Susitna-Watana Hydroelectric Project Document
ARLIS Uniform Cover Page

Title: Groundwater-related aquatic habitat	**SuWa 144**
Author(s) – Personal:	
Author(s) – Corporate: Alaska Energy Authority	
AEA-identified category, if specified: Aquatic and fish resources study requests	
AEA-identified series, if specified:	
Series (ARLIS-assigned report number): Susitna-Watana Hydroelectric Project document number 144	**Existing numbers on document:**
Published by: [Anchorage] : Susitna-Watana Hydroelectric Project, [2012]	**Date published:** 5/15/12
Published for:	**Date or date range of report:**
Volume and/or Part numbers:	**Final or Draft status, as indicated:**
Document type:	**Pagination:** 11 p.
Related work(s):	**Pages added/changed by ARLIS:**
Notes:	

1.1. Groundwater-Related Aquatic Habitat

1.2. Requestor of Proposed Study

AEA anticipates resource agencies will request this study.

1.3. Responses to Study Request Criteria (18 CFR 5.9(b))

1.3.1. Describe the goals and objectives of each study proposal and the information to be obtained

The overall goal of the study is to understand the effects of the Project on surface water-groundwater interactions as they relate to habitat for aquatic species (e.g., fish, riparian vegetation) in the Susitna River.

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 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, surface water-ground water 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 surface water-groundwater relationships of floodplain shallow alluvial aquifers at Riparian Instream Flow study sites;
6. Determine surface water-groundwater 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, dissolved oxygen, 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 surface water-groundwater interactions; and
9. Characterize the relationship between the Susitna River flow regime and shallow groundwater users (e.g., domestic wells).

1.3.2. If applicable, explain the relevant resource management goals of the agencies and/or Alaska Native entities with jurisdiction over the resource to be studied

To be completed by the requesting organization.

1.3.3. If the requester is a not resource agency, explain any relevant public interest considerations in regard to the proposed study

Fisheries resources are owned by the State of Alaska, and the Project could potentially affect these public interest resources by affecting groundwater.

1.3.4. Describe existing information concerning the subject of the study proposal and the need for additional information

Various portions of the Susitna Watershed have had different scales of groundwater and surface water-groundwater interaction studies conducted. The lower Susitna River Watershed is part of the geologic Susitna Basin (Kirschner, 1994). 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 the 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). 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 Talkeetna sedimentary basin.

Hydropower-related studies in the Susitna River Watershed during the 1980s included observations and monitoring of surface water-groundwater interaction. 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.

Since the 1980s, various wells have been drilled for domestic water supply, mining exploration, oil and gas exploration, 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; surface water-groundwater 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 surface water-groundwater interactions.

1.3.5. Explain any nexus between project operations and effects (direct, indirect, and/or cumulative) on the resource to be studied, and how the study results would inform the development of license requirements

Watana Dam and Project operations will alter the Susitna River flow regime downstream of the dam. Changes in the Susitna River flow regime have the potential to alter surface water-groundwater interactions. Potential changes to the groundwater level below floodplain surfaces supporting riparian vegetation could affect riparian vegetation processes (recruitment and maintenance). Potential changes to the amount of upwelling/downwelling in river habitats (e.g., sloughs, side channels) could affect fish spawning, incubation, and rearing habitat (particularly during winter). Water quality (e.g., temperature, dissolved oxygen, conductivity) at sloughs and side channels that are supported by groundwater upwelling could be one of the factors that determines the productivity of these aquatic habitats (spawning, incubation, rearing).

The results of this study will be integrated with other physical habitat and biological process studies (e.g., flow routing, ice processes, fish populations, instream flow, instream flow riparian) to provide a basis for impact assessment; developing any necessary avoidance and protection (A/P) measures; developing protection, mitigation, and enhancement (PME) measures; and developing resource management and monitoring plans.

1.3.6. Explain how any proposed study methodology (including any preferred data collection and analysis techniques, or objectively quantified information, and a schedule including appropriate field season(s) and the duration) is consistent with generally accepted practice in the scientific community or, as appropriate, considers relevant tribal values and knowledge

The Groundwater Aquatic Habitat Study is divided into nine study components related to the study objectives outlined in Section 1.3.1: (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 Surface Water-Groundwater Interactions, (6) Fish Habitat Surface Water-Groundwater Interactions, (7) Water Quality in Selected Habitats, (8) Winter Surface Water-Groundwater Interactions, and (9) Shallow Groundwater Users. Each of the components and its 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.

1.3.6.1. Existing Data Synthesis

- Identify existing reports and data from the 1980s and other studies (including more recent studies) on surface water-groundwater interactions and related aquatic habitat in the Susitna River.
- Identify applicable geology, soils, and other geohydrologic references for the Susitna River Basin.
- Produce a searchable and annotated bibliography of references and data sources for use by study teams and resource agencies.
- Synthesize collected references and data with respect to the objectives of this study (e.g., findings and study recommendations related to surface water-groundwater interactions and aquatic habitat).

