1985, Thompson et al. 1986). Adult coho primarily used main channel areas for migration to access tributary spawning sites (Jennings 1985). Timing of upstream migration into spawning tributaries was delayed from main channel movement due to holding and milling behavior by adult coho in the lower extent of the Middle Segment or proximal to spawning tributaries (ADF&G 1981, ADF&G 1983a). Based on observed milling and/or delay between date of radio tagging and tributary entry, the timing of tributary entry and upstream migration is estimated to occur from early August through early October, with peak movement in late August and early September (Table 5.1-4).

Adult coho salmon spawning occurred almost entirely within clear water tributaries, though occasional use of one main channel habitat has been observed in the Middle Segment (ADF&G 1984, Barrett et al. 1985, Merizon et al. 2010). Radio tracking studies conducted in 2009 indicated that approximately 1 percent of all tagged coho salmon (n = 275) spawned in mainstem (i.e., main channel, side channel and/or off-channel) habitats in the Middle Segment (Merizon et al. 2010). No spawning was observed by coho salmon in surveyed slough or tributary mouth habitats during 1980s studies (Barrett et al. 1985, Jennings 1985). Coho spawning during 1980s studies occurred from mid-August through early October and peaked during mid- and late September (Table 5.1-4). The spawn period for coho salmon main channel spawning is assumed to be the same as tributary spawning due to sparse main channel spawning data. Primary spawning tributaries in the Middle Segment are Indian River (RM 138.6), Gash Creek (RM 111.6), Chase Creek (RM 106.4), and Whiskers Creek (RM 101.4) (Jennings 1985, Thompson et al. 1986).

The timing and duration of coho egg incubation and fry emergency is not well defined in the Susitna River due to sparse winter data. The incubation period is considered to coincide with the start of spawning in mid-August and continue through fry emergence (Table 5.1-4). Coho fry emergence began prior to the start of outmigrant trap seasonal operation in mid-May 1983 and 1985, though ice cover precluded trap operation prior to this point (Schmidt et al. 1983, Roth et al. 1986). Salmon egg incubation time depends on water temperature and the duration necessary for coho egg development from the point of fertilization to fry emergence can range from 228 days at water temperatures of 2° C to 139 days at 5° C (Murray and McPhail 1988, Quinn 2005). Based on these data and approximate timing of coho salmon emergence in similar areas, coho fry emergence in the Susitna River is estimated to begin in early March (Table 5.1-4) (Scott and Crossman 1973). The small size (35 mm) of age-0+ coho captured in June and July of 1981, 1982 and 1983 suggests that emergence may continue through May or beyond (Table 5.1-4) (Jennings 1985).

Age 0+ coho salmon utilized natal tributaries for nursery habitats immediately following emergence, but many emigrated from tributaries soon after emergence to mainstem habitats between early May through October (Table 5.1-4; Figure 5.1-1) (Jennings 1985). Within the Susitna River mainstem, age-0+ coho primarily used clear upland sloughs and side sloughs relative to turbid areas affected by main channel streamflow (Figure 5.1-1) (Schmidt and Bingham 1983, Dugan et al. 1984). Many age-0+ coho salmon moved downstream to the Lower

River during the open water period based on outmigrant trap catch data (Roth et al. 1984). Downstream movement of age-0+ coho to the Lower River appeared to begin in early May, prior to outmigrant trap seasonal operation each year, and continued through October, with peak movement from late June to late August (Table 5.1-4) (Jennings 1985, Roth et al. 1986). Observed movement by age-0+ coho observed in September and October may have been a reflection of dispersal to suitable winter nursery habitats, which were primarily located in side sloughs and upland sloughs in the Middle Segment (Jennings 1985, Roth et al. 1986). Catch at the Flathorn Station (RM 22) outmigrant trap during fall suggested that some age-0+ coho may have immigrated to marine or estuarine areas (Roth and Stratton 1985).

Ages-1+ and 2+ coho salmon primarily utilize clear water natal tributaries, side sloughs, and upland sloughs as nursery habitat in the Middle Segment (Dugan et al. 1984). Juvenile coho salmon that remain in the Susitna Basin as age-1+ parr, typically disperse from natal tributaries and mainstem nursery habitats within the Middle Segment to Lower River habitats, as few age-2+ coho were captured within the Middle Segment during the 1980s (Stratton 1986). Coho parr that remain within the Middle Segment during winter utilize tributaries, side sloughs and upland sloughs as nursery habitats (Delaney et al. 1981a, Stratton 1986). During winter and early spring, juvenile coho parr disperse from nursery habitats, though the timing and pattern of this movement is not well understood. Limited data collected during winter 1984-1985 suggested that juvenile coho parr exhibit similar movements as juvenile Chinook salmon, in that downstream migration from tributaries, and possibly mainstem nursery habitats, begins between early November and February (Table 5.1-4) (Stratton 1986). Downstream movement of age-1+ coho from the Middle Segment occurs throughout the open water season, with peak activity between late May and early July (Table 5.1-4) (Schmidt et al. 1983, Roth et al. 1984, Roth et al. 1986). Age 2+ emigration from the Middle Segment habitats begins in early winter and continues through June, with peak migration in late May and early June (Table 5.1-4) (Schmidt et al. 1983, Roth et al. 1984, Roth et al. 1986).

5.1.2.4.2. Lower River

Adult coho salmon migration timing in the main channel areas of the Lower River occurred from early July through early October during studies conducted in the 1980s, with peak passage in late July and early August (Table 5.1-4) (Roth and Stratton 1985, Roth et al. 1986). Migration into tributary spawning habitats is estimated to start in mid- or late July and peak during the month of August (Table 5.1-4) (Roth and Stratton 1985, Roth et al. 1986).

Spawn timing of adult coho salmon in Lower River tributaries is slightly earlier relative to Middle Segment streams, and occurs from early or mid-August through early October, with peak spawning in late August and early September (Table 5.1-4) (Roth et al. 1986). Coho salmon spawning in the Lower River occurred almost entirely in tributary habitats during the 1980s studies, though approximately 13 percent of adult coho tagged in 2009 studies utilized Lower River mainstem areas (i.e., main channel, side channel and/or off-channel) for spawning (Roth and Stratton 1985, Roth et al. 1986, Merizon et al. 2010). No spawning was observed by coho salmon in surveyed slough or tributary mouth habitats in 1984 (Barrett et al. 1985). Primary coho spawning tributaries for coho salmon in the Lower River based on 1980s and 2009 data are the Chulitna, Deshka and Yentna rivers (Thompson et al. 1986, Merizon et al. 2010).

The timing and duration of coho salmon egg incubation and fry emergence is not well defined in the Susitna Basin due to limited information. The start of egg incubation begins coincident with the start of spawning in early August and is estimated to continue through emergence in May (Table 5.1-4) (see Section 3.5.1). Juvenile coho fry emergence is believed to begin in March and likely continues through May or later based on the small size of coho captured during June and July during the 1980s (Table 5.1-4) (Jennings 1985, Roth and Stratton 1985).

Following emergence, age 0+ coho salmon utilized natal tributaries for nursery habitat and a portion of individuals emigrated from tributaries to mainstem habitats. Age-0+ coho dispersed to mainstem habitats throughout the open water season, but peak movement occurred during late June, July and early August (Table 5.1-4) (Suchanek et al. 1985). Within the Lower River mainstem, age-0+ coho primarily used tributary mouths as nursery habitats, with little comparative use of side channel or side slough habitats (Suchanek et al. 1985). Many age-0+ coho salmon from the Middle Segment disperse downstream to suitable habitats in the Lower River during the open water period and a portion of age-0+ coho may emigrate to marine or estuarine areas during September and October based on capture at the Flathorn Station (RM 22) outmigrant trap (Roth and Stratton 1985).

Juvenile coho salmon parr (age-1+ and age-2+) primarily utilized natal tributaries and tributary mouths, side sloughs, and upland sloughs as nursery habitat during the freshwater rearing period (Dugan et al. 1984). Age-1+ coho in the Lower River redistribute to suitable habitats throughout the open water season, while a portion immigrate as smolts to estuarine areas (Roth et al. 1986). Age-2 coho were believed to rear primarily in Lower River habitats during winter based on low capture rates of age-2 fish in the Middle Segment during winter (Stratton 1986). During winter, coho parr in the Lower River used tributary mouths and side channels for nursery habitat (Delaney et al. 1981a, Stratton 1986). Age-1+ and age-2+ coho are believed to begin emigration from nursery habitats in early winter, based on limited data collected during winter in the Middle Segment, though the peak of mainstem movement likely occurs during the open water season (Roth et al. 1986, Stratton 1986). Age-1+ coho movement at the Flathorn Station (RM 22) occurred through October with peak emigration during August (Table 5.1-4) (Roth et al. 1986). Age-2+ coho emigration from the Lower River is estimated to occur between early January through mid-July and peak during June (Table 5.1-4) (Roth et al. 1986).

5.1.2.5. Pink Salmon

Pink salmon exhibit a two-year life cycle such that each spawning population is genetically distinct. In the Susitna Basin, the even-year pink salmon population is substantially larger than the population that spawns during odd years (Jennings 1985). Average combined escapement for the Yentna Basin and Susitna Basin upstream of RM 80 during 1981 to 1984 was 1,138,400 for even-year pink salmon and 93,400 for odd-year pink salmon; annual escapement was not estimated for the Susitna River downstream of RM 80 during 1981-1983, excepting the Yentna Basin (Jennings 1985). In 1984, estimated pink salmon escapement in the Middle Segment was 177,881 at Talkeetna Station (RM 103) and 116,858 at Curry Station (RM 120) which represent approximately 5 percent and 3 percent of the estimated total Susitna Basin escapement at Flathorn Station (RM 22), respectively (Jennings 1985). Escapement estimates at the Talkeetna Station (RM 103) were considered to overestimate pink salmon abundance because many adult pink tagged at that point returned downstream to spawn (Jennings 1985). Pink escapement estimated at Sunshine Station (RM 80) in 1984 represented 28 percent of the total Susitna Basin escapement, which indicates that most adult pink salmon utilize Lower River mainstem and tributary habitats.

5.1.2.5.1. Middle River

Adult pink salmon migration in the Middle River of the Susitna River during the 1980s occurred from mid-July through mid-September and typically peaked during late July and early August (Table 5.1-5) (Jennings 1985, Barrett et al. 1985, Thompson et al. 1986). Although milling and holding behavior was observed by pink salmon in the Middle Segment near Talkeetna Station (RM 103), it is not clear how long adult pink hold in main channel areas prior to migrating up spawning tributaries (Barrett et al. 1985). Adult pink use main channel areas for passage to primary spawning areas in tributaries and tributary mouths and secondary spawn sites in side slough habitats (Jennings 1985).

Adult pink salmon spawning in the Middle River begins in late July and early August in clear water tributaries and peaks during the first two weeks of August (Table 5.1-5) (Jennings 1985, Thompson et al. 1986). A small portion (5 percent) of observed spawning occurred in side slough areas; one main channel pink salmon spawning location was observed in 1984 (Jennings 1985, Barrett et al. 1985). The timing of spawning in side slough habitats is similar to that of tributaries, though spawning peaks later in August and can extend into early September (Table 5.1-5) (Jennings 1985). Indian River (RM 138.6), Portage Creek (RM 148.9), and 4th of July Creek (RM 131.1) were the principal spawning tributaries that supported a large proportion of the adult pink population in the Middle Segment during the 1980s (Jennings 1985). Among side sloughs in the Middle Segment, most pink salmon spawning occurred in Slough 11 and Slough 20 (Jennings 1985).

The timing of pink salmon egg incubation and fry emergence on the Susitna River is not well defined due to limited observations of this life stage, though the start of incubation is considered to be coincident with spawn timing. In controlled environments, the duration of pink egg incubation from the point of fertilization to hatch is approximately 173 days (Murray and McPhail 1988). In the Susitna River, emergent pink salmon fry were observed in spawning areas in Indian River (RM 138.6) and Slough 11 (RM 135.3) during late March and early April (Delaney et al. 1981). Based on these observations of pink fry emergence timing and general life history requirements, emergence of pink salmon fry is estimated to occur during March and April (Table 5.1-5) (Delaney et al. 1981a, Jennings 1985). Differences in egg incubation and fry emergence timing may occur, however, between side slough spawning areas influenced by groundwater upwelling and tributary spawning habitats fed primarily by surface streamflows (Wangaard and Burger 1983, Vining et al. 1985).

Juvenile pink salmon in the Susitna Basin immigrate to estuarine and marine areas soon after emergence as age-0+ fry and consequently exhibit minimal use of Susitna River nursery habitats during the short freshwater residence (Jennings 1985). Migration of pink fry appeared to begin prior to seasonal operation of mainstem outmigrant traps in the 1980s, and researchers during the 1980s considered it likely that many pink salmon fry in the Middle Segment migrated downstream of the trap prior to the open water season and the start of trap operation (Jennings 1985, Roth et al. 1986, Roth and Stratton 1985). At a fyke net trap operated from April through May 1985 in a Lower River side channel, pink salmon fry were initially captured in mid-May (Bigler and Levesque 1985). Downstream migration of pink fry is estimated to begin in April though sampling of downstream migrants in the Middle Segment was not done prior to May during the 1980s due to instream ice conditions (Jennings 1985, Roth and Stratton 1985). Outmigrant trapping during the 1980s at the Talkeetna Station (RM 103) indicated peak movement in the Middle River during late May and June (Table 5.1-5) (Jennings 1985, Roth et al. 1986). Although migration timing varied during the 1980s studies, few juvenile pink were captured after July (Jennings 1985). Habitat use during downstream is not well known in the Susitna Basin and it is not clear that any feeding by age-0+ pink occurs while in the Susitna River (Jennings 1985). In the Susitna River and other river systems, pink salmon utilize thalweg portions of the river channel with faster current to migrate downstream and the rate of feeding during freshwater residence often depends upon the length of migration (McDonald 1960, Roth and Stratton 1985). In short coastal streams, pink salmon fry may not feed during freshwater residence, while in larger rivers, where migration may last multiple days, pink fry may feed exogenously (Heard 1991).

5.1.2.5.2. Lower River

Adult pink salmon migration in the Lower River of the Susitna River occurs from early July to early September, though most adult pink movement was from mid-July to mid-August (Table 5.1-5) (Jennings 1985, Roth and Stratton 1985, Roth et al. 1986). Milling and holding behavior among adult pink salmon upstream of the Chulitna River confluence (RM 98.6) was identified during the 1980s, as fish tagged at the Talkeetna Station were observed spawning in Lower River tributaries (Barrett et al. 1985). Despite these observations, it is not evident that there was a substantial migratory delay for pink salmon adults between main channel and tributary areas (Barrett et al. 1985, Thompson et al. 1986).

Adult pink salmon in the Lower River spawned in tributary and tributary mouth habitats during 1984 and 1985; no pink salmon spawning was observed in main channel or side slough habitats in 1984 (Barrett et al. 1985, Thompson et al. 1986). Based on 1984 and 1985 surveys of Lower River tributaries, pink spawn timing occurred from mid-July through early September and peaked during early and mid-August (Table 5.1-5) (Barrett et al. 1985, Thompson et al. 1986). The Talkeetna River (RM 97.2), Birch Creek (RM 88.4) and Willow Creek (RM 49.1) were primary spawning tributaries for pink salmon during the 1980s (Barrett et al. 1985, Thompson et al. 1986).

The periodicity of pink salmon egg incubation and fry emergence in the Lower River of the Susitna River is similar to that described for the Middle Segment (see Section 3.6.1). Pink salmon egg incubation occurs from late July through the estimated end of emergence in mid-May (Table 5.1-5) (Jennings 1985). Emergence timing pink salmon fry likely occurs during March, April and early May in the Susitna River, based on limited observations of emergent fry during late winter (Delaney et al. 1981a).

Pink fry emigration in the Susitna River occurs soon after emergence and is similar to that described for the Middle Segment. The approximate start of pink salmon fry migration is likely during April based on observed timing of fry emergence in March and early April (Table 5.1-5) (Delaney et al. 1981a). Though it is possible much of the pink salmon fry migration occurred prior to the start of mainstem trap operation, capture records indicate that age-0+ pink movement peaked during early or late June at the Flathorn Station trap (RM 22) in 1984 and 1985 and was completed by mid- or late July (Roth and Stratton 1985, Roth et al. 1986). A difference in pink salmon fry migration timing of approximately two weeks between 1984 and 1985 was attributed to ice breakup, regional winter temperatures and adult spawn timing (Roth and Stratton 1985).

5.1.2.6. Rainbow Trout

Rainbow trout in the Susitna River are distributed throughout tributary and mainstem areas downstream of Devils Canyon (RM 150) (Schmidt et al. 1983). Comparison of 1982 capture data indicated that adult rainbow trout are more abundant in the Middle Segment of the Susitna River relative to the Lower River (Schmidt et al. 1983). Estimated abundance of rainbow trout greater than 150 mm in length during the early 1980s in the Middle Segment was approximately 4,000 fish based on a tag-recapture study conducted during 1981–1983 (Sundet and Wenger 1984). The age range of rainbow trout captured during the 1980s was up to 9 years old and all captured fish that were known to spawn were 5 years old or older (Sundet and Wenger 1984).

Adult rainbow trout in the Susitna Basin utilize clear, non-glacial tributary habitats to spawn (Schmidt et al. 1983). Adult spawning migrations from main channel holding areas to spawning tributaries began in March prior to ice breakup and continued through early June (Table 5.1-6) (Schmidt et al. 1983, Suchanek et al. 1984b, Sundet 1986). Most rainbow trout spawning occurred during late May and early June (Table 5.1-6) (Schmidt et al. 1983, Suchanek et al. 1984b, Sundet and Pechek 1985). Migration and spawn timing for rainbow trout appears to be generally similar between Middle and Lower Susitna Segments, though it was noted that timing of upstream migration into tributary habitats could occur as much as 10 days earlier in the Lower River (Sundet and Pechek 1985). Primary spawning tributaries in the 1980s were 4th of July Creek (RM 131.1) and Portage Creek (RM 148.9) in the Middle Segment and the Talkeetna River (RM 97.2), Montana Creek (RM 77.0) and Kashwitna River (RM 61.0) in the Lower River (Sundet and Pechek 1985).

After spawning, adults primarily hold and feed during the open water period in tributary and tributary mouth habitats, though some utilization of clear side slough habitat was observed during the 1980s (Table 5.1-6) (Schmidt et al. 1983). Holding and feeding areas during the open water period were closely associated with salmon spawning areas (Chinook, chum and pink salmon) (Sundet and Pechek 1985). Primary holding and feeding locations for rainbow trout were 4th of July Creek (RM 131.1) and Indian River (RM 138.6) tributary mouths and Slough 8A (RM 125.1) and Whiskers Creek Slough (RM 101.2) (Schmidt et al. 1983).

During late summer in 1983 and 1984, adult rainbow trout migrated from tributary habitats during late August and September, such that many individuals had moved to tributary mouths by mid-September and few remained in tributaries by early October (Suchanek et al. 1984b, Sundet and Wenger 1984, Sundet and Pechek 1985). Migration timing to winter holding areas in main channel and side channel areas occurred from mid-September through early February, with peak movement in October and late December (Schmidt and Estes 1983, Sundet 1986). In the Middle Segment, rainbow trout utilize main channel areas during winter, whereas tagged fish in the Lower River were observed to typically use side channel habitat during the 1980s (Sundet and Pechek 1985). By December, most adult rainbow trout were in main channel areas apart from spawning tributaries (Sundet and Wenger 1984). Movements to winter holding habitats were commonly in a downstream direction from spawning or feeding tributaries (Sundet and Pechek 1985). Many adults hold during winter close to spawning tributaries (0.1 – 4 miles), though some exhibit long-distance migrations that typically range from 10-20 miles downstream but can extend over 76 miles (Schmidt and Estes 1983, Sundet 1986). Specific habitat features of winter holding areas during the 1980s were difficult to measure, though upwelling and ice cover appeared to be common features (Schmidt et al. 1983, Sundet and Pechek 1985). Tagged rainbow trout distribution in winter was patchy and groups of fish were often observed within 100 feet of an open water lead during winter, suggesting that ice cover was important in addition to the presence of upwelling (Sundet and Pechek 1985, Sundet 1986). No radio tagged fish were observed in areas with anchor ice during radio telemetry studies in the 1980s (Sundet 1986).

There is minimal information relating to rainbow trout incubation and emergence timing in the Susitna River from studies conducted in the 1980s; however, incubation is assumed to begin in May based on observed spawn timing (Table 5.1-6) (Schmidt et al. 1983, Suchanek et al. 1984b, Sundet and Pechek 1985). The start of rainbow trout fry emergence in tributary habitats is estimated to occur in early July and continue through mid-August based on generalized incubation times for rainbow trout in cold water temperature regimes (5-8° C) (Crisp 1988, Quinn 2005).

Juvenile rainbow trout primarily reside in natal tributary habitats throughout the year, though occasional use of tributary mouths and clear sloughs has been documented (Table 5.1-6) (Schmidt et al. 1983). Capture of juvenile rainbow trout in main channel areas was very low, though use of tributary mouths and clear sloughs was observed (Sundet and Pechek 1985). Lake systems associated with the 4th of July and Portage creeks were believed to possibly supplement rainbow trout production in each basin based on analysis of juvenile scale patterns, though no direct evidence of juvenile rearing in these lakes was recorded (Sundet and Pechek 1985). Winter rearing for juvenile rainbow trout occurred primarily in tributaries with occasional use of clear side slough habitats (Schmidt et al. 1983).

5.1.2.7. Arctic Grayling

Arctic grayling occur throughout the Susitna River Basin in mainstem and tributary habitats from headwater areas in the Upper River to the downstream extent of the Lower River (Delaney et al. 1981b, Buckwalter 2011). Estimated grayling abundance was higher in the Upper River of the Susitna River relative to the Middle and Lower segments based on 1980s mark-recapture data, though comparable abundance data among segments are limited (Delaney et al. 1981b, Delaney et al. 1981c, Schmidt et al. 1983). Estimated abundance of Arctic grayling greater than 200 mm fork length in the Upper River was 10, 279 (95% confidence interval: 9,194 – 11,654) based on 1981 mark-recapture data, and was 6,783 (95% confidence interval: 4,070 – 15,152) in the Middle Segment based on 1981-1984 data (Delaney et al. 1981b, Sundet and Pechek 1985). Grayling of 200 mm fork length or greater are typically 3 years of age or older, while the maximum observed age of grayling in the Susitna Basin during the 1980s was 15 years (Delaney et al. 1981b, Schmidt et al. 1983). Sexual maturation of Arctic grayling in Alaska occurs between ages 2 – 7; male and female grayling spawners during 1984 in the Susitna Basin were aged 5 to 9 years (Sautner and Stratton 1984).

Adult grayling typically spawn in the upper extents of clear, non-glacial tributaries soon after ice breakup, though use of areas near tributary mouths for spawning was recorded during 1980s studies (Sundet and Wenger 1984). The spring spawning migration occurs concurrently with increasing tributary water temperatures during April and May and movement of some large adults into ice-free tributaries occurred prior to or during ice breakup (Table 5.1-7) (Sundet and Wenger 1984, Sundet and Pechek 1985). Spawning typically occurs in May and early June, though timing can vary among tributary habitats (Table 5.1-7) (Sundet and Wenger 1984, Sundet and Pechek 1985). Spawning occurred in early May near the mouth of Whiskers Creek, in late May near the Portage Creek tributary mouth, while large numbers of adult grayling in the upper extent of Portage Creek in early to mid-June 1984 may suggest spawning occurred in June in headwater habitats (Sundet and Pechek 1985). Adult grayling movement and spawn timing differed up to 10 days among Middle Segment tributaries and up to 20 days between tributaries in the Middle and Lower segments due to variable tributary water temperature during May and June (Sundet and Wenger 1984, Sundet and Pechek 1985).

During the open water season, many adult grayling either remain within spawning tributaries or move to nearby tributaries to feed during summer (Table 5.1-7) (Delaney et al. 1981b, Delaney et al. 1981c, Schmidt et al. 1983, Sundet and Pechek 1985). Adult grayling also use tributary mouth, side slough and main channel habitats during the open water season, though fish captured in these areas were typically of smaller size than adult grayling in tributaries which may suggest that small individuals are displaced from tributaries by larger, competitively superior fish (Schmidt et al. 1983, Sundet and Pechek 1985).

Adult grayling disperse from tributaries during early August through early October to winter holding habitats (Table 5.1-7) (Sundet and Wenger 1984, Sundet and Pechek 1985). Although many grayling use areas close to spawning tributaries during winter, some migrate long distances (10-35 miles) to winter holding habitat (Sundet and Pechek 1985, Sundet 1986). Winter habitat use of Arctic grayling in the mainstem Susitna River is not well understood, but limited radio telemetry data suggests that grayling and other resident fish species may be patchily distributed in main channel areas with overhead cover (depth and/or ice cover), very little frazil and/or anchor ice, and low water velocity (Sundet 1986). Some grayling select lake habitats associated with some tributary stream networks or deep pools located in larger tributaries in the Middle and Lower segments (Sundet and Wenger 1984, Sautner and Stratton 1984).

Incubation time for Arctic grayling eggs is generally 11 to 21 days from fertilization to hatching, depending on water temperature conditions, and young grayling actively feed within eight days of hatching (Morrow 1980). Based on this general timing, the grayling egg incubation is estimated to occur during May and June, and fry emergence likely during late May and June (Table 5.1-7).

Juvenile Arctic grayling typically reside within their natal tributaries for at least one year, though some age-0+ grayling were observed to move to tributary mouth habitats during late summer (Schmidt et al. 1983). Ages-1+ and 2+ grayling were observed to use tributary mouth, side slough and main channel habitats during summer 1982, and many were likely displaced from tributary nursery habitats by larger, competitively superior adult grayling in early summer (Schmidt et al. 1983). In general, juvenile grayling were recorded in greater abundance at tributary mouths and mixing zones at side slough mouths relative to main channel areas (Suchanek et al. 1984b). Tributaries in the Susitna Basin that support substantial Arctic grayling populations include Oshetna River (RM 233.4), Kosina Creek (RM 206.8), Portage Creek (RM 148.9), Indian River (RM 138.6), Montana Creek (RM 77.0), Kashwitna River (RM 61.0) and Deshka River (RM 40.6) (Delaney et al. 1981b, 1981c, Sundet and Pechek 1985).

5.1.2.8. Burbot

Burbot are distributed throughout the Susitna Basin and have been documented in mainstem habitats upstream of the Upper River to the downstream extent of the Lower River (Delaney et al. 1981b, Buckwalter 2011). During 1980s studies, burbot were most abundant in the Lower River of the Susitna River relative to the Middle and Upper River, presumably because of greater spawning and nursery habitat availability (Schmidt et al. 1983, Sundet and Pechek 1985). Burbot typically become sexually mature at age three or four, and were found as old as 15 years in the Susitna River during 1980s studies (Scott and Crossman 1973, Schmidt et al. 1983, Sundet and Pechek 1985).

Adult burbot exhibit strong negative phototropism and are strongly associated with turbid water areas (Morrow 1980, Schmidt et al. 1983, Sundet and Pechek 1985). During the open water season, burbot were typically captured in low velocity backwater or eddy habitats located in the Susitna River main channel and at the mouths of select tributaries and side sloughs (Delaney et al. 1981b, Schmidt et al. 1983, Sundet and Pechek 1985). Although burbot were also located in shallow, high velocity habitats, the presence of groundwater upwelling appeared to have been a common feature of habitats used by adult burbot during the 1980s (Sundet and Pechek 1985). A small number of burbot were recorded in lake habitats in the Upper River of the Susitna River during the 1980s (Sautner and Stratton 1984). During summer, adult burbot movement appears to be infrequent and over short distances, based on radio telemetry and Floy tag-recapture studies during the 1980s (Sundet and Wenger 1984).

In late summer, adult burbot begin migration to spawning locations in tributaries, tributary mouths and main channel habitats based on 1980s radio telemetry data (Schmidt and Estes 1983, Sundet 1986). Spawning migrations begin in mid-August to Lower River spawning tributaries and in September to main channel areas and movement continues through winter until spawning (Table 5.1-8) (Schmidt and Estes 1983, Sundet 1986). Burbot spawning migrations generally range from 5 – 40 miles in length, though one tagged individual during the 1980s may have migrated over 100 miles to a Lower River spawn site (Schmidt and Estes 1983). Spawning occurs from mid-January to early February in tributaries, tributary mouths and main channel habitats (Table 5.1-8) (Schmidt and Estes 1983, Sundet and Pechek 1985). Substantial spawning runs occurred in Alexander Creek (RM 10.1) and the Deshka River (RM 40.6) (Sundet and Wenger 1984, Sundet and Pechek 1985). Identification of Susitna River main channel spawn sites was difficult during the 1980s due to thick ice cover during the January and February spawn period, though observations of radio tagged burbot winter locations suggest that spawning may occur in low velocity habitats with groundwater presence and ice cover (Schmidt and Estes 1983, Sundet 1986). Burbot are typically group spawners, and multiple observations of burbot at the location of radio tagged burbot during late winter suggest that adults congregate during winter (Schmidt and Estes 1983). The prevalence of anchor ice in the Middle Segment may limit burbot spawning success and overall abundance in this portion of the Susitna River (Sundet and Pechek 1985). Post-spawning migrations occur from February through March and are typically short (0.5 – 7 miles) (Table 5.1-8) (Schmidt and Estes 1983).

Incubation and development of burbot eggs is not well documented in the Susitna River due to difficulty of sampling ice covered spawning sites during winter (Sundet and Pechek 1985). Burbot eggs may be initially neutrally buoyant following spawning, but gradually sink and become lodged within the substrate during development (McPhail and Paragamian 2000). The necessary time for burbot egg incubation may require 30 days at incubation temperatures of 6°C, 71 days at water temperatures below 2°C, and approximately 100 days or more at near 0°C temperatures (Bjorn 1940, McCrimmon 1959, McPhail and Paragamian 2000). Based on these data, burbot egg incubation is estimated to occur from mid-January through April (Table 5.1-8). Upon hatching, burbot fry are small (3-4 mm, total length), limnetic and drift passively until swimming ability and mobility improves (McPhail and Paragamian 2000). As such, emergence timing is not identified for juvenile burbot. Small age-0+ fry (15 mm, total length) were observed in mid-June in the Middle and Lower segments during 1980s studies (Sundet and Pechek 1985).

Juvenile burbot were infrequently captured in association with 1980s sampling efforts (Sundet and Pechek 1985). In the Lower River, juvenile burbot were captured in main channel and tributary habitats, and it was believed that juveniles in tributaries utilized habitats proximal to natal areas (Table 5.1-8) (Schmidt et al. 1983). Most juvenile burbot capture occurred at main channel outmigrant traps during the 1980s, though positioning of outmigrant traps near the surface of the water column did not effectively sample benthic movements of juvenile burbot (Schmidt et al. 1983).

5.1.2.9. Round Whitefish

Round whitefish are distributed among mainstem and tributary habitats in the Upper, Middle and Lower segments of the Susitna Basin, and have been recorded in mainstem areas upstream of the Upper River to RM 19 (Schmidt et al. 1983, Buckwalter 2011). Based on 1980s studies downstream of Devils Canyon (RM 150), round whitefish were more abundant in the Middle Segment compared to the Lower River, and relative use was particularly high between RM 132 – RM 151 (Sundet and Pechek 1985). The estimated population size of round whitefish in the Middle Segment in 1983 was 7,264 (95% confidence interval: 4,829 – 13,806) (Sundet and Pechek 1985). Within the Lower River, most adult round whitefish were captured between RM 60.1 and RM 98.5 (Sundet and Pechek 1985). Spawning round whitefish during 1980s studies were age 5 or older, and the maximum age observed was 12 years (Sundet and Wenger 1984, Sundet and Pechek 1985).

Adult round whitefish in the Susitna River Basin predominantly used tributary, tributary mouth and sloughs for feeding and holding habitat during the open water season during the 1980s (Sautner and Stratton 1983, Schmidt et al. 1983, Sundet and Wenger 1984, Sundet and Pechek 1985). Tributary sampling indicated that many large adult round whitefish moved upstream into large clear tributaries in the Middle Segment in June and returned downstream to mainstem areas in August and September (Table 5.1-9) (Schmidt et al. 1983, Sundet and Wenger 1984). Low capture rates of small adults in tributaries during summer may suggest that smaller individuals were competitively displaced by large adults (Schmidt et al. 1983).

During tag-recapture studies in the 1980s, most recaptured adult round whitefish exhibited little movement, though approximately 20% of recovered fish in 1983 and 1984 had moved an average of 18.5 and 16 miles in the respective years (Sundet and Wenger 1984, Sundet and Pechek 1985). Maximum observed movement of tagged round whitefish was 55.7 miles based on 1983 recapture data and 69.5 miles based on 1984 tag recaptures (Sundet and Wenger 1984, Sundet and Pechek 1985). Movement was typically downstream during summer and upstream in fall (Sundet and Wenger 1984).

In late summer, adult round whitefish migrate upstream and downstream from summer feeding habitats to spawning areas located in main channel and tributary mouth habitats, though large schools observed at the mouths of Portage Creek (RM 148.8) and Indian River (RM 138.6) may indicate tributary spawning (Schmidt et al. 1983, Sundet and Wenger 1984). Based on fishwheel capture in 1982 and 1983, upstream spawning migration in the main channel of the Middle Segment occurred during late August and September (Table 5.1-9) (Schmidt et al. 1983, Sundet and Wenger 1984). Round whitefish spawning in the Susitna Basin was believed to occur during October (Table 5.1-9) (Sundet and Wenger 1984, Sundet and Pechek 1985). Spawning sites discovered in 1983 consisted of four main channel sites (RM 102.0, RM 114.0, RM 142.0 and RM 147.0) and three tributary mouth sites [Lane Creek (RM 113.6), Indian River (RM 138.6) and Portage Creek (148.8)] (Sundet and Wenger 1984). Most sexually ripe adults were captured in pairs or small groups during the 1980s and capture locations were characterized as spawning sites if captured females discharged eggs via palpation (Sundet and Wenger 1984). After spawning, it is believed that adult round whitefish utilized mainstem areas to hold for winter, but little is known regarding winter behavior and habitat use (Sundet and Pechek 1985).

The duration of round whitefish egg incubation and timing of fry emergence in the Susitna River is not well defined by 1980s studies. Development and incubation time for round whitefish eggs has been observed to take approximately 140 days at 2.2° C, though duration can vary with water temperature and other variables (Normandeau 1969, Morrow 1980). Based on this basic incubation period and the timing of earliest age-0+ round whitefish capture in late May and June, incubation is estimated to occur from October through June and emergence likely occurs in May and June (Table 5.1-9) (Schmidt et al. 1983).

Age-0+ juvenile round whitefish are believed to utilize nursery habitats proximal to where hatching and emergence occurs, though a portion of the Middle Segment population migrated downstream in each year of 1982 and 1983 (Schmidt et al. 1983, Sundet and Wenger 1984). Downstream movement of juvenile round whitefish at the Talkeetna Station (RM 103) outmigrant trap occurred throughout the trap operational period in each year, from late May through September, and peaked in late June and July (Table 5.1-9) (Schmidt et al. 1983, Sundet and Wenger 1984). Following downstream movement, primary habitats used by juvenile round whitefish in the Middle and Lower segments were side slough, upland slough and turbid main channel and side channel areas (Schmidt et al. 1983, Sundet and Wenger 1984). In the Upper River, juvenile round whitefish were captured at tributary mouths and slough habitats (Sautner and Stratton 1983). Juvenile round whitefish may utilize turbid mainstem areas for cover (Suchanek et al. 1984b). Little is known regarding juvenile round whitefish habitat use during the winter, but based on spring capture locations during the 1980s, it was presumed that winter nursery habitats were proximal to summer habitats (Sundet and Pechek 1985).

5.1.2.10. Humpback Whitefish

Humpback whitefish are distributed throughout the Susitna Basin and have been documented from mainstem habitats upstream of the Upper River to the downstream extent of the Lower River (Schmidt et al. 1983, Buckwalter 2011). Sampling during the 1980s indicated that abundance of humpback whitefish was greater in the Lower River of the Susitna River relative to the Middle Segment (Schmidt et al. 1983, Sundet and Wenger 1984). Abundance estimates of humpback whitefish were not possible during the 1980s studies due to an insufficient number of fish captured for mark-recapture estimation. Humpback whitefish typically mature at age 4 to 6 and individuals up to 12 years of age were captured in the Susitna River during the 1980s (Morrow 1980; Schmidt et al. 1983, Sundet and Wenger 1984).

Humpback whitefish populations in Alaska are typically anadromous, though the marine distribution and the distance individuals disperse from natal rivers is not well known (Morrow 1980). In the Susitna River, a portion of the population may utilize estuarine or marine habitats for a portion of their lifespan, while most humpback whitefish appear to exhibit a riverine life history pattern based on analysis of adult scale patterns (Sundet and Wenger 1984, Sundet and Pechek 1985). High growth rates during the first two years of life, which may indicate estuarine feeding, were apparent in approximately 20% of adult humpback whitefish captured at Lower River fishwheel traps (Flathorn Station [RM 22], Yentna River Station [Yentna RM 4]) and about 5% of adults captured at the Talkeetna Station (RM 103) fishwheel in the Middle Segment (Sundet and Pechek 1985).

Adult humpback whitefish exhibited higher relative use of tributary and slough habitats for holding and feeding in summer relative to mainstem areas during studies conducted in the Middle and Lower segments during 1981-1983 (Sundet and Wenger 1984). Just one adult humpback whitefish was captured in the Upper River during 1980s studies at a tributary mouth (Sautner and Stratton 1983). In general, adult humpback whitefish exhibit little movement during summer except for spawn migrations, which in the Susitna River is an upstream migration that occurs from July through September, with peak movement during August (Table 5.1-10) (Morrow 1980, Schmidt et al. 1983, Sundet and Wenger 1984). Spawning is believed to occur during October in tributaries of the Susitna River, based on high capture of adults in tributaries during fall, but is not well documented (Table 5.1-10) (Sundet and Pechek 1985). Adult humpback whitefish captured in Deadman Lake in the Upper River were presumed to spawn within the lake (Sautner and Stratton 1984). Alaskan humpback whitefish populations utilize estuarine habitat during winter, though in the Susitna River adult humpback whitefish is largely unknown due to low winter capture rates during winter sampling (Morrow 1980, Schmidt et al. 1983). Humpback whitefish in the Middle Segment were believed to remain in that segment during winter (Sundet and Pechek 1985).

Incubation and development timing of humpback whitefish eggs is not well known, though it is presumed hatching occurs in late winter and spring (Morrow 1980). The period of humpback whitefish egg incubation is estimated to occur from the start of spawning in early October through June (Table 5.1-10). Emergence of humpback whitefish fry started prior to June during 1980s studies based on outmigrant trap capture records (Schmidt et al. 1983, Sundet and Wenger 1984). Humpback whitefish are estimated to emerge from early May through late June (Table 5.1-10).

Juvenile humpback whitefish rearing was believed to primarily occur in the Lower River in the Susitna River during the 1980s, though specific nursery habitat use was not well defined due to low and infrequent capture (Schmidt et al. 1983, Sundet and Wenger 1984). The few juvenile humpback whitefish were captured in tributary, main channel and side channel habitats (Schmidt et al. 1983). Most capture of juvenile humpback whitefish during the 1980s studies occurred at outmigrant traps. Downstream migration of juvenile humpback whitefish was observed to occur from June through October at the Talkeetna Station (RM 103) outmigrant trap, with peak movement during July and early August (Table 5.1-10) (Schmidt et al. 1983, Sundet and Wenger 1984). Approximately 20% of juvenile humpback whitefish in the Lower River and 5% in the Middle Segment were believed to use estuarine areas during the first two years of life (Sundet and Pechek 1985).

5.1.2.11. Longnose Sucker

Longnose suckers are distributed throughout mainstem habitats in Susitna Basin and have been documented from headwater tributaries upstream of the Upper River to the downstream extent of the Lower River (Delaney et al. 1981b, Buckwalter 2011). Longnose suckers were most abundant downstream of Devils Canyon (RM 150), particularly in the Lower River between RM 60 and RM 35 (Delaney et al. 1981b, Schmidt et al. 1983, Sundet and Pechek 1985). Estimated population size of longnose sucker in the Middle Segment of the Susitna River was 7,613 (95% confidence interval: 4,003 – 20,439) based on 1981-1984 mark-recapture data.

Adult longnose suckers in the Susitna Basin spawn in mainstem and tributary mouth habitats during May and early June, which corresponds with the approximate timing of other Alaskan sucker populations (Table 5.1-11) (Morrow 1980, Schmidt et al. 1983). An additional spawning period may occur in the late summer during October and/or November based on observed concentrations of adults with well-developed eggs and nuptial tubercles during September in suitable spawning habitats, though spawning during this time has not been verified (Schmidt et al. 1983, Sundet and Wenger 1984). Longnose sucker spawning typically occurs at water temperatures above 5°C (Morrow 1980).

Following spring spawning, a portion of longnose suckers in the Susitna River appeared to move upstream to summer feeding habitats and return downstream to winter holding areas, based on 1980s mark-recapture data (Sundet and Wenger 1984, Sundet and Pechek 1985). Spring upstream movement of adult suckers primarily occurred during June and July, while the timing of downstream fall movement was less defined (Table 5.1-11) (Schmidt et al. 1983, Sundet and Wenger 1984). Many suckers tagged during 1980s studies moved little during summer, which reflects summer behavior of other sucker populations (Morrow 1980, Sundet and Wenger 1984, Sundet and Pechek 1985). Adult suckers were most commonly captured at tributary and slough sites, though use of mainstem habitat was greater in the Middle Segment relative to that of the Lower River (Schmidt et al. 1983, Sundet and Wenger 1984, Sundet and Pechek 1985). High capture rates of adults in tributaries and sloughs in August and September may indicate opportunistic feeding on salmon eggs during this time (Sundet and Wenger 1984). In the Upper River, only sub-adult suckers were captured in mainstem habitats, while larger adults were captured at the mouths of suspected spawning tributaries (Sautner and Stratton 1983). Habitat utilization by adult longnose suckers during winter in the Susitna River is not well known, though winter holding is believed to occur in the mainstem and the only winter capture of a longnose sucker occurred in side channel habitat (Schmidt and Bingham 1983, Schmidt et al. 1983).

Incubation and development of longnose sucker eggs in the Susitna River has not been documented, however, general incubation time required from fertilization to hatching is one to two weeks and newly hatched fry may remain in the gravel for an additional two weeks prior to emerging (Morrow 1980). Timing of longnose sucker egg incubation is estimated to occur from early May to mid-July based on this information (Table 5.1-11). Fry emergence likely occurs during June and early July (Table 5.1-11).

Juvenile longnose sucker fry typically drift from natal sites following emergence to summer nursery areas (Morrow 1980). Suckers in the Susitna River appear to exhibit this early life history strategy, though it is not clear to what extent such dispersal occurs based on low catch at outmigrant traps at Talkeetna Station (RM 103) (Schmidt et al. 1983). Age-0+ downstream movement in the Middle Segment occurred throughout the open water period in 1982 and 1983, and exhibited a bi-modal peak during June and during late August and September, based on outmigrant traps in the Susitna River main channel and Deshka River (Table 5.1-11) (Schmidt et al. 1983, Sundet and Wenger 1984, Sundet and Pechek 1985). Summer nursery habitats used by juvenile longnose in the Susitna River during the 1980s were side channels, upland sloughs, side sloughs and to a lesser extent, tributary mouths (Schmidt et al. 1983, Sundet and Wenger 1984). Winter habitat use by juvenile suckers is not known (Schmidt et al. 1983). Shallow depth, low water velocity and turbidity or structural (i.e., aquatic or overhead vegetation) cover are considered important characteristics for juvenile longnose nursery habitat (Suchanek et al. 1984b).

5.1.2.12. Dolly Varden

Dolly Varden are widely distributed within the Susitna Basin, from headwater tributaries to the downstream extent of the Lower River (Schmidt et al. 1983, Buckwalter 2011). Estimation of relative abundance of Dolly Varden among the Upper, Middle, and/or Lower segments was not possible during 1980s studies due to low capture rates at sampling sites, though abundance of Dolly Varden downstream of Devils Canyon appeared to be lower relative to upstream populations (Schmidt et al. 1983, Sundet and Wenger 1984). The geographic ranges of the small northern and larger southern forms of Dolly Varden overlap in then Susitna River (Morrow 1980). Adult Dolly Varden of the southern form become sexually mature at 4 to 6 years of age, while maturity occurs between 7 to 9 years in the northern form (Morrow 1980).

Life history patterns of Dolly Varden can be complex and variable among habitats (Morrow 1980). General life history patterns exhibited by the southern form of Dolly Varden include amphidromous populations that spawn in stream habitat and migrate to marine areas for a portion of their life, adfluvial populations that are stream spawners but use lakes associated with natal streams for nursery and holding habitat, fluvial Dolly Varden that migrate among stream habitats, and stream resident populations that reside entirely within natal riverine habitats during their life cycle (Morrow 1980). The extent to which each life history pattern is present in the Susitna River isn't clear, though adfluvial, fluvial and stream resident populations were apparent during 1980s studies (Sautner and Stratton 1983, Schmidt et al. 1983, Sautner and Stratton 1984). Stream resident populations present in headwater areas of Susitna River tributaries were of substantially smaller size than adfluvial and fluvial populations, though comparison of morphological features among disparately-sized individuals indicated each was of the same species (Sautner and Stratton 1983, Schmidt et al. 1983, Sautner and Stratton 1984).

Adult Dolly Varden primarily reside within tributary habitats during the open water season, though apparent adfluvial populations were observed to use lakes to feed during summer (Sautner and Stratton 1983, Sundet and Wenger 1984, Sautner and Stratton 1984). Movement into tributaries occurred in June and July during 1980s studies, coincident with the timing of upstream spawning migrations of adult Chinook salmon (Table 5.1-12) (Delaney et al. 1981b). Adult Dolly Varden are believed to spawn in the upstream extents of clear tributaries during late September and October based on a small number of observations of spawning behavior and sexually ripe individuals (Table 5.1-12) (Delaney et al. 1981b, Schmidt et al. 1983, Sautner and Stratton 1984). Primary tributary habitats in the Susitna River during the 1980s were Deadman Creek (RM 186.7) in the Upper River, Portage Creek (RM 148.9) and Indian River (RM 138.6) in the Middle Segment, and the Kashwitna River (RM 61.0) in the Lower River (Delaney et al. 1981b, Schmidt et al. 1983). Fishwheel capture data at the Talkeetna Station (RM 103) in 1982 and mark-recapture data during 1982-1983 suggest upstream movement of adult Dolly Varden in the main channel in spring and fall, which may represent spring movement to tributary feeding areas and fall migration to spawning areas (Schmidt et al. 1983, Sundet and Wenger 1984). Most adult Dolly Varden are believed to migrate downstream from tributaries during September and October to winter holding habitats in the Susitna River main channel, though little is known regarding the timing of such movement or locations of winter rearing (Table 5.1-12) (Schmidt et al. 1983, Sundet and Wenger 1984). Adfluvial populations likely utilize lacustrine habitats during winter, though timing of movement from tributaries is not known (Sautner and Stratton 1984).

Dolly Varden egg incubation and development to hatching occurs over a period of approximately 130 days at 8.5°C, but may require up to approximately 240 days on the north slope of Alaska (Blackett 1968, Yoshihara 1973, Morrow 1980). After hatching, pre-emergent fry remain in the gravel for 60 – 70 days (Morrow 1980). Based on this information, Dolly Varden egg incubation is estimated to occur from mid-September through late May, and fry emergence likely occurs during April and May (Table 5.1-12).

Juvenile Dolly Varden in the Susitna Basin primarily utilize natal tributaries as summer and winter nursery habitat, though juvenile use of lakes was observed during 1980s studies (Table 5.1-12) (Delaney et al. 1981b, Sautner and Stratton 1983, Sautner and Stratton 1984). Little is known regarding possible seasonal differences in juvenile Dolly Varden habitat use because capture rates were generally very low during 1980s studies (Delaney et al. 1981b, Schmidt et al. 1983, Suchanek et al. 1984b). Dolly Varden that use lake habitats are likely part of adfluvial populations that disperse to lakes from natal tributaries (Sautner and Stratton 1984). Few juvenile Dolly Varden were captured in main channel outmigrant traps in 1982 (n=7) and 1983 (n=7) and at tributary mouths in the Susitna River mainstem, suggesting that few juveniles use mainstem habitat (Delaney et al. 1981b, Sundet and Wenger 1984, Schmidt et al. 1983). During winter, it is possible that juvenile Dolly Varden move downstream within natal tributaries, though there is no evidence that juveniles utilize mainstem habitat during winter (Schmidt et al. 1983). In headwater tributaries with adfluvial populations, juvenile Dolly Varden likely use lacustrine habitats during winter (Sautner and Stratton 1984).

5.1.2.13. Bering Cisco

The ecology of Bering cisco in Alaska is not well understood. Most Bering cisco in Alaska exhibit diadromy by dispersing to estuarine or marine habitats during winter, though some populations appear to reside entirely within freshwater (Morrow 1980). In the Susitna River, most Bering cisco appear to migrate to estuarine or marine areas as age-0+ fry, but the duration of residence in saltwater habitats is not known (ADF&G 1983a, Jennings 1985). The known distribution of Bering cisco in the Susitna Basin ranges from the 4th of July Creek confluence (RM 131.1) downstream to Cook Inlet (ADF&G 1983a, Barrett et al. 1984). Cisco predominantly used the Lower River during 1980s research; in 1984, a total of 361 adult Bering cisco were captured at the Flathorn Station (RM 22) fishwheel, while 3 were captured at the Talkeetna Station (RM 103) (Barrett et al. 1985). Age of Bering cisco captured at Susitna River fishwheels ranged from 4 to 6 (Barrett et al. 1984).

Adult Bering cisco were captured at fishwheel traps but were never captured during other summer or winter sampling in the Susitna River in 1982 (Schmidt et al. 1983). As a result, little is known regarding adult Bering cisco macro-habitat utilization for holding and feeding and periodicity of this life stage is not described here. Upstream spawning migrations of Bering cisco in the Susitna River occurred from early August through October, though fishwheel operation ended October 1 in 1982 and earlier in other years, so the end of migration is not well defined (Table 5.1-13) (ADF&G 1983a). Migration appeared to peak in late September during

1982 (Table 5.1-13) (ADF&G 1983a). Adult Bering cisco utilized mainstem areas for spawning and large concentrations of spawners were observed in the Lower River between RM 85 – RM 75 during 1980s studies (ADF&G 1983a, Barrett et al. 1984). Spawning during 1982 and 1983 occurred during September and October, with peak activity in early October (Table 5.1-13) (ADF&G 1983a, Barrett et al. 1984). No spawning was observed in the Middle Segment during 1981, 1982, or 1983 (ADF&G 1983a, Barrett et al. 1984).

Egg incubation and emergence timing is not well defined for Bering cisco populations. In general, egg incubation of other cisco (e.g., arctic cisco) occurs through the winter and early spring and fry hatch in the spring (Morrow 1980). Based on this general timing, Bering cisco egg incubation is estimated to occur from early September through June and fry emergence is presumed to occur in May and June (Table 5.1-13). Soon after emergence, cisco fry emigrate to the estuarine environment to rear (Morrow 1980). Juvenile fry emigration from natal areas in the Lower Susitna is estimated to occur from mid-May through mid-July (Table 5.1-13).

5.1.2.14. Eulachon

Eulachon in the Susitna Basin have been documented from RM 50 downstream to Cook Inlet (Barrett et al. 1984, Vincent-Lang and Queral 1984). Eulachon in the Susitna River were characterized during 1980s studies in terms of first and second runs (Vincent-Lang and Queral 1984). The approximate abundance of the first run eulachon during 1982 and 1983 was likely several hundred thousand while the size of the second run was several million (Barrett et al. 1984, Jennings 1985).

Eulachon are an anadromous species that reside in marine areas for most of their life and spawn in freshwater streams (Morrow 1980). In 1982 and 1983, adult eulachon were captured in the downstream extent of the Susitna River Lower River during the first sampling event in mid-May; ice conditions precluded sampling prior to early or mid-May in each year (Vincent-Lang and Queral 1984). The first run of adult eulachon spawning migration was believed to begin in early or mid-May and the second run was considered to start in early June (Table 5.1-14) (Vincent-Lang and Queral 1984). Barrett et al. (1984) concluded that adult eulachon spawn within 5 days of entering the Susitna River. Eulachon spawning during 1982 and 1983 occurred downstream of RM 29 in marginal areas of the Susitna River mainstem (Vincent-Lang and Queral 1984). Adult eulachon that spawned in the Lower River in 1982 were predominantly age-3+ adult fish that immigrated to marine habitats as age-0+ fry (ADF&G 1983a).

Eulachon eggs, after extrusion from the female, float to the bottom and become attached to the spawning substrate (Morrow 1980). At water temperatures between 4.4° C and 7.2° C, time required to egg hatching occurs in 30 to 40 days (Morrow 1980). Based on this, eulachon egg incubation is estimated to occur from early May through mid-July (Table 5.1-14). The hatched larvae are not strong swimmers and remain close to the substrate (Morrow 1980). Soon after hatching, young eulachon larvae passively migrate to estuarine areas where rearing occurs (Morrow 1980). Juvenile migration in the Susitna River is estimated to start in early June and continue through July (Table 5.1-14). All juvenile rearing occurs in estuarine and marine environments (Morrow 1980).

5.2. Susitna-Watana 2013-2014 Studies

The periodicity of fish habitat use in the Susitna will be described during 2013-2014 fish and aquatic studies (see AEA 2012, Section 9). Studies in 2013-2014 will be conducted in each Susitna River segment (Upper, Middle and Lower) and will target resident fishes, anadromous salmonids, and the freshwater life stages of non-salmon anadromous species. Target species proposed for 2013-2014 fish and aquatic studies include: Chinook, sockeye, chum, coho and pink salmon, rainbow trout, Arctic grayling, burbot, round whitefish, humpback whitefish, longnose sucker, Dolly Varden, Bering cisco, eulachon, northern pike, Pacific lamprey, and Arctic lamprey. Proposed target species and methods for the 2013-2014 fish and aquatic studies identified in the Revised Study Plan (RSP) (AEA 2012) will be finalized in association with Technical Work Group (TWG) meetings during spring 2013.

Adult resident fish holding and feeding habitats during summer and winter will be identified using fish tagging and tracking technologies (radio and Passive Integrated Transponder [PIT] tags) and a variety of capture techniques (AEA 2012). Adult fish capture methods proposed for 2013-2014 studies include gillnets, seines, trotlines, hoop traps, and angling. Sampling will be performed by meso-habitat type to discern periodicity of holding and feeding among resident fish species. Spawning and other seasonal migrations exhibited by resident fish species will be described based on radio telemetry and PIT tag monitoring.

Adult salmon migration timing will be monitored during 2013-2014 aquatic studies in based on fishwheel operation in the Middle and Lower segments and using radio telemetry and PIT tracking. Spawn timing and habitat utilization will be monitored using radio telemetry and PIT tracking in conjunction with ground/boat and aerial spawning surveys. Movement of tagged fish will occur at fixed stations and based on mobile aerial tracking (radio telemetry only).

The periodicity of egg incubation and emergence timing will be identified for salmon species spawning in mainstem areas using fyke net and minnow trapping, electrofishing and seining in areas of known spawning. Sampling will be performed bi-weekly to identify the period and peak of emergence for each species. Snorkeling may also be used where appropriate. Outmigrant traps (i.e., rotary screw traps) operated near tributary mouths in each segment will supplement emergence timing observations.

Juvenile fry and smolt movement timing for all species was estimated during the 1980s based primarily on capture at stationary downstream migrant traps operated in the Susitna River main channel at Talkeetna (RM 103) and Flathorn (RM 22) stations. Fish capture data from 1980s summer and winter sampling were used to supplement outmigrant trap data and to identity habitat utilization of anadromous and resident fish species. Capture sites visited during the 1980s and 2000s were located in main channel, off-channel and tributary habitats between Susitna River RM 233.4 and RM 7.1.

Periodicity information gathered during 2013-2014 will be instrumental for instream flow studies. Descriptions of the temporal and spatial utilization of mainstem and tributary habitats in the Susitna River by fish species and life stages and will be essential to evaluate potential effects of Susitna River discharge fluctuations on fish communities. Fish spawning and egg incubation are critical life history stages that are particularly sensitive to fluctuations in stream flow. Moreover, rearing and holding conditions in main channel and off-channel habitats in the Susitna River that are utilized by juvenile and adult fish can be transformed in response to changes in river discharge. During 2013–2014 instream flow studies, periodicity analyses will be used to guide habitat-specific modeling and spatial and temporal habitat analyses. Target fish species for instream flow analyses will be identified in association with TWG meetings during spring 2013.

6. TECHNICAL MEMORANDUM – HABITAT SUITABILITY CURVE DEVELOPMENT STUDIES FOR THE SUSITNA RIVER

Habitat suitability criteria (HSC) curves represent an assumed functional relationship between an independent variable, such as depth, velocity, substrate, groundwater upwelling, turbidity, etc., and the response of a species life stage to a gradient of the independent variable (suitability). In traditional instream flow studies and in particular those associated with the Instream Flow Incremental Methodology (IFIM) (Bovee 1982), HSC curves for depth, velocity, substrate, and/or cover are combined in a multiplicative fashion to rate the suitability of discrete areas of a stream for use by a species and life stage of interest (e.g., spawning, fry, juvenile, and adult). HSC curves typically serve as input into hydraulic and habitat models and translate hydraulic and channel characteristics into measures of overall habitat suitability in the form of weighted usable area (WUA), which is an index of habitat. Depending on the extent of data available, HSC curves can be developed from the literature, or from physical and hydraulic measurements made in the field in areas used by the species and life stages of interest (Bovee 1986).

This TM summarizes readily available HSC information that may be relevant to the Susitna-Watana Instream Flow Study (IFS), with a primary focus on information collected during the 1980s Su-Hydro studies. However, other relevant (i.e., from Alaska) HSC data were also compiled and presented, and as well, a summary of HSC efforts related to the current Susitna-Watana IFS that were conducted in 2012 and are proposed for 2013-2014 are likewise presented.

6.1. Su-Hydro 1980s Studies

An extensive set of HSC curves were developed as part of the 1980s Su-Hydro instream flow studies. These criteria were developed using a combination of site-specific data collected through fish sampling and literature sources, and through refinement based on the professional judgment of project biologists. Microhabitat data were collected for various species and life stages of fish, reflective of a suite of different parameters influenced by, or potentially influenced by, flow. These included water depth, water velocity, substrate, upwelling occurrence, turbidity, and cover.

Spawning HSC for chum and sockeye salmon were developed from redd observations in sloughs and side channels of the Middle Segment of the Susitna River (Vincent-Lang et al. 1984b). Data collection sites were concentrated in areas used for hydraulic simulation modeling to maximize the concomitant collection of utilization and availability data necessary for the evaluation of preference. HSC for chum salmon were modified using limited preference data; however, preference could not be incorporated for sockeye salmon. HSC for depth, velocity, and substrate were developed from this effort. Additionally, modified HSC were developed for substrate that reflected the presence or absence of upwelling. Spawning habitat utilization for Chinook, coho, and pink salmon was evaluated in tributaries of the Middle Segment of the Susitna River (Vincent-Lang et al. 1984a). Sufficient data were collected to develop depth, velocity, and substrate HSC curves for Chinook salmon. However, observations for spawning coho and pink salmon were insufficient to develop HSC. Instead, spawning HSC for these two species were based solely on literature data and modified using qualitative field observations.

HSC for rearing juvenile salmon were developed for the habitat parameters of depth, velocity, and cover used by juvenile Chinook, coho, sockeye, and chum salmon (Suchanek et al. 1984b).

These HSC were developed based on field data collected at representative tributary, slough, and side channel sites between the Chulitna River confluence and Devils Canyon (Middle Susitna River) and were considered to be specific to this reach. In addition, if differences in habitat utilization were apparent at varying turbidity levels, separate HSC were developed for turbid vs. clear water conditions for those species with sufficient sample sizes (i.e., juvenile Chinook). A subsequent effort used similar methods to verify the applicability of these juvenile salmon rearing HSC curves for the Lower River downstream of the Chulitna River confluence (Suchanek et al. 1985). Findings from this effort resulted in some modifications to HSC for use in the Lower River.

HSC for resident fish species were developed based on data collected through electrofishing, beach seining, and hook-and-line sampling in tributary mouths, tributaries, and sloughs of the middle Susitna River (Suchanek et al. 1984a). Cover and velocity HSC were developed for adult rainbow trout, arctic grayling, round whitefish, and longnose sucker. HSC for cover were developed separately for turbid vs. clear water conditions. A single depth HSC was developed for all of these species combined. Only round whitefish were collected in sufficient numbers to develop separate HSC for juveniles.

The following sections provide additional details regarding the 1980s efforts to develop HSC curves, including a description of methods, study sites, data analyses, and the resulting curve sets. A summary of species, lifestage and habitat parameters for which HSC curves were developed for the Middle and Lower Segments of the Susitna River is provided in Table 6.1-1. These curves are presented exactly as reported in their respective source references and have not been modified. Substrate curves are one exception; to allow comparability between 1980s substrate curves and those from other studies, adjusted substrate codes (Table 6.1-2) were used to standardize the curves for this habitat parameter. Because some substrate size classes overlapped, these adjusted codes are not exact.

6.1.1. Methods

The 1980s data collection and HSC curves development were conducted during several different studies, each targeting certain species and life stages. Thus, methods used to collect and develop HSC curves are presented in the following section by study.

6.1.1.1. Chum and Sockeye Salmon Spawning (Vincent-Lang et al. 1984a)

Studies related to the development of HSC for spawning chum and sockeye salmon are described by Vincent-Lang et al. (1984a). These studies were initiated in 1982 to collect measurements of depth, velocity, substrate, and upwelling at redd sites and determine the behavioral responses of spawning chum and sockeye salmon to the various levels of these habitat variables. However, utilization data collected in 1982 were inadequate to fully develop HSC because low discharge and flow conditions 1imited access of adult chum and sockeye salmon into study sites. Additional utilization data were collected in 1983 which, when combined with 1982 data, information from literature, and professional judgment of project biologists, were sufficient for developing chum and sockeye salmon spawning HSC.

6.1.1.1.1. Site Selection

Sites for the collection of utilization data in sloughs and side channels of the Middle Segment of the Susitna River (Talkeetna to Devils Canyon reach) were selected based on the presence of spawning salmon and the ability to observe their activities. Efforts were concentrated in areas of sloughs (Sloughs 8A, 9, and 21) and side channels (Side Channels 21 and Upper 11) where hydraulic simulation modeling data were being collected to maximize the collection of combined utilization and availability data, thereby allowing for the evaluation of preference. Other sloughs and side channels in the Middle Segment of the Susitna River were also surveyed for spawning activity and, if present, selected as additional study sites to extend the utilization data base. These non-modeled sites were Sloughs 9A, 11, 17, 20, and 22; habitat availability data were not collected at these sites. Spawning utilization data for chum salmon were also collected in tributary mouth habitat locations (Lane and Fourth of July creeks; Sandone et al. 1984). While these data were not included in the development of formal HSC curves, Sandone et al. (1984) did compare utilization in tributary mouth habitats with findings from slough and side channel habitats. A list of sites and the number of redds where suitability data were collected in support of HSC development are provided in Table 6.1-3.

6.1.1.1.2. Collection Methods

At each study site, spawning salmon were located by visual observation. Fish activities were observed from the stream bank for 10 to 30 minutes to determine active redd locations prior to entering the water for measurements. A redd was considered active if a female was observed to fan the substrate at least twice and a male exhibiting aggressive or quivering behavior was present during the observation period. Water depth and velocity measurements were collected at the upstream end of each active redd with a topsetting wading rod and a Marsh McBirney or Price AA meter. The general substrate composition of each redd pit was visually evaluated using the size classifications listed in Table 6.1-2. The presence of upwelling in the vicinity of the redd was assessed visually and the distance from the redd was noted. For redds within hydraulic simulation modeling study sites, staff gage readings were recorded and used to estimate the flow at the time of redd measurements based on rating curves presented by Quane et al. (1984). This flow was then used to simulate available depth, velocity, and substrate data to evaluate preference.

6.1.1.1.3. Data Analysis and HSC Curve Development

In developing HSC curves for chum and sockeye salmon spawning, Vincent-Lang et al. (1984a) first arranged redd measurements (depth and velocity) as histograms using several different incremental grouping methods. Each grouping method was used to create a unique utilization curve and statistical methods were then applied to identify which utilization curve best represented the data based on minimal variance, irregular fluctuations, and peakedness. Because substrate data were not continuous, using different grouping methods for substrate was not appropriate and the utilization data plot was treated as the best substrate utilization curve. For depth, velocity, and substrate, the best utilization curve was evaluated in terms of availability data (i.e., preference), published information, and/or the professional opinion of project biologists familiar with middle Susitna River salmon stocks to develop suitability curves.

6.1.1.2. Chinook, Coho, and Pink Salmon Spawning (Vincent-Lang et al. 1984b)

The 1980s studies related to the development of HSC for spawning Chinook, coho, and pink salmon were described by Vincent-Lang et al. (1984b). For Chinook salmon, HSC were developed based on utilization data for the habitat variables of depth, velocity, and substrate composition at spawning sites in selected tributaries of the Middle Segment of the Susitna River. These data were modified using statistical methods and the professional judgments of project biologists familiar with Susitna River Chinook salmon stocks to develop suitability criteria for Chinook salmon spawning in tributaries of the Middle Segment. Suitability criteria were also developed for coho and pink salmon spawning in tributaries of the Middle Segment based on literature information as modified using the professional judgments of project biologists familiar with the Susitna River coho and pink salmon stocks.

6.1.1.2.1. Site Selection

Out of 11 tributaries surveyed in the Middle Segment of the Susitna River, four tributaries (Portage Creek, Indian River, Fourth of July Creek, and Cheechako Creek) were found to support relatively high levels of Chinook salmon spawning and were therefore selected for collection of Chinook salmon spawning utilization data. These four tributaries supported more than 98% of the 1983 Chinook salmon spawning in the Middle Segment of the Susitna River, with the majority occurring in Portage and Indian Creeks. These four tributaries also supported more than 97% of the pink salmon spawning and more than 70% of the coho salmon spawning in tributaries of the middle reach of the Susitna River (Barrett et al. 1983). Within the selected tributaries, specific sites were chosen from helicopter reconnaissance that had high concentrations of fish and were conducive to the deployment of field personnel. A list of sites and the number of redds where suitability data were collected in support of HSC development are provided in Table 6.1-3.

6.1.1.2.2. Collection Methods

Data collection efforts were timed to coincide with peak Chinook salmon spawning activity in selected tributaries, which occurred from July 10 to August 20, 1983. Spawning salmon were located in each study stream by visual observation and the same methods described by Vincent-Lang et al. (1984b) for collecting chum and sockeye spawning utilization were used.

6.1.1.2.3. Data Analysis and HSC Curve Development

For Chinook salmon spawning, sufficient data were collected to develop HSC using utilization data collected at redds in tributaries to the Middle Segment of the Susitna River. Analytical methods were similar to those used for chum and sockeye salmon spawning summarized above and described by Vincent-Lang et al. (1984a) and Vincent-Lang et al. (1984b). Utilization data for coho and pink salmon spawning were insufficient to develop HSC. Curves for these two species were instead derived from previously published information, as modified using the opinion of field biologists familiar with Susitna River salmon stocks.

6.1.1.3. Juvenile Salmon Rearing in the Middle Susitna River (Suchanek et al. 1984a)

Studies related to the development of HSC for juvenile salmon rearing in the Middle Segment of the Susitna River are described by Suchanek et al. (1984a). These studies were conducted to support evaluations of the effects of changes in Susitna River flow regimes on habitat used by rearing juvenile salmon. In order to model changes in habitat usability, data were collected for development of suitability criteria for the habitat attributes of cover, velocity, and depth used by juvenile Chinook, coho, sockeye, and chum salmon based on representative sites between the Chulitna River confluence and Devils Canyon.

6.1.1.3.1. Site Selection

Locations selected for sampling in 1983 for this effort had substantial numbers of rearing juvenile salmon during previous studies in 1981 and 1982 or were thought to be typical sites having the potential for juvenile rearing. Sites were located in the Middle Segment of the Susitna River between Whiskers Creek (RM 101.2) and Portage Creek (RM 148.8). Seven tributary sites, two upland sloughs, and 12 other sites characterized as side sloughs or side channels (depending on mainstem flows) were sampled at least four times. Nine additional sites were sampled only once and five sites were sampled two or three times. These additional sites were chosen to represent a wider cross section of habitat conditions experienced by rearing juvenile salmon in this reach of the Susitna River in addition to the intensive sampling in tributaries, upland sloughs, side sloughs, and side channels. Limited sampling was done in the mainstem channel and large side channels because of the difficulty in sampling these areas and because high velocities in these areas was thought to limit juvenile rearing.

6.1.1.3.2. Collection Methods

Sampling was conducted during 8- to 10-day field efforts, twice monthly between May and October, 1983. Twenty-three sites were sampled from three to seven times while 12 other sites were only incidentally sampled on one or two occasions. Approximately eight staked transects from 75 to 200 feet apart were established across each study site. Sampling cells 50 feet long by six feet wide (300 ft^2) were delineated upstream from each transect along each shoreline and another mid-channel cell was located between shoreline cells. Transects were placed to maximize the within-site variability of habitat types sampled while also attempting to maintain uniform physical habitat within individual sampling cells. Cells were selected to represent a wide range of habitat types; approximately 20 cells were sampled per day.

Sampling effort was targeted at sites where rearing fish were numerous based on knowledge of seasonal movements. Sampling frequency was reduced if efforts to catch 30 or more juveniles of a species in a grid of transects were unsuccessful. Backpack electrofishing units and 1/8" mesh beach seines were used to sample cells in their entirety. Beach seining was typically limited to turbid water areas whereas electrofishing was used in clear water areas. Electrofishing was the preferred sampling method, but was found to be ineffective in turbid water. Each captured fish was identified to species and measured for total length.

After sampling for fish, a set of habitat parameters for each cell was measured even if no fish were captured. The average depth and velocity was measured and the total amount of available cover (expressed in percent areal coverage) and dominant cover type was estimated for each cell. Water temperature, dissolved oxygen, pH, conductivity, and turbidity were measured at one point in the grid, with a second measurement taken if an obvious water quality gradient existed across the grid.

6.1.1.3.3. Data Analysis and HSC Curve Development

The first step in developing HSC curves for rearing juvenile salmon was to separate data by gear type due to differences in effectiveness and because each gear was used selectively, dependent upon sampling conditions. Different types of analyses were used for Chinook and coho salmon in comparison to sockeye and chum salmon based on differences in territoriality and propensity for schooling behavior. Suitability for Chinook and coho salmon was derived by dividing total fish catch for a given habitat parameter value (utilization) by the number of cells fished with the same habitat parameter value (effort). Fish density was assumed to be a function of mean catch per cell. Differences in mean catch per cell by habitat value were analyzed with analysis of variance and least squares regression.

For sockeye and chum salmon, suitability was derived by dividing the total number of cells with fish present for a given habitat value (utilization) by the number of cells fished (effort). This modification was needed for sockeye and chum salmon because the typical schooling behavior exhibited by these species could lead to the capture of a large school within a cell, which might disproportionately affect mean catch per cell. Differences in proportional presence by habitat attribute value were analyzed with chi-square tests of association.

For all analyses, data from all sites over the entire season were pooled by species. Data from tributary sites without major runs of sockeye salmon were excluded from the sockeye suitability criteria development. Data collected between May 1 and 15, when only a small percentage of sockeye had emerged, were also excluded. Because the vast majority of chum salmon outmigrate from the upper Susitna River prior to July 15 (ADF&G 1983a), only data collected before July 15 were used to develop suitability relationships for this species.

Statistical analyses used included analysis of variance, linear regression and chi-square tests of association. All velocity and depth criteria were fit to the data by hand using professional judgment to give the best fit.

6.1.1.4. Juvenile Salmon Rearing in the Lower Susitna River (Suchanek et al. 1985)

In 1984, Suchanek et al. (1985) conducted a follow-up study to evaluate juvenile salmon rearing habitat suitability in the Lower Susitna River (below the Chulitna River confluence). The goal of the study was to verify the applicability of the suitability criteria developed for the Middle Segment of the Susitna River in 1983 by Suchanek et al. (1984b), such that the 1983 Middle River curves could be used for the Lower River unless the 1984 studies in the Lower River provided evidence for modifications.

6.1.1.4.1. Site Selection

Sampling sites included 20 habitat model sites that were normally sampled twice a month and 31 opportunistic sites which were usually sampled only once. The 20 modeled sites were distributed between the Yentna River confluence and Talkeetna. Eight of these sites were located within slough or side channel complexes. Four of the sites were normally clear-water sloughs or tributary mouths while the other sites were turbid secondary side channels at normal summer flows. Opportunistic sampling sites were selected by sampling crews as potential habitat which upon sampling might provide for a better analysis of fish abundance and distribution. Sites sampled were more diverse than the modeled sites and included areas within alluvial island complexes.

6.1.1.4.2. Collection Methods

Sampling methods were the same as those used during the 1983 studies in the Middle River (Suchanek et al. 1984a) described above.

6.1.1.4.3. Data Analysis and HSC Curve Development

Initial data analysis methods were the same as those used by Suchanek et al. (1984a) in the Middle River. However, additional methods were used to compare the Middle (1983) and Lower (1984) River data. Comparisons were made by plotting the suitability criteria derived for the Middle River on the same graph with corresponding data from the Lower River. After normalizing criteria from the two years, composite weighting factors were calculated for each cell using the 1983 suitability criteria and revised 1984 criteria. These weighting factors were then compared with catch. If the fit of the 1984 data to the 1983 suitability criteria were substantially different upon visual inspection, the 1983 criteria were modified.

6.1.1.5. Resident Fish (Suchanek et al. 1984b)

Studies related to the development of HSC for select resident fish species are described by Suchanek et al. (1984b). The microhabitat suitability for rainbow trout, Arctic grayling, round whitefish, and longnose suckers in the Middle Segment of the Susitna River were evaluated using electrofishing, beach seine, and hook and line catch data and habitat data collected at radio telemetry relocation sites (rainbow trout and burbot) and spawning sites (round whitefish).

6.1.1.5.1. Site Selection

Thirteen study sites were sampled from July to October, 1983 to develop HSC for adult resident species. These sites were located between the Chulitna River confluence and Devils Canyon and consisted of six tributary mouths, three tributaries, three side sloughs, and one upland slough. Nine slough and tributary mouth sites with relatively high numbers of adult resident fish were selected for sampling by boat electrofishing, which occurred twice a month from mid-July to October. Supplemental observations of resident fish were also obtained during other study efforts. The upper reaches of four tributaries were irregularly sampled by hook and line in conjunction with other study efforts (Sundet and Wenger 1984). Juvenile and a few adult resident fish were also captured incidentally at 35 sites sampled during the juvenile salmon studies described above (Suchanek et al. 1984a). Microhabitat was also measured at relocation sites of 24 radio tagged rainbow trout and burbot that included tributary mouths, sloughs, sites in the mainstem Susitna River between RM 100.8 and RM 148.7 and at three tributaries.

6.1.1.5.2. Collection Methods

Adult and a small number of juvenile (< 200 mm) resident fish were captured at accessible locations in the Middle Segment of the Susitna River using a boat mounted electrofishing unit. In tributaries, adult resident fish were also captured by hook and line. Juvenile resident fish at upland slough, side slough, mainstem and tributary sites were collected with beach seines and backpack electrofishing units. All resident fish were identified to species and length, sex, and sexual maturity information were recorded. Juvenile resident fish were also captured incidentally during juvenile anadromous sampling of cells and grids located at a greater diversity of sites using beach seining and backpack electrofishing as described above.

Each microhabitat study location was divided into one to three grids, located such that water quality conditions were as uniform as possible and to encompass a variety of habitat types. At tributary mouths, one grid was established in the mainstem Susitna River upstream of the tributary confluence, a second grid was established within or below the confluence where the tributary was the primary water source, and a third grid was established where the mainstem and tributary waters mixed. Slough and tributary sites each had one to three grids depending on the water quality. Grid locations were reestablished during each sampling effort to account for changes in hydraulic conditions. Each grid was subdivided into rectangular cells of varying length and width. Stream width constituted the width of cells in tributaries, which were sampled by hook and line. Cell widths at sloughs and tributary mouths, which were sampled by boat electrofishing, were typically five feet which was the average effective capture width of the boat electrofishing equipment used.

Microhabitat data was collected at relocation sites of four burbot and 20 rainbow trout that had been radio tagged in 1983. These fish were tracked from airplanes and boats and habitat measurements were taken after a radio tagged fish was relocated by boat to an area of no greater than 30 feet by 30 feet; in some cases, radio tagged fish were observed. For each cell and radio tagged fish relocation site, mean depth, mean velocity, turbidity, and other water quality parameters were measured.

6.1.1.5.3. Data Analysis and HSC Curve Development

Due to differences in habitat conditions sampled, hook and line data were analyzed separately from boat electrofishing data. Observations were grouped according to the frequency distribution of each habitat parameter. Turbidity values were grouped into three categories (1-9 NTU, 10-30 NTU, and >30 NTU) based on inflection points at which light penetration changes considerably in glacial systems in Alaska and because Chinook salmon fry were found to use turbidities >30 NTU for cover.

After grouping, Kendall rank-order correlation coefficients were calculated between habitat values and catch. Because cells varied in size, catch was standardized in terms of fish caught per 1,000 ft^2 of surface area, which was assumed to reflect density as well as suitability. Suitability was determined for velocity, depth, cover type, and percent cover. Velocity was considered an important determinant of distribution and suitability criteria were fit by hand to the distributions of catch using professional judgment for each species. Because data for velocities greater than 4.3 ft/s were not collected, it was assumed that suitability for all species was 0.0 for velocities greater than 4.5 ft/s. Depth was not considered an important determinant of distribution; therefore, suitability criteria were not fit to depth observations. However, because minimum depth was considered limiting, suitability was conservatively set to 1.0 for all depths greater than 0.6 ft and to 0.0 for depths less than 0.5 ft.

While percent cover and cover type both were considered to have potential importance in determining adult fish distribution, limited sample sizes only allowed for the consideration of cover type. Turbidity was incorporated into suitability indices for cover type because the suitability of cells without cover was found to increase as turbidity increased. This was accomplished by developing cover type suitability indices for both clear (<10 NTU) and turbid (>30 NTU) conditions.

Overall, only round whitefish juveniles were captured in sufficient numbers at juvenile salmon study sites to warrant development of HSC. The habitat parameters of velocity, depth, percent cover and cover type were examined for criteria development.

6.1.2. Results

The following sections summarize the results of HSC data collection efforts and the resulting development of HSC curves from the various 1980s studies. Results are organized and reported by species and life stage and therefore include results from multiple studies.

6.1.2.1. Chum Salmon

Chum salmon HSC curves were developed for spawning in the Middle Segment of the Susitna River (Vincent-Lang et al. 1984a) and for juvenile rearing in the Middle (Suchanek et al. 1984a) and Lower segments (Suchanek et al. 1985). The basis for the curves developed for each life stage is provided below.

6.1.2.1.1. Spawning

A total of 333 chum salmon redds were surveyed by Vincent-Lang et al. (1984a) during 1982 and 1983 for the habitat variables of depth, velocity, substrate, and the presence of upwelling groundwater. Of these redds, 131 were within hydraulic simulation modeling study sites and had associated availability data. Because of the limited number of measurements in Side Slough 8A and Side Channel 21, only utilization (128 measurements) and availability data obtained in Side Sloughs 9 and 21 were used in the evaluation of preference. This information was used to develop chum salmon spawning HSC for depth, velocity, substrate, upwelling, and a combined substrate/upwelling criteria index, which are described in the following sections.

Although depths less than 0.2 ft were available, they were not used by spawning chum salmon. Depths less than 0.2 ft were therefore assigned a suitability index of 0.0 (Figure 6.1-1). A strong preference was identified for depths between 0.8 and 2.3 ft (i.e., the frequency of utilization was greater than the frequency of available), and therefore, these depths were assigned a suitability index of 1.0. Based on published data (Hale 1981) and the opinion of project biologists familiar with chum salmon in the Middle Segment of the Susitna River, it was assumed that depths >2.3 ft would not limit chum salmon spawning within the range of conditions encountered at the study sites. Because the maximum predicted depth at all modeled study sites was 7.5 ft, the suitability index of 1.0 was extended out to 8.0 ft. For depths from 0.8 to 2.3 ft, the ratio of utilized to available habitat for the 0.2 to 0.5 ft increment was less than for the 0.5 to 0.8 ft increment. Suitability was therefore assumed to increase in an exponential fashion over the range of 0.2 to 0.8 ft, which was reflected by assigning a suitability index of 0.2 to a depth of 0.5 ft.

A general preference was exhibited by spawning chum salmon for velocities between 0.0 and 1.3 ft/s. Thus, a suitability index of 1.0 was assigned to this range of velocities (Figure 6.1-2). Suitability for higher velocities was subjectively determined because no concurrent utilization/availability data were collected for velocities exceeding 1.3 ft/s. The maximum utilized velocity was 4.3 ft/s; thus, a velocity of 4.5 ft/s was selected as a maximum value and assigned a suitability index of 0.0. Utilization from 1.3 ft/s to 2.8 ft/s was greater than from 2.8 ft/s to 4.5 ft/s. Therefore, a suitability index of 0.2 was assigned to a velocity of 2.8 ft/s.

Substrates ranging from large gravel to large cobble (reported simply as cobble) appear to be preferred for chum spawning. However, published data (Hale 1981; Wilson et al. 1981) suggest that large cobble substrates are less preferred for chum salmon spawning than large gravels and small cobbles (reported as rubble). Discussions with field personnel also suggested a potential sampling bias for larger substrates since field personnel were more likely to overestimate substrate sizes. For these reasons, a suitability index of 1.0 was assigned to large gravel and small cobble substrates (Figure 6.1-3). Larger cobble substrates were divided into several increments and assigned suitability indices ranging from 0.85 to 0.25, while boulders were assigned an index value of 0.0. Silt and smaller substrates were not utilized and were assigned a suitability index of 0.0. A small utilized to available ratio was observed for sand increments, which were assigned a low suitability index (0.025 and 0.05). This was supported by published information (Hale 1981; Wilson et al. 1981). Intermediate substrate size classes were assigned by assuming a linearly increasing suitability.

A binary approach was used to assign suitability criteria for upwelling. A suitability index of 1.0 was assigned for the presence of upwelling while a suitability index of 0.0 was assigned for the absence of upwelling (Figure 6.1-4). This approach was considered justified based on field data that indicated spawning chum salmon appear to key on upwelling (ADF&G 1983a). Suitability criteria were also developed for the combination of substrate and upwelling. When upwelling is present, criteria were identical to the individual substrate suitability criteria. However, when upwelling is not present, a suitability index of 0.0 was assigned to each substrate class.

6.1.2.1.2. Juvenile Rearing

6.1.2.1.2.1. Middle Susitna River

Suchanek et al. (1984a) captured a total of 1,157 juvenile chum salmon from 514 sample cells during efforts to collect juvenile salmon suitability criteria data in the Middle River (Table 6.1-4). This total excludes some cells that were sampled after the period of peak chum salmon outmigration to avoid biasing analyses based on the presence or absence of juvenile chum salmon. Chi-square tests indicated that the association of juvenile chum salmon presence was significant for depth, velocity, cover type, and percent cover.

To determine the relative importance of each habitat parameter, composite weighting factors were developed using various combinations of habitat parameters. The effect of depth on the distribution of juvenile salmon was not considered limiting beyond a minimum threshold, and the inclusion of depth in composite weighting factors showed only minimal improvement in the correlation with catch. Therefore, for juvenile chum and all other juvenile salmon species considered, depths greater than or equal to 0.15 ft were assigned a suitability index of 1.0 (Figure 6.1-5). Depths less than 0.15 were assigned a suitability index of 0.0 based on professional judgment.

Sample sizes were insufficient to develop separate suitability curves based on turbid vs. clear-water conditions. Thus, observations from electrofishing (clear-water) and seining (turbid-water) were pooled for analyses. Slow velocities between 0.0 and 0.35 ft/s were found to be optimal for juvenile chum salmon and were assigned a suitability index of 1.0 (Figure 6.1-6). Velocities greater than 0.35 ft/s were assigned decreasing suitability indices, reaching 0.0 at velocities of 2.10 and greater.

Compared to juvenile sockeye, Chinook, and coho salmon, chum salmon rear for the shortest duration in the Middle Susitna River (ADF&G 1983b). Suchanek et al. (1984a) observed that juvenile chum initially use substrate as cover and then rely on protection provided by schooling behavior. This was reflected by a greater relative use of large substrate for cover by chum salmon compared to other species. Mean catches of juvenile chum salmon were less in cells without object cover in turbid water, suggesting avoidance of turbid conditions. However, this may have also been an artifact of clear-water conditions predominating near emergence areas. Cover type and percent cover suitability are shown for juvenile chum salmon in Table 6.1-5.

6.1.2.1.2.2. Lower Susitna River

Sampling in 1984 by Suchanek et al. (1985) found that the use of side channels in the Lower River of the Susitna River by juvenile chum salmon was limited by high turbidities. For this reason, sampled cells with turbidities greater than 200 NTU were eliminated from suitability criteria development. Cells were also excluded from analyses if they were sampled before the date when most chum salmon outmigration occurred (July 16). After applying these criteria, 249 cells were available for analysis; juvenile chum were captured in 98 (39.4%) of these cells.

The distribution of chum presence by depth interval in the Lower River in 1984 was similar to that found in the Middle River in 1983. Thus, the criteria developed for the Middle River was generally the same as that developed for the Lower River (Figure 6.1-5). One exception was that the curve developed for the Lower River increased directly from a suitability index of 0.0 (at a depth of 0.0 ft) to 1.0 (at a depth of 0.1 ft). In contrast, the Middle Segment depth curve (used for all juvenile salmon species) increased from a suitability index of 0.0 (at a depth of 0.14 ft) to 1.0 (at a depth of 0.15 ft). Presumably, this difference represents a lack of refinement to the Lower River curve to account for a minimum depth requirement. Alternatively, 0.1-ft depth increments may have been deemed adequate for modeling efforts, making the suitability of depths between 0.0 and 0.1 irrelevant.

With respect to velocity, data collected in the Lower River in 1984 indicated that the distribution of juvenile chum presence was similar to the Middle Segment in 1983. Therefore, the suitability criteria for chum salmon developed for the Middle Segment in 1983 was selected for use in 1984 for the Lower River (Figure 6.1-6).

The relationship of chum salmon use to percent cover and cover type in the Middle Segment in 1983 was the weakest of any of the four species. In the Lower River in 1984, the 0-5% cover category and the "no cover" type had the highest proportional presence within their respective distributions, suggesting that chum salmon fry do not orient to cover during rearing. Because no trends were apparent, cover type and percent cover were not used in the 1984 analysis of chum habitat use. Thus, a suitability index of 1.0 was applied to all cover types and percentages of cover for the Lower River (Table 6.1-6). Again, the lack of a relationship between juvenile chum and cover was attributed to a reliance on schooling behavior for protection from predators rather than cover.

6.1.2.2. Sockeye Salmon

Sockeye salmon HSC curves were developed for spawning in the Middle Segment (Vincent-Lang et al. 1984a) and for juvenile rearing in the Middle (Suchanek et al. 1984a) and Lower segments (Suchanek et al. 1985). The basis for the curves developed for each life stage are provided below.

6.1.2.2.1. Spawning

During 1982 and 1983, a total of 81 sockeye salmon redds were sampled by Vincent-Lang et al. (1984a) for depth, velocity, substrate, and the presence of upwelling groundwater. Of these redds, only one was located within a hydraulic simulation modeling study site, which precluded an analysis of preference for sockeye salmon spawning. Thus, the derived sockeye salmon spawning HSC were based solely on utilization data, as modified by the professional opinion of project biologists familiar with middle Susitna River sockeye salmon stocks using literature data and accumulated field observations. This information resulted in HSC for depth, velocity, substrate, upwelling, and a combined substrate/upwelling criteria index, which are described in the following sections.

Depths from 0.0 to 0.2 ft were not utilized for spawning and were therefore assigned a suitability index of 0.0 (Figure 6.1-7). Depths that were most utilized centered around 0.75 ft, which was therefore assigned a suitability index of 1.0. It was assumed that depths greater than 0.75 ft would not likely limit sockeye salmon spawning within the range of conditions in the study sites, based on the opinion of project biologists. The suitability index of 1.0 was therefore extended out to 8.0 ft. Depths ranging from 0.2 to 0.5 ft were thought to be less suitable for spawning than depths ranging from 0.5 to 0.75 ft. Thus, a suitability index of 0.9 was assigned to a depth of 0.5 ft.

For a velocity of 0.0 ft/s, a suitability index of 1.0 was assigned (Figure 6.1-8); this suitability index was extended out to a velocity of 1.0 ft/s based on a review of literature data (USFWS 1983) and the opinion of project biologists. A suitability index of 0.0 was assigned to a velocity of 4.5 ft/s to be consistent with the endpoint of the velocity curve for chum salmon spawning. This rationale was applied because it was assumed that velocities for sockeye salmon spawning would be no greater than for chum salmon spawning and because data were not available to support lower velocities as an end point. Velocities ranging from 1.0 to 3.0 ft/s were thought to be more suitable for sockeye salmon spawning than velocities from 3.0 to 4.5 ft/s. Therefore, a suitability index of 0.10 was assigned to a velocity of 3.0 ft/s.

Large gravel and small cobble substrates appeared to be most often utilized for sockeye salmon spawning. This finding was supported by published information (USFWS 1983), and these substrates were assigned a suitability index of 1.0 (Figure 6.1-9). Large cobble and boulder substrates were also utilized for spawning but to a lesser extent. However, the apparent utilization of these 1arger substrates was thought to reflect a sampling bias toward larger substrates than smaller substrates; that is, field personnel more likely noted larger substrate sizes than smaller substrate sizes. Published information (USFWS 1983) also showed that large cobble and boulder substrates were not as preferred as large gravels and small cobble. Therefore, substrates between small cobble and large cobble were assigned a suitability index from 0.90 to 0.10, respectively. Boulders were assigned a suitability index of 0.0 as were substrates of sand and silt. Moderate utilization of small gravel substrates were observed though accumulated field experience and literature information (USFWS 1983) suggested that larger gravel substrates would be more suitable for sockeye spawning. Thus, suitability index of 0.10 were assigned to substrates between sand and small gravel, 0.50 to small gravel substrate, 0.95 to substrates between small gravel and large gravel.

Suitability criteria for upwelling were assigned using a binary approach in which a suitability index of 1.0 was assigned where upwelling was present and a suitability index of 0.0 was assigned where upwelling was absent (Figure 6.1-10). This approach was considered justified based on field data that indicated spawning sockeye salmon appear to key on upwelling (ADF&G 1983a). Suitability criteria were also developed for the combination of substrate and upwelling. When upwelling is present, criteria were identical to the individual substrate suitability criteria. However, when upwelling is not present, a suitability index of 0.0 was assigned to each substrate class.

6.1.2.2.2. Juvenile Rearing

6.1.2.2.2.1. Middle Susitna River

Suchanek et al. (1984a) captured a total of 1,006 juvenile sockeye salmon from 1,013 sample cells during efforts to collect juvenile salmon suitability criteria data in the Middle Susitna River (Table 6.1-4). To avoid biasing analyses based on the presence or absence of juvenile sockeye salmon, this total excludes some cells that were sampled in tributaries without major sockeye salmon runs or when only a small percentage of sockeye had emerged. Chi-square tests indicated that the association of juvenile sockeye salmon presence was significant for depth, velocity, cover type, and percent cover.

To determine the relative importance of each habitat parameter, composite weighting factors were developed using various combinations of habitat parameters. The effect of depth on the distribution of juvenile salmon was not considered limiting beyond a minimum threshold, and the inclusion of depth in composite weighting factors showed only minimal improvement in the correlation with catch. Therefore, for juvenile sockeye and all other juvenile salmon species considered, depths greater than or equal to 0.15 ft were assigned a suitability index of 1.0 (Figure 6.1-11). Depths less than 0.15 were assigned a suitability index of 0.0 based on professional judgment.

Sample sizes were insufficient to develop separate suitability curves based on turbid vs. clear-water conditions. Thus, observations from electrofishing (clear-water) and seining (turbid-water) were pooled for analyses. Slow velocities between 0.0 and 0.05 ft/s were found to be optimal for juvenile sockeye salmon and were assigned a suitability index of 1.0 (Figure 6.1-12). Velocities greater than 0.05 ft/s were assigned decreasing suitability indices, reaching 0.0 at velocities of 2.10 and greater.

Compared to Chinook and coho juveniles, sockeye juveniles were apparently much less dependent on cover because they are more likely to use the schooling behavior as a means of predator avoidance. Schools of sockeye juveniles were observed ranging throughout areas varying from heavy cover to no cover. However, the distribution of juvenile sockeye salmon appeared to have some relationship to cover, reflected in the suitability indices developed. Cover type and percent cover suitability are shown for juvenile sockeye salmon in Table 6.1-5.

6.1.2.2.2.2. Lower Susitna River

Sampling in 1984 by Suchanek et al. (1985) found that the use of Lower River side channels by juvenile sockeye salmon was limited by high turbidities. For this reason, sampled cells with turbidities greater than 250 NTU were eliminated from suitability criteria development. After these cells were excluded, 922 cells were available for analysis; juvenile sockeye were captured in 117 (12.7%) of these cells.

No trend was noted in the 1984 depth distribution data for the Middle River. Fish were captured in 2 of the 20 cells sampled with a depth of 0.1 ft, suggesting that this depth was suitable. The distribution of chum presence by depth interval in the Lower River in 1984 was similar to that found in the Middle Segment in 1983. Thus, the criteria developed for the Middle River was generally the same as that developed for the Lower River (Figure 6.1-11). One exception was that the curve developed for the Lower River increased directly from a suitability index of 0.0 (at a depth of 0.0 ft) to 1.0 (at a depth of 0.1 ft). In contrast, the Middle River depth curve (used for all juvenile salmon species) increased from a suitability index of 0.0 (at a depth of 0.14 ft) to 1.0 (at a depth of 0.15 ft). Presumably, this difference represents a lack of refinement to Lower River curve to account for a minimum depth requirement. Alternatively, 0.1-ft depth increments may have been deemed adequate for modeling efforts, making the suitability of depths between 0.0 and 0.1 irrelevant.

With respect to velocity, the proportional presence of juvenile sockeye in the Lower River in 1984 by velocity interval was very similar to that found in the Middle Segment in 1983. Velocities greater than 1.2 ft/s were not used by juvenile sockeye in either year, although Middle River sample sizes were smaller. Because no use was observed at velocities greater than 1.2 ft/s, the curve developed in 1984 for the Lower River was revised such that velocities greater than 1.2 ft/s had a suitability index of 0.0 (Figure 6.1-12).

