Susitna-Watana Hydroelectric Project
(FERC No. 14241)

Water Quality Modeling Study
Study Plan Section 5.6

Final Study Plan

Alaska Energy Authority

SUSITNA-WATANA HYDRO

Clean, reliable energy for the next 100 years.

July 2013

5.6. Water Quality Modeling Study

On December 14, 2012, Alaska Energy Authority (AEA) filed with the Federal Energy Regulatory Commission (FERC or Commission) its Revised Study Plan (RSP), which included 58 individual study plans (AEA 2012). Included within the RSP was the Water Quality Modeling Study, Section 5.6. RSP Section 5.6 focuses on the modeling planned for assessing the effects of the proposed Project and its operations on water quality in the Susitna River basin.

On February 1, 2013, FERC staff issued its study determination (February 1 SPD) for 44 of the 58 studies, approving 31 studies as filed and 13 with modifications. On April 1, 2013 FERC issued its study determination (April 1 SPD) for the remaining 14 studies; approving 1 study as filed and 13 with modifications. RSP Section 5.6 was one of the 13 approved with modifications. In its April 1 SPD, FERC recommended the following:

Calibration of the Hydrodynamic Model Component of EFDC

> - *We recommend that AEA incorporate water-surface elevations and flow velocities when calibrating the hydrodynamic model and that the hydrodynamic model be calibrated prior to the calibration of the water quality model component of the EFDC model.*

AEA has included FERC's modification requests in this Final Study Plan**.**

5.6.1. General Description of the Proposed Study

The collective goal of the water quality studies is to assess the impacts of the proposed Project operations on water quality in the Susitna River basin with particular reference to state water quality standards. Predicting the potential impacts of the dam and its proposed operations on water quality will require the development of a water quality model. The goal of the Water Quality Modeling Study will be to utilize the extensive information collected from the Baseline Water Quality Study to develop a model(s) to evaluate the potential impacts of the proposed Project and operations on various physical parameters within the Susitna River watershed.

A large number of water quality models are available for use on the Susitna-Watana Project. Selection of the appropriate model is based on a variety of factors, including cost, data inputs, model availability, time, licensing participant familiarity, ease of use, and available documentation. Under the current study, a multi-dimensional model capable of representing reservoir flow circulation, temperature stratification, and dam operations among other parameters is necessary. The proposed model must account for water quality conditions in the proposed Susitna-Watana Reservoir, including temperature, dissolved oxygen (DO), suspended sediment and turbidity, chlorophyll-a, nutrients, and metals, as well as water quality conditions in the Susitna River downstream of the proposed dam. The model must also simulate current Susitna River baseline conditions (in the absence of the dam) for comparison to conditions in the presence of the dam and reservoir.

The objectives of the Water Quality Modeling Study are as follows:

- With input from licensing participants, implement an appropriate reservoir and river water temperature model for use with past and current monitoring data.
- Using the data developed in Sections 5.5 (Baseline Water Quality Study) model water quality conditions in the proposed Susitna-Watana Reservoir, including (but not

necessarily limited to), temperature, DO, suspended sediment and turbidity, chlorophyll-a, nutrients, ice, and metals.

- Model water quality conditions in the Susitna River from the proposed site of the Susitna-Watana Dam downstream, including (but not necessarily limited to) temperature, suspended sediment and turbidity, and ice processes (in coordination with the Ice Processes Study).

5.6.2. Existing Information and Need for Additional Information

In the 1980s, hydrologic and temperature modeling was conducted in the Susitna River basin to predict the effects of one or more dams on downstream temperatures and flows. The modeling suite used was called H2OBAL/SNTEMP/DYRESM. The modeling suite addressed temperature and had some limited hydrodynamic representation, but it lacked the ability to predict vertical stratification or local effects. In addition, the modeling suite lacked a water quality modeling component.

Review of existing water quality and sediment transport data revealed several gaps that present challenges for calibrating a water quality model (URS 2011). Analysis of existing data was used to identify future studies needed to develop the riverine and reservoir water quality models and to eventually predict pre-Project water quality conditions throughout the drainage. Some general observations based on existing data are as follows:

- Large amounts of data were collected during the 1980s. A comprehensive data set for the Susitna River and tributaries is not available.
- The influence of major tributaries (Chulitna and Talkeetna rivers) on Susitna River water quality conditions is unknown. There are no monitoring stations in receiving water at these mainstem locations.
- Continuous temperature data and seasonal water quality data are not available for the Susitna River mainstem and sloughs potentially used for spawning and rearing habitat.

Concentrations of water quality parameters including metals in sediment immediately below the proposed Project are unknown. Metals in these sediments may become mobile once the Project begins operation. Monitoring information in the immediate vicinity of the reservoir and riverine habitat will be important for developing two models (reservoir and riverine) and coupled for predicting expected water quality conditions below the proposed dam.

5.6.3. Study Area

Water quality samples will be collected at the same locations where temperature data loggers were installed (Table 5.6-1 and Figure 5.6-1) as part of the 2012 Baseline Water Quality Study. The study area begins at RM 15.1 and extends past the proposed dam site to RM 233.4. The lowermost boundary of the monitoring that will be used for developing and calibrating models is above the area protected for beluga whale activity. Twelve mainstem Susitna River monitoring sites are located below the proposed dam site and two mainstem sites above this location for calibration of the models. Six sloughs will be included in the models and represent important fish-rearing habitat. Tributaries to the Susitna River will be monitored and include those contributing large portions of the lower river flow like the Talkeetna, Chulitna, Deshka, and Yentna rivers. A partial list of the remaining tributaries that will be included in modeling and that represent important spawning and rearing habitat for anadromous and resident fisheries include Gold Creek, Portage Creek, Tsusena Creek, Watana Creek, and Oshetna Creek. These sites were selected based on the following rationale:

- Adequate representation of locations throughout the Susitna River and tributaries above and below the proposed dam site.
- Preliminary consultation with licensing participants including co-location with other study sites (e.g., instream flow, ice processes).
- Access and land ownership issues.

