Susitna-Watana Hydroelectric Project Document
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Susitna-Watana Hydroelectric Project
(FERC No. 14241)

Geology and Soils Characterization Study
Study Plan Section 4.5

Initial Study Report

Prepared for

Alaska Energy Authority

SUSITNA-WATANA HYDRO

Clean, reliable energy for the next 100 years.

Prepared by

MWH

February 2014 Draft

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LIST OF ACRONYMS, ABBREVIATIONS, AND DEFINITIONS

Abbreviation	Definition
AEA	Alaska Energy Authority
AEIC	Alaska Earthquake Information Center
ANCSA	Alaska Native Claims Settlement Act
BLM	Bureau of Land Management
BOC	Board of Consultants
DSHA	Deterministic Seismic Hazard Assessment
FERC	Federal Energy Regulatory Commission
INSAR	Interferometric Synthetic Aperture Radar
ISR	Initial Study Report
LiDAR	Light Detection and Ranging
PSHA	Probabilistic Seismic Hazard Assessment
RSP	Revised Study Plan
RTS	Reservoir Triggered Seismicity
SPD	Study Plan Determination
USGS	United States Geologic Survey

EXECUTIVE SUMMARY

Geology and Soils Characterization Study 4.5	
Purpose	Identify and document the geology and soils resources at the dam site and reservoir areas, evaluate the potential impacts of Project construction and operation, develop mitigation measures, and acquire data to support design of the Project.
Status	Field data collection and studies have begun; however, certain elements of the field investigation and testing program were deferred to a later date. Field activities included reconnaissance geologic mapping for development of regional geology, evaluation of reservoir slope stability, assessment of mineral resources, etc.
Study Components	The key study methods include field site investigations, drilling and sampling, downhole testing and instrumentation, geophysical surveys, and instrumentation monitoring; geologic mapping of the dam site and reservoir areas; geologic characterization and identification of construction material sources; assessment of seismic hazards, mineral resources, and reservoir slope stability; monitoring of earthquake events in the Project area; and geologic and engineering analysis.
2013 Variances	Land access restrictions in 2013 limited ground studies on CIRWG lands that were scheduled to be undertaken. This restriction largely impacted geologic mapping, geotechnical exploration and testing (e.g., drilling, geophysical surveys, geo-instrumentation monitoring), and the seismic hazard study. Consequently, the field exploration and testing program will be deferred to a later date.
Steps to Complete the Study	As explained in the cover letter to this draft ISR, AEA's plan for completing this study will be included in the final ISR filed with FERC on June 3, 2014.

Geology and Soils Characterization Study 4.5	
Highlighted Results and Achievements	The regional geologic studies, terrain unit analysis update, and the preliminary reservoir slope stability studies were completed. The mineral resources assessment study was largely completed. A partial program of core drilling, sampling, and testing has been conducted at the dam site (2011–2012). A long-term earthquake monitoring network has been established and data on events are being collected. Seismic hazard studies are in progress with a preliminary probabilistic seismic hazard assessment (PSHA) and reservoir triggered seismicity studies completed and the crustal seismic source characterization study is underway.

1. INTRODUCTION

On December 14, 2012, Alaska Energy Authority (AEA) filed with the Federal Energy Regulatory Commission (FERC or Commission) its Revised Study Plan (RSP) for the Susitna-Watana Hydroelectric Project (FERC Project No. 14241), which included 58 individual study plans (AEA 2012). Included within the RSP was the Geology and Soils Characterization Study, Section 4.5. RSP Section 4.5 focuses on the methods for evaluating the geology and soils and defining the existing geological conditions at the dam site, reservoir, and access road and transmission line corridors. This is necessary for developing design criteria to ensure that the proposed Project facilities and structures will be safe and adequate to fulfill their stated functions. RSP 4.5 provided goals, objectives, and proposed methods for data collection regarding this study.

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. RSP Section 4.5 was one of the 31 study plans approved with no modifications.

Following the first study season, FERC's regulations for the Integrated Licensing Process (ILP) require AEA to "prepare and file with the Commission an initial study report describing its overall progress in implementing the study plan and schedule and the data collected, including an explanation of any variance from the study plan and schedule" (18 CFR 5.15(c)(1)). This Geology and Soils Characterization Study Initial Study Report (ISR) has been prepared in accordance with FERC's ILP regulations and details AEA's status in implementing the study, as set forth in the FERC-approved RSP as approved by FERC's February 1 SPD (referred to herein as the "Study Plan").

Following the first study season, FERC's regulations for the Integrated Licensing Process (ILP) require AEA to "prepare and file with the Commission an initial study report describing its overall progress in implementing the study plan and schedule and the data collected, including an explanation of any variance from the study plan and schedule." (18 CFR 5.15(c)(1)) This Initial Study Report (ISR) on the Geology and Soils Study has been prepared in accordance with FERC's ILP regulations and details AEA's status in implementing the study, as set forth in the FERC-approved RSP (referred to herein as the "Study Plan").

2. STUDY OBJECTIVES

The overall goals of this study are to conduct a geology and soils evaluation to define the existing geological conditions at the dam site, reservoir, and access and transmission line corridors, and to develop design criteria to ensure that the proposed Project facilities and structures will be safe and adequate to fulfill their stated functions. The study objectives are established in RSP Section 4.5.1 as follows:

- Identify the existing soil and geology at the proposed construction site, reservoir area, and access road and transmission line corridors.

- Determine the potential effects of Project construction, operation, and maintenance activities on the geology and soil resources (including mineral resources) in the Project area including identification and potential applicability of protection, mitigation, and enhancement (PM&E) measures.
- Identify known mineral resources and mineral potential of the Project area.
- Acquire soils and geologic information for the Project area for use in the preparation of a supporting design report that demonstrates that the proposed structures are safe and adequate to fulfill their stated functions.

The field investigation activities for each season will be coordinated with resource agencies and ANCSA Corporation landowners. A Geotechnical Exploration Program Work Plan (Work Plan) will be developed that outlines the field programs and information needed for submitting applications and obtaining land access permits from applicable agencies and ANCSA Corporation landowners. The Work Plan will identify field investigations and studies to be carried out to assess potential impacts to geology and soil resources in the Project area, including the dam, reservoir, and access road and transmission line corridors, and the general arrangement and foundation conditions for the dam and appurtenance structures. FERC regulations require "evaluation of unconsolidated deposits, and mineral resources at the project site" (18 CFR 5.6(d)(3)(ii)(A)). For the Exhibit E, AEA must provide a report on the geological and soil resources in the proposed Project area and other lands that would be directly or indirectly affected by the proposed action and the impacts of the proposed Project on those resources. This study report provides the basis of the information needed for the Exhibit E.

3. STUDY AREA

As established by RSP Section 4.5.3, the study area includes the dam site area, reservoir area, construction material sources, tailwater downstream of the dam, access road and transmission line corridors, airport facilities, and construction camp and permanent village sites (Figure 3.1-1).

4. METHODS AND VARIANCES IN 2013

AEA implemented the methods as described in the Study Plan with the exception of variances explained in Section 4.2. Study methods implemented in 2013 are described in the following sections organized by the following study components as found in RSP Section 4.5.4:

- Review of Project Documentation
- Regional Geologic Analysis and Minerals Resources Assessment
- Geologic and Geotechnical Investigation and Testing Program Development
- Field Geologic and Geotechnical Investigations
- Reservoir-Triggered Seismicity

- Reservoir Slope Stability Study
- Geology and Engineering Analysis

4.1.1. Review of Project Documentation

The existing documentation from the 1970s and 1980s was brought into geo-referenced, geotechnical databases to bring the information from the earlier studies into modern digital formats.

4.1.2. Regional Geologic Analysis and Mineral Resources Assessment

Existing published information, air photo interpretation and reconnaissance mapping, and new LiDAR survey data were used to (1) update information about the geology at the proposed dam site and in the surrounding Project area, including surficial and bedrock geology, geologic structure, seismicity and tectonics, mass wasting, and mineral resources; (2) determine siting of Project components or structures; (3) identify geologic features of significance; and (4) assess potential impacts (e.g., erosion) and potential mitigation measures to address impacts on geology and soil resources and Project design and construction.

