Susitna-Watana Hydroelectric Project Document
ARLIS Uniform Cover Page

Title: Geology and soils characterization study, Study plan Section 4.5, 2014-2015 Study Implementation Report. Attachment 2 : Exploration and testing program work plan 2014-2015 *Formal title:* Watana Dam exploration and testing program work plan 2014-2015	**SuWa 289**
Author(s) – Personal: Paul Richards, Todd Loar, Justin Peterson	
Author(s) – Corporate: MWH	
AEA-identified category, if specified: November 2015; Study Completion and 2014/2015 Implementation Reports	
AEA-identified series, if specified: Technical memorandum ; no. 11	
Series (ARLIS-assigned report number): Susitna-Watana Hydroelectric Project document number 289	**Existing numbers on document:** AEA11-022 TM-11-0011-122013
Published by: [Anchorage : Alaska Energy Authority, 2015]	**Date published:** December 20, 2013
Published for: Alaska Energy Authority	**Date or date range of report:**
Volume and/or Part numbers: Study plan Section 4.5	**Final or Draft status, as indicated:** v0.0
Document type:	**Pagination:** vi, 65, [15] pages. This total excludes pages withheld from the public.
Related work(s):	**Pages added/changed by ARLIS:**
Notes: Some figures of attachment 2 have not been released in accordance with FERC order number 630-A. Placeholder pages substitute for those pages. The following parts of Section 4.5 appear in separate electronic files: Attachment 1 ; Attachment 2 (two files) ; Attachment 3 ; Attachments 4-5 ; Attachment 6 ; Attachment 7 (5 files) ; Attachment 8 ; Attachment 9.	

ATTACHMENT 2: EXPLORATION AND TESTING PROGRAM WORK PLAN 2014-2015

This attachment includes some figures that contain Critical Energy Infrastructure Information (CEII), which are being withheld from public viewing, in accordance with FERC's Order No. 630-A.

DO NOT RELEASE.

SUSITNA-WATANA HYDRO

Clean, reliable energy for the next 100 years.

NTP 11
Technical Memorandum No. 11
v0.0

Watana Dam

Exploration and Testing Program Work Plan
2014-2015

AEA11-022

Prepared for:
Alaska Energy Authority
813 West Northern Lights Blvd.
Anchorage, AK 99503

Prepared by:
MWH
1835 South Bragaw St., Suite 350
Anchorage, AK 99508

December 20 2013

[This page intentionally blank.]

The following individuals have been directly responsible for the preparation, review and approval of this Technical Memorandum.

Prepared by: Paul Richards, Todd Loar, Justin Peterson

QC Review by: Peter Dickson, Bob Dugan, Mike Bruen

Approved by: M.P. Bruen

Michael Bruen, Geology, Geotechnical, Seismic Lead

Approved by: B. Sadden

Brian Sadden, Project Manager

[This page intentionally blank.]

TABLE OF CONTENTS

List of Tables

List of Figures

Explanation of Abbreviations

AAR	Alkali aggregate reactivity
ADF&G	Alaska Department of Fish and Game
ADNR	Alaska Department of Natural Resources
AEA	Alaska Energy Authority
AEIC	Alaska Earthquake Information Center
AKOSH	Alaska Occupational Safety and Health
ANCSA	Alaska Native Claims Settlement Act
ASTM	American Standard Testing Method
CIRI	Cook Inlet Region Incorporated
CFRD	Concrete faced rockfill dam
ft	feet
FERC	Federal Energy Regulatory Commission
Fugro	Fugro Consultants, Inc.
Golder	Golder Associates, Inc.
GPS	Global positioning system
INSAR	Interferometric synthetic aperture radar
ISRM	International Society of Rock Mechanics
JRC	Joint rock coefficient
LiDAR	Light detection and ranging
MASW	Multi-channel analysis of surface wave
msl	Mean sea level
MWH	MWH Americas, Inc.
NAD	North American Datum
OSHA	Occupational Safety and Health Administration
PSHA	Probabilistic seismic hazard analysis
SPT	Standard penetration test
RCC	Roller compacted concrete

RMR	Rock mass rating
RQD	Rock Quality Designation
RTS	Reservoir-triggered seismicity
UCS	Unconfined compressive strength
USBR	United States Bureau of Reclamation
USGS	United States Geological Survey
VWP	Vibrating wire piezometer
WCC	Woodward Clyde Consultants

1. INTRODUCTION

Further field investigations will be required to support on-going engineering studies for optimization of the proposed RCC dam and related operational structures, engineering feasibility, as well as the upcoming preparation of the FERC License Application for the Project. The planned 2013-15 field investigations program[1] was initiated and based on a thorough review of all historical geologic, geotechnical, and seismic studies and reports (1970s and 1980s), the results of the 2011-12 geotechnical exploration and testing program, the 2012 seismic hazard studies, the current general arrangement and details of the proposed Susitna-Watana hydroelectric facility and supporting infrastructure. Each field season of activity, using a phased approach, builds upon the existing knowledge base and understanding of the geology and geotechnical conditions and seismic characterization studies.

The geotechnical exploration and testing methods envisioned for this program include geologic mapping; rock core and soil drilling; in-situ testing, and down-hole geophysics; geotechnical instrumentation monitoring; sampling and laboratory testing; geophysical surveys; test pits and trenches; and excavation of exploratory adits. The focus of the proposed field activities will be the dam site area, reservoir area, access and transmission line corridors, and proposed dam site area infrastructure – the construction camp, airfield, permanent village and other supporting Project facilities.

The geotechnical exploration and testing program is intended to advance the understanding of geologic and geotechnical conditions in support of engineering studies and design and to reduce uncertainties and risk during construction of the dam and appurtenance facilities, reservoir area, and along site access corridors; characterize the regional seismicity; and develop the seismic source model for the Project area. More specifically, the site investigation activities are intended to focus on the following project components:

[1] Originally, the exploration and testing work plan was envisioned for the 2013-2015 field seasons. However, due to land access restrictions at the dam site for 2013, the exploration and testing program will be executed during the 2014-2015 field seasons.

- Investigations at the dam site will include collecting additional geologic and geotechnical data in the following areas:
  - Dam foundation
  - Surface powerhouse located at the toe of the dam
  - Gated spillway over the dam on the right abutment, with the chute extending downstream and ending in a flip bucket, and a plunge pool in the existing river bed
  - Diversion tunnel on the right abutment to pass Susitna River flows during construction which will be used as an emergency release during operation
  - Construction material sources to provide aggregate material for use in the RCC and mass concrete; rockfill and impervious materials for the cofferdams, and aggregate for road construction, and
  - Permanent (and temporary) site roads and access tunnel(s).
- Reservoir studies to include:
  - Reservoir rim stability
  - Potential for reservoir triggered seismicity, and
  - Identification of potential economic resources.
- Site infrastructure studies will evaluate preliminary geologic and geotechnical conditions of:
  - Potential access corridors and bridge crossings
  - A permanent bridge downstream of the dam
  - Transmission line corridors
  - Switchyards and interconnections to the interties
  - Temporary and permanent camps and construction facilities, including water draw off structure and wells
  - An airstrip, and
  - Railroad offloading facilities.
- Seismic hazard studies to include:
  - Mapping and evaluation of quaternary lineaments to identify potential seismic sources within 100 kilometers of the site, and
  - Improving the ground motion monitoring network in the region.

The field exploration and testing program work plan as outlined herein will continue to evolve and be optimized based on the new data being collected. Accordingly, the future boring locations, in situ testing requirements, geophysical survey line and trench locations, etc. will be revised and optimized as the field work progresses.

1.1 Purpose

The Susitna-Watana Exploration and Testing Program Work Plan is intended to guide implementation and execution of the overall field activities in order to collect the geological and geotechnical engineering data necessary for characterizing the site conditions, developing design criteria/parameters, and identifying technical limitations and potential constraints in support of engineering feasibility studies. The results from the field exploration and testing efforts and seismic studies will be used to characterize the geologic and geotechnical conditions and seismic hazards for the Project and develop and/or refine the engineering analysis and facilitate feasibility design, project layout and configuration, and optimization of the dam and associated facilities.

The field data will be compiled, reduced, and analyzed as the data becomes available. Regular coordination and technical team meetings will be scheduled to discuss the findings to date, identify data gaps, revise future exploration and testing program requirements as necessary, and evaluate the impact on Project layout and feasibility design.

The most effective approach for advancing the level of design from pre-feasibility, to feasibility level, to final design level for projects of this scale is to implement the field exploration and testing in phases, with each subsequent phase building from the findings and design requirements of previous phases. Accordingly, the planning and scope of work is developed for each phase of the exploration and testing program incorporating previous subsurface and testing data and studies, engineering design modifications, and on-going development of the site characterization including geologic, geotechnical, and seismic conditions; on-going refinement of design parameters; identification and characterization of suitable construction materials; reduction of geologic uncertainty in design and construction; and finalize seismic source characterization for use in deterministic and probabilistic seismic hazard evaluation.

The results of previous programs conducted during the 1970s and 1980s feasibility investigations by the Corps of Engineers (1975, 1979), Acres American, (1981, 1982), Harza-Ebasco (1983, 1984) the recent investigations by MWH and Golder (2011, 2012), as well as the studies performed by Woodward-Clyde consultants (1980, 1982) and Fugro Consultants (2013) represents the initial body of data used to develop the current program.

1.2 Project Description

The proposed Susitna-Watana Dam would be sited on the Susitna River at approximate river mile 187 **(Figure 1)**. The dam would be approximately 2.4 miles upstream of the confluence of the Susitna River and Tsusena Creek. The dam would create a 23,500-acre, 42.5 mile-long reservoir with a normal mean operating elevation of 2,050 ft. Engineering optimization studies are now underway that may result in modifications to the dam arrangement and height. The current layout and configuration of the Susitna-Watana Hydroelectric Project would include construction of an approximate 600-MW, 715-foot high hydroelectric dam on the Susitna River. The dam would have a nominal crest elevation of approximately 2,810 feet (ft.) and a crest length of approximately 2,700 ft. The dam would be designed to accommodate a raise to approximate elevation 2,225 ft. in the future. The proposed facilities would also include transmission lines to connect the project to the existing power grid, an access road to the site, and ancillary facilities. Prior to the 2012 studies, the engineering evaluations had considered both earth embankment and concrete faced rock fill dam (CFRD) alternatives for the Watana project. The previous field investigation and site characterization studies were based on these embankment dam configurations, which typically have much larger footprints and different project facility arrangements when compared to a concrete dam design. In comparison to embankment dams, a roller compacted concrete (RCC) dam would have a relatively small footprint, a different arrangement of the other project structures (i.e., diversion tunnel, spillway, and powerhouse), and different constructability and operational requirements/constraints. Since 2012, the engineering design and feasibility evaluations have been focused on an RCC dam alternative for the project (MWH, 2011).

The RCC dam arrangement would include a diversion tunnel through the right abutment, similar to previous embankment dam options; however, there would be a single diversion tunnel, the overall length would be shortened, and the portals moved closer to the dam. Additionally, the RCC design would allow the penstock to be constructed through the dam with a surface powerhouse positioned at the toe of the dam in the river channel rather than an underground structure. The spillway facility would be integrated into the crest of the RCC dam on the right abutment. Engineering feasibility studies have indicated the surface powerhouse will have three generating units and each having a nominal installed capacity of 200-MW. Overall, the proposed facility is a much more compact arrangement.

There would be a number of ancillary facilities such as control houses, switchyards, access roads, construction camp / permanent village, utilities, etc. The Construction camp, permanent village, airfield and associated infrastructure support facilities are planned to be located above the right abutment, about a mile north-northeast of the dam site **(Figure 2)**. Switchyard facilities will likely be sited above the right abutment slightly downstream of the dam centerline.

2. PREVIOUS GEOTECHNICAL EXPLORATION PROGRAMS AND SEISMIC STUDIES

The Project has been studied for a number of years since shortly after World War II. The studies of the Susitna River basin by the Corps of Engineers in 1975 and 1979 culminated in the recommendation that hydropower development should proceed at the Watana and Devil Canyon sites. Thereafter, State of Alaska through the Alaska Power Authority (now the Alaska Energy Authority) continued studies at these locations by engaging Acres American (1980-1983) and later Harza-Ebasco (1983-1986) to evaluate a number of alternatives for hydropower development at these locations and conducted extensive engineering, environmental and economic studies.

Site investigations of the Watana dam site began in 1975. The geologic and geotechnical exploration and seismic studies were carried out by the US Army Corps of Engineers, Acres American, Woodward-Clyde Consultants, and Harza-Ebasco **(Figures 3 and 4)**. The previous field exploration methods included geologic mapping, geophysical surveys (primarily seismic refraction and electrical resistivity), ground penetrating radar (GPR), soil and rock core borings, test pits and trenches, and installation and monitoring of geotechnical instrumentation (piezometers and thermistors) as well as seismic hazard studies. A summary of these Project-specific geotechnical investigations and seismic studies are provided in the following reports:

Harza-Ebasco, 1984. Susitna Hydroelectric Project, FERC Project No. 7114: 1984 Geotechnical Exploration Program, Watana Damsite. Volumes 1–2.

Harza-Ebasco, 1983. Susitna Hydroelectric Project: Watana Development Winter 1983 Geotechnical Exploration Program. Volumes 1–2.

Acres American, 1982. Susitna Hydroelectric Project: 1982 Supplement to the 1980-81 Geotechnical Report, Volumes 1–2.

Woodward-Clyde Consultants, 1982. Final Report on Seismic Studies for Susitna Hydroelectric Project.

Acres American, 1981. Susitna Hydroelectric Project: 1980-81 Geotechnical Report, Volumes 1–3.

