7. HYDROLOGY-RELATED RESOURCES

7.1. Introduction

Operation of the Susitna-Watana Project (Project) is expected to change the hydrology characteristics of the riverine portion of the drainage downstream of the proposed dam and the mainstem Susitna River reach inundated by the Project reservoir. Proposed Project operations will affect flow, water depth, surface-water elevation, channel characteristics, and sediment regimes. The potential effects of the Project on ice formation, surface and groundwater temperature and quality, mercury bioaccumulation, geomorphology and other hydrologic characteristics need to be carefully evaluated as part of the licensing process, since changes to these parameters can affect aquatic and riparian habitat quality, which can in turn affect fish populations, riparian-dependent species, and roads, bridges, structures, and recreation opportunities along the river corridor.

This section of the PSP describes the water-resource studies that will be conducted to characterize and evaluate these effects. These studies will be subject to revision and refinements in consultation with licensing participants as part of the continuing study planning process identified in the ILP. The impact assessments will inform development of any necessary protection, mitigation, and enhancement measures to be presented in the draft and final License Applications.

An additional study is being proposed on Glacial and Runoff Changes in the Upper Susitna basin, in response to written requests from the National Marine Fisheries Service (NMFS), the U.S. Fish and Wildlife Service (USFWS), as well as other licensing participants. This study will research, describe, and quantify glacial retreat and runoff changes in the Upper Susitna Watershed, and assess reasonably foreseeable impacts to the Project.

7.2. Nexus Between Project Construction / Existence / Operations and Effects on Resources to be Studied

Construction and operation of the Project have the potential to alter discharge, water chemistry, temperature, river flow, sedimentation, and ice processes in the Susitna River. Changes to these processes may affect channel morphology and aquatic habitat downstream of the Project site. Understanding existing conditions provides baseline information needed for predicting the likely extent and nature of potential changes to the river that may occur due to Project construction and operations.

For any hydropower project it is important to understand the variability of the discharge. On-going retreat of the glaciers feeding the Upper Susitna drainage, along with the anticipated long-life of the project, means that glacial retreat could have significant impacts to the ecosystem, economics of the Project, and proposed mitigation measures. These impacts from natural changes to the environment may be additive to impacts from the proposed Project operations. The effects will be varied and could include:

- Glacial retreat can affect runoff contribution from glaciers that could result in reduced summertime stream flows.
- Decreased snowpack and glacial runoff combined with increased air temperatures could change the thermal regime of the Susitna River and affect fish and aquatic invertebrates.
- Sedimentation changes could impact Project longevity and thus cost-benefit calculations for the reservoir. The rate of sedimentation is strongly tied to erosion processes, which may change as glacial ice becomes a smaller contribution to the total run-off.
- An understanding of changes in the hydrologic regime (water timing, quantity, and quality) in combination with Project operations will inform post construction monitoring needs. This could include stream temperature measurements, assessment of fish habitat conditions under changing conditions, instream flow throughout the system to assess changes in flow contribution from tributaries, and stream temperature monitoring in the reservoir and downstream.

7.3. Resource Management Goals and Objectives

Water quality in the state is regulated by a number of state and federal regulations. This includes the Federal Clean Water Act (CWA), and the state of Alaska Title 18, Chapter 70, of the Alaska Administrative Code (18 AAC 70). Aquatic resources including fish and their habitats, and wildlife resources, are generally protected by a variety of state and federal mandates. In addition, various land management agencies, local jurisdictions, and non-governmental interest groups have specific goals related to their land management responsibilities or special interests. These goals are expressed in various statutes, plans, and directives.

In addition to providing information needed to characterize the potential Project effects, these water resources studies will inform the evaluation of possible conditions for inclusion in the Project license. These studies are designed to meet FERC licensing requirements and also to be relevant to recent, ongoing, and/or planned resource management activities by other agencies.

7.4. Summary of Consultation with Agencies, Alaska Native Entities and Other Licensing Participants

These study plans have been modified in response to comments from various agency reviewers, including the NMFS, the Alaska Department of Environmental Conservation, and the U.S. Fish and Wildlife Service (USFWS). Consultation on the study plan occurred during licensing participant meetings on April 6, 2012 and the June 14, 2012 Water Resources Technical Work Group (TWG). At the June TWG meeting, study requests and comments from the various licensing participants were presented, discussed and refinements determined to address agreed upon modifications to the draft study plans.

A summary of consultations relevant to hydrology resources is provided in Table 7-4-1.

Table 7.4-1. Summary of consultation on Hydrology Related Resources study plans.

Comment Format	Date	Stakeholder	Affiliation	Subject	Response
Email	08/23/2012	Joseph Klein	ADF&G	What are the monitoring well placement sampling approach (e.g. equal spacing along linear transects, etc.) and location (e.g. for instream flow, in all habitat types?) for the various resource studies (i.e. instream flow, riparian instream flow, water quality). Also, a description of sampling intensity would be helpful (i.e. for instream flow purposes, will the objective be to characterize entire gw/sw interaction throughout entire intensive study site or only at select microhabitats).	AEA has included more detail in the Groundwater RSP Sections 7.5.4.5 and section 7.5.4.6 pertaining to well place sampling approach and location. In general, the placement of wells in transects will be determined by local hydrologic boundary conditions. Wells are generally placed close to a boundary (stream, slough, main channel) and then at increasing distance away from the boundary to help measure the pressure response from rising and falling stage levels in surface-water features (internal/external modeling boundaries). Additionally, some wells will be placed in key areas related to riparian habitat, key instream flow study needs, or to help identify hydrologic conditions near groundwater model or study area boundaries. Within each Candidate Focus Area (CFA), there will be area(s) where groundwater analysis will be focused. In some of the CFAs, this may cover a majority of the CFA area, in others it may only be a portion. The groundwater analysis areas will encompass the internal focus areas for riparian and instream to help provide the groundwater portion of the hydrologic framework being used for analysis by the various studies.
Email	08/23/2012	Joseph Klein	ADF&G	What is the duration for monitoring (I believe at the meeting it would be from installation until winter 2013-14?)	The duration of monitoring will vary for different hydrology data collection programs. The current network of gaging stations started in summer of 2012 will continue operations through the winter of 2012/13 into 2013 and 2014. Technical evaluations will be made in the summer of 2014 as to which gaging stations need to be be operated during the

Comment Format	Date	Stakeholder	Affiliation	Subject	Response
					winter of 2014/15. Groundwater monitoring programs will begin at a small scale in winter 2012/13 and the increase during summer of 2013. The monitoring of groundwater wells will continue into 2014,. At that time, a subset of the groundwater wells may be monitored for the winter of 2014/15.
Email	08/23/2012	Joseph Klein	ADF&G	How often will monitoring wells be calibrated for various parameters to be sampled pre- post- and during field monitoring?	Monitoring wells will be surveyed with a combination of RTK survey methods and optical level loop methods. This will be done at least two times a year, or more frequent if well movements are recorded. Pressure transducer measurement will be verified with manual measurement at least month during summer months, and 3-4 times during winter periods. Both calibration (for determining offsets) and verification water levels will be collected. Conductivity and temperature sensors will have calibration checks performed before field installations and field calibration checks monthly during summer months. Calibration checks during winter months will be performed at least once during the mid winter period when safe access and weather conditions allow, and before spring breakup and fall freeze-up. This process will be further described in the Groundwater Study Plan in section 7.5.4.5 and section 7.5.4.6.
Email	09/01/2012	Betsy McCracken	USFWS	**Groundwater**- The integration of the groundwater study efforts with the biological studies is not clear. Specifically, how will the groundwater study be made relevant to the scale of fish habitat and fish habitat site selection in the Susitna River? The objectives of the groundwater study should include relevance to the hierarchially nested habitats,	In the RSP, AEA has clarified how fisheries studies have been incorporated into the instream flow and groundwater aquatic studies. The groundwater aquatics study is coordinating with both Instream Flow and Fisheries studies on the selection of Focus Areas (FAs). The groundwater study will be measuring the both horizontal and vertical

Comment Format	Date	Stakeholder	Affiliation	Subject	Response
				including macro-, meso-, and micro-habitats that are influential to fish habitat selection. The groundwater study sampling design should be relevant to fish habitat and site selection. A specific objective needs to be measuring the hydraulic gradient/head (upwelling or downwelling) under the existing hydrograph and under the proposed project hydrograph release flow schedule.	head gradients through combinations of nested wells installed at different depths and shallow wells installed in surface-water habitat areas to measure the gradients between surface-water sources and underlying groundwater conditions. Details on the measurement of fluxes can be found in the RSP in section 7.4.5.6. These gradients will be compared with simulated gradients from groundwater/surface-water models under the field conditions measured in 2013 and 2014 and compared with project operation scenarios.
Email	09/11/2012	Bob Henszey	USFWS	Section 6.6.4.5 (Groundwater): The suggested four to six intensive study reaches instrumented with groundwater and surface-water recording instruments may be insufficient to address this objective if plant response will be described by process-domains (see pseudoreplication discussion above). However, hydrology is likely the most dominant physical factor required for maintaining floodplain plant communities across the various process-domains, and baring some other dominant physical factor (e.g., soil parent material, weather, etc.) it may be possible to use data from the individual intensive study-site transects to build response curves (see Henszey et al. 2004 {ne.water.usgs.gov/platte/reports/wetlands_24-3.pdf}, Figure 7 for an indication of the number of data points required to build a response curve).	The purpose of the Focus Areas (FAs) is to develop intensive enough data collection and analysis programs to define the groundwater/surface-water interactions and hydrologic cycle processes in a variety of environments so the process understanding can be used at the larger scale to evaluate potential Project affects and methods for alternating Project operations to reach desired management goals. The CFAs will be used in conjunction with hydrologic analysis to help inform the Project and agencies on the hydrologic interactions and range of natural variability in the system. Response curves for the CFA's will be evaluated as part of the Riparian Groundwater Study (see RSP 8.6.4.5).
Email	09/11/2012	Bob Henszey	USFWS	One-and-a-half growing seasons (July 2013 to September 2014) will likely provide insufficient groundwater hydrology data to fit individual species response curves (especially for annual	The study schedule for riparian growing seasons is sufficient. The model simulation tools will be used to re-analyze past hydrologic conditions (such as recent years or