For percent cover, the distribution of proportional presence was similar to that found in the Middle River of the Susitna River in 1983. The 1983 suitability relationship was therefore selected in 1984 for use in the Lower River (Table 6.1-6). For cover type, the distribution of proportional presence by cover type categories differed slightly from that found in the Middle Segment in 1983. Thus, the cover type suitabilities developed for the Middle Segment were deemed appropriate for the Lower River, with two exceptions. Because sample sizes were small (less than 25) for the cover type categories of undercut bank and overhanging riparian vegetation, suitabilities calculated for the Middle Segment were averaged with the Lower River suitabilities to give a value intermediate between the two (Table 6.1-6).

6.1.2.3. Chinook Salmon

Chinook salmon HSC curves were developed for spawning in the Middle River (Vincent-Lang et al. 1984b) and for juvenile rearing in the Middle (Suchanek et al. 1984a) and Lower segments (Suchanek et al. 1985). The basis for the curves developed for each life stage are provided below.

6.1.2.3.1. Spawning

A total of 265 Chinook salmon redds were sampled during 1983 for the habitat variables of depth, velocity, and substrate. Of these redds, the majority of measurements were made in

Portage Creek (n=137) and Indian River (n=125). This information was used to develop HSC for Chinook spawning depth, velocity, and substrate, which are described in the following sections.

Chinook salmon did not utilize depths from 0.0-0.5 ft for spawning; this range of depths was therefore assigned a suitability index of 0.0 (Figure 6.1-13). Depths ranging from 1.0 to 1.6 ft appeared to be most often utilized for spawning and were therefore assigned a suitability index of 1.0. Based on utilization patterns, a linear relationship between depth and suitability was assumed for depths between 0.5 and 1.0 ft. Because it was assumed that depths greater than 1.6 ft would not likely limit spawning, a suitability index of 1.0 was extended out to depths of 4.0 ft, which was the maximum depth commonly encountered in tributary habitats of the middle Susitna River.

Velocities ranging from 0.0-0.3 ft/s were not utilized for spawning and thus were assigned suitability indices of 0.0 (Figure 6.1-14). Velocities from 1.7 to 2.3 ft/s were most often utilized for spawning and were therefore assigned a suitability index of 1.0. Suitability indices of 0.25 and 0.60 were assigned to velocities of 0.8 and 2.6 ft/s, respectively, based on observed utilization. Velocities greater than 4.5 ft/s were considered unsuitable for spawning and assigned a suitability index of 0.0.

Utilization data indicated that small cobble substrates were the most often utilized for spawning. These size classes were assigned a suitability index of 1.0 (Figure 6.1-15). Based on literature information (Beauchamp et al. 1983; Estes et al. 1981), the suitability index of 1.0 extended to include large gravel substrates. Small gravel and smaller substrates were not utilized; however, 1iterature data (Beauchamp et al. 1983; Estes et al. 1981) indicated that small to large gravel substrates may be used by spawning Chinook salmon. A linear relationship between substrate and suitability was therefore assumed for substrates ranging from small gravel (with a suitability of 0.0) to large gravel/small cobble (with a suitability of 1.0). Large cobble and boulder substrates were a1so utilized, but to a lesser extent than small cobble substrates. However, it was assumed that the field observations were biased toward larger substrates and 1iterature information indicated that large cobble and boulder substrates were less preferred than large gravel and small cobble substrates (Beauchamp et al. 1983; Estes et al. 1981). Based on this rationale, large cobble substrates were assigned a suitability index of 0.7, large cobble/boulder substrates were assigned a suitability index of 0.35, and boulder substrates were assigned a suitability index of 0.0.

6.1.2.3.2. Juvenile Rearing

6.1.2.3.2.1. Middle Susitna River

Suchanek et al. (1984a) captured a total of 4,395 juvenile Chinook salmon from 1,260 sample cells during efforts to collect juvenile salmon suitability criteria data in the Middle Susitna River (Table 6.1-4). Chinook salmon were the only juvenile salmon captured in sufficient numbers to develop separate suitability curves based on turbid vs. clear-water conditions. Thus, observations from electrofishing (clear-water) and seining (turbid-water) were analyzed separately. Analysis of variance on clear-water data indicated that depth and velocity were not significantly related to juvenile Chinook catch when considered individually, but were significant when considered together. Both cover type and percent cover were significantly related to juvenile Chinook catch. Analysis of variance on turbid-water data indicated that juvenile Chinook catch was significantly related to velocity but not depth. The effect of object cover was not analyzed for significance because seining effectiveness was reduced by the amount and type of object cover. Moreover, object cover was considered less important when turbidity was available.

To determine the relative importance of each habitat parameter, composite weighting factors were developed using various combinations of habitat parameters. The effect of depth on the distribution of juvenile salmon was not considered limiting beyond a minimum threshold, and the inclusion of depth in composite weighting factors showed only minimal improvement in the correlation with catch. Therefore, for juvenile Chinook and all other juvenile salmon species considered, depths greater than or equal to 0.15 ft were assigned a suitability index of 1.0 (Figure 6.1-16). Depths less than 0.15 were assigned a suitability index of 0.0 based on professional judgment. While separate depth curves were not developed for clear- vs. turbid-water conditions, Suchanek et al. (1984a) suggested that juvenile Chinook preferred shallower depths in turbid water.

Under clear-water conditions, velocities between 0.35 and 0.65 ft/s were found to be optimal for juvenile Chinook salmon and were assigned a suitability index of 1.0 (Figure 6.1-17). Velocities greater than 0.65 ft/s were assigned decreasing suitability indices, reaching 0.0 at velocities of 2.60 and greater. Under turbid-water conditions, juvenile Chinook appeared to prefer slower velocities; velocities between 0.05 and 0.35 ft/s were found to be optimal and were assigned a suitability index of 1.0 (Figure 6.1-17). Velocities greater than 0.35 ft/s were assigned decreasing suitability indices, and like the clear-water curve, reached 0.0 at velocities of 2.60 and greater. Suchanek et al. (1984a) suggested that the preference for slower velocities in turbid water may be attributable to the absence of velocity breaks to rest behind when turbidity is used for cover rather than objects.

The use of object cover appeared stronger in clear-water compared to turbid water. While the limited use of object cover apparent in turbid water was partly due to gear bias from seining, Suchanek et al. (1984a) found that the distribution of juvenile Chinook salmon was clearly different in turbid water compared to clear water. Depth and velocity were considered the greatest influence on distribution in turbid water, while object cover was more important in clear water. It was concluded that turbidity was used as cover rather than object cover. Thus, suitability criteria for various cover types and percent-cover were developed for clear-water conditions, whereas turbid-water suitability criteria was only varied based on percent cover; all turbid-water cover types were assigned the same suitability (Table 6.1-5).

6.1.2.3.2.2. Lower Susitna River

Data collected in the Lower River by Suchanek et al. (1985) in 1984 showed that high turbidity may limit the distribution of Chinook salmon. Thus, sampled cells were excluded from analyses if turbidities were greater than 350 NTU. Of the remaining 1,155 sample cells, 400 were sampled in water with a turbidity of 30 NTU or less; as with sampling in the Middle River in 1983, 30 NTU was used as the breakpoint between turbid and clear water. Mean adjusted catch was 1.3 fish per cell in the 400 clear-water cells, and 1.1 fish per cell in the 755 turbid cells. Comparisons between Middle and Lower river data were made independently for clear-water and turbid-water conditions.

While Middle River efforts in 1983 suggested that depth in clear water had little effect on juvenile Chinook catch relative to other habitat parameters, Lower River efforts in 1984 suggested a more frequent use of greater depths. Based on this finding, a clear-water Lower River depth curve was developed using professional judgment in which only depths greater than 2.1 ft were assigned a suitability index of 1.0 (Figure 6.1-16). For turbid-water conditions, the Lower River depth curve was developed by adjusting the Middle River curve such that optimum depths ranged from 0.3 to 1.5 ft (Figure 6.1-16). A depth of 0.1 ft was also modified to have a suitability >0.0 based on observations of limited Chinook use at this depth.

In clear water, the distribution of Chinook catch in the Middle River in 1984 showed peak catches at velocities ranging from 0.1 to 0.3 fps. This range suggested that under clear-water conditions, Chinook used lower velocities in the Lower River compared to the Middle River. The 1984 clear-water distribution of catch by velocity interval was more similar to the 1983 turbid-water suitability criteria. Thus, the 1983 turbid-water velocity criteria from the Middle River were selected to represent the clear-water velocity criteria for the Lower River (Figure 6.1-17). Under turbid-water conditions, velocities used by juvenile Chinook were similar in the Lower and Middle River and the turbid-water Middle River velocity criteria was considered appropriate for the Lower River. Thus, the selected velocity criteria for the Lower River was identical for turbid- and clear-water conditions (Figure 6.1-17).

In clear water, the observed relationship between percent cover and catch in the Lower River was found to be very similar to the suitability criteria developed for the Middle River in 1983. Thus, the Middle River suitability criteria were considered a good estimate of this relationship for the Lower River (Table 6.1-6). Likewise, the turbid-water Middle River suitability criteria for percent cover were deemed appropriate for turbid-water conditions in the Lower River.

Clear-water cover type suitabilities derived for the Lower River in 1984 differed dramatically from those derived in the Middle River in 1983. Compared to the Middle River, debris was used less frequently in the Lower River while emergent vegetation was more frequently used. Thus, the clear-water cover type suitability criteria for the Lowe River was adjusted accordingly (Table 6.1-6). Catches in cells without object cover were also relatively higher in the Lower River than in the Middle River. However, this difference was attributed to a greater use of deeper water for cover in the Lower River, and suitability for "no cover" from the Middle River was therefore retained. While turbid-water cover type suitability criteria were not developed for the Middle River, Suchanek et al. (1985) refined cover type suitability criteria specific to the Lower River. To account for the reduced importance of object cover under turbid conditions, a maximum suitability index of 0.4 was applied to all cover types.

6.1.2.4. Coho Salmon

Coho salmon HSC curves were developed for spawning for the Middle River (Vincent-Lang et al. 1984b) and for juvenile rearing in the Middle (Suchanek et al. 1984a) and Lower River (Suchanek et al. 1985). The bases for the curves developed for each life stage are provided below.

6.1.2.4.1. Spawning

Utilization data were not collected for coho salmon spawning in the Susitna River during the 1980s. However, Vincent-Lang et al. (1984b) developed HSC for the habitat variables of depth, velocity, and substrate based entirely on previously published information, as modified using the opinion of field biologists familiar with Susitna River salmon stocks. Due to limited published information available on coho salmon spawning habitat requirements in the Susitna River watershed, the coho salmon spawning HSC developed for the Terror Lake environmental assessment (Wilson et a1. 1981) were chosen as the basis for modification.

The depth HSC developed for coho salmon spawning generally followed the Terror lake system curve, with the exception that the curve developed for the Susitna River deflected upward at a depth of 0.3 ft as opposed to 0.5 ft in the Terror Lake curve (Figure 6.1-18). This was based on the opinion of project biologists that depths less than 0.5 ft but greater than 0.3 ft, would be suitable for coho spawning. Additionally, the suitability index of 1.0 was extended out to a depth of 4.0 ft based on the opinion of project biologists that depth alone, if greater than 2.0 ft (the depth at which suitability on the Terror Lake curve begins to decline) would not likely limit coho salmon spawning.

The velocity HSC developed for coho salmon spawning generally coincided with the velocity curve developed for the Terror Lake system. The curve was smoothed slightly to reflect the opinion of field biologists familiar with coho salmon spawning in the Susitna River watershed (Figure 6.1-19).

The substrate suitability criteria curve developed for coho salmon spawning in the Terror Lake system was thought to be representative of substrate suitability for coho salmon spawning in the middle reach of the Susitna River and is reflected in the criteria presented (Figure 6.1-20).

6.1.2.4.2. Juvenile Rearing

6.1.2.4.2.1. Middle Susitna River

Suchanek et al. (1984a) captured a total of 2,020 juvenile coho salmon from 1,260 sample cells during efforts to collect juvenile salmon suitability criteria data in the Middle Susitna River (Table 6.1-4). Sample sizes were insufficient to develop separate suitability curves based on turbid vs. clear-water conditions. Juvenile coho catches were small in turbid water and electrofishing (clear-water) data were deemed sufficient for criteria development. Thus, juvenile coho criteria were developed based exclusively on catches under clear-water conditions.

Analysis of variance indicated that depth and velocity were significantly related to juvenile coho catch, as were both cover type and percent cover. To determine the relative importance of each habitat parameter, composite weighting factors were developed using various combinations of habitat parameters. The effect of depth on the distribution of juvenile salmon was not considered limiting beyond a minimum threshold, and the inclusion of depth in composite weighting factors showed only minimal improvement in the correlation with catch. Therefore, for juvenile coho and all other juvenile salmon species considered, depths greater than or equal to 0.15 ft were assigned a suitability index of 1.0 (Figure 6.1-21). Depths less than 0.15 were assigned a suitability index of 0.0 based on professional judgment.

Velocities between 0.05 and 0.35 ft/s were considered optimal for juvenile coho salmon and were assigned a suitability index of 1.0 (Figure 6.1-22). Velocities greater than 0.35 ft/s were assigned decreasing suitability indices, reaching 0.0 at velocities of 2.10 and greater.

Suchanek et al. (1984a) suggested that the distribution of juvenile coho salmon fry may be 1imited by a lack of suitable cover type, noting very strong preferences for certain cover types such as debris and undercut banks. Unlike juvenile Chinook salmon, substrate was seldom used as cover by juvenile coho. Also unlike Chinook salmon, coho salmon did not appear to use turbid water as cover. This was consistent with other studies reviewed by Suchanek et al. (1984a), including Bisson and Bilby (1982) and Sigler et al. (1984). In addition, catches of coho salmon were very low in turbid side channels (Dugan et al. 1984). However, cover types preferred by coho were also very scarce at these sites and almost impossible to sample effectively with seines. Suchanek et al. (1984a) speculated that coho may leave a site when turbidities exceed a certain level. Based on this information, suitability criteria developed for percent cover and cover type are provided in Table 6.1-5.

6.1.2.4.2.2. Lower Susitna River

Sampling in 1984 by Suchanek et al. (1985) captured few coho in habitat types other than tributary mouths in the Lower River. Therefore, only tributary mouth data were used to compare suitability criteria for the Middle and Lower River. Turbidities in the tributary mouths were generally less than 30 NTU.

A total of 345 cells with complete habitat data were sampled in tributary mouths as well as another 2 cells with partial habitat data. The mean adjusted catch in these cells was 1.2 fish/cell. Of the habitat parameters considered, cover type was most highly correlated with coho catch.

For depth, the catch distributions from the Lower River in 1984 were very different from catch distributions in the Middle River in 1983. However, after adjusting for the effects of velocity, percent cover, and cover type there was no trend in depth suitability. Therefore, depth suitability criteria for the Lower River was not changed from that developed for the Middle River (Figure 6.1-21).

For velocity, the catch distribution from the Lower River in 1984 matched closely with the suitability criteria derived for the Middle River in 1983. The Middle River velocity criteria were therefore chosen as representative for the Lower River (Figure 6.1-22).

In relation to percent cover, the distribution of coho catch data from the Lower River in 1984 showed slight differences from the Middle River data in 1983. However, after adjusting for the effects of other habitat parameters, results from the two years appeared more similar. Because the 1983 sample size was larger, the percent cover suitability relationship for the Middle River was chosen for use in the Lower River (Table 6.1-6).

Initial calculations of the suitability of cover type indicated that suitabilities in the Lower River in 1984 were similar to those found in the Middle River. However, after adjusting for the effects of other habitat parameters, some differences were apparent and the cover type suitability for the Lower River was adjusted accordingly (Table 6.1-6).

6.1.2.5. Pink Salmon Spawning

Utilization data were not collected for pink salmon spawning in tributaries of the Middle River during the 1980s. Rather, Vincent-Lang et al. (1984b) developed depth, velocity, and substrate HSC for pink salmon spawning based solely on previously published information as modified by the opinions of project biologists familiar with Susitna River pink salmon stocks. As with coho salmon, limited information was available on pink salmon spawning habitat suitability in the Susitna River watershed (Estes et al. 1981). Therefore, spawning HSC developed in the Terror Lake environmental assessment (Wilson et al. 1981) were chosen as the basis for modification.

Because the Terror River has hydraulic and physical characteristics similar to many of the larger clear water tributaries of the middle Susitna River, the curves developed for pink salmon depth, velocity, and substrate spawning suitability were considered an appropriate basis for modification by Vincent-Lang et al. (1984b). The depth suitability criteria curve developed for pink salmon spawning approximated the depth suitability curve developed for the Terror Lake system, except that the suitability index of 0.0 was extended from 0.1 to 0.3 ft (Figure 6.1-23). It was also assumed that depths less than 0.3 ft would not be suitable for pink salmon spawning. A final modification was to extend the suitability index of 1.0 out to 4.0 feet based on the opinion of field biologists that depths greater than 2.5 ft (the depth at which suitability in the Terror Lake curves begins to decline) would not likely limit pink salmon spawning in tributaries of the Middle Susitna River.

The velocity suitability criteria curve developed for pink salmon spawning generally matched the velocity suitability curve developed for the Terror Lake system except that velocities ranging from 2.0 to 5.0 ft/s were assigned slightly higher suitability indices (Figure 6.1-24). This modification was based on the opinions of project biologists that these velocities are utilized to a greater degree by spawning pink salmon in tributaries of the Middle River.

The substrate suitability criteria curve developed for pink salmon spawning in the Terror Lake system was considered representative of substrate suitability for pink salmon spawning in the Middle Susitna River (Figure 6.1-25).

6.1.2.6. Rainbow Trout Adult

Suchanek et al. (1984b) captured a total of 143 adult rainbow trout by boat electrofishing (n=44) and hook-and-line sampling (n=99) in the Middle Susitna River (Table 6.1-7). Adult rainbow trout captured by boat electrofishing were typically found in cells with water velocities less than 1.5 ft/s. Preferred cover types included rocks with diameters >3 inches, and secondarily, debris and overhanging riparian vegetation. The highest densities of adult rainbow trout were found in cells with 6 to 25% object cover and greater than 50% object cover.

Results of hook and line sampling suggested that adult rainbow trout preferred pools with depths greater than 2.0 ft. As with other adult resident species however, depth was only thought to limit the distribution of adult rainbow trout as a minimum. Therefore, for all adult resident species, depth suitability was conservatively set to 1.0 for all depths greater than 0.6 ft, and to 0.0 for depths less than 0.5 ft (Figure 6.1-26).

Results of hook and line sampling suggested that adult rainbow trout preferred pools with velocities less than 0.5 ft/s. However, because electrofishing data were collected at more cells in a wider variety of habitat types, velocity HSC were fit to the boat electrofishing data. Based on this information, velocities between 0.05 and 1.05 ft/s were assigned a suitability of 1.0, with decreasing suitability values up to 4.5 ft/s, which was assigned a suitability of 0.0 (Figure 6.1-27).

Hook and line sampling also suggested that adult rainbow trout used debris, undercut bank, and riparian vegetation cover more than cobble or boulder cover. Abundant cover was generally considered important to adult rainbow trout distribution. Because electrofishing data were collected at more cells in a wider variety of habitat types, cover type HSC were also fit to the boat electrofishing data. Since the hook and line data suggested that debris, overhanging riparian vegetation, and undercut bank cover types were more suitable than cobble or boulders, suitability for these cover types were adjusted to the suitability of cobble and boulders, which was 1.0. Suitability indices for each cover type are presented in Table 6.1-8 and were developed for both clear- and turbid-water conditions.

6.1.2.7. Arctic Grayling

Suchanek et al. (1984b) captured a total of 140 adult arctic grayling by boat electrofishing (n=138) and hook-and-line sampling (n=2) in the Middle Susitna River (Table 6.1-7). Adult arctic grayling were often found to use rocks for cover as well as high velocity and relatively deep water (Suchanek et al. 1984b). As with other adult resident species, however, depth was only thought to limit the distribution of adult arctic grayling as a minimum. Therefore, for all adult resident species, depth suitability was conservatively set to 1.0 for all depths greater than 0.6 ft, and to 0.0 for depths less than 0.5 ft (Figure 6.1-28). HSC were developed by fitting catch distributions to values of observed velocity (Figure 6.1-29) and cover type. Arctic grayling were thought to avoid high turbidity waters and make little use of turbidity for cover. Suitability indices for each cover type are presented in Table 6.1-8 and were developed for both clear- and turbid-water conditions.

6.1.2.8. Round Whitefish

Round whitefish HSC curves were developed for adults and juvenile rearing in the Middle River (Suchanek et al. 1984b). The basis for the curves developed for each life stage is provided below.

6.1.2.8.1. Adult

Suchanek et al. (1984b) captured a total of 138 adult round whitefish by boat electrofishing in the Middle Susitna River (Table 6.1-7). As with other adult resident species considered, depth was only thought to limit the distribution of adult round whitefish as a minimum. Therefore, for all adult resident species, depth suitability was conservatively set to 1.0 for all depths greater than 0.6 ft, and to 0.0 for depths less than 0.5 ft (Figure 6.1-30).

HSC for velocity (Figure 6.1-31) and cover type were developed by fitting suitability values to catch distributions. Velocity did not appear to have a strong effect on distribution, although observations most frequently occurred at velocities of 2 to 3 ft/s. Distribution of adult round whitefish was influenced by turbidity, presumably as a use of cover. Round whitefish also used object cover, most frequently in the form of cobble or boulders, debris, and overhanging riparian vegetation. Suitability indices for each cover type are presented in Table 6.1-8 and were developed for both clear- and turbid-water conditions.

6.1.2.8.2. Juvenile Rearing

Suchanek et al. (1984b) found that turbidity had a significant ($p < 0.01$) effect on the relative abundance of juvenile round whitefish. Catch rates in water with turbidity less than 30 NTU were extremely low. The total catch (n=569) of round whitefish by beach seines in turbid (greater than 30 NTU) water was predominantly comprised of age 0+ juveniles. Mean catches by velocity, depth and percent cover suggested that velocity had the greatest effect on distribution. Juvenile round whitefish showed a strong preference for water without a significant velocity. Catches in cells with little object cover were higher than in cells with large amounts of cover, suggesting that object cover is not major determinant of habitat use. However, because beach seining efficiency was greatly reduced by the amount and type of cover present, catch distributions by cover type were not presented. For round whitefish fry, shallow depths were found to be most suitable.

Round whitefish were the only juvenile resident species for which Suchanek et al. (1984b) captured sufficient numbers to develop HSC. HSC were fit to the catch distributions for both depth (Figure 6.1-32) and velocity (Figure 6.1-33) by hand using professional judgment. Suitability for turbid water for all cover types was set to 1.0 and suitability for all cover types in clear water was set to 0.0 (Table 6.1-8).

6.1.2.9. Longnose Sucker Adult

Suchanek et al. (1984b) captured a total of 157 adult longnose sucker by boat electrofishing in the Middle Susitna River (Table 6.1-7). As with other adult resident species, depth was only thought to limit the distribution of adult longnose sucker as a minimum. Therefore, for all adult resident species, depth suitability was conservatively set to 1.0 for all depths greater than 0.6 ft, and to 0.0 for depths less than 0.5 ft (Figure 6.1-34). Adult longnose sucker HSC were developed for velocity (Figure 6.1-35) and cover type by fitting observed distributions of catch. Adult longnose suckers were often found to use turbid water for cover, but also emergent or aquatic vegetation, debris, and overhanging riparian vegetation (Suchanek et al. 1984b). Shallow depths and waters of low velocity were found to be most suitable. Suitability indices for each cover type are presented in Table 6.1-8 and were developed for both clear- and turbid-water conditions.

6.1.2.10. Burbot Adult

Suchanek et al. (1984b) captured a total of 18 adult burbot by boat electrofishing in the Middle Susitna River (Table 6.1-7). Other catch data from the 1980s consistently documented adult burbot in the mainstem during the summer (ADF&G 1983c), suggesting they prefer areas of moderate to high turbidities (Suchanek et al. 1984b). Telemetry data also found burbot consistently in the mainstem. While in these mainstem areas, radio tagged burbot appeared to prefer low velocities (<1.5 ft/s) and shallow depths (approximately 2.5 ft). Burbot also appeared to prefer areas with small cobble (referred to as rubble) or large cobble (referred to as simply cobble) substrate; however, nearly all of the mainstem river between the Chulitna River confluence and Devils Canyon, where the radio tagged fish were found, had predominately small or large cobble substrate. Burbot catches were insufficient to develop HSC for this species.

6.2. Other Relevant HSC Curve Sets

While the HSC curves developed for the Susitna River during the 1980s represent the most site-specific information available for the Susitna-Watana IFS, reviewing other curve sets offers a comparative means for evaluating similarities and differences for a given species and life stage. Vincent-Lang et al. (1984a, 1984b) and Suchanek et al. (1984a) reviewed other curve sets available at the time and some of the resulting comparisons are described below. Additional HSC data were compiled, reviewed and compared with the 1980s data as part of this evaluation. Given the scope of curve sets already developed for the Susitna River, the comparisons were limited to information from Alaska studies.

6.2.1. Study Descriptions

Baldrige (1981) developed HSC curve sets for the Terror and Kizhuyak rivers, located on the northern end of Kodiak Island, Alaska. These curves were also reviewed by researchers for the Su-Hydro instream flow study of the 1980s, using an alternate reference citation (Wilson et al. 1981). Fish species present in the Terror and Kizhuyak basins include pink, chum, and coho salmon, and Dolly Varden. The Terror River basin drains a 46.3-square mile area and average annual flow is 224 cfs. The river valley is broad, U-shaped, and supports abundant vegetation. The Kizhuyak River basin drains approximately 54 square miles and monthly flows average between 24 and 370 cfs. Study reaches were located in the lower and middle reaches of the Kizhuyak River. Channel form consists of a broad, flat floodplain, leading into an intertidal delta system. Preliminary curves were formed from available literature for the Kodiak Island area. Field data collected from March through October of 1980 were used to refine the preliminary curve sets. Point measurements of depth, velocity, substrate, and temperature were made at each fish location. HSC curves for depth, velocity, and substrate were produced for spawning pink, chum, and coho salmon and Dolly Varden. Insufficient field data were collected for development of site-specific curves for coho and Dolly Varden spawning. A total of 815 observations were made for pink spawning, 121 for chum spawning, 752 for coho fry, 199 for coho juvenile, 460 for Dolly Varden fry, and 344 for Dolly Varden juvenile.

Lyons and Nadeau (1985) developed HSC curve sets for the Wilson River and Tunnel Creek, which are located in the south-central part of the Misty Fjords National Monument, about 50 miles east of Ketchikan, Alaska. Both streams have steep topography, high drainage density, shallow, porous and well-drained soils and large areas of exposed bedrock. These conditions result in a “flashy” basin hydrology. Field sampling was conducted in August and October of 1984. The Wilson River watershed encompasses 116 square miles while the Tunnel Creek watershed encompasses 9.9 square miles. The average annual discharge is 1,390 cfs in the Wilson River and 68 cfs in Tunnel Creek. Pink and chum salmon are the most abundant fish species present, though coho, Chinook, and sockeye salmon, steelhead, and Dolly Varden are also present. Habitat data were collected for pink and chum salmon. While a large number of measurements were made for pink salmon spawning, actual sample sizes are not reported. Depth and velocity measurements were made for 27 spawning chum salmon. HSC curves for Chinook and coho spawning, incubation, fry, and juveniles were based solely on pre-existing depth and velocity curves.

Estes and Kuntz (1986) collected habitat utilization data for rearing juvenile Chinook salmon in selected bank-type habitats of the Kenai River from the mouth to the outlet of Skilak Lake. Data indicated that depth, velocity, and cover could be used to assess the usability of habitat for juvenile Chinook. Velocity and cover appeared to be the most important in determining habitat usability, though a set of “weighting factors” were developed all three habitat parameters.

More recently, PLP (2011) has developed HSC curves for several species inhabiting the North and South Fork Koktuli rivers (Nushugak River tributaries) and Upper Talarik Creek (a Lake Iliamna/Kvichak River tributary). HSC curves were developed using a combination of literature information and curve sets from other studies, as well as through collecting and analyzing site-specific data for various target species and life stages. The collection of site-specific data focused on collecting data related to spawning and juvenile rearing habitat use for salmon, and adult rearing habitat use for resident salmonids. HSC data collected included microhabitat data (depth, velocity, and substrate) over redds and at observed locations of juvenile and adult habitat use from 2005 to 2008. HSC curves included the following species (and life stages): sockeye salmon (spawning and juvenile), Chinook salmon (spawning and juvenile), coho salmon (spawning and juvenile), and arctic grayling (adult).

6.2.2. HSC Data Set Comparisons

Vincent-Lang et al. (1984a) compared some of their findings with information available in the literature. For chum salmon spawning, utilization data collected within the Susitna River drainage were similar to the ranges summarized in a literature survey by Hale (1981). While Hale (1981) did not develop criteria curves to which specific comparisons could be made, the importance of upwelling groundwater to chum was emphasized which supported the binary criteria developed for upwelling by Vincent-Lang et al. (1984a). Wilson et al. (l981) developed suitability curves for chum salmon spawning that generally fell within the range of the Susitna Basin curves, although some differences were found. Differences between these curve sets are illustrated for depth (Figure 6.1-1) and velocity (Figure 6.1-2). For example, the chum salmon velocity suitability curves developed for the Susitna River indicate a peak suitability in much slower waters than do the Wilson et al. (1981) curves, although the upper limits of the two curves only differed by 0.5 ft/s. Vincent-Lang et al. (1984a) suggest this difference may be attributed to the fact that upwelling was not taken into account by Wilson et al. (1981). The substrate suitability curves for chum salmon spawning for the two studies were similar, although the Susitna River curve had a slightly wider range.

Vincent-Lang et al. (1984a) also reviewed information related to sockeye salmon spawning criteria summarized in a literature review by the U.S. Fish and Wildlife Service (USFWS 1983). The ranges of depth, velocity, and substrate conditions observed by Vincent-Lang et al. (1984a) in sloughs and side channels of the middle Susitna River were within the ranges outlined in the USFWS review. However, preference or suitability curves were not developed, limiting the value of these comparisons. Curves developed for the North/South Fork Koktuli rivers and Upper Talarik Creek (PLP 2011) were generally similar to those developed for the Susitna River (Figure 6.1-7). However, the velocity curves were considerably different (Figure 6.1-8); optimal velocities were much slower for the Susitna River curves. This difference may be related to the importance of upwelling for sockeye spawning in the Susitna River. Curves for substrate had similar optimal values, though a broader range of substrate size classes were deemed suitable for the Susitna River curve (Figure 6.1-9). For juvenile sockeye, the PLP (2011) curves were slightly different, showing higher suitability at greater depths (Figure 6.1-11), and slower velocities (Figure 6.1-12).

For Chinook spawning, the depth curve developed by Vincent-Lang et al. (1984b) for the Susitna River showed a slightly higher suitability for greater depths compared to the Wilson River/Tunnel Creek curve (Lyons and Nadeau 1985) (Figure 6.1-13). However, the depth curve for the North/South Fork Koktuli rivers and Upper Talarik Creek (PLP 2011) showed higher suitability for greater depths. Spawning velocity curves (Figure 6.1-14) showed similar deviations, with higher suitability for greater velocities compared to the North/South Fork

Koktuli rivers and Upper Talarik Creek curve (PLP 2011), and lower suitability for slower velocities compared to the Wilson River/Tunnel Creek curve (Lyons and Nadeau 1985). Substrate suitability was generally similar (Figure 6.1-15) for the Susitna River curve and the North/South Fork Koktuli rivers and Upper Talarik Creek (PLP 2011); the slight differences may be a function of standardizing the different substrate classifications used in each study.

The Susitna River depth curves developed for juvenile Chinook salmon by Suchanek et al. (1984a, 1985) showed a dramatic difference in suitability between the Middle and Lower River and under turbid- and clear-water conditions. Suchanek et al. (1984a) also reviewed depth criteria developed in other systems, noting that they varied significantly from the Susitna River curves in which optimum depths were 1.0 to 1.5 ft in clear water and less than 0.5 ft in turbid water. A depth probability-of-use curve described from Bovee (1978) showed an optimum range from 1.2 to 3.0 ft, while described from Delaney and Wadman (1979) suggest an optimum of 2.5 to 3.2 ft. Findings from Burger et al. (1982) were reviewed in which Chinook fry were observed in pools to ten ft deep and depths of less than 0.2 ft were thought to be avoided. The juvenile Chinook depth curves for the North/South Fork Koktuli rivers and Upper Talarik Creek (PLP 2011) and the Wilson River/Tunnel Creek (Lyons and Nadeau 1985) both generally fall in between the two Susitna River curves (Figure 6.1-16). The depth curve for the Kenai River, in contrast, is nearly identical to the Lower Susitna River turbid-water curve.

The various velocity curves for juvenile Chinook are generally similar, showing a decrease in suitability beyond an optimum of roughly 0.7 ft/s (Figure 6.1-17). Suchanek et al. (1984a) reviewed information from Bovee (1978) and Burger et al. (1982), indicating a probability of velocity utilization that was almost identical with the curve developed for clear water of the Susitna River with the peaks at approximately 0.2 to 0.6 ft/sec. Minnow trap Chinook catch data from the Little Susitna River was also compared (Delaney and Wadman 1979), and suggested an optimum velocity for juvenile Chinook salmon from approximately 0.3 to 0.6 ft /sec, with little use of velocities greater than 1.8 ft /s.

While coho spawning HSC data were not collected by Vincent-Lang et al. (1984b), the literature-based curves for the Susitna River are generally in agreement with other studies. Suitability reached an optimum at only a slightly greater depth (1.1 ft) for the North/South Fork Koktuli rivers and Upper Talarik Creek (PLP 2011) compared to that chosen for the Susitna River (Figure 6.1-18). Coho spawning velocity suitability was generally the same for all curves considered (Figure 6.1-19). However, optimal substrates were larger for the North/South Fork Koktuli rivers and Upper Talarik Creek curve (PLP 2011) (Figure 6.1-20).

For juvenile coho, Suchanek et al. (1984a) reviewed other studies in comparison to the Susitna River. On the Terror and Kizhuyak rivers, for example, optimum depths for coho fry were cited as from near 0.0 ft to 1.0 ft and then declining rapidly to zero at 2.5 ft (Baldrige 1981). Suchanek et al. (1984a) also cited data from Bovee (1978) indicating very 1ittle use until 1.0 ft in depth with an optimum at 2.0 ft and a gradual decline to zero use at 5.0 ft. In the Susitna River, Suchanek et al. (1984a) reported an apparent optimum suitability at approximately 1.6 to 2.0 ft with limited data above this depth. Based on these conflicting observations, Suchanek et al. (1984a) concluded that depth suitability may vary greatly from river to river for unknown reasons, but also suggested that the importance of depth may be highly correlated with other habitat parameters. Thus, the selected depth curve for juvenile coho was fairly inclusive (Figure 6.1-21).

Suchanek et al. (1984a) also reviewed other sources of information regarding juvenile coho depth suitability, concluding that the optimum velocities derived for coho in the Susitna River were very similar to velocity criteria developed for coho in other streams. This is also generally consistent with the velocity suitabilities plotted in Figure 6.1-22.

6.3. Susitna-Watana HSC Studies

6.3.1. 2012 HSC Studies

Just like the Su-Hydro 1980s studies, one of the major components associated with completion of the Susitna-Watana IFS will be the development and selection of species and life stage HSC curves. This work was initiated in 2012 and will be continued in 2013-2014. The 2012 studies were conducted over a three month period extending from July to September. Results of the 2012 surveys are presented below.

Importantly, there were no significant deviations or required revisions to the Final 2012 Instream Flow Planning Study (March 20, 2012) related to the 2012 HSC data collection effort. The only exception was the expansion of the proposed sampling area to include a portion of the Lower River Segment (RM 95.4 to RM 77.0). HSC sampling within the lower river segment was added when it became evident that IFS studies sites were being proposed for that area. As such, results of 2012 HSC surveys are reported for both the Lower and Middle River segments of the Susitna River. There were no changes to the timing or sampling methods proposed and utilized in response to expansion of the 2012 sampling area.

6.3.1.1. Mainstem Susitna River Flow and Temperature – 2012

Discharge data for the Susitna River during the 2012 data collection period was obtained from the USGS Gold Creek Station (USGS #15292000), located approximately 15 miles upstream of Curry, Alaska (http://water.usgs.gov/). From 17 July to 19 September 2012, daily discharge averaged 18,069 cubic feet per second (cfs) and ranged from a high of 29,600 cfs on 23 July to a low of 10,200 cfs on 14 September (Figure 6.3-1).

Mainstem water temperature during this time period as reported at the Whiskers Creek monitoring station ranged from a high of 16°C to a low of 5°C during the HSC sampling period of mid-July to mid-September, 2012(Figure 6.3-2).

6.3.1.2. Preliminary Selection of Target Species and Life Stages

For the 2012 HSC sampling effort, a preliminary list of target fish species for sampling included Chinook, coho, chum, and sockeye salmon; rainbow trout; arctic grayling; Dolly Varden; burbot; longnose sucker; humpback whitefish; and round whitefish. These species are generally considered the most sensitive to habitat loss through manipulation of flows in the Susitna River. Other species and life stages will be considered in collaboration with the TWG.

6.3.1.3. Study Site Selection

The 2012 collection of microhabitat use data focused on mainstem, side channel, side slough, and tributary delta habitat areas identified as having the highest abundance/use during the 1980s surveys (Table 6.3-1). This information was used to define the relative proportion of species and life stages that utilize macro habitat types and the selection and use of species and life stage specific microhabitat characteristics. The focus of the 2012 HSC curve sampling was on the upper portion of the Lower River Segment and the Middle River Segment from the confluence with Montana Creek upstream to near the proposed Watana Dam site.

The selection of study sites for the 2012 collection of HSC microhabitat data was based on several factors including:

- The distribution of the most highly utilized macrohabitat types (main channel, side slough, side channel, tributary delta) by fish species and life stage;
- Having good spatial representation of sampling sites within a segment;
- Location of the sampling sites to proposed flow routing and IFS Focus Areas (see Section 3);
- Prevailing flow conditions/visibility; and
- Accessibility and safe sampling conditions.

Table 6.3-1 provides a summary of the species and life stages, macrohabitat types, study sites, potential sampling techniques, and proposed sampling timing that was applied during the 2012 effort.

6.3.1.4. Field Data Collection

The 2012 HSC field effort focused primarily on collecting field measurements of microhabitat use by different species and life stages. These data were then used to develop preliminary site-specific HSC curves for comparison with the HSC curves developed during the 1980s studies.

Specific objectives of the 2012 field effort were to:

- Provide HSC data collection training to field personnel from other AEA contractors involved in fish studies to ensure uniformity in data collection efforts;
- Collect microhabitat utilization data for selected target fish species and life stages;
- Record different macro and mesohabitat types utilized by the different fish species and life stages;
- Recommend additional/new data collection techniques to be used during the 2013/2014 HSC data collection efforts.

The 2012 HSC field effort consisted of three separate sampling events completed during July 17–19, August 21–23, and September 17–19. During 2012 sampling, site-specific habitat data were collected at 22 Middle River Segment sites located in tributary deltas, main channel, side channel, and side slough macrohabitats between RM 178.0 and RM 101.4 (Table 6.3-2). In the Lower River Segment, 11 sites were sampled in tributary deltas, side channel and side slough habitats between RM 95.4 and RM 77.0 (Table 6.3-2). Site-specific observations were obtained using visual means in clear water areas using snorkel and pedestrian surveys and pole/beach seining methods in turbid water areas. Specific sampling methods utilized for each of these methods is provided in subsequent sections.

6.3.1.4.1. HSC Field Data Collection Training

To ensure consistent HSC data collection between field crews, field training sessions were held with crew leaders from HDR (James Brady, HDR Alaska) and LGL (Sean Burril, LGL Alaska) on July 17 and 19, 2012, respectively. Prior to the training sessions, standardized data collection forms were developed and distributed to representatives from each firm for review and comment. During the training sessions, field personnel from each firm reviewed the data collection forms, equipment needs, sampling techniques, definition of terms, quality control checks, and data storage and management procedures. HSC data collection efforts conducted by both LGL and HDR were to be focused on macro and microhabitat use by spawning anadromous (LGL) and resident fish species only. Data collection efforts by LGL were to be focused on the Middle River Segment, while HDR was focused their efforts on the Upper River Segment.

6.3.1.4.2. Spawning/Redd Surveys

The timing and location of spawning/redd surveys was based in part on the periodicity data developed from the 1980s data as well as from information obtained during radio telemetry surveys conducted as part of fisheries studies (LGL 2012 Interim Draft Report). This information was used to help identify sampling timing and areas with the highest concentration of spawning activity for the five salmon species (sockeye, coho, Chinook, pink, and chum salmon).

Although several different methods were used to identify the presence of spawning fish (biotelemetry, pedestrian survey, and snorkel surveys), once an actively spawning fish or newly constructed redd was identified in the field (Figure 6.3-3), the following measurements were made:

- Location of sample area on high-resolution aerial photographs and/or GPS location for individual or groups of measurements
- Species of fish occupying the redd or responsible for construction
- Redd dimensions (length and width in feet to nearest 0.1 ft)
- Water depth at upstream end of the redd (nearest 0.1 ft), using a top setting rod
- Mean water column velocity (feet per second to nearest 0.05 fps), using a Swoffer current meter
- Substrate size (dominant, sub-dominant, and percent dominant) characterized in accordance with a Wentworth grain size scale modified to reflect English units (Table 6.3-3)
- Water temperature (to nearest 0.1 degree Celsius)
- Indications of the presence of groundwater upwelling (changes in water clarity, temperature, or visible upwelling)
- Turbidity (using a portable turbidity meter) for each group of redds or in mainstem habitat areas with relatively large concentrations of spawning fish (this information to be used for comparison to measurements made during the 1980s survey)

6.3.1.4.3. Snorkel Survey/Fish Observations

Snorkel surveys were conducted by a team of two or three fish biologists with extensive experience in salmonid species identification. These surveys were conducted in conjunction with adult spawner surveys at those areas identified in Table 6.3-1.

Prior to each survey, a Secchi disk reading was taken to determine the visibility corridor for sampling. For this, a Secchi disk was held underwater by the data recorder, and a tape measure extended by the snorkeler from the Secchi disk outward to a point where the disk is no longer clearly visible (Figure 6.3-4). As a general rule, when visibility conditions were less than four feet, no underwater sampling occurred. Water temperature was also recorded at the beginning of each survey.

Starting at the lower/downstream point within a study area, the snorkelers proceeded in an upstream direction making observations of all microhabitat types within their line of sight (Figure 6.3-5). The following information was recorded for each observation:

- Location of sample sites or areas marked on high-resolution aerial photographs and/or GPS location recorded for individual or groups of measurements
- Fish species observed
- Assumed life stage (adult, juvenile, or fry)
- Total fish length (estimated mm)
- Number of fish observed
- Mesohabitat type
- Water depth (nearest 0.1 ft) using a top setting rod
- Location in water column (distance from the bottom)
- Focal point (location fish observed in the water column) and mean column velocity (feet per second to nearest 0.05 fps) measured using a calibrated Swoffer current meter
- Substrate size (dominant, sub-dominant, and percent dominant) characterized in accordance with a Wentworth grain size scale modified to reflect English units (Table 6.3-3)
- Proximity/affinity to habitat structure/cover features (e.g., boulder, wood debris, aquatic vegetation, undercut bank, and overhanging vegetation)
- Relevant comments pertaining to cover associations and/or behavioral characteristics of the fish observed

All data were recorded on waterproof data sheets to ensure consistent data collection between surveys. Only fish holding over a fixed position were included in the microhabitat survey. Moving fish were not enumerated in order to minimize inaccurate habitat measurements, and to prevent double-counting of fish.

6.3.1.4.4. Pole/Beach Seining

Pole seining was used in turbid water areas of all mainstem habitat types that could not be sampled with underwater techniques due to visibility limitations. Pole seines used in this effort were 4 feet in depth and 40 feet in length, 3/16-inch mesh (net body) with a 1/8-inch mesh net bag. The pole seine was operated with one person on each pole and the net was worked through the sample area in an upstream direction (Figure 6.3-6). The seine contains a collection bag in the middle to collect fish as they are directed into the net.

An attempt was made to sample fish from relatively small areas of approximately 15 feet by 15 feet with consistent depths, velocities, and substrates; however, exact size and dimensions were sometimes changed to facilitate sampling larger areas of relatively uniform habitat or when fish densities were expected to be low. The area (length and width) of each sampled area was recorded on the field form.

Once captured, fish were identified to species, counted, and released in close proximity to the capture site (Figure 6.3-7). For each area sampled, data collection was similar to that collected during snorkel surveys with the exception of fish distance from the bottom and focal velocity. Because no direct observation of the position of the fish in the water column can be made in turbid water, fish position and focal velocity could not be recorded; a single depth and velocity measurement was therefore recorded at a location with representative characteristics of the area seined. All data were recorded on waterproof data sheets. Representative digital photographs were taken of different macro and mesohabitat types where fish of different species and size classes were observed.

6.3.1.5. Data Analysis

Prior to computation of HSC curves, the microhabitat data were entered into commercially available spreadsheets and subsequently checked for data entry accuracy (QC 2). Any necessary edits or corrections were then made to the database and checked by a senior staff member for completeness (QC3). Frequency distributions were then generated for mean velocity, depth, and substrate type for each species. Frequency bin widths of 0.2 were initially used to evaluate the mean velocity and depth utilization distributions. Histogram plots of depth and mean column velocity utilization were then produced for each species and life stage for which field observations were recorded. A subset of HSC curves developed from the 2012 data were then compared with HSC curve sets produced in the 1980s to see if patterns of use were similar. HSC data collected by LGL for spawning fish/redds was reviewed for accuracy and incorporated into the larger data set. No HSC data were received from HDR.

6.3.1.6. Results

A total of 284 observations of site-specific habitat use were recorded during 2012 HSC surveys of the lower and middle segments of the Susitna River. Habitat measurements were obtained for four different life history stages (spawning, juvenile, fry, and adult) and nine different fish species including Chinook, sockeye, chum, coho, and pink salmon; rainbow trout; Arctic grayling; humpback whitefish, and longnose sucker. As previously described, microhabitat observations were concentrated in the Lower and Middle River segments of the Susitna River in macrohabitat types where significant numbers of fish had been observed during the 1980s studies. Figure 6.3-8 displays the relative location of the 2012 HSC observations collected by both R2 and LGL. Spawning HSC observations were predominately made in the Middle River Segment with only 17 of the 117 redd observations made in the Lower River Segment. The number of HSC observations for the adult, juvenile, and fry life stages were split fairly equally between the Lower and Middle River segments with 69 observations in the lower river and 98 in the middle river. A summary of results of the 2012 HSC data collection are presented below for each of the eight species mentioned above.

6.3.1.6.1. Chinook Salmon

In 2012, no Chinook salmon were found spawning in the mainstem Susitna River (Table 6.3-4). Radio telemetry surveys conducted by LGL indicated that adult Chinook were holding in the main channel of the Susitna River, but there was no evidence that any of the 352 tagged fish spawned in the main channel (LGL 2012). A total of 11 Chinook juvenile and 31 Chinook fry microhabitat measurements were recorded, with nearly half (42.8%) of the total Chinook rearing observations occurring in side channel macrohabitat areas (Table 6.3-5). Side slough and tributary delta habitats had nearly equal numbers of observations with 12 and 11, respectively (Table 6.3-5). Half of the Chinook salmon rearing observations occurred during the August 21-23 sampling effort. Thirty-one percent were made during the mid-July sampling and the remaining nineteen percent occurred during the mid-September sampling (Table 6.3-6).

Microhabitat depth measurements of Chinook fry utilization ranged from 0.5-1.9 feet with the highest frequency occurring at a depth of 1.1 feet (Figure 6.3-9). For velocity, fry utilization ranged from 0.1-1.7 feet per second (fps) with the highest frequency occurring at a velocity of 0.1 fps (Figure 6.3-9). Chinook juvenile were most frequently observed in slightly deeper water with depths ranging from 0.5-2.1 feet with peak utilization occurring at a depth of 1.5 feet (Figure 6.3-10). The range of observed velocity utilized by Chinook juvenile was also higher at 0.1-1.9 fps with the highest frequency occurring at velocities of 0.1 fps and 0.9 fps (Figure 6.3-10). Although substrate utilization for both the fry and juvenile life stages of Chinook were greatest for “fines” particle sizes (Table 6.3-3), some utilization was observed at nearly every substrate size (Figures 6.3-9 and 6.3-10).

6.3.1.6.2. Sockeye Salmon

All of the 43 observations of sockeye spawning in the mainstem Susitna River were found in the Middle River Segment in side slough macrohabitats (Table 6.3-4). Only six sockeye fry microhabitat measurement were recorded, with all but one of the observations occurring in side channel macrohabitat areas (Table 6.3-5). As expected, no juvenile sockeye were observed during the HSC surveys as outmigration in the Susitna River occurs shortly after fry emergence (Table 6.3-7 periodicity table). Although sockeye spawning was observed during all three of the HSC surveys, the largest number of redd measurements occurred during the mid-September sampling. All of the sockeye fry observations occurred during the mid-August sampling (Table 6.3-6).

Sockeye spawning depth utilization ranged from 0.7-2.3 feet with the highest frequency occurring at 1.3 feet (Figure 6.3-11). For velocity, spawning utilization ranged from 0.1-1.5 fps with the highest frequency occurring at a velocity of 0.1 fps (Figure 6.3-11). The low velocity utilized by spawning sockeye is not surprising since all observations were made in side slough macrohabitat areas with low mean column velocities. Substrate utilization ranged from sand to small cobble with the highest frequency occurring in areas with medium gravel substrates (Table 6.3-3 and Figure 6.3-11). Water depths associated with the six sockeye fry ranged from 0.7-1.7 feet (Figure 6.3-12), whereas the range of water velocities was limited to 0.1-0.9 fps (Figure 6.3-

12). Substrate utilization for sockeye fry was equally split between sand and small gravel (Figure 6.3-12).

6.3.1.6.3. Pink Salmon

Spawning pink salmon (n=17) were found in both the Lower and Middle River segments with the largest number of observations (n=14) occurring in tributary delta macrohabitats (Table 6.3-4). No fry or juvenile pink salmon life stages were observed during the 2012 HSC surveys. The absence of observations of rearing pink salmon is probably due to the early outmigration of young fish prior to mid-August when the first 2012 HSC survey occurred (Table 6.3-7 periodicity table). All of the pink salmon spawning observations occurred during the mid-August sampling (Table 6.3-6).

Pink salmon spawning depth utilization ranged from 0.5-1.9 feet with the highest frequency occurring at 1.7 feet (Figure 6.3-13). For velocity, spawning utilization ranged from 0.5-3.1 fps with the highest frequency occurring at a velocity of 2.5 fps (Figure 6.3-11). The relatively high range of velocities utilized by spawning pink salmon is not surprising since most (14 of 17) of the observations were made in tributary delta macrohabitat areas which generally have higher mean column velocities than sloughs. Substrate utilization ranged from small gravel to small cobble with the highest frequency occurring in areas with large gravel substrates (Table 6.3-3 and Figure 6.3-13).

6.3.1.6.4. Chum Salmon

Observations of chum salmon spawning were widely distributed in both the lower and middle Susitna river segments with the largest number of observations (n=43) occurring in side slough macrohabitats areas of the Middle River Segment (Table 6.3-4). Overall, chum spawning HSC measurements were collected in six different side sloughs, two tributary deltas (n=4), and one side channel (n=10) macrohabitat area. Eight chum salmon fry and no juvenile chum were observed during the 2012 HSC surveys. Observations of chum fry were nearly equally split between side channel, side slough, and tributary delta macrohabitat types. Chum salmon spawning was observed during both the mid-August and mid-September 2012 HSC samplings (Table 6.3-6).

Depth utilization by spawning chum salmon ranged from 0.3-4.3 feet with the highest frequency occurring at 0.7 feet (Figure 6.3-14). For velocity, spawning utilization ranged from 0.1-2.5 fps with the highest frequency occurring at the lowest measured velocity of 0.1 fps (Figure 6.3-14). Like spawning sockeye salmon, the low velocities utilized by spawning chum is a result of most of the microhabitat use observations being made in side slough macrohabitat areas which generally have low mean column velocities. Substrate utilization ranged from fines to small cobble with the highest frequency occurring in areas with large gravel substrates (Table 6.3-3 and Figure 6.3-14). For chum fry, water depth utilization ranged from 0.5-1.7 feet (Figure 6.3-15). Water velocity utilization ranged from 0.1-1.3 fps with the highest frequency occurring at 0.1 fps (Figure 6.3-15). Substrate utilization for chum fry ranged from fines to large cobble with the highest frequency of use found in areas with fine sediment (Figure 6.3-15).

6.3.1.6.5. Coho Salmon

Like Chinook, there was no coho salmon spawning observed in the mainstem Susitna River during the 2012 HSC surveys (Table 6.3-4). Although a total of 184 adult coho salmon were radio tagged and their movement tracked as part of LGL's adult salmon distribution study, there was no evidence of spawning activity in the main channel of the river (LGL 2012). A total of 19 juvenile and 53 coho fry microhabitat measurements were recorded (Table 6.3-5). Coho fry observations were nearly equally split with 24 measurements made in side slough habitats and 20 measurements in tributary delta macrohabitat areas (Table 6.3-5). For juvenile coho, side slough and tributary delta habitats had equal numbers of observations with eight observations in each (Table 6.3-5). The remaining three observations were made in side slough macrohabitats. Over 98 percent of the coho salmon rearing observations occurred during the mid-July and mid-August sampling effort, with only one observation made during the mid-September sampling (Table 6.3-6).

Microhabitat depth measurements for coho fry utilization ranged from 0.3-2.1 feet with the highest frequency occurring at a depth of 0.9 feet (Figure 6.3-16). For velocity, fry utilization ranged from 0.1-1.7 feet per second (fps) with the highest frequency occurring at a velocity of 0.1 fps (Figure 6.3-16). Coho juvenile were most frequently observed in slightly deeper water with depths ranging from 0.9-2.1 feet with peak utilization occurring at a depth of 1.3 feet (Figure 6.3-17). The range of observed velocity utilized by coho juvenile was slightly lower than for fry at 0.1-1.3 fps with the highest frequency occurring at velocities of 0.1 fps (Figure 6.3-17). Although substrate utilization for both the fry and juvenile life stages of coho occurred over a wide range of particle sizes, the frequency of use by both life stages has the highest for the fines substrate size (Figure 6.3-17).

6.3.1.6.6. Arctic Grayling

Observations of arctic grayling were limited to the adult, juvenile and fry life stages as no grayling spawning was observed. Although arctic grayling were observed in all four macrohabitat types, only two of the 19 total observations were made in main channel macrohabitat areas (Table 6.3-5). Arctic grayling observations were made in both the Lower and Middle River segments. Eight of the 19 arctic grayling observations were for the adult life stage and ten for the fry life stage (Table 6.3-5). No juvenile arctic grayling were observed during the 2012 HSC surveys. Arctic grayling microhabitat use observations were made during all three sampling efforts (Table 6.3-6).

Depth utilization by adult grayling ranged from 1.5-3.1 feet with the highest frequency occurring at 1.5 feet (Figure 6.3-18). For velocity, adult utilization ranged from 0.1-3.9 fps with the highest frequency occurring at the lowest measured velocity of 0.1 fps (Figure 6.3-18). Substrate utilization was limited to small and large cobble (Figure 6.3-18). Only one observation was made for the juvenile life stage; depth was 1.1 feet and velocity was 0.3 fps (Figures 6.3-19 and 6.3-20). For grayling fry, water depth utilization ranged from 0.5-1.7 feet (Figure 6.3-20). Water velocity utilization ranged from 0.1-1.7 fps with the highest frequency occurring at 0.1 fps (Figure 6.3-20). Substrate utilization for grayling fry ranged from fines to large cobble with the highest frequency of use found in areas with fine sediment (Figure 6.3-20).

6.3.1.6.7. Rainbow Trout, Humpback Whitefish, and Longnose Sucker

A combined total of 20 HSC measurements were made for the other three species of fish sampled during the surveys; rainbow trout, humpback whitefish, and longnose sucker (Table 6.3-5). The lowest number of microhabitat measurements was for longnose sucker with only two observations. No spawning observations were made for any of the three species. Seventy-percent of the observations for these species occurred in side channel and tributary delta macrohabitats (Table 6.3-5). None of the three species were detected during sampling of main channel macrohabitat areas.

Adult rainbow trout and juvenile humpback whitefish were the only species and life stage combinations with multiple HSC observations and so only those results are presented here. For rainbow trout adult, depth utilization ranged from 0.9-3.1 feet and velocity utilization ranged from 0.1-1.5 fps (Figure 6.3-21). Substrate utilization ranged from small cobble to boulder (Figure 6.3-21). For juvenile humpback whitefish, depth utilization ranged from 1.1-1.5 feet, and velocity utilization ranged from 0.1-1.1 fps (Figure 6.3-22). Substrate utilization for juvenile whitefish ranged from fines to large cobble with the highest frequency of use found in areas with fine sediment (Figure 6.3-22).

6.3.1.7. Recommendations for 2013 HSC Surveys

This TM summarized relevant information from the 1980s Su-Hydro studies and presented preliminary results of the 2012 HSC surveys. One of the goals of the 2012 HSC surveys was to evaluate the timing and distribution of HSC sampling efforts and the methods used for detecting and measuring microhabitat use by different species and life stages of fish. The following are preliminary recommendations based on results of the 2012 surveys that are designed to help refine the 2013 surveys. It is expected that these recommendations will be discussed and refined during TWG meetings planned for Q1 2013.

- Coordinate with LGL to better identify the beginning of the upstream migration period for each fish species by reviewing fish wheel capture records. Initiate spawning/redd surveys immediately following reports of fish wheel capture of adult fish.
- Work closely with LGL to utilize the results of real-time radio telemetry surveys of adult fish to assist in determining the timing and use of different macrohabitat types. Coordinate HSC spawning/redd sampling to take full advantage of real-time habitat use information obtained from the radio telemetry surveys.
- Review testing results of use of side-scan and DIDSON sonar to detect spawning in turbid main channel and side channel macrohabitat types completed by LGL in September 2012. If these methods show promise for detecting spawning in turbid water areas, work with LGL to expand the use of these methods to both lower and middle river segments to identify spawning/redd areas for microhabitat measurements.
- Based on results of 2013 Winter Pilot studies, include winter surveys of microhabitat use at a representative subset of the IFS Focus Areas. If possible, incorporate nighttime HSC surveys to detect any variations in diurnal microhabitat use by juvenile fish.
- Pursue the use of electrofishing techniques to determine meso and microhabitat use of the target species and life stages in turbid water areas. Although the use of stick seining does

appear effective in capturing fish in turbid water areas, use of this method is somewhat restricted to areas with shallow depth (<4 ft), low velocity, and small substrate sizes.

- Utilizing results of mainstem habitat mapping, conduct systematic sampling of all representative macro and mesohabitat types within each of the IFS Focus Areas. Special effort should be made to ensure that HSC sampling occurs within each of the main channel mesohabitat types present. The proposed number and distribution of 2013 HSC sampling sites will be presented to the TWG during the Q2 2013 meeting.
- Increase the frequency, duration, and distribution of summertime HSC surveys to detect potential difference in microhabitat use by different species and life stages based on spatial and/or temporal variability. HSC sampling crews will work closely with fish distribution surveys to ensure that sampling priority can be given to those macro and mesohabitat types that support the largest diversity and number of fish.

Continue to build HSC database utilizing site-specific microhabitat observations. Utilize database to identify relationships between macro, meso, and microhabitat use by target species and life stages as well as differences in use of clear water versus turbid water and areas with and without groundwater upwelling.

6.3.2. Proposed 2013-2014 Studies

The HSC surveys completed in 2012 provided an initial opportunity to test various gear sampling techniques and to collect a preliminary set of microhabitat data. The results of those surveys will be useful in refining and implementing the more rigorous HSC data collection program in 2013-2014 as specified in RSP Section 8.5.2.1.5.

7. TECHNICAL MEMORANDUM – REVIEW OF HABITAT MODELING METHODS APPLICABLE FOR THE SUSITNA RIVER

Instream flow studies invariably result in the collection of copious amounts of data that are typically evaluated via application of one or more models. These can range from empirically derived models such as those derived from expert habitat mapping (Railsback and Kadvany 2008) to more sophisticated methods involving a suite of hydraulic and habitat models such as are available via the Physical Habitat Simulation (PHABSIM) package of programs that is often referenced as part of the Instream Flow Incremental Methodology (IFIM) (Stalnaker et al. 1995; Bovee 1982). There are many other methods that have been developed and used as part of instream flow studies, some of which are described below, while others can be found in reference documents such as those of Annear et al. (2004), Locke et al. (2008) and others. This TM first describes the types of models that were used as part of the 1980s Su-Hydro studies and then summarizes the methods and models that are being proposed as part of the 2013-2014 Susitna-Watana IFS studies.

7.1. Su-Hydro 1980s Studies

The instream flow studies completed during the 1980s were conducted in the Middle and Lower River segments of the Susitna River downstream of Devils Canyon. Studies during the 1980s were designed to evaluate changes in fish habitat relative to changes in mainstem Susitna River discharge, and employed a variety of techniques that included hydraulic and/or habitat modeling and habitat mapping. In the Middle River, modeling and mapping efforts were performed at 36 sites between River Mile[6] (RM) 148 and RM 101 during 1983 and 1984 (Table 7.1-1, Figures 7.1-1 and 7.1-2). In the Lower River, hydraulic and habitat modeling was completed at 20 sites between RM 92 and RM 35 (Table 7.1-1). Fish habitat availability at different locations was modeled over a range of Susitna River discharges using one or more of the following habitat models: IFIM –IFG3 (HABTAT), Direct Input Habitat (DIHAB), and Resident Juvenile Habitat (RJHAB). The IFIM HABTAT model was used in conjunction with Instream Flow Group (IFG) hydraulic models (IFG-4), whereas no hydraulic modeling was completed in association with DIHAB or RJHAB models. In addition to these modeling techniques, two-dimensional mapping was used to quantify available habitat at tributary mouths and extrapolation analyses were proposed that were designed to project modeling results to non-modeled areas throughout the Susitna River.

Habitat model selection during the 1980s studies was based on site-specific channel and hydrologic characteristics, the desired resolution of microhabitat simulation, and the field logistics associated with each method. The output provided by IFIM HABTAT, DIHAB, and RJHAB habitat models was generally similar to that provided by the habitat mapping method used at tributary mouths. Each method characterized changes in fish habitat by relating the amounts of wetted surface area and wetted usable area for juvenile and adult fish to Susitna River discharge. More detail concerning each of the methods applied in the 1980s is provided below. More specific information concerning overall locations of methods application including numbers of transects and flows measured can be found in Appendix 3.

[6] River mile designations are those used in the 1980s studies and designated within R&M (1981a).

7.1.1. PHABSIM Models

7.1.1.1. Description

The PHABSIM group of models were developed in the late 1970s and early 80s by the USFWS Instream Flow Group (IFG) in Fort Collins, Colorado (Milhous et al. 1984; Bovee and Milhous 1978). For this reason, many of the models coined the prefix of IFG as part of their description; e.g., IFG-2, IFG-3, IFG-4 etc.). These models include both hydraulic and habitat models and are commonly used within the IFIM as a means to predict changes in fish habitat quantity relative to incremental changes in stream discharge. In the 1980s, all of the hydraulic models were one-dimensional (1D) models with their vector orientation uni-directional. The IFG models are generally suitable in areas characterized by steady or uniform flow conditions and rigid stream channels and where stream flow is assumed to be the primary determinant of fish habitat quality (Trihey 1979; Hilliard et al. 1985). The IFG hydraulic models predict conditions (i.e., water depth and velocity) within a stream section over a range of discharges based on measurements recorded at points along multiple transects. Water depth, velocity, substrate and cover conditions are recorded at each transect measurement point at multiple discharge levels. Within the IFG model, each measurement point is a cell within which mean depth and velocity and substrate and cover conditions are assigned based on measured values. The wetted surface area of the cell is calculated within the model based on measurement point spacing.

The output of the hydraulic models are entered into habitat models (e.g., HABTAT) with additional data pertaining to habitat parameter preferences (e.g., depth, velocity, substrate, cover) of individual fish species and life stages to obtain an index of fish habitat area (Weighted Usable Area [WUA]). Habitat preferences often vary among fish species and life stages and are characterized for each target fish and/or life stages (see Section 6). Within measurement cells, the fish/life stage preference values for each habitat variable are multiplied with the cell area to obtain a weighted area for that cell. All transect cells are summed to provide the total weighted useable area (WUA) at the measured discharge. The final model results depict WUA (normalized to 1,000 square feet of stream) versus flow relationships by species and life stage.

7.1.1.2. Summary of Results

During the 1980s Su-Hydro instream flow studies, IFG and HABTAT models were used to model changes in juvenile fish habitat with flow at 15 sites in the Middle Segment during 1983 and 1984 and at 6 sites in the Lower River in 1983 (Table 7.1-1; Appendix 3) (Vincent-Lang 1984b, Hilliard et al. 1985, Suchanek et al. 1985). IFG modeling sites in the Middle and Lower River segments were located in side channel and side slough habitats (no main channel habitats were modeled with PHABSIM) and were primarily used to describe changes in rearing habitat for juvenile Chinook salmon, although they were also applied to juvenile sockeye and chum salmon (Hilliard et al. 1985, Suchanek et al. 1985). Examples of IFG transect locations in various side channel habitats in the Middle Susitna River are depicted in Figure 7.1-3 and Figure 7.1-4. At IFG sites in the Middle River segment, data were measured at Susitna River discharge levels ranging from approximately 6,000 cfs to 22,000 cfs (USGS Gold Creek gaging station, RM 136.6) and juvenile Chinook rearing habitat area was modeled at discharge levels ranging from 5,000 cfs to 35,000 cfs (Hilliard et al. 1985). In the Lower River, IFG models were used to model changes in juvenile Chinook, sockeye, and chum habitat at Susitna River discharge levels ranging up to approximately 60,000 cfs to 70,000 cfs (USGS Sunshine gaging station, RM 83.9) (Suchanek et al. 1985).

In the Middle Segment, WUA for juvenile Chinook at IFG sites was positively and negatively associated with Susitna River discharge among sites (Hilliard et al. 1985). Habitat area at lower discharge levels was typically limited by depth, while at higher flows negative trends in WUA were attributed to increased water velocity (Hilliard et al. 1985). In the Lower River, Susitna River discharge was a very important factor in determining habitat conditions in side channels and side sloughs (Suchanek et al. 1985). For example, suitable habitat for juvenile Chinook salmon typically increased as side channel and slough habitats became breached by increasing Susitna River discharge, but WUA decreased at elevated discharge levels due to unsuitable turbidity and water velocity levels (Suchanek et al. 1985).

7.1.2. Direct Input Habitat (DIHAB) Model

7.1.2.1. Description

The DIHAB model was created by Trihey and Associates during the 1980s Su-Hydro studies for stream reaches that were not compatible with IFG model assumptions of steady, or gradually varied streamflow conditions (Hilliard et al. 1985). Sites in which the DIHAB model was applied were characterized by very low and spatially varied water velocities (Hilliard et al. 1985). In the Susitna River, such areas were often located on stream margins or in areas affected by backwater from the Susitna River main channel (Hilliard et al. 1985).

The DIHAB model was used to evaluate changes in fish habitat based on habitat conditions measured at points on multiple transects and at two or more Susitna River discharge levels. Data collection for DIHAB models was similar to that of IFG models, but differed in that the presence or absence of upwelling at each site was recorded in addition to water depth, current velocity and substrate data. Upwelling presence was a binary variable (i.e., present, not present) in DIHAB models. In contrast to IFIM models, DIHAB models did not incorporate hydraulic models; changes to fish habitat area over the range of empirically measured stream flows was estimated using hydraulic and channel geometry data.

The output provided by the DIHAB model was similar to that supplied by the IFG and HABTAT models in that changes in preferred fish habitat in terms of WUA or other habitat metrics were presented relative to Susitna River discharge. As noted, the DIHAB model does not incorporate hydraulic modeling, so WUA or other habitat indices were estimated by linear interpolation for discharge values that were not directly measured but were within the range of measured discharges (Hilliard et al. 1985).

7.1.2.2. Summary of Results

The DIHAB model was applied at 14 sites in the Middle River segment on main channel margins and side channels in 1984 (Table 7.1-1; Appendix 3) (Hilliard et al. 1985). DIHAB modeling during the 1983 studies targeted adult chum salmon spawning which often occurred in areas with low and/or variable current velocity and groundwater upwelling (Hilliard et al. 1985). An example of DIHAB transects location in mainstem margin and side channel habitat in the Middle Susitna River is depicted in Figure 7.1-4. Among the 14 Middle Segment sites, measured discharge levels ranged from approximately 7,500 cfs to 20,000 cfs (USGS Gold Creek gaging station, RM 136.6) and habitat conditions were modeled between Susitna River discharges of 5,000 cfs and 25,000 cfs (Hilliard et al. 1985).

In general, WUA (habitat) for adult chum spawning at backwater sites was positively associated with discharge until water depth was not limiting to chum spawning preference, at which point WUA flattened (Hilliard et al. 1985). In contrast, adult chum spawning WUA in mainstem margin areas was negatively associated with Susitna River discharge, as higher velocities limited suitability for chum spawning (Hilliard et al. 1985). In side channel habitats, trends in WUA were positive at lower discharge levels but became negative as velocities exceeded spawning preference values at higher discharges (Hilliard et al. 1985). In all areas, the amplitude of the WUA curve was positively associated with presence of upwelling and substrate quality (Hilliard et al. 1985).

7.1.3. Resident Juvenile Habitat (RJHAB) Model

7.1.3.1. Description

The RJHAB habitat model was a simplified means of estimating changes in fish habitat without using hydraulic models. Data collection methods for the RJHAB were generally similar to that of the DIHAB model, although measurement points on each transect were apportioned differently. For the RJHAB model, multiple cross-sections were established and two shoreline cells and one mid-channel cell were created for each transect at each site (Figure 7.1-5). In each cell, the mean values for water depth, current velocity, substrate, and cover were recorded. WUA (habitat) was calculated for each cell and the total site WUA was derived from the sum of WUA from all shoreline and mid-channel cells among all transects at the site (Marshall et al. 1984). WUA was calculated only for measured discharge levels, so WUA was interpolated for intervening discharges and extrapolated for flow conditions outside the measured range (Suchanek et al. 1985).

7.1.3.2. Summary of Results

RJHAB modeling was applied at six side channel, side slough, and upland slough sites in the Middle Segment in 1983 and at 16 side channel, side slough, and tributary mouth sites in the Lower River in 1984 (Table 7.1-1; Appendix 3) (Marshall et al. 1984; Suchanek et al. 1985). An example of RJHAB transect location in side slough habitat in the Middle Susitna River is depicted in Figure 7.1-4. RJHAB modeling in the Middle and Lower River segments targeted juvenile Chinook, sockeye, chum and coho salmon rearing habitat (Marshall et al. 1984; Suchanek et al. 1985). Model measurements in the Middle River segment were recorded at Susitna River discharges ranging from approximately 10,000 cfs to 30,000 cfs (USGS Gold Creek gaging station, RM 136.6) and WUA were calculated for discharge levels between 5,000 cfs and 45,000 cfs (Marshall et al. 1984). RJHAB modeling in the Middle River segment indicated that in side channel habitats, WUA peaked during a narrow range of flows that occurred following breaching of the side channel (Marshall et al. 1984). In side and upland sloughs, WUA was affected by backwater effects from the Susitna River main channel (Marshall et al. 1984). At all habitat types, WUA was strongly affected by cover (Marshall et al. 1984).

7.1.4. Habitat Mapping

7.1.4.1. Description

Two-dimensional habitat mapping was conducted at tributary mouths in the Middle River segment in 1983 to characterize changes in habitat independently of hydraulic modeling (Sandone et al. 1984). The habitat mapping method targeted adult chum spawning at the confluences of 4th of July Creek (RM 131.1) and Lane Creek (113.6) with the Susitna River main channel (Table 7.1-1). The two tributary mouth sites were considered to be representative of the 14 major tributary confluences in the Middle Segment (Sandone et al. 1984). Water depth, velocity and substrate data were collected at points on multiple transects and at several discharge levels (Sandone et al. 1984). These data were used to create two-dimensional parameter-specific maps delineating the area of suitable chum spawning habitat. The three separate parameter-specific maps were then overlaid to identify the composite area of habitat suitability that was available at each measured flow level (Sandone et al. 1984).

7.1.4.2. Summary of Results

Habitat mapping was conducted at four separate Susitna River stream flows ranging from approximately 8,000 cfs to 24,000 cfs (USGS Gold Creek gaging station, RM 136.6). Results of the mapping exercise indicated a positive association between usable habitat area at 4th of July Creek (RM 131.1) and Susitna River discharge, while at Lane Creek (RM 113.6) the relationship was slightly negative (Sandone et al. 1984).

7.1.5. Aerial Photography Interpretation – Habitat Surface Area Mapping

7.1.5.1. Description

In addition to methods that involved field data collection, the Su-Hydro instream flow studies also utilized aerial photography interpretation as a means to identify and map aquatic habitat types in the Susitna River under different flow conditions. Separate analyses were completed for the Middle River (Klinger-Kingsley et al. 1985) and Lower River (R&M Consultants et al. 1985) but both employed similar analytical techniques. These generally included completion of aerial photography of each of the river sections under different flow conditions and then identifying, delineating and digitizing specific habitat types (see Section 3) occurring within specific segments of the river under each of the flow conditions. This provided the ability to plot habitat areas (of specific habitat types) versus flow conditions for the different habitat types which could then be rolled up to provide estimates of total surface areas by habitat type for the entire river corridor (for the Middle River) or river segments (for the Lower River).

7.1.5.2. Summary of Results

Analysis of the Middle River involved aerial photo interpretation of photographs taken at mainstem discharges of 23,000 cfs, 16,000 cfs, 12,500 cfs and 9,000 cfs (Klinger-Kingsley et al. 1985), along with surface area measurements taken at four other discharges; 18,000 cfs, 10,600 cfs, 7,400 cfs, and 5,100 cfs. The analysis allowed for an interpretation of habitat transformations as flows change which are well depicted in the series of photo plates presented in Trihey and Associates (1985).

Analysis of the Lower River involved aerial photo interpretation of photographs taken at 75,200 cfs, 59,100 cfs, 36,600 cfs, 21,100 cfs, and 13,900 cfs. Because of the complexity of the Lower River, the analysis was organized into different river segments and habitat types were delineated. Representative areas were then identified for which habitat types would be mapped and wetted surface areas measured. These included; Side Channel IV-4 located within RMs 32.5-36; Willow Creek Side Channel located within RMs 49-52; Caswell Creek – RM 64, Sheep Creek – RM 66.1, Goose Creek Side Channel located within RMs 689.5-72.5, Montana Creek Side Channel located within RMs 77-78, Sunshine Slough Side Channel located within RMs 84-86.5 and Birch Creek Slough located within RMs 88.5-93 (R&M Consultants et al. 1985). More details concerning the Lower River analysis can be found in Tetra Tech (2013).

7.1.6. Extrapolation Analyses

7.1.6.1. Description

Extrapolation of habitat modeling results from modeled sites to non-modeled areas is typically performed as part of habitat analyses to evaluate the response of fish habitat quantity and/or quality in the entire stream system to discharge levels (Aaserude et al. 1985). During extrapolation analyses, it is important to assess the representativeness of modeled sites to non-modeled areas. Extrapolation is typically applied as part of IFIM in stream segments that exhibit homogenous hydrologic, hydraulic and morphological characteristics (Bovee 1982). Modeling results obtained within a reach that is representative of a homogenous segment can then be applied to non-modeled areas in the segment on a proportional length basis (Bovee 1982). In single-thread rivers, it is possible to derive a system-wide response of habitat change relative to discharge using this method (Bovee 1982, Aaserude et al. 1985). In braided or multiple-thread rivers such as the Susitna River, extrapolation of modeling results based on this method cannot always be done reliably (Mosley 1982). Although multiple-thread rivers can be divided into homogenous segments, it is often not possible to extrapolate hydraulic characteristics laterally across braided channels, which are frequently quite variable and highly dynamic (Mosley 1982).

The extrapolation methods developed during the 1980s modeling studies for the multiple-thread Susitna River differed from that of IFIM extrapolation techniques in three important ways (Table 7.1-2) (Aaserude et al. 1985, Klinger-Kingsley et al. 1985, Steward et al. 1985). First, extrapolation from modeled sites to non-modeled areas was performed based on proportional area rather than a proportional length basis to reflect the greater variability in channel widths in a multiple-thread system relative to a single channel stream (Table 7.1-2) (Aaserude et al. 1985). Secondly, Aaserude et al. (1985) noted another distinction between single- and multiple-thread rivers was that although morphologically similar areas existed in braided rivers, these areas never occurred within a continuous homogenous segment (Table 7.1-2). Areas that were morphologically similar were termed ‘Representative Groups’ by Aaserude et al. (1985), and were identified by an approach that consisted of comprehensive reconnaissance level surveys in addition to intensive study reaches where modeling occurred. A third primary difference between traditional IFIM and 1980s Susitna River extrapolation techniques was that results from 1980s modeled sites applied to non-modeled areas were adjusted to account for the greater degree of variability in structural habitat in a multiple-thread river system relative to that typically present in a single-thread river (Table 7.1-2) (Aaserude et al. 1985). Areas that are similar in terms of hydrology and/or hydraulics may exhibit disparate structural attributes that affect fish habitat quality (Aaserude et al. 1985).

7.1.6.2. Summary of Results

Extrapolation analyses were developed as part of the 1980s habitat modeling studies as a means to expand habitat-streamflow relationships developed at modeled sites to non-modeled sites. As a basis, habitats were characterized in terms of hydrologic (e.g., side channel breaching flow), hydraulic (e.g., water depth, velocity, groundwater upwelling), and structural cover (i.e., vegetation, debris, and/or substrate) attributes over a range of stream discharge levels using aerial photography and aquatic habitat survey data (Aaserude et al. 1985). Representativeness between modeled and non-modeled sites was evaluated using these data (Aaserude et al. 1985). All habitat types (e.g., mainstem, side channel, side slough, upland slough) throughout the Middle River segment were characterized, except tributary areas, at multiple discharge levels.

The methodology used by Aaserude et al. (1985) consisted of quantification, stratification, and simulation pathways. A preliminary step of quantification was to delineate areas of homogenous habitat types (e.g., mainstem, side channel, side slough, upland slough) using aerial photos (see Klinger-Kingsley et al. 1985). The response of habitat surface area to changes in discharge was measured for each habitat over several discharge levels (Klinger-Kingsley et al. 1985). Wetted surface area (WSA) was used as the metric of habitat quantity for this exercise (Aaserude et al. 1985, Klinger-Kingsley et al. 1985).

The stratification pathway classified delineated habitats into similar groups and provided a means to associate modeled and non-modeled areas. Each habitat area was classified into Representative Groups, based on hydrologic, hydraulic and structural characteristics (Table 7.1-3). Important hydrologic features used to classify habitats included breaching flow, the presence and extent of groundwater upwelling, and the transformational response of the habitat to changes in Susitna River discharge (Aaserude et al. 1985). Primary hydraulic characteristics used to distinguish Representative Groups were mean channel current velocity, dominant substrate type, and channel morphology, as an index of site hydraulics (Aaserude et al. 1985). Structural cover conditions in each habitat area were used in conjunction with cover suitability data for individual fish species and life stage to derive a Structural Habitat Index (SHI). The SHI was used to associate a modeled habitat area with non-modeled areas and was not intended to be an index of overall habitat quality (Aaserude et al. 1985).

The simulation pathway consisted of hydraulic and/or habitat modeling at representative habitats, which predicted the relationship between habitat area and Susitna River discharge. Habitat models used as part of this exercise consisted of the IFG/HABTAT, DIHAB, and RJHAB models. The available habitat at each modeled streamflow was represented as WUA.

For extrapolation of modeled results to non-modeled sites, a Habitat Area Index (HAI) was used to represent the response of available habitat relative to stream discharge for a given habitat type and was calculated as the quotient of WUA and WSA (Aaserude et al. 1985). Modeled results were extrapolated using the HAI at the modeled site and representative grouping, breaching flows, and SHI at the modeled and non-modeled habitat areas (Aaserude et al. 1985). During extrapolation, HAI were adjusted for differences in breaching discharge and SHI between modeled and non-modeled areas (Figure 7.1-6). Assumptions of the extrapolations included: 1) HAI curves of modeled areas were representative of non-modeled areas within the same Representative Group, 2) breaching flows appear on the same relative position on HAI curves, and 3) linear adjustment of HAI versus discharge curve amplitude can be derived for non-modeled areas using the ratio of SHIs for modeled and non-modeled areas (Aaserude et al.

1985). Once relationships were derived from un-modeled areas, it was then possible to integrate results into an overall assessment of habitat-flow responses within each representative group; these were presented in Steward et al. (1985). The next proposed step in the extrapolation process would have been to conduct a system-wide (at least for the Middle River segment) evaluation of habitat-flow responses that would have aggregated the responses into a system-wide habitat-flow response relationship. However, that step was never completed as part of the 1980s studies since the project was cancelled.

7.2. Susitna-Watana 2013-2014 Studies

There have been substantial advances in the development and application of instream flow methods and models since the 1980s and many of these new tools are being proposed for use as part of the 2013-2014 Susitna-Watana IFS program. Of particular note is the proposed application of two dimensional hydrodynamic modeling for much of the work. Two-dimensional models (2-D) were not available in the 1980s and therefore it was not possible to model large, contiguous sections of the river over a wide range of flows. Indeed, habitat – flow modeling of the main channel of the Susitna River was not even attempted during the 1980s studies. As a point of reference, Personal Computer (PC) development was just in its infancy so that data entry, data analysis and modeling was largely handled as a post-field activity and likely often involved main-frame computer systems.

Data collection instrumentation has likewise improved and has facilitated the application of 2D models. Most notably the advent of the Acoustic Doppler Current Profiler (ADCP) allows for the measurement and recording of a velocity array that spans the majority of the entire water column across a river cross-section efficiently, safely, and relatively quickly. Coupled with Real Time Kinematic (RTK) Global Positioning Satellite (GPS) survey instruments and bathymetric sonars, this suite of instruments now allows for the collection of accurate river bed topography in relatively long reaches of large river systems. These data allow for development of 2D hydrodynamic models that can be used not only for evaluating habitat –flow relationships via a PHABSIM analysis, but also for sediment transport modeling and fluvial geomorphological analysis. Contemporary software packages allow for much more detailed and complex analysis of large amounts of data than was possible in the 1980s and when linked within a Geographical Information System (GIS) framework, provide the ability for large-scale detailed spatial depiction of information. The IFS methods proposed for 2013-2014 will rely on many of these new technologies and analytical tools. Those methods have been presented in RSP Section 8.5 with portions reproduced here for convenience and to allow comparison with approaches applied in the 1980s.

7.2.1. Target Range of Flows

In conventional instream flow studies involving field data collection, one of the initial planning activities relates to the identification of a target range of flows that are of interest in terms of modeling and field data collection. These flows typically represent the range of flows over which project operations would have a notable effect and that would occur during biologically sensitive periods. The objective then is to collect sufficient data and information that would allow the development of models and analytical tools that can evaluate habitat conditions over the range of operational flows that may occur during those biologically sensitive periods.

During the 1980s studies, ranges of flows were identified for both the Middle River (5,000 cfs to 23,000 cfs) and Lower River (≈ 13,000 cfs to ≈ 75,000 cfs) segments as part of the habitat surface area analysis completed by Klinger-Kingsley et al. (1985) and R&M Consultants et al. (1985). As noted by Klinger-Kingsley et al. (1985), the discharge range for the Middle River was assumed to be adequate for identifying the transformation of areas from one type of habitat to another as a result of reductions in flow due to project operations, and the range of flows highlighted for the Lower River was presumably selected with that in mind.

For the 2013-2014 studies, these same general ranges of flow will likely serve as targets for the two respective segments. Recent results of hydrological analysis completed by Tetra Tech (2013) provide a comparison of average annual and monthly flows under Pre- and Post – project operations at four gage stations in the Middle and Lower segments of the river. Those data along with results of the open-water flow routing model (R2 et al. 2013), other hydrologic information (e.g., monthly exceedance flows for the Susitna River at Gold Creek (USGS No. 15292000) (Figure 7.2-1), an evaluation of channel characteristics and habitat types and their sensitivity to flows, and the periodicities of the target fish species and life stages will be used to identify appropriate ranges of flows for analysis within the two river segments. In conventional PHABSIM modeling, a rule of thumb for extrapolation of 1D hydraulic models is that the range of extrapolation can extend 0.4 x the lowest measured flow and 2.5 x the highest measured flow. Based on that convention, the range of target flows identified above would provide an extrapolation range generally within the flow ranges found under Pre-project hydrologies. However, it should be noted that there is no convention regarding the range of extrapolation for the 2-D hydrodynamic models which are being proposed for application in the FAs.

7.2.2. Habitat Model Selection

Identifying and quantifying the predicted changes in aquatic habitat in the Middle and Lower segments of the Susitna River under the proposed Project operational scenarios will require the use of several different hydraulic and biological models. Each of the models proposed for use has been selected to assist in the evaluation of the physical and biological effects of the proposed Project. Development of these models will require careful evaluation of existing data and information as well as focused discussions with technical representatives from the TWG. These models will rely in part on information and technical analyses performed in other study components as a basis for developing model structures (e.g., Habitat Mapping; other riverine process studies).

As noted above, physical habitat models are often used to evaluate alternative instream flow regimes in rivers (e.g., the Physical Habitat Simulation [PHABSIM] modeling approach developed by USGS; Bovee 1998; Waddle 2001). Methods available for assessing instream flow needs vary greatly in the issues addressed, their intended use, their underlying assumptions, and the intensity (and cost) of the effort required for the application. Many techniques have been used, ranging from those designed for localized site or specific applications to those with more general utility. The summary review reports of Wesche and Rechard (1980), Stalnaker and Arnette (1976), EA Engineering, Science and Technology (1986); the proceedings of the Symposium on Instream Flow Needs (Orsborn and Allman eds. 1976); Electric Power Research Institute (2000); and more recently the Instream Flow Council (Annear et al. 2004 and Locke et al. 2008) provide more detailed information on specific methods. The methods proposed in the IFS include a combination of approaches that vary depending on habitat types (e.g., mainstem, side channel, slough, etc.) and the biological importance of those types, as well as the particular instream flow issue (e.g., connectivity/fish passage into the habitats, provision of suitable habitat conditions in the habitats, etc.). Field efforts will be concentrated within Focus Areas (within the Middle Segment) and at representative habitat types (within the Lower Segment) and will entail collection of data suitable for 2-D modeling (Middle Segment) and 1D modeling (Lower Segment) as well as other analysis. Of particular note is that the models and analysis include a directed effort toward evaluating potential project effects of load following and the resulting fluctuations in flow that can occur on a daily basis. This type of analysis was not needed during the 1980s studies since the project configuration involved two dams one of which was a re-regulating dam. Thus, project operations in the Middle River were proposed as baseload operation and such effects (i.e., daily/hourly flow fluctuations) were not anticipated. The overall methods proposed for the 2013-2014 studies are described in more detail in RSP Section 8.5.2.1.8 and are summarized below.

Development of the models that will be used in the 2013-2014 studies will involve coordination with other resource studies and consultation with the TWG. Once final study areas (Focus Areas) and transects/study segments have been identified, proposed methods of analysis and modeling will be reviewed with the TWG. The models will be tailored based on habitat types to be measured and the selected models to be used. This will involve a combination of 1-D and 2-D modeling approaches and may also involve application of empirically-based methods. Table 7.2-1 provides a listing of potential models/methods that will be considered as part of the IFS. The most appropriate methods for selected study areas will be determined via careful review of site conditions and the underlying questions needing to be addressed.

The following section provides an overview of the habitat and hydraulic models proposed as part of the evaluation of Project-related effects including boundary conditions transects, 2-D modeling, single transect PHABSIM (1-D), stranding and trapping, and fish passage/connectivity.

7.2.2.1. Boundary Condition Transects

The upstream and downstream boundaries as well as the lateral extent of the Focus Areas have been chosen so that appropriate boundary conditions can be established for the hydraulic and bed evolution modeling. Considerations include encompassing potential inflow and outflow points to preserve the mass balance and minimize difficulties and assumptions associated with inflow points. Potential upstream connections for side channels, side sloughs, and upland sloughs were also identified and included in the modeling domain. The upstream and downstream limits on the main channel were identified to either provide relatively uniform flow conditions or sufficient distance upstream and downstream from areas of interest so that flow conditions in the area of interest are not significantly affected by the flow directions at the boundary.

Water levels measured during the cross-section and bathymetric surveys for each boundary condition transect will be used to assist in calibrating the 2-D models for each Focus Area. In addition to water surface elevations, the depths and velocities measured at the boundary transects will be used to assist with hydraulic modeling for the single transect PHABSIM sites.

7.2.2.2. 2-D Modeling

Determining the relationship between river flow and the physical and hydraulic characteristics of a river system as dynamic as the Susitna River is a complex undertaking that requires considerable investigation and coordination. This is especially true for assessing project-related impacts to small, local-scale channel areas containing unique morphology and habitat features (e.g., fish spawning, groundwater upwelling, stranding and trapping, fish passage/connectivity). To assist with this effort, 2-D hydraulic modeling will be used to evaluate the detailed hydraulic characteristics of the Susitna River within the Focus Areas where it is necessary to consider the more complex flow patterns to understand and quantify project effects under various Project operation scenarios. The 2-D model will be applied to specific Focus Areas that are representative of important habitat conditions and the various channel classification types. These sites will be chosen in coordination with the TWG. A detailed discussion of the 2-D modeling is presented in RSP Section 6.6.

Selection of the appropriate mesh size for the 2-D bed evolution mode is dictated by several factors including the size and complexity of the site feature(s); the desired resolution of output information such as water surface elevation, velocity, depth, and bed material gradation; and any limitations on the maximum number of elements that the model can simulate. The 2-D models being considered for this study are formulated with a flexible mesh, allowing the size of the model element to be varied. Figure 7.2-2 provides examples of a relatively coarse and relatively fine mesh applied to the potential Focus Area at Whiskers Slough in the Middle River Segment.

Examples of areas that may require finer mesh sizes include sloughs, smaller side channels, spawning areas, stranding and trapping areas, hydraulic control features, and tributary mouths. Areas where lower spatial resolution may be appropriate include main channel, floodplains, and large side channels. In the areas of higher resolution, the mesh size will be on the order of several feet to 25 feet. In areas where lower spatial resolution is appropriate, the mesh size may be in the range of 25 to 100 feet (RSP 6.6.4).

At some Focus Areas, two model meshes may need to be developed. One mesh would be for executing the bed evolution model, which requires orders of magnitude more time to execute than the 2-D model without the moveable bed options running. The other mesh would be associated with a fixed bed representation of the site that would be used to output the hydraulic conditions at a finer resolution for development of aquatic habitat indices. The 2-D hydrodynamic models will be linked with PHABSIM habitat models and appropriate HSC criteria to enable development of habitat-flow relationships within Focus Areas.

7.2.2.3. 1-D Modeling Single Transect PHABSIM

Consideration will also be given to the use of 1-D modeling and application and development of a single transect PHABSIM model. The PHABSIM model (Milhous et al. 1981) will likely be applied to some of the open-water flow routing model transects to develop relationships between main channel flow and habitat for the spawning and rearing life stages of the target fish species. Supplemental main channel transects will be established as needed to more fully characterize main channel habitats, either as part of the Focus Area analysis or at separate locations associated with specific habitat types. In addition, the single transect 1-D modeling approach will also be applied to the Lower Segment studies to capture representative habitat types.

7.2.2.4. Breaching Flows

The breaching or topping of off-channel habitat features by main channel river flows not only affects the quantity of water within these features but water quality (turbidity and temperature) and habitat quality as well. During the 1980s study of the Susitna River, researchers reported that although breaching flows typically increase the availability of juvenile rearing habitat in small off-channel areas, as mainstem discharge increases the quality of rearing habitat declines as velocities in nearshore areas increase (Schmidt et al. 1985). A similar finding was reported for the effect of water turbidity. Although some turbidity did increase off-channel use by juvenile Chinook salmon, high turbidity resulting from mainstem flows topping reduced juvenile fish use (Steward et al. 1985). Vining et al. 1985, reported that the winter topping of cold mainstem river water into off-channel habitats was the most significant factor contributing to high levels of embryo mortality in habitats used for chum salmon incubation in the Middle River Segment. Determining the relationship between mainstem river flow and overtopping or breaching of sensitive off-channel features will allow for the assessment of potential impacts of proposed winter Project operation scenarios.

7.2.2.5. Weighted Usable Area Habitat Metrics

The methods proposed in the IFS include a combination of approaches depending on habitat types (e.g., mainstem, side channel, slough, etc.) and the biological importance of those types, as well as the particular instream flow issue (e.g., connectivity/fish passage into the habitats, provision of suitable habitat conditions in the habitats, etc.). During the 1980s studies, methods were designed to focus on both mainstem and off-channel habitats, although mainstem analysis was generally limited to nearshore areas. PHABSIM-based 1-D models, juvenile salmon rearing habitat models, fish passage models, and others were employed and will be considered as part of the IFS plan. As part of the 2013–2014 study efforts, more rigorous approaches and intensive analyses will be applied to habitats determined as representing especially important habitats for salmonid production. As noted above, this will include both 1-D and 2-D hydraulic modeling that will be linked to habitat-based models.

As part of the Geomorphology Modeling Study (see RSP Section 6.6), several 2-D models are being considered including the Bureau of Reclamation's SRH2-D, USACE's Adaptive Hydraulics ADH, the USGS's MD_SWMS suite, DHI's MIKE 21, and the suite of River2D models (RSP Section 6.6 for a description of various 2-D model attributes and references). The River2D model is a two-dimensional, depth-averaged finite-element hydrodynamic model developed at the University of Alberta and is capable of simulating complex, transcritical flow conditions. River2D also has the capability to assess fish habitat using the PHABSIM Weighted Usable Area approach (Bovee 1982). Habitat suitability indices are input to the model and integrated with the hydraulic output to compute a weighted useable area at each node in the model domain. While evaluation of habitat indices is directly incorporated into the River2D suite of models, other 2-D models are also complementary to habitat evaluations. Selection of potential 2-D models for fish and aquatics evaluations will be coordinated with other pertinent studies and the TWG.

In response to the effect of potential load-following operations, habitat modeling using weighted usable area indices may need to be developed using both daily and hourly time steps. Evaluating the effects of changes in habitat conditions on an hourly basis may require additional habitat-specific models such as effective habitat and varial zone modeling.