Woodward-Clyde Consultants, 1980. Interim Report on Seismic Studies for Susitna Hydroelectric Project.

USACE, 1979. South-central Railbelt Area, Alaska, Upper Susitna River Basin, Supplemental Feasibility Report, Hydroelectric Power and Related Purposes. Alaska District, Anchorage, Alaska.

USACE, 1975. South-central Railbelt Area, Alaska, Upper Susitna River Basin, Interim Feasibility Report, Hydroelectric Power and Related Purposes. Alaska District, Anchorage, Alaska.

More recently, MWH was engaged by the Alaska Energy Authority (AEA) to assist in the completion of engineering feasibility studies and licensing of a revised concept of the Susitna-Watana Project. As part of this effort additional site investigations and seismic studies have been carried out and are continuing. A summary of these Project-specific geotechnical investigations **(Figure 3)** and seismic studies are provided in the following reports:

Golder, 2013. Interim Geotechnical Data Report. Prepared for MWH Americas.

Fugro, 2013. Lineament Mapping and Analysis for the Susitna-Watana Dam Site. Technical Memorandum No. 8.

Golder, 2012. Geotechnical Data Report, Watana Quarry A.

3. FIELD INVESTIGATION CONSIDERATIONS AND OBJECTIVES

The geologic, geotechnical, and seismic hazard studies to be performed during 2014-2015 will be implemented to support the ongoing engineering feasibility, FERC study plans, and the project licensing effort. These studies will be a continuation of the phased approach being used to characterize the geologic and geotechnical conditions and seismic source characterization in the Project area with focus of the investigations and studies in the dam site area that began in 2011. Multiple field investigation programs are envisioned in summer 2014, winter 2015, and summer 2015.

The objectives of the overall geotechnical exploration and testing program are to further define the geologic conditions, the rock mass engineering properties; delineate the depth of weathering and zones of alteration; investigate and evaluate geologic structural features such as discontinuities, shears, lineaments, and faults; delineate and assess the groundwater and permafrost conditions at the dam site and within the reservoir area and corridors; characterize seismic sources and evaluate potential surface faulting; assess geology and soil resources including economic minerals, aggregate, and borrow materials; assess reservoir rim slope stability; develop and update the probabilistic seismic hazard assessment; and develop preliminary design criteria for the Project. These program objectives will be achieved incrementally as the results of the explorations, testing, and engineering analyses are refined during subsequent field investigations and engineering studies.

This work plan presents a summary of the background information, technical considerations, and the exploration and testing program objectives required to advance the engineering design to the next project phase. A summary is provided of information required for the completion of engineering feasibility studies, development of feasibility level cost estimates, verification of the expected performance of the structures, and the assembly of the design criteria for the final design of the Project. The intent and purpose of the exploration and testing program described herein are broken down by project component as presented in **Table 1.**

3.1 Dam and Powerhouse Foundation

One of the most critically important design considerations for a large RCC (or other concrete) dam is related to the geologic and geotechnical conditions, variability of these conditions, and the engineering properties of the bedrock foundation. The primary geotechnical conditions that must be characterized to develop feasibility level engineering design criteria for these structures are summarized in this section.

Excavation of overburden and weathered/altered/weak rock will be required to expose a competent bedrock foundation. The depth and configuration of the foundation excavation for each of the project components must be evaluated. In addition to the foundation excavation requirements, the physical properties of the intact rock, discontinuities and geologic features, and the overall rock mass should also be characterized. This characterization includes evaluation of the following rock mass properties:

- *Properties and orientations of discontinuities:* The properties of rock mass discontinuities and geologic structures such as joint orientation, condition, shear strength, and the potential for adverse discontinuity orientations forming removable foundation blocks that could deform under normal and/or seismic loading in foundations, tunnels, or rock cuts should be evaluated. These parameters are required to perform engineering analysis of foundation block sliding, settlement and differential settlement, bearing capacity, bond strength of anchorages, rock cut slope stability, and evaluating tensile stresses at the heel and compressive stresses at the toe induced by the moments.
- *In situ rock mass stress:* The nature and configuration of the in-situ rock stresses across the dam site (and in the diversion tunnel) are also important conditions in understanding the induced stresses, design of underground structures, rock fracture patterns and conditions, influence of the project loading (localized dam and reservoir loading), and for fully assessing the foundation and abutment stability.
- *Rock Mass Permeability:* The horizontal and vertical variability of the bulk rock mass permeability (hydraulic conductivity) and potential discrete permeability of specific geologic features (shears, faults, fracture zones, alteration/weathered features,) under the high hydraulic gradients and water pressures that will be developed in the dam foundation and abutments should be evaluated. The presence of these adverse features can result in elevated and destabilizing pore pressures, piping/erosion of weak/soft geomaterials, unacceptable/uncontrolled seepage losses, or excessive weakening of portions of the rock mass. The hydraulic and engineering properties of discontinuities significantly influence the foundation behaviour, stability, and treatment requirements. With the Project located in the cold regions of Alaska, within the zone of discontinuous

permafrost, the potential for ice-filled discontinuities in the foundation pose an additional consideration in characterizing rock mass permeability and the approach to foundation treatment. Collection and analysis of permeability data is critical to develop seepage modelling parameters and to perform stability analysis of the dam. Engineering measures (grouting, drainage, and over-excavation) will be required to reduce the permeability of the rock mass.

- *Compressive strength, shear strength, tensile strength and time dependant properties:* (e.g., presence of permafrost or material prone to degradation under the loading conditions) of the rock mass must be characterized for engineering design of the project components. These properties will primarily be evaluated by in situ and laboratory as described in Sections 4.0 and 5.0.
- *Deformation Modulus (Erm):* An evaluation of the deformation modulus of the rock mass (E_{rm}) composing the dam and powerhouse foundation should be conducted. This parameter governs the configuration, location, and magnitude of stresses induced in the concrete structures due to differential or unanticipated settlements or deformations. Features can subsequently be engineered into the structural design of the Project to accommodate the potential foundation deformations and settlements identified. However, the deformation modulus of a rock mass is typically highly variable across the site, therefore it is essential that the rock mass conditions representing the variations in the geologic conditions (i.e., competent to weak rock; shears; highly fractured zones; alteration/weathered zones; etc.) be delineated with as much detail as is feasible to reduce geologic uncertainties and to develop comprehensive foundation design criteria for the structures. These heterogeneities should be included into the feasibility structural design of the facility to the greatest extent practicable.

3.2 Diversion Tunnel and Portals

Design and construction of a diversion tunnel and portals requires a thorough understanding of many of the same geologic and geotechnical conditions that will be evaluated for the dam foundation. This includes:

- The type, thickness, and distribution of soils and/or weak rock that will require excavation;
- Rock quality and rock mass deformation modulus along the tunnel alignment;
- Rock mass compressive, shear, and tensile strengths, and time dependent rock properties;
- Properties and orientations of discontinuities;
- In situ rock mass stress; and
- Rock mass and discrete discontinuity permeability, due to the secondary permeability of the rock mass.

Geologic and geotechnical data is required characterize the underground conditions and rock mass behaviour along the alignment and including the portal areas and will include analysis/modelling to develop rock support and lining requirements and design, estimate groundwater inflow and treatment requirements in the tunnel, identify the potential for poor ground conditions, and portal configuration and support requirements. The diversion tunnel and gate chambers would be constructed using heading and bench method using conventional drill and blast techniques.

The primary technical constraints associated with the tunnel construction at the project site are summarized:

- Potential discontinuities that run subparallel to the proposed tunnel alignment. These features can form tension cracks that may result in large-scale block instabilities and can be problematic during construction. The delineation of discontinuity patterns and geologic features should be evaluated and mapped.
- Identification of the presence of highly permeable and/or weak rock associated with fracture zones, faults, shears, etc. that require special attention (pre-grouting, heavy support, drainage) or can cause cave-ins or uncontrolled groundwater inflow conditions.
- The thickness and engineering conditions of the overburden material (talus and colluvium) and weathered/weak rock in the portal areas. Consideration should be given to the design of the cut slope configuration and support requirements in the portal areas. Ice break-up conditions will need to be factored into the upstream portal design.
- Changed stress conditions and potential increased loading of the tunnel liner following construction of the dam (which sits over the tunnel alignment) and filling of the reservoir.
- The potential for high internal water pressures due to minimum ground cover, specifically on the downstream end of the tunnel segment and portal area.
- Design and construction of the gate chamber/structures that will be required for emergency release during operation.

3.3 Spillway

The gated spillway structure is currently positioned on the right side of the dam with the spillway chute extending downstream along the lower right abutment ending in a flip bucket and a plunge pool in the existing river channel. Geological and geotechnical considerations for the spillway structure are related to the following conditions that must be further evaluated for feasibility design:

- The right abutment slope downstream of the dam and in the vicinity of the spillway chute is steep and rugged with diorite bedrock outcrops in the area. Much of the slope is buried with talus and/or colluvial materials. Preliminary assessments indicate that the talus and colluvium in this area may be quite thick, particularly toward the lower (outside) portions of the slope. The spillway chute must be constructed and founded on competent bedrock along its entire alignment. Constraining the thickness and extent of the talus in this area is critical for optimizing the spillway configuration and design requirements.

- Large rock cuts may be required to achieve the necessary chute grade and elevations. The rock excavation and training wall will likely require significant stabilization and/or geometry consideration (e.g., temporary and permanent rock anchoring, wall reinforcement, engineered benched excavation slopes).
- Planned rock excavations may provide a significant amount of construction material for use in other parts of the project (rip rap, aggregate, etc.). The properties of talus and rock planned for excavation should be evaluated to assess their suitability as construction material.
- Groundwater conditions should be evaluated to assess the need for relief drains and anchoring to enhance spillway stability.
- The primary considerations with respect to the location and configuration of the plunge pool are related to the potential for rock scour and progressive undercutting or back-cutting of the spillway structure or tailrace downstream of the powerhouse. Analysis and evaluation of the scour potential will require an assessment of geomechanical properties and potential geometries of geologic features/defects (faults, shears, weathered/altered zones) in the river channel and especially the flip bucket and plunge pool areas.

3.4 Reservoir

As currently conceptualized, the dam will impound a reservoir of approximately 42 miles long with a total surface area of approximately 23,500 acres. The Watana reservoir will operate at a maximum elevation of El. 2,050 feet msl, with a potential maximum drawdown of up to 200 feet annually to a minimum operational level of El. 1,850 feet msl. The resulting reservoir perimeter will be in contact with moderate to steep slopes along the Susitna river valley that are composed of variable surficial geologic deposits and underlying bedrock type and configuration.

A critical aspect of the safe construction and operation of such a facility is related to the stability of the slopes surrounding the reservoir during the anticipated normal operating conditions. Mass movement and slope instabilities in proximity to the dam can cause damage to structures or potentially impact the safe operation of the Project. Large slope failures within the reservoir impoundment can induce surge waves that can overwhelm the structure and cause damage to the facility or propagate a flood wave around abutments and downstream.

The planned field investigations performed for the reservoir perimeter focus on characterizing the potential failure mechanism and geology of existing landslides within the reservoir area. This field mapping and interpretation will characterize: the geologic conditions, including groundwater and permafrost conditions, the geometry and triggering conditions that are most likely to cause slope failure, the type and size of these potential failures, and identify the locations in and around the reservoir where these geologic configurations are present and potential slope instabilities are possible based on the anticipated reservoir operating conditions and loading.

3.5 Infrastructure and Supporting Facilities

The proposed hydropower project configuration will also include a significant amount of construction relating to the supporting infrastructure and related facilities. These facilities will be for both construction and for the permanent operations and include: roads, bridges, airfield, maintenance and office facilities, switchyards, operations buildings, transmission towers, pipelines, water treatment and distribution, and construction camp and permanent village.

Geologic mapping, geotechnical drilling, and testing programs are the most useful and effective way to begin evaluating the most likely layout and configuration of these project components. Each individual component will require its own, site specific evaluation to identify the potential technical design issues or constraint. The focus of the current geologic and geotechnical studies is simply to identify the most effective layout/alignment and evaluate the geotechnical issues unique to these project components.

3.6 Construction Materials

Construction materials for the project likely require large quantities of aggregate (coarse gravel and sand) composed of durable, fresh, inert material and to a lesser extent impervious, rockfill and rip rap materials. Construction materials must be free of clay minerals (that degrade and/or hydrate and slake) or amorphous or metastable crystalline silicate minerals (that could result in alkali silica reaction with the concrete). The likely source (Quarry M) of the coarse fraction of the aggregate for the RCC and concrete is composed primarily of igneous intrusive bedrock (diorite) located upstream from the dam site on the left abutment. The sand fraction of the aggregate may come from processed alluvial materials (screened and washed) or from crushing of the aggregate derived from Quarry M.