Comment Format	Date	Stakeholder	Affiliation	Subject	Response
				species), and may not be enough data to reasonably predict groundwater relationships with river stage and to verify the model predictions with independent data. Precipitation may also dramatically affect transient but critical groundwater levels (a few days to a week or more of elevated water levels), which would be difficult to evaluate with limited data. How will these potential problems be addressed?	80s information) to gain additional data for the development of responsive curves. Data from Long-Term Ecological Research (LTER) sites such as the Bonanza Creek Experimental Forest (BCEF) will be compared with the evaluations in the Susitna riparian study areas to help expand the process understanding of riparian responces to groundwater/surface-water interactions. Precipitation data will be measured at each of the riparian focus areas. Shielded summer precipitation gages will be installed in early spring 2013 in time for the 2013 summer season. The information will be compared with the recent update to the statewide precipitation evaluation and new index maps. Additionally, precipitation information collected by the Glacier Runoff Study will be incorporated into the precipitation analysis for the riparian focus areas.
Email	09/11/2012	Bob Henszey	USFWS	In addition to the Work Products described in Section 6.6.4.5.2, the products should provide water-level summary statistics for each location (e.g., point, plot, or transect) that will be used to test and fit plant response curves, such as growing season cumulative frequency, 7-day moving average, 10-day moving average, 14-day moving average, and arithmetic mean (see Henszey et al. 2004 {ne.water.usgs.gov/platte/reports/wetlands_24-3.pdf}, Table 1).	The Groundwater Study will provide the time series for measured and simulated groundwater levels to help provide the summary statistics needed for developing plant-response curves. This is further described in the Instream Flow Riparian Groundwater Study Plan in Section 8.6.4.5 (previously in Section 6.6.4.5.2).
Email	09/11/2012	Bob Henszey	USFWS	Section 6.6.4.7 (Succession Models and Flow Response Guilds) appears to potentially address the USFWS's Objective 6 request; however, two critical referenced papers (Merritt et al. 2010 and Pearlstine et al. 1985)	Additional detail has been added to the Riparian Instream Flow RSP Section 8.6.4.7 to demonstrate that USFWS Objective 6 will be met by the proposed methods. A description of the hydrologic gradient

Comment Format	Date	Stakeholder	Affiliation	Subject	Response
				were not included in the Literature Cited. These references were not provided until 8/28/2012, and the USFWS has had insufficient time to review these papers in detail. The concept of the PSP response guilds is similar to the USFWS's request to develop plant community response curves, but the PSP methods are insufficient to evaluate if our requested Objective 6 will be met. The USFWS requested evaluating specific water-level summary statistics (see above discussion for groundwater) with a rigorous curve-fitting technique similar to Henszey et al. (2004). The methods should provide sufficient detail to show how quantifiable (not qualitative) hydrologic (surface-water and groundwater) gradients will be constructed to show the optimum and range of favorable water levels required for maintaining floodplain species/communities.	analyses is provided in Section 7.5: Groundwater. AEA has revised the Groundwater RSP at Section 7.5.4.5] to provide more detail to show how quantifiable hydrologic gradient will be constructed. The groundwater and surface water field measurements for continuous monitored stations will be 15 minutes or less. Model simulations will also 15 minutes or less, based on analysis of modeling results. This information will produce time series data sets, from which water level summary statistics can be calculated for a range of analysis objectives, such as running averages in hourly and daily increments.

7.5. Groundwater-Related Aquatic Habitat Study

7.5.1. General Description of the Proposed Study

7.5.1.1. Study Goals and Objectives

The overall goal of the study is to understand the effects of the Project on groundwater and surface-water (GW/SW) interactions as they relate to habitat for aquatic species (e.g., fish, riparian vegetation) in the Susitna River. Additionally, there is one study task evaluating the potential impacts to shallow groundwater well users in the river area. The study is designed to be a coordinated effort with other studies to help guide their data-collection activities related to GW/SW interpretative goals. The study will use existing information, data collected by this and other studies to provide an overall understanding of watershed to local scale groundwater processes and GW/SW interactions.

The objectives of the study are as follows:

1. Synthesize historical data available for Susitna River groundwater and groundwater related aquatic habitat, including the 1980s and other studies;
2. Use available information to characterize the large-scale geohydrologic process-domains/terrain of the Susitna River (e.g., geology, topography, geomorphology, regional aquifers, shallow ground water aquifers, GW/SW interactions);
3. Assess the effect of Watana Dam/Reservoir on groundwater and groundwater related aquatic habitat in the vicinity of the dam;
4. Map groundwater influenced aquatic habitat (e.g., upwelling areas, springs);
5. Determine the GW/SW relationships of floodplain shallow alluvial aquifers at Riparian Instream Flow study sites;
6. Determine GW/SW relationships of upwelling/downwelling at Instream Flow Study sites in relation to spawning, incubation, and rearing habitat (particularly in the winter);
7. Characterize water quality (e.g., temperature, DO, conductivity, nutrients) of selected upwelling areas where groundwater is a primary determinant of fish habitat (e.g., incubation and rearing in side channels and sloughs, upland sloughs);
8. Characterize the winter flow in the Susitna River and how it relates to GW/SW interactions; and
9. Characterize the relationship between the Susitna River flow regime and shallow groundwater users (e.g., domestic wells).

7.5.2. Existing Information and Need for Additional Information

Various portions of the Susitna Watershed have had different scales of groundwater and GW/SW interaction studies reported. The lower Susitna Watershed is part of the geologic Susitna Basin

(Kirschner, 1994) (Figure 7.5.1). This region has generally been referred to as the lower Susitna River. The major physiographic regions of the Susitna Watershed are described in Wahrhaftig (1994), and include the Alaska Range on northern portion of the watershed which also forms the watershed boundary in the headwaters of the watershed. The Talkeetna Mountains cross the central portion of the watershed and result in physiographic features such as Devils Canyon and Watana Canyon. The Upper Matanuska Valley covers the lower portion of the watershed, which is bounded on the downstream end by Cook Inlet. The watershed scale geology covers a range of highly metamorphic marine sedimentary formations, referred to as Flysch belts (Beikman, 1994) (Figure 7.5.2). There are also younger volcanic deposits in the middle portion of the watershed. The Susitna River flows out of the Talkeetna Mountains in the vicinity of Talkeetna, where it then flows through the sedimentary Susitna Basin.

Hydropower-related studies in the Susitna Watershed during the 1980s included observations and monitoring of GW/SW interactions. These studies focused on river habitats such as sloughs that were determined to be important fish habitat. A large amount of physical hydrology data (e.g., stage-discharge relationships, main stage versus upwelling discharge, piezometers), water quality data (e.g., temperature), aquatic habitat and other observations were reported for various study sites (primarily at Slough 8a and Slough 9).

Since the 1980s, various wells have been drilled for domestic water supply, mining exploration, oil and gas exploration, railroad operations and other activities associated with resource development or evaluations in the watershed.

A Groundwater-Related Aquatic Habitat Study is needed because riparian vegetation processes (recruitment, maintenance of existing vegetation) and fish habitat (spawning, incubation, and rearing) in the Susitna River are partially dependent on groundwater levels; GW/SW interactions (upwelling and downwelling), and water quality. In addition, shallow groundwater wells used by residents (e.g., domestic) may also be dependent on Susitna River GW/SW interactions.

The information developed in this study will be used for the affected environment and environmental effects portion (Exhibit E environmental report) of the Project license application and to determine what, if any, protection, mitigation, or enhancement measures may be appropriate for the Project license.

7.5.3. Study Area

The study areas related to groundwater processes primarily cover the Susitna River from the Parks Highway bridge (RM 84, located near USGS Gage - Susitna River at Sunshine) to an area just upstream of the dam (RM 184) for detailed studies. If hydrologic modeling shows the Project impact extends below RM 84, or focus areas are located below RM84, then the study area will be extended downstream to the point the simulation proposed Project operations do not indicate significant variations in hydrologic conditions. The review of background information and large-scale geohydrologic process-domains/terrain of the Susitna River cover the complete Susitna Watershed. This overview at a watershed scale is important for determining the boundary conditions affecting groundwater flow conditions along the river corridor.

7.5.4. Study Methods

The Groundwater Aquatic Habitat Study is divided into nine study components related to the study objectives outlined in Section 7.5.1.1: (1) Existing Data Synthesis, (2) Geohydrologic

Process-Domains and Terrain; (3) Watana Dam / Reservoir, (4) Upwelling / Springs Broad-Scale Mapping, (5) Riparian Vegetation Dependency on GW/SW Interactions; (6) Fish Habitat GW/SW Interactions; (7) Water Quality in Selected Habitats, (8) Winter GW/SW Interactions, and (9) Shallow Groundwater Users. Each of the components and their related study methods are explained further in the following subsections. The methods described represent standard approaches for summarizing data and assessing the physical/biological processes related to groundwater and aquatic habitat.

7.5.4.1. Existing Data Synthesis

Data from prior Susitna River hydroelectric evaluations and other studies will be used to help develop a detailed reference source of available data to support the study elements and GW/SW interactions and processes related to potential project operations and design. The addition of the historical data will help provide a more thorough review of the geohydrology of the watershed and relevant GW/SW interactions and how they may change under the various Project operational designs. The use of existing information will also help meet the need for detailed analysis under the proposed Project timeframe. The specific steps of the data synthesis include;

- Identify existing reports and data from the 1980s licensing effort, prior studies, and more recent studies that relate to geohydrology of the Susitna Watershed and GW/SW interactions and related aquatic habitat in the Susitna River.
- Identify applicable geology, soils, and other geohydrologic references for the Susitna Watershed. Information collected by the Geology and Soils Study (Section 4.5). Water quality data will be provided by the Baseline Water Quality Study (Section 5.5) for groundwater and surface water (Figure 7.5.3). Additional water-quality data will be provided by Instream Flow Study historical information reviews.
- Produce a searchable and annotated bibliography of references and data sources for use by study teams and resource agencies. The annotated bibliography will be coordinated with the ARLIS resource library staff to follow their Susitna reference standards. The annotated bibliography will be provided to ARLIS as part of their Project resource collection program.
- Synthesize collected references and data with respect to the objectives of this study (e.g., understanding the potential impacts of the Project on GW/SW interactions and aquatic habitat).