The recently acquired LiDAR imagery was used to compile geologic information for a large area. The approach that had been used for this Project, which was developed during the Trans-Alaska Pipeline geotechnical investigations (Kreig and Reger 1972), was to undertake a terrain unit analysis, i.e., the identification of landforms resulting from geomorphic origin or mode of deposition. This effort included an update to the original terrain unit mapping developed from aerial photographs completed in the 1980s (Acres American 1982a).

A survey of the mineral resources was performed to assess proven and probable mineral resource potential and mining activity in the impoundment area using existing data. The impoundment area is the area where access to mineral resources may be affected by the Project. In addition to the impoundment area, the road and transmission corridors were evaluated for potential quarry and aggregate sites and known mineral deposits to identify whether access to mineral resources may be adversely or beneficially affected by the Project. The survey included mapping of known mineral deposits and identification of likely areas of mineral resources, plus field reconnaissance of selected areas of high mineral potential, review of area mining claims, and analysis of mineral potential from borings and other sampling work done for the dam and other facilities through ongoing geotechnical investigations.

Recently-acquired LiDAR and INSAR data in the region were used to identify lineament features and to examine the regional landscape for potential faults for evaluation of activity and Project significance. Field reconnaissance, geologic mapping, and subsurface investigations, if necessary, were performed and the data were used to update the seismic source characterization model, site-specific ground motion evaluations, and probabilistic seismic hazard assessment (PSHA).

4.1.3. Geologic and Geotechnical Investigation and Testing Program Development

The development of a 2014–2015 geologic and geotechnical exploration and testing program Work Plan for completion of geologic and geotechnical field studies for engineering feasibility, final design and construction was completed. The Work Plan is centered on continuation of data collection efforts and studies to supplement previous field site investigations and testing performed in the 1970s–1980s and more recently in 2011–2013. Based on review of the existing data including previous geologic mapping, subsurface investigations, and laboratory testing, additional site investigations and testing will be conducted as described below:

- Delineate and characterize geology and soil resources including geologic features, rock structure, and weathering/alteration zones.
- Undertake physical and chemical testing, as well as petrographic analysis, to characterize the geology and soils materials, as appropriate.
- Evaluate lineaments' and faults' relative level of activity and significance to site-specific ground motion evaluations for the Project.
- Delineate and characterize construction material sources for the dam and appurtenant structures, access road, and construction camp.
- Determine the effects of discontinuous permafrost on the dam foundation and abutments relative to foundation treatment, grouting, and drainage, as well as reservoir slope stability and access road and transmission line construction.
- Evaluate the effect of Project features on permafrost and periglacial features (thawing of permafrost), as well as the impact of these features on permanent structures, work camps, temporary construction areas, road corridors, transmission lines, etc.
- Evaluate the need for, and potential sources of borrow materials for ancillary facilities including upland structures, access roads, and transmission lines.
- Evaluate potential waste stockpiles and storage sites including plans to help reduce the impact of these facilities on adjacent areas.
- Evaluate plans and methods for the reclamation of borrow area and quarry sites.
- Evaluate the Project's impact on access to geologic resources (mineral resources) by reviewing existing state and federal databases, as well as readily available geologic maps and surveys.
- Conduct a preliminary evaluation of the effect of soils composition in the Project area on construction, operation, and maintenance of the proposed Project.

- Evaluate potential reservoir leakage on the right abutment just upstream of the dam site (e.g., relict channel).
- Establish seismic monitoring stations in the Project area to augment the stations in the Alaska Earthquake Information Center network to monitor and detect any local earthquakes.

4.1.4. Field Geologic and Geotechnical Investigations

Geologic and geotechnical field investigations are being carried out in phases each study year with portions of that work contributing to the report on geology and soils in 2013 and with updates in subsequent year(s). The geotechnical investigations and testing undertaken as part of the Project feasibility, licensing, and design effort are to include geologic mapping, drilling, sampling and in situ testing, test trenches, pump tests, exploratory adits, laboratory testing, instrumentation monitoring, etc. Initial and limited geologic exploration and testing programs were undertaken in the 2011–2012 seasons to investigate the dam foundation and a new quarry site for concrete aggregate material. This included installation and monitoring of geotechnical instrumentation and reconnaissance geologic mapping in the Project area for understanding the regional geology, and was also associated with terrain unit analysis, the mineral resources study, seismic hazard study, and reservoir area geology. Multiple field investigation programs are planned for continuation in subsequent year(s).

4.1.5. Reservoir-Triggered Seismicity

Seismic hazard study and evaluations are being undertaken for the Project under a separate study (see RSP Section16.6) and include conducting a crustal seismic source characterization study; identifying and evaluating lineaments and if tectonic in nature; completing a fault evaluation process; developing a new subduction seismic source model; preparing a deterministic and probabilistic seismic hazard assessment, including ground motion estimates; and developing seismic design criteria for the Project. In addition, a long-term earthquake monitoring system was installed and the seismicity data are being collected to better understand the seismological characteristics of local terrain or regional area and seismic hazards in the Project area, and to provide a baseline of seismic activity prior to impoundment of the reservoir for assessing potential reservoir triggered seismicity. The Geology and Soils and Seismic Hazard characterization will contribute information to the overall study.

4.1.6. Reservoir Slope Stability Study

A preliminary assessment was made of reservoir rim stability based on the geologic conditions in the reservoir area, particularly in the reservoir drawdown zone. Geologic information from the previous study on reservoir slope stability (Acres American 1982a) as well as LiDAR imagery, geologic and terrain unit mapping, field investigations, and instrumentation monitoring were used to assess the stability and erosion concerns of the reservoir rim area. Key factors in this study are the planned reservoir level and anticipated range of drawdown, rock and soil type and conditions, presence of permafrost, topography, and slope aspect and conditions.

4.1.7. Long-Term Earthquake Monitoring System

A long-term seismic monitoring system is to be established in the Project area to monitor and document earthquake events (see RSP Section 16.6). The system was expanded in 2013 and currently consists of seven instrumented locations within about 30 miles of the dam site, four 6-component strong motion and broadband seismograph station, and three 3-component broadband seismograph stations. Previously (2012) four seismograph stations had been installed. The monitoring system is linked and integrated into the Alaska Seismographic Network operated by the Alaska Earthquake Center for real-time data acquisition, processing, and analysis.

4.1.8. Geologic and Engineering Analyses

Geologic and engineering analyses are being undertaken to identify and evaluate construction material sources to provide adequate quantities of suitable materials for construction; to evaluate horizontal alignments and foundation design for the access road, construction and permanent camps, and transmission line corridor; and to identify potential re-use of excavated materials and/or disposal areas. The geology and engineering study includes an assessment of soil erosion potential along the transmission and access road corridors, along with other effects of design and construction on geology and soils, and identification of the suitability of measures to reduce and mitigate impacts.

Additionally, a number of geologic, seismic, and engineering analyses are being undertaken to develop the geologic model for the dam site area and to assess foundation design, abutment stability, seepage and piping potential, slope stability, ground motion, and site-specific probabilistic seismic hazards for the dam site area. These activities will also help identify impacts and measures to mitigate impacts to geology and soil resources.

4.2. Variances from Study Plan

Due to land access restrictions in the study area, which were unanticipated for the 2013 field season, the planned field exploration and testing program, specifically geologic mapping, geophysical surveys, drilling and testing, and excavation of an exploratory adit at the dam site, was deferred. In areas where land access restrictions were imposed, no on-the-ground activities could be performed. In these areas, field investigation and data collection were limited to aerial reconnaissance, a high-level review in connection with reconnaissance geologic mapping activities associated with development of the regional geology, mineral resources assessment, and continuation of seismic hazard studies.