Eight of the sites are mainstem monitoring sites that were previously used for SNTEMP modeling in the 1980s. Thirty-one of the sites are Susitna River mainstem, tributary, or slough locations, most of which were also monitored in the 1980s.

5.6.4. Study Methods

This section provides the rationale for selection of the water quality model to be used for this Project. For the current Project, the model needs to be capable of simulating both river and reservoir environments. It also needs to be a multi-dimensional dynamic model that includes hydrodynamics, water temperature, water quality, and sediment transport modules and considers ice formation and break-up.

Ice dynamics evaluated in the Ice Processes Study will be used to inform the water quality model. Ice formation and break-up will have a profound impact on hydrodynamics and water quality conditions in the reservoir and riverine sections of the basin. Ice cover affects transfer of oxygen to and from the atmosphere and this directly affects the dissolved oxygen concentration at points along the water column. The output from the Ice Processes Study (Section 7.6) will provide boundary conditions for the water quality model.

The model will need to be configured for the reservoir and internally coupled with the downstream river model. This will form a holistic modeling framework that can accurately simulate changes in the hydrodynamic, temperature, and water quality regime within the reservoir and downstream. The model for use in this study should feature an advanced turbulence closure scheme to represent vertical mixing in reservoirs, and be able to predict future conditions. Thus, it will be capable of representing the temperature regime within the reservoir without resorting to arbitrary assumptions about vertical mixing coefficients.

The model will need to have the ability to simulate an entire suite of water quality parameters, and the capacity for internal coupling with the hydrodynamic and temperature modeling processes. The model will need to be configured to simulate the impact of the proposed Project on temperature as well as DO, nutrients, algae, turbidity, total suspended solids (TSS), and other key water quality features both within the reservoir and for the downstream river. This avoids the added complexity associated with transferring information among multiple models and increases the efficiency of model application.

Other important factors used for selecting the water quality model included the following:

- The model and code are easily accessible and are part of the public domain.
- The model is commonly used and accepted by EPA and other regulatory agencies.

- The water quality model will be available for current and future use and remain available for the life of the project and beyond (including upgraded versions).
- Model output can be compared to relevant ADEC water quality criteria (18 ACC 70.020(b)).

The following sections summarize the capabilities of models considered for use on this project and outline characteristics of those previously used with historical data from the Susitna River drainage and others commonly used for water quality modeling for regulatory decision-making.

5.6.4.1. H2OBAL/SNTEMP/DYRESM Model Review

The existing H2OBAL/SNTEMP/DYRESM model of the Susitna River basin is perhaps the most obvious candidate model to implement when assessing the effects of the originally proposed Project. The existing model was expressly configured to represent the unique conditions in the Susitna River basin. However, the modeling suite is limited to flow and temperature predictions. Hydrodynamics are simplified, and water quality is not addressed.

The Arctic Environmental Information and Data Center (AEIDC) previously completed a study that examined the temperature and discharge effects if the proposed Project was completed and compared the effects to the natural stream conditions, without a dam and reservoir system (AEIDC 1983a). The study also assessed the downstream point at which post-Project flows would be statistically the same as natural flows. Multiple models were used in the assessment: SNTEMP, a riverine temperature model; H2OBAL, a water balance program; and DYRESM, a reservoir hydrodynamic model.

The simulation period covered the years 1968 through 1982. Only the summer period was simulated, using historical meteorological and hydrological data to represent normal, maximum, and minimum stream temperature conditions, represented by the years 1980, 1977, and 1970, respectively (AEIDC 1983a). Post-project modifications were applied to these summer periods to compare natural conditions to post-Project stream temperatures. Due to a lack of data, a monthly time-step was used in these summer condition simulations.

Mainstem discharges from the Susitna-Watana Dam site were estimated from statistically-filled stream flow data and the H2OBAL program, which computes tributary inflow on a watershed area-weighted basis. Post-Project flows were predicted for both a one-dam scenario and a two-dam scenario using release discharge estimates from a reservoir operation schedule scenario in the FERC License Application. Flows derived from H2OBAL were input into SNTEMP.

SNTEMP is a riverine temperature simulation model that can predict temperature on a daily basis and for longer time periods. This allows for the analysis of both critical river reaches at a fine scale and the full river system over a longer averaging period (AEIDC 1983b). SNTEMP was selected because it contains a regression model that can fill in data gaps in temperature records. This is useful because data records in the Susitna River watershed are sparse. SNTEMP can also be calibrated to adjust for low-confidence input parameters. SNTEMP outputs include average daily water temperatures and daily maximum and minimum temperatures.

SNTEMP contains several sub-models, including a solar radiation model that predicts solar radiation based on stream latitude, time of year, topography, and meteorological conditions (AEIDC 1983b). SNTEMP was modified to include the extreme shading conditions that occur in the basin by developing a monthly topographic shading parameter. Modifications were also made to represent the winter air temperature inversions that occur in the basin. Sub-models are also included for heat flux, heat transport, and flow mixing.

SNTEMP validation indicated that upper tributary temperatures were under-predicted (AEIDC 1983b). Most of the data for the tributaries were assumed or estimated, leading to uncertainty. Five key poorly defined variables were identified as possible contributors to the under-prediction of temperatures: stream flow, initial stream temperature, stream length, stream width and distributed flow temperatures. Distributed flow temperatures were highlighted as the most important of the five variables. During calibration, groundwater temperature parameters were adjusted to modify distributed flow and improve tributary temperature prediction.