7.5.4.2. Geohydrologic Process-Domains and Terrain

Project operations could have impacts along the river from the dam and reservoir location to below the confluences of the Chulitna and Talkeetna Rivers. Site specific studies will help characterize these influences for key aquatic habitat and riparian study areas. The

- Define the significant geohydrologic units in the Susitna Basin that provide groundwater recharge to the mainstem and associated side channels and sloughs. ASTM standard D5979 will be used to help define the geohydrologic units (ASTM, 2008b).
- Relate the geohydrologic units (e.g. bedrock, alluvial) to geomorphologic and riparian mapping units (process-domain river segments) in coordination with the Geomorphology and Instream Riparian Studies (Montgomery, 1999).

- Define the groundwater regional scale to local flow systems in the mainstem reaches and the relationship with the process-domain river segments. Similar studies for the Tanana Watershed have been reported by Anderson, 1970. ASTM standard D6106 will be used to help characterize the groundwater aquifers relevant to Project proposed operations.
- Identify the relationship between the process-domain river segments and the planned intensive study areas to help transfer the analysis of potential Project affects on GW/SW interaction from the individual study areas back to the larger process-domain river segments.

7.5.4.3. Watana Dam/Reservoir

The construction and operations of the dam and reservoir and supporting infrastructure may influence groundwater conditions downstream of the dam and the characteristics of the discontinuous permafrost conditions in the vicinity of Project operations. Variation in reservoir levels will result in transient head conditions on the upstream side of the dam. Project engineering programs and the Geology and Soils Study (Section 4.5) will provide information to help evaluate the groundwater conditions in the Project area and evaluate the potential for the groundwater impacts downstream of the dam.

- Evaluate engineering geology information from the dam and reservoir area. Information will be used from the Geology and Soils Study (Section 4.5) and past geotechnical studies of the proposed dam location (Figure 7.5.3). This will include geologic well logs, pump tests, seismic data if available, permafrost information, water level records.
- Coordinate with the engineering efforts and geomorphology and fluvial geomorphology modeling (Section 5.8, 5.9) studies to utilize existing data-collection programs and evaluate the need for additional data collection in the Project area to evaluate groundwater conditions.
- Describe the pre-Project groundwater conditions at the Watana Dam and Reservoir vicinity.
- Characterize the known permafrost and bedrock hydrogeology at the Watana Dam vicinity.
- Develop conceptual GW/SW models of the pre-Project and post-Project conditions.
- Identify the key potential groundwater pathways for groundwater flow with the Project (e.g., Deadman Creek drainage) and how the proposed dam construction designs will affect groundwater flow. The engineering design of the dam includes a goal of grouting all groundwater pathways that could be subject to bypass groundwater flow in the vicinity of the dam.
- Evaluate the potential changes in the groundwater flow system as a result of Project operations.

7.5.4.4. Upwelling / Springs Broad-Scale Mapping

The proposed Project operations could impact ice formation and related GW/SW interactions. Broad-based mapping will be used to understand the pre-Project conditions and GW/SW interaction and relationships along the river corridor. This will help evaluate the potential spatial distribution of propose Project operations. The following methods will be used to map GW/SW interactions and upwelling during winter and summer seasons.

- Aerial and GPS mapping of winter open leads, Spring 2012, 13, 14 (Ice Processes Study (Section 5.10) (Figure 7.5.3). Open leads from RM 0 to RM 250 will be mapped aerially or by satellite imagery and documented using GPS-enabled cameras. Leads will be classified by location (main channel, side channel, slough, tributary mouth) and type (thermal or velocity, where identifiable). The upstream and downstream limits of each open lead will be located using an Archer handheld mapping GPS or from orthophotographs, and the width of each lead will be estimated. Open leads in the Middle River will be compared with the location of open leads documented in 1984-1985 in the Middle River, as appropriate. To provide some context, air temperatures from 1984-1985 will be compared with air temperatures measured during the 2012-2013 and 2013-2014 winter seasons from the closest long term site with data covering both periods. GIS coverages of open leads will be developed. The general focus for ground water studies will cover the portion of the Susitna River from RM 84 (located near USGS Gage on Susitna River at Sunshine) to RM 184 (near the proposed dam location).
- Aerial photography of the ice free period showing turbid and clear water habitat, summer 2012-Summer 2014 (Instream Flow Studies (Section 8.5)). Aerial photography at a range of flows from 5,000 cfs to 23,000 cfs will be collected in the Geomorphology and Instream Flow Studies to map geomorphic change and to document habitat surface area versus discharge. The aerial photography will be used to document turbid and clear water (i.e., groundwater influenced) habitats. Clearwater inflow from side drainages (e.g. Portage Creek), will be separated from those dominated by groundwater recharge (upwelling) to surface-water features.

In a study performed by Harza-Ebasco Susitna Joint Venture (1984) turbidity and concurrent, co-located sediment concentration measurements were collected under various flow conditions at three different locations on the Susitna River (near Cantwell, near Chase, and at Gold Creek). It was found that turbidity was well-correlated with suspended sediment concentration ($r^2 = 0.92$). This suggests the potential Project impacts on turbidity in the Susitna may be assessed by determining potential Project impacts on suspended sediment concentrations.

- Conduct a pilot thermal imaging assessment of a portion of the Susitna River, fall 2012 or during 2013 (Baseline Water Quality Study (Section 5.5) (Figure 7.5-3). Thermal imagery of a portion of the Susitna River (e.g., 10 miles of the Middle River) will be collected. Data from the thermal imagery will be ground-truthed and the applicability and resolution of the data will be determined in terms of identifying water temperatures and thermal refugia/upwelling. The thermal imaging assessment will build on the similar studies reported in the 80s (Sandone and Estes, 1984) and evaluate the potential applications with current thermal imaging technology. In coordination with the Instream Flow and fish studies, a determination will be made as to whether additional thermal imaging data will be applicable and whether or not additional thermal imaging will be collected to characterize river-temperature conditions. If the pilot study is successful, then a description of thermal refugia throughout the project area can be mapped using aerial imagery calibrated with on-the-ground verification.
- Identify potential GW/SW interaction areas based on observations of spawning or rearing fish (Fish Population Studies (Section 9)). Where aggregations of spawning fish or rearing fish are observed from radio telemetry data, sonar, visual spawning surveys, or

other sampling (electrofishing, seining) that potentially are related to groundwater upwelling, test whether or not upwelling is present by using temperature profiling techniques (e.g., measuring the vertical temperature profile or measuring the temperature along the bottom of the river along a transect).

- Characterize the identified upwelling/spring areas at a reconnaissance level whether the identified upwelling/spring areas using the methods outlined above are likely either to be (1) main flow/stage dependent, (2) regional/upland groundwater dependent, or (3) mixed influence.

7.5.4.5. Riparian Vegetation Dependency on Surface-Water / Groundwater Interactions

Coordinate project activities with the Ice Processes (Section 7.6), Geomorphology (Section 6.5), Riparian (Section11.6), and Instream Flow studies (Section 8.5). The work under this objective will be accomplished by the Riparian Instream Flow Study (Section 8.6). Figure 7.5.3 shows the relationship in interdependencies between these studies and the riparian groundwater study element.

- Select representative intensive riparian vegetation study reaches suitable for the overlapping needs of the Ice Processes (Section7.6), Water Quality (Section 5.5), Geomorphology (Section 6.5), Botanical Riparian (Sections 11.6, 8.6), and Instream Flow GW/SW studies. For example, the riparian instream flow, aquatic instream flow and water quality studies all need quantitative information regarding the relationship between river stage, upwelling areas and floodplain shallow aquifer groundwater levels. Field sampling GW/SW designs will be coordinated to accommodate the various study objectives.
- Develop physical modeling studies of select intensive study reaches representative of Susitna Project Area riverine process-domains (Montgomery 1999). Physical models, including surface-water hydraulic (1-D and 2-D), geomorphic-reach analyses, GW/SW interactions, and ice processes will be integrated such that physical process controls of riparian vegetation recruitment and establishment may be quantitatively assessed under both existing conditions and dam operation flow regimes.
- Collect empirical data related to GW/SW interactions (e.g., piezometers, water levels, water temperature and conductivity, tracer studies). GW/SW interaction data will be collected at the intensive study reaches utilizing multiple transects of arrays of groundwater wells, piezometers and stage gages. Wells will be placed to help describe the hydrologic conditions at internal boundaries (such as sloughs, side channels, ponds) and at varying distances from these boundaries to help measure the time lag in water level responses in the water table to changes in surface-water stage changes (such as a precipitation runoff peak). Well locations will also take into account the riparian vegetation mapping units and have wells in areas to make sure various units are represented. Some wells will be placed at certain boundaries of the groundwater model simulation domains to provide model boundary input data, or validation data sets. Additional information, such as unfrozen volumetric soil-moisture content and soil temperature profiles will be measured to help understand the characteristics of active freeze/thaw processes and moisture transfer from infiltration and underlying dynamic

groundwater tables in the soil horizon critical to riparian root zones. Table 7.5-1 shows a listing of the data collection system sensors and measurements. The GW/SW data will be used to quantify, and model, the relationship between floodplain shallow surface aquifers and floodplain plant community types.

- Precipitation data will be measured at each of the riparian Focus Areas. Shielded summer precipitation gages will be installed in early spring 2013 in time for the 2013 summer season. The information will be compared with the recent update to the statewide precipitation evaluation and new index maps. Additionally, precipitation information collected by the Glacier Runoff Study will be incorporated into the precipitation analysis for the riparian focus areas.
- In groundwater wells and surface-water measurement stations, the minimum recording interval for water levels, temperature, and other parameters will be 15 minutes. There will be some locations close to surface-water sources where stage changes are expected to be rapid, data collection intervals may be reduced down to 1-minute. In all cases, hourly maximum, minimum, and average values will also be recorded, as well as daily statistics. The data collection intervals are intended on providing data to study and understand transient pressure pulses in the GW/SW systems and provide both input and calibration data sets for groundwater model development and simulations goals. The current network of gaging stations started in summer of 2012 will continue operations through the winter of 2012/13 into 2013 and 2014. Technical evaluations will be made in the summer of 2014 as to which gaging stations need to be operated during the winter of 2014/15. Groundwater monitoring programs will begin at a small scale in winter 2012/13 and the increase during summer of 2013. The monitoring of groundwater wells will continue into 2014. At that time, a subset of the groundwater wells may be monitored for the winter of 2014/15.
- Monitoring wells will be surveyed with a combination of RTK survey methods and optical level loop methods. This will be done at least two times a year, or more frequent if well movements are recorded. Pressure transducer measurement will be verified with manual measurement at least month during summer months, and 3-4 times during winter periods. Both calibration (for determining offsets) and verification water levels will be collected. Conductivity and temperature sensors will have calibration checks performed before field installations and field calibration checks monthly during summer months. Calibration checks during winter months will be performed at least once during the mid winter period when safe access and weather conditions allow, and before spring breakup and fall freeze-up.
- The Groundwater Study will provide the time series for measured and simulated groundwater levels to help provide the summary statistics needed for developing plant-response curves. The groundwater and surface water field measurements for continuous monitored stations will be 15 minutes or less. Model simulations will also 15 minutes or less, based on analysis of modeling results. This information will produce time series data sets, from which water level summary statistics can be calculated for a range of analysis objectives, such as running averages in hourly and daily increments.
- Where appropriate, develop MODFLOW (USGS 2005 and USGS 2012) GW/SW interaction models of floodplain shallow alluvial aquifer and surface-water relationships.