As a consequence, the methods of data collection for the dam site, consisting of geologic mapping, drilling and in situ testing, surface geophysical surveys, excavation of exploratory adits, and geotechnical instrumentation installation and monitoring as well as the methods of data collection for the proposed Project infrastructure (e.g., proposed access roads and transmission corridors and camp/village) are being re-scheduled for future field seasons. Several broader study area field investigation efforts were restricted, specifically related to geology and soils methods of investigation and data collection, including regional geologic mapping, mineral resources survey, drilling at Watana Creek, and field reconnaissance to ground-truth interpretations for the terrain unit mapping and preliminary slope stability evaluation. The seismic hazard studies, lineament, and fault evaluation in connection with the crustal seismic source evaluation were curtailed due to access restrictions, in particular in the dam site, lower reservoir, and Fog Lakes areas.

5. RESULTS

5.1.1. Review of Project Documentation

The existing geologic, geotechnical, and seismic documentation from the 1970s and 1980s was brought into geo-referenced, geotechnical databases to build new information databases in digital formats, which will be developed and expanded upon through additional data collection from future phases of field investigations. The data currently in digital format includes boring and test pit logs, laboratory testing data, and geotechnical instrumentation monitoring data for groundwater and ground temperature.

Additionally, several 1980s drawings (e.g., exploration plans), which were in the Alaska State Plane, Zone 4, NAD27 coordinate system, were updated to the present coordinate system, NAD83, and included on base topographic maps and GIS-databases created from the recently acquired LiDAR imagery (Acres American 1982b; Harza-Ebasco 1983).

Some of the rock cores from the earlier field investigations are being stored by the ADNR DGGS in Eagle River and were reviewed to ascertain what samples remained from the 1980s studies and to become familiar with the bedrock conditions at the dam site prior to beginning the recent field investigations.

5.1.2. Regional Geologic Studies

Existing published information, air photo interpretation, reconnaissance mapping, and new LiDAR survey data are being used to (1) update information about the geology and soils resources in the Project area with a focus in the dam site area, including the surficial and bedrock geology, geologic structure, seismicity and tectonics, mass wasting, and mineral resources; (2) determine the siting of some Project components and/or structures; (3) identify geologic features of significance that may impact the general arrangement and design of Project components or need to be mitigated through excavation, support, treatment, etc.; and (4) assess potential impacts to the geology and soil resources and develop appropriate mitigation measures relative to design, construction, and operation of the Project. The various methods being employed for this study include both desktop studies and field investigations and are described below.

5.1.2.1. Terrain Unit Analysis

Terrain unit analysis was undertaken using a desktop approach for generating and compiling geologic information for the large area beyond the dam site area that has had limited investigation. Terrain unit mapping was a product of the interpretations of aerial photographs and “bare earth” 3D digital imagery, terrain unit analysis, and limited field reconnaissance. Utilizing these techniques, landforms resulting from geomorphic origin or mode of deposition were identified and cataloged as terrain units. *Terrain unit* is a special purpose term comprising landforms expected to occur from the ground surface to a depth of about 25 feet.

The general objective of this effort was to review and update the 1982 terrain unit mapping interpretation using more advanced aerial imagery (e.g., LIDAR, INSAR models) (Acres American 1982a). The analysis included the area from about 7 miles west of the dam site to just east of Vee Canyon (about 38 miles east of the dam site) and about 7 miles north–south centered on the Susitna River. Fifteen landforms were identified that document the geologic features and general geotechnical conditions, noting such geologic and terrain factors as soil types, permafrost, potentially unstable slopes, etc. An example of the work product created to document the terrain units is presented on Figure 5.1-1.

5.1.2.2. Reservoir Slope Stability Study

A preliminary assessment was made of the potential for a major landslide or slope failure that could threaten or negatively impact the safety or safe operation of the dam and/or associated critical facilities. Additionally, the study also includes an assessment of the potential slope conditions as a result of mass wasting and erosion processes along the reservoir rim that may develop following reservoir impoundment, based on the anticipated reservoir operation conditions. This preliminary assessment performed as a desktop study was based on the current Project physical parameters, reservoir operational levels, and geologic, topographic, and vegetation conditions.

Geologic information from the previous study on reservoir slope stability (Acres American 1982a) as well as LiDAR imagery-3D “bare earth” model, the terrain unit analysis (see Section 4.1.2.1), and published geologic maps were used to identify and assess areas of concern. Key factors that were considered in this study were the anticipated range of reservoir drawdown, rock and soil type and conditions, delineation of areas of frozen ground (e.g., permafrost), topography, slope aspect and conditions, and current location and types of mass wasting. A GIS map book was created to compile the data and preliminary interpretation including terrain unit maps, current slope mass wasting, and anticipated future slope conditions post-impoundment (Figure 5.1-2).

5.1.2.3. Mineral Resources Assessment

A desktop study and field reconnaissance was undertaken to document and assess the mineral resources in the dam and reservoir area, including the corridors. This assessment was conducted to determine if and where mineral resources, metallic and non-metallic resources, may be affected by the Project in either a beneficial or detrimental way. The study included identifying mining claims and prospects in the Project area from data sources (e.g., State of Alaska mining claim website); field reconnaissance of selected areas of high mineral potential, mineral licks, and mining claims; and consultations with active miners and geologists familiar with the area (USGS, BLM, Alaska Earth Sciences, CIRI, and claimholders). Additionally, several rock samples were collected and chemically analyzed for a wide range of potentially economic minerals.

Preliminary maps of active mining claims, known mineral deposits, and mineral prospects have been produced based on a review of the State of Alaska database. An example map of active mining claims for the Project area and adjacent lands is presented on Figure 5.1-3. Based on the data compiled on the claims and regional geology, a 5-day field reconnaissance was conducted in late August 2013 to evaluate and/or confirm the information on the claims, to review areas of high mineral potential, and to obtain rock samples.

The survey also included identification of non-metallic resources, potential construction material sources, rock quarry, and aggregate sites that might be considered and utilized along the transportation and transmission corridors (e.g., Gold Creek, Denali, and Chulitna corridors) during construction or might be adversely or beneficially affected as a result of the Project. The approximate extent of the feasible non-metallic resource was classified by deposit type and mapped.

The mineral resources assessment also included the identification and review of potential sources of acid rock drainage (ARD) and mineral licks (Figure 5.1-4) that provide nutrients to wildlife. As part of this study, rock outcrops were reviewed for characteristics that were highly oxidized, which could result in acidic runoff.

Ground access was limited due to land access restrictions in 2013 and only locations on state and federal lands were visited on the ground.

5.1.2.4. Regional Geologic Mapping

A regional geologic map is currently being compiled based on available geologic map data, aerial imagery, and recently-acquired LiDAR and INSAR data. Data from these available sources were compiled, and areas of interest were investigated to verify the geologic unit and structure mapped previously during a 10-day field mapping program. The reconnaissance geologic mapping effort collected data related to soil or rock type, grain size, composition, degree of weathering, hardness/strength, rock structure and characteristics, geomorphic landform type, groundwater springs or seepage, unfrozen or frozen condition, etc.

A regional geologic map is currently being compiled; a draft work in progress document is provided herein (Figure 5.1-5). The geologic data is being compiled in a GIS database.

5.1.3. Geologic and Geotechnical Field Investigation and Testing Program Development

The development of a geologic and geotechnical exploration and testing program Work Plan for completion of geologic and geotechnical field studies for engineering feasibility, licensing, and ultimately for final design and construction was completed.

5.1.4. Field Geologic and Geotechnical Investigations

In 2011 and 2012, eleven borings were completed at the dam site and two potential construction material sources (Quarry A and M) on the south side of the river. Diorite bedrock was encountered in the dam site and Quarry M while andesite and diorite were encountered in Quarry A. Water pressure testing was conducted and geotechnical instruments, vibrating wire piezometers, and temperature acquisition cables were installed in many of the borings. In a few borings, downhole optical and acoustical surveys were performed. Rock core samples were selected from the subsurface investigations and laboratory testing performed to determine the engineering properties of the rock material (e.g., unconfined compressive strength, LA abrasion, freeze-thaw).