7.2.2.6. Effective Spawning/Incubation Habitat Analyses

Operation of the Susitna-Watana Project has the potential to influence the quantity and quality of spawning habitat by altering stream flow in the main channel and off-channel areas of the Susitna River. While changes in physical conditions (i.e., depth, velocity, and substrate) will determine the suitability of habitat for salmon spawning, the subsequent survival of eggs and alevins can be influenced by a different suite of flow-related processes. The eggs of Pacific salmon are laid in nests, or egg pockets, dug by the female in the gravel of the streambed. The female then covers the egg pockets with several inches of gravel by vigorous body and tail movements. Eggs within the spawning site (redd) incubate through the winter and depending on water temperature, hatch in late winter through spring, then remain within the redd as alevin until emergence. Mortality during the incubation period, which includes the egg and alevin stages, is generally high and can be caused by scour associated with flood flows or dewatering and freezing during low flow conditions. The location of redds within the river channel may have a major influence on redd survival. If redds are constructed toward the center of the channel when mainstem flows are low, redds may be scoured by winter flood events. If redds are constructed along the channel margins or in off-channel areas when mainstem flows are high, redds are at risk of dewatering or freezing when flows drop during the winter incubation season. In the Susitna River, as elsewhere, upwelling areas provide stable intergravel conditions and warmer temperatures during the winter incubation period, providing some protection from dewatering or freezing.

Flow changes can influence the prevalence of groundwater upwelling, which in turn can affect the rate of survival and development for eggs and alevins. In the Susitna River, Vining et al. (1985) suggested that upwelling is the single most important feature in maintaining the integrity of incubation in slough habitat as well as localized areas in side channel habitats. Upwelling and intergravel flow also play an important role in determining the water quality at redd sites, particularly with respect to temperature and dissolved oxygen concentrations. Winter increases in mainstem flow or stage may affect upwelling by:

- Decreasing the rate of groundwater upwelling from the adjacent floodplain.
- Diluting relatively warm, stable, upwelling habitats when side channels are breached by mainstem flow.
- Changing the rate of intergravel flows associated with hydraulic gradients between main channel and off-channel habitats.

The risks posed by flow-related processes on salmonid redds and egg/alevin incubation will be assessed by developing an effective spawning/incubation model that incorporates separate but integrated analyses for each process. The spawning/incubation model will be based on identifying potential use of discrete channel areas (cells) by spawning salmonids on an hourly basis. Use of each cell by spawning fish will be assumed to occur if the minimum water depth is suitable and velocity and substrate suitability indices are within an acceptable range defined by HSC/HSI. Species-specific HSC/HSI information used to identify potential use of a cell by spawning fish will be developed as described in RSP Section 8.5.4.5. If suitable spawning conditions exist, that cell will then be tracked on an hourly time step from the initiating time step through emergence to predict whether eggs and alevin within that cell were subject to interrupted upwelling, dewatering, scour, freezing, or unsuitable water.

This process will be repeated for each hour of the potential spawning period based on the species and life stage periodicities. If sufficient site-specific periodicity information is available, each hour can be weighted depending on whether it occurs during the peak or off-peak of the spawning period. If hydraulic conditions during the spawning season were considered suitable for spawning in a particular cell during the initiating time step, and conditions remained suitable for egg viability every hour through emergence, then the cell area at the initiating time step would be considered effective spawning/incubation habitat. This process is repeated for each cell within the habitat unit containing suitable spawning habitat at time step 1, and the entire process repeated for each time step through the end of incubation. The resulting areas will then be summed to determine the cumulative total effective spawning/incubation area for the habitat unit under existing conditions and alternative operational scenario for each hydrologic year under consideration.

All of the analyses associated with the effective spawning/incubation model will be performed at each of the Focus Areas with suitable spawning habitat. The results of the effective spawning/incubation analysis will be a reach-averaged area calculated by weighting the effective spawning area derived for each Focus Area by the proportion of Focus Area within the geomorphic reach (RSP Section 8.5.4.7). The results are calculated in terms of weighted area (similar to PHABSIM results) and do not represent actual area dimensions. The results cannot be used to calculate numbers of emergent fry but instead provide habitat indicators that will be used to conduct comparative analyses of alternative operating scenarios under various hydrologic conditions.

7.2.2.7. Varial Zone Analysis

Fluctuations in flow will cause shallow portions of the river channel to alternate between wet and dry conditions; this area of alternating wet and dry is referred to as the varial zone (Figure 7.2-3). Flow reductions along the channel margins can cause stranding and trapping of juvenile fish and benthic macroinvertebrates within the varial zone. Repeated dewatering of the varial zone can result in reduced macroinvertebrate and algae density, diversity, and growth (Fisher and LaVoy 1972; Dos Santos et al. 1988).

Analyses of Project effects on the downstream varial zone can be quantified as the frequency, magnitude, and timing of downramping events exceeding specified downramping rates; the frequency, number, and timing of downramping events that occur following varying periods of inundation; and the frequency, timing, and magnitude of potential stranding and trapping of aquatic organisms.

The proposed load-following operations of the Project will affect hourly flow fluctuations downstream of the Watana Dam site. Based on analyses of studies of the effects of hydropower load-following operations in Washington State, it is generally assumed that faster rates of water surface elevation reduction are correlated to an increased risk of stranding of aquatic organisms (Hunter 1992). Salmonid fry are particularly susceptible to stranding and the daily and seasonal timing of downramping events will influence the potential risk to aquatic organisms.

The goal of the downramping analysis will be to quantify the frequency, magnitude, and timing of downramping rates by downramping event by geomorphic reach downstream of the Watana

Dam site. The objectives of this analysis will be to quantify reach-averaged downramping events by rate under existing conditions and under alternative operating scenarios for selected hydrologic years. Using the results of the mainstem flow routing models, a post-processing routine will be used to identify those specific hourly time periods when the water surface elevations are decreasing (i.e., downramping). For those time periods, the hourly reduction in water surface elevation will then be computed and expressed in units of inches per hour. A frequency analysis will be conducted on the hourly downramping hours by downramping event by geomorphic reach. The frequency analysis will determine the number of downramping events exceeding selected numeric categories. These categories will be selected in collaboration with the TWG, but for planning purposes, the following categories are proposed:

- Greater than 0 but less than 1 inch per hour
- Greater than 1 but less than 2 inches per hour
- Greater than 2 but less than 4 inches per hour
- Greater than 8 inches per hour
- Exceeding downramping guidelines developed by Hunter (1992).

The number of events where downramping rates exceed these categories will be tabulated by month and by annual total under existing conditions and for alternative operating scenarios.

The frequency, number, and timing of downramping events that occur following varying periods of inundation will be quantified to evaluate the effects of downramping events on organisms exhibiting a range of colonization rates. This varial zone analysis can be conducted by total Focus Area or can be conducted by discrete habitat types within a Focus Area (e.g., main channel, side channel, sloughs) using an hourly time step integrated over a specified period that considers antecedent fluctuations in water surface elevations.

7.2.2.8. Fish Stranding and Trapping

Though stranding and trapping are related processes, there are differences that require two separate analyses for the effects. Both analyses develop indices that represent the potential effect of reductions in water levels during downramping events on fish and other aquatic organisms. Stranding involves the beaching of fish as the water levels recede and is typically associated with low gradient shoreline areas or cover conditions that attract fish to areas where dewatering occurs. Mortality occurs when stranded fish are beached on dewatered portions of the channel bed. As water levels recede, some fish may become trapped in channel depressions or pools. Although trapped fish may survive for short periods of time, the potential for mortality increases based on factors including temperature fluctuations, reduction in dissolved oxygen, predation, and stranding as the water in the pool infiltrates the substrate.

The approach to the stranding and trapping analyses will be similar to other analyses involving the evaluation of the effects of water surface elevation fluctuations in the varial zone. Stranding and trapping indices utilize results of the mainstem flow routing models to determine the water surface elevations on an hourly basis within Focus Areas. Stage fluctuations are applied within Focus Areas using the digital terrain models to quantify the frequency, timing, and magnitude of stranding events under existing conditions and alternative operational scenarios. The results of the mainstem flow routing models and the digital terrain models are also combined to quantify the frequency, timing, and duration of trapping events for discrete channel features within Focus Areas. The stranding and trapping analyses determine evaluation indices based on each water level fluctuation cycle.

The stranding and trapping analyses track the period of dewatering (stranding) or the period of disconnection (trapping). Fish are assumed to return to potential stranding and trapping areas shortly after the water surface elevation rises to once again inundate/connect the side channel areas. Stranding and trapping indices are not treated as values that are summed on an hourly basis; instead, stranding and trapping are viewed as a series of events, and part of the index expression includes this frequency of events. Therefore, the results are computed at the end of an event based on the duration of the event, and then results are summed over the series of events.

Downramping rates will be determined as part of the stranding analyses including the exceedance of specific numeric categories ranging from 1 inch per hour to over 8 inches per hour. For trapping analyses, ramping rates will not be directly incorporated as a factor in the calculation of the indices. Strong relationships between ramping rate and incidence of trapping are not consistently demonstrated in previous studies (Hunter 1992; Higgins and Bradford 1996; R.W. Beck and Associates 1989). The results of both stranding and trapping evaluation indicators can be quantified under existing conditions and alternative operational scenarios for selected hydrologic conditions.

The indices for stranding and trapping are based on equations that relate physical characteristics of the stranding and trapping sites to the potential for stranding and trapping to occur. The information for the physical site characteristics will be derived from the bathymetry and mapping through the application of GIS. The index equations have physical factors related to site area, depth, and cover conditions. The observations and data collected during the stranding and trapping field surveys will assist in developing the ratings for several of these factors (RSP Section 8.5.4.5).

For planning purposes, potential stranding areas are defined as areas with a bed slope of 4 percent or less, excluding depression areas that are included in the trapping area analysis. Stranding areas are also defined as areas with features, such as emergent vegetation found alongside slough margins, which are observed to contribute to an increased risk of stranding regardless of bed slope based on the results of site-specific surveys. Specific stranding zones are defined at elevation intervals to allow for tracking of dewatering of stranding areas as the water surface elevation rises and falls. Stranding areas are also defined as contiguous areas of 1,000 square feet or greater. The potential presence of fish in a stranding site is assumed to be directly proportional to the size of the stranding area. RSP Section 8.5.4 presents a detailed description of the equations and indexes use to calculate the potential for stranding and trapping events.

7.2.2.9. Fish Passage/Off-channel Connectivity

Several environmental variables may affect fish passage and connectivity within sloughs and side channels and tributary deltas. In general, at a given passage area the water conditions (primarily depth) interact with conditions of the channel (length and uniformity, substrate size) to characterize the passage conditions that a particular fish encounters when attempting to migrate into, within, and out of a slough, side channel, or tributary delta. The likelihood of a particular fish successfully navigating through a difficult passage reach will depend on the environmental conditions as well as the individual capabilities and condition of the fish.

Depth passage in sloughs, upland sloughs, side channels, and at tributary delta mouths will be assessed following the methods of Sautner et al. (1984) that focus on salmon passage in sloughs and side channels. Two-dimensional modeling, not available in the 1980s, will also be applied. Although salmon passage remains a key concern, the passage methods are generally applicable to other species where depth passage criteria are known or can be developed. The main goal of the fish passage and off-channel connectivity is to evaluate the potential creation of fish passage barriers within existing habitats (tributaries, sloughs, side channels, off-channel habitats) related to future flow conditions and water surface elevations. Further details concerning the fish barrier and passage analysis are presented in RSP 9.12.

7.2.3. Temporal and Spatial Habitat Analyses

The IFS will result in the collection of data and development of different types of habitat-flow relationships from spatially distinct locations within each of the Focus Areas, and from selected cross-sectional transects outside of the Focus Areas that contain a variety of habitat types. Types of relationships will include but not be limited to those founded on PHABSIM that depict WUA or habitat versus flow by species and life stage; effective habitat versus discharge relationships that define how spawning and incubation areas respond to flow changes; varial zone analysis that quantifies areas of stranding and trapping relative to flow change; and groundwater-surface water flow relationships relative to upwelling and spawning habitats. Additional components that will factor into the habitat – flow relationships will include those associated with breaching flows, upwelling, water temperature, and turbidity. These relationships will be part of the analytical framework and conceptual models that will be used in evaluating the operational effects of the Project (RSP Section 8.5.4.8) on different habitats. This will require both a temporal analysis that focuses on how the various habitat response variables change with flow over biologically important time periods (i.e., periodicity), and a spatial analysis that can be used not only for evaluating specific relationships on a site/transect specific or Focus Area basis, but also for expanding or extrapolating results from measured to unmeasured habitats within the river. This latter analysis is needed in order to assess system-wide Project effects.

7.2.3.1. Temporal Analysis

Temporal analysis will involve the integration of hydrology, Project operations, the Mainstem Open-water Flow Routing Model, and the various habitat-flow response models to project spatially explicit habitat changes over time. Several analytical tools will be utilized for evaluating Project effects on a temporal basis. This will include development and completion of habitat-time series that represent habitat amounts resulting from flow conditions occurring over different time steps (e.g., daily, weekly, monthly), as well as separate analysis that address effects of rapidly changing flows (e.g., hourly) on habitat availability and suitability.

The Mainstem Open-water Flow Routing Model and habitat models will be used to process output from the Project operations model. This will be done for different operating scenarios, hydrologic time periods (e.g., ice free periods: spring, summer, fall; ice-covered period: winter [will rely on Ice Processes Model – Section 7.6]), Water Year types (wet, dry, normal), and biologically sensitive periods (e.g., migration, spawning, incubation, rearing) and will allow for the quantification of Project operation effects on the following:

- Habitat areas (for each habitat type – main channel, side channel, slough, etc.) by species and life stage; this will also allow for an evaluation of the effects of breaching flows on these respective habitat areas and biologically sensitive periods (e.g., breaching flows in side channels during egg incubation period resulting in temperature change).
- Varial zone area (i.e., the area that may become periodically dewatered due to Project operations, subjecting fish to potential stranding and trapping and resulting in reduced potential invertebrate production).
- Effective spawning areas for fish species of interest (i.e., spawning sites that remain wetted through egg incubation and hatching).
- Other riverine processes that will be the focus of the Geomorphology (see Sections 6.5 and 6.6), Water Quality Modeling (see Section 5.6), and Ice Processes (see Section 7.6) studies including mobilization and transport of sediments, channel form and function, water temperature regime, and ice formation and decay timing. The IFS studies will be closely linked with these studies and will incorporate various model outputs in providing a comprehensive evaluation of instream flow-related effects on fish and aquatic biota and habitats.

As an example, using the habitat versus flow relationships (based on HSC and HSI metrics described in RSP Sections 8.5.4.5.1.1 and 8.5.4.5.1.2) developed within the different Focus Areas and at selected cross-sections, an evaluation of habitat change over time can be completed using habitat time series analysis. The basic premise of a habitat time series analysis is that the physical habitat in a stream at any given time can be calculated from the stream flow using the equation:

$$HA(t) = WUA\{Q(t)\}$$

where WUA = physical habitat versus flow relationship for a given species and life stage;

Q(t) = stream flow at time t; and

HA(t) = habitat area for time t.

The results of the time series analysis will be compared under baseline (unregulated) conditions with one or more Project Operational Scenarios. This type of analysis will be done for each biologically relevant period (e.g., adult migration and holding, spawning, incubation, juvenile rearing, and others) for a given species and life stage, and for different Water Year types (e.g., wet, normal, dry). Consideration will also be given to identifying year types that reflect cold, normal, and above average air temperatures. The analysis will include development of habitat-duration curves that depict habitat exceedances based on the hydrologic record.

7.2.3.2. Spatial Analysis

How the data and habitat-flow relationships collected and developed from one location relate to other unmeasured locations is the focus of the spatial analysis. This analysis is crucial to providing an overall understanding of how Project operations may affect habitats and riverine processes on a system-wide basis and will feed directly into the Integrated Resource Analysis

(RSP Section 8.5.4.8). This analysis will be completed in 2014 after all data are collected and respective models have been developed. Just like the temporal analysis, the final procedure(s) for completing spatial analysis will be developed collaboratively with the TWG and with input from other resource disciplines.

Completion of spatial analyses of the Susitna River will be challenging given its length, widely variable size (width), diverse geomorphologies, and complex habitat types. This variability is readily apparent in the Middle River Segment and becomes even more pronounced in the Lower River Segment with the addition of flow from the Talkeetna and Chulitna rivers and resulting expanded floodplain. This will require the development of an approach that considers the distinctiveness of the different habitat types within a given area and at the same time the similarity of these habitat types to other areas. Development of habitat – flow relationships for specific habitat types (e.g., side channel, side slough) and mesohabitat types (riffle, run, pool, etc.) from one area should then, with appropriate adjustment for dimensional differences and other distinguishing factors, be expandable to unmeasured areas containing similar characteristics.

A substantial effort was already advanced toward development of a spatial habitat analysis approach as part of the 1980s studies (Aaserude et al. 1985; Klinger-Kingsley et al. 1985; Steward et al. 1985) (see Section 7.1.6). Inspection of those studies indicates that although the tools and computational techniques that were applied may be outdated, the general principles and precepts that served to guide development of the approach remain sound today. As a result, they provide a good starting point from which to build a more contemporary approach founded on new sampling technologies and more sophisticated models that will provide for a more robust spatial analysis, including procedures for extrapolation of habitat-flow relationships from measured to unmeasured areas.

Importantly, the 1980s studies made a clear distinction regarding extrapolation approaches that are suited for single thread channel versus those for multi-thread channels. Aaserude et al. (1985) correctly noted that for single thread channels, it is appropriate and is routinely done today to utilize extrapolation procedures that are based on proportional lengths of mesohabitat types that are identified as part of a habitat mapping exercise. This approach was originally fostered by Morhardt et al. (1983) and has remained in use since. Indeed, this approach, or some modification thereof, will be utilized for extrapolating PHABSIM-based habitat–flow relationships derived from main channel mesohabitat specific transects (e.g., riffle, run, pool, etc.) as identified from the Characterization of Aquatic Habitats Study (RSP Section 9.9) to unmeasured mesohabitats within a given geomorphic reach. This will be done in a series of steps that include the following:

- Completion of habitat mapping (see Section 9.9) that will delineate main channel mesohabitats into categories of cascades, riffle, pool, run, and glide as described in Section 8.5.4.2.1.1.
- Determination of percentages of each mesohabitat type within each geomorphic reach.
- Assignment of existing transects (those already established as input to the open-water flow routing model (RSP Section 8.5.4.3) and new main channel transects established either as part of the detailed Focus Area studies (RSP Section 8.5.4.6.1.2) or added to capture a specific main channel habitat not represented by the existing transects to a specific mesohabitat category.

- Weigh each of the transects within a given geomorphic reach based on the percentages of mesohabitats represented in the reach (e.g., in a reach that is 30 percent riffle with 6 riffle transects; each transect would be assigned a weighting factor of 5 percent (30 percent/6) of the total reach length).
- Apply additional transect weighting based on location to account for tributary and accretion flow.
- Derive habitat-flow relationships (by species and life stage) for a given geomorphic reach based on transect specific habitat-flow relationships by mesohabitat type weighted by the percentages of the reach (based on lineal distance) containing each mesohabitat type (as determined from habitat mapping).

This latter step will then result in a composited habitat-flow relationship that considers all mesohabitat types within a given geomorphic reach. Further compositing of relationships for all geomorphic reaches (with consideration for flow accretion, etc.) will allow for the derivation of habitat-flow relationships (by species and life stage) for the entire segment of the main channel Susitna River. Coupled with the open-water flow routing model, these relationships can then be used to evaluate how main channel habitats may vary under different operational scenarios and will provide one of the tools necessary for completing the spatial analysis.

A different approach will be needed for multi-thread channels because they contain multiple habitat types (e.g., side channel, side slough, upland slough, etc.) within which each may contain multiple mesohabitat types (e.g., riffle, run, pool, etc.). In addition, flows within some of the habitat types may be governed by groundwater-surface water interactions that cannot be modeled directly by PHABSIM. The framework for evaluating multi-channel habitats described in Aaserude et al. (1985) provides a logical construct for achieving this and as noted above, is the starting point for the current Instream Flow Study. Unlike the approach for a single thread channel where a reasonable assumption is that habitat-flow response relationships will generally be similar among mesohabitat types, the diversity of habitats within a multi-thread channel means that habitat-flow responses are dynamic and highly variable. In addition, multi-thread channels are spatially discontinuous and disconnected so that it is not possible to extrapolate entire multi-channel units to others. As noted by Aaserude et al. (1985), the braided river environment is too dynamic and variable for the development of quantitative relationships between discharge and physical habitat variables such as depth, velocity, and channel structure on a river corridor-wide basis for use in extrapolation. Instead, an approach for evaluating habitat is needed that focuses on portions of the river corridor but then relates the findings of those portions to other areas of similar character.

The method presented by Aaserude et al. (1985) was based on the provision of two separate databases, the first containing habitat-flow response relationships for the full range of habitat and mesohabitat types found within selected portions of the river, the second an expansive database consisting of aerial imagery and targeted measurements of a select number of habitat response variables from essentially all of the habitat types found within the primary multi-threaded channels in the Middle River Segment. Input to the first database was provided largely by a number of site-specific studies that included application of PHABSIM (IFG), DIHAB, and RJHAB models to define habitat-flow response relationships in different habitat types, as well as surveys to determine breaching flows. However, the “one size fits all” concept that may be valid for expansion of mesohabitat types does not apply to the multi-thread network of channels in the

Susitna River. Consequently, further stratification of the habitat types (side channel, side slough, upland slough, etc.) was needed and resulted in the designation of 10 “representative groups” that provided a sub-level of categorization to the habitat types (Steward et al. 1985; Aaserude et al. 1985). These 10 groups consisted of “identifiable combinations of flow – related attributes” (Steward et al. 1985) that were deemed readily distinguishable and included the following:

- Group I – Predominantly upland sloughs. Areas are highly stable due to persistence of non-breached conditions. Area hydraulics characterized by pooled clear water with velocities frequently near 0 fps and depths > 1 ft. Pools commonly connected by short riffles with velocities < 1 fps and depths < 0.5 ft.
- Group II – Side sloughs that are characterized by relatively high breaching flows (>19,500 cfs), clear water caused by upwelling groundwater and large channel length to width ratios (> 15:1).
- Group III – Areas with intermediate breaching flows and relatively broad channel sections. These areas consist of side channels which transform into side sloughs at mainstem discharges ranging from 8,200 to 16,000 cfs. These areas are distinguishable from Group II by lower breaching flows and smaller length to width ratios. Upwelling water is present.
- Group IV – Side channels that are breached at low flows and possess intermediate mean velocities (2–5 fps) at a mainstem discharge of approximately 10,000 cfs.
- Group V – Mainstem and side shoal areas that transform to clear water side sloughs as mainstem flows recede. Transformations generally occur at moderate to high breaching flows.
- Group VI – Similar to Group V. Sites within this group are primarily overflow channels that parallel the adjacent mainstem, usually separated by sparsely vegetated gravel bar. Upwelling may or may not be present. Habitat transformations within this group are variable in type and timing.
- Group VII – Side channels that breach at variable yet fairly low mainstem discharges and exhibit characteristic riffle/pool sequence. Pools are frequently large backwater areas near the mouth of the sites.
- Group VIII – Area that dewater at relatively high flows. Flow direction at the head of the channels tends to deviate sharply (> 30 degrees) from the adjacent mainstem.
- Group IX – Secondary mainstem channels that are similar to the primary mainstem channels in habitat character, but distinguished as being smaller and conveying a lesser proportion of the total discharge. Areas within this group have low breaching discharges and are frequently similar in size to large side channels, but have characteristic mainstem features, such as relatively swift velocities (> 5fps) and coarser substrate.
- Group X – Large mainstem shoals and margins of mainstem channels that show signs of upwelling.

Another element of the method described by Aaserude et al. (1985) that was used as part of the representative group designation was its consideration of habitat transformation wherein mainstem areas may functionally transition from side channels to side sloughs and ultimately become dewatered as flows recede. A total of 11 habitat transformation categories were defined and considered when comparing flow conditions; these included comparative categories of clear vs. turbid water, upwelling present vs. absent, and distinct vs. indistinct side channel formation.

Model development from which to base habitat-flow response relationships within each of the groups relied upon the site-specific models applied at different study areas. In addition to traditional metrics of weighted usable area (WUA), a number of other metrics were derived that included Wetted Surface Area (WSA), Gross Habitat Area (GHA), a Habitat Availability Index (HAI), a Habitat Distribution Index (HDI), and a Habitat Quality Index (HQI). These relationships were then applied to un-modeled areas assigned to different "representative groups" taking into account two important distinguishing characteristics—structural habitat quality and breaching flow. Structural habitat quality was evaluated for each site based on field data that considered cover type, percent cover, dominant substrate size, substrate embeddedness, channel geometry, and riparian vegetation. From this, a Structural Habitat Index (SHI) was computed for each un-modeled area. Breaching flows were likewise determined for each unmeasured area. These two elements were then used as adjustment factors for defining the derived non-modeled habitat – flow response relationship. Once relationships were derived from un-modeled areas, it was then possible to integrate results into an overall assessment of habitat-flow responses within each representative group; these were presented in Steward et al. (1985). The next step in the process would have been to conduct a system-wide (at least for the Middle River Segment) evaluation of habitat-flow responses that would have aggregated the responses into a system-wide habitat-flow response relationship. However, this step was never completed as part of the 1980s studies.

7.2.4. Instream Flow Study Integration

As described in Section 2, construction and operation of the proposed Project will change downstream flow conditions on an hourly, daily, and seasonal basis. Load-following operations will increase the frequency, timing, and magnitude of hourly and daily flow fluctuations, and increased flow releases during winter months will be followed by decreased flow releases as the reservoir refills. The effects of such flow changes will vary depending on the operational rules guiding power generation. The suite of Project operational rules governing hourly, daily, and seasonal dam releases are termed operational scenarios. Scenarios developed to benefit one specific resource may have a detrimental effect on another resource. For instance, maintaining high flow releases during the spring salmon smolt out-migration period may delay reservoir refill and could affect Project releases for late summer coho rearing. An operational scenario designed to benefit one resource, such as cottonwood germination, may have an unintended detrimental effect on another resource. Constraints on Project flow releases to benefit one natural resource may affect the ability of AEA to meet its energy needs. Identifying an operational scenario that satisfies the interests of all parties requires an evaluation of multiple resource benefits and risks.

Tools to inform the evaluation of flow scenarios have been developed in support of other water control decisions. A Decision Support System (DSS) was developed to support the evaluation of alternative flow regimes on resources of the Black Canyon of the Gunnison National Park (Auble et al. 2009). The DSS developed by Auble was intended to provide decision-makers with the tools to manage large data sets of simulated flow alternatives and evaluate the relative desirability of those alternatives with respect to natural resources. The intent was not to evaluate alternatives, but to provide a tool for informing the evaluation of alternatives. The basic approach was to array differences among alternative flow regimes by calculating values of indicator variables representing different habitat characteristics or processes of the riverine ecosystem. Auble noted that the scientific understanding and quantitative relations between flow and the physical and biological responses of riverine systems are complex and may be imperfectly represented by the indicators. Disagreement about the relative importance or weighting of multiple resource concerns can delay or derail the decision-making process. Ideally, a DSS requires a balance between simplification of assumptions to reduce complexity and oversimplification that does not reflect the constituent variables and calculations. Auble produced a set of indicators grouped into several areas of natural resources concerns. The indicators were replicable calculations that reflected conditions or processes within each area of concern. Alternatives were compared directly in terms of these indicators, each of which could be individually understood and challenged in terms of the assumptions involved in the calculations. Different users could make different decisions using this system because they might weight the importance of multiple indicators differently or value different aspects of the system. Thus, the goal of the DSS was not to make a decision, but rather to reduce the complexity of information and focus attention on trade-offs involved in the decision.

The Yakima River DSS (Bovee et al. 2008) was designed to quantify and display the consequences of alternative water management scenarios to provide water releases for fish, agriculture, and municipal water supply. Output of the Yakima River DSS consisted of a series of conditionally formatted scoring tables that compiled changes in evaluation indicators. Increases in the values of selected indicators were reflected in a color-coded scoring matrix to provide decision-makers with a quick visual assessment of the overall results of an operating scenario. The scoring matrix required that evaluation indicators used to describe resources be rated as comparative values. A variety of weighting strategies were provided during the decision-making process to reflect the relative importance of different indicators.

In support of relicensing decisions for the Baker River Hydroelectric Project, FERC No. 2150, a DSS-style matrix was developed to evaluate multiple resource concerns under alternative operational scenarios (Hilgert et al. 2008). The focus of the operations and aquatic habitat analyses was to identify a mode of operation that would protect aquatic resources while meeting multiple licensing participant interests. Aquatic habitat analyses were run concurrent with analyses of economic, flood control, and other resources. Various licensing participants championed different approaches to the relationships between minimum and maximum flow releases, minimum and maximum reservoir pool levels, and downramping rates. Through study and analysis, some scenarios were proven infeasible and abandoned, others were modified, and others were dissected and recombined with other approaches. Alternative operational scenarios were evaluated using a matrix that presented indicators of resource concerns without applying comparative weighting factors. Collaboration among licensing participants gradually led to consensus on a preferred flow management plan that contributed led to a Settlement Agreement.

Evaluation of Project effects on Susitna River resources will require inventive modeling approaches that integrate aquatic habitat modeling with evaluation of riverine processes such as groundwater-surface water interactions, water quality, and ice processes. The number of reaches, habitat types, target species and life stages, and resource-specific models will result in large data sets for multiple resources that will be difficult to comprehend when evaluating alternative operational scenarios. A DSS-type process will be needed to evaluate the benefit and potential impacts of alternative operational scenarios. For illustration purposes, an example matrix was developed (Table 7.2-2) to display a range of potential indicator variables including the following:

- Power
- Hydrologic
- Reservoir
- Ramping rates
- Stranding and trapping
- Salmon spawning and incubation
- Salmon rearing
- Other fish species
- Riparian
- Recreation
- Other aquatic conditions

As habitat-specific models are developed, they will be used to evaluate existing conditions and the effects of alternative operational scenarios for multiple resources and riverine processes. A Project operations model will be used to simulate Project inflow, outflow, power generation, and reservoir pool levels for alternative operational scenarios under a range of hydrologic years. The operations model will be used to quantify revenue from power generation based on operational constraints selected for each alternative scenario. Types of constraints may include maximum and minimum instream flow releases, ramping rates, and reservoir levels. These constraints may be varied within a hydrologic year according to schedules specified for each alternative. Operations model output may include simulated reservoir elevations, turbine, spill, and total outflow, as well as hourly stream flow immediately below the powerhouse. Output from the operations model will be used as input for the downstream habitat models. Hourly flows immediately below the powerhouse will be routed downstream using the mainstem open-water flow routing models (see RSP Section 8.5.4.3) and Ice Processes Model (see RSP 7.6).

Each habitat and riverine processes model can be used to develop large data sets of hourly habitat conditions. The DSS-type process will be used to focus attention on those attributes that the TWG believes are highest priority in evaluating the relative desirability of alternative scenarios with respect to natural resources. Evaluation indicators selected for a DSS-type matrix represent a preliminary analysis to identify the most promising scenarios. When discussion of alternatives focuses on only a few remaining scenarios, those final scenarios will be evaluated using the larger data set of habitat indicators to ensure that environmental effects are consistent with the initial analyses.

The selection of indicator variables will be developed in collaboration with the TWG. For planning purposes, it is assumed that values for each evaluation indicator will be developed and presented for a range of alternative operational scenarios without rating or comparative weighting of various resources. Although incorporating a relative weighting system similar to the Yakima River DSS (Bovee et al. 2008) would simplify the evaluation process, reaching consensus on weighting factors may divert attention from understanding and discussing the merits of constituent variables. Table 7.2-2 represents one option to present Project decision-makers with information on the effects of alternative operational scenarios on resource values. Development of a DSS-type process, and supporting software to efficiently process data analyses, will be initiated in collaboration with the TWG after the initial results of the various habitat modeling efforts are available in 2014. The intent is to prepare the DSS-type evaluation process by early 2015 to assist scenario evaluations in support of the License Application.

8. TECHNICAL MEMORANDUM – BIOLOGICALLY RELEVANT PHYSICAL PROCESSES IN THE SUSITNA RIVER

From a riverine ecosystem perspective, the flow regime of a given system serves not only to create and maintain the structure of the habitat (i.e., channel morphology) that is defined by the interaction of flow with the local geology, but also the associated physical processes that can express themselves in biologically meaningful ways. Understanding those processes and their linkage to flow regime is an integral component when considering instream flows for fish, aquatics, and riparian natural resources, especially when considering the effects of flow regulation. Importantly, such physical processes can go beyond those typically defined at the microhabitat level such as the parameters of depth, velocity and substrate that are part of the elements comprising HSC.

This TM serves to describe the processes that were identified in the Susitna River during the 1980s Su-Hydro studies that were considered biologically relevant, and how those processes may be influenced by flow regulation. This is followed by a brief discussion of how the 2013-2014 studies will be addressing these processes.

8.1. Su-Hydro 1980s Studies

A number of biologically relevant physical processes were identified during the early 1980s Su-Hydro studies of the Susitna River including groundwater, turbidity, water clarity, ice, and substrate composition. These processes were investigated primarily as part of biological studies to determine their influence on fish distribution and abundance and salmon egg incubation and survival. Investigators concluded relatively early-on that these factors in addition to, or in combination with, discharge were important components to fish and aquatic habitat and could be affected by the proposed hydroelectric development (Trihey 1982, Estes and Bingham 1982). During later phases, the studies became more focused on acquiring specific information that could be used in the development of instream flow models (see Section 7). Those studies included investigations of species and lifestage specific HSI models that considered turbidity, water clarity, and the presence of groundwater upwelling (see Section 7, Habitat Utilization and Habitat Suitability Curve Development Studies).

8.1.1. Groundwater Upwelling

During the winter of 1981-1982 Trihey (1982) investigated water temperatures at 13 sites in the Middle River Segment between RM 125 and RM 143 and compared surface water to intergravel measurements. These sites were selected because they had observations of salmon spawning earlier in 1981 and they were the first sites evaluated that suggested the importance of groundwater upwelling to fish species in the Susitna River. Measurements of surface and intergravel water temperature at these sites revealed that intergravel temperatures were higher and more stable than surface water temperatures (e.g., Figure 8.1-1). Trihey (1982) offered the following three hypotheses developed from his observations:

1. Mid-winter water temperatures in the sloughs are independent of mainstem water temperatures.
2. River stage appears to be influencing groundwater upwelling in the sloughs.

3. Spawning success at upwelling areas in side channels appears to be limited by availability of suitable substrate (streambed materials).

Flow changes can influence the prevalence of groundwater upwelling, which in turn can affect the rate of survival and development for eggs and alevins. In the Susitna River, Vining et al. (1985) suggested that upwelling is the single most important feature in maintaining the integrity of incubation in slough habitat as well as localized areas in side channel habitats. Upwelling and intergravel flow also play an important role in determining the water quality at redd sites, particularly with respect to temperature and dissolved oxygen concentrations. Thus, increases in winter discharge and stage that may result from the operation of a hydroelectric project may affect upwelling by:

- Decreasing the rate of groundwater upwelling from the adjacent floodplain.
- Diluting relatively warm, stable, upwelling habitats when side channels are breached by mainstem flow.
- Changing the rate of intergravel flows associated with hydraulic gradients between main channel and off-channel habitats.

In addition to the importance to incubating salmon eggs, groundwater inflows to sloughs were also considered potentially important as overwintering habitat (Dugan et al. 1984). Groundwater upwelling locations were mapped at a number of survey locations in the Middle and Lower River as part of the Su-Hydro Aquatics Studies. Estes and Schmidt (1983, Appendix F) reported the location of approximately 90 upwelling sites in the Middle River (Figure 8.1-2). Examples of upwelling locations at Slough 8A and Slough 21, which were sampled as DFH sites during 1982 and sampled during winter studies by Hoffman et al. (1983), are provided in Figures 8.1-2 to 8.1-4.

Intensive winter studies were implemented in March 1983 (Hoffman et al. (1983) and 1984-1985 (Vining et al. 1985; described in the previous section). Hoffman et al. (1983) reported on surface and intergravel water temperature monitoring at seven sites during the winter of 1982 to 1983 and also conducted incubation and emergences studies. In addition to water temperature, Hoffman et al. (1983) also monitored dissolved oxygen, pH, and specific conductance levels and noted the importance of dissolved oxygen exchange as a factor affecting egg incubation. Continuous surface and intergravel monitoring sites were established at six sloughs (Sloughs 21, 19, 16B, 11, 9, and 8A) and the mainstem at LRX 29 and Gold Creek. Measurements were collected from late August 1982 through early June 1983. Sites were chosen because they were known chum salmon and/or sockeye salmon spawning locations.

Incubation and emergence studies were conducted at seven sites during the winter of 1982-83 (Sloughs 21, 20, 11, 9 and 8A) and two side channels (A and B located at RM 136.2 and 137.3, respectively; Hoffman et al. 1983). Standpipes located along each bank of the selected sloughs were used to measure intergravel water temperature and chemistry (10 per bank, 20 total per location). Sampling at these locations occurred during April 15 to 18 and April 29 to May 2. Eggs were sampled once per month from September 1982 through May 1983 using a high pressure water jet to dislodge eggs into a mesh sack.

The 1982-1983 winter study (Hoffman et al. 1983) and 1984-1985 study (Vining et al. 1985) confirmed patterns of surface- and ground-water temperature observed by Trihey (1982). Intergravel water temperatures in slough habitats tend to be relatively stable (Hoffman et al.

1983). Vining et al. (1985) observed similar patterns for sloughs and side channels where upwelling was present. At tributary and mainstem sites Vining et al. (1985) observed that intergravel temperatures were variable and approach 0°C in October, which indicated intergravel waters were originating from surface waters. The continuous monitoring stations demonstrated intergravel water temperatures in areas with upwelling were warmer than surface waters during the ice covered period. As the spring thaw begins (about mid-April in 1983), intergravel temperatures then become cooler than surface water temperatures.

Monitoring during three days in mid-April and four days in late-April,1983, at sites with standpipes placed along slough banks indicated substantial variability in upwelling water temperatures with no consistent relationship between right bank and left bank standpipes at a site (Hoffman et al. 1983). Average intergravel temperatures were cooler than surface waters, which was consistent to the patterns observed from continuous monitoring.

Mean intergravel dissolved oxygen measurements ranged from 4.6 mg/L at Slough 8A during both sampling periods to 8.5 mg/L at Slough 11 during the first sampling period of 1983 (Hoffman et al. 1983). Intergravel dissolved oxygen was substantially lower than surface water dissolved oxygen that ranged from a mean of 9.1 mg/L at Slough 21 during the first sampling period to 11.2 mg/L at Slough 8A during the second sampling period. Measurements of pH were found to be within suitable levels for both intergravel and surface water. Significant differences and a significant interaction were found for specific conductance between sites and between left and right banks within the sites. Hoffman et al. (1983) concluded that multiple water sources were the cause of these differences. Vining et al. (1985) observed similar patterns for dissolved oxygen and pH. For specific conductance, Vining et al. (1985) observed similar patterns in sloughs; however, specific conductance was lower in tributary sites, which were not studied by Hoffman et al. (1983), than slough and mainstem sites.

Bigler and Levesque (1985) monitored surface and intergravel water temperature, egg development, outmigration, and substrate composition at three Lower River side channels where relatively high levels of chum salmon spawning was documented. The three sites included the Trapper Creek side channel (RM 91.6), Sunset Side Channel (RM 86.9), and Circular Side Channel (RM 75.3). Chum salmon surveys and instream flow modeling were also conducted at these sites. Egg development was also monitored at the Birch Creek Camp Mainstem (RM 88.6) site and a fyke net deployed for two days in early May 1984.

Similar to Hoffman et al. (1983), Bigler and Levesque (1985) observed that most of these chum salmon spawning areas had upwelling and intergravel temperatures were higher than surface water temperatures. In general, eggs developed through the alevin and emergence stage at all sites. The upper portion of the Sunset Side Channel did not have groundwater upwelling and eggs laid in this portion of the study site froze.

As described above, substantial effort was expended to understand groundwater effects (i.e., temperature and dissolved oxygen) that are important to salmon egg incubation rates and survival. The results of these studies led to the development of alternative HSC curves for chum and pink salmon spawning that could be used in the instream flow models (see Section 7, Habitat Utilization and Habitat Suitability Curve Development Studies).

Determining overwintering locations and habitat conditions for juvenile salmon and resident fish species was difficult during the 1980s because fish captures in general decline in the winter period. In addition, because of logistical and safety considerations relatively few sites could be sampled in the winter and those were infrequently sampled. Nevertheless, studies concluded that upwelling in sloughs was an important factor contributing to favorable overwintering habitat for Chinook and to a lesser extent coho salmon (Roth and Stratton 1985, Stratton 1986). Roth and Stratton (1985) reported that young of the year Chinook salmon became more concentrated in upwelling areas of sloughs as temperatures declined during late September and early October.

8.1.2. Turbid and Clear Water Zones

Typical of glacial fed streams and rivers, the Susitna River is extremely turbid during most of the year (Harza-Ebasco 1985). Turbidity, as measured in nephelometric turbidity units (NTUs) is a metric of light penetration which is an important factor affecting primary productivity. Turbidity in the Susitna River was primarily determined by levels of inorganic glacial flour suspended in the water. Glacial water from the Chulitna River, with turbidity measured as high as 1,920 NTU, is a major contributor of turbidity to the mainstem Susitna River. The maximum turbidity level measured in the Talkeetna River during 1982 was 272 NTU. Turbidity is affected by the amount of glacial melt and precipitation in the form of rain. Consequently, turbidity tends to be high in the summer and low in the winter (Harza-Ebasco 1985; Figure 8.1-5). Turbidity levels tended to decline in a downstream direction below the Three Rivers Confluence. Maximum turbidity measurements at Sunshine and Susitna stations were 1,056 and 790 NTU, respectively.

Turbidity in side channels and side sloughs was affected by inflows from clear water tributaries and groundwater (Harza-Ebasco 1985). In addition, breaching at the heads of side sloughs or side channels allowed turbid mainstem water to flow through. When flows were below breaching levels, turbidity was substantially lower and less variable (Figure 8.1-6).

While turbidity information was collected at fish sampling sites during 1981, the study design for 1982 explicitly considered turbid mainstem water, clear water from tributaries or groundwater, and mixing zones, as well as water velocity and how the mainstem river stage influenced conditions. During 1982, 17 sites referred to as Designated Fish Habitat (DFH) sites were surveyed twice monthly from June through September during the open water season (Estes and Schmidt 1983). Twelve sites were located in the Middle River (Whiskers Creek and Slough to Portage Creek Mouth) and five were located in the Lower River (Goose Creek and Side Channel to Birch Creek and Slough; Tables 4.2-1 and 4.2-2).

Habitat zones were delineated within each DFH site based upon the influence of mainstem flow, tributary flow, and water velocity (Table 8.1-1; Figure 8.1-7). Because the zones were based upon flow characteristics, the size of the zones may have varied from survey to survey. As part of the statistical analysis the nine zones were aggregated into Hydraulic and Water Source Zones (Table 8.1-2). In addition to statistical tests to determine associations between fish species catch per unit effort and aggregate hydraulic and water source zones, tests were also run to examine correlations between catch per unit effort and habitat variables including water temperature, turbidity, and velocity (Schmidt and Bingham (1983, Appendix E).

Similarly, sampling of Juvenile Anadromous Habitat Study (JAHS) sites during 1983 and 1984 occurred in a systematic fashion within grids delineated at each site (Figure 8.1-8; Dugan et al. 1984, Suchanek et al. 1984a, 1985). Each 6 ft by 30 ft sampling cell was intended to be relatively homogeneous with respect to temperature, turbidity, depth, velocity, cover and substrate composition. Cells within a site were then selected such that the full range of conditions were sampled. Analysis of the fish collections by beach seine and backpack electrofishing and the physical factors measured within each cell were used in the development of habitat suitability curves (HSC) for juvenile salmon species (Suchanek et al. 1984a, 1985; also see Section 8.1.1.3 Juvenile Salmon Rearing in the Middle Susitna River).

Surveys for juvenile anadromous and resident fish with monitoring of turbidity in areas sampled led to a number of conclusions regarding the influence of turbid and clear water zones on habitat utilization. Turbidity was found to be a significant factor in analysis of variance of catch rates for Age 0 Chinook and coho juveniles (Dugan et al. 1984). Chinook juveniles were found to use relatively turbid water greater than 30 NTU as cover (Dugan et al. 1984, Suchanek et al. 1984a). In contrast, coho juveniles were found to prefer relatively clear water zones. Nevertheless, separate HSC for turbid (>30 NTU) and clear water (<30 NTU) were only developed for Chinook salmon juveniles, because there was insufficient data for coho salmon (Suchenek et al. 1984).

Turbidity was also considered an important factor incorporated into cover HSC for rainbow trout adult, Arctic grayling adult, round whitefish adult and juveniles, and longnose sucker adult (Suchanek et al. 1984b). Suchanek et al. (1984b) found these species utilized cover differently depending upon whether using turbid or clear water. In general, rainbow trout and Arctic grayling had higher catch rates in areas with lower turbidity levels while round whitefish and longnose sucker had higher catch rates in more turbid areas (Suchanek et al. 1984b). Turbidity levels were also considered an important factor affecting habitat utilization by burbot, humpback whitefish, and Dolly Varden (Schmidt and Bingham 1983), but catch rates were insufficient for developing HSC (Suchanek et al. 1984b). Adult burbot tended to be more common in turbid mainstem and mixed water sources. Similar to round whitefish, humpback whitefish were also more commonly captured in turbid mainstem and mixed water rather than clear water areas. Dolly Varden were more commonly associated with tributaries and tributary mouths with relatively low turbidity.

8.1.3. Ice Processes and Open Water Leads

A discussion of ice processes and open water leads was presented as part of RSP Section 7.6 and is summarized herein because of their overall relevance when discussing physical processes. As noted in Section 7.6, ice affects the Susitna River for approximately seven months of the year, between October and May. When air and water temperatures drop below freezing in September and October, border ice grows along the banks of the river, and frazil ice begins accumulating in the water column and flowing downstream. Flowing ice eventually clogs the channel in shallow or constricted reaches, or at tidewater, forming ice bridges. Frazil pans flowing downstream accumulate against ice bridges, causing the ice cover to progress upstream. By January, much of the river is under a stable ice cover, with the exception of persistent open leads corresponding with warm upwelling water or turbulent, high-velocity flows. Flows generally drop slowly throughout the winter until snowmelt commences in April. During April and May, river stages rise and the ice cover weakens, eventually breaking into pieces and flushing downstream (R&M 1982a). Ice jams are recurrent events in some reaches of the river. If severe, jams can flood upstream and adjacent areas, drive ice overbank onto gravel bars and into sloughs and side channels, shear-off or scar riparian vegetation, and threaten infrastructure such as the Alaska Railroad and riverbank property (R&M 1982a).

Ice processes were documented between the mouth of the Susitna River (RM 0) and the proposed dam site (RM 184) between 1980 and 1985 (R&M 1981b, 1982b, 1983, 1984, 1985, 1986). Winter observations have spanned a range of climatic conditions. The freeze-up period of 1985 was unusually cold, with about twice the accumulated freezing-degree days as the long-term average (R&M 1986), while the freeze-up period of 1984 was warm (R&M 1985). In the 1980s modeling studies, cold, average, and warm conditions were simulated using records from the winters of 1971–1972, 1976–1977, and 1981–1982, respectively (Harza-Ebasco 1984). The winter of 1971–1972 still stands as one of the coldest on record at Talkeetna; however, according to the Western Regional Climate Data Center, the warmest winter on record occurred in 2002–2003. Both freeze-up and break-up progressions were monitored using aerial reconnaissance. Locations of ice bridges during freeze-up and ice jams during break-up were recorded each season.

In addition to its effect on river morphology, riparian function, and sediment transport, ice processes influence the freeze-up and ice cover on salmon spawning and overwintering habitat areas. Water levels at certain sloughs in the Middle River and Lower River were monitored during the winter to determine whether staging during freeze-up and ice cover diverted water into side channels and sloughs (R&M 1984). Changes in water levels in spawning sloughs and side channels as a result of ice processes can have adverse effects in several ways (Vining et al. 1985). First, inflows of cold mainstem water into areas with warmer groundwater upwelling can result in longer incubation times. Secondly, large decreases in flows relative to flows during spawning can result in some redds being dewatered and subjected to freezing.

Ice processes can also affect the quality of overwinter habitat (Brown et al 2011). For example, anchor ice can reduce the amount of interstitial space between large cobbles and boulders, which is used as cover and resting locations by salmonids. Large amounts of frazil ice drifting in the water column can also cause fish to move location, which can be stressful under low temperature conditions (Brown et al. 2011).

As part of winter studies, ADF&G mapped the location of open leads. Open leads typically occurred in areas of groundwater upwelling or in areas of relatively high water velocity where turbulence tends to maintain open areas. Barrett et al. (1985) reported that upwelling, bank seepage, or open leads were present during the winter 1983 at 10 of 12 mainstem/side channel sites in the Lower River with chum salmon spawning observed during 1984. Spawning in sloughs was also associated the presence of upwelling, bank seepage, or open leads as well as the presence of tributaries (Barrett et al. 1985).

Freeze-up and melt-out processes in the Middle River (between Gold Creek and Talkeetna) were modeled using ICECAL, a numerical model developed by the USACE Cold Regions Research and Engineering Laboratory (CRREL) (Harza-Ebasco 1984). The model utilized the outputs from a temperature model developed for the river (SNTEMP) and empirical data on frazil production and ice-cover progression derived from observations. Representative year types were modeled under both the proposed 1980s Watana-only and Watana-Devils Canyon operations, including a cold winter (1971–1972), a very warm winter (1976–1977), a warm winter (1982–1983), and an average winter (1981–1982). The results of the model included predictions of the extent of ice cover, the timing of ice-cover progression, ice surface elevations, and the inundated area beneath the ice cover for selected cross-sections. The elevation of water flowing beneath the ice was compared to the elevation necessary to overtop slough berms at selected fish habitat study areas in the Middle River in order to assess the impacts of Project operation on winter flow in these sloughs. Empirical data on frazil production and ice-cover progression was used to estimate changes in ice-cover progression between tidewater and Talkeetna. Reservoir ice was simulated using a DYRESM model and calibrated to conditions at Eklutna Lake (Harza-Ebasco 1986).

Key findings of the 1980s modeling effort included the following (for the Watana-only scenarios):

- The open water reach would likely extend 44–57 miles downstream of the dam site.
- Ice thicknesses were generally similar under project conditions, where ice was predicted to occur.
- Winter water surface elevations under ice would be 2–7 feet higher under project conditions, and would result in the flooding of some sloughs with mainstem water in the Middle River without mitigation.
- Freeze-up would be delayed by 2–5 weeks in the fall, and ice-out would occur 5–7 weeks earlier in the spring.
- Ice jams during break-up would be reduced in severity post-project because of the regulation of spring snowmelt flows.

8.1.4. Substrate Composition

Substrate composition is determined primarily by geomorphic processes that produce a state of dynamic equilibrium with the upstream water and sediment supply by adjusting their physical characteristics to the imposed conditions (Chorley et al. 1984; Lane 1955). These physical characteristics, that include gradient, channel geometry, planform, and boundary materials (stream bed and banks), form the habitat that is used by the aquatic and riparian organisms, and they occur and adjust at a variety of spatial and temporal scales.

Substrate composition is an important factor contributing to quality of spawning, rearing, and overwintering habitat quality (Bjornn and Reiser 1991). During the 1980s Su-Hydro studies, substrate composition was typically described as part of characterizing the physical environment at sampling sites. Species and life stage specific suitability of substrate can be described and incorporated into instream flow modeling. Habitat suitability curves (HSC) development and collection of substrate composition data at instream flow modeling sites was in important part of the 1980s Su-Hydro studies (see Section 7, Habitat Utilization and Habitat Suitability Curve Development Studies).

In addition, substrate composition, and more specifically the level of fines (particles less than 0.08 inches in diameter), were studied as part of chum and sockeye egg incubation studies (e.g., Vining et al. 1985). The presence of excessive amounts of fines may result primarily in two types of adverse effects (Bjornn and Reiser 1991). The first is that fines can reduce the amount of intergravel flow such that eggs do not receive sufficient oxygen and that waste products are not removed from the redd. The second is that influxes of fines during incubation can entomb a redd and prevent alevins from emerging. Vining et al. (1985) observed that slough habitats had the highest level of fines, followed by side channel, tributary, and mainstem habitats (Figure 8.1-9). However, sediment composition sampled directly from redds were much lower (Figure 8.1-10). The difference in the amount of fines between redd samples and overall can be at least partially explained by the redd digging process by salmon females which can remove substantial amounts of fines (Bjornn and Reiser 1991). Vining et al. (1985) suggested that egg survival at

Susitna River study sites approached zero when fines (< 0.08 inches in diameter) in redds exceeded 16 percent (Figure 8.1-Figure 8.1-11).

One of the early conclusions from the surveys conducted during 1981 and 1982 was that little to no salmon spawning occurred in the main channel habitats because of high water velocities and unsuitable spawning substrate. Mainstem substrates generally consisted of boulder and cobble size materials with interstitial spaces filled with a grout-like mixture of small gravels and glacial sands (Estes and Schmidt 1983). In contrast, the more protected side channels and side sloughs often included smaller substrates that were occasionally disturbed during high flow events that breached berms at the head of the channel or slough. In addition, many side channels and sloughs had upwelling from hyporheic or groundwater sources that provided more stable and higher temperatures during egg incubation than mainstem water (Hoffman et al. 1983).

Fines can also adversely affect overwintering habitat for juvenile salmon. As temperatures cool during the late fall and winter, salmonids tend to use areas with low water velocity such as deep pools, high levels of cover such as large woody debris or coarse substrate (large cobble and boulders), and areas with upwelling (Brown et al. 2011). High levels of fines can fill the interstitial spaces between coarse substrate which reduces the amount of available habitat and can reduce upwelling groundwater (Vining et al. 1985).

8.2. Susitna-Watana 2013-2014 Studies

In terms of the 2013-2014 studies, essentially all of the processes identified during the 1980s studies and described above (e.g., groundwater- upwelling, intergravel water temperature, water turbidity and water clarity, ice processes, and substrate composition) will be evaluated as part of one or more of the proposed studies. In addition, several other processes that were not explicitly studied or that were not studied in any detail during the 1980s will also be evaluated. These include detailed fluvial geomorphology studies/processes (see RSP 6.5 and 6.6), studies of large woody debris recruitment (see RSP 6.5.4.9) and an extensive evaluation of riparian community processes and interactions with flows (see RSP 8.6).

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10. TABLES

Table 2.1-1. Types of instream flow and fish related studies conducted as part of the Su-Hydro Fish and Aquatics Study Program during 1981 to 1986.

Year	Adult Anadromous Studies	Resident and Juvenile Studies	Aquatic Habitat Studies
1981	Mainstem escapement monitoring (gillnet, electrofishing, fishwheel, and sonar sampling); radio-tracking, run timing, age and length, sex ratios, aerial and foot spawning surveys between Cook Inlet and Devils Canyon plus the Yentna River and selected tributaries (ADF&G 1981a).	Resident fish distribution, abundance, age, length, sex composition, and floy tagging from Cook Inlet to Devils Canyon (Delaney et al. 1981a) and upstream of Devils Canyon (Delaney et al. 1981b); Juvenile anadromous winter and summer distribution, abundance, age, and length (Delaney et al. 1981c).	Measurement of physical parameters including hydrology (flow), hydraulics (water stage and velocity), water quality, and morphologic mapping at selected sites (Estes et al. 1981).
1982	Mainstem escapement monitoring (fishwheels, sonar) downstream of Devils Canyon, tagging, radio-tracking, run timing, age composition, fecundity, aerial and foot spawning surveys, eulachon and Bering cisco spawning surveys (ADF&G 1983).	Chum and sockeye egg incubation and intergravel water monitoring in the Middle River (Hoffman et al. 1983); Distribution and abundance of resident fish and juvenile salmon downstream of Devils Canyon, radio-tracking of resident fish, emergence and outmigration of juvenile salmon, food habitats of juvenile salmon (Schmidt et al. (1983); Distribution and abundance of resident fish upstream of Devils Canyon, tributary habitat, passage barriers, and fish distribution/abundance, lake habitat and fish distribution (Sautner and Stratton 1983).	Characterization of spawning and rearing habitat for anadromous and resident fish (Estes and Schmidt 1983); Slough hydrogeology (Burgess 1983); Side slough access by spawning salmon (Trihey 1982);
1983	Mainstem escapement monitoring (fishwheels, sonar) downstream of Devils Canyon, tagging, run timing, age composition, fecundity, aerial and foot spawning surveys, eulachon and Bering cisco spawning surveys (Barrett et al. 1984).	Outmigration of juvenile salmon upstream of Talkeetna, distribution and abundance of juvenile salmon upstream of Talkeetna (Schmidt et al. 1984a); Temperature effects on chum and sockeye salmon egg development (Wangaard and Burger 1983); Access and transmission corridor aquatic study (Schmidt et al. 1984b)	Collection of hydrologic and water quality information and information needed for modeling adult salmon spawning habitat and access into selected sloughs used for spawning (Sautner et al. 1984); Juvenile salmon and resident fish rearing suitability criteria and habitat modeling (Schmidt et al. 1984a); Assessment of access into Indian and Portage creeks by spawning salmon (Trihey 1983).

Year	Adult Anadromous Studies	Resident and Juvenile Studies	Aquatic Habitat Studies
1984	Mainstem escapement monitoring (fishwheels, sonar) downstream of Devils Canyon, tagging, run timing, age composition, aerial and foot spawning surveys (Barrett et al. 1985).	Migration and growth of juvenile salmon (Roth and Stratton 1985); Abundance and distribution of juvenile salmon (Suchanek et al. 1985); Abundance, distribution, and radio-tracking of resident fish in the lower Middle River (Sundet and Pechek 1985); Invertebrate food sources for Chinook salmon juveniles (Hansen and Richards 1985). Water quality monitoring and chum egg incubation study in the lower Middle River (Vining et al. 1985); Intergravel water temperature, substrate composition, chum spawning habitat, and egg incubation in the Lower River (Bigler and Levesque 1985)	Collection of hydrologic and water quality information and information needed for modeling spawning and rearing flow:habitat relationships (Quane et al. 1985); Instream flow relationships for juvenile salmon (Suchanek et al. 1985); Access of spawning salmon into tributaries downstream of Talkeetna (Ashton and Trihey 1985); Chum spawning habitat in the Lower River instream flow model development (Bigler and Levesque 1985).
1985	Mainstem escapement monitoring (fishwheels) downstream of Devils Canyon, tagging, run timing, age composition, aerial and foot spawning surveys (Thompson et al. 1986); Summary of fishery data (Hoffman 1985).	Winter distribution of burbot and rainbow trout (Sundet 1986); Winter distribution, abundance, movement, and length of juvenile Chinook and coho salmon (Stratton 1986); Migration and growth of juvenile salmon (Roth et al. 1986). Preliminary results of primary productivity and macroinvertebrate monitoring in the Susitna and Kasilof rivers (Wilson 1985),	Characterization of aquatic habitats in the lower Middle River (Aaserude et al. 1985); Juvenile Chinook salmon instream flow modeling (Steward et al. 1985); Response of water surface area to discharge in the Yentna to Talkeetna Reach (Ashton and Klinger-Kingsley 1985) and Talkeetna to Devils Canyon Reach (Klinger Kingsley et al. 1985). Development of quantitative relationships regarding the influences of incremental changes in streamflow, stream temperature and water quality on fish habitats in the Middle River (Trihey and Associates and Entrix 1985).
1986	No field, laboratory, or desktop studies.	No field, laboratory, or desktop studies.	Chum salmon spawning instream flow modeling (Trihey and Hilliard 1986).

Table 3.1-1. Designated Fish Habitat Sites surveyed June through September 1982. Source: Estes and Schmidt (1983).

Reach	Site	Historic River Mile
Lower River	GOOSE CREEK 2 AND SIDE CHANNEL	73.1
	WHITEFISH SLOUGH	78.7
	RABIDEUX CREEK AND SLOUGH	83.1
	SUNSHINE CREEK AND SIDE CHANNEL	85.7
	BIRCH CREEK AND SLOUGH	88.4
Middle River	WHISKERS CREEK AND SLOUGH	101.2
	SLOUGH 6A	112.3
	LANE CREEK AND SLOUGH 8	113.6
	SLOUGH 8A	125.3
	SLOUGH 9	129.2
	4th OF JULY CREEK-MOUTH	131.1
	SLOUGH 11	135.3
	INDIAN RIVER—MOUTH	138.6
	SLOUGH 19	140.0
	SLOUGH 20	140.1
	SLOUGH 21	142.0
	PORTAGE CREEK-MOUTH	148.8

Table 3.1-2. Description of habitat zones sampled at Designated Fish Habitat Sites: June through September 1982 (From Estes and Schmidt 1983).

Zone Code	Description
1	Areas with a tributary or ground water source which are not influenced by mainstem stage and which usually have a significant[1] surface water velocity.
2	Areas with a tributary or ground water source which have no appreciable[1] surface water velocity as a result of a hydraulic barrier created at the mouth of a tributary or slough by mainstem stage.
3	Areas of significant surface water velocities, primarily influenced by the mainstem, where tributary or slough water mixes with the mainstem water.
4	Areas of significant water surface velocities which are located in a slough or side channel above a tributary confluence (or in a slough where no tributary is present) when the slough head is open.
5	Areas of significant water surface velocities which are located in at slough or side channel below a tributary confluence when the slough head is open.
6	Backwater areas with no appreciable surface water velocities which result from a hydraulic barrier created by mainstem stage which occur in a slough or side channel above a tributary confluence (or in a slough or side channel where no tributary is present), when the head of the slough is open.
7	Backwater areas with no appreciable surface water velocities which result from a hydraulic barrier created by mainstem stage which occur in a slough or side channel below a tributary confluence, when the head of the slough is open.
8	Backwater areas consisting of mainstem eddies.
9	A pool with no appreciable surface water surface velocities which is created by a geomorphological feature of a free-flowing zone or from a hydraulic barrier created by a tributary; not created as a result of mainstem stage.

Notes:

1 "Significant" and "appreciable" surface water velocities mean a velocity of at least 0.5 ft/sec. However, there are site-specific exceptions to this, based on local morphology.

Table 3.1-3. Aggregate Hydraulic (H), Water Source (W) and Velocity (V) zones. Source: Estes and Schmidt (1983), Schmidt et al. (1983).

Aggregate Zone	Habitat Zone Included	Definition
H-I	1, 4, 5, 9	not backed up by mainstem
H-II	2, 6, 7, 8	backed up by mainstem
H-III	3	mainstem
W-I	1, 2	tributary water and/or ground water only
W-II	4, 6, 8, sometimes 3	mainstem water only
W-III	5, 7, sometimes 3	mixed water sources
V-I[1]	1, 3, 4, 5	Fast water
V-II[1]	2, 6, 7, 8, 9	Slow water

Notes:

1 The habitat zones included in aggregate zones V-I and V-II were not provided in the source documents. Zone descriptions were used to classify which zones were fast and slow water.

Table 3.1-4. JAHS sample sites for the AJ and AH components of the Aquatic Studies Program during 1983 and 1984.

Site	River Mile	Macro-habitat Type[2]	1983/1984 Sampling[1] Fish Distri-bution Site	RJHAB Modeling Site	IFIM Modeling Site	1982 DFH Site	1982 SFH Site	1981 Sample Site
Eagles Nest Side Channel[3]	36.2	SC	X	X				
Hooligan Side Channel[3]	36.2	SC	X	X				
Kroto Slough Head	36.3	SS	X	X				
Rolly Creek Mouth	39.0	T	X	X			X	
Bear Bait Side Channel	42.9	SC	X	X				
Last Chance Side Channel	44.4	SC	X	X				
Rustic Wilderness Side Channel	59.5	SC	X	X				
Caswell Creek Mouth[3]	63.0	T	X	X			X	X
Island Side Channel	63.2	SC	X	X	X			
Mainstem West Bank	74.4	SC	X		X			
Goose 2 Side Channel	74.8	SC	X	X		X		
Circular Side Channel	75.3	SC	X		X			
Sauna Side Channel	79.8	SC	X		X			
Sucker Side Channel[3]	84.8	SC	X	X				
Beaver Dam Slough[3]	86.3	T	X	X				
Beaver Dam Side Channel[3]	86.3	SC	X	X				
Sunset Side Channel[3]	86.9	SC	X		X			
Sunrise Side Channel[3]	87.0	SC	X	X				
Birch Slough[3]	89.4	T	X	X		X		X
Trapper Creek Side Channel	91.6	SC	X	X	X			
Whiskers Creek Slough	101.2	SS/SC	X	X		X		X
Whiskers Creek[4]	101.2	T	X			X		X
Slough 3B	101.4	SS	X					
Mainstem at head of Whiskers Creek Slough[4]	101.4	SC	X					
Chase Creek	106.9	T	X				X	
Slough 5	107.6	US	X	X				
Oxbow I	110.0	SC/SS	X					
Slough 6A	112.3	US	X	X		X		X
Mainstem above Slough 6A[4]	112.4	SC	X					
Lane Creek[4]	113.6	T	X			X		X
Slough 8	113.6	SS	X	X		X		
Mainstem II	114.4	SC/SS	X					X
Lower McKenzie Creek[4]	116.2	T	X				X	
Upper McKenzie Creek[4]	116.7	T	X				X	
Side Channel below Curry[4]	117.8	SC	X					
Oxbow II[4]	119.3	SC/SS	X					
Slough 8A	125.3	SS	X		X	X		
Side Channel 10A	127.1	SC	X	X				
Slough 9	129.2	SS/SC	X		X	X		
Slough/Side Channel 10	133.8	SC/SS	X		X		X	X

Site	River Mile	Macro-habitat Type[2]	1983/1984 Sampling[1] Fish Distri-bution Site	RJHAB Modeling Site	IFIM Modeling Site	1982 DFH Site	1982 SFH Site	1981 Sample Site
Lower Side Channel 11[4]	134.6	SC	X		X			
Slough 11	135.3	SS	X			X		X
Upper Side Channel 11[4]	136.2	SC	X		X			
Indian River-Mouth	138.6	T	X			X		X
Indian River-TRM 10.1	138.6	T	X					
Slough 19[4]	140.0	US	X			X		
Slough 20[4]	140.1	SS/SC	X			X		X
Side Channel 21	140.6	SC			X			
Slough 21	142.0	SS/SC			X	X		
Slough 22	144.3	SS/SC	X	X				
Jack Long Creek[4]	144.5	T	X				X	
Portage Creek Mouth	148.8	T	X			X		X
Portage Creek TRM 4.2	148.8	T	X					
Portage Creek TRM 8.0	148.8	T	X					

Notes:

1 Sites from RM 36.2 to RM 91.6 were sampled in 1984 (Suchanek et al. 1985). Sites from RM 101.2 to 148.8 were sampled in 1983 (Dugan et al. 1984).

2 T – Tributary
US – Upland Slough
SS – Side Slough
SC – Side Channel

3 Located within representative side channel or slough complexes mapped by Ashton and Klinger-Kingsley (1985).

4 Sites sampled less than 3 times in 1983.

Table 3.3-1. Locations, descriptions and selection rationale of final Focus Areas for detailed study in the Middle River Segment of the Susitna River. Focus Area identification numbers (e.g., Focus Area 184) represent the truncated Project River Mile (PRM) at the downstream end of each Focus Area.

Focus Area ID	Common Name	Description	Geomorphic Reach	Location (PRM)		Area Length (mi)	Habitat Types Present							Fish use in 1980s		Instream Flow Studies in 1980s			Rationale for Selection
				Upstream	Downstream		Main Channel, Single	Main Channel, Split	Side Channel	Tributary Mouth	Side Slough	Upland Slough	Beaver Complex	Spawning	Rearing	IFG	DIHAB	RJHAB	
Focus Area-184	Watana Dam	Area approximately 1.4 miles downstream of dam site	MR-1	185.7	184.7	1.0	X	X	X					*N/A*	*N/A*	*N/A*	*N/A*	*N/A*	Focus Area-184 length comprises 50% of MR-1 reach length (2 miles long) and contains split main channel and side channel habitat present in this reach.
Focus Area-173	Stephan Lake, Complex Channel	Wide channel near Stephan Lake with complex of side channels	MR-2	175.4	173.6	1.8	X		X	X	X			*N/A*	*N/A*	*N/A*	*N/A*	*N/A*	Focus Area-173 contains a complex of main channel and off-channel habitats within wide floodplain. Represents greatest channel complexity within MR-2. Reach MR-2 is 15.5 miles long and channel is generally straight with few side channels and moderate floodplain width (2-3 main channel widths).
Focus Area-171	Stephan Lake, Simple Channel	Area with single side channel and vegetated island near Stephan Lake	MR-2	173.0	171.6	1.4	X		X	X				*N/A*	*N/A*	*N/A*	*N/A*	*N/A*	The single main channel with wide bars, single side channel and moderate floodplain channel width in Focus Area-171 are characteristic of MR-2. Reach MR-2 channel morphology is generally straight with few side channels and moderate floodplain width (2-3 main channel widths).
Focus Area-151	Portage Creek	Single channel area at Portage Creek confluence	MR-5	152.3	151.8	0.5	X			X				X	X				Focus Area-151 is a single main channel and thus representative of the confined Reach MR-5. Portage Creek is a primary tributary of the Middle Segment and the confluence supports high fish use.
Focus Area-144	Side Channel 21	Side channel and side slough complex approximately 2.3 miles upstream Indian River	MR-6	145.7	144.4	1.3	X	X	X	X	X		X	X	X	X			Focus Area-144 contains a wide range of main channel and off-channel habitats, which are common features of Reach MR-6. Side Channel 21 is a primary salmon spawning area. Reach MR-6 is 26 miles long (30% of Middle Segment length) and is characterized by a wide floodplain and complex channel morphology with frequent channel splits and side channels.
Focus Area-141	Indian River	Area covering Indian River and upstream channel complex	MR-6	143.4	141.8	1.6	X	X	X	X		X	X	X	X		X		Focus Area-141 includes the Indian River confluence, which is a primary Middle Susitna River tributary, and a range of main channel and off-channel habitats. Channel and habitat types present in Focus Area-141 are typical of complex Reach MR-6. High fish use of the Indian River mouth has been documented and DIHAB modeling was performed in main channel areas.
Focus Area-138	Gold Creek	Channel complex including Side Channel 11 and Slough 11	MR-6	140.0	138.7	1.3	X	X	X		X	X	X	X	X	X			The Focus Area-138 primary feature is a complex of side channel, side slough and upland slough habitats, each of which support high adult and juvenile fish use. Complex channel structure of Focus Area-138 is characteristic of Reach MR-6. IFG modeling was performed in side channel habitats.
Focus Area-128	Skull Creek Complex	Channel complex including Slough 8A and Skull Creek side channel	MR-6	129.7	128.1	1.6	X	X	X	X	X			X	X	X	X		Focus Area-128 consists of side channel, side slough and tributary confluence habitat features that are characteristic of the braided MR-6 reach. Side channel and side slough habitats support high juvenile and adult fish use and habitat modeling was completed in side channel and side slough habitats.
Focus Area-115	Lane Creek	Area 0.6 miles downstream of Lane Creek, including Upland Slough 6A	MR-7	116.5	115.3	1.2	X	X	X			X	X		X	X		X	Focus Area-115 contains side channel and upland slough habitats that are representative of MR-7. Reach MR-7 is a narrow reach with few braided channel habitats. Upland Slough 6A is a primary habitat for juvenile fish and habitat modeling was done in side channel and upland slough areas.
Focus Area-104	Whiskers Slough	Whiskers Slough Complex	MR-8	106.0	104.8	1.2	X	X	X	X	X	X		X	X	X	X	X	Focus Area-104 contains diverse range of habitat, which is characteristic of the braided, unconfined Reach MR-8. Focus Area-104 habitats support juvenile and adult fish use and a range of habitat modeling methods were used in side channel and side slough areas.

Table 4.1-1. Deployment of fishwheel (F) and sonar stations (S) from 1981 to 1985. Sources: ADF&G (1982), ADF&G (1983b), Barrett et al. (1984), Barrett et al. (1985), Thompson et al. (1986).

Station	River Mile	1981		1982		1983		1984		1985	
		Gear	Period of Operation	Gear	Period of Operation	Gear	Period of Operation	Gear	Period of Operation	Gear	Period of Operation
Flathorn Station	22							4F	6/29 to 9/3	4F-6F	5/26 to 9/3
Susitna Station	26.7	2F, 2S	6/27 to 9/2	2F, 2S	7/1 to 9/5						
Yentna Station	28, TRM 04	2F, 2S	6/29 to 9/7	2F, 2S	6/27 to 9/5	2F, 2S	6/30 to 9/5	2F, 2S	7/1 to 9/5		
Sunshine Station	80	4F, 2S	6/23 to 9/15	4F, 2S	6/4 to 10/1	4F	6/3 to 9/11	4F	6/4 to 9/10	4F	6/3 to 9/10
Talkeetna Station	103	4F, 2S	6/22 to 9/15	4F, 2S	6/5 to 9/14	4F	6/7 to 9/12	4F	6/3 to 9/11		
Curry Station	120	2F	6/15 to 9/21	2F	6/9 to 9/18	2F	6/9 to 9/14	2F	6/9 to 9/14	2F	6/10 to 9/12

Table 4.1-2. Number of fish radio-tagged by year in the Middle Susitna River (MR) and Lower Susitna River (LR). Source: ADF&G (1981), ADF&G (1983a), Schmidt et al. (1983), Sundet and Wenger (1984), Sundet and Pechek (1985), Sundet (1986).

Species	1981	1982	1983	1984
Chinook salmon	16 – MR	16 – MR		
Coho salmon	10 – MR	16 – MR		
Chum salmon	11 – MR	18 – MR		
Rainbow trout		5 – LR	29 – MR	36 – LR 13 – MR
Burbot		5 – LR	4 – MR	14 – LR 3 – MR[1]
Arctic grayling				6 – MR

1. The position of three radio-tagged burbot were reported in Sundet and Pechek (1985), but the number tagged was not.

Table 4.1-3. Deployment of incline plane traps from 1982 to 1985. Stations with two traps had one each river bank. S=Stationary, M=Mobile. Sources: Schmidt et al. (1983), Roth et al. (1984), Roth and Stratton (1985), Roth et al. (1986)

		1982		1983		1984		1985	
Station	River Mile	No. Traps	Period of Operation	No. Traps	Period of Operation	No. Traps	Period of Operation	No. Traps	Period of Operation
Flathorn Station	22.4					1 S 1 M	5/20 to 10/1 7/12 to 9/13	2 S 1 M	5/27 to 9/23 6/6 to 8/24
Talkeetna Station	103.0	1 S	6/18 to 10/12	2 S	5/18 to 8/30	2 S	5/14 to 10/6	1 S	5/27 to 10/12

Table 4.2-1. Sites sampled in the Middle Susitna River 1981 to 1985. Does not included selected habitat sites (SFH) sampled during 1981 and 1982. Macrohabitat type was not reported for all sites. Source: Delaney et al. (1981a), Schmidt et al. (1983), Schmidt et al. 1984, Suchanek et al. (1985), Sundet and Pechek (1985), Sundet (1986), Stratton (1986).

						1984			1985
Site	RM	Macro-habitat Type	1981 Habitat Locations	1982 DFH Site	1983 JAHS Site	JA Tagging/ Marking Site	Resident Fish	JAHS	JA Sampling Site
Whiskers Creek Slough	101.2	SS/SC	X	X	X		X		
Whiskers Creek	101.2	T	X	X	X				
Slough 3B	101.4	SS			X				
Mainstem at head of Whiskers Creek Slough 4	101.4	SC			X				
Chase Creek	106.9	T			X				
Slough 5	107.6	US			X				
Oxbow I	110	SC/SS			X				
Slough 6A	112.3	US	X	X	X		X		X
Mainstem above Slough 6A	112.4	SC			X				
Lane Creek	113.6	T	X	X	X		X		
Slough 8	113.6	SS		X	X				
Mainstem II	114.4	SC/SS	X		X				
Lower McKenzie Creek	116.2	T			X				
Upper McKenzie Creek	116.7	T			X				
Side Channel below Curry	117.8	SC			X				
Oxbow II	119.3	SC/SS			X				
Mainstem Susitna – Curry	120.7		X						
Susitna Side Channel	121.6		X						
Slough 8B	122.2					X			
Moose Slough	123.5					X			
Mainstem Susitna – Gravel Bar	123.8		X						
Skull Creek	124.7						X		
Slough 8A	125.3	SS	X	X	X	X	X		X
Side Channel 10A	127.1	SC			X				X
Slough 9	129.2	SS/SC		X	X	X			
Fourth of July Creek – Mouth	131.1		X	X			X		
Slough 9A	133.6								X
Slough/Side Channel 10	133.8	SC/SS	X		X	X			X
Lower Side Channel 11	134.6	SC			X				
Slough 11	135.3	SS	X	X	X	X			

Site	RM	Macro-habitat Type	1981 Habitat Locations	1982 DFH Site	1983 JAHS Site	1984			1985
						JA Tagging/ Marking Site	Resident Fish	JAHS	JA Sampling Site
Slough 14	135.9								X
Upper Side Channel 11	136.2	SC			X	X			
Mainstem Susitna Gold Creek	136.9		X						
Slough 15	137.2								X
Slough 16	137.7								X
Mainstem West Bank	137.3 to 138.3						X		
Indian River – Mouth	138.6	T	X	X	X		X		X
Indian River – TRM 1.9	138.6								X
Indian River – TRM 2.3	138.6								X
Indian River – TRM 10.1	138.6	T			X				
Indian River – TRM 11.9	138.6								X
Indian River TRM 0.0 to 12.3	138.6					X			X
Slough 17	138.9								X
Slough 19	140	US		X	X	X			X
Slough 20	140.1	SS/SC	X	X	X	X	X		X
Side Channel 21						X			
Slough 21	142	SS/SC		X		X			X
Anna Creek Slough	143.2								X
Slough 22	144.3	SS/SC			X	X			X
Jack Long Creek	144.5	T			X		X		
Mainstem Susitna – Island	146.9		X						
Mainstem	147.0 to 148.0						X		
Portage Creek Mouth	148.8	T	X	X	X		X		X
Portage Creek TRM 4.2	148.8	T			X				
Portage Creek TRM 8.0	148.8	T			X				
Mainstem Eddy	150.1						X		

Table 4.2-2. Sites sampled in the Lower Susitna River 1981 to 1984. Does not included selected habitat sites (SFH) sampled during 1981 and 1982. Macrohabitat type was not reported for all sites. Source: Delaney et al. (1981a), Schmidt et al. (1983), Schmidt et al. (1984), Suchanek et al. (1985), Sundet and Pechek (1985), Sundet (1986), Stratton (1986).

Site	RM	Macro-habitat Type	1981 Habitat Locations	1982 DFH Site	1983 JAHS Site	1984		
						JA Tagging/ Marking Site	Resident Fish	JAHS
Alexander Creek	10.1		X					
Anderson Creek	23.8		X					
Kroto Slough Mouth	30.1		X					
Mainstem Susitna Slough	31.0		X					
Eagles Nest Side Channel	36.2	SC						X
Hooligan Side Channel	36.2	SC						X
Kroto Slough Head	36.3	SS						X
Mid Kroto Slough	36.3		X					
Rolly Creek Mouth	39.0	T						X
Deshka River	40.6		X					
Bear Bait Side Channel	42.9	SC						X
Delta Islands	44.0		X					
Last Chance Side Channel	44.4	SC						X
Little Willow Creek	50.5		X					
Rustic Wilderness	58.1		X					
Rustic Wilderness Side Channel	59.5	SC						X
Kashwitna River	61.0		X					
Caswell Creek Mouth	63.0	T	X					X
Island Side Channel	63.2	SC						X
Slough West Bank	65.6		X					
Sheep Creek Slough	66.1		X					
Goose Creek	72.0 & 73.1		X					
Mainstem West Bank	74.4	SC	X					X
Goose 2 Side Channel	74.8	SC		X				X
Circular Side Channel	75.3	SC						X
Montana Creek	77.0		X					
Sauna Side Channel	79.8	SC						X
Rabideaux Creek and Slough	83.1			X				
Mainstem 1	84.0		X					
Sucker Side Channel	84.8	SC						X
Sunshine Creek	85.7		X					

Site	RM	Macro-habitat Type	1981 Habitat Locations	1982 DFH Site	1983 JAHS Site	1984		
						JA Tagging/ Marking Site	Resident Fish	JAHS
Sunshine Creek and Side Channel	85.7			X				
Beaver Dam Slough	86.3	T						X
Beaver Dam Side Channel	86.3	SC						X
Sunset Side Channel	86.9	SC						X
Sunrise Side Channel	87.0	SC						X
Birch Creek Slough	88.4		X					
Birch Creek	89.2	T	X					X
Birch Creek and Slough	88.4			X				
Trapper Creek Side Channel	91.6	SC						X
Whitefish Slough	78.7			X				
Cache Creek Slough	95.5		X					
Cache Creek	96.0		X					

Table 4.3-1. Fish community in the Susitna River drainage. Source: Jennings (1985), Delaney et al. (1981b).

Common Name	Scientific Name	Susitna River Segment				Tributaries	Lakes
		Lower	Middle River[1] Lower	Middle River[1] Upper	Upper		
Arctic grayling	*Thymallus arcticus*	X	X	X	X	X	
Dolly Varden	*Salvelinus malma*	X	X	X	X	X	
Humpback whitefish	*Coregonus pidschian*	X	X		X		
Round whitefish	*Prosopium cylindraceum*	X	X	X	X	X	
Burbot	*Lota lota*	X	X	X	X		
Longnose sucker	*Catostomus catostomus*	X	X	X	X	X	
Sculpin[2]	*Cottid*	X	X	X	X	X	
Eulachon	*Thaleichthys pacificus*	X					
Bering cisco	*Coregonus laurettae*	X					
Threespine stickleback	*Gasterosteus aculeatus*	X	X			X	
Ninespine stickleback	*Pungitius pungitius*	X					
Arctic lamprey	*Lethenteron japonicum*	X	X			X	
Chinook salmon	*Oncorhynchus tshawytscha*	X	X	X	X	X	
Coho salmon	*Oncorhynchus kisutch*	X	X			X	
Chum salmon	*Oncorhynchus keta*	X	X			X	
Pink salmon	*Oncorhynchus gorbuscha*	X	X			X	
Sockeye salmon	*Oncorhynchus nerka*	X	X			X	
Rainbow trout	*Oncorhynchus mykiss*	X	X			X	
Northern pike	*Esox lucius*	X	?			X	X
Lake trout	*Salvelinus namaycush*					X	X

Notes:

1 The Lower Middle River is from the confluence of the Chulitna River to Devils Canyon. Upper Middle River is from Devils Creek to the proposed Watana Dam Site.

2 Sculpin primarily include slimy sculpin (*C. cognatus*), but may also include coastrange sculpin (*C. aleuticus*), sharpnose sculpin (*C. acuticeps*), Pacific staghorn sculpin (*Leptocottus armatus*) and possibly others.

Table 4.3-2. Information from Buckwalter (2011) Synopsis of ADF&G's Upper Susitna Drainage Fish Inventory, August 2011.

Stream	River Mile	Date	Lifestage	Number of Fish	Method	Reference
Above Devils Canyon (RM 152)						
Fog Creek	176.7	8/1/2003	adults	2	helicopter/foot	Buckwalter 2011, AWC Survey ID: FSS03USU01
Tsusena Creek	181.3	8/1/2003	adults	1	helicopter/foot	Buckwalter 2011, AWC Survey ID: FSS03USU02
Fog Creek	176.7	8/13/2003	juveniles	5	electrofishing	Buckwalter 2011, AWC Survey ID: FSS0305A01
Fog Creek Trib	176.7	8/6/2011	juveniles	8	electrofishing	Buckwalter 2011, AWC Survey ID: FSS1104c01
Fog Creek	176.7	8/6/2011	redds			Survey ID: FSS1104B01
Above Watana Dam Site (RM 184)						
Kosina Creek	201	8/14/2003	juveniles	1	electrofishing	Buckwalter 2011, AWC Survey ID: FSS0306A01
Oshetna River	225	8/14/2003	juveniles	3	electrofishing	Buckwalter 2011, AWC Survey ID: FSS0306A05
Kosina Creek	201	8/15/2003	juveniles	2	electrofishing	Buckwalter 2011, AWC Survey ID: FSS0307A06
Kosina Creek	201	7/27/2011	adults	1	helicopter/foot	Buckwalter 2011, Survey ID: FSS1101G04

Table 4.3-3. Estimated Arctic grayling population sizes in tributaries to the upper Middle and Upper Susitna River during 1981 and 1982. Source: Delaney et al. (1981b), Sautner and Stratton (1983).

		1981[1]		1982[1]	
Stream	River Mile	Point Estimate (fish)	95% Confidence Interval (fish)	Point Estimate (fish)	Point Estimate (fish/mile)
Oshetna River	233.4	2,017	1,525-2,976	2,426	1,103
Goose Creek	224.9	1,327	1,016-1,913	949	791
Jay Creek	203.9	1,089	868-1,462	1,592	455
Kosina Creek	202.4	2,787	2,228-3,720	5,544	1,232
Watana Creek	190.4			3,925	324
Deadman Creek	186.7	979	604-2,575	734	1,835
Tsusena Creek	181.3	1,000	743-1,530		
Fog Creek	176.7	176	115-369		440
Upper Susitna River		10,279	9,194-11,654	16,346[2]	

Notes:

1 Fish densities were not reported for 1981. Confidence intervals were not reported for 1982.

2 Total of point estimates from 1982 plus 1981 point estimates for Tsusena and Fog creeks.

Table 4.3-4. Chinook salmon escapement survey results from 1982 to 1985 upstream of RM 152. Surveys conducted by helicopter. Source: ADF&G (1983a), Barrett et al. (1984), Barrett et al. (1985), Thompson et al. (1986).

Stream	1982				1983				1984				1985			
	# Flights	Date of Peak Count	Peak Count	APA Source/PDF Page	# Flights	Date of Peak Count	Peak Count	APA Source/PDF Page	# Flights	Date of Peak Count	Peak Count	APA Source/PDF Page	# Flights	Date of Peak Count	Peak Count	APA Source/PDF Page
Cheechako Cr	9	6-Aug	16	589/314	2	1-Aug	25	1450/111	7	1-Aug	29	2748/60, 506	11	24-Jul	18	3412/127
Chinook Cr	5	6-Aug	5	589/314	2	1-Aug	8	1450/111	7	1-Aug	15	2748/60, 506	11	23-Aug	1	3412/128
Devil Cr	5		0	589/314	1	1-Aug	1	1450/111	6		0	2748/60, 506	11		0	3412/128
Fog Cr	0			2748/60	0			2748/60	4	21-Jul	2	2748/60, 506	3		0	3412/128
Bear Cr	0				0			2748/151	4		0	2748/506	3		0	3412/128
Tsusena Cr	0				0			2748/151	4		0	2748/507	3		0	3412/128
Deadman Cr	0				0				3		0	2748/507	0			
Watana Cr	0				0				2		0	2748/507	0			

Table 5.1-1. Periodicity of Chinook salmon utilization among macro-habitat types in the Middle (RM 184 – 98.5) and Lower (RM 98.5 – 0.0) segments of the Susitna River by life history stage. In the Upper Segment (RM 260 – RM 184), adult Chinook are believed to exhibit similar habitat use to that shown for the Middle Segment, while juvenile Chinook rearing and migration timing in this segment is not known. Shaded areas indicate timing of utilization by macro-habitat type and dark gray areas represent areas and timing of peak use.

	Habitat Type																	
Life Stage	Main Channel	Side Channel	Tributary Mouth	Side Slough	Upland Slough	Tributary	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Middle Susitna River																		
Adult Migration																		
Spawning																		
Incubation																		
Fry Emergence																		
Age 0+ Rearing																		
Age 0+ Migration																		
Age 1+ Rearing																		
Age 1+ Migration																		
Lower Susitna River																		
Adult Migration																		
Spawning																		
Incubation																		
Fry Emergence																		
Age 0+ Rearing																		
Age 0+ Migration																		
Age 1+ Rearing																		
Age 1+ Migration																		

Table 5.1-2. Periodicity of sockeye salmon utilization among macro-habitat types in the Middle (RM 184 – 98.5) and Lower (RM 98.5 – 0.0) segments of the Susitna River by life history stage. Shaded areas indicate timing of utilization by macro-habitat type and dark gray areas represent areas and timing of peak use.

Life Stage	Habitat Type: Main Channel	Side Channel	Tributary Mouth	Side Slough	Upland Slough	Tributary	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Middle Susitna River																		
Adult Migration																		
Spawning																		
Incubation																		
Fry Emergence																		
Age 0+ Rearing																		
Age 0+ Migration																		
Age 1+ Rearing																		
Age 1+ Migration																		
Lower Susitna River																		
Adult Migration[1]																		
Spawning																		
Incubation																		
Fry Emergence																		
Age 0+ Rearing																		
Age 0+ Migration																		
Age 1+ Rearing																		
Age 1+ Migration																		

Notes:

1 First run sockeye migration timing occurs during May and June and second run sockeye migration is July through September.

Table 5.1-3. Periodicity of chum salmon utilization among macro-habitat types in the Middle (RM 184 – 98.5) and Lower (RM 98.5 – 0.0) segments of the Susitna River by life history stage. Shaded areas indicate timing of utilization by macro-habitat type and dark gray areas represent areas and timing of peak use.

	Habitat Type																	
Life Stage	Main Channel	Side Channel	Tributary Mouth	Side Slough	Upland Slough	Tributary	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Middle Susitna River																		
Adult Migration																		
Spawning																		
Incubation																		
Fry Emergence																		
Age 0+ Rearing																		
Age 0+ Migration																		
Lower Susitna River																		
Adult Migration																		
Spawning																		
Incubation																		
Fry Emergence																		
Age 0+ Rearing																		
Age 0+ Migration																		

Table 5.1-4. Periodicity of coho salmon utilization among macro-habitat types in the Middle (RM 184 – 98.5) and Lower (RM 98.5 – 0.0) segments of the Susitna River by life history stage. Shaded areas indicate timing of utilization by macro-habitat type and dark gray areas represent areas and timing of peak use.

	Habitat Type																	
Life Stage	Main Channel	Side Channel	Tributary Mouth	Side Slough	Upland Slough	Tributary	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Middle Susitna River																		
Adult Migration																		
Spawning																		
Incubation																		
Fry Emergence																		
Age 0+ Rearing																		
Age 0+ Migration																		
Age 1+ Rearing																		
Age 1+ Migration																		
Age 2+ Rearing																		
Age 2+ Migration																		
Lower Susitna River																		
Adult Migration																		
Spawning																		
Incubation																		
Fry Emergence																		
Age 0+ Rearing																		
Age 0+ Migration																		
Age 1+ Rearing																		
Age 1+ Migration																		
Age 2+ Rearing																		
Age 2+ Migration																		

Table 5.1-5. Periodicity of pink salmon utilization among macro-habitat types in the Middle (RM 184 – 98.5) and Lower (RM 98.5 – 0.0) segments of the Susitna River by life history stage. Shaded areas indicate timing of utilization by macro-habitat type and dark gray areas represent areas and timing of peak use.

Life Stage	Habitat Type: Main Channel	Side Channel	Tributary Mouth	Side Slough	Upland Slough	Tributary	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Middle Susitna River																		
Adult Migration																		
Spawning																		
Incubation																		
Fry Emergence																		
Age 0+ Migration																		
Lower Susitna River																		
Adult Migration																		
Spawning																		
Incubation																		
Fry Emergence																		
Age 0+ Migration																		

Table 5.1-6. Periodicity of rainbow trout utilization among macro-habitat types in the Susitna River by life history stage. Shaded areas indicate timing of utilization by macro-habitat type and dark gray areas represent areas and timing of peak use.

	Habitat Type																	
Life Stage	Main Channel	Side Channel	Tributary Mouth	Side Slough	Upland Slough	Tributary	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Adult Holding																		
Adult Migration																		
Spawning																		
Incubation																		
Fry Emergence																		
Juvenile Rearing																		

Table 5.1-7. Periodicity of Arctic grayling utilization among macro-habitat types in the Susitna River by life history stage. Shaded areas indicate timing of utilization by macro-habitat type and dark gray areas represent areas and timing of peak use.

	Habitat Type																	
Life Stage	Main Channel	Side Channel	Tributary Mouth	Side Slough	Upland Slough	Tributary	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Adult Holding																		
Adult Migration																		
Spawning																		
Incubation																		
Fry Emergence																		
Juvenile Rearing																		

Table 5.1-8. Periodicity of burbot utilization among macro-habitat types in the Susitna River by life history stage. Shaded areas indicate timing of utilization by macro-habitat type and dark gray areas represent areas and timing of peak use.

Life Stage	Habitat Type: Main Channel	Side Channel	Tributary Mouth	Side Slough	Upland Slough	Tributary	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Adult Holding																		
Adult Migration																		
Spawning																		
Incubation																		
Juvenile Migration																		
Juvenile Rearing																		

Table 5.1-9 Periodicity of round whitefish utilization among macro-habitat types in the Susitna River by life history stage. Shaded areas indicate timing of utilization by macro-habitat type and dark gray areas represent areas and timing of peak use.

	Habitat Type																	
Life Stage	Main Channel	Side Channel	Tributary Mouth	Side Slough	Upland Slough	Tributary	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Adult Holding																		
Adult Migration																		
Spawning																		
Incubation																		
Fry Emergence																		
Juvenile Migration																		
Juvenile Rearing																		

Table 5.1-10. Periodicity of humpback whitefish utilization among macro-habitat types in the Susitna River by life history stage. Shaded areas indicate timing of utilization by macro-habitat type and dark gray areas represent areas and timing of peak use.

Life Stage	Habitat Type: Main Channel	Side Channel	Tributary Mouth	Side Slough	Upland Slough	Tributary	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Adult Holding																		
Adult Migration																		
Spawning																		
Incubation																		
Fry Emergence																		
Juvenile Migration																		
Juvenile Rearing[1]																		

Notes:
1 A portion of juvenile humpback whitefish may utilize estuarine habitats to rear during the first two years of life.

Table 5.1-11 Periodicity of longnose sucker in the Susitna River by life history stage and habitat type. Shaded areas represent utilization of habitat types and temporal periods and dark gray areas indicate peak use.

	Habitat Type																	
Life Stage	Main Channel	Side Channel	Tributary Mouth	Side Slough	Upland Slough	Tributary	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Adult Holding																		
Adult Migration																		
Spawning[1]																		
Incubation																		
Fry Emergence																		
Juvenile Migration																		
Juvenile Rearing																		

Notes:

1 Longnose sucker typically spawn in spring, however, a second unconfirmed spawn period may occur during the late summer in October or November.

Table 5.1-12. Periodicity of Dolly Varden in the Susitna River by life history stage and habitat type. Shaded areas represent utilization of habitat types and temporal periods and dark gray areas indicate peak use.

	Habitat Type																	
Life Stage	Main Channel	Side Channel	Tributary Mouth	Side Slough	Upland Slough	Tributary	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Adult Holding																		
Adult Migration																		
Spawning																		
Incubation																		
Fry Emergence																		
Juvenile Rearing																		

Table 5.1-13. Periodicity of Bering cisco utilization among macro-habitat types in the Susitna River by life history stage. Shaded areas indicate timing of utilization by macro-habitat type and dark gray areas represent areas and timing of peak use.