Water temperatures are derived from USGS gages, but when data were lacking, SNTEMP computed equilibrium temperatures and then estimated initial temperatures from a regression model. AEIDC noted that the reliability of the regression models "restricts the accuracy of the physical process temperature simulations" (1983a). The level of confidence in the regression model varies by the amount of gage data available. Continuous data yielded higher confidence, while years with only grab sample data notably decreased the confidence in the predicted temperatures.

The DYRESM model is a one-dimensional, hydrodynamic model designed specifically for medium size reservoirs (Patterson et al. 1977). The size limitation ensures that the assumptions of the model algorithm remain valid. DYRESM predicts daily temperature and salinity variations with depth and the temperature and salinity of off-take supply. The reservoir is modeled as horizontal layers with variable vertical location, volume, temperature and salinity. Mixing between layers is through amalgamation. Inflow and withdrawal are modeled by changes in the horizontal layer thickness and insertion or removal of layers, as appropriate. The model incorporates up to two submerged off-takes and one overflow outlet. Model output is on a daily time-step.

The DYRESM model was run to simulate the reservoir scenario for 1981 conditions (AEIDC 1983a). Other reservoir release temperature estimates were not available. The AEIDC report cautions that the results from 1981 may not be representative of other years due to annual variations in meteorology, hydrology, reservoir storage, and power requirements. The lack of reservoir release temperature data limited the simulation of downstream temperatures under operational conditions to one year. AEIDC noted that the "effort to delineate river reaches where post-project flows differ significantly from natural flows has been unsuccessful" (AEIDC 1983a). This was attributed in large part to the lack of estimates for the reservoir release temperatures. Additional data were needed to increase the predictive ability of SNTEMP.

Perhaps the biggest limitations of the existing H2OBAL/SNTEMP/DYRESM modeling suite are the lack of suitable data, simplified hydrology, and the lack of a water quality component. Modeling is limited to discharge and temperature. Other issues that limit the suitability of the modeling suite for the Water Quality Modeling Study are the chronic under-prediction of upper tributary temperatures, and the inability to predict vertical stratification within the reservoir.

5.6.4.2. Other Modeling Approaches

Two other modeling approaches may provide better results than the previously used H2OBAL/SNTEMP/DYRESM model. These are discussed below.

5.6.4.3. Two-Dimensional Approach (CE-Qual-W2)

The U.S. Army Corps of Engineers' CE-QUAL-W2 model is a two-dimensional, longitudinal/vertical (laterally averaged), hydrodynamic and water quality model (Cole et al. 2000). The model can be applied to streams, rivers, lakes, reservoirs, and estuaries with variable grid spacing, time-variable boundary conditions, and multiple inflows and outflows from point/nonpoint sources and precipitation.

The two major components of the model include hydrodynamics and water quality kinetics. Both of these components are coupled (i.e., the hydrodynamic output is used to drive the water quality output at every time-step). The hydrodynamic portion of the model predicts water surface elevations, velocities, and temperature. The water quality portion of the model can simulate 21 constituents including DO, suspended sediment, chlorophyll-a, nutrients, and metals. A dynamic shading algorithm is incorporated to represent topographic and vegetative cover effects on solar radiation.

5.6.4.4. Three-Dimensional Approach (EFDC)

The Environmental Fluid Dynamics Code (EFDC) model was originally developed at the Virginia Institute of Marine Science and is considered public domain software (Hamrick 1992). This model is now being supported by EPA. EFDC is a dynamic, three-dimensional, coupled water quality and hydrodynamic model. In addition to hydrodynamic, salinity, and temperature transport simulation capabilities, EFDC is capable of simulating cohesive and non-cohesive sediment transport, near field and far field discharge dilution from multiple sources, eutrophication processes, the transport and fate of toxic contaminants in the water and sediment phases, and the transport and fate of various life stages of finfish and shellfish. The EFDC model has been extensively tested, documented, and applied to environmental studies world-wide by universities, governmental agencies, and environmental consulting firms.

The structure of the EFDC model includes four major modules: (1) a hydrodynamic model, (2) a water quality model, (3) a sediment transport model, and (4) a toxics model. The water quality portion of the model simulates the spatial and temporal distributions of 22 water quality parameters including DO, suspended algae (three groups), periphyton, various components of carbon, nitrogen, phosphorus and silica cycles, and fecal coliform bacteria. Salinity, water temperature, and total suspended solids are needed for computation of the 22 state variables, and they are provided by the hydrodynamic model. EFDC incorporates solar radiation using the algorithms from the CE-QUAL-W2 model.

5.6.4.5. Qualitative Comparison of Models

Table 5.6-2 presents an evaluation of the models' applicability to a range of important technical needs that support baseline water quality monitoring study objectives along with regulatory, and management considerations. Technical criteria refer to the ability to simulate the physical system in question, including physical characteristics/processes and constituents of interest. Regulatory criteria reflect the ability of a model to use and compare results to water quality standards or procedural protocol. Management criteria outline another set of selection elements for a water quality model and these comprise operational or economic constraints imposed by the end-user and include factors such as financial and technical resources. The relative importance of each group of criteria for model selection, as it pertains to the Project, are presented alongside the models' applicability ratings. Although the evaluation is qualitative, it is useful in selecting a model based on the factors that are most critical to this Project.