In 2013, the planned field investigation and testing program—which included geologic mapping, surface geophysical surveys, drilling and in situ testing, geotechnical instrumentation monitoring, excavation of an exploratory adit as well as laboratory testing of samples collected at the dam site and/or infrastructure areas—was deferred to due to land access restrictions. The program included a winter geologic mapping program to access rock outcrops to collect information on the bedrock conditions and to evaluate lineaments in the dam foundation area and a spring/summer program of mapping, geophysical surveys, drilling, instrumentation monitoring, and excavation of the exploratory adit.

An assessment was made of the 1970s and 1980s geotechnical instrumentation to determine what if any of the boreholes or instruments in the area of interest (e.g., dam site) could be recovered and automated. Dataloggers were installed in five borings from the 1970s and 1980s for recording ground temperature (4) and groundwater (1) measurements. In addition, seven borings from 2012 were instrumented and dataloggers installed for continuous recording of ground temperature and/or groundwater measurements. Some data have been obtained from the dataloggers; however, due to the restricted access matter, the data record is not complete. In addition to those borings with dataloggers, there are several borings (3) where manual measurements were made. Based on the data collected during the 1980s on ground temperature, it appears that frozen ground conditions exist in the south abutment (DH-24) and may be present in the lower north abutment (Figure 5.1.6).

Some geologic mapping was performed in 2011–2012 to obtain additional geologic data in the vicinity of the proposed dam foundation, in particular on the right or north abutment. The data obtained during the mapping are being used along with the LiDAR to update the bedrock geology map for the dam site previously developed by Acres American (1982b).

5.1.5. Geologic and Engineering Analyses

Geologic and engineering analyses were undertaken utilizing the geologic and geotechnical data that had been obtained during the earlier (1970s–1980s) and more recent field investigations and laboratory testing. These data formed the framework of the geologic characterization and development of a geologic model for optimization of the general arrangement, development of foundation and underground structures designs, and preliminary geotechnical assessments of abutment stability and the dam foundation for development of finite element models for analysis.

5.1.6. Seismic Hazard Study

The crustal seismic source field evaluation of identified lineaments and potential faults is underway. In 2013, about 50% of the lineament features were evaluated. Field evaluations were undertaken to assess the geomorphologic landforms and characteristics around the lineaments and to identify positive evidence for (or against) tectonic deformation associated with the lineament. On-the-ground field mapping and evaluation are required in the dam site and reservoir areas on CIRWG lands

A preliminary assessment of the potential for reservoir triggered seismicity (RTS) to occur during and after filling of the reservoir was completed. Empirical data suggest that most RTS events will have relatively small magnitudes and would most likely occur within 10 years of initial reservoir filling. From these types of observations, ICOLD (2011) and Allen (1982) suggest that maximum RTS magnitudes may be on the order of 6.3 and 6.5, respectively. The results of the crustal seismic source assessment and additional seismic event data are needed to improve the understanding of the local geologic and seismotectonic characteristics that are significant to RTS. In 2015, the RTS study will be revisited and updated.

The long-term seismic monitoring network for the Project was expanded in 2013. Three additional seismograph stations were added and one GPS station. This brings the total project network to seven seismograph stations, four 6-component broadband and strong motion stations, and three 3-component broadband stations, and one GPS monitoring station. The stations are all located within 31 miles of the proposed dam site. Data on seismic events in the area are provided to the Alaska Earthquake Information Center (AEIC) in real-time. For additional information on the seismic hazard studies, see ISR 16.6.

6. DISCUSSION

Limited progress was made with respect to field investigations and testing in 2013 due to land access restrictions, with ground access only on state and federal lands. The tasks undertaken were mostly desktop studies with some field reconnaissance, primarily in the broader regional area and not the dam site and lower reservoir area, which was to be the focus for the field work. Therefore, limited field reconnaissance was undertaken to verify the interpretations made from the desktop studies, i.e., regional geologic data collection, mineral resources and slope stability assessments, and seismic hazard studies.

Additional efforts have been made in the planning of future phases of field investigations and testing to be under taken as a result of the delay in the data collection efforts (see Section 5.1.3). Geologic and engineering analysis undertaken in 2013 has been based on the data primarily obtained during the 1970s and 1980s field investigation and testing programs as augmented by the recent limited field work in 2011–2012. The engineering work tasks have included selection of appropriate engineering properties of soils and rock, characterization of rock mass, development of design criteria, evaluation of abutment stability and feasibility design, and development of general arrangement, foundation excavation, and treatment for the dam and powerhouse, underground structure support, and lining, etc.

7. COMPLETING THE STUDY

[As explained in the cover letter to this draft ISR, AEA's plan for completing this study will be included in the final ISR filed with FERC on June 3, 2014.]