	Habitat Type																	
Life Stage	Main Channel	Side Channel	Tributary Mouth	Side Slough	Upland Slough	Tributary	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Adult Holding[1]																		
Adult Migration																		
Spawning																		
Incubation																		
Fry Emergence																		
Juvenile Migration[2]																		

Notes:

1 Adult Bering Cisco holding and feeding habitat use in the Susitna River is not known; it is possible these fish reside in marine areas until spawning.

2 Juvenile rearing is not represented here because Bering cisco fry migrate to marine nursery habitats soon after hatching.

Table 5.1-14. Periodicity of eulachon utilization among macro-habitat types in the Susitna River by life history stage. Shaded areas indicate timing of utilization by macro-habitat type and dark gray areas represent areas and timing of peak use.

	Habitat Type																	
Life Stage	Main Channel	Side Channel	Tributary Mouth	Side Slough	Upland Slough	Tributary	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Adult Migration																		
Spawning																		
Incubation																		
Juvenile Migration[1]																		

Notes:

1 Juvenile rearing is not represented here because eulachon larvae migrate soon after hatching to estuarine nursery habitats to rear.

Table 6.1-1. Species, lifestages, and habitat parameters for which HSC curves have been developed for the Middle (M) and Lower (L) Susitna River.

Species	Life Stage	Depth	Velocity	Substrate	Cover
Chum Salmon	Spawning	M	M	M[U]	
	Juvenile	M,L	M,L		M,L
Sockeye Salmon	Spawning	M	M	M[U]	
	Juvenile	M,L	M,L		M,L
Chinook Salmon	Spawning	M	M	M	
	Juvenile	M,L	M,L		M,L
Coho Salmon	Spawning	M	M	M	
	Juvenile	M,L	M,L		M,L
Pink Salmon	Spawning	M	M	M	
Rainbow Trout	Adult	M	M		M
Arctic Grayling	Adult	M	M		M
Round Whitefish	Adult	M	M		M
	Juvenile	M	M		M
Longnose Sucker	Adult	M	M		M

Table 6.1-2. Substrate codes used in the development of HSC curves for the Susitna River during studies in the 1980s (Vincent-Lang et al. 1984a, 1984b) and for three Bristol Bay drainages (North/South Fork Koktuli Rivers and Upper Talarik Creek; PLP 2011).

Basin	Literature Code[1]	Adjusted Code[1]	Substrate	Size (inches)	Size (mm)
Susitna River (Vincent-Lang et al. 1984a, 1984b)	1	1	Silt	NA	NA
	2	1.5	Silt/Sand	NA	NA
	3	2	Sand	NA	NA
	4	2.5	Sand/Small Gravel	NA	NA
	5	3	Small Gravel	1/8-1	0.125-25
	6	4	Small Gravel/Large Gravel	NA	NA
	7	5	Large Gravel	1-3	25-76
	8	5.5	Large Gravel/Rubble	NA	NA
	9	6	Rubble	3-5	76-127
	10	6.5	Rubble/Cobble	NA	NA
	11	7	Cobble	5-10	127-254
	12	7.5	Cobble/Boulder	NA	NA
	13	8	Boulder	>10	>254
North/South Fork Koktuli Rivers and Upper Talarik Creek (PLP 2011)	1	0	Vegetation	NA	NA
	1.99	0.99	Vegetation	NA	NA
	2	1	Fines	<1/16	<2
	2.99	1.99	Fines	<1/16	<2
	3	3	Small Gravel	1/16-3/4	2-16
	3.99	3.99	Small Gravel	1/16-3/4	2-16
	4	5	Large Gravel	3/4-2.5	16-64
	4.99	5.99	Large Gravel	3/4-2.5	16-64
	5	6	Small Cobble	2.5-5	64-128
	5.99	6.99	Small Cobble	2.5-5	64-128
	6	7	Large Cobble	5-10	128-256
	6.99	7.99	Large Cobble	5-10	128-256
	7	8	Boulder	>10	>256

Notes:

1 "Literature codes" were standardized for comparability purposes by assigning "adjusted codes" used to present substrate information in this document.

Table 6.1-3. Number of salmon redds observed in spawning HSC data collection efforts in the Middle Segment Susitna River during 1982-1983 studies.

Species	Location	HRM	Habitat Type	# Redds
Chum	Slough 8A	125.3	Slough	52
	Slough 9	126.3	Slough	76
	Fourth of July Creek	131.0	Tributary Mouth	28
	Slough 9A	133.3	Slough	24
	Slough 11	135.3	Slough	34
	Upper Side Channel 11	136.2	Side Channel	2
	Indian River	138.6	Tributary Mouth	3
	Slough 17	138.9	Slough	6
	Slough 20	140.1	Slough	11
	Side Channel 21	140.6	Side Channel	2
	Slough 21	141.1	Slough	83
	Slough 22	144.3	Slough	12
Sockeye	Slough 8A	125.3	Slough	17
	Slough 11	135.3	Slough	42
	Slough 17	138.9	Slough	2
	Slough 21	141.1	Slough	20
Chinook	Fourth of July Creek	131.0	Tributary	1
	Indian River	138.6	Tributary	125
	Portage Creek	148.9	Tributary	137
	Chechako Creek	152.5	Tributary	2

Table 6.1-4. Sampling effort (number of cells sampled) and juvenile salmon catch (all age classes) by gear type in the Middle Susitna River during 1981-1982 studies (Suchanek et al. 1984b)

Species	Electrofishing		Beach Seining		Total	
	Effort	Catch	Effort	Catch	Effort	Catch
Chinook	871	3066	389	1329	1260	4395
Coho	871	1907	389	113	1260	2020
Sockeye[1]	658	814	355	192	1013	1006
Chum[2]	408	1152	106	5	514	1157

Notes:

2 Cells removed from consideration if located in tributaries without major runs or sampled when only a small percentage of sockeye had emerged.

3 Cells removed from consideration if sampled after period of peak chum outmigration.

Table 6.1-5. Cover type and percent cover habitat suitability criteria for juvenile salmon in the Middle Susitna River (Suchanek et al. 1984b).

Cover Type	Code	Percent Cover	Chinook (clear)	Chinook (turbid)	Chum	Coho	Sockeye
No cover	1.1	0-5%	0.01	0.45	0.29	0.00	0.11
Emergent vegetation	2.1	0-5%	0.01	0.57	0.29	0.03	0.18
	2.5	76-100%	0.12	1.00	0.53	0.29	0.47
Aquatic vegetation	3.1	0-5%	0.07	0.57	0.29	0.07	0.39
	3.5	76-100%	0.68	1.00	0.53	0.65	1.00
Debris/deadfall	4.1	0-5%	0.11	0.57	0.47	0.10	0.19
	4.5	76-100%	1.00	1.00	0.87	0.90	0.49
Overhanging riparian vegetation	5.1	0-5%	0.06	0.57	0.40	0.04	0.30
	5.5	76-100%	0.61	1.00	0.74	0.38	0.78
Undercut banks	6.1	0-5%	0.10	0.57	0.40	0.12	0.11
	6.5	76-100%	0.97	1.00	0.74	1.00	0.29
Large gravel (1-3")	7.1	0-5%	0.07	0.57	0.37	0.03	0.17
	7.5	76-100%	0.63	1.00	0.68	0.24	0.44
Rubble (3-5")	8.1	0-5%	0.09	0.57	0.54	0.02	0.12
	8.5	76-100%	0.81	1.00	1.00	0.18	0.30
Cobble or boulder (>5")	9.1	0-5%	0.09	0.57	0.46	0.02	0.11
	9.5	76-100%	0.89	1.00	0.86	0.18	0.29

Table 6.1-6. Cover type and percent cover habitat suitability criteria for juvenile salmon in the Lower Susitna River (Suchanek et al. 1985).

Cover Type	Code	Percent Cover	Chinook (clear)	Chinook (turbid)	Chum	Coho	Sockeye
No cover	1.1	0-5%	0.01	0.15	1.00	0.00	0.18
Emergent vegetation	2.1	0-5%	0.11	0.23	1.00	0.05	0.39
	2.2	6-25%	0.33	0.30	1.00	0.14	0.54
	2.3	26-50%	0.55	0.33	1.00	0.24	0.70
	2.4	51-75%	0.78	0.39	1.00	0.33	0.85
	2.5	76-100%	1.00	0.40	1.00	0.42	1.00
Aquatic vegetation	3.1	0-5%	0.10	0.23	1.00	0.04	0.23
	3.2	6-25%	0.32	0.30	1.00	0.13	0.32
	3.3	26-50%	0.53	0.33	1.00	0.21	0.41
	3.4	51-75%	0.76	0.39	1.00	0.30	0.50
	3.5	76-100%	0.97	0.40	1.00	0.38	0.59
Debris/deadfall	4.1	0-5%	0.05	0.15	1.00	0.08	0.21
	4.2	6-25%	0.17	0.20	1.00	0.24	0.29
	4.3	26-50%	0.28	0.20	1.00	0.39	0.37
	4.4	51-75%	0.39	0.20	1.00	0.55	0.45
	4.5	76-100%	0.50	0.20	1.00	0.70	0.53
Overhanging riparian vegetation	5.1	0-5%	0.04	0.15	1.00	0.07	0.25
	5.2	6-25%	0.13	0.20	1.00	0.20	0.34
	5.3	26-50%	0.21	0.20	1.00	0.33	0.44
	5.4	51-75%	0.30	0.20	1.00	0.46	0.54
	5.5	76-100%	0.38	0.20	1.00	0.59	0.63
Undercut banks	6.1	0-5%	0.11	0.23	1.00	0.12	0.25
	6.2	6-25%	0.33	0.30	1.00	0.34	0.34
	6.3	26-50%	0.55	0.33	1.00	0.56	0.44
	6.4	51-75%	0.78	0.39	1.00	0.78	0.54
	6.5	76-100%	1.00	0.40	1.00	1.00	0.63
Large gravel (1-3")	7.1	0-5%	0.02	0.15	1.00	0.02	0.18
	7.2	6-25%	0.08	0.20	1.00	0.06	0.24
	7.3	26-50%	0.13	0.20	1.00	0.10	0.32
	7.4	51-75%	0.18	0.20	1.00	0.14	0.38
	7.5	76-100%	0.23	0.20	1.00	0.18	0.45
Rubble (3-5")	8.1	0-5%	0.03	0.15	1.00	0.02	0.18
	8.2	6-25%	0.10	0.20	1.00	0.06	0.24
	8.3	26-50%	0.17	0.20	1.00	0.10	0.32
	8.4	51-75%	0.23	0.20	1.00	0.14	0.38
	8.5	76-100%	0.30	0.20	1.00	0.18	0.45
Cobble or boulder (>5")	9.1	0-5%	0.03	0.15	1.00	0.02	0.18
	9.2	6-25%	0.11	0.20	1.00	0.06	0.24

Cover Type	Code	Percent Cover	Chinook (clear)	Chinook (turbid)	Chum	Coho	Sockeye
	9.3	26-50%	0.18	0.20	1.00	0.10	0.32
	9.4	51-75%	0.25	0.20	1.00	0.14	0.38
	9.5	76-100%	0.32	0.20	1.00	0.18	0.45

Table 6.1-7. Adult resident fish catch by gear type in the Middle Segment Susitna River during 1981-1982 studies (Suchanek et al. 1984b). Sampling effort involved boat electrofishing in 176 cells and hook-and-line sampling in 79 cells.

Species	Boat Electrofishing	Hook and Line
Rainbow trout	44	99
Arctic grayling	138	2
Round whitefish	384	
Longnose sucker	157	
Burbot	18	
Humpback whitefish	15	
Dolly Varden	2	

Table 6.1-8. Cover type habitat suitability criteria for resident fish in the Middle Susitna River (Suchanek et al. 1984b).

Cover Type	Code	Rainbow Trout (Adult)		Arctic Grayling (Adult)		Round Whitefish (Adult)		Round Whitefish (Juvenile)		Longnose Sucker (Adult)	
		Clear	Turbid	Clear	Turbid	Clear	Turbid	Clear	Turbid	Clear	Turbid
No cover	1	0.00	0.29	0.00	0.07	0.00	0.26	0.00	1.00	0.00	0.47
Emergent vegetation	2	0.00	0.29	0.00	0.07	0.47	0.47	0.00	1.00	1.00	1.00
Aquatic vegetation	3	0.00	0.29	0.00	0.07	0.47	0.47	0.00	1.00	1.00	1.00
Debris/deadfall	4	1.00	1.00	0.14	0.14	0.65	0.65	0.00	1.00	0.46	0.47
Overhanging riparian vegetation	5	1.00	1.00	0.14	0.14	0.65	0.65	0.00	1.00	0.46	0.47
Undercut banks	6	1.00	1.00	0.14	0.14	0.65	0.65	0.00	1.00	0.46	0.47
Large gravel (1-3")	7	0.00	0.29	0.00	0.07	0.33	0.33	0.00	1.00	0.00	0.47
Rubble (3-5")	8	0.77	0.77	0.69	0.69	0.41	0.41	0.00	1.00	0.00	0.47
Cobble or boulder (>5")	9	1.00	1.00	1.00	1.00	1.00	1.00	0.00	1.00	0.00	0.47

Table 6.3-1. Summary of the proposed target species and life stages, macro-habitat types, sample sites, potential sampling techniques, and sampling timing applied during 2012 HSC curve validation surveys.

Species	Life Stage	River Segment	Macro-Habitat Areas[1]	Sample Sites[1]	Possible Sampling Technique	Sample Timing[1]
Chinook	Juvenile	Middle River	Slough, side channel, tributary mouths	Slough 21, 8A, and 6A	Snorkel, electrofishing, seining	June, July, August, September
	Spawning	Middle River	Tributary, mainstem	Indian R., 4th of July Cr., Lane Cr.	Pedestrian survey, side scan sonar, DIDSON	July, August
Sockeye	Juvenile	Middle River	Slough, side channel, tributary mouths	Slough 20, 9, 8, 6A	Snorkel, electrofishing, seining	June, July, August, September
	Spawning	Middle River	Slough, and side channels	Slough 11, 8A,	Pedestrian survey, side scan sonar, DIDSON	August, September, October
Coho	Juvenile	Middle River	Slough, side channel, tributary mouths	Slough 6A, Lane Cr., Birch & Sunshine Cr.	Snorkel, electrofishing, seining	June, July, August, September
	Spawning	Middle River	Tributary mouths	Indian R., 4th of July Cr., Slough 8A	Pedestrian survey	August, September
Chum	Juvenile	Middle River	Slough, side channel, tributary mouths	Slough 21, 9, and 6A	Snorkel, electrofishing, seining	June, July, August,
	Spawning	Middle River	Slough, side channel, mainstem	Slough 21, 11, and 8A	Pedestrian survey, side scan sonar, DIDSON	August, September
Pink	Juvenile	Middle River	Slough, side channel, tributary mouths	None specified	Snorkel, electrofishing, seining	June, July
	Spawning	Middle River	Slough, side channel, tributary mouths	Slough 21, 15, and 11	Pedestrian survey	July, August

Notes:
1 ADF&G 1983 – Synopsis of the 1982 Aquatic Studies and Analysis of Fish and Habitat Relationships

Table 6.3-2. Site-specific habitat suitability measurements recorded during 2012 at Middle and Lower Susitna River sampling sites, by fish life stage.

Susitna River Segment	River Mile	Site Name	Habitat Type	Fish Life Stage	Number of Observations
Middle	178.3	178.3R	Side Channel	Fry	6
				Juvenile	4
				Adult	5
Middle	176.6	Fog Creek mouth	Tributary Mouth	Fry	4
				Adult	1
Middle	174.2	174.2L	Mainstem	N/A	0
Middle	144.4	Slough 22	Side Slough	Fry	5
				Adult	1
Middle	141.8	Slough 21	Side Slough	N/A	0
Middle	141.2	Side Channel 21	Side Channel	Fry	9
				Adult	7
Middle	138.6	Indian River Mouth	Tributary Mouth	Fry	11
				Adult	8
Middle	135.6	Slough 11	Side Slough	Adult	8
Middle	133.9	Slough 10	Upland Slough	N/A	0
Middle	133.7	Slough 9A	Side Slough	Adult	19
Middle	131.2	Unnamed Side Channel	Side Channel	Adult	11
Middle	131.1	4th of July Creek Mouth	Tributary Mouth	Fry	3
				Adult	8
Middle	128.8	Slough 9	Side Slough	Adult	15
Middle	125.3	Skull Creek	Side Slough	Adult	26
Middle	122.5	Slough 8B	Side Slough	N/A	0
Middle	121.0	Tulips Creek mouth	Tributary Mouth	N/A	0
Middle	115.0	115.0R	Side Channel	Fry	2
Middle	113.7	Slough 8	Side Slough	Fry	4
				Juvenile	1
Middle	113.6	Lane Cr Mouth	Tributary Mouth	Fry	2
				Adult	1
Middle	112.5	Slough 6A	Upland Slough	Fry	15
Middle	101.4	Whiskers Slough	Side Slough	Fry	13
				Adult	3
Middle	101.4	Whiskers Creek Mouth	Tributary Mouth	Fry	12
Lower	95.4	Cache Creek slough	Side Slough	Fry	6
				Juvenile	1
Lower	95.4	Unnamed Side Channel	Side Channel	Fry	4
				Juvenile	1
Lower	93.5	Unnamed Side Channel	Side Channel	Fry	4
				Juvenile	1
Lower	91.6	Trapper Creek Side Channel	Side Channel	Fry	12
				Juvenile	4
Lower	91.5	Trapper Creek	Tributary Mouth	Fry	4
Lower	91.5	Birch Slough	Side Slough	Fry	2
	89.2	Birch Slough	Side Slough	Fry	1
Lower	85.2	Sunshine Creek Side Channel	Side Channel	Fry	13
				Juvenile	3
Lower	85.1	Sunshine Creek	Tributary Mouth	Fry	18
Lower	83.1	Rabideux Creek	Tributary Mouth	N/A	0

Susitna River Segment	River Mile	Site Name	Habitat Type	Fish Life Stage	Number of Observations
Lower	77.0	Montana Creek	Tributary Mouth	Adult	7
			Side Channel	Adult	10

Table 6.3-3. Proposed substrate classification system for use in development of HSC/HSI curves for the Susitna-Watana Project (adapted from Wentworth 1922).

Substrate Code	Substrate Type	Size (Decimal Inches)	Size (mm)
1	Silt, Clay, or Organic	<0.01	<0.1
2	Sand	0.01-0.10	0.1-2.0
3	Small Gravel	0.10-0.30	2.0-8.0
4	Medium Gravel	0.30-1.25	8.0-32
5	Large Gravel	1.25-2.50	32-64
6	Small Cobble	2.50-5.0	64-128
7	Large Cobble	5.0-10.0	128-256
8	Boulder	>10.0	>256
9	Bedrock		

Table 6.3-4. Number of spawning redds sampled by river reach and macrohabitat type during HSC surveys of the Susitna River, Alaska (combined R2 and LGL datasets).

Macrohabitat Type	River Segment	Salmon Species				
		Chinook	Sockeye	Pink	Chum	Coho
Sloughs						
Slough 21	Middle	0	0	0	7	0
Slough 11	Middle	0	4	0	4	0
4th of July Slough	Middle	0	0	0	11	0
Slough 10	Middle	0	0	0	0	0
Slough 9A	Middle	0	4	0	19	0
Slough 9	Middle	0	14	0	1	0
Slough 8a	Middle	0	21	0	1	0
Whiskers Slough	Middle	0	0	3	0	0
Tributary Delta						
Indian River	Middle	0	0	0	3	0
4th of July Cr.	Middle	0	0	7	1	0
Montana Cr.	Lower	0	0	7		0
Side Channel						
Montana Cr.	Lower	0	0	0	10	0
Total		0	43	17	57	0

Table 6.3-5. Number of HSC made within each of the major macrohabitat types for each target species and life stage during the 2012 HSC surveys of the Susitna River, Alaska.

	Number of HSC Observations by Macrohabitat Type			
Species & Life Stage	**MC**	**SC**	**SS**	**T. Delta**
Chinook				
Juvenile	0	3	4	4
Fry	1	15	8	7
Sockeye				
Spawning	0	0	43	0
Fry	0	5	0	1
Pink				
Spawning	0	0	3	14
Chum				
Spawning	0	10	43	4
Fry		3	3	2
Coho				
Juvenile	0	8	3	8
fry	3	6	24	20
Arctic Grayling				
Adult	1	3	0	4
Juvenile	0	1	0	0
Fry	1	3	4	2
Rainbow Trout				
Adult	0	0	1	6
Juvenile	0	0	1	0
Fry	0	0	0	1
Whitefish				
Juvenile	0	3	3	1
Fry	0	2	0	0
Longnose Sucker				
Adult	0	1	0	0
Juvenile	0	0	1	0
Total	6	63	141	74
Percent of Total	2%	22%	50%	26%

Table 6.3-6. Number of HSC observations made within each of the major macrohabitat types for each target species and life stage during the 2012 HSC surveys of the Susitna River, Alaska.

Species & Life Stage	Number and Percent of HSC Observations by 2012 Survey Date			
	July (17-19)	Aug (21-23)	Sep (17-19)	Total Obs.
Chinook				
Juvenile		11 (100%)		11
Fry	13 (41.9%)	10 (32.3%)	8 (25.8%)	31
Sockeye				
Spawning		11 (25.6%)	32 (74.4%)	43
Fry		6 (100%)		6
Pink				
Spawning		17 (100%)		17
Chum				
Spawning		56 (98.2%)	1 (1.8%)	57
Fry	3 (37.5%)	5 (62.5%)		8
Coho				
Juvenile	5 (26.3%)	14 (73.7%)		19
Fry	44 (83%)	8 (15.1%)	1 (1.9%)	53
Arctic Grayling				
Adult	4 (50%)		4 (50%)	8
Juvenile			1 (100%)	1
Fry	1 (10%)	4 (40%)	5 (50%)	10
Rainbow Trout				
Adult	7 (100%)			7
Juvenile	1 (100%)			1
Fry		1 (100%)		1
Whitefish				
Juvenile		5 (71.4%)	2 (28.6%)	7
Fry		2 (100%)		2
Longnose Sucker				
Adult		1 (100%)		1
Juvenile		1 (100%)		1
Total/Percent of Total	78/27.5%	152/53.5%	54/19%	284

Table 6.3-7. Periodicity of Pacific salmon habitat utilization in the Middle Segment (RM 184-98.5) of the Susitna River by species and life history stage. Shaded areas indicate timing of utilization and dark gray areas represent peak use.

Species	Life Stage	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Chinook Salmon	Adult Migration												
	Spawning												
	Incubation												
	Fry Emergence												
	Rearing (0+)												
	Rearing (1+)												
	Juvenile Migration (0+)												
	Juvenile Migration (1+)												
Chum Salmon	Adult Migration												
	Spawning												
	Incubation												
	Fry Emergence												
	Rearing (0+)												
	Juvenile Migration (0+)												
Coho Salmon	Adult Migration												
	Spawning												
	Incubation												
	Fry Emergence												
	Rearing (0+)												
	Rearing (1+)												
	Rearing (2+)												
	Juvenile Migration (0+)												
	Juvenile Migration												

Species	Life Stage	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
	(1+)												
	Juvenile Migration (2+)												
Sockeye Salmon[1]	Adult Migration[1]												
	Spawning[1]												
	Incubation												
	Fry Emergence												
	Rearing (0+)												
	Rearing (1+)												
	Juvenile Migration (0+)												
	Juvenile Migration (1+)												
Pink Salmon[2]	Adult Migration												
	Spawning												
	Incubation												
	Fry Emergence												
	Juvenile Migration (0+)												

Notes:

1 First-run and second-run sockeye salmon exhibit distinct timing of adult migration and spawning, and utilize separate areas for spawning. Periodicity presented here represent that of second-run sockeye, as first-run sockeye do not utilize the Middle Susitna River.

2 No rearing period for age 0+ pink salmon is identified because this species migrates to the estuary soon after emergence.

Table 7.1-1. Instream flow sites and habitat modeling methods used during the 1980s in the Middle and Lower Susitna River (Marshall et al. 1984; Sandone et al. 1984; Vincent-Lang et al. 1984b; Hilliard et al. 1985; Suchanek et al. 1985).

River Mile	Site Name	Susitna Segment	Habitat Type	Site Type	No. of Transects	Year(s) Measured
35.2	Hooligan Side Channel	Lower	Side Channel	RJHAB	5	1984
36.2	Eagles Nest Side Channel	Lower	Side Channel	RJHAB	4	1984
36.3	Kroto Slough Head	Lower	Side Slough	RJHAB	5	1984
39.0	Rolly Creek Mouth	Lower	Tributary Mouth	RJHAB	6	1984
42.9	Bear Bait Side Channel	Lower	Side Channel	RJHAB	5	1984
44.4	Last Chance Creek Side Channel	Lower	Side Channel	RJHAB	6	1984
59.5	Rustic Wilderness Side Channel	Lower	Side Channel	RJHAB	5	1984
63.0	Caswell Creek	Lower	Tributary Mouth	RJHAB	8	1984
63.2	Island Side Channel	Lower	Side Channel	IFG-4, RJHAB	9	1984
74.4	Mainstem West Bank	Lower	Side Slough	IFG-4	7	1984
74.8	Goose 2 Side Channel	Lower	Side Channel	RJHAB	6	1984
75.3	Circular Side Channel	Lower	Side Channel	IFG-4	6	1984
79.8	Sauna side channel	Lower	Side Channel	IFG-4	4	1984
84.5	Sucker side channel	Lower	Side Channel	RJHAB	6	1984
86.3	Beaver Dam side channel	Lower	Side Channel	RJHAB	5	1984
86.3	Beaver Dam Slough	Lower	Side Slough	RJHAB	5	1984
86.9	Sunset side channel	Lower	Side Channel	IFG-4	7	1984
87.0	Sunrise side channel	Lower	Side Channel	RJHAB	7	1984
88.4	Birch Slough	Lower	Side Slough	RJHAB	8	1984
91.6	Trapper Creek side channel	Lower	Side Channel	IFG-4, RJHAB	5	1984
101.2	101.2 R, Whiskers East	Middle	Side Channel	IFG-4	9	1984
101.4	Whiskers Slough	Middle	Side Slough	RJHAB	8	1983
101.5	101.5 L, Whiskers West	Middle	Side Channel	IFG-2	5	1984
101.7	101.7 L	Middle	Side Channel	DIHAB	4	1984
105.8	105.8 L	Middle	Mainstem	DIHAB	4	1984
107.6	Slough 5	Middle	Upland Slough	RJHAB	9	1983
112.5	Slough 6A	Middle	Upland Slough	RJHAB	8	1983
112.6	112.6 L, Side Channel 6A	Middle	Side Channel	IFG-2	9	1984
113.6	Lane Creek mouth	Middle	Tributary Mouth	Habitat Mapping	7	1983
113.7	Slough 8	Middle	Side Slough	RJHAB	5	1983
114.1	114.1 R	Middle	Side Channel	DIHAB	3	1984
115.0	115.0 R	Middle	Side Channel	DIHAB	4	1984
118.9	118.9 L	Middle	Mainstem	DIHAB	3	1984
119.1	119.1 L	Middle	Mainstem	DIHAB	3	1984
119.2	119.2 R, Little Rock side channel	Middle	Side Channel	IFG-2	5	1984
125.2	125.2 R	Middle	Side Channel	DIHAB	2	1984
125.3	Skull Creek	Middle	Side Slough	IFG-4	11	1983
128.8	Slough 9	Middle	Side Slough	IFG-4	10	1983
130.2	130.2 R	Middle	Side Channel	DIHAB	3	1984
131.1	4th of July Creek mouth	Middle	Tributary Mouth	Habitat Mapping	8	1983
131.3	131.3 L	Middle	Side Channel	DIHAB	4	1984
131.7	131.7 L	Middle	Side Channel	IFG-4	7	1984
132.6	132.6 L, Side channel 10A	Middle	Side Channel	IFG-4, RJHAB	9	1983-1984
133.8	133.8 R	Middle	Mainstem	DIHAB	3	1984
133.8	Side channel 10	Middle	Side Channel	IFG-4	4	1983
134.9	Lower Side channel 11	Middle	Side Channel	IFG-2	6	1983

River Mile	Site Name	Susitna Segment	Habitat Type	Site Type	No. of Transects	Year(s) Measured
136.0	136.0 L, Slough 14	Middle	Side Channel	IFG-4	6	1984
136.3	Upper Side channel 11	Middle	Side Channel	IFG-4	4	1983
137.5	137.5 R	Middle	Side Channel	DIHAB	3	1984
138.7	138.7 L	Middle	Mainstem	DIHAB	3	1984
139.0	139.0 L	Middle	Mainstem	DIHAB	4	1984
139.4	139.4 L	Middle	Side Channel	DIHAB	3	1984
141.2	Side channel 21	Middle	Side Channel	IFG-4	5	1983
141.8	Slough 21	Middle	Side Slough	IFG-4	5	1983
144.4	Slough 22	Middle	Side Slough	RJHAB	8	1983
147.1	147.1 L, Fat Canoe SC	Middle	Side Channel	IFG-2	6	1984

Table 7.1-2. Representative Groups used as part of the methodology to extrapolate results from modeled to non-modeled areas in the Middle Susitna River during 1980s studies. Source: Aaserude et al. (1985).

Extrapolation for Single-Thread River System (IFIM)	Extrapolation for Multiple-Thread River System (Aaserude et al. 1985)
Proportional length basis	Proportional area basis
Continuous segments	Discontinuous segments termed 'Representative Groups'
Intensively studied representative reaches	Intensively studied representative reaches plus general reconnaissance level survey of entire river system
Extrapolation from representative reaches to associated subsegments without adjustment	Extrapolation from representative reaches to associated representative groups with adjustment to account for inequalities in structural habitat between specific areas

Table 7.1-3. Representative Groups used as part of the methodology to extrapolate results from modeled to non-modeled areas in the Middle Susitna River during 1980s studies. Source: Aaserude et al. (1985).

Representative Group	Description
Group I	Predominantly upland sloughs. Areas are highly stable due to persistence of non-breached conditions. Area hydraulics characterized by pooled clear water with velocities frequently near 0 fps and depths > 1 ft. Pools commonly connected by short riffles with velocities < 1 fps and depths < 0.5 ft.
Group II	Side sloughs that are characterized by relatively high breaching flows (>19,500 cfs), clear water caused by upwelling groundwater and large channel length to width ratios (> 15:1).
Group III	Areas with intermediate breaching flows and relatively broad channel sections. These areas consist of side channels which transform into side sloughs at mainstem discharges ranging from 8,200 to 16,000 cfs. These areas are distinguishable from Group II by lower breaching flows and smaller length to width ratios. Upwelling water is present.
Group IV	Side channels that are breached at low flows and possess intermediate mean velocities (2–5 fps) at a mainstem discharge of approximately 10,000 cfs.
Group V	Mainstem and side shoal areas that transform to clear water side sloughs as mainstem flows recede. Transformations generally occur at moderate to high breaching flows.
Group VI	Similar to Group V. Sites within this group are primarily overflow channels that parallel the adjacent mainstem, usually separated by sparsely vegetated gravel bar. Upwelling may or may not be present. Habitat transformations within this group are variable in type and timing.
Group VII	Side channels that breach at variable yet fairly low mainstem discharges and exhibit characteristic riffle/pool sequence. Pools are frequently large backwater areas near the mouth of the sites.
Group VIII	Area that dewater at relatively high flows. Flow direction at the head of the channels tends to deviate sharply (> 30 degrees) from the adjacent mainstem.
Group IX	Secondary mainstem channels that are similar to the primary mainstem channels in habitat character, but distinguished as being smaller and conveying a lesser proportion of the total discharge. Areas within this group have low breaching discharges and are frequently similar in size to large side channels, but have characteristic mainstem features, such as relatively swift velocities (> 5fps) and coarser substrate.
Group X	Large mainstem shoals and margins of mainstem channels that show signs of upwelling.

Table 7.2-1. Assessment of physical and biological processes and potential habitat modeling techniques.

Physical and Biological Processes	Habitat Types			
	Mainstem	Side Channel	Slough	Tributary Mouths
Spawning	PHAB/VZM	PHAB	PHAB/HabMap	PHAB/RFR
Incubation	RFR/VZM	PHAB	PHAB/HabMap	PHAB/RFR
Juvenile Rearing	PHAB/RFR	PHAB	PHAB/HabMap	PHAB/RFR
Adult Holding	RFR	RFR	PHAB/HabMap	PHAB/RFR
Macroinvertebrates	VZM/WP	VZM/WP	PHAB/HabMap/WP	N/A
Standing/Trapping	VZM	VZM	VZM/WP	VZM/WP
Upwelling/Downwelling	FLIR	HabMap/FLIR	HabMap/FLIR	HabMap/FLIR
Temperature	WQ	WQ	WQ	WQ
Ice Formation	IceProcesses/WQ/RFR	IceProcesses/WQ/RFR	HabMap/Open leads	N/A

Notes:

1 PHAB-Physical Habitat Simulation Modeling (1-D, 2-D, and empirical); VZM-Effective Spawning and Incubation/Varial Zone Modeling; RFR-River Flow Routing Modeling; FLIR – Forward-looking Infrared Imaging; HabMap-Surface Area Mapping; WQ-Water Quality Modeling; WP-Wetted Perimeter Modeling.

Table 7.2-2. Conceptual Comparison of Multiple Resource Indicators of the Effects of Alternative Operational Scenarios for the Susitna-Watana Hydroelectric Project. Indicators to be coordinated with resource-specific working groups.

(Indicators provided for illustration purposes only)

		Existing Conditions (EC-01)	Scenario 1 (Ver. 1/20/15) (OS-01)	Scenario 2 (Ver. 02/14/15) (OS-02)	Scenario 3 (Ver. 02/14/15) (OS-03)
Run Description	Average monthly MIF(cfs)				
	Max generation Nov-Mar (cfs)				
	Min generation Nov-Mar (cfs)				
	Max generation Apr-Oct (cfs)				
	Min generation Apr-Oct (cfs)				
	Ramping Rates				
	Evaluation Indicators				
Power	Weighted average generation Nov-Mar (MWh)⑤				
	Weighted average generation Apr-Oct (MWh)⑤				
	Weighted annual dependable capacity (MWh)⑤				
Hydrologic	Max 1-day flow (cfs) wet / avg /dry	wet / avg / dry	wet / avg / dry	wet / avg / dry	wet / avg / dry
	Min 2-day low, Nov-Mar (cfs)				
	Min 2-day low Jul-May as % of 2-day max Jul-Sep				
	Freshets (Apr-Jun) $[Q_c]>1.5*[Q_{C-1}+Q_{C-2}+Q_{C-3}]/3$				
	Water Particle Travel Time, 25% exceedance, Apr-Jun				
	Other IHA statistics				
Reservoir	Average reservoir volume (KAF)	wet / avg /dry	wet / avg / dry	wet / avg / dry	wet / avg / dry
	Min 2-day reservoir volume (KAF)				
	Weighted annual euphotic zone (KAF)				
	Other Biological/recreation indicators				
Ramping	Weighted avg annual total, Middle Susitna, reach-averaged (ra) downramping events >1-inch pr hour⑤				
	Weighted average annual total, Middle Susitna, reach-averaged downramping events > 2-inch per hour⑤				
	Weighted average annual total, Middle Susitna, reach-averaged downramping events > 4-inches per hour ⑤				
Varial Zone	Median annual, MS, reach-averaged (ra) channel width-ft ⑤				
	Total varial zone, MS, 12-hr/12-hr, ra, median annual channel width-ft ⑤				
	Total varial zone, MS, 12-hr/7-day, ra, median annual channel width-ft ⑤				
	Total varial zone, MS, 12-hr/30-day, ra, median annual channel width-ft ⑤				

Evaluation Indicators *(Indicators provided for illustration purposes only)*		Existing Conditions (EC-01)	Scenario 1 (Ver. 1/20/15) (OS-01)	Scenario 2 (Ver. 02/14/15) (OS-02)	Scenario 3 (Ver. 02/14/15) (OS-03)
Potential Salmon Habitat	Chum spawning habitat, Devils Canyon to 3 Rivers (DCto3R) reach-averaged(ra), **gross channel width,** (ft)⑤				
	Chum **effective spawning/incubation,** DCto3R-reach-averaged (ra), channel width accounting for dewatering, groundwater/surface water interactions, water quality effects, **net width** (ft)⑤				
	Coho effective spawning/incubation, DCto3R-ra, **net width**, (ft)⑤				
	Sockeye effective spawning and incubation, DCto3R-ra, slough/side channel, **net width** (ft)⑤				
	Pink effective spawning/incubation, DCto3R-ra, slough/side channel, **net width** (ft)⑤				
	Coho juvenile habitat, open-water, DCto3R-ra, channel width (ft) ⑤				
	Coho juvenile habitat, ice-period, DCto3R-ra, channel width (ft) ⑤				
	Chinook juvenile habitat, ice-period, DCto3R-ra, slough/side channel width (ft) ⑤				
Other Fish	Grayling average minimum spawning, Watana Dam to Devils Canyon (DtoDC), reach averaged WUA, (ft^2)⑤				
	Northern pike effective spawning and incubation, DCto3R-reach averaged slough/side channel net width (ft)⑤				
Riparian	Wet meadow area, reach averaged, DC to3R, post-licensing yrs 10-20 (acres)⑤				
	Scrub thickets, reach averaged, DC to 3R, post-licensing yrs 10-20 (acres)⑤				
	Floodplain plant community colonization area, reach averaged, DC to 3R, post-licensing yrs 10-20 (acres)⑤				
	Other riparian indicators				
Recreation	Devils Canyon to 3R, tour boat accessible, May to Sep (days)				
	Three Rivers to Sunshine, days channel exceeds minimum boating depth, May to Sep				
	Devils Canyon to 3 R, upstream extent of January ice cover for snow machine travel				
	Other recreation/access indicators				
Other Aquatics	Other potential indicators of Project effects such as: ▫ minimum slough area, ▫ percent of river length mobilized-D_{25} ▫ downstream extent of ice-free zone, ▫ 30-day wetted euphotic streambed, ▫ other reaches, seasons, life stages, mesohabitats to be determined in consultation with TWG				

Notes:

1. Average of five select years weighted by likelihood of occurrence (Dry Year* 0.077, Somewhat Dry Year* 0.231, Average Year * 0.462, Somewhat Wet Year * 0.115, Wet Year*0.115) (values are for illustration purposes only)

Table 8.1-1. Description of habitat zones sampled at Designated Fish Habitat Sites: June through September 1982 (From Estes and Schmidt 1983).

Zone Code	Description
1	Areas with a tributary or ground water source which are not influenced by mainstem stage and which usually have a significant[1] surface water velocity.
2	Areas with a tributary or ground water source which have no appreciable[1] surface water velocity as a result of a hydraulic barrier created at the mouth of a tributary or slough by mainstem stage.
3	Areas of significant surface water velocities, primarily influenced by the mainstem, where tributary or slough water mixes with the mainstem water.
4	Areas of significant water surface velocities which are located in a slough or side channel above a tributary confluence (or in a slough where no tributary is present) when the slough head is open.
5	Areas of significant water surface velocities which are located in at slough or side channel below a tributary confluence when the slough head is open.
6	Backwater areas with no appreciable surface water velocities which result from a hydraulic barrier created by mainstem stage which occur in a slough or side channel above a tributary confluence (or in a slough or side channel where no tributary is present), when the head of the slough is open.
7	Backwater areas with no appreciable surface water velocities which result from a hydraulic barrier created by mainstem stage which occur in a slough or side channel below a tributary confluence, when the head of the slough is open.
8	Backwater areas consisting of mainstem eddies.
9	A pool with no appreciable surface water surface velocities which is created by a geomorphological feature of a free-flowing zone or from a hydraulic barrier created by a tributary; not created as a result of mainstem stage.

Notes:

1 "Significant" and "appreciable" surface water velocities mean a velocity of at least 0.5 ft/sec. However, there are site-specific exceptions to this, based on local morphology.

Table 8.1-2. Aggregate Hydraulic (H), Water Source (W) and Velocity (V) zones. Source: Estes and Schmidt (1983), Schmidt et al. (1983).

Aggregate Zone	Habitat Zone Included	Definition
H-I	1, 4, 5, 9	not backed up by mainstem
H-II	2, 6, 7, 8	backed up by mainstem
H-III	3	mainstem
W-I	1, 2	tributary water and/or ground water only
W-II	4, 6, 8, sometimes 3	mainstem water only
W-III	5, 7, sometimes 3	mixed water sources
V-I[1]	1, 3, 4, 5	Fast water
V-II[1]	2, 6, 7, 8, 9	Slow water

Notes:

1 The habitat zones included in aggregate zones V-I and V-II were not provided in the source documents. Zone descriptions were used to classify which zones were fast and slow water.

11. FIGURES

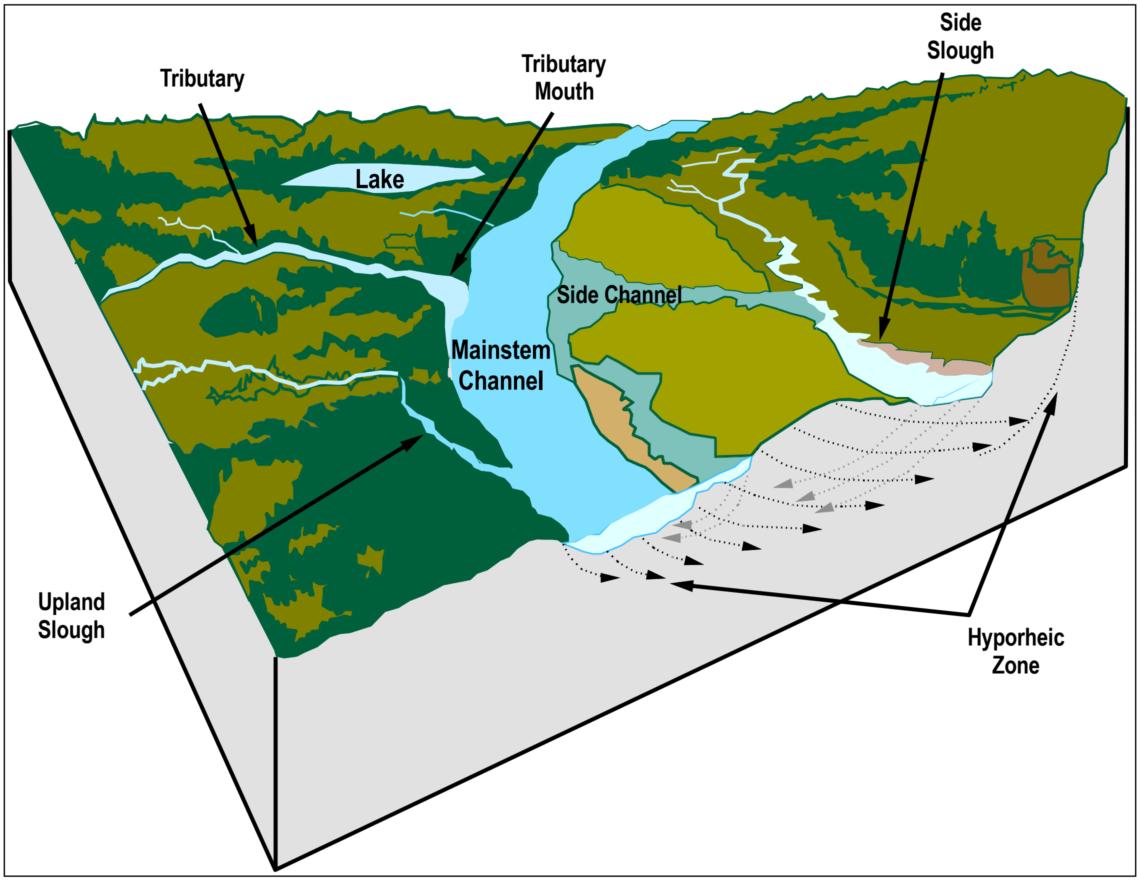


Figure 3.1-1. Habitat types identified in the middle reach of the Susitna River during the 1980s studies (adapted from ADF&G 1983b; Trihey 1982).

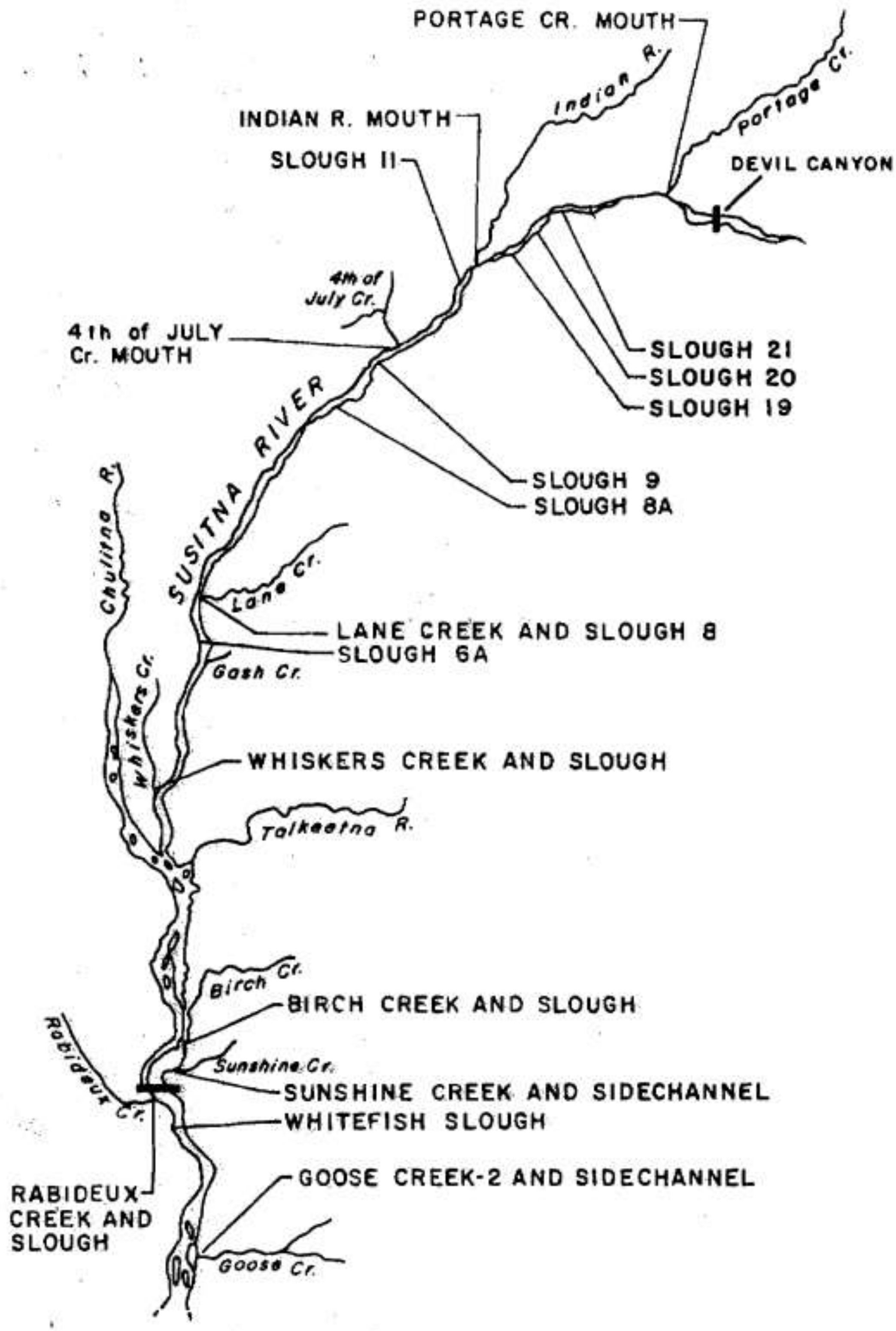


Figure 3.1-2. Map of Designated Fish Habitat (DFH) sites sampled on the Susitna River, June through September 1982. Source: Schmidt et al. (1983).

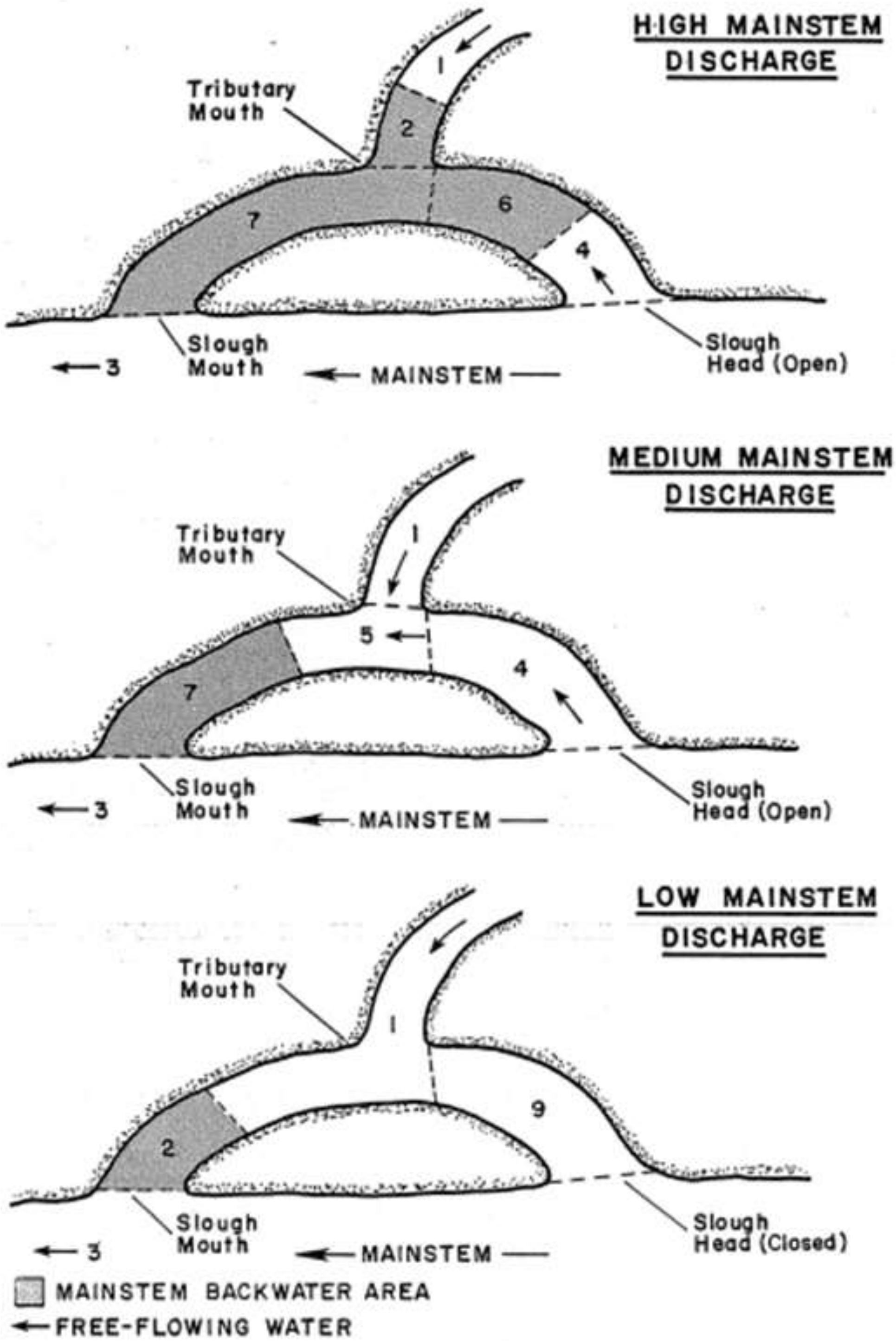


Figure 3.1-3. Hypothetical slough with delineated habitat zones. Source: Estes and Schmidt (1983).

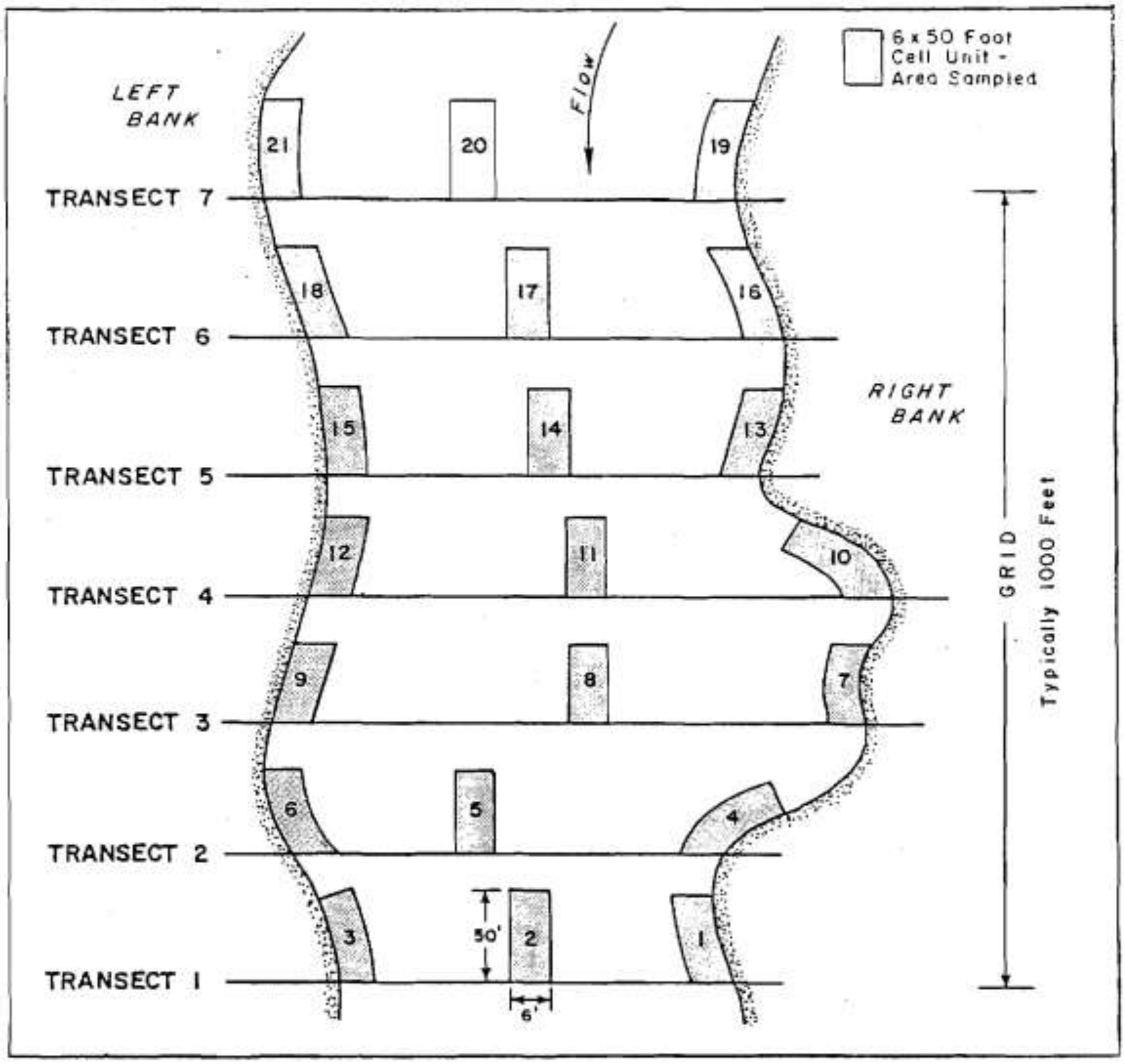


Figure 3.1-4. Typical arrangement of transects, grids, and cells at a JAHS site. Source: Dugan et al. (1984).

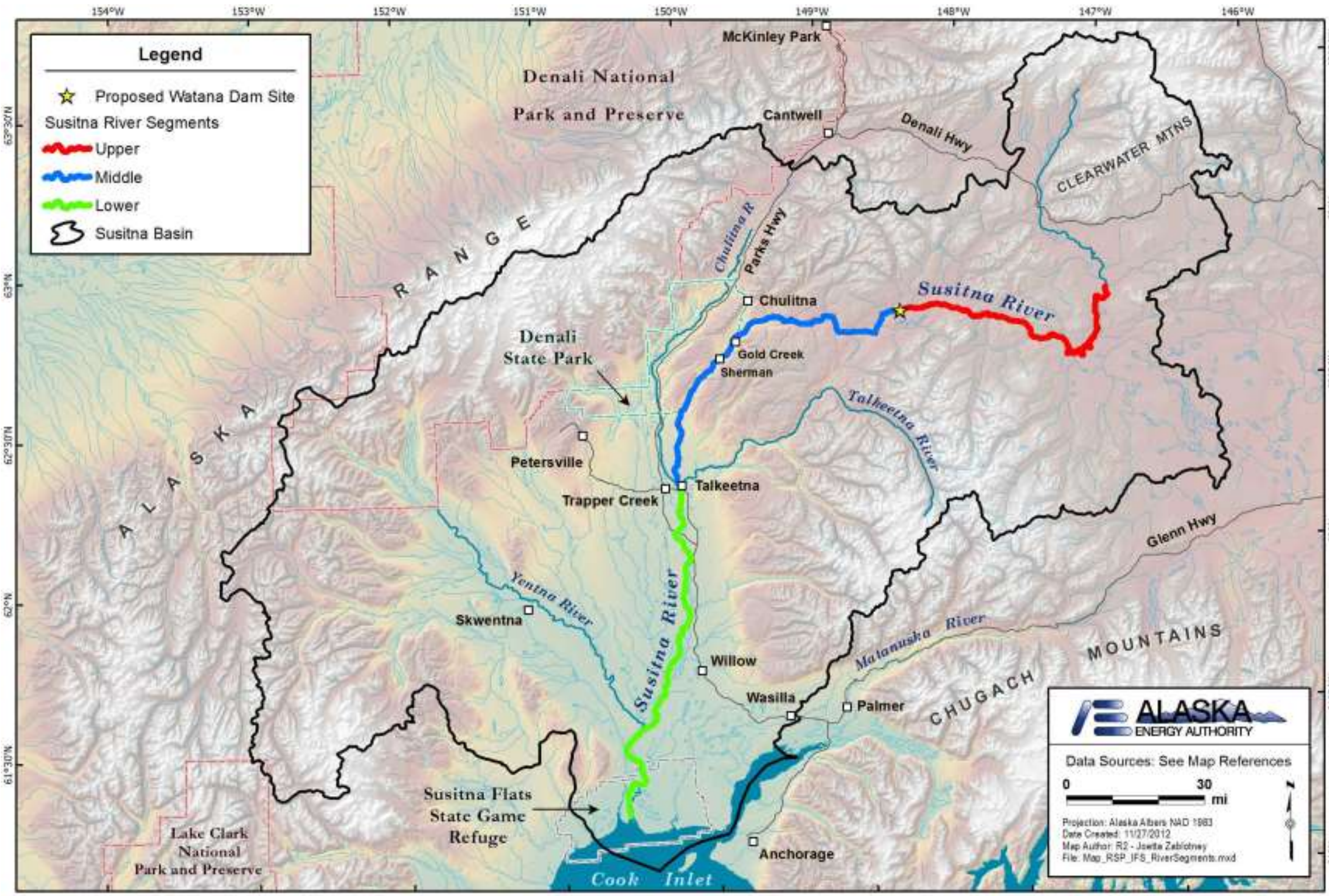


Figure 3.2-1. Map depicting the Upper, Middle and Lower Segments of the Susitna River potentially influenced by the Susitna-Watana Hydroelectric Project.

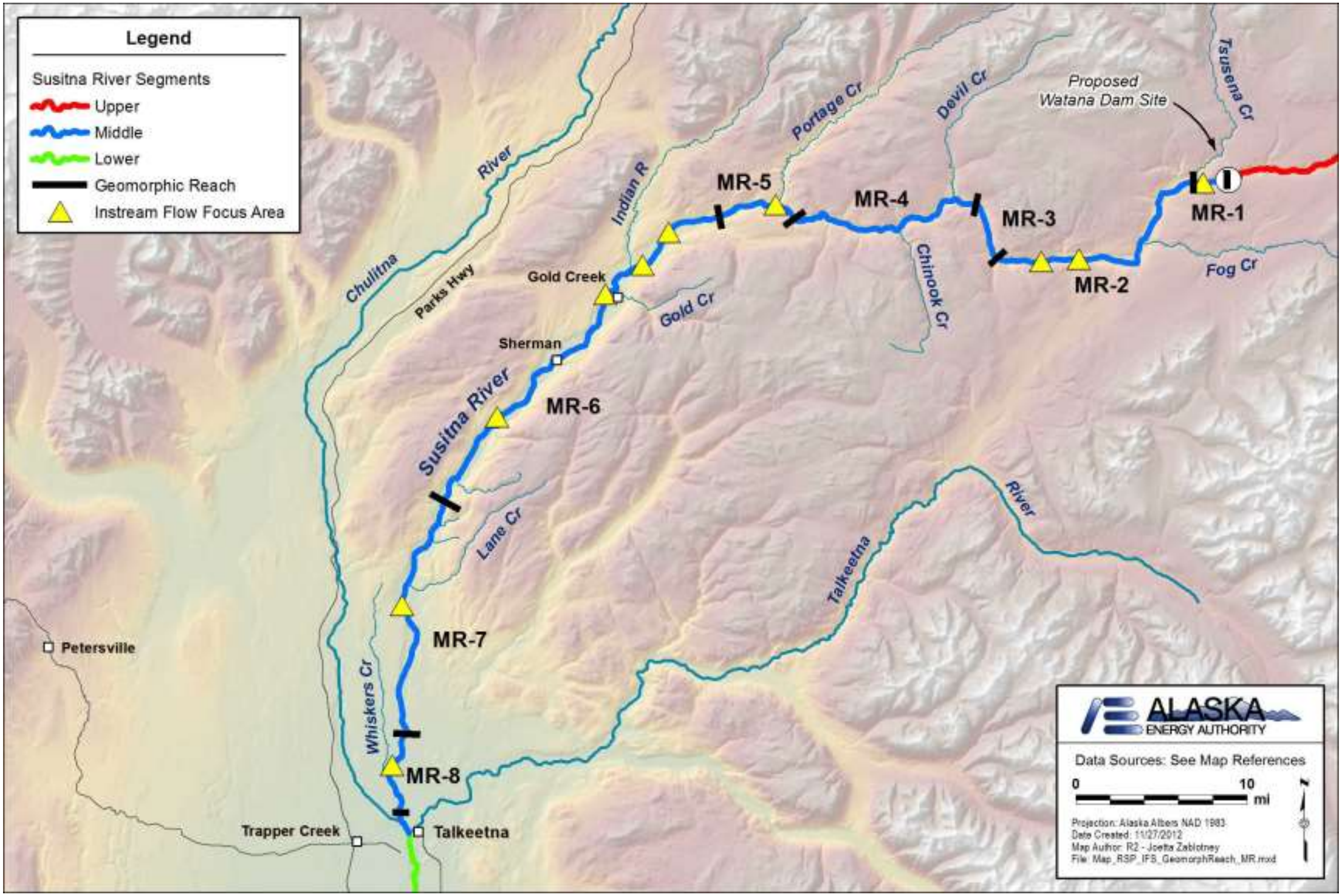


Figure 3.3-1. Map of the Middle Segment of the Susitna River depicting the eight Geomorphic Reaches and locations of proposed Focus Areas. No Focus Areas are proposed for in MR-3 and MR-4 due to safety issues related to sampling within or proximal to Devils Canyon.

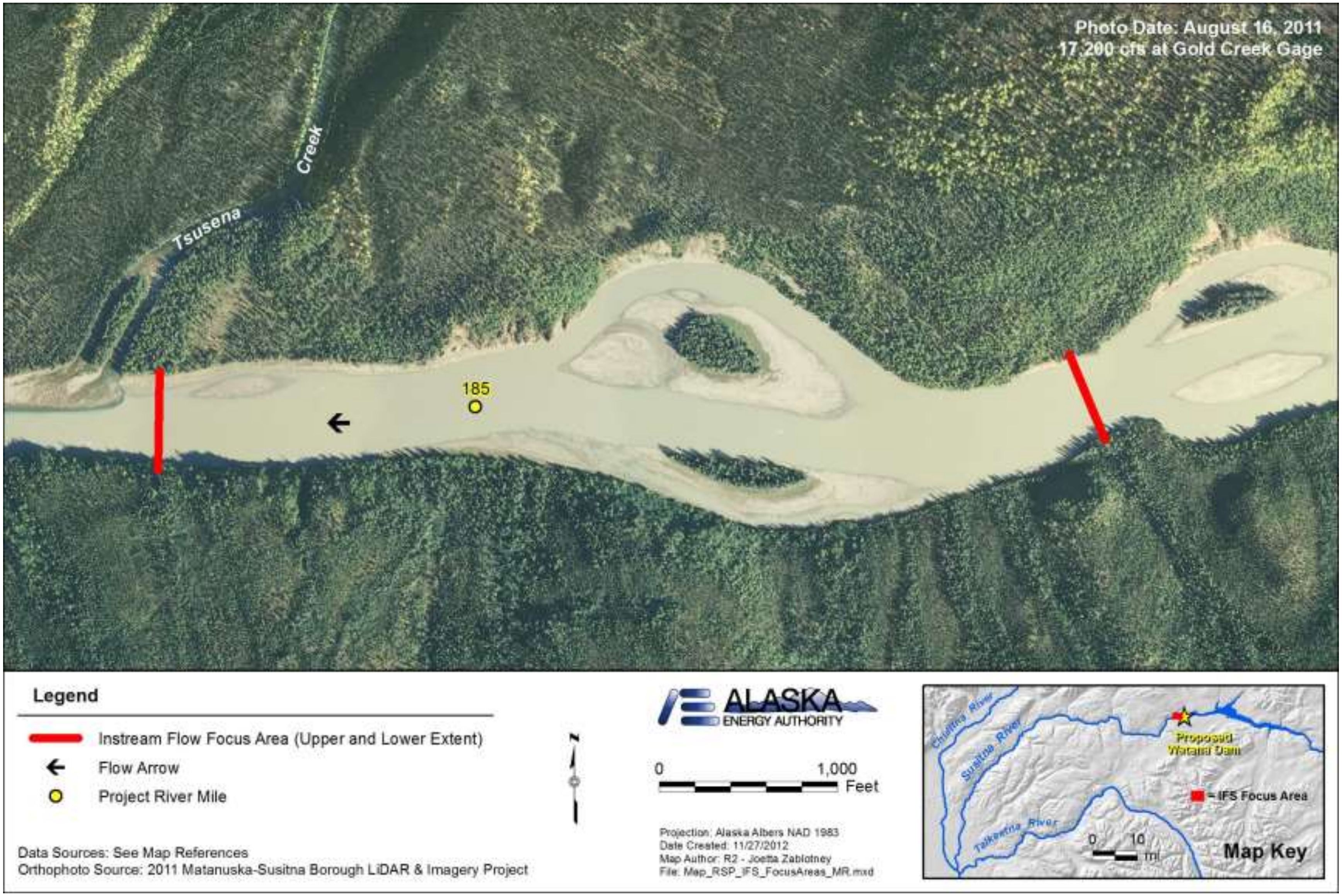


Figure 3.3-2. Map showing Focus Area 184 that begins at Project River Mile 184.7 and extends upstream to PRM 185.7. The Focus Area is located about 1.4 miles downstream of the proposed Watana Dam site near Tsusena Creek.

Figure 3.3-3. Map showing Focus Area 173 beginning at Project River Mile 173.6 and extends upstream to PRM 175.4. This Focus Area is near Stephan Lake and consists of main channel and a side channel complex.

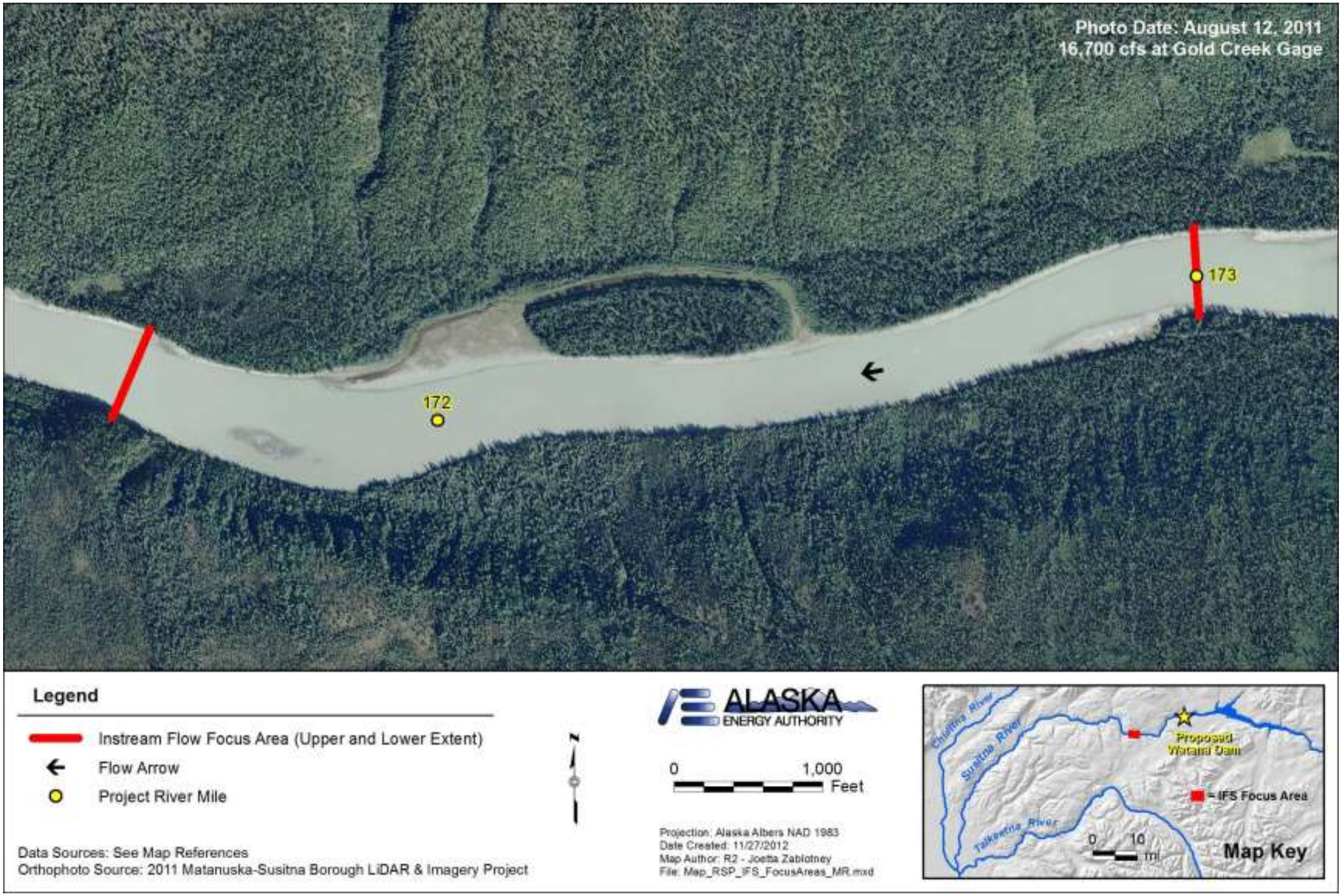


Figure 3.3-4. Map showing Focus Area 171 beginning at Project River Mile 171.6 and extends upstream to PRM 173. This Focus Area is near Stephan Lake and consists of main channel and a single side channel with vegetated island.

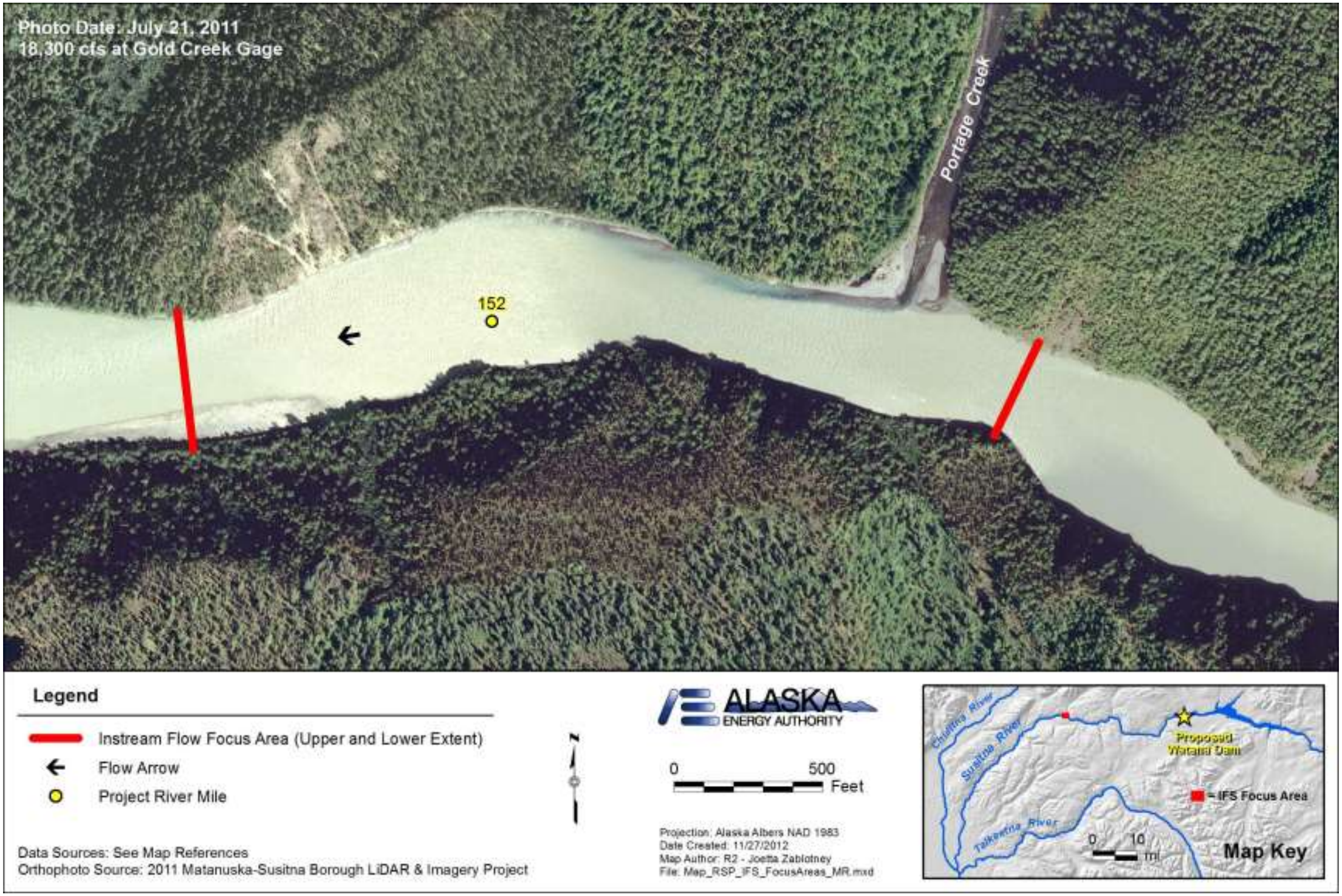


Figure 3.3-5. Map showing Focus Area 151 beginning at Project River Mile 151.8 and extends upstream to PRM 152.3. This single main channel Focus Area is at the Portage Creek confluence.

Figure 3.3-6. Map showing Focus Area 144 beginning at Project River Mile 144.4 and extends upstream to PRM 145.7. This Focus Area is located about 2.3 miles upstream of Indian River and includes Side Channel 21 and Slough 21.

Figure 3.3-7. Map showing Focus Area 141 beginning at Project River Mile 141.8 and extends upstream to PRM 143.4. This Focus Area includes the Indian River confluence and a range of main channel and off-channel habitats.

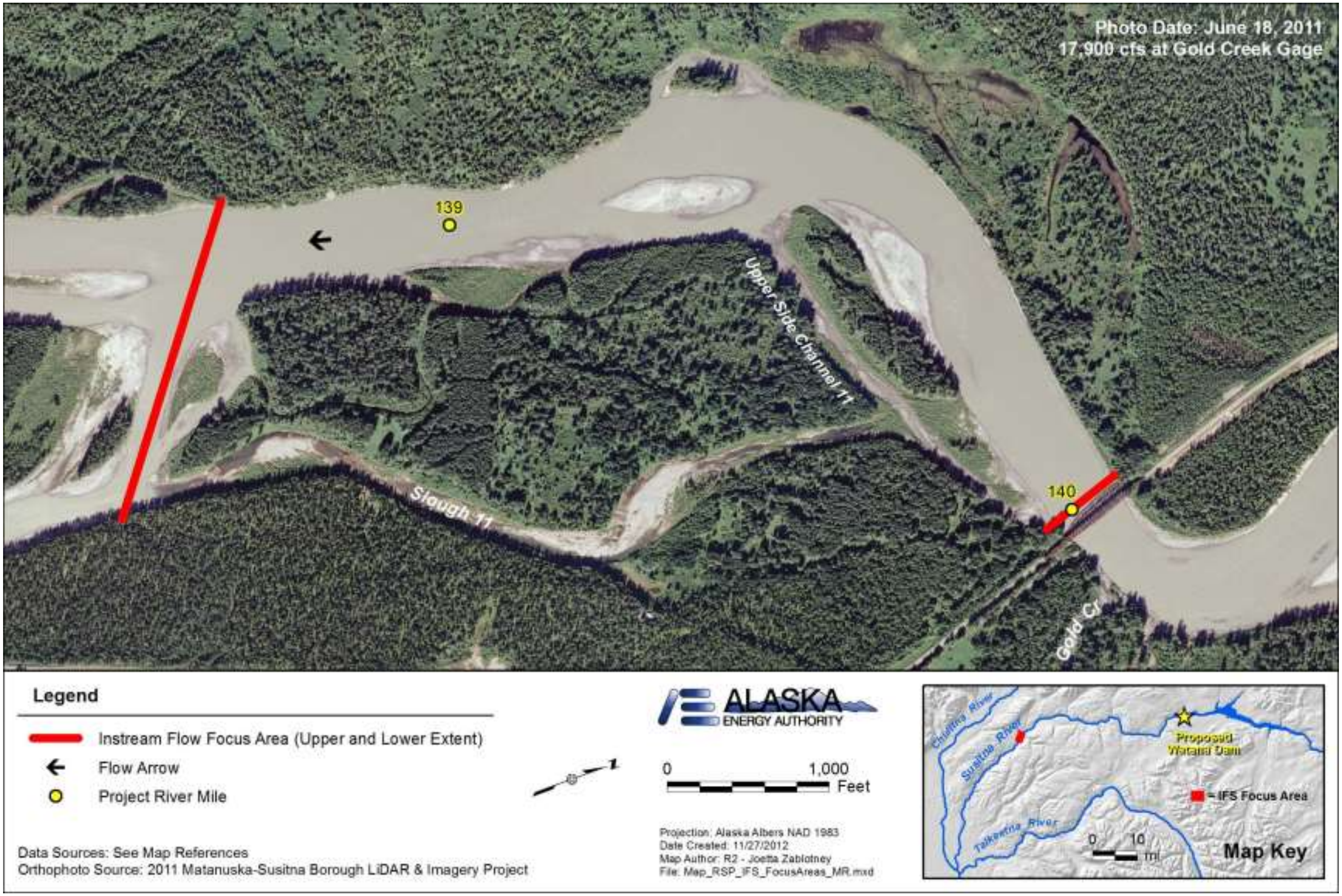


Figure 3.3-8. Map showing Focus Area 138 beginning at Project River Mile 138.7 and extends upstream to PRM 140. This Focus Area is near Gold Creek and consists of a complex of side channel, side slough and upland slough habitats including Upper Side Channel 11 and Slough 11.

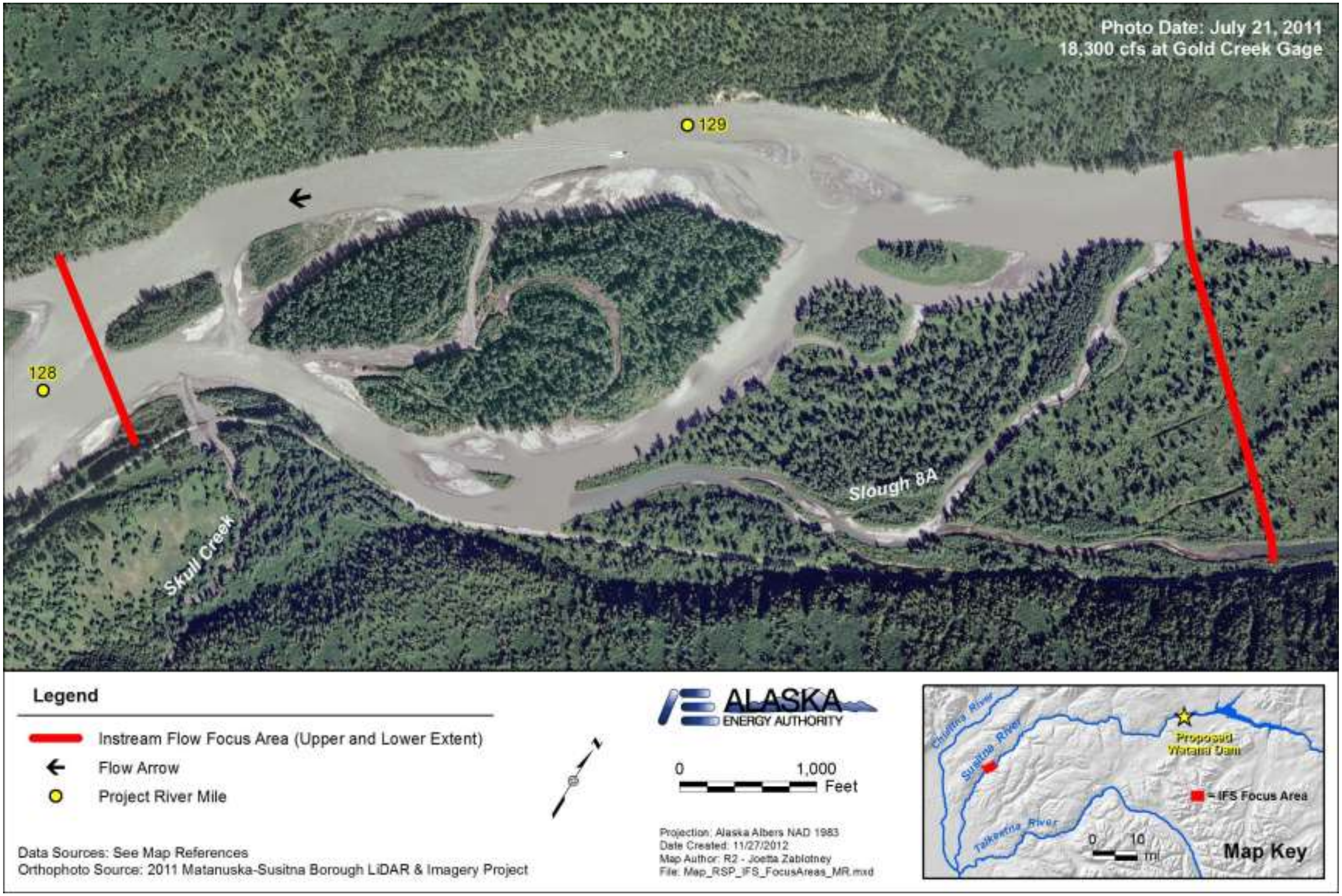


Figure 3.3-9. Map showing Focus Area 128 beginning at Project River Mile 128.1 and extends upstream to PRM 129.7. This Focus Area consists of side channel, side slough and tributary confluence habitat features including Skull Creek.

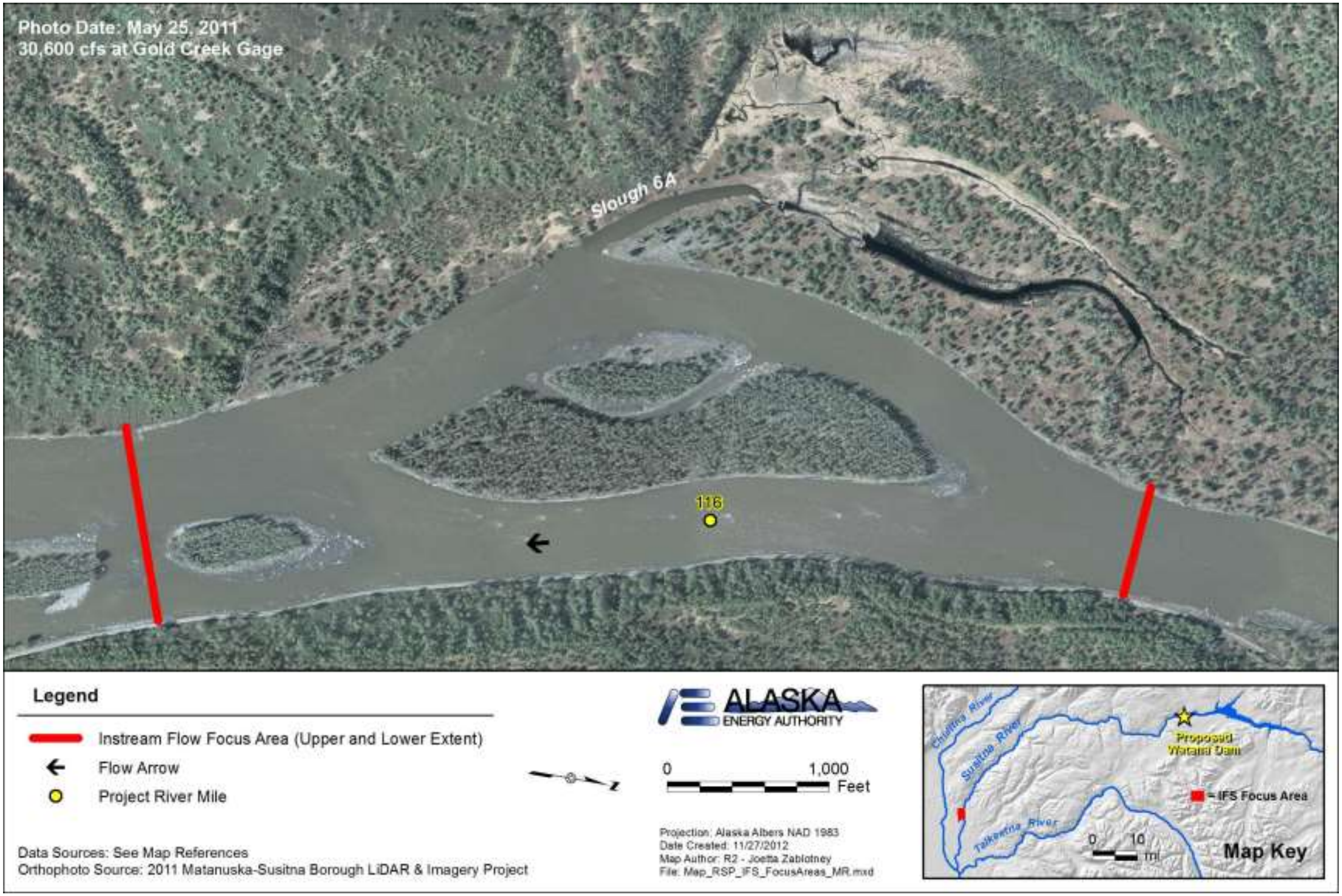


Figure 3.3-10. Map showing Focus Area 115 beginning at Project River Mile 115.3 and extends upstream to PRM 116.5. This Focus Area is located about 0.6 miles downstream of Lane Creek and consists of side channel and upland slough habitats including Slough 6A.

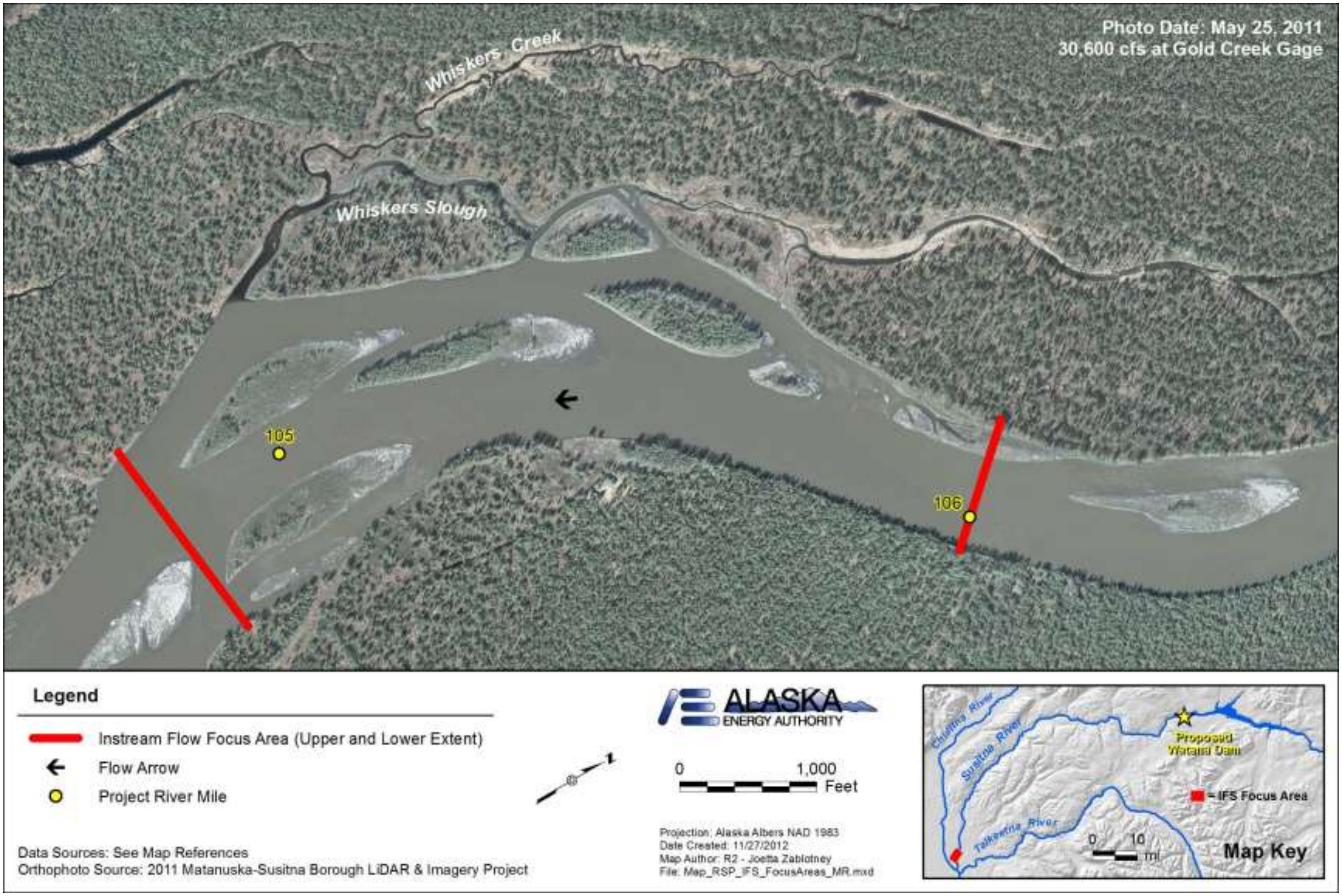


Figure 3.3-11. Map showing Focus Area 104 beginning at Project River Mile 104.8 and extends upstream to PRM 106. This Focus Area covers the diverse range of habitats in the Whiskers Slough complex.

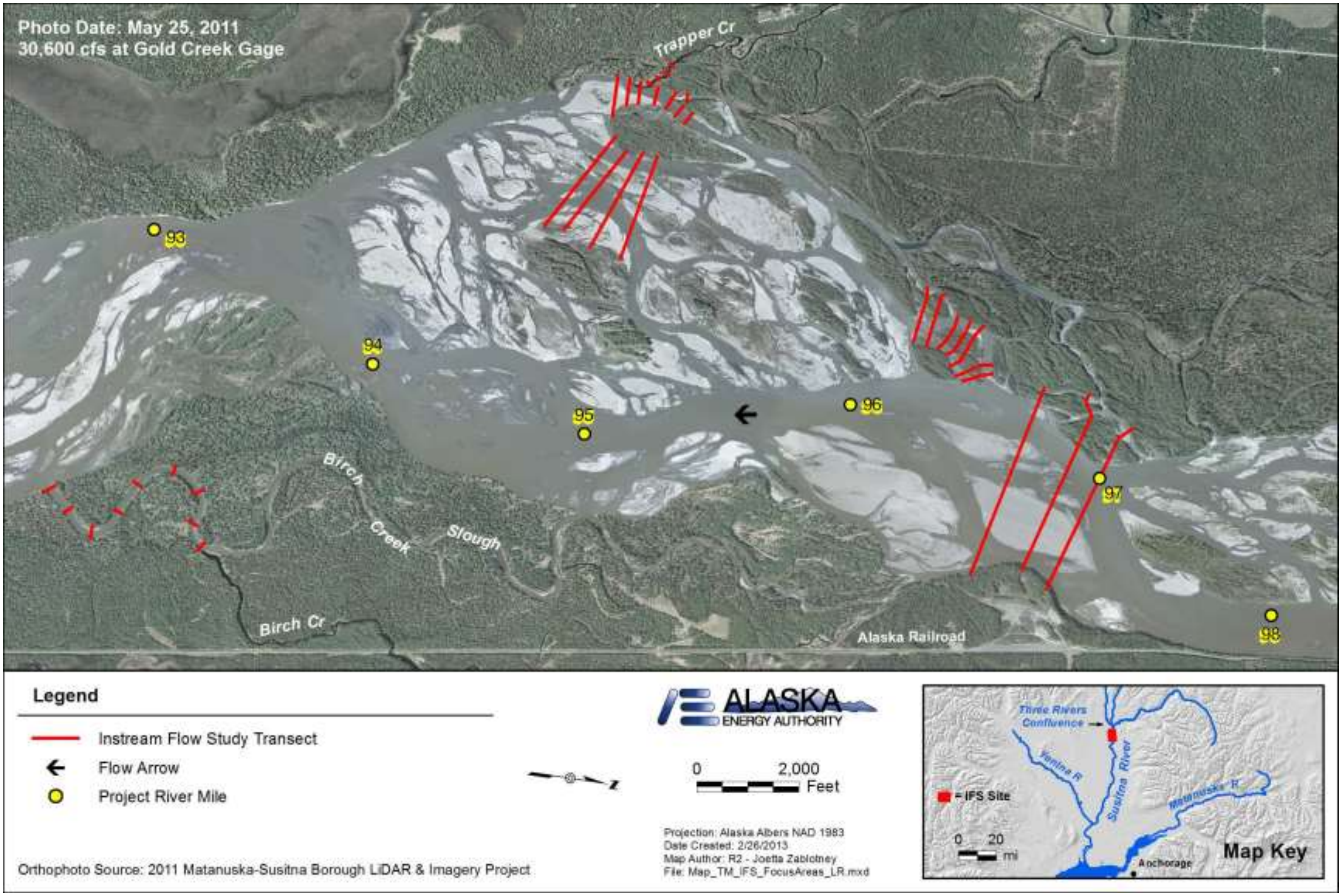


Figure 3.3-12. Map showing proposed location of lower Susitna River instream flow-fish habitat transects in Geomorphic Reach LR-1 in the vicinity of Trapper Creek. The proposed location, number, angle, and transect endpoints are tentative pending on-site confirmation during open-water conditions. Where feasible, instream flow fish habitat transects will be co-located with geomorphology, open-water flow routing, and instream flow-riparian transects.