5.6.4.6. Technical Considerations

The following discussion highlights some of the key technical considerations for modeling associated with the Project and compares the ability of CE-QUAL- W2 and EFDC to address these considerations. For informational purposes, the H2OBAL/SYNTEMP/DYRESM modeling suite is also discussed in the technical considerations. Based on a review of the literature, some key factors that will likely be important in the modeling effort include the following:

1. Prediction of vertical stratification in the reservoir when the dam is present
2. Nutrient and algae representation
3. Sediment transport
4. Ability to represent metals concentrations
5. Integration between temperature and ice dynamics models
6. Capability of representing local effects (i.e., Focus Areas)

5.6.4.6.1. Predicting Vertical Stratification

Both EFDC and CE-QUAL-W2 are equipped with turbulence closure schemes that allow prediction of temporally/spatially variable vertical mixing strength based on time, weather condition, and reservoir operations. Therefore, both are capable of evaluating the impact of dam/reservoir operations/climate change on reservoir stratification. In contrast, the existing H2OBAL/SYNTEMP/DYRESM model does not have the necessary predictive capability because vertical stratification is represented based on parameterization through calibration. Therefore, it cannot represent the response of vertical mixing features to the changes in external forces.

5.6.4.6.2. Nutrient and Algae Representation

Both EFDC and CE-QUAL-W2 are capable of simulating dynamic interactions between nutrients and algae in reservoirs and interactions between nutrients and periphyton in riverine sections. This is very important for addressing the potential impact of the proposed Project on water quality and ecology in the river. EFDC has better nutrient predictive capabilities due to its sediment diagenesis module, which simulates interactions between external nutrient loading and bed-water fluxes. EFDC is thus capable of predicting long-term effects of the proposed Project. CE-QUAL-W2 does not have such a predictive capability. The existing H2OBAL/SNTEMP/DYRESM modeling suite is not capable of representing nutrient and algae interactions.

5.6.4.6.3. Sediment Transport

EFDC is fully capable of predicting sediment erosion, transport, and settling/deposition processes. CE-QUAL-W2 has limited sediment transport simulation capabilities. It handles water column transport and settling; however, it is not capable of fully predicting sediment bed re-suspension and deposition processes. H2OBAL/SNTEMP/DYRESM is not capable of simulating sediment transport. Reservoir trap efficiency will be simulated using EFDC and will use estimates for sediment inflow determined by the Geomorphology Study (Section 6.5).

5.6.4.6.4. Ability to Represent Metals Concentrations

EFDC is fully capable of simulating fate and transport of metals in association with sediments in both rivers and reservoirs. CE-QUAL-W2 does not have a module to simulate metals; however, a simplified representation can be implemented using the phosphorus slot in the model and simple partitioning (to couple with its basic sediment transport representation). The H2OBAL/SNTEMP/DYRESM is not capable of addressing metals issues.

5.6.4.6.5. Toxicity Modeling

The EFDC model will generate the water quality input for the Biotic Ligand Model (BLM). The BLM will be utilized to predict potential toxicity of copper, silver, cadmium, zinc, nickel, and lead to aquatic life. The BLM is focused on determining toxicity of individual metals to binding sites on tissue like gill filaments of freshwater fish while considering other factors that compete for the same binding sites.

The BLM will be restricted from use if the combination of water quality monitoring results for metals concentrations in sediments and surface water show little or no detectable concentrations and the water quality model shows that changes, if any, to water quality conditions that mobilize metals does not occur. This is part of the pathways analysis for individual metals toxics and is where decisions for use of secondary models (like BLM) in addition to the EFDC primary model will be made.

Borgmann et al. 2008 outline several assumptions under which toxicity of metals concentrations at sites of bioaccumulation interactions are additive. The use of the BLM to estimate a toxic effect from mixtures of metals must satisfy several unknowns and, as stated by the authors, should be used with caution and other strategies for these toxicity estimates considered.

5.6.4.6.6. Integration between Temperature and Ice Dynamics Models

The CE-QUAL-W2 model has a coupled temperature-ice simulation module, which is of moderate complexity and predictive capability. EFDC has a slightly simpler ice representation that was previously applied to a number of Canadian rivers (e.g., Lower Athabasca River and the North Saskatchewan River in Alberta, Canada). Both models, however, can be coupled to external ice models with a properly designed interface to communicate temperature results. Fully predictive simulation within either model would require code modification to handle the interaction between temperature simulation, ice formation and transport, hydrodynamics simulation, and water quality simulation.

5.6.4.6.7. Capability of Representing Local Effects

CE-QUAL-W2 is a longitudinal-vertical two-dimensional model; therefore, it is capable of resolving spatial variability in the longitudinal and vertical directions. It is not capable of representing high-resolution local effects such as lateral discharge, areas affected by secondary circulation, or certain habitat characteristic changes. EFDC is a three-dimensional model that can be configured at nearly any spatial resolution to represent local effects. H2OBAL/SNTEMP/DYRESM is a one-dimensional modeling suite and therefore has limited capability representing local effects.

5.6.4.7. Conclusion

Based on the evaluation of each model presented in Section 5.6.4.6, the EFDC model has been selected for further use in this study. A Water Quality Modeling Study, Sampling and Analysis, Quality Assurance Project Plan is included in Attachment 5-2.

5.6.4.8. Reservoir and River Downstream of Reservoir Modeling Approach

Reservoir modeling will focus on the length of the river from above the expected area of reservoir inundation to the proposed dam location. It will involve first running the without project scenario, or initial condition. This initial condition represents current baseline conditions in the absence of the dam. Subsequently, the model will represent the proposed reservoir condition when the dam is in place. The reservoir representation will be developed based on the local bathymetry and dimensions of the proposed dam. A three-dimensional model will be developed for the proposed reservoir to represent the spatial variability in hydrodynamics and water quality in longitudinal, vertical, and lateral directions. The model will be able to simulate flow circulation in the reservoir, turbulence mixing, temperature dynamics, nutrient fate and transport, interaction between nutrients and algae, sediment transport, and metals transport. The key feature that needs to be captured is water column stratification during the warm season and the de-stratification when air temperatures cool down. The capability of predictively representing the stratification/de-stratification period is of critical importance for evaluating the impact of the dam because this is the critical water quality process in the reservoir.