8. LITERATURE CITED

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9. FIGURES

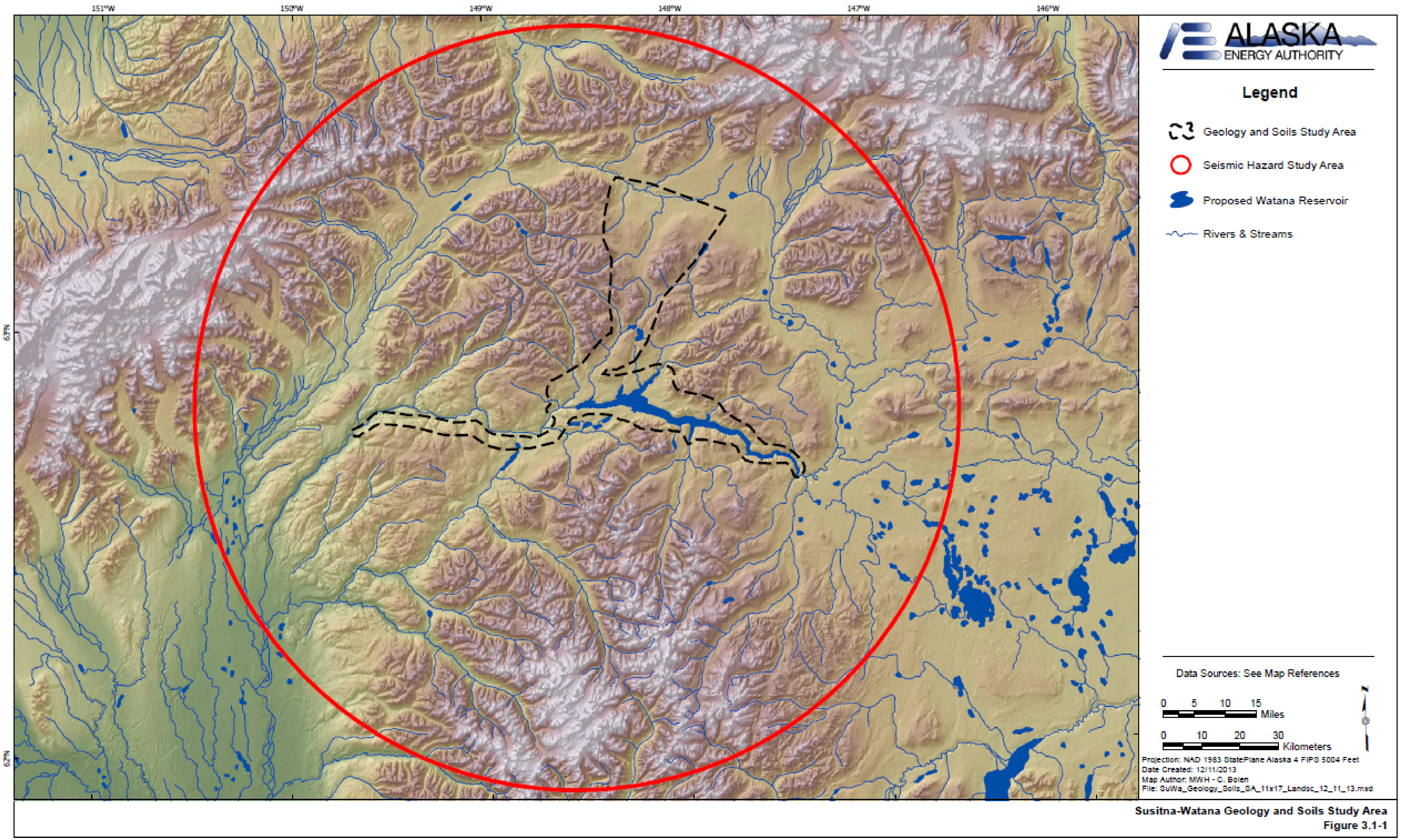


Figure 3.1-1. Susitna Watana Project Area

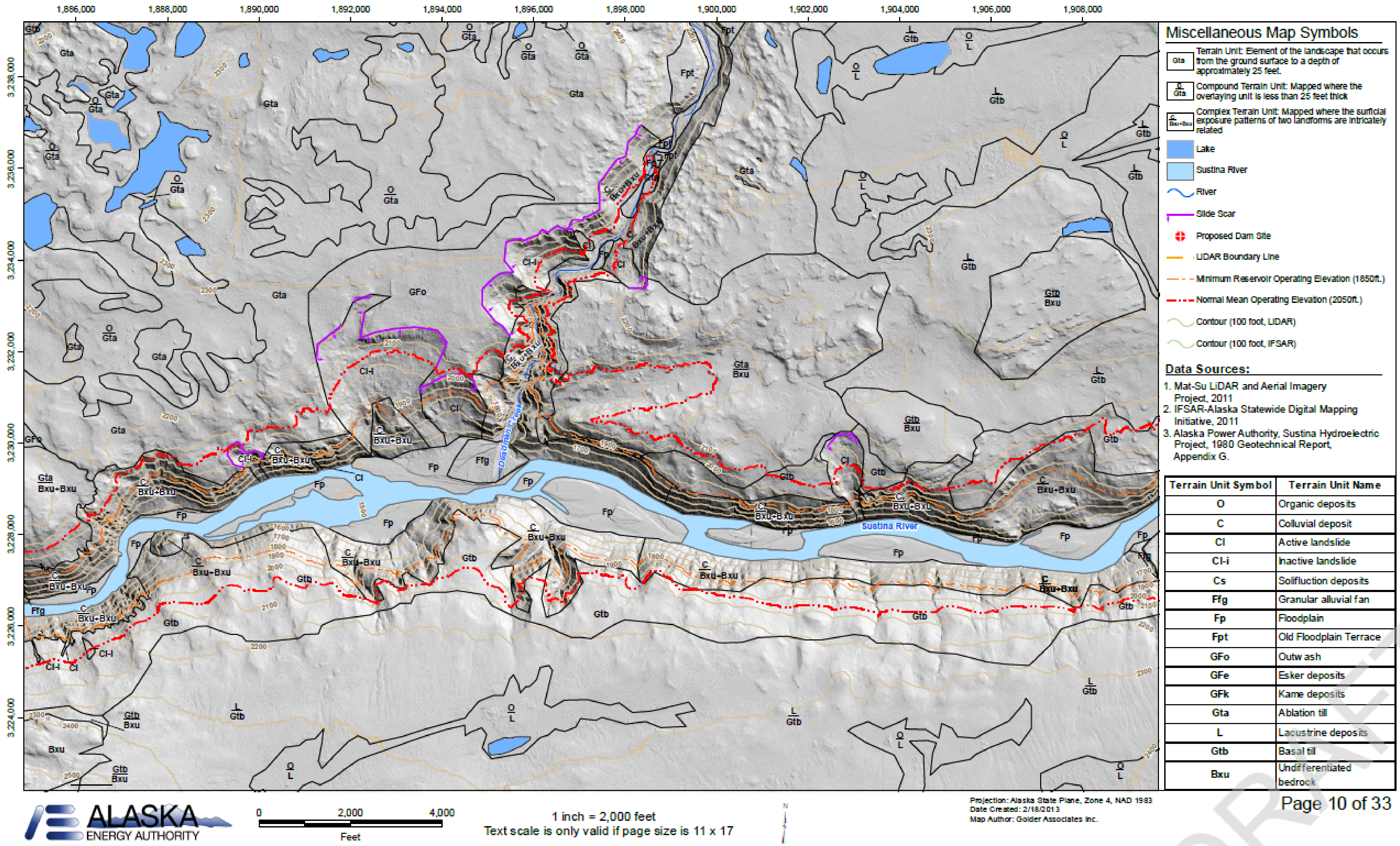


Figure 5.1-1. Terrain Unit Analysis, Watana Site to Upstream of Deadman Creek

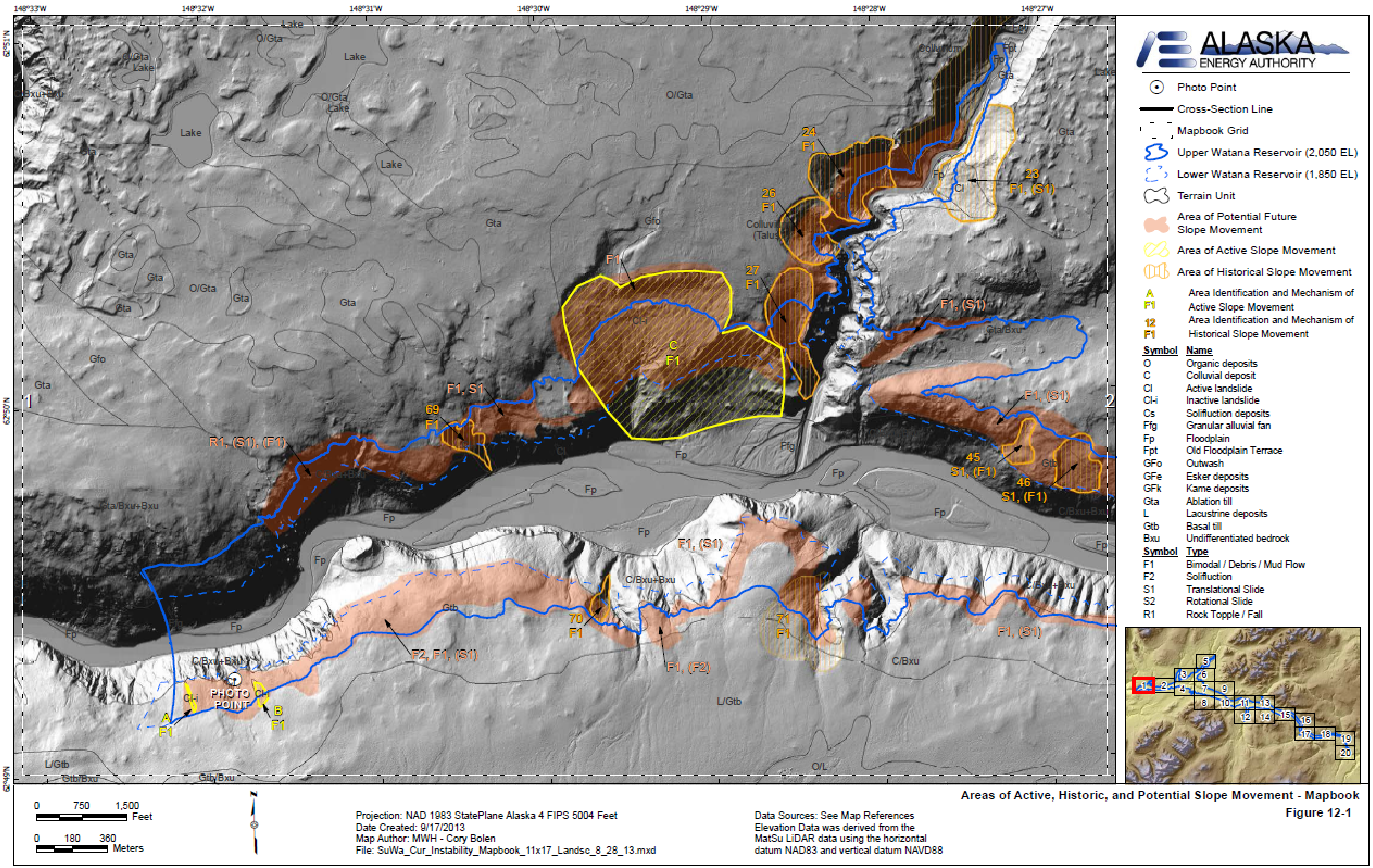


Figure 5.1-2. Preliminary Assessment of Reservoir Rim Stability – Watana Site to Deadman Creek