MODFLOW GW/SW interaction models will be used to model GW/SW relationships using empirical monitoring data collected at intensive study reach GW/SW monitoring stations. Similar approaches to understanding GW/SW interactions have been reported in Nakanishi and Lilly, 1998. ASTM standard D6170 will also be used to help determine the model code and approach used for analysis (ASTM, 2008b). ASTM standard D5981 will be used to help develop calibration goals and procedures for groundwater modeling efforts (ASTM, 2008c). The groundwater models may be developed for three different purposes (after Anderson, Woessner, 1992);

  - Generic: used to analyze flow in hypothetical hydrogeologic systems, may not need calibration, useful for helping frame regulatory guidelines
  - Interpretative: used as a framework for studying system dynamics and/or organizing field data, may not require calibration
  - Predictive: used to predict the future, requires calibration

- Generic and interpretative models may be used to help improve process understanding, design of data collection field programs, and developing the frame work for predictive models. Predictive models will used to simulate Project effects. The application of snowmelt and precipitation runoff stage-change events will be used to develop and calibrate groundwater models. Independent hydrologic events will be used to validate the models. So, a year with snowmelt peak and 3 precipitation peaks may provide three peaks for model development and calibration and one event to validate the model simulation capabilities. Figure 7.5-4 shows an example of how the last three years of daily discharge data would be used to help provide data for model development, calibration, and validation. Data from the 2013-14 study periods will be used to provide similar information as that provide for the period of record shown in the figure. The interaction between the river stage changing and adjacent groundwater is shown in Figure 7.5-5. An example of GW/SW interactions is shown in Figure 7.5-6 for the Chena River and a line of adjacent wells installed at varying distances from the river up to 8,800 feet away (Nakanishi and Lilly, 1998). The pressure response to the river stage changes is seen in Figure 7.5-6. The three main stage peaks on the Chena River are seen in each well out to the furthest well 8,800 feet away. Figure 7.5-7 illustrates the application of river and groundwater levels being used as boundary conditions for a two-dimensional groundwater flow model.
- The purpose of the Focus Areas (FAs) is to develop intensive enough data collection and analysis programs to define the groundwater/surface-water interactions and hydrologic cycle processes in a variety of environments so the process understanding can be used at the larger scale to evaluate potential Project affects and methods for alternating Project operations to reach desired management goals. The FAs will be used in conjunction with hydrologic analysis to help inform the Project and agencies on the hydrologic interactions and range of natural variability in the system. Response curves for the CFA's will be evaluated as part of the Riparian Groundwater Study (see RSP 8.6.4.5).
- Predictive models of groundwater response to dam operational flow regime will be developed from the empirically developed models.

- Collect field data on riparian plant communities in coordination with Botanical Riparian Studies. Riparian floodplain plant community characterization and mapping at each intensive study reach will overlap in design with the Botanical Riparian Survey of the entire project study area. Some additional more intensive riparian plant community measurements concerning dendrochronology, soils and effective plant community rooting zones will be done in support of the riparian vegetation GW/SW interaction analyses. Riparian plant community characterization will follow the Botanical Riparian survey methods utilizing an Integrated Terrain Unit (ITU) approach (Jorgenson et. al. 2003) for mapping riparian habitats to Level IV of the Alaska Vegetation Classification (Viereck et al. 1992).
- Develop integrated physical process and plant succession models in coordination with the Instream Flow, Geomorphology, Ice Processes and Botanical Riparian Study Teams. The riparian vegetation GW/SW interactions study approach and design will be integrated with the findings of the riparian plant community succession and geomorphology, ice processes physical processes modeling to characterize physical processes and riparian plant community relationships. The results of these studies will be used to assess (1) changes to physical processes due to dam operations, and (2) response of riparian plant communities to operations alterations of natural flow and ice processes regimes.

7.5.4.6. Aquatic Habitat Groundwater / Surface-Water Interactions

Coordinate project activities related to fish habitat with the Ice Processes, Instream Flow Riparian Study, Geomorphology Studies and Water Quality Study. The work under this objective will be accomplished by the Instream Flow Study. GW/SW interactions have been shown to strongly influence salmonid habitat use and biological functions including selection of spawning and rearing habitats, as well as egg/alevin survival. Understanding these interactions relative to fish will require close coordination with other studies focused on riverine processes that are likewise influenced by these interactions. The Instream Flow Program Lead and the Groundwater Aquatics Study Lead will work closely with other study leads (Fisheries, Ice, Geomorphology, Water Quality) to ensure the groundwater studies are fully integrated.

- Habitat mapping that incorporates groundwater affected aquatic habitat. This work will expand on the results of the Upwelling/Springs Broad-Scale Mapping (Section 5.7.4.4) and will provide a more intensive evaluation of specific study sites identified as exhibiting GW/SW interactions. Selection of sites will be based in part on results of the upwelling/springs mapping tasks as well as results of previous investigations (e.g., 1980s studies) of certain sites that have indicated a groundwater influence. Study sites will be selected that are representative of different types of GW/SW /hyporheic flow connections including main and side channel (side slough) head, floodplain groundwater lateral flow, and direct groundwater upwelling. Sites will include those known (based on 1980s studies) to be used by fish, and to the extent identifiable, sites that exhibit groundwater influence but are not extensively used by fish. Consideration will also be given to completion of egg survival studies as a means to compare egg survival at these different locations. These studies will allow for a comparative assessment of groundwater related parameters and surface-flow linkages that are influencing fish use and will be important for characterizing other sites and expanding results from measured to unmeasured areas.

A variety of techniques will be considered for implementation at each site with the final determination based on site specific characteristics. These will include installation of pressure transducers (mainstem – side channel – side slough – other) to assess linkages of surface flow to other habitats and potential groundwater influence, installation of piezometers to monitor/map GW/SW upwelling areas, installation of Mark VI standpipes to monitor hyporheic water quality (temperature and dissolved oxygen concentration), dye injection to trace surface-hyporheic flow paths, handheld Thermal Infrared Imaging (TIR), thermal profiling (including installation of a spatial array of temperature monitors at surface and subsurface points), and others. The selection will be made collaboratively with the Geomorphology, Riparian, Water Quality and Fisheries study leads.

- Where appropriate, develop MODFLOW (USGS 2005 and USGS 2012) GW/SW interaction models of floodplain shallow alluvial aquifer and surface-water relationships. MODFLOW GW/SW interaction models will be used to model GW/SW relationships using empirical monitoring data collected at intensive study reach GW/SW monitoring stations. These approaches are described in Section 7.5.4.5 for the Riparian Groundwater study element. The location of groundwater wells and surface-water water-level or gaging stations will be coordinated with the Riparian data collection program. For the develop and calibration of the study-area scale modeling, well placements will be similar, as well as data collection intervals (minimum of 15-minute). Additionally, instream aquatic applications will need to characterize difference in groundwater conditions adjacent to and under surface water sources that are being evaluated for variations in instream flow conditions important for fisheries ecosystem functions. This would include the installation of groundwater and surface-water observation stations in sloughs and side channels that are both productive and nonproductive. The duration of monitoring will vary for different hydrology data collection programs. The current network of gaging stations started in summer of 2012 will continue operations through the winter of 2012/13 into 2013 and 2014. Technical evaluations will be made in the summer of 2014 as to which gaging stations need to be operated during the winter of 2014/15. Groundwater monitoring programs will begin at a small scale in winter 2012/13 and the increase during summer of 2013. The monitoring of groundwater wells will continue into 2014. At that time, a subset of the groundwater wells may be monitored for the winter of 2014/15.
- Monitoring wells will be surveyed with a combination of RTK survey methods and optical level loop methods. This will be done at least two times a year, or more frequent if well movements are recorded. Pressure transducer measurement will be verified with manual measurement at least month during summer months, and 3-4 times during winter periods. Both calibration (for determining offsets) and verification water levels will be collected. Conductivity and temperature sensors will have calibration checks performed before field installations and field calibration checks monthly during summer months. Calibration checks during winter months will be performed at least once during the mid winter period when safe access and weather conditions allow, and before spring breakup and fall freeze-up.
- Hydraulic unsteady flow routing to identify water-surface elevations. As noted in Figure 6.5-3 in Section 6.5, the mainstem flow routing model will serve to predict water-surface elevations under different flow conditions longitudinally throughout the length of the river below the Watana Dam site (RM 184). The model will thus be able to predict water

surface elevations (WSEs) proximal to the intensive study sites noted above, as well as other areas identified as being groundwater influenced. The WSEs empirically measured in side channels, sloughs and groundwater wells installed in the floodplain at the intensive study sites can therefore be related to mainstem WSEs allowing for a detailed analysis of spatial and temporal changes in WSE under different operating conditions, including base load and load following scenarios.

- HSC and HSI development that includes groundwater related parameters (upwelling / downwelling). Development of HSC and HSI will follow the general procedures outlined in the Instream Flow Study as noted under Section 6.5.4.4.1. Parameters specific to groundwater that will be measured where appropriate include turbidity, evidence of upwelling/downwelling currents, substrate characteristics, and water temperature. Other parameters may also be included. These parameters will be incorporated into the development of HSC type curves that reflect utilization of these parameters by fish. This work will be closely coordinated with the Fish Studies (Section 9).
- Develop mainstem, side channel, slough habitat models that incorporate GW/SW related processes (main channel head, upwelling / downwelling) (Figure 8.5-2). An integral part of the SWIFS will be development of habitat-specific models that can be used in evaluating flow (and WSE) relationships between the mainstem river and other habitat types (including those influenced by groundwater), under different operational scenarios. These types of models (e.g., flow routing) are generally described in more detail in the Instream Flow Study (Section 8.5).
- The groundwater aquatics study is coordinating with both Instream Flow and Fisheries studies on the selection of Focus Areas (FAs). The groundwater study will be measuring the both horizontal and vertical head gradients through combinations of nested wells installed at different depths and shallow wells installed in surface-water habitat areas to measure the gradients between surface-water sources and underlying groundwater conditions. Details on the measurement of fluxes can be found in the RSP in section 7.4.5.6. These gradients will be compared with simulated gradients from groundwater/surface-water models under the field conditions measured in 2013 and 2014 and compared with project operation scenarios.