With the dam in place, the original river will be converted into a slow flowing reservoir; therefore, any sediment previously mobilized will likely settle in the reservoir, disrupting the natural sediment transport processes. Before the construction of the dam, primary production is likely driven by periphyton. After construction of the dam, periphyton will be largely driven out of existence due to deep water conditions typical of a reservoir environment. In lieu of periphyton, phytoplankton will likely be the dominant source of primary production of the ecological system with the dam in place. Nutrients from upstream will have longer retention in the reservoir, providing nutrient sources to fuel phytoplankton growth. All processes would need to be predictively simulated by both the reservoir model and the pre-reservoir river model for the same river segment.

Because the dam is not in place when the model is constructed, proper calibration of the model using actual reservoir data is not possible. To achieve reasonable predictions of water quality conditions in the proposed reservoir, a literature survey will be conducted to acquire parameterization schemes of the model. An uncertainty analysis approach will also be developed to account for the lack of data for calibration, therefore enhancing the reliability of reservoir model predictions.

Downstream of the proposed dam location, a river model will also be developed to evaluate the effects of the proposed Project. The same model platform used for the reservoir model will be implemented for the river model (at a minimum the two models will be tightly coupled). The river model will be capable of representing conditions in both the absence and presence of the dam. The downstream spatial extent of this model will be the lowermost monitoring site on the Susitna River mainstem (RM 15.1) extending downstream of the Susitna-Talkeetna-Chulitna confluence. Water quality modeling will extend into the lower river and will use channel topography and flow data at select locations in order to develop a model for predicting water quality conditions under various Project operational scenarios.

Flow, temperature, TSS, DO, nutrients, turbidity (continuous at USGS sites and bi-weekly at additional locations required for calibrating the model), and chlorophyll-a output from the reservoir model will be directly input into the downstream river model. This will enable downstream evaluation of potential impacts of the proposed Project on hydrodynamic, temperature, and water quality conditions.

The river model will be calibrated and validated using available data concurrently with the initial reservoir condition model (representing absence of the dam). Output from the models will be used directly in other studies (e.g., Ice Processes, Productivity, and Instream Flow studies).

The EFDC model will be calibrated in order to simulate water quality conditions for load-following analysis. When calibrating the EFDC model, water-surface elevations and flow velocities will be incorporated. The hydrodynamic component of the model will be calibrated prior to the calibration of the water quality model component of the EFDC model. Organic carbon content from inflow sources will be correlated with mercury concentrations determined from the Baseline Water Quality Study discussed in Section 5.5. Predicted water quality conditions established by Project operations and that promote methylation of mercury in the bioaccumulative form will be identified by location and intensity in both riverine and reservoir habitats. Water temperature modeling and routing of fluctuating flows immediately prior to and during ice cover development may be conducted with a separate thermodynamics-based ice process model River 1-D ice-processes model; the Susitna Hydraulic and Thermal Processes Model (Section 7.6.3.2).

Modeling of mercury concentrations in dissolved and in methylated form will be done by updating the EFDC model to simulate three sorptive toxic variables representing mercury (Hg) states. Algorithms have been successfully used with EFDC in other studies and will be modified to account for potential sources of Hg as the reservoir is filled (e.g., soils, vegetation, air deposition). Other metals parameters will be modeled if significant concentrations are identified from surface water and sediment. However, cumulative impacts of multiple metals on aquatic life are difficult to predict using the proposed modeling strategy because there are associated uncertainties. Measuring additivity or synergism of toxics effects is possible using laboratory bioassays, but may not be adequately predicted by a model. The level of uncertainty in extrapolating results from laboratory to field conditions is large and potentially unreliable. A suggested approach for estimating toxicity mixtures would be to develop a weight of evidence (WOE) algorithm that produces a weighting factor for re-calculating the potential chronic and acute toxic effects of a mixture (Mumtaz et al. 1998).

5.6.4.8.1 Focus Areas

The EFDC model will be used to predict water quality conditions at a finer scale of resolution for Focus Areas. The increased intensity of sampling at transects 100 m apart and at three locations across each transect will improve resolution for predictions at approximately 100 m longitudinally and a smaller distance laterally. This model will be embedded within the larger-scale EFDC model used for the entire riverine component of the Project area. An embedded model can also be used for predicting conditions in sloughs and selected braided areas of the mainstem Susitna River.

Some of the water quality parameters listed in Section 5.5.4.4 will be used to predict conditions within the Focus Areas to determine if suitability of habitat for life stages of select fish species is maintained or changes under each of the operational scenarios. The EFDC model calibrated for each of the Focus Areas will have a time-step component so that conditions and areal extent are described for each of the water quality parameters and are associated with load-following.

5.6.4.8.2 Scales for Modeling and Resolution of the Output

The large-scale EFDC model calibrated using the mainstem water quality monitoring data will have a longitudinal predictive resolution between 250 m and 1 kilometer (km) depending on lateral variability of conditions and the run-time selected. Single channel areas of the mainstem Susitna River and sloughs may not require higher resolution predictions if water quality conditions are uniform. The uniformity of conditions will be evaluated by measuring across transects at a few locations in the drainage to determine if lateral variability is low.

Grid size in the model determines spatial resolution of predicted water quality conditions. The riverine (and reservoir) areas of the Project are divided into equal-sized grids and the center of each represents the predicted water quality condition. The grid size is dependent on a number of characteristics of the Project area. These characteristics include elevation changes throughout the length of the drainage, length of the water body that will be modeled, surrounding terrain, and length of time the model is run for predicting temporal changes. Each of the factors ultimately determines the resolution of the predictive capability of the EFDC model.