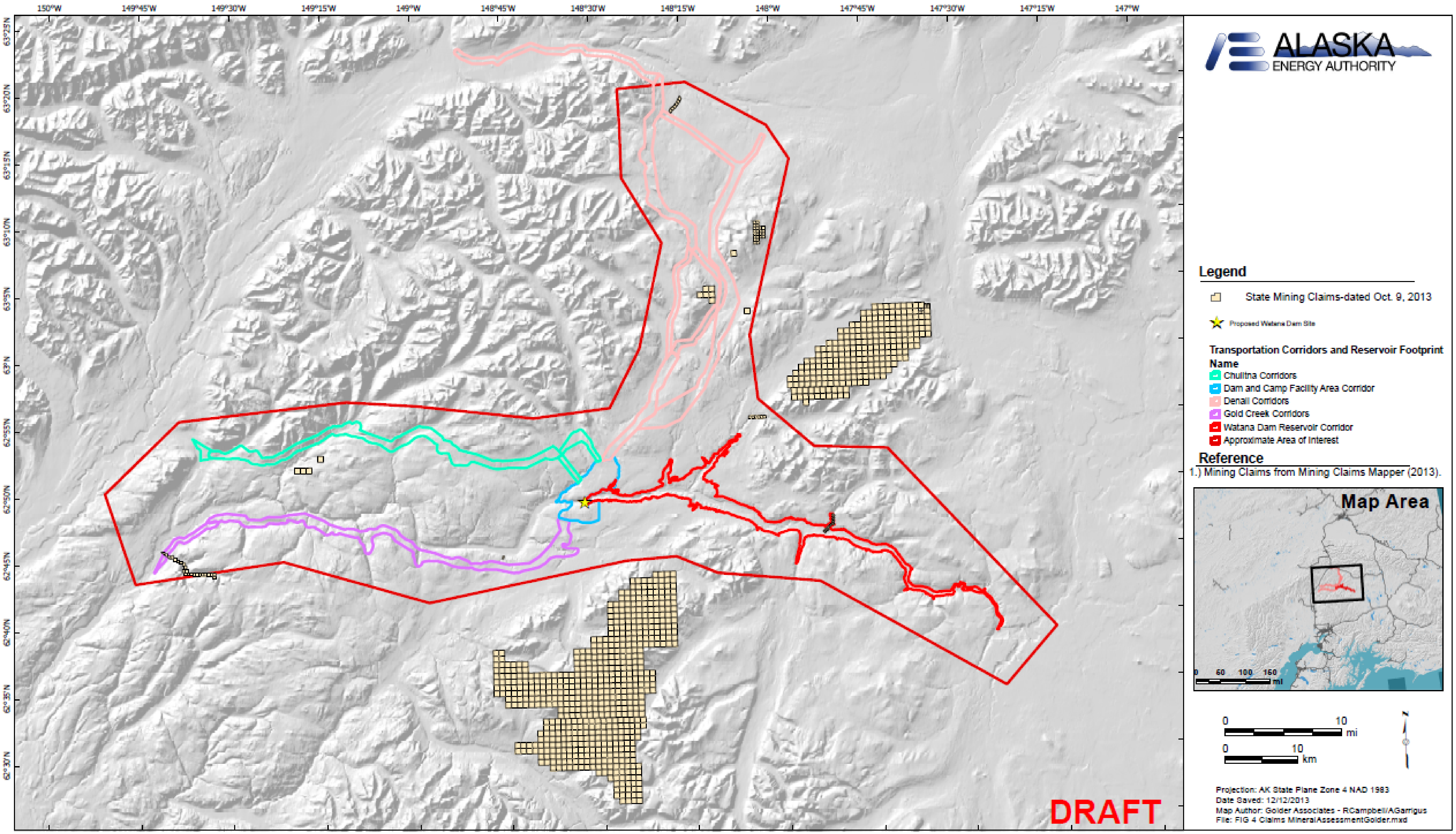


Figure 5.1-3. Locations of State Mining Claims in Project Area

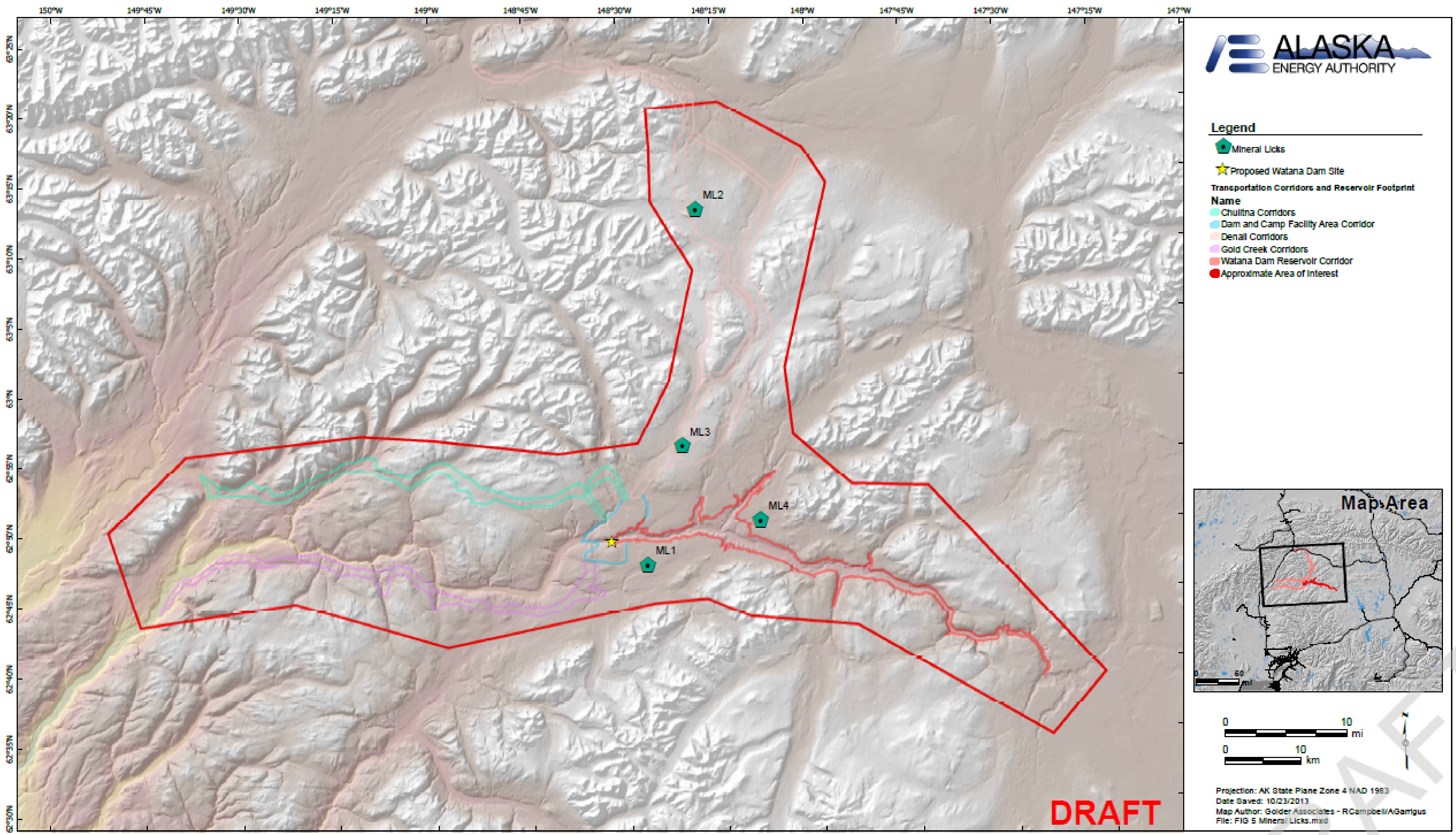


Figure 5.1-4. Locations of Mineral Licks in the Project Area

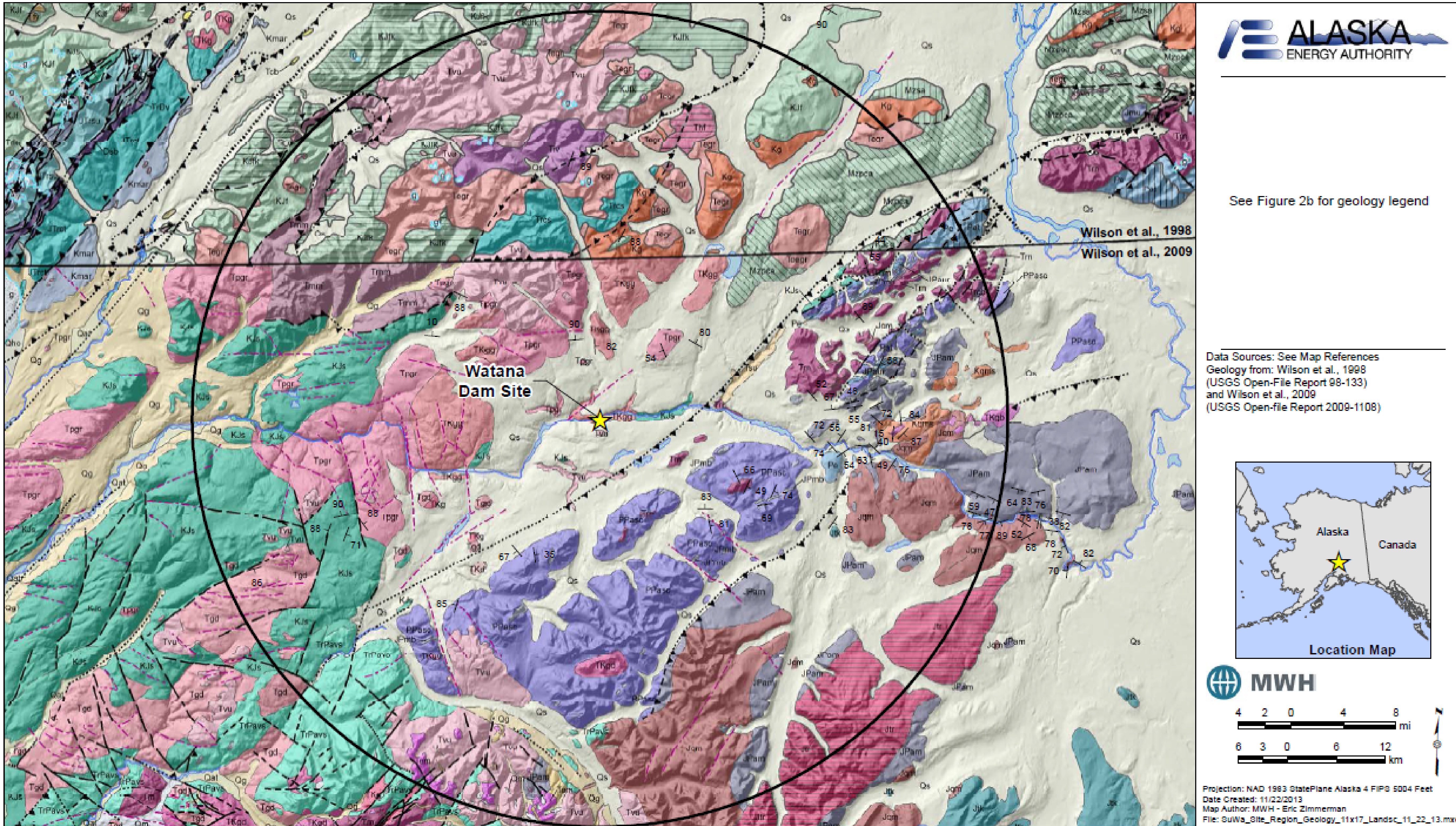


Figure 5.1-5. Regional Geologic Map for the Project Area

g	Ice fields or glaciers
	Water

QUATERNARY DEPOSITS

Qs	Surficial deposits, undifferentiated
Qat	Alluvium along major rivers and terraces (Holocene)
Qlc	Landslide and colluvial deposits (Holocene and Upper Pleistocene)
Qm	Glacial deposits, undivided (Quaternary)
Qho	Younger outwash deposits (Holocene)
Qg	Major moraine and kame deposits (Upper Pleistocene)

TERTIARY ROCKS

Sedimentary Rocks

Tsu	Sedimentary rocks, undivided
Tn	Nenana Gravel
Tcb	Coal-bearing rocks
Tfv	Fluviatile sedimentary rocks and subordinate volcanic rocks

Igneous Rocks

Volcanic and Hypabyssal Rocks

Tvu	Tertiary volcanic rocks, undivided
Thf	Hypabyssal felsic and intermediate intrusions

Intrusive Rocks

Tiv	Granitic and volcanic rocks, undivided
Ti	Intrusive rocks, undivided

OLIGOCENE

Toegr	Granitic rocks

EOCENE

Tem	Mafic volcanic rocks
Tegr	Granite and granodiorite

PALEOCENE

Tgd	Biotite-hornblende-granodiorite
Tpgr	Granitic rocks of Paleocene age

TERTIARY AND/OR CRETACEOUS

Sedimentary Rocks

TKd	Dikes and sills

Igneous Rocks

Intrusive Rocks

TKg	Granitic rocks
TKgd	Granodiorite, tonalite and monzonite dikes, and stocks
TKgb	Gabbroic rocks

Metamorphic Rocks

TKgg	Gneissose granitic rocks

UNDIVIDED MESOZOIC ROCKS

METAMORPHIC ROCKS

Mzsa	Schist and amphibolite
Mzpca	Phyllite, pelitic schist, calc-schist, and amphibolite of the Maclaren metamorphic belt

CRETACEOUS

Melange

Kmar	Melanges of the Alaska Range
TrSl	Limestone blocks

Igneous Rocks

Volcanic and hypabyssal rocks

Ksva	Andesitic subvolcanic rocks
Kg	Granitic Rocks

Plutonic

Kqms	Quartz monzonite, monzonite, and syenite

CRETACEOUS AND/OR JURASSIC

Sedimentary Rocks

KJs	Argillite, chert, sandstone, and limestone