7.5.4.7. Water Quality in Selected Habitats

Water-quality characteristics are likely to vary with GW/SW interactions and potential impacts due to proposed Project operations. Coordinate project water-quality activities with the Instream Flow Riparian Study (Section 8.6), Geomorphology Studies (Section 6.5,6.6) and Instream Flow Studies (Section 8.5). The work under this objective will be accomplished by the Baseline Water Quality Study (Section 5.5). The following methods will be used in coordination with the indicated studies to understand water quality characteristics and the variation between groundwater and surface water. This will help evaluate the potential changes in water quality related to GW/SW interactions and potential impacts related to proposed Project operations.

- At selected instream flow, fish population, and riparian study sites collect basic water chemistry (temperature, DO, conductivity, pH, turbidity, redox potential) that define habitat conditions and characterize GW/SW interactions (Section 5.5). For example, where possible, characterize differences between groundwater representative of regional groundwater conditions, groundwater in the mixing zone at the GW/SW interface (slough or river bed), and surface-water sources (sloughs and side channels).

- Characterize the water quality differences between a set of key productive aquatic habitat types (3-5 sites) and a set of non-productive habitat types (3-5 sites) that are related to the absence or presence of groundwater upwelling to improve the understanding of the water-quality differences and related GW/SW processes. For example, use the Fish Population Study (Sections 7.5, 7.6, 7.9) results and coordinate with the Instream Flow Study (Section 6.5) to select paired productive and non-productive habitats (also see the second bullet in this section).

7.5.4.8. Winter Groundwater / Surface-Water Interactions

Winter GW/SW interactions are critical to aquatic habitat functions. Proposed Project operations will have an impact on the winter flow conditions of the mainstem and side channels and sloughs. The collection of hydrologic conditions (i.e. water levels, discharge, ice conditions) is critical to understanding current winter flow conditions and evaluating the potential impacts of Project operations. The following methods will be used to help measure and evaluate winter flow conditions and associated GW/SW interactions.

- Measure water levels/pressure at the continuous gaging stations on the Susitna River during winter flow periods. Continuous gaging stations will be measuring water levels and temperature as part of the Instream Flow studies taking place. Water levels measured during full ice cover are generally referred to as water pressure and represent the hydrostatic head of the river. The Project is expected to increase average monthly flows in the Susitna River during the winter months, and this may have an impact on GW/SW interactions during that season.
- Measure winter discharge measurements to help identify key sections of the mainstem with groundwater baseflow recharge to the river (upwelling). Winter discharge will be measured as part of the Instream Flow (Section 6) studies and in coordination with USGS winter measurement efforts at USGS gaging stations to identify winter gaining and losing reaches. These field activities will be closely coordinated with the Ice Process studies (Section 5.10).
- In key study areas, measure channel/slough temperature profiles to help characterize the GW/SW interactions and temporal variations over the winter flow season.

7.5.4.9. Shallow Groundwater Users

There are a number of groundwater wells located in the Susitna River floodplain, which have demonstrated the interconnections between groundwater and surface water. The influence of proposed Project operations could change water levels and water quality water supply wells. A majority of the wells are expected to be private homeowner wells. The below methods will be used to evaluate the potential impacts of the Project on water supply wells in the area under potential impact by the Project.

- Use the Alaska Department of Natural Resources Well Log Tracking System (WELTS) and the USGS Groundwater Site Inventory (GWSI) Database to map domestic and other water-supply wells along the Susitna River downstream of the proposed Watana Reservoir.

- At a reconnaissance level stratify the wells by potential to be affected by the Susitna River flow regime (high, medium, and low) using factors such as depth and proximity to the Susitna River. Select a small number of representative wells with high potential to be affected by the Susitna River flow regime and monitor well levels and river stage. River stage information will come from correlations with the gaging stations measuring water levels that are part of the Instream Flow studies.
- Based on the results from the well monitoring and an analysis of potential Project operations flow data, determine the potential effects of the Project on shallow groundwater wells and determine if additional monitoring of wells may be appropriate. ASTM method D6030 will be used to help address groundwater vulnerability (ASTM 2008).

7.5.5. Consistency with Generally Accepted Scientific Practice

The proposed study methodology was cooperatively developed with the assistance of science and technical experts from state and federal management agencies. The methods for data collection, data analysis, modeling, and interpretation are consistent with common scientific and professional practices. ASTM and USGS standards and practices will be used with each study component as applicable. Many of these technical experts have experience in multiple FERC licensing and relicensing proceedings. The scope of each of the studies is consistent with common approaches used for other FERC proceedings and reference specific protocols and survey methodologies, as appropriate.

7.5.6. Schedule

The groundwater study will occur in 2013 and 2014 study period, Table 7.5-2. Coordination with other study groups will occur throughout the project period, Figures 7.5-3, 7.5-4, 7.5-5. The collection of information for the existing data synthesis will be initiated at the beginning of the study period and be completed by the end of summer 2013. The definition and development of geohydrologic process domains and terrains will take place in the same time period, to help guide other study design and field efforts during the summer of 2013.

Winter focus studies will begin with existing data collections activities started in 2012 and increase with the installation of data collection systems in study sites in early summer 2013. Data from water quality, instream flow and other studies will be provided after data quality assurance have been completed, normally within a month of data collection in the field. Coordination with each of the associated studies providing data will occur at the beginning of the study period and be part of the schedules for each study. The Initial Study Report and the Updated Study Report will be issued within 1 and 2 years of FERC’s Study Plan Determination (i.e., February 1, 2013).

7.5.7. Level of Effort and Cost

The level of effort for the groundwater study objectives is distributed in this and other studies. The groundwater study costs reflect the analysis of data collected in this and other studies. The study objectives and associated primary costs associated with each objective for the 2013-14 study period are:

- 7.5.4.1 - Existing Data Synthesis
  - Groundwater Study
- 7.5.4.2 - Geohydrologic Process-Domains and Terrain
  - Groundwater Study
- 7.5.4.3 - Watana Dam / Reservoir
  - Groundwater Study–analysis only
  - Engineering, Geology (Section 4.5), Geomorphology (Section 6.5, 6.6) studies include field and data collection costs
- 7.5.4.4 - Upwelling / Springs Broad-Scale Mapping
  - Groundwater Study–analysis only
  - Ice Processes (Section 7.6), Geomorphology (Section 6.5, 6.6), Instream Flow (Section 8.5), Water Quality (Section 5.5, 5.6) studies include field and data collection costs
- 7.5.4.5 - Riparian Vegetation Dependency on Groundwater / Surface-Water Interactions
  - Groundwater Study–field installation of groundwater wells and data collection stations and instrumentation, coordination and analysis
  - Riparian Instream Study (Section 8.6) includes field and data collection costs
- 7.5.4.6 - Fish Habitat Groundwater / Surface-Water Interactions
  - Groundwater Study – field installation of groundwater wells and data collection stations and instrumentation in combination with Instream (Section 8.5), coordination and analysis
  - Instream Flow Study (Section 8.5) also includes field and data collection costs
- 7.5.4.7 - Water Quality in Selected Habitats
  - Groundwater Study–coordination and analysis only, some sensors in coordination with Riparian and Instream study elements
  - Water Quality (Section 5.5, 5.6), Instream Flow (Section 8.5) studies include field and data collection costs
- 7.5.4.8 - Winter Groundwater / Surface-Water Interactions
  - Groundwater Study–field data collection, coordination and analysis
  - Instream Flow Study (Section 8.5) also includes some field and data collection costs
- 7.5.4.9 - Shallow Groundwater Users
  - Groundwater Study

The groundwater study costs are estimated to be $1,800,000 to $2,850,000 beyond the data collection costs allocated throughout the studies mentioned above. The final cost will be determined by the number of focus area sites that are selected and are included in the riparian and instream study focus areas. The instrumentation, wells, installation and analysis could be $250,000 depending on scale of each site