5.6.5. Consistency with Generally Accepted Scientific Practice

Models will be the primary method used for predicting potential impacts to water quality conditions in both the proposed reservoir and the riverine portion of the Susitna basin. The models will be developed for each of the reservoir and riverine sections of the Susitna River and will be used to predict conditions resulting from Project operations under several operational scenarios. In the absence of a dam and data describing actual water quality conditions in the proposed reservoir, models are the only way to predict potential changes that may occur in the Susitna River from the presence of a dam. The 401 Water Quality Certification process includes the use of baseline assessment information and the use of models. The use of models is a scientifically accepted practice for predicting impacts to water quality and generating operational scenario outputs to inform the Project certification. The model selection process evaluated model features required for use in a river setting with braided channels, glacial water source, and ability to predict conditions in more than two-dimensions. The evaluation and proposed documentation describing performance and use of the model are accepted scientific practice for generating defensible and high quality data. The output from model calibration and predictions are consistent with recommended steps in generating high quality data as guided by a Credible Data Policy.

5.6.6. Schedule

The planned schedule for the study plan is presented in Table 5.6-3. Close coordination will be maintained with the water quality studies to make sure the data generated is sufficient and appropriate for the modeling effort. The model selection was made in July 2012, and the selection process is provided here. The water quality model will begin to be calibrated starting in the middle of 2013, as the data becomes available from the field. We anticipate producing an initial study report in the first quarter of 2014. After that will be a period of re-calibrations, verification runs, and generating operating scenarios for the proposed reservoir. The final modeling report will be complete in the first quarter of 2015.

5.6.7. Relationship with Other Studies

Figure 5.6-2 shows the interdependencies between existing data and related historical studies, specific output for each element of the Water Quality studies, and where the output information generated in the Water Quality studies will be directed. This chart provides details describing the flow of information related to the Water Quality studies, from historical data collection to current data collection. Data were examined in a Water Quality Data Gap Analysis (URS 2011) and this information was used, in part, to assist in making decisions about the current design for the Baseline Water Quality Modeling Study and for ensuring that current modeling efforts would be able to compare the 1980s study results with current modeling results.

Integral portions of this interdependency chart are results from the Ice Processes Study and from the Fish and Aquatic Instream Flow Study. The Ice Processes Study will support water quality model development (Section 5.6) with information about timing and conditions for ice formation and ice break-up. The Fish and Aquatic Instream Flow Study represents the effort to develop a hydraulic routing model that will be coupled with the EFDC water quality model. Water quality monitoring efforts for field parameters, general chemistry, and metals (including mercury) will be used as a calibration data set for developing the predictive EFDC model.

5.6.8. Level of Effort and Cost

The estimated cost for the proposed water quality modeling effort in 2013 and 2014, including planning, model calibration and development, modeling various operational scenarios, and reporting is approximately $1,750,000.

5.6.9. Literature Cited

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5.6.10. Tables

Table 5.6-1. Proposed Susitna River Basin Water Quality and Temperature Monitoring Sites.

Susitna River Mile	Description	Susitna River Slough ID	Latitude (decimal degrees)	Longitude (decimal degrees)
15.1	Susitna above Alexander Creek	NA	61.4014	-150.519
25.8[3]	Susitna Station	NA	61.5454	-150.516
28.0	Yentna River	NA	61.589	-150.468
29.5	Susitna above Yentna	NA	61.5752	-150.248
40.6[3]	Deshka River	NA	61.7098	-150.324
55.0[1]	Susitna	NA	61.8589	-150.18
83.8[3]	Susitna at Parks Highway East	NA	62.175	-150.174
83.9[3]	Susitna at Parks Highway West	NA	62.1765	-150.177
97.0	LRX 1	NA	62.3223	-150.127
97.2	Talkeetna River	NA	62.3418	-150.106
98.5	Chulitna River	NA	62.5574	-150.236
103.0[2,3]	Talkeetna	NA	62.3943	-150.134
113.0[2]	LRX 18	NA	62.5243	-150.112
120.7[2,3]	Curry Fishwheel Camp	NA	62.6178	-150.012
126.0	--	8A	62.6707	-149.903
126.1[2]	LRX 29	NA	62.6718	-149.902
129.2[3]	--	9	62.7022	-149.843
130.8[2]	LRX 35	NA	62.714	-149.81
135.3	--	11	62.7555	-149.7111
136.5	Susitna near Gold Creek	NA	62.7672	-149.694
136.8[3]	Gold Creek	NA	62.7676	-149.691
138.0[1]	--	16B	62.7812	-149.674
138.6[3]	Indian River	NA	62.8009	-149.664
138.7[2]	Susitna above Indian River	NA	62.7857	-149.651
140.0	--	19	62.7929	-149.615
140.1[2]	LRX 53	NA	62.7948	-149.613
142.0	--	21	62.8163	-149.576
148.0	Susitna below Portage Creek	NA	62.8316	-149.406
148.8[2]	Susitna above Portage Creek	NA	62.8286	-149.379
148.8	Portage Creek	NA	62.8317	-149.379
148.8[3]	Susitna above Portage Creek	NA	62.8279	-149.377
165.0[1]	Susitna	NA	62.7899	-148.997
180.3[1]	Susitna below Tsusena Creek	NA	62.8157	-148.652
181.3[3]	Tsusena Creek	NA	62.8224	-148.613
184.5[1]	Susitna at Watana Dam site	NA	62.8226	-148.533
194.1	Watana Creek	NA	62.8296	-148.259
206.8	Kosina Creek	NA	62.7822	-147.94

Susitna River Mile	Description	Susitna River Slough ID	Latitude (decimal degrees)	Longitude (decimal degrees)
223.7[3]	**Susitna near Cantwell**	NA	62.7052	147.538
233.4	Oshetna Creek	NA	62.6402	-147.383

1 Site not sampled for water quality or temperature in the 1980s or location moved slightly from original location.
2 Proposed mainstem Susitna River temperature monitoring sites for purposes of 1980s SNTEMP model evaluation.
3 Locations with overlap of water quality temperature monitoring sites with other studies.