The primary technical constraints for the aggregate quarry and material processing are summarized:

- The most important parameters for the aggregate quarry will be the quality of the rock (UCS, RQD, RMR parameters and AAR potential) , the overall joint spacing and average intact block volume, and delineating the spatial presence of poor rock (shears, faults, alteration/weathered zones) within the quarry area. The quarry can then be configured to target the most suitable aggregate material.
- The major considerations for construction are likely material suitability, available volumes, accessibility (haul distance and material management/schedule), processing requirements, and production rates.
- Large zones of hydrothermally altered diorite, where mineral alteration has formed clayey minerals, are typically adverse to the overall strength and long term performance of the material. The aggregate must be stronger than the concrete matrix, so weak rock or rock that is susceptible to chemical break down is not acceptable.
- The aggregate should not contain silicate minerals that react with alkali-hydroxides in the cement to form a hydrous gel. This process, known as alkali-silica reaction (ASR), severely deteriorates the concrete and jeopardizes the integrity of the structures. While diorite does not typically contain amorphous or metastable crystalline silicate minerals, many extrusive igneous rocks (such as andesite) do contain this version of silica. Andesite flows overlie the diorite in the upper left abutment and may be present in other areas. AAR testing of the rock and mix designs will be required.
- Ideally, the quarry area would be composed of fresh, highly fractured diorite. This would allow for relatively high fragmentation during quarry development and therefore little crushing of the aggregate would be required. However, based on available drill data the overall rock quality is generally fresh and suitable aggregate materials can be obtained by crushing and screening of the materials.
- Generating the sand fraction may involve crushing of the material generated from the rock quarry, or possibly construction of a secondary processing area to screen and wash alluvial materials from the river channel. Considerations with processing in-situ soils in this environment are associated with the gradation and moisture content of the material. It is difficult to screen and process wet soils with more than about 15-20% fines and there are significant sediment control issues related to this process. Drying material may not be feasible at the scale of production in this climate.

In addition to concrete aggregate, rockfill, rip rap, and impervious materials will be needed for cofferdam construction and road base material will be needed for road construction. Due to the limited volume of materials needed for the cofferdams, most of these construction materials may come from overburden stripping in Quarry M (e.g., glacial till), excavation of river alluvium, and rock excavations (e.g., diversion tunnel and portal). If additional impervious materials are needed these could be excavated from Borrow Area D. Since these are temporary structures, there is a little more latitude in the material properties and there should be no significant technical constraints. The glacial till in the area has adequate fine material percentages (>20%) to meet the core requirements. The soil conditions overlying Quarry M will need to be investigated during this program.

For the site and Project access roads, considerable road base material, sand and gravel material, will need to be produced to construct the roads. Based on reconnaissance mapping, several potential deposits of coarse material for road construction have been identified. The primary technical concerns for the road base material are:

- Delineation of suitable well drained coarse material with minimal fines in the volumes required
- Of importance will be the accessibility of the surficial deposits along the corridor routes to minimize haul distance and material management/schedule.

3.7 Seismic Studies

Regional geologic mapping, trenching, and seismic monitoring will be conducted to collect additional data for characterizing seismic sources of potential significance to ground motion and surface faulting evaluations within the Project area with emphasis in the dam site area. Initial geologic reconnaissance mapping will focus on sites selected from the 2012 desktop lineament evaluations and from previous investigations described in Section 3.0. Lineament mapping and analysis was begun in 2013, but due to the land access restrictions, will need to be completed in 2014. Based on the results of the lineament mapping and analysis, additional detailed mapping and trenching may be required of potential significant seismic sources near the dam site.

Seismic monitoring and the cataloguing of earthquake events will be continued. In 2013, the seismic monitoring network was expanded from four to seven seismograph stations. The data being collected will be used in updating the terrain model and for use in the seismic hazard analysis.

4. PROPOSED EXPLORATION

The proposed 2014-2015 exploration and testing program will focus primarily on the dam site, specifically the dam foundation and abutments and the ancillary structures such as the diversion tunnel, spillway, and plunge pool as well as broader studies in the reservoir area, access and transmission corridors, and Project area. The explorations program will also include the continued data collection and maintenance of the geotechnical instrumentation and long-term seismic monitoring stations that have been installed in previous and subsequent field investigations.

In our review of the geologic, geotechnical and seismic data and the more recent results of the exploration and testing programs completed in 2011-2013 and the on-going development of the geologic and seismotectonic models and site characterization, additional investigations and testing will be required to support engineering feasibility as outlined in this work plan. The focus of the investigations and testing will include but is not limited to:

- Assess the foundation conditions and stability relevant to the RCC dam in the abutments and river channel; design of foundation preparation and treatment criteria;
- Ice filled joints ("permafrost") – determine extent of frozen ground and potential impact to rock mass shear strength and foundation design, including excavation and treatment;
- Characterize and evaluate the geologic features (e.g., fracture and shear zones) that have been delineated in the dam site area, assess the likelihood of a "Watana lineament"; perform surface fault evaluation assessing potential activity and influence on the general arrangement and design;
- Diversion tunnel – portal siting optimization, assess anticipated bedrock conditions, and evaluate rock slope design and stability;
- Plunge pool erosion or scour potential downstream of the powerhouse in the river channel;
- Relict Channel – characterize potential seepage and piping as well as treatment alternatives in the buried valley area on the right abutment, upstream of the dam;
- Characterize the potential construction material sources for the Project; rock quality and waste factor for the concrete aggregate source (Quarry M), impervious material source; and sand and gravel sources for Project infrastructure, camp, airfield, and access roads;
- Evaluate seismic sources that may influence the design of the project; develop seismic criteria;

- Update the PSHA, deterministic and probabilistic seismic hazard evaluation and develop ground motion estimates using a risk based approach;
- Characterize the geology and soil resources in the Project area;
- Assess mineral resources in the reservoir area; and,
- Evaluate reservoir rim stability and erosion.

Details of the proposed exploration and testing program are outlined in the following sub-sections.

4.1 Geologic Mapping

Geological mapping was carried out during the feasibility studies leading up to the 1980s FERC license application. The geological maps from the exercises at that time have been re-generated in a GIS system, and the new topographic data (Horizontal North American Datum of 1983 [NAD83] and Vertical North American Datum of 1988 [NAD88]) available in 2012 that were generated from the detailed, digital terrain models constructed from the Interferometric Synthetic Aperture Radar (IFSAR) elevation data and the MatSu Borough- North Susitna Laser Detection and Ranging (LiDAR) data). Further geologic mapping will be carried out under this work plan to supplement the previous geological mapping, fill in data gaps, and to reflect the information required for the new project arrangement and facilities.

The 2014-2015 geologic mapping efforts will focus on the geologic conditions at the dam site, the reservoir area, access road corridors, and the continuation of seismic sources assessment in the Project area. Detailed mapping in the Watana dam area will focus on delineating the variable soil types (i.e., alluvium, colluvium, talus, various glacial deposits, and landslide features) and also estimating thicknesses of deposits, geomorphic features, delineating rock outcrops to a greater detail, measuring rock structural features (joints, shears, faults, contacts) in the dam area, identifying areas exhibiting slope instability, stress relief, and/or potentially unfavourable rock wedges or blocks, and collecting detailed data sufficient to map at the scale of the project features (1:100,1:200 scale depending on the features targeted during the mapping effort).

Geologic mapping efforts will be performed by two person teams periodically from through October. These mapping efforts will be used to supplement and update the existing geologic maps of the site as well as support the geological, seismic, engineering, and environmental studies in support of FERC licensing. The Project Field Manual will provide the guidelines for measuring and describing the rock and discontinuity conditions, roughness and the JRC concept (ref. ISRM, Hoek and Bray (2002), Barton and Choubey (1977, USBR). The field data will be collected in a spreadsheet and compiled with the data from previous investigations. The activities associated with the geologic mapping are described below.

- Rock type and description, degree of weathering or alteration, rock harness/strength
- Identify potentially adverse geologic features, geomechanical conditions, potential geologic defects (e.g., contacts, faults/shears, etc.), or other geologic conditions (e.g., weathering, alteration zones) and collect additional geomechanical data to support engineering analysis of major project components (i.e., the dam and powerhouse foundations, diversion tunnel, spillway foundation, and rock quarry area). The discontinuity data to be collected as part of the mapping efforts include:
- Discontinuity data
  - type (i.e., joint, fault, shear, gouge, vein, foliation, fabric, etc.),
  - orientation (dip / dip direction; strike/dip),
  - spacing of discontinuity sets,
  - persistence (i.e., trace length),
  - openness (i.e., aperture),
  - infilling (thickness, composition),
  - roughness, and
  - springs, groundwater seepage, if any.
- Map the geomorphological features in the dam and reservoir areas to delineate glacial deposits/features, areas of slope instability and identify the likely slope failure mechanisms, delineation of potential frozen ground, and evaluate the ground temperature variability of the foundation beneath the proposed dam and powerhouse.
- Scanline surveys will be performed on both the right and left banks of the river in areas that are accessible and provide sufficient lengths of outcrop exposures. Scan lines may be positioned at 90 degrees to each other if possible to minimize sampling orientation bias. Thus two scan lines form a set and complete the data sampling at a given location.

If there is not sufficient outcrop to perform these surveys, a single scanline may be performed.

- Full-peripheral mapping of the exploratory adits to characterize the rock mass at depth, perform discontinuity surveys, and obtain geomechanical data.

The geologic mapping will utilize results from initial reconnaissance-level mapping performed in 2012, historical data, and desktop studies to assess the need for modification of the proposed geotechnical investigation and the general arrangement. Mapping will be compiled at a large scale that is applicable for the intent and target of the mapping effort. A geologic model of the site will be developed using the previous mapping and subsurface data, coupled with the information obtained during the 2014-2015 investigations.

4.2 Drilling and Logging

The proposed 2014 geotechnical drilling and sampling field program is planned to focus on the dam foundation, spillway, and diversion tunnel portals. This will involve drilling on the abutments. In addition, preliminary exploration will also be undertaken along the access corridors, construction camp area, and reservoir. In 2015 a winter program will be undertaken which will focus the powerhouse and dam foundation beneath the river channel, drilling off the frozen river, and a summer program focusing on the dam foundation, Quarry M, and from within the exploratory adits. Naturally, the 2015 program may be optimized based on the conditions encountered during the 2014 exploration and testing effort as well as project general arrangement refinements made for the dam, spillway, diversion tunnel or other features. The 2014 and currently envisioned 2015 explorations of the dam area are outlined below.

- <u>2014 Exploration Phase</u>. The 2014 phase of the exploratory drilling will be focused in the dam area and will include rock core and overburden drilling in the areas of the dam foundation footprint, including the diversion tunnel portal and spillway areas and Quarry M.
- These investigations include approximately 13 rock core borings with a total estimated footage of 5,250 linear feet (**Figure 5**). Each boring will be advanced with a portable, skid-mounted drill rig. The drilling will be conducted using wireline triple-tube, split barrel HQ-sized (HQ, core diameter = 2.5-in) rock coring methods. Hole lengths are anticipated to range from 250 to 700 feet. As currently planned all drilling will be performed in angle drill holes, inclined from 10° to 30° from vertical. The drilling will be performed in such a manner as to minimize sample disturbance and maximize core or

sample recovery. Details regarding these borings and their location are presented in **Table 2**.

- The infrastructure and reservoir explorations will also be conducted during the 2014 field season. These explorations will include approximately 26 subsurface borings with a total drilling footage of approximately 1000 feet **(Figure 6)**. Investigations of the reservoir area will be selected based on observed field conditions, and will focus on areas of geotechnical interest such as thick soil deposits, mass wasting, and the presence of frozen ground (e.g., Watana Creek). Investigations for the supporting infrastructure include subsurface explorations of the proposed camp/village and airfield areas north of the dam site between Deadman and Tsusena Creek. Corridor explorations will focus on the Denali Corridor to the north and the Gold Creek Corridor to the west-southwest.
- The reservoir, infrastructure, and corridor borings will be advanced using a helicopter portable, skid-mounted drill rig capable of drilling mud-rotary, hollow-stem auger, and rock core drilling methods. Hole depths will likely range from 30 to 50 feet deep, although the final drill depth at each hole will be controlled by the materials encountered and purpose of the hole. Each of these borings is currently planned as vertical holes. The preliminary locations of the infrastructure and reservoir explorations are listed in **Table 3**.
- 2015 Exploration Phase. The 2015 phase of the exploratory drilling will be focused in the dam area and will include rock core and overburden drilling in the areas of the dam foundation footprint, both the river channel and abutments, drilling form the exploratory adits, and Quarry M. A winter program will be undertaken to investigation the rock conditions beneath the main structures in the river, with emphasis on the rock foundation conditions **(Figure 7)**. In the past, drilling in the river channel primarily focused on the river alluvium while the investigation of the rock conditions was secondary, particularly with the previous dam type, an earthfill dam. The winter 2015 explorations are planned to include 16 borings with a total drilling footage of approximately 3300 lineal feet **(Table 4)**. These borings will confirm the depth of alluvium and evaluate the rock conditions beneath the river. Due to the alluvium thickness, only vertical holes are planned. The preliminary locations of the infrastructure and reservoir explorations are listed in **Table 4**.
- Plans for the 2015 summer explorations currently include an allowance for 14 borings, five each in the dam foundation area and Quarry M, and four borings to be drilled for the exploratory adits **(Table 5)**. The location of the borings in Quarry M are shown on the exploration plan **(Figure 7)** however the final locations will be determined based on the results of the 2014 drilling and geophysical surveys. These borings will investigate the rock quality and the suitability of the material as an aggregate source to a greater depth as well as the soil properties of the thick overburden as a potential impervious material source for use as core material in the cofferdams. Relative to the borings in the dam site and exploratory adits, the boring locations and details will be determined after reviewing the results of the 2014 drilling and geophysical surveys and therefore are not indicated.

The total footage for the summer 2015 drilling effort is estimated at about 4800 lineal feet. The preliminary locations of the infrastructure and reservoir explorations are listed in **Table 5**.

- The drilling will be conducted using wireline triple-tube, split barrel HQ-sized (HQ, core diameter = 2.5-in) rock coring methods. Hole lengths are anticipated to range from 120 to 400 feet. As currently planned all drilling will be performed in angle drill holes, inclined from 10° to 30° from vertical. The drilling will be performed in such a manner as to minimize sample disturbance and maximize core or sample recovery.