1.3.6.2. Geohydrologic Process-Domains and Terrain

- Define the significant geohydrologic units in the Susitna Basin that provide groundwater recharge to the mainstem and associated side channels and sloughs.

- 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).

- Identify the relationship between the process-domain river segments and the planned intensive study areas to help transfer the groundwater and surface-water interaction results from the individual study areas back to the larger process-domain river segments.

1.3.6.3. Watana Dam/Reservoir

- Evaluate engineering geology information from the dam and reservoir area.

- Coordinate with the engineering and geomorphology studies to use existing data collection programs and evaluate the need for additional data collection.

- Describe the pre-Project groundwater conditions at the Watana Dam and in the Reservoir vicinity.

- Characterize the known permafrost and bedrock hydrogeology in the Watana Dam vicinity.

- Develop conceptual surface water-groundwater models of pre-Project and post-Project conditions.

- Identify 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.

- Evaluate potential changes in the groundwater flow system as a result of the Project.

1.3.6.4. Upwelling / Springs Broad-Scale Mapping

- Aerial and GPS mapping of winter open leads, spring 2012-spring 2014 (Ice Processes Study)

  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. GIS coverages of open leads will be developed.

- Aerial photography of the ice-free period showing turbid and clear water habitat, summer 2012-summer 2014 (Geomorphology and Instream Flow Studies).

  Aerial photography at a range of flows from 5,000 cfs to 23,000 cfs will be collected as part of 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.

- Conduct a pilot thermal imaging assessment of a portion of the Susitna River, fall 2012 or during 2013 (Baseline Water Quality Study).

  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 1980s (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, a description of thermal refugia throughout the Project vicinity can be mapped using aerial imagery calibrated with on-the-ground verification.

- Identify potential groundwater areas based on observations of spawning or rearing fish (Fish Population Studies).

  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, but where upwelling is not visually observable (e.g., deep or turbid water), select a subset of sites and 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.

  Characterize 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.

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

- Coordinate study activities with the Ice Processes, Water Quality, Geomorphology, Botanical Riparian, and Instream Flow studies. The work under this objective will be accomplished by the Riparian Instream Flow Study.

  Select representative intensive riparian vegetation study reaches suitable for the overlapping needs of the Ice Processes, Water Quality, Geomorphology, Botanical

Riparian, and Instream Flow surface water-groundwater 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 surface-water / groundwater designs will be coordinated to accommodate the various study objectives.

- Develop physical modeling studies of select intensive study reaches representative of Project vicinity riverine process-domains (Montgomery 1999).

  Physical models, including hydraulic (1-D and 2-D), geomorphic reach analyses, surface water-groundwater 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 surface-water-groundwater interactions (e.g., piezometers, water levels, water temperature, and conductivity, tracer studies).

  Surface water-groundwater interaction data will be collected at the intensive study reaches using multiple transects of arrays of groundwater wells, piezometers, and stage gages. 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. The surface water and groundwater data will be used to quantify, and model, the relationship between floodplain shallow surface aquifers and floodplain plant community types.

- Where appropriate, develop MODFLOW surface water-groundwater interaction models of floodplain shallow alluvial aquifer and surface water relationships.

  MODFLOW surface water-groundwater interaction models will be used to model surface water-groundwater relationships using empirical monitoring data collected at intensive study reach surface water-groundwater monitoring stations. Similar approaches to understanding surface water-groundwater interactions have been reported in Nakanishi and Lilly (1998). 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 surface water-groundwater interaction analyses. Riparian plant community characterization will follow the Botanical Riparian survey methods using 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 surface water-groundwater 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.

1.3.6.6. Fish Habitat Surface Water / Groundwater Interactions

- Coordinate study 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.

  Surface water-groundwater 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 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 1.3.6.4) and will provide a more intensive evaluation of specific study sites identified as exhibiting surface water-groundwater 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 surface water-groundwater/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 surface-groundwater upwelling areas, installation of Mark VI standpipes to monitor hyporheic water quality, 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.

- Hydraulic unsteady flow routing to identify water surface elevations.

  As noted in the draft SWIFS 2013-2014 study plan, the mainstem flow routing model will serve to predict water surface elevations (WSEs) 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 WSEs proximal to the intensive study sites noted above, as well as other areas identified as being groundwater influenced. The WSEs empirically measured 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.

- Habitat suitability criteria (HSC) and habitat suitability index (HSI) development that includes groundwater related parameters (upwelling / downwelling).

  Development of HSC and HSI will follow the general procedures outlined in the draft SWIFS Instream Flow Study Plan: "Habitat suitability information will address fish responses to changes in depth, velocity, substrate, cover, groundwater, turbidity, indices of stranding and trapping (depressions and isolated pools), rates of colonization, and stranding and trapping mortality. 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 and Aquatics Program.

- Develop mainstem, side channel, and slough habitat models that incorporate surface water-groundwater related processes (main channel head, upwelling / downwelling).

  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 draft SWIFS Instream Flow Study Plan.

1.3.6.7. Water Quality in Selected Habitats

- Coordinate water quality activities with the Instream Flow Riparian Study, Geomorphology Studies, and Instream Flow Studies. The work under this objective will be accomplished as part of the Water Quality Study.