Locations in bold font represent that both temperature and water quality samples are collected from a site.

Table 5.6-2. Evaluation of models based on technical, regulatory, and management criteria.

●*High Suitability* ◐ *Medium Suitability* ○ *Low Suitability*				
Considerations	*Relative Importance*	*H2OBAL/SNTEMP/DYRESM*	*CE QUAL W2*	*EFDC*
		Technical Criteria		
Physical Processes:				
• advection, dispersion	High	◐	●	●
• momentum	High	○	●	●
• compatible with external ice simulation models	High	○	●	●
• reservoir operations	High	◐	●	●
• predictive temperature simulation (high latitude shading)	High	◐	●	●
Water Quality:				
• total nutrient concentrations	High	○	●	●
• dissolved/particulate partitioning	Medium	○	●	●
• predictive sediment diagenesis	Medium	○	○	●
• sediment transport	High	○	◐	●
• algae	High	○	●	●
• dissolved oxygen	High	○	●	●
• metals	High	○	◐	●
Temporal Scale and Representation:				
• long term trends and averages	Medium	◐	◐	●
• continuous – ability to predict small time-step variability	High	○	●	●
Spatial Scale and Representation:				
• multi-dimensional representation	High	○	◐	●
• grid complexity - allows predictions at numerous locations throughout model domain	High	○	◐	●

●High Suitability ◐ Medium Suitability ○ Low Suitability				
Considerations	*Relative Importance*	*H2OBAL/SNTEMP/DYRESM*	*CE QUAL W2*	*EFDC*
• suitability for local scale analyses, including local discharge evaluation	Medium	○	◐	●
Regulatory Criteria				
Enables comparison to AK criteria	High	○	●	●
Flexibility for analysis of scenarios, including climate change	High	◐	●	●
Technically defensible (previous use/validation, thoroughly tested, results in peer-reviewed literature, TMDL studies)	High	◐	●	●
Management Criteria				
Existing model availability	High	●	●	●
Data needs	High	●	●	●
Public domain (non-proprietary)	High	●	●	●
Cost	Medium	●	◐	◐
Time needed for application	Medium	N/A	◐	◐
Licensing participant community familiarity	Low	●	◐	◐
Level of expertise required	Low	●	●	●
User interface	Low	◐	◐	◐
Model documentation	Medium	◐	●	●

Table 5.6-3. Schedule for Implementation of the Modeling 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	1 Q
Coordination with water quality data collection and analysis				——	——	——	——	——	——				
Model Evaluation/Selection			——										
Model Calibration (Water Quality)							——	——					
Initial Study Report									Δ				
Re-calibration adjustments										——	——		
Verification runs											——		
Generate Results for Operational Scenarios										——	——	——	
Updated Study Report													▲

Legend:

—— Planned Activity
Δ Initial Study Report
▲ Updated Study Report

5.6.11. Figures

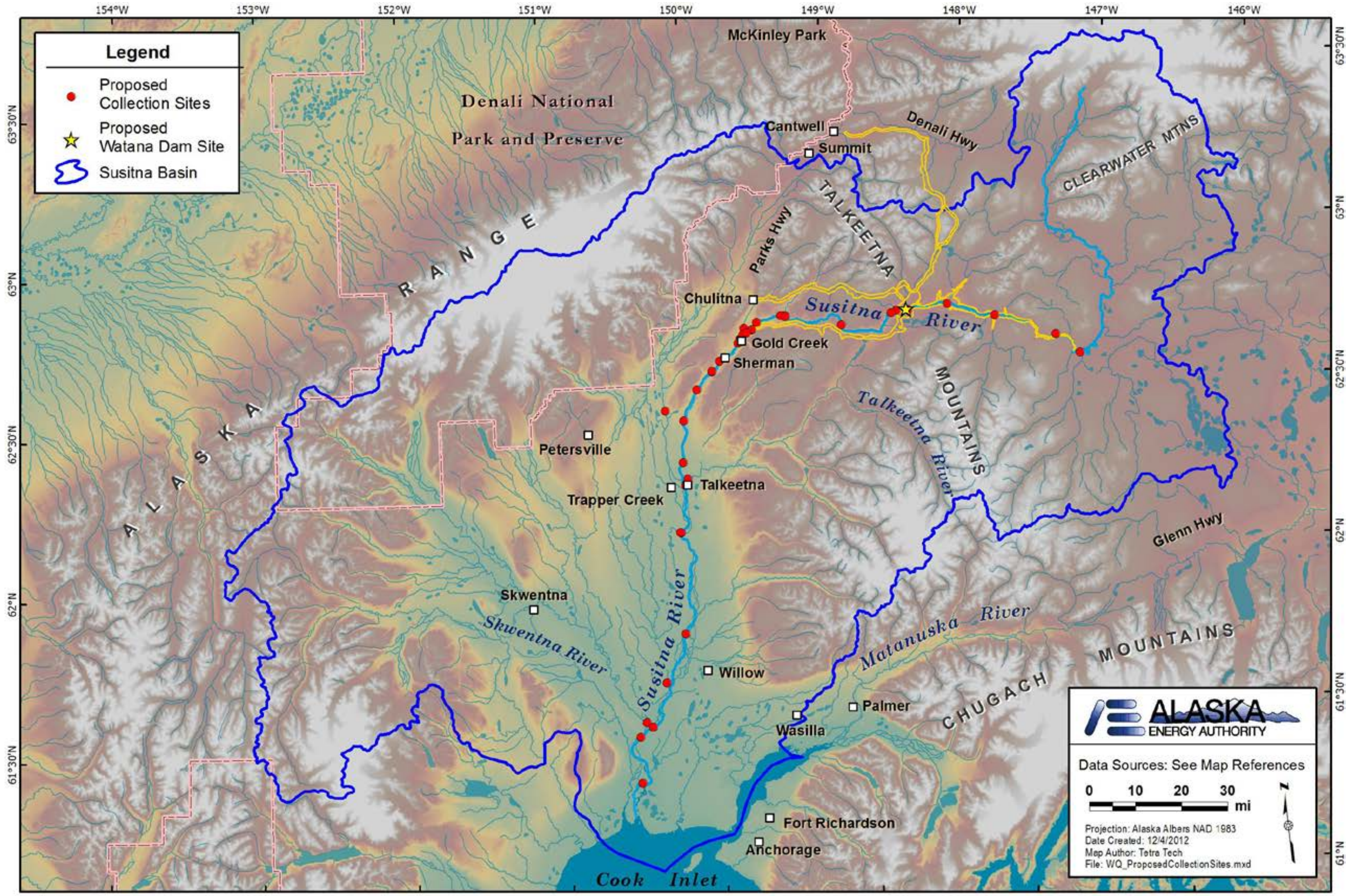

Figure 5.6-1. Proposed 2012 Stream Water Quality and Temperature Data Collection Sites for the Susitna-Watana Hydroelectric Project.

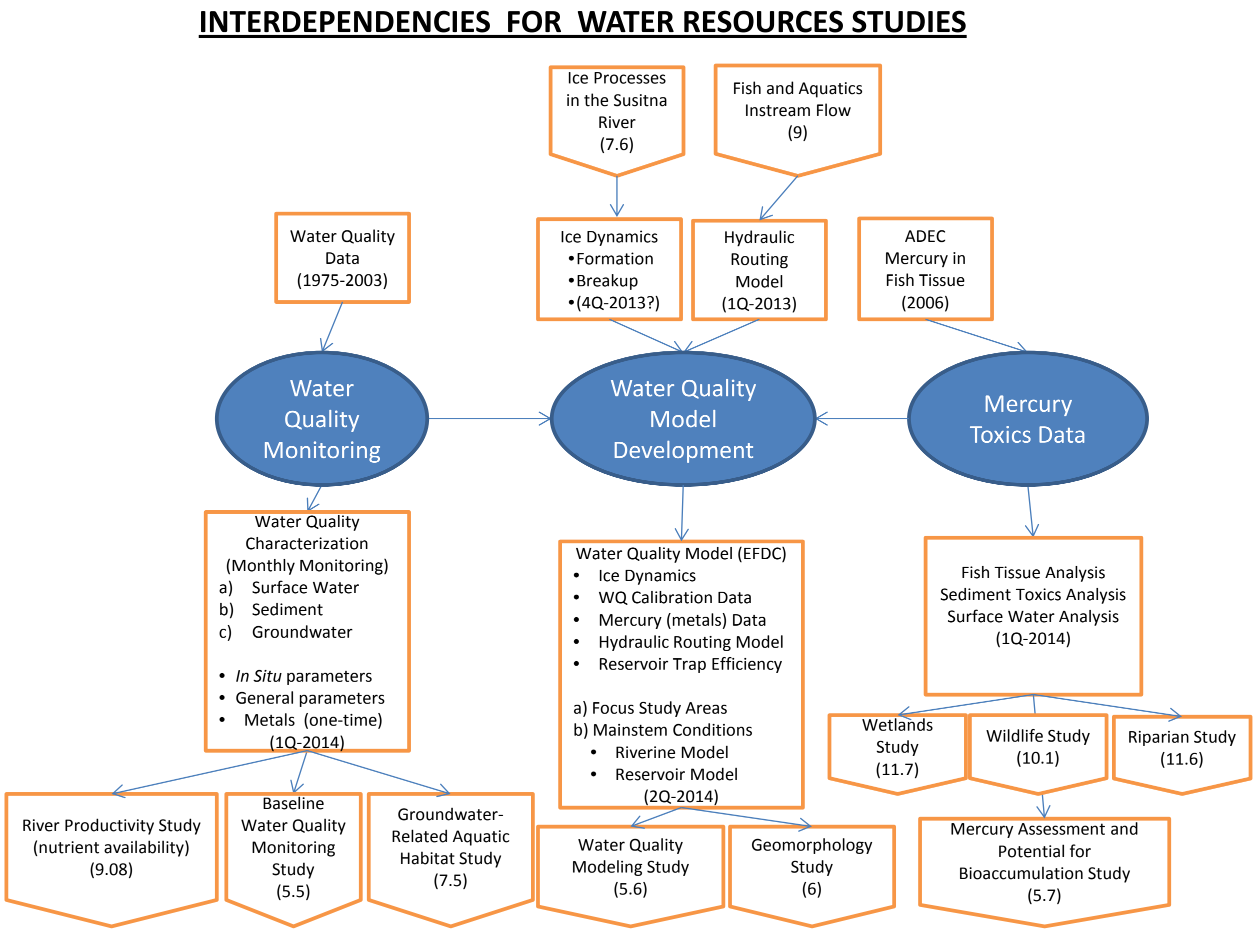

Figure 5.6-2. Interdependencies for water resources studies.