KJf	Kahiltna flysch sequence
KJfk	Flysch sequence
KJcg	Conglomerate, sandstone, siltstone, shale, and volcanic rocks

JURASSIC

Sedimentary Rocks

JTrlm	Limestone and marble
Jtk	Talkeetna Formation

JURASSIC (continued)

Igneous Rocks

Jmu	Mafic and ultramafic rocks

Plutonic Rocks

Jtr	Alaska-Aleutian Range batholith, Trondhjemite
Jqm	Granodiorite and quartz monzonite

Metamorphic Rocks

JPaur	Uranatina metaplutonic complex
Jpmu	Plutonic and metamorphic rocks, undifferentiated
JPam	Amphibolite
JPmb	Marble

TRIASSIC

Sedimentary Rocks

Trcs	Calcareous sedimentary rocks
TrPavs	Basaltic to andesitic metavolcanic and sedimentary rocks

Plutonic Rocks

Trgb	Gabbro, diabase, and metagabbro

Volcanic Rocks

Trn	Nikolai Greenstone and related similar rocks

Metamorphic Rocks

Trnm	Metavolcanic and associated metasedimentary rocks

MESOZOIC AND PALEOZOIC

Assemblages and Sequences

JTrsu	Red and brown sedimentary rocks and basalt
JTrct	Crystal tuff, argillite, chert, graywacke, and limestone
Trk	Kamishak Formation [includes some volcanic rocks]
Trr	Red beds
TrDv	Volcanic and sedimentary rocks
Dsb	Serpentinite, basalt, chert and gabbro, Late Devonian

PALEOZOIC

Assemblages and Sequences (Skolai Group)

Pe	Eagle Creek Formation, marine argillite and limestone, lower greenschist facies (equivalent to Hasen Creek Formation)
PPasc	Station Creek and Slana Spur Formation, and equivalent rocks
Pat	Station Creek Formation, andesitic volcanic rocks (correlated with Tetelna volcanics)

Ice contact (glacier limit)
Shoreline or riverbank
Lineament
Stratigraphic contact
Concealed shear zone
Fault - Certain
Fault - Approximate
Fault - Inferred
Fault - Inferred (queried)
Fault - Concealed
Thrust fault - Certain
Thrust fault - Approximate
Thrust fault - Inferred
Thrust fault - Concealed

2013 Strike/Dip Field Data for Bedrock Outcrops

Note: Strike/Dip symbol may not be in the exact location on this map due to overlapping and symbol representation.