- At selected instream flow, fish population, and riparian study sites collect basic water chemistry (temperature, dissolved oxygen, conductivity, pH, turbidity, redox potential) that define habitat conditions and characterize surface water-groundwater interactions. For example, where possible, characterize differences between groundwater representative of regional groundwater conditions, groundwater in the mixing zone at the surface water-groundwater 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 surface water-groundwater processes. For example, use the Fish Population Study results and coordinate with the Instream Flow Study to select paired productive and non-productive habitats (also see the second bullet in this section).

1.3.6.8. Winter Groundwater / Surface-Water Interactions

- Measure water levels and pressure at the continuous gaging stations on the Susitna River.

  Continuous gaging stations will be measuring water levels and temperature as part of Instream Flow studies. Water levels measured during full ice cover are generally referred to as water pressure and represent the hydrostatic head of the river.

- Measure winter discharge measurements to help identify key sections of the mainstem with groundwater baseflow recharge to the river (upwelling).

  Winter discharge measurements will be measured as part of the Instream Flow 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.

1.3.6.9. Shallow Groundwater Users

- 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 their 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 as part of the Instream Flow studies.

- Based on the results of 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 is required.

1.3.7. Describe considerations of level of effort and cost, as applicable, and why any proposed alternative studies would not be sufficient to meet the stated information needs.

Some of the work identified under the objectives identified in Section 1.3.1 will be completed as part of other licensing studies (as described in the previous section). Tasks addressed solely under this plan could potentially cost between $350,000 and $700,000.

1.3.8. Literature Cited

Anderson, G.S., 1970, Hydrologic reconnaissance of the Tanana Basin, central Alaska, 4 sheets, scale 1:1,000,000.

Beikman, H.M., 1994, Geologic map of Alaska, in Plafker, George, and Berg, H.C., The Geology of Alaska: Geological Society of America, 1 sheet, scale 1:2,500,000.

Jorgenson, M. T., J.E. Roth, M. Emers, S.F. Schlentner, D.K. Swanson, E.R. Pullman, J.S. Mitchell, and A.A. Stickney. 2003. An ecological land survey in the Northeast Planning Area of the National Petroleum Reserve–Alaska, 2002. ABR, Inc., Fairbanks, AK. 128 pp.

Kenneson, D.G. 1980. Surficial Geology of the Susitna-Chulitna River Area, Alaska, Part 1: Text, Susitna Basin Planning Background Report. Prepared for Land and Resource Planning Section Division of Research and Development, Alaska Department of Natural Resources, March 1980. 35 pp.

Kenneson, D.G. 1980. Surficial Geology of the Susitna-Chulitna River Area, Alaska, Part 2: Maps, Susitna Basin Planning Background Report. Prepared for Land and Resource Planning Section Division of Research and Development, Alaska Department of Natural Resources, March 1980. 27 pp.

Kirschner, C.E., 1994, Sedimentary basins in Alaska, in Plafker, George, and Berg, H.C., The Geology of Alaska: Geological Society of America, 1 sheet, scale 1:2,500,000.

Montgomery, D. 1999. Process domains and the river continuum. Journal of the American Water Resources Association 35 (2): 397-410.

Nakanishi, A.S., and Lilly, M.R., 1998, Estimate of aquifer properties by numerically simulating ground-water/surface-water interactions, Fort Wainwright, Alaska: U.S. Geological Survey Water-Resources Investigations Report 98-4088, 27 p.

R2 Resource Consultants, Inc. 2003. Baker River Project Relicensing (FERC No. 2150), Large Woody Debris Budget, Aquatic Resource Study A-20. Prepared by R2 Resource Consultants, Redmond, WA, prepared for Puget Sound Energy, Inc., Bellevue, WA. 105 pp.

R2 Resource Consultants, Inc. 2004. Baker River Project Relicensing (FERC No. 2150), Lower Baker Physical Habitat Mapping, Aquatic Resource Study A-02. Prepared by R2 Resource Consultants, Redmond, WA, prepared for Puget Sound Energy, Inc., Bellevue, WA. 105 pp.

Sandone, G., and C.C. Estes. 1984. Evaluations of the effectiveness of applying infrared imagery techniques to detect upwelling ground water. Chapter 10 in: C.C. Estes, and D.S. Vincent-Lang, editors. Aquatic habitat and instream flow investigations, May-October 1983. Susitna Hydro Aquatic Studies. Report No.3. Alaska Department of Fish and Game, Anchorage, Alaska. APA Document #1939.

Viereck, L.A., C.T. Dyrness, A.R. Batten, and K.J. Wenzlick. 1992. The Alaska Vegetation Classification. Pacific Northwest Research Station, U.S. Forest Service, Portland, OR. Gen. Tech. Rep. PNW-GTR-286. 278 pp.

Wahrhaftig, Clyde, 1994, Physiographic divisions of Alaska, in Plafker, George, and Berg, H.C., The Geology of Alaska: Geological Society of America, 1 sheet, scale 1:2,500,000.