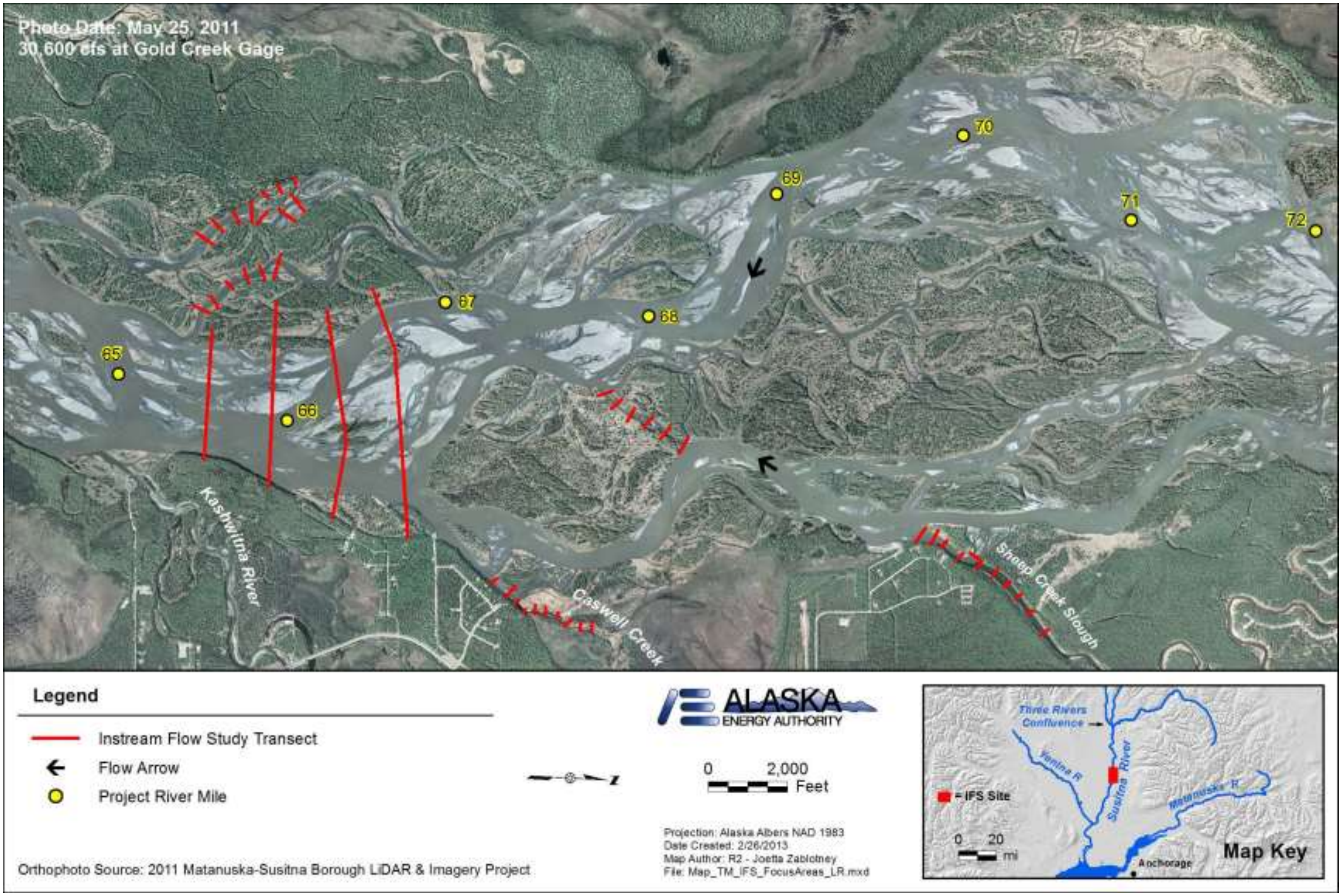


Figure 3.3-13. Map showing proposed location of lower Susitna River instream flow-fish habitat transects in Geomorphic Reach LR-2 in the vicinity of Caswell Creek. The proposed location, number, angle, and transect endpoints are tentative pending on-site confirmation during open-water conditions. Where feasible, instream flow fish habitat transects will be co-located with geomorphology, open-water flow routing and instream flow-riparian transects.

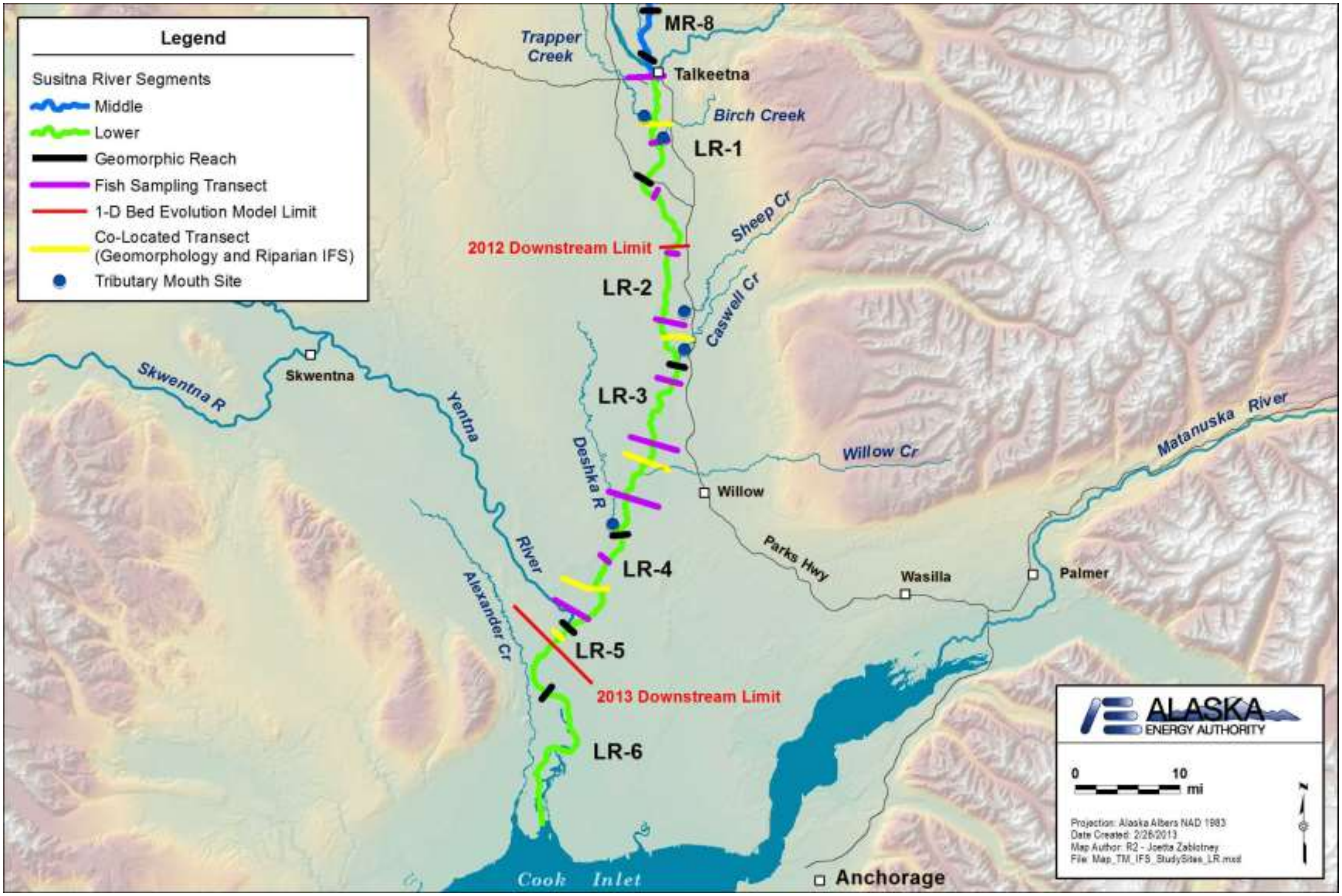


Figure 3.3-14. Map of the Lower Segment of the Susitna River depicting the six Geomorphic Reaches and locations of proposed 2013 study areas for geomorphology, instream flow–fish, instream flow-riparian and fish distribution and abundance.

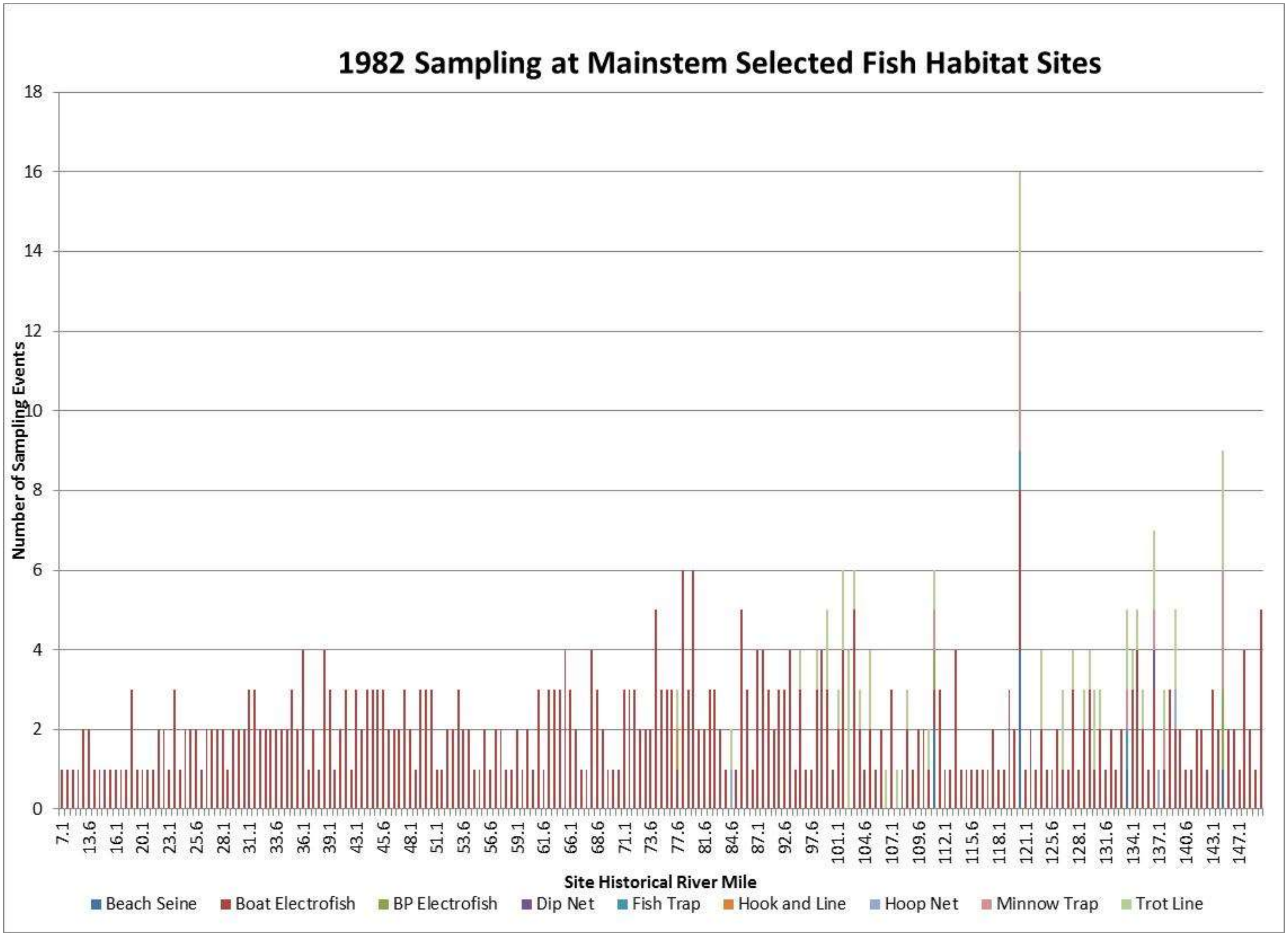


Figure 4.2-1. Sampling effort at 225 mainstem Selected Fish Habitat sites during 1982. Data Source: Schmidt et al. (1983).

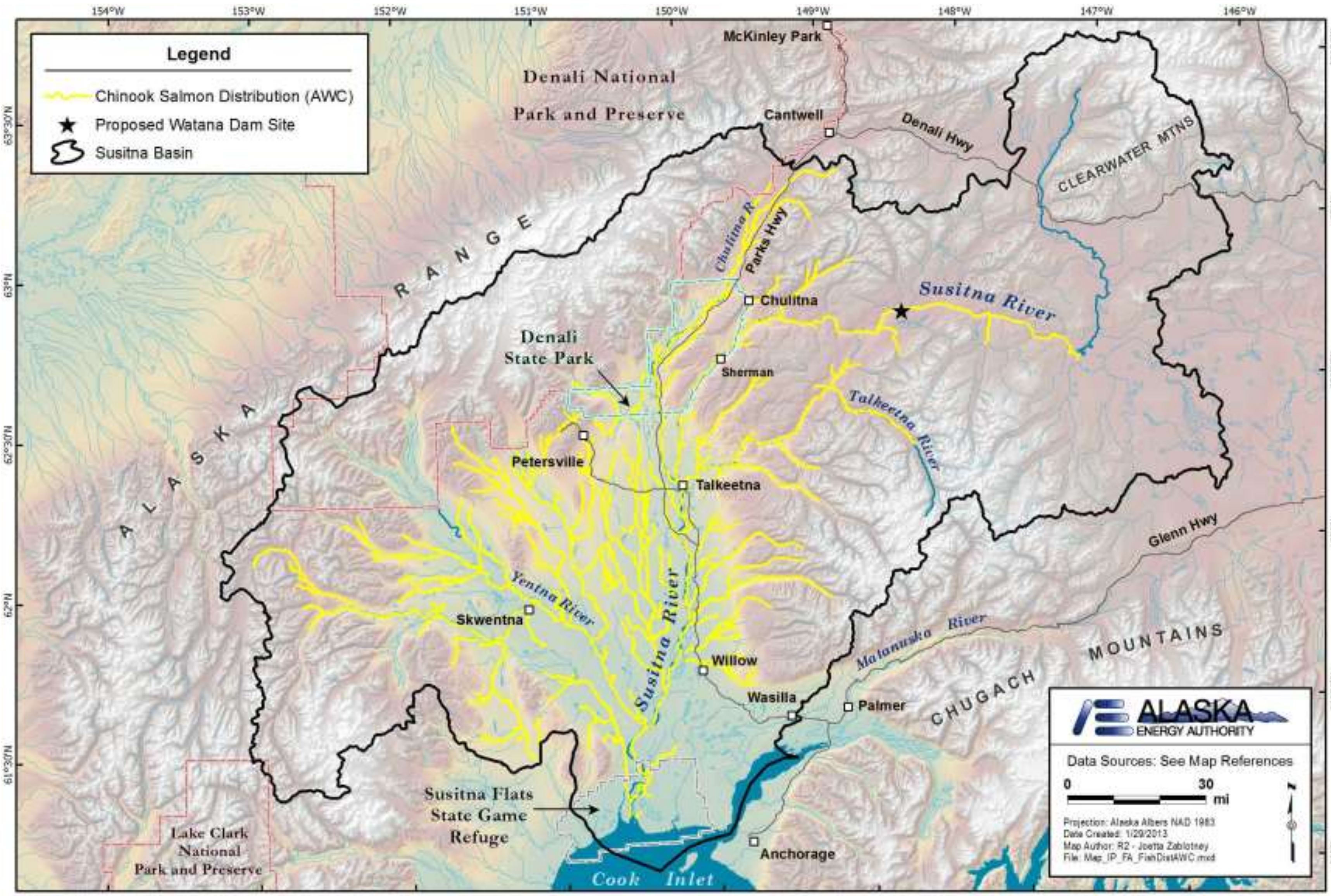


Figure 4.3-1. Distribution of Chinook salmon in the Susitna River Basin from ADF&G's Anadromous Waters Catalog.

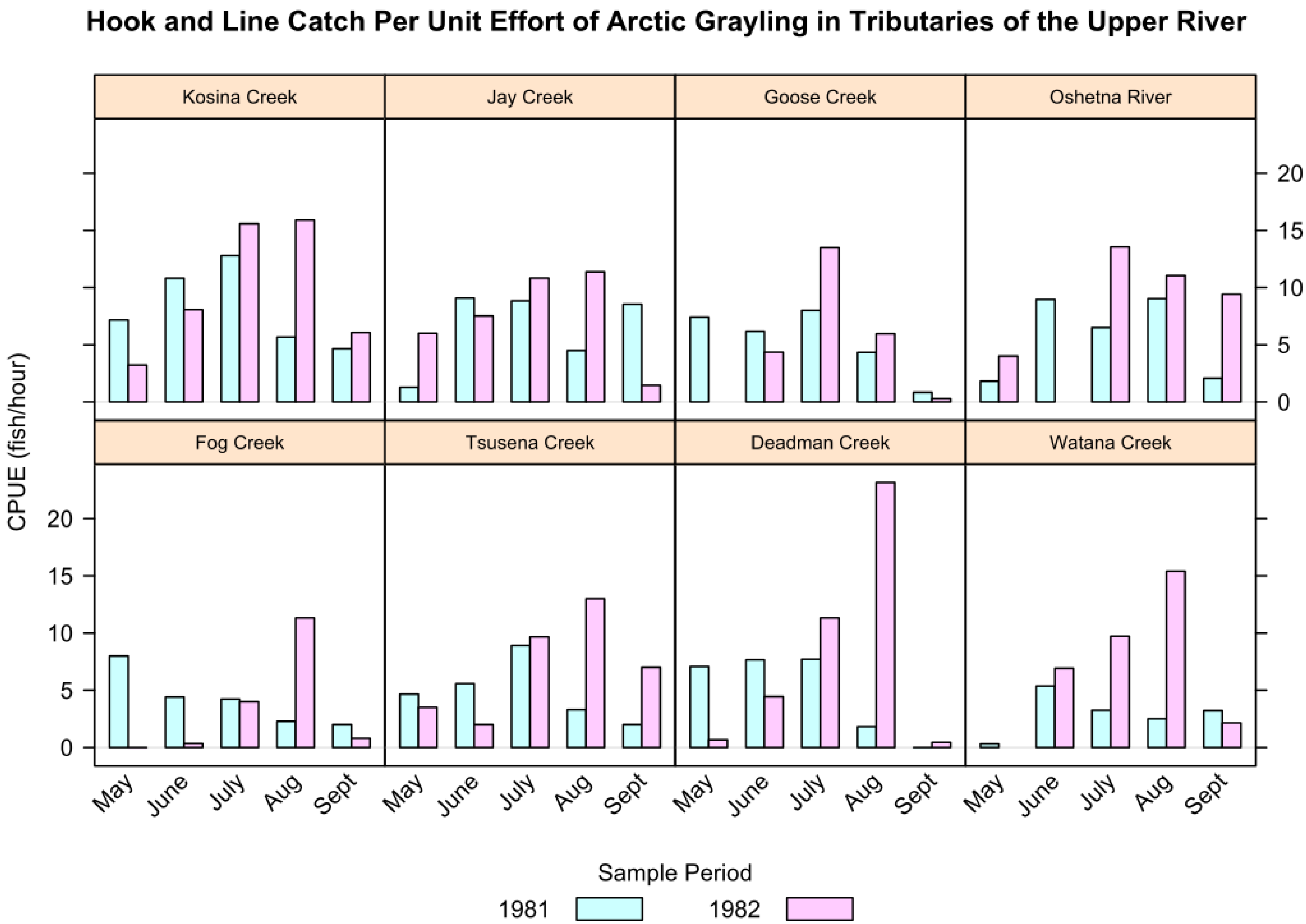


Figure 4.3-2. Catch per unit effort of Artic grayling by hook and line in tributaries to the upper Middle and Upper Susitna River during 1981 and 1982.The absence of a line at zero indicates no sampling occurred at that site and period. Data Source: Delaney et al. (1981c), Sautner and Stratton (1983).

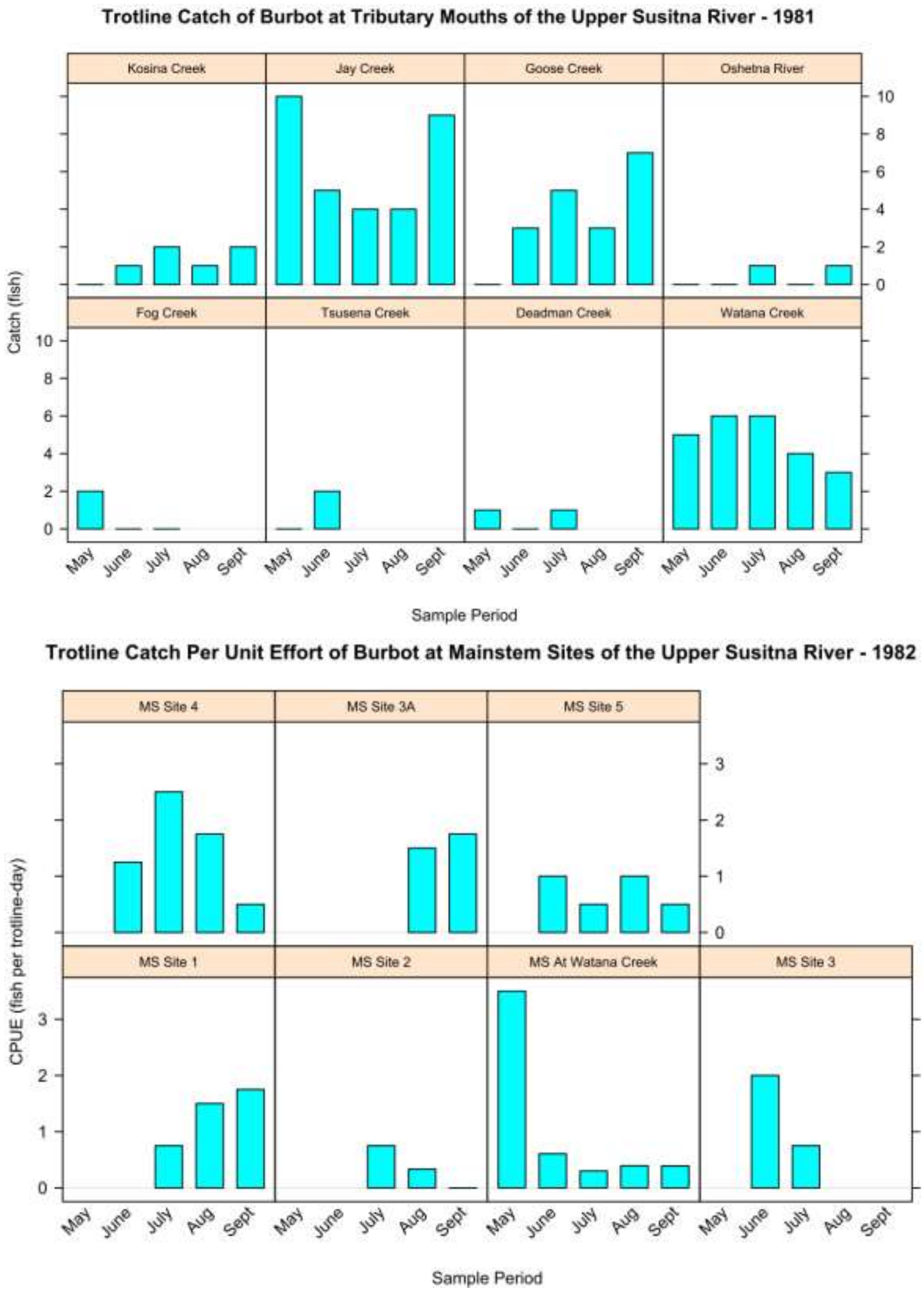


Figure 4.3-3. Total catch of burbot by trotlines during 1981 (top) at tributary mouths and CPUE of burbot at mainstem sites in the Upper Susitna River during 1982 (bottom). Data Sources: Delaney et al. (1981c), Sautner and Stratton (1983).

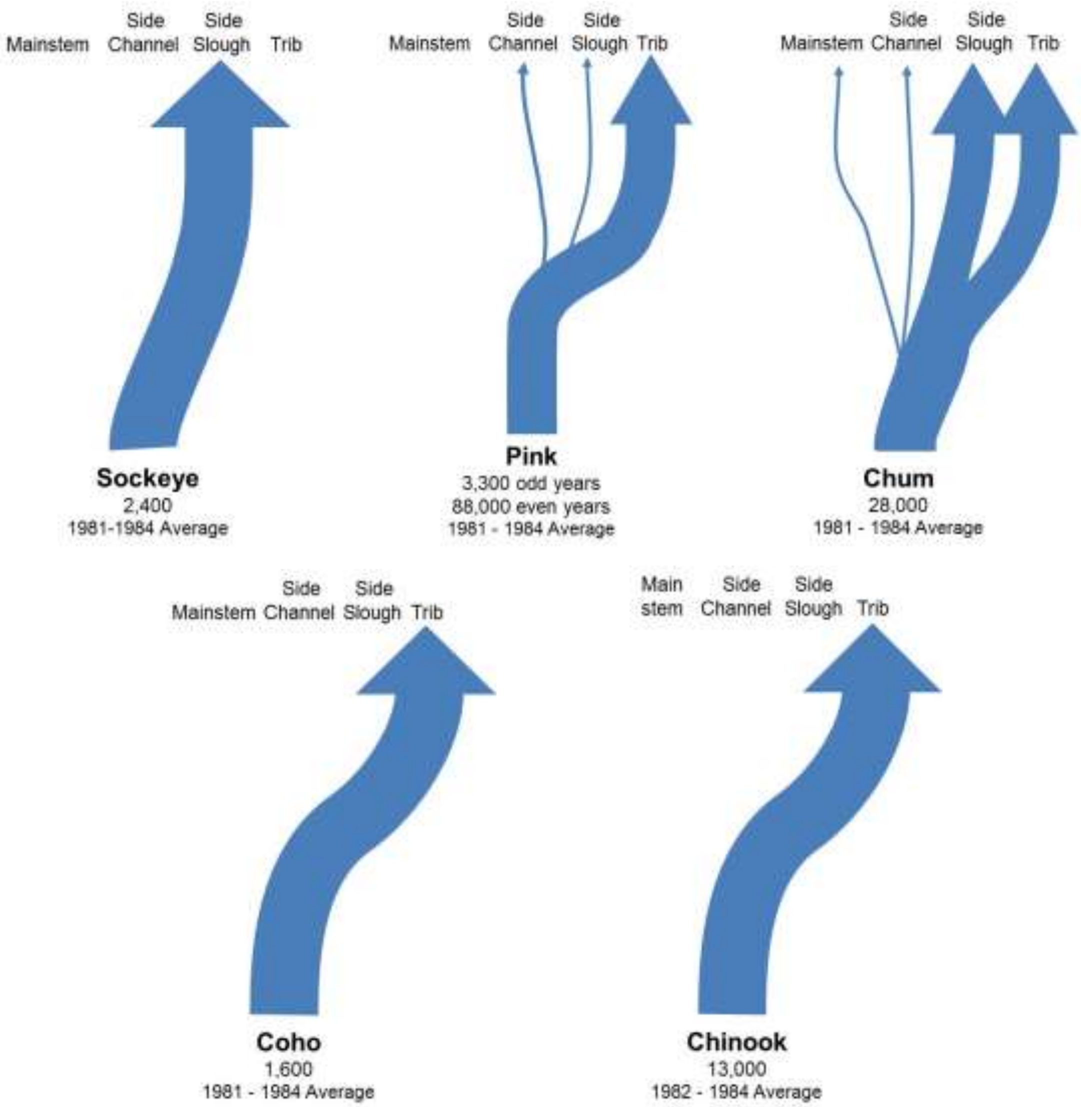


Figure 4.3-4. Spawning habitat utilization by anadromous salmon species and average run size in the middle Susitna River. Large arrows indicate primary spawning habitat and thin arrows indicate secondary spawning habitat. Source: Trihey and Entrix (1985) as modified from Sautner et al. (1984). Run size information from Barrett et al. (1985).

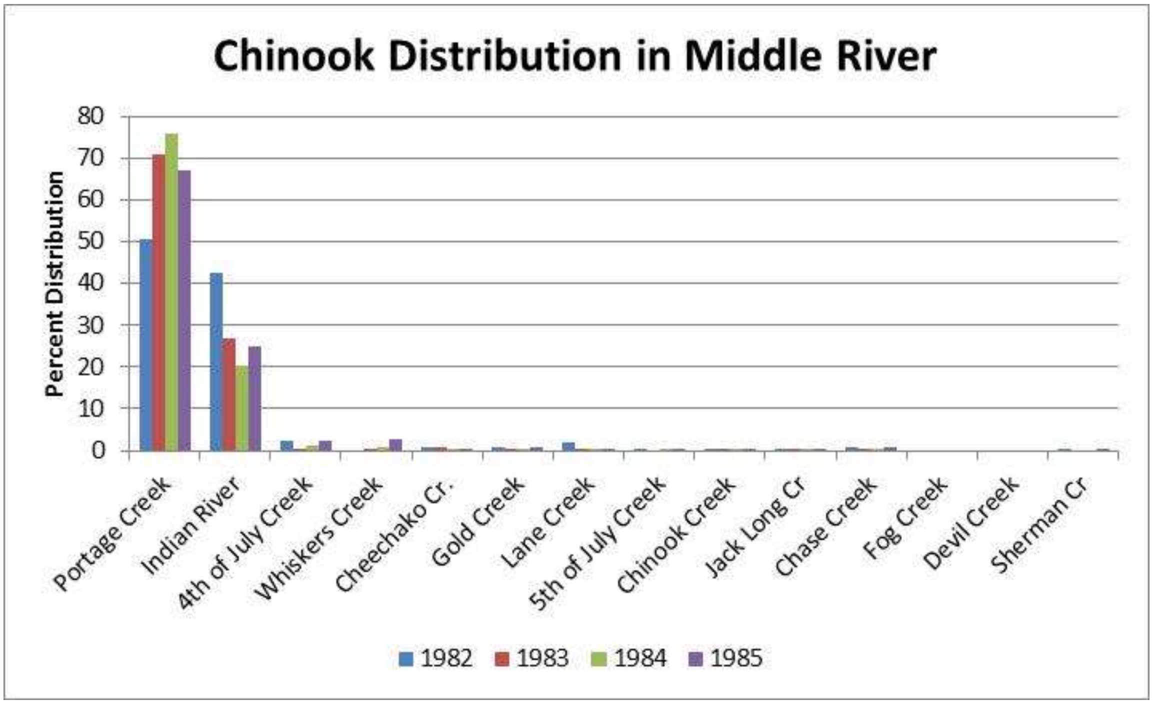


Figure 4.3-5. Distribution of Chinook salmon spawning in the Middle River 1982 to 1985. Sources: Thompson et al. (1986); Barrett et al. (1985, 1984, 1983). Age of Return.

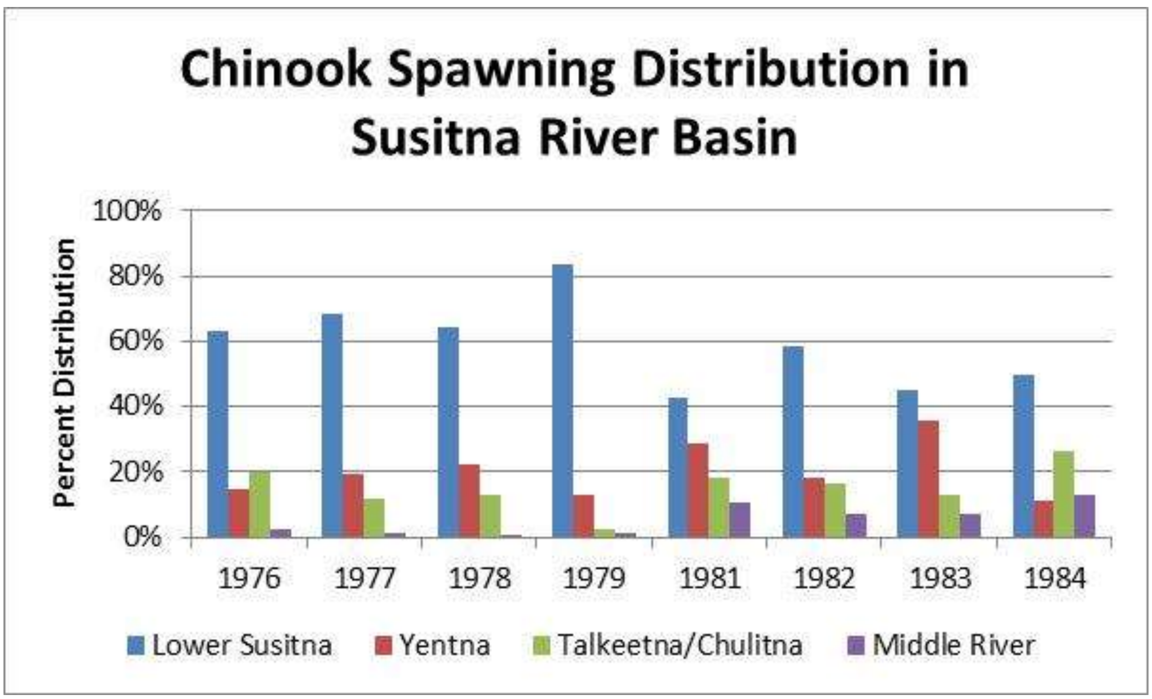


Figure 4.3-6. Distribution of Chinook Salmon spawning in the Susitna River 1976 to 1984. Source: Jennings (1985).

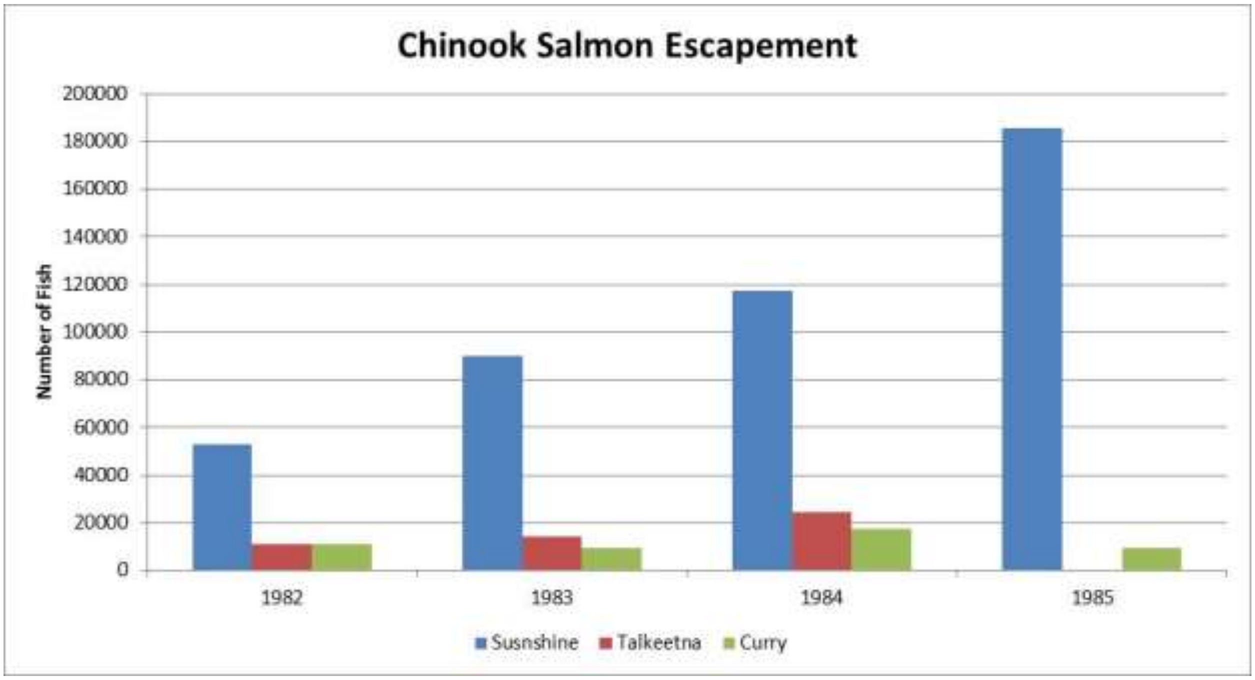


Figure 4.3-7. Escapement to Sunshine, Talkeetna, and Curry stations based upon mark-recapture techniques. No escapement estimates were made for Talkeetna Station during 1985. Source: ADF&G (1983a), Barrett et al. (1984), Barrett et al. (1985), Thompson et al. (1986).

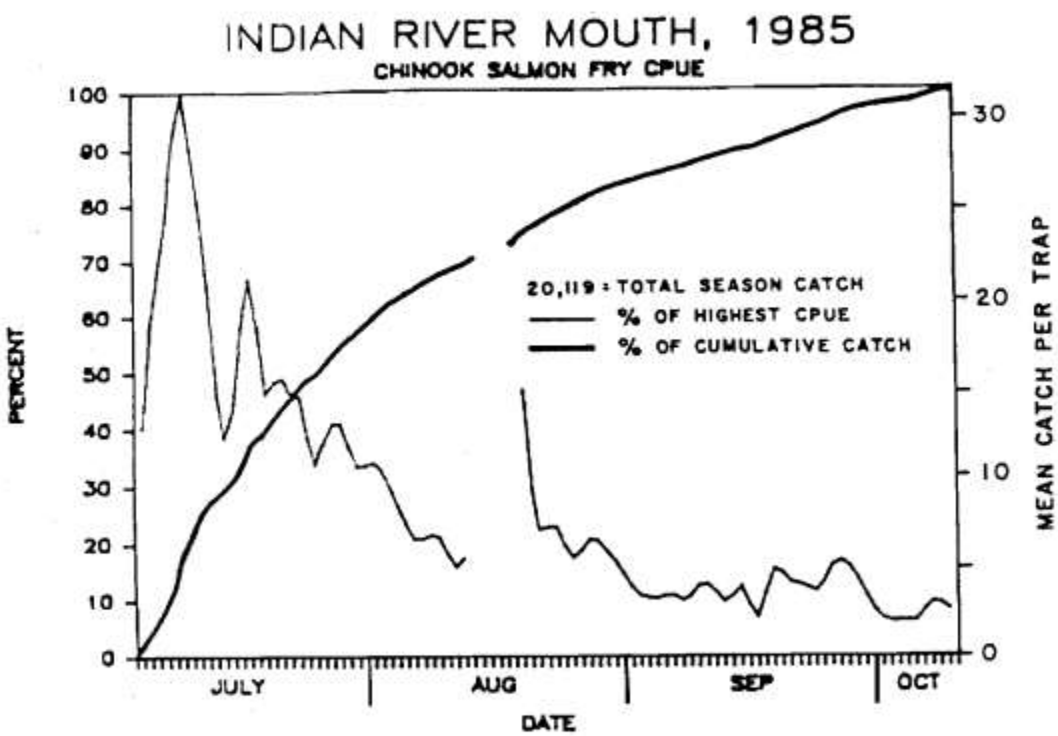


Figure 4.3-8. Chinook salmon (age 0+) daily catch per unit effort and cumulative catch recorded at the mouth of Indian River. Source: Roth et al. (1986).

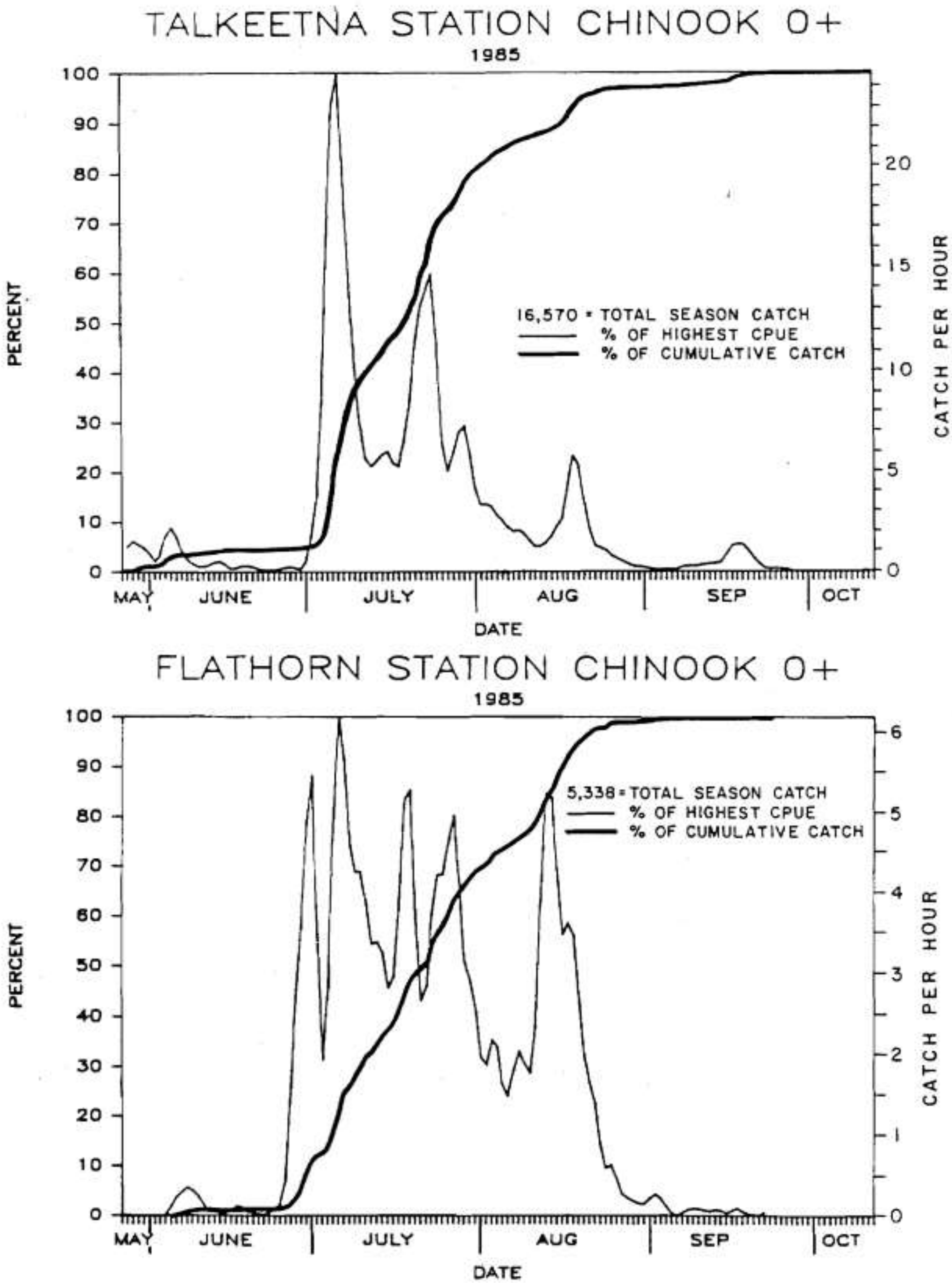
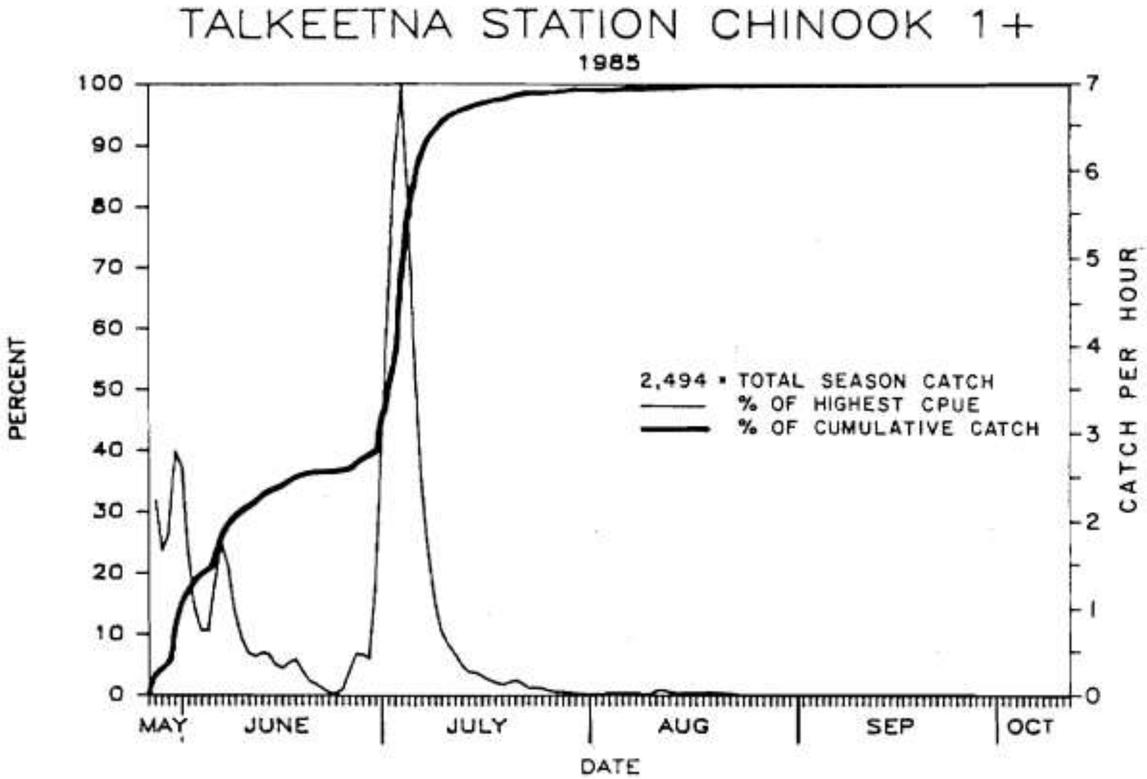


Figure 4.3-9. Chinook salmon (age 0+) daily catch per unit effort and cumulative catch recorded at the Talkeetna (upper figure) and Flathorn (lower figure) stationary outmigrant traps, 1985. Source: Roth et al. (1986).



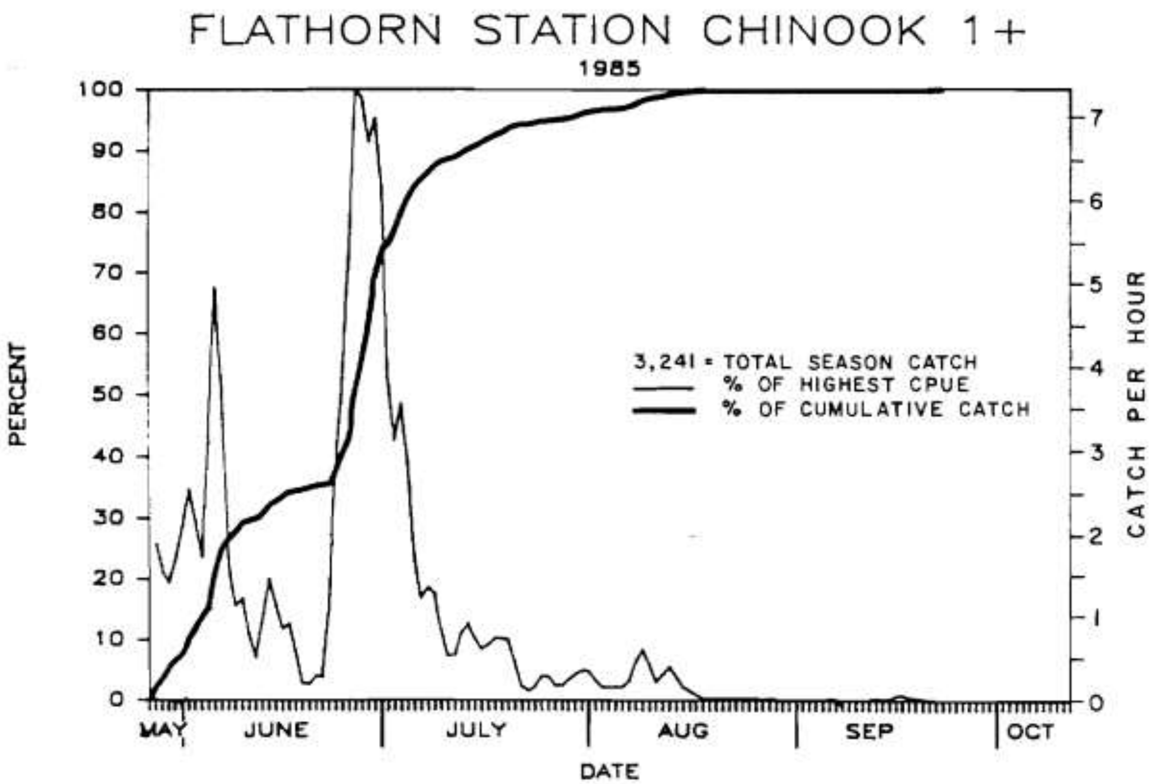


Figure 4.3-10. Chinook salmon (age 1+) daily catch per unit effort and cumulative catch recorded at the Talkeetna (upper figure) and Flathorn (lower figure) stationary outmigrant traps, 1985. Source: Roth et al. (1986).

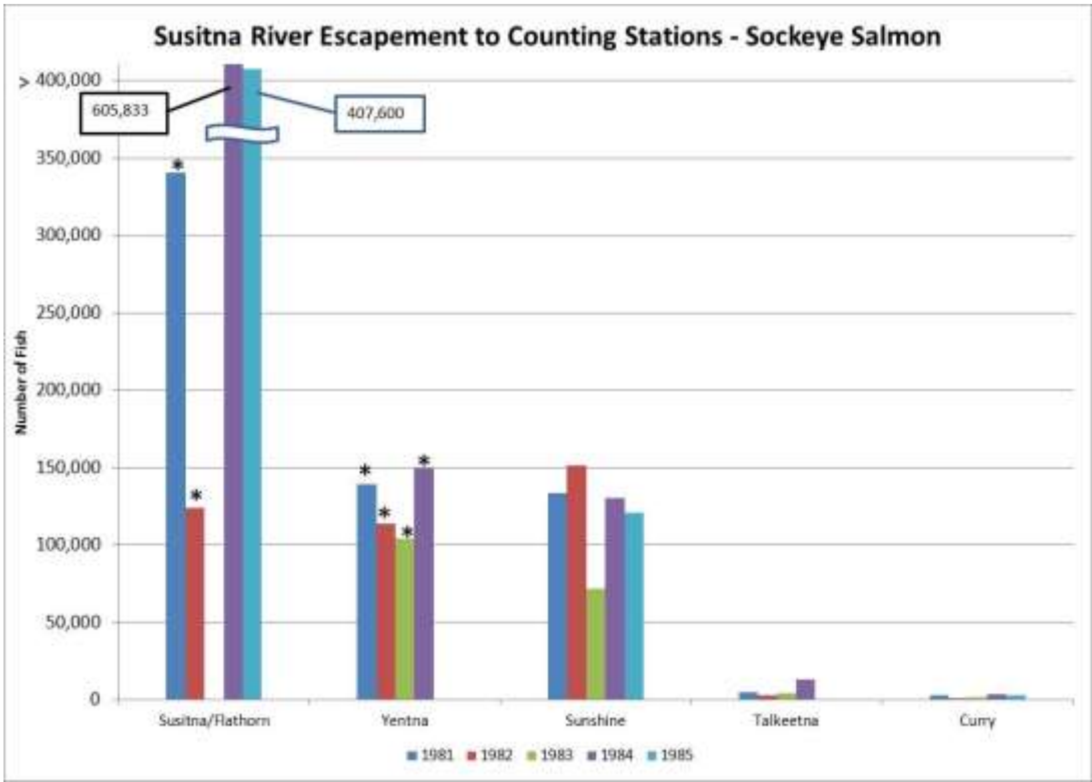


Figure 4.3-11. Second run sockeye salmon escapement estimates to the Susitna River 1981 to 1985. No estimates for the following stations and years Susitna/Flathorn (1982, 1983), Yentna (1982, 1985), and Talkeetna (1985). *: Estimate based upon apportionment of sonar counts. Source: ADF&G (1981), ADF&G (1983a), Barrett et al. (1984), Barrett et al. (1985), Thompson et al. (1986).

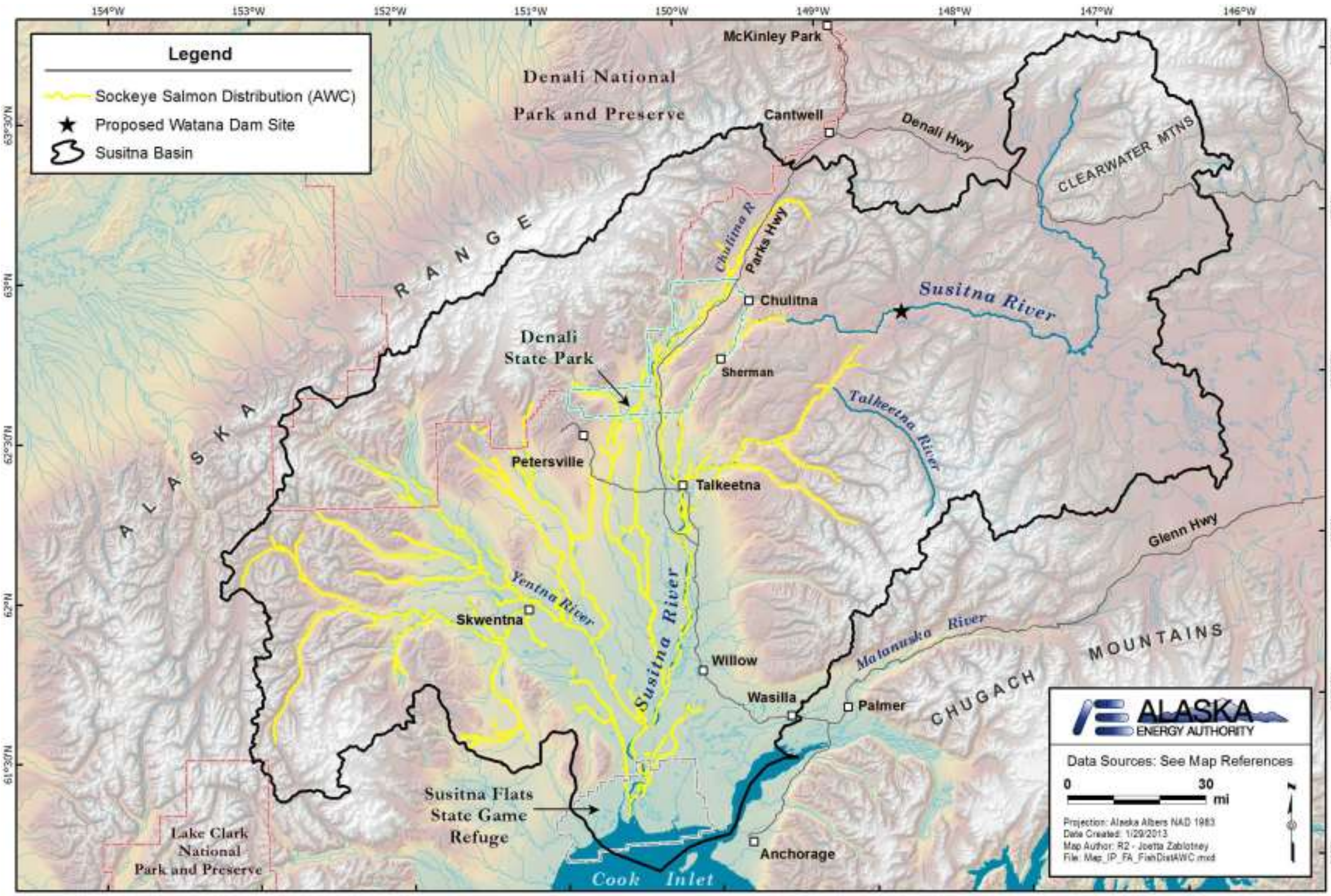


Figure 4.3-12. Distribution of sockeye salmon in the Susitna River Basin from ADF&G's Anadromous Waters Catalog.

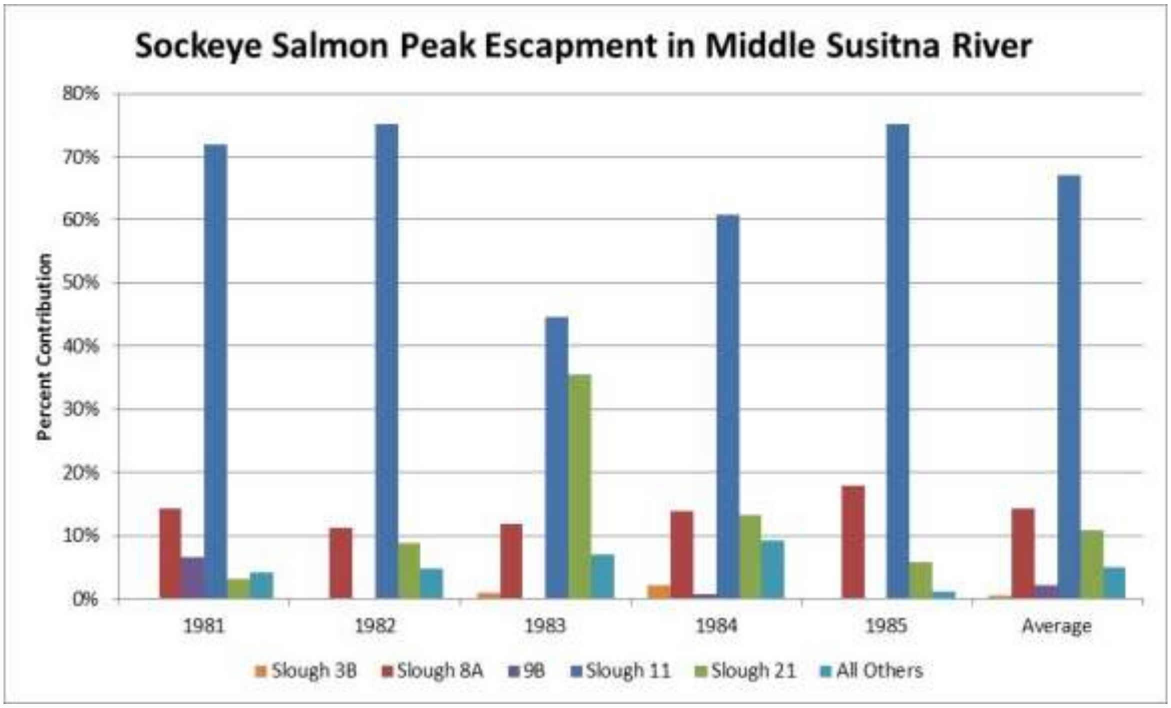


Figure 4.3-13. Distribution of sockeye spawning in Middle Susitna River sloughs. Source: Jennings (1985), Thompson et al. (1986).

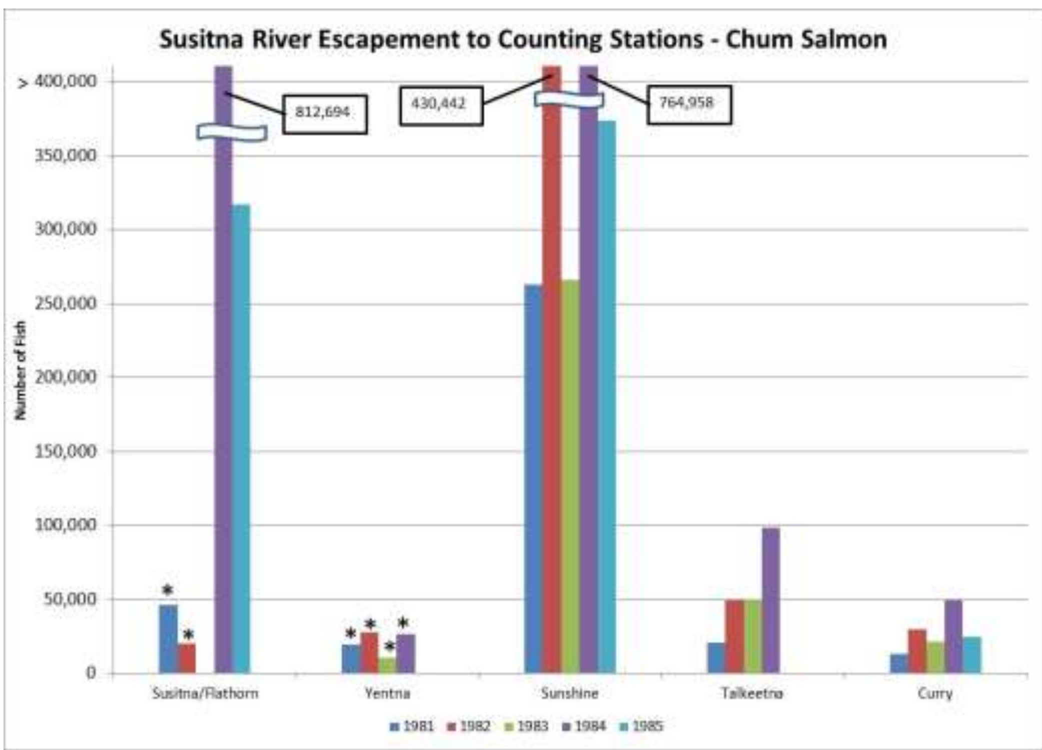


Figure 4.3-14. Chum salmon escapement estimates to the Susitna River 1981 to 1985. No estimates for the following stations and years Susitna/Flathorn (1982, 1983), Yentna (1982, 1985), and Talkeetna (1985). *: Estimate based upon apportionment of sonar counts. Source: ADF&G (1981), ADF&G (1983a), Barrett et al. (1984), Barrett et al. (1985), Thompson et al. (1986).

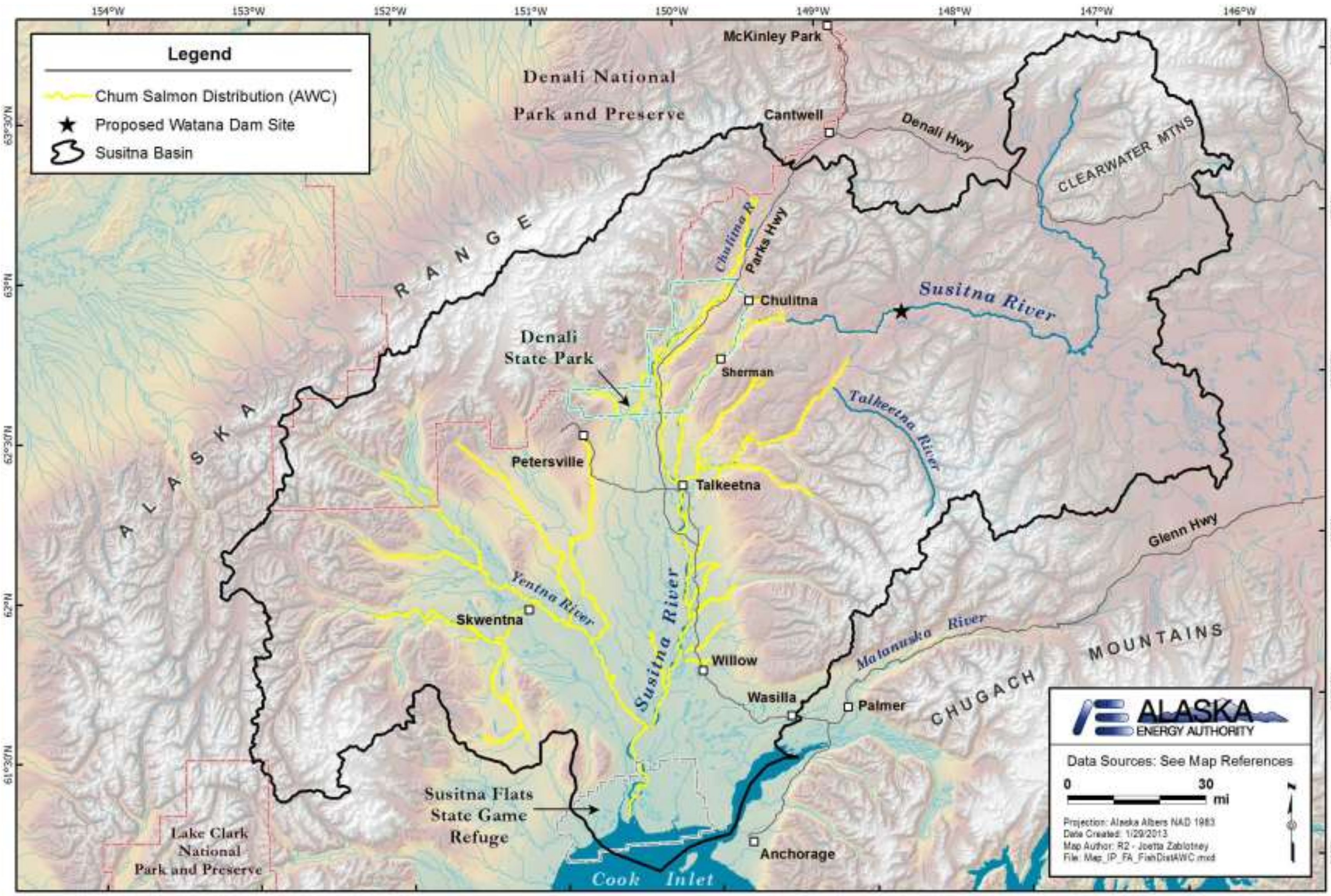


Figure 4.3-15. Distribution of chum salmon in the Susitna River Basin from ADF&G's Anadromous Waters Catalog.

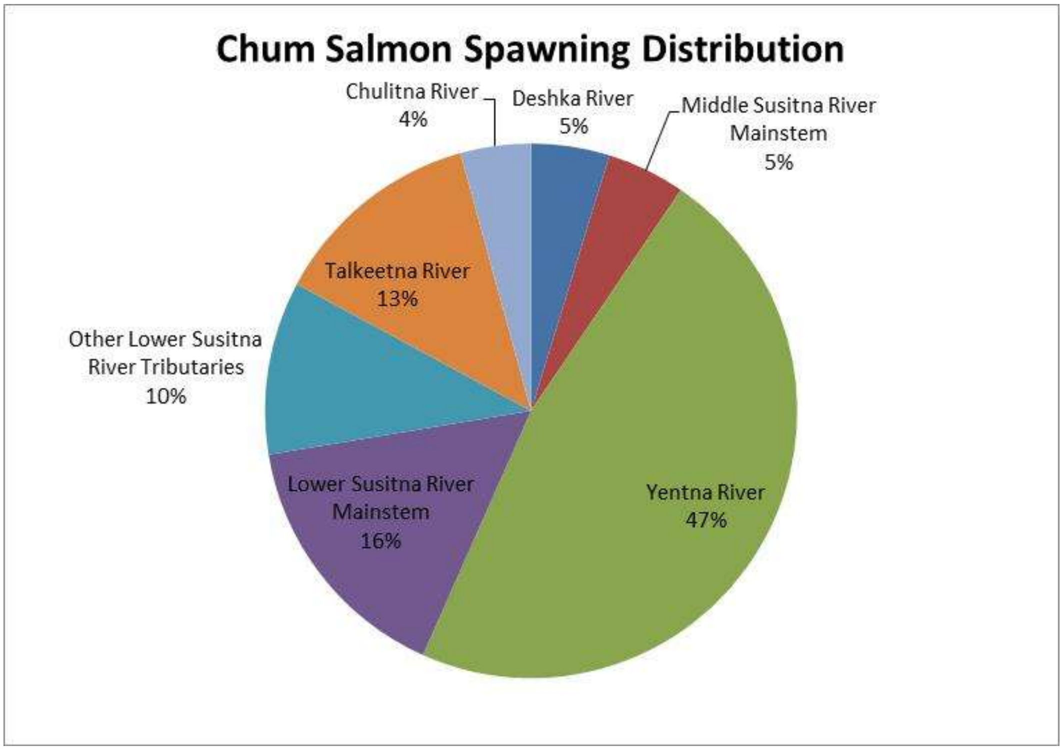


Figure 4.3-16. Spawning distribution of 210 chum salmon radio-tagged at Flathorn during 2009. Data Source: Merizon et al. (2010).

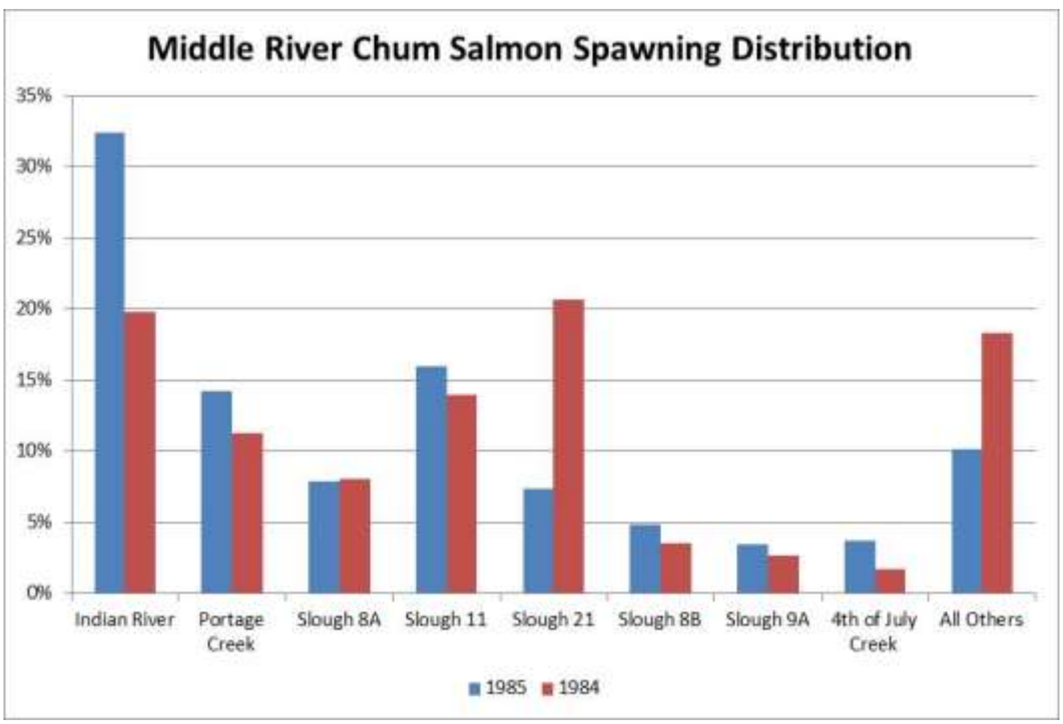


Figure 4.3-17. Chum salmon spawning distribution among tributaries and sloughs in the Middle Susitna River based upon peak counts. Data Source: Barrett et al. (1985), Thompson et al. (1986).

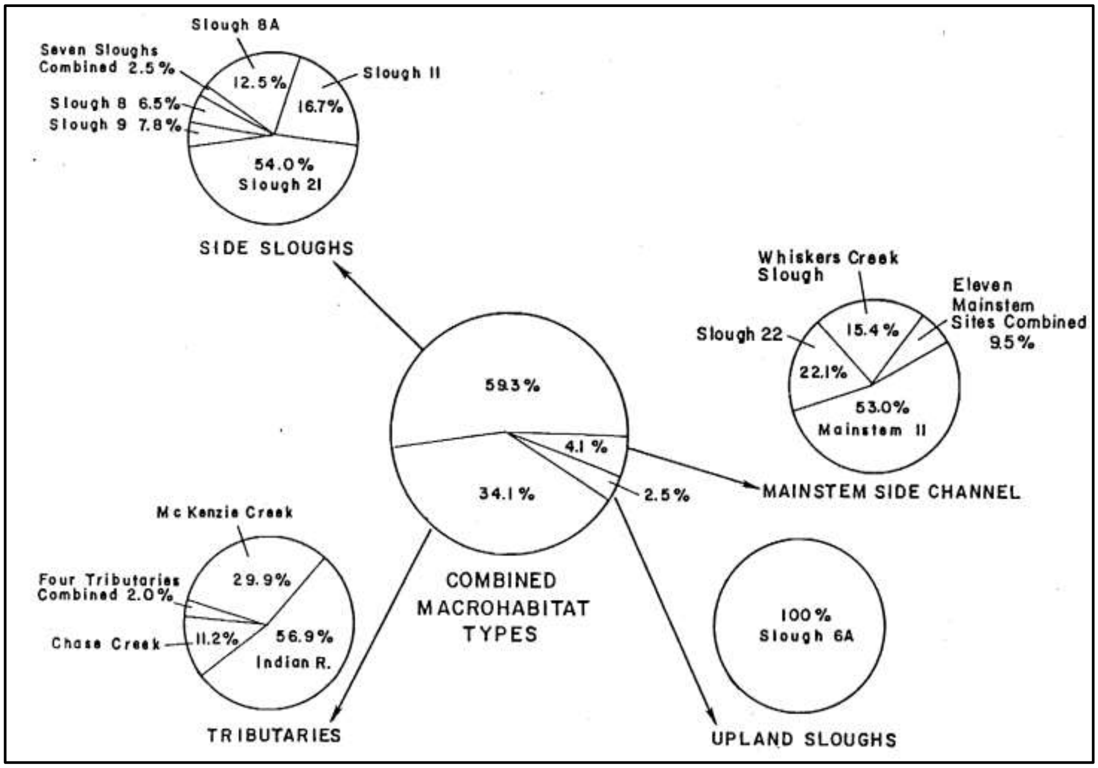


Figure 4.3-18. Density distribution and juvenile chum salmon by macrohabitat type on the Susitna River between the Chulitna River confluence and Devils Canyon, May through November 1983. Percentages are based on mean catch per cell. Source: Dugan et al. (1984).

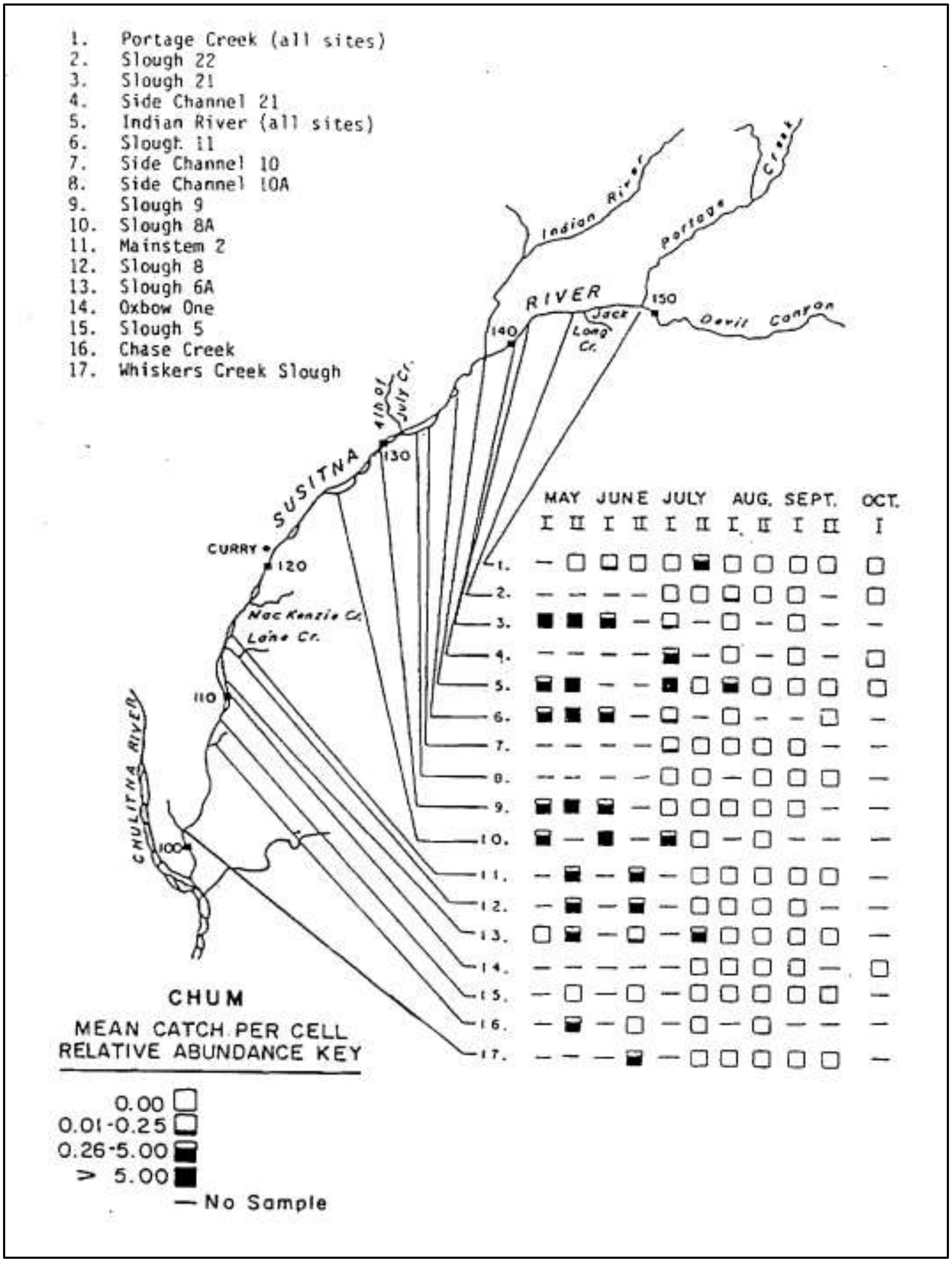


Figure 4.3-19. Seasonal distribution and relative abundance of juvenile chum salmon on the Susitna River between the Chulitna River confluence and Devils Canyon, May through November 1983. Source: Dugan et al. (1984).

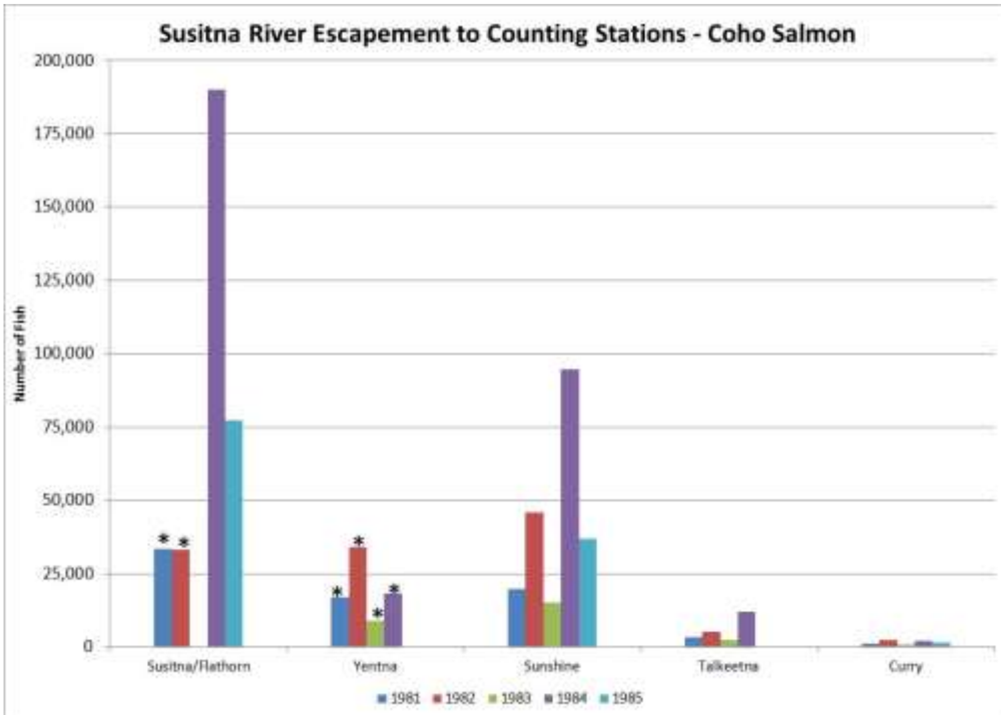


Figure 4.3-20. Coho salmon escapement estimates to the Susitna River 1981 to 1985. No estimates for the following stations and years Susitna/Flathorn (1982, 1983), Yentna (1982, 1985), and Talkeetna (1985). *: Estimate based upon apportionment of sonar counts. Source: ADF&G (1981), ADF&G (1983a), Barrett et al. (1984), Barrett et al. (1985), Thompson et al. (1986).

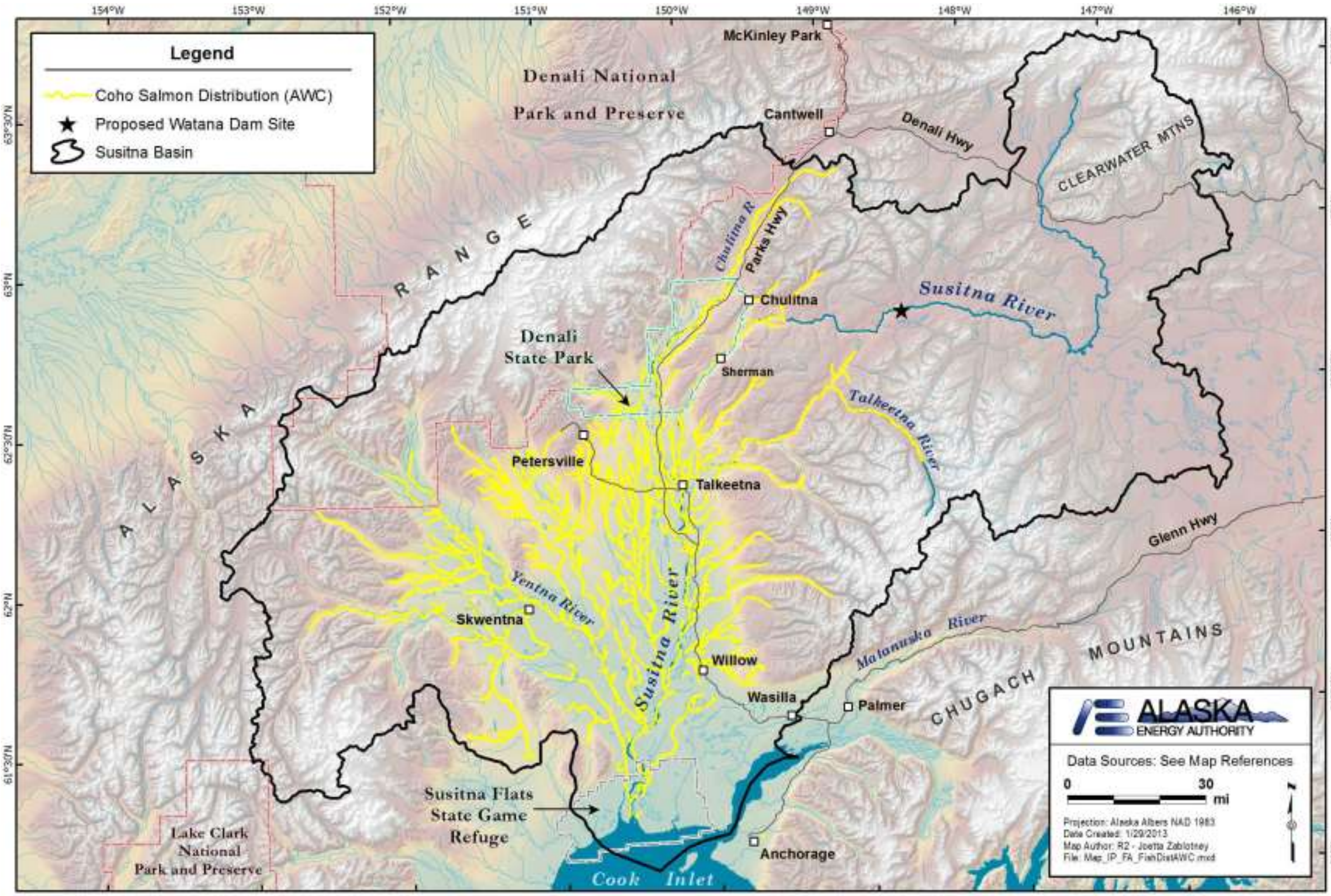


Figure 4.3-21. Distribution of coho salmon in the Susitna River Basin from ADF&G's Anadromous Waters Catalog.

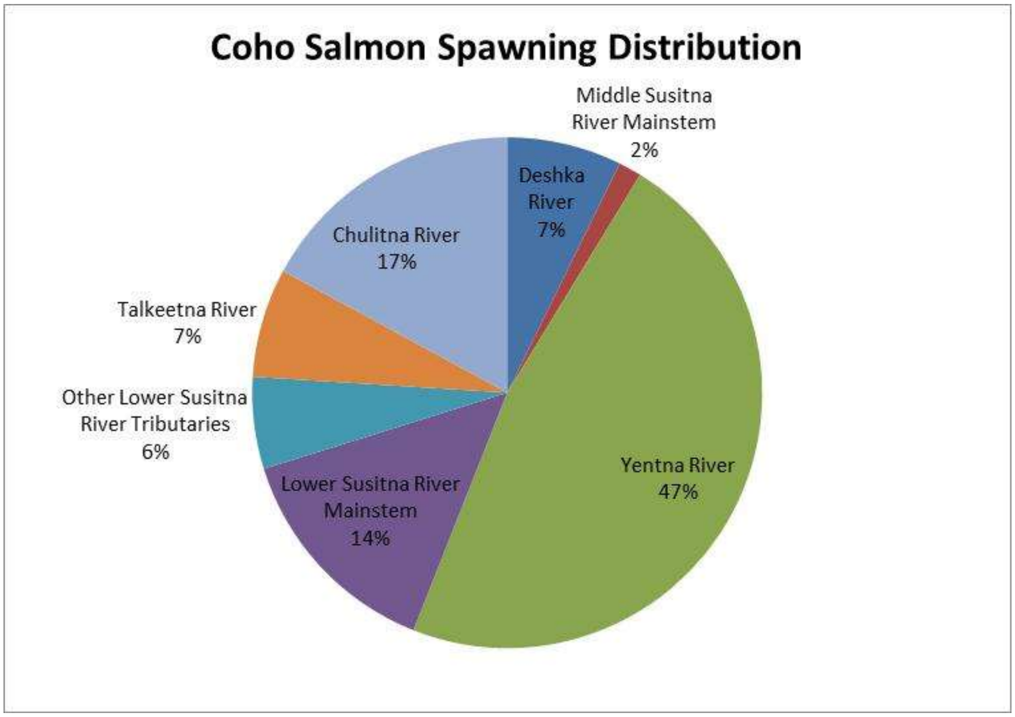


Figure 4.3-22. Spawning distribution of 275 coho salmon radio-tagged at Flathorn during 2009. Source: Merizon et al. (2010).

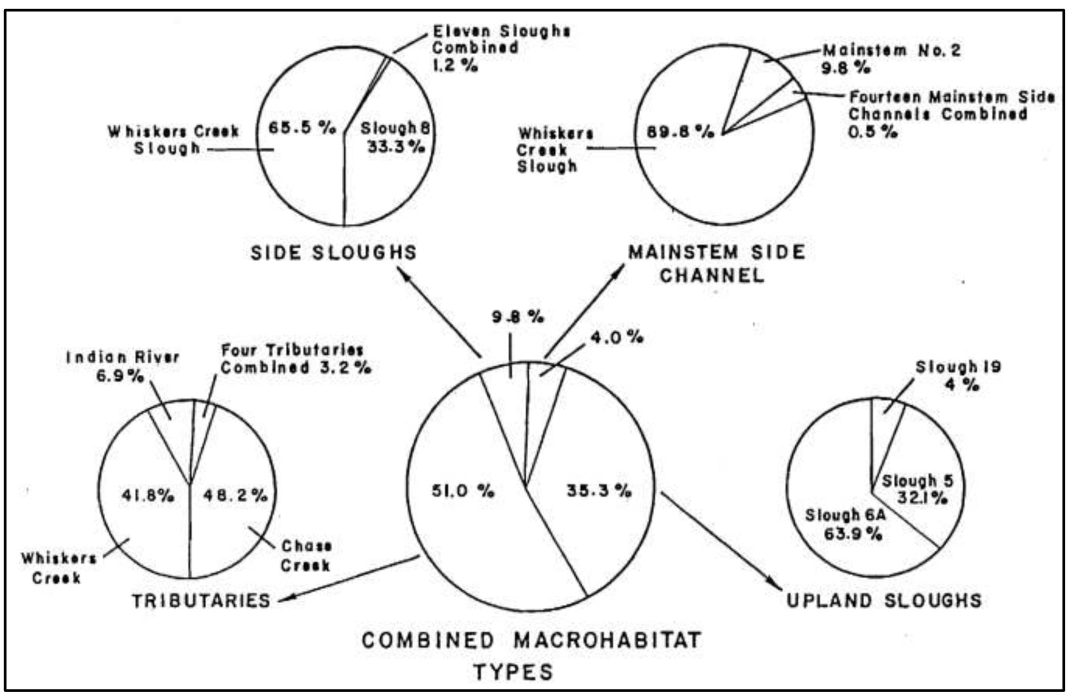


Figure 4.3-23. Density distribution and juvenile coho salmon by macrohabitat type on the Susitna River between the Chulitna River confluence and Devils Canyon, May through November 1983. Percentages are based on mean catch per cell. Source: Dugan et al. (1984).

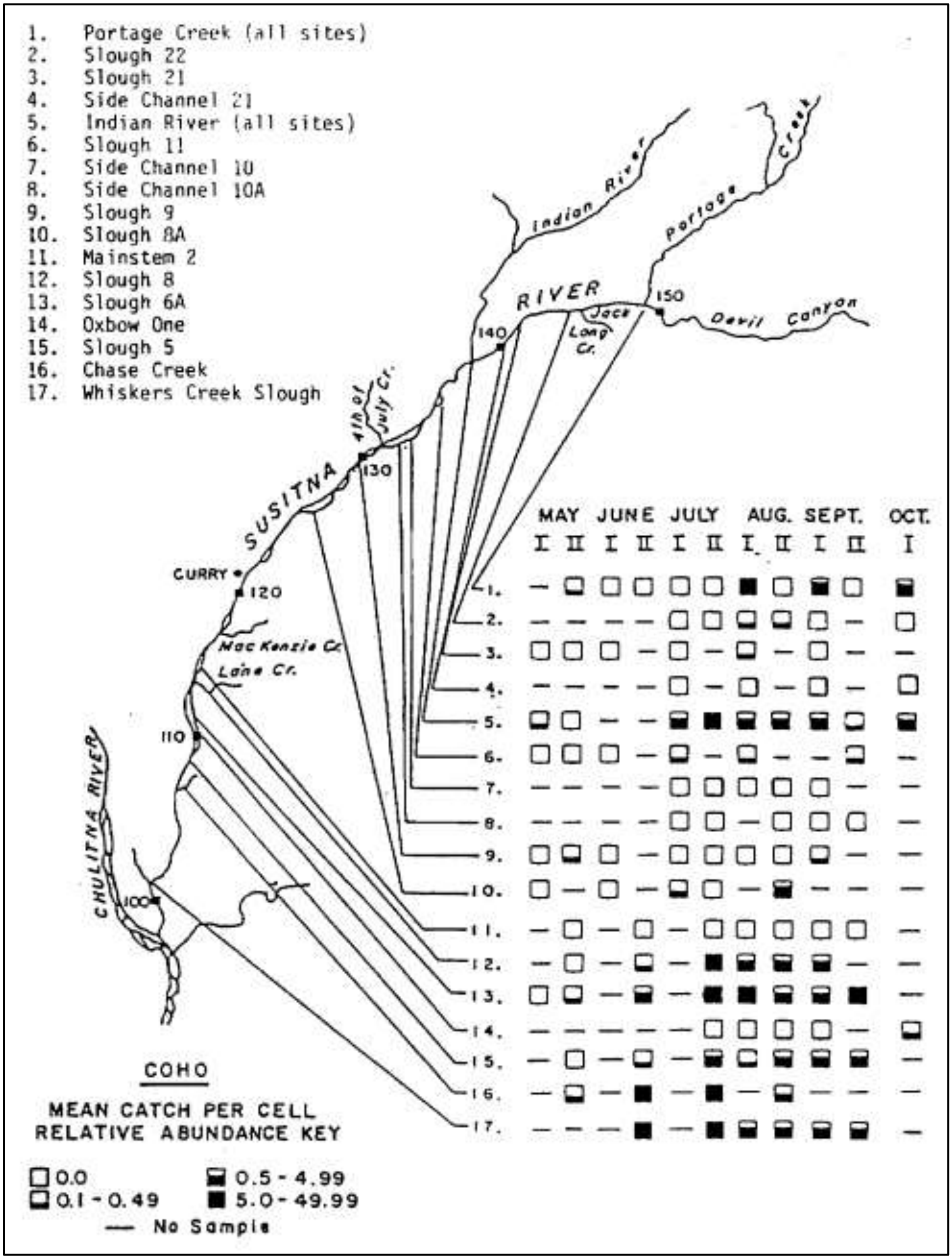


Figure 4.3-24. Seasonal distribution and relative abundance of juvenile coho salmon on the Susitna River between the Chulitna River confluence and Devils Canyon, May through November 1983. Source: Dugan et al. (1984).

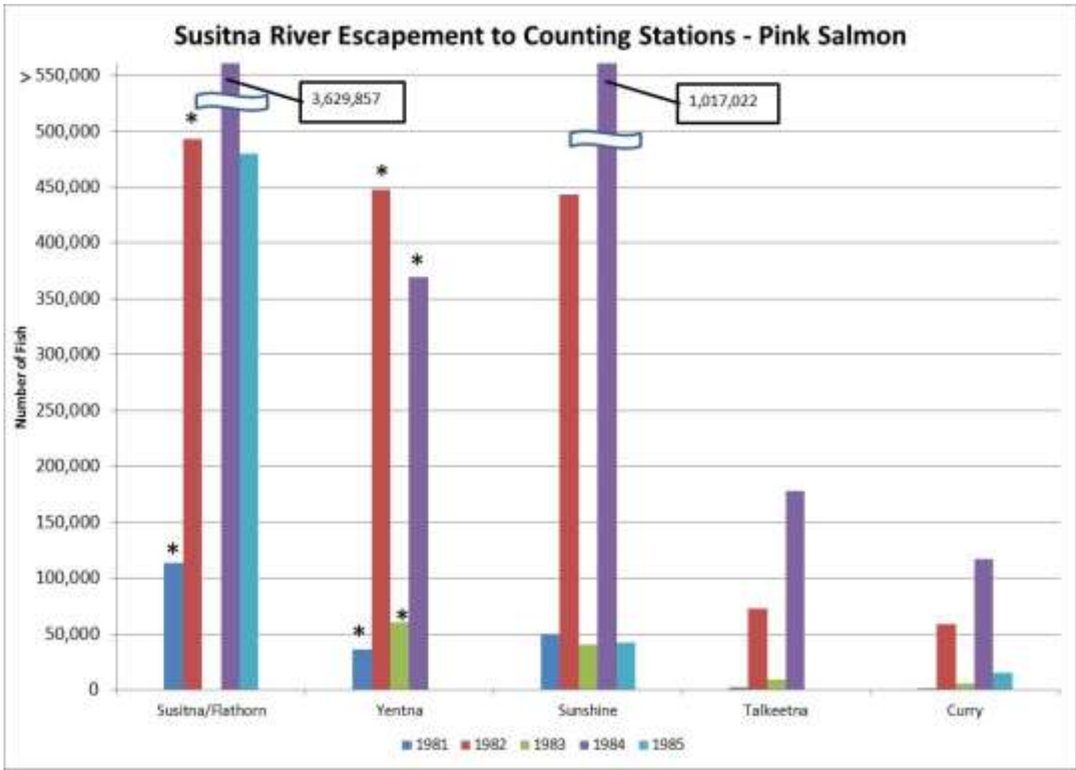


Figure 4.3-25. Pink salmon escapement estimates to the Susitna River 1981 to 1985. No estimates for the following stations and years Susitna/Flathorn (1982, 1983), Yentna (1982, 1985), and Talkeetna (1985). *: Estimate based upon apportionment of sonar counts. Source: ADF&G (1981), ADF&G (1983a), Barrett et al. (1984), Barrett et al. (1985), Thompson et al. (1986).