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7.5.9. Figures

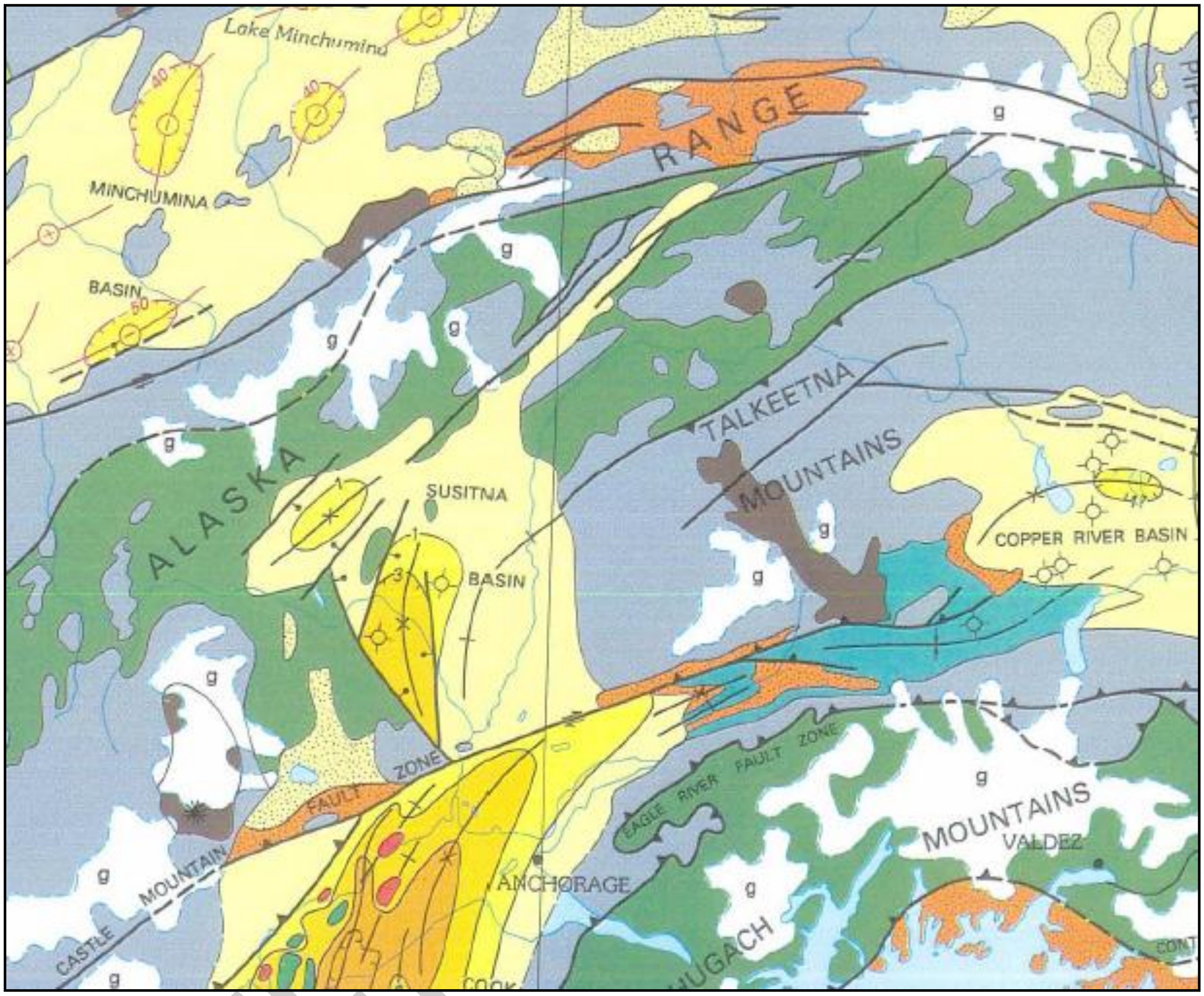

Figure 7.5-1. Sedimentary basins and geologic structure in Susitna Watershed (modified from Kirschner 1994).

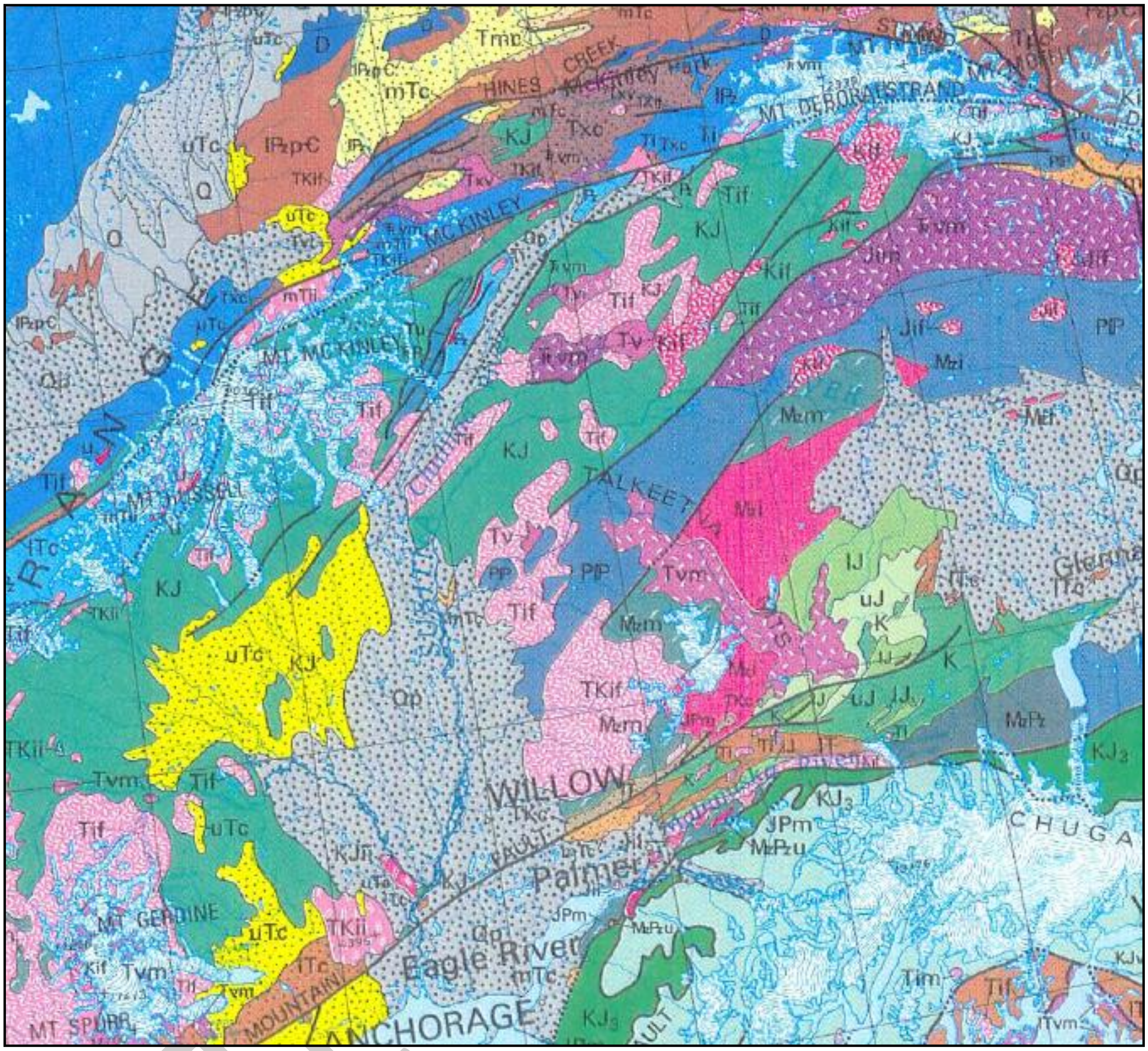

Figure 7.5-2. Geologic units in Susitna Watershed (modified from Beikman 1994).

STUDY INTERDEPENDENCIES FOR GROUNDWATER-RELATED AQUATIC HABITAT STUDY

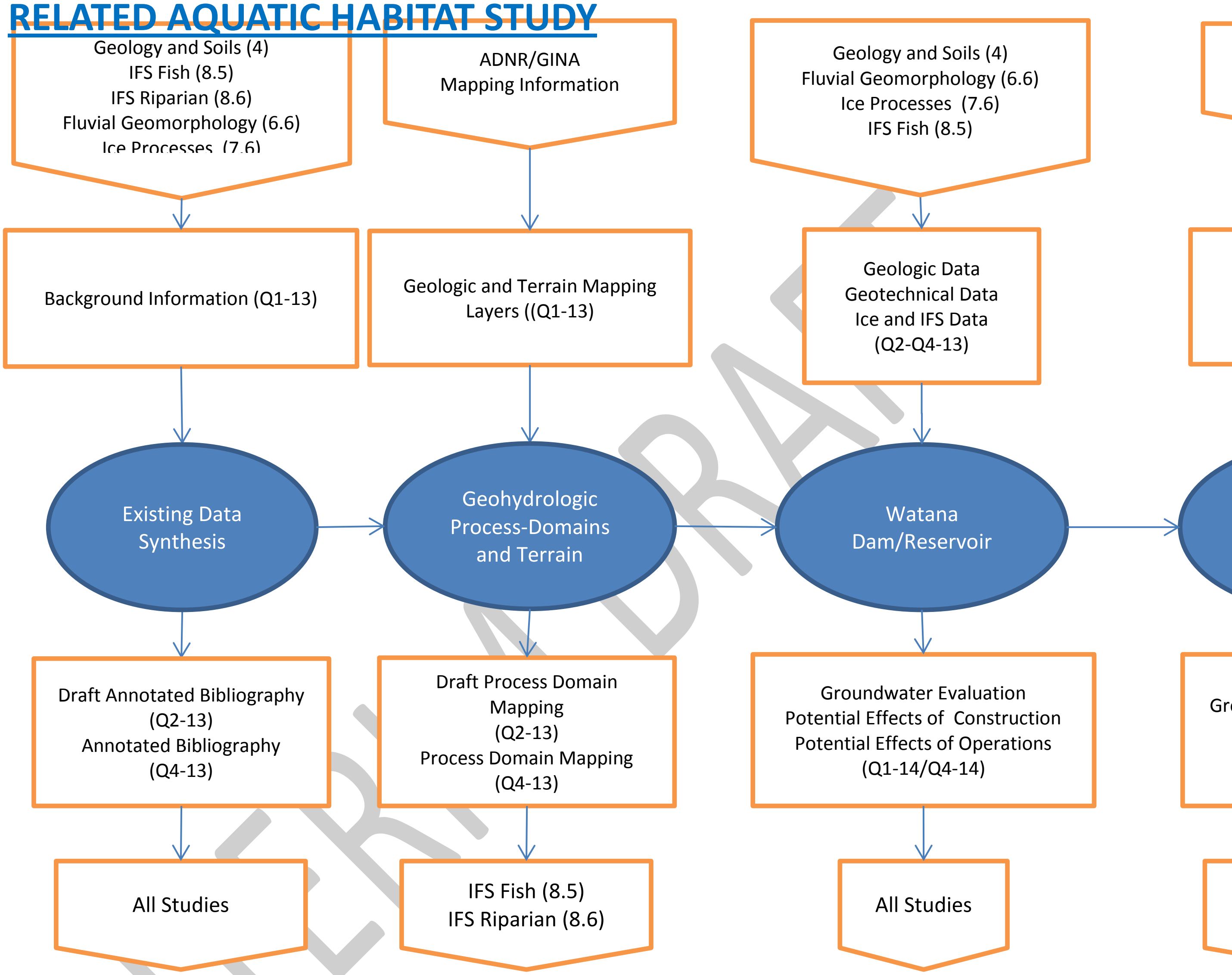

Figure 7.5-3. Study interdependencies for the groundwater-related aquatic habitat study.