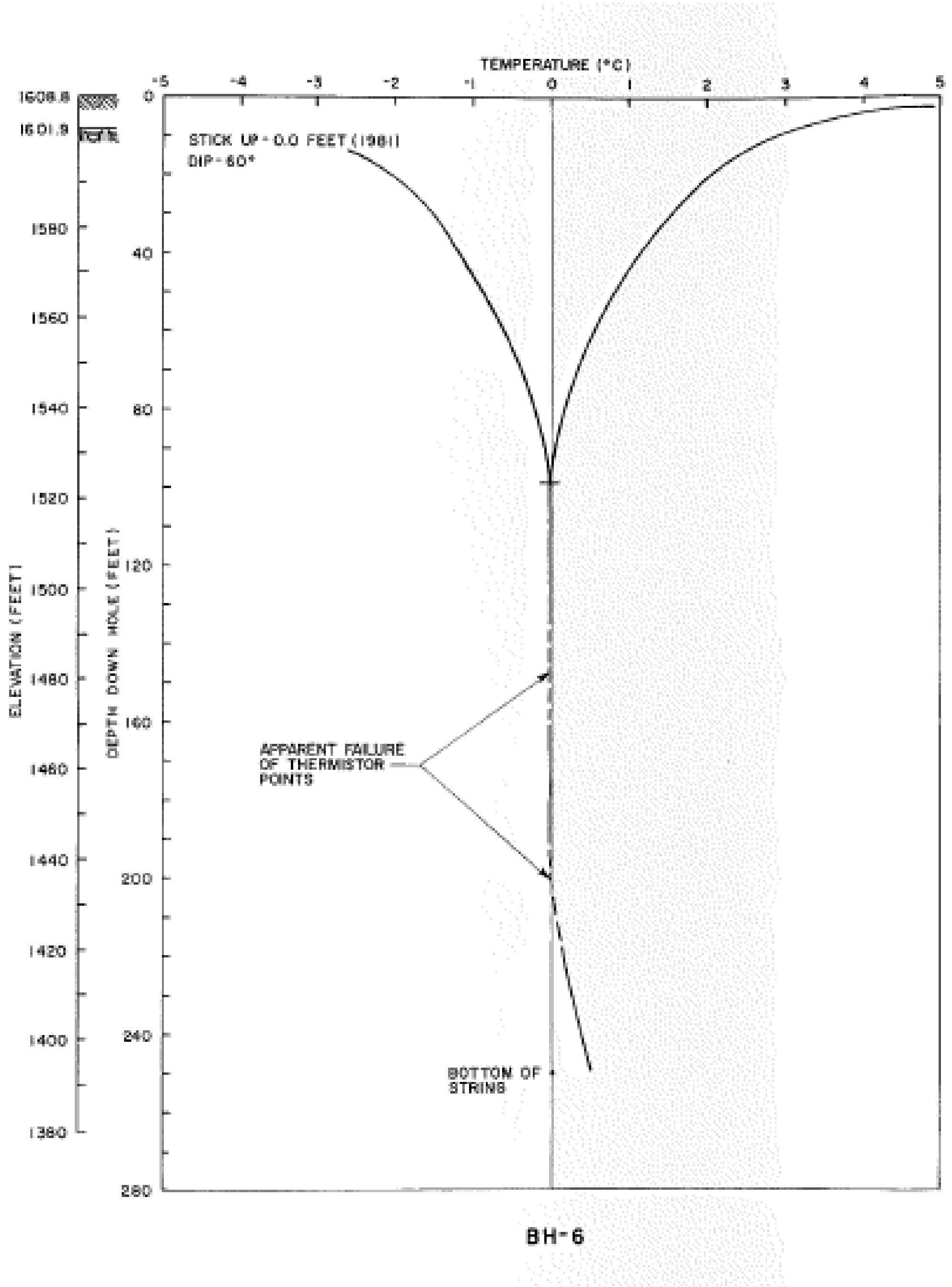
ALASKA ENERGY AUTHORITY

Geology from: Wilson et al., 1998 (USGS Open-File Report 98-133) and Wilson et al., 2009 (USGS Open-file Report 2009-1108)

MWH

Projection: NAD 1983 StatePlane Alaska 4 FIPS 5004 Feet
Date Created: 11/22/2013
Map Author: MWH - Eric Zimmerman
File: SuWa_Site_Region_Geology_LEG_11x17_Landsc_11_22_13.mxd

Figure 5.1-6. Regional Geologic Map for the Project Area – Legend



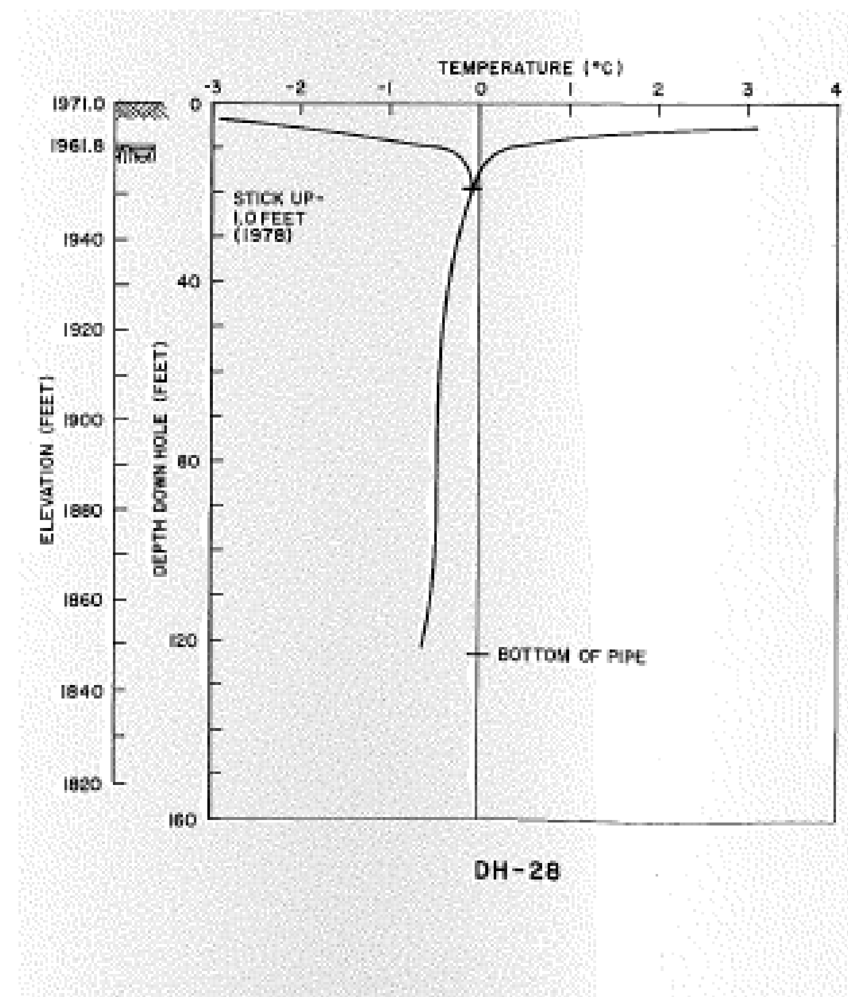


Figure 5.1-7. Ground Temperature Data Plots – Examples