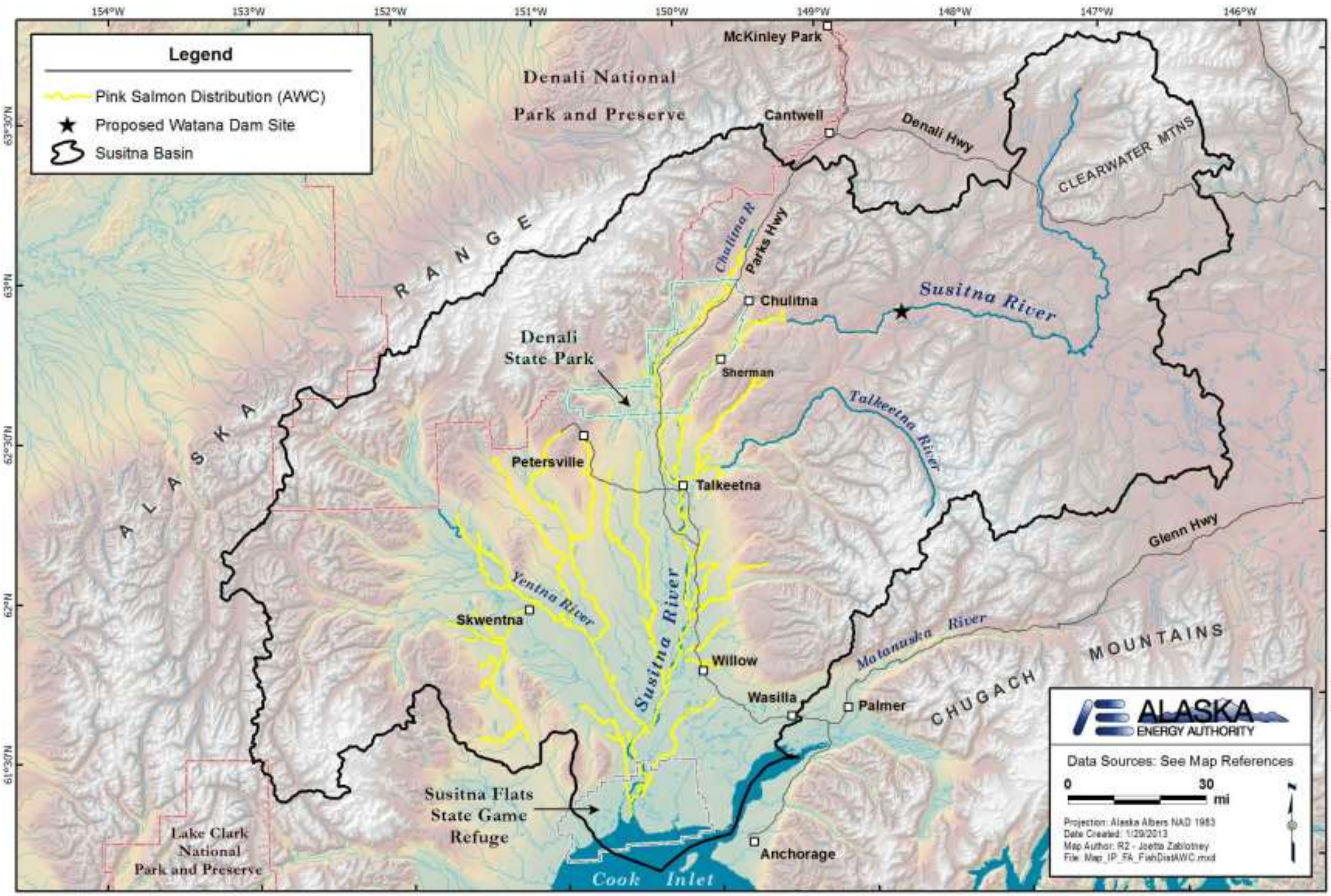


Figure 4.3-26. Distribution of pink salmon in the Susitna River Basin from ADF&G's Anadromous Waters Catalog.

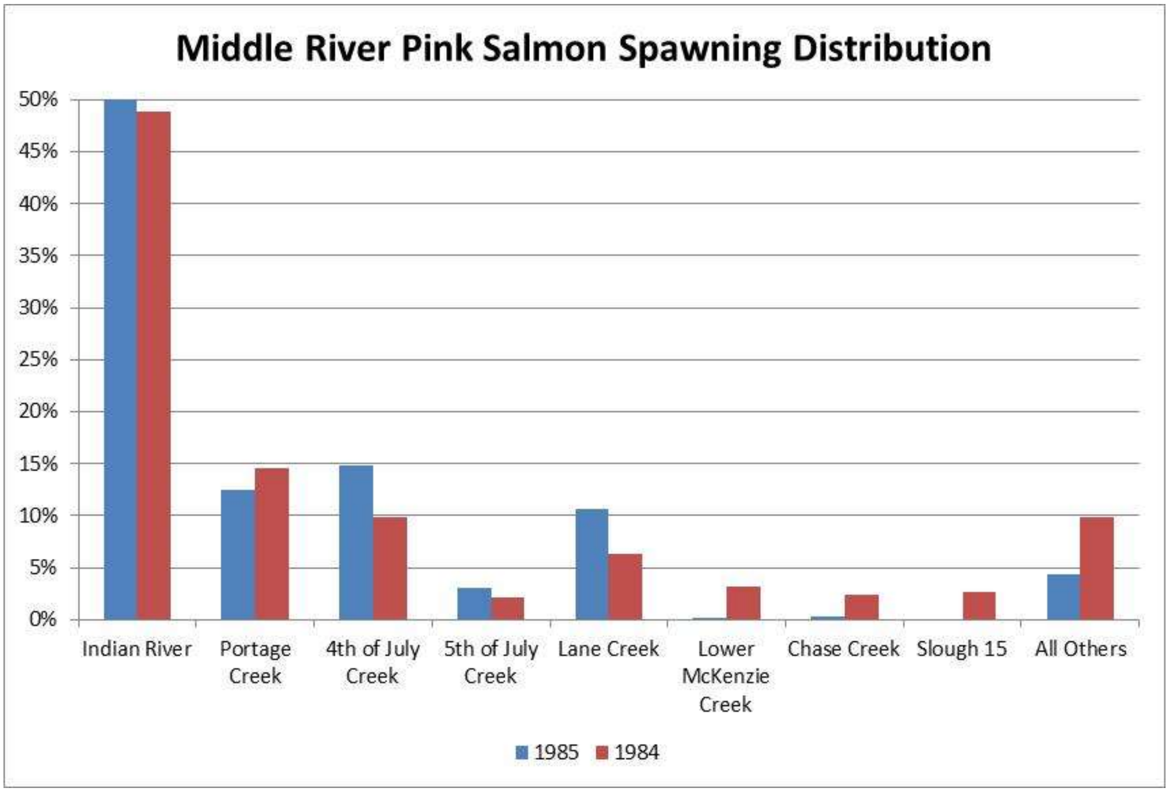


Figure 4.3-27. Pink salmon spawning distribution among tributaries in the Middle Susitna River based upon peak counts.Source: Barrett et al. (1985), Thompson et al. (1986).

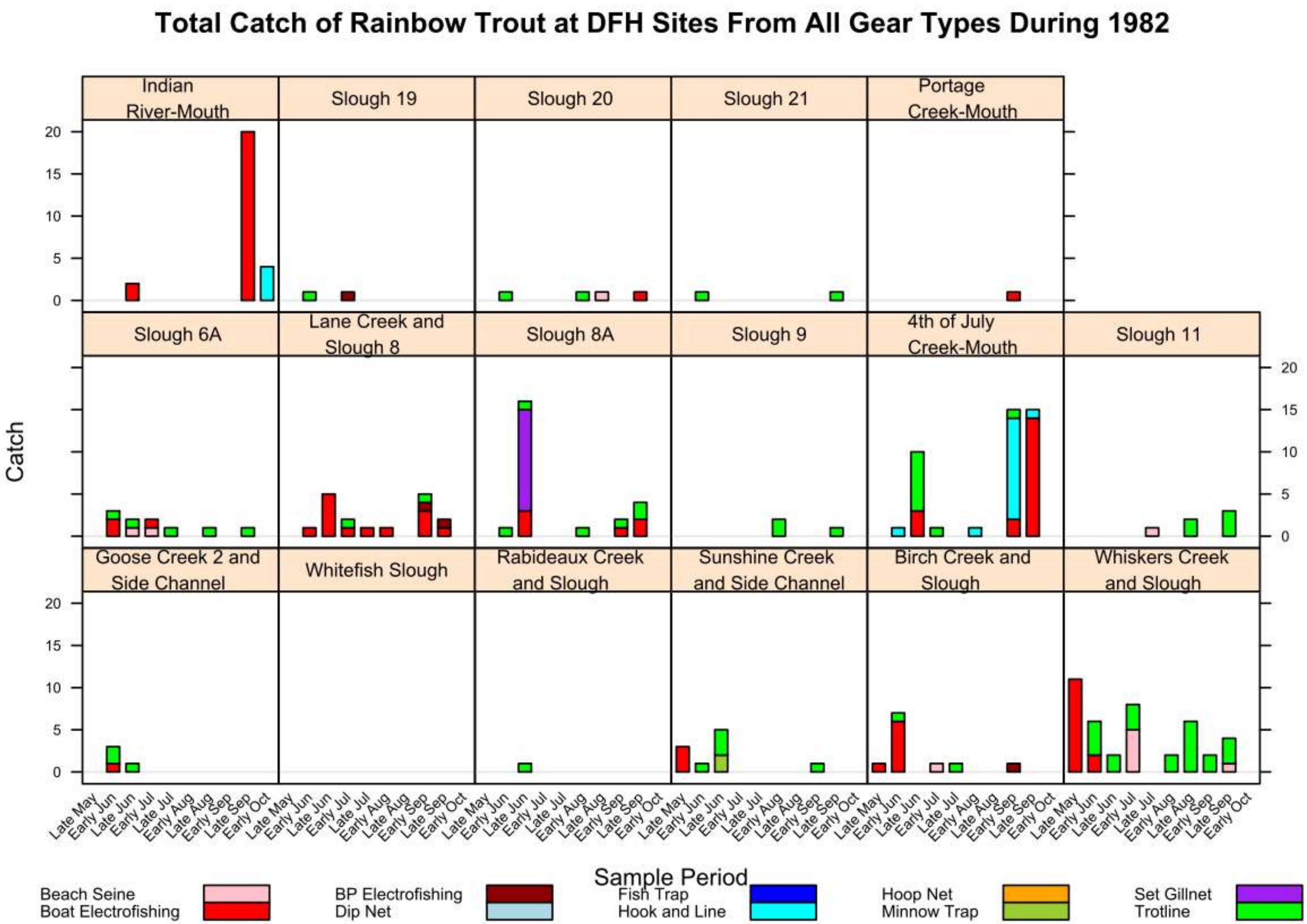


Figure 4.3-28. Total catch of rainbow trout at DFH sites within the middle and lower Susitna River segments during 1982. Data from Schmidt et al. (1983).

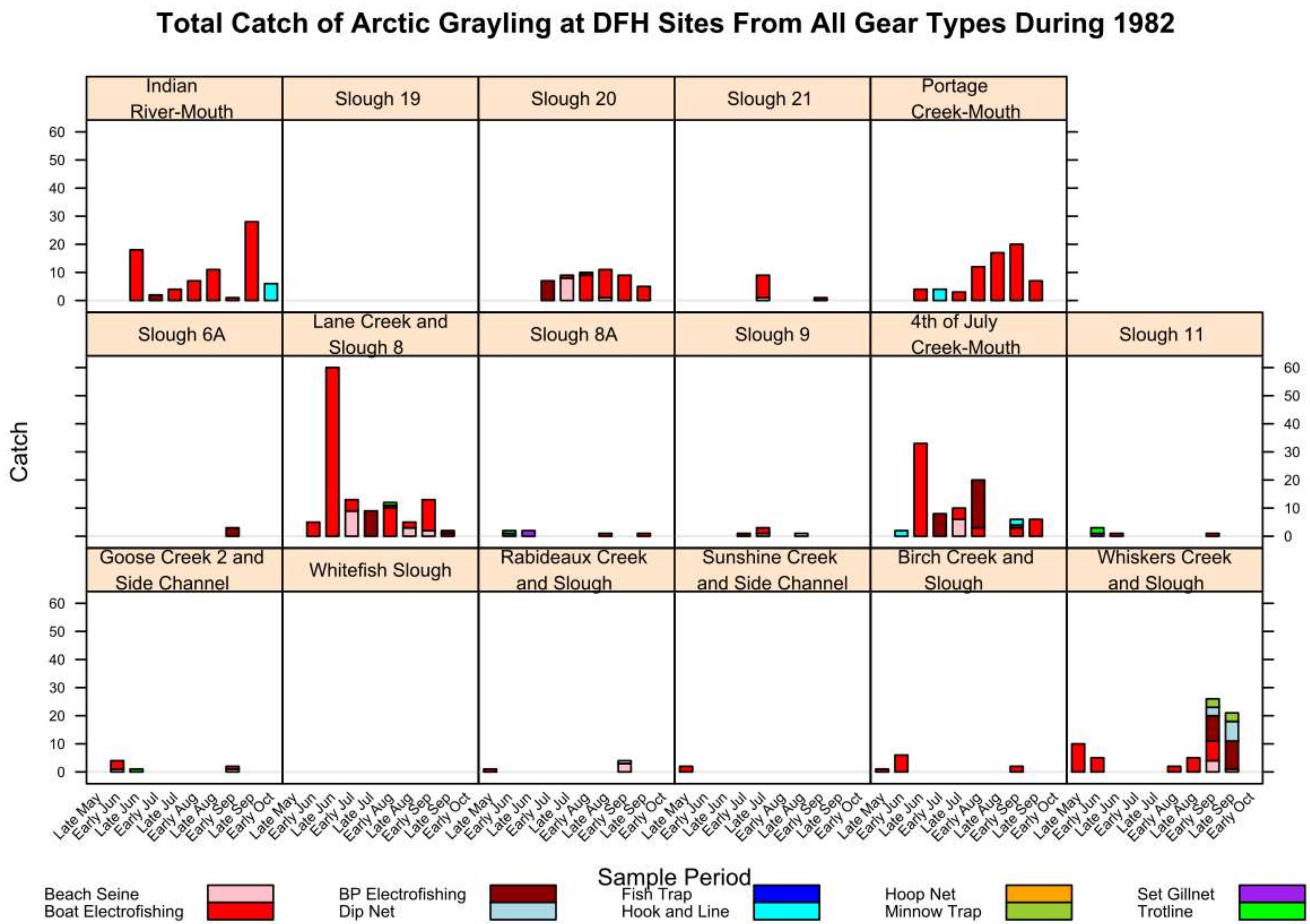


Figure 4.3-29. Total catch of Artic grayling at DFH sites in the Lower and Middle Susitna River during 1982. Data Source: Schmidt et al. (1983).

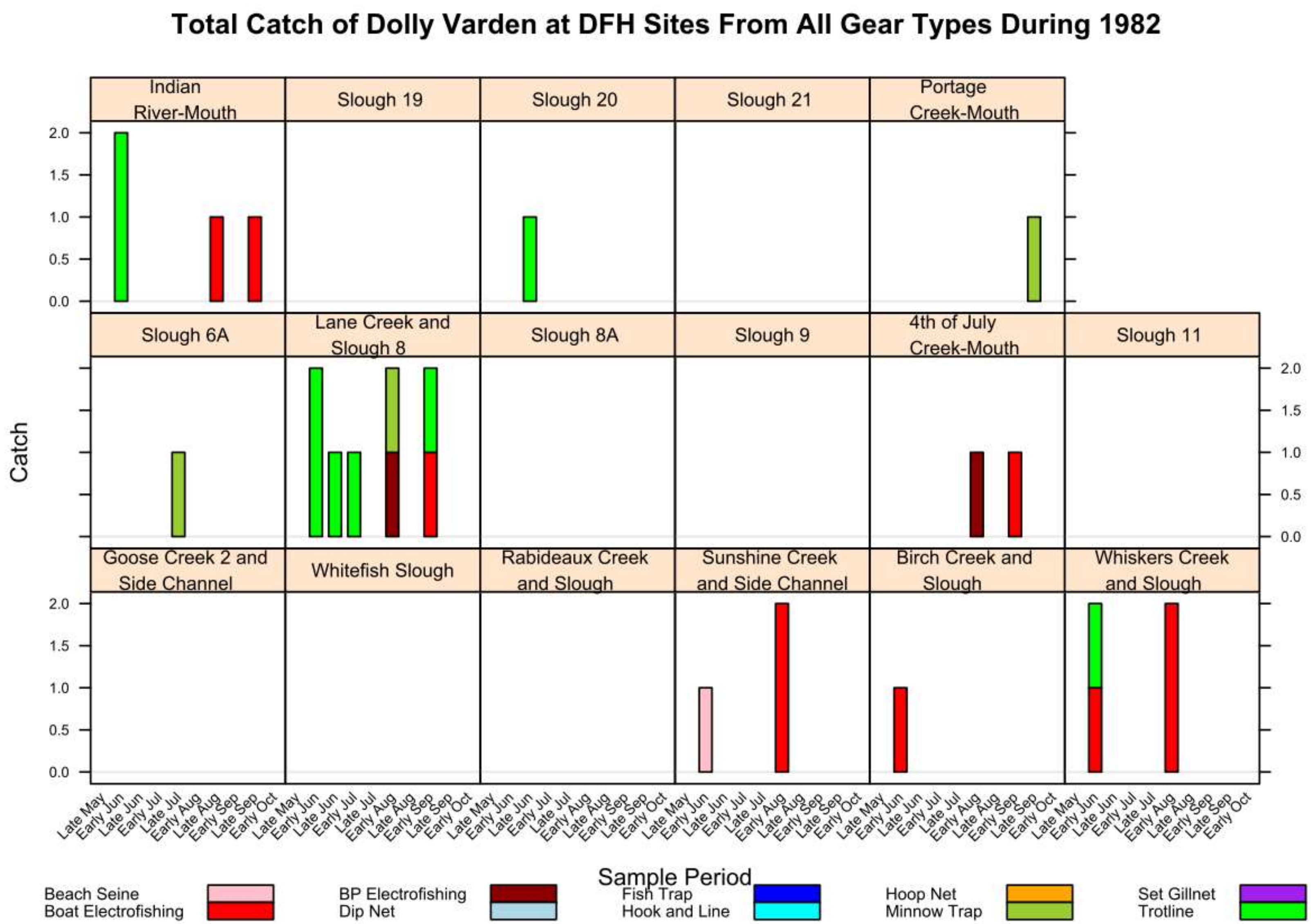


Figure 4.3-30. Total catch of Dolly Varden at DFH sites during 1982 by gear type. Data Source: Schmidt et al. (1983).

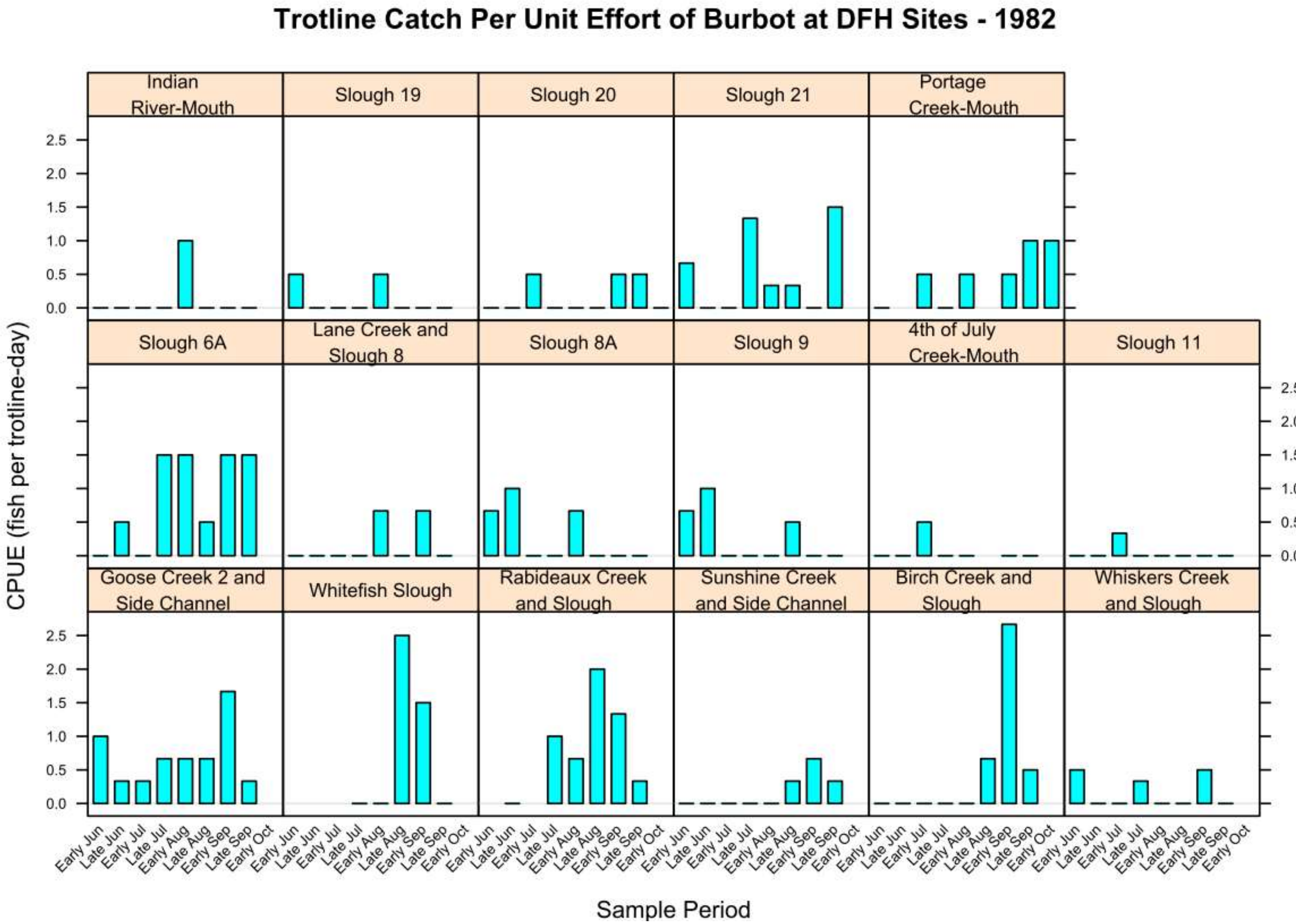


Figure 4.3-31. CPUE of burbot at DFH sites during 1982. Data Source: Schmidt et al. (1983)

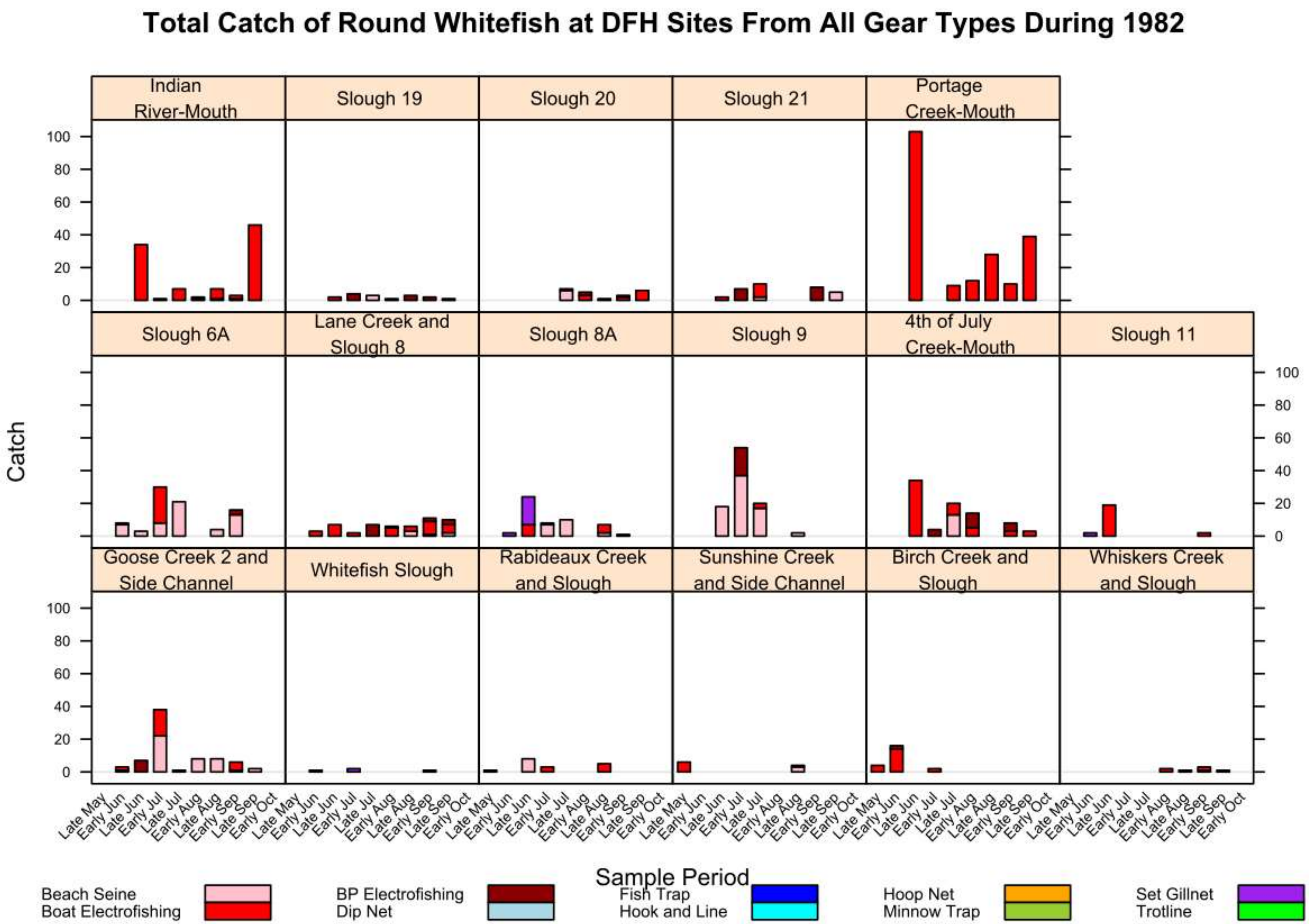


Figure 4.3-32. Total catch of round whitefish at DFH sites during 1982 by gear type. Data Source: Schmidt et al. (1983).

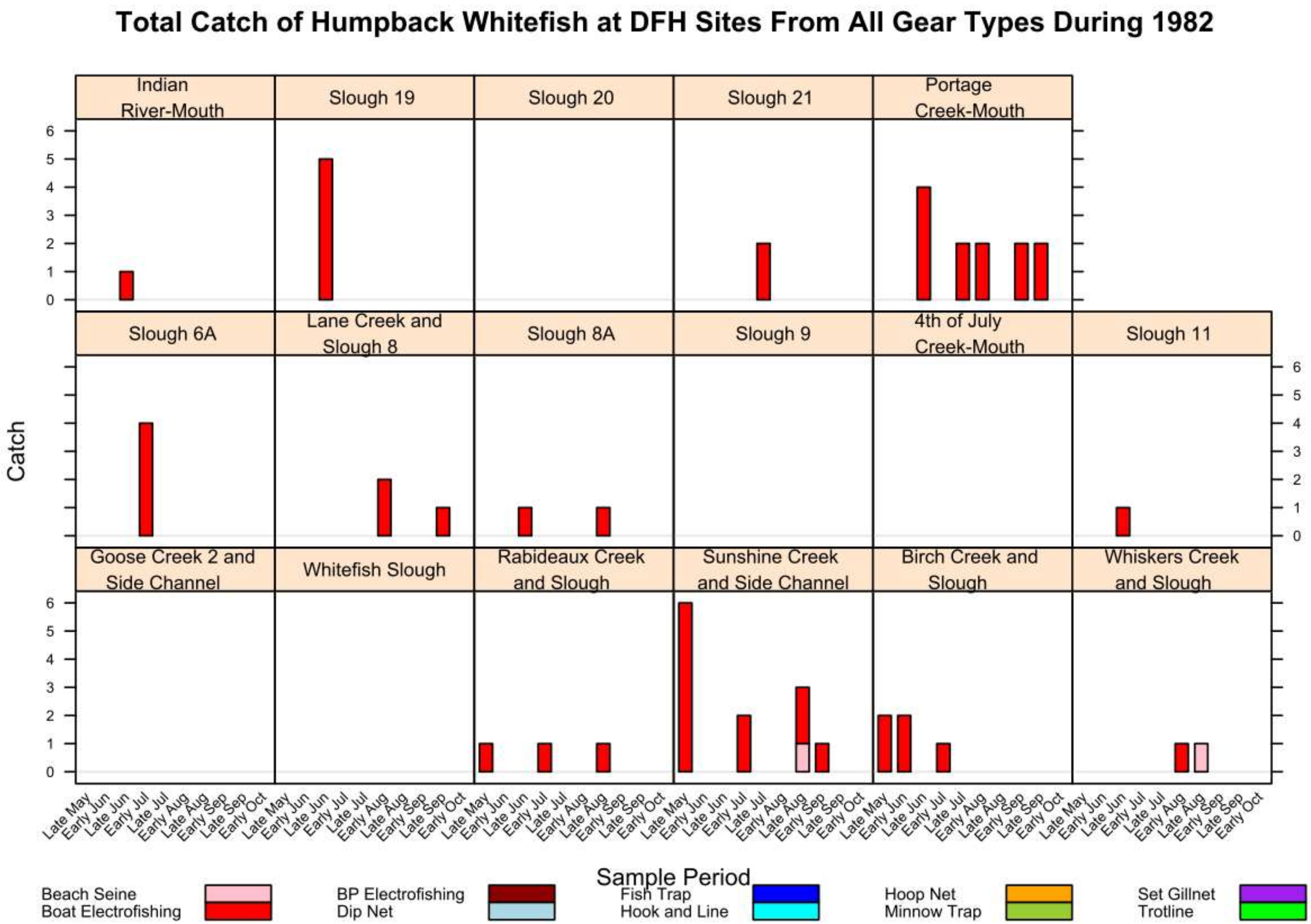


Figure 4.3-33. Total catch of humpback whitefish at DFH sites during 1982 by gear type. Data Source: Schmidt et al. (1983).

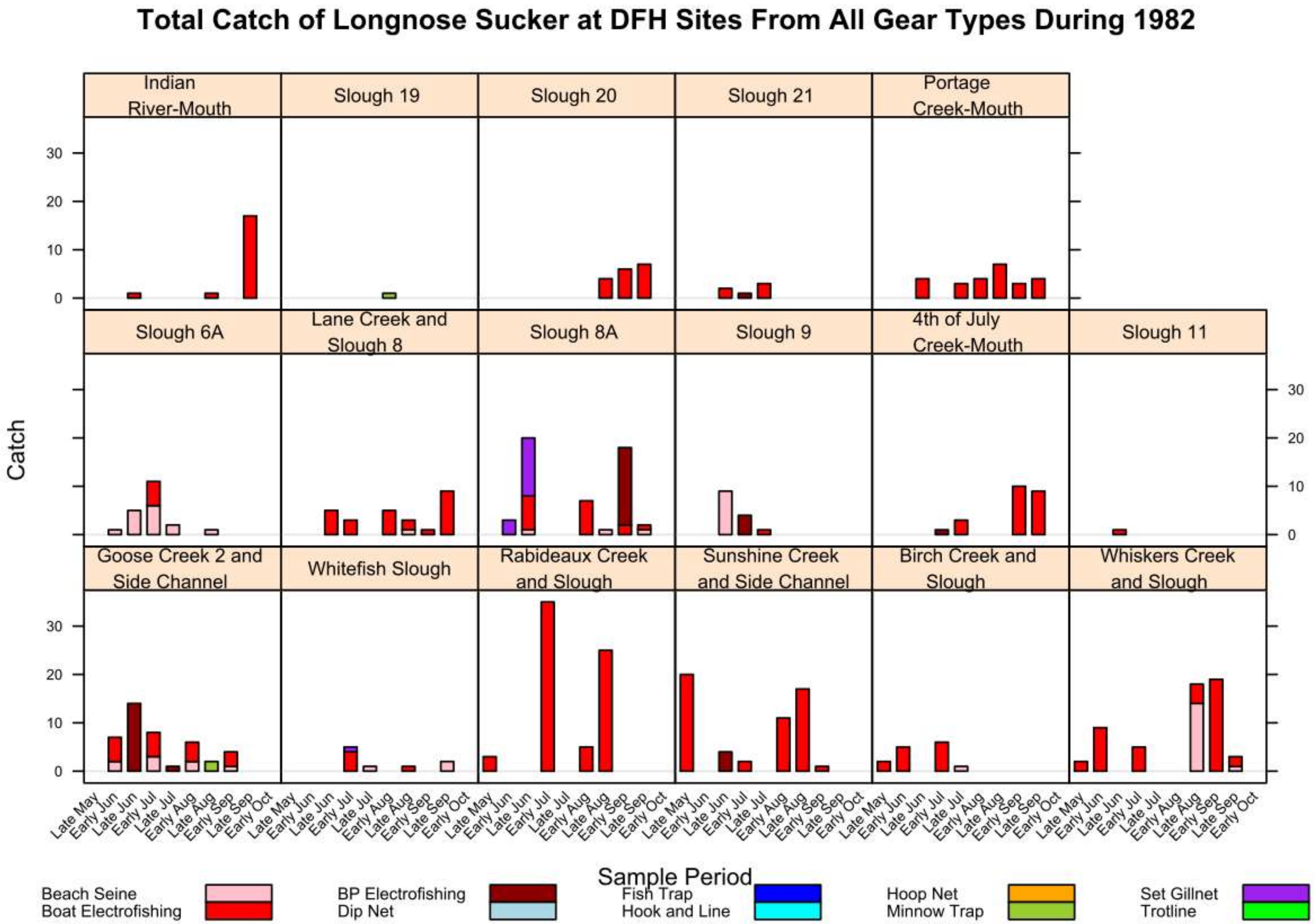


Figure 4.3-34. Total catch of longnose sucker at DFH sites during 1982 by gear type. Data Source: Schmidt et al. (1983).

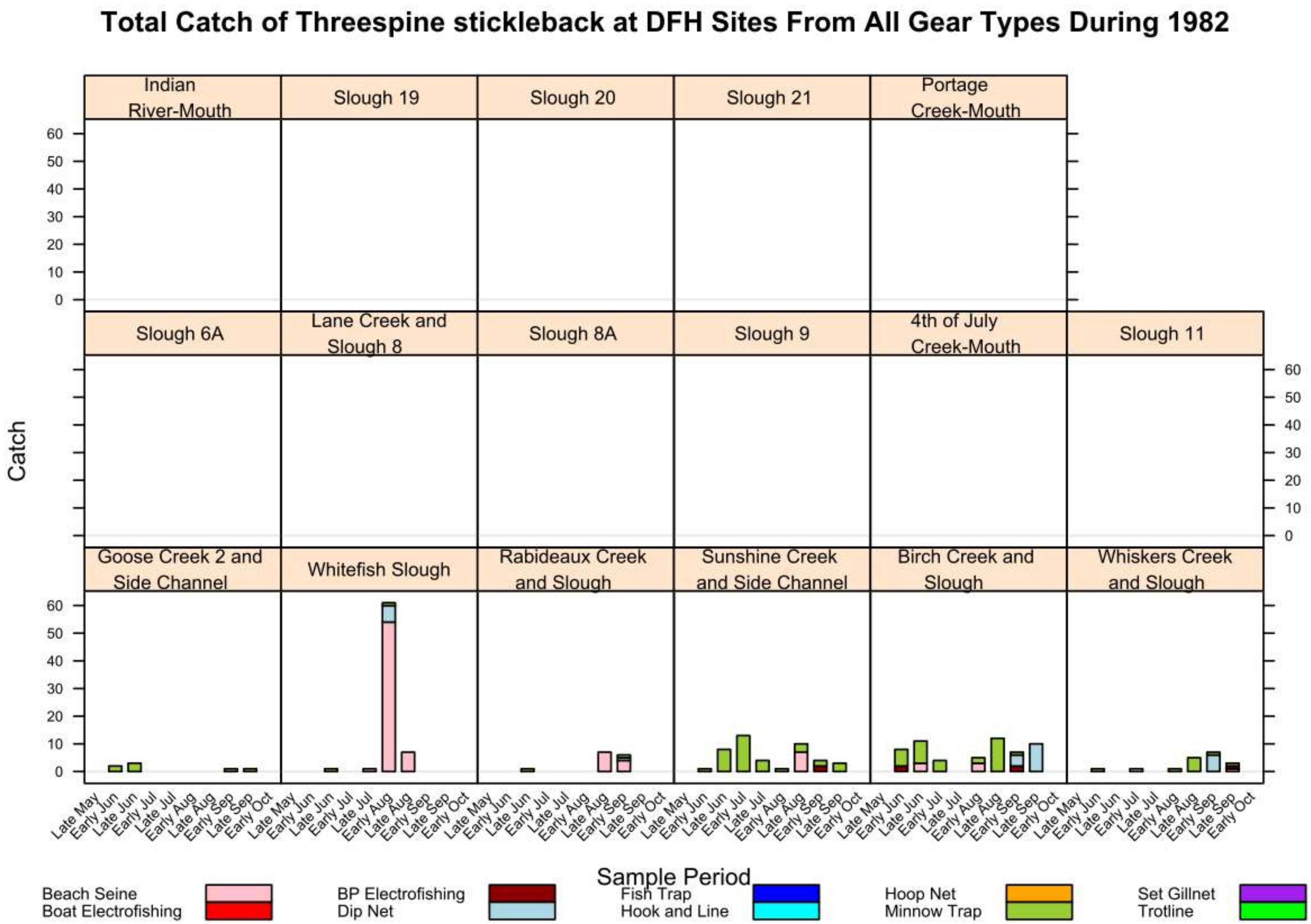


Figure 4.3-35. Total catch of threespine stickleback at DFH sites during 1982 by gear type. Data Source: Schmidt et al. (1983).

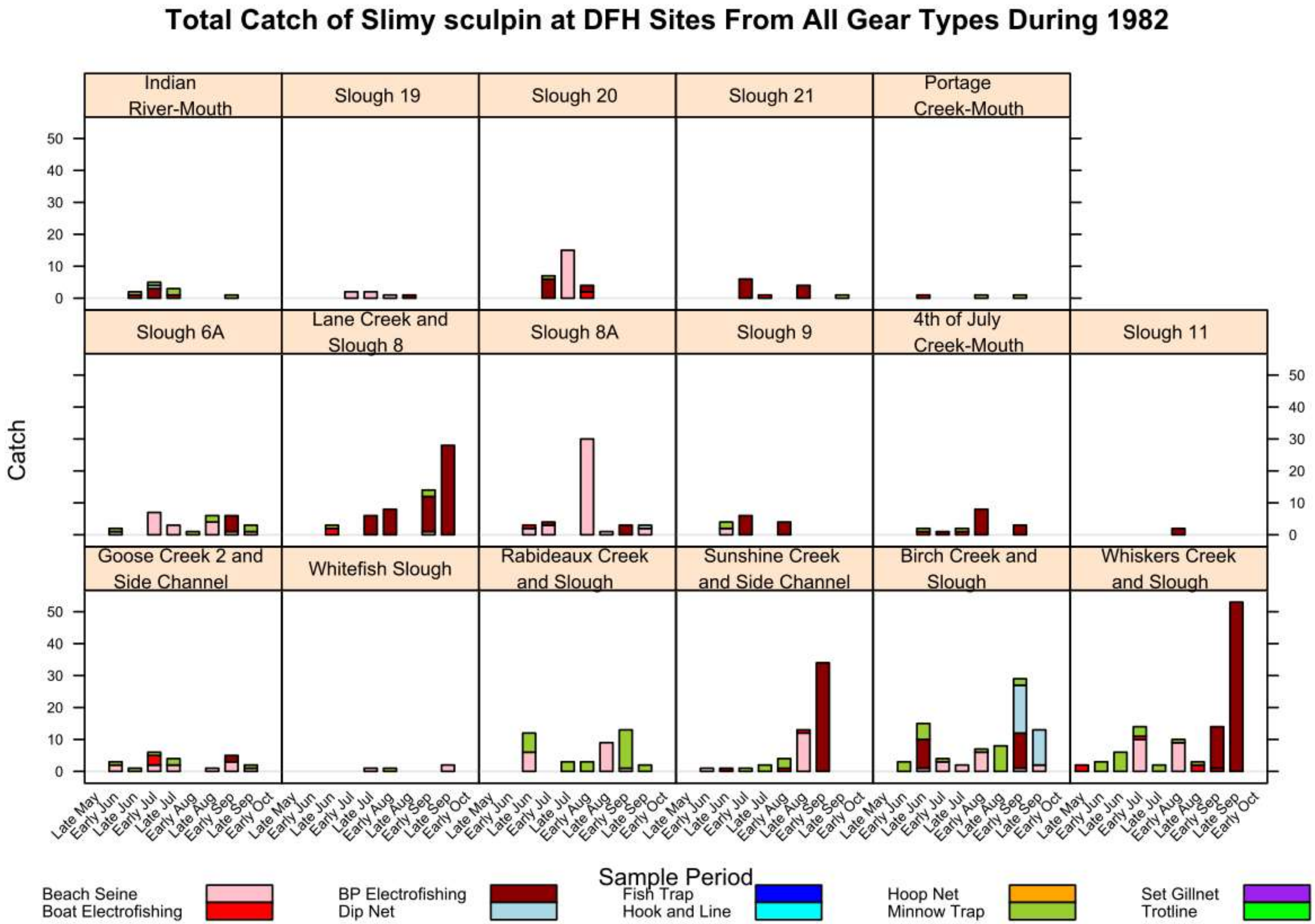


Figure 4.3-36. Total catch of slimy sculpin at DFH sites during 1982 by gear type. Data Source: Schmidt et al. (1983).

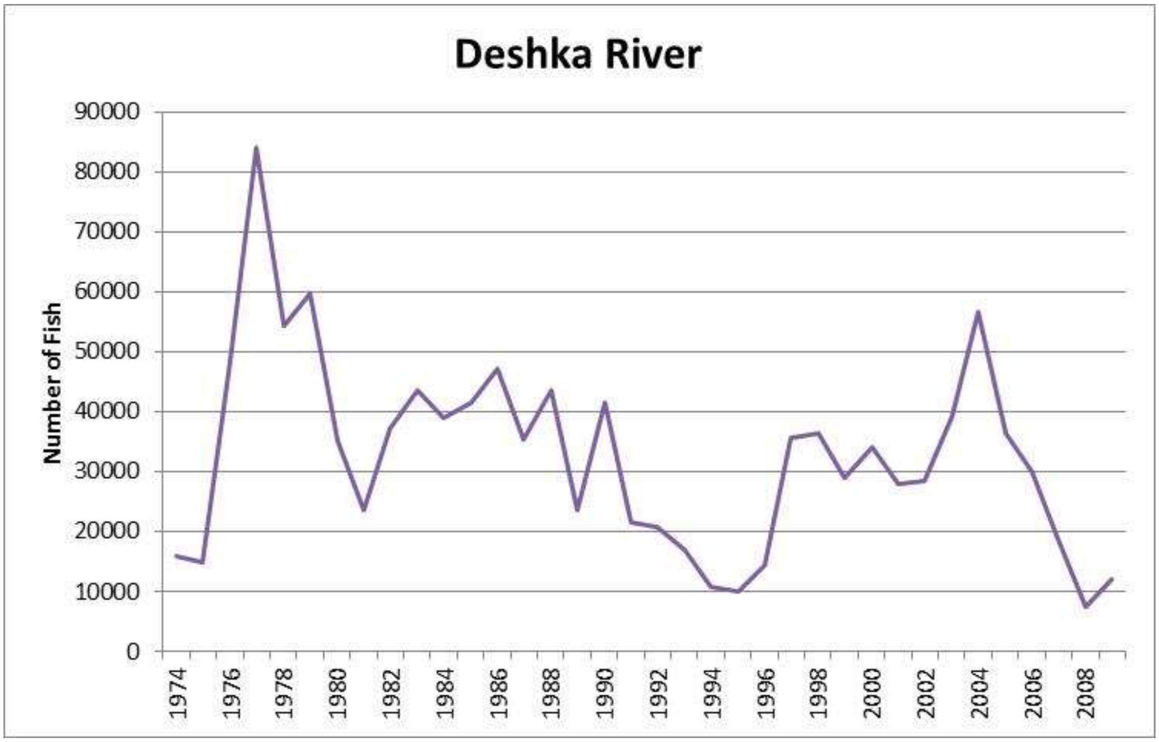


Figure 4.3-37. Deshka River Chinook salmon escapement. Source: Fair et al. (2010).

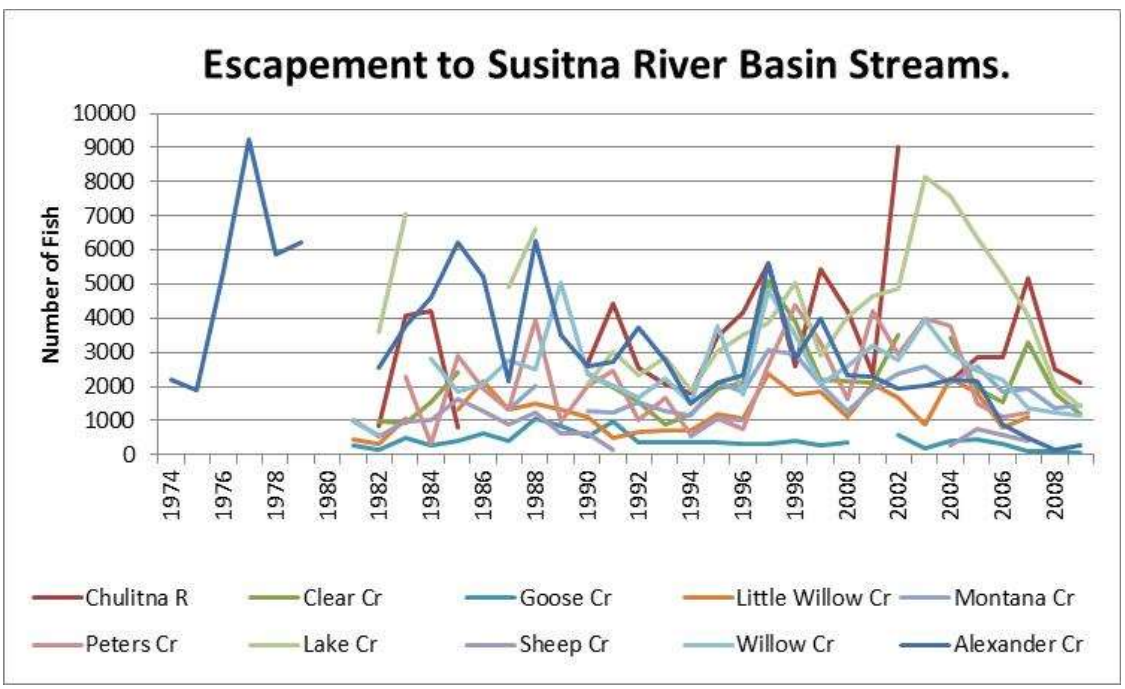


Figure 4.3-38. Escapement of Chinook salmon to Susitna River index streams other than the Deshka River. Source: Fair et al. (2010).

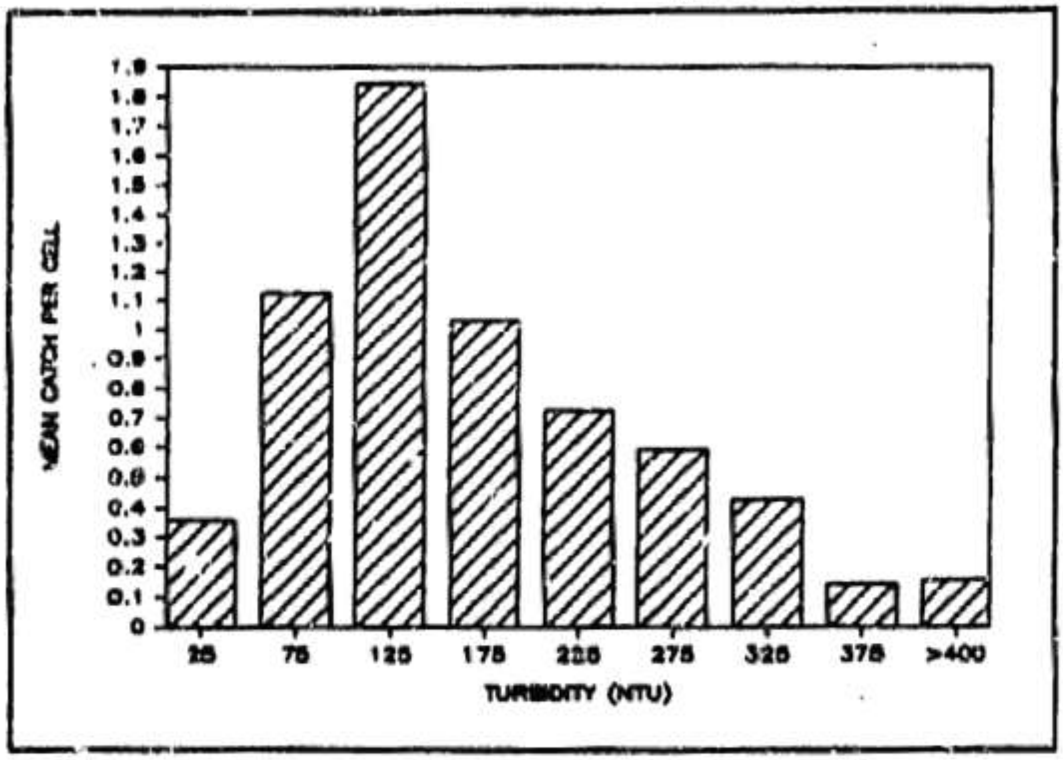
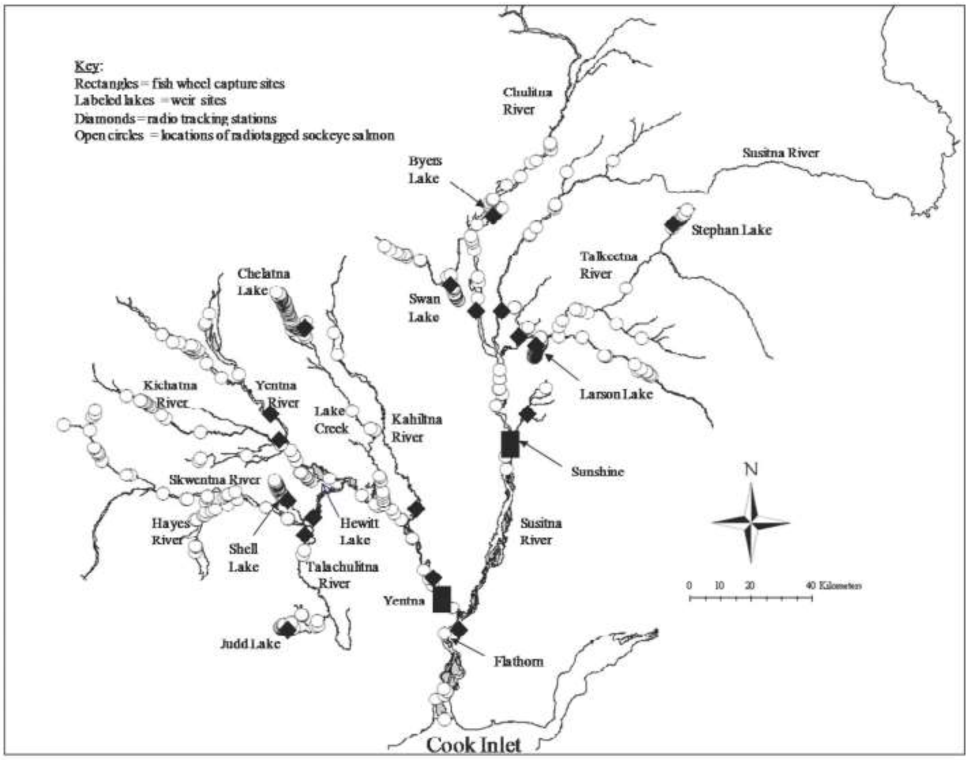


Figure 4.3-39. Mean catch rate of juvenile Chinook salmon at JAHS sites by turbidity bin in the Lower Susitna River, 1984. Source: Suchanek et al. (1985).



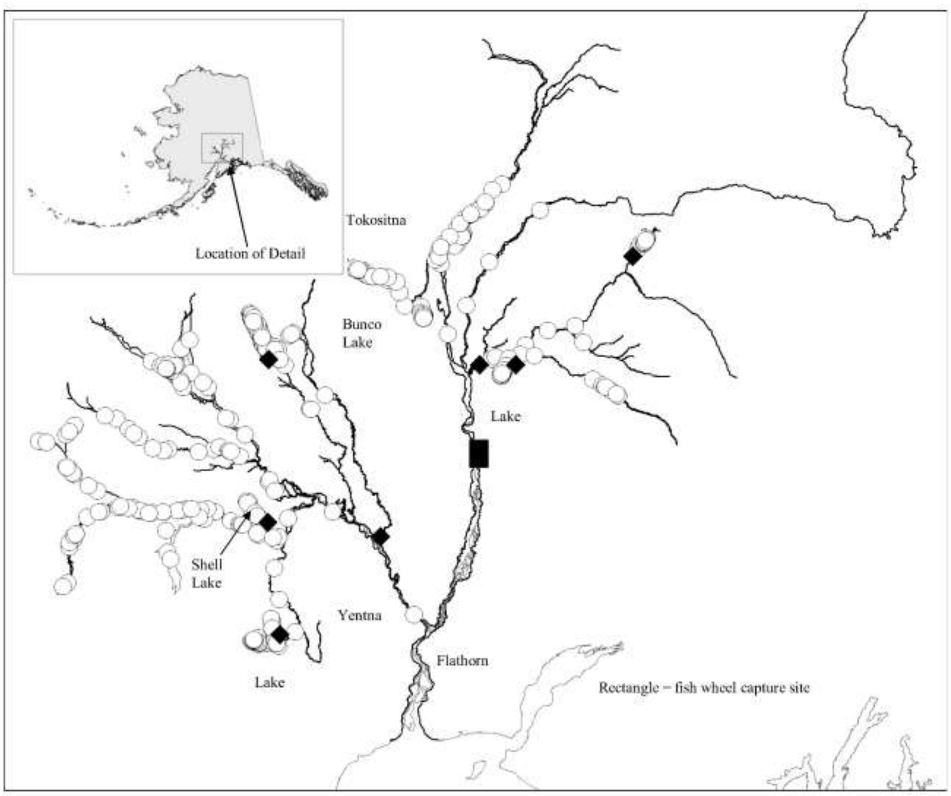


Figure 4.3-40. Location of fish wheel capture sites, weirs, and radio-tracking stations in the Susitna River drainage, and the terminal distribution of radio-tagged sockeye salmon based on aerial surveys, 2007 (top) and 2008 (bottom). Terminal location does not necessarily mean a spawning location Source: Yanusz et al. (2011a, 2011b).

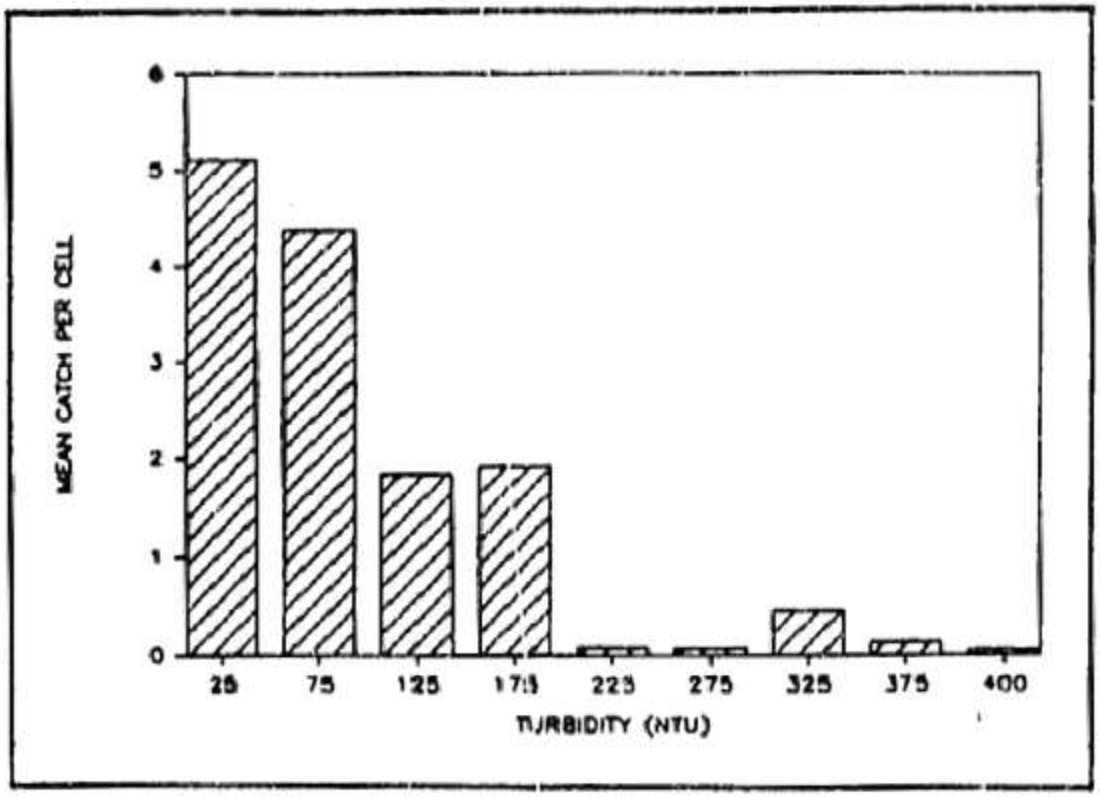


Figure 4.3-41. Average chum fry catch rates at side channels in the lower river by turbidity bin during June through mid-July 1984. Source: Suchanek et al. (1985)

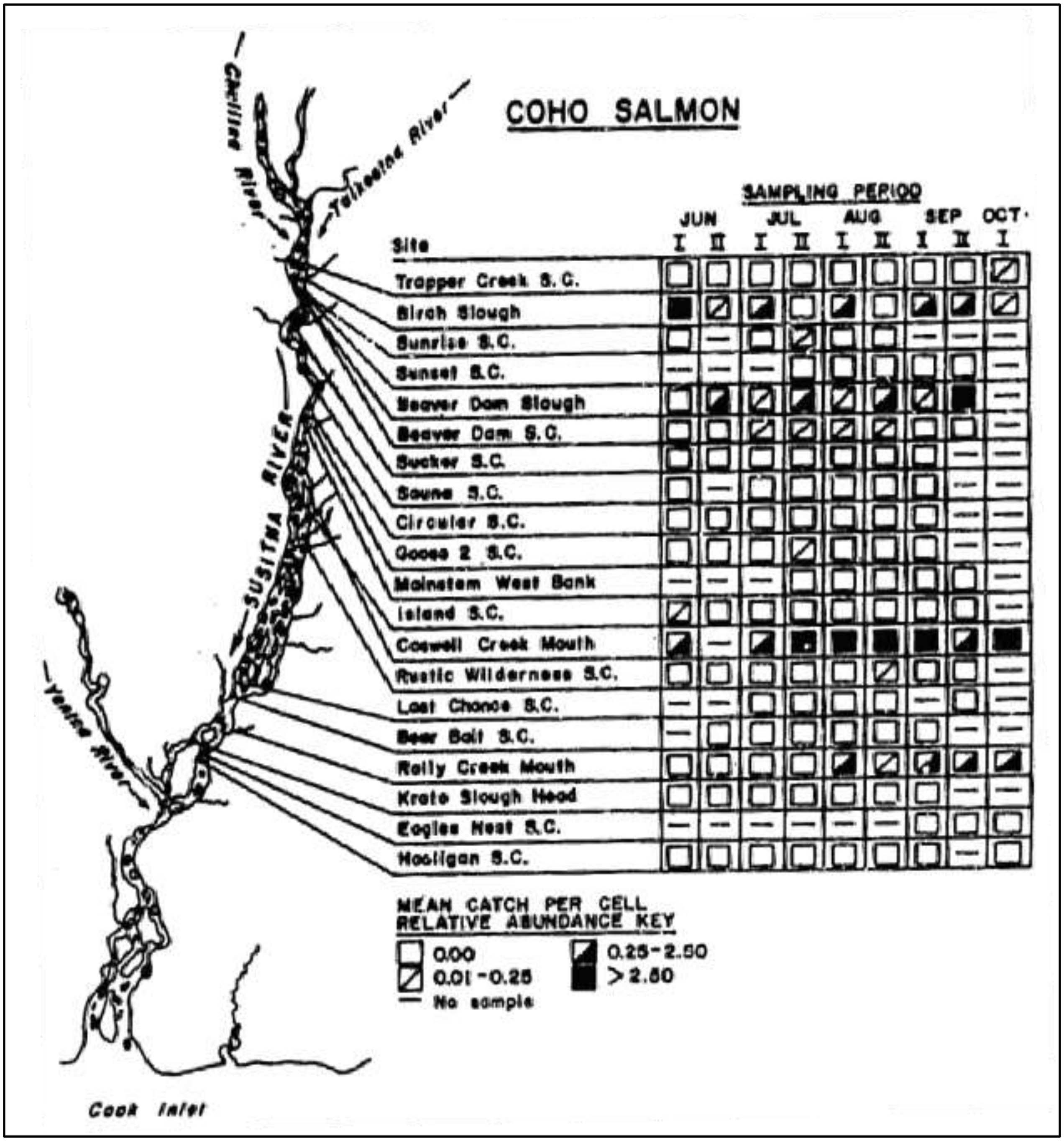


Figure 4.3-42. Seasonal distribution and relative abundance of juvenile coho salmon on the Lower Susitna River during the open water period, 1984. Sources: Suchanek et al. (1985).

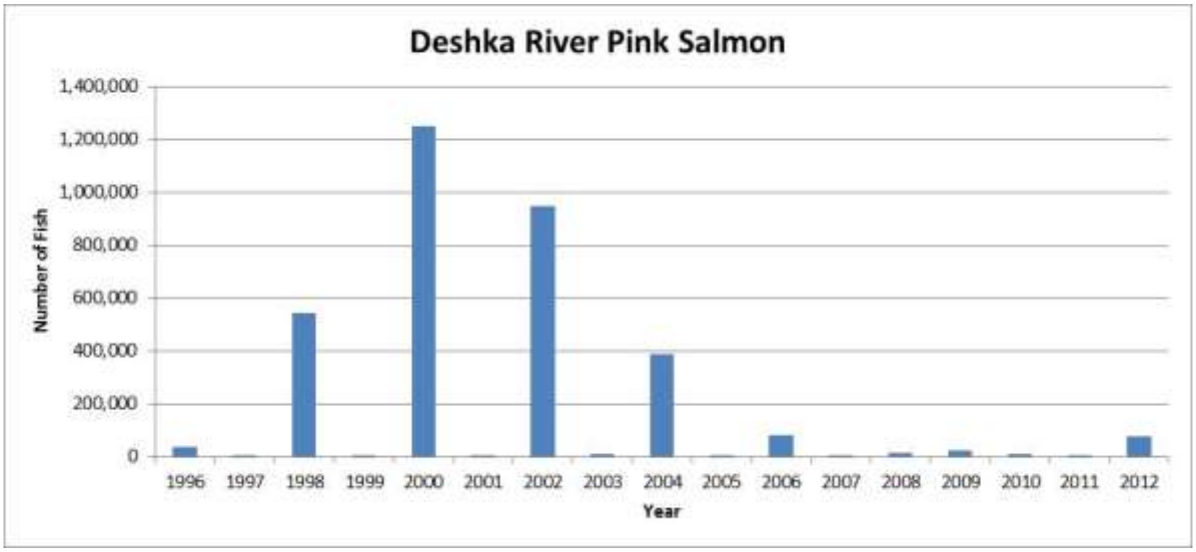


Figure 4.3-43. Pink salmon escapement estimates to the Deshka River 1996 to 2012. Source: http://www.adfg.alaska.gov/sf/FishCounts/.

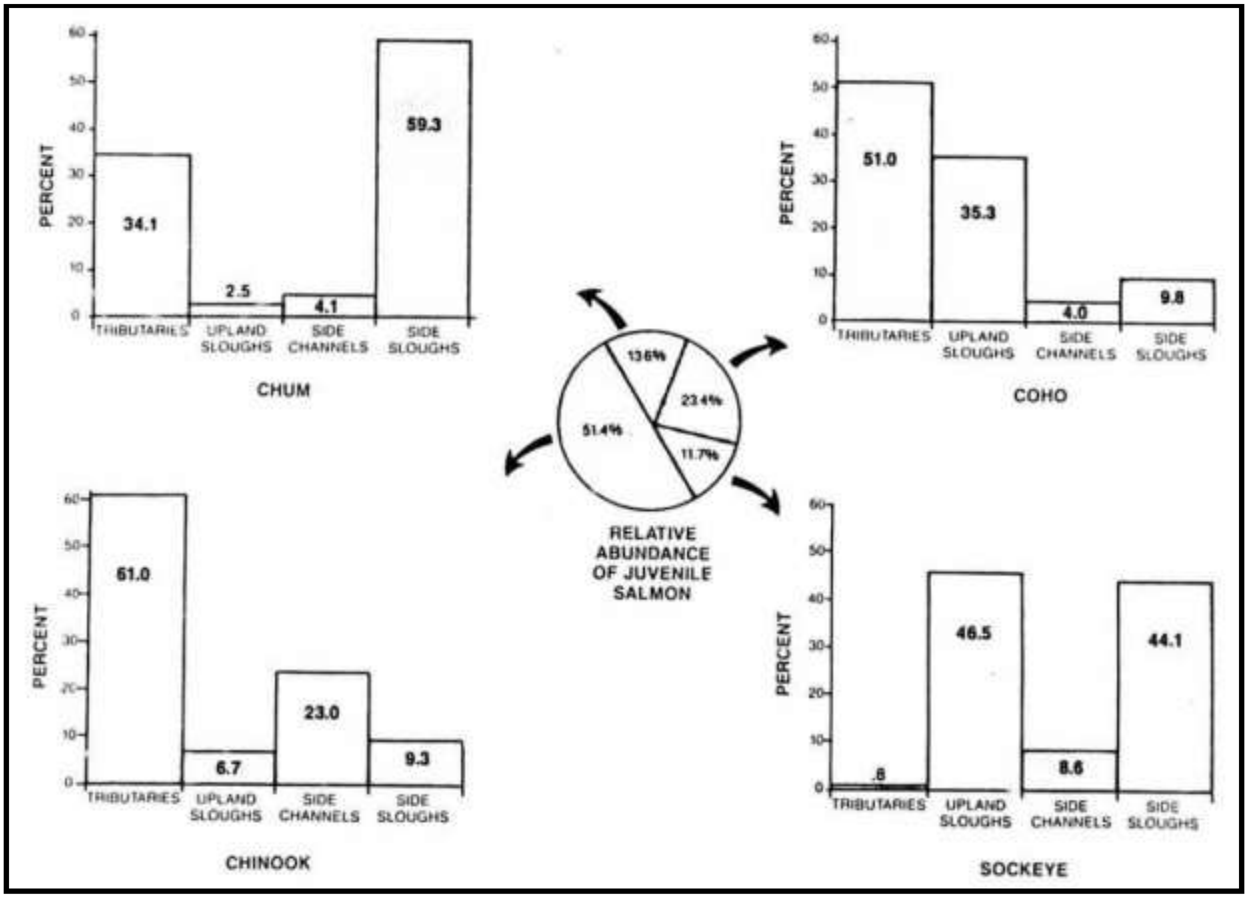


Figure 5.1-1. Relative abundance of juvenile Pacific salmon species in the Middle Segment of the Susitna River among macro-habitat types during the open water season. Sources: Trihey and Associates and Entrix (1985) and Dugan et al. (1984).

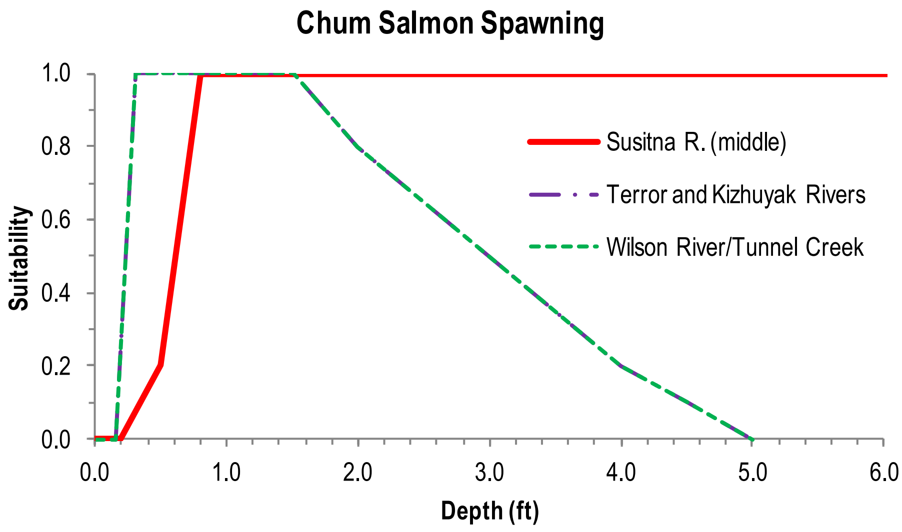


Figure 6.1-1. Depth HSC developed during the 1980s for chum salmon spawning in the Middle Susitna River (Vincent-Lang et al. 1984b), the Terror and Kizhuyak Rivers (Baldrige 1981), and Wilson River/Tunnel Creek (Lyons and Nadeau 1985).

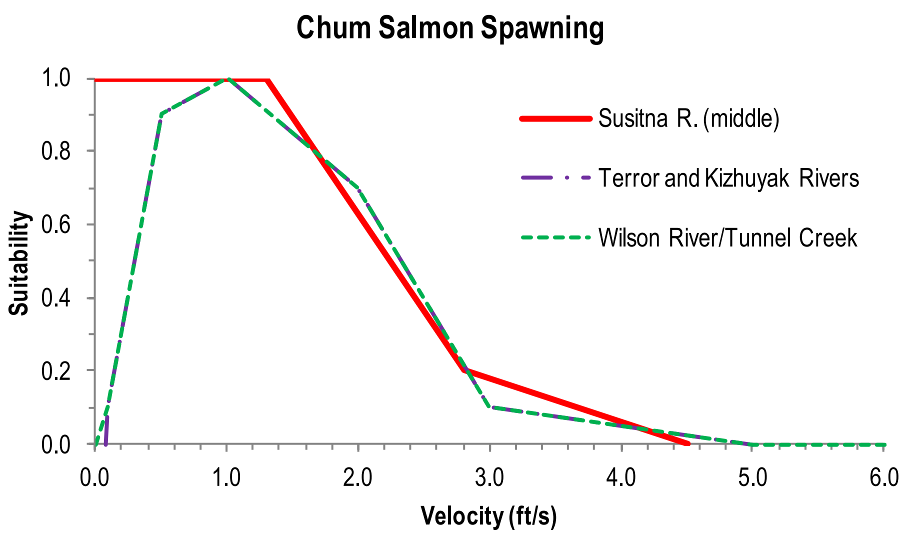


Figure 6.1-2. Velocity HSC developed during the 1980s for chum salmon spawning in the Middle Susitna River (Vincent-Lang et al. 1984b), the Terror and Kizhuyak Rivers (Baldrige 1981), and Wilson River/Tunnel Creek (Lyons and Nadeau 1985).

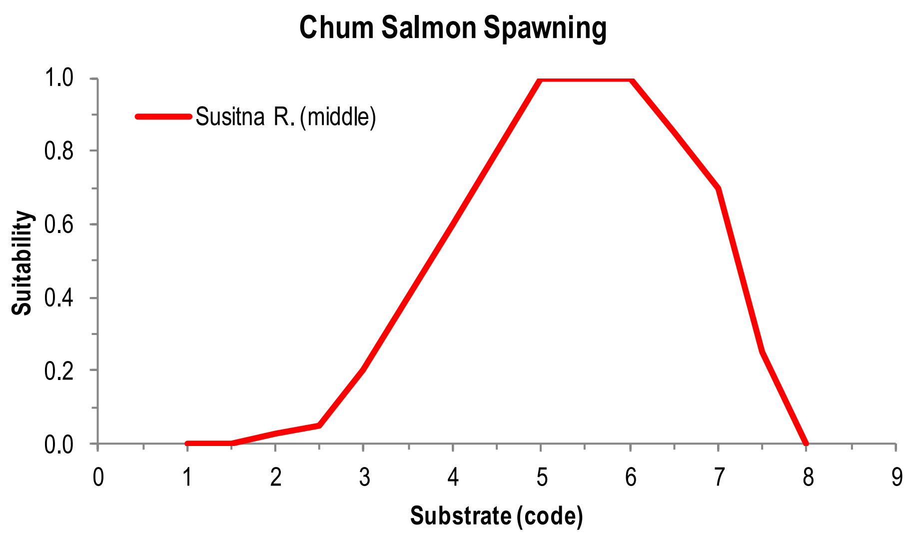


Figure 6.1-3. Substrate HSC developed during the 1980s for chum salmon spawning in the Middle Susitna River (Vincent-Lang et al. 1984b).

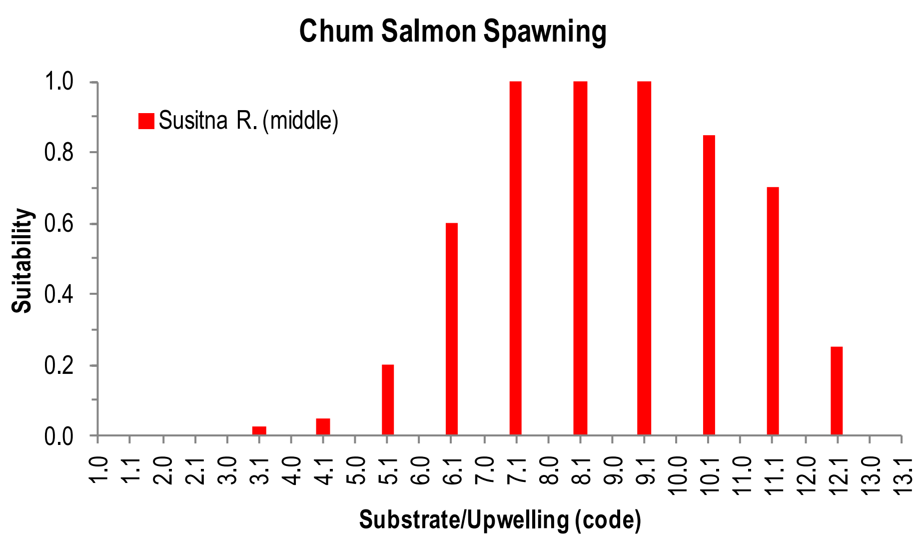


Figure 6.1-4. Combined substrate/upwelling HSC developed during the 1980s for chum salmon spawning in the Middle Susitna River (Vincent-Lang et al. 1984b). Codes ending in ".0" indicate upwelling absent and codes ending in ".1" indicate upwelling present.

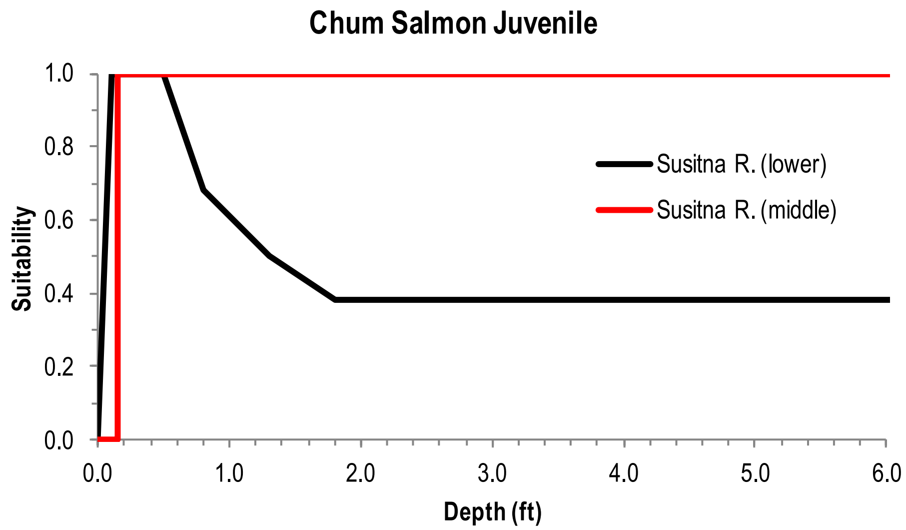


Figure 6.1-5. Depth HSC developed during the 1980s for juvenile chum salmon in the Lower (Suchanek et al. 1985) and Middle (Suchanek et al. 1984a) Susitna River.

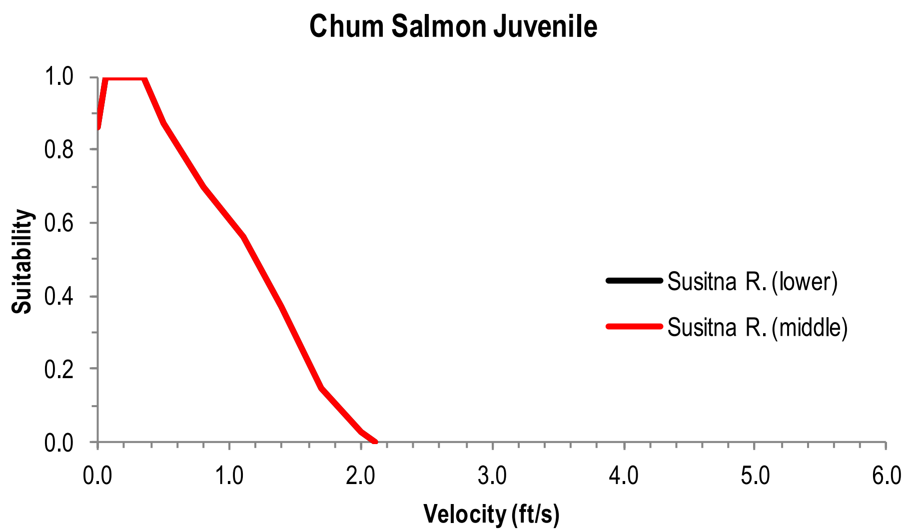


Figure 6.1-6. Velocity HSC developed during the 1980s for juvenile chum salmon in the Lower (Suchanek et al. 1985) and Middle (Suchanek et al. 1984a) Susitna River. Note that the two curves are identical based on verification efforts in the Lower River.

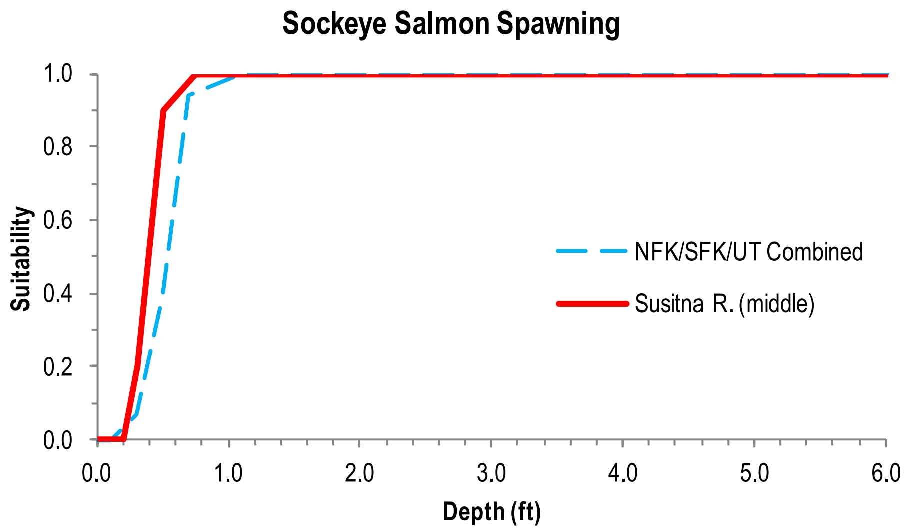


Figure 6.1-7. Depth HSC developed during the 1980s for sockeye salmon spawning in the Middle Susitna River (Vincent-Lang et al. 1984b), and from combined observations in the North (NFK) and South (SFK) Koktuli Rivers and Upper Talarik Creek (PLP 2011).

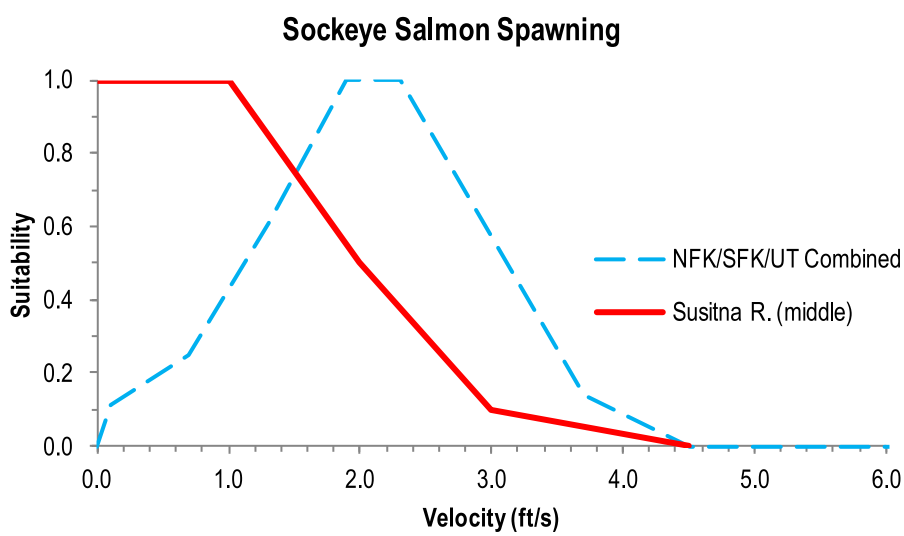


Figure 6.1-8. Velocity HSC developed during the 1980s for sockeye salmon spawning in the Middle Susitna River (Vincent-Lang et al. 1984b), and from combined observations in the North (NFK) and South (SFK) Koktuli Rivers and Upper Talarik Creek (PLP 2011)

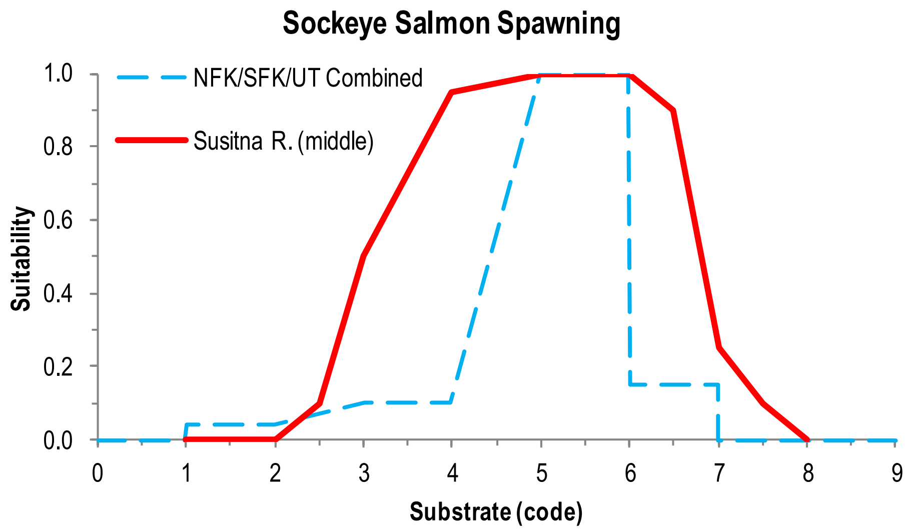


Figure 6.1-9. Substrate HSC developed during the 1980s for sockeye salmon spawning in the Middle Susitna River (Vincent-Lang et al. 1984b), and from combined observations in the North (NFK) and South (SFK) Koktuli Rivers and Upper Talarik Creek (PLP 2011).

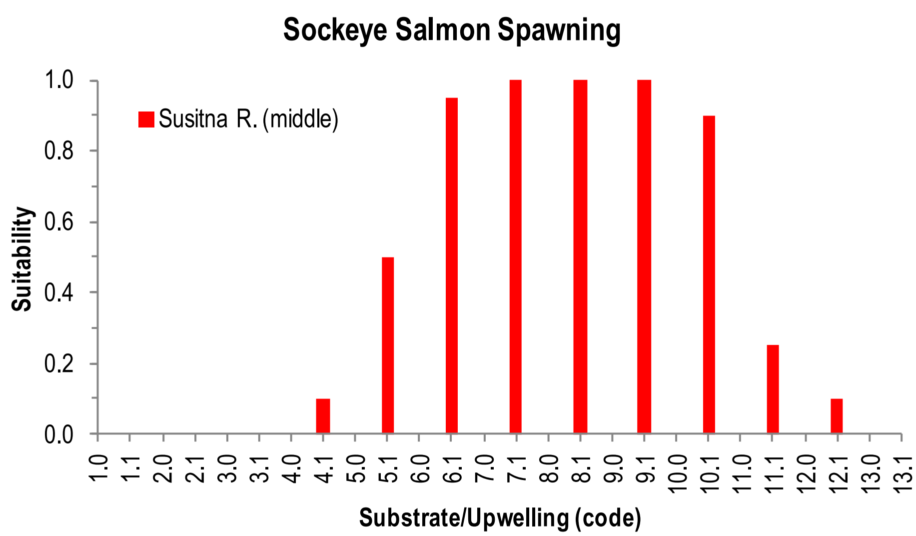


Figure 6.1-10. Combined substrate/upswelling HSC developed during the 1980s for sockeye salmon spawning in the Middle Susitna River (Vincent-Lang et al. 1984b). Codes ending in ".0" indicate upwelling absent and codes ending in ".1" indicate upwelling present.

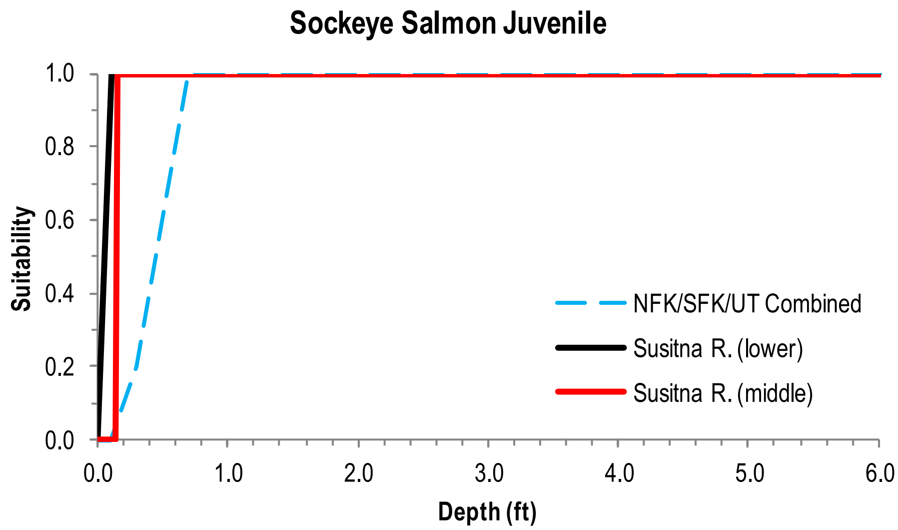


Figure 6.1-11. Depth HSC developed during the 1980s for juvenile sockeye salmon in the Lower (Suchanek et al. 1985) and Middle (Suchanek et al. 1984a) Susitna River, and from combined observations in the North (NFK) and South (SFK) Koktuli Rivers and Upper Talarik Creek (PLP 2011).

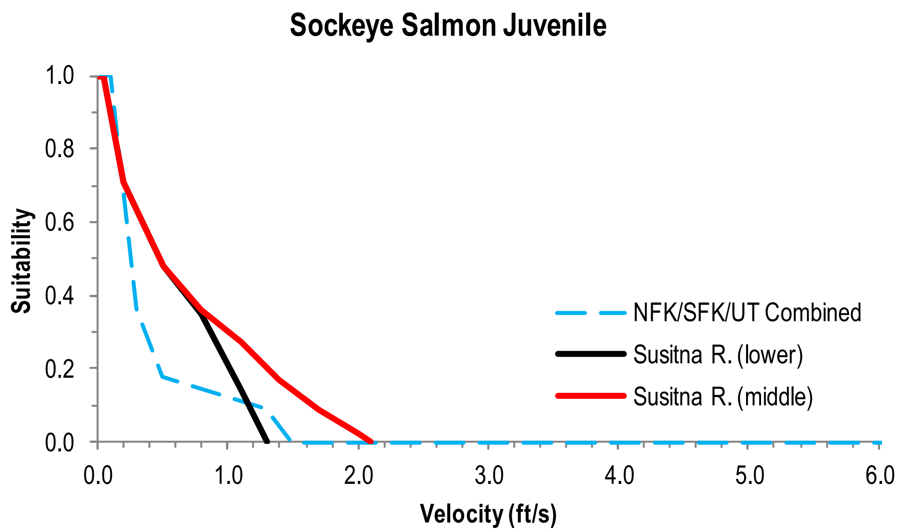


Figure 6.1-12. Velocity HSC developed during the 1980s for juvenile sockeye salmon in the Lower (Suchanek et al. 1985) and Middle (Suchanek et al. 1984a) Susitna River, and from combined observations in the North (NFK) and South (SFK) Koktuli Rivers and Upper Talarik Creek (PLP 2011).

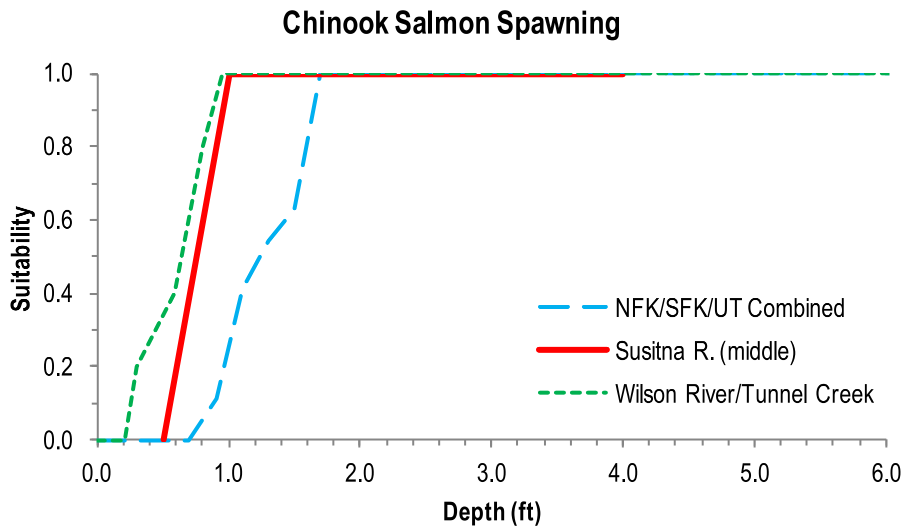


Figure 6.1-13. Depth HSC developed during the 1980s for Chinook salmon spawning in the Middle Susitna River (Vincent-Lang et al. 1984a), from combined observations in the North (NFK) and South (SFK) Koktuli Rivers and Upper Talarik Creek (PLP 2011), and for Wilson River/Tunnel Creek (Lyons and Nadeau 1985).

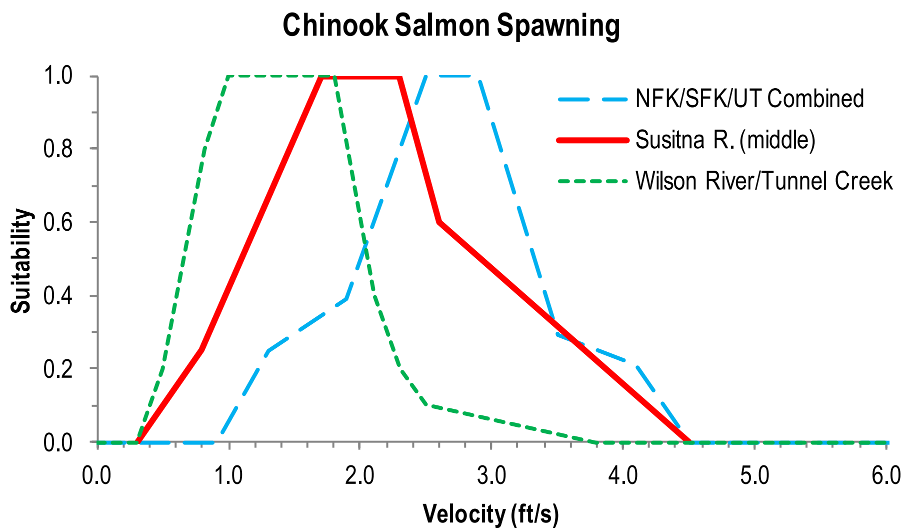


Figure 6.1-14. Velocity HSC developed during the 1980s for Chinook salmon spawning in the Middle Susitna River (Vincent-Lang et al. 1984a), from combined observations in the North (NFK) and South (SFK) Koktuli Rivers and Upper Talarik Creek (PLP 2011), and for Wilson River/Tunnel Creek (Lyons and Nadeau 1985).

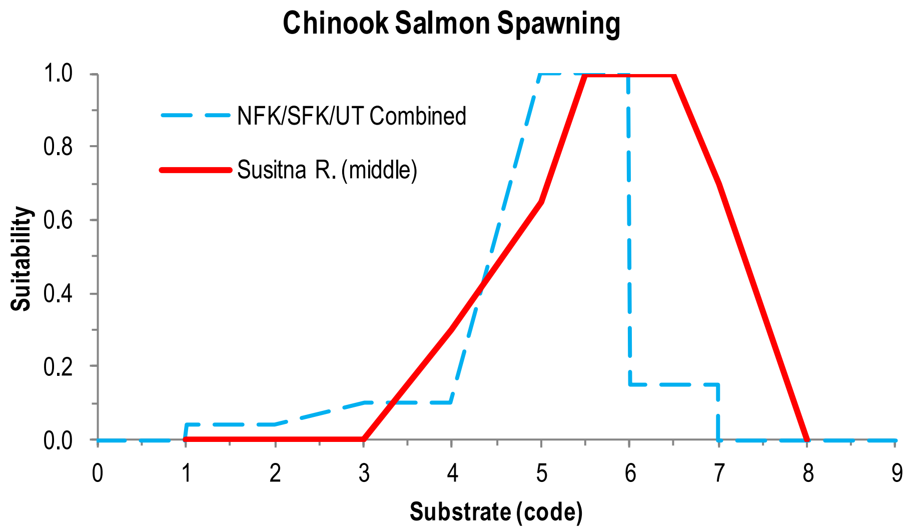


Figure 6.1-15. Substrate HSC developed during the 1980s for Chinook salmon spawning in the Middle Susitna River (Vincent-Lang et al. 1984a), and from combined observations in the North (NFK) and South (SFK) Koktuli Rivers and Upper Talarik Creek (PLP 2011).