STUDY INTERDEPENDENCIES FOR GROUNDWATER-RELATED AQUATIC HABITAT STUDY

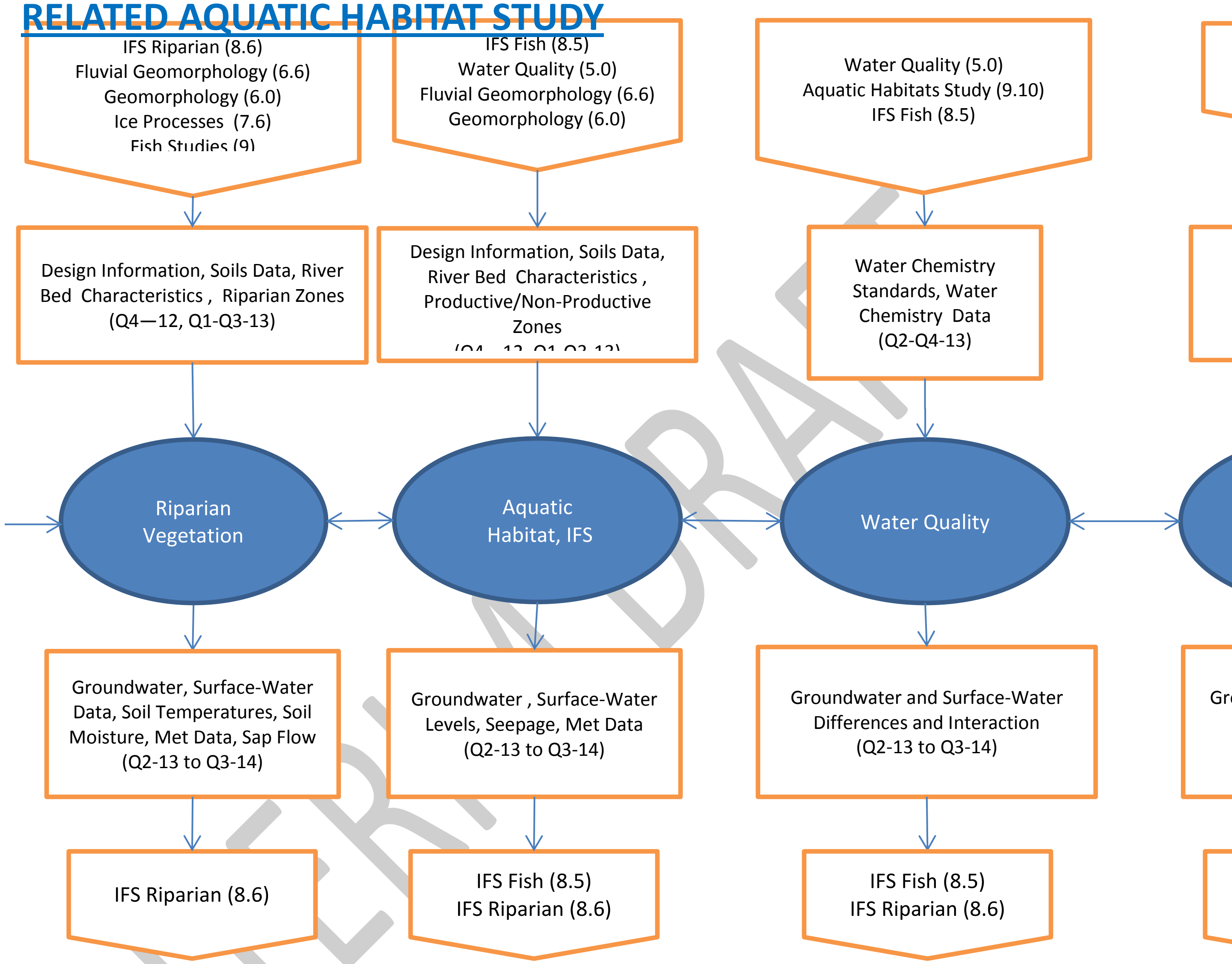

Figure 7.5-3. Study interdependencies for the groundwater-related aquatic habitat study (continued).

STUDY INTERDEPENDENCIES FOR GROUNDWATER-RELATED AQUATIC HABITAT STUDY

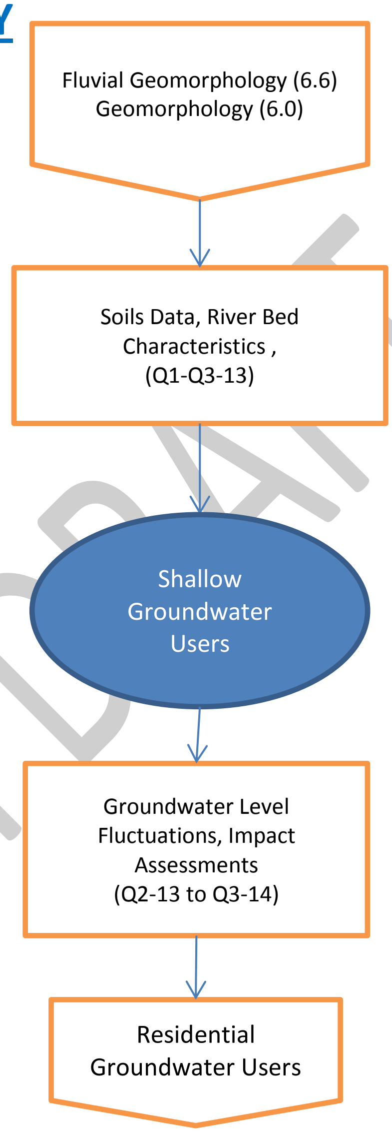

Figure 7.5-3. Study interdependencies for the groundwater-related aquatic habitat study (continued).

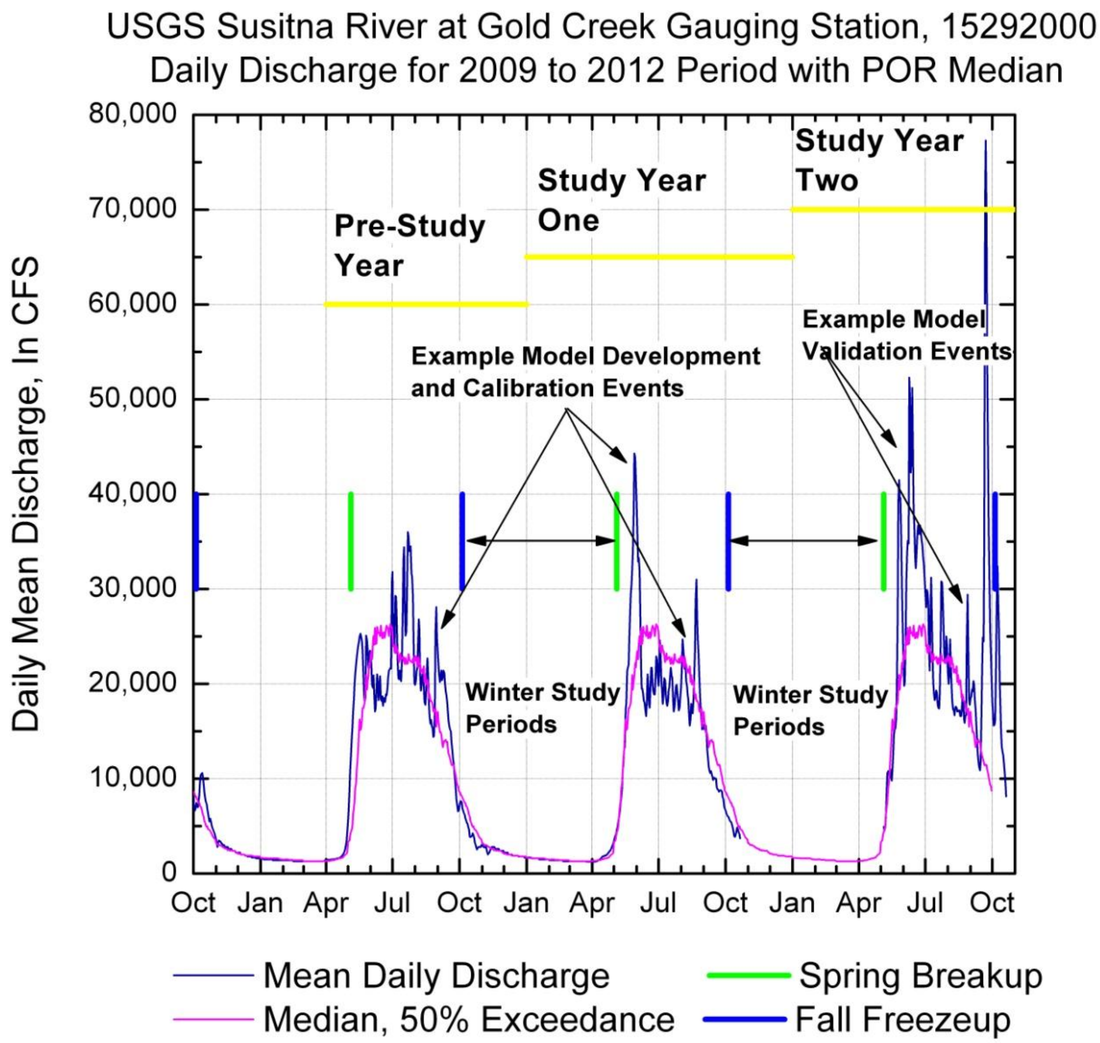

Figure 7.5-4. Discharge hydrograph record for the Susitna River at Gold Creek to help illustrate the use of snowmelt or precipitation peaks for collection of data for hydrologic model (surface and groundwater) development, calibration, and validation. The daily discharge for the last three years is shown to illustrate how future hydrologic data will be used with the modeling development planned for the study.