Prior to drilling, site preparation including clearing and removal of brush and some trees, will be required to allow safe access to the drill sites with equipment and for personnel access. On the steeper slopes, localized ground surface levelling will be necessary to create a work pad to set the drill and ancillary equipment. In addition, landing sites will need to be prepared for the helicopter for supporting the drilling operation.

Water used for the drilling and in situ testing will be obtained from nearby ponds, lakes and/or the Susitna River. This will require long hose lines, pumps and tanks to stage the water to the drill sites. When weather forecasts indicate that overnight lows will be near or below freezing, water supply lines will be drained to preclude the formation of ice in the water supply lines.

The drilling will be conducted in general accordance with the guidelines presented in ASTM D2113 – Standard Practice for Rock Core Drilling and Sampling of Rock for Site Investigation, and the Project Field Manual. Rock core will be handled and transported in general accordance with the guidelines presented by ASTM D5079 – Standard Practices for Preserving and Transporting Rock Core Samples.

The drilling, sampling, and testing program will be managed, directed, and logged by an experienced engineering geologist and/or geological engineer familiar with standard soil classification (Unified Soil Classification System, ASTM D2488) and rock classification methods (International Society for Rock Mechanics and US Bureau of Reclamation, Engineering Geology Field Manual, 1998, 2001), and rock core handling and logging practices. Rock and soil classification methodologies and standard operating procedures (SOPs) are also presented in the Project Field Manual. Data and information recorded and collected for each of the drill holes will include the following applicable data:

- Location (GPS coordinates), approximate elevations and drilling depths,
- Drilling conditions (drill rates, methods, times, amount of drilling fluid return circulation and color, inclination and bearing, rig behavior),
- Core recovery (%) and Rock quality designation (RQD, %),
- Fracture frequency (number of fractures per each 10-ft interval),
- Permeability test results (constant head, falling head, and packer tests,
- Description and classification of the geology and discontinuities
  - Unit name/ID, lithology, grain-size, color, texture, weathering/alteration, relative strength, hardness, slaking potential, geo-structure (i.e., fault/shear, foliation, bedding, etc.).
  - Discontinuity depth, angle, type, width, type of infilling, amount of infilling, surface shape, roughness of surface, and spacing.
- Estimated depth to the groundwater table and delineation of frozen ground,
- Drilling and/or drillers comments and observations,
- Rock core and soil photographs,
- Down-hole testing, sampling, or surveying:
  - SPT split spoon drive sampler blow counts
  - Sample type and interval
  - Rock pressuremeter/dilatometer testing
  - Water pressure testing
  - Geophysical survey/testing (oriented down-hole acoustic/optical imaging, caliper, temperature).

Only minor amounts of drilling spoils are anticipated as a result of using rock coring methods to advance the borings. Slightly more spoils will be generated by mud-rotary, hollow stem auger or casing advancer drilling methods. These spoils will be uniformly spread on the ground near the borehole to blend in with natural environment. The site will be left in a condition as close to pre-exploration conditions as is practical.

4.3 Drill Hole In-Situ Testing and Instrumentation

In-situ field testing may include a number of testing methods in the drill holes to obtain geotechnical data for feasibility engineering design. Brief descriptions of the in situ testing methods and instrumentation are presented as follows:

- Water pressure testing and permeability testing:
  - Permeability testing (constant or falling head tests) may be performed in the overburden soils material. The appropriate test intervals and test pressures for conducting the hydraulic conductivity testing will be selected in the field based on soil stratigraphy, groundwater level, hole stability and efficiency of the operation.
  - Water pressure testing (packer testing) will be performed using either single or double packer arrangements. Single packers are undertaken using a down-stage method while double packers would require testing in an up-stage sequencing effort or for straddling specific geologic features.
- Oriented, optical and/or acoustic televiewer surveys: Many of the drill holes in the dam area will be surveyed with an acoustic and/or optical televiewer to obtain subsurface images of the in-situ rock mass condition and discontinuity orientation data downhole.
  - Downhole geophysical surveys may be performed in some drill holes and would potentially include natural gamma, neutron, and temperature logging:
- Instrumentation: upon completion of drilling, sampling, and testing, geotechnical instrumentation consisting of piezometers and thermistors will be installed in selected drill holes. Piezometers will consist of either 1-inch slotted PVC pipe and/or vibrating wire piezometers (VWPs). Borings with VWPs will be fully grouted in accordance with the manufacturer’s recommendations. Borings with standpipe piezometers will be backfilled with clean, uniform sized silica sand and sealed with bentonite chips. The installed VWPs and thermistor strings will be equipped with data loggers to record groundwater level and ground temperature readings at regular intervals. The data logging equipment will be protected by a metal housing at the top of the exploration.

Quarterly instrumentation monitoring events are planned as part of the exploration investigation program. These events will consist of collecting manual readings, downloading data from dataloggers, and maintenance and includes instrumentation installed during the 2011-12 and previous site investigations (1980s). Field crews will assess instrumentation conditions, replace or charge datalogger batteries, and identify necessary repairs (**Figure 8**). A list of functioning instrumentation is presented in **Table 6**.

4.4 Geophysical Surveys

Approximately 17 seismic refraction survey lines ranging in length from 1,100 to 4,400 feet, totaling approximately 44,500 feet, are planned for the 2014 field investigation (**Figures 5** and **9**; **Table 7**). The surveys will focus on the dam foundation, the bypass tunnel, and Quarry M. Data from the geophysical surveys will be used to determine the profile of the rock-overburden interface, the relative density of the overburden soils, the location of weathered or fractured/sheared rock, and the elastic modulus of rock and soil.

Geophysical surveys include investigation of the relict channel and Borrow Area D as well. These surveys will be used to delineate the depth to bedrock and refine the subsurface model of soil and rock conditions of the relict channel. This subsurface data will be useful in performing seepage analysis and the potential for leakage and/or piping along the right abutment just upstream of the dam.

There may be a need to perform geophysical surveys in the river channel to further delineate the thickness of the alluvium and depth to bedrock as well as delineation of geologic features. This work would need to be scheduled during a winter program to use the ice cover for access. At this time, geophysical survey footage is not included in the tabulated future investigations as the number of lines and lengths have not been determined. Moreover, the results of the initial drilling in the river channel during the 2015 winter program would further define these needs.

Additionally, Multi-channel Analysis of Surface Wave (MASW) points will be conducted to evaluate the vertical profile of shear wave velocities at specific points in the dam foundation area. This data will be useful for determining the engineering properties of the rock mass (e.g., shear wave velocities, deformation modulus).

4.5 Lineament Mapping

A field reconnaissance will be performed to ground-truth the desktop topographic data, LiDAR- and INSAR-derived DEM data based lineament mapping, and to document potentially significant lineaments or suspect geomorphic features identified during mapping. This task began in 2013 but due to the land access restrictions, the field reconnaissance was limited to those lineaments and features on state and federal lands. Thus the lineaments in the dam site and lower reservoir area in particular, will be investigated in 2014. The lineament field reconnaissance will involve:

- Aerial flyovers of the site area and/or general Talkeetna area to observe features that may have been identified during lineament mapping, in order to develop degree of confidence in the interpretation of such features as tectonic or non-tectonic in origin.
- Documentation of outcrops, exposures, or geomorphic surfaces that may assist in assessing Quaternary seismotectonics.
- Collection and submittal of samples for age dating to develop a chronologic sequence for Quaternary deposits or rock units identified in the area local to the reconnaissance.
- Identification of future locations for investigation of surficial geologic mapping, evaluation of potential fault activity and/or sampling for age-dating.

The field reconnaissance observations will be documented by notes, photographs, or other standard reconnaissance techniques and interpretations made of available field evidence for the presence or absence of potential shallow crustal seismic sources (faults). A determination will then be made as to the features significance with respect to Quaternary faulting and their potential as seismic sources of significance to the Susitna Watana Dam seismic hazard evaluations. Age dating methods will be selected based on the properties of materials exposed in the dam site area (e.g., Sowers et al. 1994). Data and findings from these studies will be used as input to update the seismic source model for ground motion evaluations and to evaluate seismic sources in the Project area (**Figure 10**).

4.6 Trench Investigations

Excavations (trenching) will be performed to evaluate the presence or absence of fault structures and to assess paleoseismic activity, based on the results of the lineament mapping and considerations of shallow crustal seismic source potential. The locations of the excavations will be estimated from desktop studies and refined during the lineament mapping reconnaissance effort. Final trench locations will be dependent on access and permit approvals. It is estimated that two trenches may be required to investigate features of interest within close proximity to the dam site. Trenches will be excavated and backfilled using mechanized earth excavation equipment, and will be shored for safety and stability. Trench exposures will be mapped and logged in detail by trained professional geologists applying a high standard of documentation. Samples for age-dating will be collected to develop chronology of soil or sediment units exposed in the trenches. It is anticipated that the data from the paleoseismic trenches will be incorporated into subsequent seismic hazard analyses of fault activity assessments and estimated ground shaking.

4.7 Exploratory Adits

The excavation of two exploratory adits are planned, one in each abutment in the dam foundation area. The adits would be excavated to provide a better understanding of the subsurface rock conditions and behaviour at depth and to evaluate in-situ rock properties at these locations.

Rock mass deformability and competence are two of the most critically important parameters governing the behaviour of the foundation, stability, and safety of a large RCC dam. Additionally, other geomechanical conditions in the foundation relating to the configuration and magnitude of the in-situ stress, rock mass shear strength, the extent and condition of discontinuities and shear/fault zones, groundwater conditions, the extent and presence of ice-filled joints, the likely foundation treatment requirements, the presence of erodible or weak/weathered zones or features, and overall rock conditions are important aspects of the dam foundation that require characterization for design and construction of the proposed facility. These conditions can best characterized within an exploratory adit where the rock condition is closer to in situ than in samples collected from drill holes.

The exploratory adits will be excavated in the abutments of the proposed dam (**Figure 11**). The first adit will be excavated in 2014 in the lower left abutment, above the Susitna River high water level. The second adit will be excavated in 2015, in the lower right abutment, near the dam axis. The approximately 8 ft. by 8 ft. adits will be approximately 400 to 450 feet long with one or two short side drifts of up to 40 feet in length and/or alcoves to intersect geologic features and/or to perform in situ testing. The final alignment and siting of the portal will be determined based on field geologic reconnaissance and the latest general arrangement. **Table 8** presents preliminary properties of the proposed test adits.

Full peripheral geologic mapping will be completed to document the geologic conditions, assess support requirements and to identify locations for sampling and/or in situ testing. Investigations from within the adit will likely include drilling and geophysical surveys, shear wave velocity and petite sismique methods, and/or in-situ testing to evaluate the geomechanical properties of the rock (i.e., deformation modulus and in situ stress).

4.8 Test Grouting Program

In order to evaluate the approach to foundation grouting, particularly in those areas of the bedrock foundation that may be frozen, a test grouting program will be undertaken of the dam foundation near the proposed dam axis. The goal of the grouting program will be to evaluate the approach and effectiveness of grouting in the frozen foundation, left abutment, which will likely include thawing the rock mass. The ability to thaw the rock mass, in particular the discontinuities that may be filled with ice, will be evaluated. The radius of influence of creating a narrow thaw bulb will be assessed. A short grout curtain, single row will be constructed to an intermediate depth and several instruments will be installed in nearby borings to evaluate the effectiveness of future foundation grouting during construction. This information will be essential to the future design development and to contractors bidding on the project.

4.9 Test Blasting

Large quantities of construction materials, particularly rock aggregate, will need to be produced for the RCC and mass concrete at the site for dam, powerhouse, spillway and other appurtenance structures. A quarry, Quarry M, has been identified just upstream of and on the left abutment of the dam site. Rock outcrops exist along the steep valley slope up to about El. 1900, but above the break in slope, the quarry area is covered by a thick overburden. At about El. 1900, a location will be selected to investigate the suitability and fragmentation of the rock in a test drilling and blasting program. This work would be performed by the underground contractor in combination with the excavation of the second exploratory adit. This information will be essential to the further evaluation of the suitability of the diorite as concrete aggregate and the proposed quarry identified to provide the construction material for use in concrete.

4.10 Mineral Resources Survey

A mineral resources survey is planned to be conducted within the dam reservoir area as part of the geology and soils study plan and preparation of the future FERC license. This survey will include a review of existing mining prospects and claims, geologic reconnaissance, and chemical assay testing of selected samples. State and federal mining records will be queried to identify active mining claims within the areas that will be inundated by the reservoir. Available data regarding the claim such as production, mineral occurrences, and estimated reserves will be catalogued when available. The mineral survey will include a geologic reconnaissance of the reservoir area to identify areas were minerals of economic interest are most likely to occur. Samples will be collected from selected field locations for assay testing. Assay testing will be conducted in accordance with ASTM E1915 guidelines. Details of the planned mineral survey work will be presented by Golder in a separate document. This field activity will be undertaken in 2013 but due to the land access restrictions may require an update in 2014 when private land access may become available.

5. LABORATORY TESTING

The laboratory testing program will include testing of rock and soil samples to define the engineering properties of the geologic materials. Rock samples will be selected from drill core, surficial deposits and bedrock outcrops. Soil samples will be selected from borings (e.g., SPT samples) or surface bulk samples. The laboratory testing program will be tailored based on the soil and rock conditions encountered and in particular the variability in the geologic materials. A preliminary listing of the proposed laboratory testing methods are presented in **Tables 9 and 10**.

5.1 Rock Core and Soil Sample Storage

Rock core and soil sample storage will be in accordance with the guidelines presented in ASTM D2113 and the Project Field Manual.