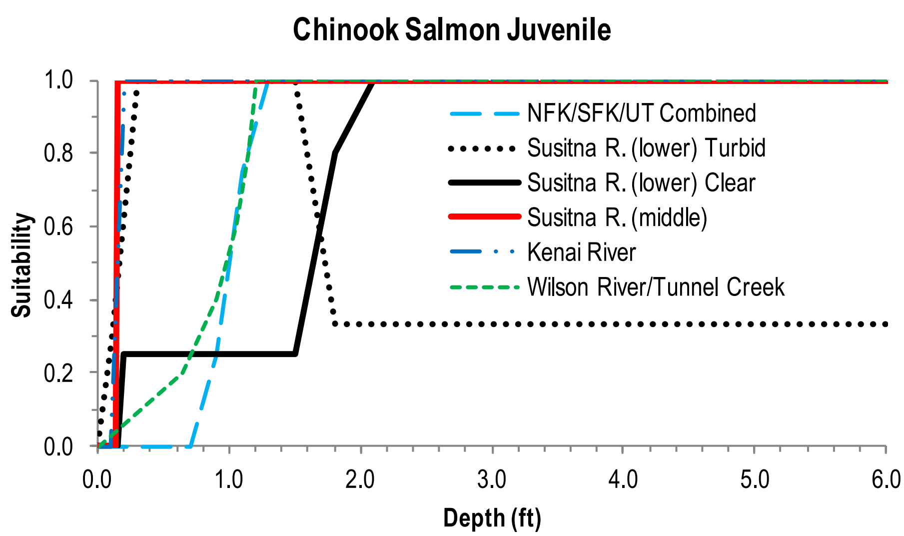


Figure 6.1-16. Depth HSC developed during the 1980s for juvenile Chinook salmon in the Lower (Suchanek et al. 1985) and Middle (Suchanek et al. 1984a) Susitna River, from combined observations in the North (NFK) and South (SFK) Koktuli Rivers and Upper Talarik Creek (PLP 2011), for Wilson River/Tunnel Creek (Lyons and Nadeau 1985), and for the Kenai River (Estes and Kuntz 1986).

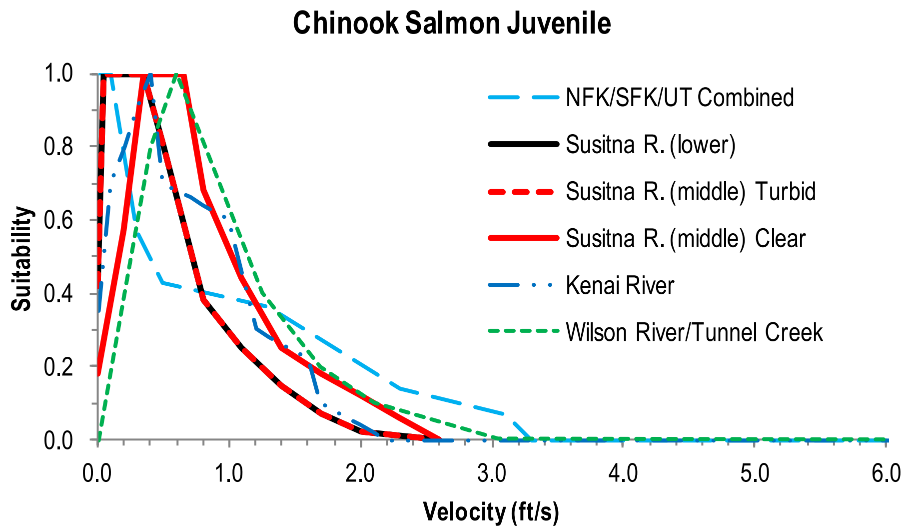


Figure 6.1-17. Velocity HSC developed during the 1980s for juvenile Chinook salmon in the Lower (Suchanek et al. 1985) and Middle (Suchanek et al. 1984a) Susitna River, from combined observations in the North (NFK) and South (SFK) Koktuli Rivers and Upper Talarik Creek (PLP 2011), for Wilson River/Tunnel Creek (Lyons and Nadeau 1985), and for the Kenai River (Estes and Kuntz 1986).

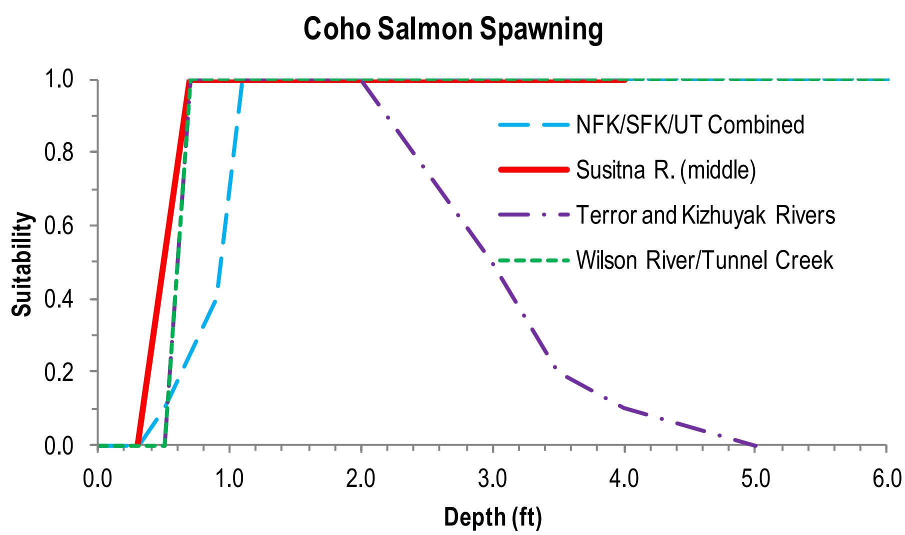


Figure 6.1-18. Depth HSC developed during the 1980s for coho salmon spawning in the Middle Susitna River (Vincent-Lang et al. 1984a), from combined observations in the North (NFK) and South (SFK) Koktuli Rivers and Upper Talarik Creek (PLP 2011), for the Terror and Kizhuyak Rivers (Baldrige 1981), and for Wilson River/Tunnel Creek (Lyons and Nadeau 1985).

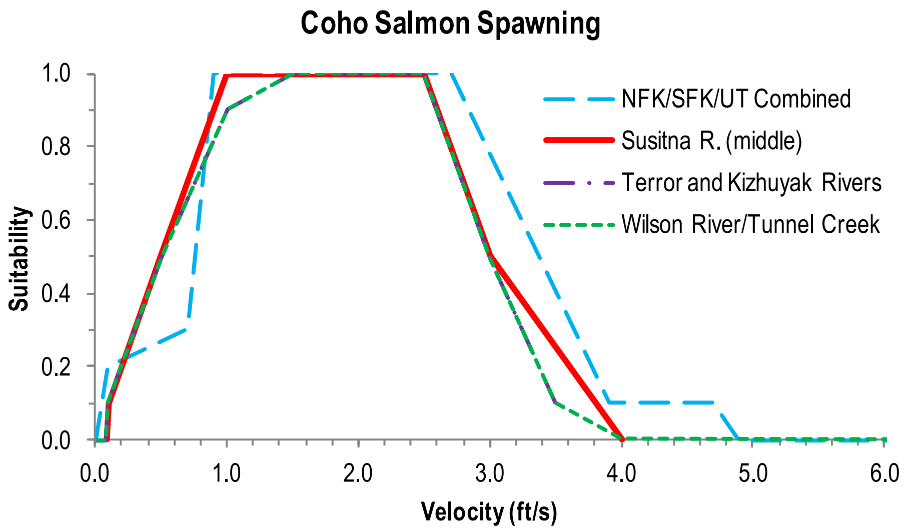


Figure 6.1-19. Velocity HSC developed during the 1980s for coho salmon spawning in the Middle Susitna River (Vincent-Lang et al. 1984a, from combined observations in the North (NFK) and South (SFK) Koktuli Rivers and Upper Talarik Creek (PLP 2011), for the Terror and Kizhuyak Rivers (Baldrige 1981), and for Wilson River/Tunnel Creek (Lyons and Nadeau 1985).

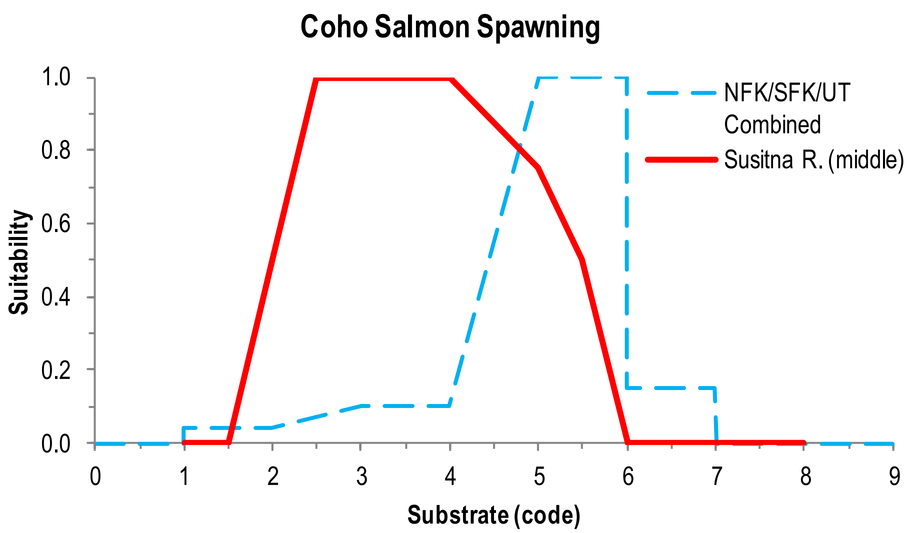


Figure 6.1-20. Substrate HSC developed during the 1980s for coho salmon spawning in the Middle Susitna River (Vincent-Lang et al. 1984a), and from combined observations in the North (NFK) and South (SFK) Koktuli Rivers and Upper Talarik Creek (PLP 2011).

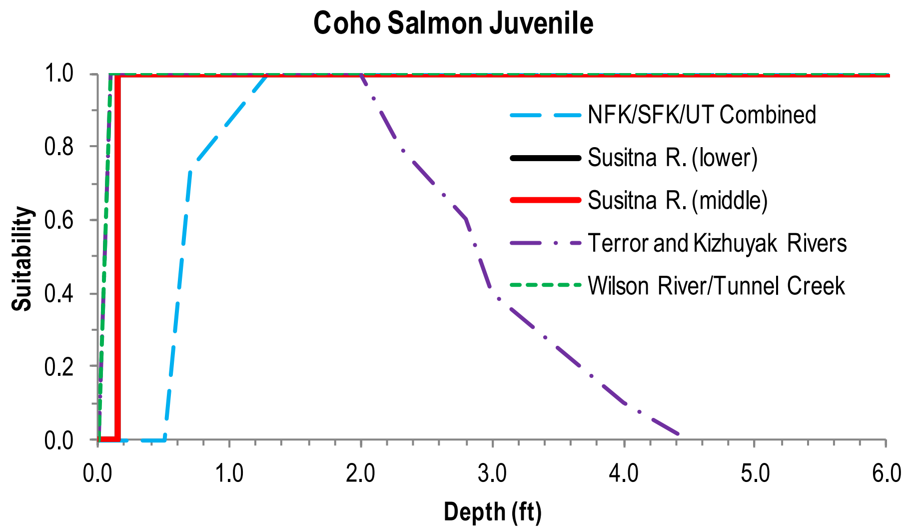


Figure 6.1-21. Depth HSC developed during the 1980s for juvenile coho salmon in the Lower (Suchanek et al. 1985) and Middle (Suchanek et al. 1984a) Susitna River, from combined observations in the North (NFK) and South (SFK) Koktuli Rivers and Upper Talarik Creek (PLP 2011), for the Terror and Kizhuyak Rivers (Baldrige 1981), and for Wilson River/Tunnel Creek (Lyons and Nadeau 1985). Note that the Middle and Lower Susitna River curves are identical based on verification efforts in the Lower River.

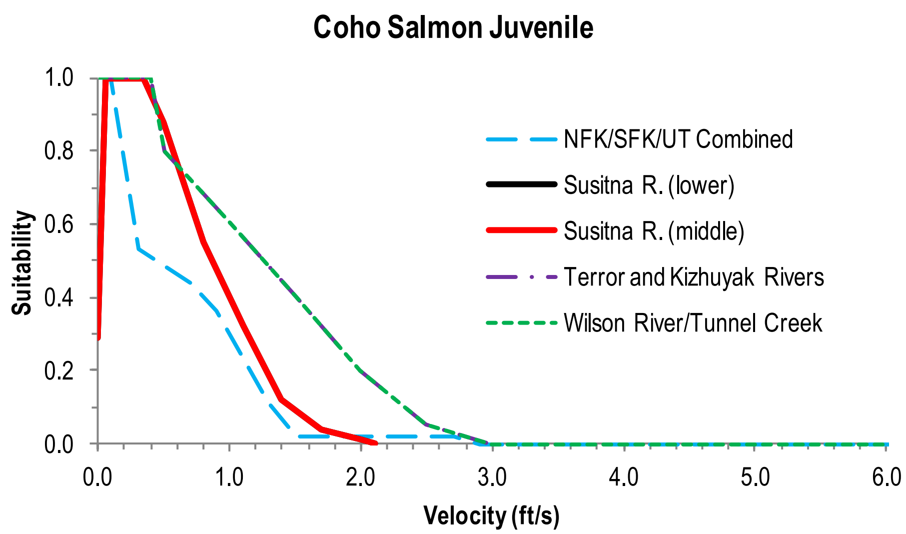


Figure 6.1-22. Velocity HSC developed during the 1980s for juvenile coho salmon in the Lower (Suchanek et al. 1985) and Middle (Suchanek et al. 1984a) Susitna River, from combined observations in the North (NFK) and South (SFK) Koktuli Rivers and Upper Talarik Creek (PLP 2011), for the Terror and Kizhuyak Rivers (Baldrige 1981), and for Wilson River/Tunnel Creek (Lyons and Nadeau 1985). Note that the Middle and Lower Susitna River curves are identical based on verification efforts in the Lower River.

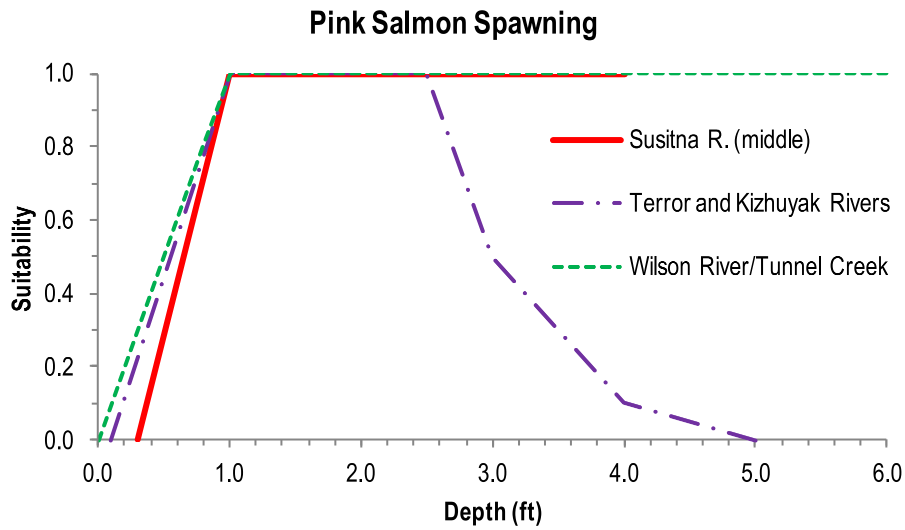


Figure 6.1-23. Depth HSC developed during the 1980s for pink salmon spawning in the Middle Susitna River (Suchanek et al. 1984a), the Terror and Kizhuyak Rivers (Baldrige 1981), and Wilson River/Tunnel Creek (Lyons and Nadeau 1985).

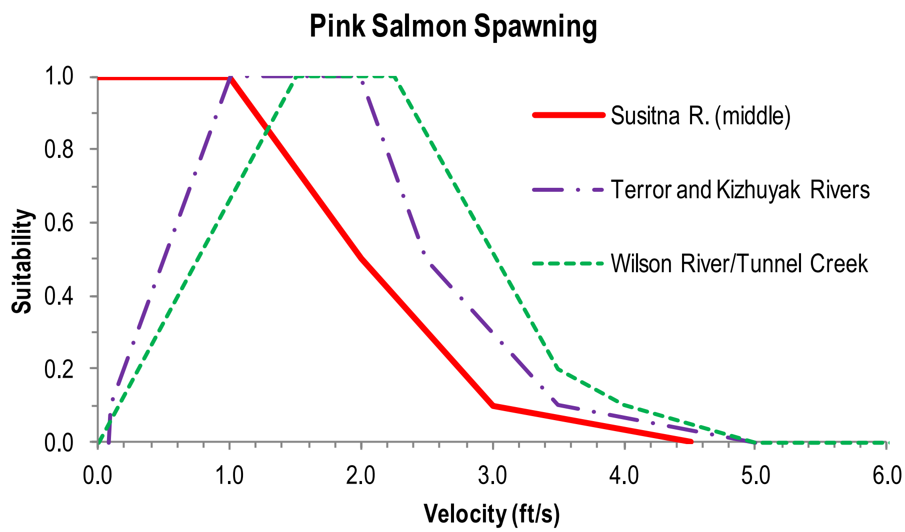


Figure 6.1-24. Velocity HSC developed during the 1980s for pink salmon spawning in the Middle Susitna River (Suchanek et al. 1984a), the Terror and Kizhuyak Rivers (Baldrige 1981), and Wilson River/Tunnel Creek (Lyons and Nadeau 1985).

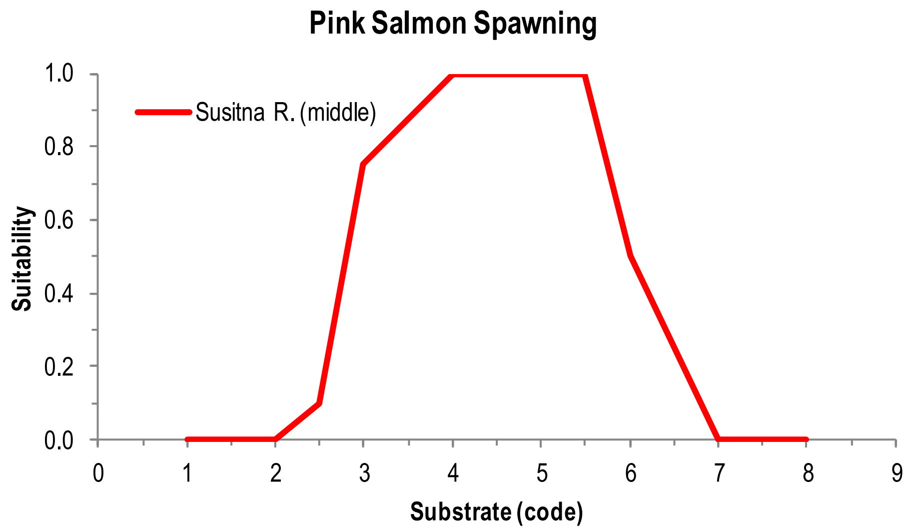


Figure 6.1-25. Substrate HSC developed during the 1980s for pink salmon spawning in the Middle Susitna River (Vincent-Lang et al. 1984a).

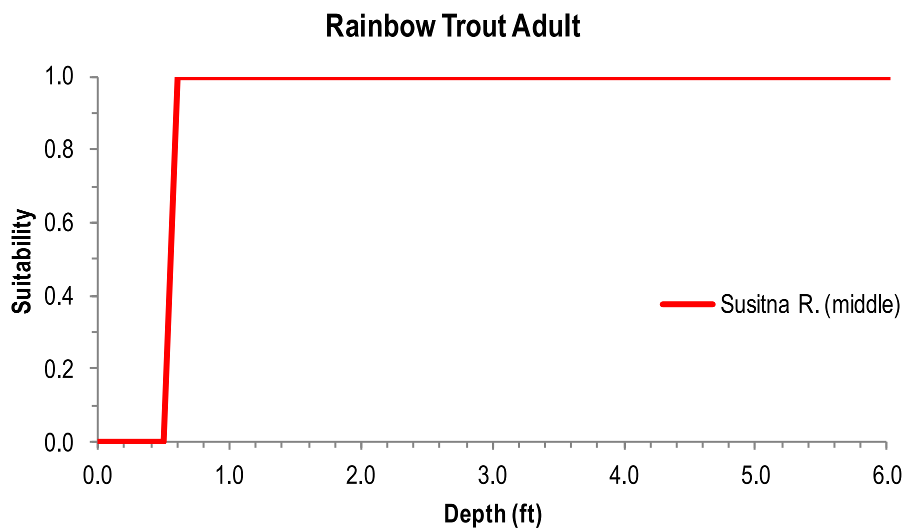


Figure 6.1-26. Depth HSC developed during the 1980s for rainbow trout adult in the Middle Susitna River (Suchanek et al. 1984b).

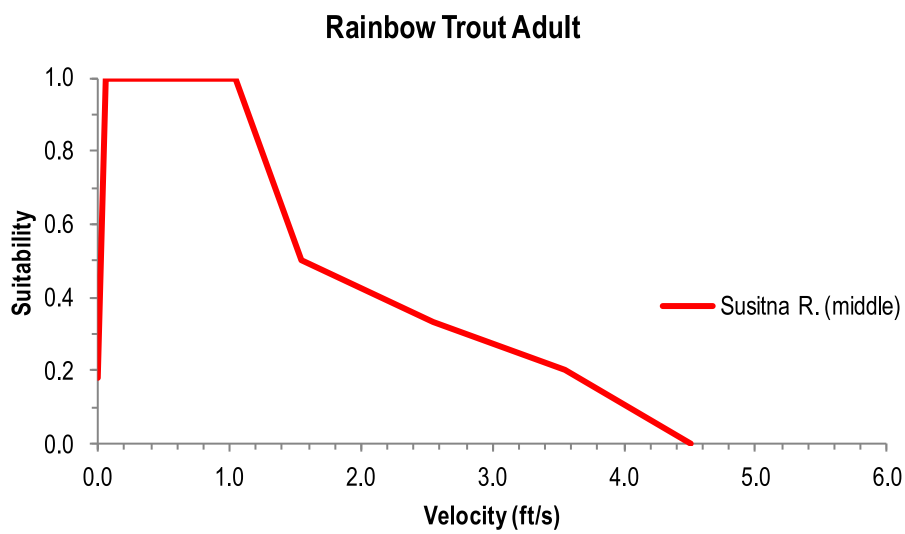


Figure 6.1-27. Velocity HSC developed during the 1980s for rainbow trout adult in the Middle Susitna River (Suchanek et al. 1984b).

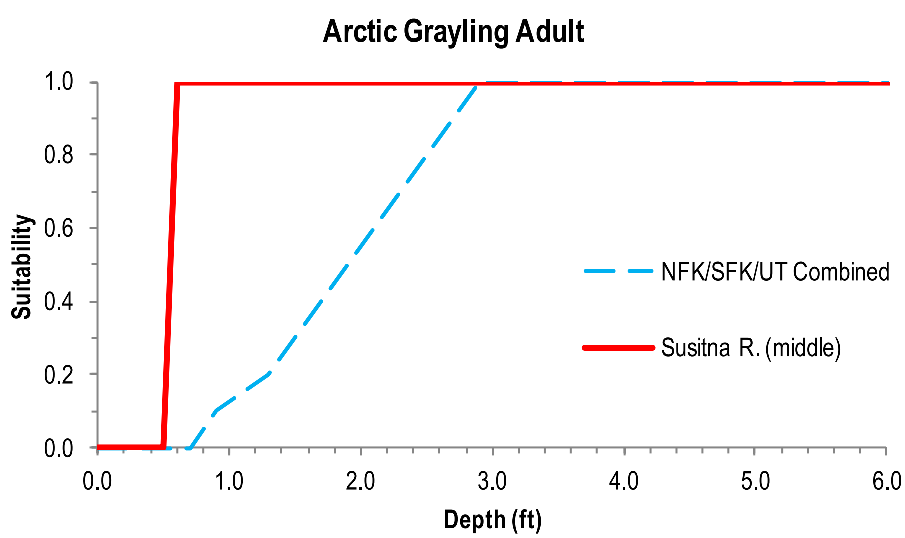


Figure 6.1-28. Depth HSC developed during the 1980s for adult arctic grayling in the Middle Susitna River (Suchanek et al. 1984b), and from combined observations in the North (NFK) and South (SFK) Koktuli Rivers and Upper Talarik Creek (PLP 2011).

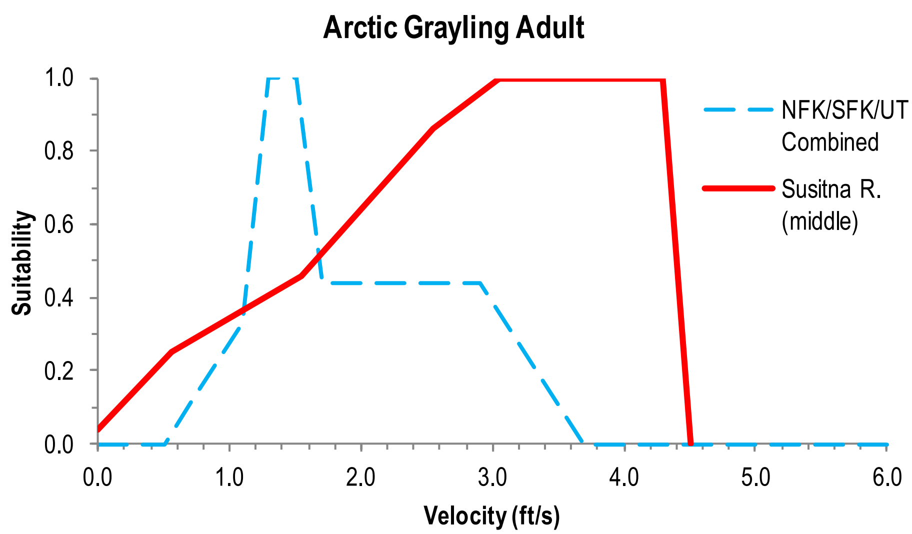


Figure 6.1-29. Velocity HSC developed during the 1980s for adult arctic grayling in the Middle Susitna River (Suchanek et al. 1984b), and from combined observations in the North (NFK) and South (SFK) Koktuli Rivers and Upper Talarik Creek (PLP 2011).

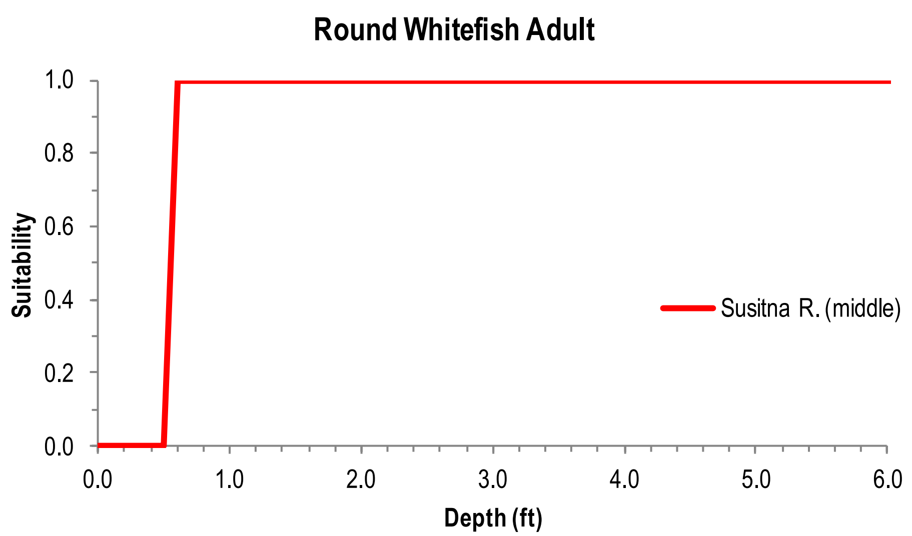


Figure 6.1-30. Depth HSC developed during the 1980s for adult round whitefish in the Middle Susitna River (Suchanek et al. 1984b)

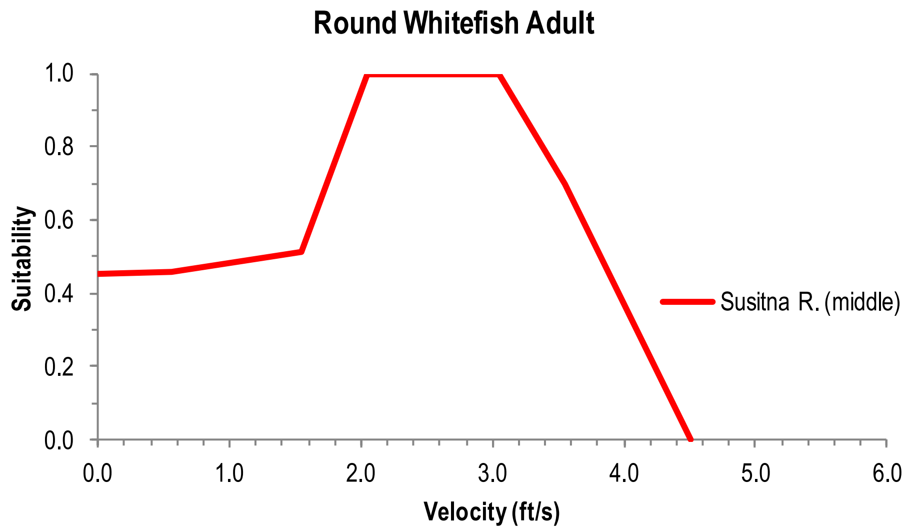


Figure 6.1-31. Velocity HSC developed during the 1980s for adult round whitefish in the Middle Susitna River (Suchanek et al. 1984b)

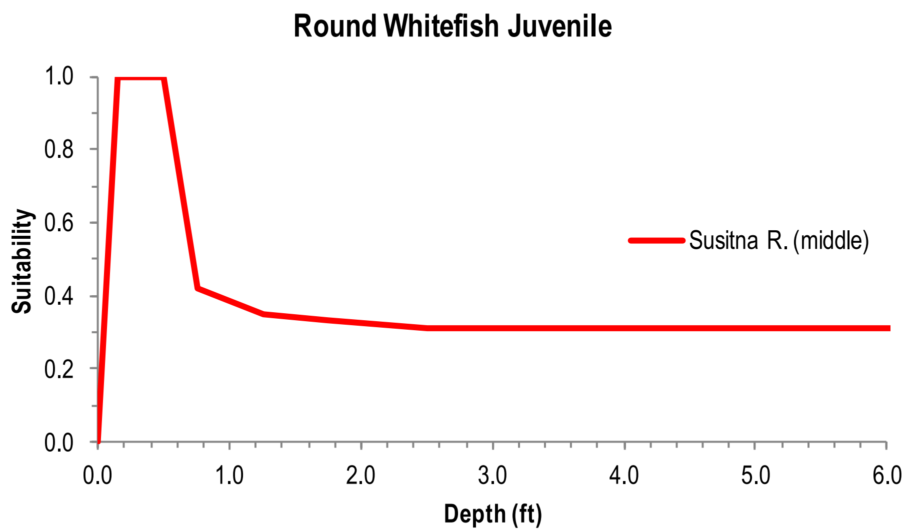


Figure 6.1-32. Depth HSC developed during the 1980s for juvenile round whitefish in the Middle Susitna River (Suchanek et al. 1984b).

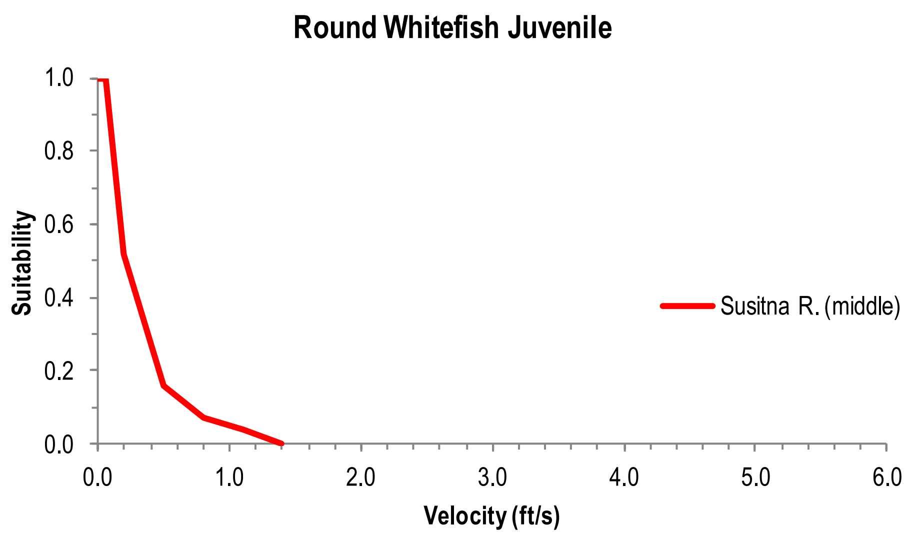


Figure 6.1-33. Velocity HSC developed during the 1980s for juvenile round whitefish in the Middle Susitna River (Suchanek et al. 1984b).

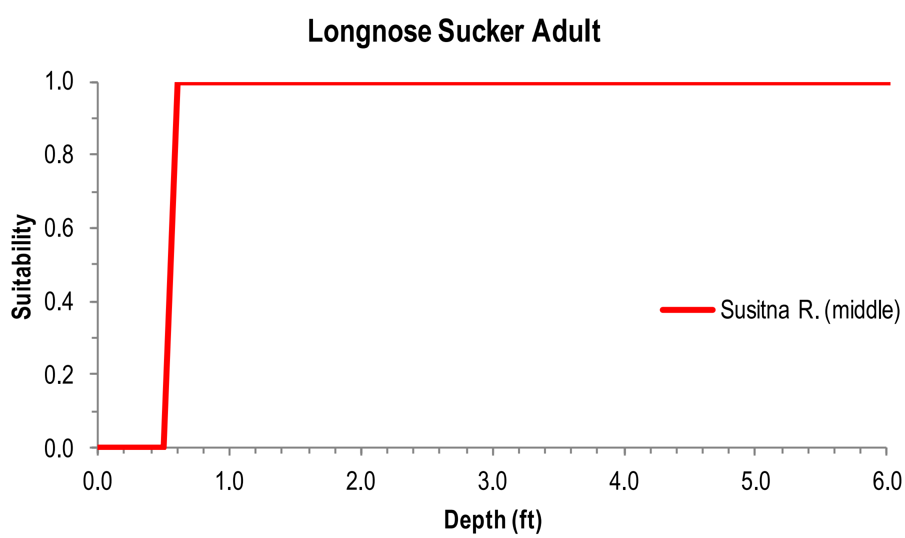


Figure 6.1-34. Depth HSC developed during the 1980s for adult longnose sucker in the Middle Susitna River (Suchanek et al. 1984b).

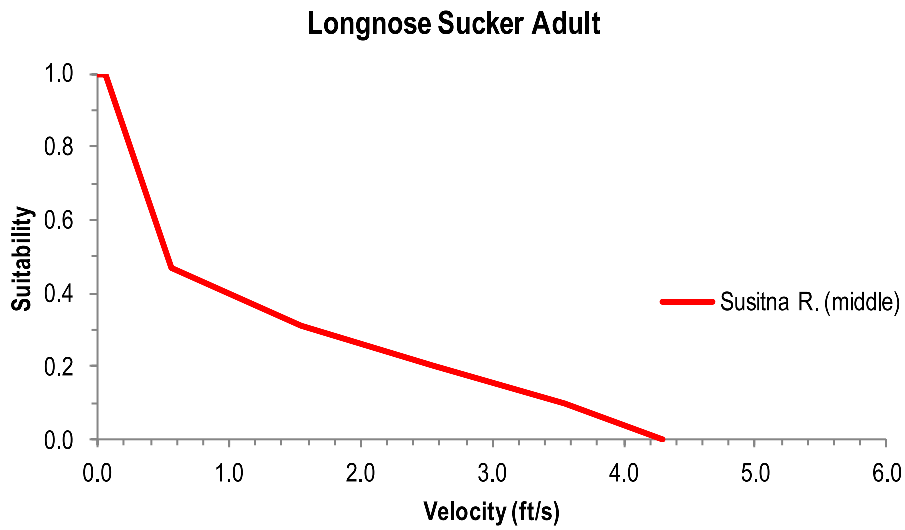


Figure 6.1-35. Velocity HSC developed during the 1980s for adult longnose sucker in the Middle Susitna River (Suchanek et al. 1984b).

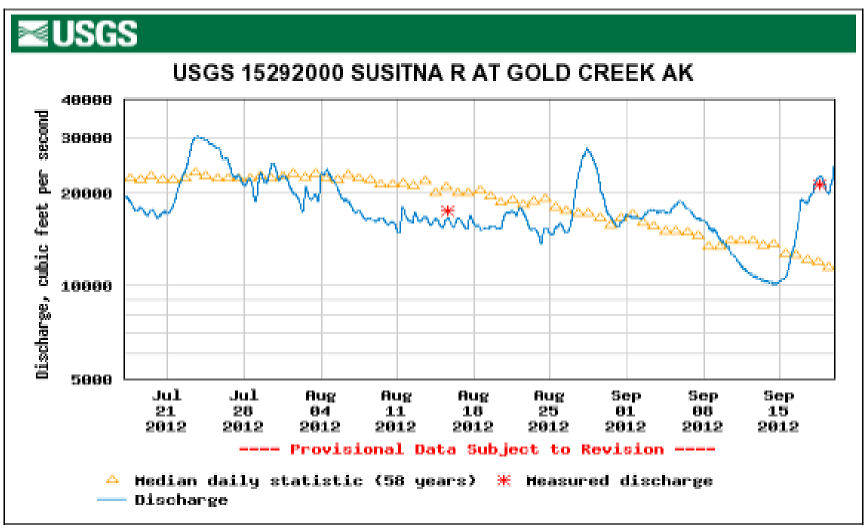


Figure 6.3-1. Daily discharge values from the USGS gage at Gold Creek (#15292000) on the Susitna River, from 17 July to 19 September 2012.

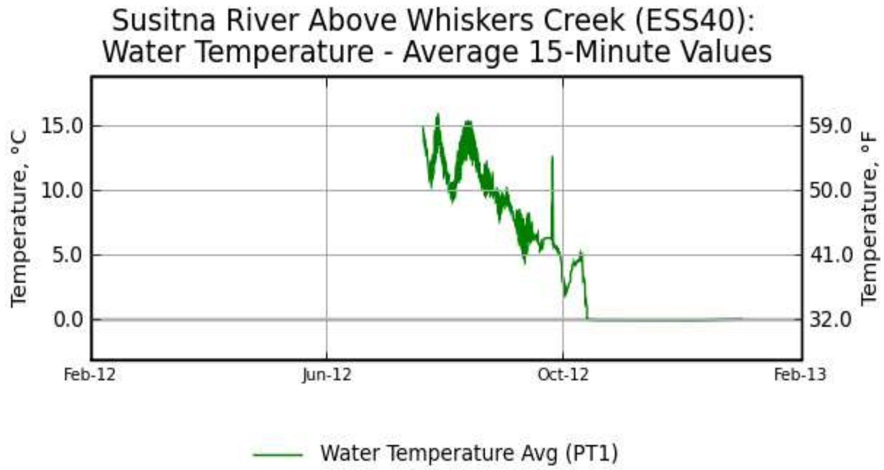


Figure 6.3-2. Water temperature values from the mainstem Susitna River upstream of Whiskers Creek from July through October 2012.

Figure 6.3-3. Example of a typical redd observed during spawning surveys. Depth, velocity, substrate, and redd dimensions were measured at each redd.

Figure 6.3-4. Example photos of methods used to evaluate visibility conditions using a secchi disk prior to conducting microhabitat snorkel surveys.

Figure 6.3-5. Utilizing snorkel surveys to identify fish habitat use of tributaries delta areas of the Susitna River, Alaska.

Figure 6.3-6. Utilizing stick/pole seine surveys to identify fish habitat use in turbid water areas of Susitna River, Alaska.

Figure 6.3-7. Adult arctic grayling captured during seining surveys of turbid water areas downstream of the proposed Watana Dam site.

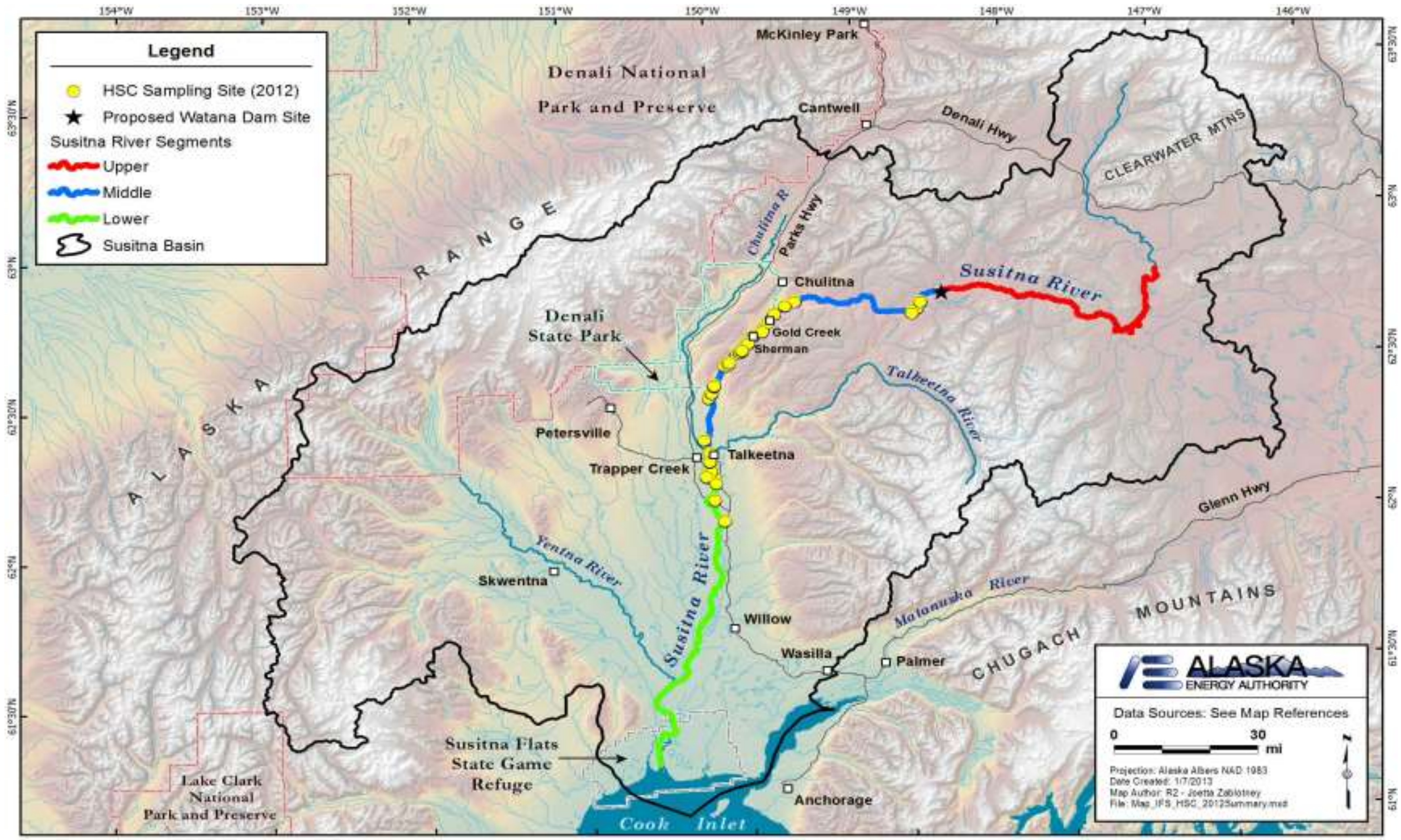


Figure 6.3-8. Map depicting the Upper, Middle and Lower Segments of the Susitna River potentially influenced by the Susitna-Watana Hydroelectric Project and 2012 HSC sampling locations.

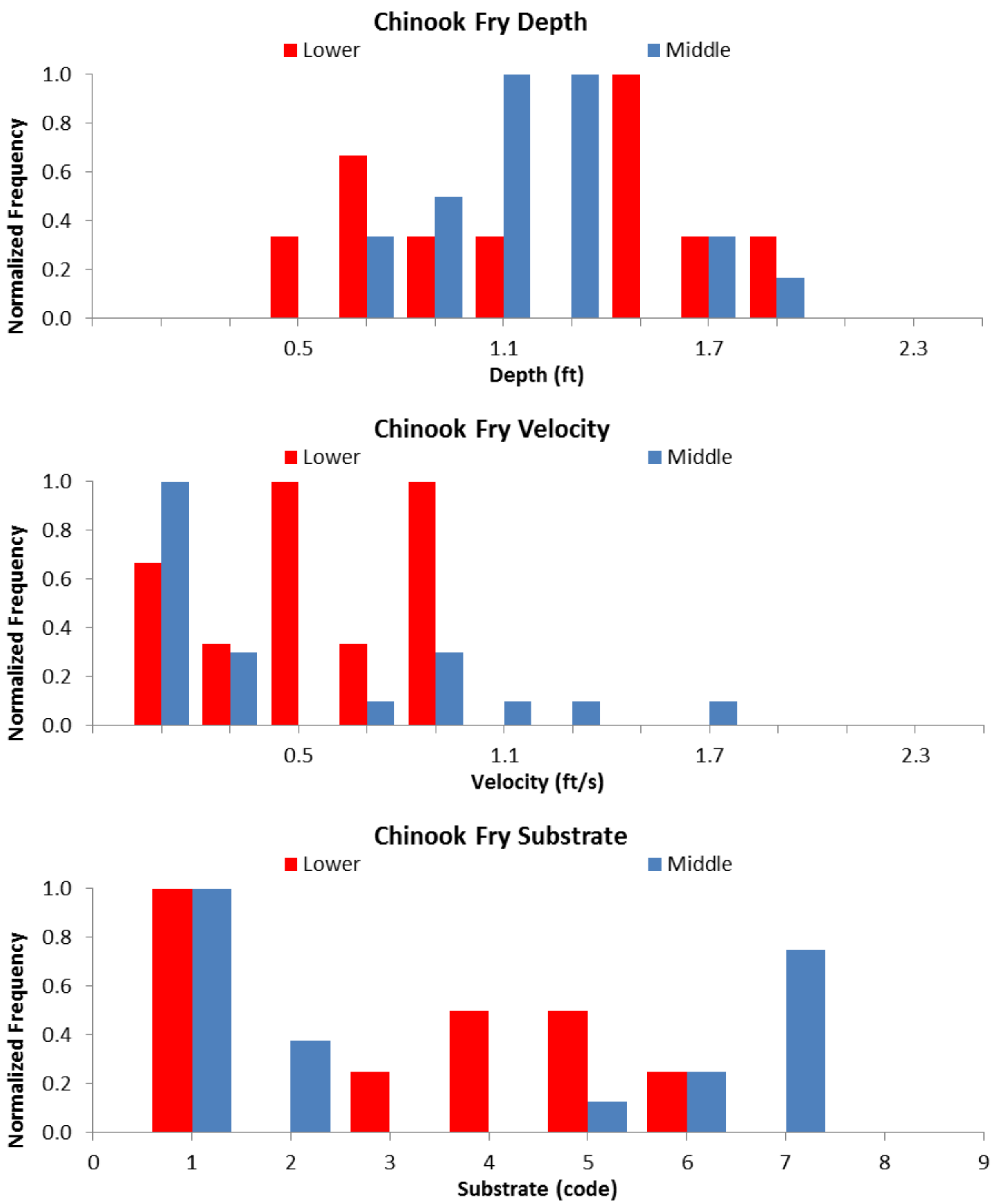


Figure 6.3-9. Histogram plots of 2012 HSC observations for juvenile Chinook salmon normalized to the maximum frequency equal to 1.0 for depth (top), velocity (middle), and substrate (bottom) microhabitat components, Susitna River, Alaska.

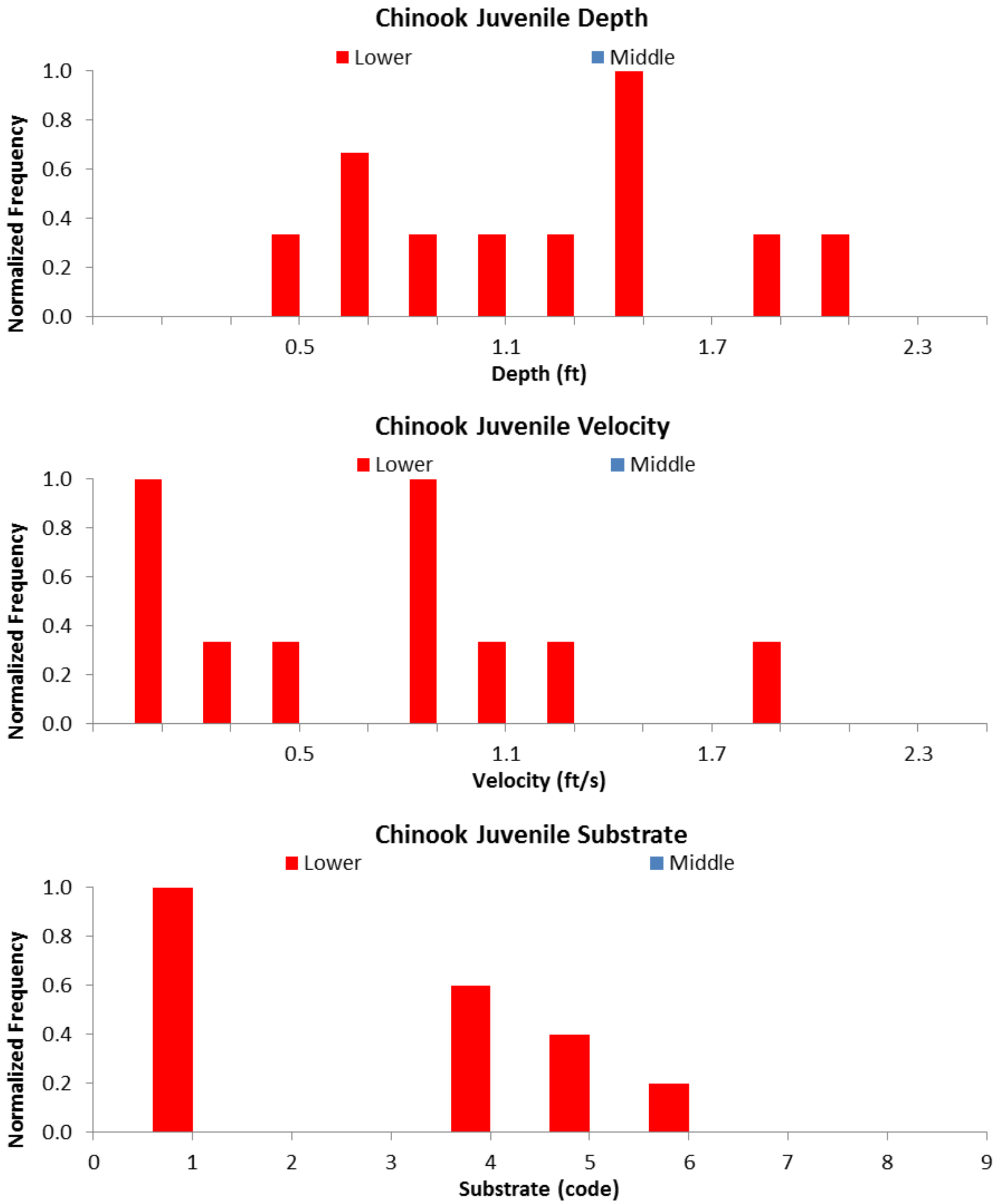


Figure 6.3-10. Histogram plots of 2012 HSC observations for juvenile Chinook salmon normalized to the maximum frequency equal to 1.0 for depth (top), velocity (middle), and substrate (bottom) microhabitat components, Susitna River, Alaska.

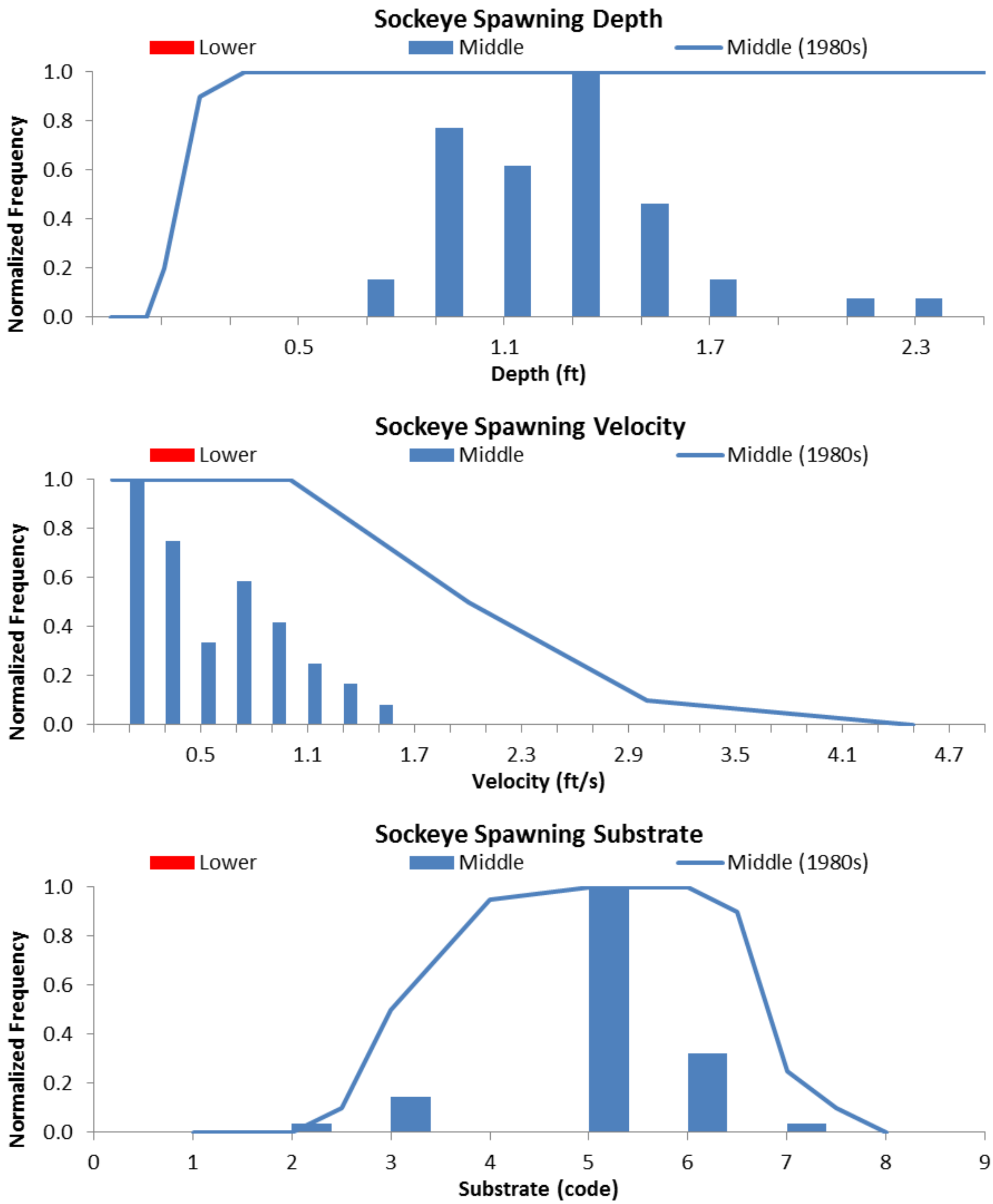


Figure 6.3-11. Histogram plots of 2012 HSC observations for sockeye salmon spawning normalized to the maximum frequency equal to 1.0 for depth (top), velocity (middle), and substrate (bottom) microhabitat components, Susitna River, Alaska.

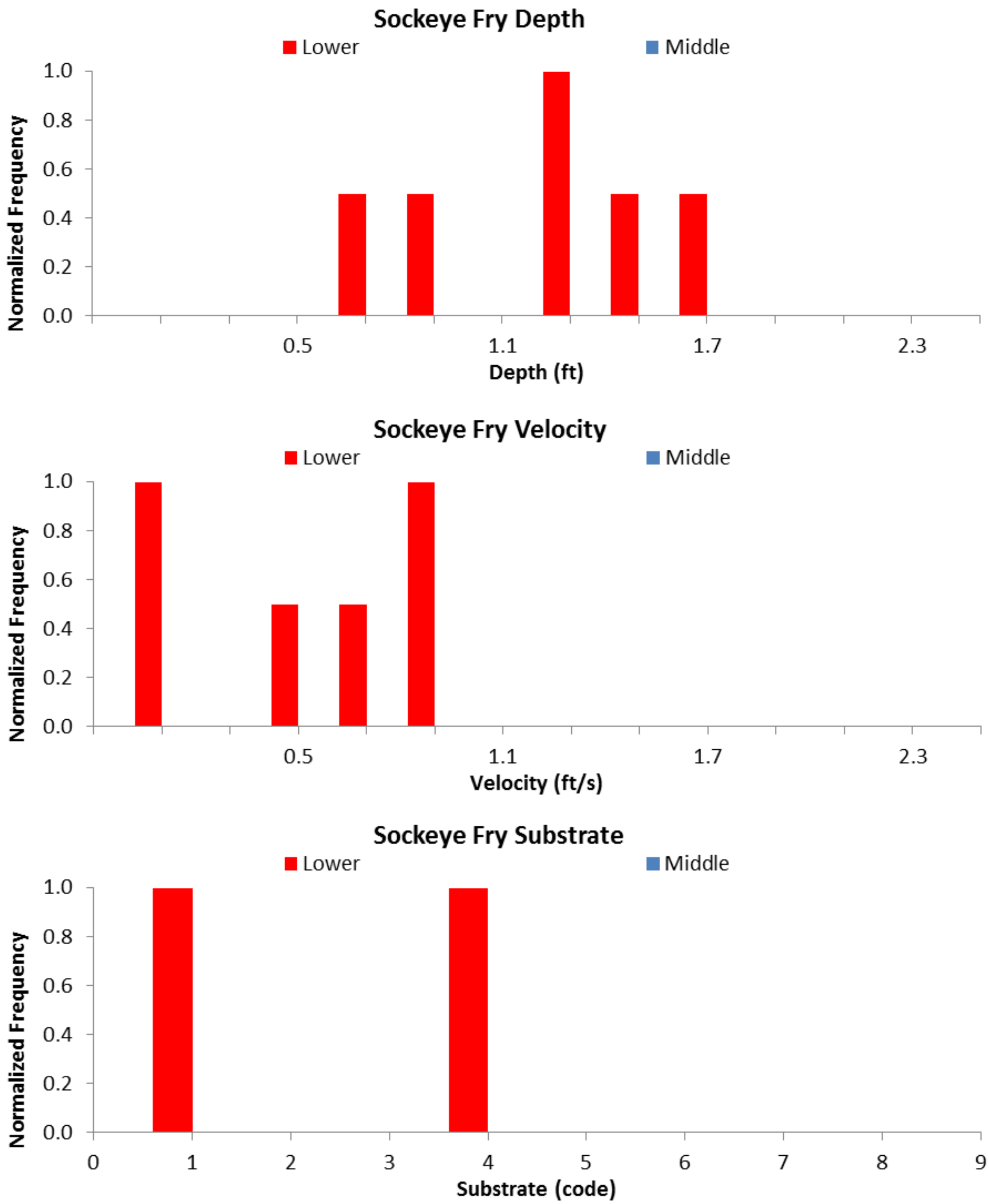


Figure 6.3-12. Histogram plots of 2012 HSC observations for fry sockeye salmon normalized to the maximum frequency equal to 1.0 for depth (top), velocity (middle), and substrate (bottom) microhabitat components, Susitna River, Alaska.

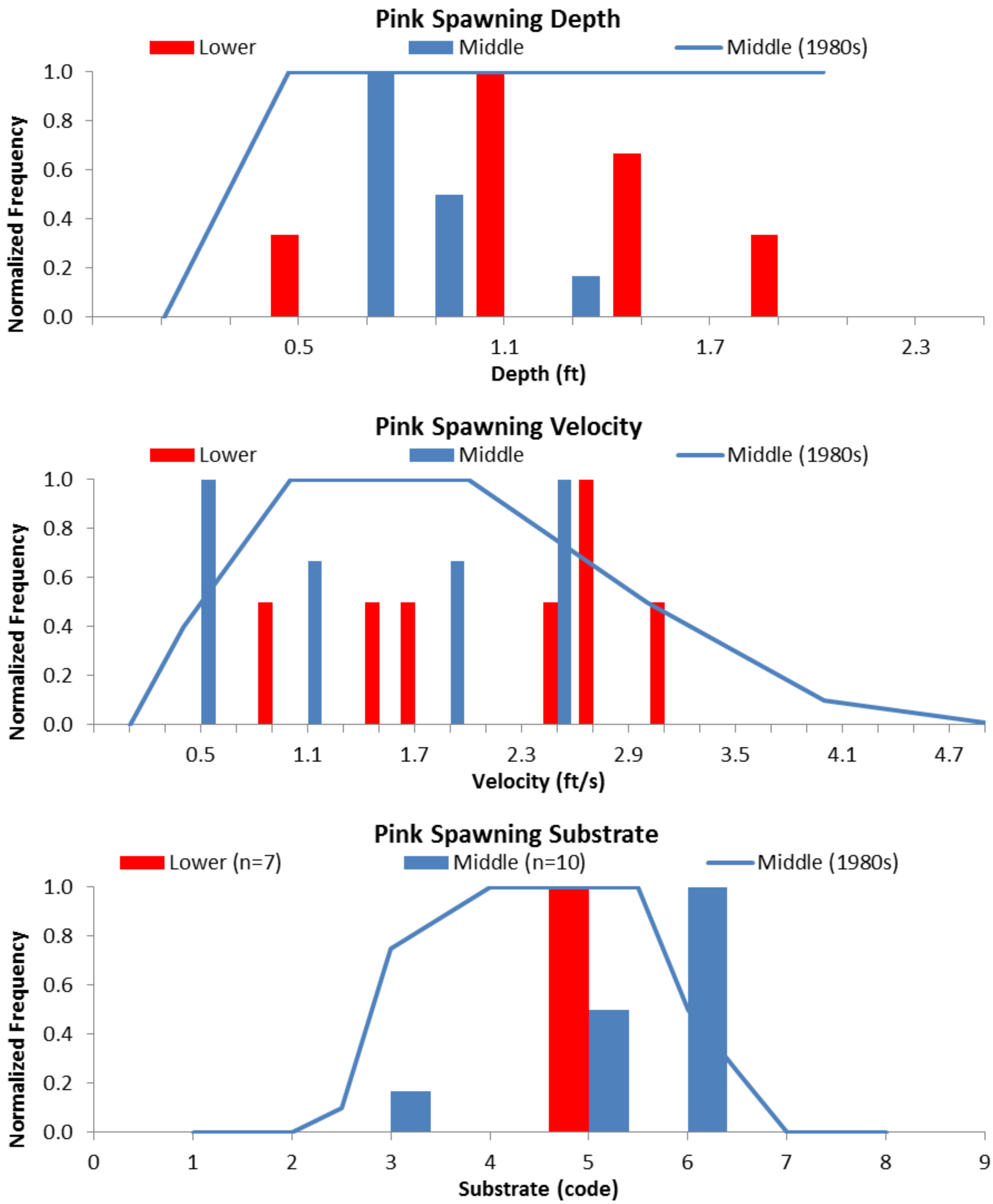


Figure 6.3-13. Histogram plots of 2012 HSC observations for pink salmon spawning normalized to the maximum frequency equal to 1.0 for depth (top), velocity (middle), and substrate (bottom) microhabitat components, Susitna River, Alaska.

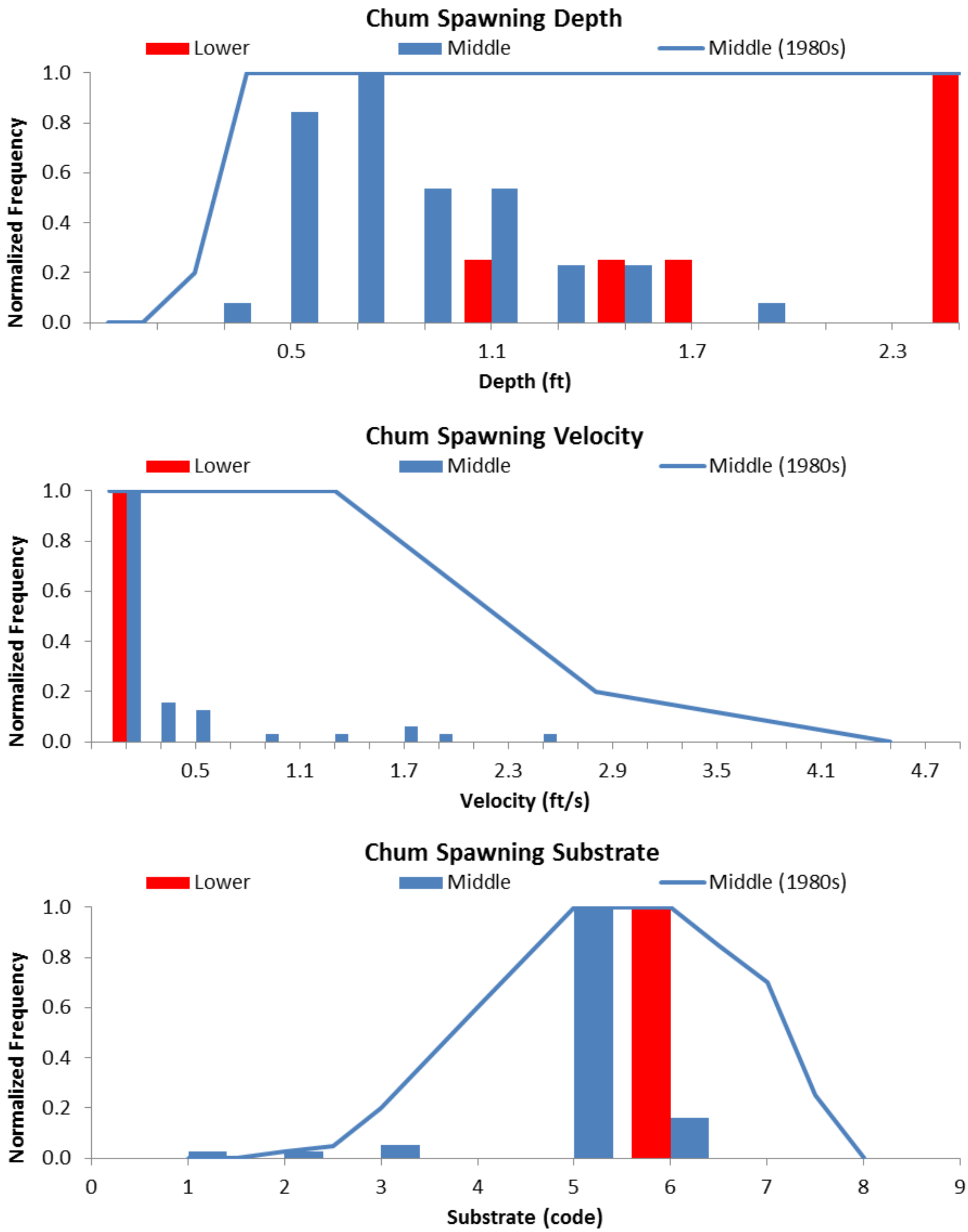


Figure 6.3-14. Histogram plots of 2012 HSC observations for chum salmon spawning normalized to the maximum frequency equal to 1.0 for depth (top), velocity (middle), and substrate (bottom) microhabitat components, Susitna River, Alaska.

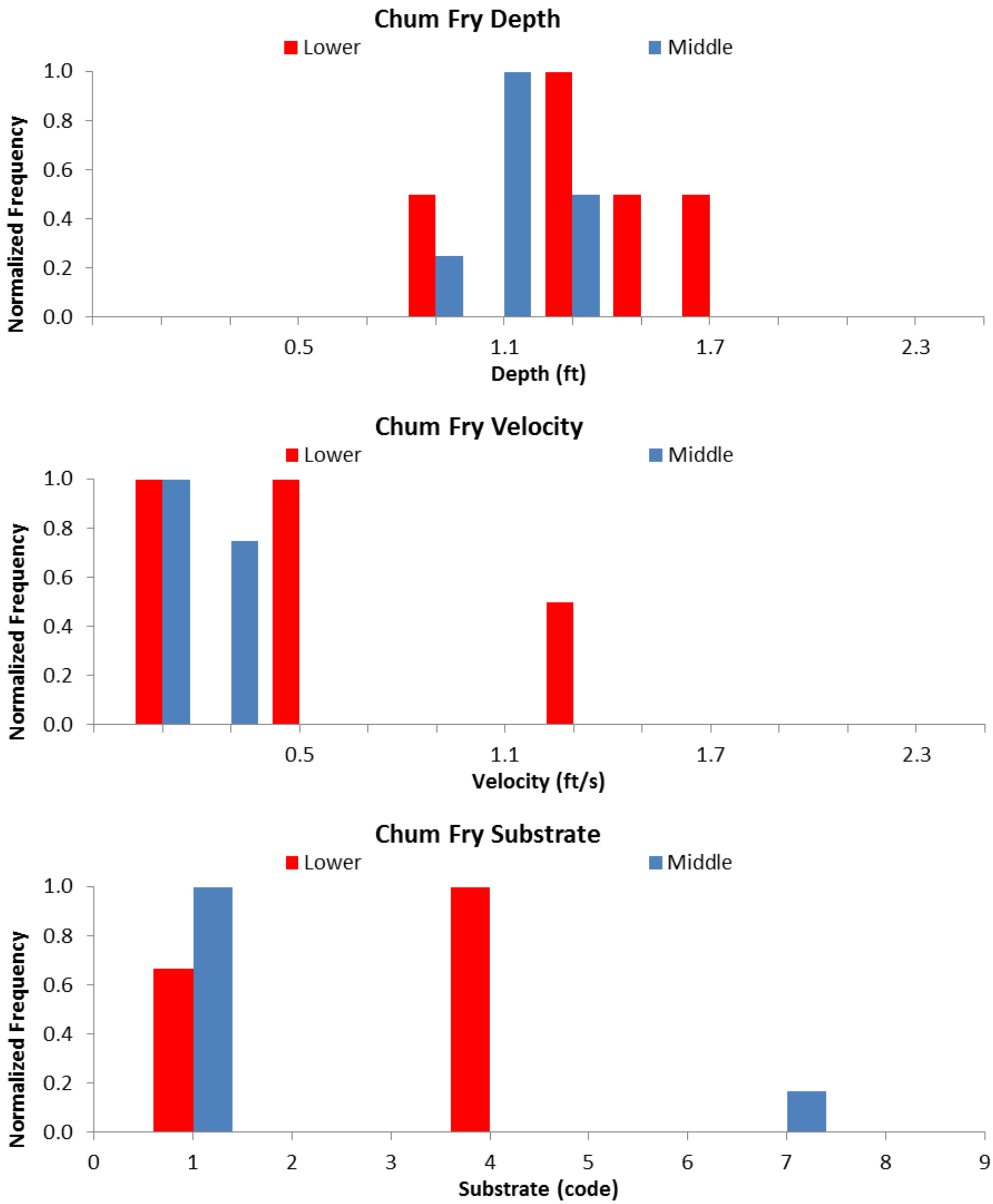


Figure 6.3-15. Histogram plots of 2012 HSC observations for fry chum salmon normalized to the maximum frequency equal to 1.0 for depth (top), velocity (middle), and substrate (bottom) microhabitat components, Susitna River, Alaska.

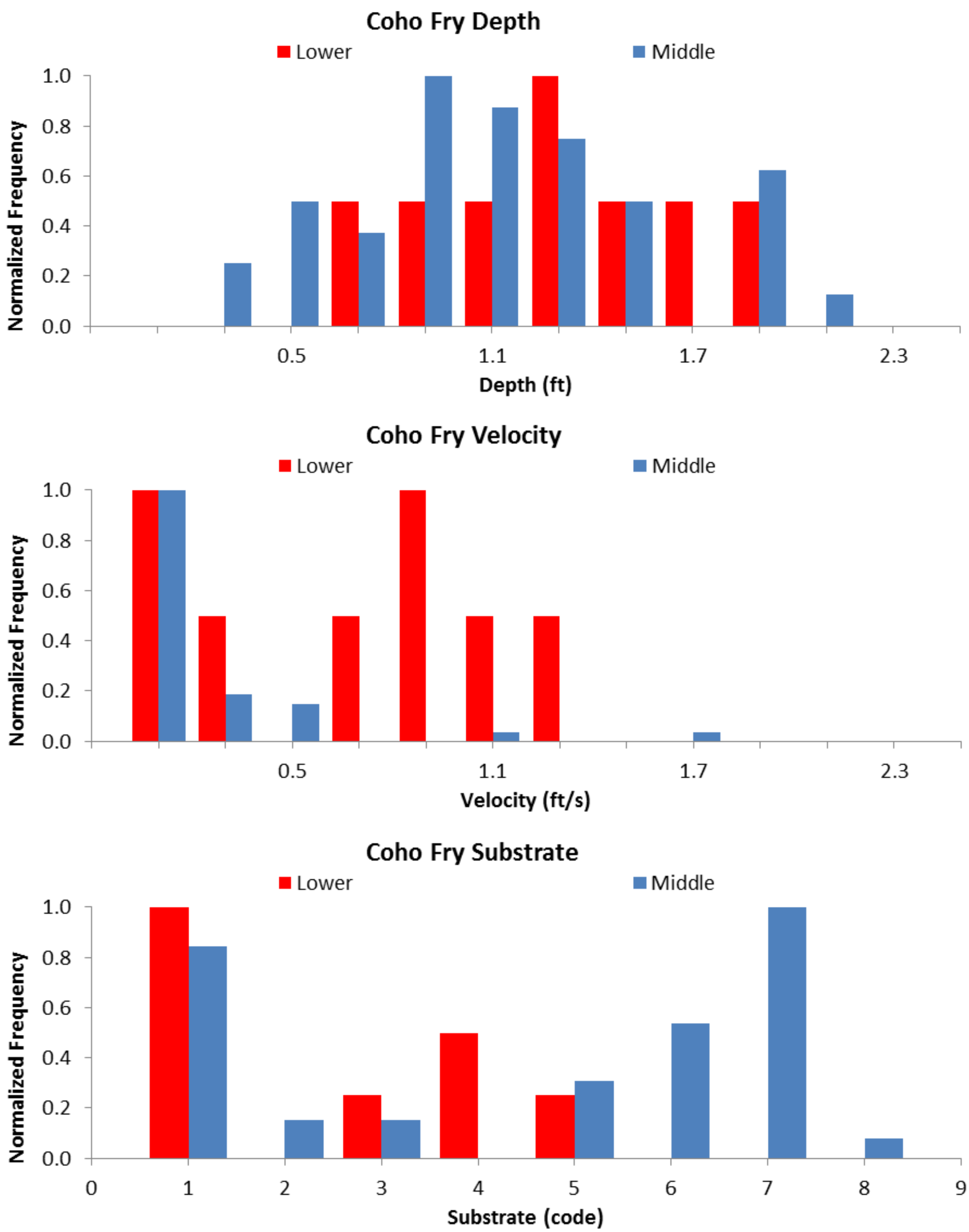


Figure 6.3-16. Histogram plots of 2012 HSC observations for fry coho salmon normalized to the maximum frequency equal to 1.0 for depth (top), velocity (middle), and substrate (bottom) microhabitat components, Susitna River, Alaska.

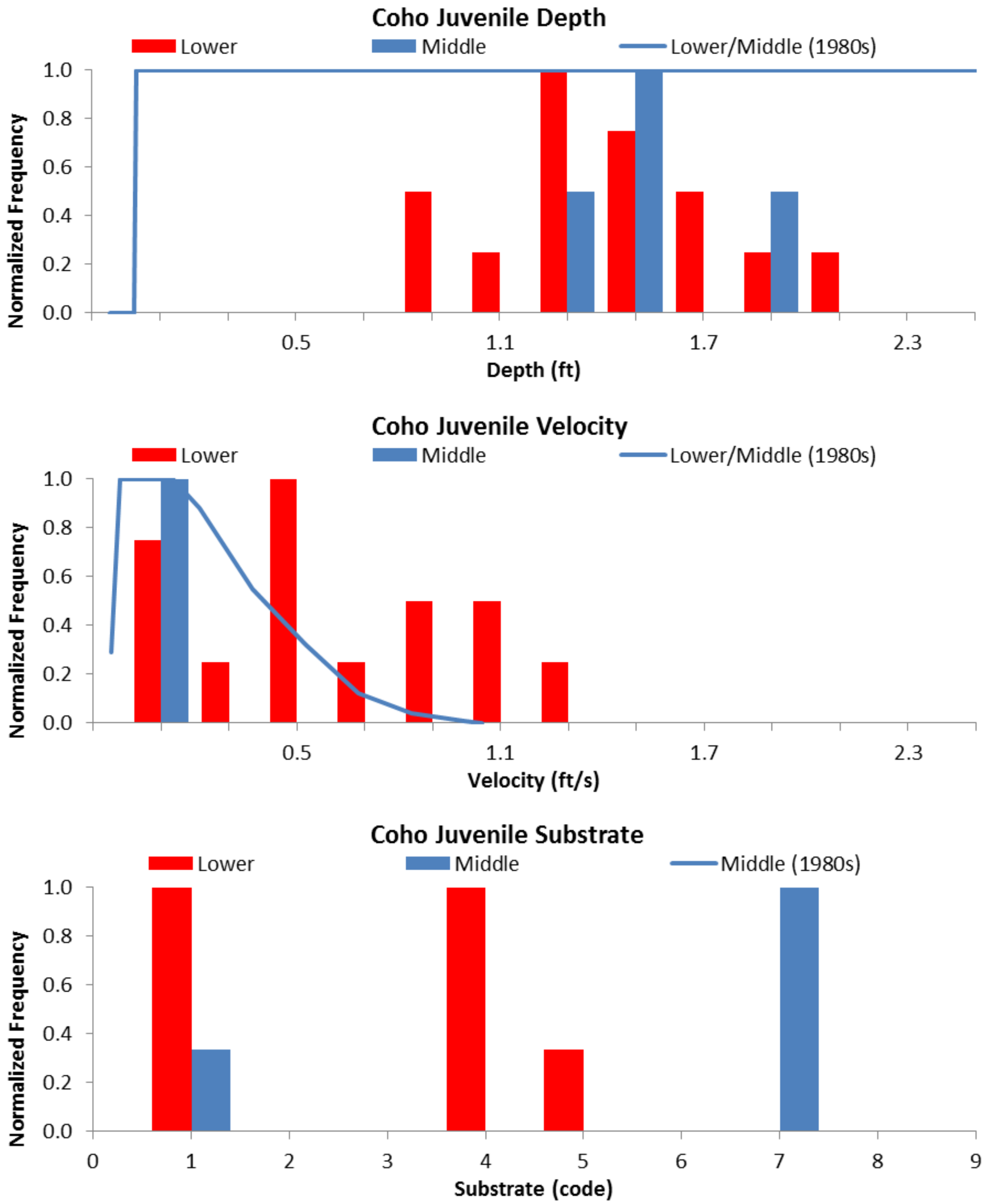


Figure 6.3-17. Histogram plots of 2012 HSC observations for juvenile coho salmon normalized to the maximum frequency equal to 1.0 for depth (top), velocity (middle), and substrate (bottom) microhabitat components, Susitna River, Alaska.

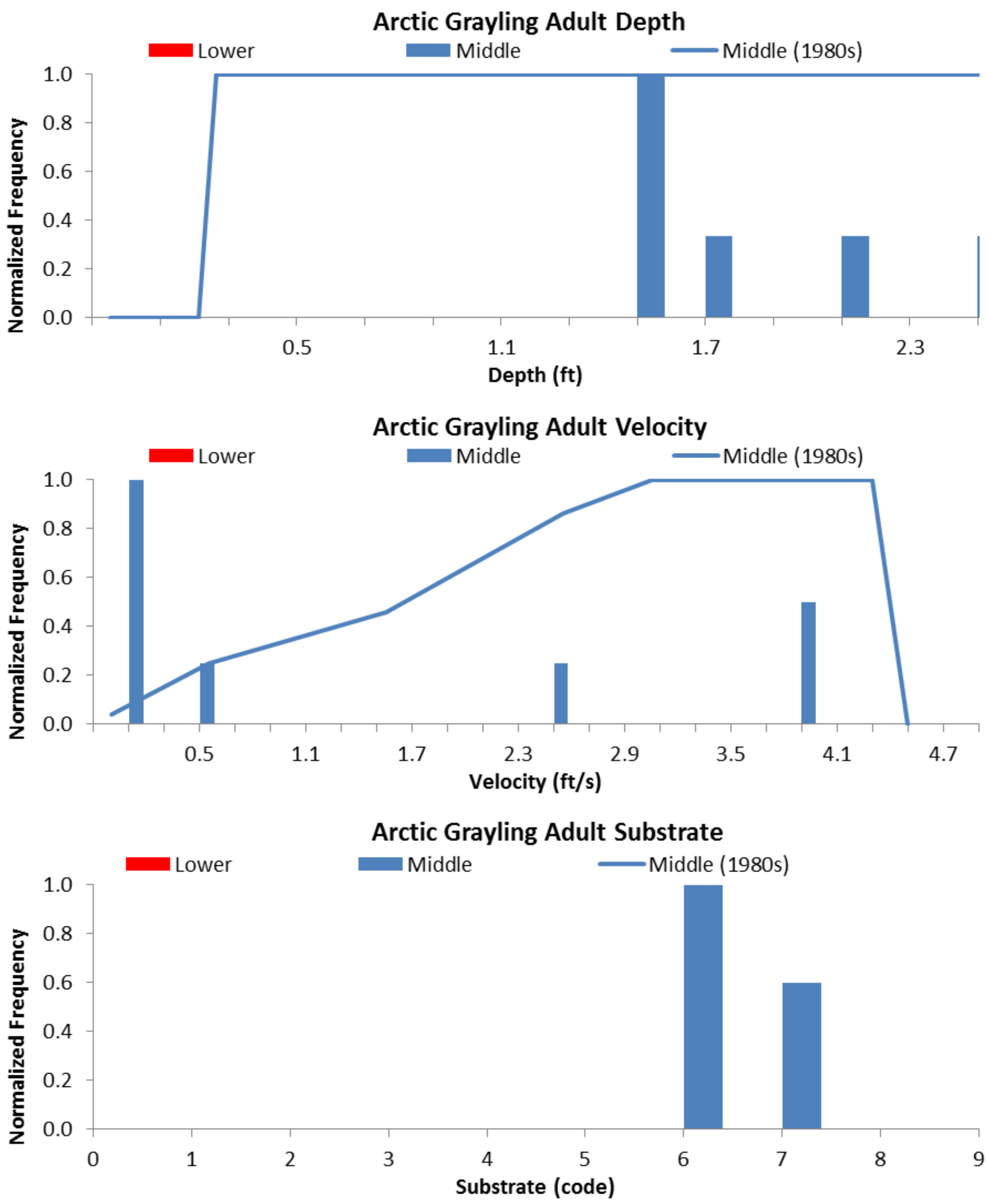


Figure 6.3-18. Histogram plots of 2012 HSC observations for adult artic grayling normalized to the maximum frequency equal to 1.0 for depth (top), velocity (middle), and substrate (bottom) microhabitat components, Susitna River, Alaska.

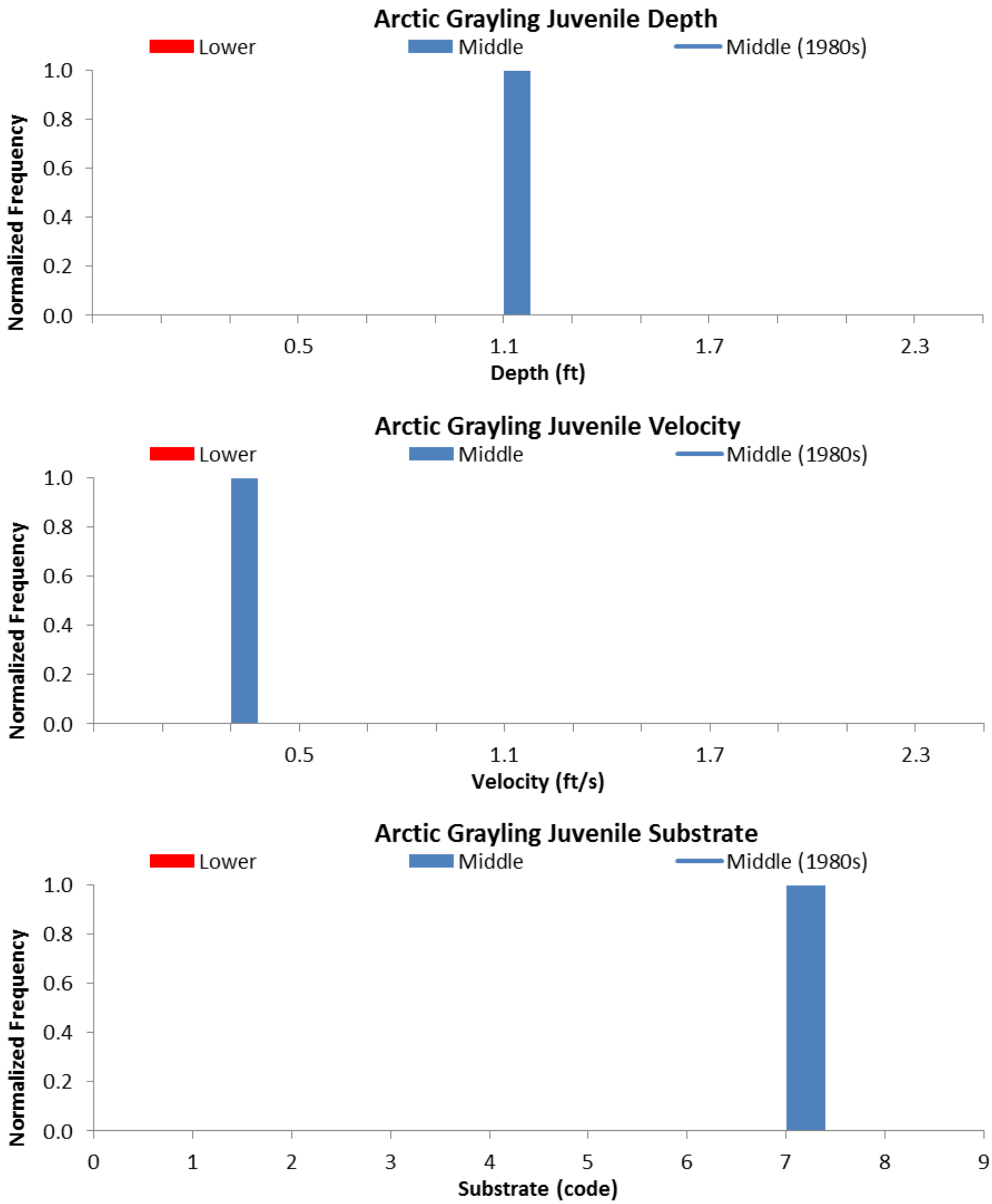


Figure 6.3-19. Histogram plots of 2012 HSC observations for juvenile arctic grayling normalized to the maximum frequency equal to 1.0 for depth (top), velocity (middle), and substrate (bottom) microhabitat components, Susitna River, Alaska.

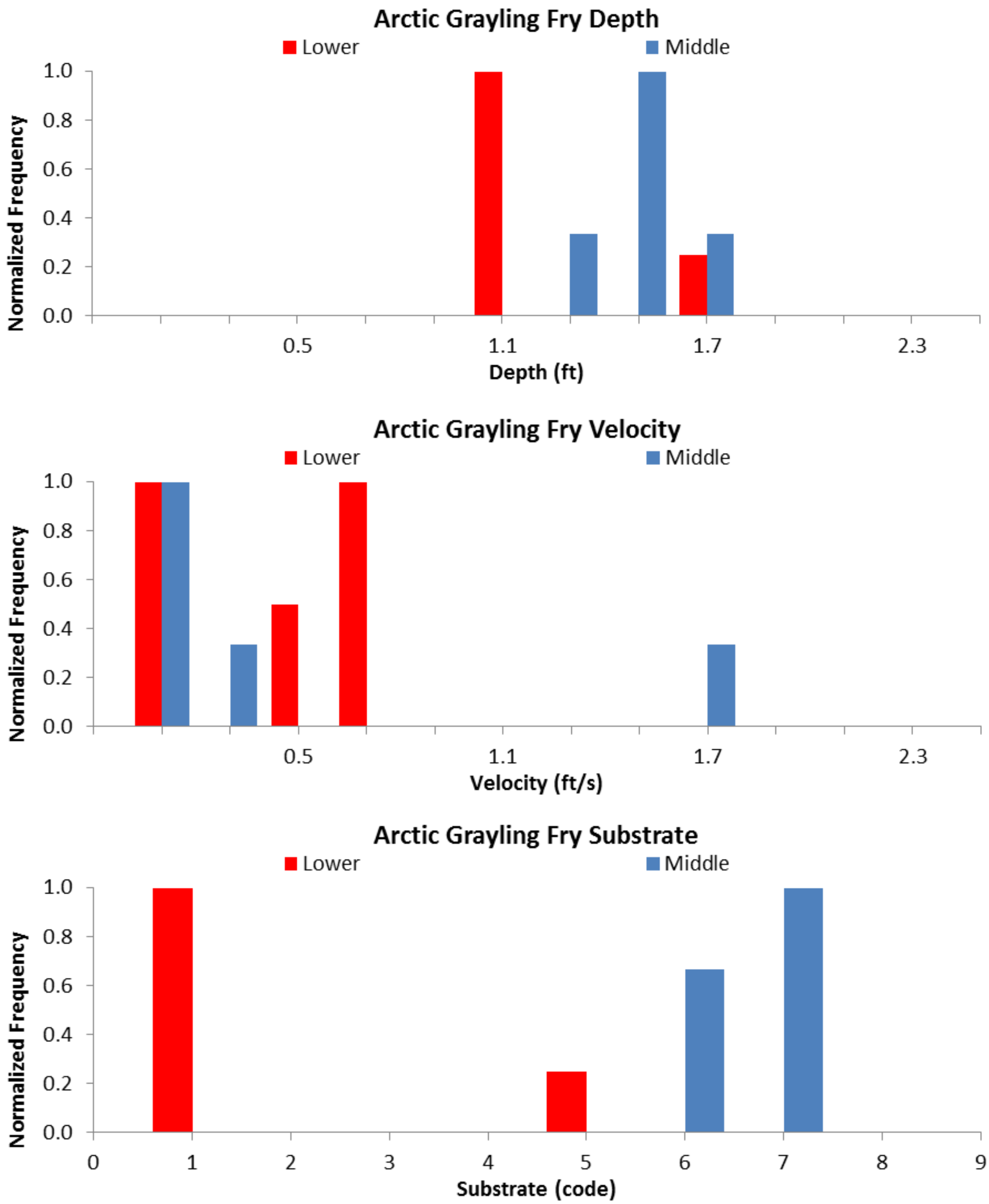


Figure 6.3-20. Histogram plots of 2012 HSC observations for fry arctic grayling normalized to the maximum frequency equal to 1.0 for depth (top), velocity (middle), and substrate (bottom) microhabitat components, Susitna River, Alaska.

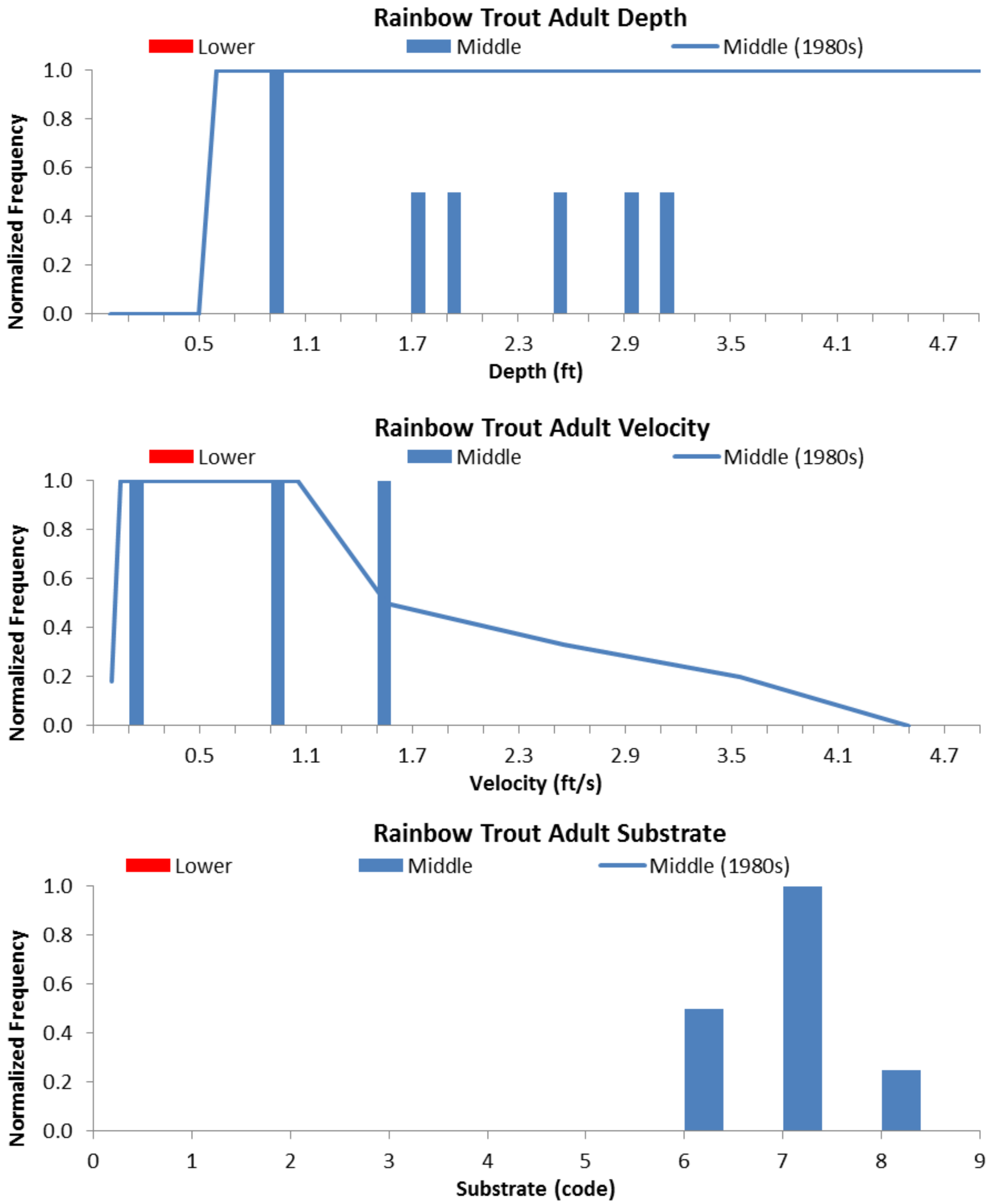


Figure 6.3-21. Histogram plots of 2012 HSC observations for adult rainbow trout normalized to the maximum frequency equal to 1.0 for depth (top), velocity (middle), and substrate (bottom) microhabitat components, Susitna River, Alaska.