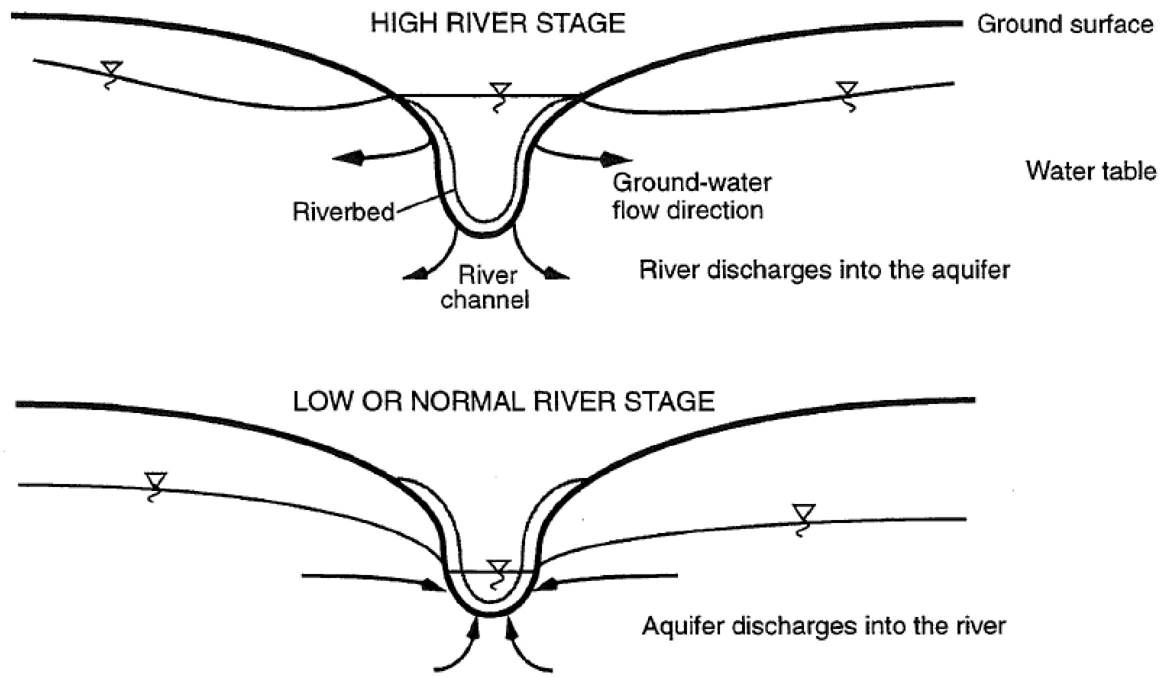

Figure 7.5-5. Illustration of groundwater and surface-water interactions with changing stage levels.

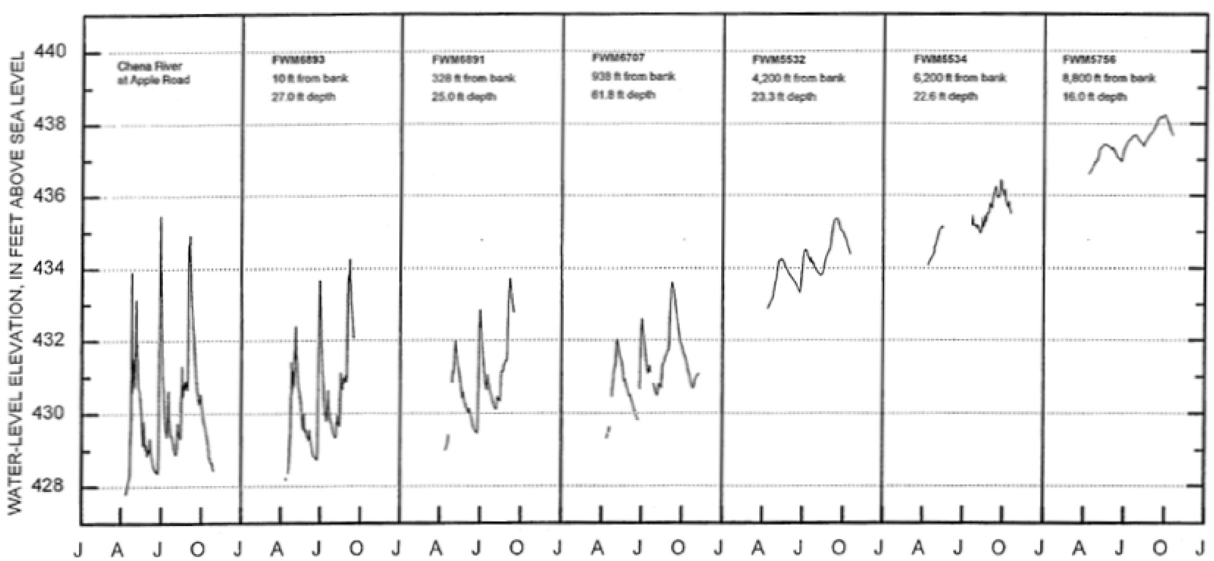

Figure 7.5-6. Groundwater responses to stage changes in the Chena River. The Chena River stage is shown on the left, with groundwater levels show for wells that are increasing distances away from the Chena River. The spring snowmelt peal and two primary precipitation peaks in the Chena River can be seen in each of the groundwater hydrographs shown, the furthest well being 8,800 feet from the Chena River on a north-south line (Nakanishi and Lilly, 1998).

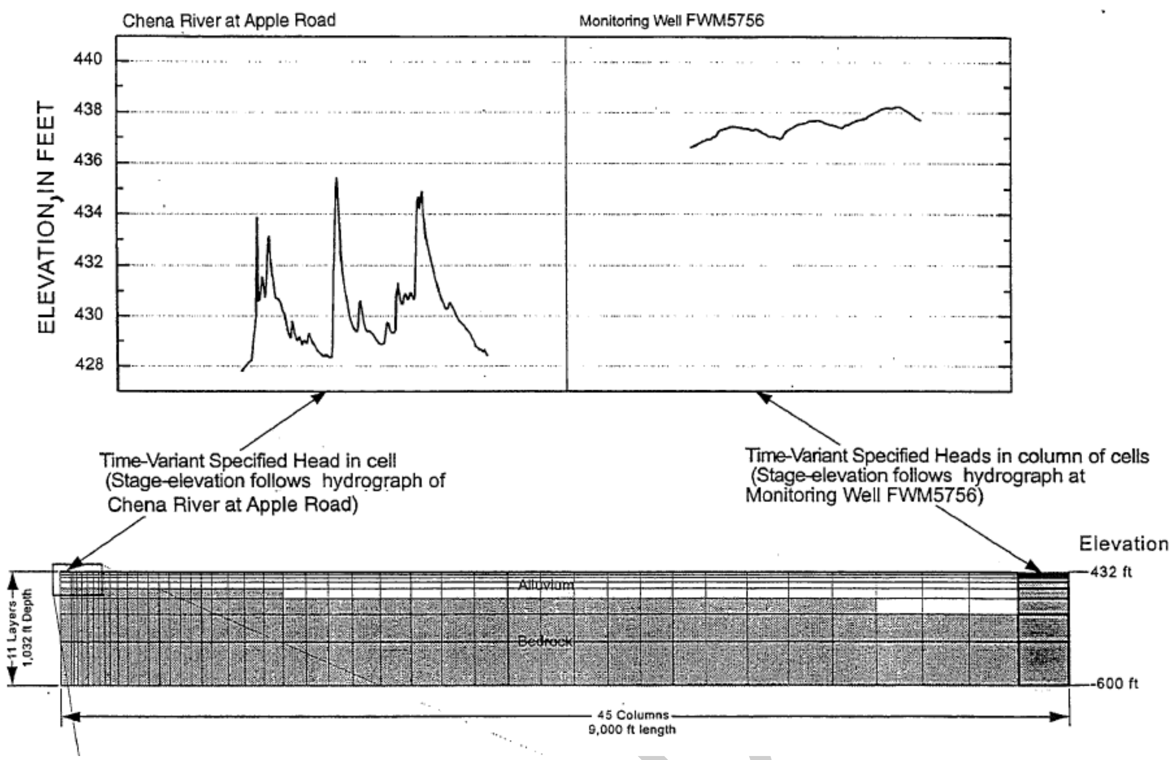

Figure 7.5-7. An example of applying surface-water stage conditions and groundwater levels from a well as input to boundary conditions to a two-dimensional groundwater model. This model was used to help develop determine the properties in a regional three-dimensional groundwater model (Nakanishi and Lilly, 1998).

7.5.10. Tables

Table 7.5-1. Data collection parameters and associated sensors for a GWSW riparian monitoring system.

Process	Parameter	Sensor Type
Surface-water stage fluctuation	Pressure – calculated water levels	CSI CS 450 Pressure transducer
Groundwater stage fluctuation	Pressure – calculated water levels	CSI CS 450 Pressure transducer
Active-layer freezing and thawing	Resistance – calculated temperature	GWS-YSI Vertical thermistor strings
Active-layer freezing and thawing, Moisture availability	Unfrozen volumetric moisture content (%)	CSI CS616 Soil-moisture sensors
Evapotranspiration	Air temperature, Relative Humidity	CSI HC2S3 AT/RH sensor
Evapotranspiration	Wind Speed, Direction	RM Yound 05103 WS/WD sensor
Evapotranspiration	Radiation	CMP3 – Kipp & Zonen Pyranometer
Evapotranspiration	Soil-surface temperature	GWS-YSI Thermistor
Evapotranspiration	Precipitation	TI 525-US Tipping bucket rain gage
Plant transpiration	Delta-Temperature	DI – Dynagage and TDP sensors and sap flow algorithms

Notes:

1 Campbell Scientific Inc., CSI; Dynomax Inc., DI; Texas Instruments, TI, GW Scientific, GWS.

Table 7.5-2. Schedule for implementation of the Groundwater-Related Aquatic Habitat Study.

Activity	2012				2013				2014				2015	
	1 Q	2 Q	3 Q	4 Q	1 Q	2 Q	3 Q	4 Q	1 Q	2 Q	3 Q	4 Q	1Q	2Q
7.5.4.1 Existing Data Synthesis					—	—●	—	—●						
7.5.4.2 Geohydrology Process-Domains and Terrain					—	—●—	—	—●						
7.5.4.3 Watana Dam/Reservoir						—	—	—	—●—	—	—	—●		
7.5.4.4 Upwelling/Springs Broad-Scale Mapping						—	—	—	—●—	—	—	—●		
7.5.4.5 Riparian Vegetation Dependency on SW/GW Interactions					—	—	—	—●—	—	—	—	—●		
7.5.4.6 Aquatic Habitat GW/SW Interactions				—	—	—●—	—	—	—●—	—	—	—●		
7.5.4.7 Water Quality in Selected Habitats				—	—	—●—	—	—	—●—	—	—	—●		
7.5.4.8 Winter GW/SW Interactions				—	—	—●		—	—	—●				
7.5.4.9 Shallow Groundwater Users					—	—	—	—●—	—	—	—	—●		
Initial Study Report /Updated Study Report										—Δ—	—	—	—▲	

Legend:
- —— Planned Activity
- ● Technical Memorandum or Interim Product
- Δ Initial Study Report
- ▲ Updated Study Report