Soil samples and rock core obtained from drilling will be logged and photographed. The rock core samples will be placed in wooden core boxes and will be transported to the AEA Warehouse, rock core storage facility located at 2601 Commercial Drive, Anchorage, Alaska. Rock core boxes shall be sorted by hole number and ordered sequentially from top to bottom in the storage racks provided at the rock core storage facility.

Once photographed and classified, all soil samples will be transported to Golder's soil lab at 2121 Abbott Road, Anchorage, Alaska. Upon the completion of laboratory soil testing, soil samples will be transported and permanently stored at the AEA Warehouse.

5.2 Rock Testing

The engineer or geologist overseeing rock coring operations will collect, package, and ship rock core samples in accordance with ASTM D5079 and the Project Field Manual. In addition to this standard, the engineer or geologist overseeing the drilling will conduct the following tasks:

- Photograph core in the core sleeve (or tray) prior to placing the rock in the box. Core shall be in photographed in a moist condition without excess surface water.

- Mark mechanical breaks in the core with an indelible marker or crayon.
- Mark the depth of the core with an indelible marker or crayon.
- Indicate core orientation by placing two parallel lines, one green and one red, along the axis of the core. The green line will be to the right of the red line while looking down the axis of the hole. The lines will be spaced less than about 1-inch apart.
- Each rock core box shall be photographed once it is properly labeled. The rock should be photographed in even light and while in a moist condition.

Actual testing methods and quantities will be selected based on the soil and rock conditions encountered in the field; however based on anticipated conditions the laboratory testing methods may include the following (**Table 9**):

- Standard Test Method for Density, Relative Density (Specific Gravity), and Absorption of Coarse Aggregate (ASTM C127).
- Standard Test Method for Determination of the Point Load Strength Index of Rock (ASTM D5731, ISRM).
- D2938 Standard Test Method for Compressive Strength and Elastic Moduli of Intact Rock Core Specimens under Varying States of Stress and Temperatures (ASTM D7012).
- Standard Test Method for Splitting Tensile Strength of Intact Rock Core Specimens (ASTM D3967).
- Standard Test Method for Performing Laboratory Direct Shear Strength Tests of Rock Specimens Under Constant Normal Force (ASTM D5607, D4554, ISRM).
- Standard Test Method for Laboratory Determination of Pulse Velocities and Ultrasonic Elastic Constants of Rock (ASTM D2845).
- Standard Test Method for Resistance to Degradation of Small-Size Coarse Aggregate by Abrasion and Impact in the Los Angeles Machine (ASTM D131, C131).

- Standard Test Method for Soundness of Aggregates by Use of Sodium Sulfate or Magnesium Sulfate (ASTM C88).
- Standard Test Method for Resistance of Coarse Aggregate to Degradation by Abrasion in the Micro-Deval Apparatus (ASTM D6928).
- Standard Test Method for Aggregate Durability Index (ASTM D3744)
- Standard Test Method for Potential Alkali-Silica Reactivity of Aggregates (Chemical Method; ASTM C289).
- Standard Test Method for Potential Alkali Reactivity of Aggregates (Mortar-Bar Method, ASTM C1260).
- Standard Test Method for Evaluation of Durability of Rock for Erosion Control Under Freezing and Thawing Conditions (ASTM D5312).
- Standard Guide for Petrographic Examination of Aggregates for Concrete Including polished thin- sections (ASTM C295).
- Standard Test Method for Analysis of Metal Bearing Ores and Related Materials for Carbon, Sulfur, and Acid-Base Characteristics (ASTM E1915-11).

5.3 Soil Testing

The engineer or geologist overseeing soil sampling operations will collect, package, and ship soil samples in accordance with ASTM D4220 and the Project Field Manual. In addition to this standard, the engineer or geologist overseeing the soil sampling shall photograph all samples as they are collected.

Actual testing methods and quantities will be selected based on the soil and rock conditions encountered in the field; however based on anticipated conditions the laboratory testing methods may include the following (**Table 10**):

- Standard Test Method for Density, Relative Density (Specific Gravity), and Absorption of Coarse Aggregate (ASTM C127).

- Standard Test Method for Determination of Natural Moisture Content (ASTM D2216).
- Standard Test Methods for Liquid Limit, Plastic Limit and Plasticity Index of Soils (ASTM D4318).
- Standard Test Methods for Moisture, Ash, and Organic Matter of Peat and Other Organic Soils (ASTM D2974)
- Standard Practice for Dry Preparation of Soil Samples for Particle-Size Analysis and Determination of Soil Constants (ASTM D421).
- Standard Test Method for Particle-Size Analysis of Soils (ASTM D422).
- Standard Test Method for Permeability of Granular Soils (Constant Head) (ASTM D2434).
- Standard Test Method for Consolidated Undrained Triaxial Compression Test for Cohesive Soil (ASTM D4767).
- Method for Consolidated Drained Triaxial Compression test for Soils (ASTM D7181).
- Standard Test Method for Load Controlled Cyclic Triaxial Strength of Soil (ASTM D5311)
- Standard test Methods for the determination of the Modulus and Damping Properties of Soils Using the Cyclic Triaxial Apparatus (ASTM D3999).

6. LONG-TERM EARTHQUAKE MONITORING SYSTEM

A long-term earthquake monitoring system network was established in the project area during the 2012-2013 field seasons (**Figure 12**). The existing system consists of seven seismograph monitoring stations and one GPS station that were installed by the Alaska Earthquake Information Center (AEIC) under direct contract to AEA.

The microseismic earthquake monitoring system consists of four combined 6-component strong motion and broadband seismograph stations located at the dam site plus three other locations within 10 miles of the dam site. Three, 3-component broadband seismograph stations were also installed located northeast and east of the dam site, at a distance of 20 to 32 miles from the dam site. The GPS station was installed at the dam site, adjacent to the WAT1 seismograph station, located high on the north abutment of the dam site. The data from these instruments, seismograph and GPS stations, are telemetered in real time to a repeater site just east of the Parks Highway, which relays the data to a receiver in Honolulu that is part of the State WAN system.

The seismograph and GPS stations are located within 32 miles of the dam site and the network system data is summarized in **Table 11**. The seismographs will monitor low magnitude earthquake events (weak motion) that occur in the area of the proposed dam site and reservoir continuously, and would also be used to record the strong motion seismic events occurring in south-central Alaska. Periodic maintenance of the instrument sites will be required to maintain the data collection network. Generally, maintenance will be performed once each year.

7. MANAGEMENT AND CONTROL OF FIELD EXPLORATION AND TESTING

7.1 Consistency of Data

All data will be collected and documented in accordance with best practices and the Project Field Manual. The field manual will provide field staff with guidance for the collection, classification, and consistent and thorough documentation of geotechnical field data. In general, methods presented in the manual will follow established industry-recognized guidelines and standards (such as those of ASTM, ISRM, and USBR).

All soil and geologic logs, sketches and maps, photographs, and field reporting and other related field generated documentation will be reviewed by the MWH Field Manager and/or Manager of Geologic and Seismic Studies. The Field Manager will be responsible for establishing consistency between documents and will review these documents for conformance with the Field Manual and established guidelines.

7.2 Communications

Effective and open communication is the key to having well-informed team members in a timely manner. Communication begins with having an awareness of the project scope of work and information, communication protocols, contractual and project requirements, as well as an awareness of other AEA consultants and contractors roles (e.g., logistics, aircraft, environmental) on the project. All of which will assist in carrying out the field geologic/geotechnical and engineering work tasks in a safe and efficient manner. Communications are distributed consistently and timely to all team members; processed in a manner that maintains the confidentiality of legally protected communications to the maximum extent reasonably possible and consistent with State public records disclosure requirements and critical energy infrastructure information (CEII). Communications and disclosure of project information to the public is by and as authorized by AEA.

The field geologists/engineers are required to coordinate field work with the Field Manager and Manager of Geologic and Seismic Studies. All engineer/geologist teams will be equipped with a satellite phone and/or two way radios to maintain communication lines among all drill rig operations and with the helicopter services. Questions or problems associated with the site investigation program as relates to drilling, testing, sampling, or related activities should be brought to the attention of the Field Manager immediately for clarification.

Reference is made to the Project Communication Plan – Field. Field communications shall be noted in the engineer/geologist field book for record, and if of significant importance noted or referred to on the Daily Report.

Field investigations will be summarized in weekly progress reports by the MWH Field Manager. The weekly progress reports shall concisely describe the following:

- Tasks being performed and/or completed during the week
- Pertinent progress metrics such as:
- – Drilled footage, tunnel advancement, geophysical survey footage, etc.;
- – Number and type of in situ testing performed;
- – Mechanical issues
- – Delays – mechanical, weather delays
- Tasks to be performed the following week; and
- Safety related incidents or near-misses and issue logs,

8. ROLES AND RESPONSIBILITIES

The field geotechnical exploration program will be performed by an integrated team made of staff from MWH and its subconsultants, Golder and Fugro, AEIC (under contract directly with AEA) and various drilling, excavation and geophysical contractors. MWH and Golder will be responsible for executing the geotechnical investigations of the proposed dam site area. MWH will provide direction and oversight of the field geologic and seismic team activities which will be coordinated with AEA's Engineering Manager and Field Logistics Coordinator. A summary of project roles and responsibilities is presented in the following paragraphs.

Geologic Mapping. Geologic mapping at the dam site will be conducted by an integrated team of MWH and Golder geologists and/or geological engineers. The field geologists/engineers will work as a team and will be responsible for geologic mapping and reconnaissance in specific areas identified based on the current dam arrangement or for the purposes of regional geologic check. At the dam site, the team will discuss potential changes to the arrangement with the Field Manager that may occur during engineering optimization studies in order to adjust the area for mapping if necessary.

Geologic mapping in the reservoir area will be conducted by Golder geologists and/or engineers. Mapping activities in the reservoir area will focus on reservoir rim stability and identification of potential economic resources. In addition, the specific responsibilities of the field engineer/geologist include:

- Maintain a field notebook that includes the following: daily activities, weather conditions, on-site personnel, geologic data collection, soil or rock type and description, weathering/alteration, major discontinuities and their characteristics, rock outcrop size and location, geomorphic expression or features, frozen or unfrozen ground, samples, etc.
- Plot basic geologic data on a field map on a daily basis. The map will include outcrops, basic lithology, and structural measurements. Separate notes and maps will be kept for on-going geologic interpretations.

- Develop and update geologic sections based on conditions encountered during the field mapping and borings. The sections will be updated as relevant data is obtained.
- Maintain communication with and coordinate field work with helicopter services and Field Manager and Lead Geologist in home offices.
- Prepare a brief Daily Report(s) in a format approved by the Field Manager that summarizes the daily field activities.

Regional geologic seismic mapping will be carried out to ground-truth the desktop LiDAR-based regional geology of the reservoir area and lineament mapping. General fly-over and spot checks on the ground will be undertaken to inspect, bedrock or surficial geology exposures, potentially lineaments and geomorphic features identified by the aerial photographic mapping. The field reconnaissance will be conducted by two-person teams of senior geologist personnel.

The field reconnaissance observations will be documented by notes, photographs, sketches for later incorporation into the regional geology and seismic/lineament work products.

Drilling Program. Geotechnical drilling, testing, and sampling will be managed and directed by field personnel from MWH and Golder. The geologists / engineers from both will be responsible for logging of rock core, in situ testing, sampling, and instrumentation installation and rehabilitation; discussing potential changes to the drilling program with the Field Manager and Lead Geologist as necessary; and daily coordination with the drilling subcontractor and helicopter support services. Site drilling will be conducted by a drilling contractor under a sub-contract to Golder. The field geologists/engineers should refer to this Work Plan memorandum and the MWH Field Manual for guidelines, procedures, and standards used during the investigation in order to achieve the program objectives. In addition, the specific responsibilities of the MWH and Golder field engineers/geologists include:

- Approving borehole setups at the desired borehole locations, or if not possible, at an acceptable alternate location.

- Verifying the reference point, coordinates and elevation, from which depth measurements are made.
- Providing technical direction to the drilling subcontractor regarding drilling operations, sampling and testing intervals, water pressure tests, instrumentation installation, and other technical direction as may be necessary.
- Performing field characterizations and measurements of soil samples and rock cores, and preparing field geologic logs (20-ft of borehole per sheet); testing records for all drilling, sampling, and testing activities; and instrumentation record drawings.
- Preserving weak or fragile segments of rock core and samples using Saran wrap, half-rounds, and wax (if necessary).
- Taking photographs of soil, rock core, and samples, drilling procedures, and related field activities.
- Consulting the Field Manager about terminating a borehole in the event of instability or slow drilling.
- Consulting the Field Manager about extending a borehole to obtain additional information of geologic importance.
- Maintaining a field notebook that includes the following: daily activities, weather conditions, on-site personnel, equipment, problems or difficulties, driller downtime and stand-by time, drill footage, meetings and discussions, sketches/photos of drilling and testing equipment and setups, non-compliance issues, and other items relevant to the exploration program.
- Maintaining communication with and coordinating field work with the Field Manager and Lead Geologist and other inspectors/supervisors on site and in home office.
- Verifying the drilling subcontractor's compliance with the specifications throughout the drilling program.

- Preparing a Daily Report(s) in a format provided by MWH and Golder that summarizes the daily field activities and accurate documentation of measurement and payment items.
- Recording necessary groundwater and ground temperature measurements and verifying functionality of instruments installed in new and existing borings.

The driller will be responsible for providing all labor, equipment and materials necessary to conduct drilling, sampling, and in situ testing at the locations specified by the field geologist/engineer. The driller shall assist field geologists with boxing up core, moving core boxes for photography, completing instrumentation installation, and preparing samples for shipment.