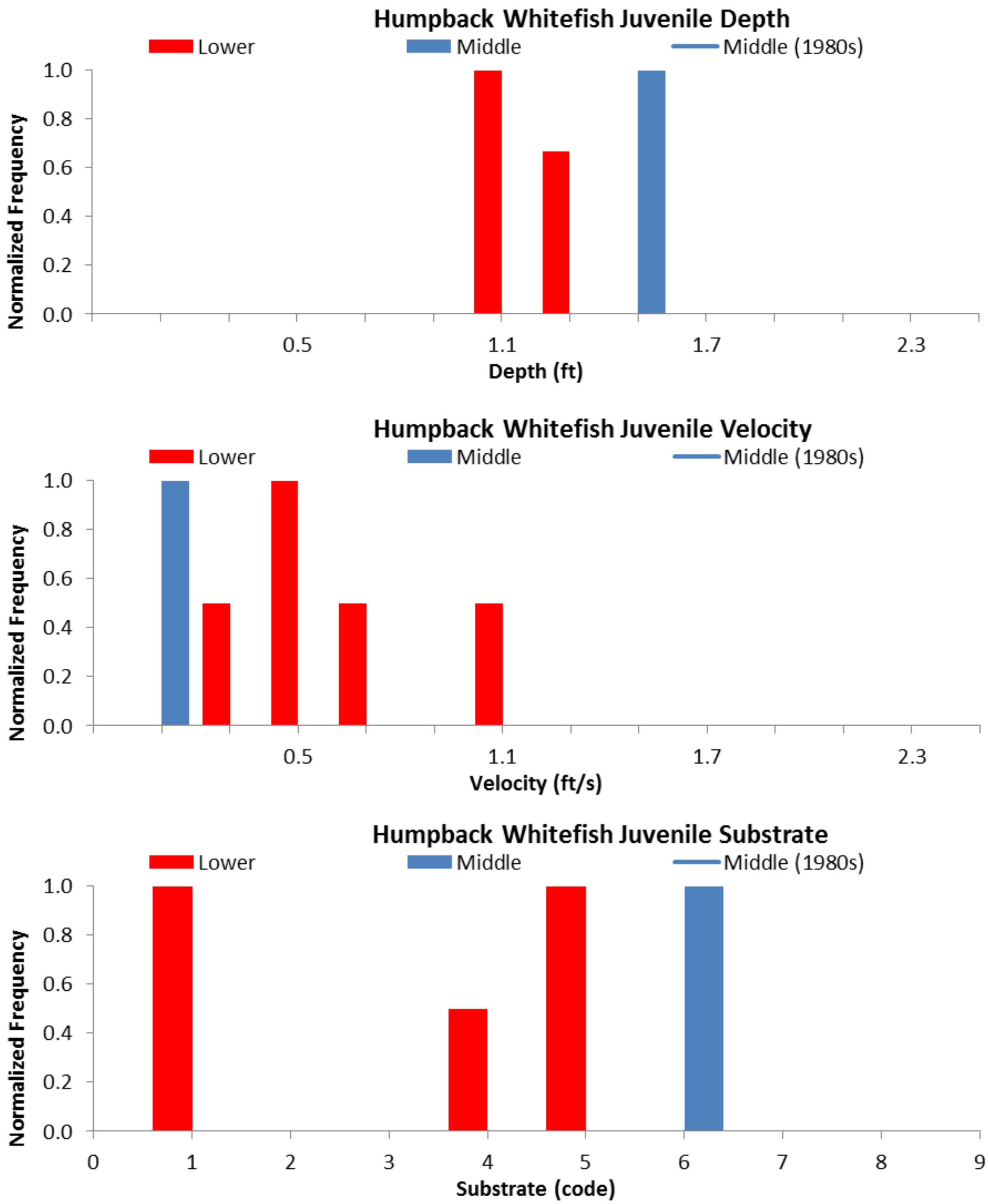


Figure 6.3-22. Histogram plots of 2012 HSC observations for juvenile humpback whitefish normalized to the maximum frequency equal to 1.0 for depth (top), velocity (middle), and substrate (bottom) microhabitat components, Susitna River, Alaska.

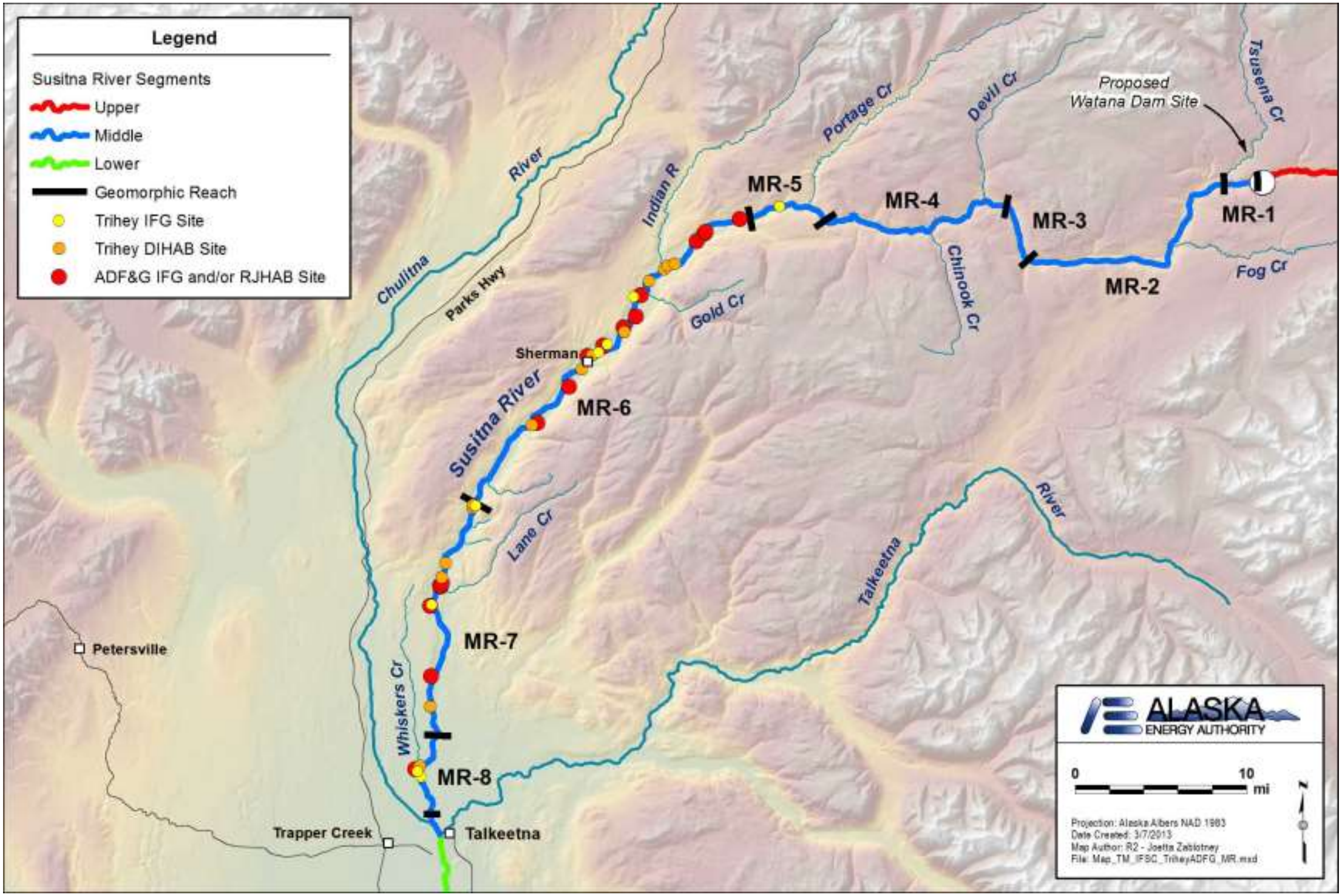


Figure 7.1-1. Locations of instream flow habitat modeling sites established in the Middle Segment of the Susitna River during the 1980s Su-Hydro studies.

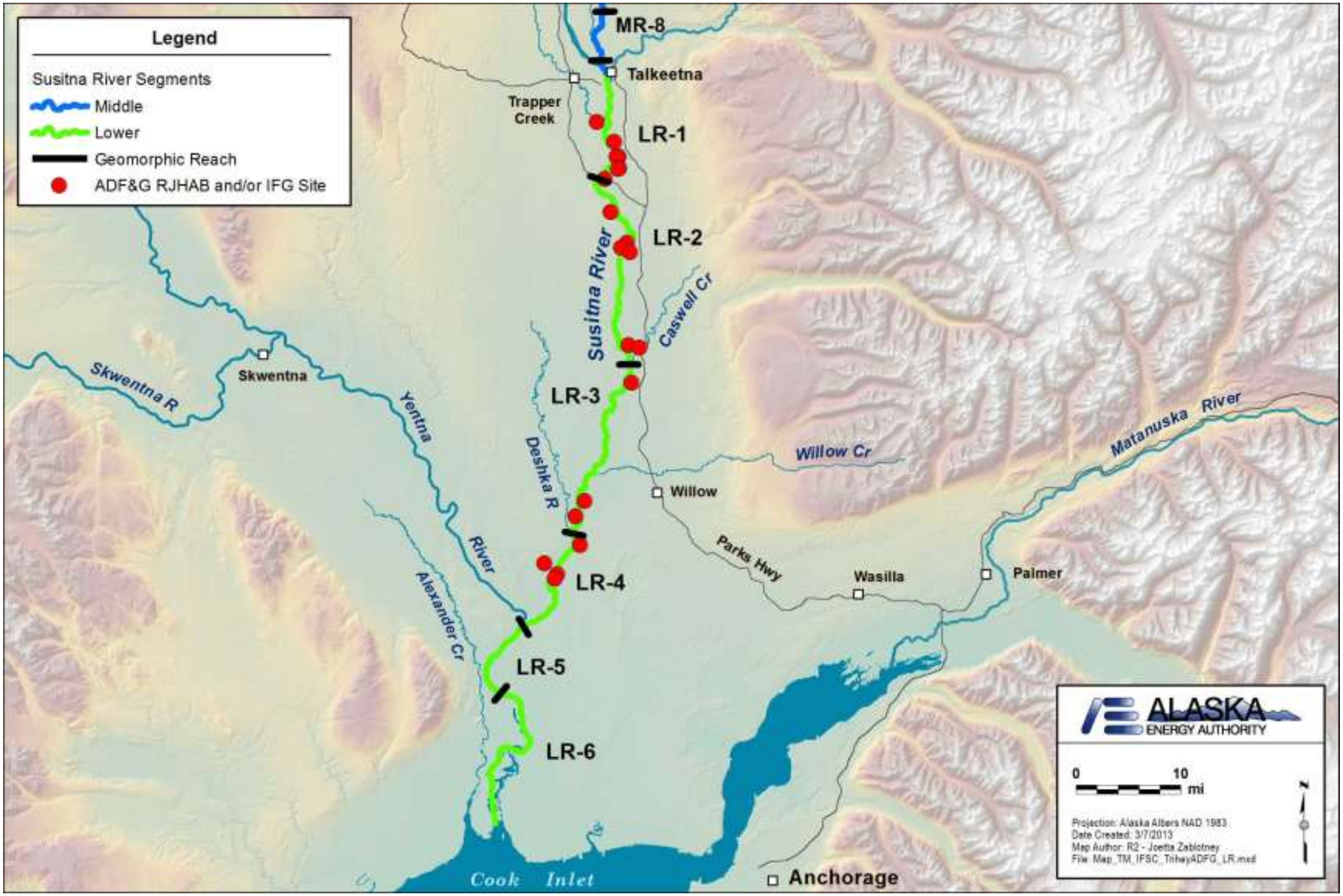


Figure 7.1-2. Locations of instream flow habitat modeling sites established in the Lower Segment of the Susitna River during the 1980s Su-Hydro studies.

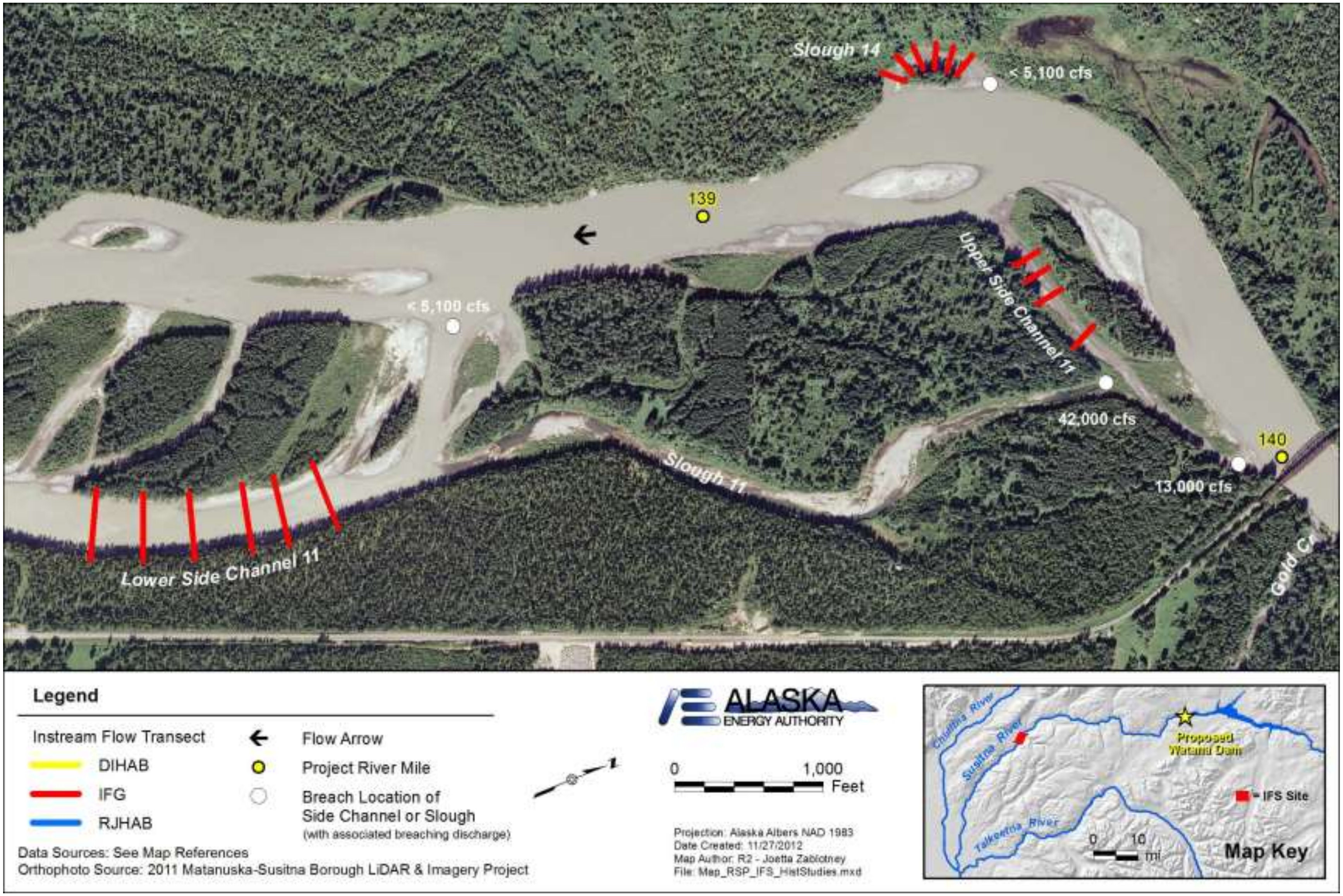


Figure 7.1-3. Locations of instream flow transects and model types applied during the 1980s Su-Hydro studies in lower and upper Side Channel 11 and in Slough 11, located near Gold Creek. Breaching flows based on those studies are also depicted for various side channel and side slough habitats.

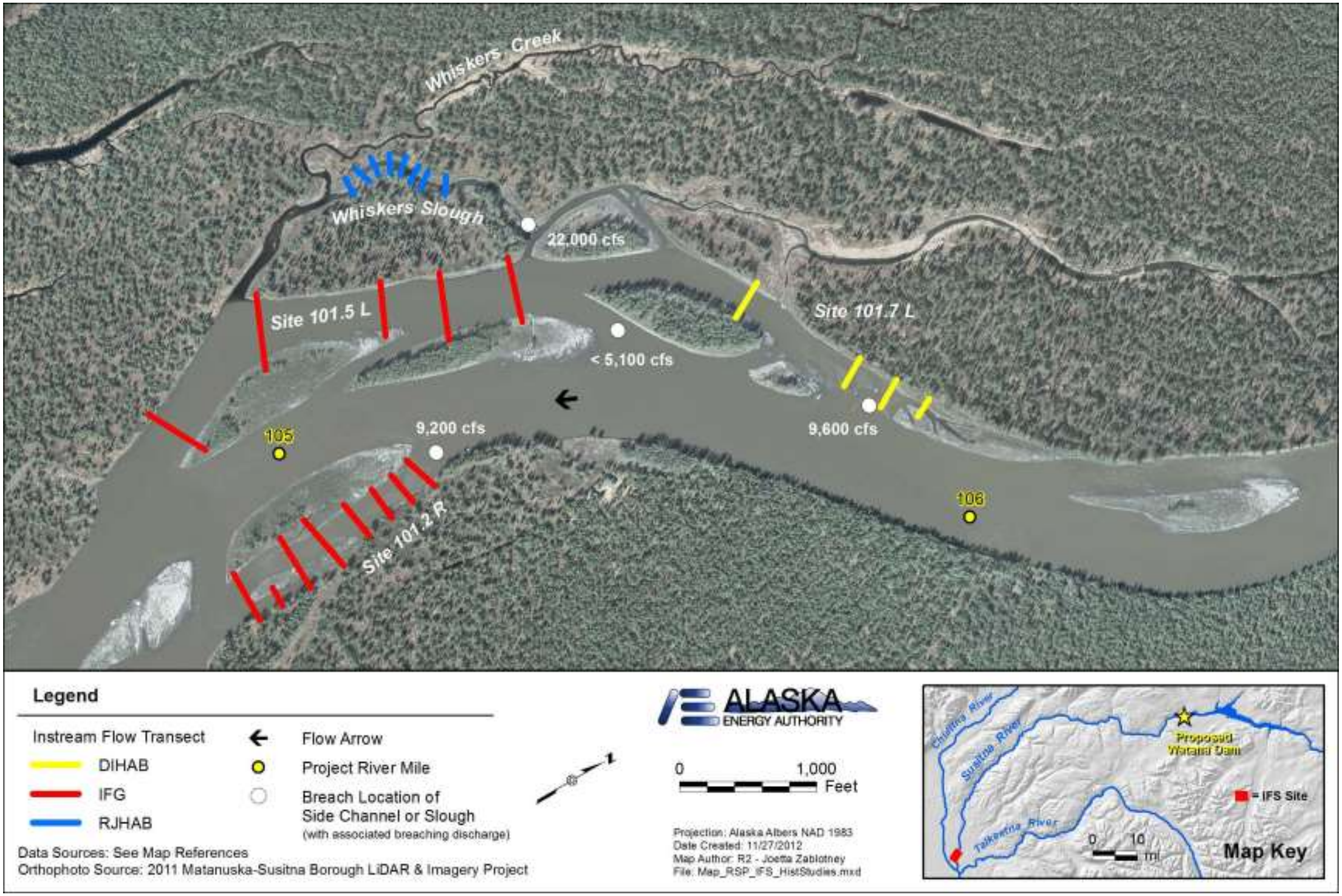


Figure 7.1-4. Locations of instream flow transects and model types applied during the 1980s Su-Hydro studies in the Whiskers Slough complex. Breaching flows based on those studies are also depicted for various side channel and side slough habitats.

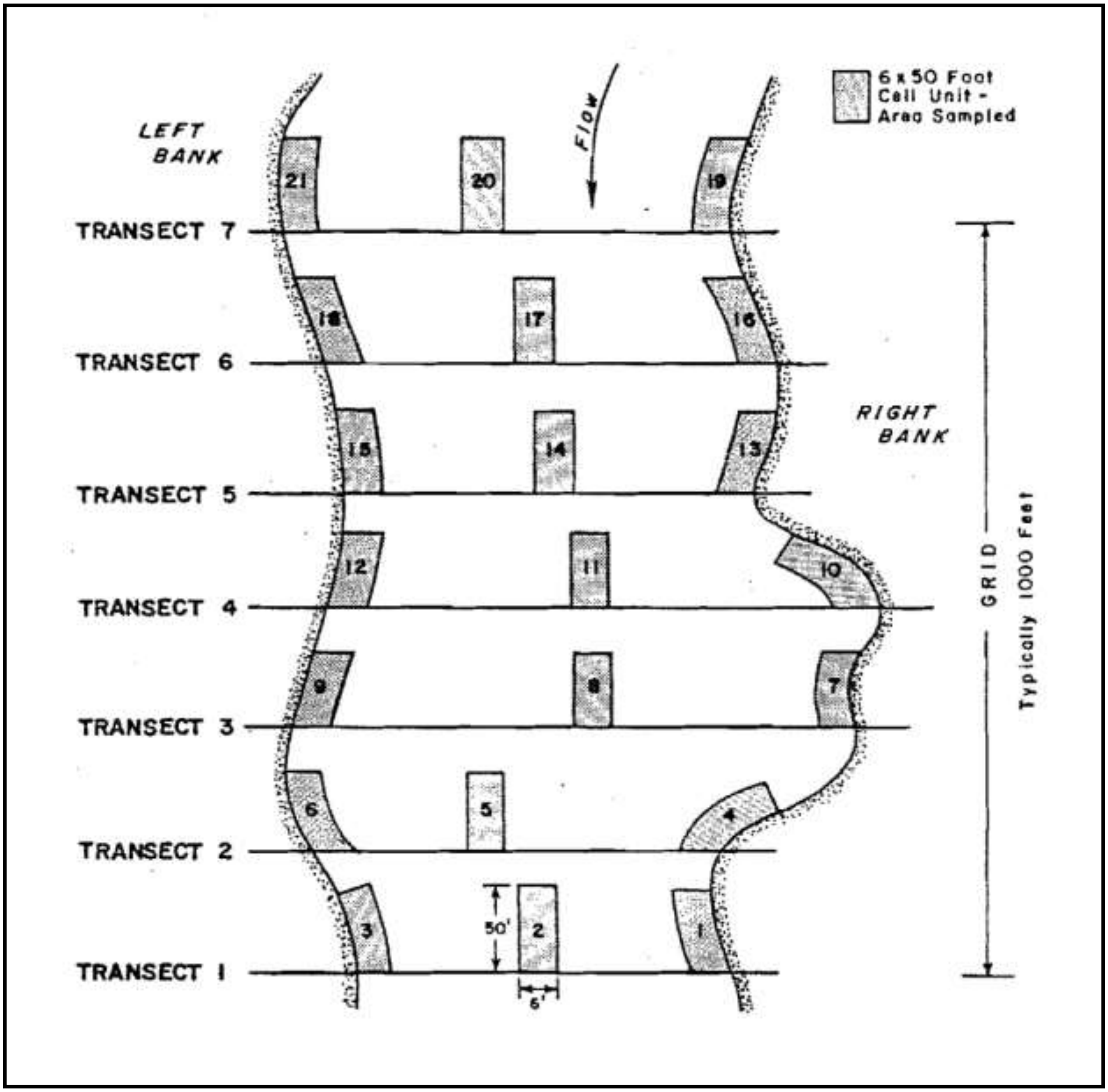


Figure 7.1-5. Illustration of the grid and cell sampling scheme employed at RJHAB modeling study sites. Sources: Marshall et al. (1984).

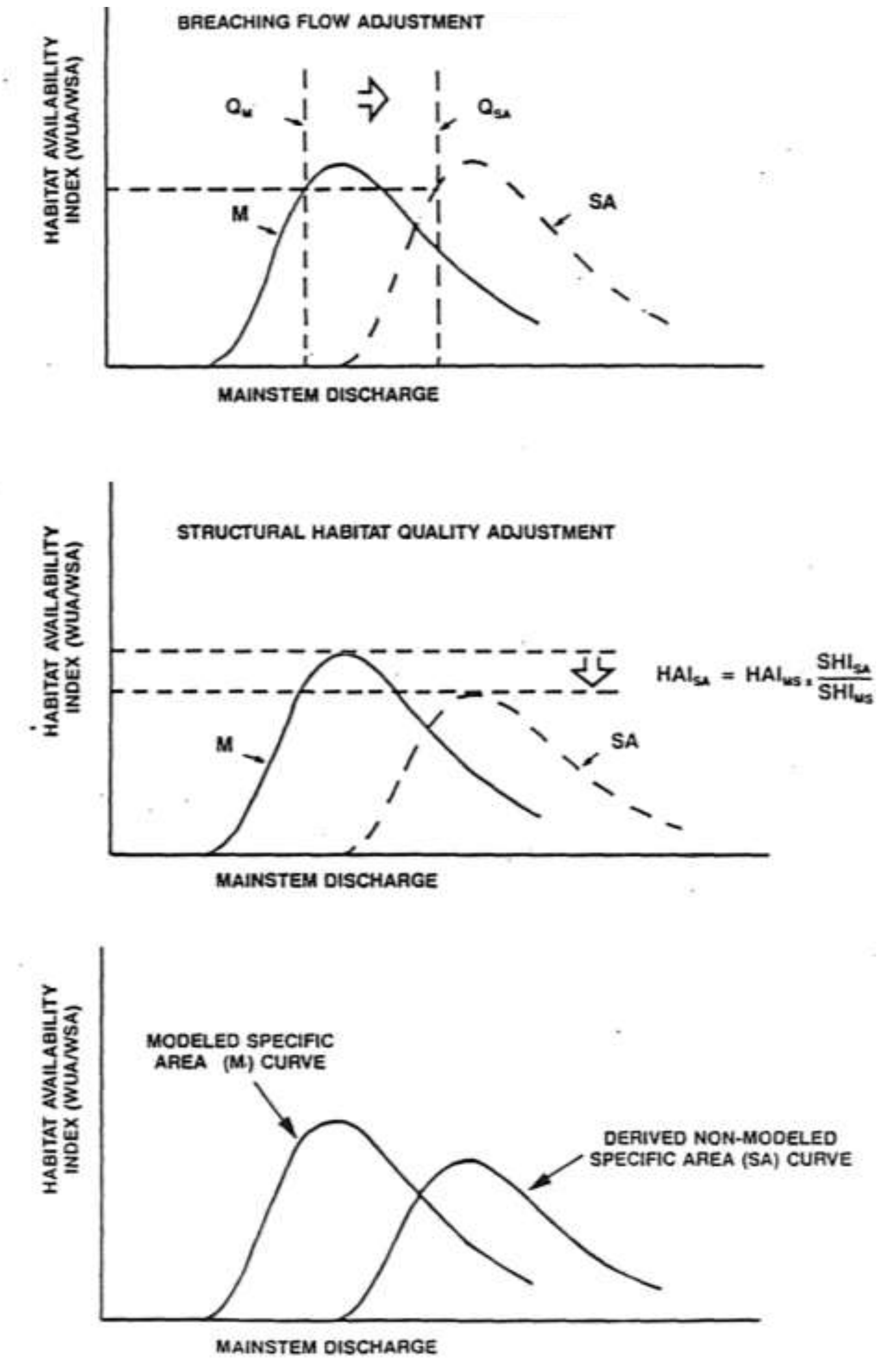


Figure 7.1-6. Conceptual figures illustrating procedure used for deriving non-modeled specific area (sa) Habitat Availability Index curve using a modeled curve in a mainstem (ms) habitat, as applied during the 1980s Su-Hydro Studies (see Aaserude et al. 1985; Steward et al. 1985). The procedure included lateral shifts (upper figure) due to adjustments from differences in breaching flows (Qms, Qsa) as well as vertical shifts (middle figure) proportional to structural habitat indices (SHIsa/SHIms) to account for differences in structural habitat quality. The lower figure shows final hypothetical modeled and non-modeled specific area curves. Source: Aaserude et al. (1985).

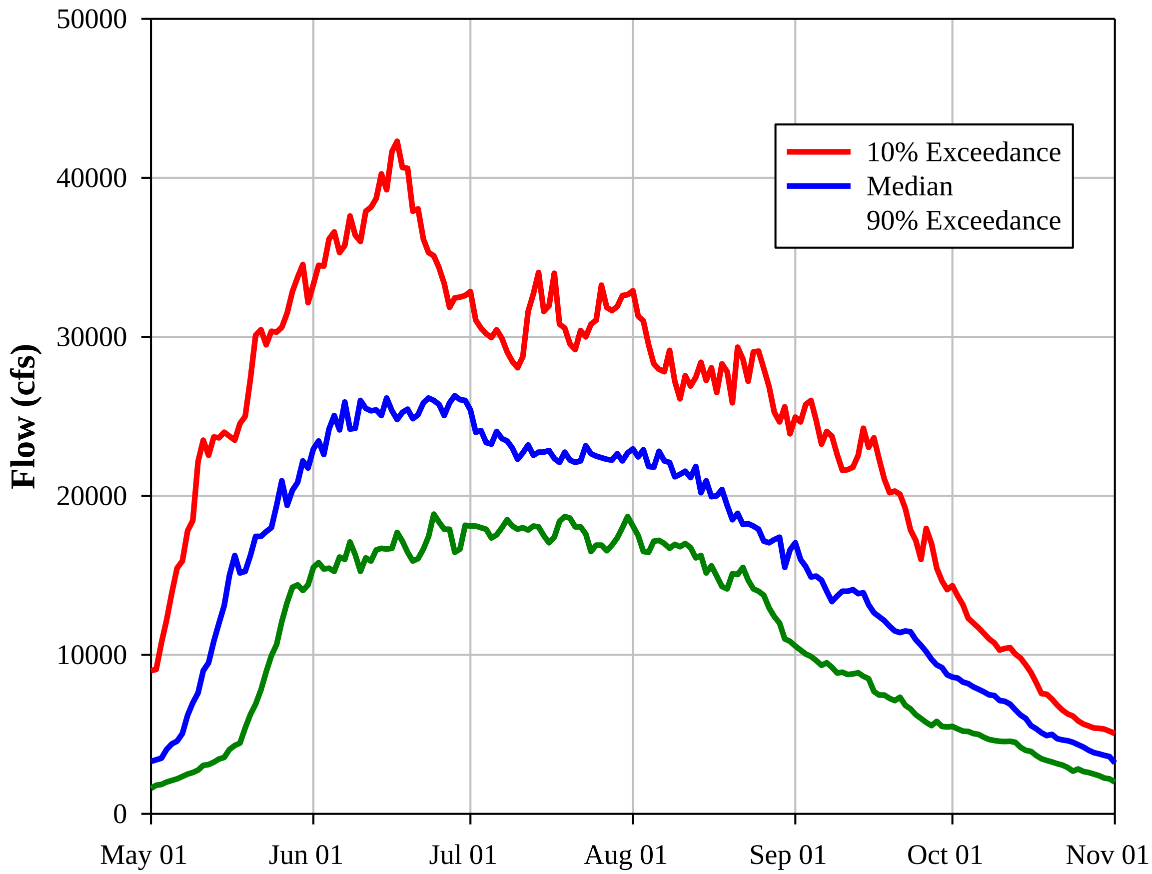


Figure 7.2-1. Exceedance flow values (USGS gage at Gold Creek), target sampling flows and anticipated model extrapolation range for the Susitna River, Alaska.

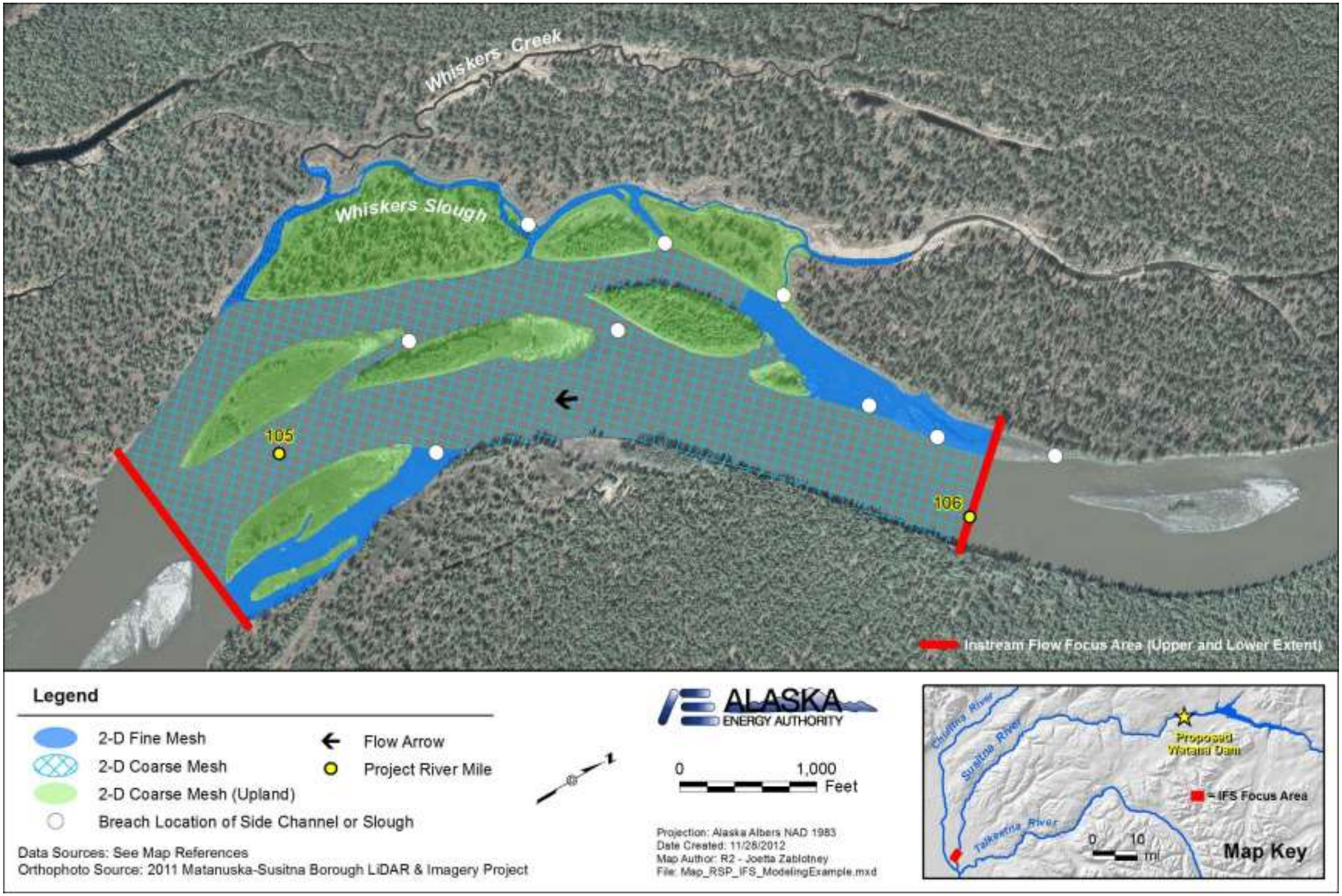


Figure 7.2-2. Conceptual layout of 2-D coarse and fine mesh modeling within the proposed Whiskers Slough Focus Area.

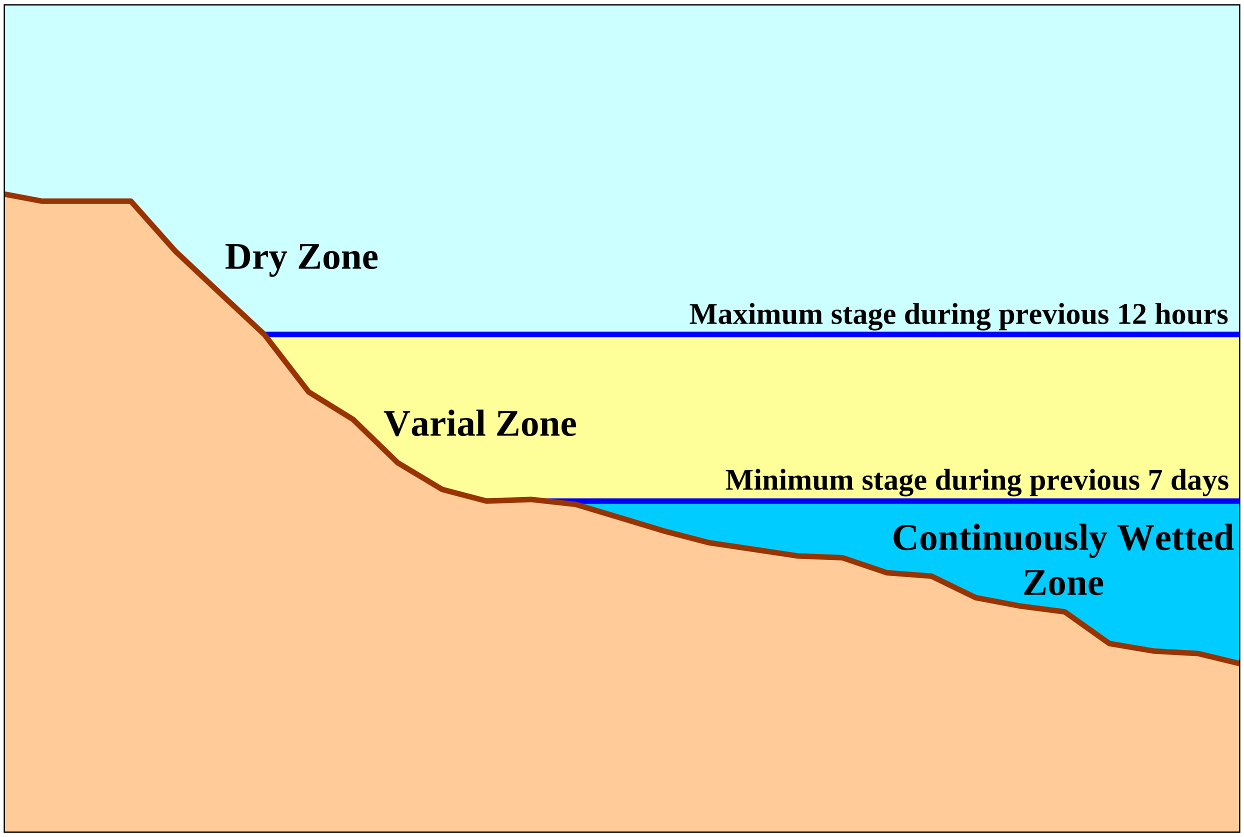


Figure 7.2-3. Conceptual framework of the varial zone model.

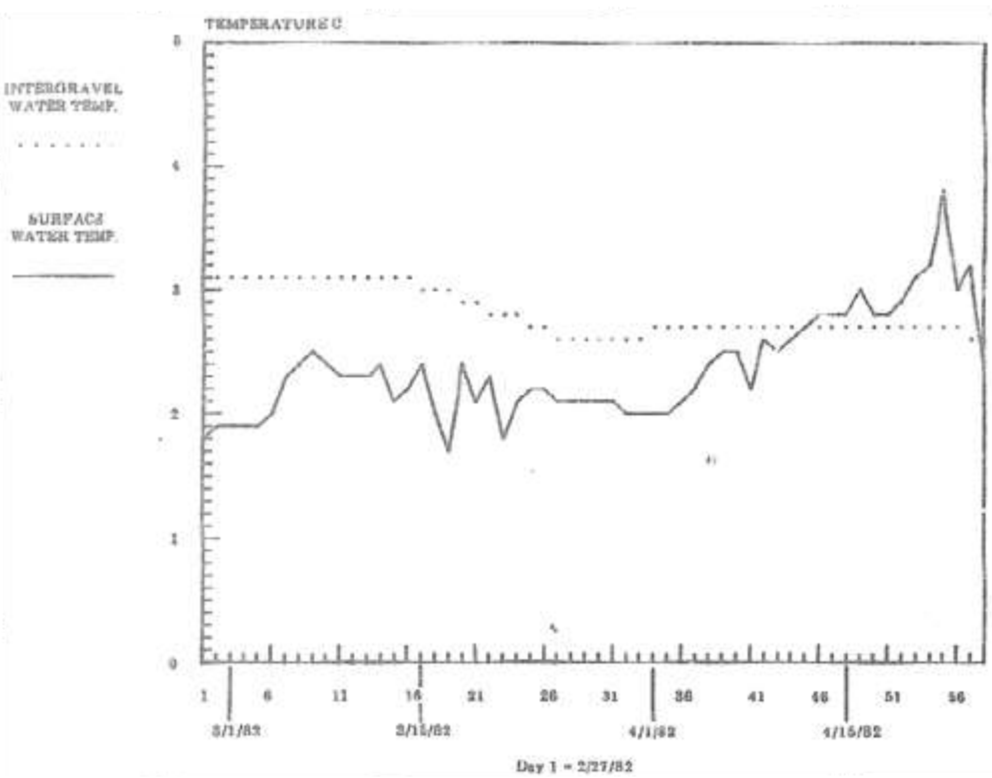


Figure 8.1-1. Mean daily intergravel and surface water temperature data from a spawning site in Slough 8A. Source: Trihey (1982).

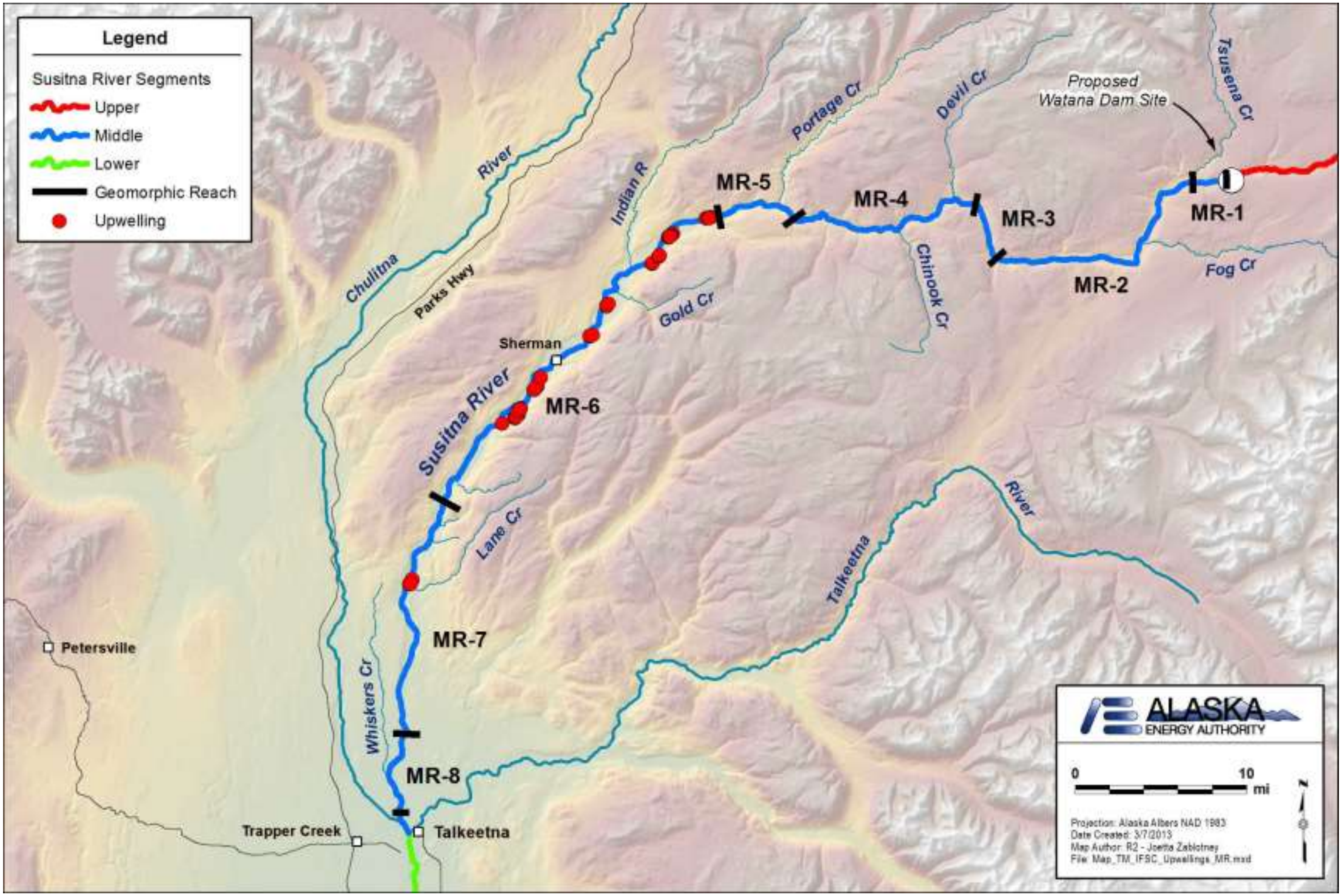


Figure 8.1-2. Upwelling locations in the Middle Susitna River reported by Estes and Schmidt (1983).

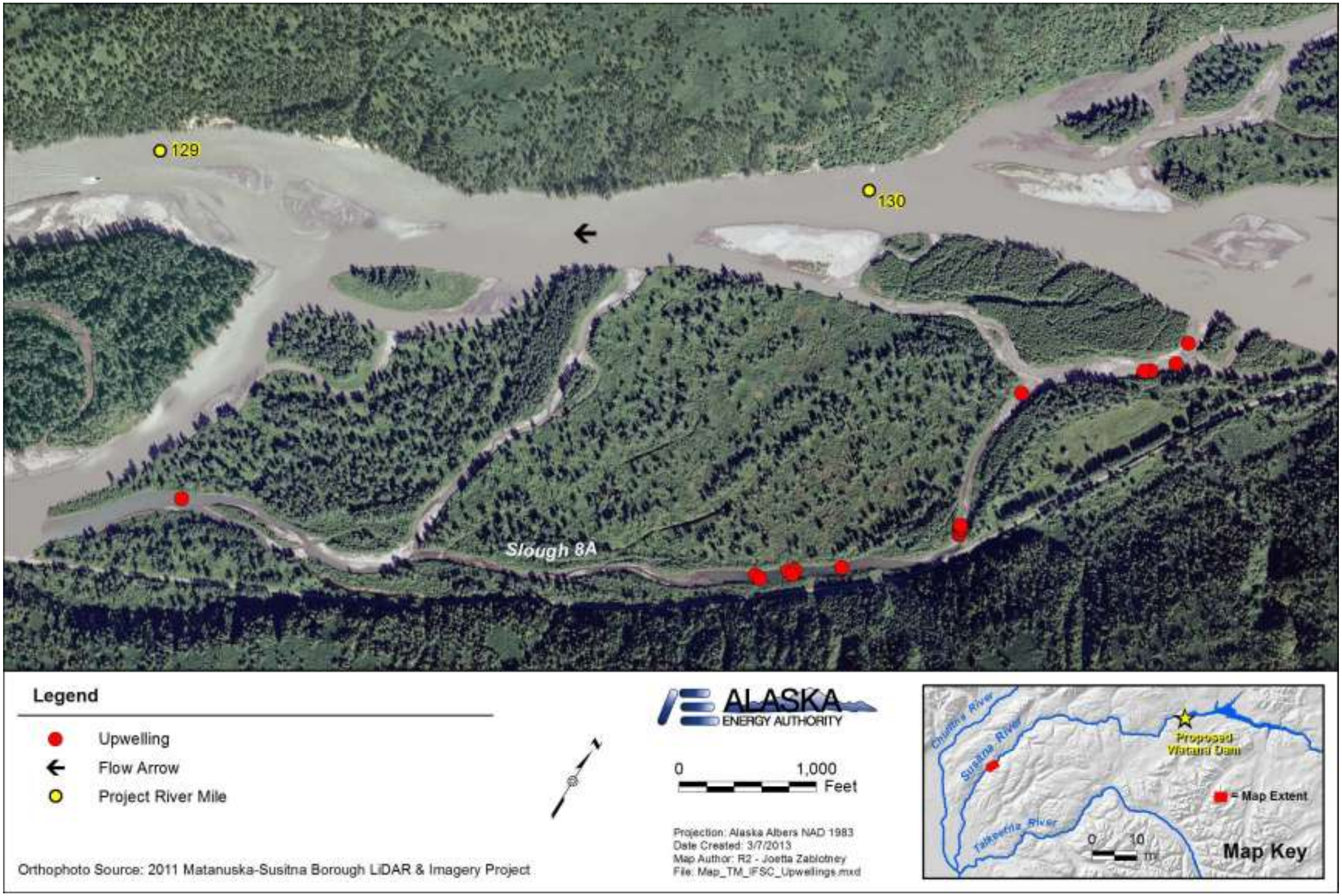


Figure 8.1-3. Upwelling locations at Slough 8A reported by Estes and Schmidt (1983).

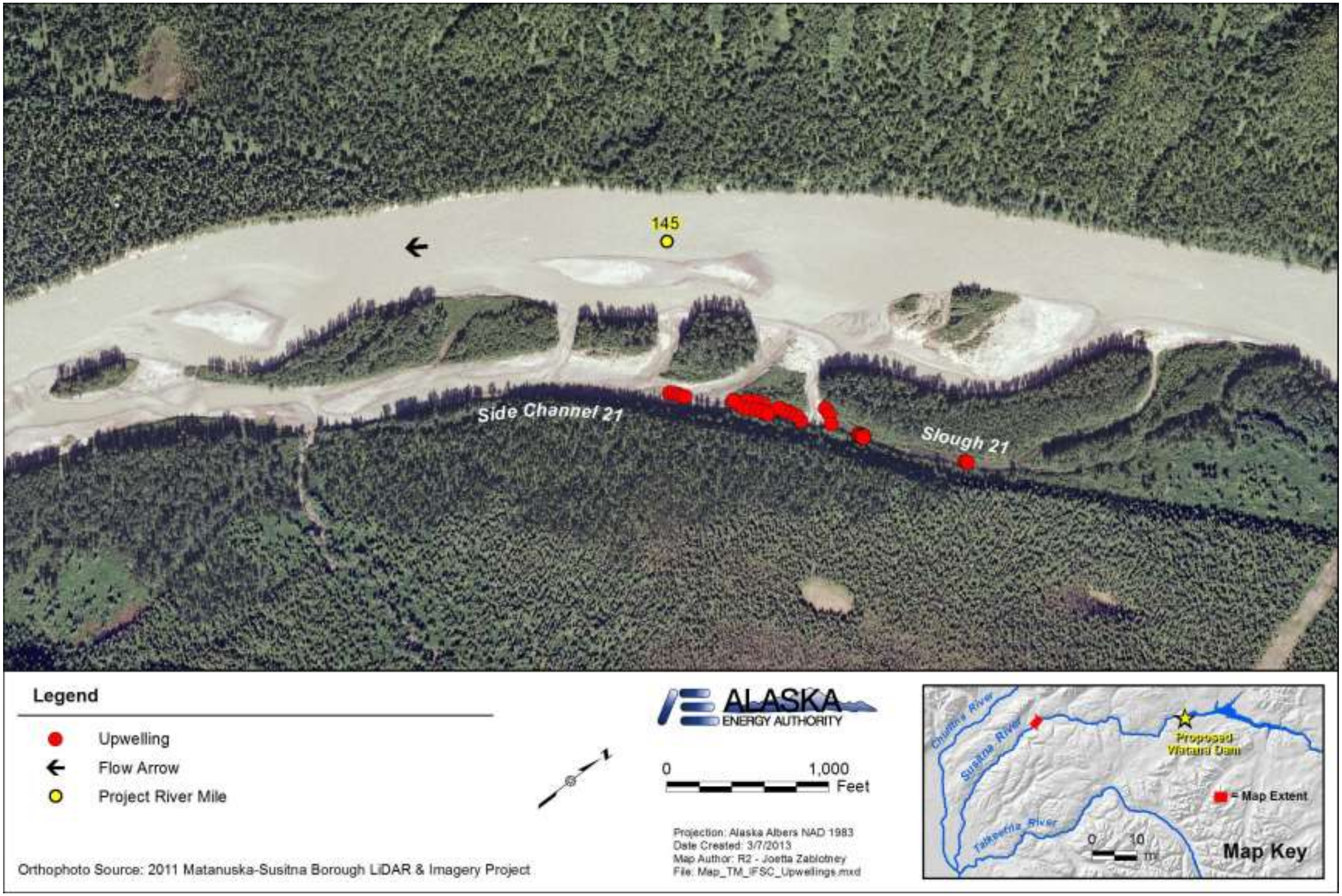


Figure 8.1-4. Upwelling locations at Slough 21 reported by Estes and Schmidt (1983).

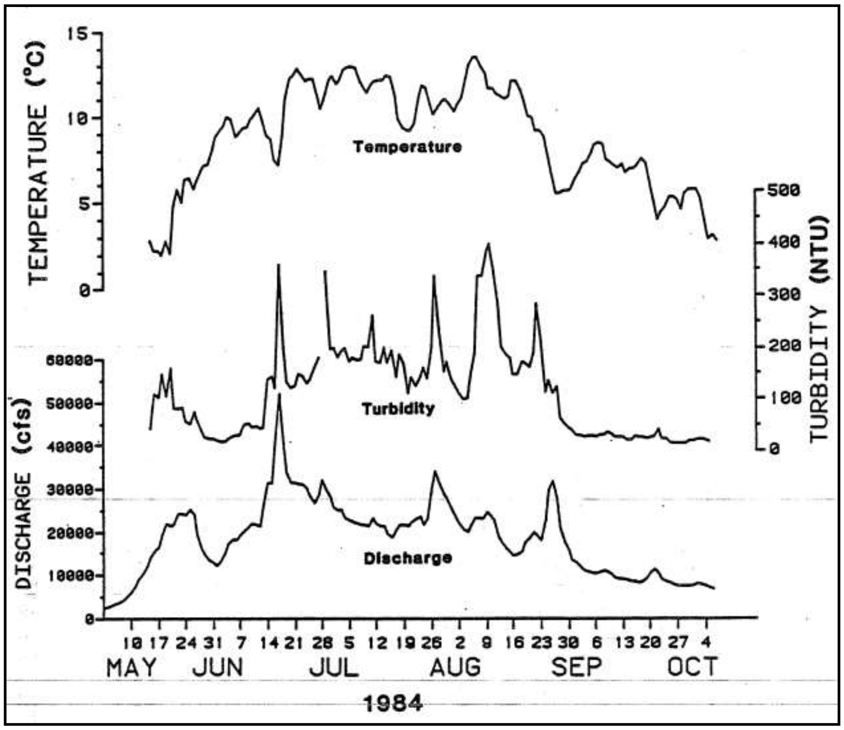


Figure 8.1-5. Turbidity and temperature measured at the Gold Creek Station and discharge measured at the Talkeetna Station during 1984. Source: Harza-Ebasco (1985).

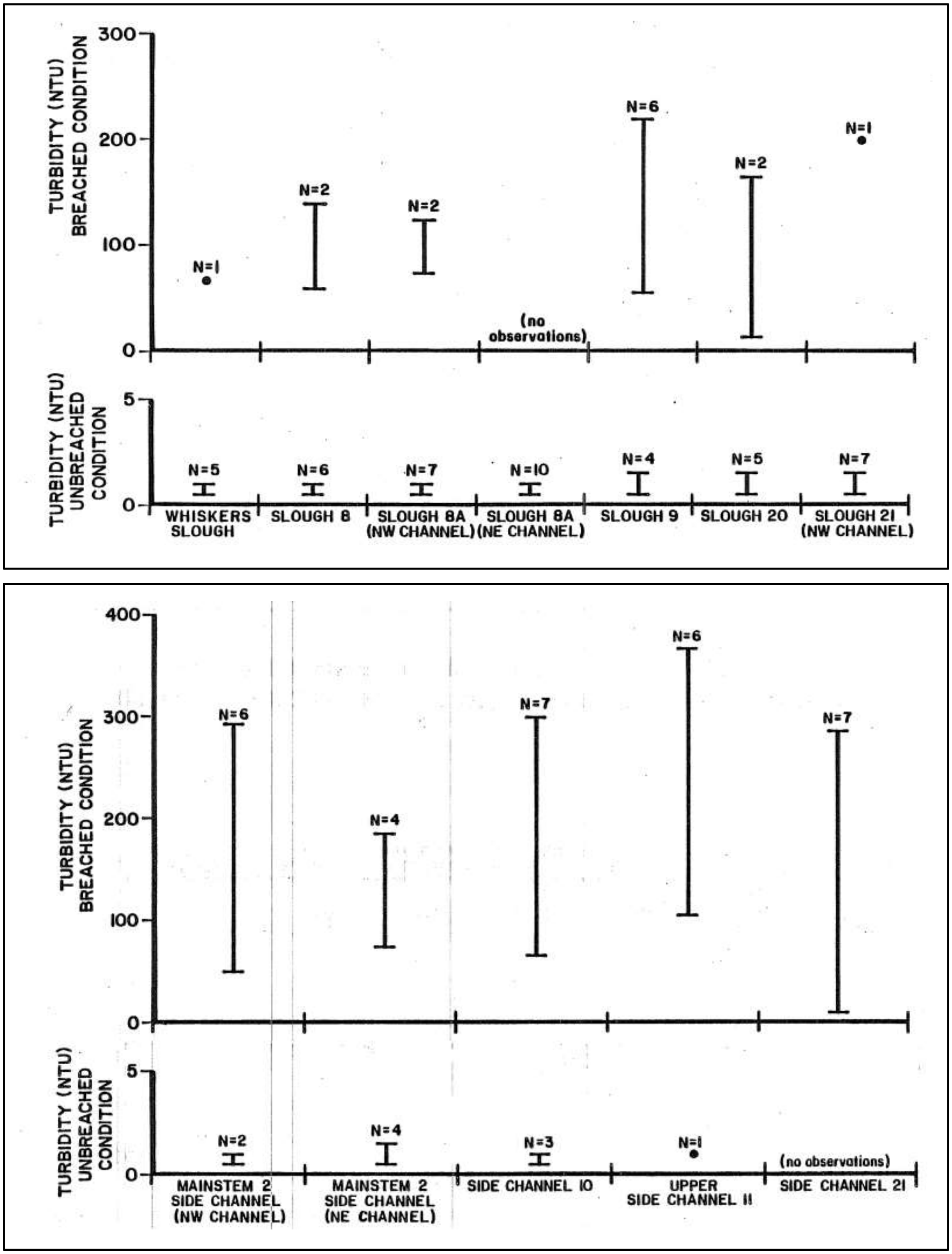


Figure 8.1-6. Range of turbidity during breached and unbreached conditions at twelve side sloughs and side channels. Source: Harza-Ebasco (1985).

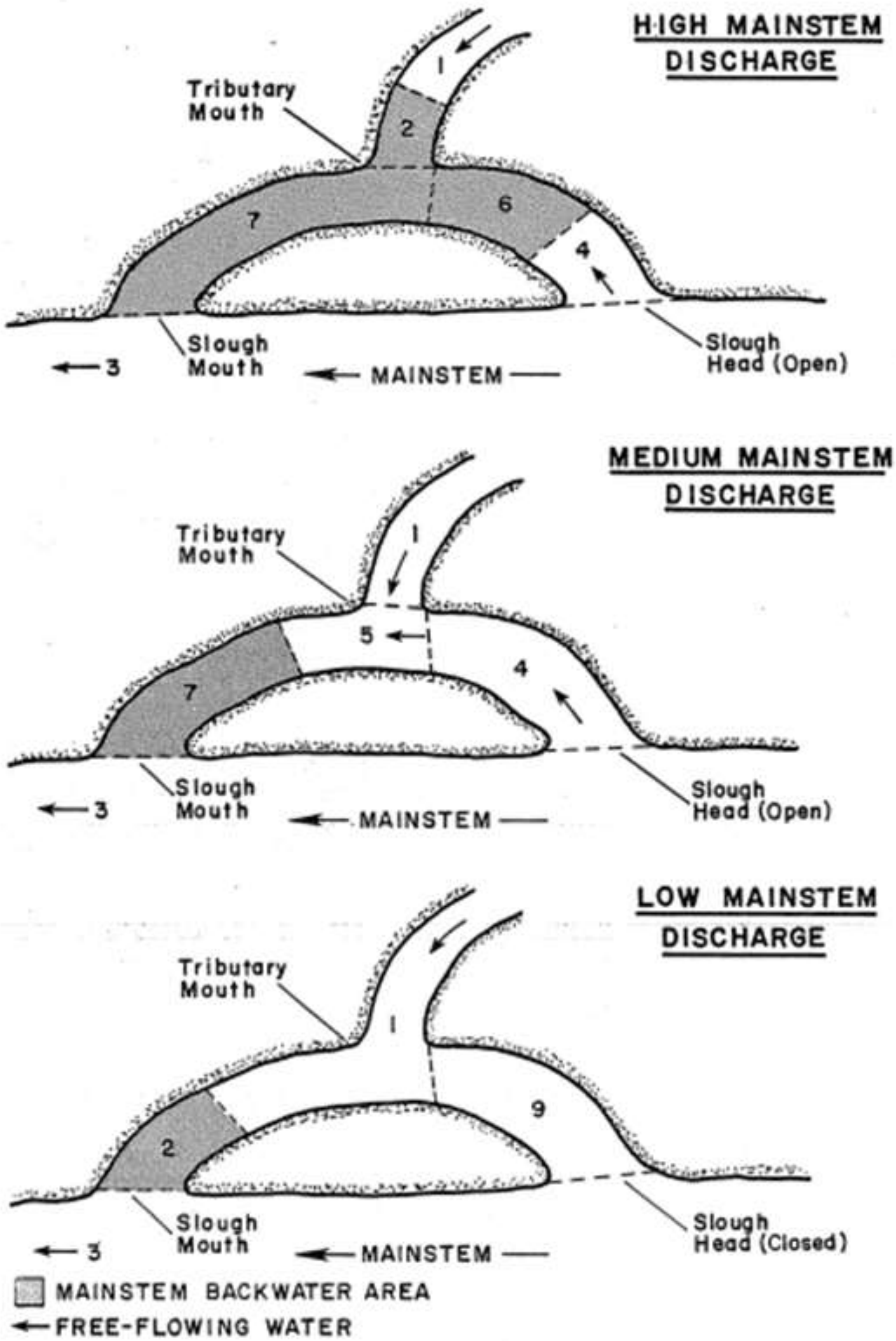


Figure 8.1-7. Hypothetical slough with delineated habitat zones. Source: Estes and Schmidt (1983).

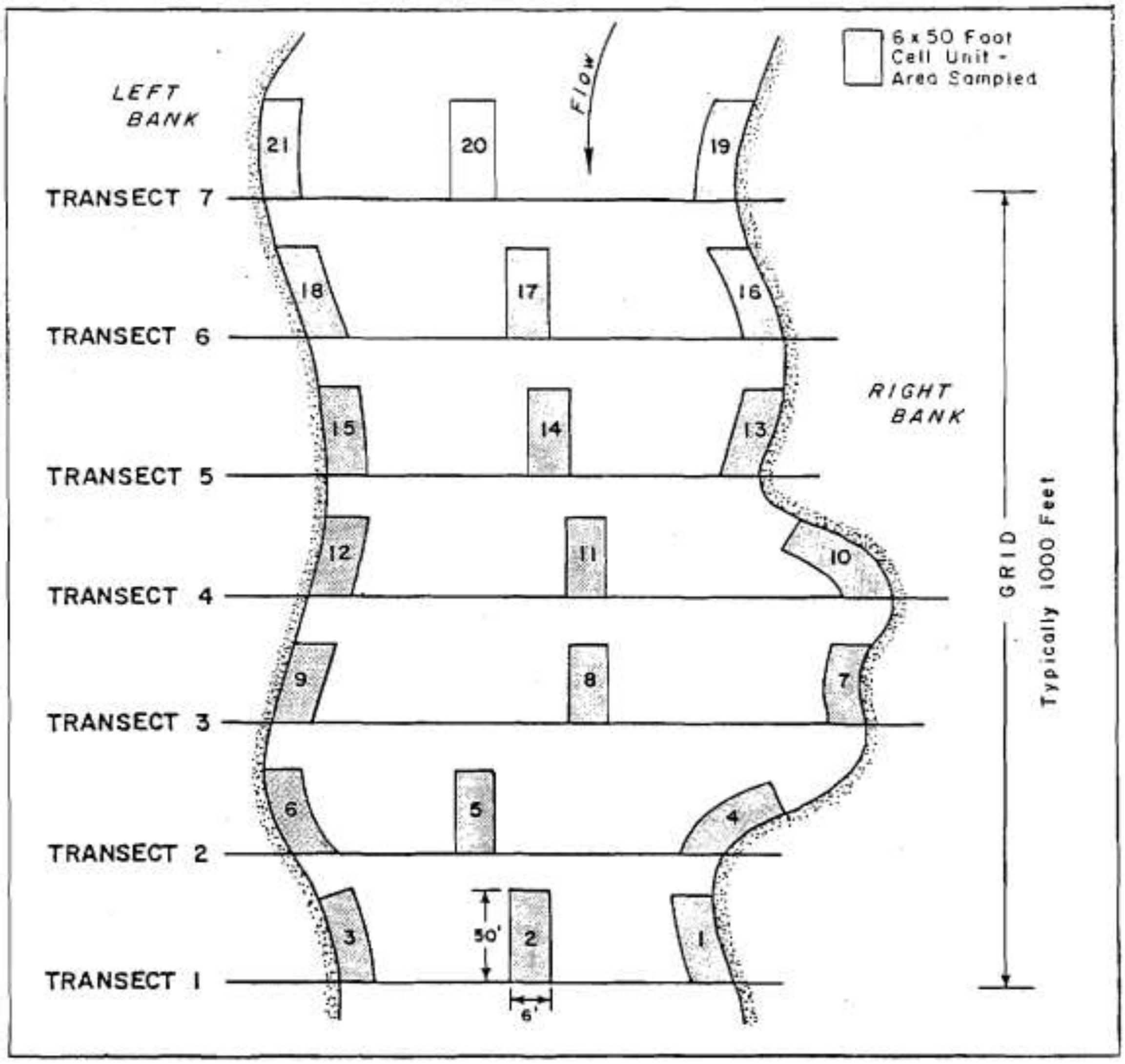


Figure 8.1-8. Typical arrangement of transects, grids, and cells at a JAHS site. Source: Dugan et al. (1984).

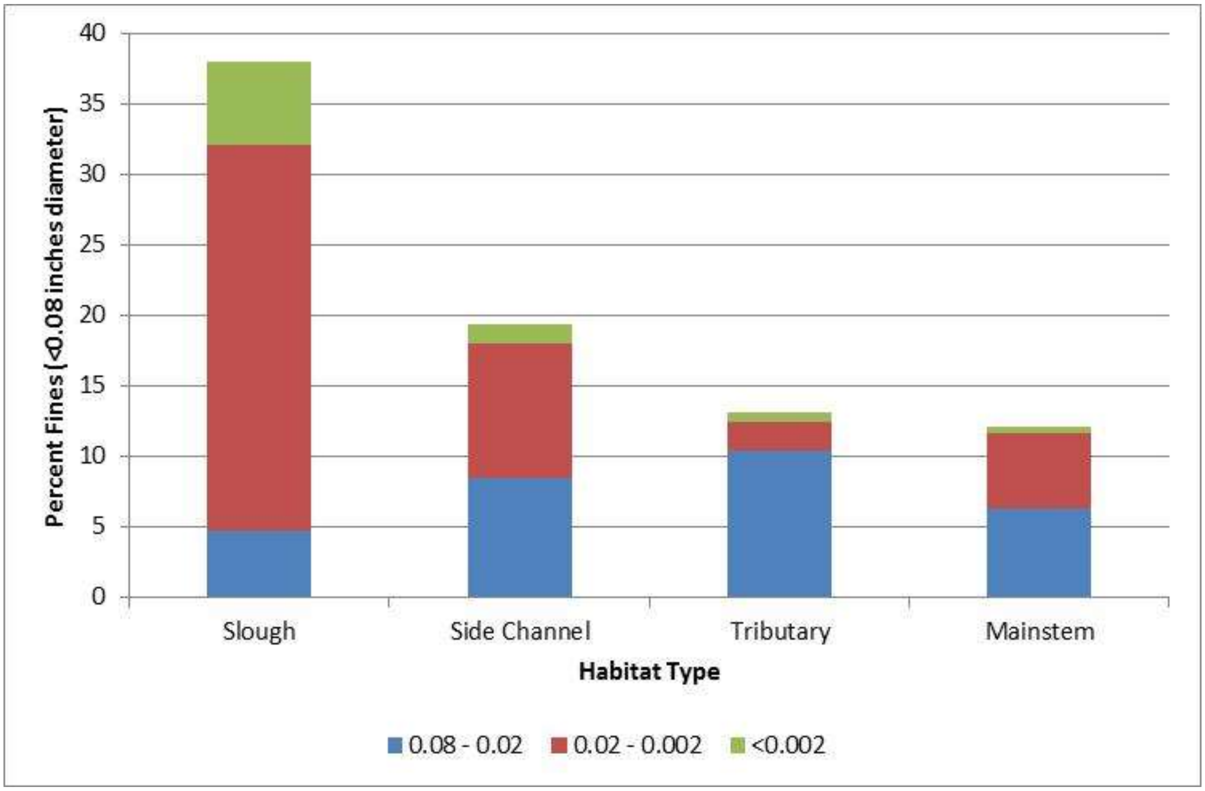


Figure 8.1-9. Percent size composition of fine substrate (<0.08 in. diameter) of McNeil samples collected in various habitat types in the middle Susitna River, Alaska. Source: Vining et al. (1985).

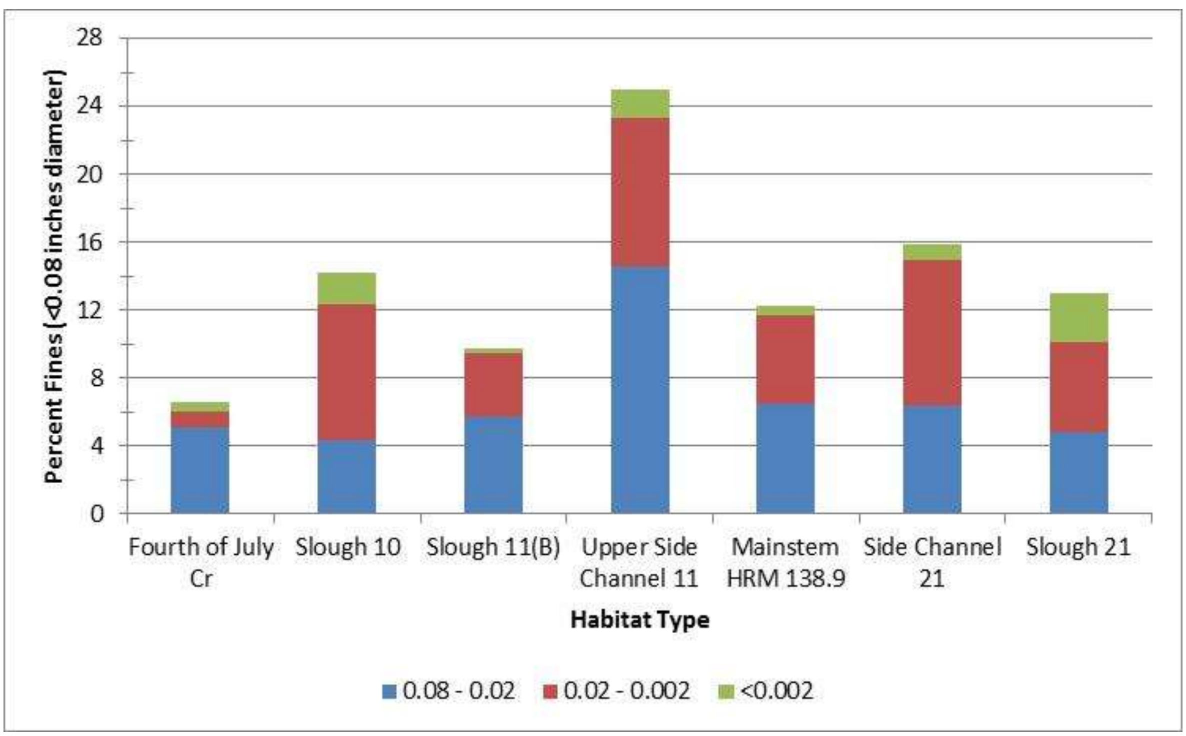


Figure 8.1-10. Percent size composition of fine substrate (<0.08 in. diameter) in McNeil samples collected at chum salmon redds during May 1984 in study sites of middle Susitna River, Alaska. Source Vining et al. (1985).

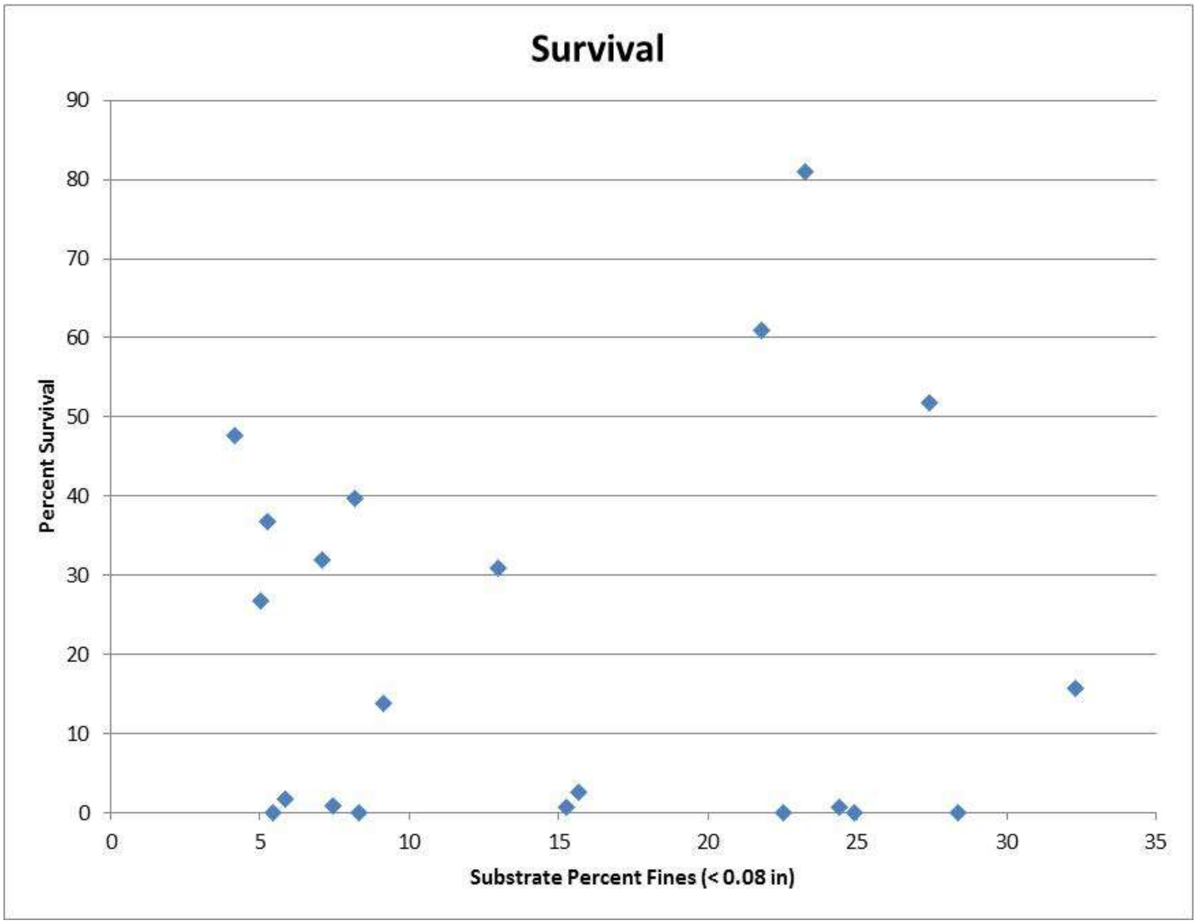


Figure 8.1-11. Relationship between percent survival of salmon embryos and the percent of fine substrate (<0.08 in. diameter) within Whitlock-Vibert Boxes removed from artificial redds within selected habitats of the middle Susitna River, Alaska. Source: Vining et al. (1985).

APPENDIX 1. INDEX OF LOCATION NAMES AND RIVER MILE

Sorted By River Mile			Sorted By Location Name	
Location Name	**River Mile**		**Location Name**	**River Mile**
Alexander Creek	10.1		Alexander Creek	10.1
Flathorn Station	18.2		Anderson Creek	23.8
Anderson Creek	23.8		Answer Creek	84.0
Susitna Station	25.5		Birch Creek	88.4
Kroto Slough Mouth	30.1		Birch Creek Slough	88.4
Yentna River	30.1		Byers Creek (Chulitna R)	98.6
Mainstem Susitna Slough	31.0		Cache Creek	96.0
Mid Kroto Slough	36.3		Cache Creek Slough	95.5
Deshka River	40.6		Caswell Creek	63.0
Delta Islands	44.0		Chase Creek	106.4
Little Willow Creek	50.5		Cheechako Creek	152.4
Rustic Wilderness	58.1		Chinook Creek	157.0
Kashwitna River	61.0		Chulitna River	98.6
Caswell Creek	63.0		Curry Station	120.0
Slough West Bank	65.6		Dead Horse Creek	120.9
Sheep Creek Slough	66.1		Deadman Creek	186.7
Goose Creek	72.0		Delta Islands	44.0
Montana Creek	77.0		Deshka River	40.6
Sunshine Station	80.0		Devil Creek	161.0
Rabideaux Creek Slough	83.1		Devils Canyon Back Eddy	150.0
Parks Highway Bridge	83.9		Fat Canoe Island	147.0
Answer Creek	84.0		Fifth of July Creek	123.7
Question Creek	84.1		Fish Creek (Talkeetna R)	97.2
Sunshine Creek	85.7		Flathorn Station	18.2
Birch Creek Slough	88.4		Fog Creek	176.7
Birch Creek	88.4		Fourth of July Creek	131.1
Cache Creek Slough	95.5		Gash Creek	111.6
Cache Creek	96.0		Gold Creek	136.7
Fish Creek (Talkeetna R)	97.2		Gold Creek Bridge	136.7
Talkeetna River	97.2		Goose Creek	72.0
Byers Creek (Chulitna R)	98.6		Goose Creek	231.3
Troublesome Creek (Chulitna R)	98.6		Indian River	138.6
Swan Lake (Chulitna R)	98.6		Jack Long Creek	144.5
Chulitna River	98.6		Jay Creek	208.5
Slough 1	99.6		Kashwitna River	61.0
Slough 2	100.2		Kosina Creek	206.8
Whiskers Creek Slough	101.2		Kroto Slough Mouth	30.1
Whiskers Creek	101.4		Lane Creek	113.6
Slough 3B	101.4		Little Portage Creek	117.7
Slough 3A	101.9		Little Willow Creek	50.5
Talkeetna Station	103.0		Lower McKenzie Creek	116.2
Slough 4	105.2		Mainstem Susitna Slough	31.0
Chase Creek	106.4		Mid Kroto Slough	36.3
Slough 5	107.6		Montana Creek	77.0
Slough 6	108.2		Moose Slough	123.5

Sorted By River Mile			Sorted By Location Name	
Location Name	River Mile		Location Name	River Mile
Oxbow I	110.2		Oshetna River	233.4
Slash Creek	111.5		Oxbow I	110.2
Gash Creek	111.6		Parks Highway Bridge	83.9
Slough 6A	112.3		Portage Creek	148.9
Slough 7	113.2		Question Creek	84.1
Lane Creek	113.6		Rabideaux Creek Slough	83.1
Slough 8	113.7		Rustic Wilderness	58.1
Lower McKenzie Creek	116.2		Sheep Creek Slough	66.1
Upper McKenzie Creek	116.7		Sherman Creek	130.8
Little Portage Creek	117.7		Side Channel 10A	132.1
Curry Station	120.0		Skull Creek	124.7
Dead Horse Creek	120.9		Slash Creek	111.5
Susitna Side Channel	121.6		Slough 1	99.6
Slough 8D	121.8		Slough 10	133.8
Slough 8C	121.9		Slough 10	133.8
Slough 8B	122.2		Slough 10 Side Channel	133.7
Moose Slough	123.5		Slough 11	135.3
Fifth of July Creek	123.7		Slough 12	135.4
Slough A prime	124.6		Slough 13	135.9
Slough A	124.7		Slough 14	135.9
Skull Creek	124.7		Slough 15	137.2
Slough 8A	125.1		Slough 16B	137.3
Slough B	126.3		Slough 17	138.9
Slough 9	128.3		Slough 18	139.1
Slough 9B	129.2		Slough 19	139.7
Sherman Creek	130.8		Slough 2	100.2
Fourth of July Creek	131.1		Slough 20	140.0
Side Channel 10A	132.1		Slough 21	141.1
Slough 10 Side Channel	133.7		Slough 21 Side Channel	140.5
Slough 10	133.8		Slough 21A	144.3
Slough 9A	133.8		Slough 22	144.3
Slough 10	133.8		Slough 3A	101.9
Slough 11	135.3		Slough 3B	101.4
Slough 12	135.4		Slough 4	105.2
Slough 13	135.9		Slough 5	107.6
Slough 14	135.9		Slough 6	108.2
Gold Creek	136.7		Slough 6A	112.3
Gold Creek Bridge	136.7		Slough 7	113.2
Slough 15	137.2		Slough 8	113.7
Slough 16B	137.3		Slough 8A	125.1
Indian River	138.6		Slough 8B	122.2
Slough 17	138.9		Slough 8C	121.9
Slough 18	139.1		Slough 8D	121.8
Slough 19	139.7		Slough 9	128.3
Slough 20	140.0		Slough 9A	133.8

Sorted By River Mile			Sorted By Location Name	
Location Name	**River Mile**		**Location Name**	**River Mile**
Slough 21 Side Channel	140.5		Slough 9B	129.2
Slough 21	141.1		Slough A	124.7
Slough 21A	144.3		Slough A prime	124.6
Slough 22	144.3		Slough B	126.3
Jack Long Creek	144.5		Slough West Bank	65.6
Fat Canoe Island	147.0		Sunshine Creek	85.7
Portage Creek	148.9		Sunshine Station	80.0
Devils Canyon Back Eddy	150.0		Susitna Side Channel	121.6
Cheechako Creek	152.4		Susitna Station	25.5
Chinook Creek	157.0		Swan Lake (Chulitna R)	98.6
Devil Creek	161.0		Talkeetna River	97.2
Fog Creek	176.7		Talkeetna Station	103.0
Tsusena Creek	181.3		Troublesome Creek (Chulitna R)	98.6
Deadman Creek	186.7		Tsusena Creek	181.3
Watana Creek	194.1		Upper McKenzie Creek	116.7
Kosina Creek	206.8		Watana Creek	194.1
Jay Creek	208.5		Whiskers Creek	101.4
Goose Creek	231.3		Whiskers Creek Slough	101.2
Oshetna River	233.4		Yentna River	30.1

APPENDIX 2. LISTING OF FISH AND AQUATIC STUDIES DOCUMENTS AND REPORTS RESULTING FROM THE 1980S SU-HYDRO PROJECT (EACH OF THESE DOCUMENTS SHOULD BE COMPILED AND MADE AVAILABLE AS PDFS FOR SEPARATE DISK THAT CAN BE ATTACHED TO THE COMPENDIUM)

Citation	Year	Title	APA Document Number	No. of APA Docs
Aaserude et al. 1985	1985	Characterization of aquatic habitats in the Talkeetna-to-Devil Canyon segment of the Susitna River, Alaska	2919	1
ADF&G 1981	1981	Adult Anadromous Fisheries Project	324	1
ADF&G 1982a	1982	Aquatic Studies Procedures Manual and Appendices	3554, 3555	2
ADF&G 1982b	1982	Stock Separation Feasibility	320	1
ADF&G 1983a	1983	Adult Anadromous Fish Studies, 1982 and Appendices	588, 589	2
ADF&G 1983b	1983	Aquatic Studies Procedures Manual	938	1
ADF&G 1983c	1983	Summarization of Volumes 2, 3, 4; Parts I and II, and 5	96	1
ADF&G 1984	1984	ADF&G Su Hydro Aquatic Studies (May 1983 - June 1984) Procedures Manual and Appendices	885, 886	2
ADF&G 1985	1985	Resident and Juvenile Anadromous Studies Procedures Manual	3014	1
Ashton and Klinger-Kingsley 1985	1985	Response of Aquatic Habitat Surface Areas to Discharge in the Yentna to Talkeetna Reach of the Susitna River.	2774	1
Ashton and Trihey 1985	1985	Assessment of Access by Spawning Salmon into Tributaries of the Lower Susitna River	2775	1
Barrett 1974	1974	An Assessment of the Anadromous Fish Populations in the Upper Susitna River Watershed between Devil Canyon and Chulitna River	1612	1
Barrett 1975	1975	December, January, and February Investigations on the Upper Susitna River Watershed Between Devil Canyon And Chulitna River	1609	1
Barrett et al. 1984	1984	Adult Anadromous Fish Investigations (May -October 1983)	1450	1
Barrett et al. 1985	1985	Adult Anadromous Fish Investigations (May - October 1984)	2748	1
Barrick et al. 1983	1983	Upper Susitna River Salmon Enhancement Study, Draft report	522	1
Bigler and Levesque 1985	1985	Lower Susitna River Preliminary Chum Salmon Spawning Habitat Assessment	3504	1
Blakely et al. 1985	1985	Salmon Passage Validation Studies	2854	1
Burgess 1983	1983	Slough Hydrogeology Report	519	1
Cannon 1986	1986	Susitna River Aquatic Studies Review: Findings And Recommendations	3501	1
Delaney et al. 1981a	1981	Resident Fish Investigation on the Lower Susitna River	318	1
Delaney et al. 1981b	1981	Juvenile Anadromous Fish Study on the Lower Susitna River	1310	1
Delaney et al. 1981c	1981	Resident Fish Investigation on the Upper Susitna River	316	1
Dugan et al. 1984	1984	The distribution and relative abundance of juvenile salmon in the Susitna River drainage	1784	1
Entrix 1985a	1985	Access Corridor, Construction Zone And Transmission Corridor Fish Impact Assessment and Mitigation Plan	2921	1
Entrix 1985b	1985	Impoundment Area Fish Impact Assessment and Mitigation Plan	2922	1
Estes and Bingham 1983	1982	Aquatic Studies Program 1982	517	1

Citation	Year	Title	APA Document Number	No. of APA Docs
Estes and Schmidt 1983	1983	Aquatic Habitat and Instream Flow Studies 1982 (Parts I and II). Part II and Appendices A, B-D, E-J available on ARLIS.	585, 586, 587	3
Estes et al. 1981	1981	Aquatic Habitat and Instream Flow Project; Volume 1 and Volume2, Parts 1 and 2.	311, 312, 1307	3
Friese 1975	1975	Preauthorization Assessment of Anadromous Fish Population Upper Susitna River Watershed in the Vicinity of Proposed Devil Canyon Hydroelectric Project	549	1
Hansen and Richards 1985	1985	Availability of Invertebrate Food Sources for Rearing Juvenile Chinook Salmon In Turbid Susitna River Habitats	2846	1
Harza-Ebasco 1985	1985	Susitna Hydroelectric Project License Application Exhibit E Chapters 1 and 2 (Tables, Figures); Chapter 3 (References); Chapter 10	3430, 3431, 3432, 3433, 3435, 3438	6
Harza-Ebasco and R&M 1984	1984	Slough Geohydrology Studies	1718	1
Hilliard et al. 1985	1985	Hydraulic relationships and model calibration procedures at 1984 study sites in the Talkeetna-to-Devil Canyon segment of the Susitna River, Alaska and Appendices A-C	2898, 2899	2
Hoffman 1985	1985	Summary Of Salmon Fishery Data For Selected Middle Susitna River Sites	2749	1
Hoffman et al. 1983	1983	Winter Aquatic Studies (October 1982 - May 1983)	397	1
Jennings 1985	1985	Fish Resources and Habitats in the Middle Susitna River	2744	1
Klinger and Trihey 1984	1984	Response of Aquatic Habitat Surface Areas to Mainstem Discharge in the Talkeetna to Devil Canyon Reach of the Susitna River, Alaska.	1693	1
Klinger-Kingsley et al. 1985	1985	Response of aquatic habitat surface areas to mainstem discharge in the Talkeetna-to-Devil Canyon segment of the Susitna River, Alaska and Appendix 1 (Maps)	2945, 2945_maps	2
Marshall et al. 1984	1984	Juvenile salmon rearing habitat models	1784	1
Meyer et al. 1984	1984	Assessment of the Effects of the Proposed SHP on Instream Temperature and Fishery Resources in the Watana to Talkeetna Reach	2330	1
Quane et al. 1984	1984	Stage and discharge investigations	1930	1
Quane et al. 1985	1985	Hydrological Investigations at Selected Lower Susitna River Study Sites	2736	1
R&M 1981	1981	Attachment D to Hydrographic Surveys: Susitna River Mile Index	483	1
Riis 1977	1977	Pre-authorization Assessment of the Proposed Susitna River Hydroelectric Projects: Preliminary Investigations of Water Quality and Aquatic Species Composition	1610	1
Riis and Friese 1978	1978	Preliminary Environmental Assessment of Hydroelectric Development on the Susitna River	1613	1
Roth and Stratton 1985	1985	The migration and growth of juvenile salmon in Susitna River, 1985	2836	1

Citation	Year	Title	APA Document Number	No. of APA Docs
Roth et al. 1984	1984	The outmigration of juvenile salmon from the Susitna River above the Chulitna River confluence	1784	1
Roth et al. 1986	1986	The Migration and Growth of the Juvenile Salmon in the Susitna River, 1985	3413	1
Sandone et al. 1984	1984	Evaluations of chum salmon spawning habitat in selected tributary mouth habitats of the middle Susitna River	1937	1
Sautner and Stratton 1983	1983	Upper Susitna River Impoundment Studies 1982	590	1
Sautner and Stratton 1984	1984	Access and transmission corridor studies	2049	1
Sautner et al. 1984	1984	An evaluation of passage conditions for adult salmon in sloughs and side channels of the middle Susitna River	1935	1
Schmidt and Bingham 1983	1983	Report Synopsis of the 1982 Aquatic Studies and Analysis of Fish and Habitat Relationships and Appendices	40a_ver2, 40	2
Schmidt and Stratton 1984	1984	Population dynamics of Arctic grayling in the Upper Susitna Basin	2049	1
Schmidt et al. 1983	1983	Resident and Juvenile Anadromous Fish Studies on Susitna, Below Devil Canyon and Appendices	486, 487	2
Seagren and Wilkey 1985a	1985	Preliminary Evaluations of Potential Fish Mitigation Sites in the Middle Susitna River	2908	1
Seagren and Wilkey 1985b	1985	Summary of Water Temperature and Substrate Data from Selected Salmon Spawning and Groundwater Upwelling Sites in the Middle Susitna River	2913	1
Steward et al. 1985	1985	Response of juvenile Chinook habitat to mainstem discharge in the Talkeetna to Devil Canyon Segment of the Susitna River, Alaska	2909	1
Stratton 1986	1986	Summary of juvenile Chinook and coho salmon winter studies in the Middle Susitna River, 1984-1985	3063	1
Suchanek et al. 1984a	1984	Resident fish habitat studies	1784	1
Suchanek et al. 1984b	1984	Juvenile salmon rearing suitability criteria	1784	1
Suchanek et al. 1985	1985	The relative abundance, distribution, and instream flow relationships of juvenile salmon in the Lower Susitna River	2836	1
Sundet 1986	1986	Winter resident fish distribution and habitat studies conducted in the Susitna River below Devil Canyon, 1984-1985	3062	1
Sundet and Pechek 1985	1985	Resident fish distribution and life history in the Susitna River below Devil Canyon	2837	1
Sundet and Wenger 1984	1984	Resident fish distribution and population dynamics in the Susitna River below Devil Canyon	1784	1
Thompson et al. 1986	1986	Adult Salmon Investigations (May-October 1985) and Appendix	3412, 3412_v2	2
Trihey & Associates and Entrix 1985	1985	Instream flow relationships report, Volume 1	3060	1
Trihey & Associates and Entrix 1985	1985	Instream flow relationships report, Volume 2	3061	1
Trihey 1982a	1982	1982 Winter Temperature Study Open File Report	526	1

Citation	Year	Title	APA Document Number	No. of APA Docs
Trihey 1982b	1982	Preliminary Assessment of Access by Spawning Salmon to Side Slough Habitat above Talkeetna	510	1
Trihey 1983	1983	Preliminary Assessment of Access by Spawning Salmon into Portage Creek and Indian River	508	1
Trihey and Hilliard 1986	1986	Response of Chum Salmon Spawning Habitat to Discharge in the Talkeetna to Devil Canyon Segment of the Susitna River, Alaska	3423	1
Vincent-Lang and Queral 1984	1984	Eulachon spawning habitat in the Lower Susitna River	1934	1
Vincent-Lang et al. 1984a;	1984	Habitat suitability criteria for Chinook, coho, and pink salmon spawning in tributaries of the middle Susitna River	1938	1
Vincent-Lang et al. 1984b	1984	An evaluation of chum and sockeye salmon spawning habitat in sloughs and side channels of the Middle Susitna River	1936	1
Vining et al. 1985	1985	An evaluation of the incubation life-phase of chum salmon in the middle Susitna River, Alaska, and Appendices A-E; Appendix F	2658, 2659	2
Wangaard and Burger 1983	1983	Effects of Various Water Temperature Regimes on the Egg and Alevin Incubation of Susitna River Chum and Sockeye Salmon	317	1
Wilson 1985	1985	Task 31 Primary Production Monitoring Report	4018	1
Wilson et al. 1984	1984	Effects of Project-related Changes in Temperature, Turbidity and Stream Discharge on Upper Susitna Salmon Resources During June - Sept	454	1
Woodward-Clyde Consultants 1984	1984	Interim Mitigation Plan for Chum Spawning Habitat in Side Sloughs of the Middle Susitna River	2332	1

APPENDIX 3. SUMMARY OF 1980S INSTREAM FLOW HABITAT MODELING SITES

Appendix 3 is provided in a separate file.