Geophysical Surveys. Geophysical surveys will be conducted by a subcontracted consultant that is yet to be named. This work will be conducted under the direction of MWH. Geophysical crews will conduct surveys in the area of the dam, Quarry M, and in the relict channel. Geophysical survey crews will report to the Field Manager who will coordinate the work with the AEA project manager. The specific responsibilities of the field engineer/geologist include:

- Maintaining a field notebook that includes the following: daily activities, weather conditions, on-site personnel, geologic data collection, activity progress, etc.
- Providing the coordinates of the geophones and seismic sources for each survey with sub-meter accuracy.
- Verifying the reference point, coordinates and elevation, from which depth measurements are made.
- Maintaining photographic records of geophysical surveys and other significant field activities.
- Maintaining communications and coordinate field work with the Field Manager, Lead Geologist, and other inspectors/supervisors on site.

- Preparing a Daily Report(s) in a format provided by MWH that summarizes the daily field activities and maintains accurate documentation of measurement and payment items.

The geophysical contractor will be responsible for providing all brush removal, labor, equipment and materials necessary to conduct the survey.

Lineament Trenching. Fugro, as a subconsultant to MWH, will be responsible for conducting and overseeing trenching operations including subcontracting an excavation and shoring contractor, trench mapping, and site restoration. Fugro will coordinate all trenching related work with the Field Manager to relay project needs, communicate field progress, and coordinate logistical support. The specific responsibilities of the trenching geologists include:

- Approving trench locations.
- Surveying the trench coordinates within sub-meter accuracy, and verifying the reference point, coordinates and elevation, from which the coordinates are referenced.
- Providing technical direction to the trenching and shoring subcontractor regarding operations, sampling, mapping, and other technical direction as may be necessary.
- Conducting detailed mapping of the trench including geologic descriptions of all soil, rock and water conditions, sketches of the subsurface profile, photographs of all excavations, and any data relevant to the geologic and seismic settings of the site.
- Maintaining a field notebook that includes, but is not limited to, the following: daily activities, weather conditions, on-site personnel, equipment, problems or difficulties, subcontractor stand-by time, meetings and discussions, sketches/photos of drilling, non-compliance issues, and other items relevant to the trenching program.
- Maintaining communication with and coordinate field work with the Field Manager and Lead Geologist and other inspectors/supervisors on site.
- Preparing a Daily Report(s) in a format provided by MWH that summarizes the daily field activities and accurately documents of measurement and payment items.

Seismic Monitoring Network Enhancements. The Alaska Earthquake Information Center (AEIC) continue to maintain and operate the long term earthquake monitoring system. A total of seven instrument stations have been installed. MWH geologists / engineers will provide field support. The specific responsibilities of the field geologist/technician include:

- Verifying the reference point, coordinates and elevation of the station site.
- Developing an as-build sketch of the installed equipment/station, photo documentation of site conditions and installed station, etc.
- Maintaining communication with and coordinate field work with the Field Manager and Manager of Geologic and Seismic Studies.
- Preparing a brief Daily Report(s) in a format approved by the Field Manager that summarizes the daily field activities.

Exploratory Adit Excavation. Exploratory adits are planned to be excavated in the left abutment by a currently unnamed tunnelling contractor. Adit excavation shall be carried out under a contract developed and prepared by MWH. Detailed geomechanical and geological mapping and field testing performed in the test adits will be conducted by MWH; however, some of the in-situ testing performed in the test adits may require specialty subcontractors. A detailed work plan specific for the test adit work will be developed by MWH.

8.1 Subcontract Procurement

Subcontractors for production-type work, such as rock core drilling, test grouting and adit excavation, will be selected on a best value competitive bid basis. Subcontracts will contain a clear, concise, detailed explanation of the objectives of the task, work to be performed, milestones, scope, and specifications.

9. HEALTH AND SAFETY

The Alaska Occupational Safety and Health (AKOSH) regulations and Occupational Safety and Health Administration (OSHA) Standards for Construction (Title 29, Code of Federal Regulations Part 1926) are applicable to this project. Safety guidelines for personnel involved in the field operations shall comply with the AEA Health and Safety Plan and the project-specific health and safety plan developed for this field program prepared by each firm. Each firm will be responsible for the on-site health and safety of its employees.

All personnel participating in field activities will be briefed on prudent planning, logistical and communication protocol and field and safety practices prior to being transported by helicopter to the site locations or lodging facility to begin field activities.

Reference is made to the project-specific safety manuals (MWH, Golder, Fugro and AEIC). Project-specific health and safety manuals will also be provided by the various subcontracts (e.g., drilling, geophysical surveys, underground excavation).

10. PERMITS AND LAND ACCESS

Permits and land access permissions will be required from a number of state and federal agencies, native corporations, and private land owners in support of the field activities outlined in this Work Plan. These permits and land access permissions will be required before any localized clearing, drilling, mapping, or other field work may begin. Permits from state and federal agencies or native corporations will be obtained by AEA. The following list represents the required permits and agreements that will be required for the field work include:

Permits

- Alaska Department of Natural Resources (ADNR) – Temporary Water Use Permit
- Alaska Department of Fish and Game (ADF&G) – Fish Habitat Permit and Raptor Clearance
- Alaska Office of History & Archaeology (OHA) and State Historic Preservation Office (SHPO) – Finding of "No Historic Properties Affected" – Northern Land Use Research

Land Access Agreements

- Cook Inlet Region, Incorporated (CIRI)
- Knikatnu, Incorporated
- Tyonek Native Corporation
- Bureau of Land Management
- State of Alaska Department of Natural Resources

The permits and agreements will indicate any special conditions, instructions and/or requirements to be followed in implementing the geotechnical field program. At the conclusion of the field program, a summary briefing memorandum will be prepared to outline the field activities accomplished and list the permanent instruments left in place for submittal to the native corporations.

11. LOGISTICS AND SCHEDULE

11.1 Field Camp

AEA will procure a field camp facility that will be located at Stephan Lake Lodge (SLL), the Fog Lakes or the utilization of both locations. For the 2013 field season, field teams were housed at SLL. In 2014-15, for the summer field season, lodging is anticipated to utilize both SLL and Fog Lakes due to high demand and for safety reasons. Generally the summer field season activities are scheduled for the period between about May 1 and October 31. For the winter program planned for 2015, it is anticipated that this program would occur between late January through early April. All field explorations staff will be housed at the Stephan Lake Lodge Facility while the facility is open. For the short duration tasks, or for tasks that take place when the camp is not operational such as field geologic reconnaissance and instrumentation installation during the winter months, lodging will either be in Talkeetna or the nearest field camp if available to the dam site and depending upon availability.

11.2 Transportation

Transportation between the Anchorage area and the Project site for personnel involved in the field operations is to be arranged and coordinated with AEA's Logistics Coordinator. Transportation from the lodging facility to the field locations (e.g., dam site drilling operation, geologic mapping, instrumentation monitoring, etc.) will be by AEA- or MWH-contracted helicopter service. Arrangements will be made in advance to schedule the appropriate transportation for the field operations. Daily usage of the helicopter service shall be scheduled to maximize the productivity of the field activities, taking into account the helicopter service restrictions and safety. Priority will be given to the drilling and in situ testing operation.

For the drilling and in situ testing program, a helicopter with the capability of slinging equipment, with a sling capacity of about 2,000 lbs. will be utilized to support the field operation.

During peak helicopter demand periods or periods outside the AEA-contracted field season, helicopter service will be arranged by MWH and its subconsultants for the short duration tasks. Due to the high demand for helicopter services during the field season, helicopter transport activities and logistical requirements will need to be scheduled well in advance.

11.3 Schedule

- Based on current funding levels and planning, the anticipated schedule for the 2014-15 exploration program are as shown in Figure 15. The key milestone dates are as follows:
- Geologic Mapping – winter mapping along the river during low flow levels (March-April). Summer mapping to be scheduled prior to leaf out and after leaves have fallen (May and September).
- Drilling at Dam Site – May start, assuming cleaning and brushing is completed in April.
- Geophysical Surveys – for maximum benefit this task should begin in early May, thus brushing is needed in April.
- Exploratory adit – early start would be May to take advantage of longer daylight hours due to 24-hour operation.

12. REFERENCES

Acres American, 1981. Susitna Hydroelectric Project, 1980-81 Geotechnical Report. Prepared for Alaska Power Authority.

Acres American, 1982. Susitna Hydroelectric Project, 1982 Supplements to the 1980-81 Geotechnical Report. Prepared for Alaska Power Authority.

ASTM, 2011. Annual Book of Standards. ASTM International, West Conshohocken, PA.

Fugro Consultants, 2011. NTP 6 Seismic Studies, Technical Memorandum No. 1, Seismic Hazard Characterization and Ground Motion Analyses for Watana Damsite.

Fugro Consultants, 2013. Lineament Mapping and Analysis for the Susitna-Watana Dam Site. Technical Memorandum No. 8. Prepared for Alaska Energy Authority.

Golder Associates, 2012. Technical Memorandum Watana Rock Core Review – Railbelt Large Hydro Engineering Program. Prepared for MWH Americas.

Golder Associates, 2012. Geotechnical Data Report, Watana Quarry A. Prepared for Alaska Energy Authority.

Golder Associates, 2013. Interim Geotechnical Data Report. Prepared for Alaska Energy Authority.

Harza-Ebasco, 1983. Watana Development, Winter 1983 Geotechnical Exploration Program. Prepared for Alaska Power Authority.

Harza-Ebasco, 1984. Susitna Hydroelectric Project, Federal Energy Regulatory Commission Project 7114, 1984 Geotechnical Exploration Program, Watana Damsite. Prepared for Alaska Power Authority.

ISRM, 1981. Suggested Methods for the Quantitative Description of Discontinuities in Rock Masses, ed. E. T. Brown. Pergamon Press, Oxford, UK.

ISRM, 1985. Suggested Method for Determining Point Load Strength. International Journal of Rock Mechanics and Mining Sciences, Pergamon Press, Oxford, UK.

MWH, 2011. Pre-Application Document. Prepared for Alaska Energy Authority.

USACE, 1975. Southcentral Railbelt Area, Alaska, Upper Susitna River Basin, Interim Feasibility Report, Hydroelectric Power and Related Purposes.

USACE, 1979. Southcentral Railbelt Area, Alaska, Upper Susitna River Basin, Supplemental Feasibility Report, Hydroelectric Power and Related Purposes.

USGS, 1998. Geologic Map of Central (Interior) Alaska. Compiled by Wilson, Fredric H., Dover, James H., Bradley, Dwight C., Weber, Florence R., Bundtzen, Thomas K., and Haeussler, Peter J. Open-File Report 98-133.

USGS, 1965b. Permafrost Map of Alaska. Prepared by O. J. Ferrians, Jr. Miscellaneous Geological Investigations Map I-445. Scale 1:250,000.

USGS, 1974. Reconnaissance Geologic Investigation in the Talkeetna Mountains. Prepared by Bela Csejtey, Jr. Open File Report 74-147.

USGS, 1978. Reconnaissance Geologic Map and Geochronology, Talkeetna Mountains Quadrangle, Northern Part of Anchorage Quadrangle, and Southwest Corner of Healy Quadrangle, Alaska. Prepared by Csejtey, Bela, Nelson, W. H., Jones, D. L., Silberling, N. J., Dean, R. M., Morris, M. S., Lanphere, M. A., Smith, J. G., and Silberman, M. L. Open-File Report 78-558A.

Woodward-Clyde Consultants, 1982. Final Report on Seismic Studies for Susitna Hydroelectric Project. Prepared for Acres American Incorporated.

Woodward-Clyde Consultants, 1980. Interim Report on Seismic Studies for Susitna Hydroelectric Project. Prepared for Acres American Incorporated.

TABLES

Table 1. Required Engineering Design Information

Facility	Project Component	Required Engineering Design Information
Dam	Foundation	Rock mass strength; discontinuity characterization; rock deformation characteristics; rebound/in-situ strength; shear, alteration, and fracture zones; depth to rock and nature of overburden; weathering/alteration profile; presence of linear feature forming river channel; existing rock temperature measurements; lithology.
	Abutments	Rock mass strength; joint orientation; joint continuity and conditions; joint friction angle; roughness; infilling; ice; shear, fault, alteration and fracture zones; depth to rock and nature of overburden; weathering/alteration profile; existing rock temperature measurements, abutment excavation and treatment requirements; identification and characterization of potential kinematically removable foundation rock blocks; rock slope stability and stabilization requirements.
	Materials	RCC aggregate quarry material characteristics; depth to rock, rock engineering properties, delineation of alteration or weathering zones in the quarry; quarry design and layout requirements; fragmentation, crushing, and/or washing requirements.
Foundation Treatment	Adits	Detailed rock mass characterization; geologic structure; rock joint orientation and character; delineation of joint ice filling; existing rock temperature measurements; weathering/alteration conditions and profiles, rock mass competency; rock mass engineering properties (deformation modulus, shear strength, in-situ strength); ground behavior and spatial design considerations.
	Grout blanket/curtain	Characterization of discontinuity orientations, persistence, infillings; rock mass permeability, lugeon values; shear zones and fracture zones; rock deformation and stress field; groutability; extent of frozen ground, particularly the presence of ice filled discontinuities thawing of abutment rock; post-construction grouting optimization of grout hole patterns.
Powerhouse	Foundation	Rock mass strength; discontinuities; rock deformation characteristics; rebound; in-situ stress conditions; shear zones and fracture zones; depth to rock; weathering profile; excavation and support requirements
Spillway	Chute foundation	Joint orientation; joint continuity; joint friction angle; roughness; infilling; ice existing rock temperature measurements; thickness of overburden (talus); drainage requirements, cut slope stability requirements, chute and slope anchoring parameters
	Plunge Pool	Rock mass characterization, joint orientations and characteristics (i.e., continuity, opening, infilling, strength, roughness, etc.); rock depth and weathering/alteration profile; presence of geological structures (shears/fracture zones); develop rock erodibility index parameters and remediation requirements.
Diversion Tunnel		Rock mass engineering properties; discontinuity characteristics and orientation; shear, alteration and fracture zones; construction requirements, tunnel configuration, initial and final support requirements; effects of in-situ stresses; groutability; gate chamber design.
Relict Channel		Permeability and seepage potential through the overburden, interbedded sequence of glacial and fluvial deposits; piping potential and internal stability of materials; spatial extent of permafrost; stability of material under reservoir loading; depth to rock and rock profile
Permanent site Roads	Roads Access Tunnels to Powerhouse	Subgrade engineering properties; depth to rock; joint orientation; permafrost conditions; shear zones and fracture zones; borrow materials; slope stability

Facility	Project Component	Required Engineering Design Information
Permanent Bridge		Depth to rock; rock quality and characteristics; and joint characterization
Access road	Access Road	Engineering parameters of subgrade materials; depth to rock; slope stability; borrow areas; extent of permafrost;
	Bridges	Rock mass characterization, weathering profile; nature and thickness of overburden soils
Transmission Lines		Defer to detailed design
Switchyards	Switchyard	Overburden depth and engineering properties
	Connections	Soil conditions; bearing capacity
Camps	Camps	Soil conditions; bearing capacity
	Water extraction site	Rock profile
	Wells	Trial well and pumping tests
Airstrip		Soil conditions; bearing capacity
Railroad yard		Soil conditions; bearing capacity

Table 2. Proposed 2014 Drilling Program – Dam Site Area

Borehole Number	Elevation (approx.)	Coordinates		Inclination (from Vert)	Azimuth	Depth (feet)			Objective
		Northing	Easting			Soil	Rock	Total	
Dam and Appurtenant Structures									
DH14-09	1475	3226686.2	1884907.4	30°	190°	25	675	700	Right abutment at river level. Investigate the bedrock foundation and likelihood of Watana lineament or fault beneath the dam. Determine if frozen ground in lower right abutment. Instrumentation.
DH14-10	1460	3226246.8	1884610.1	30°	030°	30	670	700	Left abutment at river level. Investigate the bedrock foundation and likelihood of Watana lineament or fault beneath the dam. Determine if frozen ground in lower left abutment. Instrumentation.
DH14-11	2075	3227760.7	1884383.8	20°	025°	30	220	250	Right abutment dam foundation, rock type and engineering characteristics, instrumentation for groundwater and temperature.
DH14-12	1860	3227311.4	1884783.0	20°	310°	35	365	400	Right abutment dam foundation, rock type and engineering characteristics, instrumentation for groundwater and temperature
DH14-13	1570	3227106.5	1886043.8	20°	330°	25	175	200	Investigate rock conditions in the area of the upstream diversion tunnel portal. Determine if frozen ground in lower right abutment. Instrumentation for groundwater and ground temperature.
DH14-14	1540	3226735.3	1883882.6	20°	335°	30	270	300	Investigate rock conditions in the area of the downstream diversion tunnel portal. Thick overburden potential and fracture/shear zones. Determine if frozen ground in lower right abutment. Instrumentation for groundwater and ground temperature.
DH14-15	1640	3226808.6	1884753.2	20°	350°	25	375	400	Right abutment dam foundation and NW-trending geologic feature that passes beneath dam, geologic and engineering characteristics in particular degree of fracturing and alteration, instrumentation for groundwater and temperature.

Borehole Number	Elevation (approx.)	Coordinates		Inclination (from Vert)	Azimuth	Depth (feet)			Objective
		Northing	Easting			Soil	Rock	Total	
DH14-16	1615	3226619.7	1884442.7	30°	025°	10	390	400	Lower right abutment, adjacent to powerhouse, NW trending geologic feature, potential access tunnel. Assess rock foundation, slope and underground conditions. Geologic and engineering characteristics of bedrock. Determine if lower abutment is frozen, instrumentation for groundwater and temperature.
DH14-17	1710	3225829.5	1884301.4	20°	130	35	265	300	Investigate area with limited rock exposure on left abutment, near spillway location. Potential geologic feature(s). Access rock type, geologic and engineering characteristics, determine fi frozen ground. Instrumentation for groundwater and temperature.
DH14-18	2130	3224854.2	1884335.2	20°	250	25	275	300	Left abutment dam foundation conditions, geologic and engineering characteristics, instrumentation for groundwater and temperature. Determine if ice is present in discontinuities.
DH14-19	1995	3225354.0	1884796.6	20°	230	15	235	250	Left abutment dam foundation conditions, geologic and engineering characteristics, instrumentation for groundwater and temperature. Determine if ice is present in discontinuities.
Quarry M									
DH14-20	2130	3225380.0	1885865.8	15°		25	525	550	Investigate new quarry alternative to about El. 1600; instrumentation for groundwater and temperature
DH14-21	2115	3225561.5	1886857.8	15°		50	450	500	Investigate new quarry alternative to about El. 1650; instrumentation for groundwater and temperature

Table 3. Proposed 2014 Drilling Program – Infrastructure and Reservoir Areas

Borehole Number	Elevation (approx.)	Feature	Coordinates		Township & Section	Depth (feet)			Objective
			Latitude	Longitude		Soil	Rock	Total	
BH14-01	2330	Camp/Airfield	62.845573	148.500413	S032N005E/22	30		30	Airfield Foundation
BH14-02	2360	Camp/Airfield	62.848483	148.470110	S032N005E	30		30	Airfield Foundation
BH14-03	2355	Camp/Airfield	62.846962	148.484963	S032N005E/23	30		30	Airfield Foundation
BH14-04	2240	Camp/Airfield	62.845682	148.526292	S032N005E/21	30		30	Creek Crossing
BH14-05	2320	Camp/Airfield	62.844708	148.512926	S032N005E/23	30		30	Camp Foundation
BH14-06	2300	Camp/Airfield	62.864418	148.490718	S032N005E/21	30		30	Road Design
BH14-07	2500	North Access	62.891524	148.454668	S032N005E/21	30		30	Road Design
BH14-08	3130	North Access	63.023546	148.301213	F022S004W/10	30		30	Road Design
BH14-09	3200	North Access	63.041288	148.192217	F022S003W/6	30		30	Road Design
BH14-10	1900	Watana Creek	62.841591	148.265282	S032N006E/23	50		50	Slope Stability
BH14-11	2050	Watana Creek	62.876744	148.183000	S032N007E/8	50		50	Slope Stability
BH14-12	2050	Watana Creek	62.850025	148.210530	S032N007E/19	50		50	Slope Stability
BH14-13	1850	Reservoir	62.752989	147.747560	S031N009E/27	50		50	Slope Stability
BH14-14	2050	Reservoir	62.778396	148.032285	S031N008E/18	50		50	Slope Stability
BH14-15	2050	Reservoir	62.817680	148.233052	S032N007E/31	50		50	Slope Stability
BH14-16	2000	South Access	62.758469	148.637252	S031N004E/24	20	10	30	Road Design
BH14-17	2280	South Access	62.784612	148.589036	S031N005E/7	20	10	30	Road Design
BH14-18	3330	North Access	63.251583	148.344886	F019S004W/20	20	10	30	Road Design
BH14-19	3400	North Access	63.136549	148.227856	F020S004W/36	30		30	Road Design
BH14-20	1920	South Access	62.744718	148.852235	S031N003E/26	20	10	30	Bridge Foundation
BH14-21	2250	South Access	62.791105	149.087834	S031N002E/9	20	10	30	Road Design
BH14-22	1700	South Access	62.806752	149.353933	S031N001E/6	30	10	40	Bridge Foundation
BH14-23	1400	South Access	62.800982	149.541303	S031N001W/6	30	10	40	Bridge Foundation
BH14-24	1760	South Access	62.800315	149.296320	S031N001E/4	15	25	40	Bridge Foundation
BH14-25	1880	South Access	62.748048	148.997258	S031N002E17	15	25	40	Bridge Foundation
BH14-26	2050	South Access	62.748646	148.997885	S031N002E/28	15	25	40	Bridge Foundation

Table 4. Proposed 2015 River Drilling Program – Dam Site Area

Borehole Number	Elevation (approx.)	Coordinates (approx.)		Inclination (from Vert)	Azimuth	Depth (feet)			Objective
		Northing	Easting			Soil	Rock	Total	
DH15-22	1455	3226634.7719	1884983.5165	0	0	70	330	400	Dam foundation
DH15-23	1455	3226459.2075	1885047.4168	0	0	70	330	400	Dam foundation
DH15-24	1455	3226546.4043	1884790.5223	0	0	70	105	175	Dam foundation
DH15-25	1455	3226477.4387	1884839.0336	0	0	70	105	175	Dam foundation
DH15-26	1455	3226379.7316	1884812.8530	0	0	70	105	175	Dam foundation
DH15-27	1455	3226464.3491	1884270.1805	0	0	70	105	175	Powerhouse foundation
DH15-28	1455	3226371.6344	1884283.4508	0	0	70	105	175	Powerhouse foundation
DH15-29	1455	3226259.3143	1884294.5241	0	0	70	105	175	Powerhouse foundation
DH15-30	1455	3226447.1638	1883836.9139	0	0	70	70	140	Downstream cofferdam
DH15-31	1455	3226307.0766	1883816.8567	0	0	70	70	140	Downstream cofferdam
DH15-32	1455	3226197.5011	1883794.8323	0	0	70	70	140	Downstream cofferdam
DH15-33	1455	3226605.2777	1883236.9357	0	0	70	200	270	Plunge pool rock conditions
DH15-34	1455	3226482.8368	1883203.8311	0	0	70	200	270	Plunge pool rock conditions
DH15-35	1460	3226775.9188	1885649.3538	0	0	70	100	170	Upstream cofferdam foundation
DH15-36	1455	3226638.2706	1885678.7738	0	0	70	125	195	Upstream cofferdam foundation
DH15-37	1455	3226501.9587	1885709.5313	0	0	70	100	170	Upstream cofferdam foundation

Table 5. Proposed 2015 Summer Drilling Program – Dam Site Area

Borehole Number	Elevation (approx.)	Coordinates		Inclination (from Vert)	Azimuth	Depth (feet)			Objective
		Northing	Easting			Soil	Rock	Total	
Quarry M									
DH15-38	2003	3225613.4280	1885768.0313	20°	TBD	25	375	400	Investigate soil type; rock quality to El. ~1600; install instrumentation
DH15-39	1985	3225839.5000	1886376.2957	20°	TBD	25	375	400	Investigate soil type; rock quality to El. ~1600; install instrumentation
DH15-40	2037	3226215.5299	1887367.4655	20°	TBD	70	330	400	Investigate rock quality to El. ~1600; install instrumentation
DH15-41	2144	3225164.9986	1886461.2954	10°	TBD	40	360	400	Investigate soil type; rock quality to El.~1600; install instrumentation
DH15-42	2195	3225183.7153	1887174.8018	10°	TBD	15	385	400	Investigate rock quality to El. ~1600; install instrumentation
DH15-43	2297	3225702.0563	1887654.9158	10°	TBD	20	380	400	Investigate rock quality to El. ~1600; install instrumentation
Dam Site									
DH15-44		TBD	TBD				0	400	Dam foundation
DH15-45		TBD	TBD					400	Dam foundation
DH15-46		TBD	TBD					300	Dam foundation
DH15-47		TBD	TBD					300	Dam foundation
DH15-48		TBD	TBD	TBD	TBD	0	150	150	Investigate rock mass from adit
DH15-49		TBD	TBD	TBD	TBD	0	150	150	Investigate rock mass from adit
DH15-50		TBD	TBD	TBD	TBD	0	50	50	Investigate rock mass from adit
DH15-51		TBD	TBD	TBD	TBD	0	50	50	Investigate rock mass from adit

Table 6. Geotechnical Instrumentation - Existing

Exploration	Standpipe Piezometer	Pneumatic Piezometer	Vibrating Wire Piezometer	Thermistor Probe or TAC	Data Logger
Dam Site, New					
DH12-01			X	X	X
DH12-02			X	X	X
DH12-03			X	X	X
DH12-04			X	X	X
DH12-08			X	X	X
Dam Site, Historical					
DH-28				X	
DH-24				X	
BH-03				X	
DH84-02	X				
Quarry M, New					
DH12-05			X		X
DH12-06			X	X	X
DH12-07	X				
Quarry A, New					
G11-DH01	X				
G11-DH21	X				
G11-DH03	X				
Borrow Area D, Historical					
AH-D05	X				
AH-D06				X	
AH-D07				X	
AH-D08				X	
AH-D11	X				
AH-D12				X	
AH-D13				X	
AH-D14	X				
AH-D19		X			
AH-D29		X			
AP-8				X	
AP-9				X	
DR-22	X			X	
DR-26				X	
DH84-01		X			
DH84-04A	X	X			
DH84-09	X			X	
DH84-10		X			
AH-D20				X	
AH-D23				X	
AH-D24				X	
AH-D26		X			
AH-D28		X			

Exploration	Standpipe Piezometer	Pneumatic Piezometer	Vibrating Wire Piezometer	Thermistor Probe or TAC	Data Logger
AH-D30		X			
DR18				X	
DR19				X	
HD83-01				X	
HD83-02		X			
HD83-06				X	
HD83-07				X	
HD83-08				X	
HD83-09				X	
HD83-49				X	
HD83-50				X	
HD83-52	X				

Table 7. Proposed Geophysical Survey Lines for 2014

Number	Description	Length	Drill Hole Calibration
Dam Site			
SL14-01	Investigate the general foundation rock quality along the dam alignment, right abutment, river level to El. 2250.	2000	DH12-4, DH13-9, DH13-11, DH13-12
SL14-02	Right abutment near top of dam, investigate the continuation of GF 4. Line is oriented subparallel to the slope (E-NE to W-SW).	1100	DH-10, DH-11, DH13-11
SL14-03	Investigate the thickness of overburden (e.g., talus) at the portals and general rock quality along the diversion tunnel alignment. Intersect potential NW-SE geologic features, GF-4, GF-5 for persistence and impact to general rock quality.	2400	DH-13-13, DH12-3, DH13-14
SL14-04	Investigate area of the valley slope lacking in bedrock outcrops, where geologic feature GF-6 trends through the area, and crosses close to end of the spillway chute. N-S line from river level to about El. 2050	3400	DH-21, BH-12, BH-8
SL14-05	Investigate overburden thickness upstream of the dam, Quarry M area, and persistence of geologic features (NW-SE trending?).	2200	DH13-17 nearby
SL14-06	Investigate Quarry M thickness of overburden, general quality of bedrock based on seismic velocities and identify potential weak zones or features trending NW-SE or possibly N-S.	2600	DH12-1, near DH12-6
SL-14-07	Investigate dam foundation and Quarry M thickness of overburden, general quality of bedrock based on seismic velocities, and identify potential weak zones or features trending NW-SE or possibly N-S.	3800	DH-24, DH13-20
SL14-08	Investigate thickness of overburden, general quality of bedrock based on seismic velocities and identify potential weak zones trending NW-SE. Adjust location based on results of SL13-06 and SL13-07.	1100	DH12-6, DH25
SL-14-09	Investigate thickness of overburden, general quality of bedrock based on seismic velocities and identify potential weak zones trending NW-SE. Adjust location based on results of SL13-06 and SL13-07.	1100	DH12-5, DH13-21TBD
Alternative	Left abutment, dam axis foundation if it differs from SL81-21 or if previous seismic line information is suspect.	(1300)	DH12-1; DH13-18, DH13-19
Relict Channel			
SL14-10	Investigate persistence of geologic features to the north abutment at the dam site. East-west lien would intersect N-S and NW-SE features.	2800	N/A
SL14-11	Investigate the bedrock valley or relict channel, define the location of valley and its thalweg. Define top of rock. Needed for development of pumping test program.	4000	Near DR-22, HD83-52

Number	Description	Length	Drill Hole Calibration
SL14-12	Investigate the bedrock valley or relict channel, define the approximate location of the valley and its thalweg. Define top of rock. Needed for development of pumping test program.	4400	TBD
SL14-13	Investigate the bedrock valley or relict channel along the valley trend, direction of flow. Define top of rock. Needed for development of pumping test program. Line location may be adjusted based on results of SL13-11, SL13-12.	4000	TBD
SL14-14	Investigate the bedrock valley or relict channel along the valley trend, direction of flow. Define top of rock. Needed for development of pumping test program. Line location may be adjusted based on results of SL13-11, SL13-12.	4000	TBD
Reservoir			
SLR14-01	Investigate and delineate the top of rock in the area of extensive slope instability in the Watana Creek area. Optimize the location of borings. Investigate the geologic conditions.	2000	TBD
SLR14-02	Investigate and delineate the top of rock in the area of extensive slope instability in the Watana Creek area. Optimize the location of borings. Investigate the geologic conditions.	2000	TBD

Table 8. Proposed Exploratory Adits at the Dam Site 2014, 2015

Number	Description	Length, ft.	Objective
Dam Site			
Adit A	Left Abutment just above river level near the dam axis. Portal to be excavated at about El.1530. One side drift.	500	Exploratory adits shall be excavated horizontally in the abutments of the dam foundation to observe the rock conditions at depth (access to drilling in the abutment slope precludes drilling), investigate the existence of frozen ground, specifically ice-filled joints, geologic features, and to carry out in-situ tests.
Adit B	Right abutment just above river level, near the dam axis. Portal to be excavated at about El. 1490. One side drift.	500	Exploratory adits shall be excavated horizontally in the abutments of the dam foundation to observe the rock conditions at depth in the dam foundation and the upstream control gate area, investigate the existence of frozen ground, specifically ice-filled joints, geologic features, and to carry out in-situ tests

Table 9. Proposed Laboratory Testing of Rock Samples

Standard	Description	Sample Type
ASTM C127	Standard Test Method for Density, Relative Density (Specific Gravity), and Absorption of Coarse Aggregate Specific Gravity	Core
ASTM D5731, ISRM	Standard Test Method for Determination of the Point Load Strength Index of Rock	Core
ASTM D7012, D2938	Standard Test Method for Compressive Strength and Elastic Moduli of Intact Rock Core Specimens under Varying States of Stress and Temperatures	Core
ASTM D3967	Standard Test Method for Splitting Tensile Strength of Intact Rock Core Specimens	Core
ASTM D5607, D4554, ISRM	Standard Test Method for Performing Laboratory Direct Shear Strength Tests of Rock Specimens Under Constant Normal Force - (intact, sawcut, natural joint, 3 residual points)	Core
ASTM D2845	Standard Test Method for Laboratory Determination of Pulse Velocities and Ultrasonic Elastic Constants of Rock	Core
ASTM D131, C131	Standard Test Method for Resistance to Degradation of Small-Size Coarse Aggregate by Abrasion and Impact in the Los Angeles Machine	Core or Bulk
ASTM C88	Standard Test Method for Soundness of Aggregates by Use of Sodium Sulfate or Magnesium Sulfate	Core or Bulk
ASTM D6928	Micro-Deval Abrasion	Core or Bulk
ASTM D3744	Durability Index	Core or Bulk
ASTM C289	Standard Test Method for Potential Alkali-Silica Reactivity of Aggregates (Chemical Method)	Core or Bulk
ASTM C1260	Standard Test Method for Potential Alkali Reactivity of Aggregates (Mortar-Bar Method)	Core or Bulk
ASTM C1293	Concrete Prism	Core or Bulk
ASTM D5312	Standard Test Method for Evaluation of Durability of Rock for Erosion Control Under Freezing and Thawing Conditions	Bulk
ASTM C295	Standard Guide for Petrographic Examination of Aggregates for Concrete; Including polished thin- sections	Core
ASTM E1915-11	Standard Test Method for Analysis of Metal Bearing Ores and Related Materials for Carbon, Sulfur, and Acid-Base Characteristics	Core or Bulk

Table 10. Proposed Laboratory Testing of Soil Samples

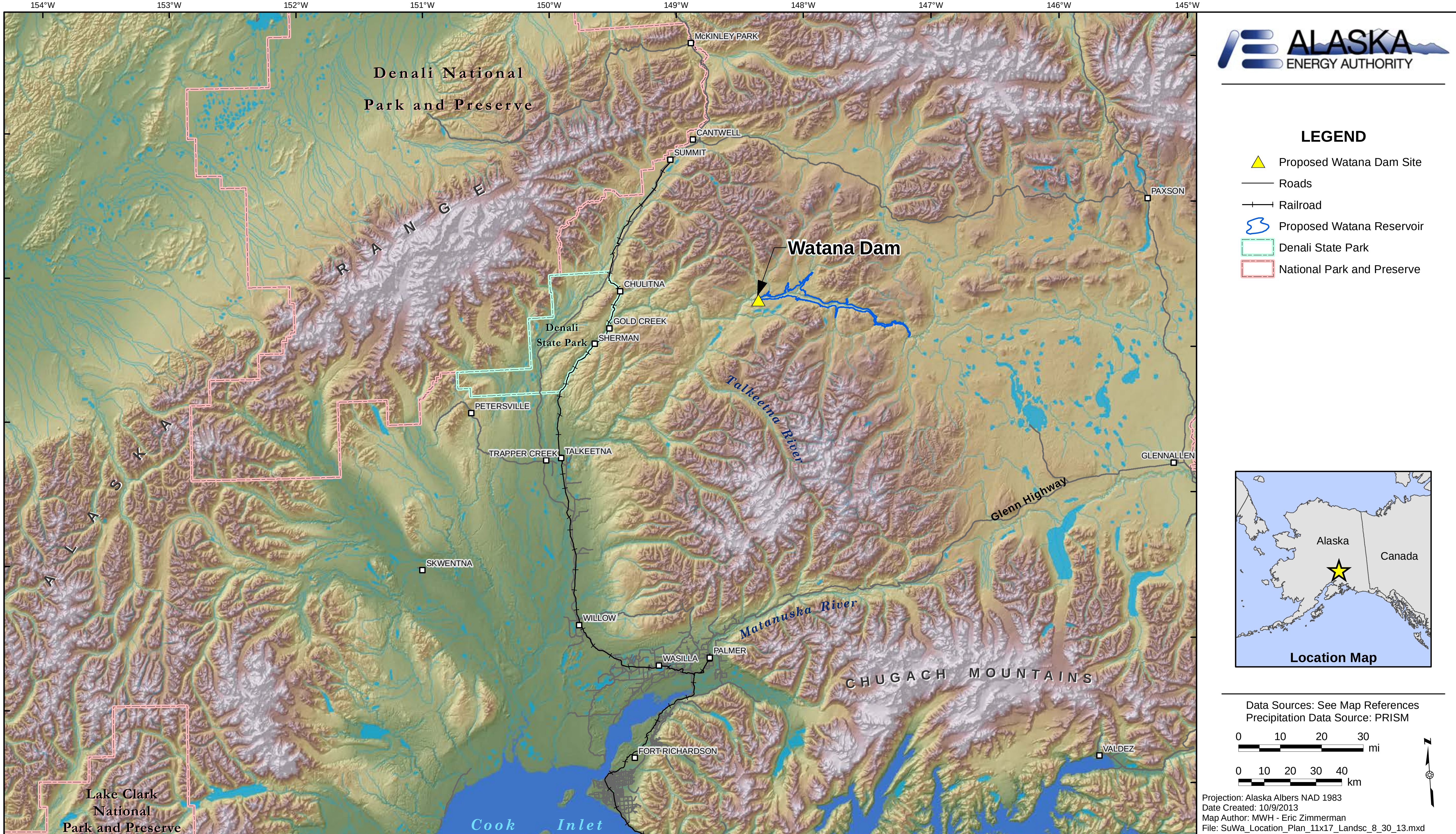
Standard	Description	Sample Type	Quantity (Preliminary)
ASTM C127	Standard Test Method for Density, Relative Density (Specific Gravity), and Absorption of Coarse Aggregate	SPT	0
ASTM D 2216	Standard Test Method for Determination of Natural Moisture Content	SPT	200
ASTM D 4318	Atterberg Limits	SPT	50
ASTM D 2974	Organic content tests	SPT	10
ASTM C127 and C128	Specific gravity	SPT	10
ASTM D 421	Mechanical grain size gradation	SPT, Bulk	50
ASTM D 422	Hydrometer grain size gradation	SPT	50
ASTM D 2434	Permeability tests	SPT	4
ASTM D131, C131	Standard Test Method for Resistance to Degradation of Small-Size Coarse Aggregate by Abrasion and Impact in the Los Angeles Machine	Soil, Bulk	6
ASTM C88	Standard Test Method for Soundness of Aggregates by Use of Sodium Sulfate or Magnesium Sulfate	Bulk	6
ASTM C289	Standard Test Method for Potential Alkali-Silica Reactivity of Aggregates (Chemical Method)	Bulk	0
ASTM C1260	Standard Test Method for Potential Alkali Reactivity of Aggregates (Mortar-Bar Method)	Bulk	0
ASTM D5312	Standard Test Method for Evaluation of Durability of Rock for Erosion Control Under Freezing and Thawing Conditions	Bulk	0
ASTM D2166	Standard Test for Unconfined Compression Test	Undisturbed	12
ASTM D4767	Standard Test Method for Consolidated Undrained Triaxial Compression Test	Undisturbed	12

Table 11. Long-Term Earthquake Monitoring Network Summary

Number	Type	General Location	Coordinates, NAD83 (approx.)		Elevation (approx)	Distance From Dam Site (approx.)
			Lat.	Long.		
WAT1	Broadband, Strong Motion	Dam Site	62.82941N	148.55079W	2381	
WAT2	Broadband, Strong Motion	Tsusena Butte	62.96283N	148.58549W	4480	10 mi
WAT3	Broadband, Strong Motion	Upper Fog Creek	62.68129N	148.53742W	5041	10 mi
WAT4	Broadband	Jay Creek	62.83492N	147.94271W	3893	20 mi
WAT5	Broadband	Deadman Mtn.	63.06243N	148.22858W	5548	20 mi
WAT6	Broadband	Oshetna Area	62.58083N	147.74001W	5515	32 mi
WAT7	Broadband, Strong Motion	West of Dam Site	62.83312N	148.84764W	4042	9 mi
WAT1G	GPS	Dam Site	62.82946N	148.55105W	2417	
ToHon	Repeater	Near Honolulu	62.99494N	149.26302W	5453	25 mi

Note: Instruments installed in 2012 and 2013 field seasons.

FIGURES



Location Plan
Figure 1

Figure 2. General Site Area Plan

This figure contains Critical Energy Infrastructure Information (CEII), which is being withheld from public viewing, in accordance with FERC's Order No. 630-A.

DO NOT RELEASE.

Figure 3. Dam Site Exploration Plan - 2012

This figure contains Critical Energy Infrastructure Information (CEII), which is being withheld from public viewing, in accordance with FERC's Order No. 630-A.

DO NOT RELEASE.